NEC

Preliminary User's Manual

V850ES/JG3-L

32-bit Single-Chip Microcontrollers

Hardware

μPD70F3737
μPD70F3738

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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/JG3-L and design application systems using these products.

Purpose

This manual is intended to give users an understanding of the hardware functions of the V850ES/JG3-L 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/JG3-L
→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/JG3-L
→See **CHAPTER 30 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.

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
Note:	Footnote for item marked with **Note** in the text
Caution:	Information requiring particular attention
Remark:	Supplementary information
Numeric representation:	Binary ... xxxx or xxxxB Decimal ... xxxx Hexadecimal ... xxxxH

Prefix indicating power of 2 (address space, memory capacity):

K (kilo): 2^{10} = 1,024

M (mega): 2^{20} = $1{,}024^2$

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/JG3-L

Document Name	Document No.
V850ES Architecture User's Manual	U15943E
V850ES/JG3-L 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 Flash Programming Function		U18371E
CA850 Ver. 3.20 C Compiler Package	Operation	U18512E
	C Language	U18513E
	Assembly Language	U18514E
	Link Directives	U18415E
PM+ Ver. 6.30 Project Manager		U18416E
ID850QB Ver. 3.40 Integrated Debugger	Operation	U18604E
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	U18601E
	User Open Interface	U18212E
RX850 Ver. 3.20 Real-Time OS	Basics	U13430E
	Installation	U17419E
	Technical	U13431E
	Task Debugger	U17420E
RX850 Pro Ver. 3.21 Real-Time OS	Basics	U18165E
	Installation	U17421E
	Task Debugger	U17422E
AZ850 Ver. 3.30 System Performance Analyzer		U17423E
PG-FP4 Flash Memory Programmer		U15260E
PG-FP5 Flash Memory Programmer		U18865E

CONTENTS

CHAPTER 12 REAL-TIME OUTPUT FUNCTION (RTO) 417

CHAPTER 13 A/D CONVERTER 424

CHAPTER 14 D/A CONVERTER 460

CHAPTER 15 ASYNCHRONOUS SERIAL INTERFACE A (UARTA) 465

CHAPTER 16 3-WIRE VARIABLE-LENGTH SERIAL I/O (CSIB) 501

CHAPTER 17 I²C BUS 551

CHAPTER 1 INTRODUCTION

The V850ES/JG3-L 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/JG3-L 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/JG3-L 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/JG3-L enables an extremely high cost-performance for applications that require super low power consumption, such as digital cameras, electrical power meters, and mobile terminals.

Table 1-1 lists the products of the V850ES/JG3-L and V850ES/JF3-L.

The V850ES/JF3-L is a model of the V850ES/JG3-L with reduced I/O, timer/counter, and serial interface functions.

Table 1-1. V850ES/Jx3-L Product List

Generic Name		V850ES/JF3-L		V850ES/JG3-L	
Part Number		μPD70F3735	μPD70F3736	μPD70F3737	μPD70F3738
Internal memory	Flash memory	128 KB	256 KB	128 KB	256 KB
	RAM	8 KB	16 KB	8 KB	16 KB
Memory space	Logical space	64 MB			
	External memory area	15 MB			
External bus interface		Address bus: 18 Address data bus: 16 Multiplexed bus mode output supported		Address bus: 22 Address data bus: 16 Separate bus/multiplexed bus mode selectable	
General-purpose register		32 bits × 32 registers			
Clock	Main clock (oscillation frequency)	Ceramic/crystal (in PLL mode: f_X = 2.5 to 5 MHz (multiplied by 4), in clock through mode: f_X = 2.5 to 10 MHz) External clock (in PLL mode: f_X = 2.5 to 5 MHz (multiplied by 4), in clock through mode: f_X = 2.5 to 5 MHz)			
	Subclock (oscillation frequency)	Crystal (f_{XT} = 32.768 kHz)			
	Internal oscillator	f_R = 220 kHz (TYP.)			
	Minimum instruction execution time	50 ns (main clock (f_{XX}) = 20 MHz)			
	DSP function	32 × 32 = 64: 200 to 250 ns (at 20 MHz) 32 × 32 + 32 = 32: 300 ns (at 20 MHz) 16 × 16 = 32: 50 to 100 ns (at 20 MHz) 16 × 16 + 32 = 32: 150 ns (at 20 MHz)			
I/O port		I/O: 66 (5 V tolerant/N-ch open-drain output selectable: 25)		I/O: 84 (5 V tolerant/N-ch open-drain output selectable: 31)	
Timer	16-bit TMP	4 channels		6 channels	
	16-bit TMQ	1 channel		1 channel	
	16-bit TMM	1 channel		1 channel	
	Watch timer	1 channel		1 channel	
	WDT	1 channel		1 channel	
Real-time output port		4 bits × 1 channel, 2 bits × 1 channel, or 6 bits × 1 channel			
10-bit A/D converter		8 channels		12 channels	
8-bit D/A converter		1 channel		2 channels	
Serial interface		CSIB: 2 channels UARTA: 2 channels CSIB/I^{2}C bus: 1 channel UARTA/I^{2}C bus: 1 channel		CSIB: 3 channels UARTA/CSIB: 1 channel CSIB/I^{2}C bus: 1 channel UARTA/I^{2}C bus: 2 channels	
DMA controller		4 channels (transfer target: on-chip peripheral I/O, internal RAM, external memory)			
Interrupt source	External	9 (9)$^{\text{Note}}$		9 (9)$^{\text{Note}}$	
	Internal	40		48	
Power save function		HALT/IDLE1/IDLE2/STOP/subclock/sub-IDLE/ low-voltage STOP/low-voltage subclock/low-voltage sub-IDLE mode			
Reset source		$\overline{\text{RESET}}$ pin input, watchdog timer 2 (WDT2), clock monitor (CLM), low-voltage detector (LVI)			
CRC function		16-bit error detection code generated for 8-bit unit data			
On-chip debug		MINICUBE™, MINICUBE2 supported			
Operating power supply voltage		2.2 to 3.6 V @5 MHz, 2.7 to 3.6 V @20 MHz			
Operating ambient temperature		−40 to +85°C			
Package		80-pin LQFP (12 × 12 mm) 80-pin LQFP (14 × 14 mm)		100-pin LQFP (14 × 14 mm) 100-pin LQFP (14 × 20 mm)	

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

1.2 Features

- Minimum instruction execution time: 50 ns (operating with main clock (f_{XX}) of 20 MHz: V_{DD} = 2.7 to 3.6 V)
  200 ns (operating with main clock (f_{XX}) of 5 MHz: V_{DD} = 2.2 to 3.6 V)
  30.5 μs (operating with subclock (f_{XT}) of 32.768 kHz)
- General-purpose registers: 32 bits × 32 registers
- CPU features: Signed multiplication (16 × 16 → 32): 1 to 2 clocks
  Signed multiplication (32 × 32 → 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: 8/16 KB (see **Table 1-1**)
      Flash memory: 128/256 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: 55 sources
  Software exceptions: 32 sources
  Exception trap: 2 sources
- I/O lines: I/O ports: 84
- Timer function: 16-bit interval timer M (TMM): 1 channel
  16-bit timer/event counter P (TMP): 6 channels
  16-bit timer/event counter Q (TMQ): 1 channel
  Watch timer: 1 channel
  Watchdog timer: 1 channel
- Real-time output port: 6 bits × 1 channel
- Serial interface: Asynchronous serial interface A (UARTA)
  3-wire variable-length serial interface B (CSIB)
  I^{2}C bus interface (I^{2}C)
  UARTA/CSIB: 1 channel
  UARTA/I^{2}C: 2 channels
  CSIB/I^{2}C: 1 channel
  CSIB: 3 channels
- A/D converter: 10-bit resolution: 12 channels
- D/A converter: 8-bit resolution: 2 channels
- DMA controller: 4 channels
- 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/low-voltage STOP/subclock/sub-IDLE/low-voltage subclock/low-voltage sub-IDLE mode
○ Package: 100-pin plastic LQFP (14 × 20)
100-pin plastic LQFP (fine pitch) (14 × 14)

1.3 Application Fields

Digital cameras, electrical power meters, mobile terminals, digital home electronics, other consumer devices

1.4 Ordering Information

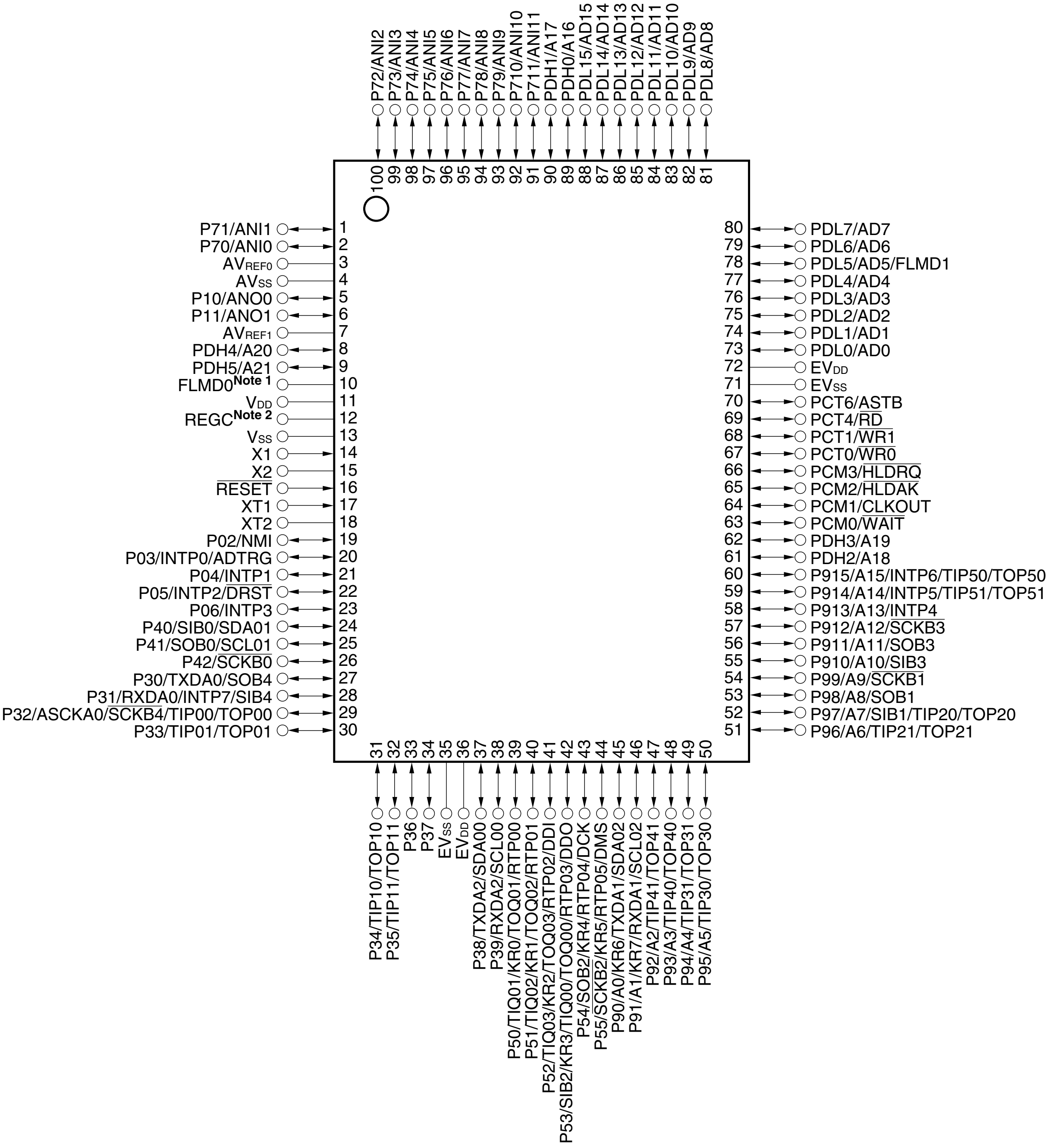
Part Number	Package	Internal Flash Memory
μPD70F3737GC-UEU-AX	100-pin plastic LQFP (fine pitch) (14 × 14)	128 KB
μPD70F3738GC-UEU-AX	100-pin plastic LQFP (fine pitch) (14 × 14)	256 KB
μPD70F3737GF-GAS-AX	100-pin plastic LQFP (14 × 20)	128 KB
μPD70F3738GF-GAS-AX	100-pin plastic LQFP (14 × 20)	256 KB

Remark The V850ES/JG3-L is a lead-free product.

1.5 Pin Configuration (Top View)

100-pin plastic LQFP (14 × 20)

μPD70F3737GF-GAS-AX μPD70F3738GF-GAS-AX

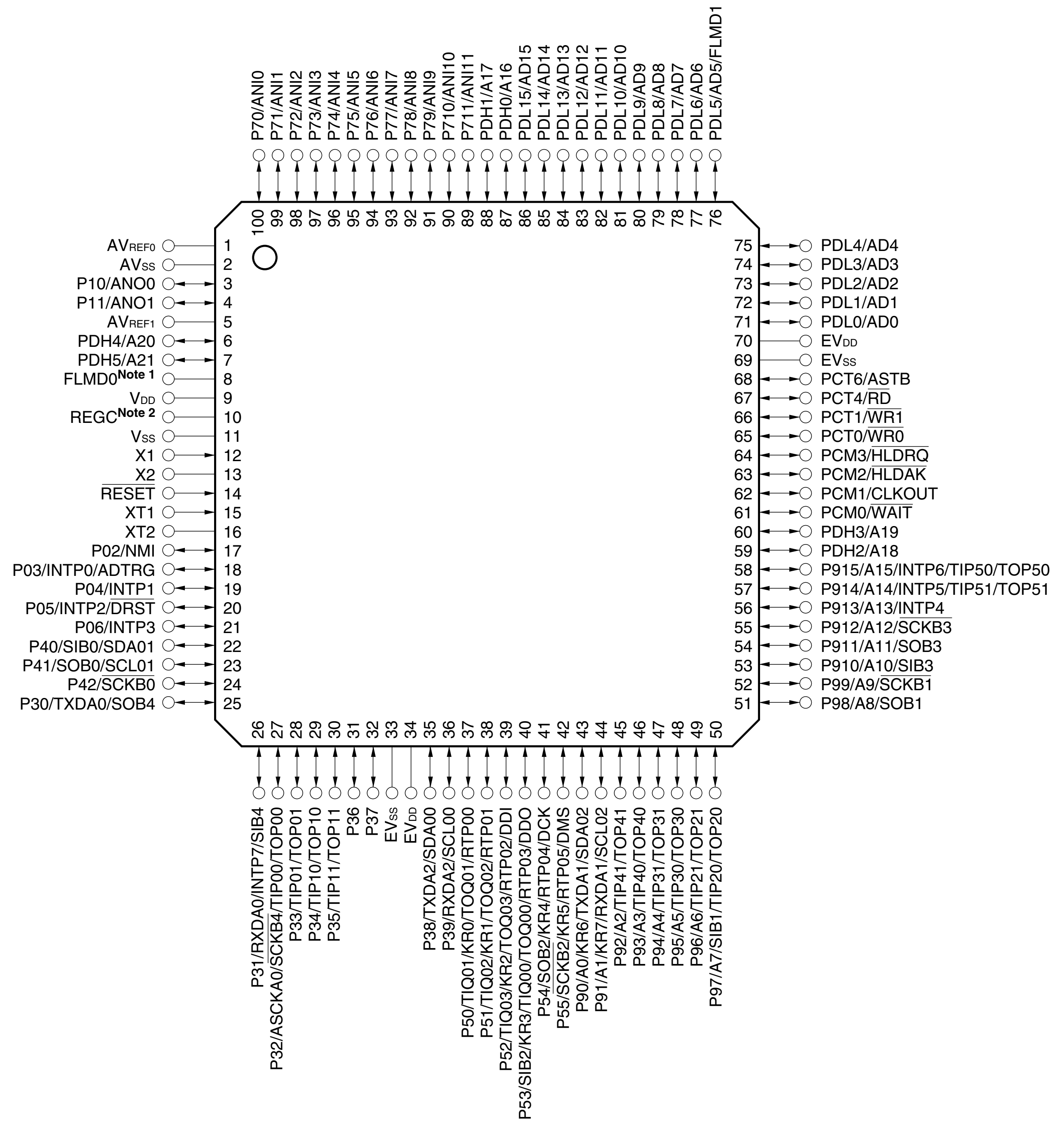


Notes 1. Connect this pin to V_{SS} in the normal mode.

2. Connect the REGC pin to V_{SS} via a 4.7 μF (preliminary value) capacitor.

100-pin plastic LQFP (fine pitch) (14 × 14)

μPD70F3737GC-UEU-AX μPD70F3738GC-UEU-AX



Notes 1. Connect this pin to V$_{SS}$ in the normal mode.

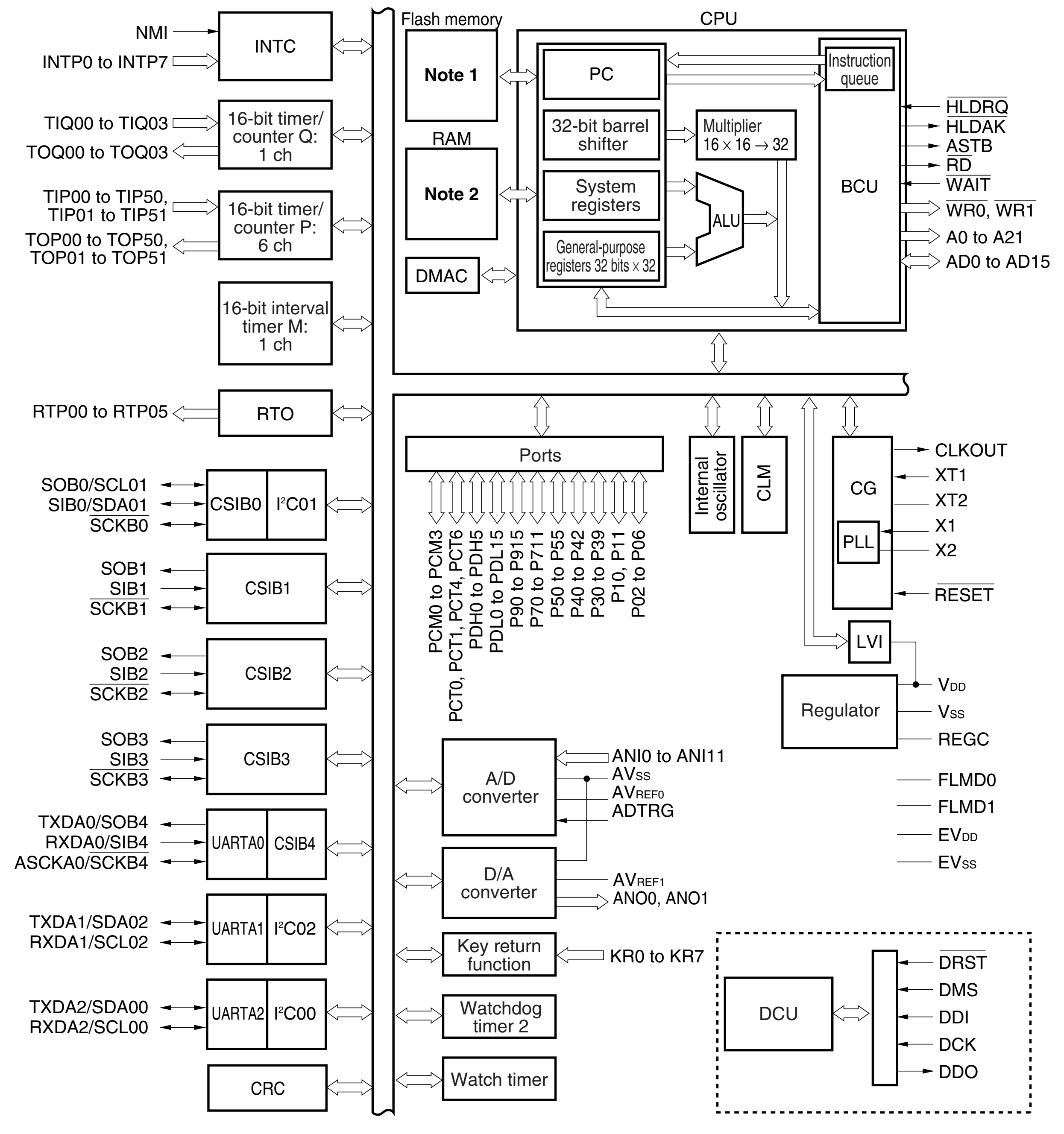
2. Connect the REGC pin to V$_{SS}$ via a 4.7 μF (preliminary value) capacitor.

Pin names

A0 to A21:	Address bus
AD0 to AD15:	Address/data bus
ADTRG:	A/D trigger input
ANI0 to ANI11:	Analog input
ANO0, ANO1:	Analog output
ASCKA0:	Asynchronous serial clock
ASTB:	Address strobe
AV$_{REF0}$, AV$_{REF1}$:	Analog reference voltage
AV$_{SS}$:	Analog V$_{SS}$
CLKOUT:	Clock output
DCK:	Debug clock
DDI:	Debug data input
DDO:	Debug data output
DMS:	Debug mode select
$\overline{\text{DRST}}$:	Debug reset
EV$_{DD}$:	Power supply for external pin
EV$_{SS}$:	Ground for external pin
FLMD0, FLMD1:	Flash programming mode
$\overline{\text{HLDAK}}$:	Hold acknowledge
$\overline{\text{HLDRQ}}$:	Hold request
INTP0 to INTP7:	External interrupt input
KR0 to KR7:	Key return
NMI:	Non-maskable interrupt request
P02 to P06:	Port 0
P10, P11:	Port 1
P30 to P39:	Port 3
P40 to P42:	Port 4
P50 to P55:	Port 5
P70 to P711:	Port 7
P90 to P915:	Port 9
PCM0 to PCM3:	Port CM
PCT0, PCT1, PCT4, PCT6:	Port CT
PDH0 to PDH5:	Port DH
PDL0 to PDL15:	Port DL
$\overline{\text{RD}}$:	Read strobe
REGC:	Regulator control
$\overline{\text{RESET}}$:	Reset
RTP00 to RTP05:	Real-time output port
RXDA0 to RXDA2:	Receive data
$\overline{\text{SCKB0}}$ to $\overline{\text{SCKB4}}$:	Serial clock
SCL00 to SCL02:	Serial clock
SDA00 to SDA02:	Serial data
SIB0 to SIB4:	Serial input
SOB0 to SOB4:	Serial output
TIP00, TIP01, TIP10, TIP11, TIP20, TIP21, TIP30, TIP31, TIP40, TIP41, TIP50, TIP51, TIQ00 to TIQ03:	Timer input
TOP00, TOP01, TOP10, TOP11, TOP20, TOP21, TOP30, TOP31, TOP40, TOP41, TOP50, TOP51, TOQ00 to TOQ03:	Timer output
TXDA0 to TXDA2:	Transmit data
V$_{DD}$:	Power supply
V$_{SS}$:	Ground
$\overline{\text{WAIT}}$:	Wait
$\overline{\text{WR0}}$:	Lower byte write strobe
$\overline{\text{WR1}}$:	Upper byte write strobe
X1, X2:	Crystal for main clock
XT1, XT2:	Crystal for subclock

1.6 Function Block Configuration

1.6.1 Internal block diagram



Notes 1. μPD70F3737: 128 KB
μPD70F3738: 256 KB

2. μPD70F3737: 8 KB
μPD70F3738: 16 KB

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 × 16 bits → 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) Flash memory (ROM)

This is a 256/128 KB flash memory mapped to addresses 0000000H to 003FFFFH/0000000H to 001FFFFH.

It can be accessed from the CPU in one clock during instruction fetch.

(4) RAM

This is a 16/8 KB RAM mapped to addresses 3FFB000H to 3FFEFFFH/3FFD000H to 3FFEFFFH. 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 INTP7) from on-chip peripheral hardware and external hardware. Eight levels of interrupt priorities can be specified for these interrupt requests, and multiplexed servicing control can be performed.

(6) Clock generator (CG)

A main clock oscillator and subclock oscillator are provided and generate the main clock oscillation frequency (f_X) and subclock frequency (f_{XT}), respectively. There are two modes: In the clock-through mode, f_X is used as the main clock frequency (f_{XX}) as is. In the PLL mode, f_X is used multiplied by 4.

The CPU clock frequency (f_{CPU}) can be selected from among 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). The internal oscillator supplies the clock for watchdog timer 2 and timer M.

(8) Timer/counter

Six-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 subclock or the 32.768 kHz clock 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/JG3-L includes three kinds of serial interfaces: asynchronous serial interface A (UARTA), 3-wire variable-length serial interface B (CSIB), and an I^{2}C bus interface (I^{2}C).

In the case of UARTA, data is transferred via the TXDA0 to TXDA2 pins and RXDA0 to RXDA2 pins.

In the case of CSIB, data is transferred via the SOB0 to SOB4 pins, SIB0 to SIB4 pins, and $\overline{\text{SCKB0}}$ to $\overline{\text{SCKB4}}$ pins.

In the case of I^{2}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 12 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 the 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 a 16-bit CRC (Cyclic Redundancy Check) code upon setting of 8-bit data is provided on-chip.

(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 following general-purpose port functions and control pin functions are available.

Port	I/O	Alternate Function
P0	5-bit 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
P7	12-bit I/O	A/D converter analog input
P9	16-bit I/O	External address bus, serial interface, key interrupt input, timer I/O, external interrupt
PCM	4-bit I/O	External control signal
PCT	4-bit I/O	External control signal
PDH	6-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 in the V850ES/JG3-L 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}	$\overline{\text{RESET}}$, ports 0, 3 to 5, 9, CM, CT, DH, DL

(1) Port pins

(1/3)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
P02	19	17	I/O	Port 0 5-bit I/O port Input/output can be specified in 1-bit units. N-ch open-drain output can be specified in 1-bit units. 5 V tolerant.	NMI
P03	20	18			INTP0/ADTRG
P04	21	19			INTP1
P05[Note]	22	20			INTP2/$\overline{\text{DRST}}$
P06	23	21			INTP3
P10	5	3	I/O	Port 1 2-bit I/O port Input/output can be specified in 1-bit units.	ANO0
P11	6	4			ANO1
P30	27	25	I/O	Port 3 10-bit I/O port Input/output can be specified in 1-bit units. N-ch open-drain output can be specified in 1-bit units. 5 V tolerant.	TXDA0/SOB4
P31	28	26			RXDA0/INTP7/SIB4
P32	29	27			ASCKA0/$\overline{\text{SCKB4}}$/TIP00/TOP00
P33	30	28			TIP01/TOP01
P34	31	29			TIP10/TOP10
P35	32	30			TIP11/TOP11
P36	33	31			–
P37	34	32			–
P38	37	35			TXDA2/SDA00
P39	38	36			RXDA2/SCL00
P40	24	22	I/O	Port 4 3-bit I/O port Input/output can be specified in 1-bit units. N-ch open-drain output can be specified in 1-bit units. 5 V tolerant.	SIB0/SDA01
P41	25	23			SOB0/SCL01
P42	26	24			$\overline{\text{SCKB0}}$
P50	39	37	I/O	Port 5 6-bit I/O port Input/output can be specified in 1-bit units. N-ch open-drain output can be specified in 1-bit units. 5 V tolerant.	TIQ01/KR0/TOQ01/RTP00
P51	40	38			TIQ02/KR1/TOQ02/RTP01
P52	41	39			TIQ03/KR2/TOQ03/RTP02/DDI
P53	42	40			SIB2/KR3/TIQ00/TOQ00/RTP03/ DDO
P54	43	41			SOB2/KR4/RTP04/DCK
P55	44	42			$\overline{\text{SCKB2}}$/KR5/RTP05/DMS

Note Incorporates a pull-down resistor. It can be disconnected by clearing the OCDM.OCDM0 bit to 0.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(2/3)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
P70	2	100	I/O	Port 7 12-bit I/O port Input/output can be specified in 1-bit units.	ANI0
P71	1	99			ANI1
P72	100	98			ANI2
P73	99	97			ANI3
P74	98	96			ANI4
P75	97	95			ANI5
P76	96	94			ANI6
P77	95	93			ANI7
P78	94	92			ANI8
P79	93	91			ANI9
P710	92	90			ANI10
P711	91	89			ANI11
P90	45	43	I/O	Port 9 16-bit I/O port Input/output can be specified in 1-bit units. N-ch open-drain output can be specified in 1-bit units. 5 V tolerant (P90 to P96).	A0/KR6/TXDA1/SDA02
P91	46	44			A1/KR7/RXDA1/SCL02
P92	47	45			A2/TIP41/TOP41
P93	48	46			A3/TIP40/TOP40
P94	49	47			A4/TIP31/TOP31
P95	50	48			A5/TIP30/TOP30
P96	51	49			A6/TIP21/TOP21
P97	52	50			A7/SIB1/TIP20/TOP20
P98	53	51			A8/SOB1
P99	54	52			A9/$\overline{\text{SCKB1}}$
P910	55	53			A10/SIB3
P911	56	54			A11/SOB3
P912	57	55			A12/$\overline{\text{SCKB3}}$
P913	58	56			A13/INTP4
P914	59	57			A14/INTP5/TIP51/TOP51
P915	60	58			A15/INTP6/TIP50/TOP50
PCM0	63	61	I/O	Port CM 4-bit I/O port Input/output can be specified in 1-bit units.	$\overline{\text{WAIT}}$
PCM1	64	62			CLKOUT
PCM2	65	63			$\overline{\text{HLDAK}}$
PCM3	66	64			$\overline{\text{HLDRQ}}$
PCT0	67	65	I/O	Port CT 4-bit I/O port Input/output can be specified in 1-bit units.	$\overline{\text{WR0}}$
PCT1	68	66			$\overline{\text{WR1}}$
PCT4	69	67			$\overline{\text{RD}}$
PCT6	70	68			ASTB

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(3/3)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
PDH0	89	87	I/O	Port DH 6-bit I/O port Input/output can be specified in 1-bit units.	A16
PDH1	90	88			A17
PDH2	61	59			A18
PDH3	62	60			A19
PDH4	8	6			A20
PDH5	9	7			A21
PDL0	73	71	I/O	Port DL 16-bit I/O port Input/output can be specified in 1-bit units.	AD0
PDL1	74	72			AD1
PDL2	75	73			AD2
PDL3	76	74			AD3
PDL4	77	75			AD4
PDL5	78	76			AD5/FLMD1
PDL6	79	77			AD6
PDL7	80	78			AD7
PDL8	81	79			AD8
PDL9	82	80			AD9
PDL10	83	81			AD10
PDL11	84	82			AD11
PDL12	85	83			AD12
PDL13	86	84			AD13
PDL14	87	85			AD14
PDL15	88	86			AD15

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(2) Non-port pins

(1/6)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
A0	45	43	Output	Address bus for external memory (when using separate bus) N-ch open-drain output selectable. 5 V tolerant.	P90/KR6/TXDA1/SDA02
A1	46	44			P91/KR7/RXDA1/SCL02
A2	47	45			P92/TIP41/TOP41
A3	48	46			P93/TIP40/TOP40
A4	49	47			P94/TIP31/TOP31
A5	50	48			P95/TIP30/TOP30
A6	51	49			P96/TIP21/TOP21
A7	52	50			P97/SIB1/TIP20/TOP20
A8	53	51			P98/SOB1
A9	54	52			P99/$\overline{\text{SCKB1}}$
A10	55	53			P910/SIB3
A11	56	54			P911/SOB3
A12	57	55			P912/$\overline{\text{SCKB3}}$
A13	58	56			P913/INTP4
A14	59	57			P914/INTP5/TIP51/TOP51
A15	60	58			P915/INTP6/TIP50/TOP50
A16	89	87	Output	Address bus for external memory	PDH0
A17	90	88			PDH1
A18	61	59			PDH2
A19	62	60			PDH3
A20	8	6			PDH4
A21	9	7			PDH5
AD0	73	71	I/O	Address bus/data bus for external memory	PDL0
AD1	74	72			PDL1
AD2	75	73			PDL2
AD3	76	74			PDL3
AD4	77	75			PDL4
AD5	78	76			PDL5/FLMD1
AD6	79	77			PDL6
AD7	80	78			PDL7
AD8	81	79			PDL8
AD9	82	80			PDL9
AD10	83	81			PDL10
AD11	84	82			PDL11
AD12	85	83			PDL12
AD13	86	84			PDL13
AD14	87	85			PDL14
AD15	88	86			PDL15

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(2/6)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
ADTRG	20	18	Input	A/D converter external trigger input. 5 V tolerant.	P03/INTP0
ANI0	2	100	Input	Analog voltage input for A/D converter	P70
ANI1	1	99			P71
ANI2	100	98			P72
ANI3	99	97			P73
ANI4	98	96			P74
ANI5	97	95			P75
ANI6	96	94			P76
ANI7	95	93			P77
ANI8	94	92			P78
ANI9	93	91			P79
ANI10	92	90			P710
ANI11	91	89			P711
ANO0	5	3	Output	Analog voltage output for D/A converter	P10
ANO1	6	4			P11
ASCKA0	29	27	Input	UARTA0 baud rate clock input. 5 V tolerant.	P32/$\overline{\text{SCKB4}}$/TIP00/TOP00
ASTB	70	68	Output	Address strobe signal output for external memory	PCT6
AV$_{REF0}$	3	1	–	Reference voltage input for A/D converter/positive power supply for port 7	–
AV$_{REF1}$	7	5		Reference voltage input for D/A converter/positive power supply for port 1	–
AV$_{SS}$	4	2	–	Ground potential for A/D and D/A converters (same potential as V$_{SS}$)	–
CLKOUT	64	62	Output	Internal system clock output	PCM1
DCK	43	41	Input	Debug clock input. 5 V tolerant.	P54/SOB2/KR4/RTP04
DDI	41	39	Input	Debug data input. 5 V tolerant.	P52/TIQ03/KR2/TOQ03/RTP02
DDO^{Note}	42	40	Output	Debug data output. N-ch open-drain output selectable. 5 V tolerant.	P53/SIB2/KR3/TIQ00/TOQ00/RTP03
DMS	44	42	Input	Debug mode select input. 5 V tolerant.	P55/$\overline{\text{SCKB2}}$/KR5/RTP05
$\overline{\text{DRST}}$	22	20	Input	Debug reset input. 5 V tolerant.	P05/INTP2
EV$_{DD}$	36, 72	34, 70	–	Positive power supply for external (same potential as V$_{DD}$)	–
EV$_{SS}$	35, 71	33, 69	–	Ground potential for external (same potential as V$_{SS}$)	–
FLMD0	10	8	Input	Flash memory programming mode setting pin	–
FLMD1	78	76			PDL5/AD5
$\overline{\text{HLDAK}}$	65	63	Output	Bus hold acknowledge output	PCM2
$\overline{\text{HLDRQ}}$	66	64	Input	Bus hold request input	PCM3

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

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(3/6)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
INTP0	20	18	Input	External interrupt request input (maskable, analog noise elimination). Analog noise elimination or digital noise elimination selectable for INTP3 pin. 5 V tolerant.	P03/ADTRG
INTP1	21	19			P04
INTP2	22	20			P05/$\overline{\text{DRST}}$
INTP3	23	21			P06
INTP4	58	56			P913/A13
INTP5	59	57			P914/A14/TIP51/TOP51
INTP6	60	58			P915/A15/TIP50/TOP50
INTP7	28	26			P31/RXDA0/SIB4
KR0$^{\text{Note 1}}$	39	37	Input	Key interrupt input (on-chip analog noise eliminator). 5 V tolerant.	P50/TIQ01/TOQ01/RTP00
KR1$^{\text{Note 1}}$	40	38			P51/TIQ02/TOQ02/RTP01
KR2$^{\text{Note 1}}$	41	39			P52/TIQ03/TOQ03/RTP02/DDI
KR3$^{\text{Note 1}}$	42	40			P53/SIB2/TIQ00/TOQ00/ RTP03/DDO
KR4$^{\text{Note 1}}$	43	41			P54/SOB2/RTP04/DCK
KR5$^{\text{Note 1}}$	44	42			P55/$\overline{\text{SCKB2}}$/RTP05/DMS
KR6$^{\text{Note 1}}$	45	43			P90/A0/TXDA1/SDA02
KR7$^{\text{Note 1}}$	46	44			P91/A1/RXDA1/SCL02
NMI$^{\text{Note 2}}$	19	17	Input	External interrupt input (non-maskable, analog noise elimination). 5 V tolerant.	P02
$\overline{\text{RD}}$	69	67	Output	Read strobe signal output for external memory	PCT4
REGC	12	10	–	Connection of regulator output stabilization capacitance (4.7 μF (preliminary value))	–
$\overline{\text{RESET}}$	16	14	Input	System reset input	–
RTP00	39	37	Output	Real-time output port. N-ch open-drain output selectable. 5 V tolerant.	P50/TIQ01/KR0/TOQ01
RTP01	40	38			P51/TIQ02/KR1/TOQ02
RTP02	41	39			P52/TIQ03/KR2/TOQ03/DDI
RTP03	42	40			P53/SIB2/KR3/TIQ00/TOQ00/ DDO
RTP04	43	41			P54/SOB2/KR4/DCK
RTP05	44	42			P55/$\overline{\text{SCKB2}}$/KR5/DMS
RXDA0	28	26	Input	Serial receive data input (UARTA0 to UARTA2) 5 V tolerant.	P31/INTP7/SIB4
RXDA1	46	44			P91/A1/KR7/SCL02
RXDA2	38	36			P39/SCL00

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.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(4/6)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
$\overline{\text{SCKB0}}$	26	24	I/O	Serial clock I/O (CSIB0 to CSIB4) N-ch open-drain output selectable. 5 V tolerant.	P42
$\overline{\text{SCKB1}}$	54	52			P99/A9
$\overline{\text{SCKB2}}$	44	42			P55/KR5/RTP05/DMS
$\overline{\text{SCKB3}}$	57	55			P912/A12
$\overline{\text{SCKB4}}$	29	27			P32/ASCKA0/TIP00/TOP00
SCL00	38	36	I/O	Serial clock I/O (I^{2}C00 to I^{2}C02) N-ch open-drain output selectable. 5 V tolerant.	P39/RXDA2
SCL01	25	23			P41/SOB0
SCL02	46	44			P91/A1/KR7/RXDA1
SDA00	37	35	I/O	Serial transmit/receive data I/O (I^{2}C00 to I^{2}C02) N-ch open-drain output selectable. 5 V tolerant.	P38/TXDA2
SDA01	24	22			P40/SIB0
SDA02	45	43			P90/A0/KR6/TXDA1
SIB0	24	22	Input	Serial receive data input (CSIB0 to CSIB4) 5 V tolerant.	P40/SDA01
SIB1	52	50			P97/A7/TIP20/TOP20
SIB2	42	40			P53/KR3/TIQ00/TOQ00/ RTP03/DDO
SIB3	55	53			P910/A10
SIB4	28	26			P31/RXDA0/INTP7
SOB0	25	23	Output	Serial transmit data output (CSIB0 to CSIB4) N-ch open-drain output selectable. 5 V tolerant.	P41/SCL01
SOB1	53	51			P98/A8
SOB2	43	41			P54/KR4/RTP04/DCK
SOB3	56	54			P911/A11
SOB4	27	25			P30/TXDA0

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(5/6)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
TIP00	29	27	Input	External event count input/capture trigger input/external trigger input (TMP0). 5 V tolerant.	P32/ASCKA0/$\overline{\text{SCKB4}}$/TOP00
TIP01	30	28		Capture trigger input (TMP0). 5 V tolerant.	P33/TOP01
TIP10	31	29		External event count input/capture trigger input/external trigger input (TMP1). 5 V tolerant.	P34/TOP10
TIP11	32	30		Capture trigger input (TMP1). 5 V tolerant.	P35/TOP11
TIP20	52	50		External event count input/capture trigger input/external trigger input (TMP2). 5 V tolerant.	P97/A7/SIB1/TOP20
TIP21	51	49		Capture trigger input (TMP2). 5 V tolerant.	P96/A6/TOP21
TIP30	50	48		External event count input/capture trigger input/external trigger input (TMP3). 5 V tolerant.	P95/A5/TOP30
TIP31	49	47		Capture trigger input (TMP3). 5 V tolerant.	P94/A4/TOP31
TIP40	48	46		External event count input/capture trigger input/external trigger input (TMP4). 5 V tolerant.	P93/A3/TOP40
TIP41	47	45		Capture trigger input (TMP4). 5 V tolerant.	P92/A2/TOP41
TIP50	60	58		External event count input/capture trigger input/external trigger input (TMP5). 5 V tolerant.	P915/A15/INTP6/TOP50
TIP51	59	57		Capture trigger input (TMP5). 5 V tolerant.	P914/A14/INTP5/TOP51
TIQ00	42	40		External event count input/capture trigger input/external trigger input (TMQ0). 5 V tolerant.	P53/SIB2/KR3/TOQ00/RTP03/DDO
TIQ01	39	37		Capture trigger input (TMQ0). 5 V tolerant.	P50/KR0/TOQ01/RTP00
TIQ02	40	38			P51/KR1/TOQ02/RTP01
TIQ03	41	39			P52/KR2/TOQ03/RTP02/DDI

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(6/6)

Pin Name	Pin No.		I/O	Function	Alternate Function
	GF	GC			
TOP00	29	27	Output	Timer output (TMP0) N-ch open-drain output selectable. 5 V tolerant.	P32/ASCKA0/$\overline{\text{SCKB4}}$/TIP00
TOP01	30	28			P33/TIP01
TOP10	31	29		Timer output (TMP1) N-ch open-drain output selectable. 5 V tolerant.	P34/TIP10
TOP11	32	30			P35/TIP11
TOP20	52	50		Timer output (TMP2) N-ch open-drain output selectable. 5 V tolerant.	P97/A7/SIB1/TIP20
TOP21	51	49			P96/A6/TIP21
TOP30	50	48		Timer output (TMP3) N-ch open-drain output selectable. 5 V tolerant.	P95/A5/TIP30
TOP31	49	47			P94/A4/TIP31
TOP40	48	46		Timer output (TMP4) N-ch open-drain output selectable. 5 V tolerant.	P93/A3/TIP40
TOP41	47	45			P92/A2/TIP41
TOP50	60	58		Timer output (TMP5) N-ch open-drain output selectable. 5 V tolerant.	P915/A15/INTP6/TIP50
TOP51	59	57			P914/A14/INTP5/TIP51
TOQ00	42	40	Output	Timer output (TMQ0) N-ch open-drain output selectable. 5 V tolerant.	P53/SIB2/KR3/TIQ00/RTP03/DDO
TOQ01	39	37			P50/TIQ01/KR0/RTP00
TOQ02	40	38			P51/TIQ02/KR1/RTP01
TOQ03	41	39			P52/TIQ03/KR2/RTP02/DDI
TXDA0	27	25	Output	Serial transmit data output (UARTA0 to UARTA2) N-ch open-drain output selectable. 5 V tolerant.	P30/SOB4
TXDA1	45	43			P90/A0/KR6/SDA02
TXDA2	37	35			P38/SDA00
V_{DD}	11	9	–	Positive power supply pin for internal	–
V_{SS}	13	11	–	Ground potential for internal	–
$\overline{\text{WAIT}}$	63	61	Input	External wait input	PCM0
$\overline{\text{WR0}}$	67	65	Output	Write strobe for external memory (lower 8 bits)	PCT0
$\overline{\text{WR1}}$	68	66		Write strove for external memory (higher 8 bits)	PCT1
X1	14	12	Input	Connection of resonator for main clock	–
X2	15	13	–		–
XT1	17	15	Input	Connection of resonator for subclock	–
XT2	18	16	–		–

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

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[Note 1]	During Reset (Except When Power Is Turned On)	HALT Mode[Note 2]	IDLE1, IDLE2, Sub-IDLE Mode[Note 2]	STOP Mode[Note 2]	Idle State[Note 3]	Bus Hold
P05/$\overline{\text{DRST}}$	Pulled down	Pulled down[Note 4]	Held	Held	Held	Held	Held
P10/ANO0, P11/ANO1	Undefined	Hi-Z	Held	Held	Hi-Z	Held	Held
P53/DDO		Hi-Z[Note 5]	Held	Held	Held	Held	Held
AD0 to AD15	Hi-Z[Note 6]	Hi-Z[Note 6]	**Notes 7, 8**	Hi-Z	Hi-Z	Held	Hi-Z
A0 to A15			Undefined[Notes 7, 9]				
A16 to A21			Undefined[Note 7]				
$\overline{\text{WAIT}}$			–	–	–	–	–
CLKOUT			Operating	L	L	Operating	Operating
$\overline{\text{WR0}}$, $\overline{\text{WR1}}$			H[Note 7]	H	H	H	Hi-Z
$\overline{\text{RD}}$							
ASTB							
$\overline{\text{HLDAK}}$			Operating[Note 7]				L
$\overline{\text{HLDRQ}}$				–	–	–	Operating
Other port pins	Hi-Z	Hi-Z	Held	Held	Held	Held	Held

Notes 1. Duration until 1 ms elapses after the supply voltage reaches the operating supply voltage range (lower limit) when the power is turned on.

2. Operates while an alternate function is operating.

3. 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.

4. 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.

5. DDO output is specified in the on-chip debug mode.

6. The bus control pins function alternately as port pins, so they are initialized to the input mode (port mode).

7. Operates even in the HALT mode, during DMA operation.

8. In separate bus mode: Hi-Z
In multiplexed bus mode: Undefined

9. 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
		GF	GC		
P02	NMI	19	17	10-D	Input: Independently connect to EV_{DD} or EV_{SS} via a resistor. Output: Leave open.
P03	INTP0/ADTRG	20	18		
P04	INTP1	21	19		
P05	INTP2/$\overline{\text{DRST}}$	22	20	10-N	Input: Independently connect to EV_{SS} via a resistor. Fixing to V_{DD} level is prohibited. Output: Leave open. Internally pull-down after reset by $\overline{\text{RESET}}$ pin.
P06	INTP3	23	21	10-D	Input: Independently connect to EV_{DD} or EV_{SS} via a resistor. Output: Leave open.
P10, P11	ANO0, ANO1	5, 6	3, 4	12-D	Input: Independently connect to AV_{REF1} or AV_{SS} via a resistor. Output: Leave open.
P30	TXDA0/SOB4	27	25	10-G	Input: Independently connect to EV_{DD} or EV_{SS} via a resistor. Output: Leave open.
P31	RXDA0/INTP7/SIB4	28	26	10-D	
P32	ASCKA0/$\overline{\text{SCKB4}}$/TIP00	29	27		
P33	TIP01/TOP01	30	28		
P34	TIP10/TOP10	31	29		
P35	TIP11/TOP11	32	30		
P36	–	33	31	10-G	
P37	–	34	32		
P38	TXDA2/SDA00	37	35	10-D	
P39	RXDA2/SCL00	38	36		
P40	SIB0/SDA01	24	22		
P41	SOB0/SCL01	25	23		
P42	$\overline{\text{SCKB0}}$	26	24		
P50	TIQ01/KR0/TOQ01/RTP00	39	37		
P51	TIQ02/KR1/TOQ02/RTP01	40	38		
P52	TIQ03/KR2/TOQ03/RTP02/DDI	41	39		
P53	SIB2/KR3/TIQ00/TOQ00/RTP03/DDO	42	40		
P54	SOB2/KR4/RTP04/DCK	43	41		
P55	$\overline{\text{SCKB2}}$/KR5/RTP05/DMS	44	42		
P70 to P711	ANI0 to ANI11	2, 1, 100-91	100-89	11-G	Input: Independently connect to AV_{REF0} or AV_{SS} via a resistor. Output: Leave open.

Remark GF: 100-pin plastic LQFP (14 × 20)

GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(2/3)

Pin	Alternate Function	Pin No.		I/O Circuit Type	Recommended Connection
		GF	GC		
P90	A0/KR6/TXDA1/SDA02	45	43	10-D	Input: Independently connect to EV$_{DD}$ or EV$_{SS}$ via a resistor. Output: Leave open.
P91	A1/KR7/RXDA1/SCL02	46	44		
P92	A2/TIP41/TOP41	47	45		
P93	A3/TIP40/TOP40	48	46		
P94	A4/TIP31/TOP31	49	47		
P95	A5/TIP30/TOP30	50	48		
P96	A6/TIP21/TOP21	51	49		
P97	A7/SIB1/TIP20/TOP20	52	50		
P98	A8/SOB1	53	51	10-G	
P99	A9/$\overline{\text{SCKB1}}$	54	52	10-D	
P910	A10/SIB3	55	53		
P911	A11/SOB3	56	54	10-G	
P912	A12/$\overline{\text{SCKB3}}$	57	55	10-D	
P913	A13/INTP4	58	56		
P914	A14/INTP5/TIP51/TOP51	59	57		
P915	A15/INTP6/TIP50/TOP50	60	58		
PCM0	$\overline{\text{WAIT}}$	63	61	5	
PCM1	CLKOUT	64	62		
PCM2	$\overline{\text{HLDAK}}$	65	63		
PCM3	$\overline{\text{HLDRQ}}$	66	64		
PCT0, PCT1	$\overline{\text{WR0}}$, $\overline{\text{WR1}}$	67, 68	65, 66		
PCT4	$\overline{\text{RD}}$	69	67		
PCT6	ASTB	70	68		
PDH0 to PDH3	A16 to A19	89, 90 61, 62	87, 88 59, 60		
PDH4, PDH5	A20, A21	8, 9	6, 7		
PDL0 to PDL4	AD0 to AD4	73-77	71-75		
PDL5	AD5/FLMD1	78	76		
PDL6 to PDL15	AD6 to AD15	79-88	77-86		

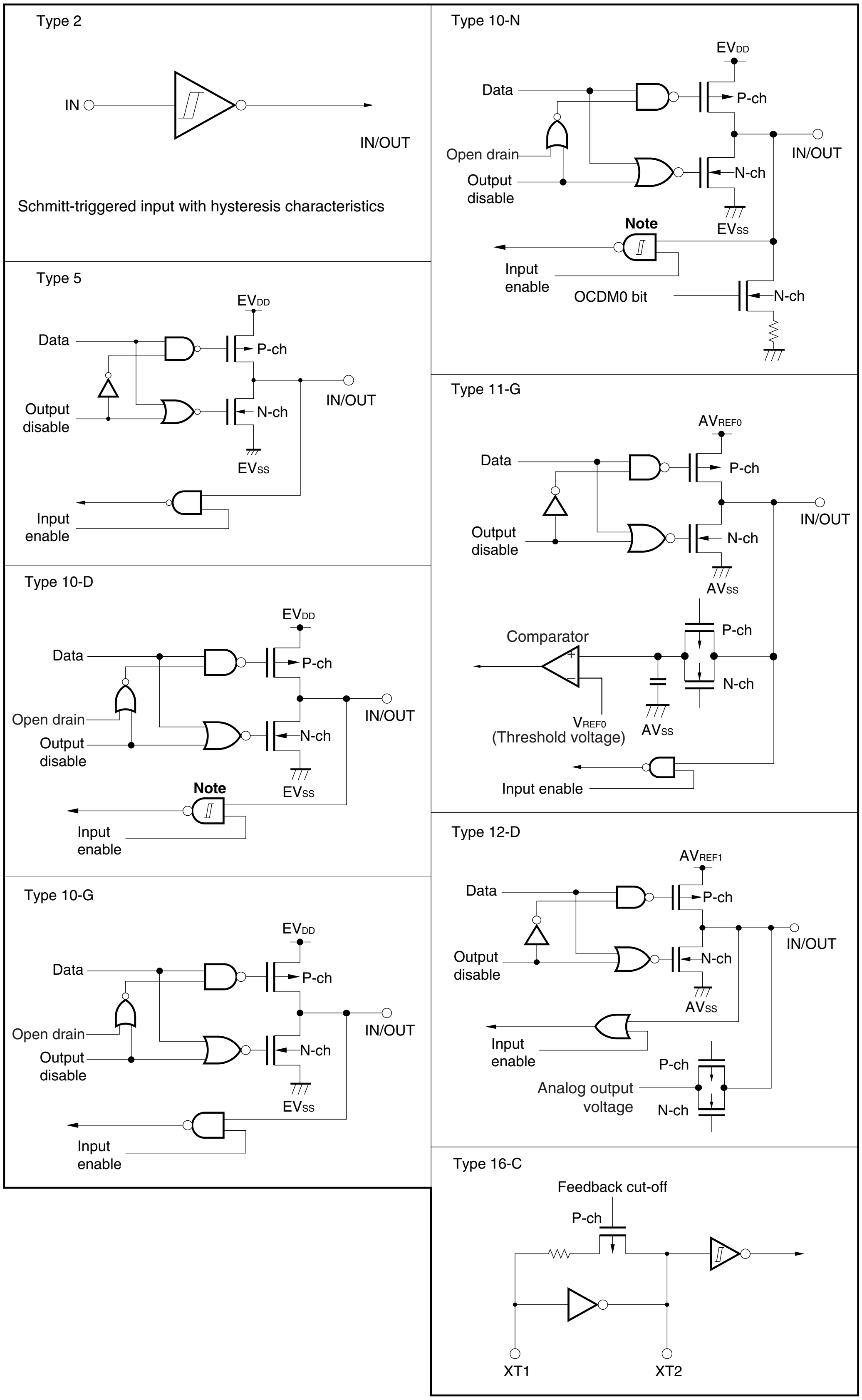
Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(3/3)

Pin	Alternate Function	Pin No.		I/O Circuit Type	Recommended Connection
		GF	GC		
AV_{REF0}	–	3	1	–	Directly connect to V_{DD} and always supply power.
AV_{REF1}	–	7	5	–	Directly connect to V_{DD} and always supply power.
AV_{SS}	–	4	2	–	Directly connect to V_{SS} and always supply power.
EV_{DD}	–	36, 72	34, 70	–	Directly connect to V_{DD} and always supply power.
EV_{SS}	–	35, 71	33, 69	–	Directly connect to V_{SS} and always supply power.
FLMD0	–	10	8	–	Directly connect to V_{SS} in a mode other than the flash memory programming mode.
REGC	–	12	10	–	Connect regulator output stabilization capacitance (4.7 μF (preliminary value)).
$\overline{\text{RESET}}$	–	16	14	2	–
V_{DD}	–	11	9	–	–
V_{SS}	–	13	11	–	–
X1	–	14	12	–	–
X2	–	15	13	–	–
XT1	–	17	15	16-C	Connect to V_{SS}.
XT2	–	18	16	16-C	Leave open.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

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 pins may output an undefined level temporarily even during reset.

- P10/ANO0 pin
- P11/ANO1 pin
- P53/SIB2/KR3/TIQ00/TOQ00/RTP03/DDO pin

CHAPTER 3 CPU FUNCTION

The CPU of the V850ES/JG3-L is based on RISC architecture and executes almost all instructions with one clock by using a 5-stage pipeline.

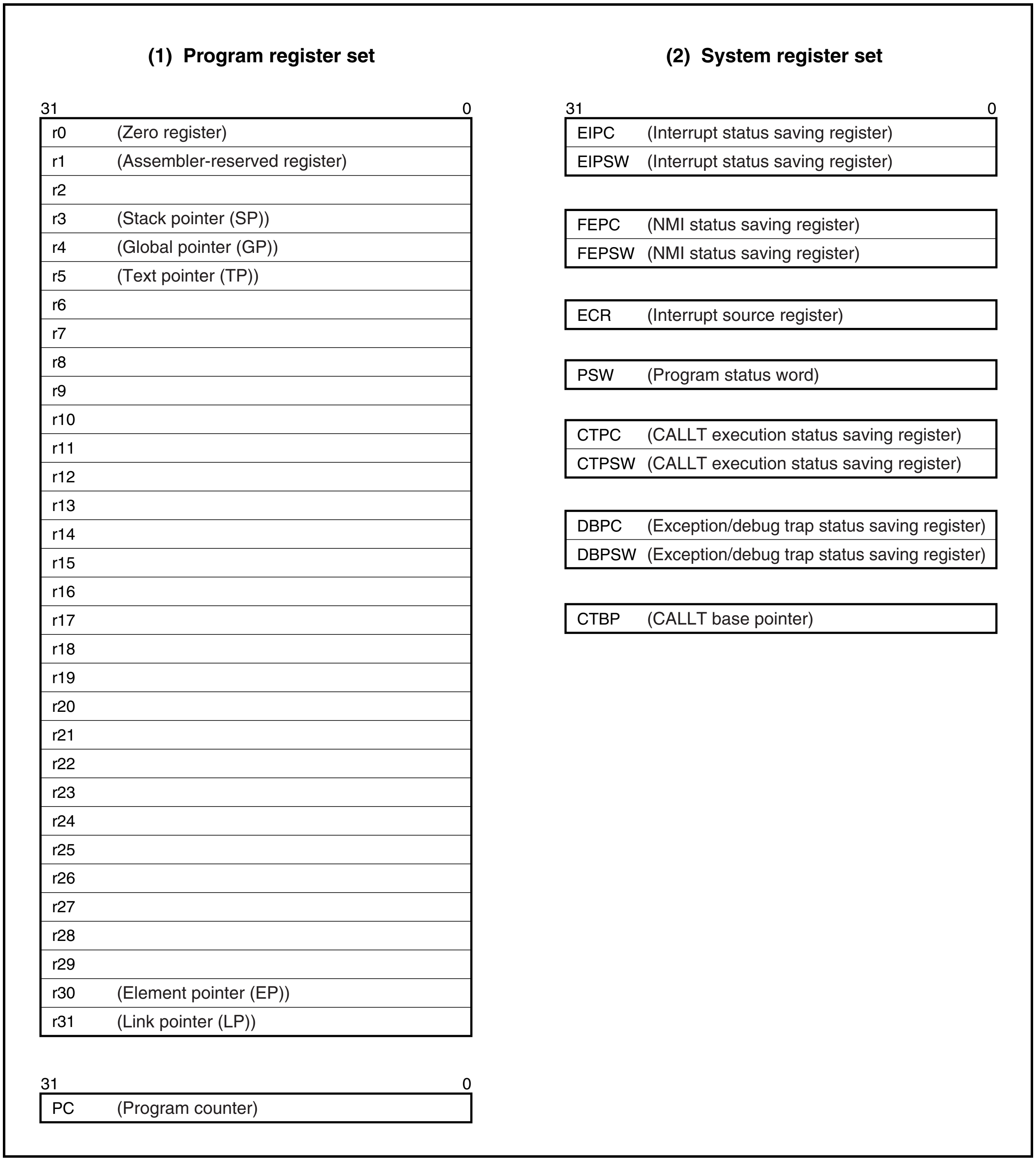
3.1 Features

- Minimum instruction execution time: 50 ns (operating with main clock (f_{XX}) of 20 MHz: V_{DD} = 2.7 to 3.6 V)
  200 ns (operating with main clock (f_{XX}) of 5 MHz: V_{DD} = 2.2 to 3.6 V)
  30.5 μs (operating with subclock (f_{XT}) of 32.768 kHz)
- Memory space Program (physical address) space: 64 MB linear
  Data (logical address) space: 4 GB linear
- General-purpose registers: 32 bits × 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/JG3-L 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**.



(1) Program register set

31 0

r0	(Zero register)
r1	(Assembler-reserved register)
r2	
r3	(Stack pointer (SP))
r4	(Global pointer (GP))
r5	(Text pointer (TP))
r6	
r7	
r8	
r9	
r10	
r11	
r12	
r13	
r14	
r15	
r16	
r17	
r18	
r19	
r20	
r21	
r22	
r23	
r24	
r25	
r26	
r27	
r28	
r29	
r30	(Element pointer (EP))
r31	(Link pointer (LP))

31 0

PC	(Program counter)

(2) System register set

31 0

EIPC	(Interrupt status saving register)
EIPSW	(Interrupt status saving register)

FEPC	(NMI status saving register)
FEPSW	(NMI status saving register)

ECR	(Interrupt source register)

PSW	(Program status word)

CTPC	(CALLT execution status saving register)
CTPSW	(CALLT execution status saving register)

DBPC	(Exception/debug trap status saving register)
DBPSW	(Exception/debug trap status saving register)

CTBP	(CALLT base pointer)

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

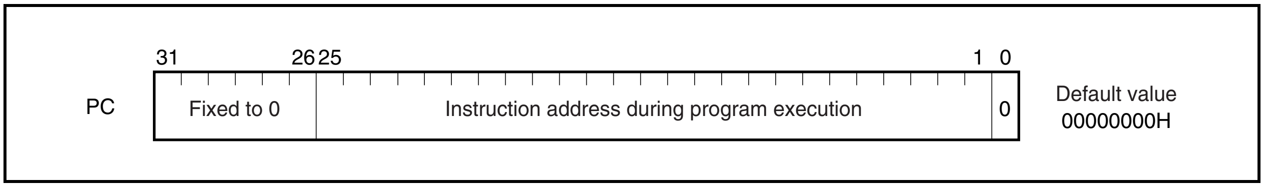
Name	Usage	Operation
r0	Zero register	Always holds 0.
r1	Assembler-reserved register	Used as working register to create 32-bit immediate data
r2	Register for address/data variable (if real-time OS does not use r2)	
r3	Stack pointer	Used to create a stack frame when a function is called
r4	Global pointer	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 32 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)[Note 1]	√	√
1	Interrupt status saving register (EIPSW)[Note 1]	√	√
2	NMI status saving register (FEPC)[Note 1]	√	√
3	NMI status saving register (FEPSW)[Note 1]	√	√
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)	√[Note 2]	√[Note 2]
19	Exception/debug trap status saving register (DBPSW)	√[Note 2]	√[Note 2]
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 DBRET instruction execution.

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).

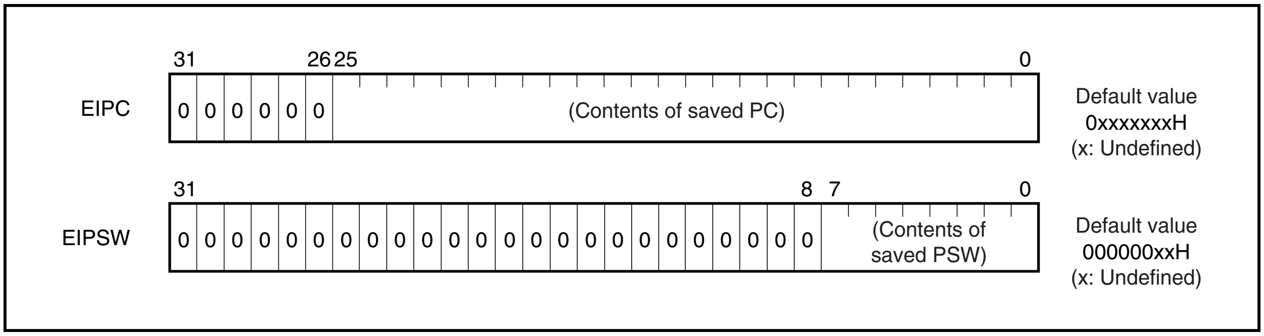
The address of the instruction next to the instruction under execution, except some instructions (see **19.8 Periods in Which Interrupts Are Not Acknowledged by CPU**), is saved to EIPC when a software exception or a maskable interrupt occurs.

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.

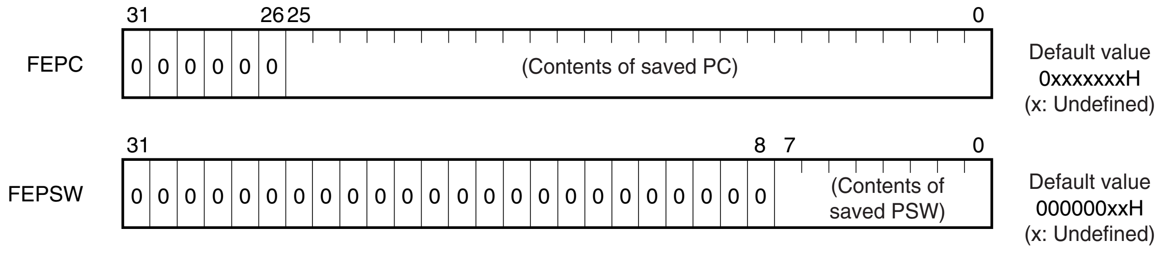
The address of the instruction next to the one of the instruction under execution, except some instructions, is saved to FEPC when an NMI occurs.

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.

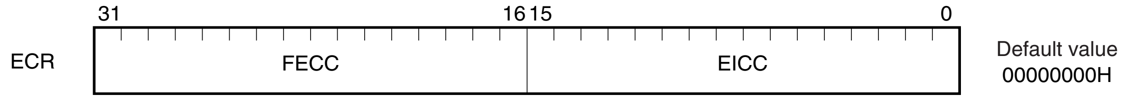
Bits 31 to 26 of FEPC and bits 31 to 8 of FEPSW are reserved for future function expansion (these bits are always fixed to 0).

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.



Bit position	Bit name	Meaning
31 to 16	FECC	Exception code of non-maskable interrupt (NMI)
15 to 0	EICC	Exception code of exception or maskable interrupt

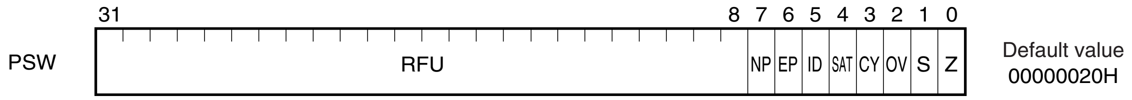
(4) Program status word (PSW)

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. 0: NMI is not being serviced. 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. 0: Exception is not being processed. 1: Exception is being processed.
5	ID	Indicates whether a maskable interrupt can be acknowledged. 0: Interrupt enabled 1: Interrupt disabled
4	SAT^{Note}	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. 0: Not saturated 1: Saturated
3	CY	Indicates whether a carry or a borrow occurs as a result of an operation. 0: Carry or borrow does not occur. 1: Carry or borrow occurs.
2	OV^{Note}	Indicates whether an overflow occurs during operation. 0: Overflow does not occur. 1: Overflow occurs.
1	S^{Note}	Indicates whether the result of an operation is negative. 0: The result is positive or 0. 1: The result is negative.
0	Z	Indicates whether the result of an operation is 0. 0: The result is not 0. 1: The result is 0.

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

(2/2)

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)

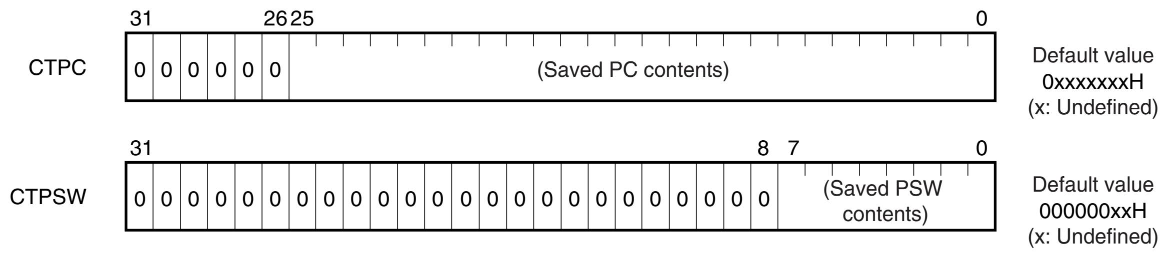
CTPC and CTPSW are CALLT execution status saving registers.

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.

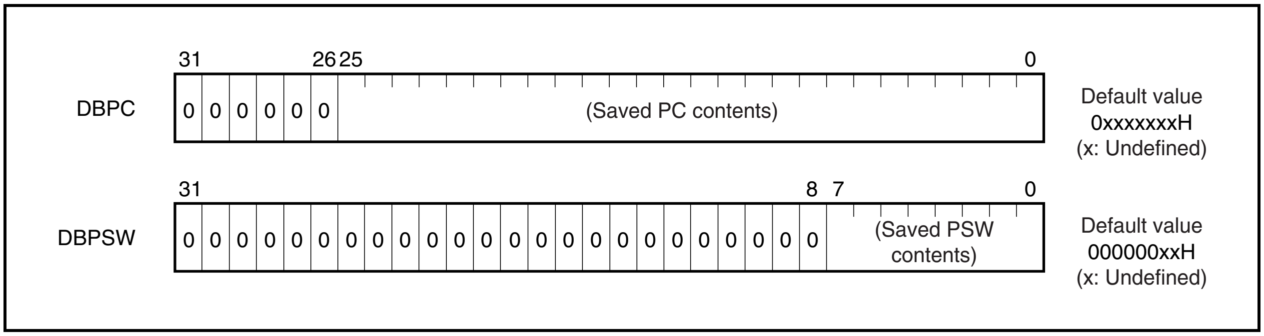
The contents to be saved to DBPC are the address of the instruction next to the one that is being executed when an exception trap or debug trap occurs.

The current contents of the PSW are saved to DBPSW.

This register 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).

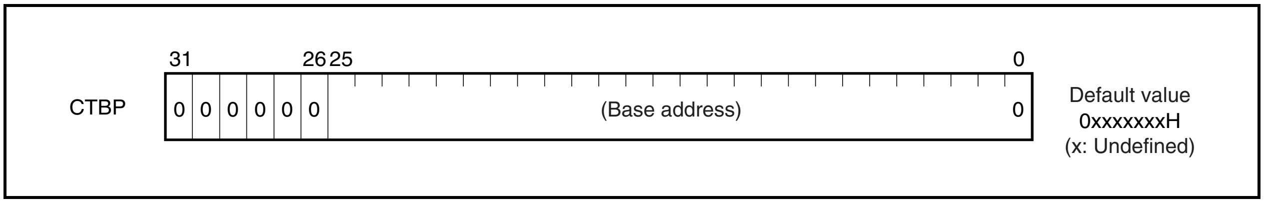
The value of DBPC is restored to the PC and the value of DBPSW to the PSW by the DBRET instruction.



(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/JG3-L 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/JG3-L is provided with an on-chip debug function that employs the JTAG (Joint Test Action Group) communication specifications.
For details, see **CHAPTER 29 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, make sure that a low level is input 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

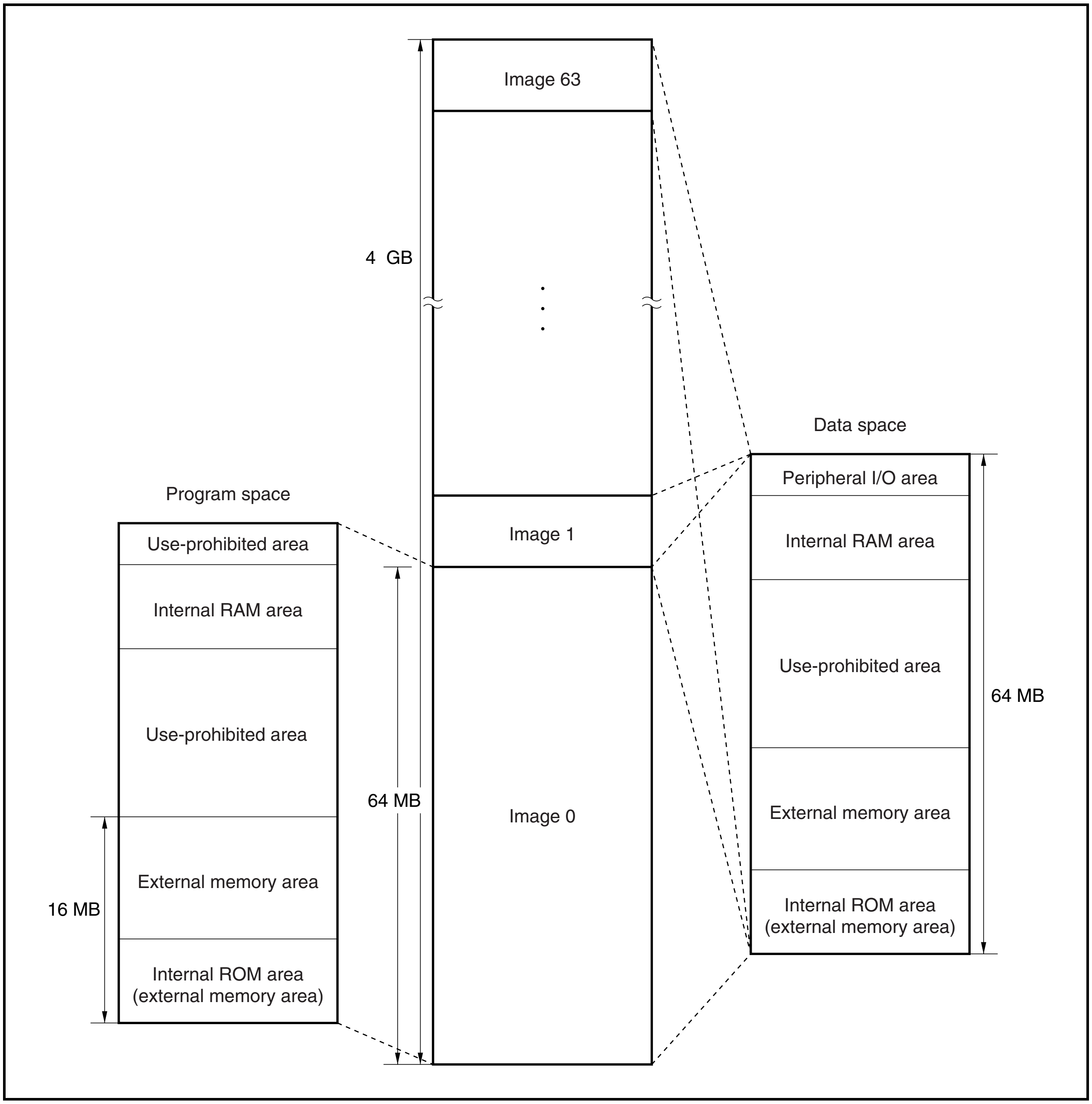
Remark L: Low-level input
H: High-level input
×: Don’t care

3.4 Address Space

3.4.1 CPU address space

For instruction addressing, up to a combined total of 16 MB of external memory area and 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



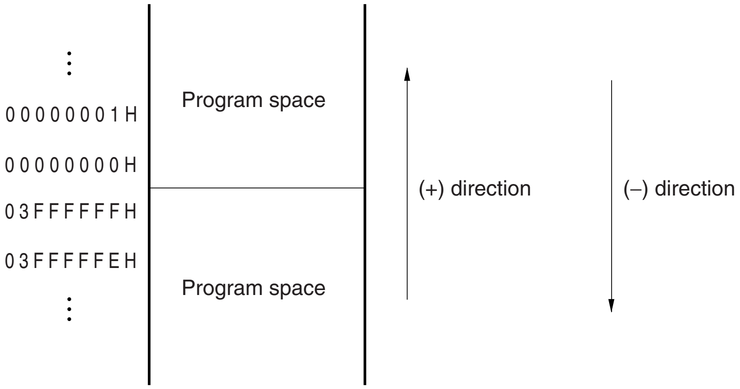
3.4.2 Wraparound of CPU address space

(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.

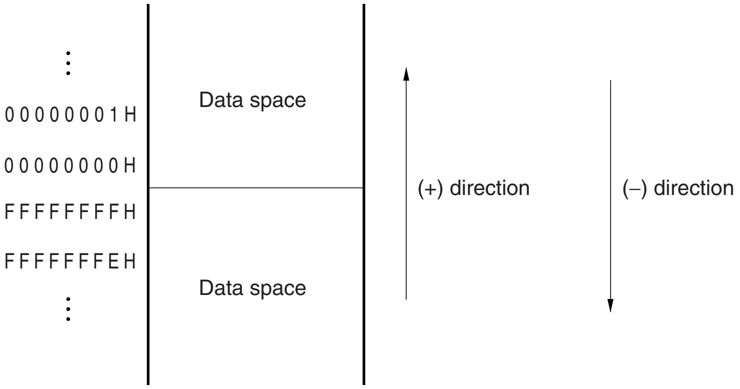
Caution Because the 4 KB area of addresses 03FFF000H to 03FFFFFFH is an on-chip peripheral I/O area, instructions cannot be fetched from this area. Therefore, do not execute an operation in which the result of a branch address calculation affects this area.



(2) Data space

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

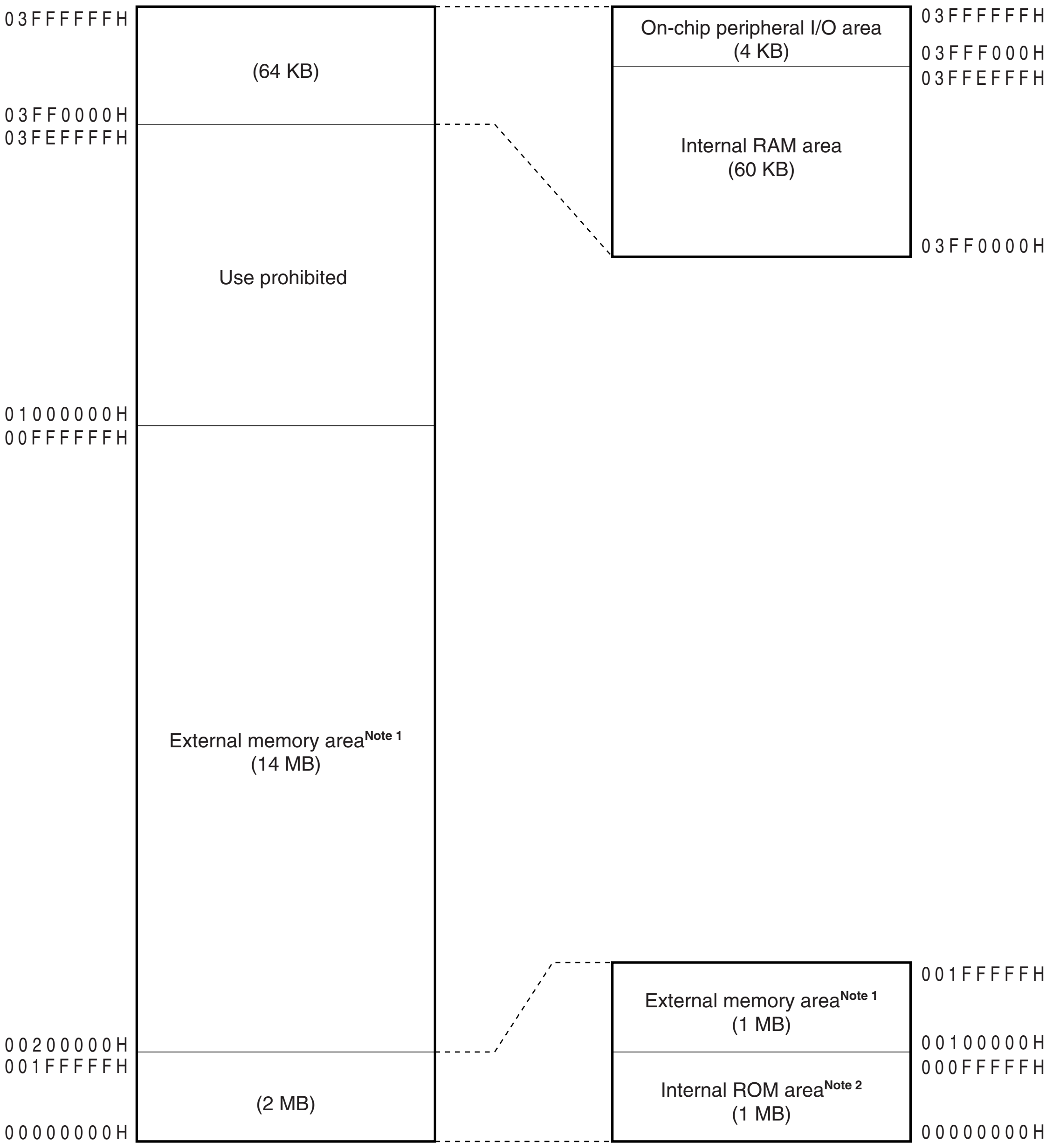
Therefore, the highest address of the data space, FFFFFFFFH, and the lowest address, 00000000H, are contiguous, and wraparound occurs at the boundary of these addresses.



3.4.3 Memory map

The areas shown below are reserved in the V850ES/JG3-L.

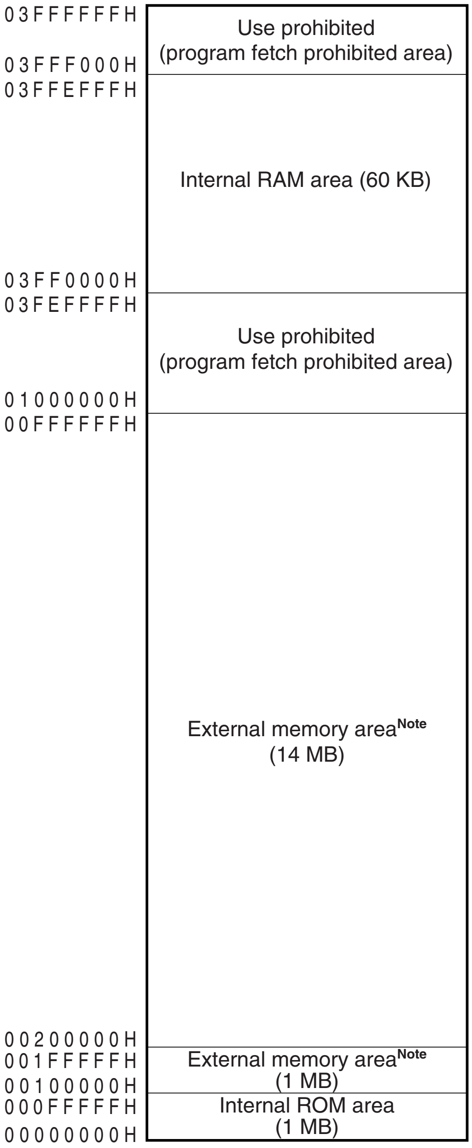
Figure 3-2. Data Memory Map (Physical Addresses)



Notes 1. The V850ES/JG3-L has 22 address pins, so the external memory area appears as a repeated 4 MB image.

2. Fetch access and read access to addresses 00000000H to 000FFFFFH is made to the internal ROM area. However, data write access to these addresses is made to the external memory area.

Figure 3-3. Program Memory Map



Note The V850ES/JG3-L has 22 address pins, so the external memory area appears as a repeated 4 MB image.

3.4.4 Areas

(1) Internal ROM area

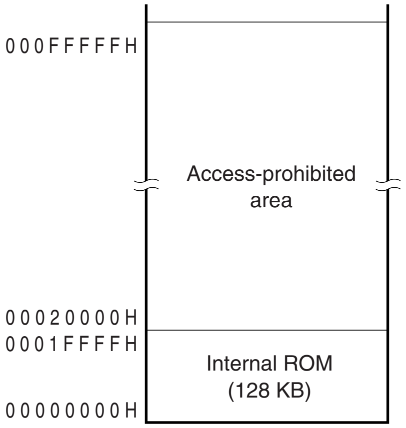
Up to 1 MB is reserved as an internal ROM area.

(a) Internal ROM (128 KB)

128 KB are allocated to addresses 00000000H to 0001FFFFH in the μPD70F3737.

Accessing addresses 00020000H to 000FFFFFH is prohibited.

Figure 3-4. Internal ROM Area (128 KB)

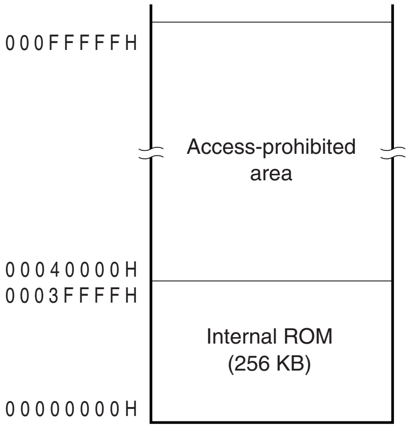


(b) Internal ROM (256 KB)

256 KB are allocated to addresses 00000000H to 0003FFFFH in the μPD70F3738.

Accessing addresses 00040000H to 000FFFFFH is prohibited.

Figure 3-5. Internal ROM Area (256 KB)



(2) Internal RAM area

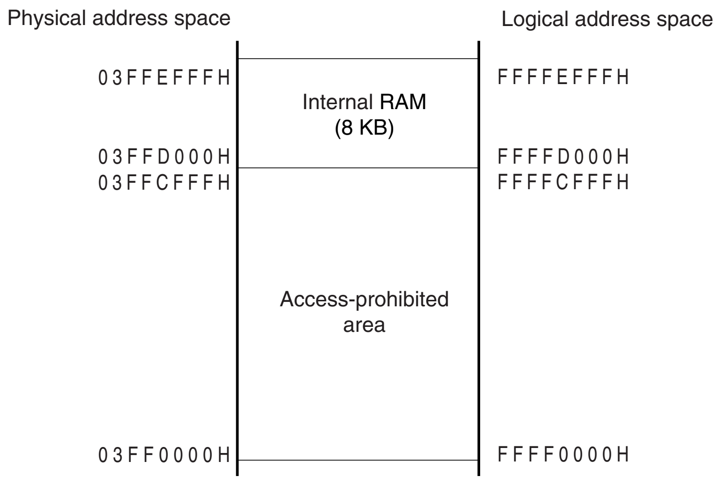
Up to 60 KB are reserved as the internal RAM area.

(a) Internal RAM (8 KB)

8 KB are allocated to addresses 03FFD000H to 03FFEFFFH of the μPD70F3737.

Accessing addresses 03FF0000H to 03FFCFFFH is prohibited.

Figure 3-6. Internal RAM Area (8 KB)

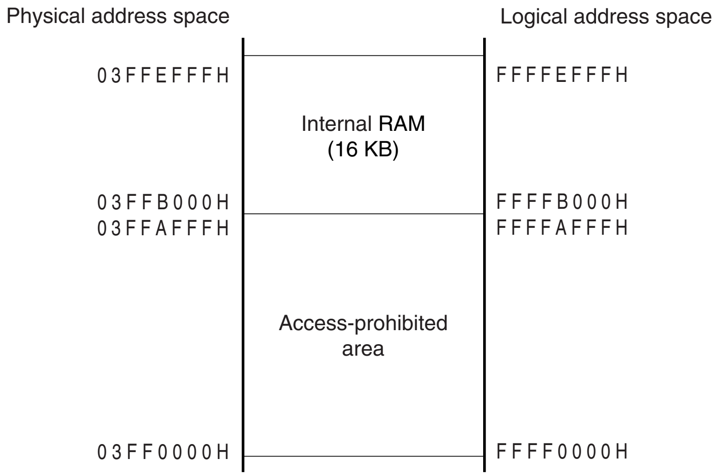


(b) Internal RAM (16 KB)

16 KB are allocated to addresses 03FFB000H to 03FFEFFFH of the μPD70F3738.

Accessing addresses 03FF0000H to 03FFAFFFH is prohibited.

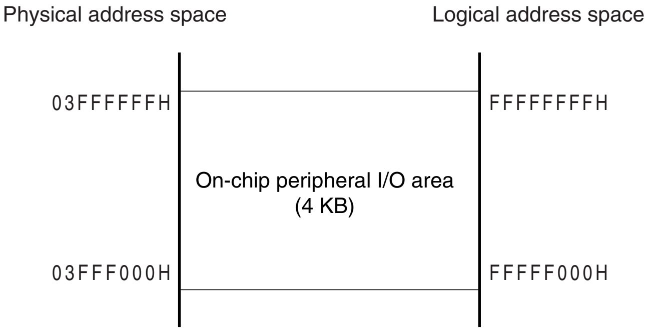
Figure 3-7. Internal RAM Area (16 KB)



(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 3-8. 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. The internal ROM/RAM area and on-chip peripheral I/O area are assigned to successive addresses.

When accessing the internal ROM/RAM area by incrementing or decrementing addresses using a pointer operation or such, be careful not to access the on-chip peripheral I/O area by mistakenly extending over the internal ROM/RAM area boundary.

(4) External memory area

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

Caution The V850ES/JG3-L has 22 address pins (A0 to A21), so the external memory area appears as a repeated 4 MB image.

3.4.5 Recommended use of address space

The architecture of the V850ES/JG3-L 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 ±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
16 KB	03FFB000H to 03FFEFFFH
8 KB	03FFD000H to 03FFEFFFH

(2) Data space

With the V850ES/JG3-L, 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 ±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: μPD70F3738

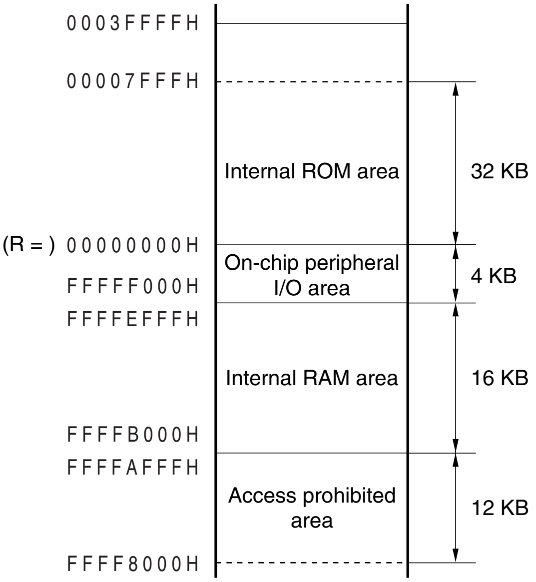
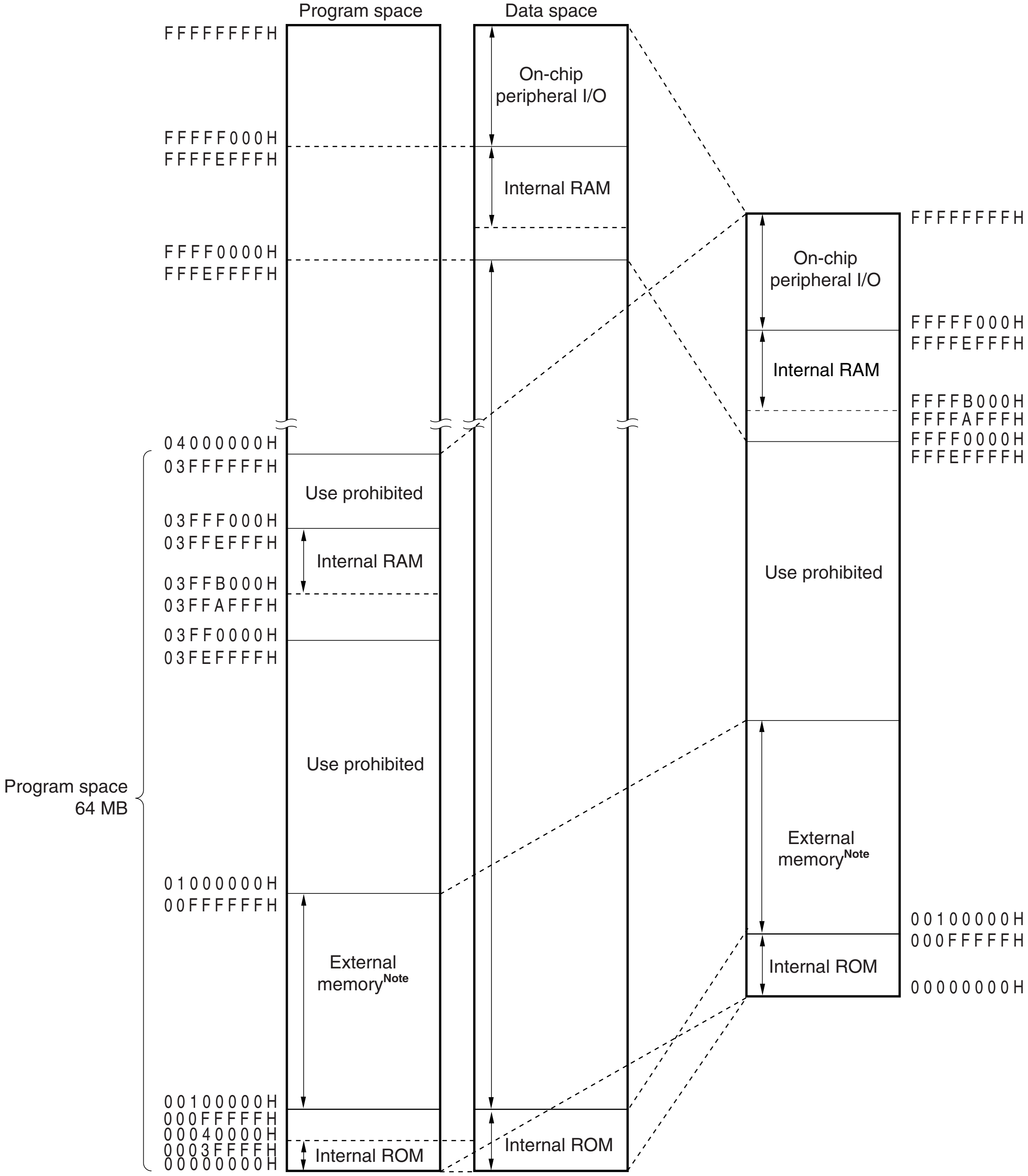


Figure 3-9. Recommended Memory Map



Note The V850ES/JG3-L has 22 address pins, so the external memory area appears as a repeated 4 MB image.

Remarks 1. ↕ indicates the recommended area.

2. This figure is the recommended memory map of the μPD70F3738.

3.4.6 Peripheral I/O registers

(1/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF004H	Port DL register	PDL	R/W			√	0000H[Note]
FFFFF004H	Port DL register L	PDLL		√	√		00H[Note]
FFFFF005H	Port DL register H	PDLH		√	√		00H[Note]
FFFFF006H	Port DH register	PDH		√	√		00H[Note]
FFFFF00AH	Port CT register	PCT		√	√		00H[Note]
FFFFF00CH	Port CM register	PCM		√	√		00H[Note]
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
FFFFF02AH	Port CT mode register	PMCT		√	√		FFH
FFFFF02CH	Port CM mode register	PMCM		√	√		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
FFFFF04AH	Port CT mode control register	PMCCT		√	√		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
FFFFF0C2H	DMA transfer count register 1	DBC1				√	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

Note The output latch is 00H or 0000H. When these registers are in the input mode, the pin statuses are read.

(2/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF0D2H	DMA addressing control register 1	DADC1	R/W			√	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
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
FFFFF132H	Interrupt control register	TP1OVIC		√	√		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

(3/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF140H	Interrupt control register	TP3CCIC0	R/W	√	√		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
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

(4/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF214H	A/D conversion result register 2	ADA0CR2	R			√	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
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
FFFFF331H	Regulator protection register	REGPR			√		00H
FFFFF332H	Regulator output voltage level control register	REGOVL0			√		00H
FFFFF340H	IIC division clock select register	OCKS0			√		00H
FFFFF344H	IIC division clock select register	OCKS1			√		00H
FFFFF400H	Port 0 register	P0		√	√		00H[Note]
FFFFF402H	Port 1 register	P1		√	√		00H[Note]
FFFFF406H	Port 3 register	P3				√	0000H[Note]
FFFFF406H	Port 3 register L	P3L		√	√		00H[Note]
FFFFF407H	Port 3 register H	P3H		√	√		00H[Note]
FFFFF408H	Port 4 register	P4		√	√		00H[Note]

Note The output latch is 00H or 0000H. When these registers are input, the pin statuses are read.

(5/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF40AH	Port 5 register	P5	R/W	√	√		00H[Note]
FFFFF40EH	Port 7 register L	P7L		√	√		00H[Note]
FFFFF40FH	Port 7 register H	P7H		√	√		00H[Note]
FFFFF412H	Port 9 register	P9				√	0000H[Note]
FFFFF412H	Port 9 register L	P9L		√	√		00H[Note]
FFFFF413H	Port 9 register H	P9H		√	√		00H[Note]
FFFFF420H	Port 0 mode register	PM0		√	√		FFH
FFFFF422H	Port 1 mode register	PM1		√	√		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
FFFFF42EH	Port 7 mode register L	PM7L		√	√		FFH
FFFFF42FH	Port 7 mode register H	PM7H		√	√		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
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
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
FFFFF540H	TMQ0 control register 0	TQ0CTL0		√	√		00H
FFFFF541H	TMQ0 control register 1	TQ0CTL1		√	√		00H
FFFFF542H	TMQ0 I/O control register 0	TQ0IOC0		√	√		00H

Note The output latch is 00H or 0000H. When these registers are input, the pin statuses are read.

(6/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF543H	TMQ0 I/O control register 1	TQ0IOC1	R/W	√	√		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
FFFFF5C5H	TMP3 option register 0	TP3OPT0		√	√		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

(7/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
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
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
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

(8/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFF82CH	PLL control register	PLLCTL	R/W	√	√		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
FFFFF891H	Low-voltage detection level select register	LVIS			√		00H
FFFFF8B0H	Prescaler mode register 0	PRSM0		√	√		00H
FFFFF8B1H	Prescaler compare register 0	PRSCM0			√		00H
FFFFF9FCH	On-chip debug mode register	OCDM		√	√		01H
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		√		FFH
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		√		FFH
FFFFFA27H	UARTA2 transmit data register	UA2TX	R/W		√		FFH
FFFFFC00H	External interrupt falling edge specification register 0	INTF0		√	√		00H
FFFFFC06H	External interrupt falling edge specification register 3	INTF3		√	√		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
FFFFFC33H	External interrupt rising edge specification register 9H	INTR9H		√	√		00H
FFFFFC60H	Port 0 function register	PF0		√	√		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

(9/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
FFFFFC72H	Port 9 function register	PF9	R/W			√	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
FFFFFD36H	CSIB3 transmit data register	CB3TX	R/W			√	0000H
FFFFFD36H	CSIB3 transmit data register L	CB3TXL			√		00H
FFFFFD40H	CSIB4 control register 0	CB4CTL0		√	√		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

(10/10)

Address	Function Register Name	Symbol	R/W	Manipulatable Bits			Default Value
				1	8	16	
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
FFFFFDAAH	IIC flag register 2	IICF2	R/W	√	√		00H
FFFFFDBEH	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/JG3-L has the following seven 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)
- 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).)[Note]
<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).

After reset: Undefined W Address: FFFFF1FCH

	7	6	5	4	3	2	1	0
PRCMD	REG7	REG6	REG5	REG4	REG3	REG2	REG1	REG0

(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/JG3-L.

- 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/JG3-L 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 kHz ≤ f_{CLK} < 16.6 MHz	00H	0 (no waits)
16.6 MHz ≤ f_{CLK} ≤ 20 MHz	01H	1

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

For details, see **CHAPTER 29 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, see **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 status. If this wait status 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) (n = 0 to 5)	TPnCNT	Read	1 or 2
	TPnCCR0, TPnCCR1	Write	• 1st access: No wait • Continuous write: 3 or 4
		Read	1 or 2
16-bit timer/event counter Q (TMQ)	TQ0CNT	Read	1 or 2
	TQ0CCR0 to TQ0CCR3	Write	• 1st access: No wait • Continuous write: 3 or 4
		Read	1 or 2
Watchdog timer 2 (WDT2)	WDTM2	Write (when WDT2 operating)	3
Real-time output function (RTO)	RTBL0, RTBH0	Write (RTPC0.RTPOE0 bit = 0)	1
A/D converter	ADA0M0	Read	1 or 2
	ADA0CR0 to ADA0CR11	Read	1 or 2
	ADA0CR0H to ADA0CR11H	Read	1 or 2
I^2C00 to I^2C02	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) 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
satadd reg1, reg2
and reg1, reg2
add reg1, reg2
mulh reg1, reg2
not reg1, reg2
satadd imm5, reg2
tst reg1, reg2
add imm5, reg2
shr imm5, reg2
satsubr reg1, reg2
or reg1, reg2
subr reg1, reg2
cmp reg1, reg2
sar imm5, reg2
satsub reg1, reg2
xor reg1, reg2
sub reg1, reg2
cmp imm5, reg2
shl imm5, reg2

<Example>

<i> ld.w [r11], r10
•
•
•
<ii> mov r10, r28
<iii> sld.w 0x28, 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.

(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> For 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

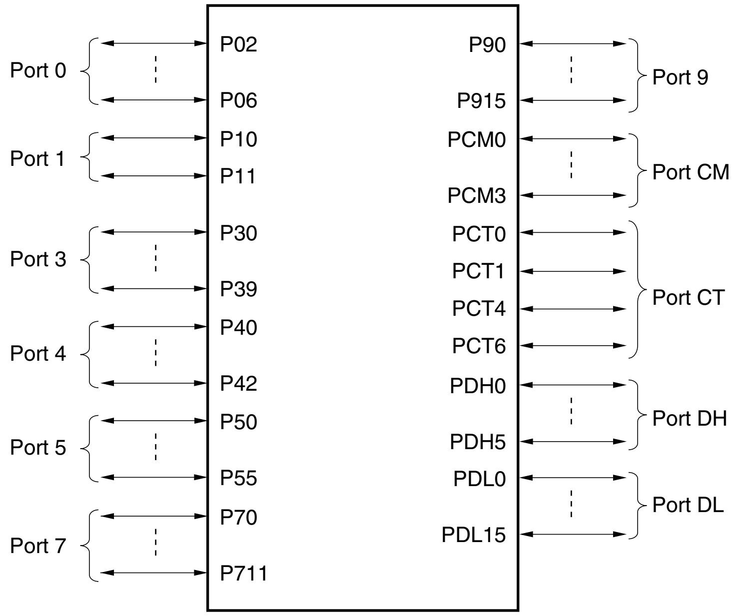
○ I/O ports: 84
  - 5 V tolerant/N-ch open-drain output selectable: 31 (ports 0, 3 to 5, 9 (P90 to P96))

○ Input/output specifiable in 1-bit units

4.2 Basic Port Configuration

The V850ES/JG3-L features a total of 84 I/O ports consisting of ports 0, 1, 3 to 5, 7, 9, CM, CT, DH, and DL. The port configuration is shown below.

Figure 4-1. Port Configuration Diagram



Caution Ports 0, 3 to 5, and 9 (P90 to P96) are 5 V tolerant.

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

Power Supply	Corresponding Pins
AV_{REF0}	Port 7
AV_{REF1}	Port 1
EV_{DD}	$\overline{\text{RESET}}$, ports 0, 3 to 5, 9, CM, 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 5, 7, 9, CD, CM, CT, DH, DL) Port n mode control register (PMCn: n = 0, 3 to 5, 9, CM, CT, DH, DL) Port n function control register (PFCn: n = 0, 3 to 5, 9) Port n function control expansion register (PFCEn: n = 3, 5, 9) Port n function register (PFn: n = 0, 3 to 5, 9)
Ports	I/O: 84

(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.

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

	7	6	5	7	3	2	1	0
Pn	Pn7	Pn6	Pn5	Pn4	Pn3	Pn2	Pn1	Pn0

Pnm	Control of output data (in output mode)
0	Output 0.
1	Output 1.

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 (PMnm = 0)	Data is written to the output latch[Note]. 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 (PMnm = 1)	Data is written to the output latch. The pin status is not affected[Note].	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.

After reset: FFH   R/W

	7	6	5	4	3	2	1	0
PMn	PMn7	PMn6	PMn5	PMn4	PMn3	PMn2	PMn1	PMn0

PMnm	Control of input/output mode
0	Output mode
1	Input mode

(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.

After reset: 00H   R/W

	7	6	5	4	3	2	1	0
PMCn	PMCn7	PMCn6	PMCn5	PMCn4	PMCn3	PMCn2	PMCn1	PMCn0

PMCnm	Specification of operation mode
0	Port mode
1	Alternate function mode

(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.

After reset: 00H R/W

	7	6	5	4	3	2	1	0
PFCn	PFCn7	PFCn6	PFCn5	PFCn4	PFCn3	PFCn2	PFCn1	PFCn0

PFCnm	Specification of alternate function
0	Alternate function 1
1	Alternate function 2

(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.

After reset: 00H R/W

	7	6	5	4	3	2	1	0
PFCEn	PFCEn7	PFCEn6	PFCEn5	PFCEn4	PFCEn3	PFCEn2	PFCEn1	PFCEn0

	7	6	5	4	3	2	1	0
PFCn	PFCn7	PFCn6	PFCn5	PFCn4	PFCn3	PFCn2	PFCn1	PFCn0

PFCEnm	PFCnm	Specification of alternate function
0	0	Alternate function 1
0	1	Alternate function 2
1	0	Alternate function 3
1	1	Alternate function 4

(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.

After reset: 00H R/W

	7	6	5	4	3	2	1	0
PFn	PFn7	PFn6	PFn5	PFn4	PFn3	PFn2	PFn1	PFn0

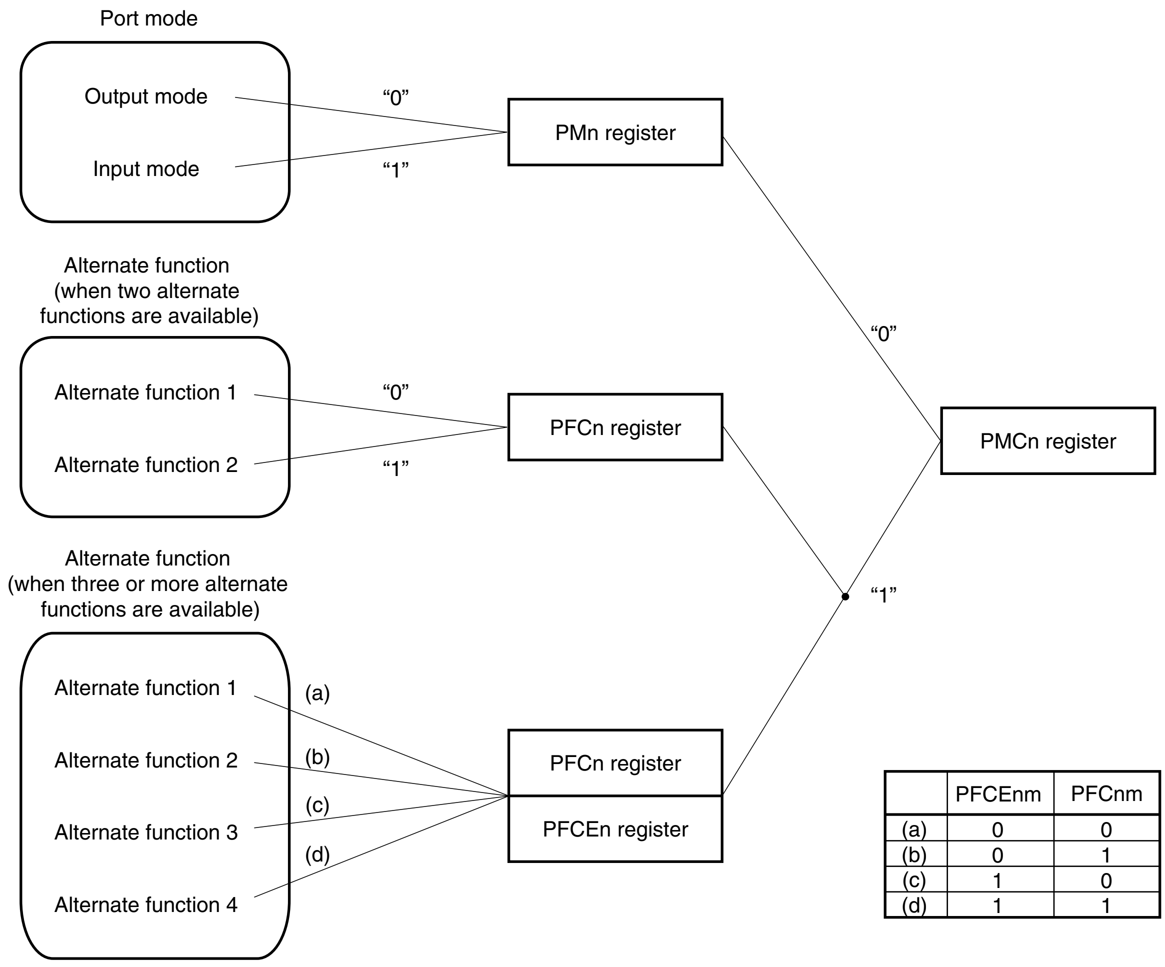
PFnm[Note]	Control of normal output/N-ch open-drain output
0	Normal output (CMOS output)
1	N-ch open-drain output

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



	PFCEnm	PFCnm
(a)	0	0
(b)	0	1
(c)	1	0
(d)	1	1

Remark Set the alternate functions in the following sequence.

<1> Set the PFCn and PFCEn registers.
<2> Set the PFCn register.
<3> Set the INTRn or INTFn register (to specify an external interrupt pin).

If the PMCn register is set first, an unintended function may be set while the PFCn and PFCEn registers are being set.

4.3.1 Port 0

Port 0 is a 5-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
	GF	GC				
P02	19	17	NMI	Input	Selectable as N-ch open-drain output	L-1
P03	20	18	INTP0/ADTRG	Input		N-1
P04	21	19	INTP1	Input		L-1
P05	22	20	INTP2/$\overline{\text{DRST}}^{\text{Note}}$	Input		AA-1
P06	23	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 P02 to P06 pins have hysteresis characteristics in the input mode of the alternate function, but do not have hysteresis characteristics in the port mode.**

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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	0	0

P0n	Output data control (in output mode) (n = 2 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	1	1

PM0n	I/O mode control (n = 2 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	0	0

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

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	0	0

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

(5) Port 0 function register (PF0)

After reset: 00H R/W Address: FFFFFC60H

	7	6	5	4	3	2	1	0
PF0	0	PF06	PF05	PF04	PF03	PF02	0	0

PF0n	Control of normal output or N-ch open-drain output (n = 2 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
	GF	GC				
P10	5	3	ANO0	Output	–	A-2
P11	6	4	ANO1	Output	–	A-2

Caution When the power is turned on, the P10 and P11 pins may output an undefined level temporarily even during reset.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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 1. When using P1n as the alternate function (ANOn pin output), set the PM1n bit to 1.

2. 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
	GF	GC				
P30	27	25	TXDA0/SOB4	Output	Selectable as N-ch open-drain output	G-3
P31	28	26	RXDA0/INTP7/SIB4	Input		N-3
P32	29	27	ASCKA0/$\overline{\text{SCKB4}}$/TIP00/TOP00	I/O		U-1
P33	30	28	TIP01/TOP01	I/O		G-1
P34	31	29	TIP10/TOP10	I/O		G-1
P35	32	30	TIP11/TOP11	I/O		G-1
P36	33	31	–	–		C-1
P37	34	32	–	–		C-1
P38	37	35	TXDA2/SDA00	I/O		G-12
P39	38	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.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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 FFFFF446H,
PMC3L FFFFF446H, PMC3H FFFFF447H

	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/$\overline{\text{SCKB4}}$ 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 1. 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.

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

2. 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.

3. 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

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 I/O

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	$\overline{\text{SCKB4}}$ I/O
1	0	TIP00 input
1	1	TOP00 output

PFC31	Specification of P31 pin alternate function
0	RXDA0 input/INTP7[Note] input
1	SIB4 input

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

Note INTP7 and RXDA0 are alternate functions. 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 FFFFFC66H,
PF3L FFFFFC66H, PF3H FFFFFC67H

	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 a pull-up resistor at EV_{DD} or higher is connected to an output pin, 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
	GF	GC				
P40	24	22	SIB0/SDA01	I/O	Selectable as N-ch open-drain output	G-6
P41	25	23	SOB0/SCL01	I/O		G-12
P42	26	24	$\overline{\text{SCKB0}}$	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.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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	$\overline{\text{SCKB0}}$ 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: FFFFFC68H

	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 a pull-up resistor at EV$_{DD}$ or higher is connected to an output pin, 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
	GF	GC				
P50	39	37	TIQ01/KR0/TOQ01/RTP00	I/O	Selectable as N-ch open-drain output	U-5
P51	40	38	TIQ02/KR1/TOQ02/RTP01	I/O		U-5
P52	41	39	TIQ03/KR2/TOQ03/RTP02/DDI$^{\text{Note}}$	I/O		U-6
P53	42	40	SIB2/KR3/TIQ00/TOQ00/RTP03/DDO$^{\text{Note}}$	I/O		U-7
P54	43	41	SOB2/KR4/RTP04/DCK$^{\text{Note}}$	I/O		U-8
P55	44	42	$\overline{\text{SCKB2}}$/KR5/RTP05/DMS$^{\text{Note}}$	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/$\overline{\text{DRST}}$ 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**.

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.

Remark GF: 100-pin plastic LQFP (14 × 20)

GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(1) Port 5 register (P5)

After reset: 00H (output latch) R/W Address: FFFFF40AH

	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: FFFFF42AH

	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: FFFFF44AH

	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	$\overline{\text{SCKB2}}$ 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: FFFFF46AH

	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$^{\text{Note}}$ 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[Note] input
1	0	TOQ03 input
1	1	RTP02 output

PFCE51	PFC51	Specification of P51 pin alternate function
0	0	Setting prohibited
0	1	TIQ02 input/KR1[Note] 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[Note] input
1	0	TOQ01 output
1	1	RTP00 output

Note KRn and TIQ0m are alternate functions. 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 TQ0IOC2.TQ0EES0, TQ0IOC2.TQ0EES1 bits = 0 TQ0IOC2.TQ0ETS0, TQ0IOC2.TQ0ETS1 bits = 0

(7) Port 5 function register (PF5)

After reset: 00H R/W Address: FFFFFC6AH

	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_{DD} or higher, be sure to set the PF5n bit to 1.

4.3.6 Port 7

Port 7 is a 12-bit port for which I/O settings can be controlled in 1-bit units.

Port 7 includes the following alternate-function pins.

Table 4-9. Port 7 Alternate-Function Pins

Pin Name	Pin No.		Alternate-Function Pin Name	I/O	Remark	Block Type
	GF	GC				
P70	2	100	ANI0	Input	–	A-1
P71	1	99	ANI1	Input		A-1
P72	100	98	ANI2	Input		A-1
P73	99	97	ANI3	Input		A-1
P74	98	96	ANI4	Input		A-1
P77	97	95	ANI5	Input		A-1
P76	96	94	ANI6	Input		A-1
P77	95	93	ANI7	Input		A-1
P78	94	92	ANI8	Input		A-1
P79	93	91	ANI9	Input		A-1
P710	92	90	ANI10	Input		A-1
P711	91	89	ANI11	Input		A-1

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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	0	0	0	0	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 11)
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	1	1	1	1	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 11)
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.

4.3.7 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 4-10. Port 9 Alternate-Function Pins

Pin Name	Pin No.		Alternate-Function Pin Name	I/O	Remark	Block Type
	GF	GC				
P90	45	43	A0/KR6/TXDA1/SDA02	I/O	Selectable as N-ch open-drain output	U-10
P91	46	44	A1/KR7/RXDA1/SCL02	I/O		U-11
P92	47	45	A2/TIP41/TOP41	I/O		U-12
P93	48	46	A3/TIP40/TOP40	I/O		U-12
P94	49	47	A4/TIP31/TOP31	I/O		U-12
P95	50	48	A5/TIP30/TOP30	I/O		U-12
P96	51	49	A6/TIP21/TOP21	I/O		U-13
P97	52	50	A7/SIB1/TIP20/TOP20	I/O		U-14
P98	53	51	A8/SOB1	Output		G-3
P99	54	52	A9/$\overline{\text{SCKB1}}$	I/O		G-5
P910	55	53	A10/SIB3	I/O		G-2
P911	56	54	A11/SOB3	Output		G-3
P912	57	55	A12/$\overline{\text{SCKB3}}$	I/O		G-5
P913	58	56	A13/INTP4	I/O		N-2
P914	59	57	A14/INTP5/TIP51/TOP51	I/O		U-15
P915	60	58	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.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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 1. 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.

2. 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 1. 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.

2. 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 FFFFF452H,
PMC9L FFFFF452H, PMC9H FFFFF453H

	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/$\overline{\text{SCKB3}}$ 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/$\overline{\text{SCKB1}}$ I/O

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

Remarks 1. 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.

2. 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.

(2/2)

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 and PFCE9 registers to 0000H.

After reset: 0000H R/W Address: PFC9 FFFFF472H,
PFC9L FFFFF472H, PFC9H FFFFF473H

	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 **4.3.7 (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 and PFCE9 registers to 0000H.

After reset: 0000H R/W Address: PFCE9 FFFFF712H,
PFCE9L FFFFF712H, PFCE9H FFFFF713H

	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 **4.3.7 (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	$\overline{\text{SCKB3}}$ 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	$\overline{\text{SCKB1}}$ 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[Note]
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 FFFFFC72H,
PF9L FFFFFC72H, PF9H FFFFFC73H

	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 a pull-up resistor at EV_{DD} or higher is connected to output pins P90 to P96, be sure to set the PF9n bit to 1.

Pull up output pins P97 to P915 at the same potential as EV_{DD}, even when they are used as N-ch open-drain output pins.

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.

4.3.8 Port CM

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

Port CM includes the following alternate-function pins.

Table 4-11. Port CM Alternate-Function Pins

Pin Name	Pin No.		Alternate-Function Pin Name	I/O	Remark	Block Type
	GF	GC				
PCM0	63	61	$\overline{\text{WAIT}}$	Input	–	D-1
PCM1	64	62	CLKOUT	Output		D-2
PCM2	65	63	$\overline{\text{HLDAK}}$	Output		D-2
PCM3	66	64	$\overline{\text{HLDRQ}}$	Input		D-1

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(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	0	0	PCM3	PCM2	PCM1	PCM0

PCMn	Output data control (in output mode) (n = 0 to 3)
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	1	1	PMCM3	PMCM2	PMCM1	PMCM0

PMCMn	I/O mode control (n = 0 to 3)
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

4.3.9 Port CT

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

Port CT includes the following alternate-function pins.

Table 4-12. Port CT Alternate-Function Pins

Pin Name	Pin No.		Alternate-Function Pin Name	I/O	Remark	Block Type
	GF	GC				
PCT0	67	65	$\overline{\text{WR0}}$	Output	–	D-2
PCT1	68	66	$\overline{\text{WR1}}$	Output		D-2
PCT4	69	67	$\overline{\text{RD}}$	Output		D-2
PCT6	70	68	ASTB	Output		D-2

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(1) Port CT register (PCT)

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

	7	6	5	4	3	2	1	0
PCT	0	PCT6	0	PCT4	0	0	PCT1	PCT0

PCTn	Output data control (in output mode) (n = 0, 1, 4, 6)
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	1	PMCT6	1	PMCT4	1	1	PMCT1	PMCT0

PMCTn	I/O mode control (n = 0, 1, 4, 6)
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	$\overline{\text{RD}}$ output

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

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

4.3.10 Port DH

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

Port DH includes the following alternate-function pins.

Table 4-13. Port DH Alternate-Function Pins

Pin Name	Pin No.		Alternate-Function Pin Name	I/O	Remark	Block Type
	GF	GC				
PDH0	89	87	A16	Output	–	D-2
PDH1	90	88	A17	Output		D-2
PDH2	61	59	A18	Output		D-2
PDH3	62	60	A19	Output		D-2
PDH4	8	6	A20	Output		D-2
PDH5	9	7	A21	Output		D-2

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(1) Port DH register (PDH)

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

	7	6	5	4	3	2	1	0
PDH	0	0	PDH5	PDH4	PDH3	PDH2	PDH1	PDH0

PDHn	Output data control (in output mode) (n = 0 to 5)
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	1	1	PMDH5	PMDH4	PMDH3	PMDH2	PMDH1	PMDH0

PMDHn	I/O mode control (n = 0 to 5)
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	0	0	PMCDH5	PMCDH4	PMCDH3	PMCDH2	PMCDH1	PMCDH0

PMCDHn	Specification of PDHn pin operation mode (n = 0 to 5)
0	I/O port
1	Am output (address bus output) (m = 16 to 21)

4.3.11 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 4-14. Port DL Alternate-Function Pins

Pin Name	Pin No.		Alternate-Function Pin Name	I/O	Remark	Block Type
	GF	GC				
PDL0	73	71	AD0	I/O	–	D-3
PDL1	74	72	AD1	I/O		D-3
PDL2	75	73	AD2	I/O		D-3
PDL3	76	74	AD3	I/O		D-3
PDL4	77	75	AD4	I/O		D-3
PDL5	78	76	AD5/FLMD1^{Note}	I/O		D-3
PDL6	79	77	AD6	I/O		D-3
PDL7	80	78	AD7	I/O		D-3
PDL8	81	79	AD8	I/O		D-3
PDL9	82	80	AD9	I/O		D-3
PDL10	83	81	AD10	I/O		D-3
PDL11	84	82	AD11	I/O		D-3
PDL12	85	83	AD12	I/O		D-3
PDL13	86	84	AD13	I/O		D-3
PDL14	87	85	AD14	I/O		D-3
PDL15	88	86	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 28 FLASH MEMORY**.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

(1) Port DL register (PDL)

After reset: 0000H (output latch) R/W Address: PDL FFFFF004H,
PDLL FFFFF004H, PDLH FFFFF005H

	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 FFFFF024H,
PMDLL FFFFF024H, PMDLH FFFFF025H

	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

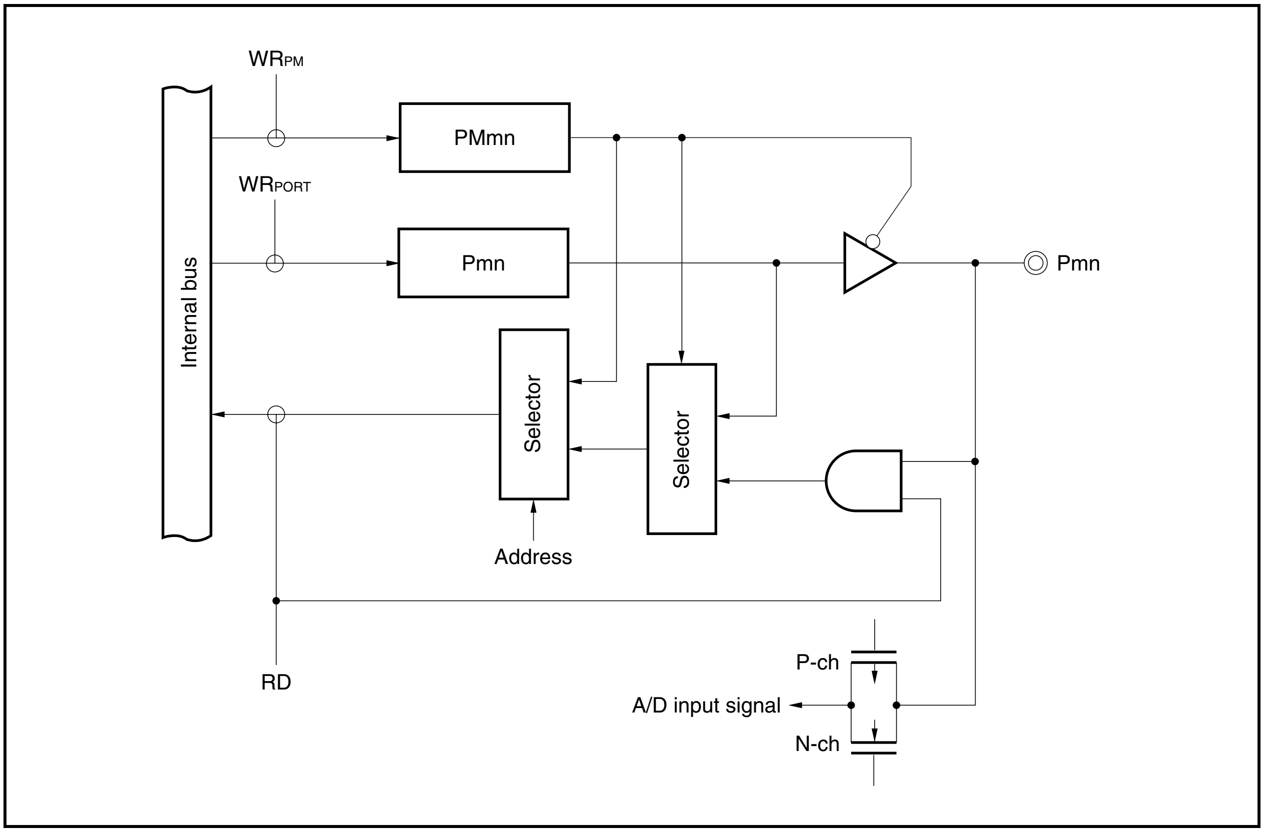


Figure 4-4. Block Diagram of Type A-2

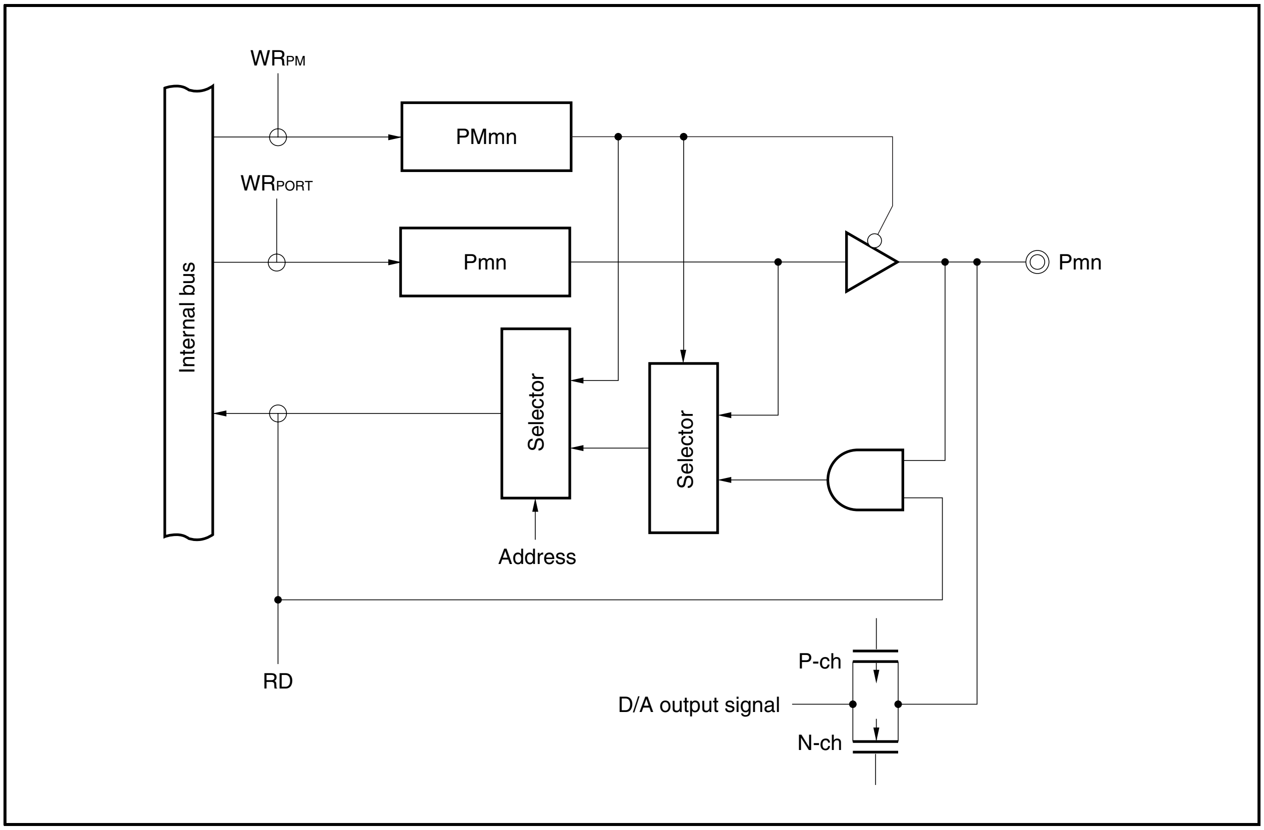


Figure 4-5. Block Diagram of Type C-1

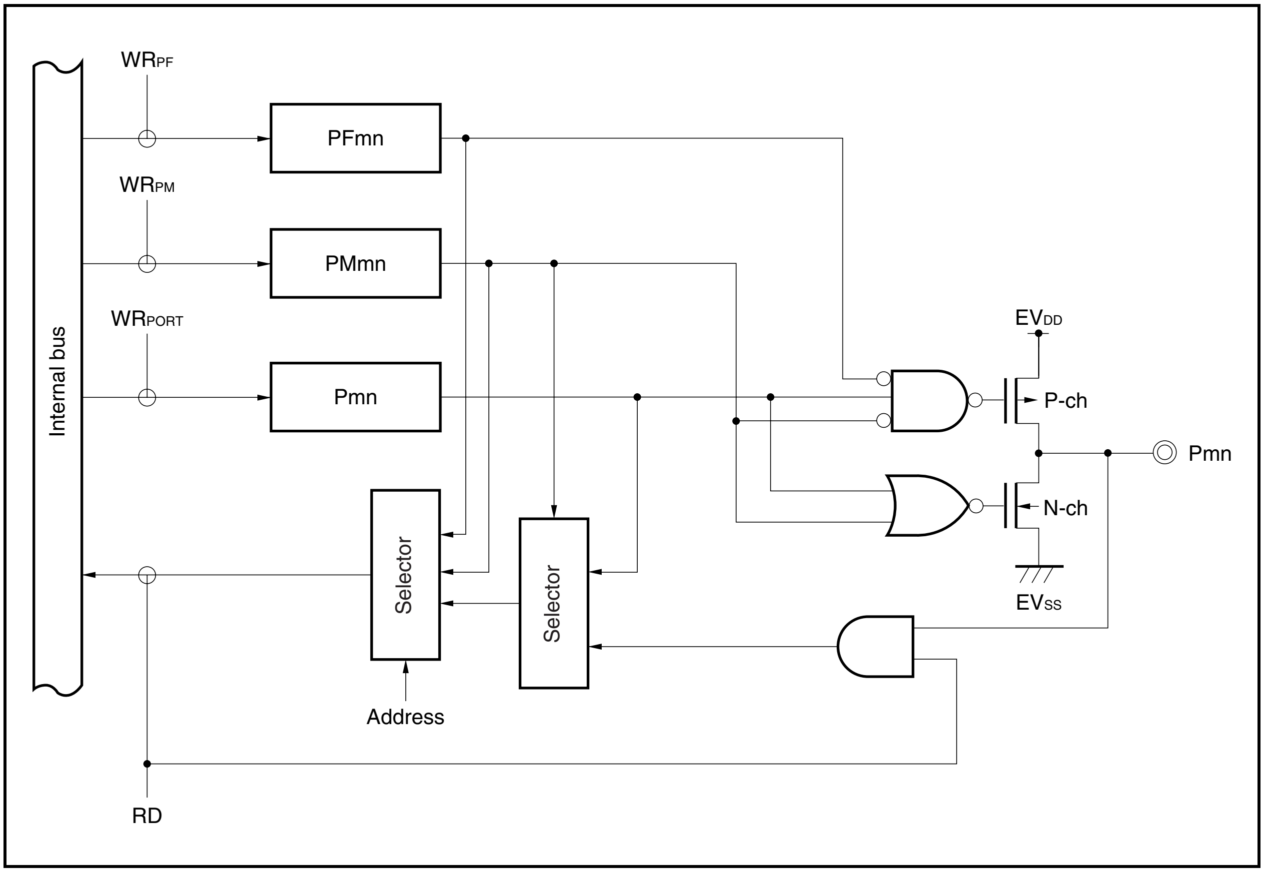


Figure 4-6. Block Diagram of Type D-1

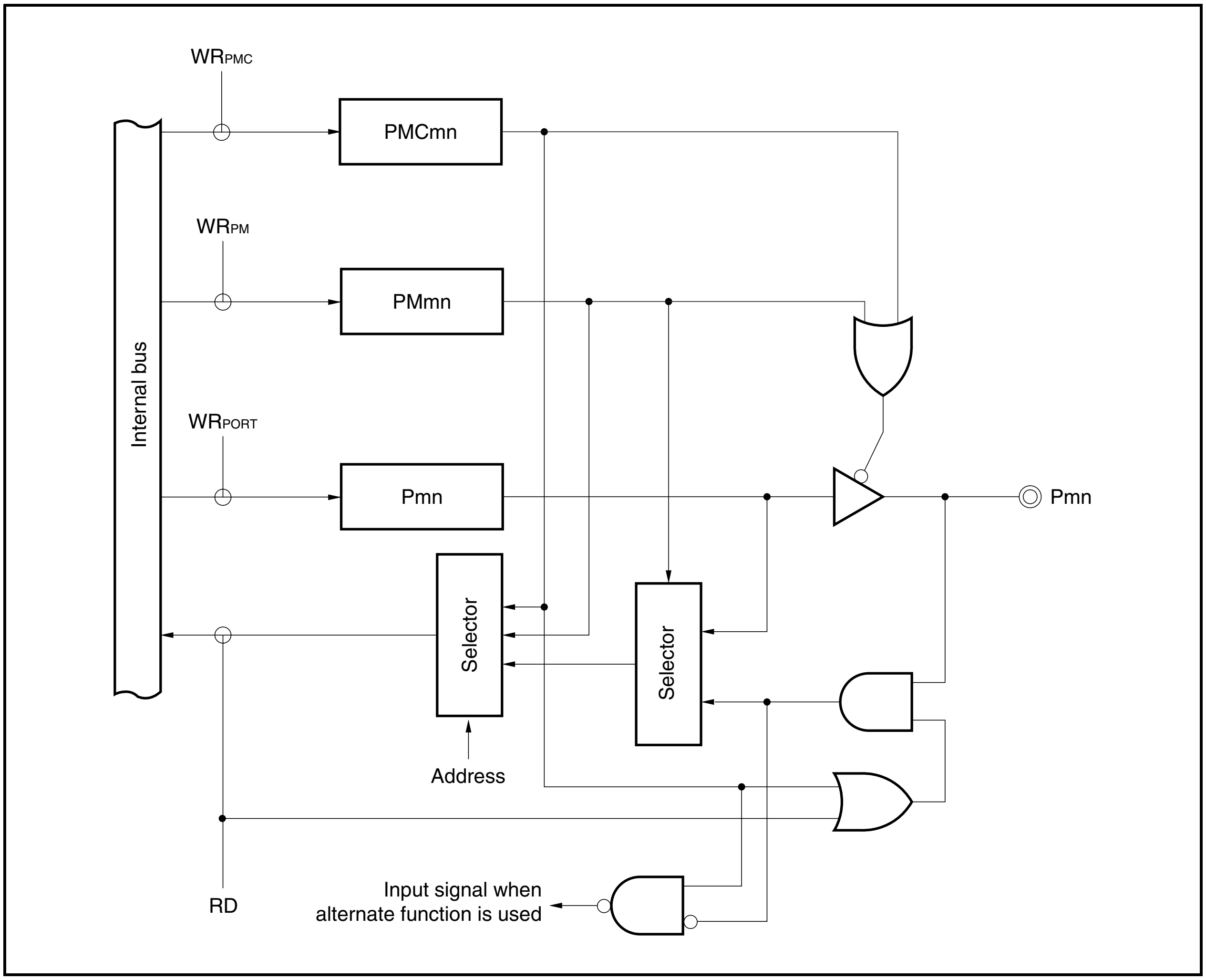


Figure 4-7. Block Diagram of Type D-2

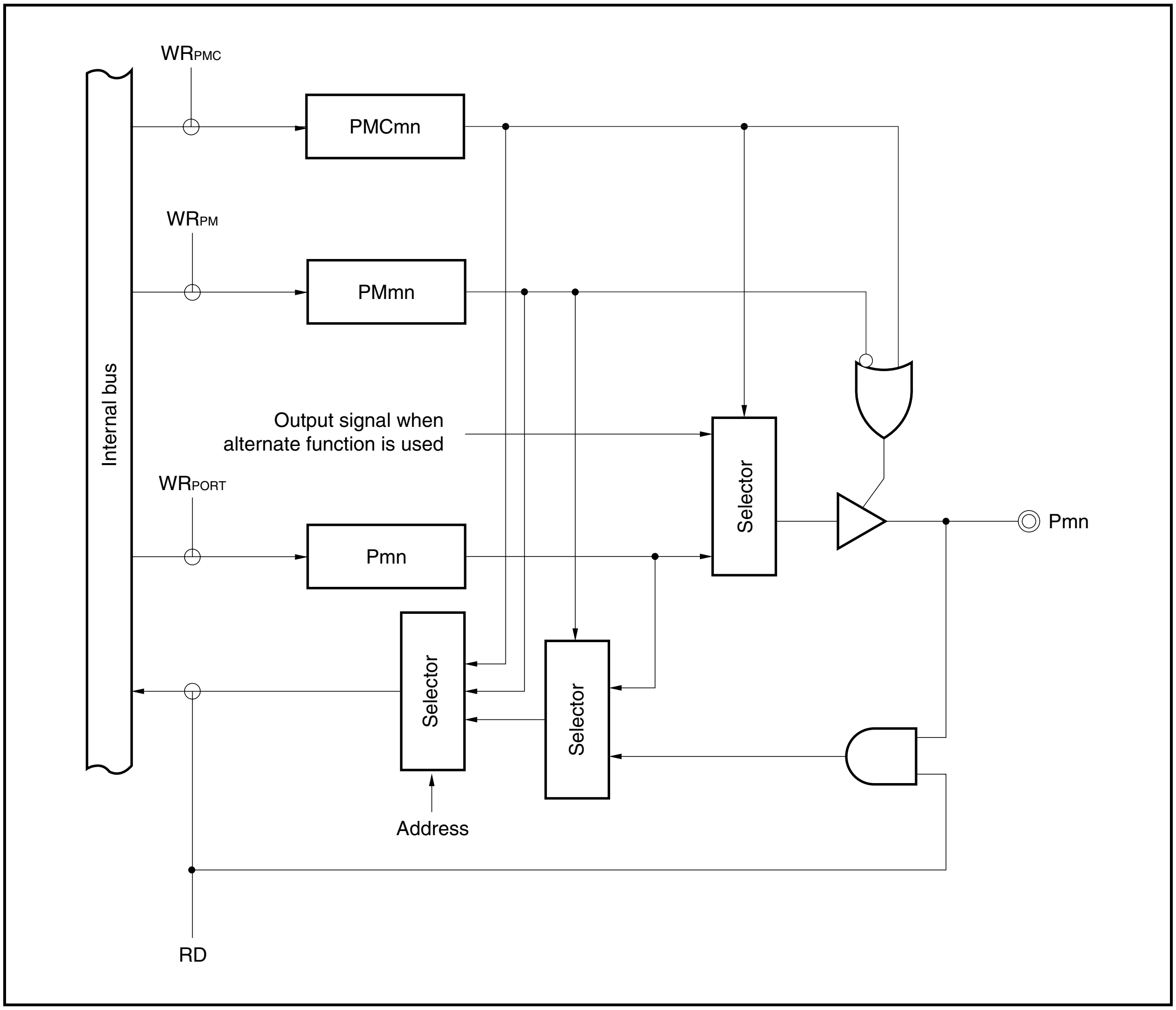


Figure 4-8. Block Diagram of Type D-3

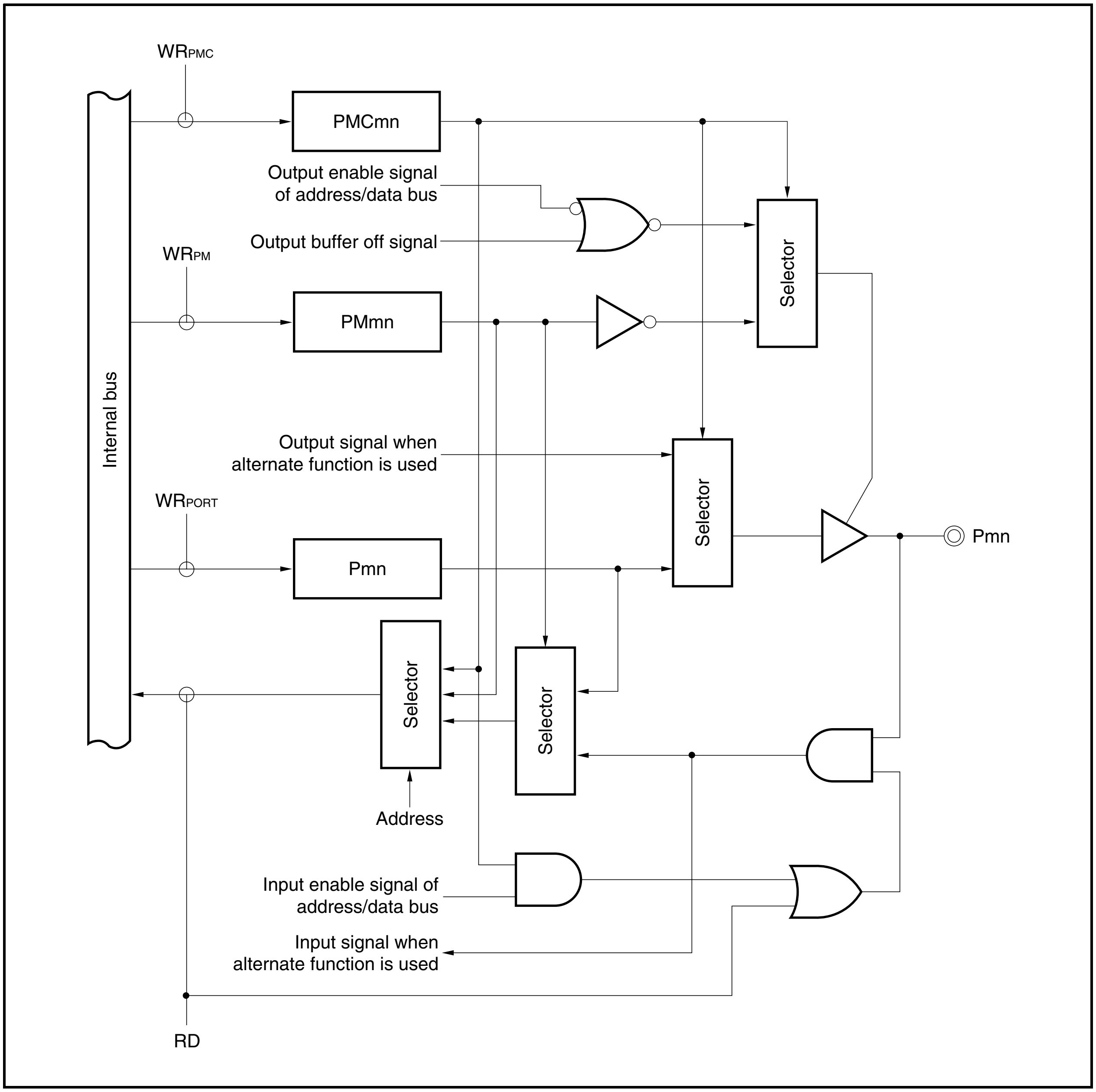
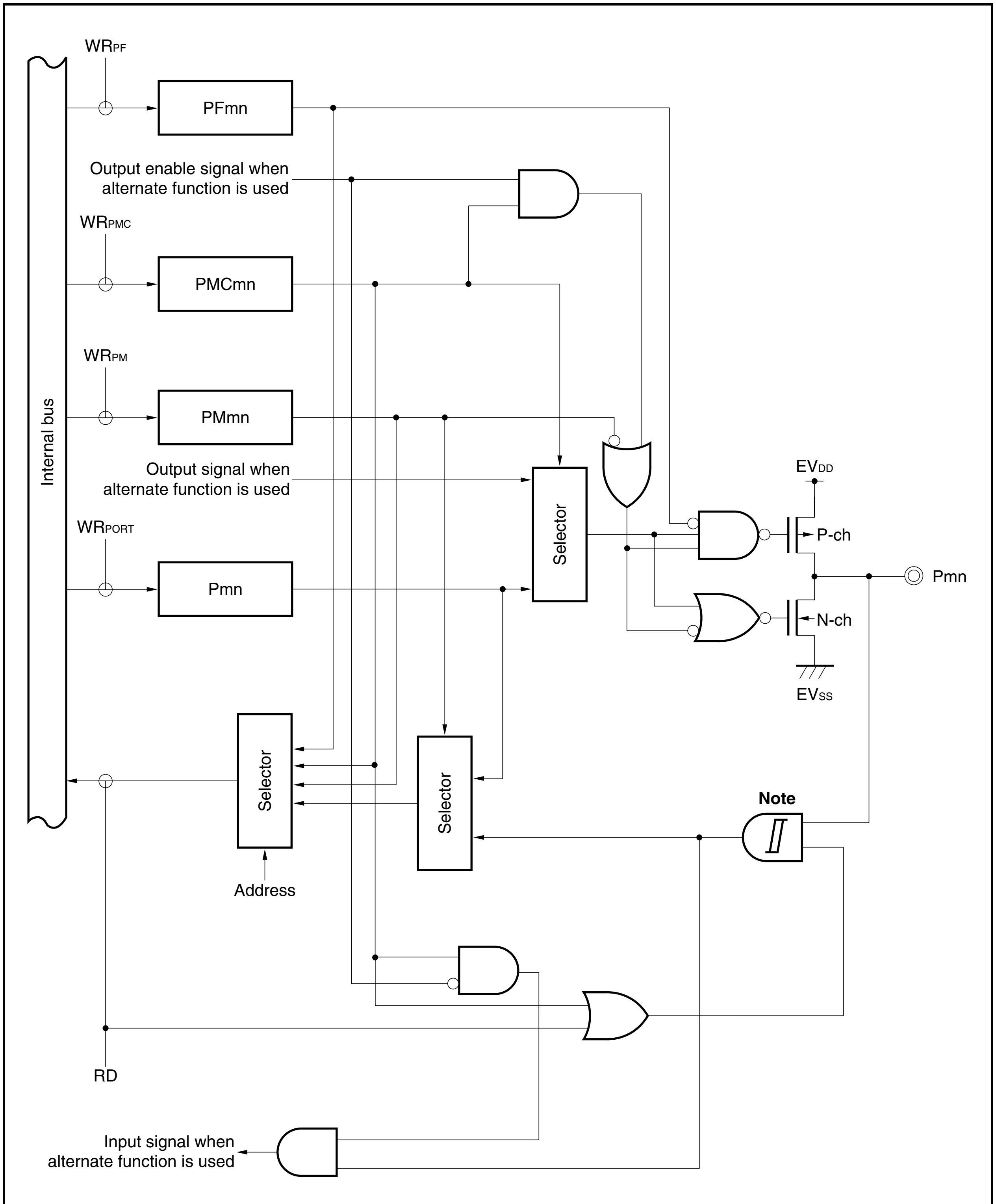
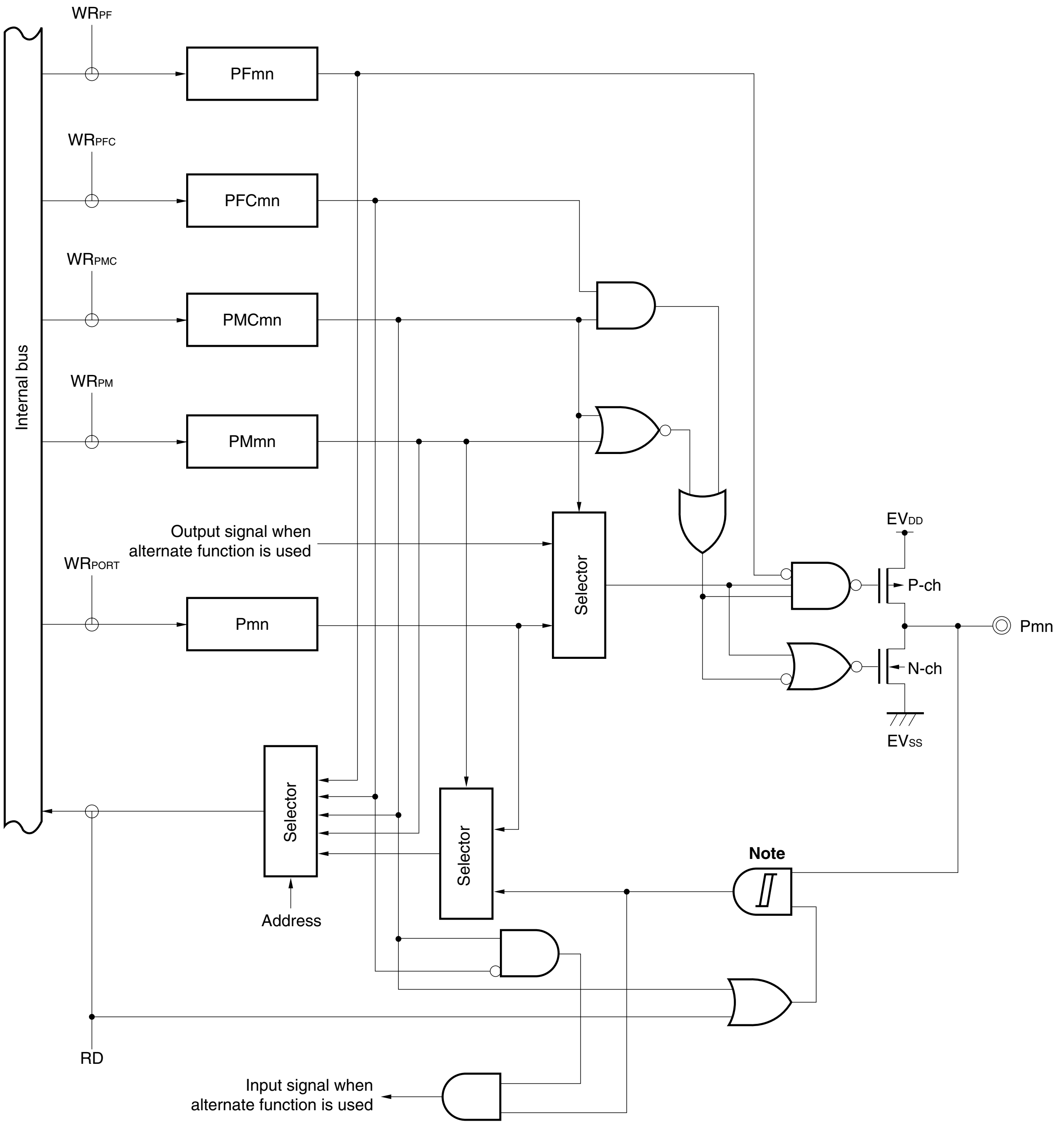


Figure 4-9. Block Diagram of Type E-3



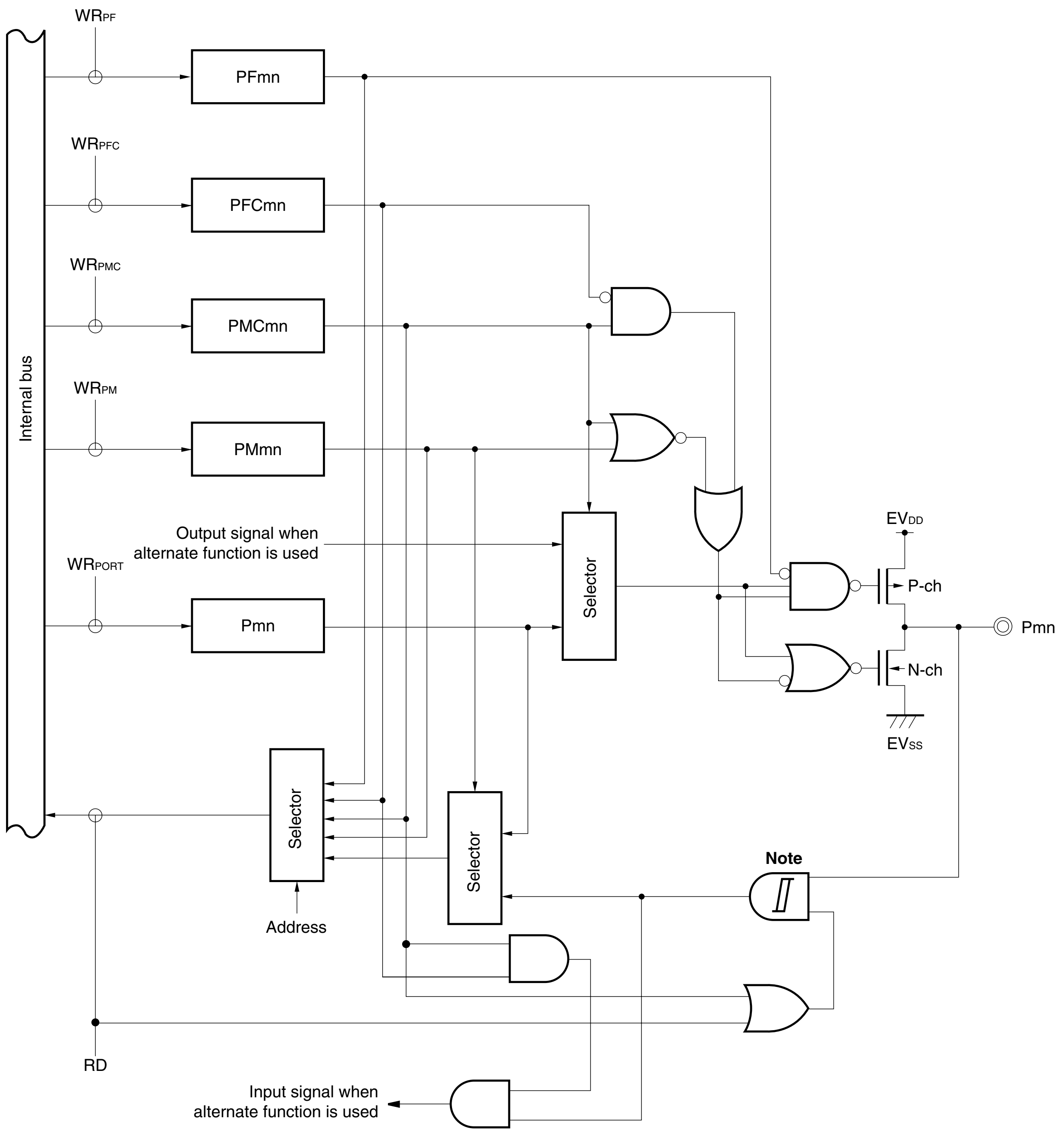
Note Hysteresis characteristics are not available in port mode.

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



Note Hysteresis characteristics are not available in port mode.

Figure 4-11. Block Diagram of Type G-2



Note Hysteresis characteristics are not available in port mode.

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

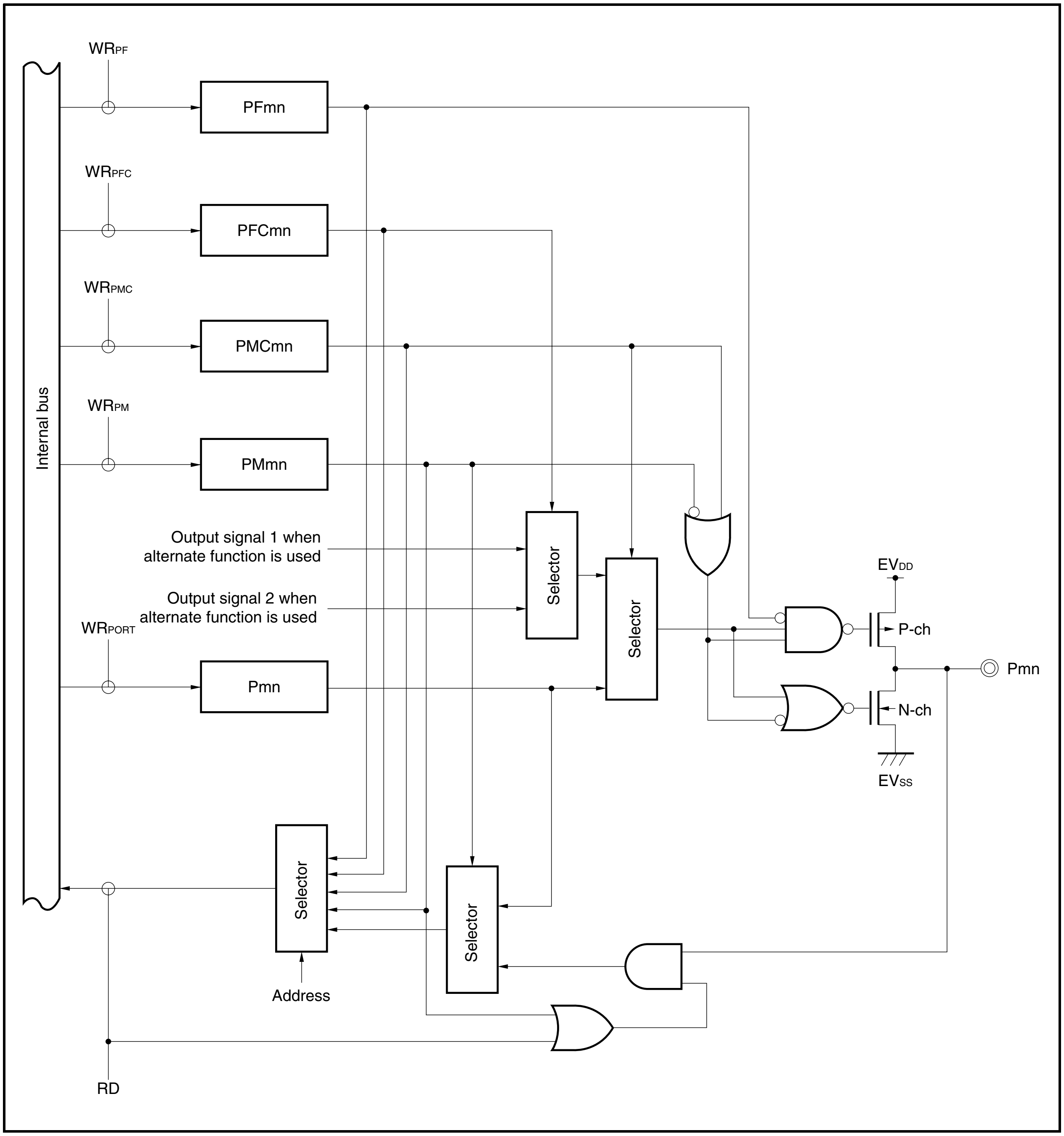
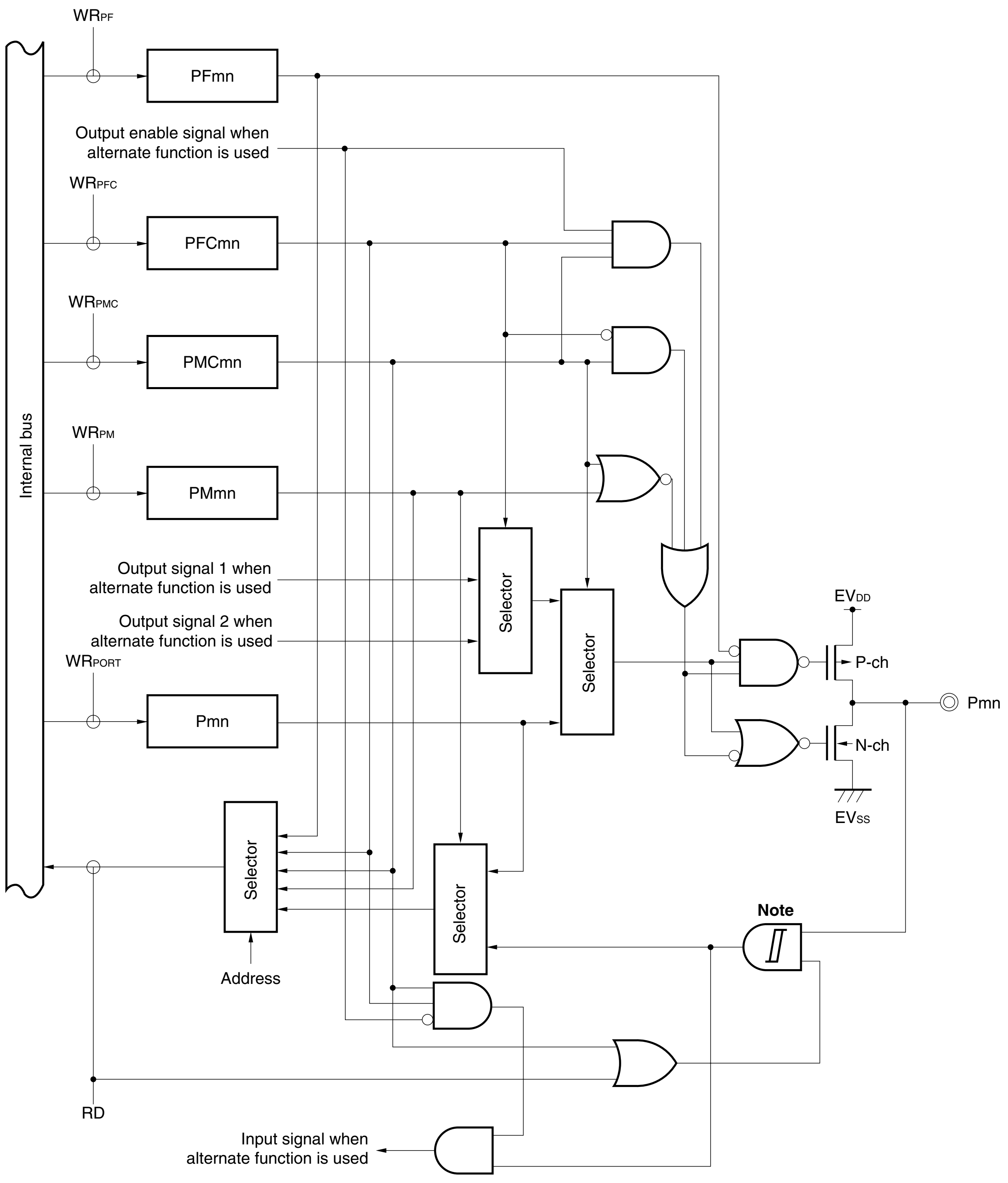
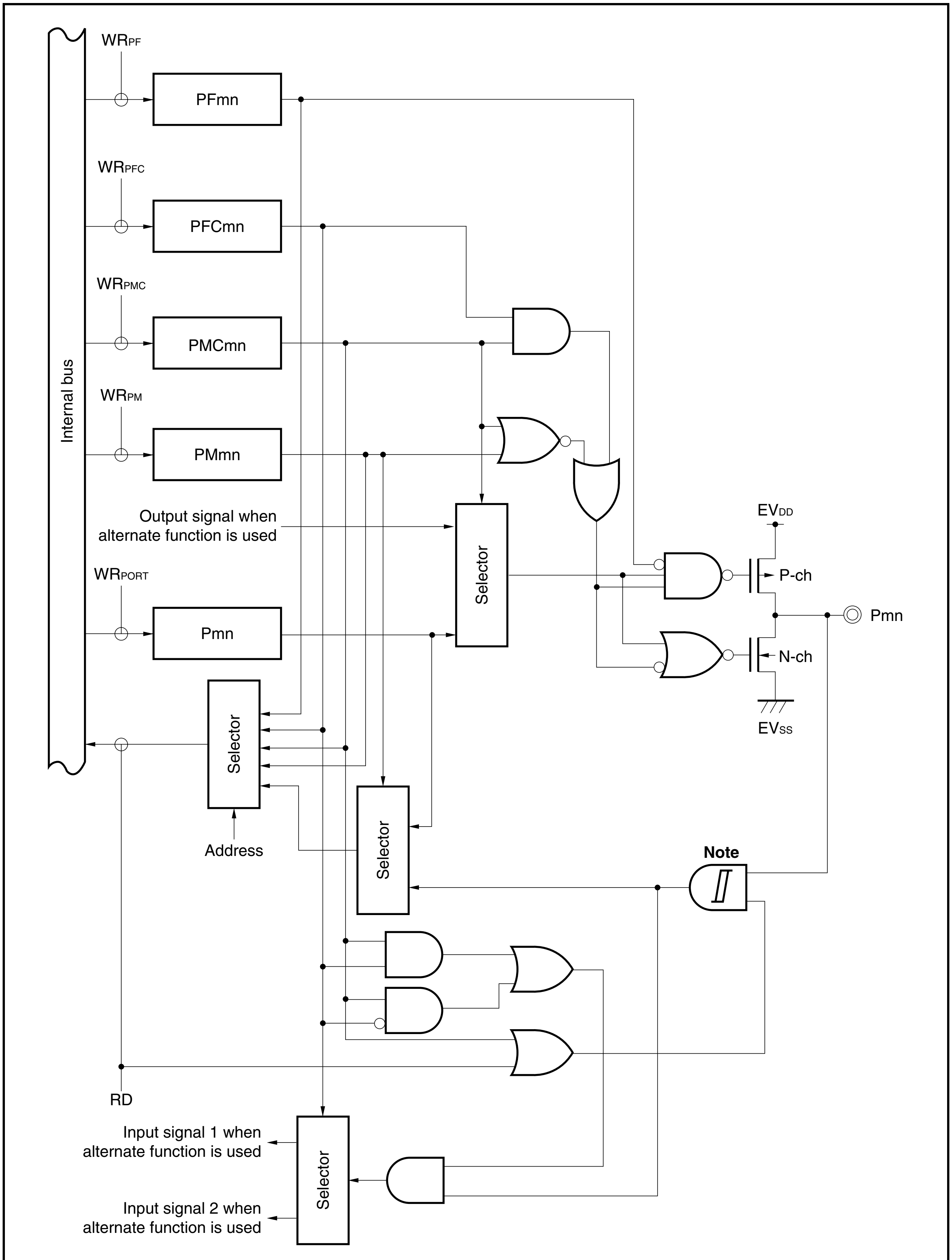


Figure 4-13. Block Diagram of Type G-5



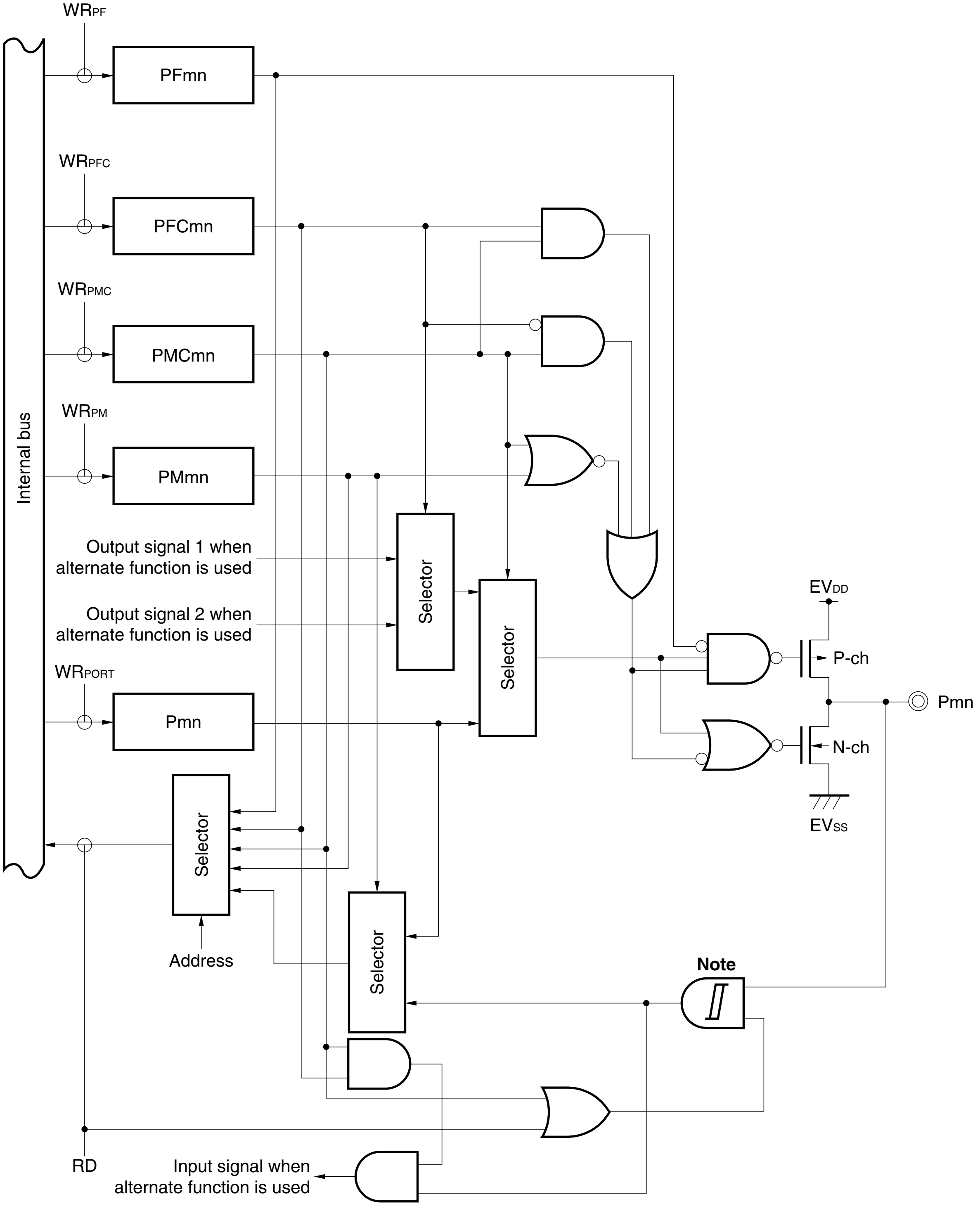
Note Hysteresis characteristics are not available in port mode.

Figure 4-14. Block Diagram of Type G-6



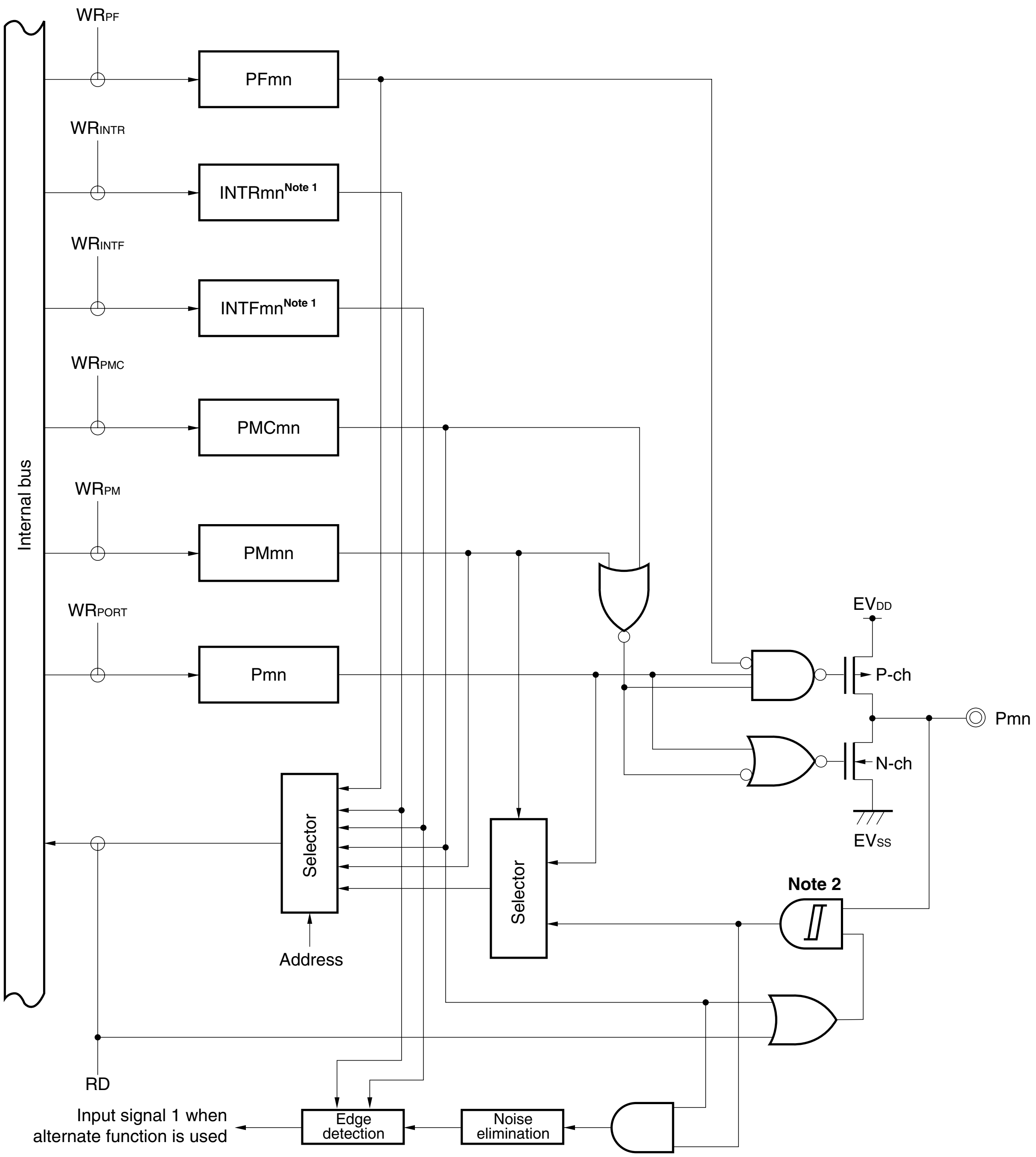
Note Hysteresis characteristics are not available in port mode.

Figure 4-15. Block Diagram of Type G-12



Note Hysteresis characteristics are not available in port mode.

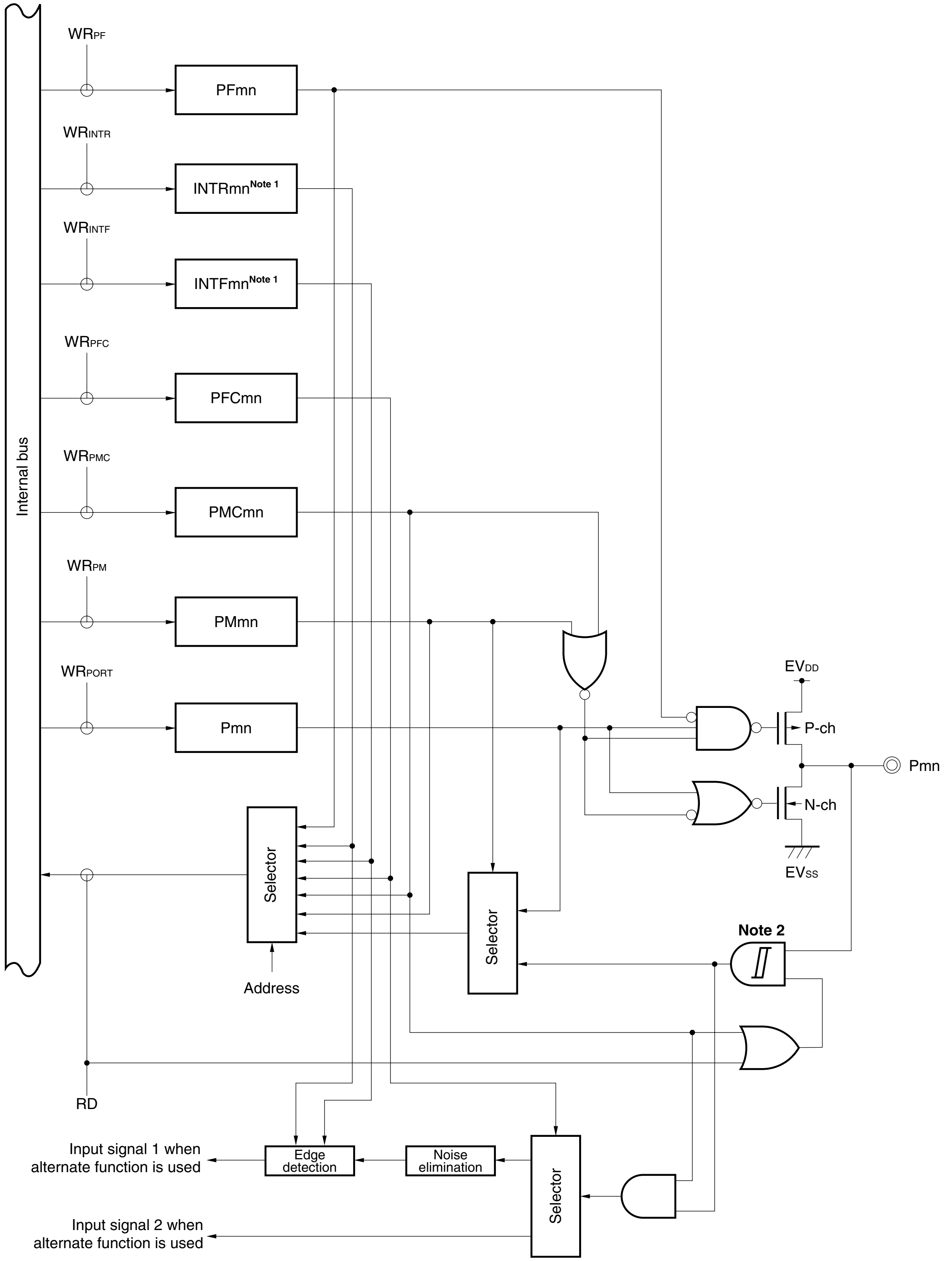
Figure 4-16. Block Diagram of Type L-1



Notes 1. See **19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP7)**.

2. Hysteresis characteristics are not available in port mode.

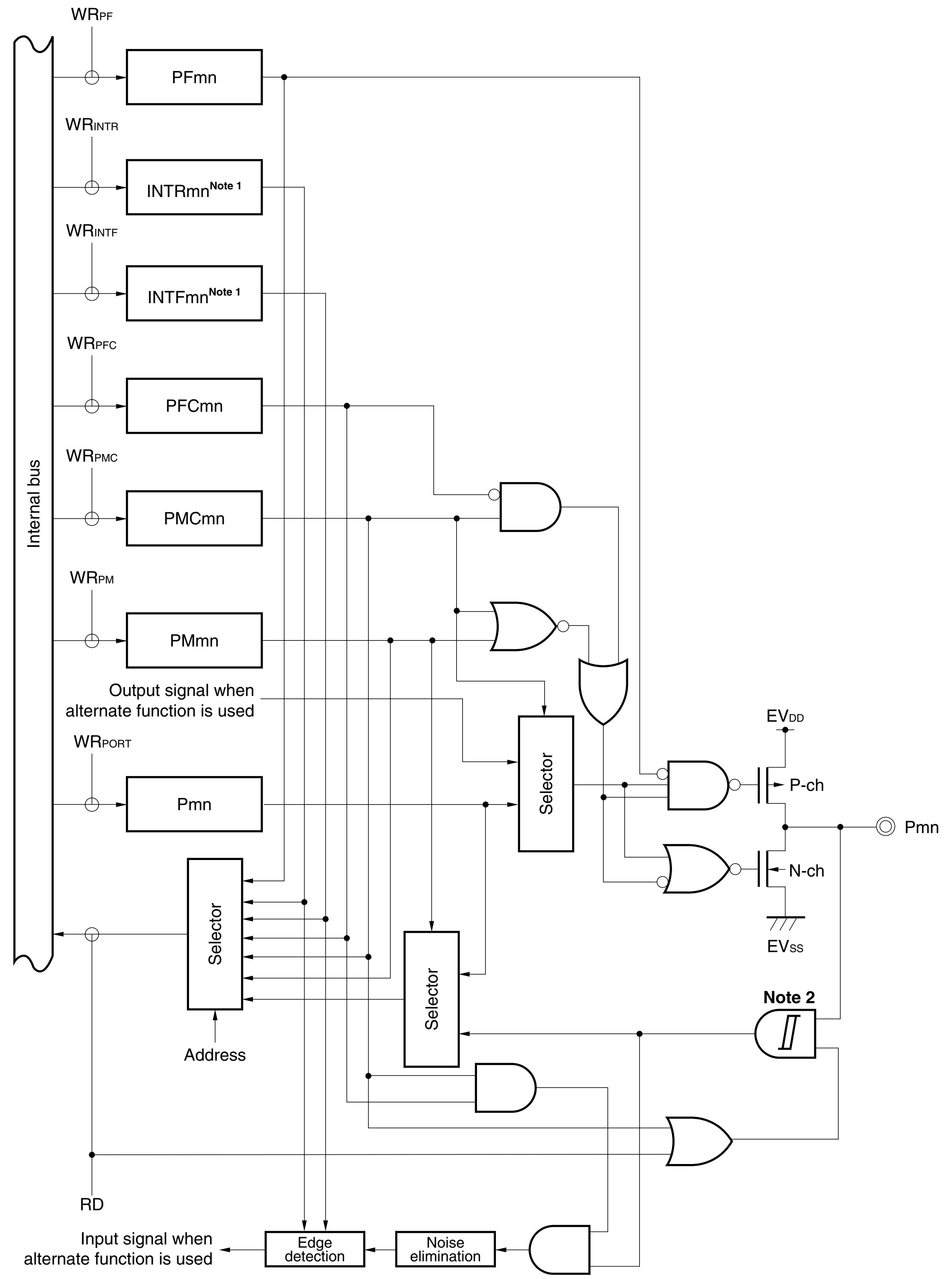
Figure 4-17. Block Diagram of Type N-1



Notes 1. See **19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP7)**.

2. Hysteresis characteristics are not available in port mode.

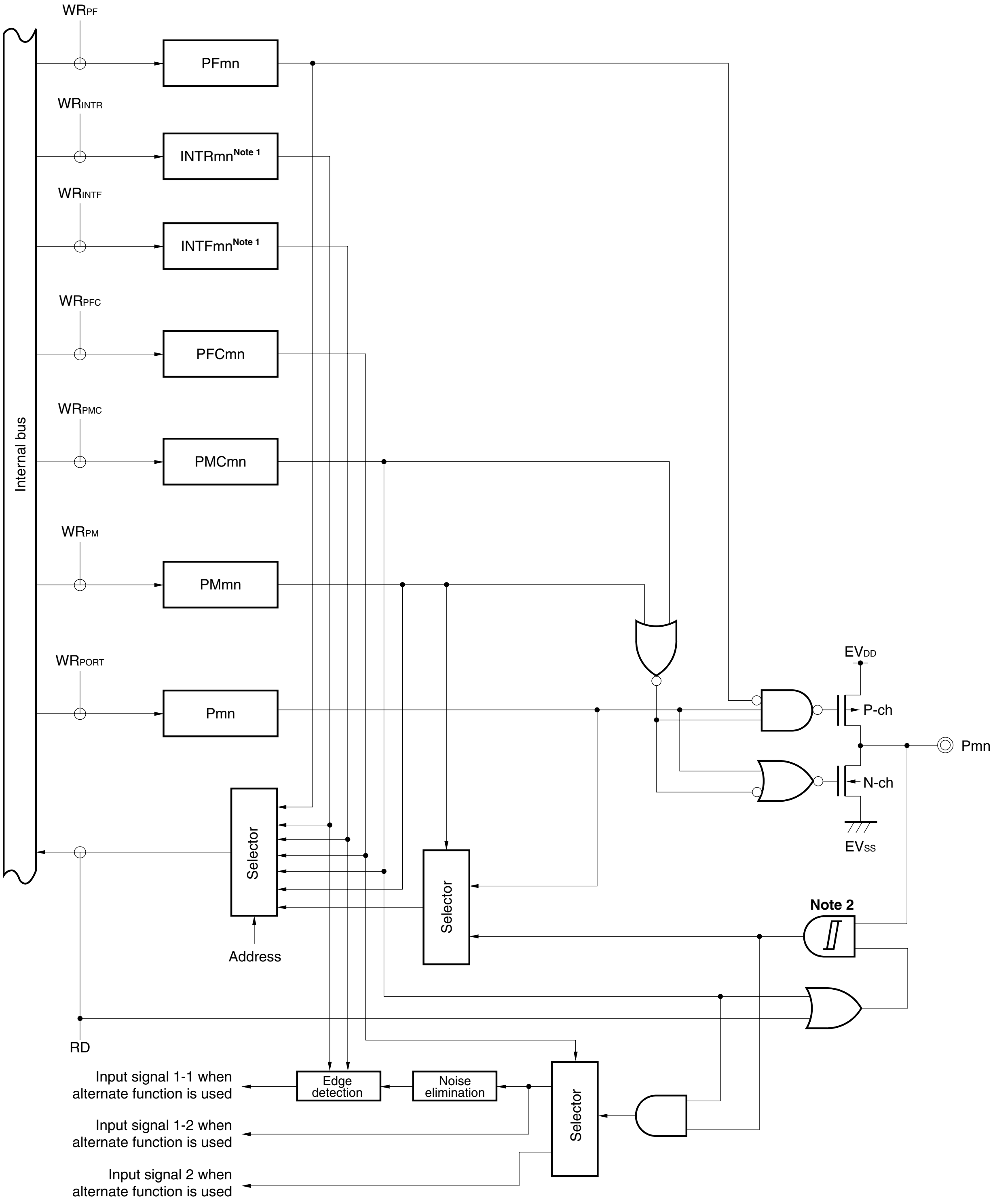
Figure 4-18. Block Diagram of Type N-2



Notes 1. See **19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP7)**.

2. Hysteresis characteristics are not available in port mode.

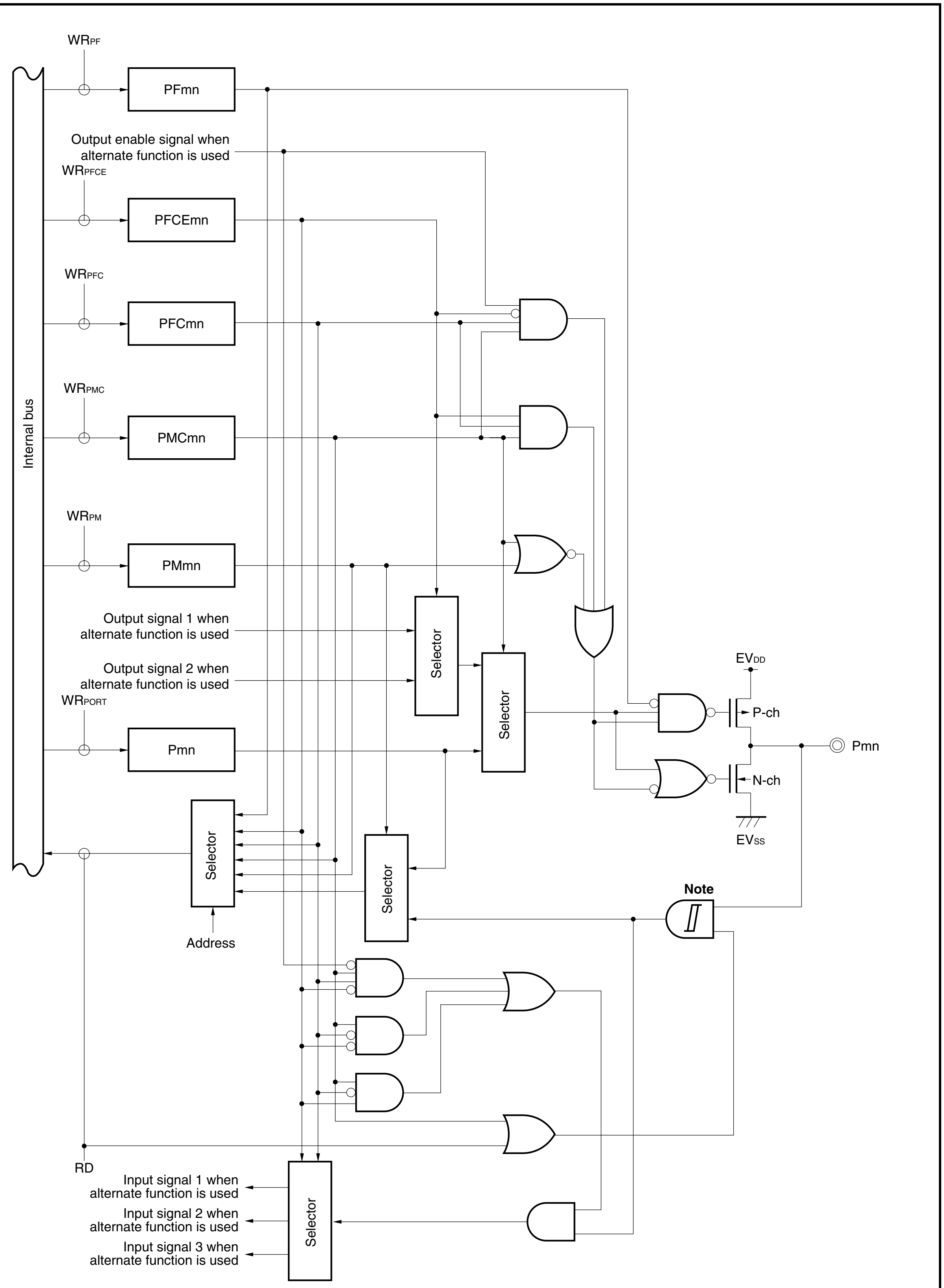
Figure 4-19. Block Diagram of Type N-3



Notes 1. See **19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP7)**.

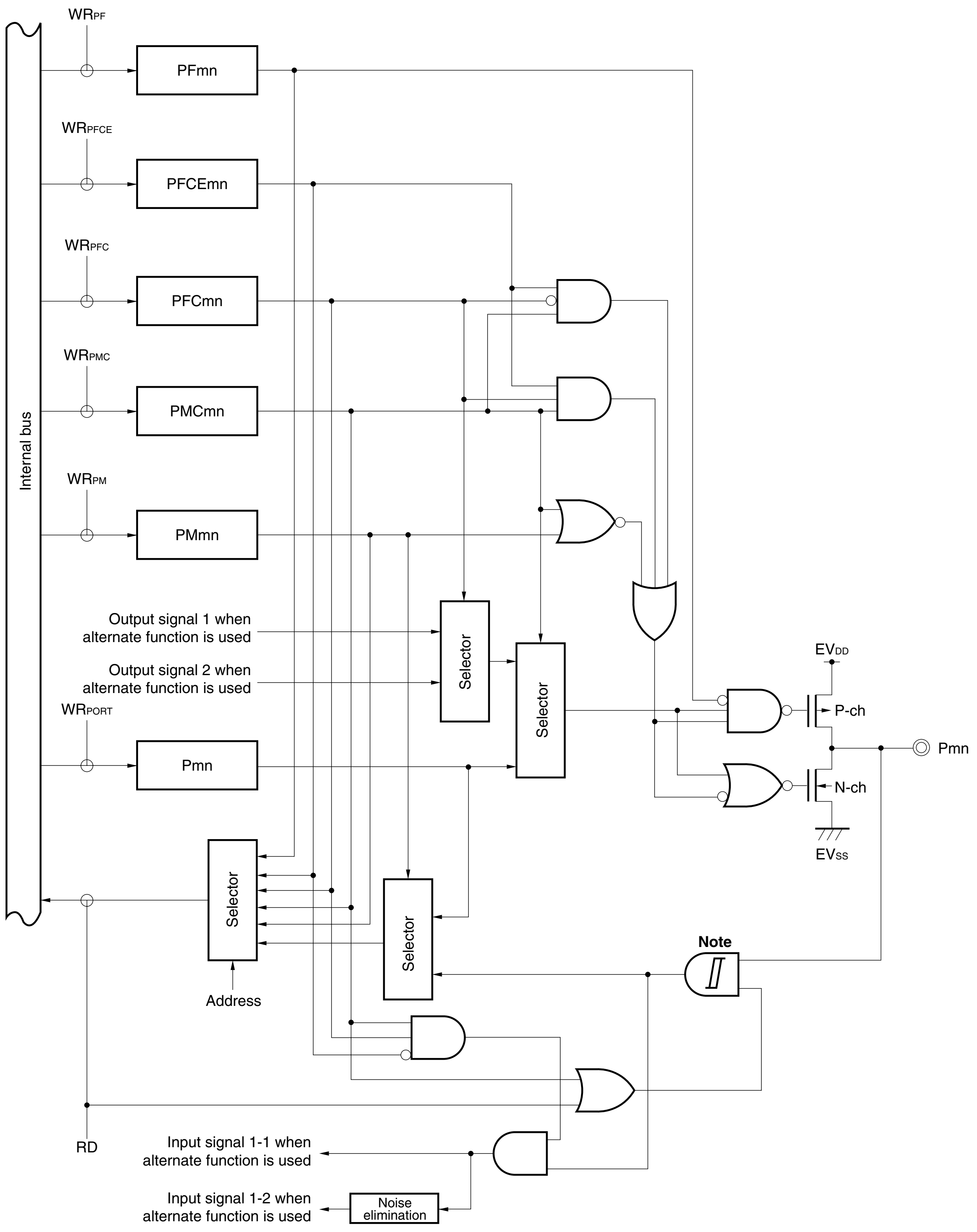
2. Hysteresis characteristics are not available in port mode.

Figure 4-20. Block Diagram of Type U-1



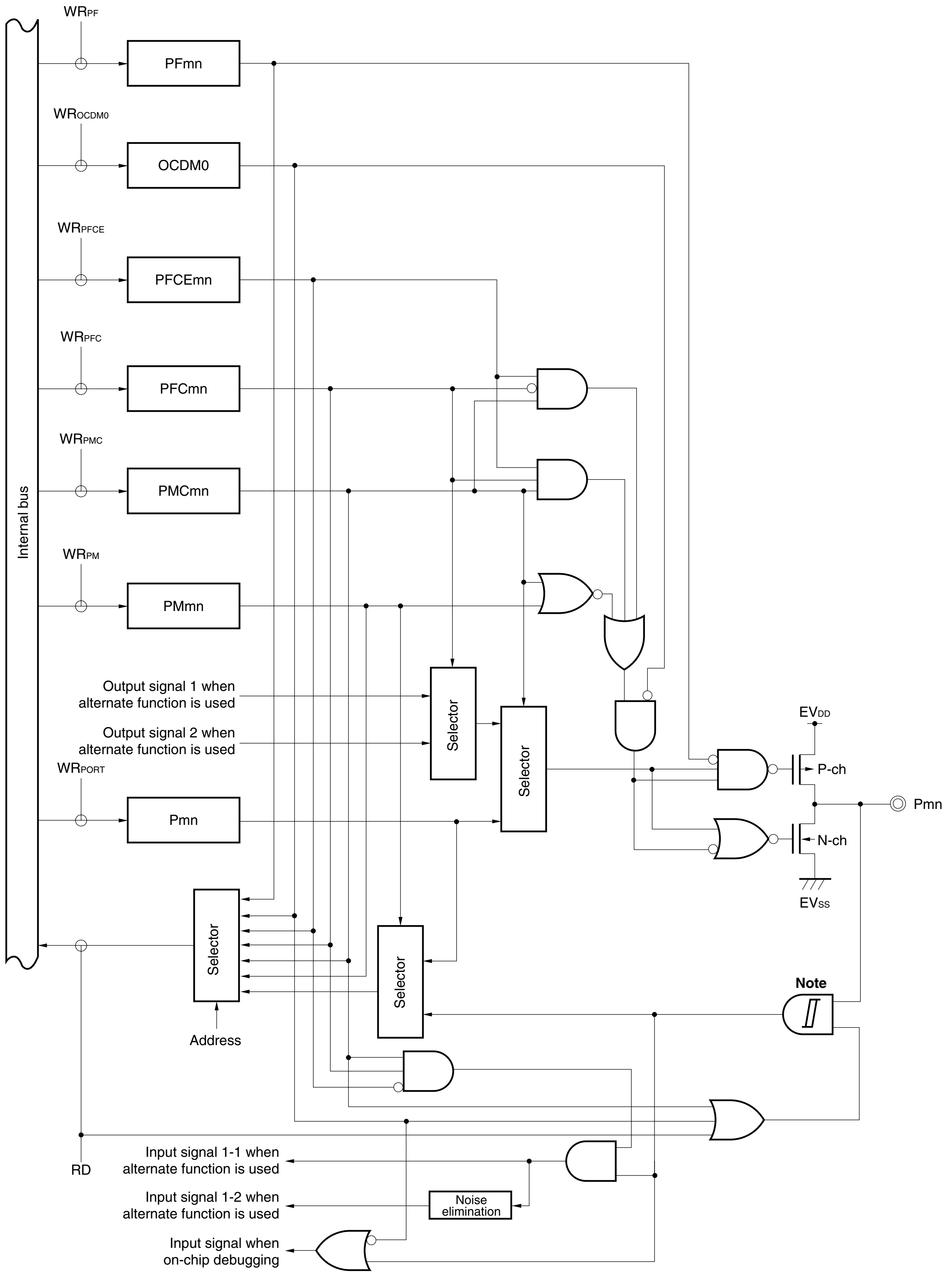
Note Hysteresis characteristics are not available in port mode.

Figure 4-21. Block Diagram of Type U-5



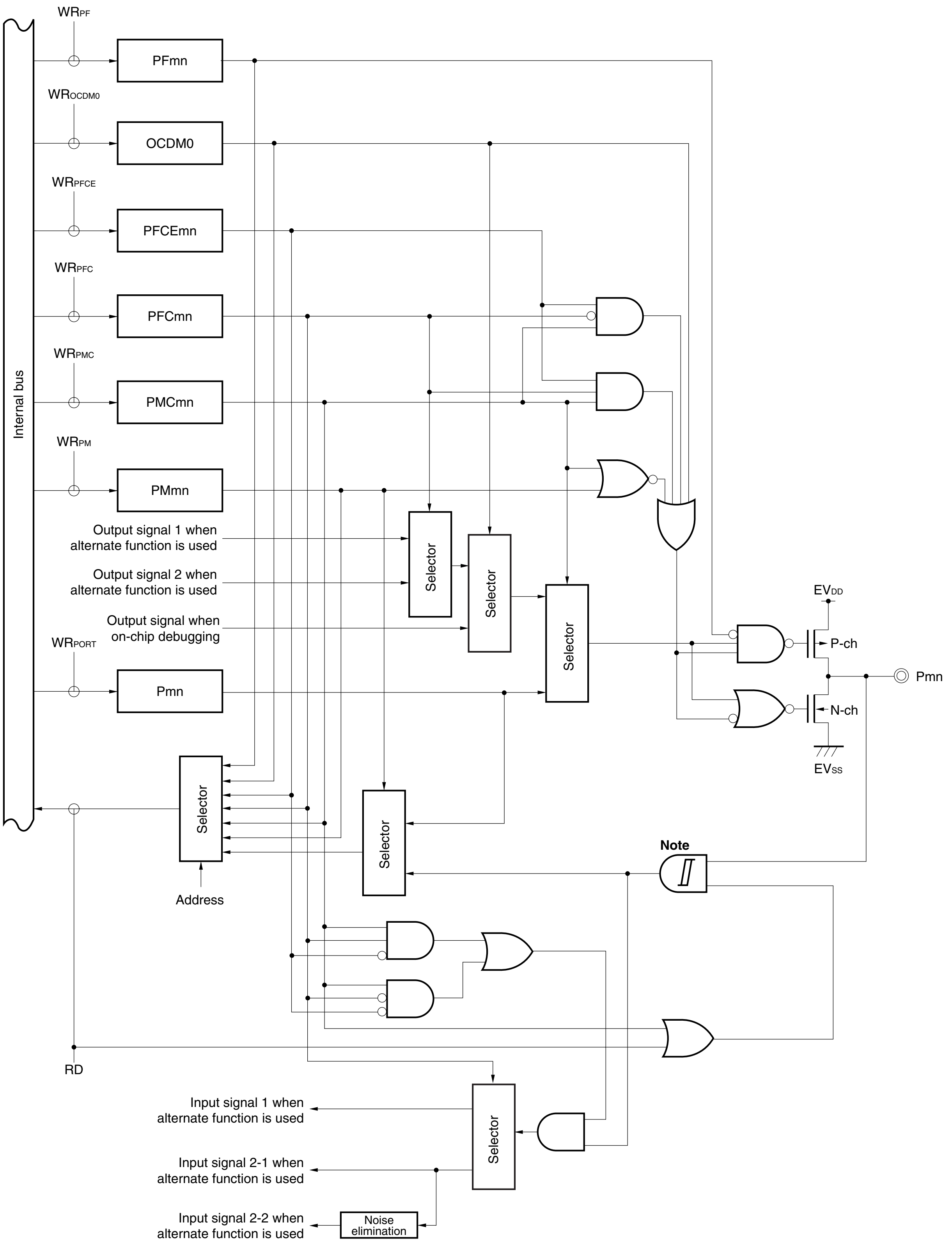
Note Hysteresis characteristics are not available in port mode.

Figure 4-22. Block Diagram of Type U-6



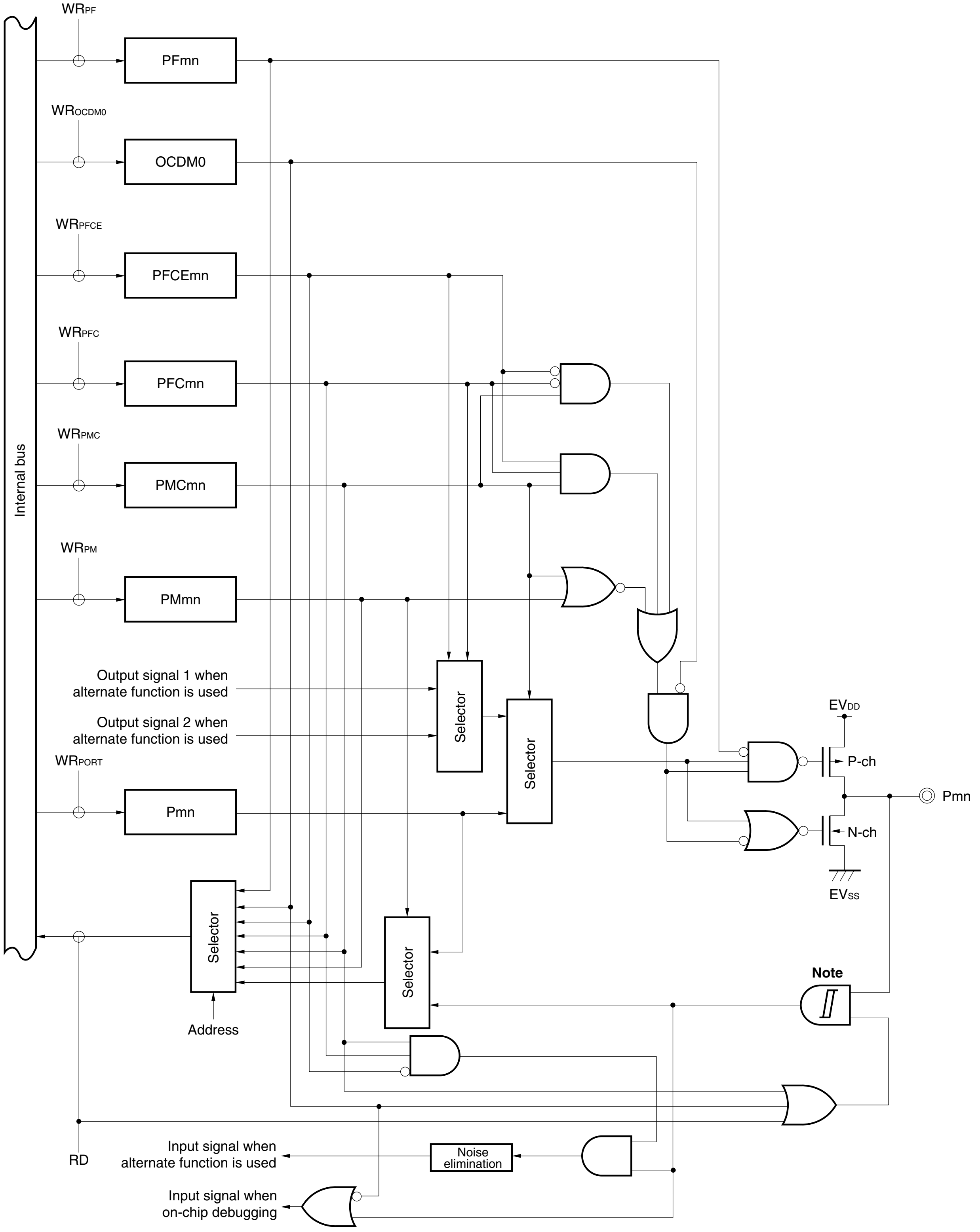
Note Hysteresis characteristics are not available in port mode.

Figure 4-23. Block Diagram of Type U-7



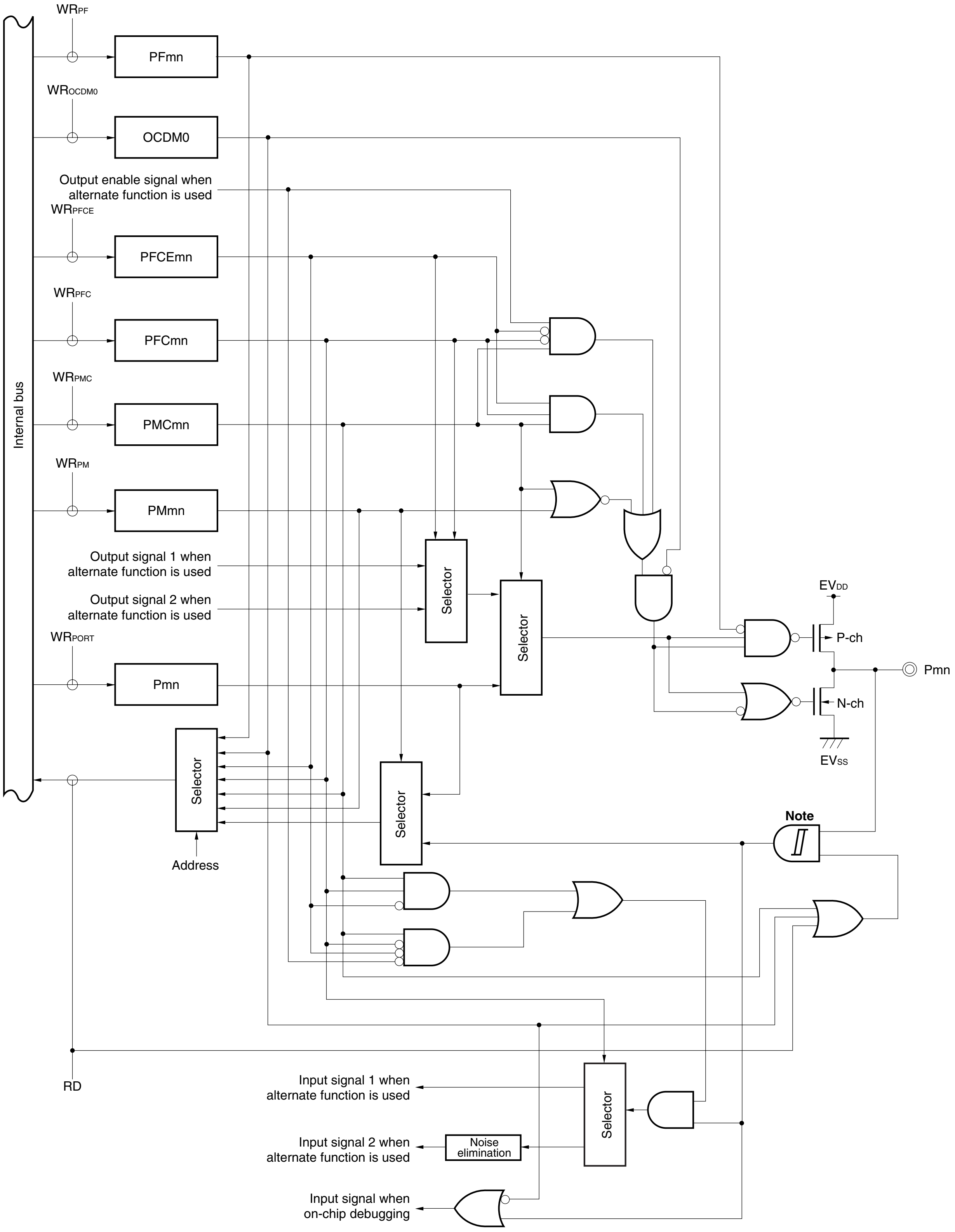
Note Hysteresis characteristics are not available in port mode.

Figure 4-24. Block Diagram of Type U-8



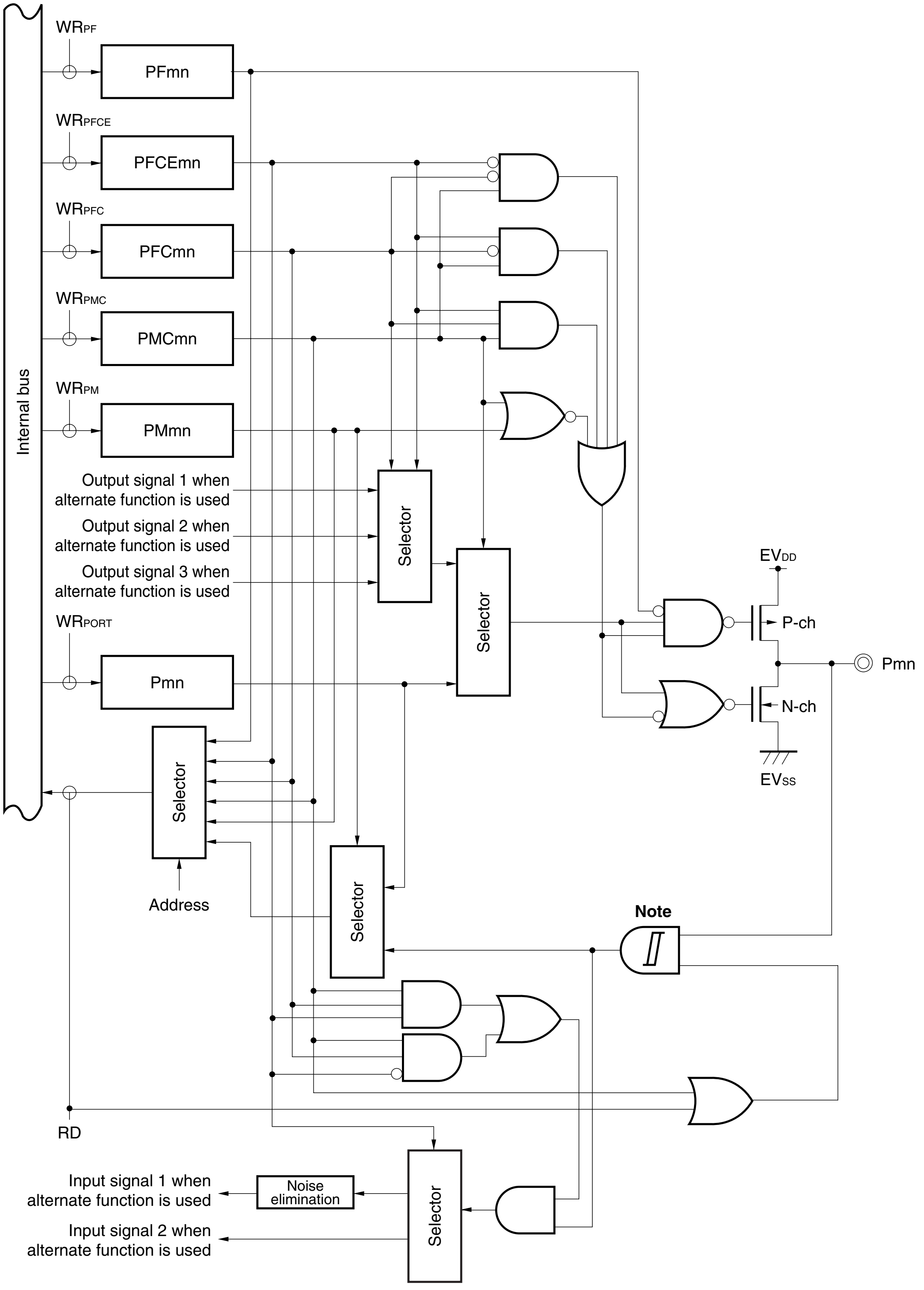
Note Hysteresis characteristics are not available in port mode.

Figure 4-25. Block Diagram of Type U-9



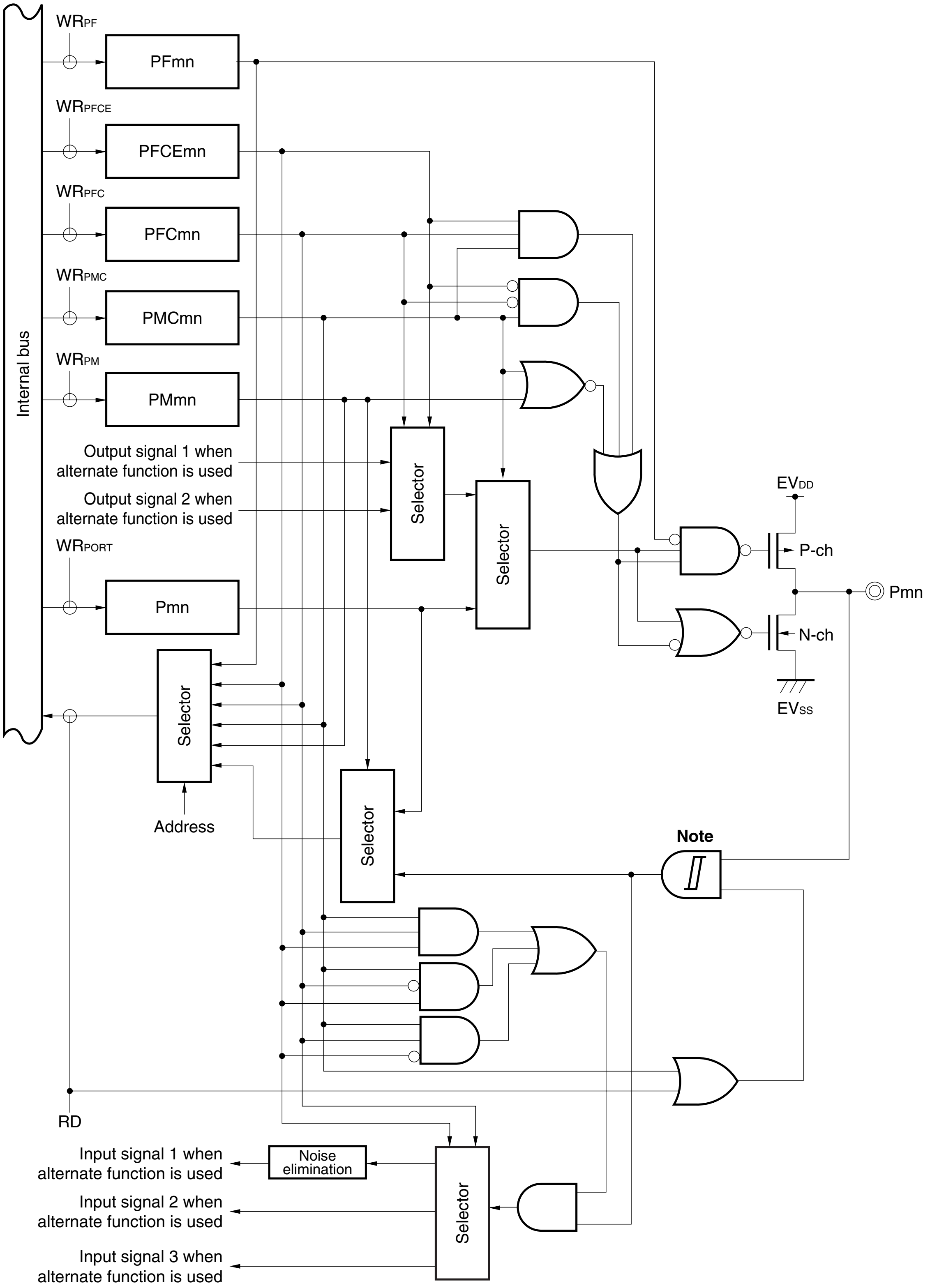
Note Hysteresis characteristics are not available in port mode.

Figure 4-26. Block Diagram of Type U-10



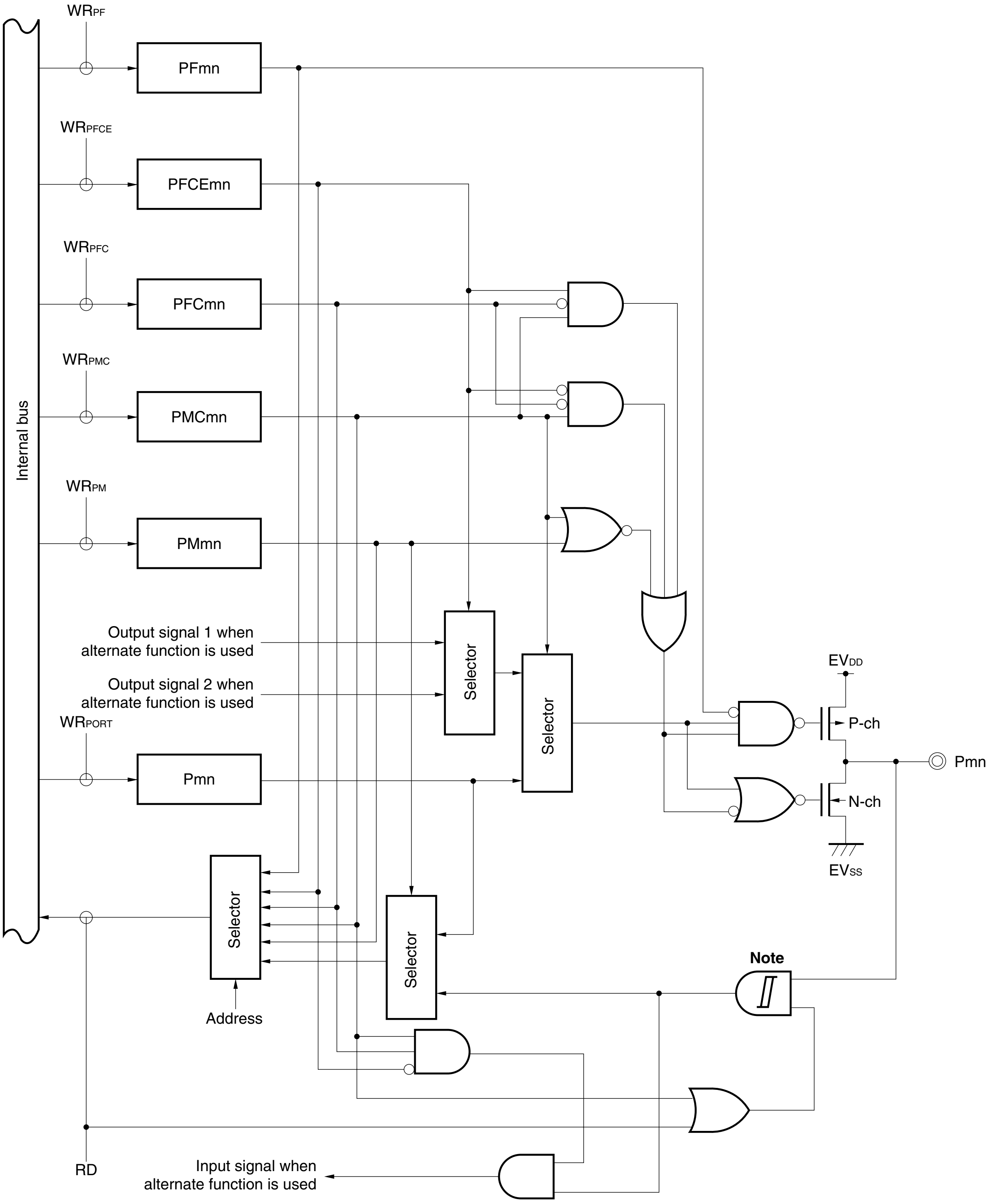
Note Hysteresis characteristics are not available in port mode.

Figure 4-27. Block Diagram of Type U-11



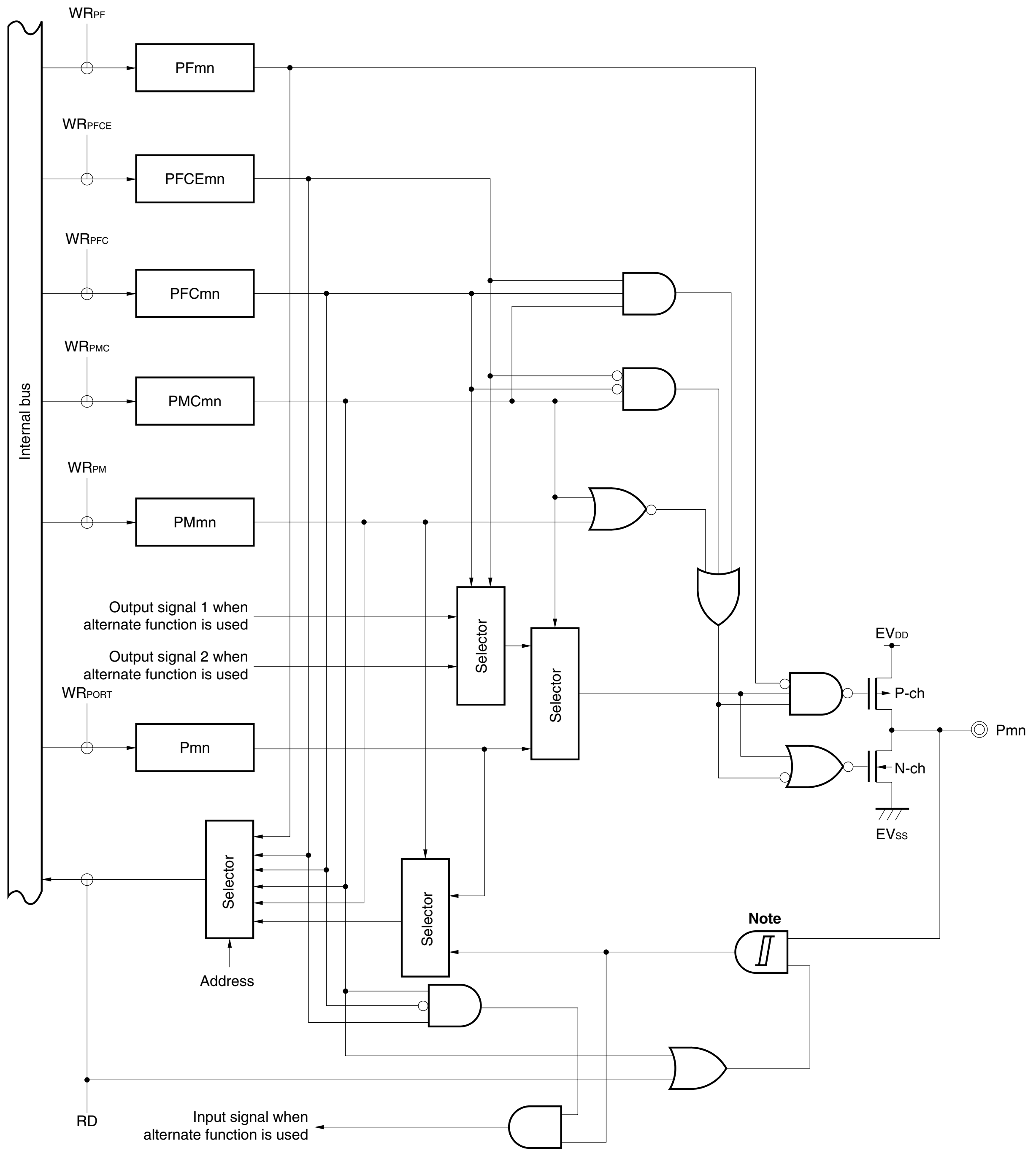
Note Hysteresis characteristics are not available in port mode.

Figure 4-28. Block Diagram of Type U-12



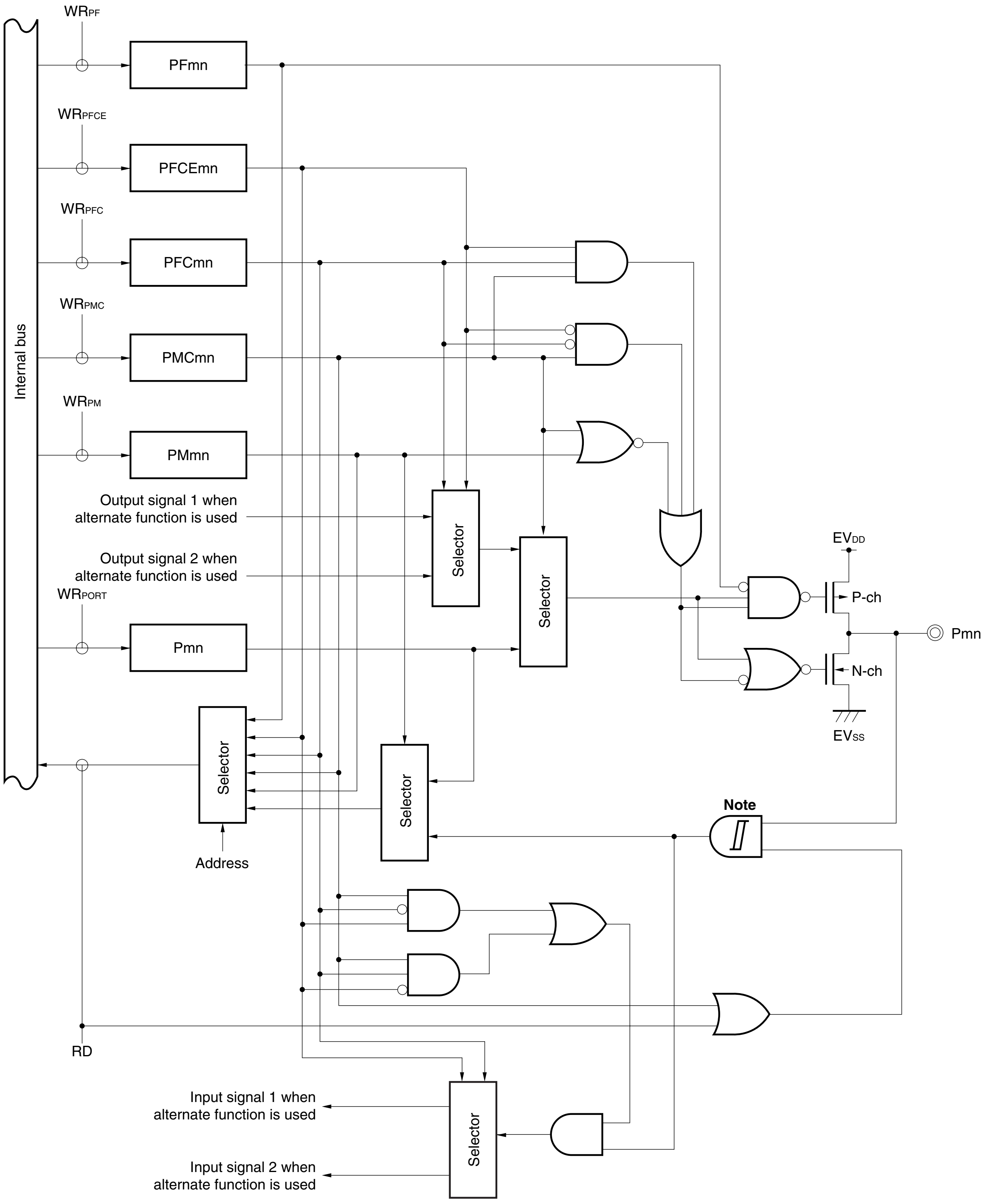
Note Hysteresis characteristics are not available in port mode.

Figure 4-29. Block Diagram of Type U-13



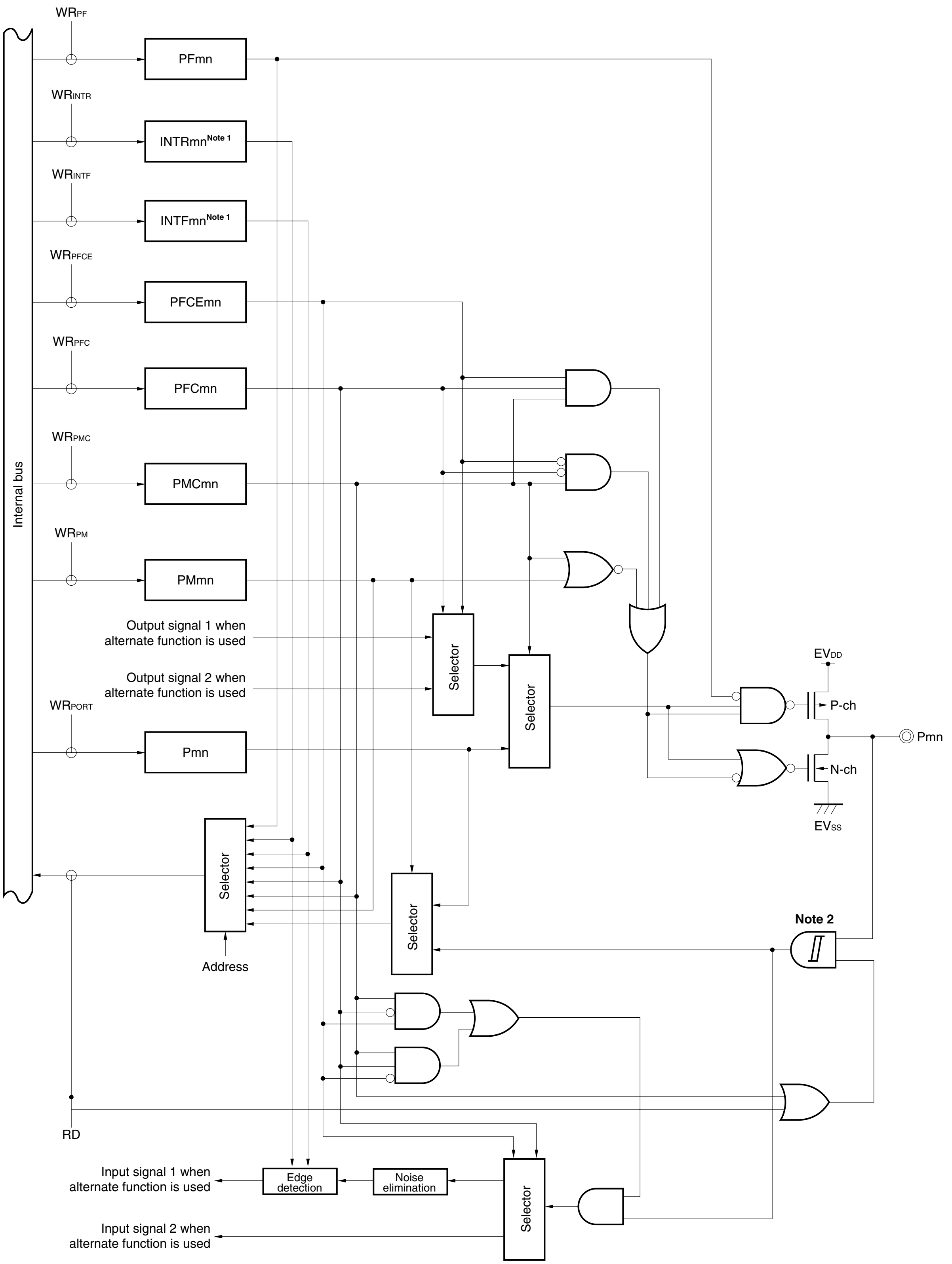
Note Hysteresis characteristics are not available in port mode.

Figure 4-30. Block Diagram of Type U-14



Note Hysteresis characteristics are not available in port mode.

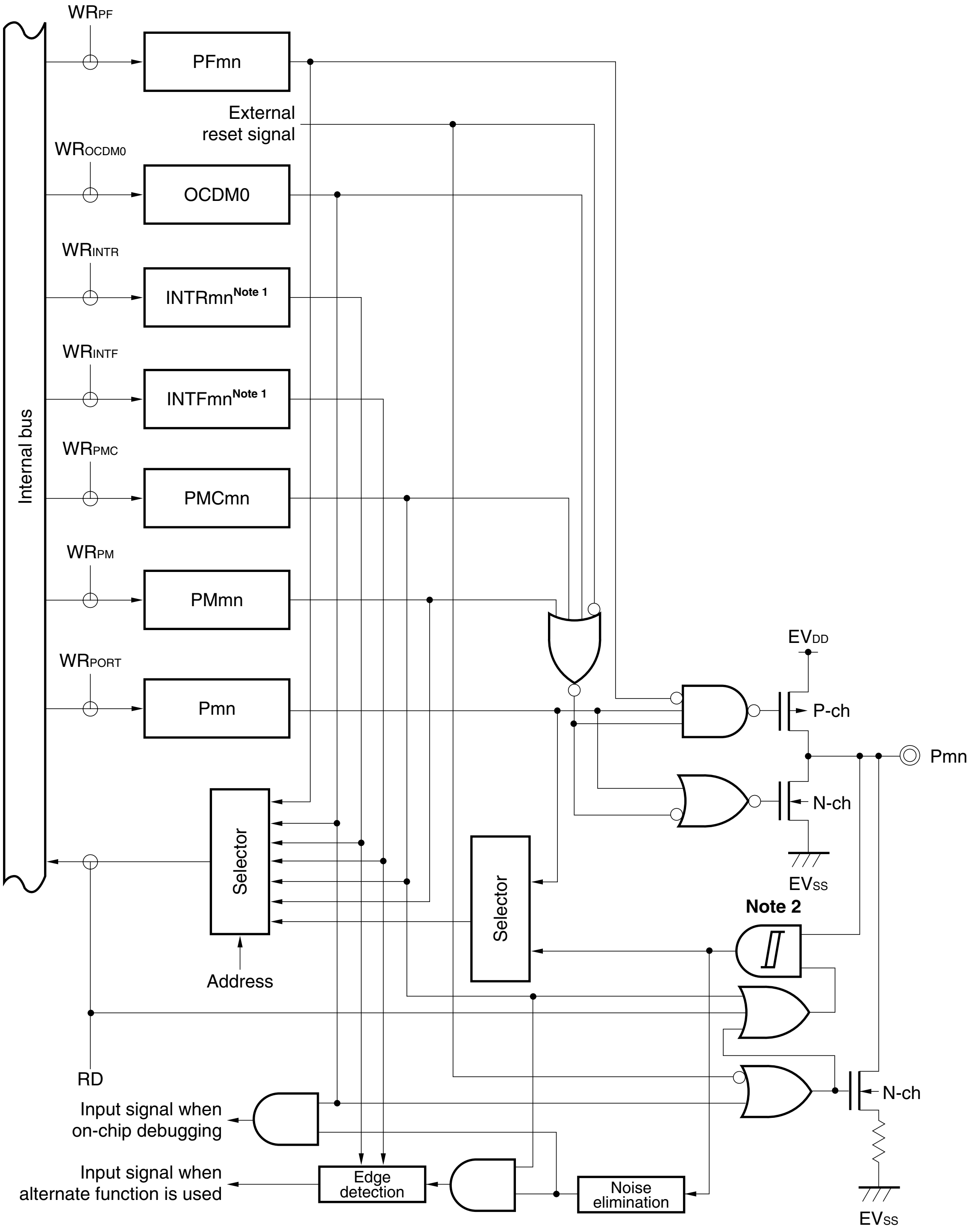
Figure 4-31. Block Diagram of Type U-15



Notes 1. See **19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP7)**.

2. Hysteresis characteristics are not available in port mode.

Figure 4-32. Block Diagram of Type AA-1



Notes 1. See **19.6 External Interrupt Request Input Pins (NMI and INTP0 to INTP7)**.

2. Hysteresis characteristics are not available in port mode.

4.5 Port Register Settings When Alternate Function Is Used

Table 4-15 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 4-15. Settings When Port Pins Are Used for Alternate Functions (1/7)

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	Other Bits (Registers)
	Name	I/O						
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	–	–	OCDM0 (OCDM) = 1
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	–	**Note**, PFC31 = 0	
	INTP7	Input	P31 = Setting not required	PM31 = Setting not required	PMC31 = 1	–	**Note**, 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	
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	

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

Caution When using one of the P10 and P11 pins as an I/O port and the other as a D/A output pin (ANO0, ANO1), do so in an application where the port I/O level does not change during D/A output.

Table 4-15. Settings When Port Pins Are Used for Alternate Functions (2/7)

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	Other Bits (Registers)
	Name	I/O						
P34	TIP10	Input	P34 = Setting not required	PM34 = Setting not required	PMC34 = 1	–	PFC34 = 0	
	TOP10	Output	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	PF38 (PF3) = 1
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	PF39 (PF3) = 1
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	PF40 (PF4) = 1
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	PF41 (PF4) = 1
P42	$\overline{\text{SCKB0}}$	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	KRM0 (KRM) = 0
	KR0	Input	P50 = Setting not required	PM50 = Setting not required	PMC50 = 1	PFCE50 = 0	PFC50 = 1	TQ0TIG2, TQ0TIG3 (TQ0IOC1) = 0
	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	

Table 4-15. Settings When Port Pins Are Used for Alternate Functions (3/7)

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	Other Bits (Registers)
	Name	I/O						
P51	TIQ02	Input	P51 = Setting not required	PM51 = Setting not required	PMC51 = 1	PFCE51 = 0	PFC51 = 1	KRM1 (KRM) = 0
	KR1	Input	P51 = Setting not required	PM51 = Setting not required	PMC51 = 1	PFCE51 = 0	PFC51 = 1	TQ0TIG4, TQ0TIG5 (TQ0IOC1) = 0
	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	KRM2 (KRM) = 0
	KR2	Input	P52 = Setting not required	PM52 = Setting not required	PMC52 = 1	PFCE52 = 0	PFC52 = 1	TQ0TIG6, TQ0TIG7 (TQ0I0C1) = 0
	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	OCDM0 (OCDM) = 1
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	KRM3 (KRM) = 0
	KR3	Input	P53 = Setting not required	PM53 = Setting not required	PMC53 = 1	PFCE53 = 0	PFC53 = 1	TQ0TIG0, TQ0TIG1 (TQ0IOC1) = 0, TQ0EES0, TQ0EES1 (TQ0IOC2) = 0, TQ0ETS0, TQ0ETS1 (TQ0IOC2) = 0
	TOQ00	Output	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	OCDM0 (OCDM) = 1
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	OCDM0 (OCDM) = 1
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	OCDM0 (OCDM) = 1

Table 4-15. Settings When Port Pins Are Used for Alternate Functions (4/7)

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	Other Bits (Registers)
	Name	I/O						
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	–	–	–	
P90	A0	Output	P90 = Setting not required	PM90 = Setting not required	PMC90 = 1	PFCE90 = 0	PFC90 = 0	**Note 1**
	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	PF90 (PF9) = 1
P91	A1	Output	P91 = Setting not required	PM91 = Setting not required	PMC91 = 1	PFCE91 = 0	PFC91 = 0	**Note 1**
	KR7	Input	P91 = Setting not required	PM91 = Setting not required	PMC91 = 1	PFCE91 = 0	PFC91 = 1	
	RXDA1/KR7[Note 2]	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	PF91 (PF9) = 1

Notes 1. When setting pins A0 to A15 as the alternate function, set all 16 bits of the PMC9 register to FFFFH 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 4-15. Settings When Port Pins Are Used for Alternate Functions (5/7)

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	Other Bits (Registers)
	Name	I/O						
P92	A2	Output	P92 = Setting not required	PM92 = Setting not required	PMC92 = 1	PFCE92 = 0	PFC92 = 0	**Note**
	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	**Note**
	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	**Note**
	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	**Note**
	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	**Note**
	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	
P97	A7	Output	P97 = Setting not required	PM97 = Setting not required	PMC97 = 1	PFCE97 = 0	PFC97 = 0	**Note**
	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	**Note**
	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	**Note**
	$\overline{\text{SCKB1}}$	I/O	P99 = Setting not required	PM99 = Setting not required	PMC99 = 1	–	PFC99 = 1	

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

Table 4-15. Settings When Port Pins Are Used for Alternate Functions (6/7)

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	Other Bits (Registers)
	Name	I/O						
P910	A10	Output	P910 = Setting not required	PM910 = Setting not required	PMC910 = 1	–	PFC910 = 0	**Note**
	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	**Note**
	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	**Note**
	$\overline{\text{SCKB3}}$	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	**Note**
	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	**Note**
	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	**Note**
	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	
PCM0	$\overline{\text{WAIT}}$	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	$\overline{\text{HLDAK}}$	Output	PCM2 = Setting not required	PMCM2 = Setting not required	PMCCM2 = 1	–	–	
PCM3	$\overline{\text{HLDRQ}}$	Input	PCM3 = Setting not required	PMCM3 = Setting not required	PMCCM3 = 1	–	–	
PCT0	$\overline{\text{WR0}}$	Output	PCT0 = Setting not required	PMCT0 = Setting not required	PMCCT0 = 1	–	–	
PCT1	$\overline{\text{WR1}}$	Output	PCT1 = Setting not required	PMCT1 = Setting not required	PMCCT1 = 1	–	–	
PCT4	$\overline{\text{RD}}$	Output	PCT4 = Setting not required	PMCT4 = Setting not required	PMCCT4 = 1	–	–	
PCT6	ASTB	Output	PCT6 = Setting not required	PMCT6 = Setting not required	PMCCT6 = 1	–	–	

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

Table 4-15. Settings When Port Pins Are Used for Alternate Functions (7/7)

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	Other Bits (Registers)
	Name	I/O						
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	–	–	
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[Note]	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	–	–	
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	–	–	

Note Since this pin is set in the flash memory programming mode, it does not need to be manipulated using the port control register. For details, see **CHAPTER 28 FLASH MEMORY**.

4.6 Cautions

4.6.1 Cautions on setting port pins

(1) In the V850ES/JG3-L, 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[Note 1]:	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
<4> Set the INTRn and INTFn registers[Note 2]:	External interrupt setting

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.

Notes 1. N-ch open-drain output pin only
2. Only when the external interrupt function is selected

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 (PMC41 bit = 0, PFC41 bit = 0, 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^2C 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)

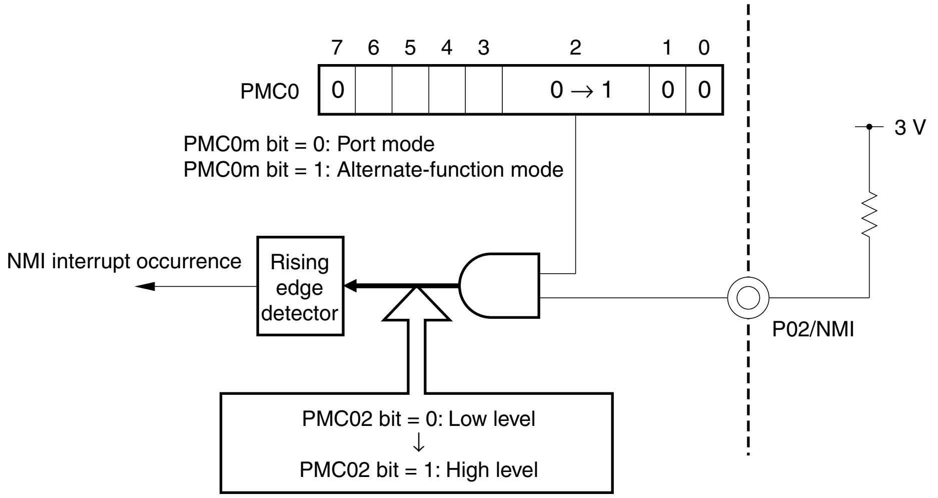
The input signal to the alternate-function block is low level when the PMCn.PMCnm bit is 0 due to the AND output of the PMCn register set value and the pin level. Thus, depending on the port setting and alternate-function operation enable timing, unexpected operations may occur. Therefore, switch between 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 4-33 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 4-33. Example of Switching from P02 to NMI (Incorrect)



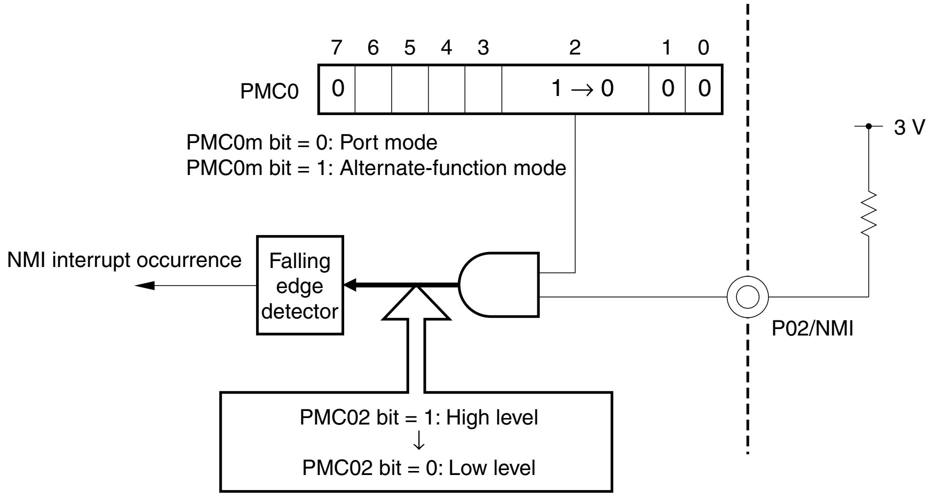
Remark m = 2 to 6

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

When the P02/NMI pin is pulled up as shown in Figure 4-34 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 (PMC02 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 4-34. Example of Switching from NMI to P02 (Incorrect)



Remark m = 2 to 6

(2) 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.

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/JG3-L.

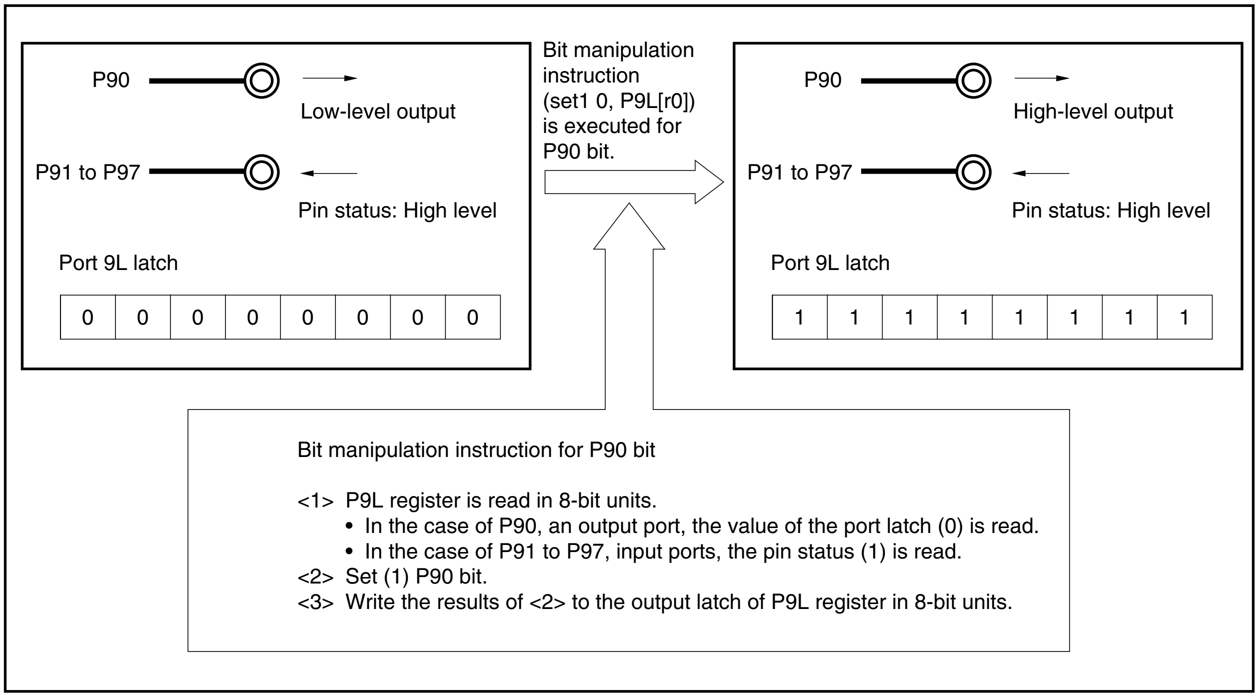
<1> The Pn register is read in 8-bit units.
<2> The targeted one bit is manipulated.
<3> The Pn register is written in 8-bit units.

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 4-35. Bit Manipulation Instruction (P90 Pin)



Bit manipulation instruction for P90 bit

<1> P9L register is read in 8-bit units.
  - In the case of P90, an output port, the value of the port latch (0) is read.
  - In the case of P91 to P97, input ports, the pin status (1) is read.

<2> Set (1) P90 bit.
<3> Write the results of <2> to the output latch of P9L register in 8-bit units.

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 kΩ 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 P10, P11, and P53 pins when power is turned on

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

- P10/ANO0 pin
- P11/ANO1 pin
- 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.

P02 to P06
P31 to P35, P38, P39
P40 to P42
P50 to P55
P90 to P97, P99, P910, P912 to P915

CHAPTER 5 BUS CONTROL FUNCTION

The V850ES/JG3-L 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 output with a minimum of 3 bus cycles and a separate bus output 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 4 MB of physical memory connectable

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 A21	PDH0 to PDH5	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	

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 A21	PDH0 to PDH5	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	

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

Bus Control Pin	Separate Bus Mode		Multiplexed Bus Mode	
	Internal ROM/RAM	Peripheral I/O	Internal ROM/RAM	Peripheral I/O
Address/data bus (AD15 to AD0)	Low level	Undefined	Hi-Z	Hi-Z
Address bus (A21 to A16)	Low level	Undefined	Low level	Undefined
Address bus (A15 to A0)	High level	High level	Low level	Undefined
Control signal	Inactive	Inactive	Inactive	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.

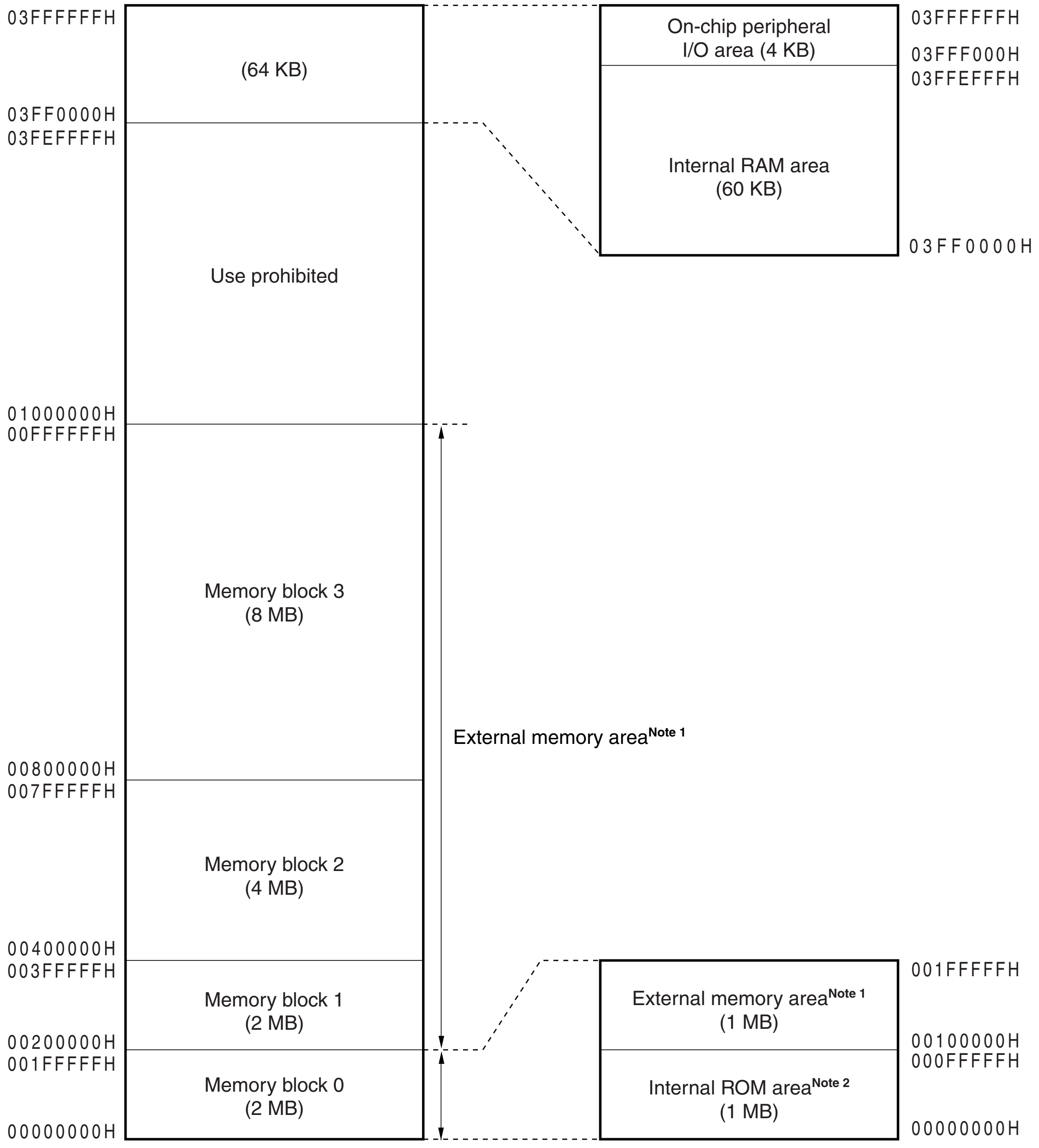
5.2.2 Pin status in each operation mode

For the pin status of the V850ES/JG3-L 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



Notes 1. The V850ES/JG3-L has 22 address pins, so the external memory area appears as a repeated 4 MB image.

2. This area is an external memory area in the case of a data write access.

5.4 External Bus Interface Mode Control Function

The V850ES/JG3-L has 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: FFFFFFBEH

	7	6	5	4	3	2	1	0
EXIMC	0	0	0	0	0	0	0	SMSEL

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	$1^{\text{Note 1}}$	$3 + n^{\text{Note 2}}$
Instruction fetch (branch)	2	$2^{\text{Note 1}}$	$3 + n^{\text{Note 2}}$
Operand data access	3	1	$3 + n^{\text{Note 2}}$

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 memory block n 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/JG3-L is selected by memory blocks 0 to 3.

(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
		Memory block 3		Memory block 2		Memory block 1		Memory block 0

BSn0	Data bus width of memory block n 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/JG3-L 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/JG3-L supports only the little-endian format.

Figure 5-2. Little-Endian Address in Word

31 24	23 16	15 8	7 0
000BH	000AH	0009H	0008H
0007H	0006H	0005H	0004H
0003H	0002H	0001H	0000H

(1) Data space

The V850ES/JG3-L 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.

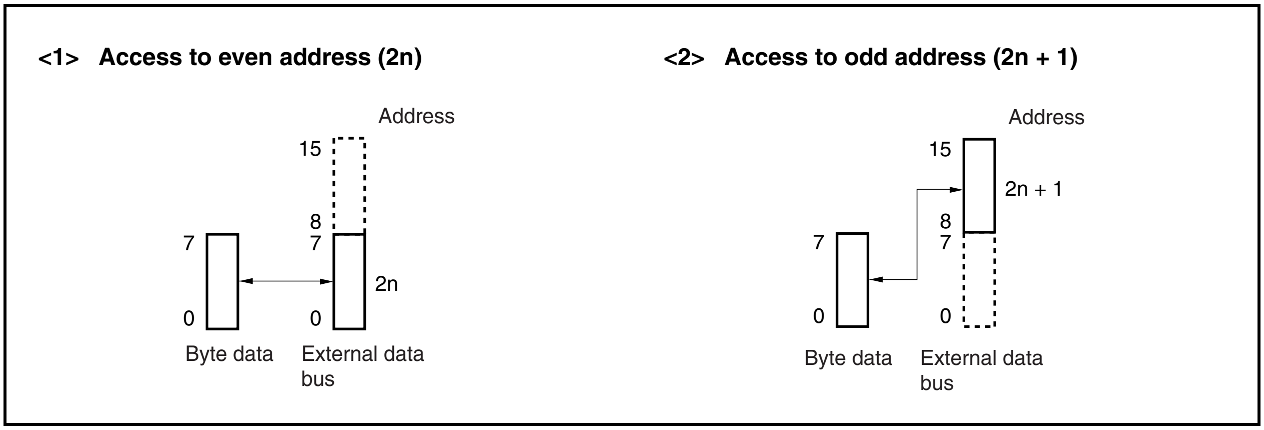
(b) Word-length data access

(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)

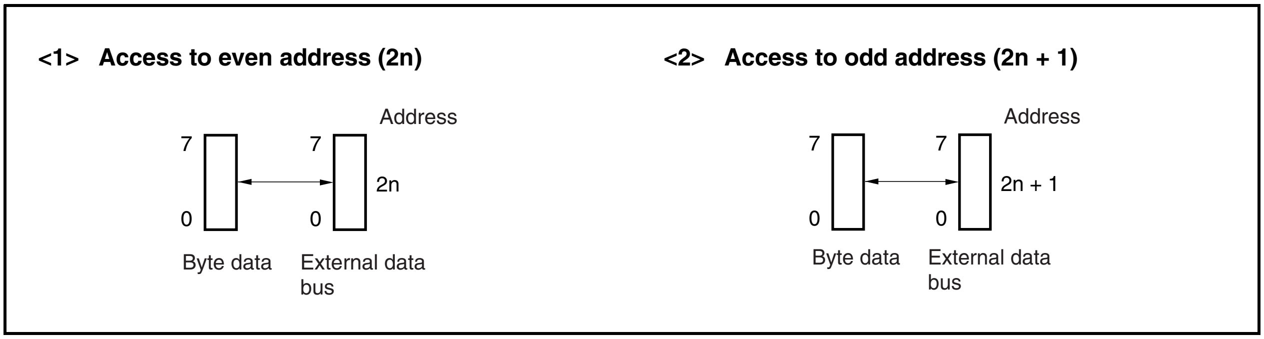
(a) 16-bit data bus width



<1> Access to even address (2n)

<2> Access to odd address (2n + 1)

(b) 8-bit data bus width

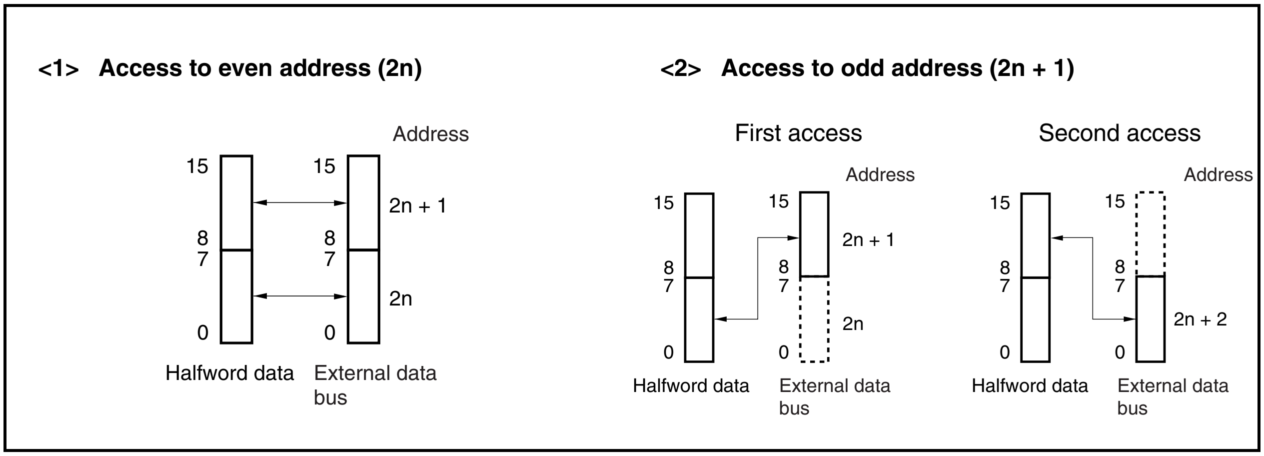


<1> Access to even address (2n)

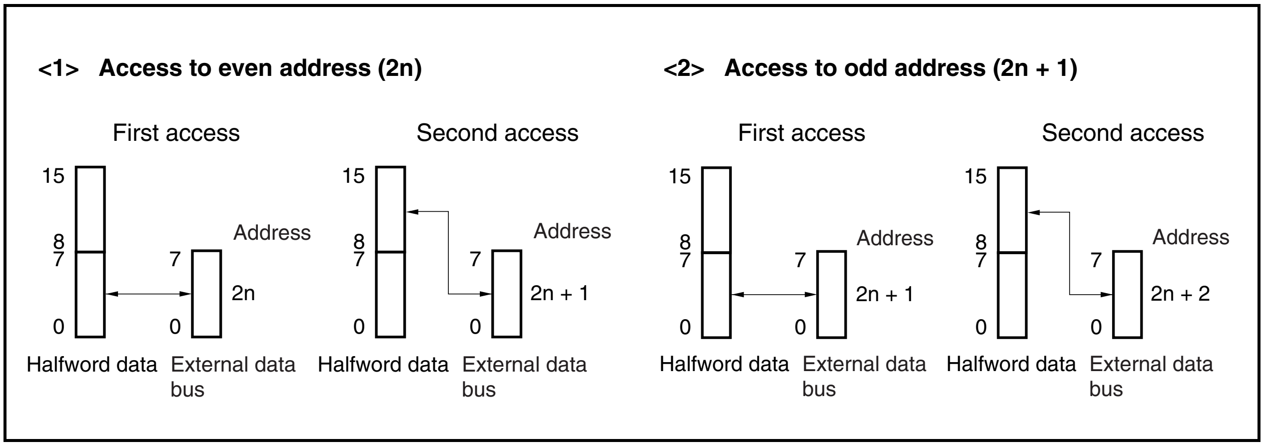
<2> Access to odd address (2n + 1)

(3) Halfword access (16 bits)

(a) With 16-bit data bus width



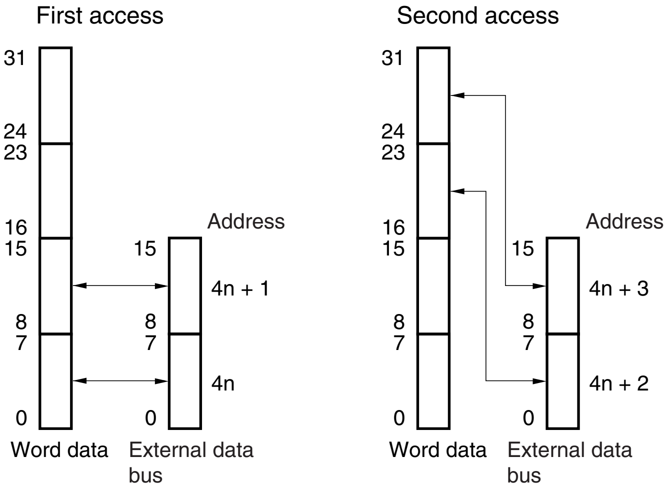
(b) 8-bit data bus width



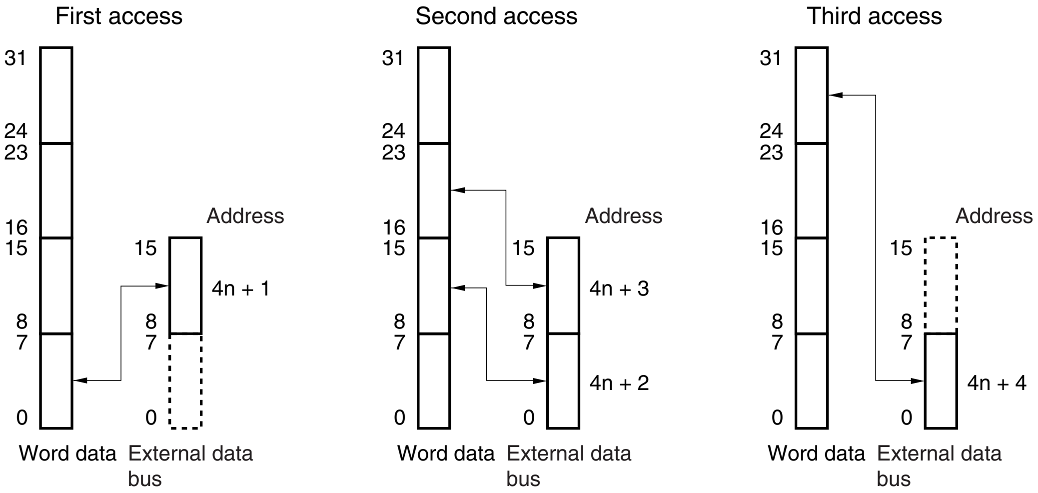
(4) Word access (32 bits)

(a) 16-bit data bus width (1/2)

<1> Access to address (4n)

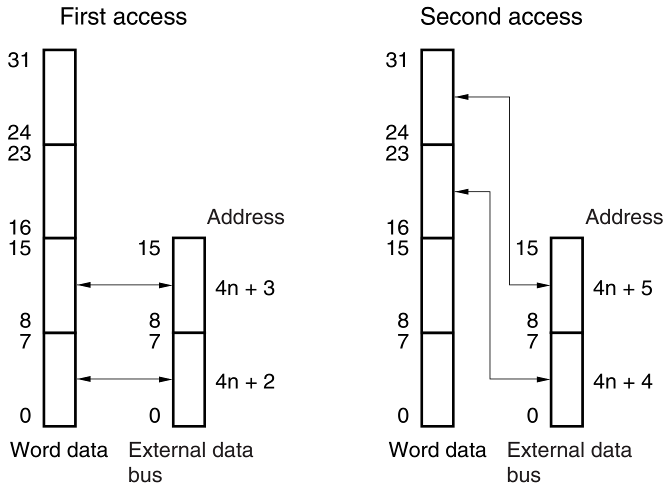


<2> Access to address (4n + 1)

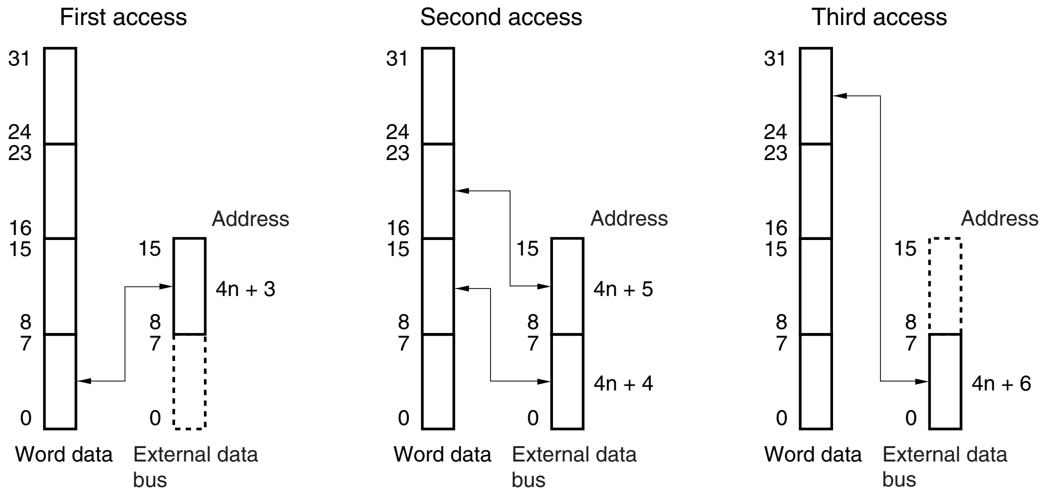


(a) 16-bit data bus width (2/2)

<3> Access to address (4n + 2)

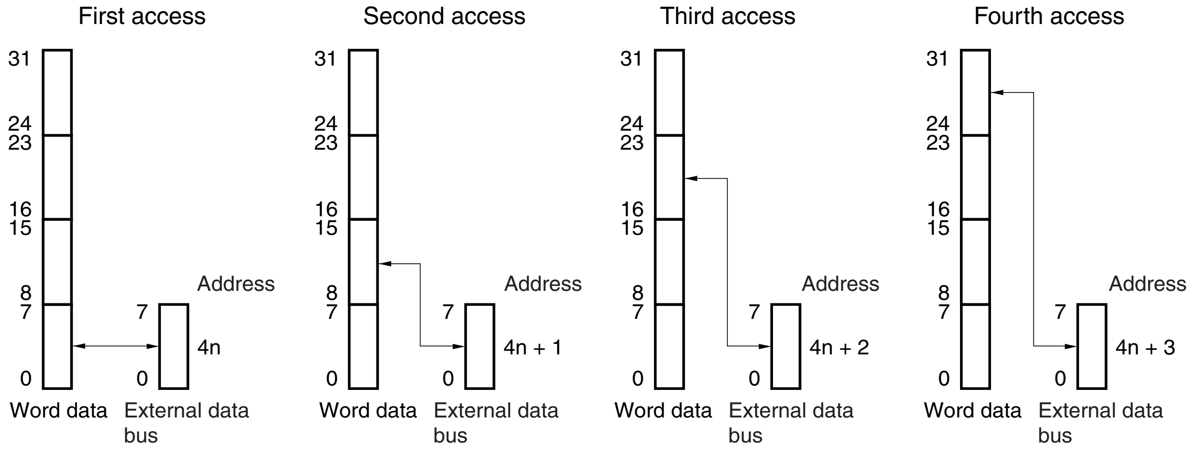


<4> Access to address (4n + 3)

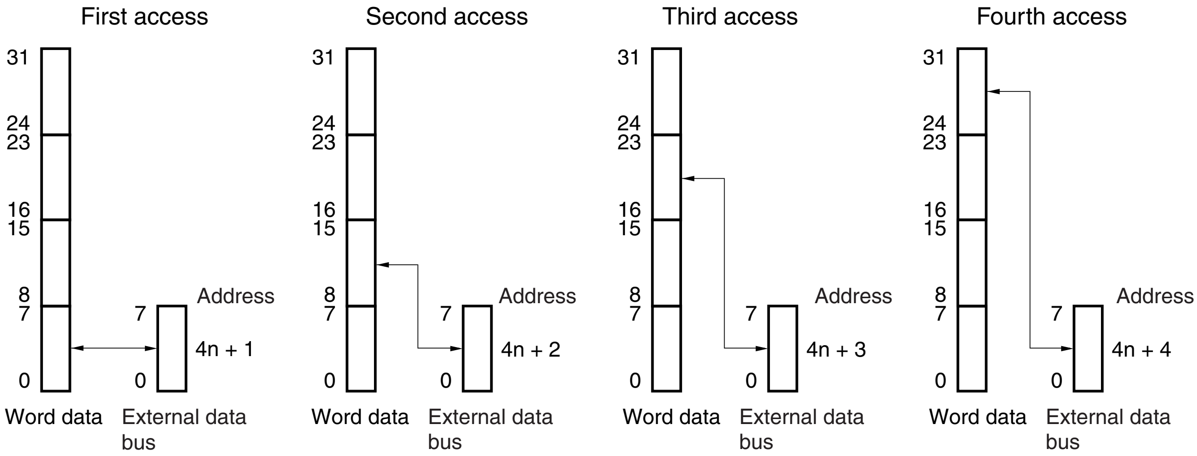


(b) 8-bit data bus width (1/2)

<1> Access to address (4n)

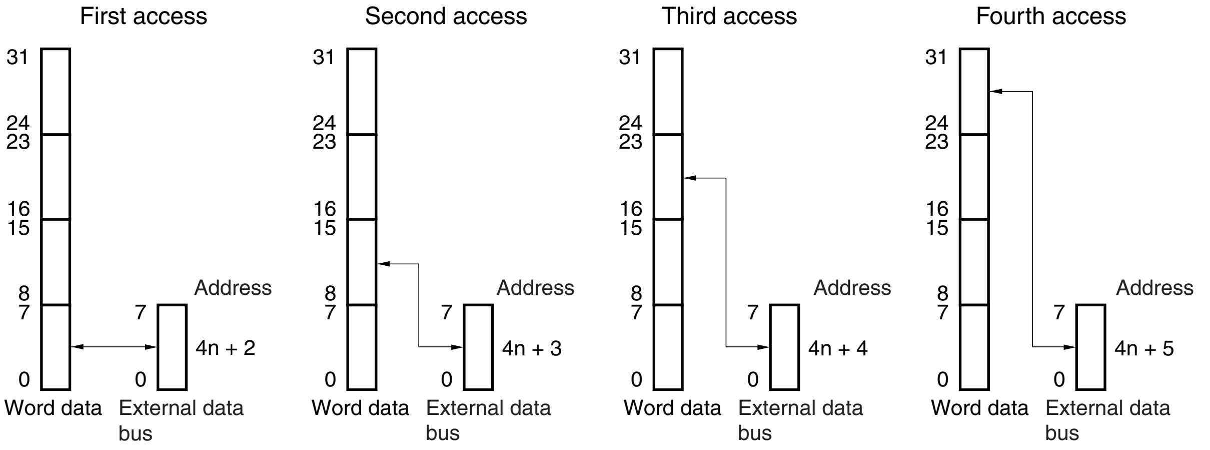


<2> Access to address (4n + 1)

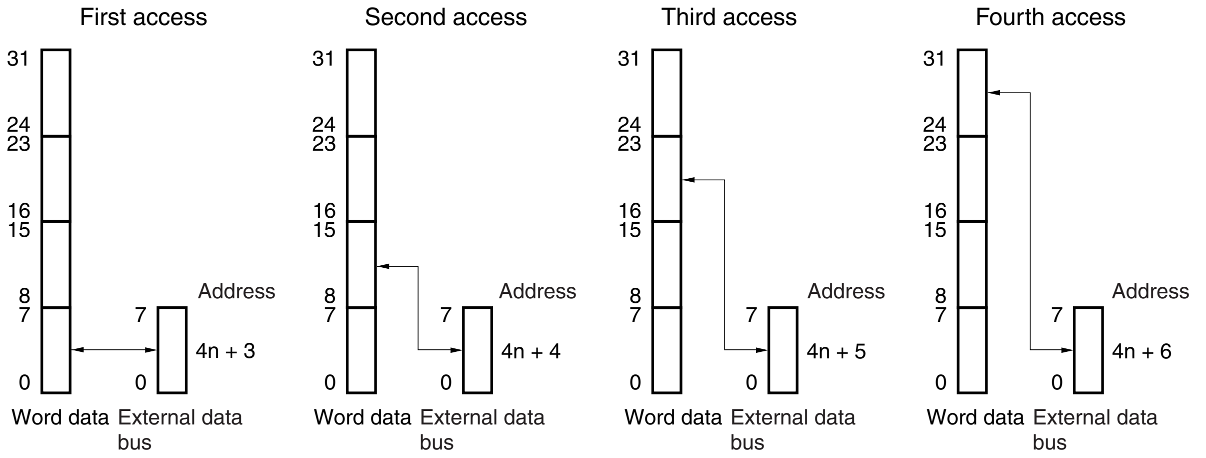


(b) 8-bit data bus width (2/2)

<3> Access to address (4n + 2)



<4> Access to address (4n + 3)



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 memory block 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.

After reset: 7777H R/W Address: FFFFF484H

	15	14	13	12	11	10	9	8
DWC0	0	DW32	DW31	DW30	0	DW22	DW21	DW20
		Memory block 3				Memory block 2		

	7	6	5	4	3	2	1	0
	0	DW12	DW11	DW10	0	DW02	DW01	DW00
		Memory block 1				Memory block 0		

DWn2	DWn1	DWn0	Number of wait states inserted in memory block n space (n = 0 to 3)
0	0	0	None
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 ($\overline{\text{WAIT}}$).

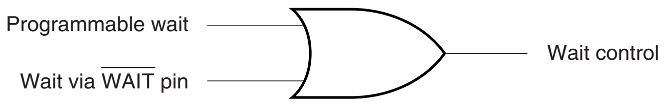
When the PCM0 pin is set to alternate function, the external wait function is enabled.

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

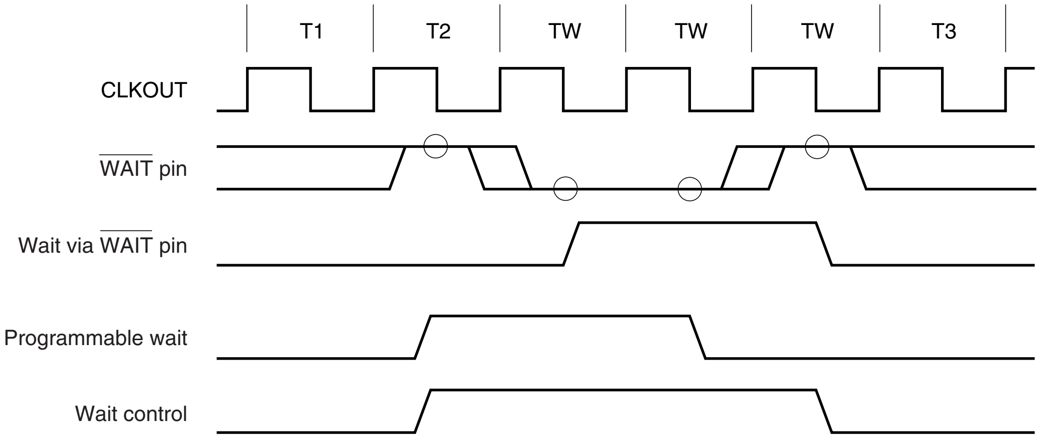
Wait cycles are inserted as the result of an OR operation between the wait cycles specified by the set value of the programmable wait and the wait cycles controlled by the $\overline{\text{WAIT}}$ pin.



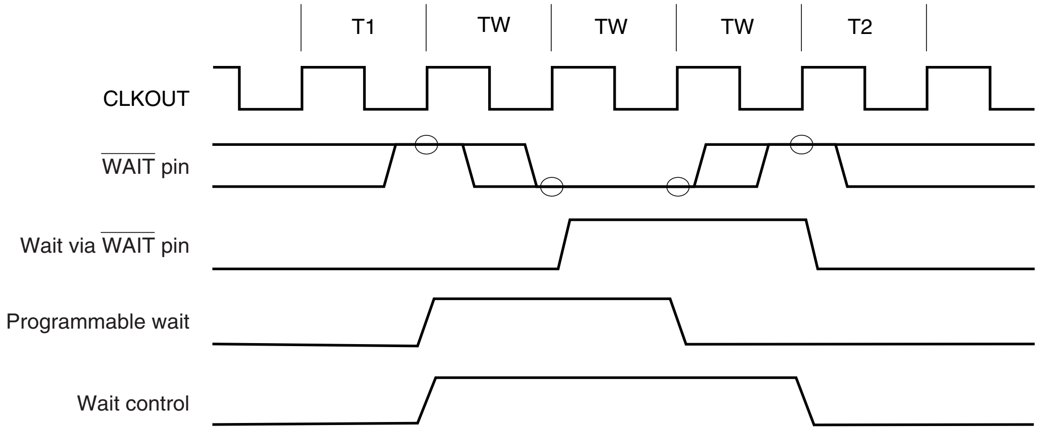
For example, if the timing of the programmable wait and the $\overline{\text{WAIT}}$ pin signal is as illustrated below, three wait states will be inserted in the bus cycle.

Figure 5-3. Inserting Wait Example

(a) Multiplexed bus



(b) Separate bus



Remark The circles indicate the sampling timing.

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 memory block area (memory blocks 0 to 3).

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.

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
	Memory block 3		Memory block 2		Memory block 1		Memory block 0	

AHWn	Specifies insertion of address hold wait (n = 0 to 3)
0	Not inserted
1	Inserted

ASWn	Specifies insertion of address setup wait (n = 0 to 3)
0	Not inserted
1	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 memory block 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
	Memory block 3		Memory block 2		Memory block 1		Memory block 0	

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.

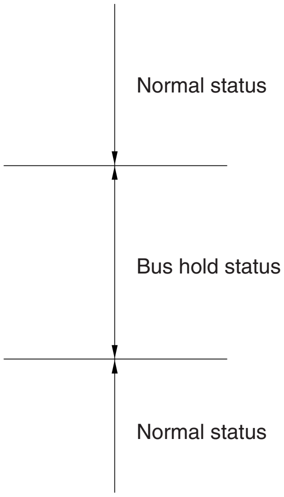
Status	Data Bus Width	Access Type	Timing at Which Bus Hold Request Is Not Acknowledged
CPU bus lock	16 bits	Word access to even address	Between first and second access
		Word access to odd address	Between first and second access
			Between second and third access
		Halfword access to odd address	Between first and second access
	8 bits	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

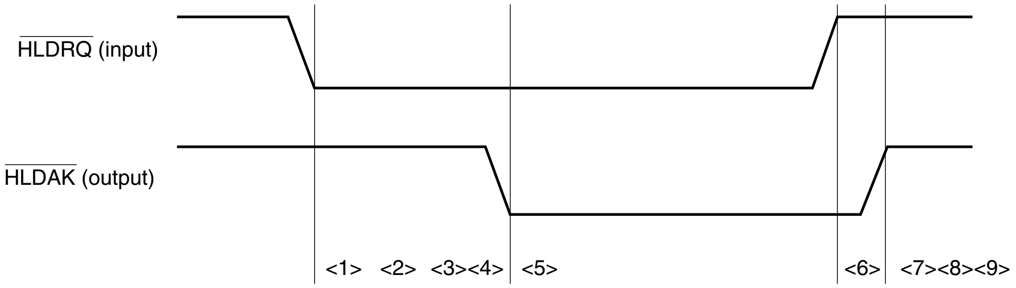
5.8.2 Bus hold procedure

The bus hold status transition procedure is shown below.

<1> $\overline{\text{HLDRQ}}$ = 0 acknowledged
<2> All bus cycle start requests inhibited
<3> End of current bus cycle
<4> Shift to bus idle status
<5> $\overline{\text{HLDAK}}$ = 0

<6> $\overline{\text{HLDRQ}}$ = 1 acknowledged
<7> $\overline{\text{HLDAK}}$ = 1
<8> Bus cycle start request inhibition released
<9> Bus cycle starts





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 $\overline{\text{HLDRQ}}$ pin is asserted.

In the HALT mode, the $\overline{\text{HLDAK}}$ pin is asserted as soon as the $\overline{\text{HLDRQ}}$ pin has been asserted, and the bus hold status is entered. When the $\overline{\text{HLDRQ}}$ pin is later deasserted, the $\overline{\text{HLDAK}}$ 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.

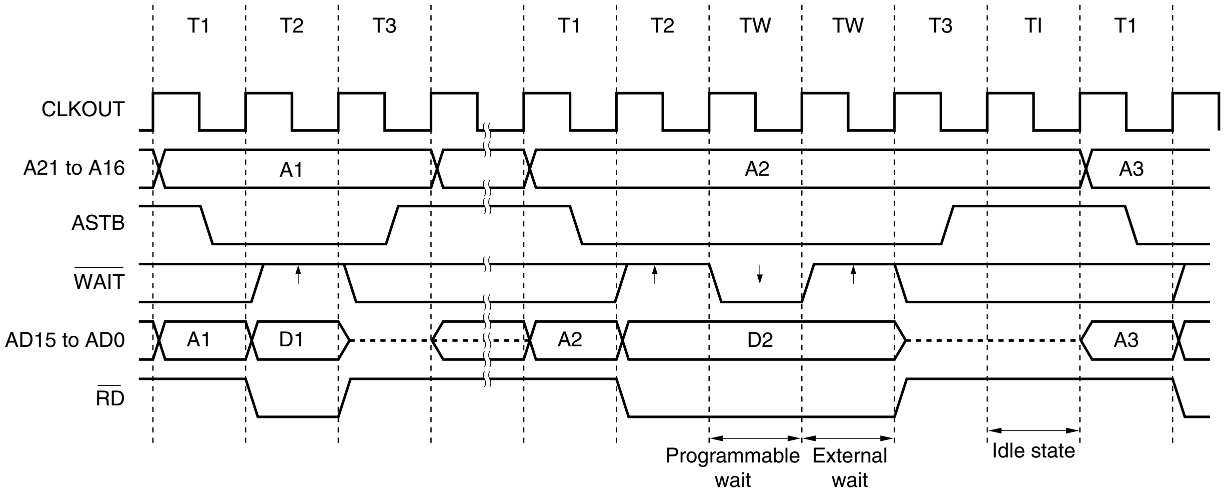
If an instruction is executed for two or more accesses, an instruction fetch and bus hold are not inserted between accesses due to bus size limitations.

Table 5-4. Bus Priority

Priority	External Bus Cycle	Bus Master
High	Bus hold	External device
	DMA transfer	DMAC
↕	Operand data access	CPU
	Instruction fetch (branch)	CPU
Low	Instruction fetch (successive)	CPU

5.10 Bus Timing

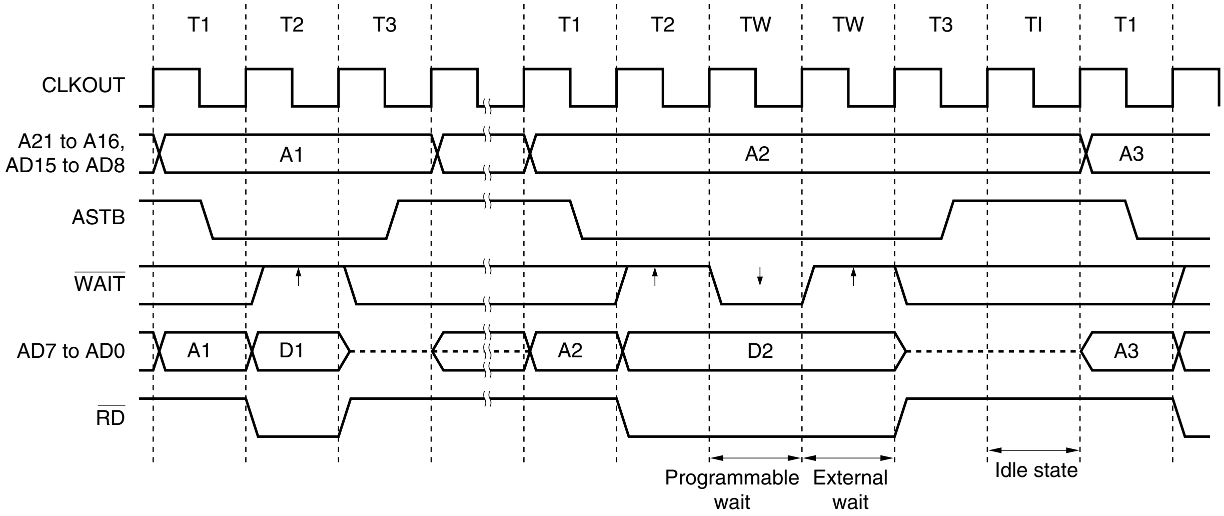
Figure 5-4. Multiplexed Bus Read Timing (Bus Size: 16 Bits, 16-Bit Access)



8-bit Access	Odd Address	Even Address
AD15 to AD8	Active	Hi-Z
AD7 to AD0	Hi-Z	Active

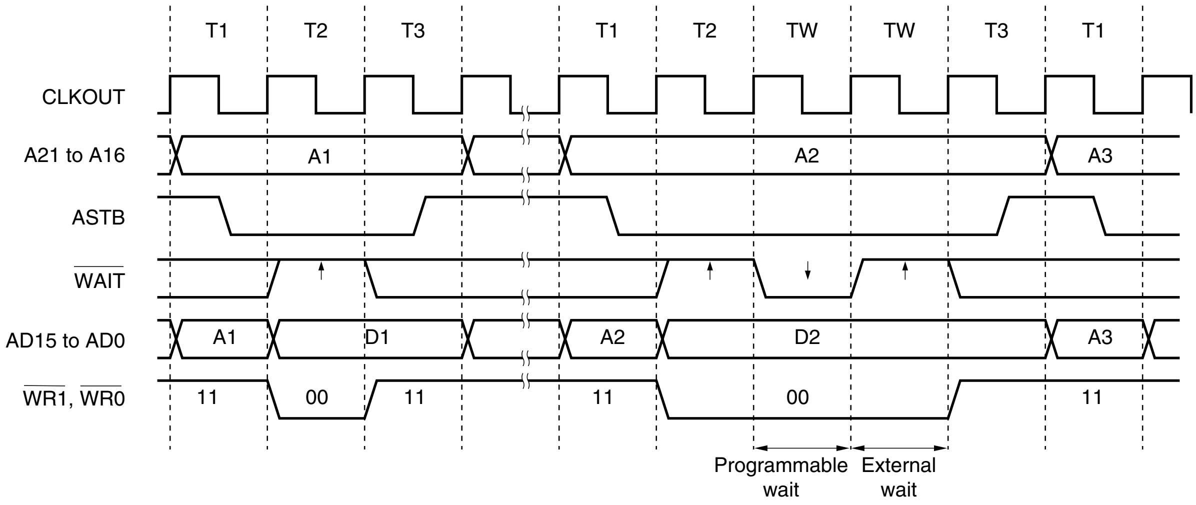
Remark The broken lines indicate high impedance.

Figure 5-5. Multiplexed Bus Read Timing (Bus Size: 8 Bits)



Remark The broken lines indicate high impedance.

Figure 5-6. Multiplexed 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
$\overline{\text{WR1}}$, $\overline{\text{WR0}}$	01	10

Figure 5-7. Multiplexed Bus Write Timing (Bus Size: 8 Bits)

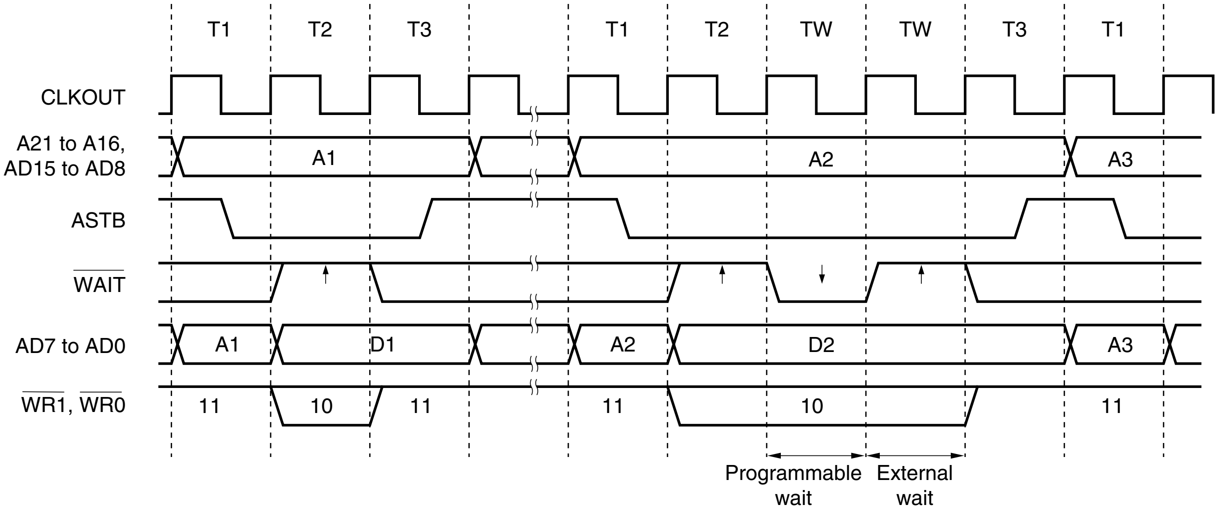
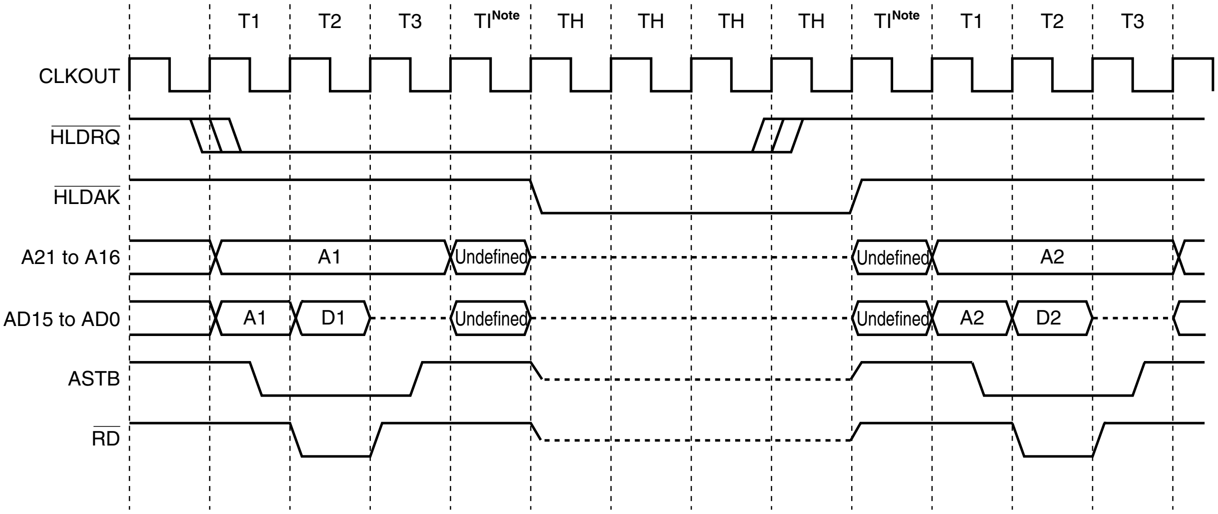


Figure 5-8. Multiplexed Bus Hold Timing (Bus Size: 16 Bits, 16-Bit Access)

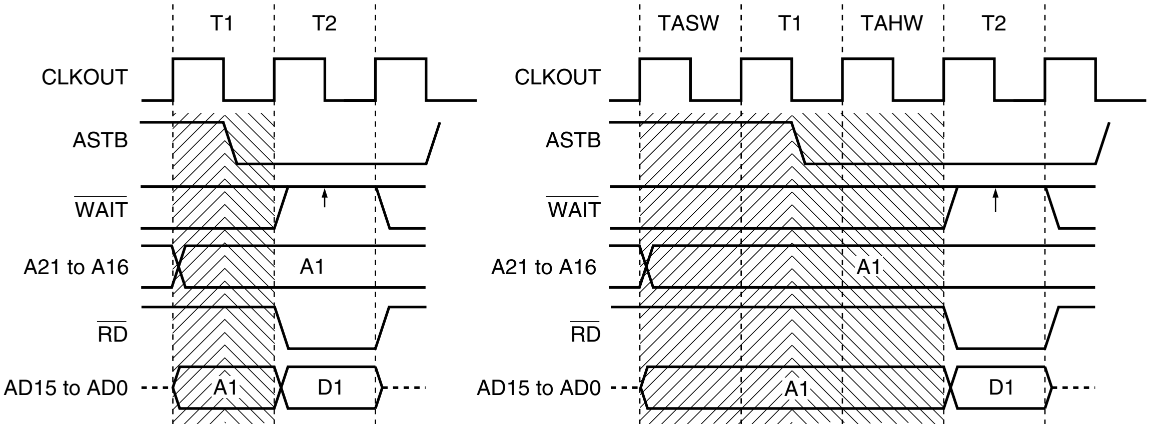


Note This idle state (TI) does not depend on the BCC register settings.

Remarks 1. See **Table 2-2** for the pin statuses in the bus hold mode.

2. The broken lines indicate high impedance.

Figure 5-9. Address Wait Timing (Bus Size: 16 Bits, 16-Bit Access)

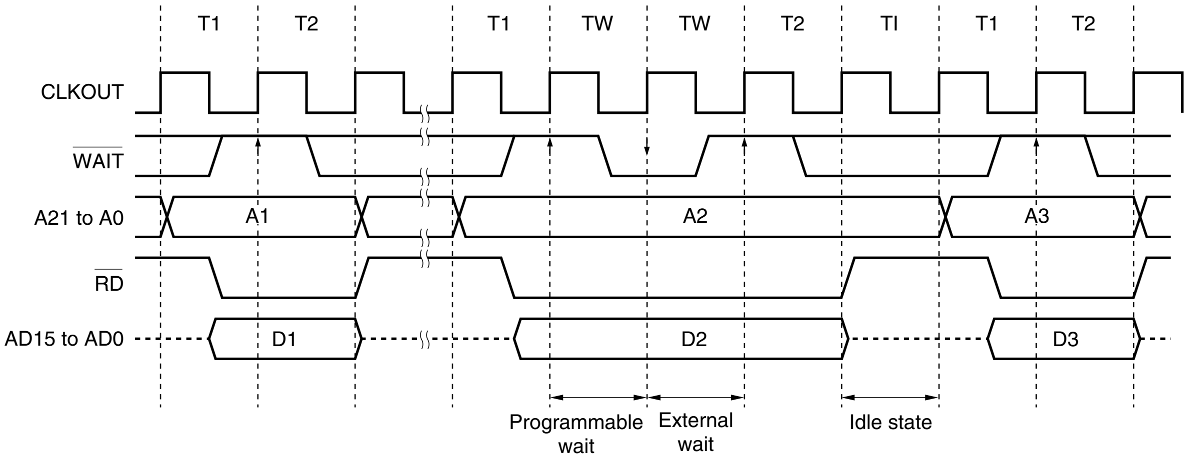


Remarks 1. TASW (address setup wait): Image of high-level width of T1 state expanded.

2. TAHW (address hold wait): Image of low-level width of T1 state expanded.

3. The broken lines indicate high impedance.

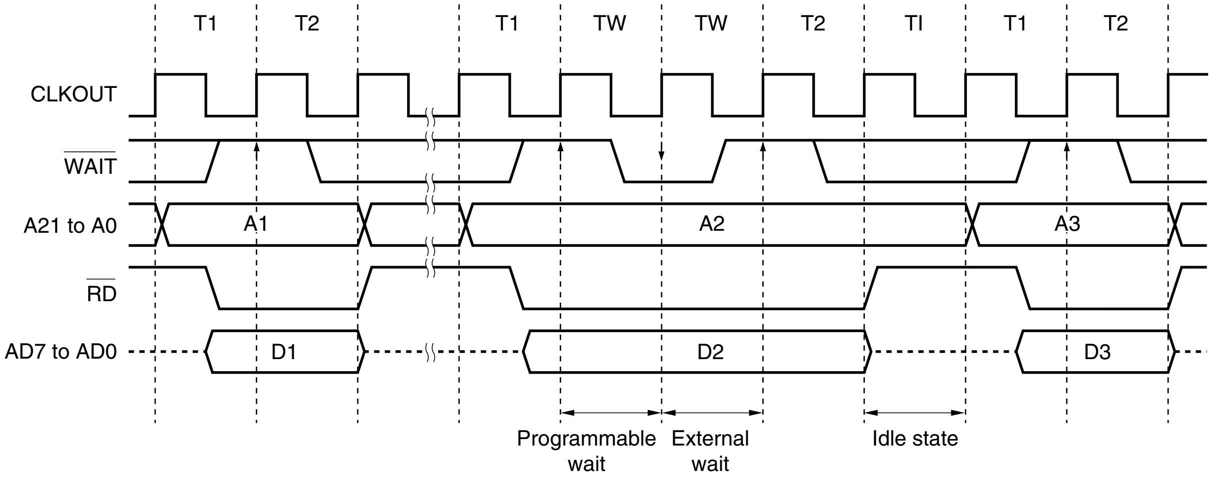
Figure 5-10. Separate Bus Read Timing (Bus Size: 16 Bits, 16-Bit Access)



8-bit Access	Odd Address	Even Address
AD15 to AD8	Active	Hi-Z
AD7 to AD0	Hi-Z	Active

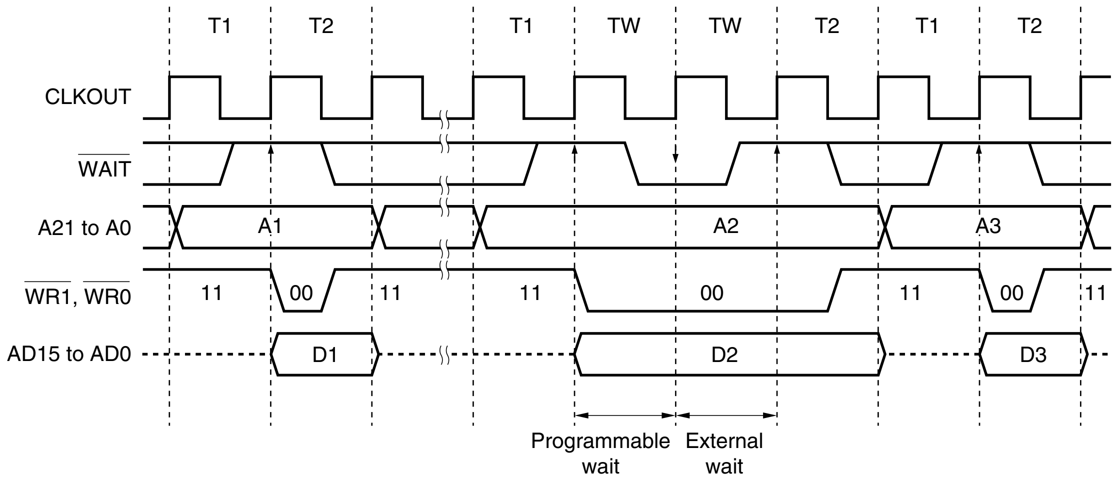
Remark The broken lines indicate high impedance.

Figure 5-11. Separate Bus Read Timing (Bus Size: 8 Bits)



Remark The broken lines indicate high impedance.

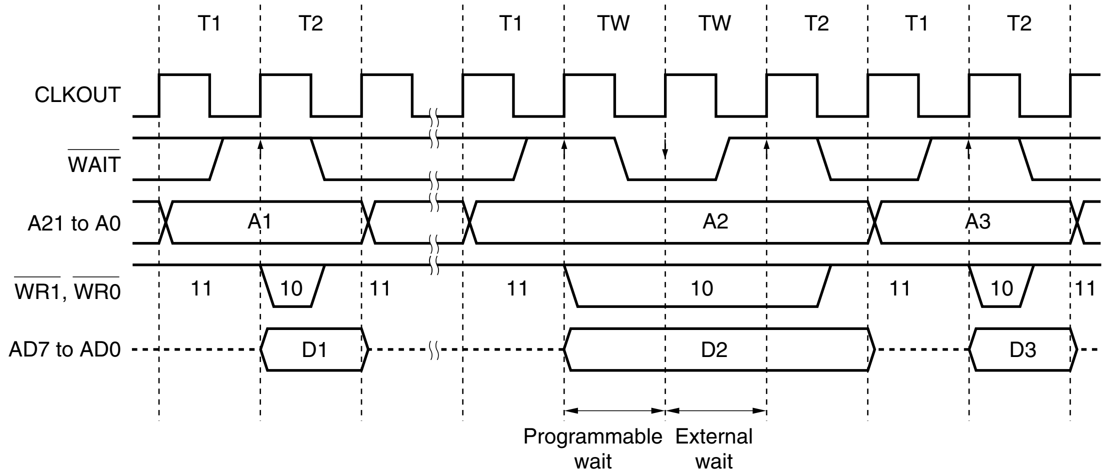
Figure 5-12. Separate Bus Write Timing (Bus Size: 16 Bits, 16-Bit Access)



8-bit Access	Odd Address	Even Address
AD15 to AD8	Active	Undefined
AD7 to AD0	Undefined	Active
$\overline{\text{WR1}}$, $\overline{\text{WR0}}$	01	10

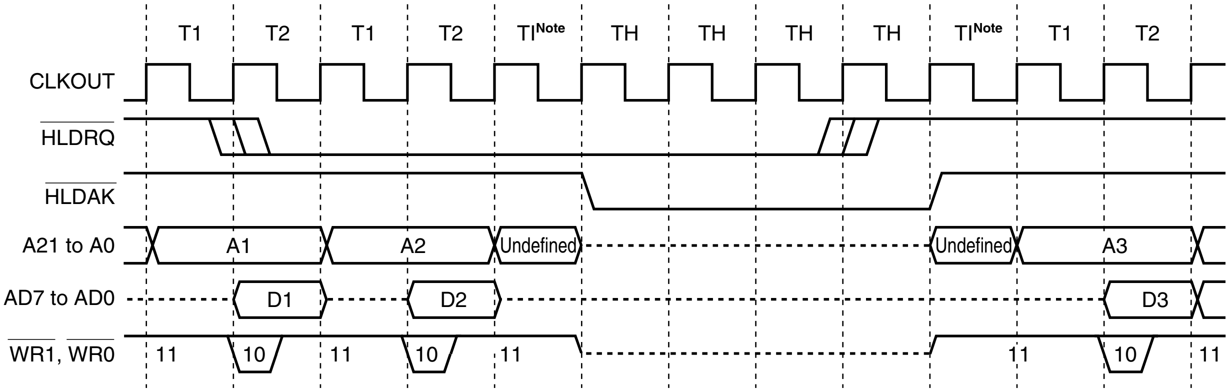
Remark The broken lines indicate high impedance.

Figure 5-13. Separate Bus Write Timing (Bus Size: 8 Bits)



Remark The broken lines indicate high impedance.

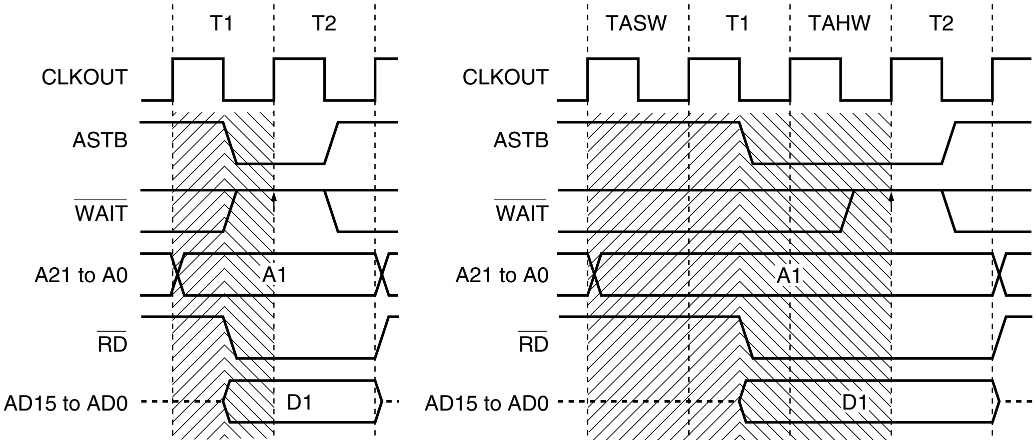
Figure 5-14. Separate Bus Hold Timing (Bus Size: 8 Bits, Write)



Note This idle state (TI) does not depend on the BCC register settings.

Remark The broken lines indicate high impedance.

Figure 5-15. Address Wait Timing (Separate Bus Read, Bus Size: 16 Bits, 16-Bit Access)



Remarks 1. TASW (address setup wait): Image of high-level width of T1 state expanded.

2. TAHW (address hold wait): Image of low-level width of T1 state expanded.

3. The broken lines indicate high impedance.

CHAPTER 6 CLOCK GENERATION FUNCTION

6.1 Overview

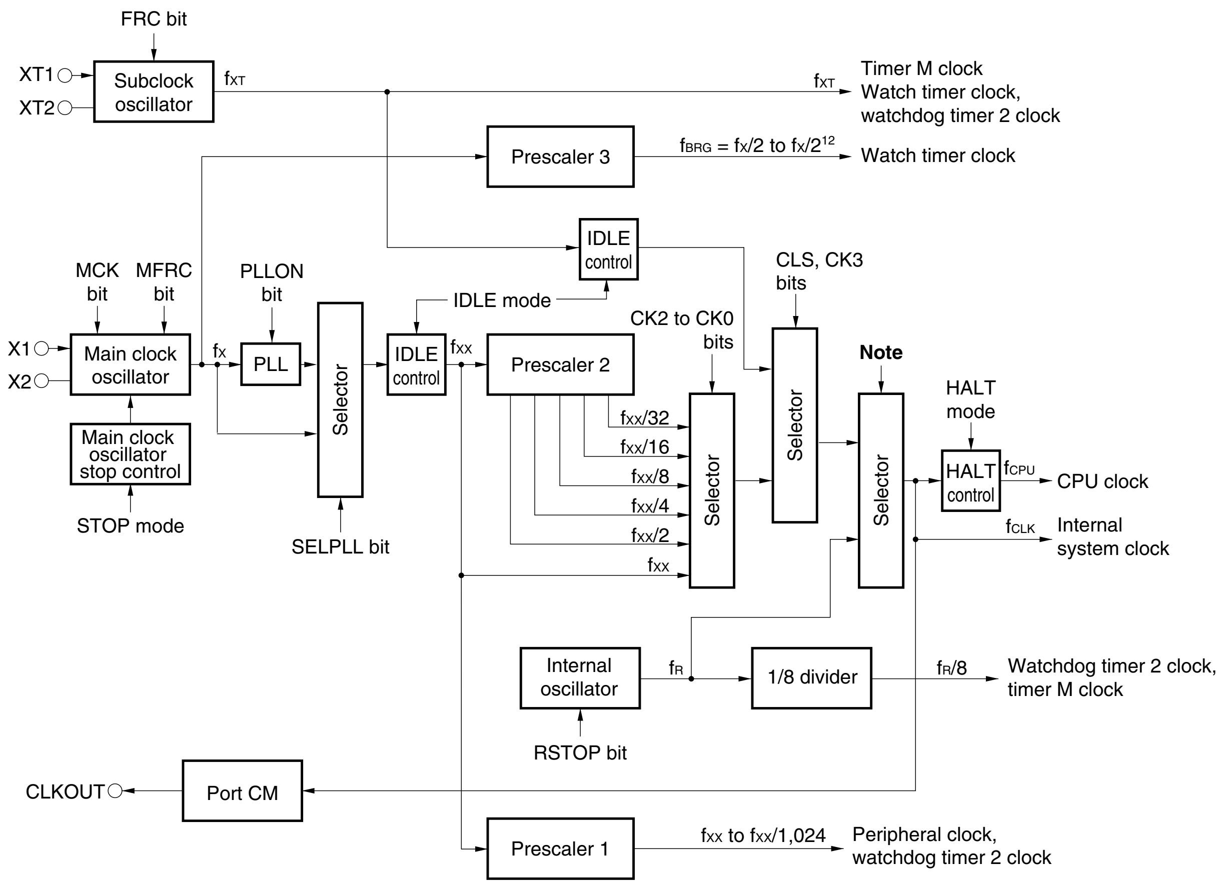
The following clock generation functions are available.

- 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 (f_{XX} = 10 to 20 MHz)
- Subclock oscillator
  - f_{XT} = 32.768 kHz
- Multiply (×4) function by PLL (Phase Locked Loop)
  - Clock-through mode/PLL mode selectable (f_X = 2.5 to 5 MHz)
- 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



Note The internal oscillation clock is selected when watchdog timer 2 overflows during the oscillation stabilization time.

Remark

f_X:	Main clock oscillation frequency
f_{XX}:	Main clock frequency
f_{CLK}:	Internal system clock frequency
f_{XT}:	Subclock frequency
f_{CPU}:	CPU clock frequency
f_{BRG}:	Watch timer clock frequency
f_R:	Internal oscillation clock frequency

(1) Main clock oscillator

The main clock oscillator connects the ceramic/crystal resonator to X1 and X2 pins and 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

The external clock of the following frequency is input to the X1 pin.

- In clock-through/PLL mode
  f_X = 2.5 to 5 MHz

(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 TMP5, TMQ0, TMM0, CSIB0 to CSIB4, UARTA0 to UARTA2, I^2C00 to I^2C02, ADC, DAC, 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, RAM, and DMA 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.

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 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[Note]	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

- 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.
- Before setting the MCK bit from 0 to 1, stop the on-chip peripheral functions operating with the main clock.
- 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.

MFRC	Use of main clock on-chip feedback resistor
0	Used (when ceramic/crystal resonator is used)
1	Not used (when external clock is used)

CLS[Note]	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.

3. When the external clock is used, set the MFRC bit to "1" so as not to use the internal feedback resistor.

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:
    clrl        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:
    setl        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.CCLSF bit = 1). Do not set the RSTOP bit to 1.

2. The internal oscillator oscillates if the CCLS.CCLSF 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^{Note} R Address: FFFFF82EH

	7	6	5	4	3	2	1	0
CCLS	0	0	0	0	0	0	0	CCLSF

CCLSF	CPU operation clock status
0	Operating on main clock (f_X) or subclock (f_{XT}).
1	Operating on internal oscillation clock (f_R).

Note If WDT overflow occurs during oscillation stabilization after a reset is released, the CCLSF 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 Operation Status / Target Clock	PCC Register								
	CLK Bit = 0, MCK Bit = 0					CLS Bit = 1, MCK Bit = 0		CLS Bit = 1, MCK Bit = 1	
	During Reset	During Oscillation Stabilization Time Count	HALT Mode	IDLE1, IDLE2 Mode	STOP Mode	Subclock Mode	Sub-IDLE Mode	Subclock Mode	Sub-IDLE Mode
Main clock oscillator (f_X)	×	√	√	√	×	√	√	×	×
Subclock oscillator (f_{XT})	√	√	√	√	√	√	√	√	√
CPU clock (f_{CPU})	×	×	×	×	×	√	×	√	×
Internal system clock (f_{CLK})	×	×	√	×	×	√	×	√	×
Main clock (in PLL mode, f_{XX})	×	√Note	√	×	×	√	√	×	×
Peripheral clock (f_{XX} to f_{XX}/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_{CLK}) from the CLKOUT pin.

The internal system clock (f_{CLK}) 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/JG3-L, an operating clock that is 4 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:	Input clock = 2.5 to 5 MHz (output: 10 to 20 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 (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	Setting prohibited

Cautions 1. The PLL mode cannot be used at f_X = 5.0 to 10.0 MHz.

2. Be sure to set bits 3 and 1 to “1” and set bits 7 to 4, 2, and 0 to “0”.

3. Be sure to set the CKC register to 0AH. If a value other than 0AH is set, the operation is not guaranteed.

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[Note]
- 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}/fx
0	1	2^{11}fx
1	0	2^{12}/fx
1	1	2^{13}/fx (default value)

Cautions 1. Set so that the lockup time is at least 800 μs.

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 at least 1 ms.
- IDLE2 mode: Set the OSTS register so that the setup time is at least 350 μs.

(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 at least 1 ms.
- IDLE2 mode: Set the OSTS register so that the setup time is at least 800 μs.

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).
  The times required for restoration from the IDLE2 and STOP modes are as follows.

- STOP mode: Set the OSTS register so that the oscillation stabilization time is at least 1 ms.
- IDLE2 mode: Set the OSTS register so that the setup time is at least 350 μs.

CHAPTER 7 16-BIT TIMER/EVENT COUNTER P (TMP)

Timer P (TMP) is a 16-bit timer/event counter.
The V850ES/JG3-L has six timer/event counter channels, TMP0 to TMP5.

7.1 Overview

An outline of TMPn 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 5

7.2 Functions

TMPn 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 5

7.3 Configuration

TMPn includes the following hardware.

Table 7-1. Configuration of TMPn

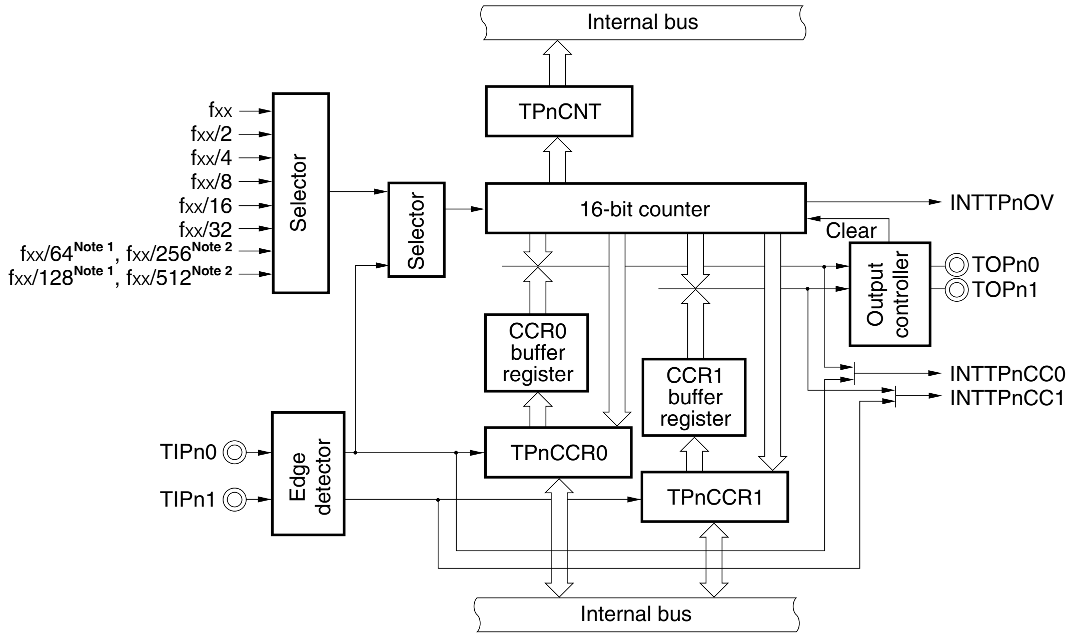
Item	Configuration
Timer register	16-bit counter
Registers	TMPn capture/compare registers 0, 1 (TPnCCR0, TPnCCR1) TMPn counter read buffer register (TPnCNT) CCR0, CCR1 buffer registers
Timer inputs	2 (TIPn0$^{\text{Note 1}}$, TIPn1 pins)
Timer outputs	2 (TOPn0, TOPn1 pins)
Control registers$^{\text{Note 2}}$	TMPn control registers 0, 1 (TPnCTL0, TPnCTL1) TMPn I/O control registers 0 to 2 (TPnIOC0 to TPnIOC2) TMPn option register 0 (TPnOPT0)

Notes 1. The TIPn0 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 TIPn0, TIPn1, TOPn0, and TOPn1 pins, see **Table 4-15 Settings When Port Pins Are Used for Alternate Functions**.

Remark n = 0 to 5

Figure 7-1. Block Diagram of TMPn



Notes 1. TMP0, TMP2, TMP4

2. TMP1, TMP3, TMP5

Remark fxx: Main clock frequency

(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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

2. n = 0 to 5

(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

	<7>	6	5	4	3	2	1	0
TPnCTL0 (n = 0 to 5)	TPnCE	0	0	0	0	TPnCKS2	TPnCKS1	TPnCKS0

TPnCE	TMPn operation control
0	TMPn operation disabled (TMPn reset asynchronously[Note]).
1	TMPn operation enabled. TMPn operation started.

TPnCKS2	TPnCKS1	TPnCKS0	Internal count clock selection	
			n = 0, 2, 4	n = 1, 3, 5
0	0	0	fxx	
0	0	1	fxx/2	
0	1	0	fxx/4	
0	1	1	fxx/8	
1	0	0	fxx/16	
1	0	1	fxx/32	
1	1	0	fxx/64	fxx/256
1	1	1	fxx/128	fxx/512

Note TPnOPT0.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 fxx: 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 FFFFF591H, TP1CTL1 FFFFF5A1H,
TP2CTL1 FFFFF5B1H, TP3CTL1 FFFFF5C1H,
TP4CTL1 FFFFF5D1H, TP5CTL1 FFFFF5E1H

	7	<6>	<5>	4	3	2	1	0
TPnCTL1 (n = 0 to 5)	0	TPnEST	TPnEEE	0	0	TPnMD2	TPnMD1	TPnMD0

TPnEST	Software trigger control
0	–
1	Generate a valid signal for external trigger input. • In one-shot pulse output mode: A one-shot pulse is output with writing 1 to the TPnEST bit as the trigger. • In external trigger pulse output mode: A PWM waveform is output with writing 1 to the TPnEST bit as the trigger.

TPnEEE	Count clock selection
0	Disable operation with external event count input. (Perform counting with the count clock selected by the TPnCTL0.TPnCK0 to TPnCK2 bits.)
1	Enable operation with external event count input. (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 the 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

	7	6	5	4	3	<2>	1	<0>
TPnIOC0 (n = 0 to 5)	0	0	0	0	TPnOL1	TPnOE1	TPnOL0	TPnOE0

TPnOL1	TOPn1 pin output level setting[Note]
0	TOPn1 pin starts output at high level
1	TOPn1 pin starts output at low level

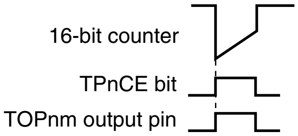
TPnOE1	TOPn1 pin output setting
0	Timer output disabled • When TPnOL1 bit = 0: Low level is output from the TOPn1 pin • When TPnOL1 bit = 1: High level is output from the TOPn1 pin
1	Timer output enabled (a square wave is output from the TOPn1 pin).

TPnOL0	TOPn0 pin output level setting[Note]
0	TOPn0 pin starts output at high level
1	TOPn0 pin starts output at low level

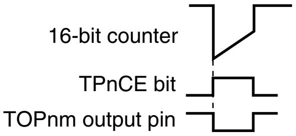
TPnOE0	TOPn0 pin output setting
0	Timer output disabled • When TPnOL0 bit = 0: Low level is output from the TOPn0 pin • When TPnOL0 bit = 1: High level is output from the TOPn0 pin
1	Timer output enabled (a square wave is output from the TOPn0 pin).

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

	7	6	5	4	3	2	1	0
TPnIOC1 (n = 0 to 5)	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.

(5) TMPn I/O control register 2 (TPnIOC2)

The TPnIOC2 register is an 8-bit register that controls the valid edge of the external event count input signal (TIPn0 pin) and external trigger input signal (TIPn0 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: TP0IOC2 FFFFF594H, TP1IOC2 FFFFF5A4H,
TP2IOC2 FFFFF5B4H, TP3IOC2 FFFFF5C4H,
TP4IOC2 FFFFF5D4H, TP5IOC2 FFFFF5E4H

	7	6	5	4	3	2	1	0
TPnIOC2 (n = 0 to 5)	0	0	0	0	TPnEES1	TPnEES0	TPnETS1	TPnETS0

TPnEES1	TPnEES0	External event count input signal (TIPn0 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

TPnETS1	TPnETS0	External trigger input signal (TIPn0 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 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.

2. 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.

3. 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.

(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

	7	6	5	4	3	2	1	<0>
TPnOPT0 (n = 0 to 5)	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
• 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. • 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. • The TPnOVF bit is not cleared even when the TPnOVF bit or the TPnOPT0 register are read when the TPnOVF bit = 1. • 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.	

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**

After reset: 0000H R/W Address: TP0CCR0 FFFFF596H, TP1CCR0 FFFFF5A6H,
TP2CCR0 FFFFF5B6H, TP3CCR0 FFFFF5C6H,
TP4CCR0 FFFFF5D6H, TP5CCR0 FFFFF5E6H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TPnCCR0 (n = 0 to 5)																

(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**

After reset: 0000H R/W Address: TP0CCR1 FFFFF598H, TP1CCR1 FFFFF5A8H,
TP2CCR1 FFFFF5B8H, TP3CCR1 FFFFF5C8H,
TP4CCR1 FFFFF5D8H, TP5CCR1 FFFFF5E8H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TPnCCR1 (n = 0 to 5)																

(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**

After reset: 0000H R Address: TP0CNT FFFFF59AH, TP1CNT FFFFF5AAH,
TP2CNT FFFFF5BAH, TP3CNT FFFFF5CAH,
TP4CNT FFFFF5DAH, TP5CNT FFFFF5EAH

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TPnCNT (n = 0 to 5)																

7.5 Operation

TMPn can perform the following operations.

Operation	TPnCTL1.TPnEST Bit (Software Trigger Bit)	TIPn0 Pin (External Trigger Input)	Capture/Compare Register Setting	Compare Register Write
Interval timer mode	Invalid	Invalid	Compare only	Anytime write
External event count mode[Note 1]	Invalid	Invalid	Compare only	Anytime write
External trigger pulse output mode[Note 2]	Valid	Valid	Compare only	Batch write
One-shot pulse output mode[Note 2]	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[Note 2]	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).

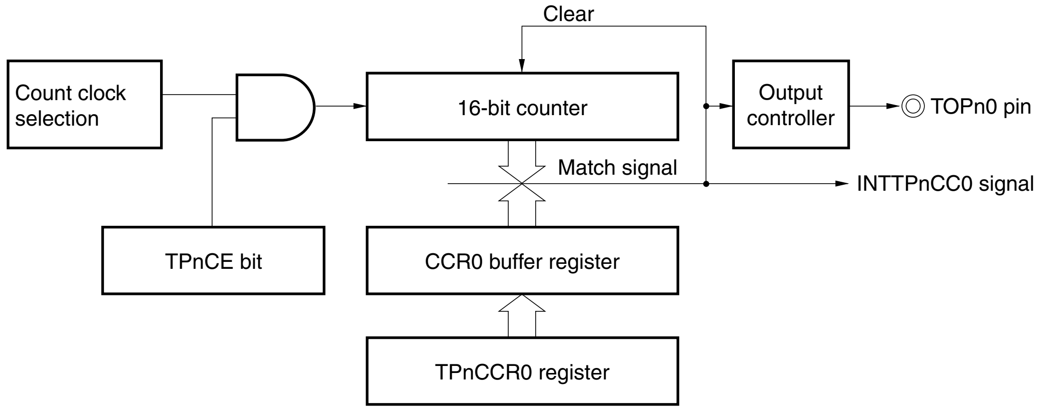
Remark n = 0 to 5

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.

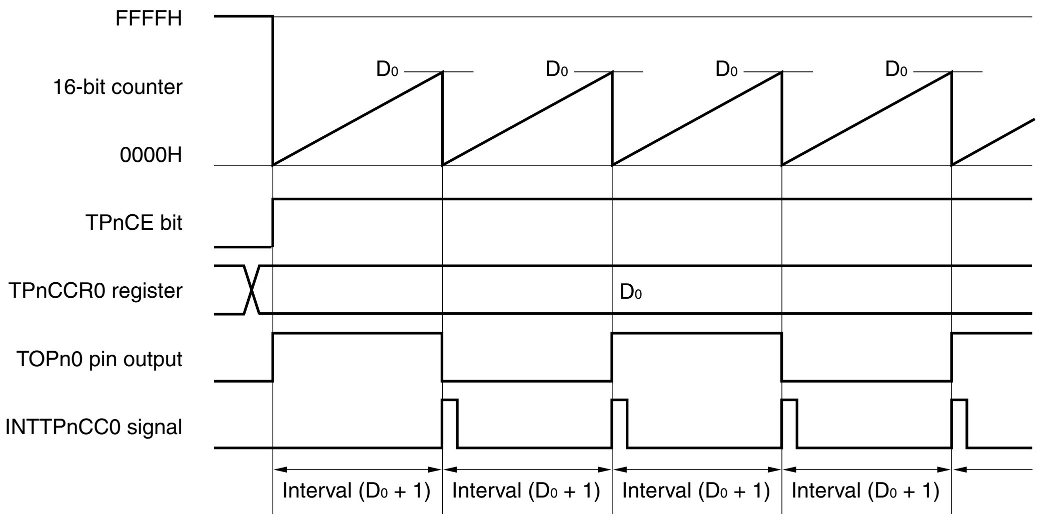
Usually, the TPnCCR1 register is not used in the interval timer mode.

Figure 7-2. Configuration of Interval Timer



Remark n = 0 to 5

Figure 7-3. Basic Timing of Operation in Interval Timer Mode



Remark n = 0 to 5

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.

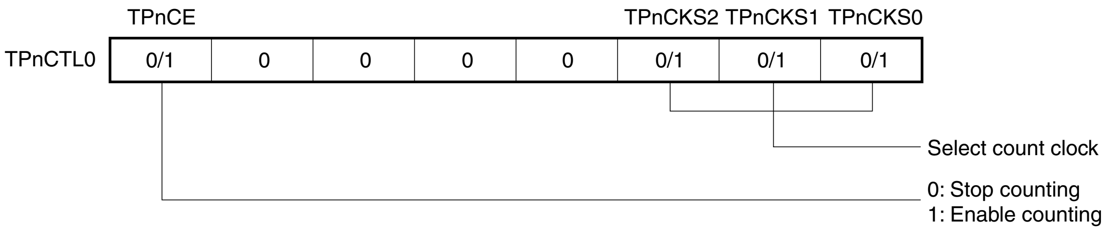
The interval can be calculated by the following expression.

Interval = (Set value of TPnCCR0 register + 1) × Count clock cycle

Remark n = 0 to 5

Figure 7-4. Register Setting for Interval Timer Mode Operation (1/2)

(a) TMPn control register 0 (TPnCTL0)

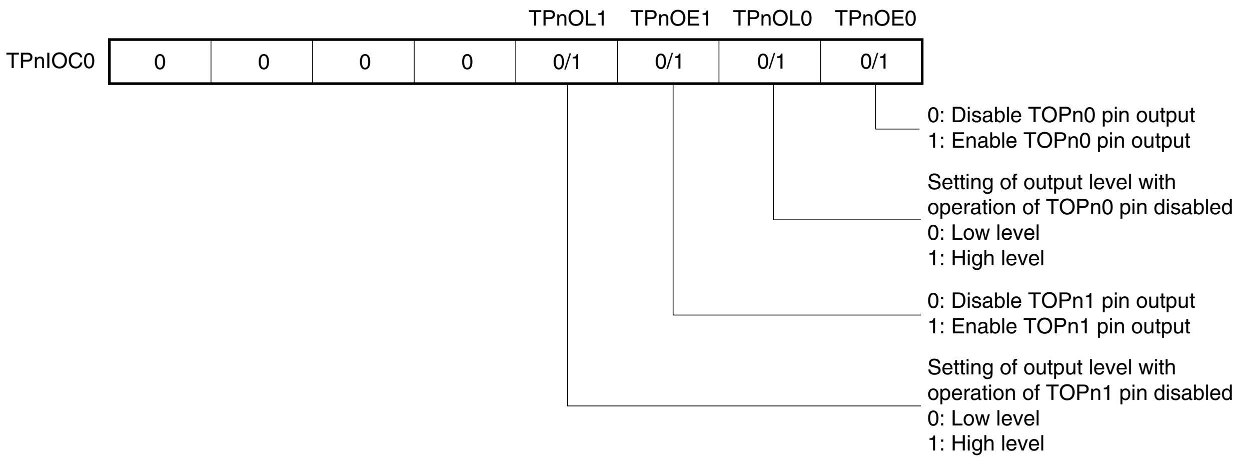


(b) TMPn control register 1 (TPnCTL1)

Note 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 **7.5.1 (2) (d) Operation of TPnCCR1 register**).

Figure 7-4. Register Setting for Interval Timer Mode Operation (2/2)

(c) TMPn I/O control register 0 (TPnIOC0)



(d) TMPn counter read buffer register (TPnCNT)

By reading the TPnCNT register, the count value of the 16-bit counter can be read.

(e) TMPn capture/compare register 0 (TPnCCR0)

If the TPnCCR0 register is set to D_0, the interval is as follows.

Interval = $(D_0 + 1) \times$ Count clock cycle

(f) TMPn capture/compare register 1 (TPnCCR1)

Usually, the TPnCCR1 register is not used in the interval timer mode. However, the set value of the TPnCCR1 register is transferred to the CCR1 buffer register. A 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.

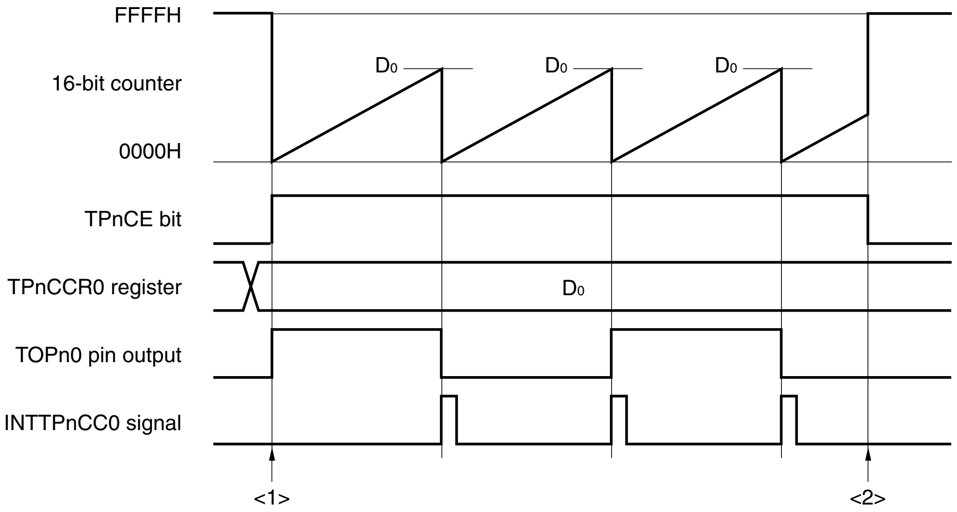
Therefore, mask the interrupt request by using the corresponding interrupt mask flag (TPnCCMK1).

Remarks **1.** TMPn I/O control register 1 (TPnIOC1), TMPn I/O control register 2 (TPnIOC2), and TMPn option register 0 (TPnOPT0) are not used in the interval timer mode.

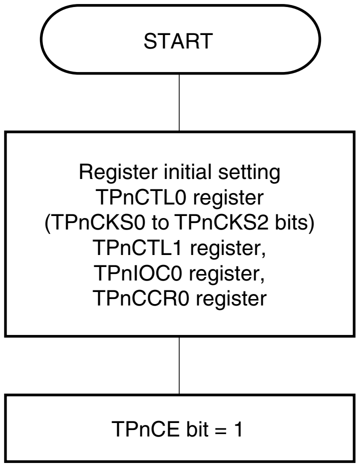
2. n = 0 to 5

(1) Interval timer mode operation flow

Figure 7-5. Software Processing Flow in Interval Timer Mode



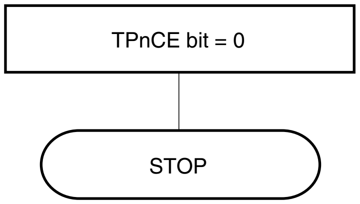
<1> Count operation start flow



Initial setting of these registers is performed before the TPnCE bit is set to 1.

The TPnCKS0 to TPnCKS2 bits can be set when counting starts (TPnCE bit = 1).

<2> Count operation stop flow



The counter is initialized and counting is stopped by clearing the TPnCE bit to 0.

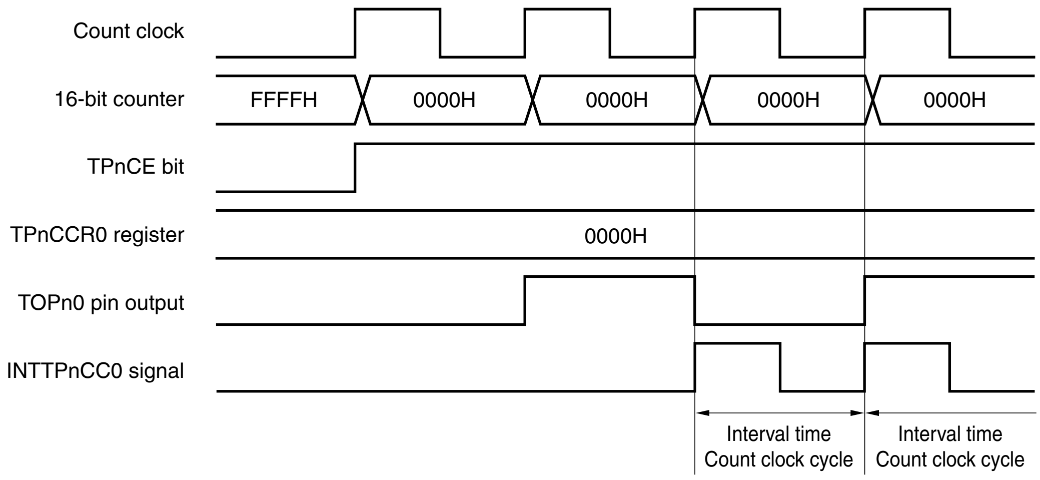
Remark n = 0 to 5

(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 of the second clock or later, and the output of the TOPn0 pin is inverted.

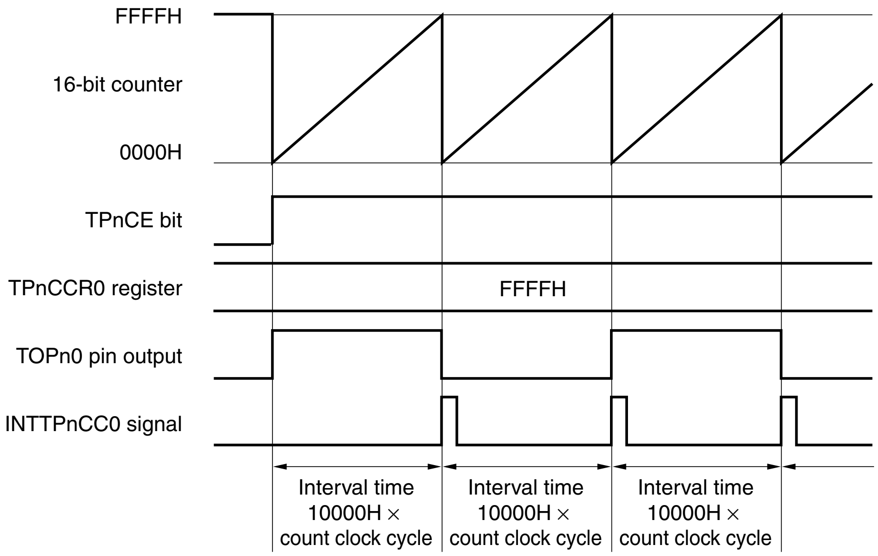
The value of the 16-bit counter is always 0000H.



Remark n = 0 to 5

(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.

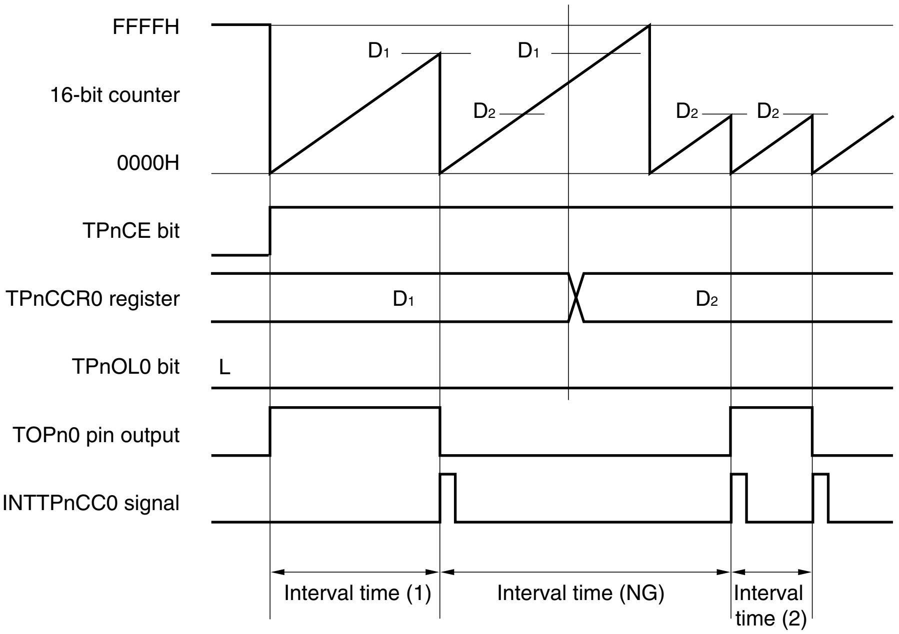


Remark n = 0 to 5

(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.



Remarks **1.** Interval time (1): (D_1 + 1) × Count clock cycle
Interval time (NG): (10000H + D_2 + 1) × Count clock cycle
Interval time (2): (D_2 + 1) × Count clock cycle

2. n = 0 to 5

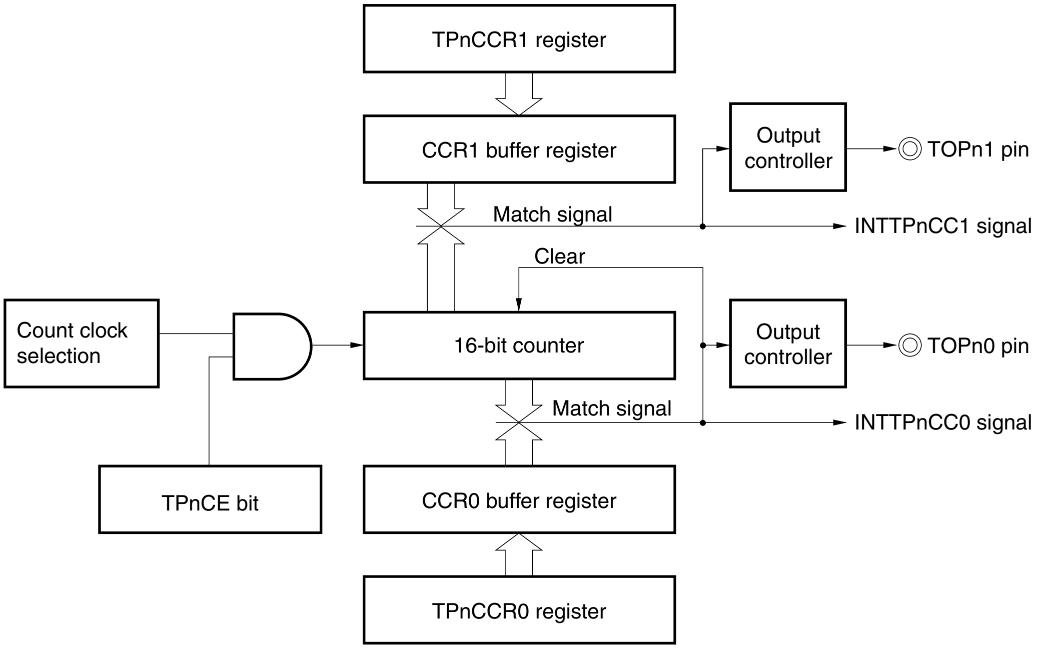
If the value of the TPnCCR0 register is changed from D_1 to D_2 while the count value is greater than D_2 but less than D_1, the count value is transferred to the CCR0 buffer register as soon as the TPnCCR0 register has been rewritten. Consequently, the value of the 16-bit counter that is compared is 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) × Count clock cycle" or "(D_2 + 1) × Count clock cycle" originally expected, but may be generated at an interval of "(10000H + D_2 + 1) × Count clock period".

(d) Operation of TPnCCR1 register

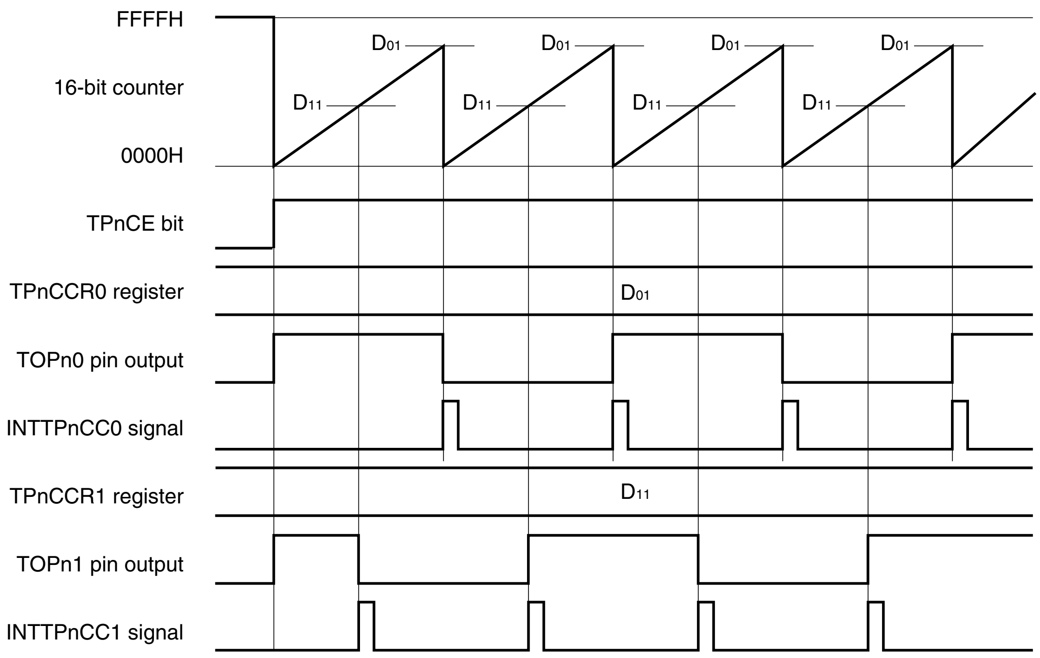
Figure 7-6. Configuration of TPnCCR1 Register



Remark n = 0 to 5

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.

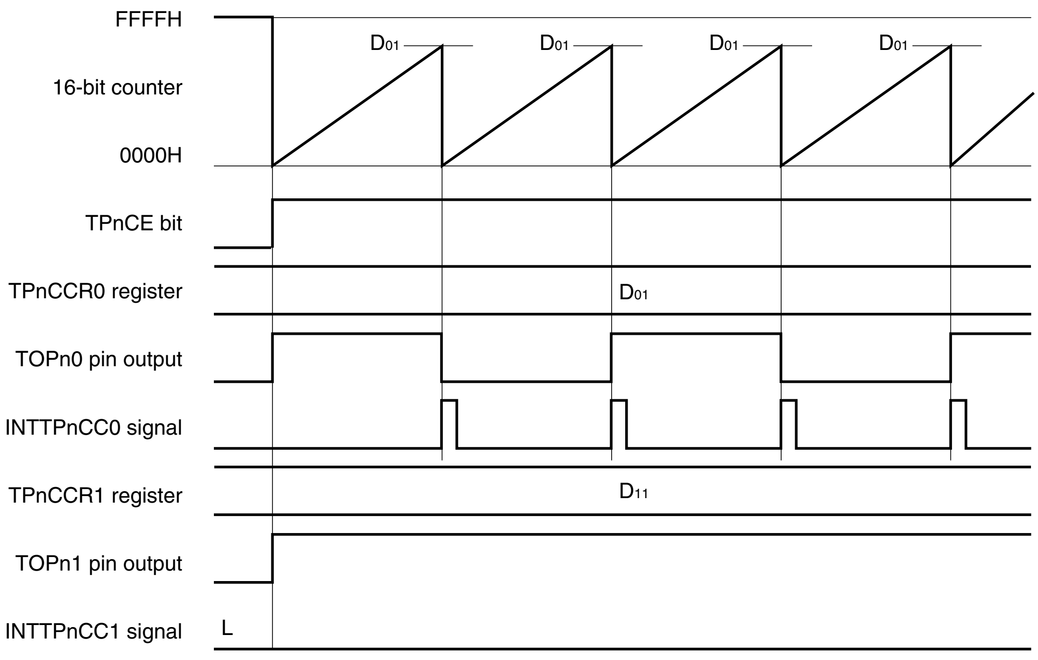
Figure 7-7. Timing Chart When $D_{01} \geq D_{11}$



Remark n = 0 to 5

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 $D_{01} < D_{11}$



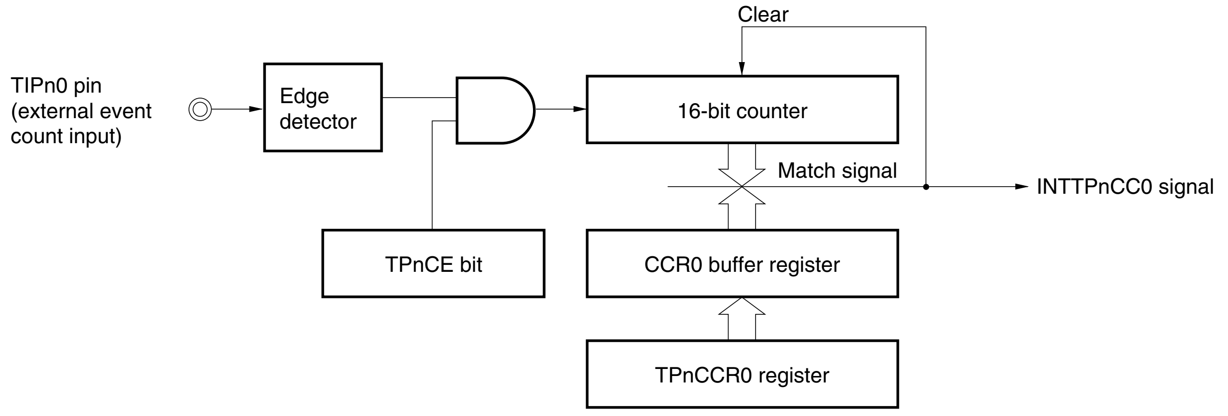
Remark n = 0 to 5

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.

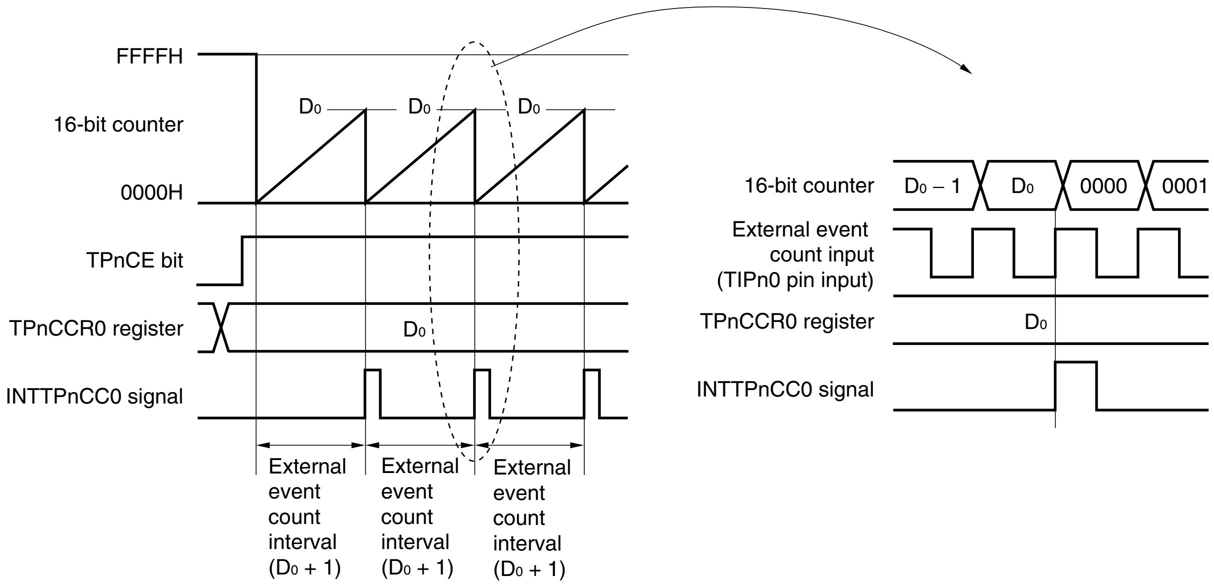
Usually, the TPnCCR1 register is not used in the external event count mode.

Figure 7-9. Configuration in External Event Count Mode



Remark n = 0 to 5

Figure 7-10. Basic Timing in External Event Count Mode



Remarks **1.** This figure shows the basic timing when the rising edge is specified as the valid edge of the external event count input.

2. n = 0 to 5

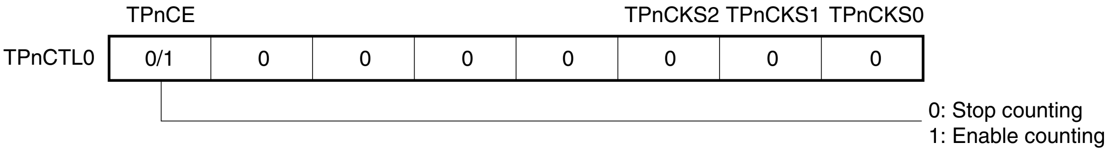
When the TPnCE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H. The counter counts each time the valid edge of external event count input is detected. Additionally, the set value of the TPnCCR0 register is transferred to the CCR0 buffer register.

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.

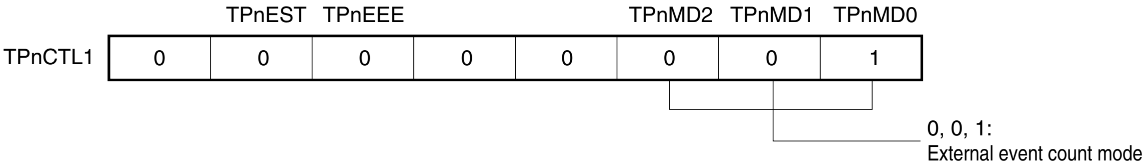
The INTTPnCC0 signal is generated each time the valid edge of the external event count input has been detected (set value of TPnCCR0 register + 1) times.

Figure 7-11. Register Setting for Operation in External Event Count Mode (1/2)

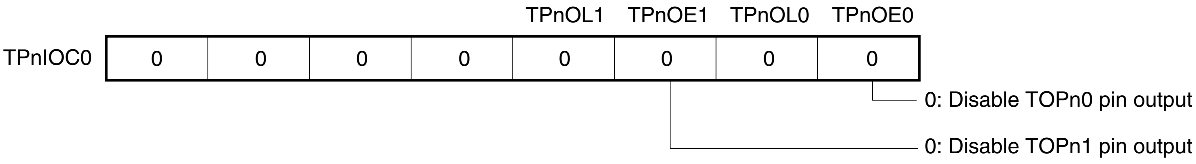
(a) TMPn control register 0 (TPnCTL0)



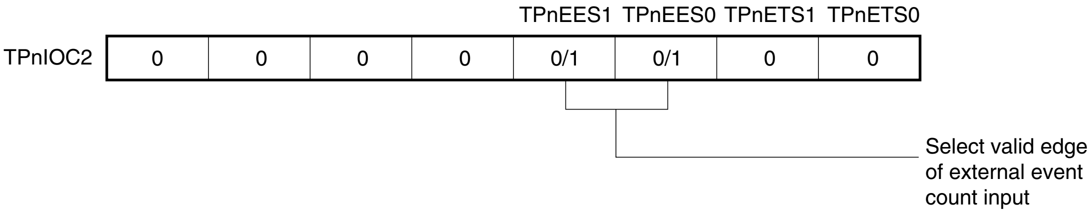
(b) TMPn control register 1 (TPnCTL1)



(c) TMPn I/O control register 0 (TPnIOC0)



(d) TMPn I/O control register 2 (TPnIOC2)



(e) TMPn counter read buffer register (TPnCNT)

The count value of the 16-bit counter can be read by reading the TPnCNT register.

Figure 7-11. Register Setting for Operation in External Event Count Mode (2/2)

(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).

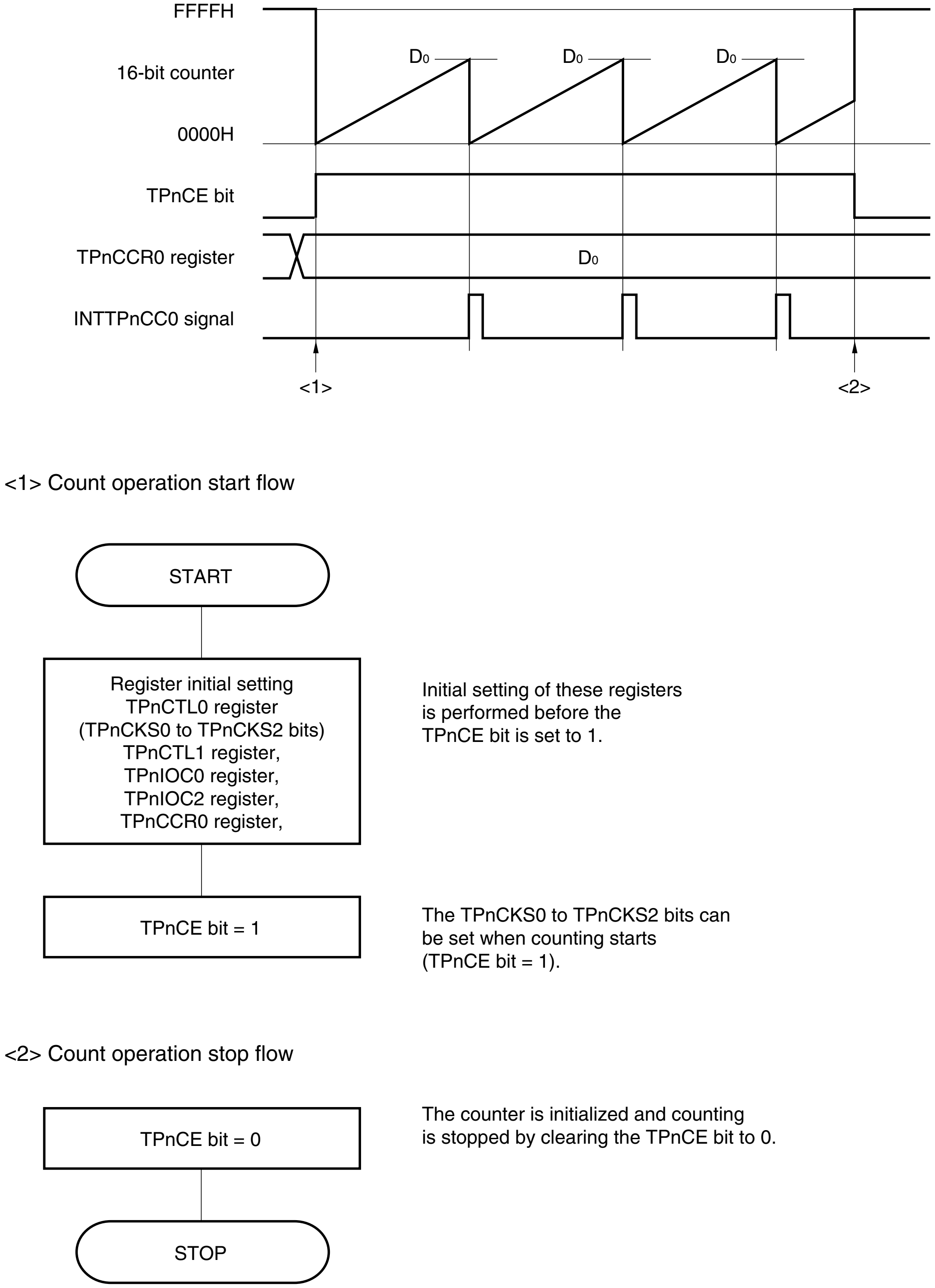
Caution When an external clock is used as the count clock, the external clock can be input only from the TIPn0 pin. At this time, set the TPnIOC1.TPnIS1 and TPnIOC1.TPnIS0 bits to 00 (capture trigger input (TIPn0 pin): no edge detection).

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 5

(1) External event count mode operation flow

Figure 7-12. Flow of Software Processing in External Event Count Mode



Initial setting of these registers is performed before the TPnCE bit is set to 1.

The TPnCKS0 to TPnCKS2 bits can be set when counting starts (TPnCE bit = 1).

The counter is initialized and counting is stopped by clearing the TPnCE bit to 0.

Remark n = 0 to 5

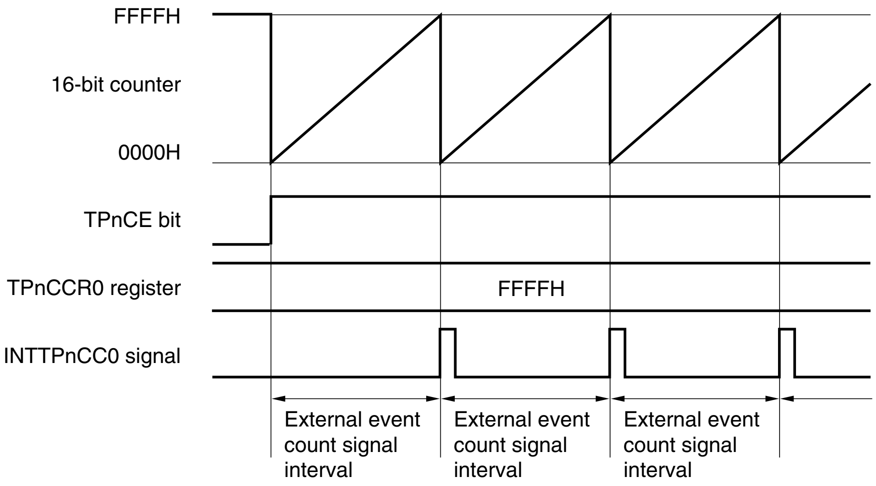
(2) Operation timing in external event count mode

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.

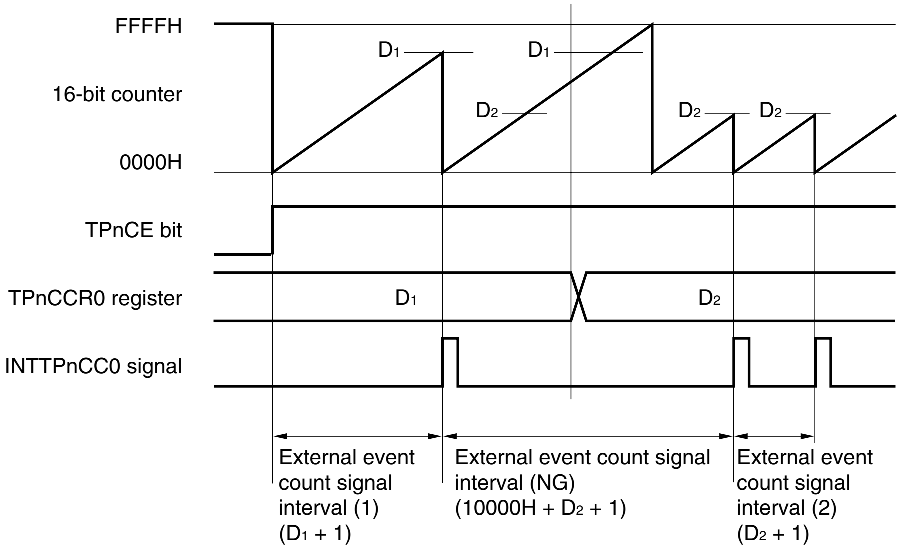


Remark n = 0 to 5

(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.



Remark n = 0 to 5

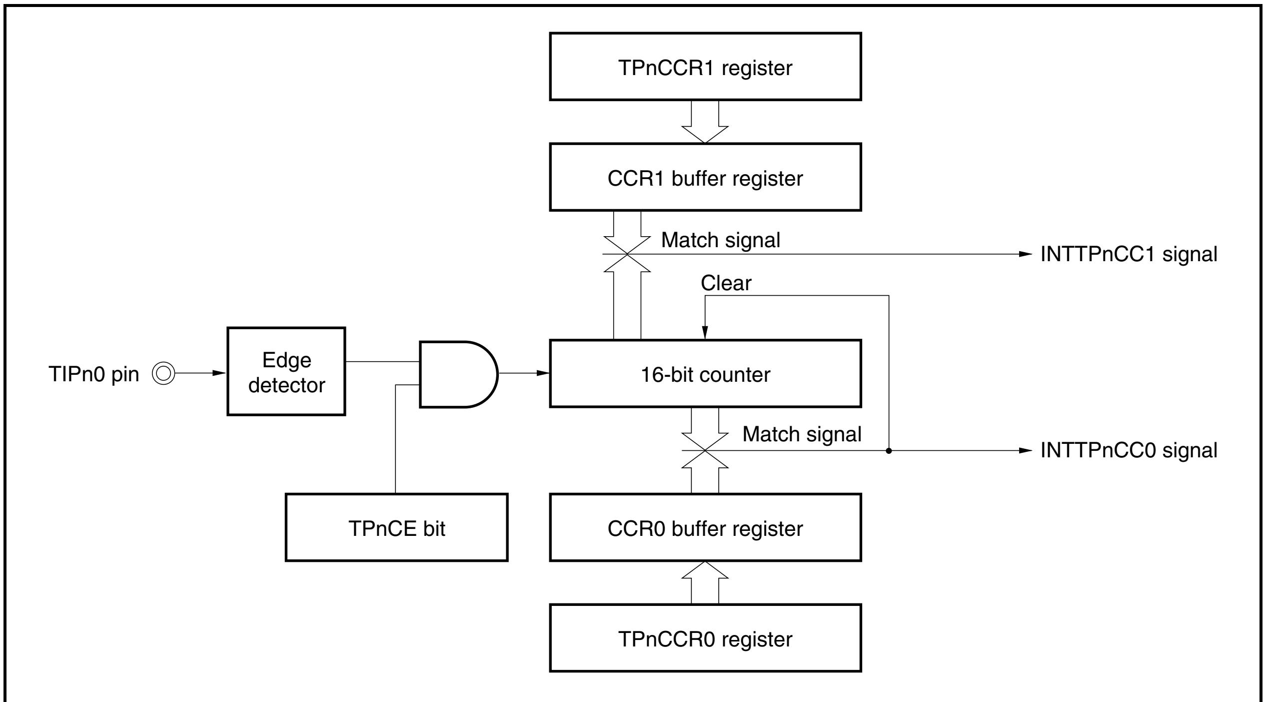
If the value of the TPnCCR0 register is changed from D_1 to D_2 while the count value is greater than D_2 but less than D_1, the count value is transferred to the CCR0 buffer register as soon as the TPnCCR0 register has been rewritten. Consequently, the value that is compared with the 16-bit counter 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

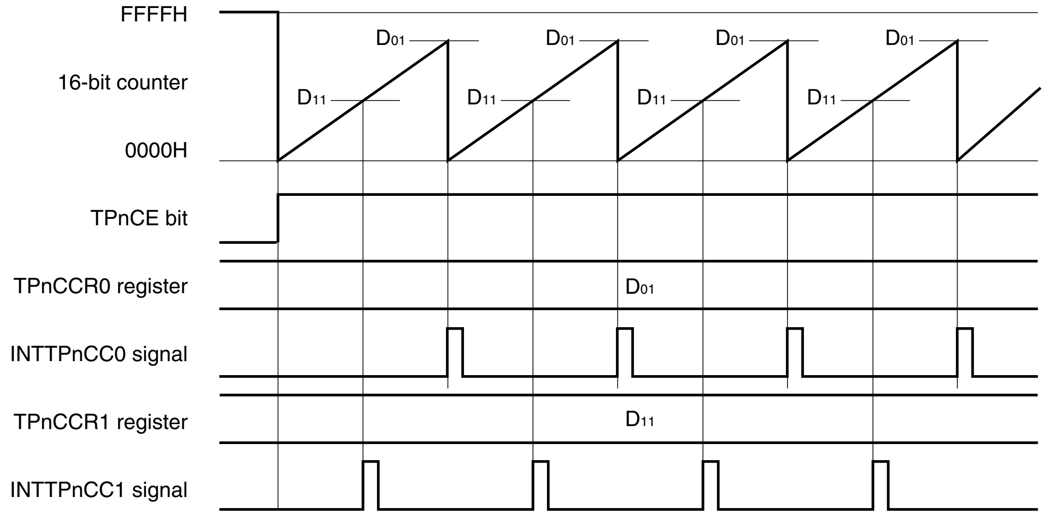
Figure 7-13. Configuration of TPnCCR1 Register



Remark n = 0 to 5

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.

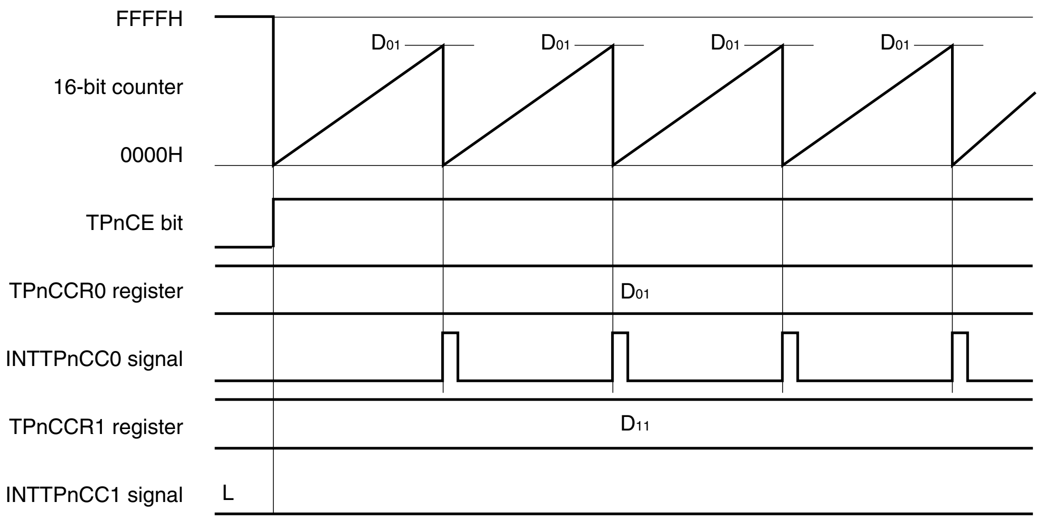
Figure 7-14. Timing Chart When $D_{01} \geq D_{11}$



Remark n = 0 to 5

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 $D_{01} < D_{11}$



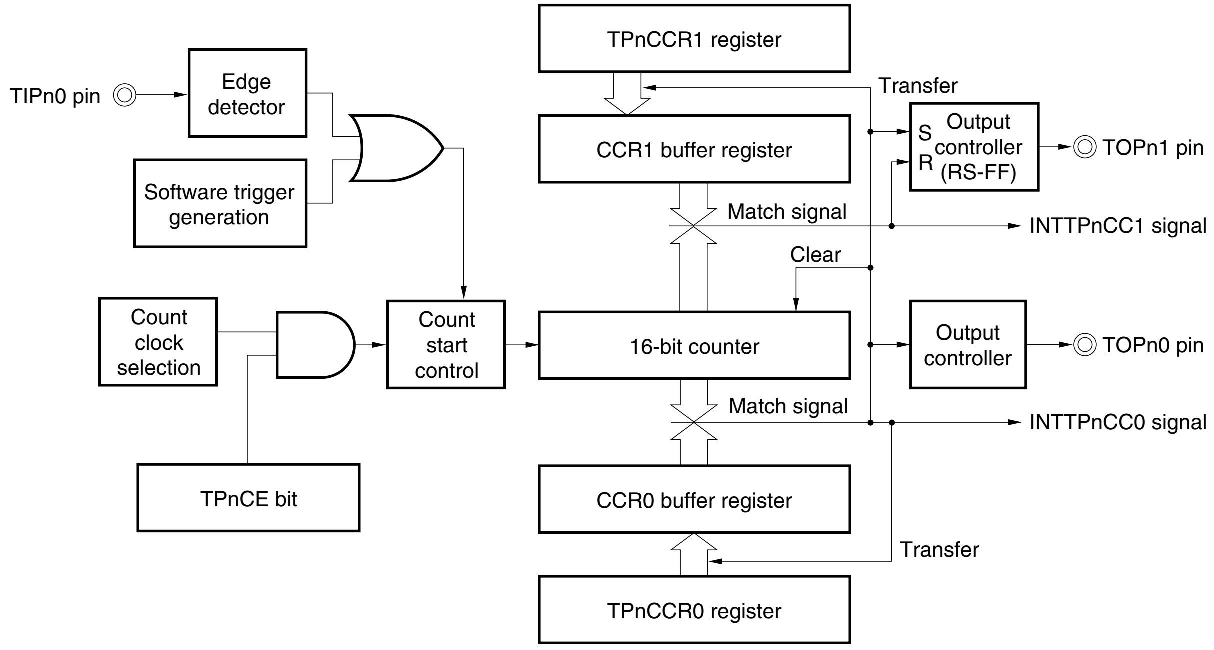
Remark n = 0 to 5

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.

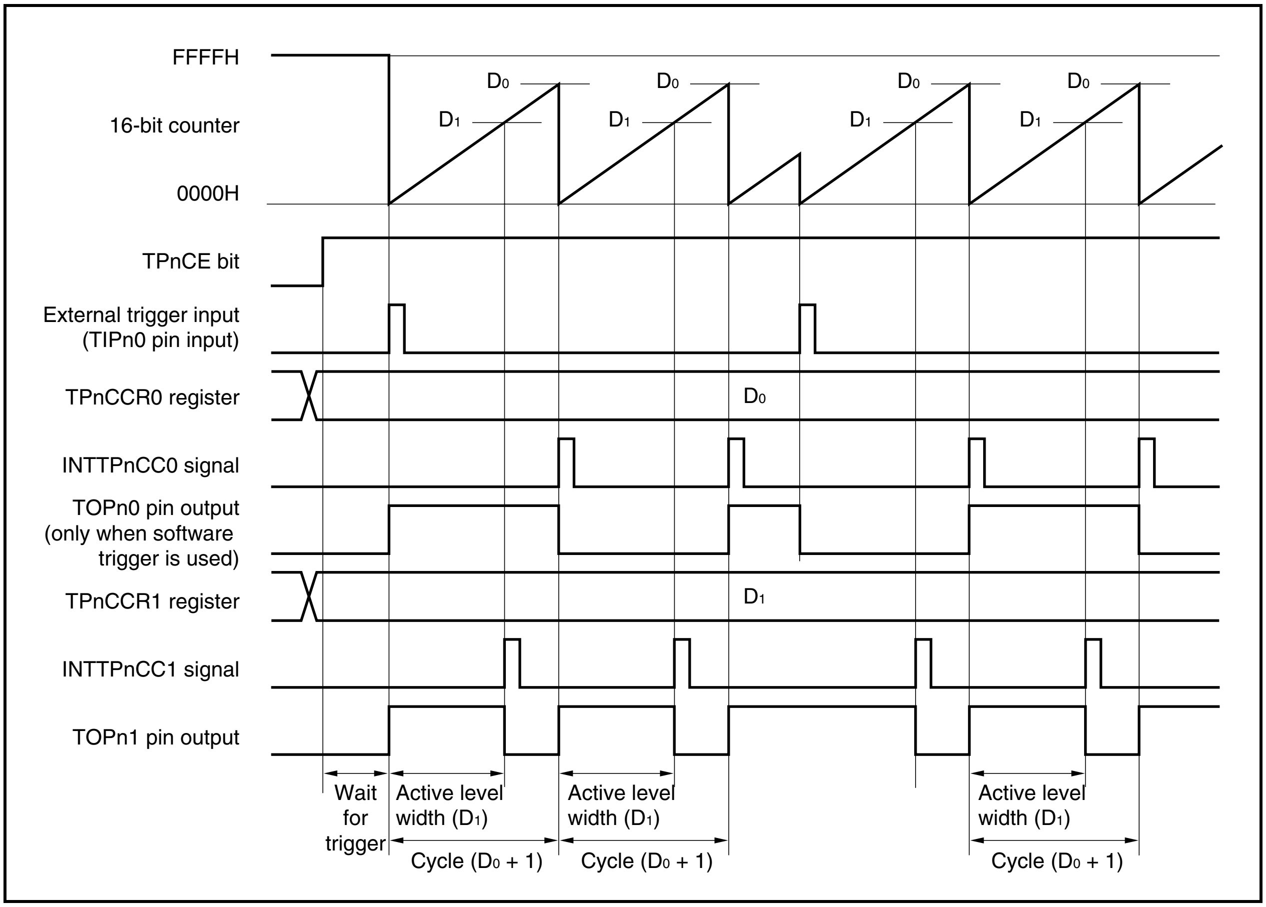
Pulses can also be output by generating a software trigger instead of using the external trigger. When using a software trigger, a square wave that has one cycle of the PWM waveform as half its cycle can also be output from the TOPn0 pin.

Figure 7-16. Configuration in External Trigger Pulse Output Mode



Remark n = 0 to 5

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.

Active level width = (Set value of TPnCCR1 register) × Count clock cycle
Cycle = (Set value of TPnCCR0 register + 1) × Count clock cycle
Duty factor = (Set value of TPnCCR1 register)/(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.

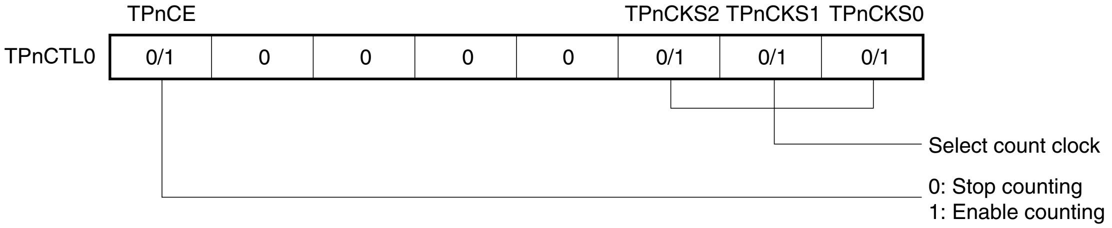
The value set to the TPnCCRm register is transferred to the CCRm buffer register when the count value of the 16-bit counter matches the value of the CCRm buffer register and the 16-bit counter is cleared to 0000H.

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 5, m = 0, 1

Figure 7-18. Setting of Registers in External Trigger Pulse Output Mode (1/2)

(a) TMPn control register 0 (TPnCTL0)



	TPnCE					TPnCKS2	TPnCKS1	TPnCKS0
TPnCTL0	0/1	0	0	0	0	0/1	0/1	0/1

TPnCKS2 to TPnCKS0: Select count clock

TPnCE:
0: Stop counting
1: Enable counting

(b) TMPn control register 1 (TPnCTL1)

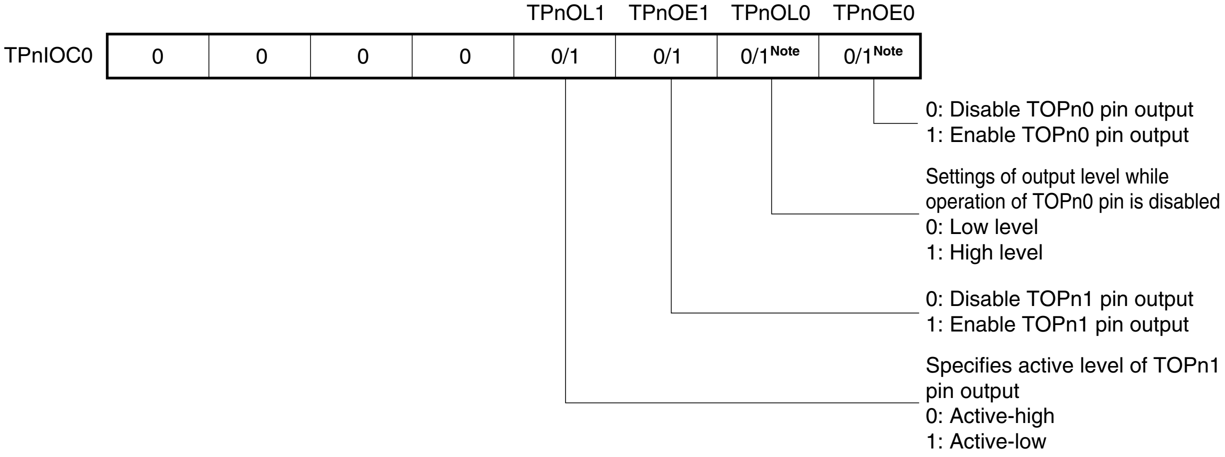
		TPnEST	TPnEEE			TPnMD2	TPnMD1	TPnMD0
TPnCTL1	0	0/1	0	0	0	0	1	0

TPnMD2 to TPnMD0:
0, 1, 0:
External trigger pulse output mode

TPnEEE:
0: Operate on count clock selected by TPnCKS0 to TPnCKS2 bits

TPnEST: Generate software trigger when 1 is written

(c) TMPn I/O control register 0 (TPnIOC0)



					TPnOL1	TPnOE1	TPnOL0	TPnOE0
TPnIOC0	0	0	0	0	0/1	0/1	0/1[Note]	0/1[Note]

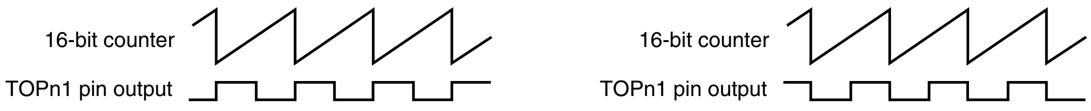
TPnOE0:
0: Disable TOPn0 pin output
1: Enable TOPn0 pin output

TPnOL0:
Settings of output level while operation of TOPn0 pin is disabled
0: Low level
1: High level

TPnOE1:
0: Disable TOPn1 pin output
1: Enable TOPn1 pin output

TPnOL1:
Specifies active level of TOPn1 pin output
0: Active-high
1: Active-low

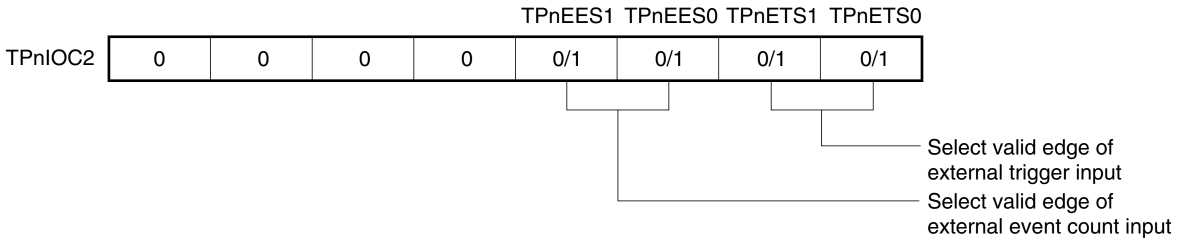
- When TPnOL1 bit = 0
- When TPnOL1 bit = 1



Note Clear this bit to 0 when the TOPn0 pin is not used in the external trigger pulse output mode.

Figure 7-18. Setting of Registers in External Trigger Pulse Output Mode (2/2)

(d) TMPn I/O control register 2 (TPnIOC2)



					TPnEES1	TPnEES0	TPnETS1	TPnETS0
TPnIOC2	0	0	0	0	0/1	0/1	0/1	0/1

(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.

Cycle = $(D_0 + 1) \times$ Count clock cycle

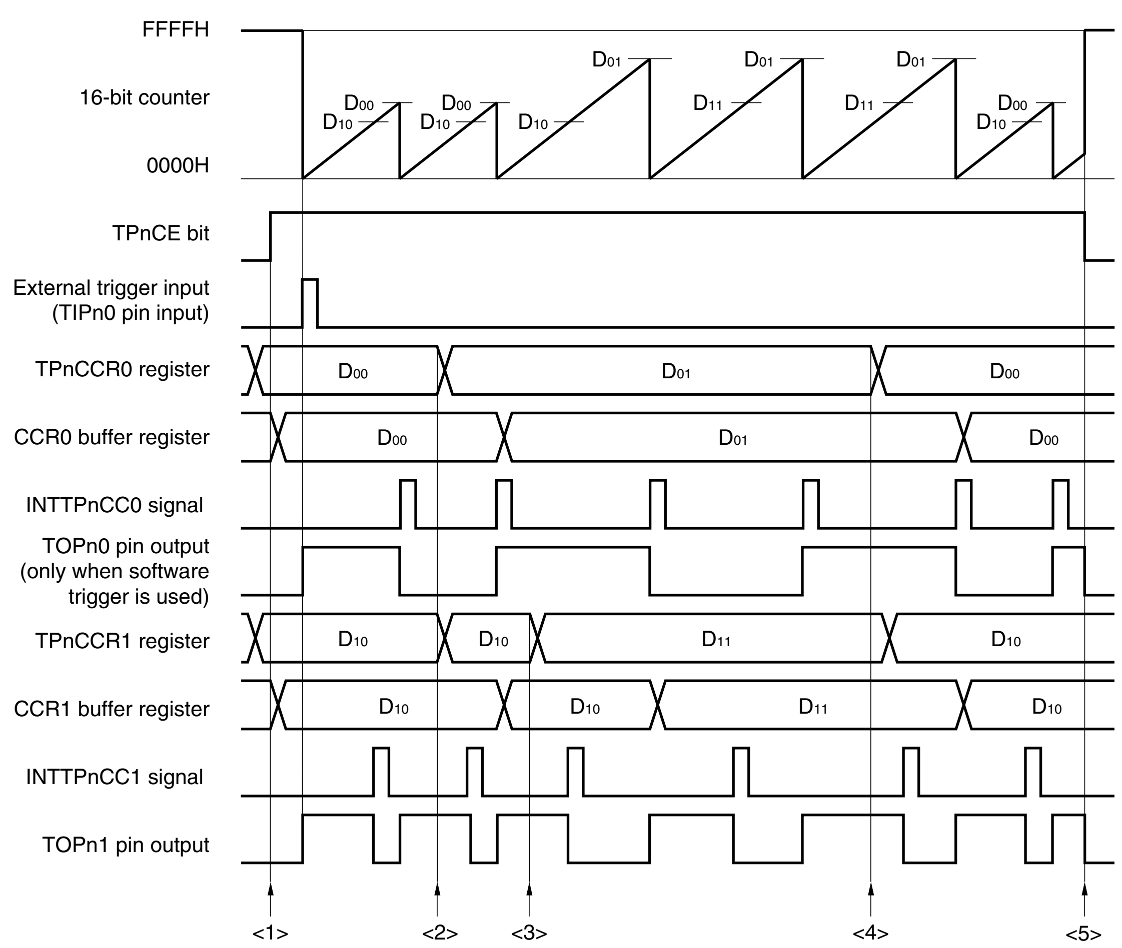
Active level width = $D_1 \times$ Count clock cycle

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 5

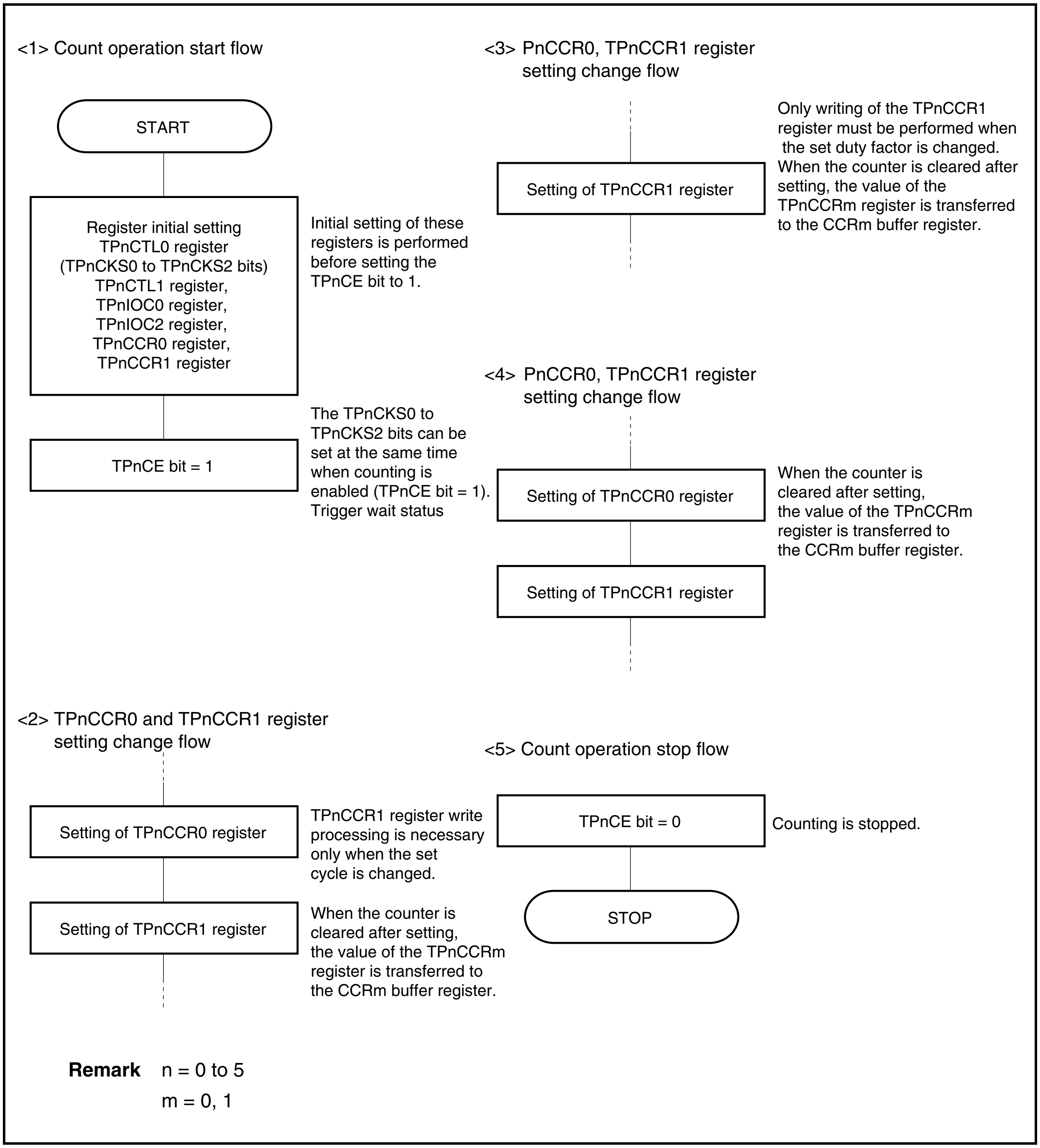
(1) Operation flow in external trigger pulse output mode

Figure 7-19. Software Processing Flow in External Trigger Pulse Output Mode (1/2)



Remark n = 0 to 5

Figure 7-19. Software Processing Flow in External Trigger Pulse Output Mode (2/2)



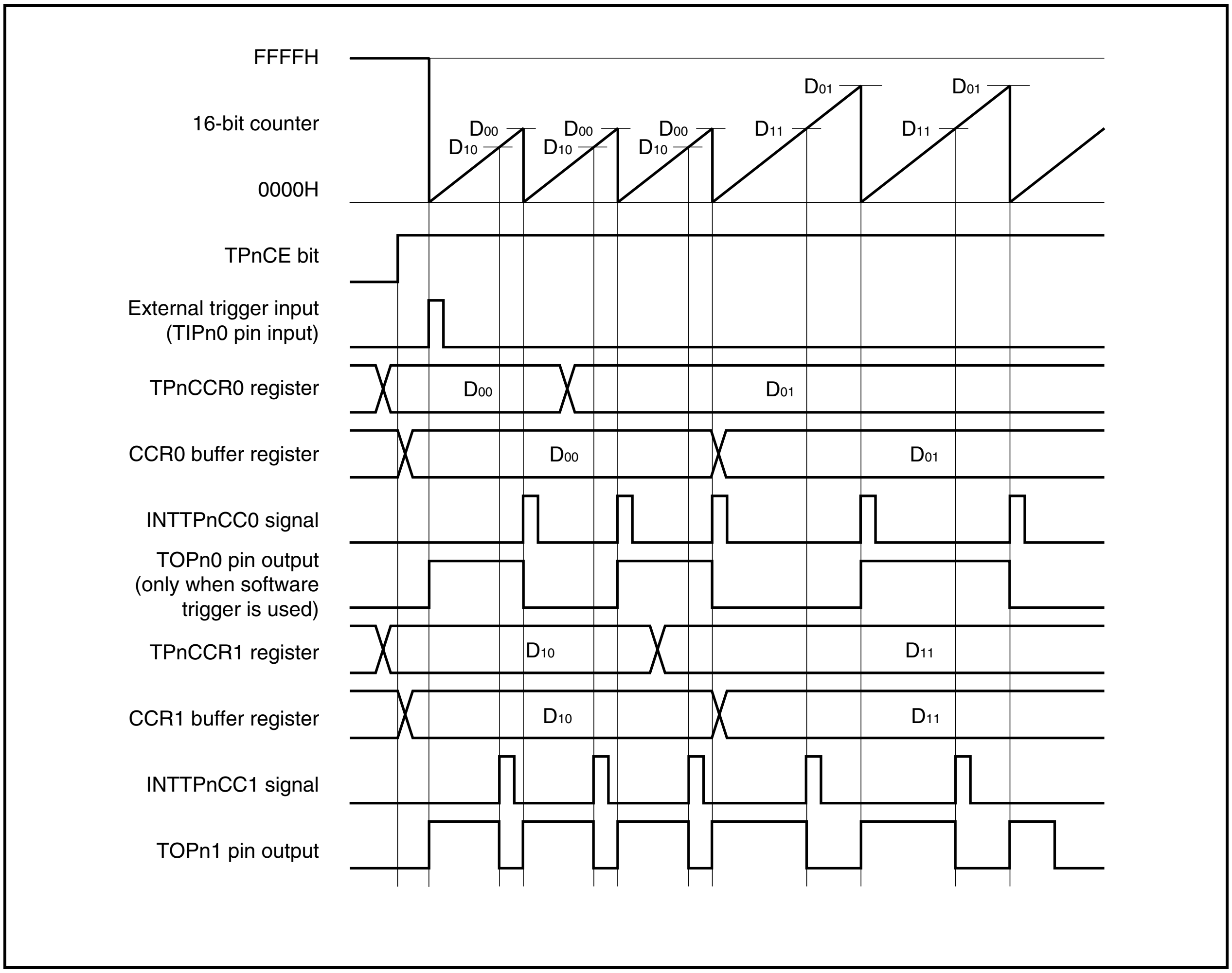
Remark n = 0 to 5
m = 0, 1

(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.

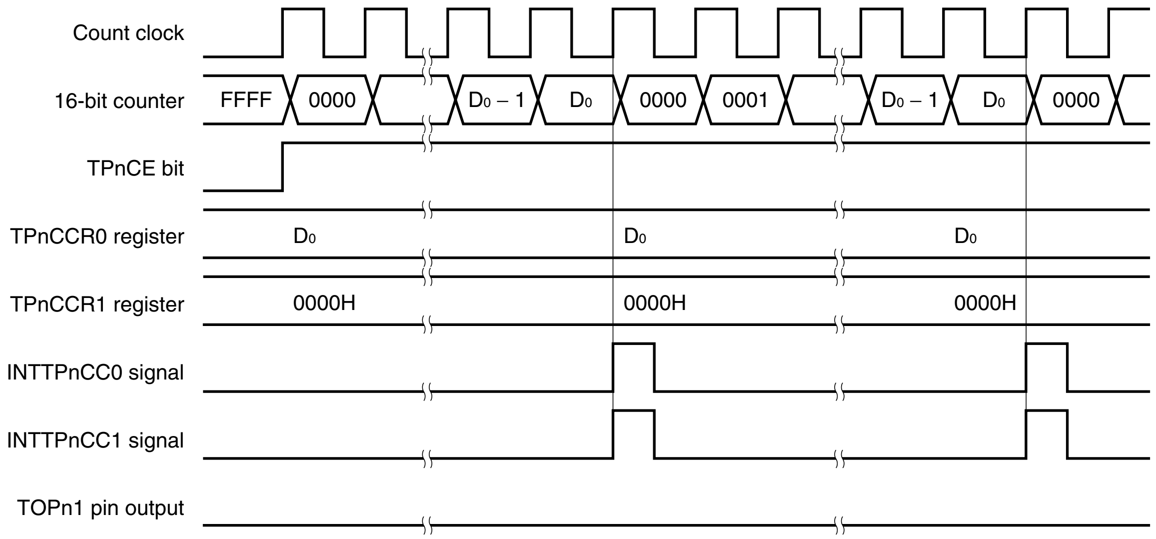
After data is written to the TPnCCR1 register, the value written to the TPnCCRm register is transferred to the CCRm buffer register in synchronization with clearing of the 16-bit counter, and is used as the value compared with the 16-bit counter.

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 5
m = 0, 1

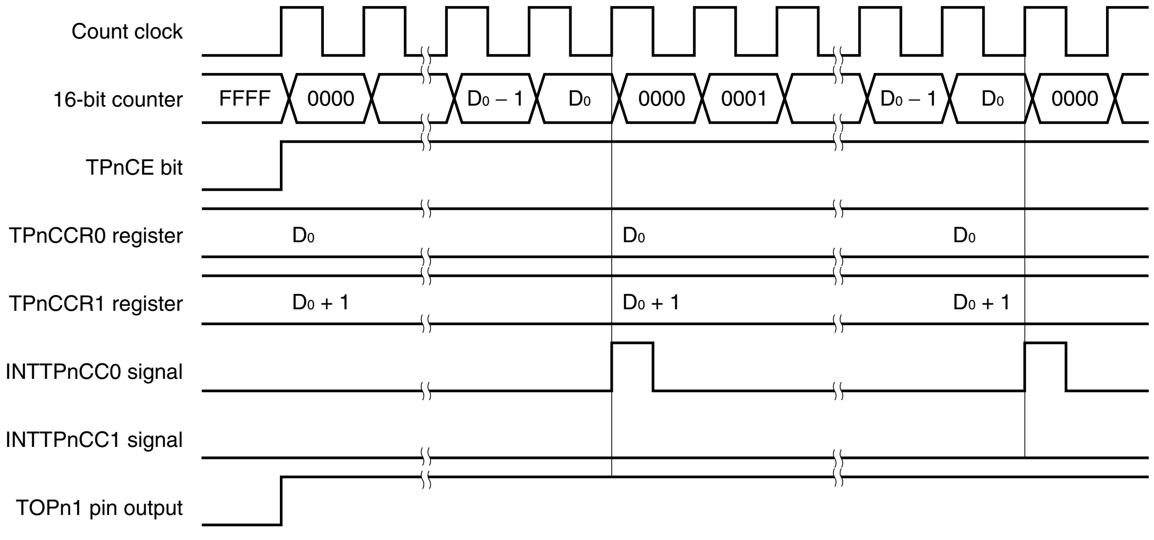
(b) 0%/100% output of PWM waveform

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.



Remark n = 0 to 5

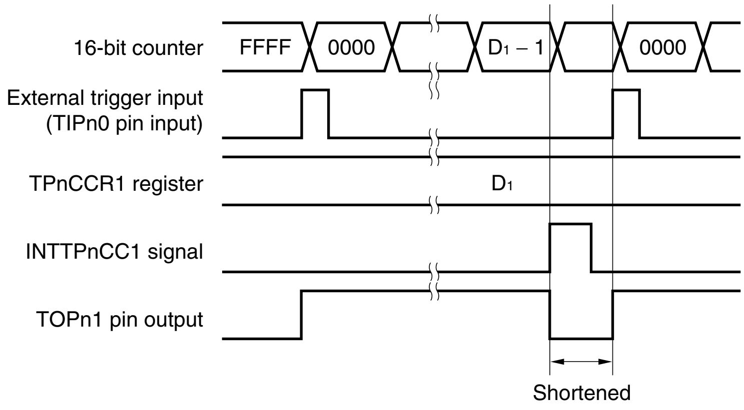
To output a 100% waveform, set a value of (set value of TPnCCR0 register + 1) to the TPnCCR1 register. If the set value of the TPnCCR0 register is FFFFH, 100% output cannot be produced.



Remark n = 0 to 5

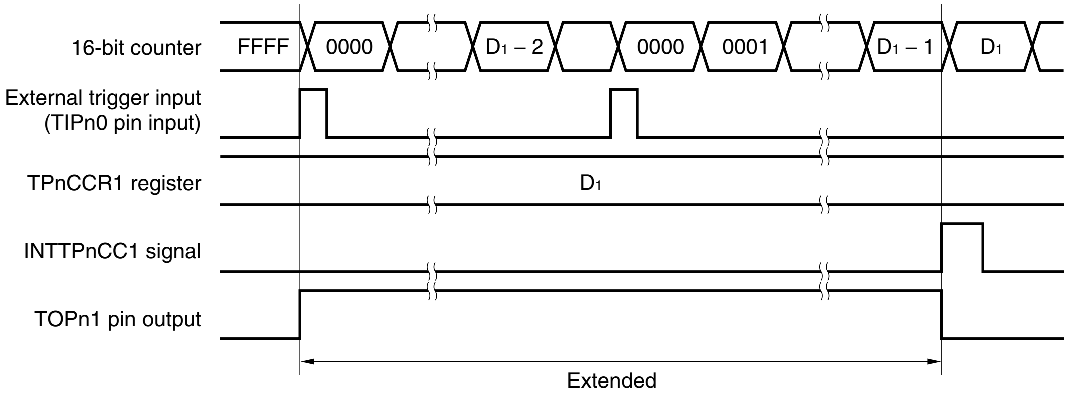
(c) Conflict between trigger detection and match with TPnCCR1 register

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.



Remark n = 0 to 5

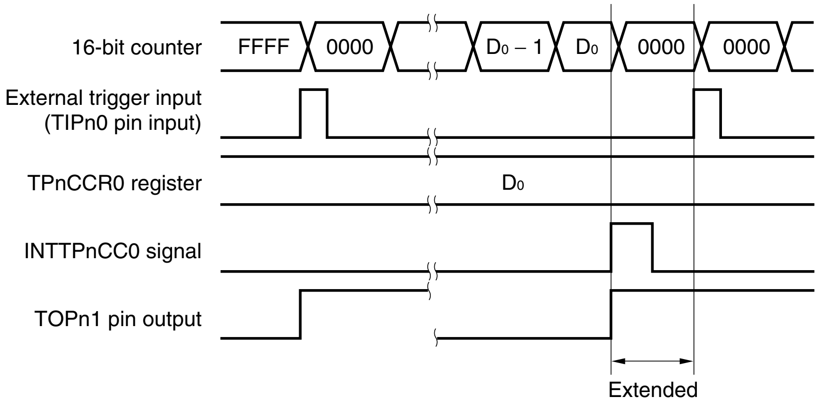
If the trigger is detected immediately before the INTTPnCC1 signal is generated, the INTTPnCC1 signal is not generated, and the 16-bit counter is cleared to 0000H and continues counting. The output signal of the TOPn1 pin remains active. Consequently, the active period of the PWM waveform is extended.



Remark n = 0 to 5

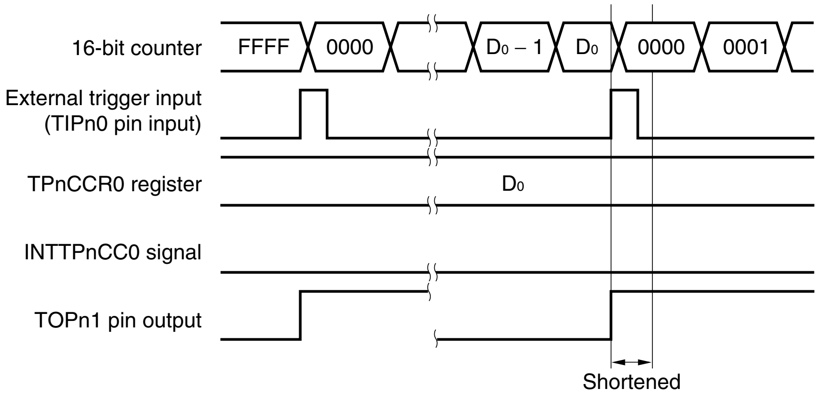
(d) Conflict between trigger detection and match with TPnCCR0 register

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.



Remark n = 0 to 5

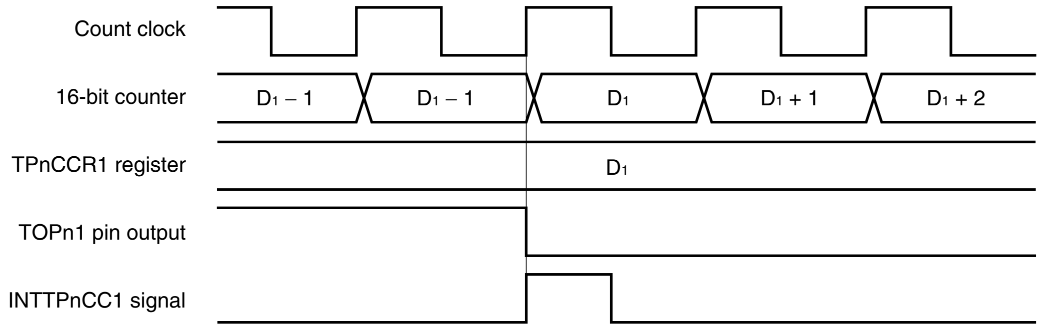
If the trigger is detected immediately before the INTTPnCC0 signal is generated, the INTTPnCC0 signal is not generated. The 16-bit counter is cleared to 0000H, the TOPn1 pin is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.



Remark n = 0 to 5

(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.



Remark n = 0 to 5

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.

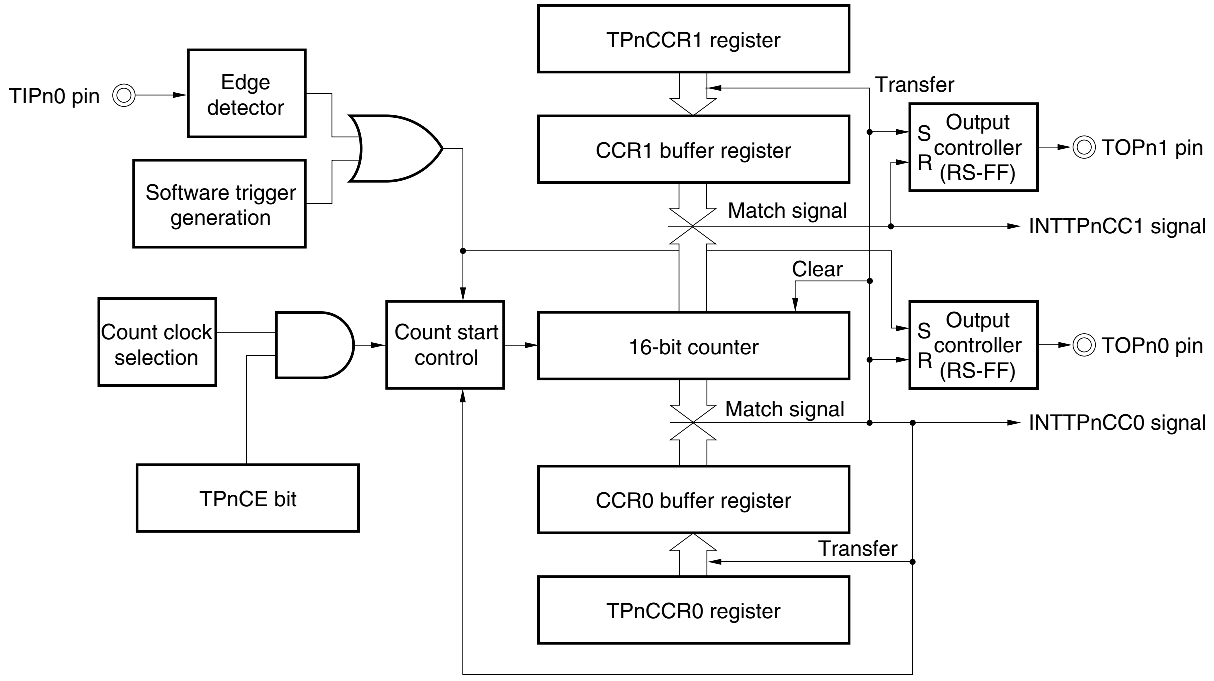
In the external trigger pulse output mode, however, it is generated one clock earlier. This is because the timing is changed to match the timing of changing the output signal of the TOPn1 pin.

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.

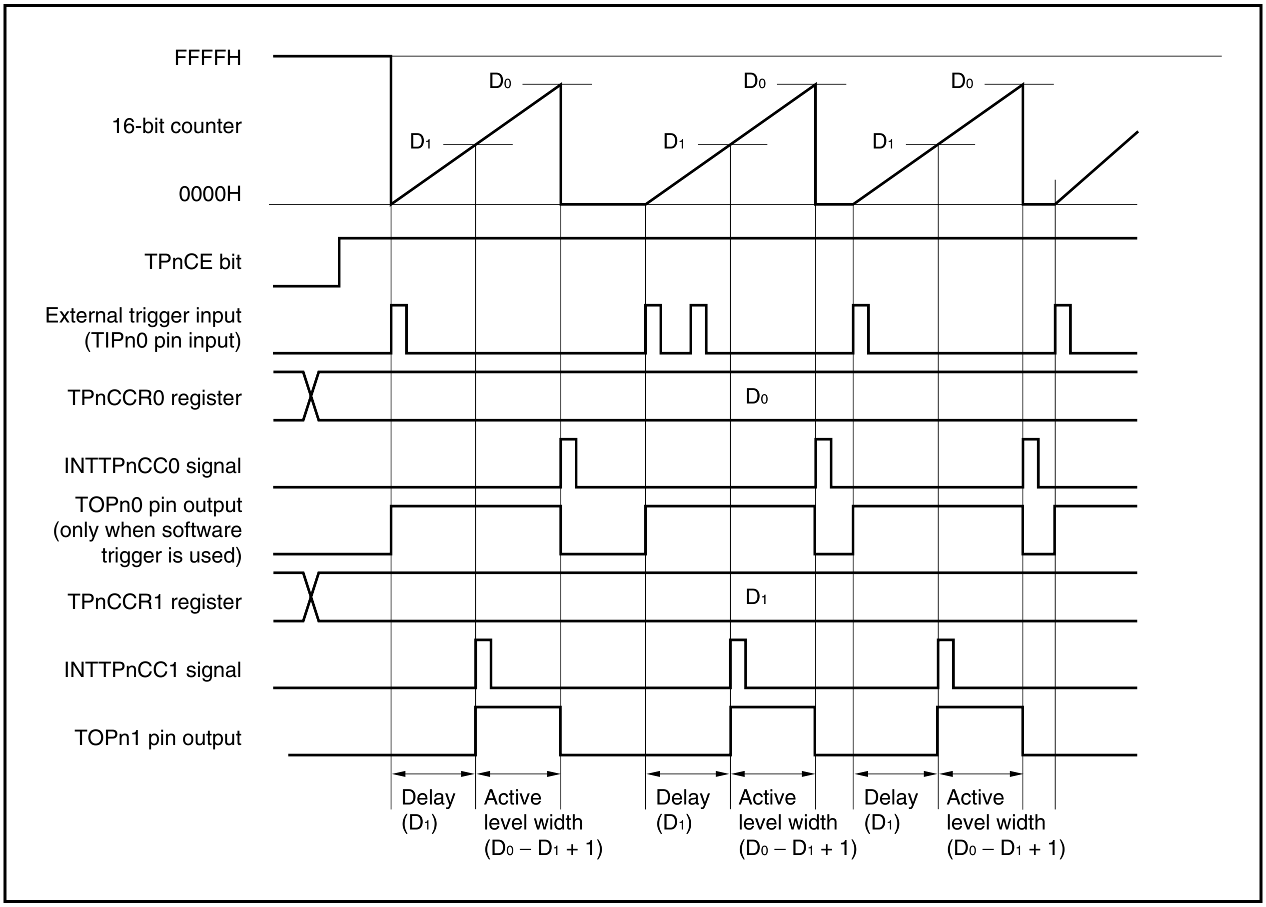
Instead of the external trigger, a software trigger can also be generated to output the pulse. When the software trigger is used, the TOPn0 pin outputs the active level while the 16-bit counter is counting, and the inactive level when the counter is stopped (waiting for a trigger).

Figure 7-20. Configuration in One-Shot Pulse Output Mode



Remark n = 0 to 5

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.

Output delay period = (Set value of TPnCCR1 register) × Count clock cycle

Active level width = (Set value of TPnCCR0 register – Set value of TPnCCR1 register + 1) × Count clock cycle

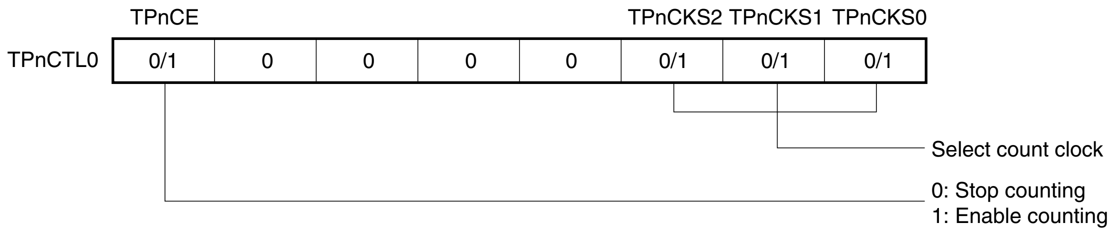
The compare match interrupt request signal INTTPnCC0 is generated when the 16-bit counter counts after its count value matches the value of the CCR0 buffer register. The compare match interrupt request signal INTTPnCC1 is generated when the count value of the 16-bit counter matches the value of the CCR1 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 5

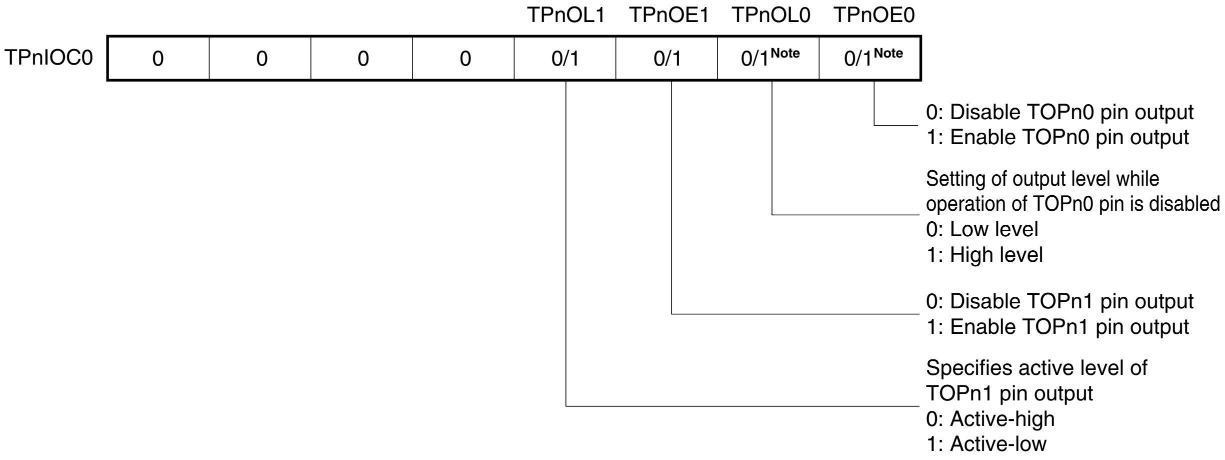
Figure 7-22. Setting of Registers in One-Shot Pulse Output Mode (1/2)

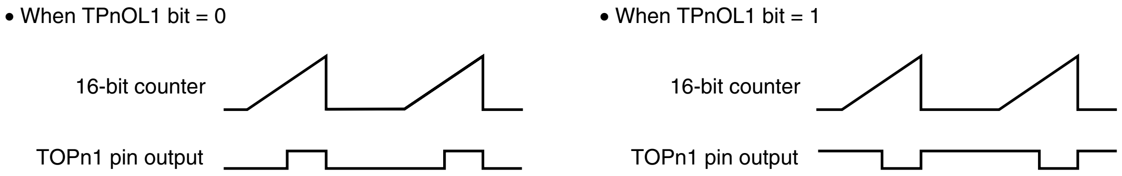
(a) TMPn control register 0 (TPnCTL0)



(b) TMPn control register 1 (TPnCTL1)

(c) TMPn I/O control register 0 (TPnIOC0)

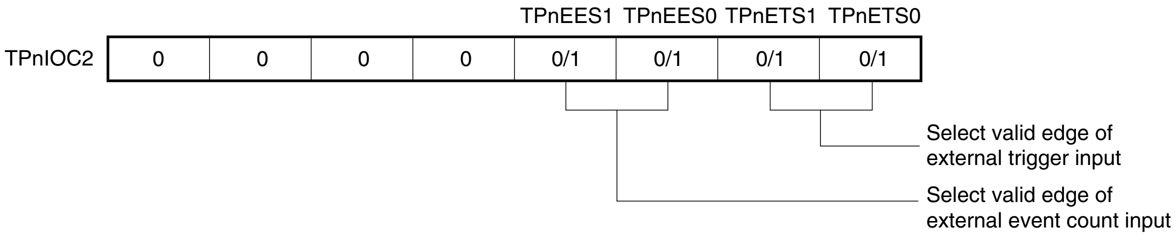




Note Clear this bit to 0 when the TOPn0 pin is not used in the one-shot pulse output mode.

Figure 7-22. Setting of Registers in One-Shot 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 active level width and output delay period of the one-shot pulse are as follows.

Active level width = $(D_0 - D_1 + 1) \times$ Count clock cycle

Output delay period = $D_1 \times$ Count clock cycle

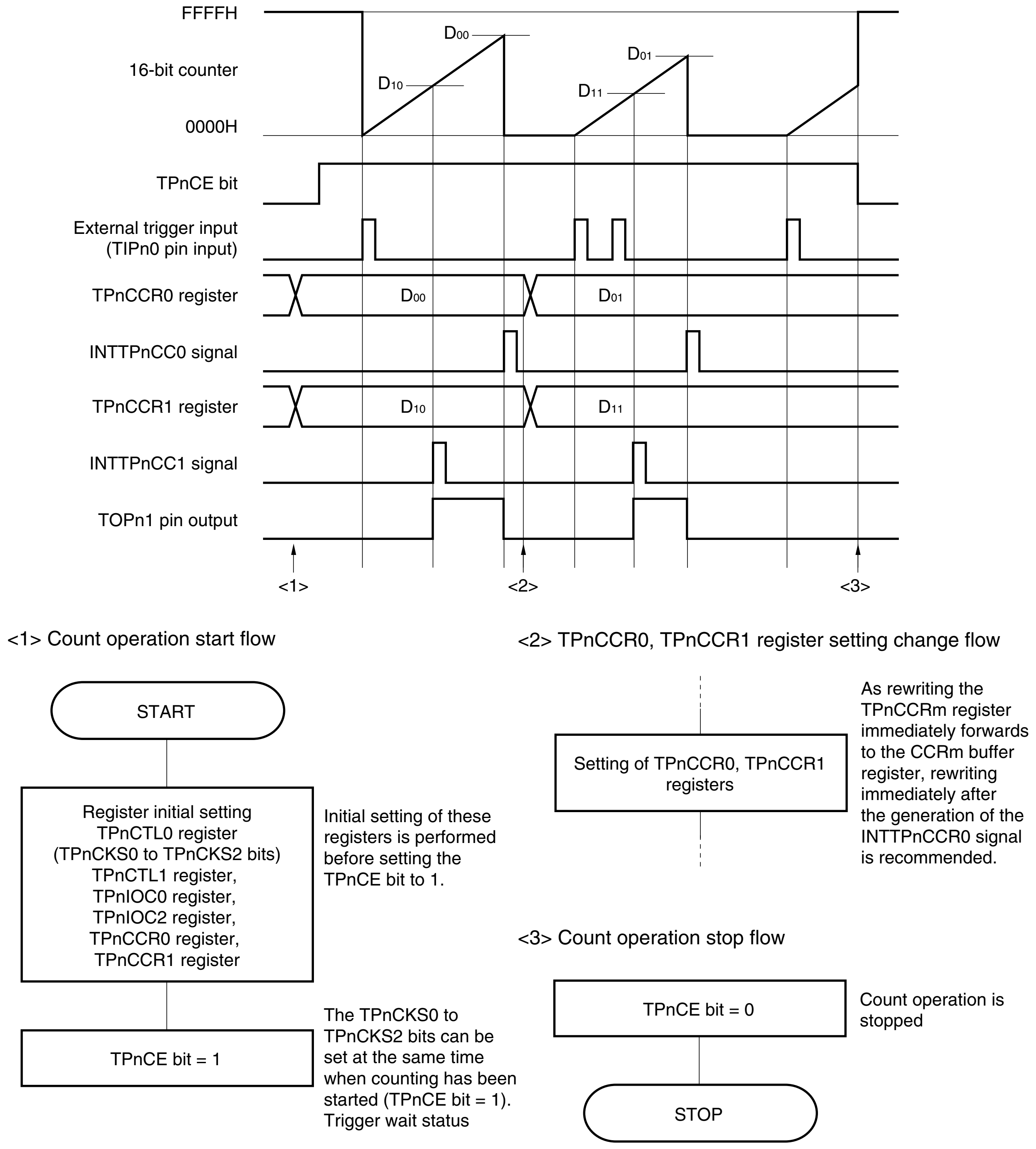
Caution One-shot pulses are not output in the one-shot pulse output mode if the value set for the TPnCCR1 register is greater than that for the TPnCCR0 register.

Remarks **1.** TMPn I/O control register 1 (TPnIOC1) and TMPn option register 0 (TPnOPT0) are not used in the one-shot pulse output mode.

2. n = 0 to 5

(1) Operation flow in one-shot pulse output mode

Figure 7-23. Software Processing Flow in One-Shot Pulse Output Mode



<1> Count operation start flow

Initial setting of these registers is performed before setting the TPnCE bit to 1.

The TPnCKS0 to TPnCKS2 bits can be set at the same time when counting has been started (TPnCE bit = 1).
Trigger wait status

<2> TPnCCR0, TPnCCR1 register setting change flow

As rewriting the TPnCCRm register immediately forwards to the CCRm buffer register, rewriting immediately after the generation of the INTTPnCCR0 signal is recommended.

<3> Count operation stop flow

Count operation is stopped

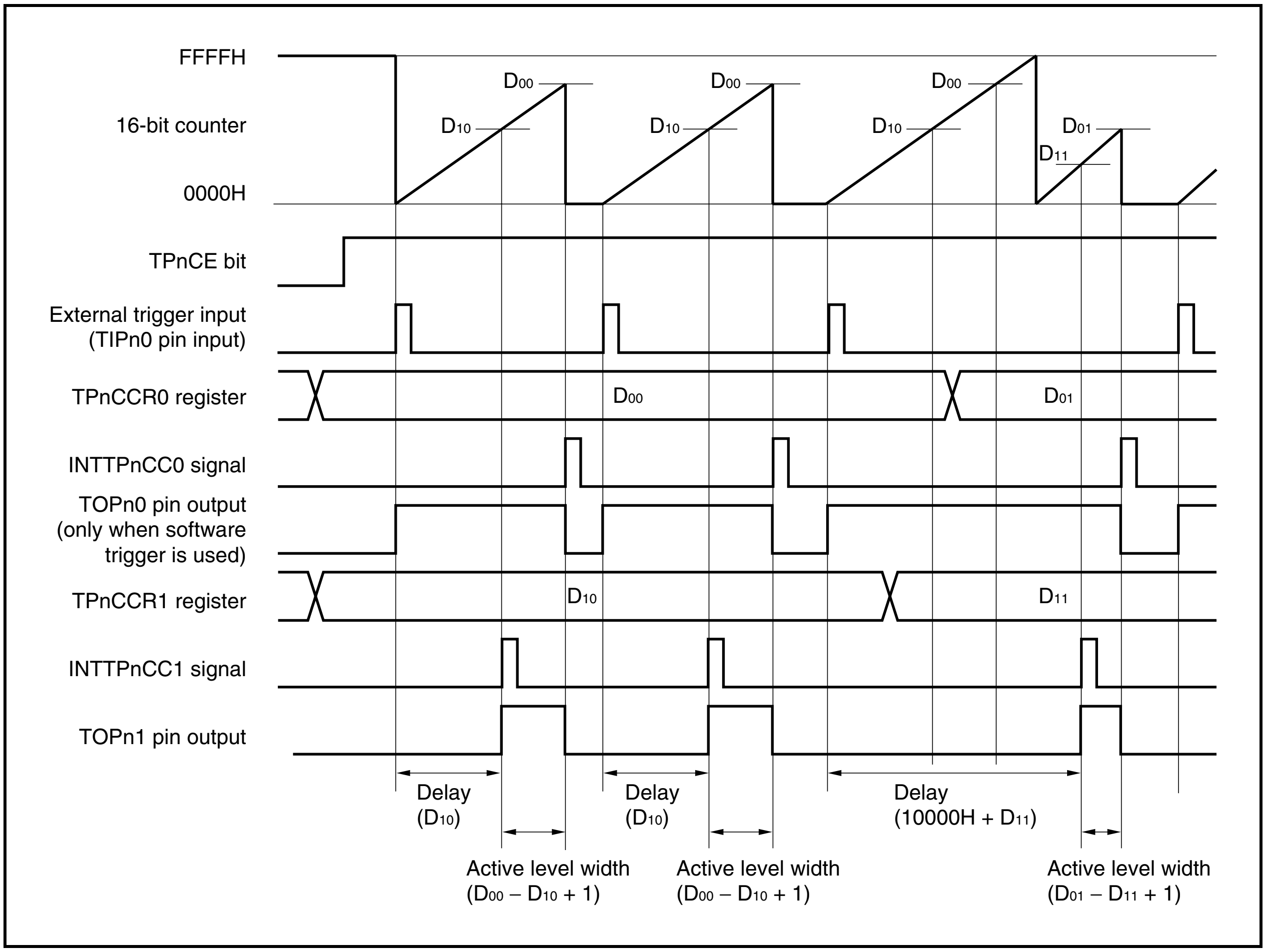
Remark n = 0 to 5
m = 0, 1

(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.



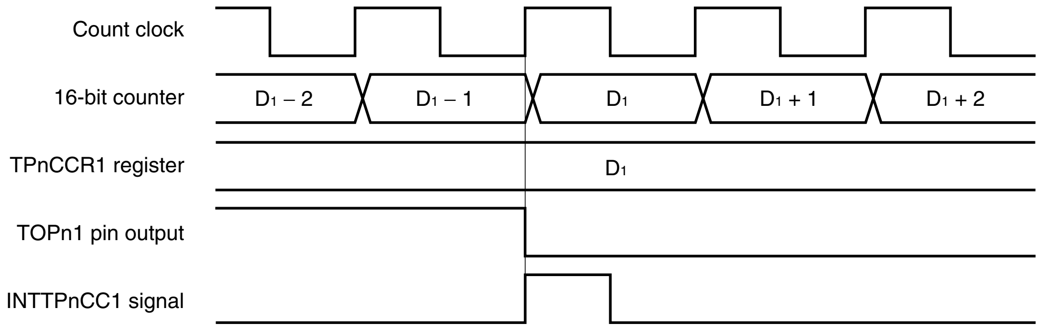
When the TPnCCR0 register is rewritten from D_{00} to D_{01} and the TPnCCR1 register from D_{10} to D_{11} where $D_{00} > D_{01}$ and $D_{10} > D_{11}$, if the TPnCCR1 register is rewritten when the count value of the 16-bit counter is greater than D_{11} and less than D_{10} and if the TPnCCR0 register is rewritten when the count value is greater than D_{01} and less than D_{00}, 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_{11}, the counter generates the INTTPnCC1 signal and asserts the TOPn1 pin. When the count value matches D_{01}, 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 5
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.



Remark n = 0 to 5

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.

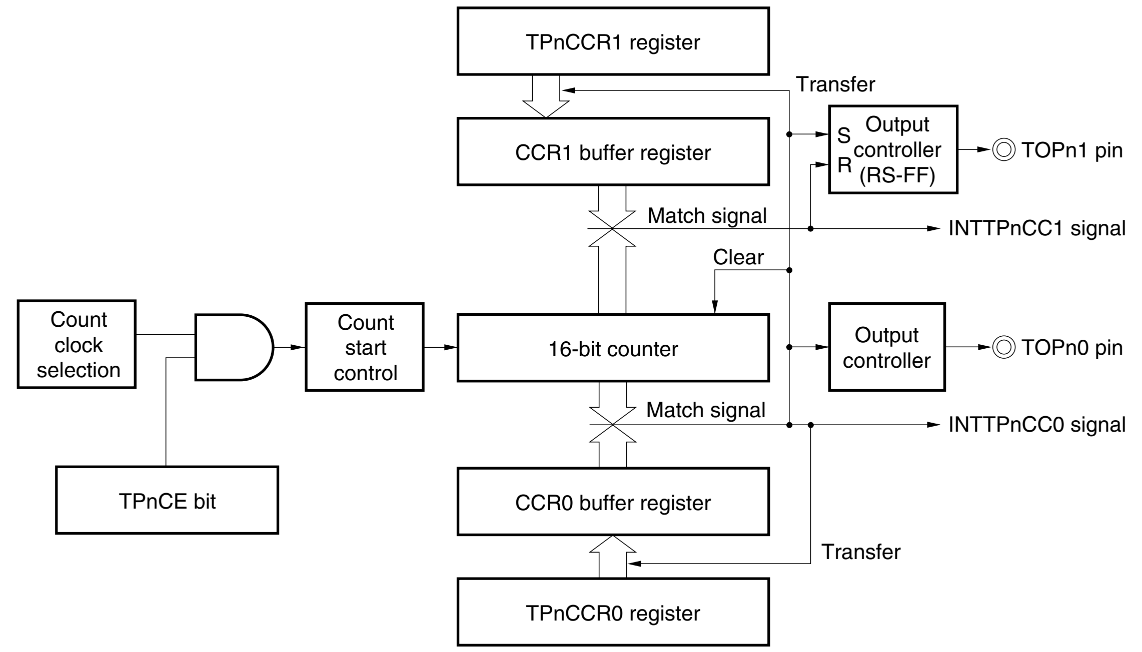
Remark n = 0 to 5

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.

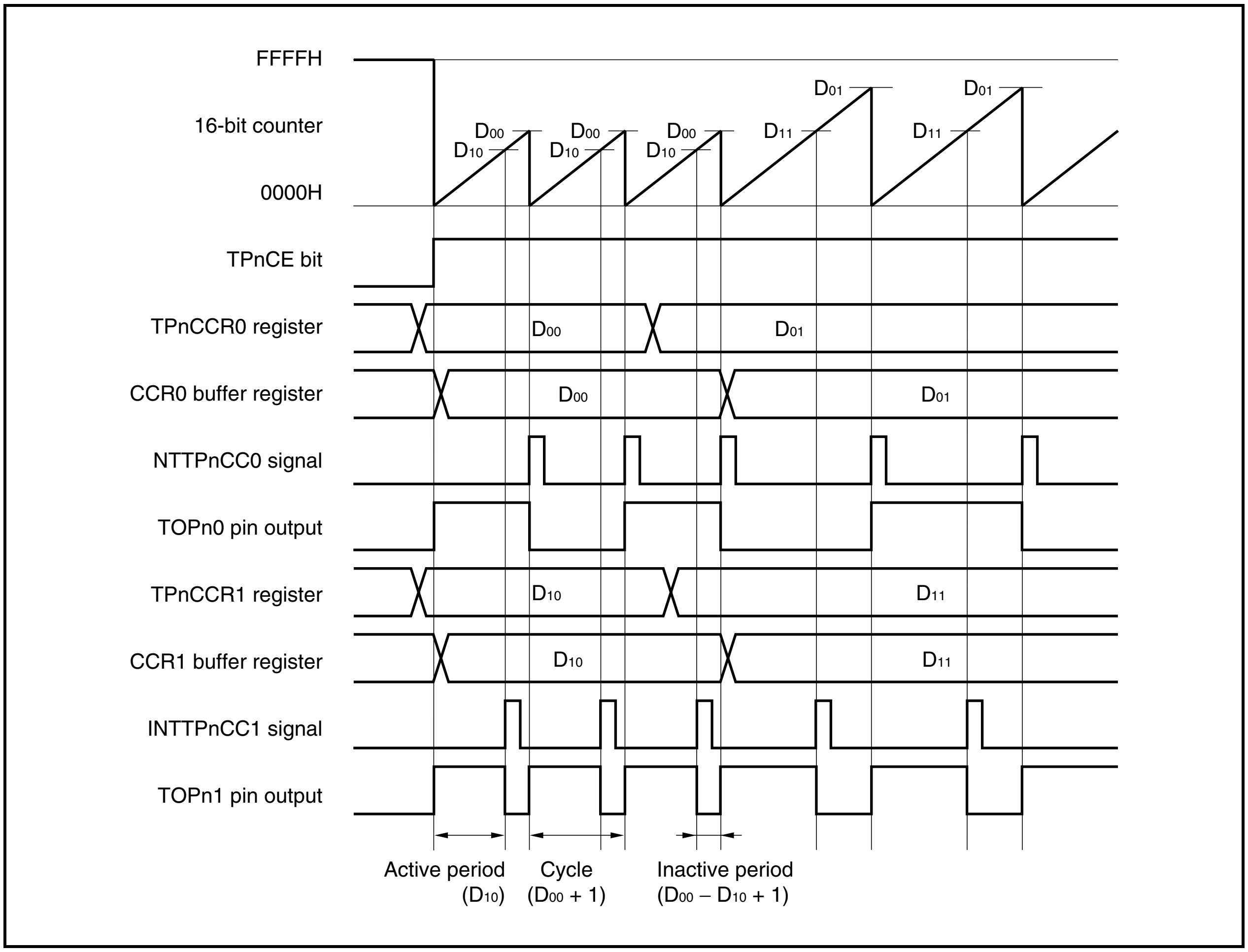
In addition, a pulse with one cycle of the PWM waveform as half its cycle is output from the TOPn0 pin.

Figure 7-24. Configuration in PWM Output Mode



Remark n = 0 to 5

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.

Active level width = (Set value of TPnCCR1 register) × Count clock cycle
Cycle = (Set value of TPnCCR0 register + 1) × Count clock cycle
Duty factor = (Set value of TPnCCR1 register)/(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 5, m = 0, 1

Figure 7-26. Setting of Registers in PWM Output Mode (1/2)

(a) TMPn control register 0 (TPnCTL0)

	TPnCE					TPnCKS2	TPnCKS1	TPnCKS0
TPnCTL0	0/1	0	0	0	0	0/1	0/1	0/1

TPnCKS2 to TPnCKS0: Select count clock$^{\text{Note 1}}$

TPnCE:
0: Stop counting
1: Enable counting

(b) TMPn control register 1 (TPnCTL1)

		TPnEST	TPnEEE			TPnMD2	TPnMD1	TPnMD0
TPnCTL1	0	0	0/1	0	0	1	0	0

TPnMD2 to TPnMD0:
1, 0, 0:
PWM output mode

TPnEEE:
0: Operate on count clock selected by TPnCKS0 to TPnCKS2 bits
1: Count external event input signal

(c) TMPn I/O control register 0 (TPnIOC0)

					TPnOL1	TPnOE1	TPnOL0	TPnOE0
TPnIOC0	0	0	0	0	0/1	0/1	0/1$^{\text{Note 2}}$	0/1$^{\text{Note 2}}$

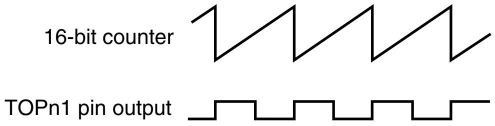
TPnOE0:
0: Disable TOPn0 pin output
1: Enable TOPn0 pin output

TPnOL0:
Setting of output level while operation of TOPn0 pin is disabled
0: Low level
1: High level

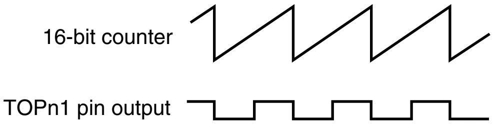
TPnOE1:
0: Disable TOPn1 pin output
1: Enable TOPn1 pin output

TPnOL1:
Specifies active level of TOPn1 pin output
0: Active-high
1: Active-low

- When TPnOL1 bit = 0



- When TPnOL1 bit = 1



Notes 1. The setting is invalid when the TPnCTL1.TPnEEE bit = 1.

2. Clear this bit to 0 when the TOPn0 pin is not used in the PWM output mode.

Figure 7-26. Register Setting in PWM Output Mode (2/2)

(d) TMPn I/O control register 2 (TPnIOC2)

					TPnEES1	TPnEES0	TPnETS1	TPnETS0
TPnIOC2	0	0	0	0	0/1	0/1	0	0

TPnEES1, TPnEES0: Select valid edge of external event count input.

(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.

Cycle = $(D_0 + 1) \times$ Count clock cycle

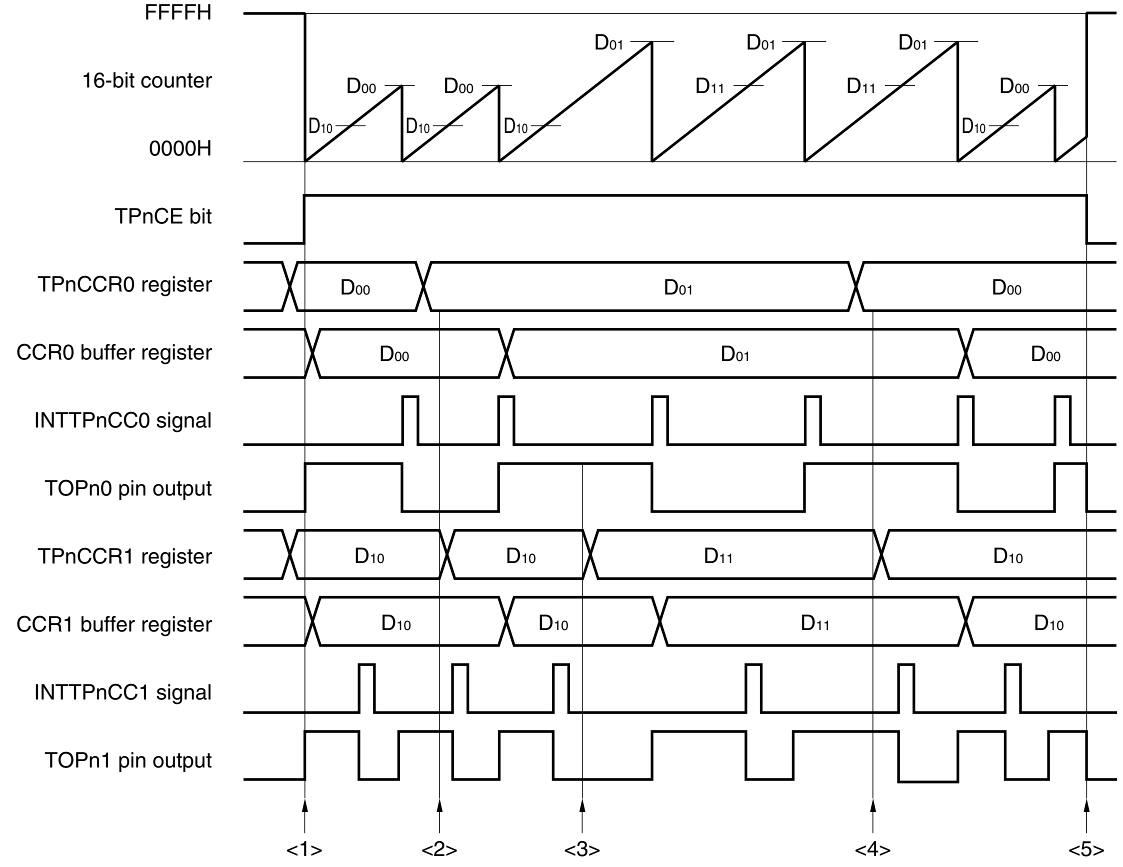
Active level width = $D_1 \times$ Count clock cycle

Remarks **1.** TMPn I/O control register 1 (TPnIOC1) and TMPn option register 0 (TPnOPT0) are not used in the PWM output mode.

2. n = 0 to 5

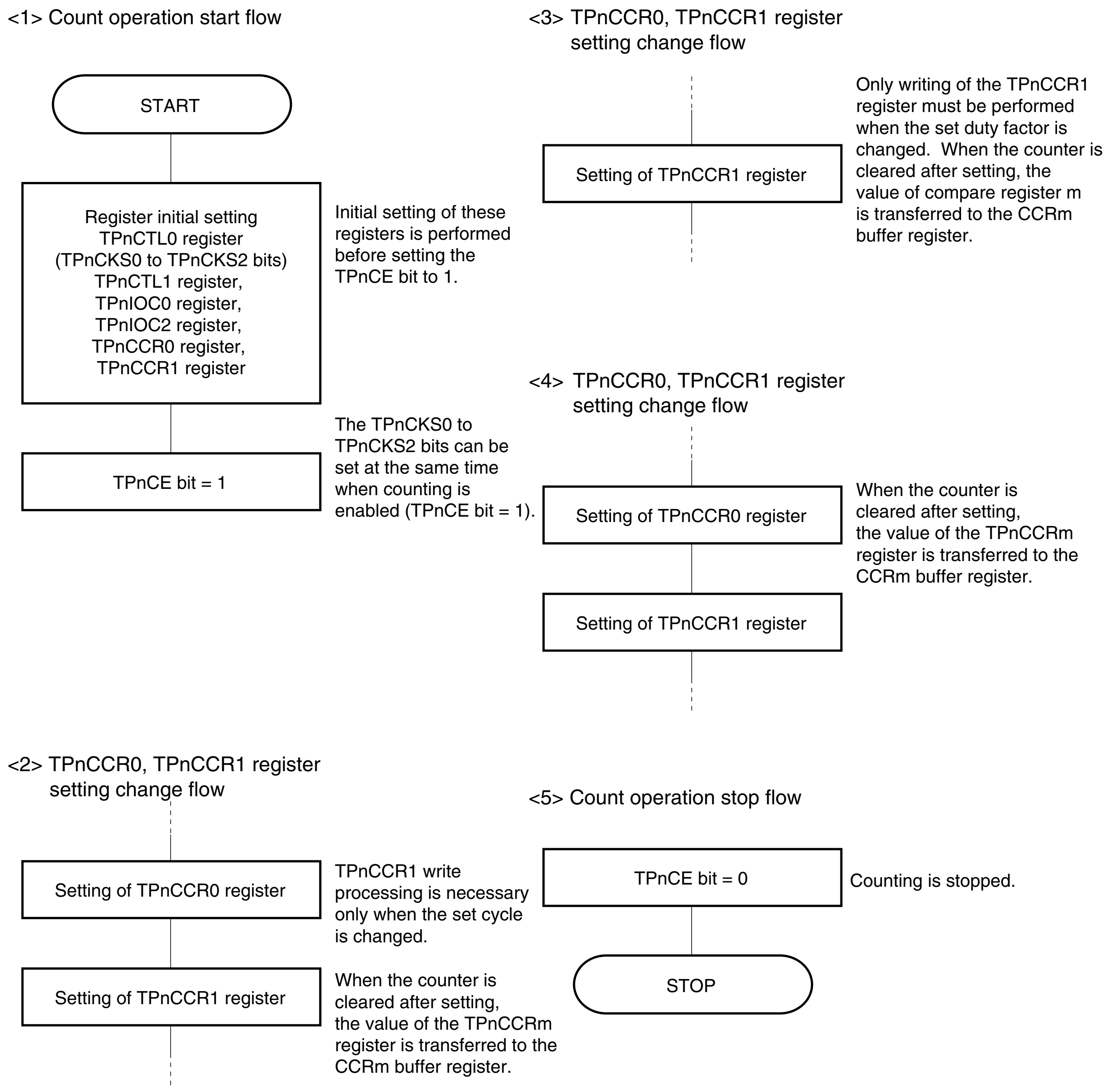
(1) Operation flow in PWM output mode

Figure 7-27. Software Processing Flow in PWM Output Mode (1/2)



Remark n = 0 to 5
m = 0, 1

Figure 7-27. Software Processing Flow in PWM Output Mode (2/2)



Initial setting of these registers is performed before setting the TPnCE bit to 1.

The TPnCKS0 to TPnCKS2 bits can be set at the same time when counting is enabled (TPnCE bit = 1).

TPnCCR1 write processing is necessary only when the set cycle is changed.

When the counter is cleared after setting, the value of the TPnCCRm register is transferred to the CCRm buffer register.

Only writing of the TPnCCR1 register must be performed when the set duty factor is changed. When the counter is cleared after setting, the value of compare register m is transferred to the CCRm buffer register.

When the counter is cleared after setting, the value of the TPnCCRm register is transferred to the CCRm buffer register.

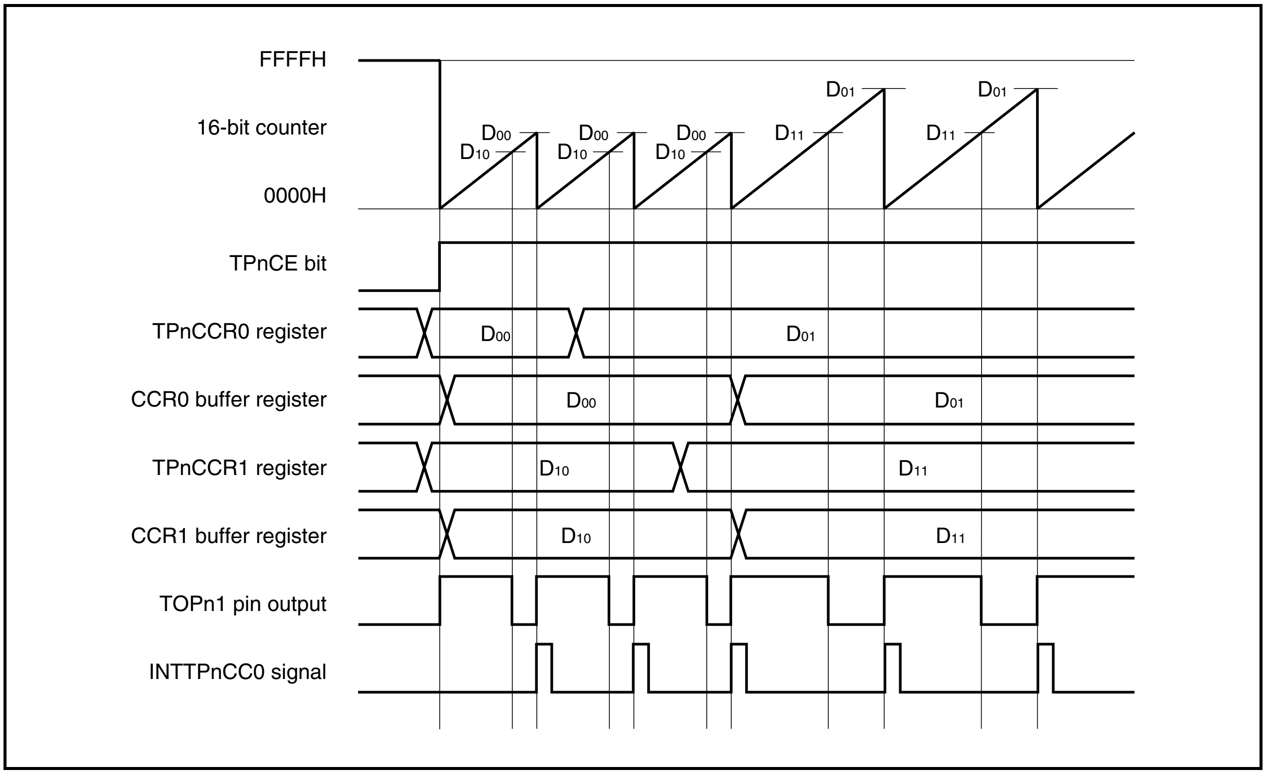
Counting is stopped.

Remark n = 0 to 5
m = 0, 1

(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.

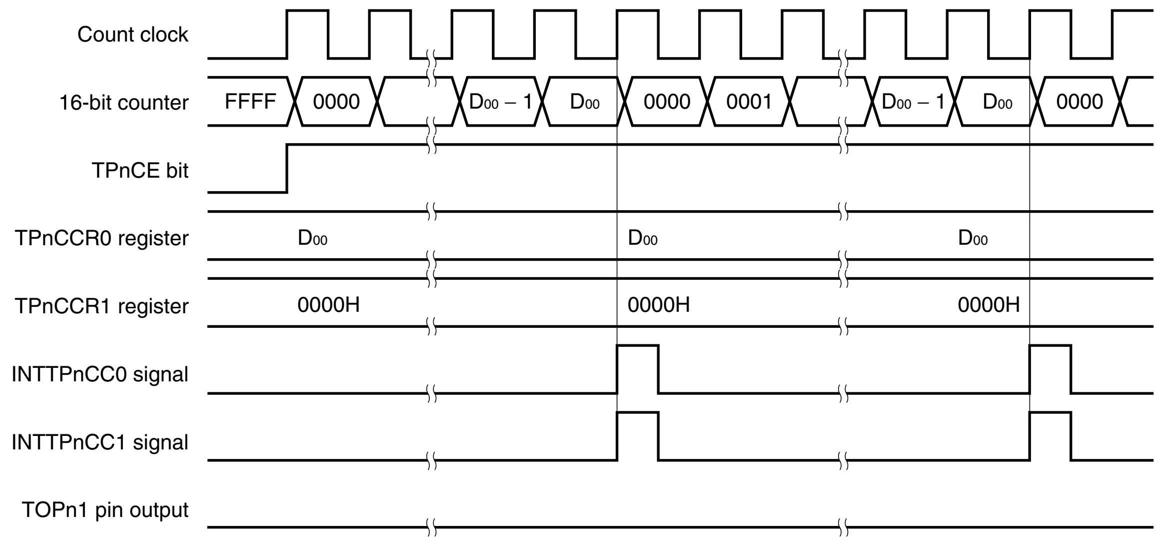
After data is written to the TPnCCR1 register, the value written to the TPnCCRm register is transferred to the CCRm buffer register in synchronization with clearing of the 16-bit counter, and is used as the value compared with the 16-bit counter.

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 5, m = 0, 1

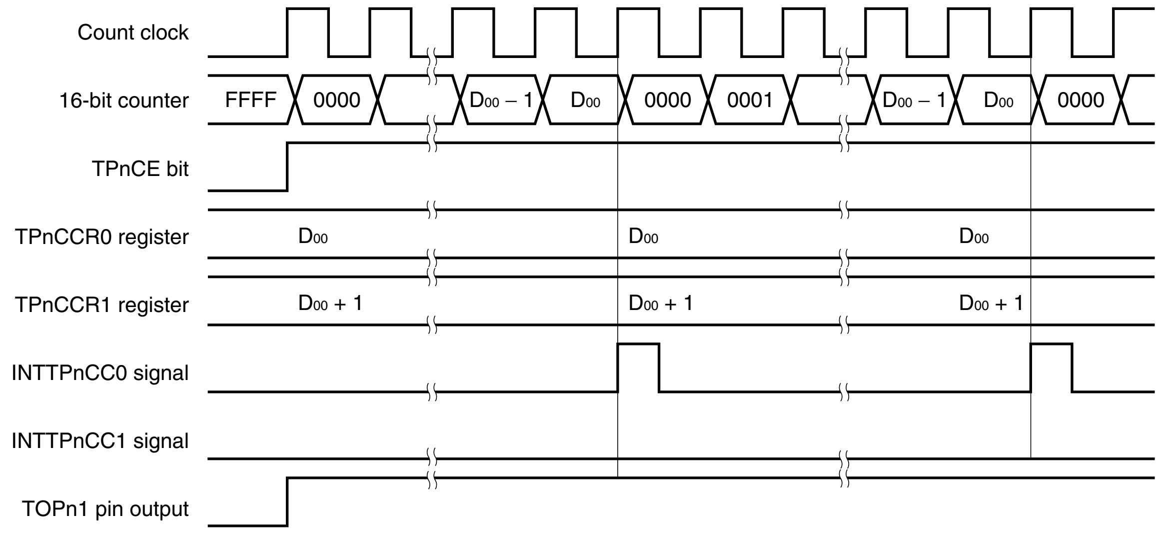
(b) 0%/100% output of PWM waveform

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.



Remark n = 0 to 5

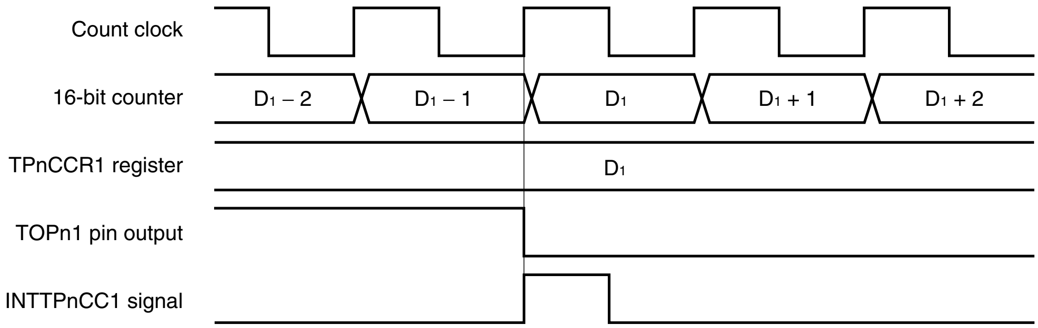
To output a 100% waveform, set a value of (set value of TPnCCR0 register + 1) to the TPnCCR1 register. If the set value of the TPnCCR0 register is FFFFH, 100% output cannot be produced.



Remark n = 0 to 5

(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.



Remark n = 0 to 5

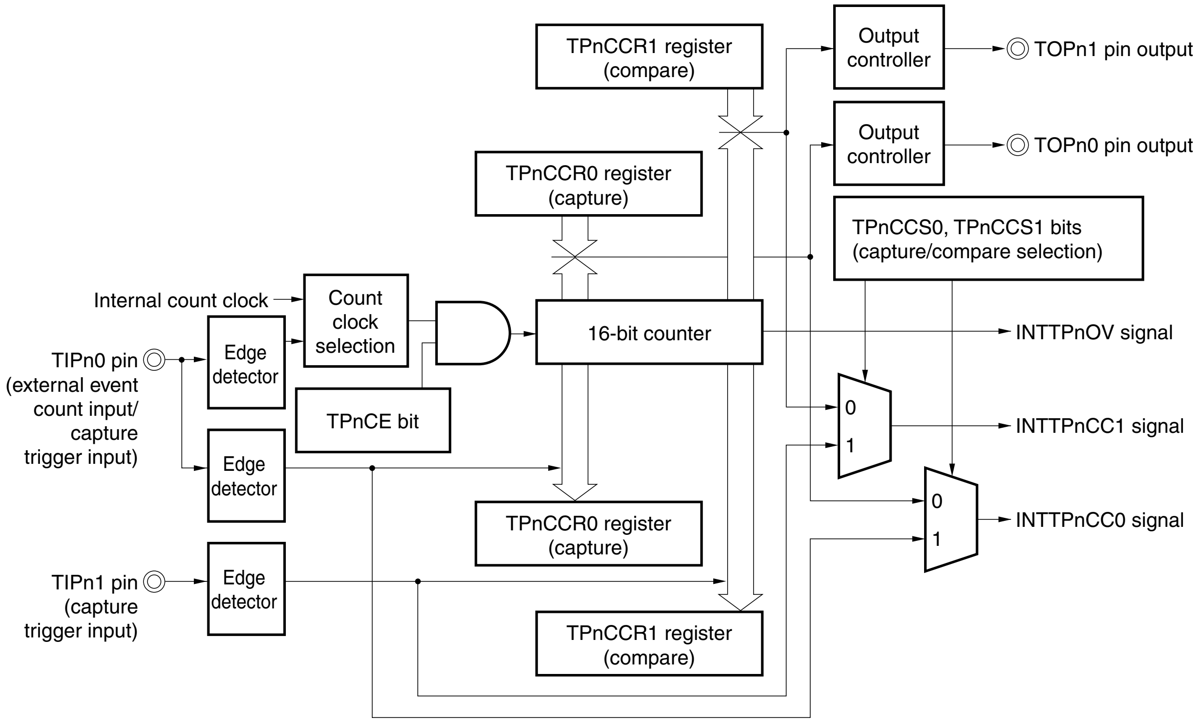
Usually, the INTTPnCC1 signal is generated in synchronization with the next counting up after the count value of the 16-bit counter matches the value of the TPnCCR1 register.

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



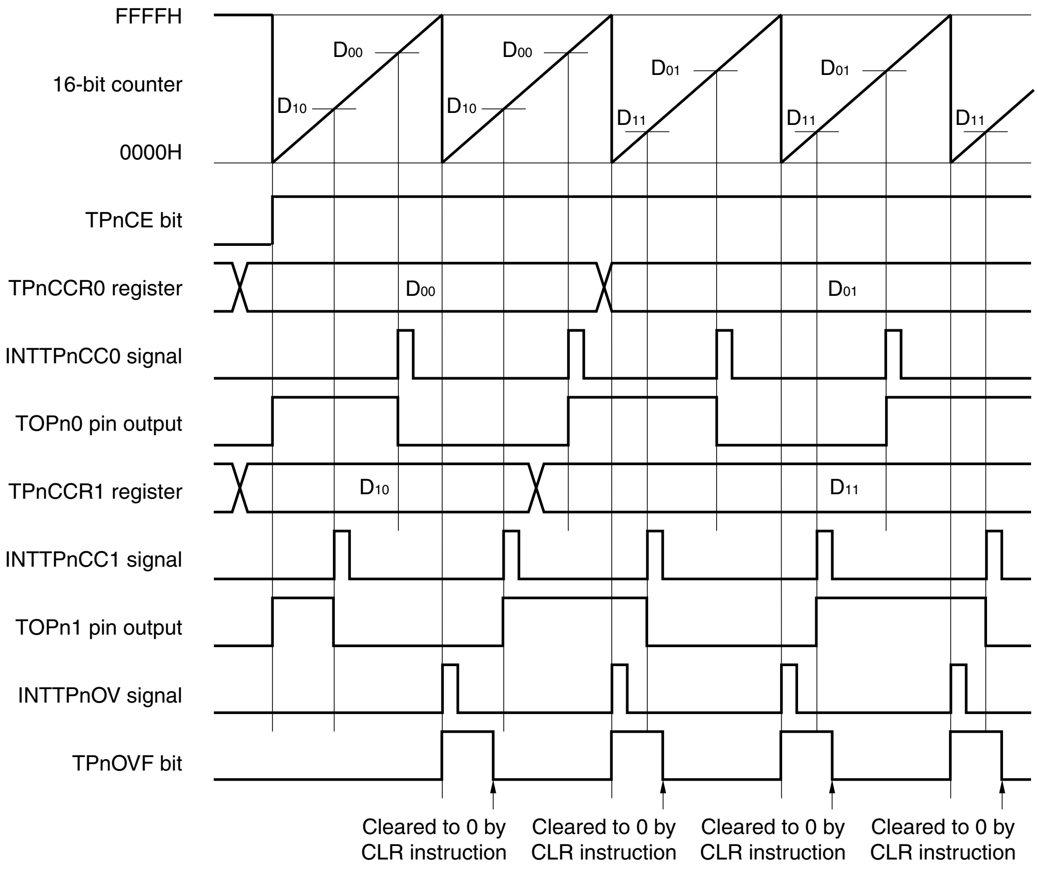
Remark n = 0 to 5
m = 0, 1

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)

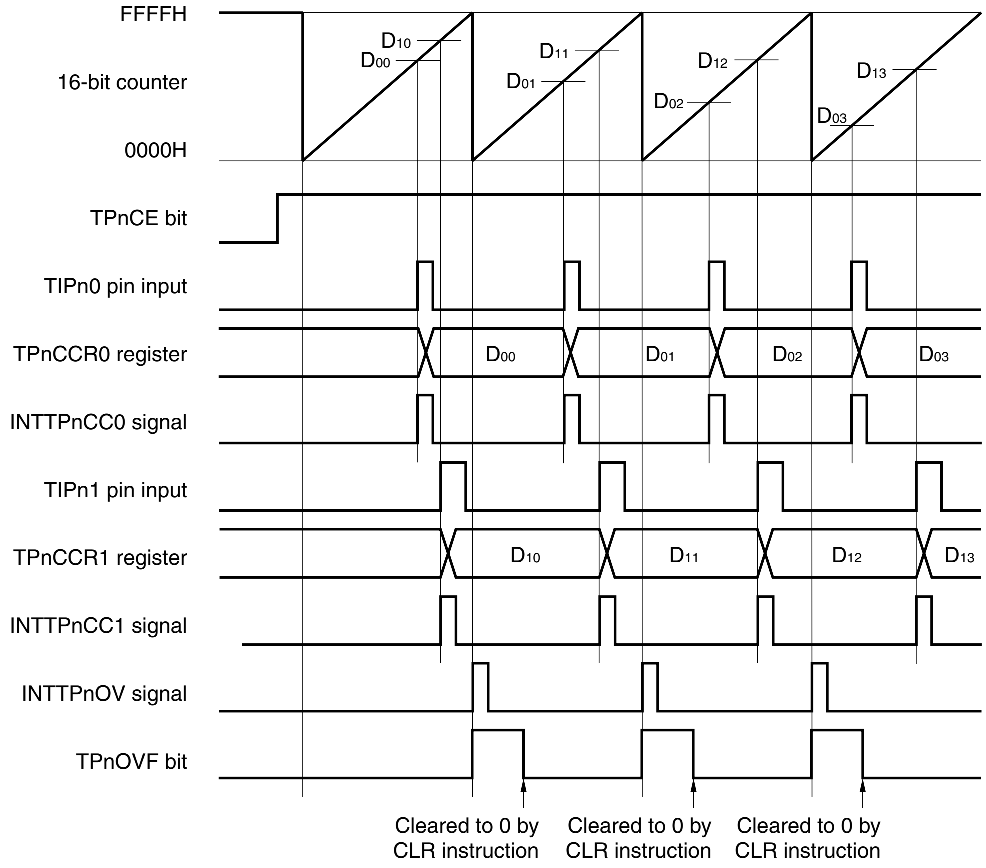


Remark n = 0 to 5
m = 0, 1

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.

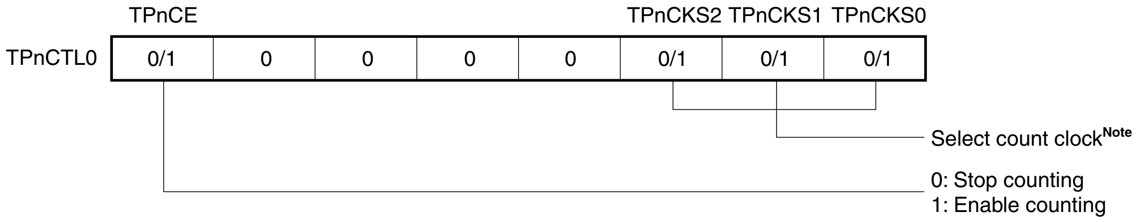
Figure 7-30. Basic Timing in Free-Running Timer Mode (Capture Function)



Remark n = 0 to 5

Figure 7-31. Register Setting in Free-Running Timer Mode (1/2)

(a) TMPn control register 0 (TPnCTL0)



Note The setting is invalid when the TPnCTL1.TPnEEE bit = 1

(b) TMPn control register 1 (TPnCTL1)

(c) TMPn I/O control register 0 (TPnIOC0)

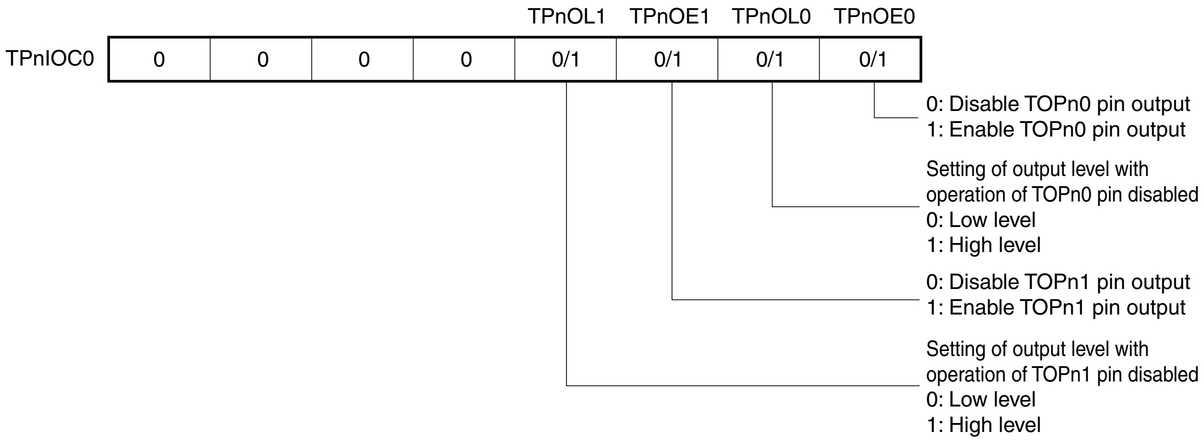
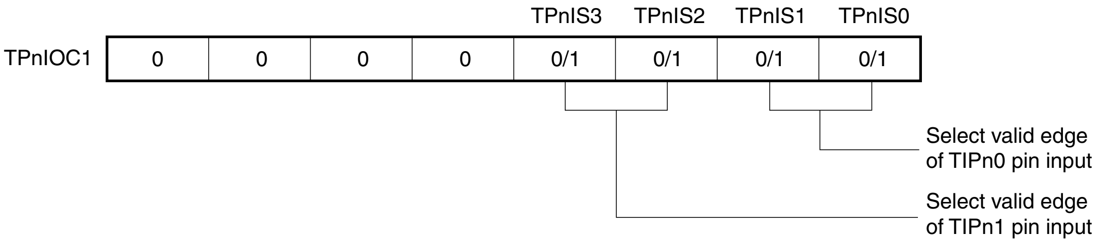
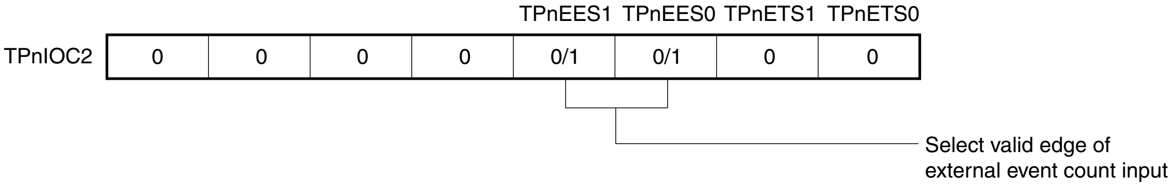


Figure 7-31. Register Setting in Free-Running Timer Mode (2/2)

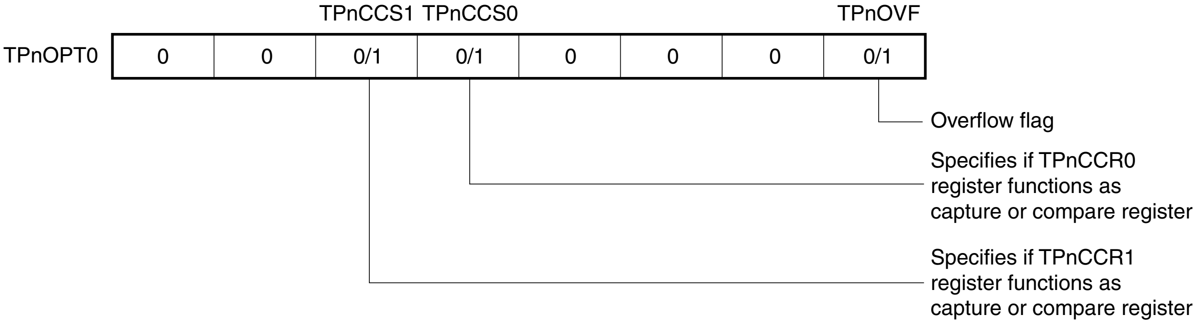
(d) TMPn I/O control register 1 (TPnIOC1)



(e) TMPn I/O control register 2 (TPnIOC2)



(f) TMPn option register 0 (TPnOPT0)



(g) TMPn counter read buffer register (TPnCNT)

The value of the 16-bit counter can be read by reading the TPnCNT register.

(h) TMPn capture/compare registers 0 and 1 (TPnCCR0 and TPnCCR1)

These registers function as capture registers or compare registers depending on the setting of the TPnOPT0.TPnCCSm 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 TIPnm pin is detected.

When the registers function as compare registers and when D_m is set to the TPnCCRm register, the INTTPnCCm signal is generated when the counter reaches (D_m + 1), and the output signal of the TOPnm pin is inverted.

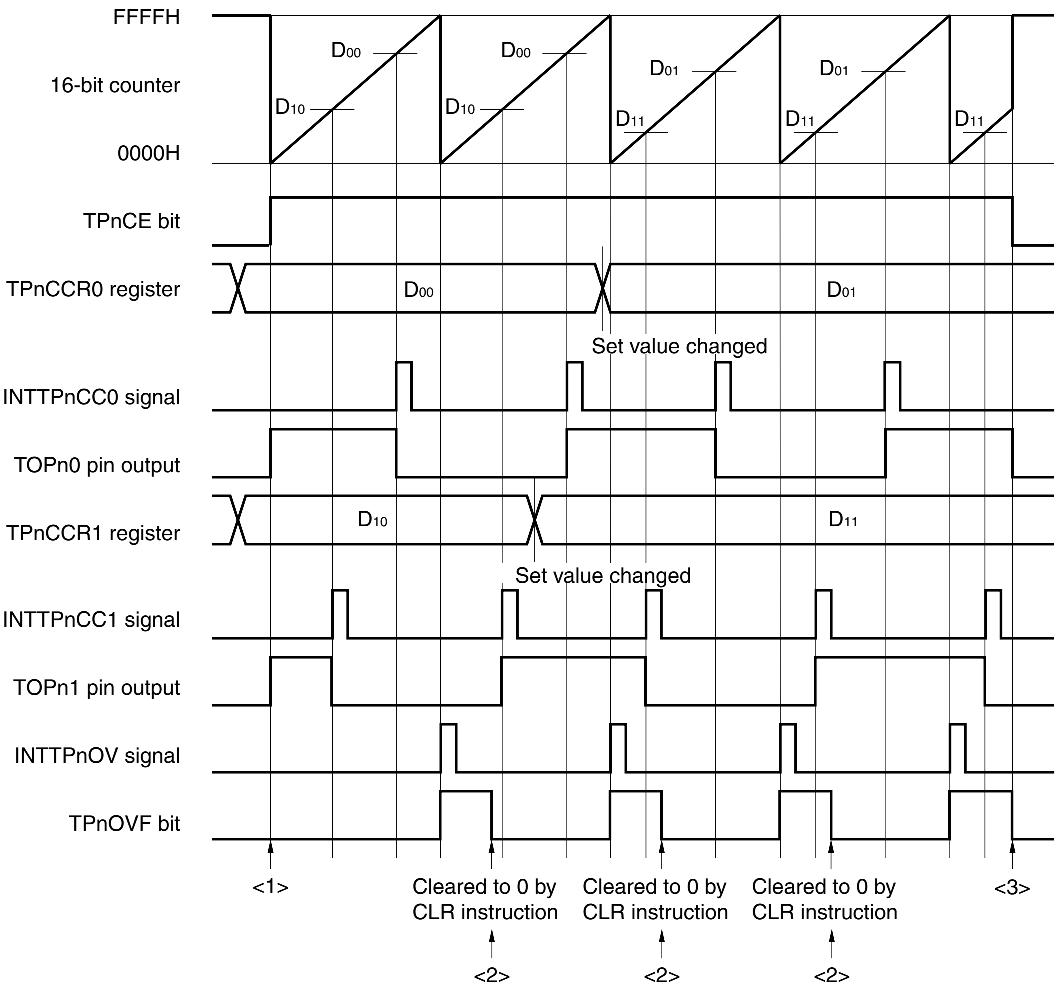
Remark n = 0 to 5

m = 0, 1

(1) Operation flow in free-running timer mode

(a) When using capture/compare register as compare register

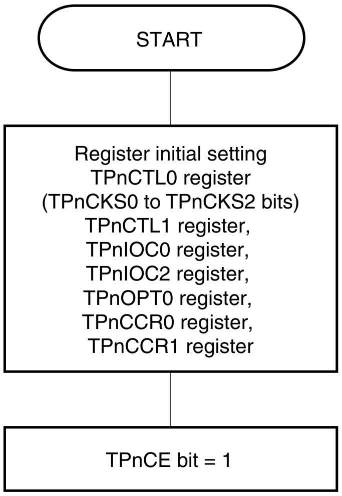
Figure 7-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (1/2)



Remark n = 0 to 5

Figure 7-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (2/2)

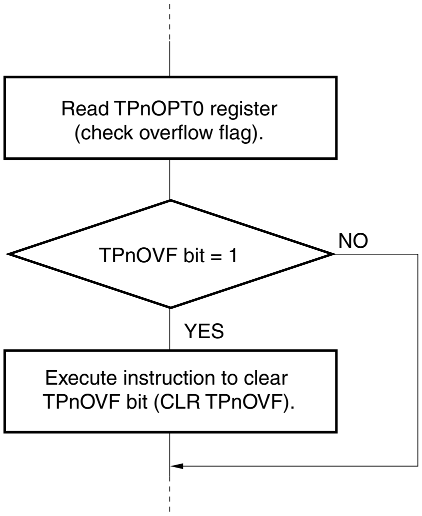
<1> Count operation start flow



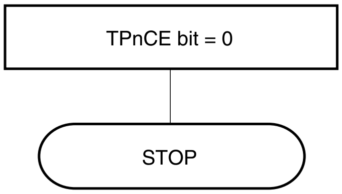
Initial setting of these registers is performed before the TPnCE bit is set to 1.

The TPnCKS0 to TPnCKS2 bits can be set when counting starts (TPnCE bit = 1).

<2> Overflow flag clear flow



<3> Count operation stop flow

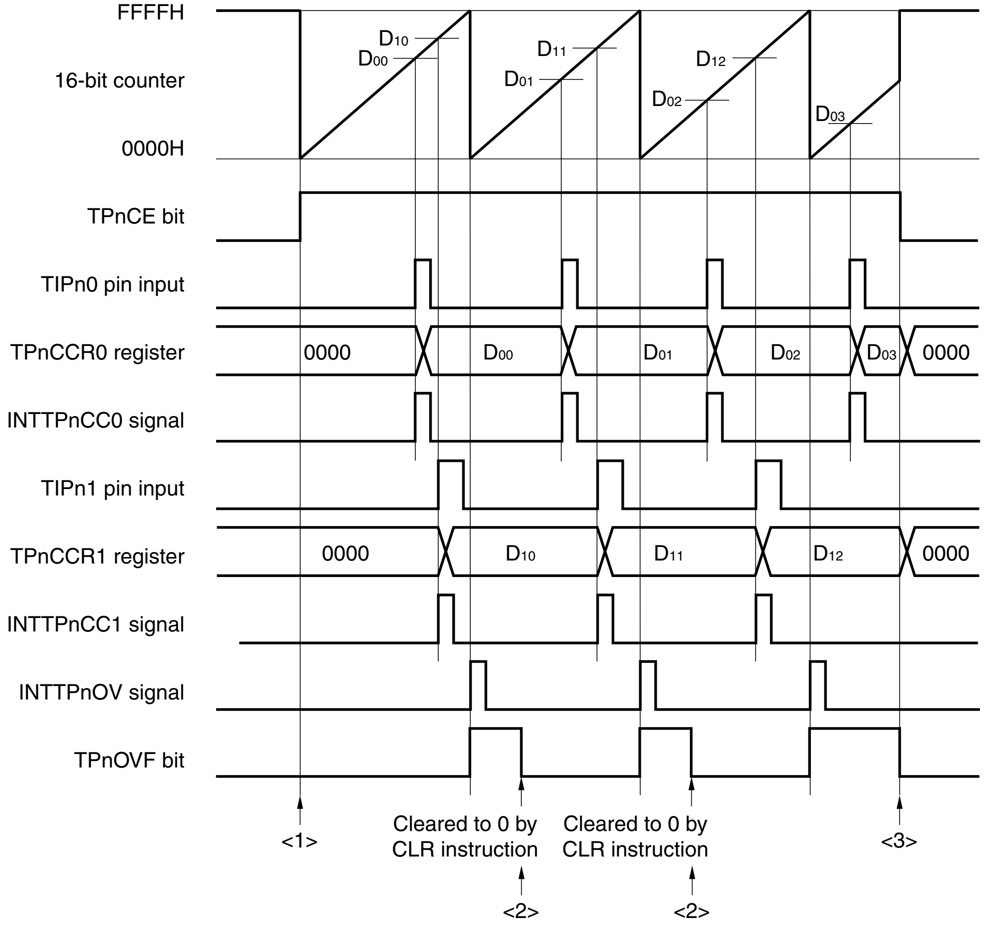


Counter is initialized and counting is stopped by clearing TPnCE bit to 0.

Remark n = 0 to 5

(b) When using capture/compare register as capture register

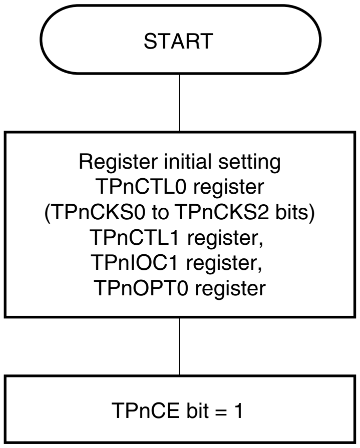
Figure 7-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (1/2)



Remark n = 0 to 5

Figure 7-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (2/2)

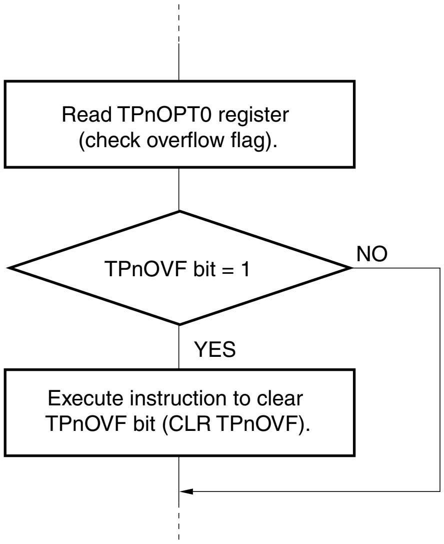
<1> Count operation start flow



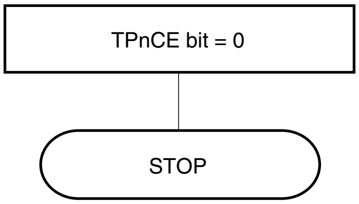
Initial setting of these registers is performed before the TPnCE bit is set to 1.

The TPnCKS0 to TPnCKS2 bits can be set when counting starts (TPnCE bit = 1).

<2> Overflow flag clear flow



<3> Count operation stop flow



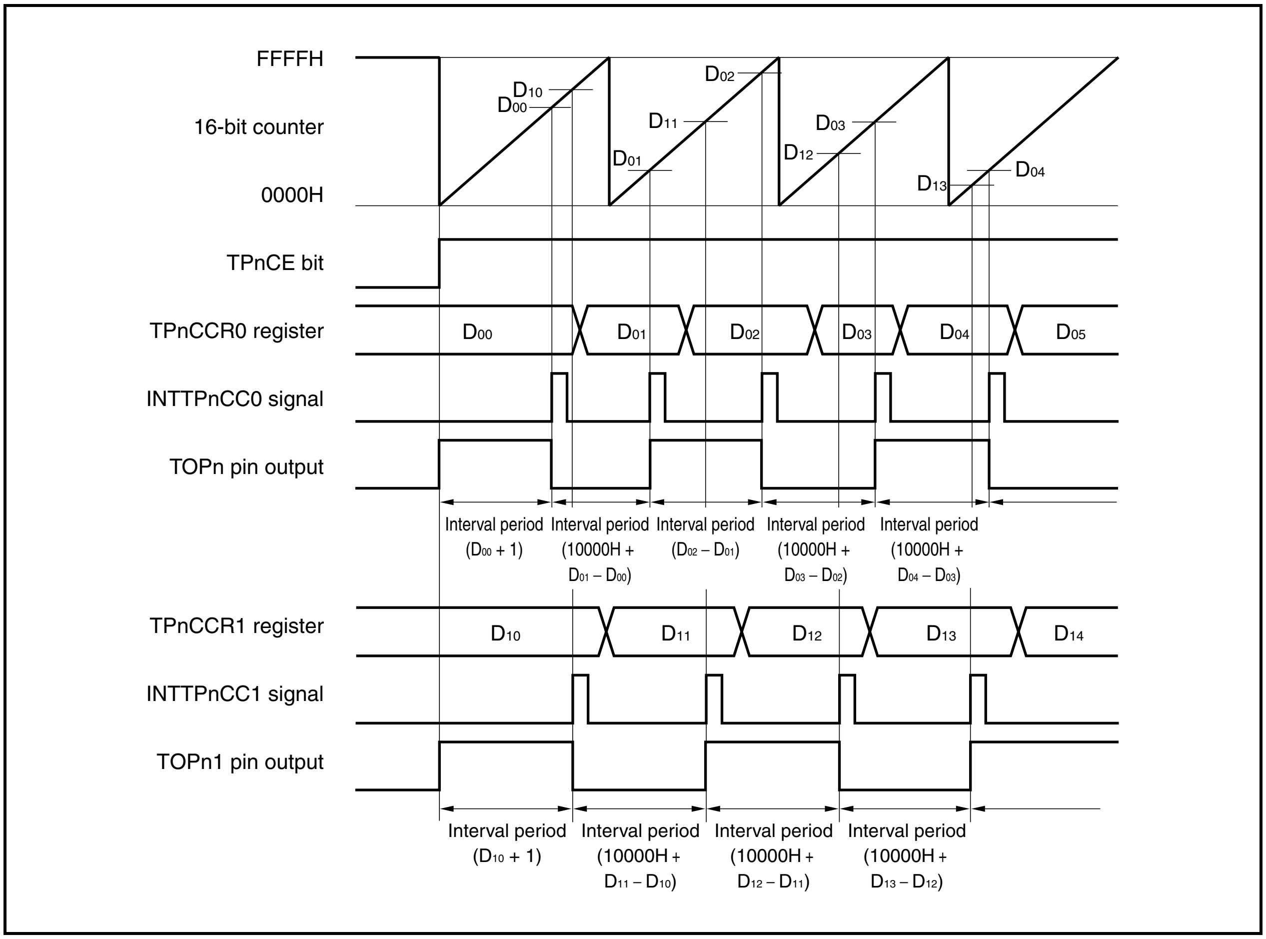
Counter is initialized and counting is stopped by clearing TPnCE bit to 0.

Remark n = 0 to 5

(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_m" 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

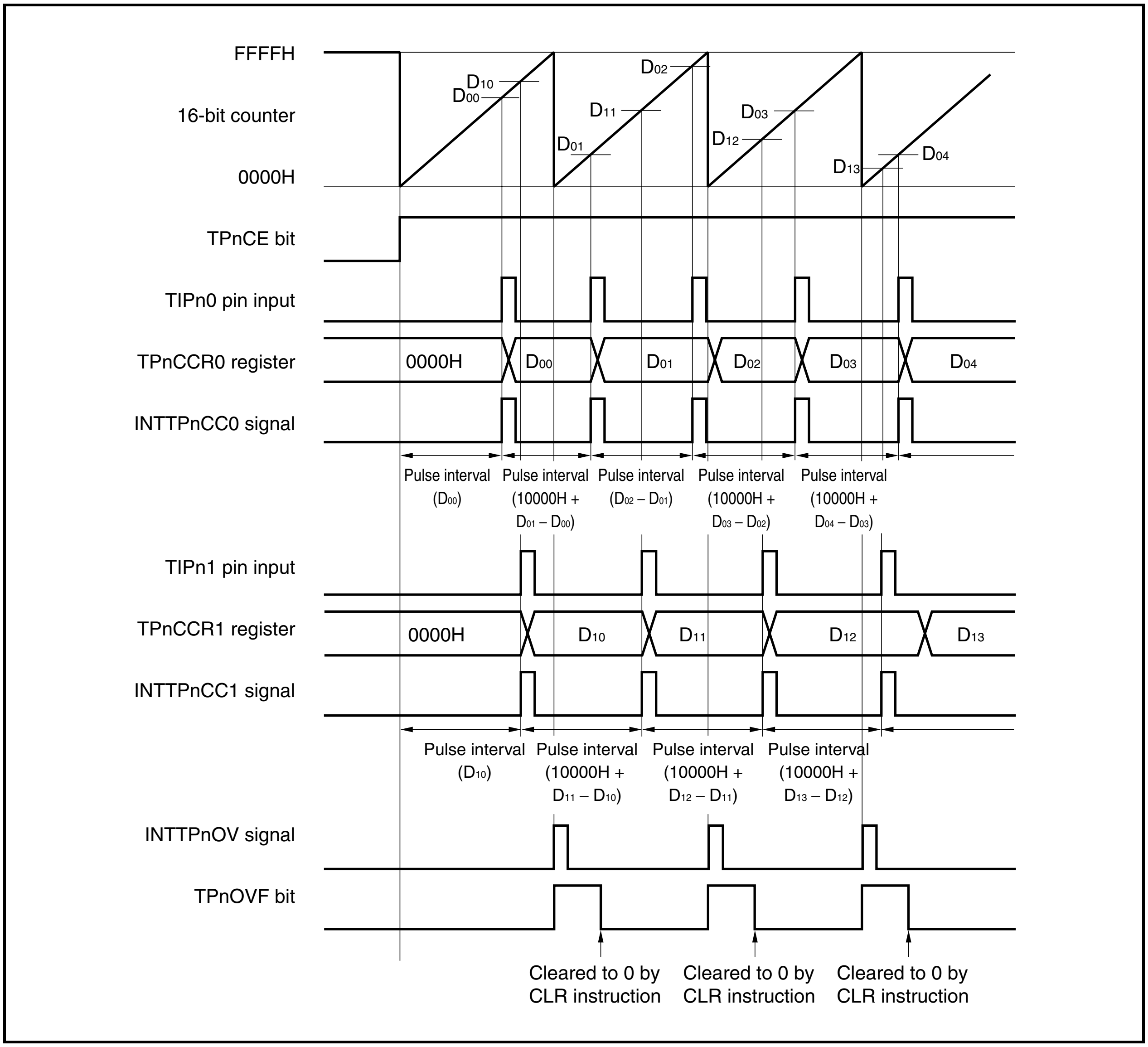
(If the calculation result is greater than FFFFH, subtract 10000H from the result and set this value to the register.)

Remark n = 0 to 5

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.

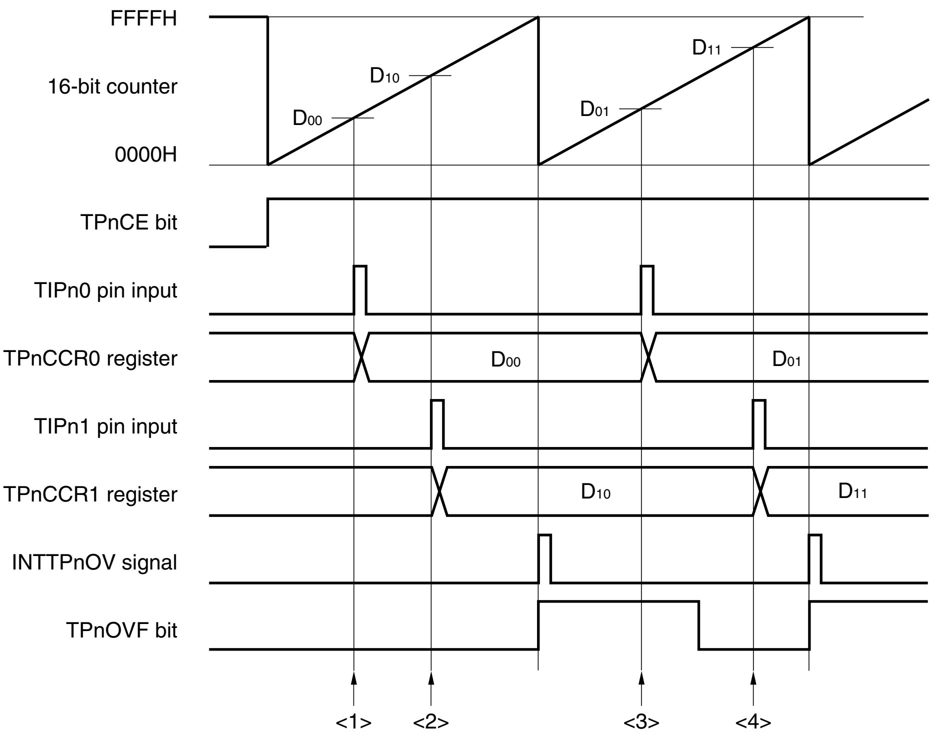
To measure a pulse width, the pulse width can be calculated by reading the value of the TPnCCRm register in synchronization with the INTTPnCCm signal, and calculating the difference between the read value and the previously read value.

Remark n = 0 to 5
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.

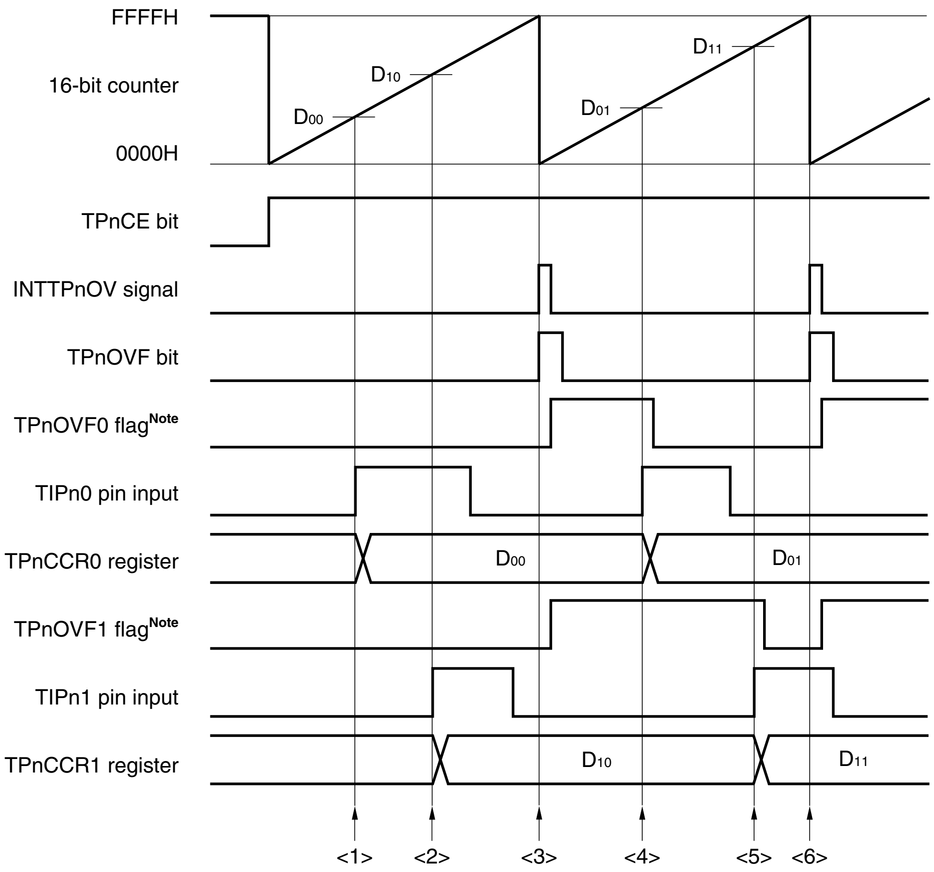
<1> Read the TPnCCR0 register (setting of the default value of the TIPn0 pin input).
<2> Read the TPnCCR1 register (setting of the default value of the TIPn1 pin input).
<3> Read the TPnCCR0 register.
Read the overflow flag. If the overflow flag is 1, clear it to 0.
Because the overflow flag is 1, the 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.

(1/2)

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.

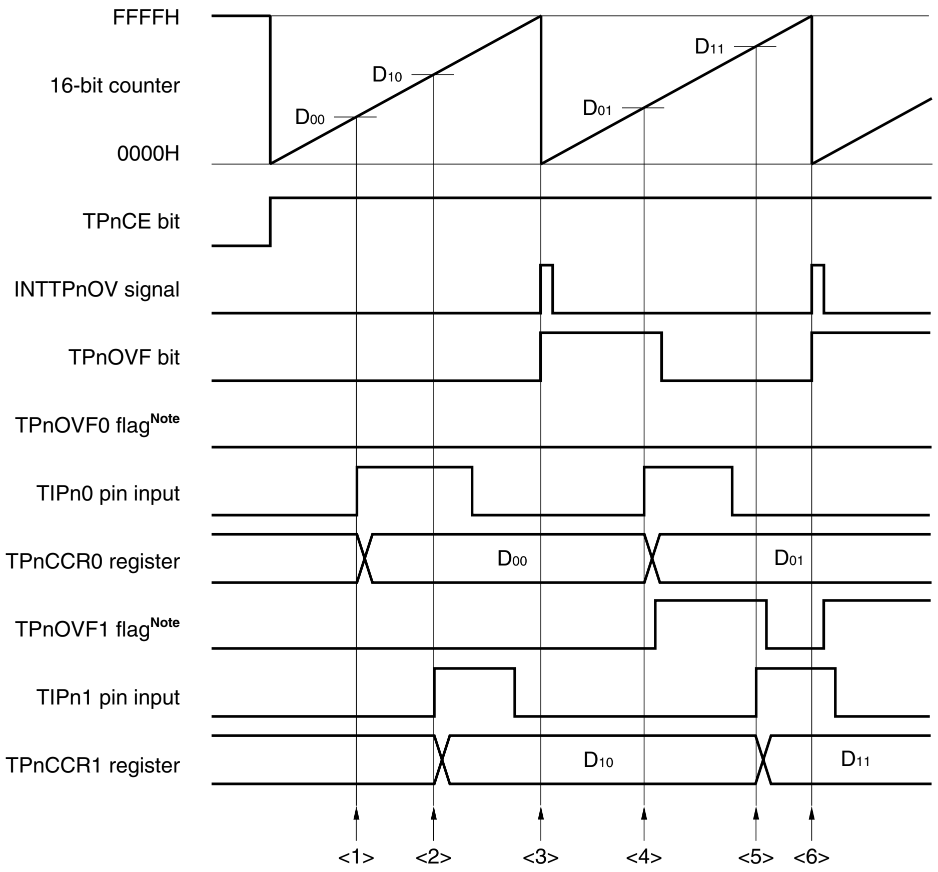
<4> Read the TPnCCR0 register.
Read the TPnOVF0 flag. If the TPnOVF0 flag is 1, clear it to 0.
Because the TPnOVF0 flag is 1, the pulse width can be calculated by (10000H + D_{01} – D_{00}).

<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>

(2/2)

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.

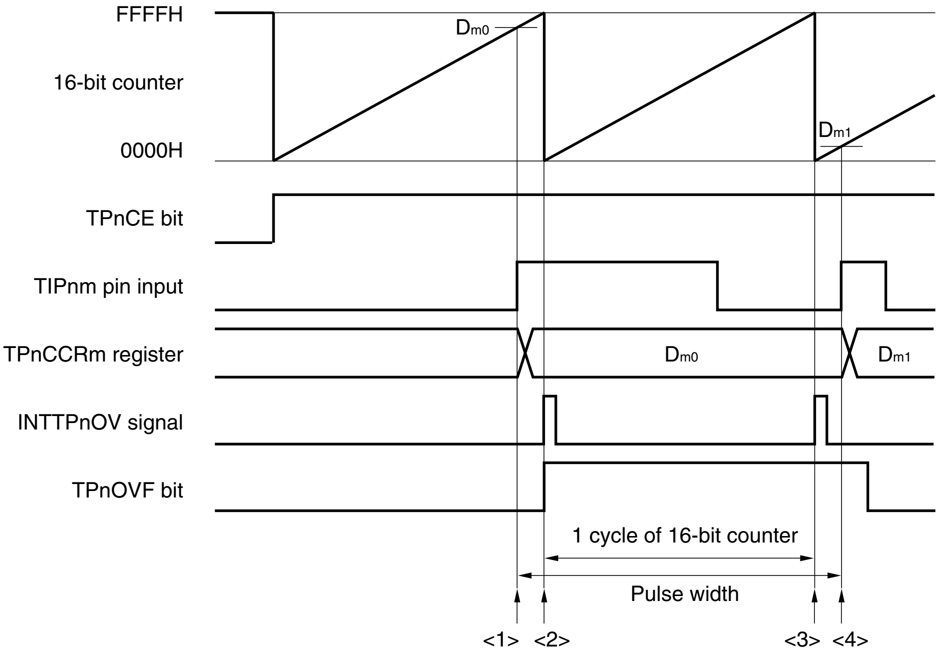
Because the TPnOVF1 flag is 1, the pulse width can be calculated by (10000H + D_{11} – D_{10}) (correct).

<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.

Example of incorrect processing when capture trigger interval is long



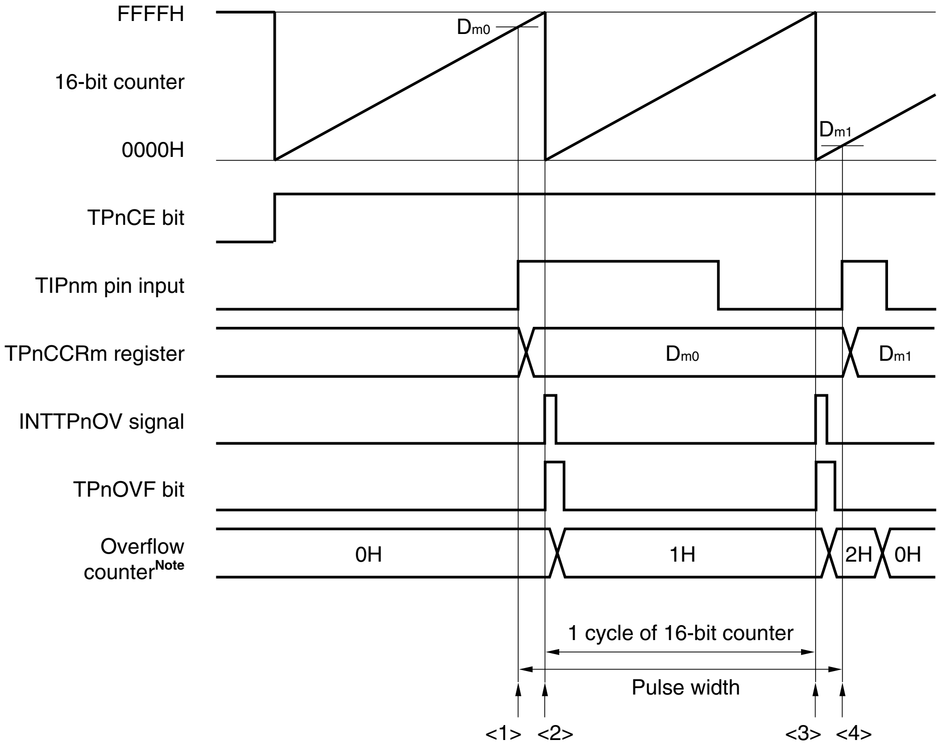
The following problem may occur when long pulse width is measured in the free-running timer mode.

<1> Read the TPnCCRm register (setting of the default value of the TIPnm pin input).
<2> An overflow occurs. Nothing is done by software.
<3> An overflow occurs a second time. Nothing is done by software.
<4> Read the TPnCCRm 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_{m1} – D_{m0}) (incorrect).
Actually, the pulse width must be (20000H + D_{m1} – D_{m0}) because an overflow occurs twice.

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).

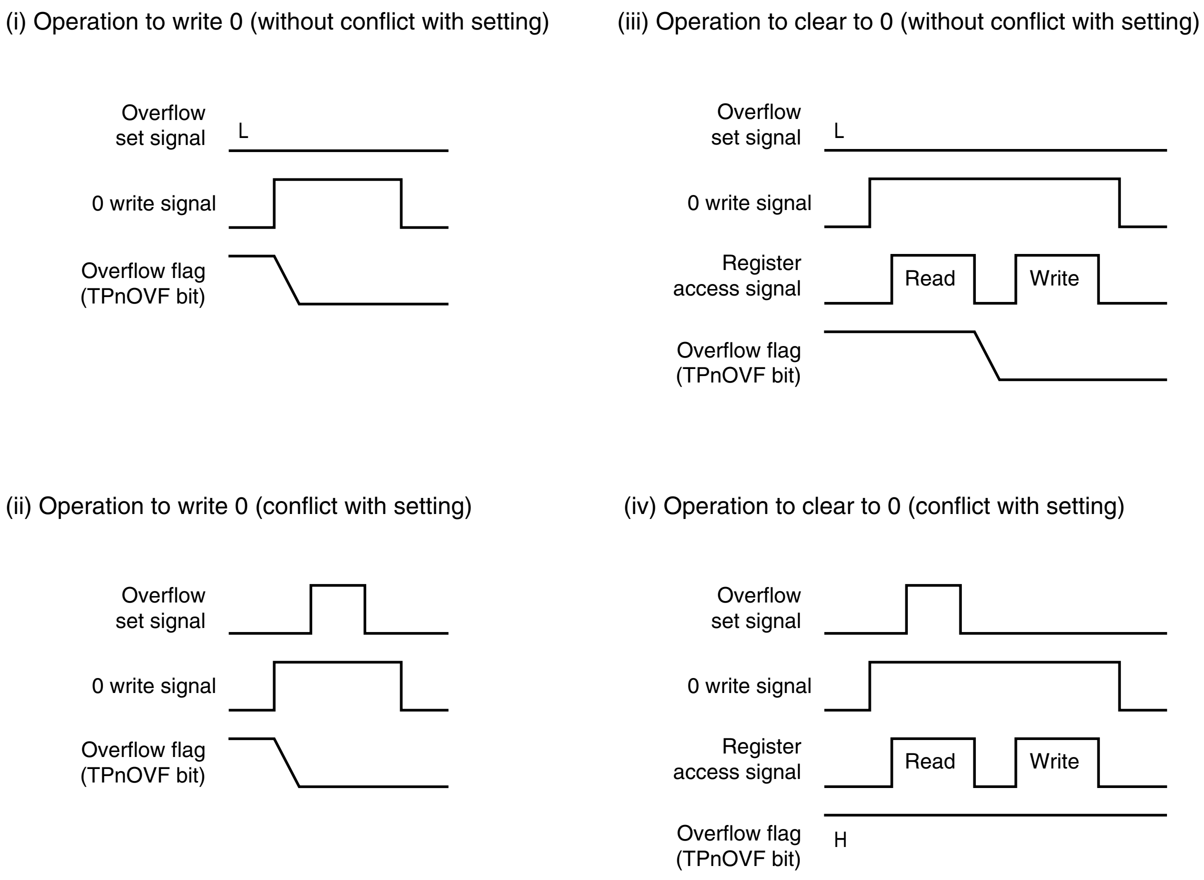
<2> An overflow occurs. Increment the overflow counter and clear the overflow flag to 0 in the overflow interrupt servicing.

<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 × 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.



(i) Operation to write 0 (without conflict with setting)

(iii) Operation to clear to 0 (without conflict with setting)

(ii) Operation to write 0 (conflict with setting)

(iv) Operation to clear to 0 (conflict with setting)

Remark n = 0 to 5

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.

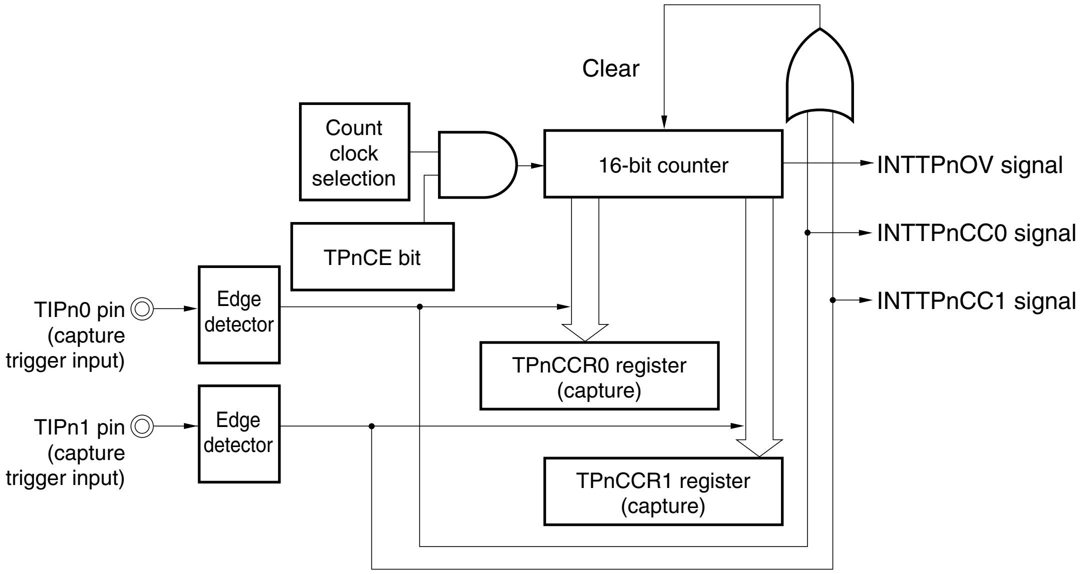
7.5.7 Pulse width measurement mode (TPnMD2 to TPnMD0 bits = 110)

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.

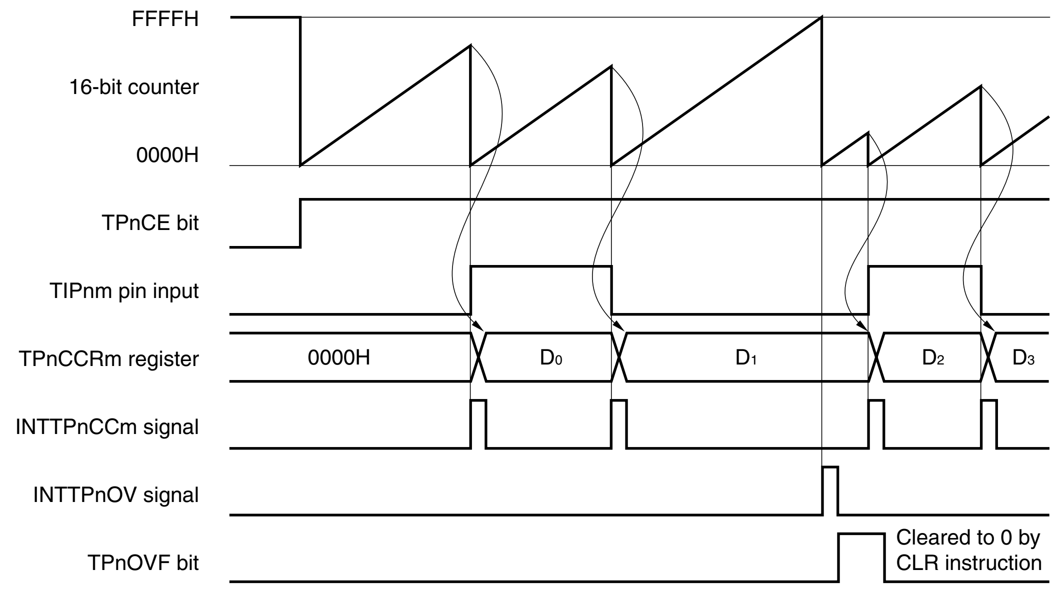
Select either the TIPn0 or TIPn1 pin as the capture trigger input pin. Specify "No edge detected" by using the TPnIOC1 register for the unused pins.

Figure 7-34. Configuration in Pulse Width Measurement Mode



Remark n = 0 to 5
m = 0, 1

Figure 7-35. Basic Timing in Pulse Width Measurement Mode



Remark n = 0 to 5
m = 0, 1

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.

Pulse width = Captured value × 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.

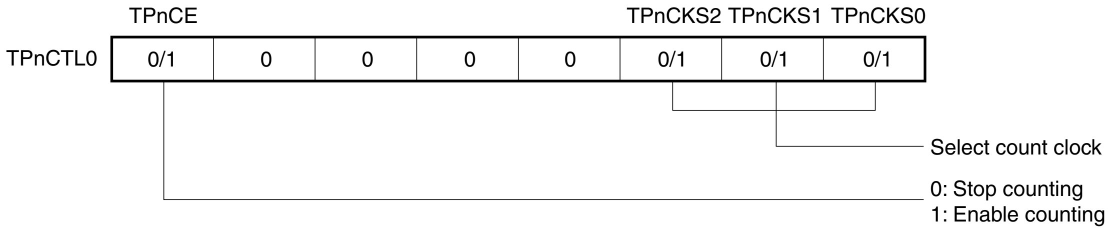
If the overflow flag is set to 1, the pulse width can be calculated as follows.

Pulse width = (10000H × TPnOVF bit set (1) count + Captured value) × Count clock cycle

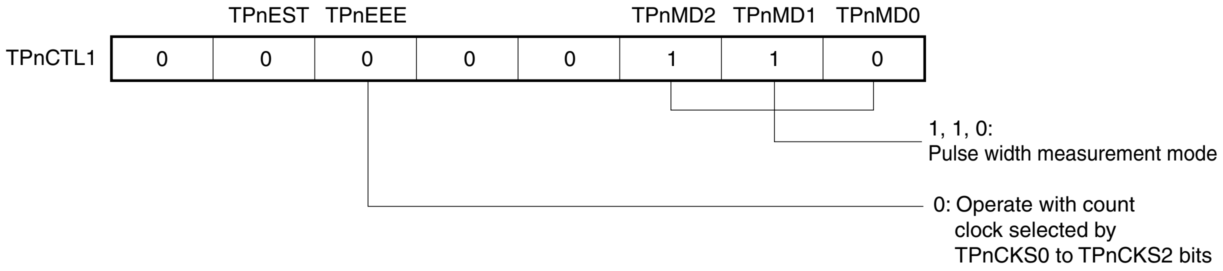
Remark n = 0 to 5
m = 0, 1

Figure 7-36. Register Setting in Pulse Width Measurement Mode (1/2)

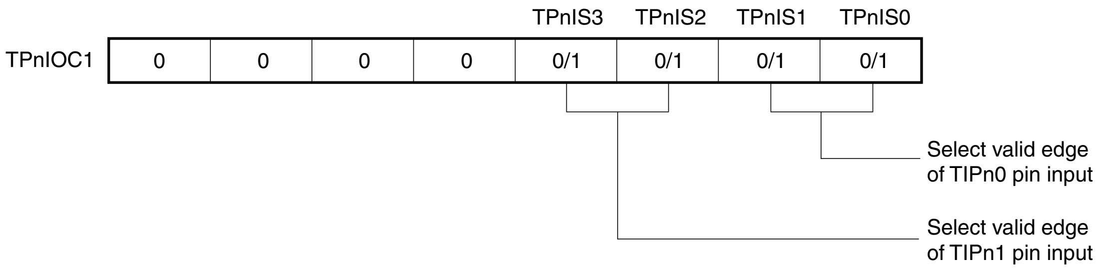
(a) TMPn control register 0 (TPnCTL0)



(b) TMPn control register 1 (TPnCTL1)



(c) TMPn I/O control register 1 (TPnIOC1)



(d) TMPn I/O control register 2 (TPnIOC2)

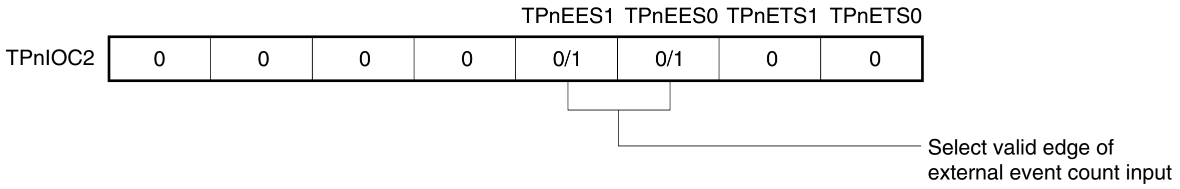


Figure 7-36. Register Setting in Pulse Width Measurement Mode (2/2)

(e) TMPn option register 0 (TPnOPT0)

			TPnCCS1	TPnCCS0				TPnOVF
TPnOPT0	0	0	0	0	0	0	0	0/1

Overflow flag

(f) TMPn counter read buffer register (TPnCNT)

The value of the 16-bit counter can be read by reading the TPnCNT register.

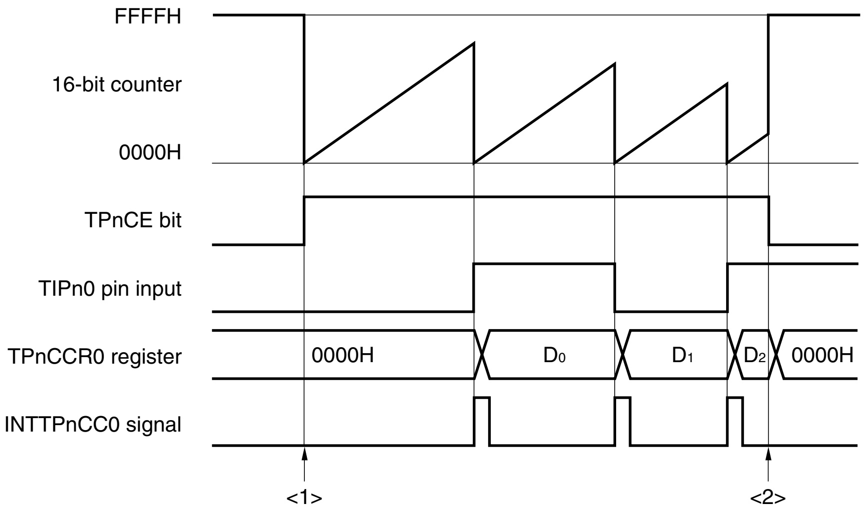
(g) TMPn capture/compare registers 0 and 1 (TPnCCR0 and TPnCCR1)

These registers store the count value of the 16-bit counter when the valid edge input to the TIPnm pin is detected.

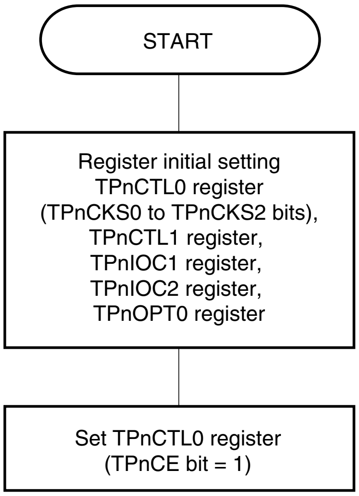
Remarks **1.** TMPn I/O control register 0 (TPnIOC0) is not used in the pulse width measurement mode.
2. n = 0 to 5
m = 0, 1

(1) Operation flow in pulse width measurement mode

Figure 7-37. Software Processing Flow in Pulse Width Measurement Mode



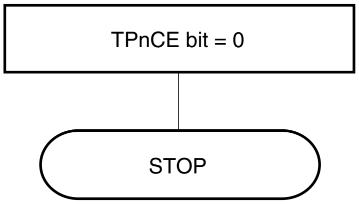
<1> Count operation start flow



Initial setting of these registers is performed before the TPnCE bit is set to 1.

The TPnCKS0 to TPnCKS2 bits can be set when counting starts (TPnCE bit = 1).

<2> Count operation stop flow



The counter is initialized and counting is stopped by clearing the TPnCE bit to 0.

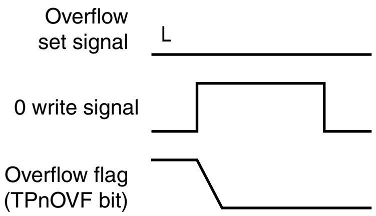
Remark n = 0 to 5

(2) Operation timing in pulse width measurement mode

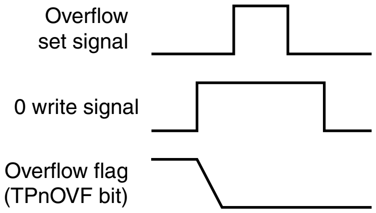
(a) Clearing overflow flag

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.

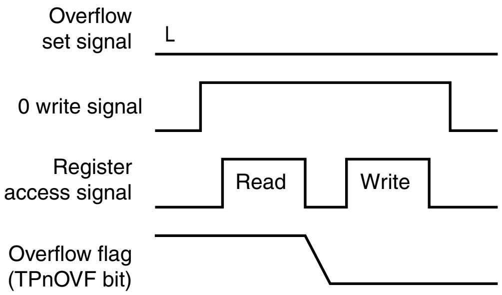
(i) Operation to write 0 (without conflict with setting)



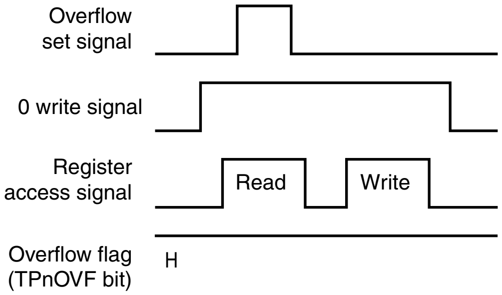
(ii) Operation to write 0 (conflict with setting)



(iii) Operation to clear to 0 (without conflict with setting)



(iv) Operation to clear to 0 (conflict with setting)



Remark n = 0 to 5

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	–	
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 5

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 5
m = 0, 1

7.6 Selector Function

In the V850ES/JG3-L, the capture trigger input for TMP1 can be selected from the input signal via the port/timer alternate-function pin (TIP10/TIP11) and the peripheral I/O (TMP/UARTA) input signal via the UARTA reception alternate-function pin (RXDA0/RXDA1).

By using this function, the following is possible.

- The TIP10 and TIP11 input signals of TMP1 can be selected from the port/timer alternate-function pins (TIP10 and TIP11 pins) and the UARTA reception alternate-function pins (RXDA0 and RXDA1).
  → When the RXDA0 or RXDA1 signal of UART0 or UART1 is selected, the LIN reception transfer rate and baud rate error of UARTA can be calculated.

Cautions 1. When using the selector function, set the capture trigger input of TMP before connecting the timer.

2. When setting the selector function, first disable the peripheral I/O to be connected (TMP or UARTA).

The capture input for the selector function is specified by 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.

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	0	0	ISEL4	ISEL3	0	0	0

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. To set ISEL3 and ISEL4 bits to 1, set the corresponding pin in the capture input mode.

2. Be sure to clear bits 7 to 5 and 2 to 0 to "0".

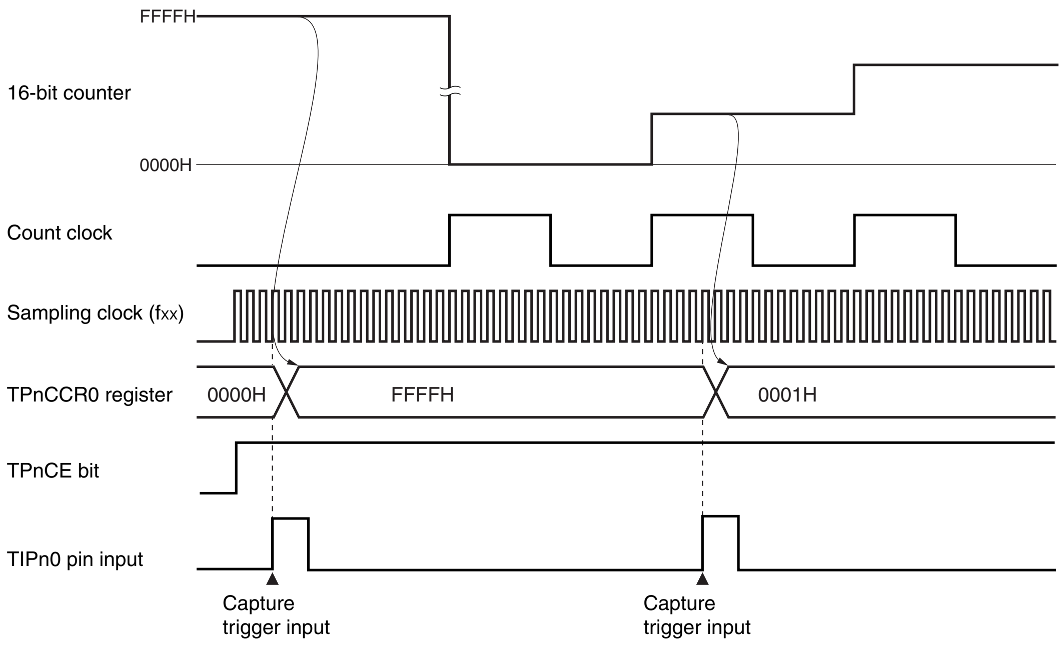
7.7 Cautions

(1) Capture operation

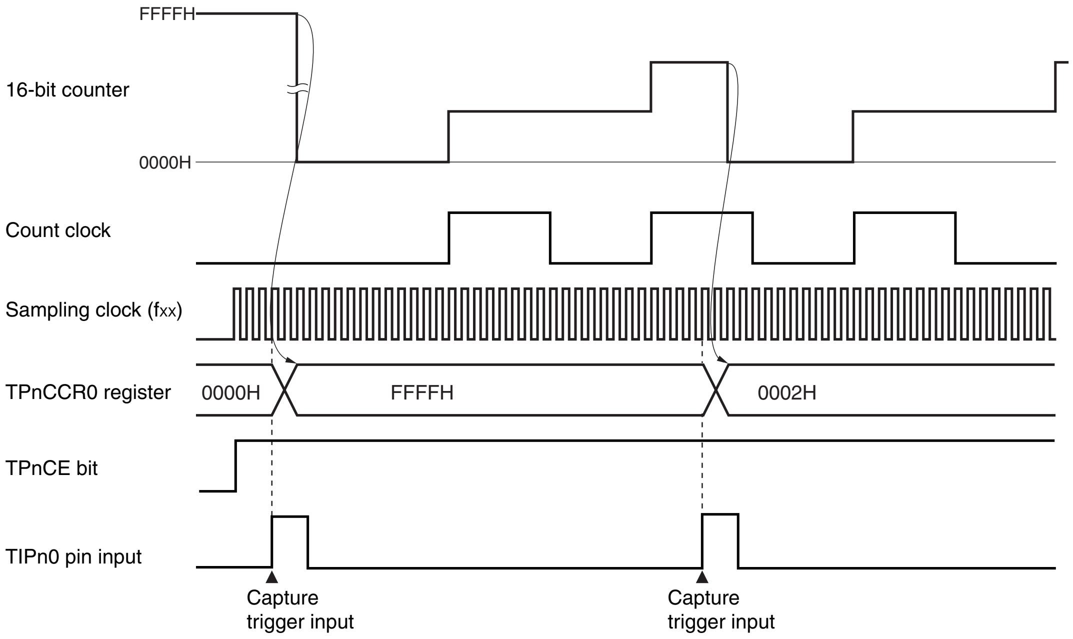
When the capture operation is used and a slow clock is selected as the count clock, FFFFH, not 0000H, may be captured in the TPnCCR0 and TPnCCR1 registers, or the capture operation may not be performed (capture interrupt does not occur) if the capture trigger is input immediately after the TPnCE bit is set to 1.

The same operation results during the period in which no external event counts are input while the capture operation is used and an external event count input is used as a count clock.

(a) Free-running timer mode



(b) Pulse width measurement mode



CHAPTER 8 16-BIT TIMER/EVENT COUNTER Q (TMQ)

Timer Q (TMQ) is a 16-bit timer/event counter.
The V850ES/JG3-L 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.

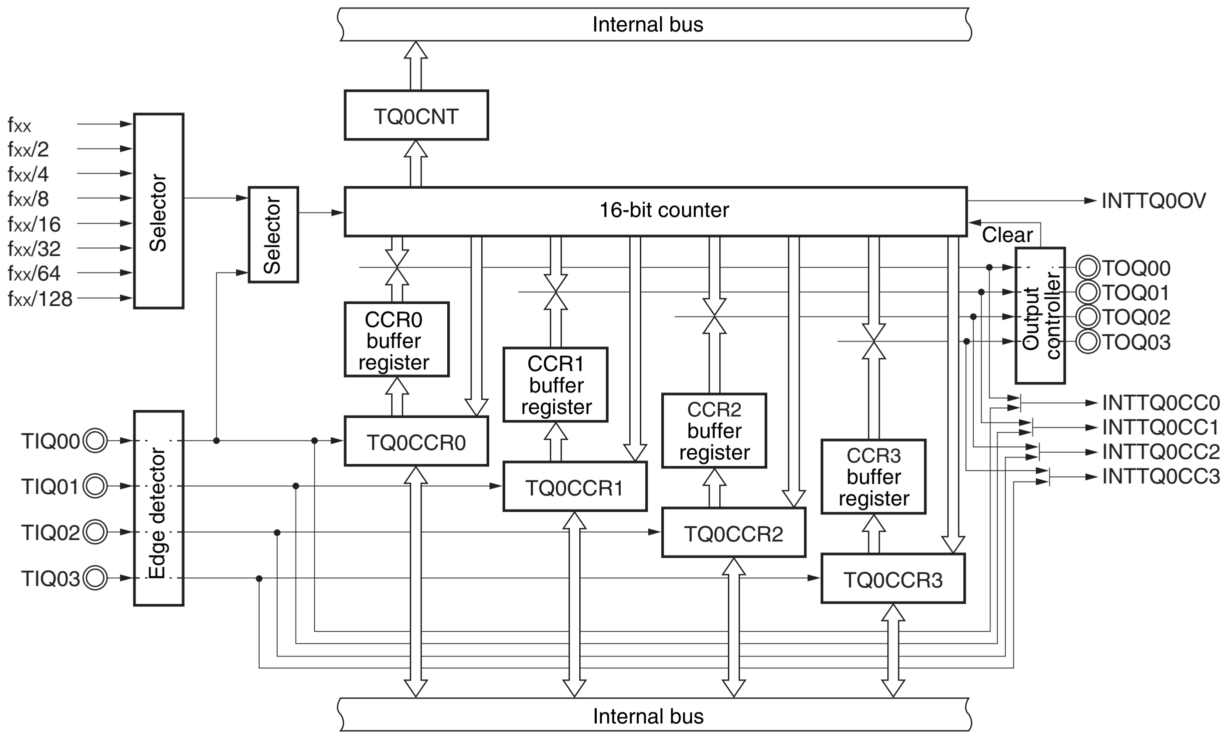
Table 8-1. Configuration of TMQ0

Item	Configuration
Timer register	16-bit counter
Registers	TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3) TMQ0 counter read buffer register (TQ0CNT) CCR0 to CCR3 buffer registers
Timer inputs	4 (TIQ00[Note 1] to TIQ03 pins)
Timer outputs	4 (TOQ00 to TOQ03 pins)
Control registers[Note 2]	TMQ0 control registers 0, 1 (TQ0CTL0, TQ0CTL1) TMQ0 I/O control registers 0 to 2 (TQ0IOC0 to TQ0IOC2) 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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

Figure 8-1. Block Diagram of TMQ0



Remark fxx: Main clock frequency

(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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

(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[Note]).
1	TMQ0 operation enabled. TMQ0 operation started.

TQ0CKS2	TQ0CKS1	TQ0CKS0	Internal count clock selection
0	0	0	f_{XX}
0	0	1	$f_{XX}/2$
0	1	0	$f_{XX}/4$
0	1	1	$f_{XX}/8$
1	0	0	$f_{XX}/16$
1	0	1	$f_{XX}/32$
1	1	0	$f_{XX}/64$
1	1	1	$f_{XX}/128$

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_{XX}: 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. • In one-shot pulse output mode: A one-shot pulse is output with writing 1 to the TQ0EST bit as the trigger. • In external trigger pulse output mode: A PWM waveform is output with writing 1 to the TQ0EST bit as the trigger.

TQ0EEE	Count clock selection
0	Disable operation with external event count input. (Perform counting with the count clock selected by the TQ0CTL0.TQ0CK0 to TQ0CK2 bits.)
1	Enable operation with external event count input. (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

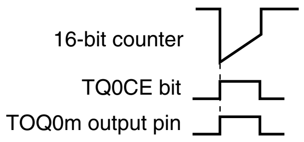
	7	<6>	5	<4>	3	<2>	1	<0>
TQ0IOC0	TQ0OL3	TQ0OE3	TQ0OL2	TQ0OE2	TQ0OL1	TQ0OE1	TQ0OL0	TQ0OE0

TQ0OLm	TOQ0m pin output level setting (m = 0 to 3)^{Note}
0	TOQ0m pin starts output at high level
1	TOQ0m pin starts output at low level

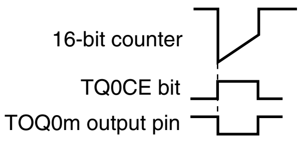
TQ0OEm	TOQ0m pin output setting (m = 0 to 3)
0	Timer output disabled • When TQ0OLm bit = 0: Low level is output from the TOQ0m pin • When TQ0OLm bit = 1: High level is output from the TOQ0m pin
1	Timer output enabled (A square wave is output from the TOQ0m pin).

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: FFFFF545H

	7	6	5	4	3	2	1	<0>
TQ0OPT0	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
• 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. • 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. • The TQ0OVF bit is not cleared even when the TQ0OVF bit or the TQ0OPT0 register are read when the TQ0OVF bit = 1. • 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.	

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**

After reset: 0000H R/W Address: FFFFF546H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TQ0CCR0																

(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**

After reset: 0000H R/W Address: FFFFF548H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TQ0CCR1																

(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**

After reset: 0000H R/W Address: FFFFF54AH

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TQ0CCR2																

(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**

After reset: 0000H R/W Address: FFFFF54CH

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TQ0CCR3																

(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**

After reset: 0000H R Address: FFFFF54EH

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TQ0CNT																

8.5 Operation

TMQ0 can perform the following operations.

Operation	TQ0CTL1.TQ0EST Bit (Software Trigger Bit)	TIQ00 Pin (External Trigger Input)	Capture/Compare Register Setting	Compare Register Write
Interval timer mode	Invalid	Invalid	Compare only	Anytime write
External event count mode[Note 1]	Invalid	Invalid	Compare only	Anytime write
External trigger pulse output mode[Note 2]	Valid	Valid	Compare only	Batch write
One-shot pulse output mode[Note 2]	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[Note 2]	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

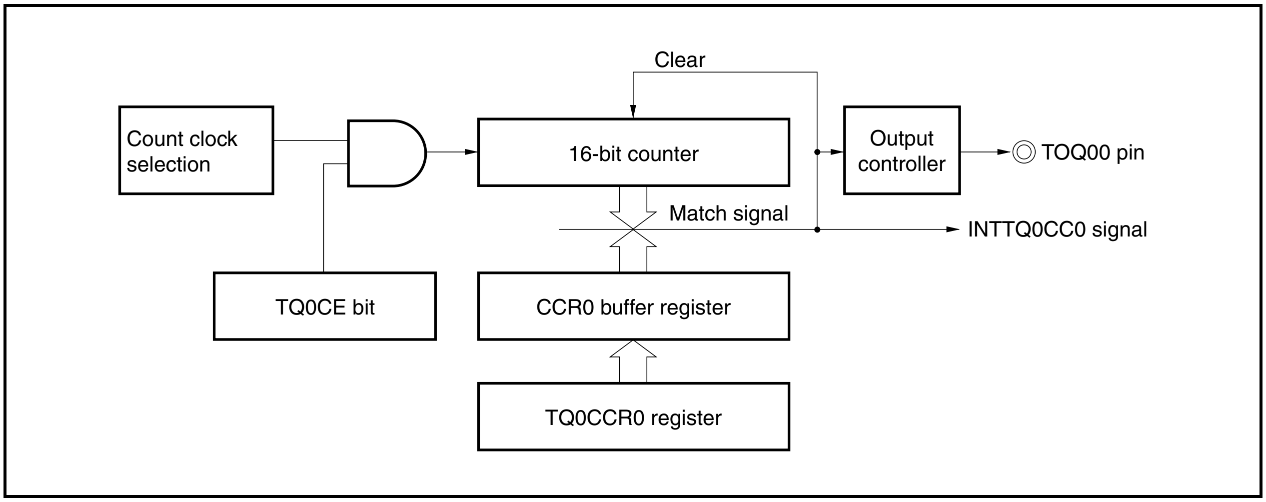
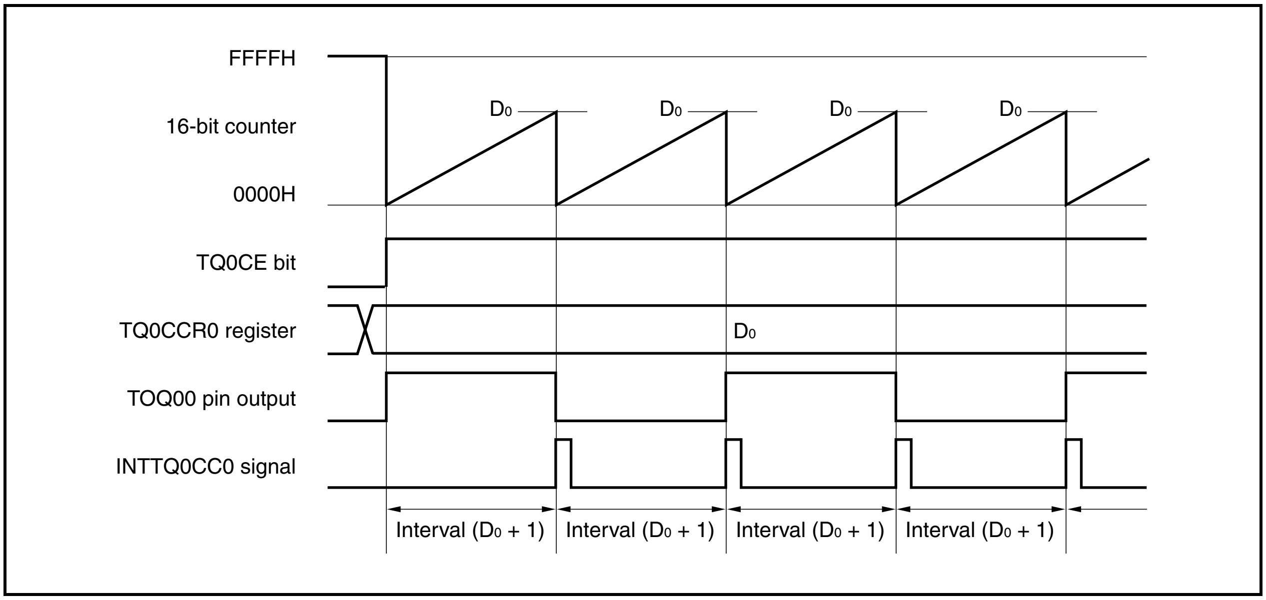


Figure 8-3. Basic Timing of Operation in Interval Timer Mode



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.

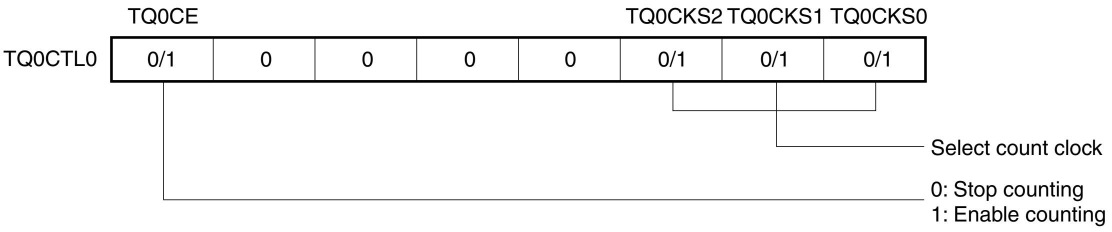
When the count value of the 16-bit counter matches the value of the CCR0 buffer register, the 16-bit counter is cleared to 0000H, the output of the TOQ00 pin is inverted, and a compare match interrupt request signal (INTTQ0CC0) is generated.

The interval can be calculated by the following expression.

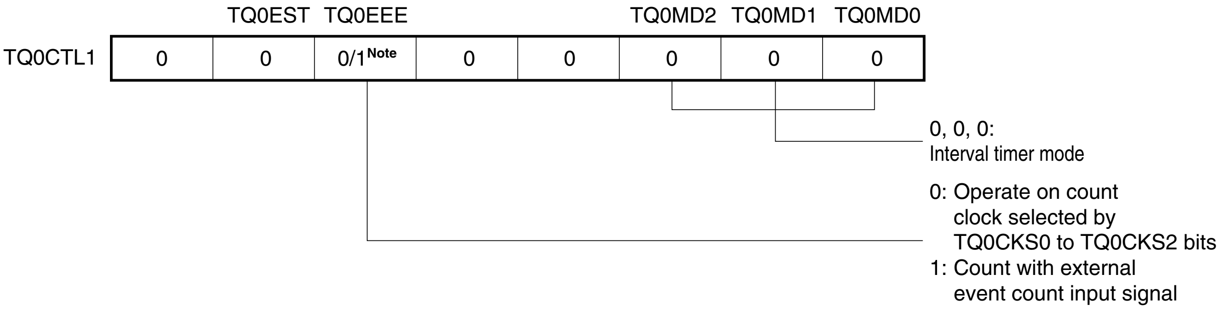
Interval = (Set value of TQ0CCR0 register + 1) × Count clock cycle

Figure 8-4. Register Setting for Interval Timer Mode Operation (1/2)

(a) TMQ0 control register 0 (TQ0CTL0)



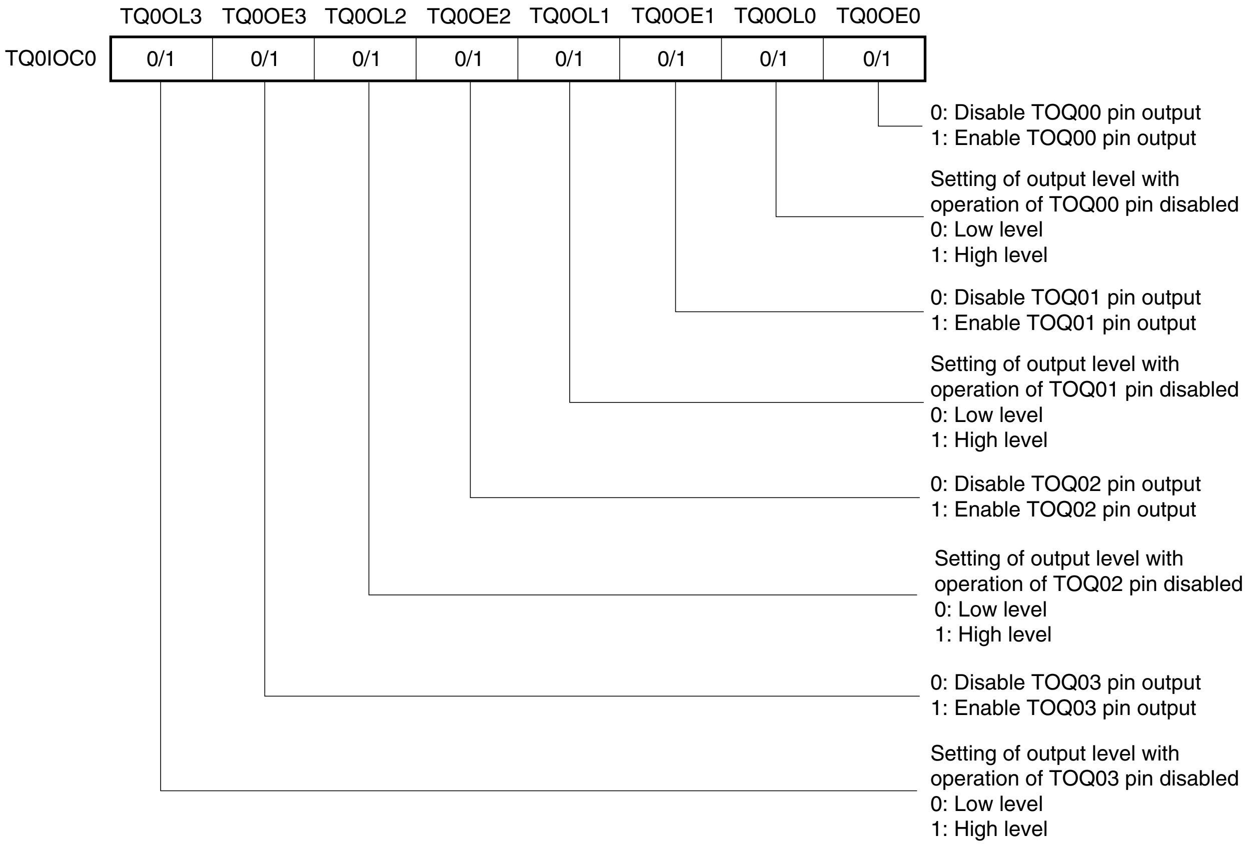
(b) TMQ0 control register 1 (TQ0CTL1)



Note This bit can be set to 1 only when the interrupt request signals (INTTQ0CC0 and INTTQ0CCk) are masked by the interrupt mask flags (TQ0CCMK0 and TQ0CCMKk) and the timer output (TOQ0k) is performed at the same time. However, the TQ0CCR0 and TQ0CCRk registers must be set to the same value (see **8.5.1 (2) (d) Operation of TQ0CCR1 to TQ0CCR3 registers**) (k = 1 to 3).

Figure 8-4. Register Setting for Interval Timer Mode Operation (2/2)

(c) TMQ0 I/O control register 0 (TQ0IOC0)



(d) TMQ0 counter read buffer register (TQ0CNT)

By reading the TQ0CNT register, the count value of the 16-bit counter can be read.

(e) TMQ0 capture/compare register 0 (TQ0CCR0)

If the TQ0CCR0 register is set to D_0, the interval is as follows.

Interval = $(D_0 + 1) \times$ Count clock cycle

(f) TMQ0 capture/compare registers 1 to 3 (TQ0CCR1 to TQ0CCR3)

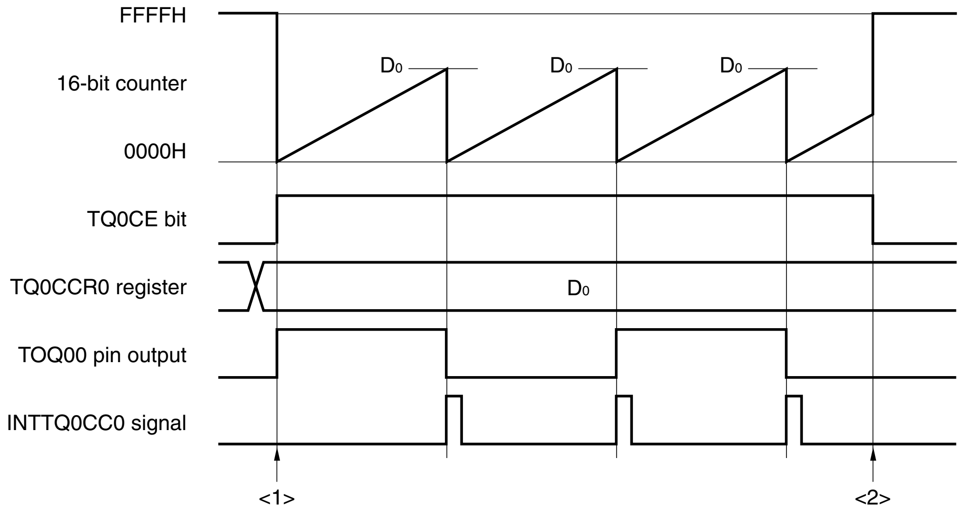
Usually, the TQ0CCR1 to TQ0CCR3 registers are not used in the interval timer mode. However, the set value of the TQ0CCR1 to TQ0CCR3 registers are transferred to the CCR1 to CCR3 buffer registers. The compare match interrupt request signals (INTTQ0CC1 to INTTQ0CCR3) is generated when the count value of the 16-bit counter matches the value of the CCR1 to CCR3 buffer registers.

Therefore, mask the interrupt request by using the corresponding interrupt mask flags (TQ0CCMK1 to TQ0CCMK3).

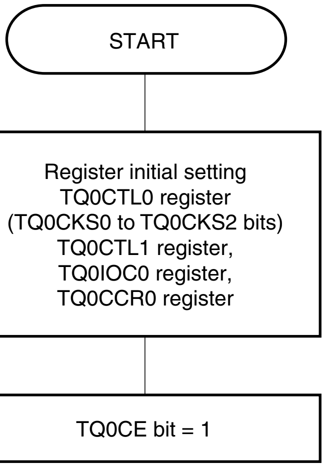
Remark TMQ0 I/O control register 1 (TQ0IOC1), TMQ0 I/O control register 2 (TQ0IOC2), and TMQ0 option register 0 (TQ0OPT0) are not used in the interval timer mode.

(1) Interval timer mode operation flow

Figure 8-5. Software Processing Flow in Interval Timer Mode



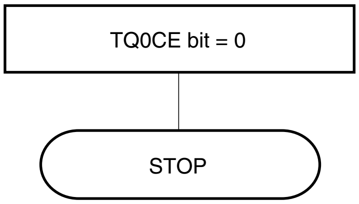
<1> Count operation start flow



Initial setting of these registers is performed before the TQ0CE bit is set to 1.

The TQ0CKS0 to TQ0CKS2 bits can be set when counting starts (TQ0CE bit = 1).

<2> Count operation stop flow



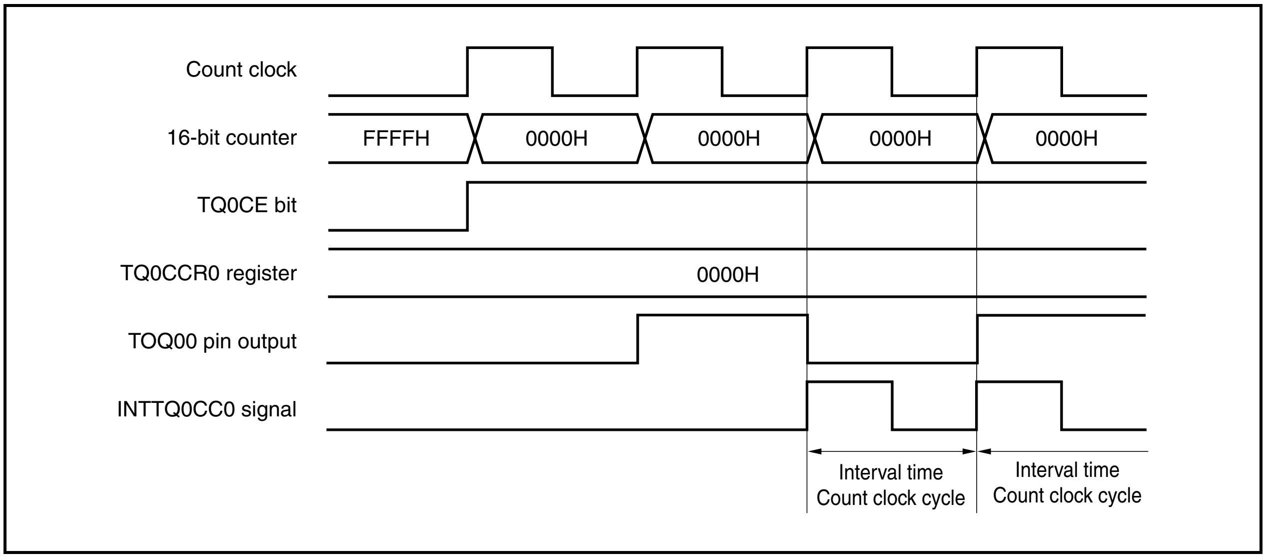
The counter is initialized and counting is stopped by clearing the TQ0CE bit to 0.

(2) Interval timer mode operation timing

(a) Operation if TQ0CCR0 register is set to 0000H

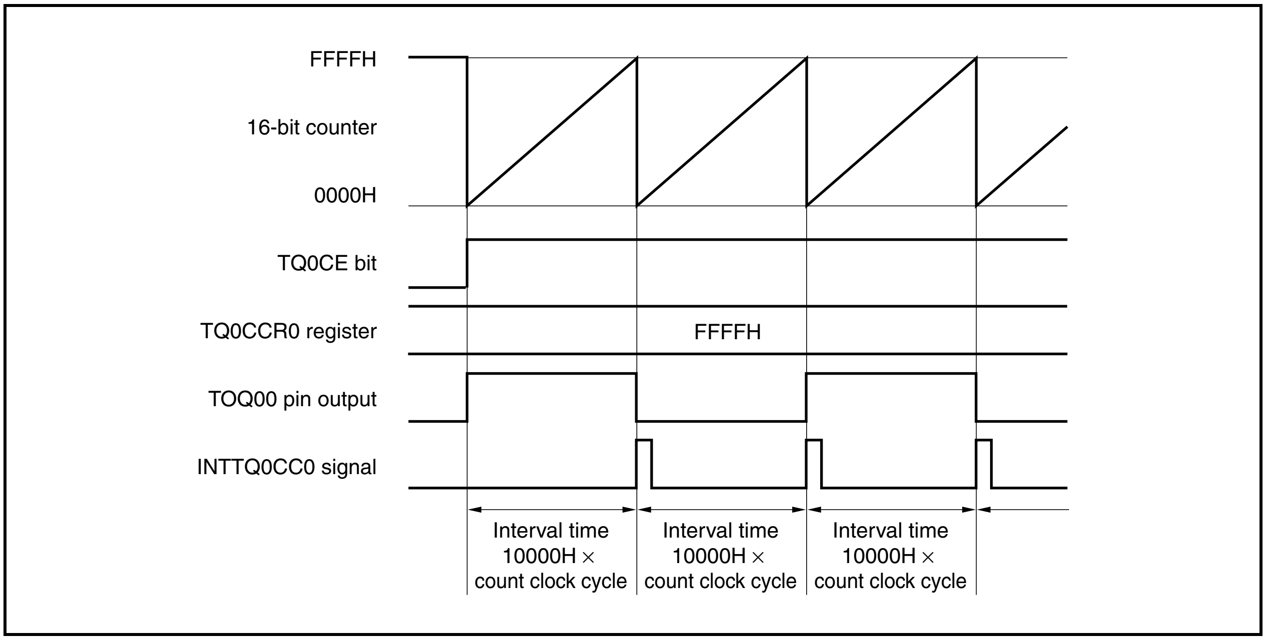
If the TQ0CCR0 register is set to 0000H, the INTTQ0CC0 signal is generated at each count clock of the second clock or later, and the output of the TOQ00 pin is inverted.

The value of the 16-bit counter is always 0000H.



(b) Operation if TQ0CCR0 register is set to FFFFH

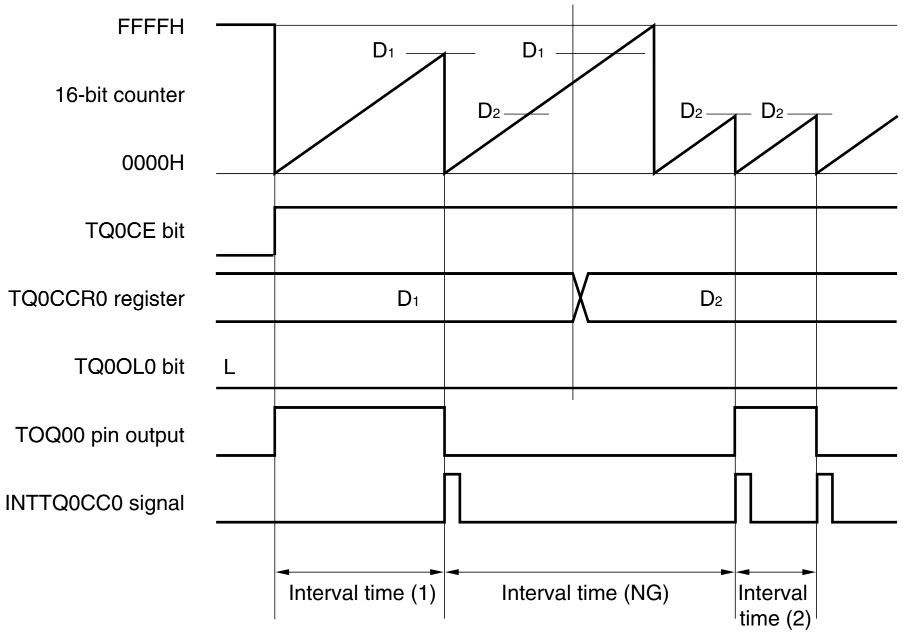
If the TQ0CCR0 register is set to FFFFH, the 16-bit counter counts up to FFFFH. The counter is cleared to 0000H in synchronization with the next count-up timing. The INTTQ0CC0 signal is generated and the output of the TOQ00 pin is inverted. At this time, an overflow interrupt request signal (INTTQ0OV) 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.



Remark Interval time (1): $(D_1 + 1) \times$ Count clock cycle
Interval time (NG): $(10000H + D_2 + 1) \times$ Count clock cycle
Interval time (2): $(D_2 + 1) \times$ Count clock cycle

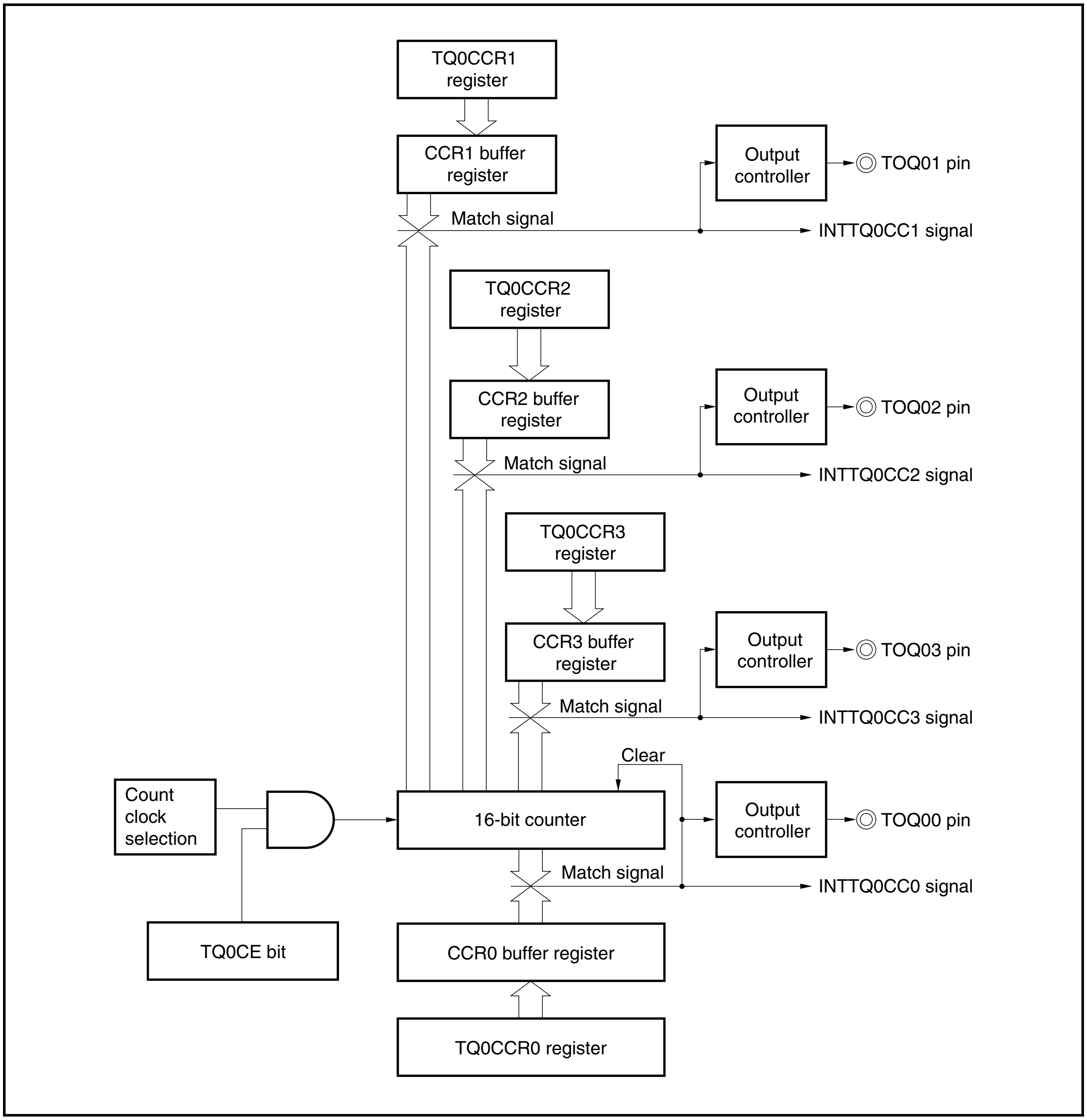
If the value of the TQ0CCR0 register is changed from D_1 to D_2 while the count value is greater than D_2 but less than D_1, the count value is transferred to the CCR0 buffer register as soon as the TQ0CCR0 register has been rewritten. Consequently, the value of the 16-bit counter that is compared is 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 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 "$(D_1 + 1) \times$ Count clock cycle" or "$(D_2 + 1) \times$ Count clock cycle" originally expected, but may be generated at an interval of "$(10000H + D_2 + 1) \times$ Count clock period".

(d) Operation of TQ0CCR1 to TQ0CCR3 registers

Figure 8-6. Configuration of TQ0CCR1 to TQ0CCR3 Registers

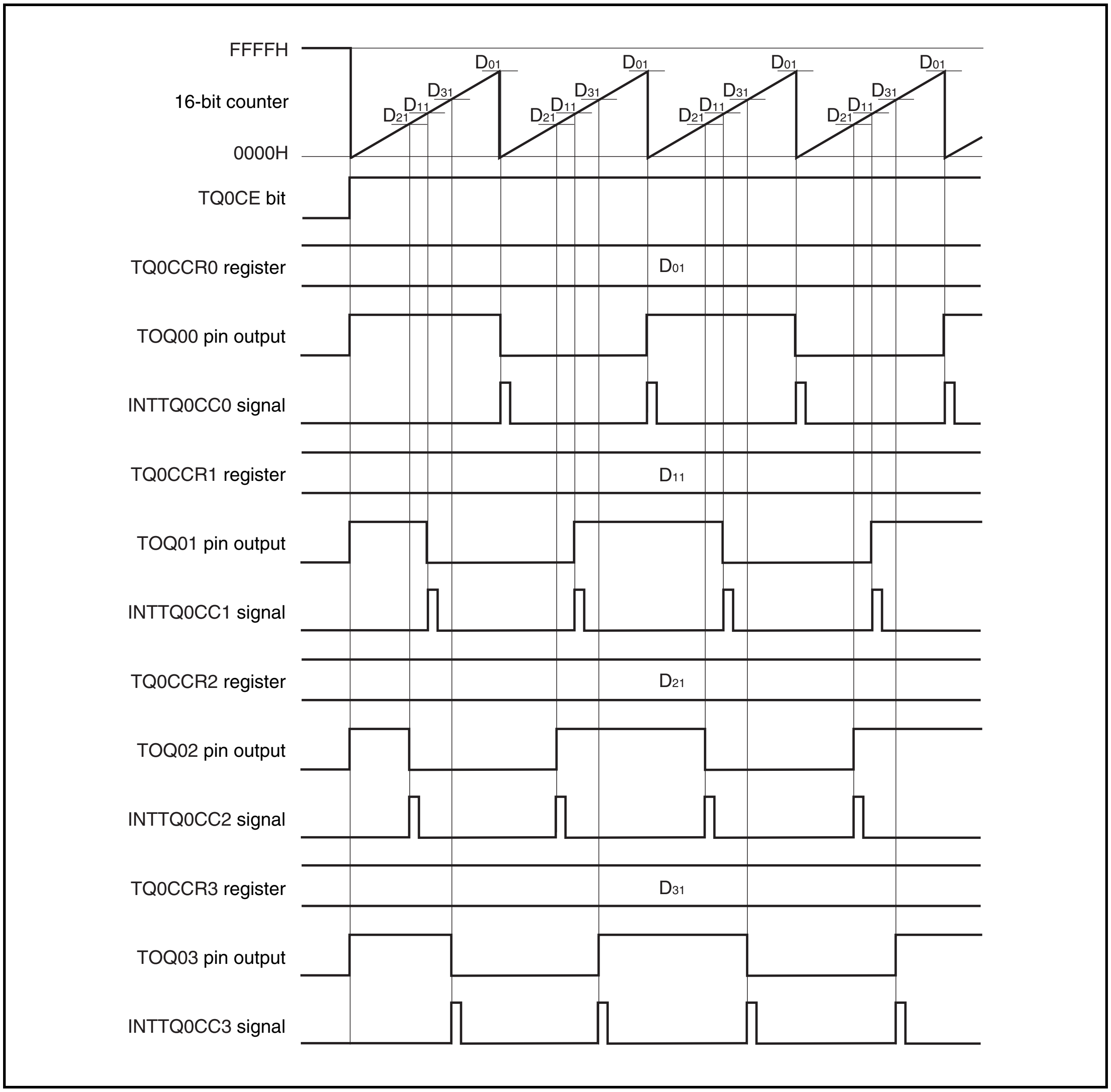


If the set value of the TQ0CCRk register is less than the set value of the TQ0CCR0 register, the INTTQ0CCk signal is generated once per cycle. At the same time, the output of the TOPQ0k pin is inverted.

The TOQ0k pin outputs a square wave with the same cycle as that output by the TOQ00 pin.

Remark k = 1 to 3

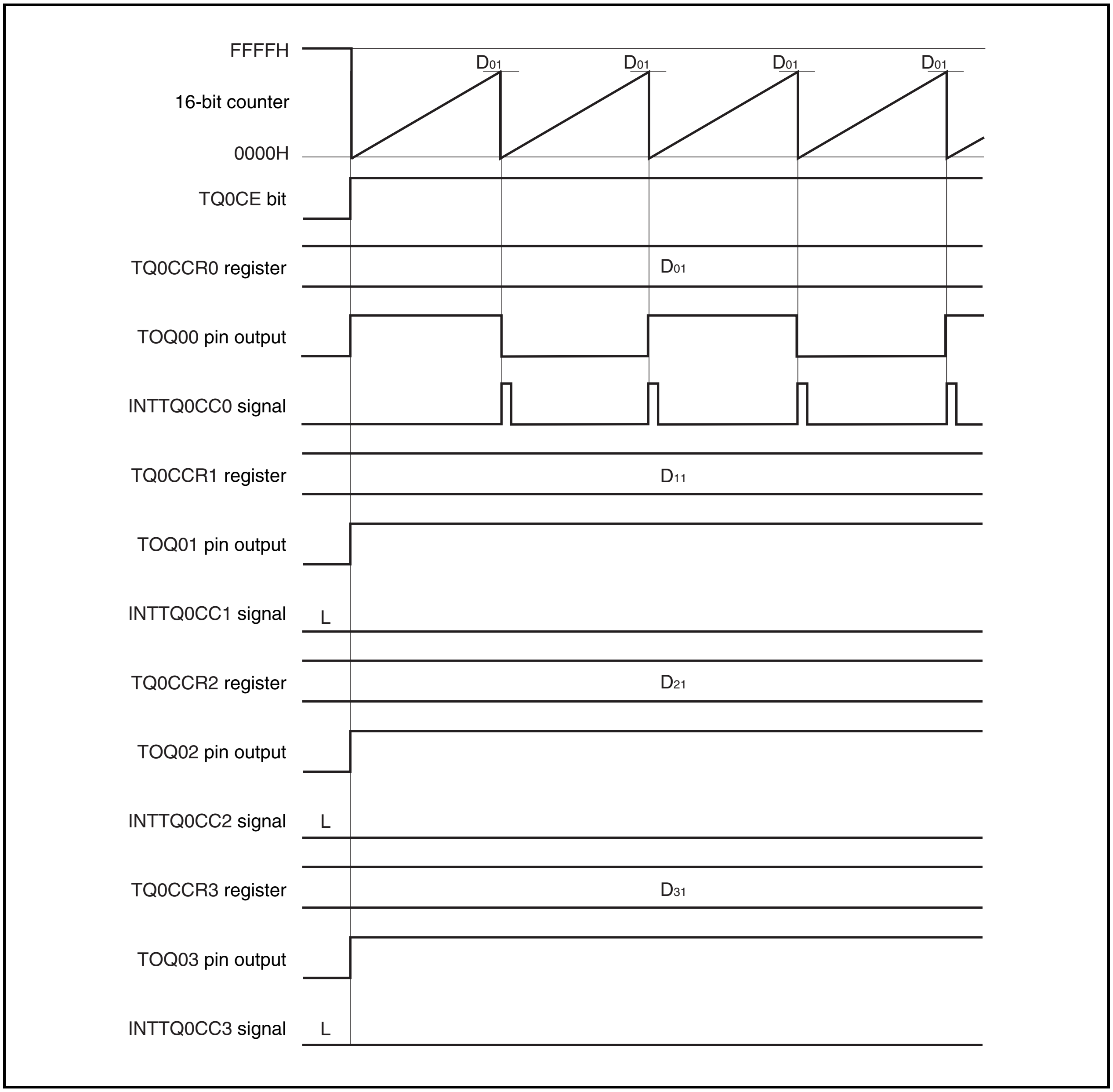
Figure 8-7. Timing Chart When $D_{01} \geq D_{k1}$



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 TOQ00 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

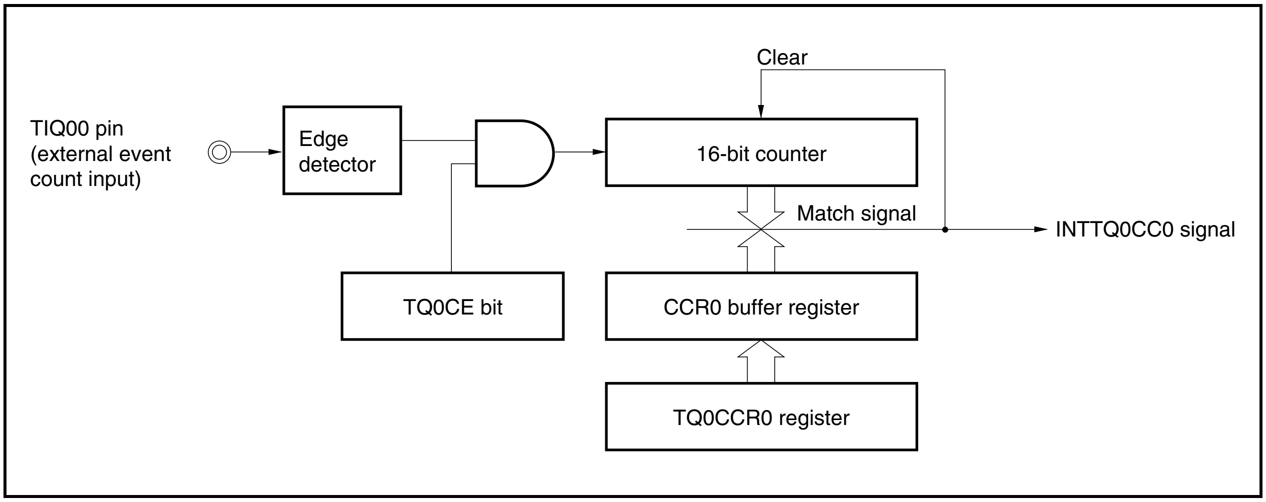
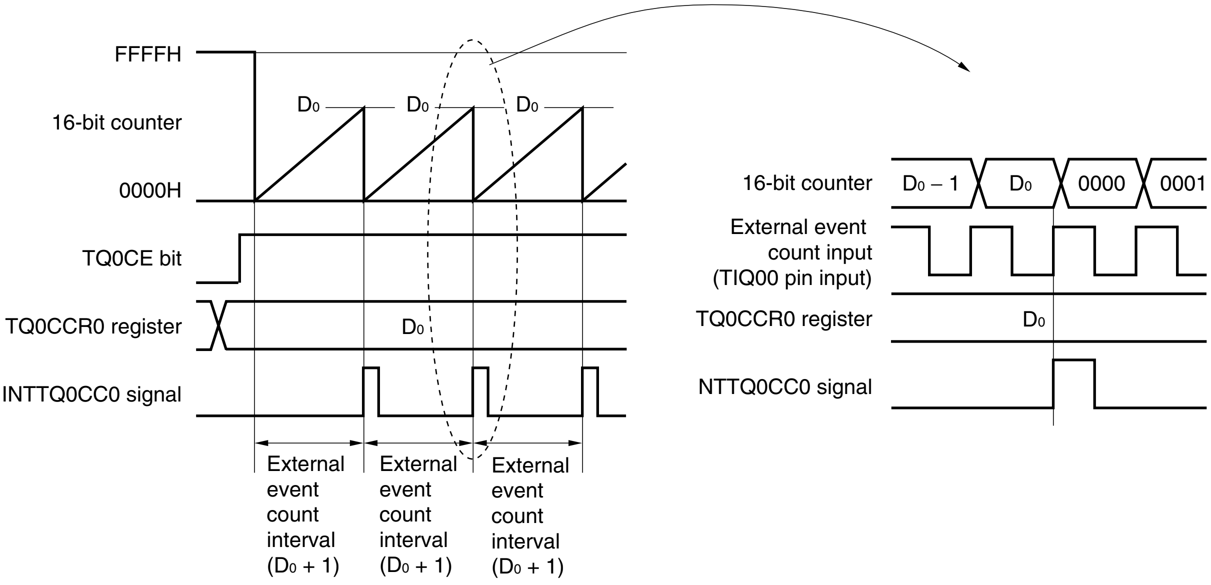


Figure 8-10. Basic Timing in External Event Count Mode



Remark This figure shows the basic timing when the rising edge is specified as the valid edge of the external event count input.

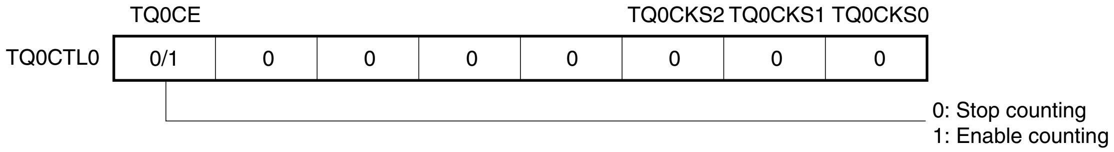
When the TQ0CE bit is set to 1, the value of the 16-bit counter is cleared from FFFFH to 0000H. The counter counts each time the valid edge of external event count input is detected. Additionally, the set value of the TQ0CCR0 register is transferred to the CCR0 buffer register.

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.

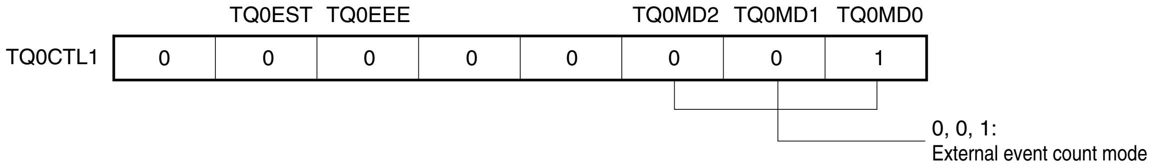
The INTTQ0CC0 signal is generated each time the valid edge of the external event count input has been detected (set value of TQ0CCR0 register + 1) times.

Figure 8-11. Register Setting for Operation in External Event Count Mode (1/2)

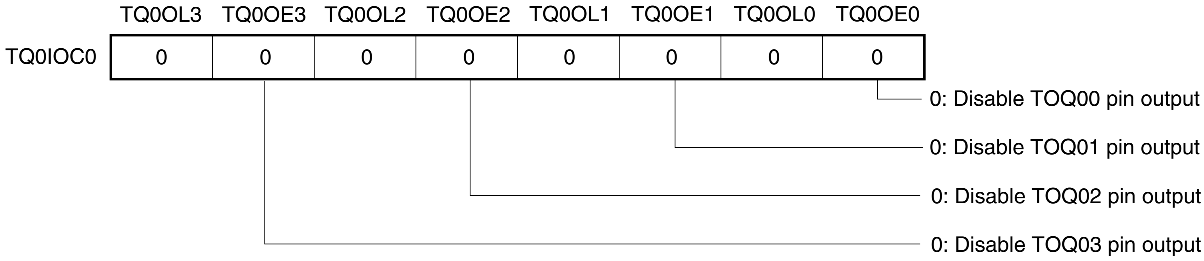
(a) TMQ0 control register 0 (TQ0CTL0)



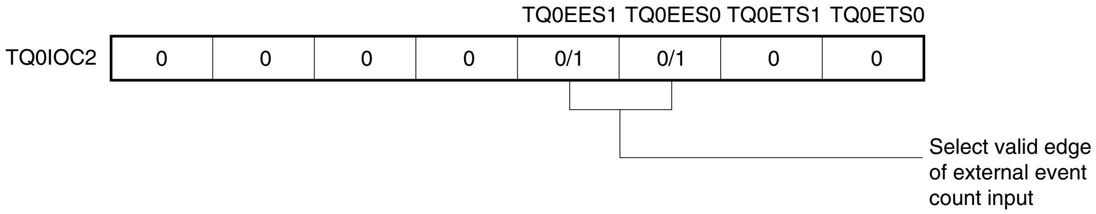
(b) TMQ0 control register 1 (TQ0CTL1)



(c) TMQ0 I/O control register 0 (TQ0IOC0)



(d) TMQ0 I/O control register 2 (TQ0IOC2)



(e) TMQ0 counter read buffer register (TQ0CNT)

The count value of the 16-bit counter can be read by reading the TQ0CNT register.

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.

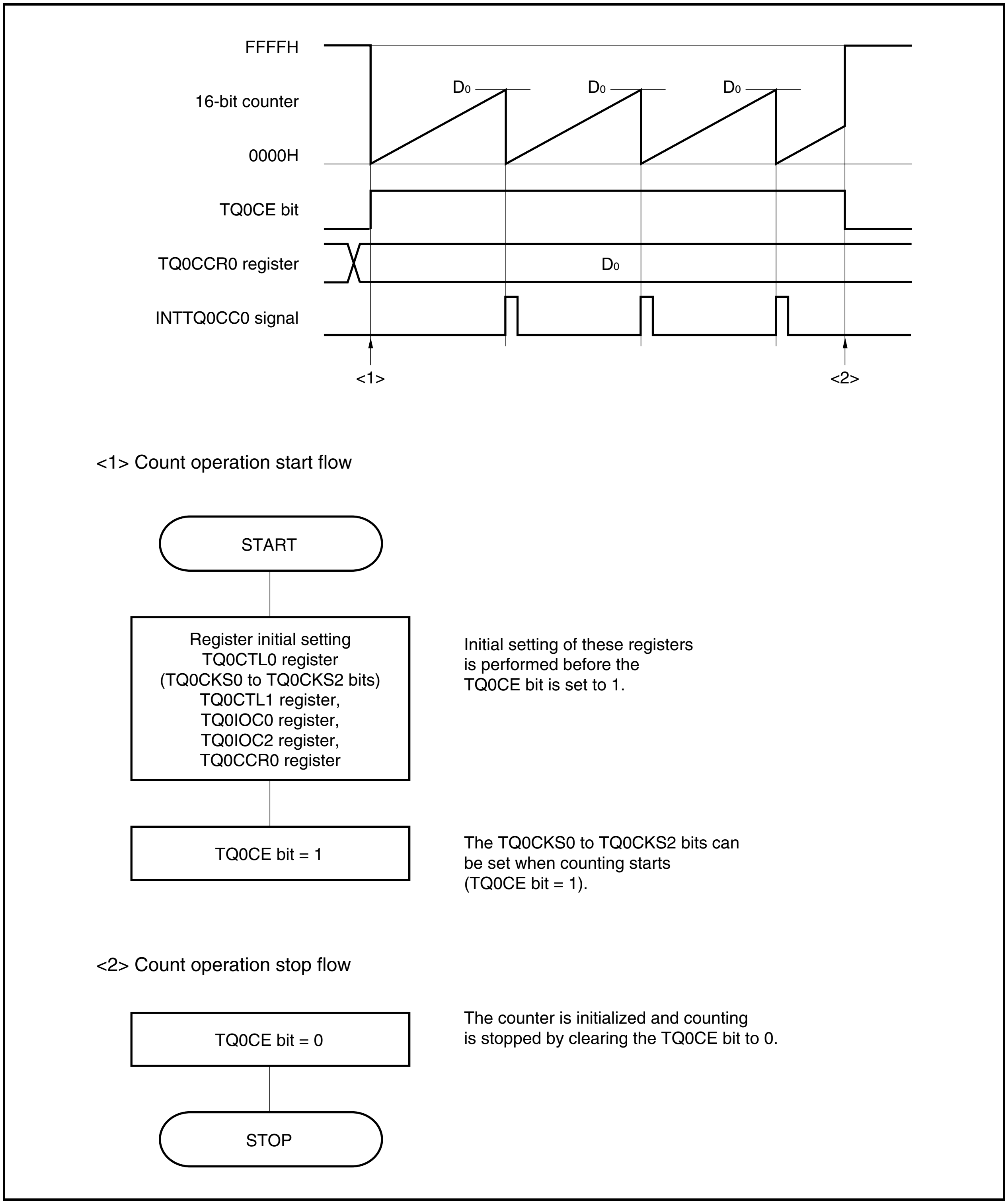
Therefore, mask the interrupt signal by using the interrupt mask flags (TQ0CCMK1 to TQ0CCMK3).

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



<1> Count operation start flow

Initial setting of these registers is performed before the TQ0CE bit is set to 1.

The TQ0CKS0 to TQ0CKS2 bits can be set when counting starts (TQ0CE bit = 1).

<2> Count operation stop flow

The counter is initialized and counting is stopped by clearing the TQ0CE bit to 0.

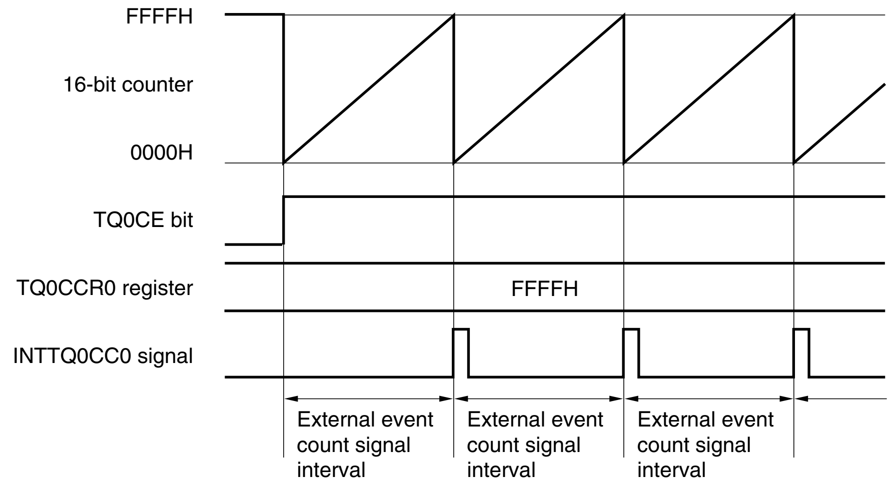
(2) Operation timing in external event count mode

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

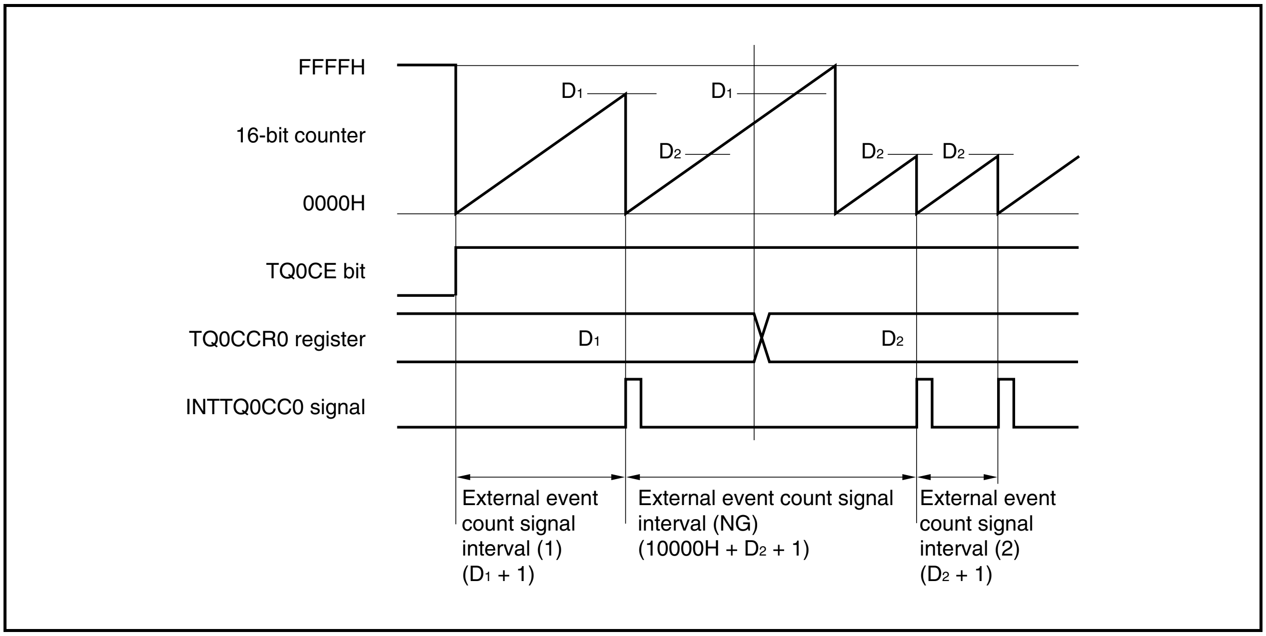
If the TQ0CCR0 register is set to FFFFH, the 16-bit counter counts to FFFFH each time the valid edge of the external event count signal has been detected. The 16-bit counter is cleared to 0000H in synchronization with the next count-up timing, and the INTTQ0CC0 signal is generated. At this time, the 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.



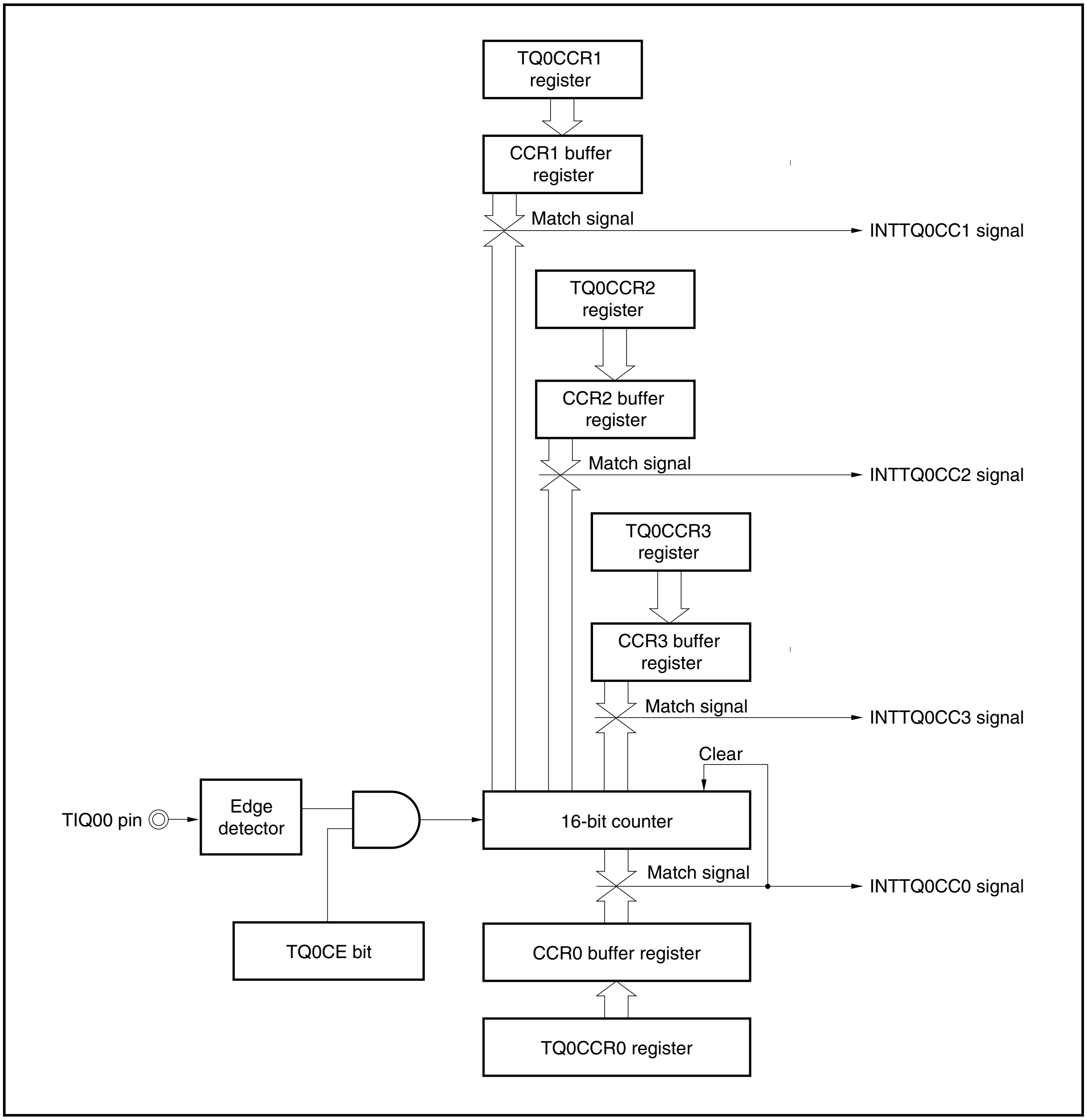
If the value of the TQ0CCR0 register is changed from D_1 to D_2 while the count value is greater than D_2 but less than D_1, the count value is transferred to the CCR0 buffer register as soon as the TQ0CCR0 register has been rewritten. Consequently, the value that is compared with the 16-bit counter 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

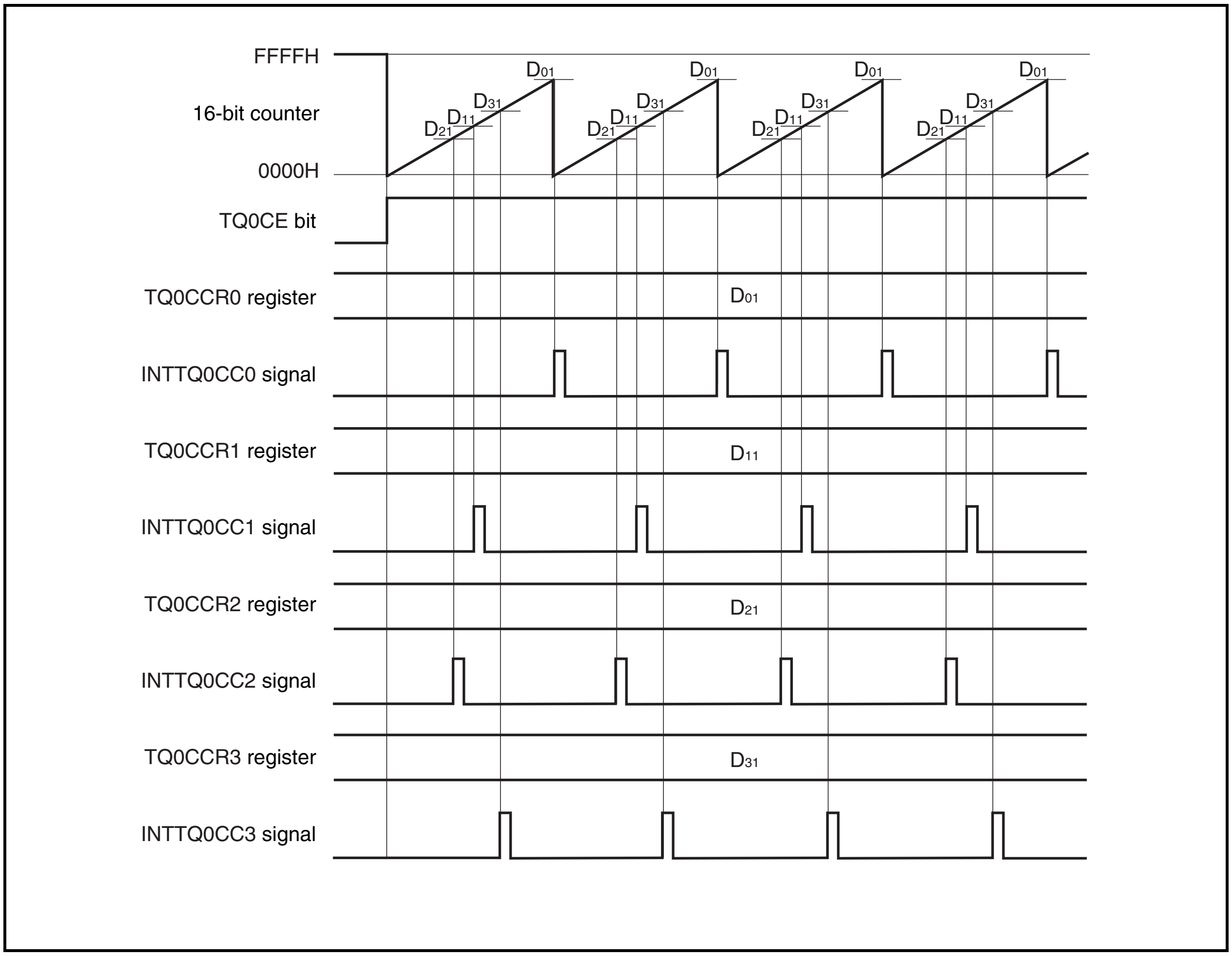
Figure 8-13. Configuration of TQ0CCR1 to TQ0CCR3 Registers



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

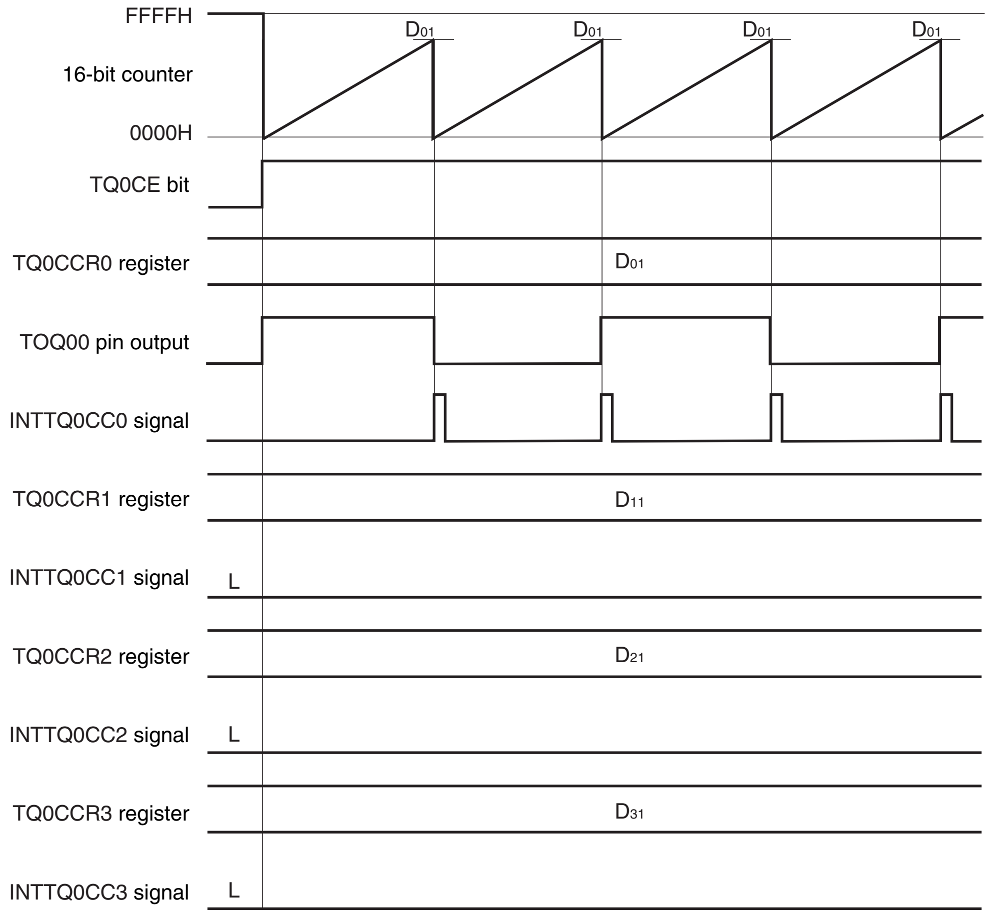
Figure 8-14. Timing Chart When $D_{01} \geq D_{k1}$



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

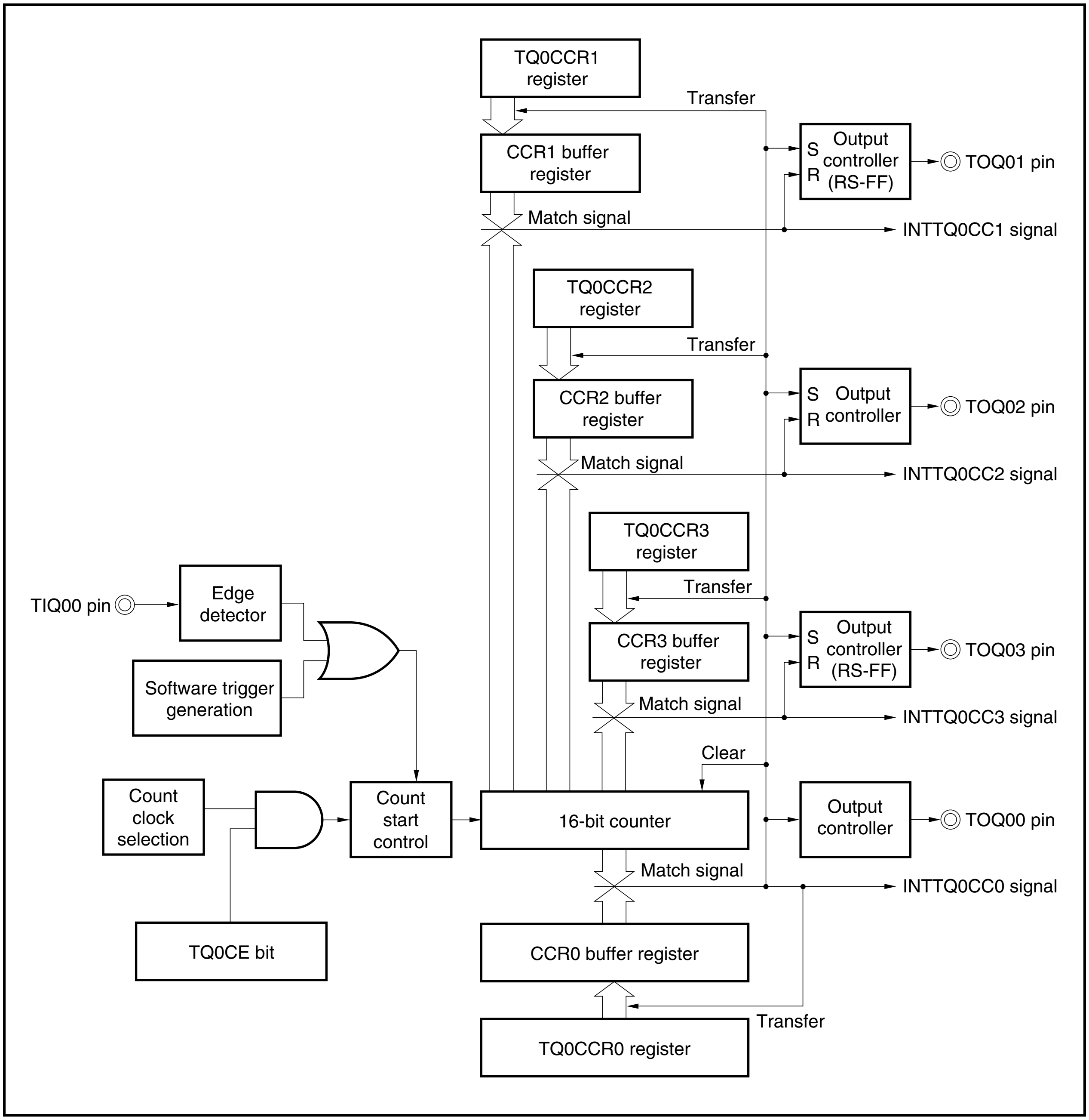
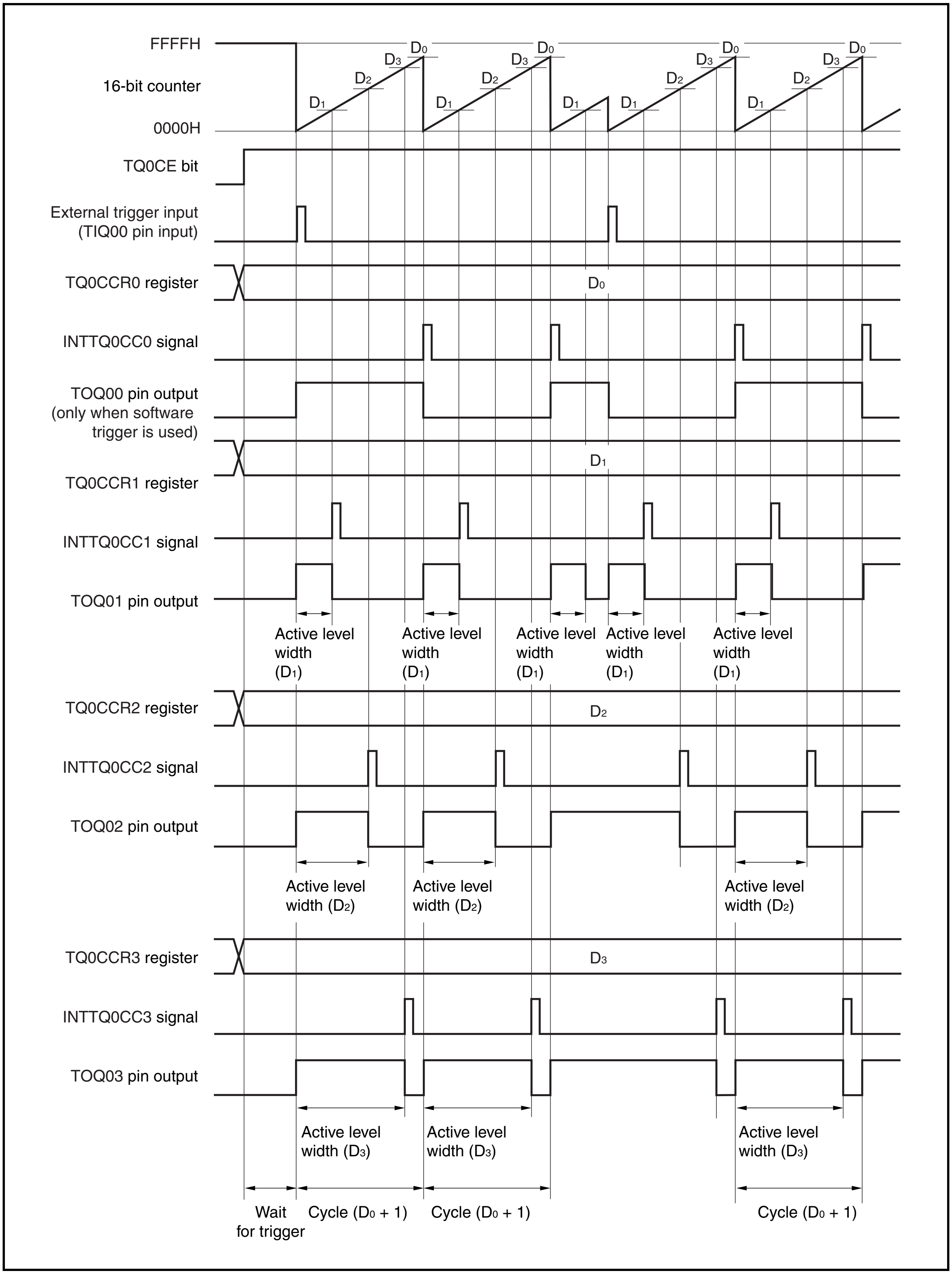


Figure 8-17. Basic Timing in External Trigger Pulse Output Mode



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.

Active level width = (Set value of TQ0CCRk register) × Count clock cycle
Cycle = (Set value of TQ0CCR0 register + 1) × Count clock cycle
Duty factor = (Set value of TQ0CCRk register)/(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.

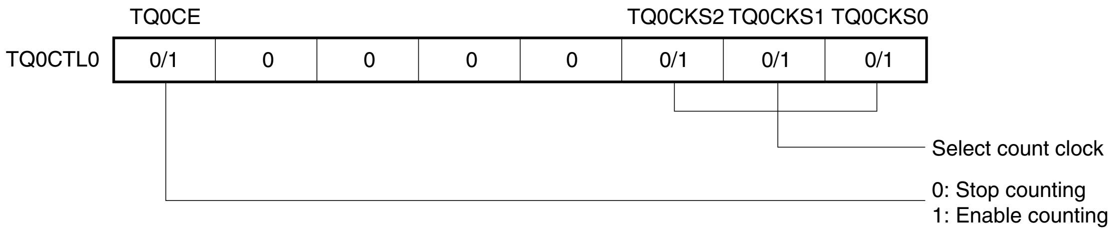
The value set to the TQ0CCRm register is transferred to the CCRm buffer register when the count value of the 16-bit counter matches the value of the CCR0 buffer register and the 16-bit counter is cleared to 0000H.

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. Setting of Registers in External Trigger Pulse Output Mode (1/3)

(a) TMQ0 control register 0 (TQ0CTL0)



(b) TMQ0 control register 1 (TQ0CTL1)

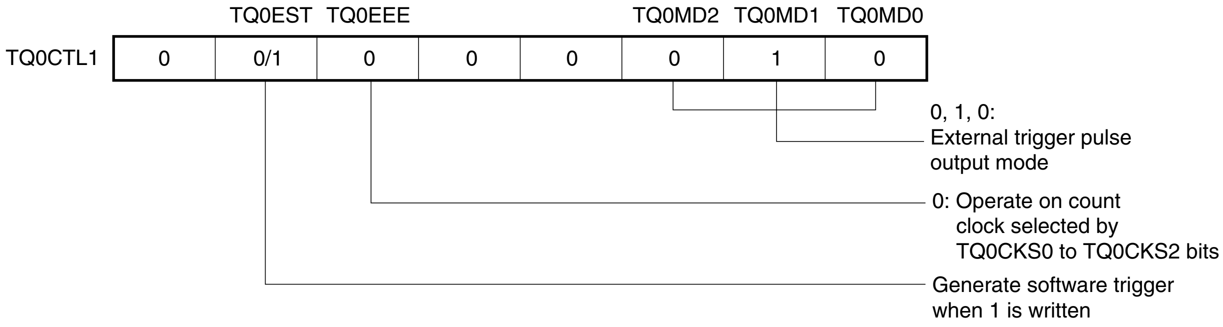
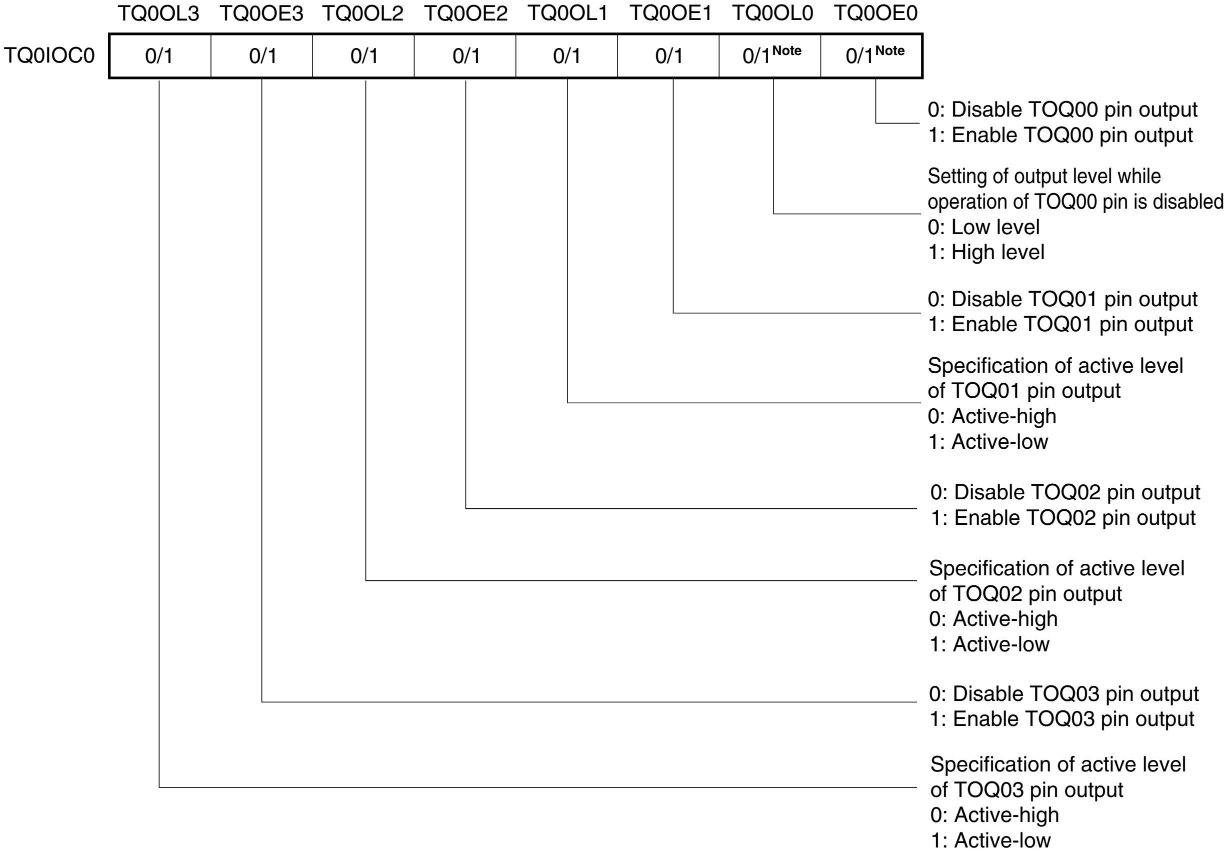


Figure 8-18. Setting of Registers in External Trigger Pulse Output Mode (2/3)

(c) TMQ0 I/O control register 0 (TQ0IOC0)



	TQ0OL3	TQ0OE3	TQ0OL2	TQ0OE2	TQ0OL1	TQ0OE1	TQ0OL0	TQ0OE0
TQ0IOC0	0/1	0/1	0/1	0/1	0/1	0/1	0/1^{Note}	0/1^{Note}

0: Disable TOQ00 pin output
1: Enable TOQ00 pin output

Setting of output level while operation of TOQ00 pin is disabled
0: Low level
1: High level

0: Disable TOQ01 pin output
1: Enable TOQ01 pin output

Specification of active level of TOQ01 pin output
0: Active-high
1: Active-low

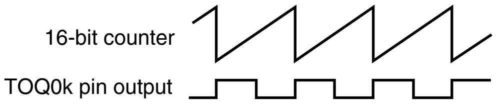
0: Disable TOQ02 pin output
1: Enable TOQ02 pin output

Specification of active level of TOQ02 pin output
0: Active-high
1: Active-low

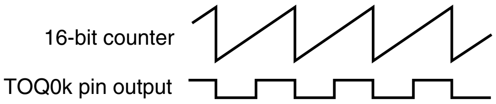
0: Disable TOQ03 pin output
1: Enable TOQ03 pin output

Specification of active level of TOQ03 pin output
0: Active-high
1: Active-low

- When TQ0OLk bit = 0

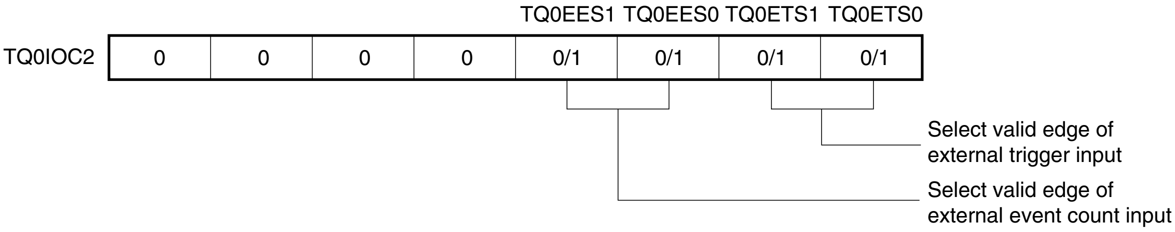


- When TQ0OLk bit = 1



Note Clear this bit to 0 when the TOQ00 pin is not used in the external trigger pulse output mode.

(d) TMQ0 I/O control register 2 (TQ0IOC2)



					TQ0EES1	TQ0EES0	TQ0ETS1	TQ0ETS0
TQ0IOC2	0	0	0	0	0/1	0/1	0/1	0/1

Select valid edge of external trigger input

Select valid edge of external event count input

Figure 8-18. Setting of Registers in External Trigger 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, 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.

Cycle = $(D_0 + 1) \times$ Count clock cycle
TOQ01 pin PWM waveform active level width = $D_1 \times$ Count clock cycle
TOQ02 pin PWM waveform active level width = $D_2 \times$ Count clock cycle
TOQ03 pin PWM waveform active level width = $D_3 \times$ 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)

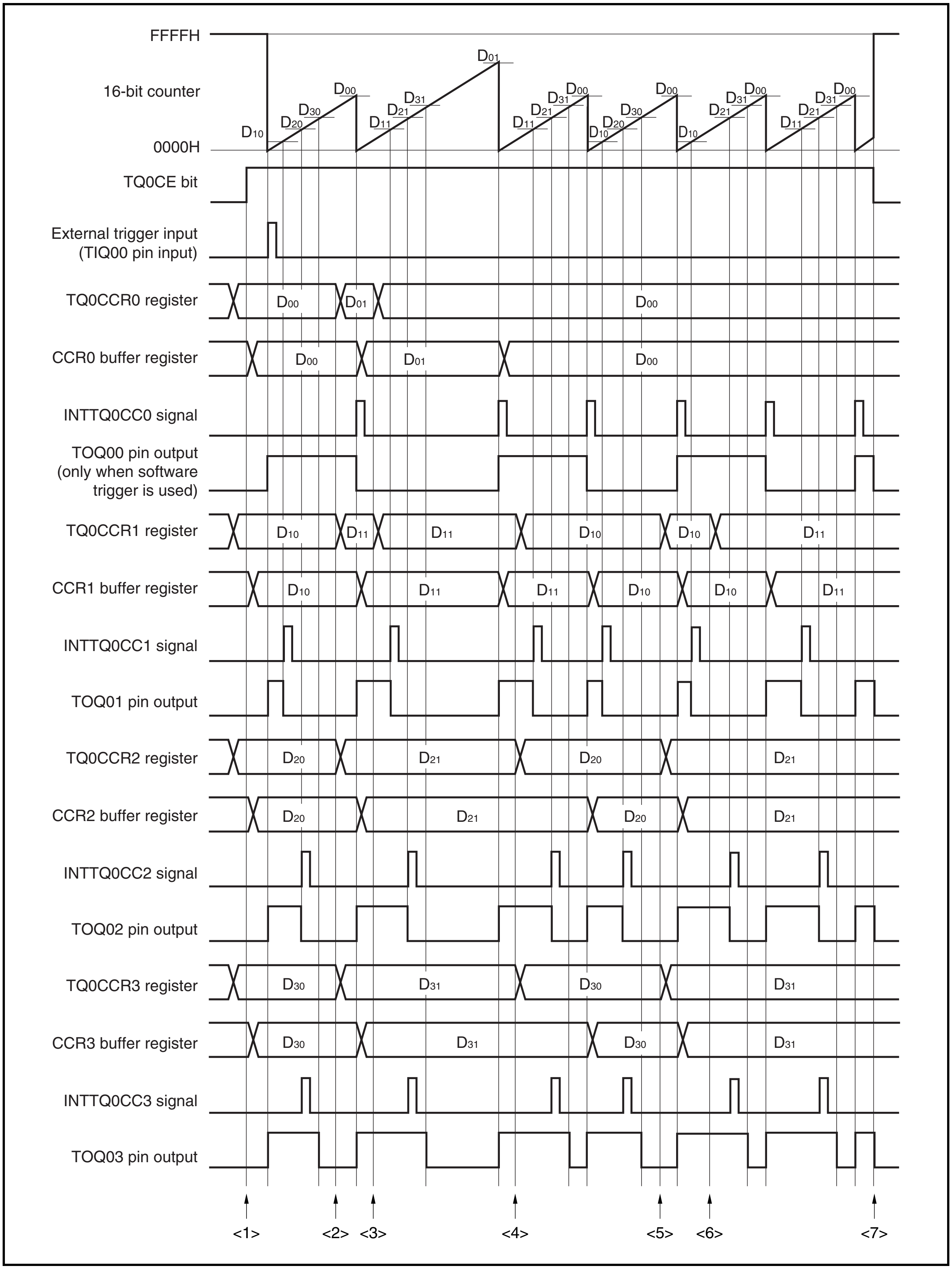
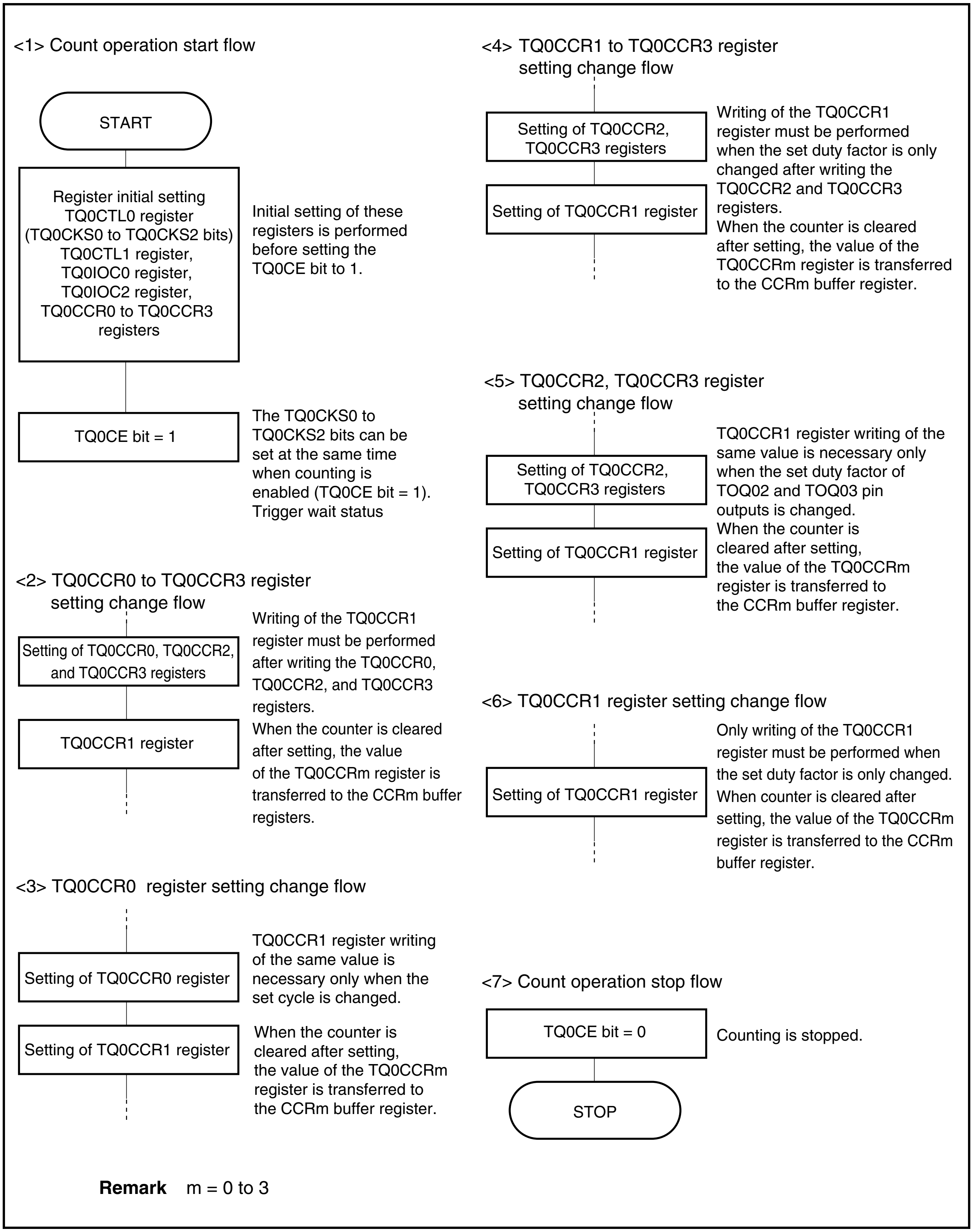


Figure 8-19. Software Processing Flow in External Trigger Pulse Output Mode (2/2)



<1> Count operation start flow

Initial setting of these registers is performed before setting the TQ0CE bit to 1.

The TQ0CKS0 to TQ0CKS2 bits can be set at the same time when counting is enabled (TQ0CE bit = 1).
Trigger wait status

<2> TQ0CCR0 to TQ0CCR3 register setting change flow

Writing of the TQ0CCR1 register must be performed after writing the TQ0CCR0, TQ0CCR2, and TQ0CCR3 registers.
When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer registers.

<3> TQ0CCR0 register setting change flow

TQ0CCR1 register writing of the same value is necessary only when the set cycle is changed.

When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<4> TQ0CCR1 to TQ0CCR3 register setting change flow

Writing of the TQ0CCR1 register must be performed when the set duty factor is only changed after writing the TQ0CCR2 and TQ0CCR3 registers.
When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<5> TQ0CCR2, TQ0CCR3 register setting change flow

TQ0CCR1 register writing of the same value is necessary only when the set duty factor of TOQ02 and TOQ03 pin outputs is changed.
When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<6> TQ0CCR1 register setting change flow

Only writing of the TQ0CCR1 register must be performed when the set duty factor is only changed.
When counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<7> Count operation stop flow

Counting is stopped.

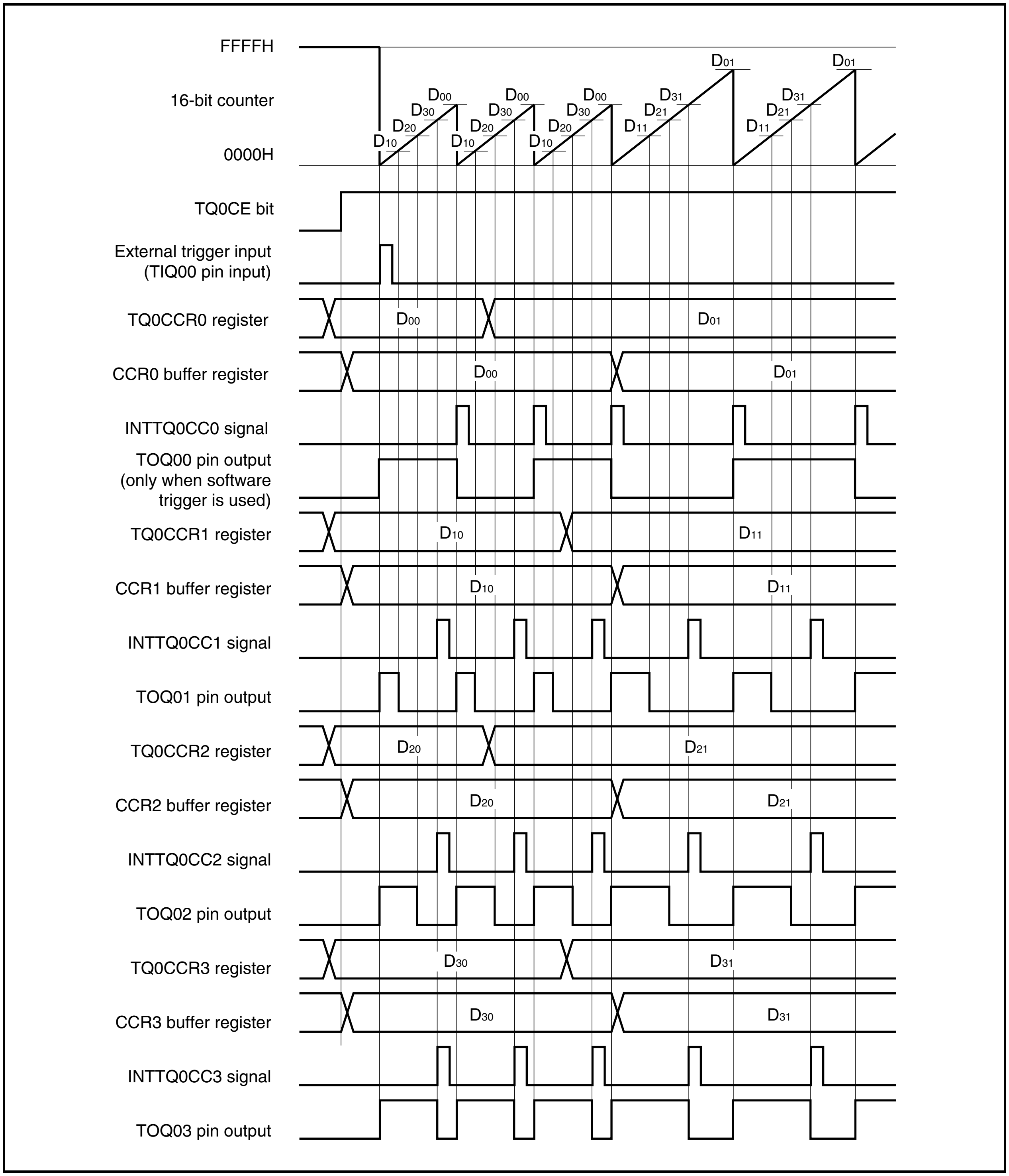
Remark m = 0 to 3

(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.

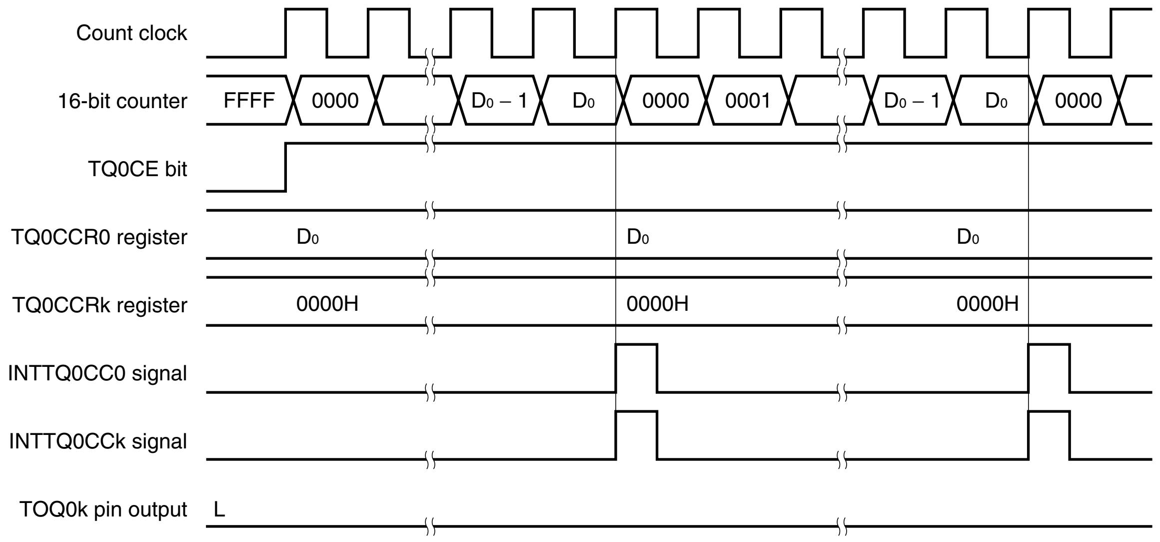
After data is written to the TQ0CCR1 register, the value written to the TQ0CCRm register is transferred to the CCRm buffer register in synchronization with clearing of the 16-bit counter, and is used as the value compared with the 16-bit counter.

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

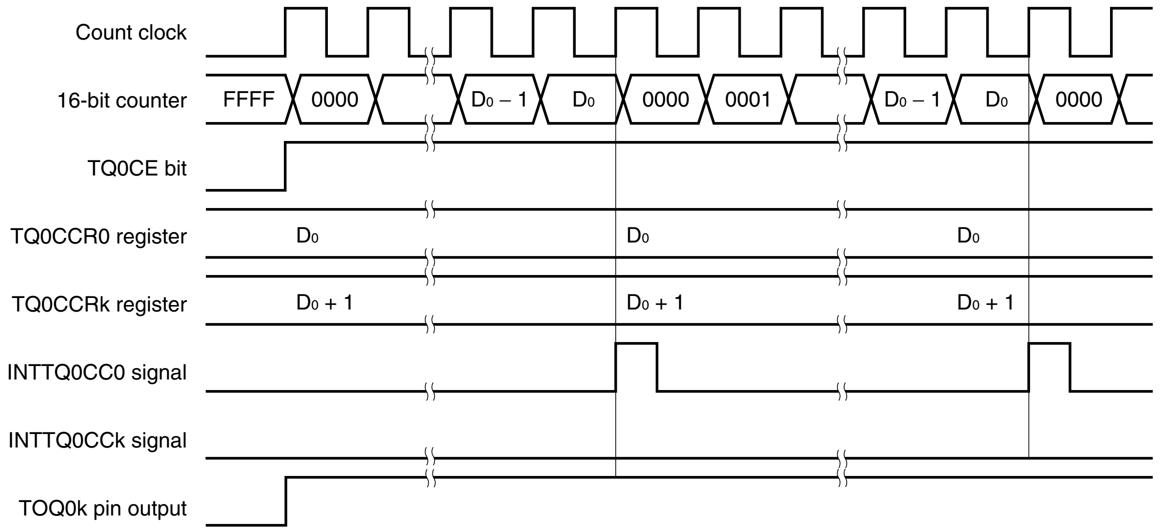
(b) 0%/100% output of PWM waveform

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.



Remark k = 1 to 3

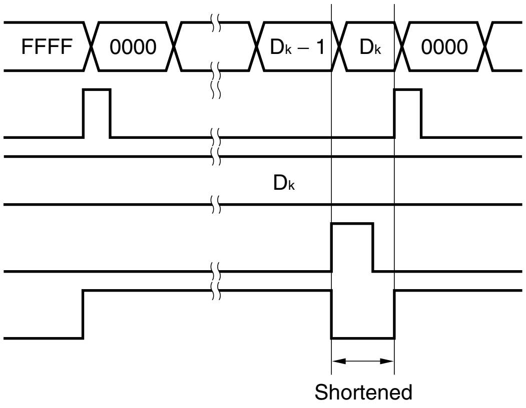
To output a 100% waveform, set a value of (set value of TQ0CCR0 register + 1) to the TQ0CCRk register. If the set value of the TQ0CCR0 register is FFFFH, 100% output cannot be produced.



Remark k = 1 to 3

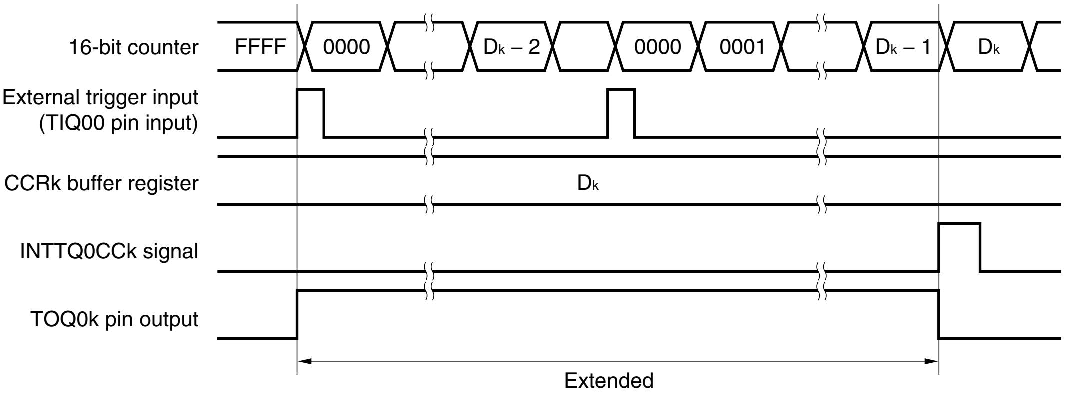
(c) Conflict between trigger detection and match with CCRk buffer register

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 pin is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.



Remark k = 1 to 3

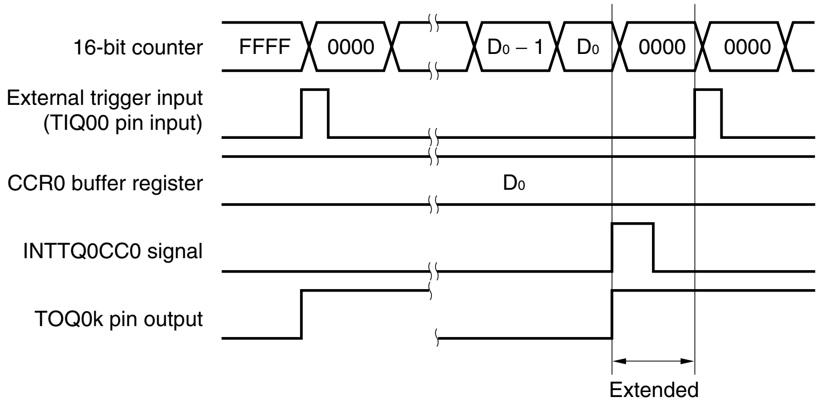
If the trigger is detected immediately before the INTTQ0CCk signal is generated, the INTTQ0CCk signal is not generated, and the 16-bit counter is cleared to 0000H and continues counting. The output signal of the TOQ0k pin remains active. Consequently, the active period of the PWM waveform is extended.



Remark k = 1 to 3

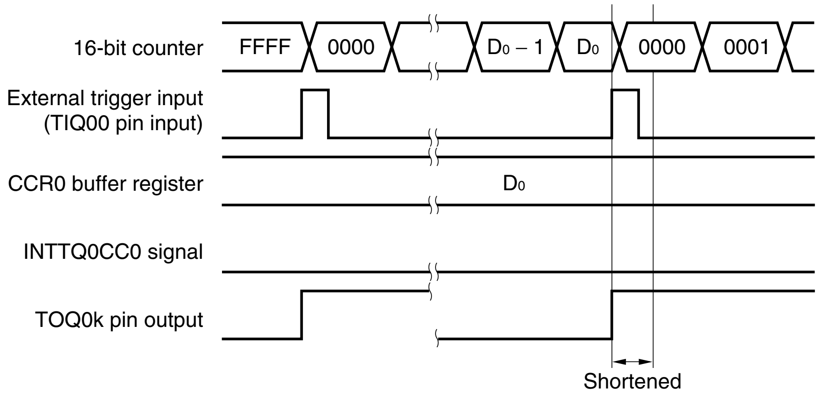
(d) Conflict between trigger detection and match with CCR0 buffer register

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.



Remark k = 1 to 3

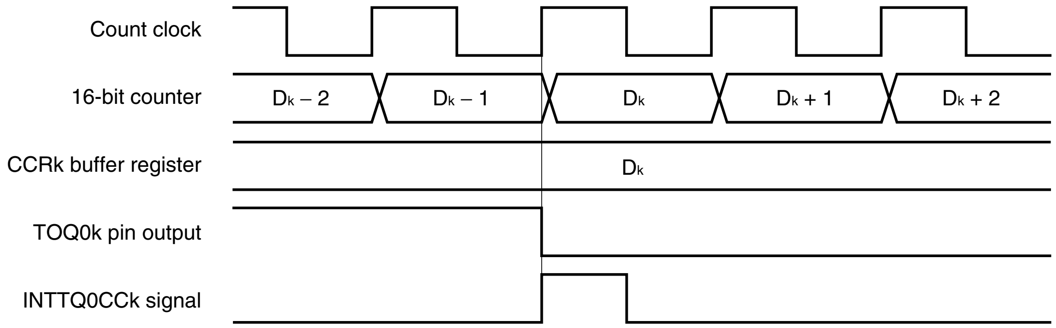
If the trigger is detected immediately before the INTTQ0CC0 signal is generated, the INTTQ0CC0 signal is not generated. The 16-bit counter is cleared to 0000H, the TOQ0k pin is asserted, and the counter continues counting. Consequently, the inactive period of the PWM waveform is shortened.



Remark k = 1 to 3

(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.



Remark k = 1 to 3

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

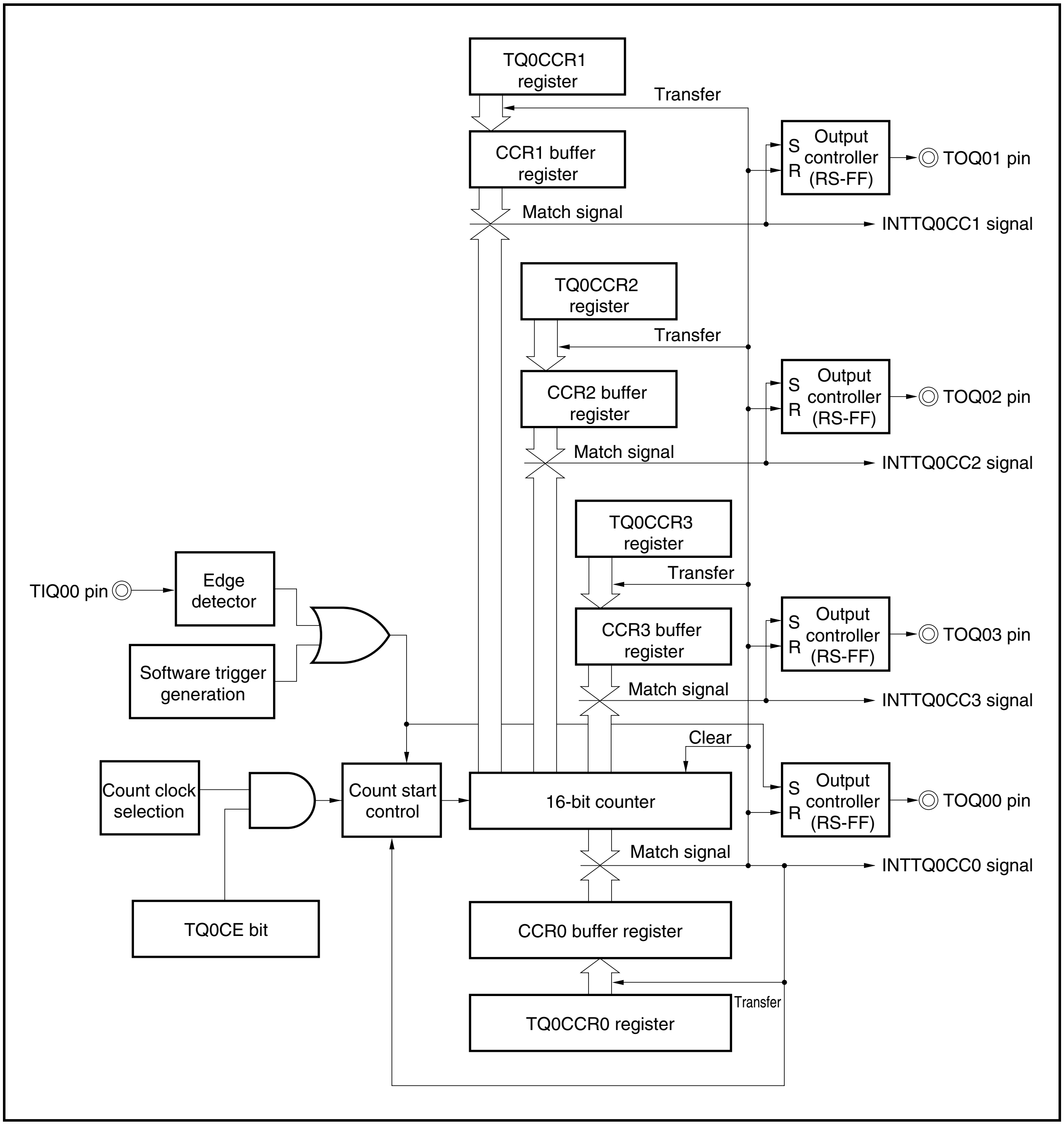
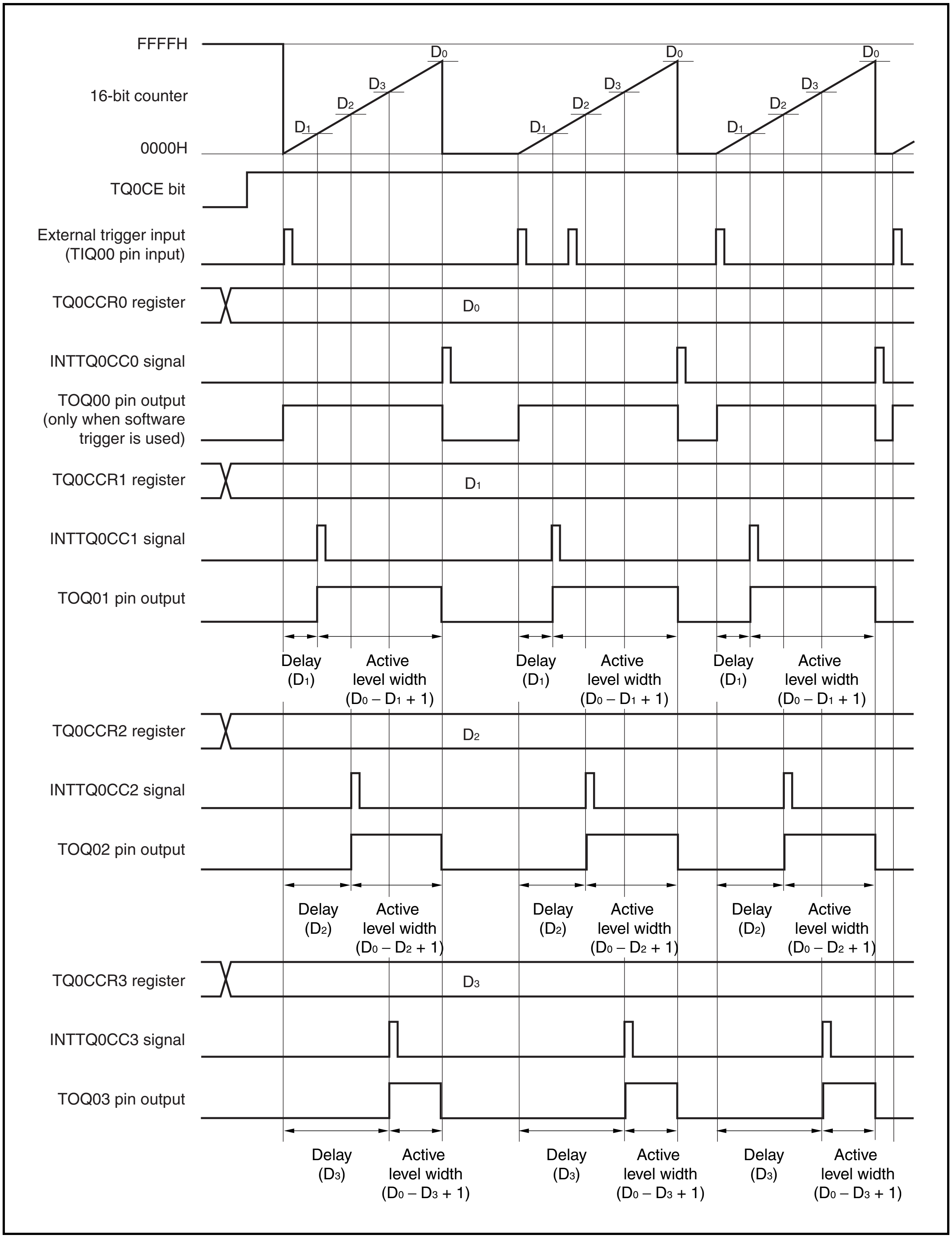


Figure 8-21. Basic Timing in One-Shot Pulse Output Mode



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.

Output delay period = (Set value of TQ0CCRk register) × Count clock cycle
Active level width = (Set value of TQ0CCR0 register – Set value of TQ0CCRk register + 1) × Count clock cycle

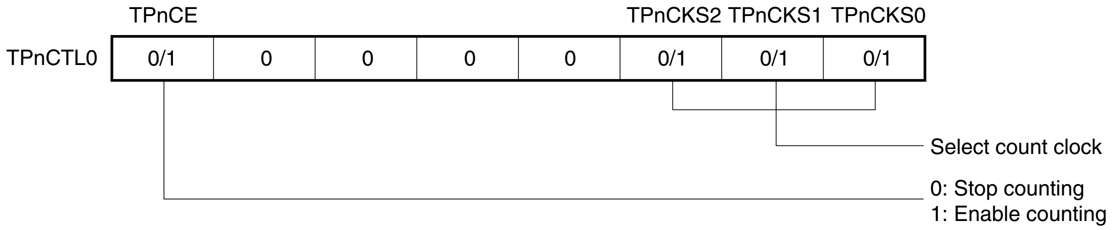
The compare match interrupt request signal INTTQ0CC0 is generated when the 16-bit counter counts after its count value matches the value of the CCR0 buffer register. The compare match interrupt request signal INTTQ0CCk is generated when the count value of the 16-bit counter matches the value of the CCRk 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. Setting of Registers in One-Shot Pulse Output Mode (1/3)

(a) TMQ0 control register 0 (TQ0CTL0)



(b) TMQ0 control register 1 (TQ0CTL1)

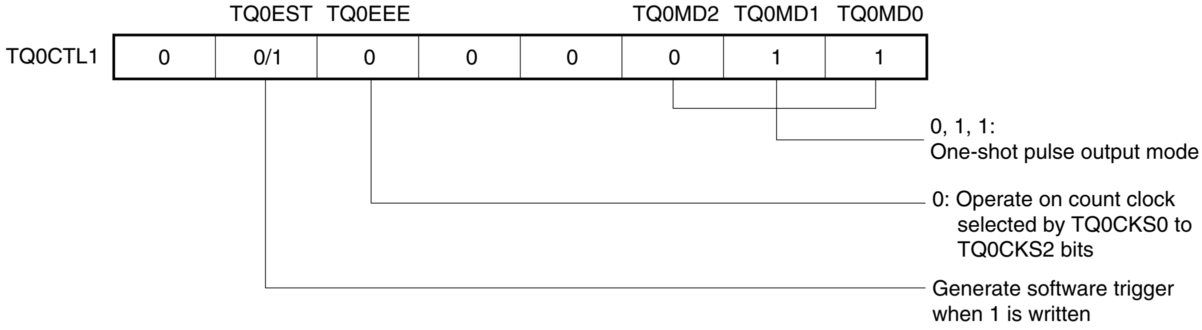
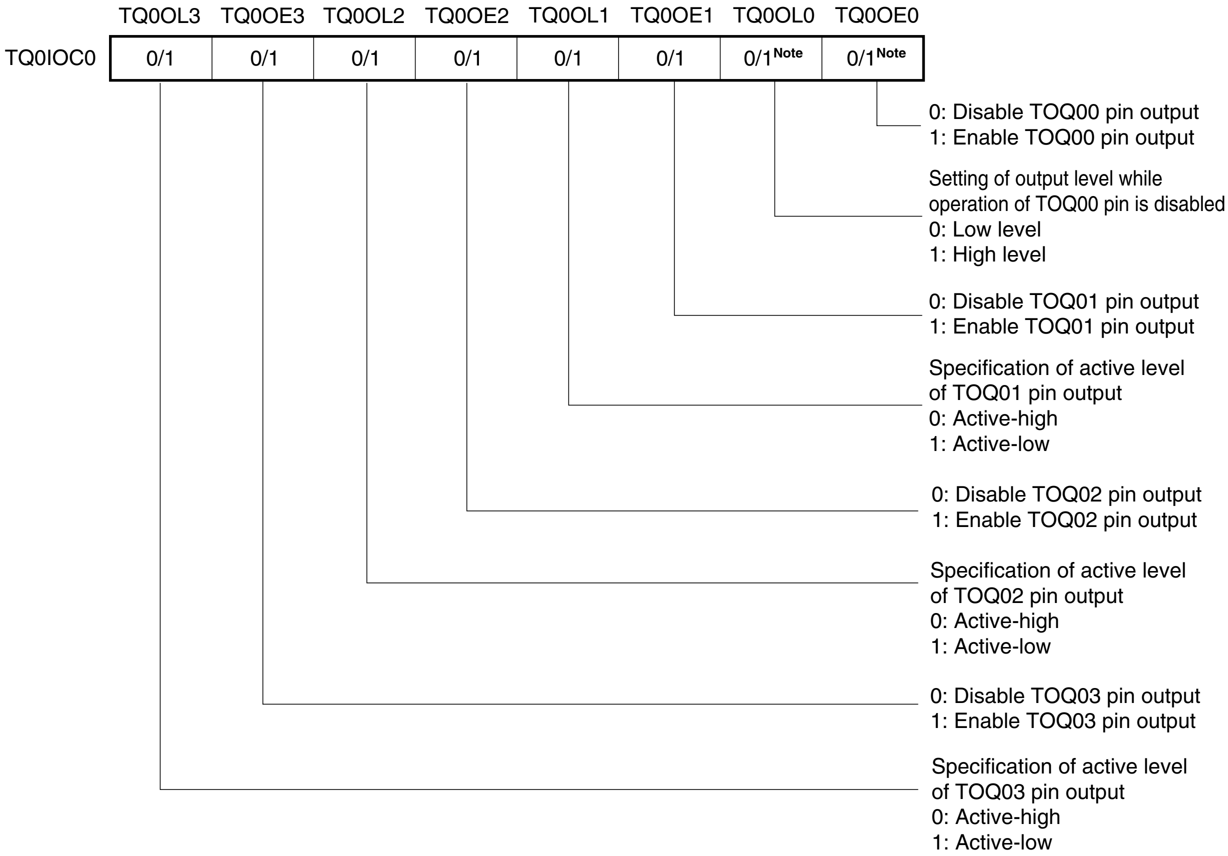


Figure 8-22. Register Setting in One-Shot Pulse Output Mode (2/3)

(c) TMQ0 I/O control register 0 (TQ0IOC0)



	TQ0OL3	TQ0OE3	TQ0OL2	TQ0OE2	TQ0OL1	TQ0OE1	TQ0OL0	TQ0OE0
TQ0IOC0	0/1	0/1	0/1	0/1	0/1	0/1	0/1$^{\text{Note}}$	0/1$^{\text{Note}}$

0: Disable TOQ00 pin output
1: Enable TOQ00 pin output

Setting of output level while operation of TOQ00 pin is disabled
0: Low level
1: High level

0: Disable TOQ01 pin output
1: Enable TOQ01 pin output

Specification of active level of TOQ01 pin output
0: Active-high
1: Active-low

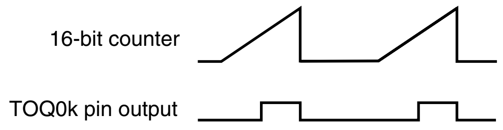
0: Disable TOQ02 pin output
1: Enable TOQ02 pin output

Specification of active level of TOQ02 pin output
0: Active-high
1: Active-low

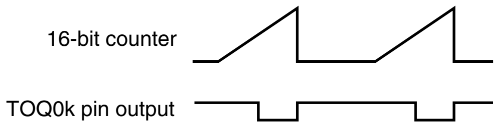
0: Disable TOQ03 pin output
1: Enable TOQ03 pin output

Specification of active level of TOQ03 pin output
0: Active-high
1: Active-low

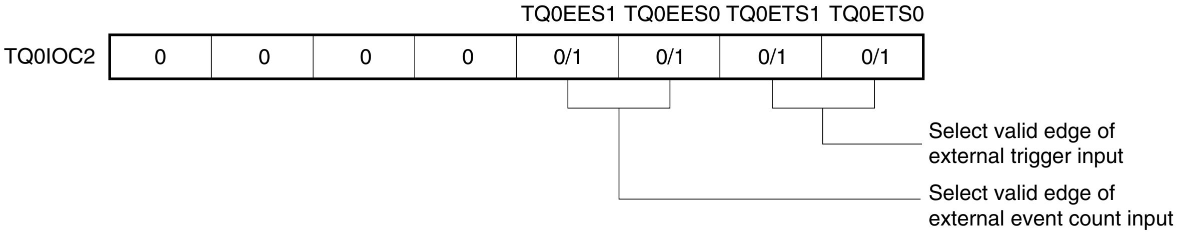
- When TQ0OLk bit = 0



- When TQ0OLk bit = 1



(d) TMQ0 I/O control register 2 (TQ0IOC2)



					TQ0EES1	TQ0EES0	TQ0ETS1	TQ0ETS0
TQ0IOC2	0	0	0	0	0/1	0/1	0/1	0/1

Select valid edge of external trigger input

Select valid edge of external event count input

Note Clear this bit to 0 when the TOQ00 pin is not used in the one-shot pulse output mode.

Figure 8-22. Register Setting 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 = $(D_0 - D_k + 1) \times$ Count clock cycle

Output delay period = $D_k \times$ Count clock cycle

Caution One-shot pulses are not output in the one-shot pulse output mode if the value set for the TQ0CCRk register is greater than that for 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)

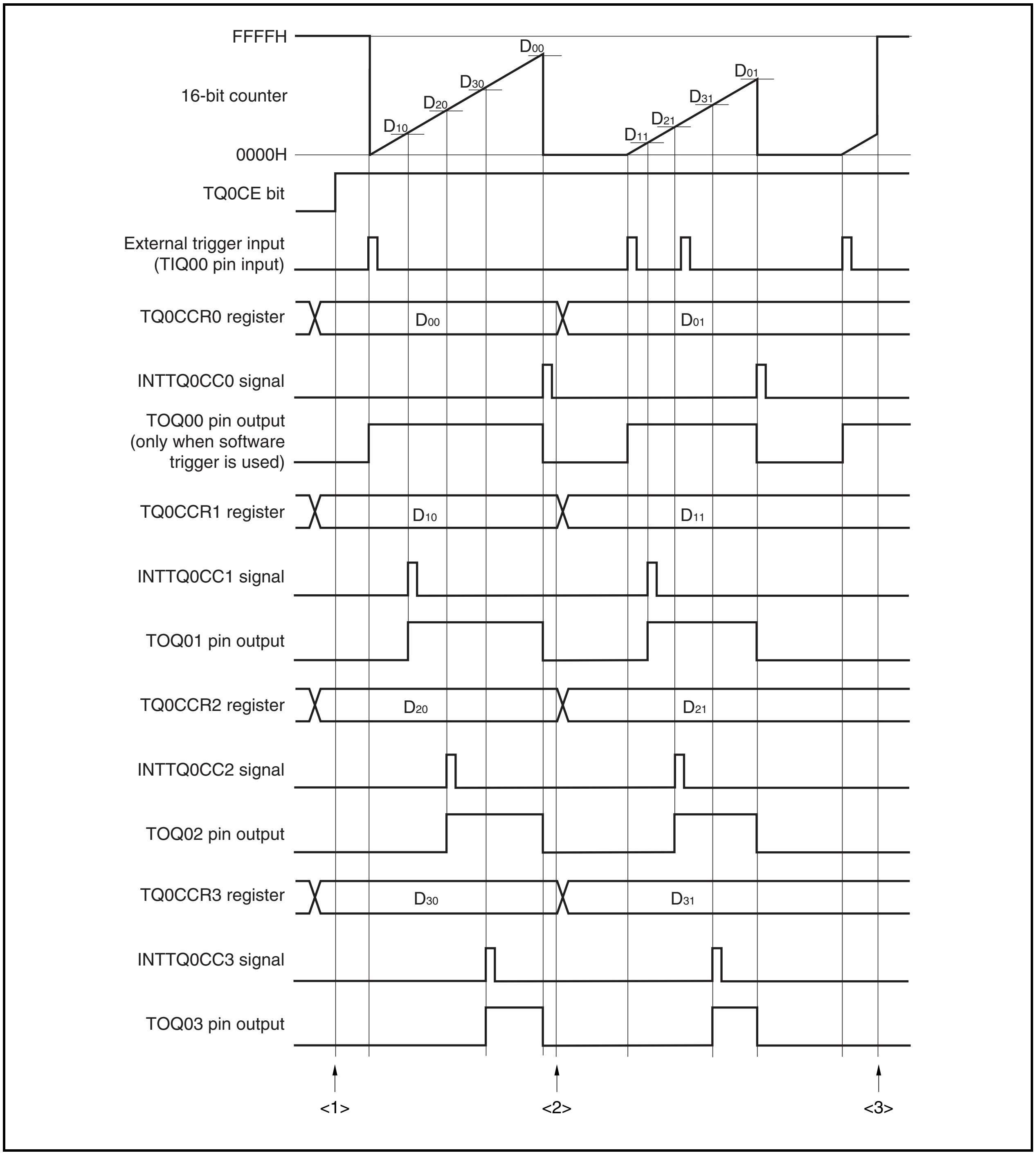
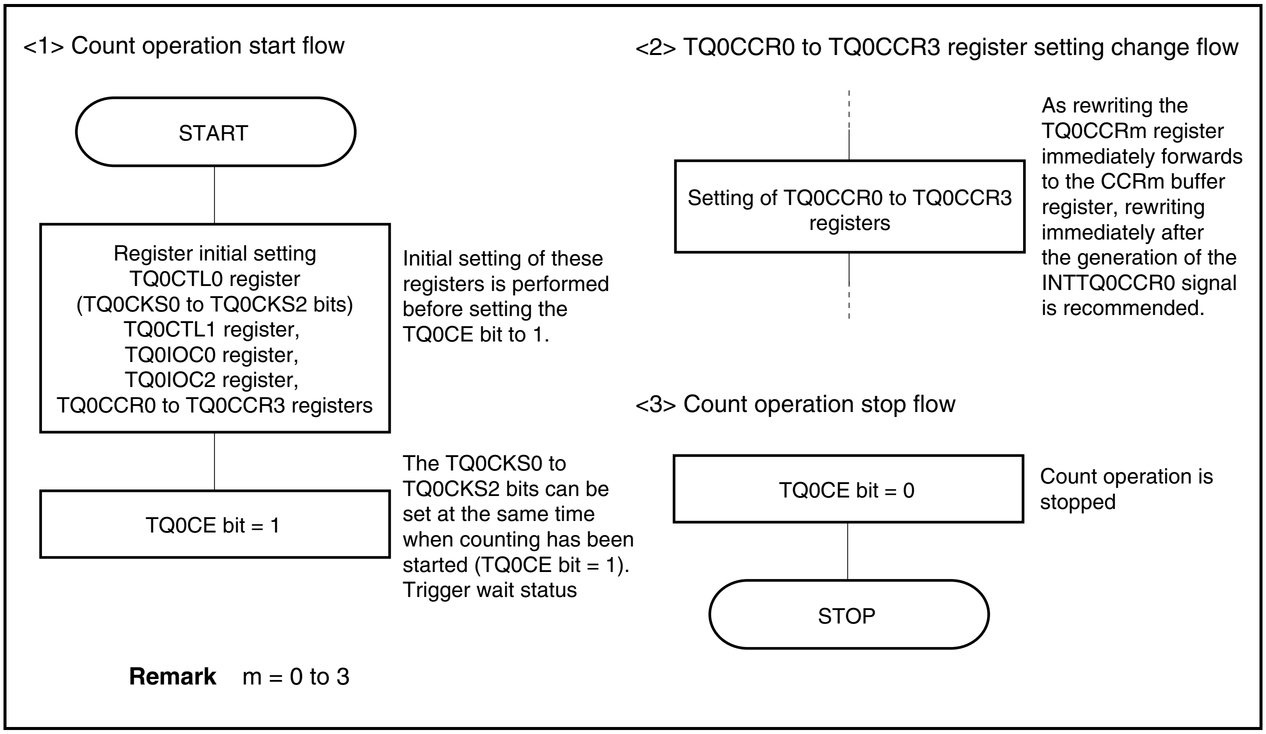


Figure 8-23. Software Processing Flow in One-Shot Pulse Output Mode (2/2)



Initial setting of these registers is performed before setting the TQ0CE bit to 1.

The TQ0CKS0 to TQ0CKS2 bits can be set at the same time when counting has been started (TQ0CE bit = 1). Trigger wait status

As rewriting the TQ0CCRm register immediately forwards to the CCRm buffer register, rewriting immediately after the generation of the INTTQ0CCR0 signal is recommended.

Count operation is stopped

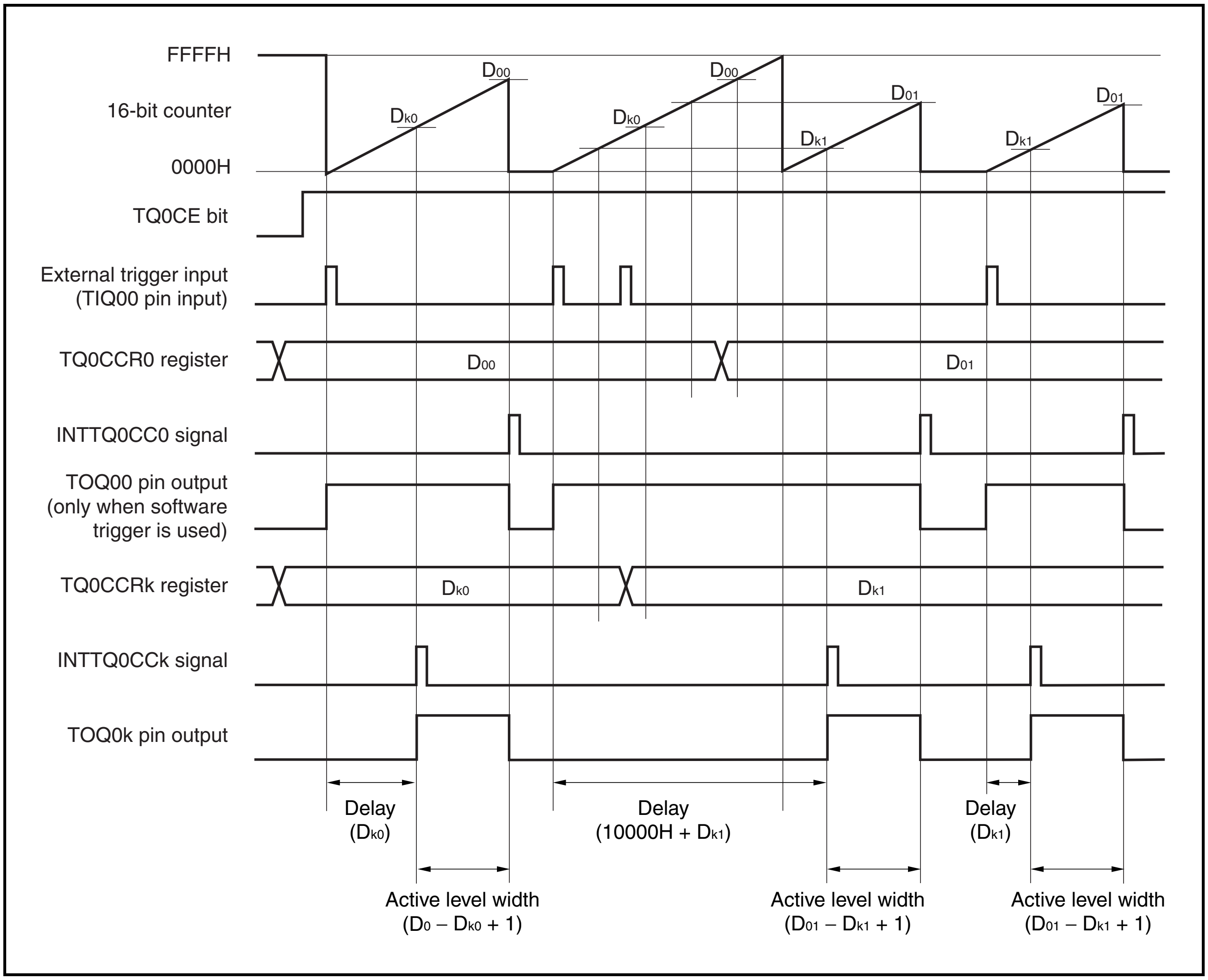
Remark m = 0 to 3

(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.



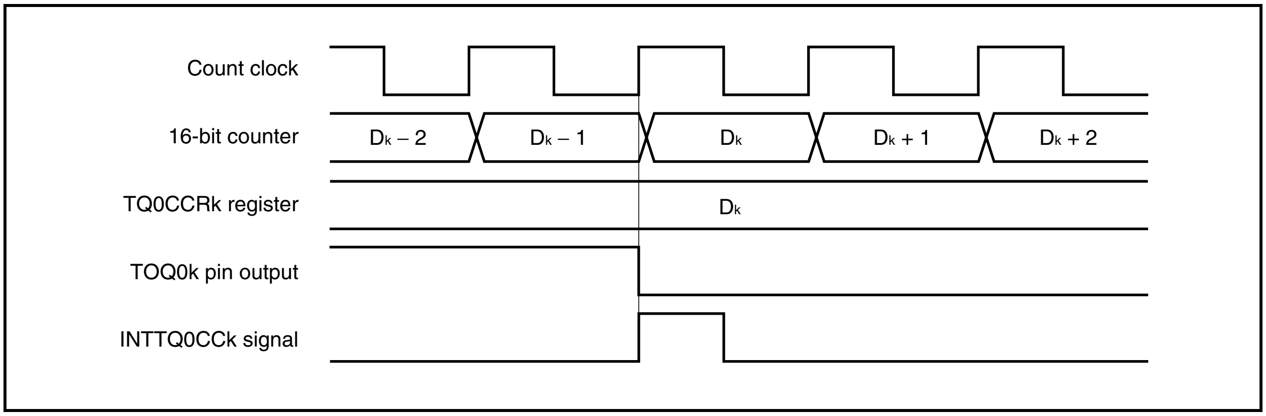
When the TQ0CCR0 register is rewritten from D_{00} to D_{01} and the TQ0CCRk register from D_{k0} to D_{k1} where $D_{00} > D_{01}$ and $D_{k0} > D_{k1}$, if the TQ0CCRk register is rewritten when the count value of the 16-bit counter is greater than D_{k1} and less than D_{k0} and if the TQ0CCR0 register is rewritten when the count value is greater than D_{01} and less than D_{00}, 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_{k1}, the counter generates the INTTQ0CCk signal and asserts the TOQ0k pin. When the count value matches D_{01}, 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

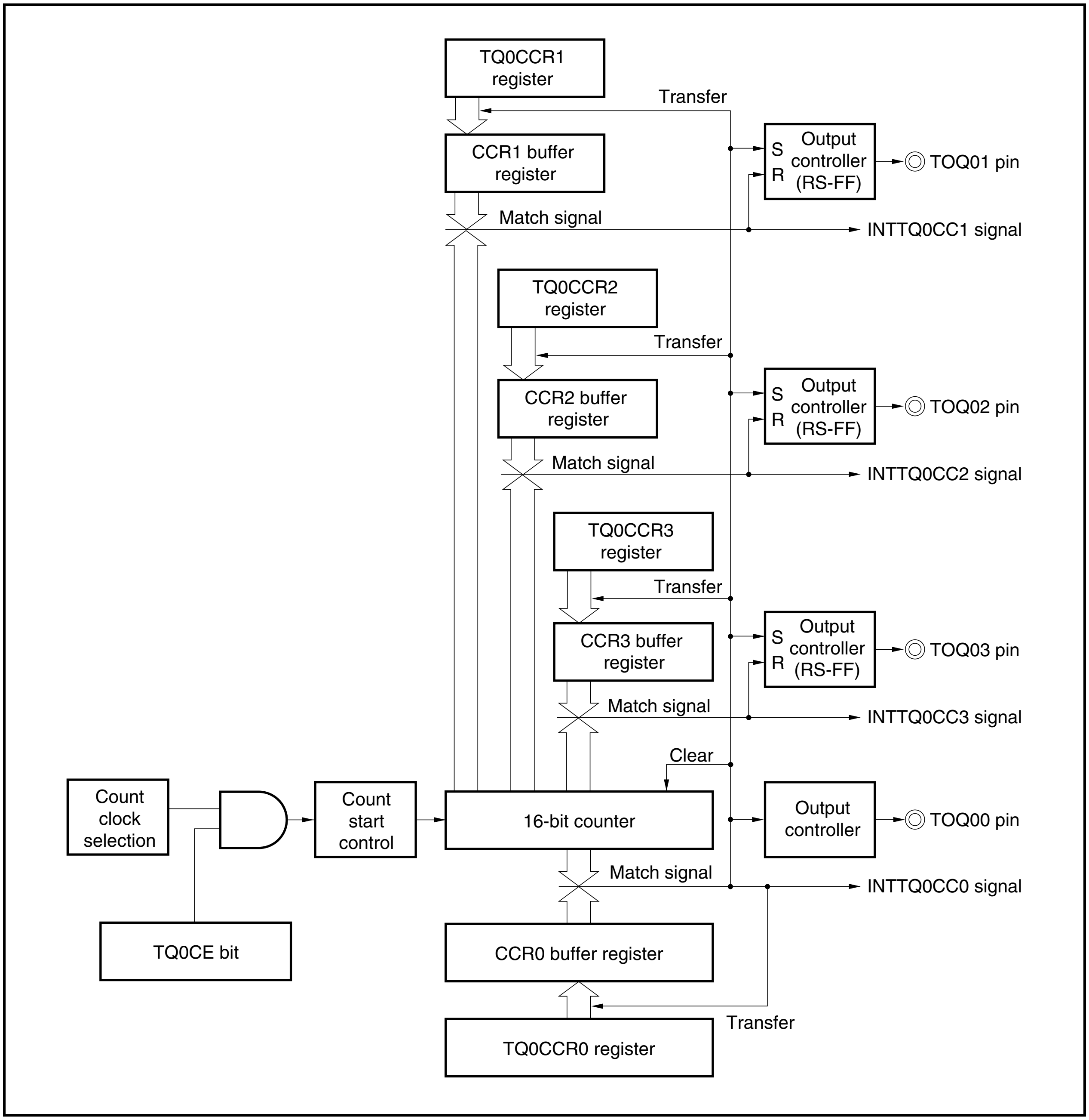
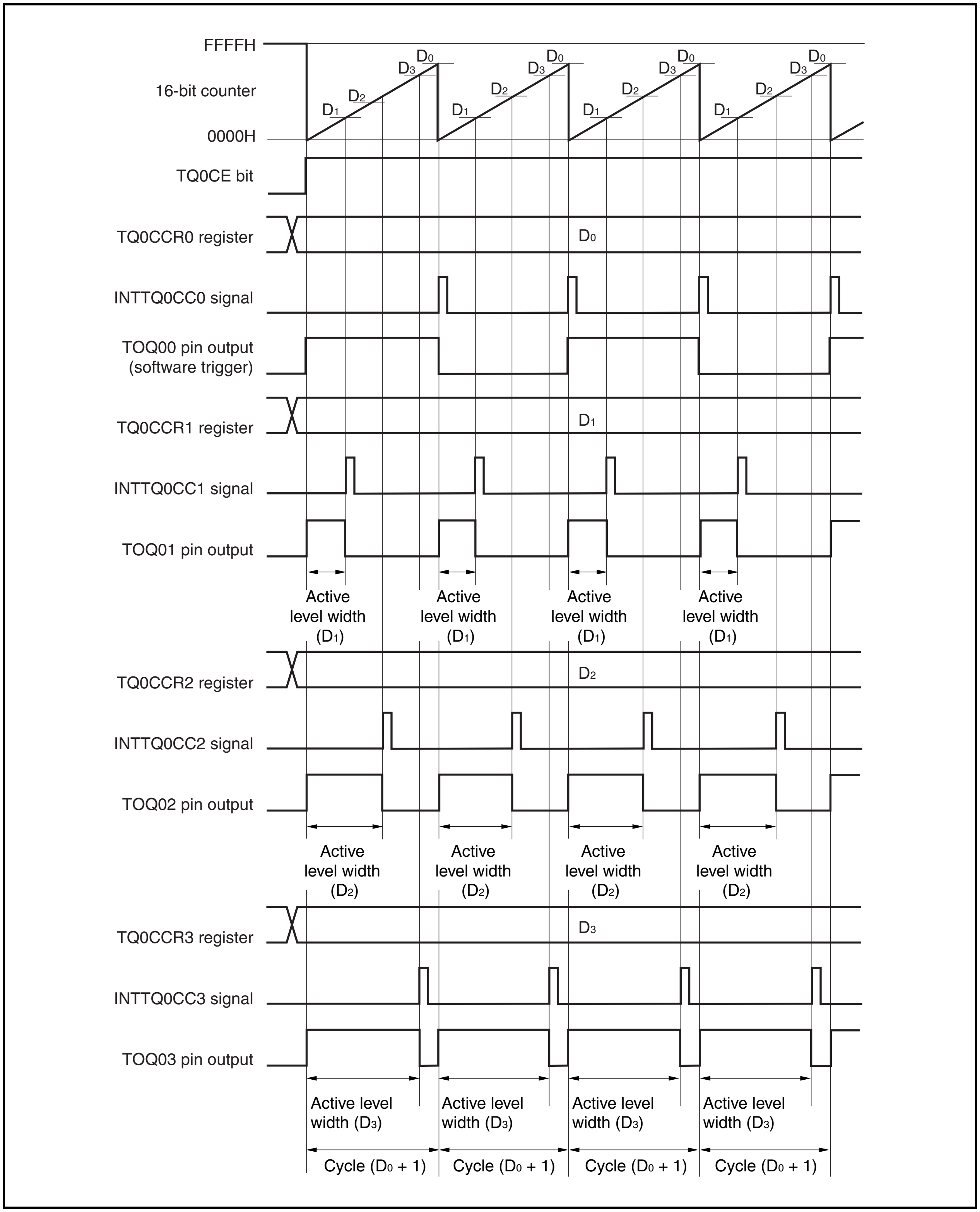


Figure 8-25. Basic Timing in PWM Output Mode



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.

Active level width = (Set value of TQ0CCRk register) × Count clock cycle
Cycle = (Set value of TQ0CCR0 register + 1) × Count clock cycle
Duty factor = (Set value of TQ0CCRk register)/(Set value of TQ0CCR0 register + 1)

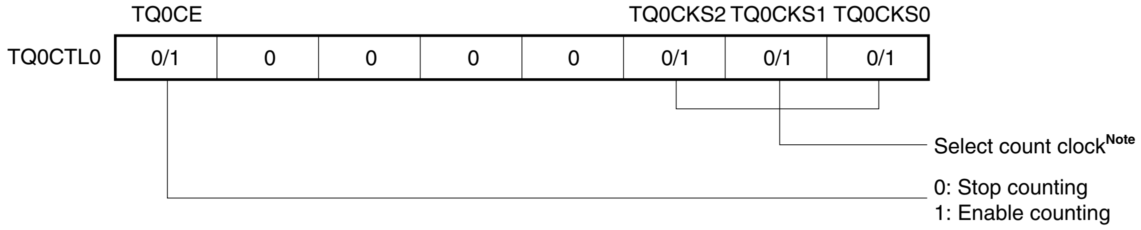
The PWM waveform can be changed by rewriting the TQ0CCRm register while the counter is operating. The newly written value is reflected when the count value of the 16-bit counter matches the value of the CCR0 buffer register and the 16-bit counter is cleared to 0000H.

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.

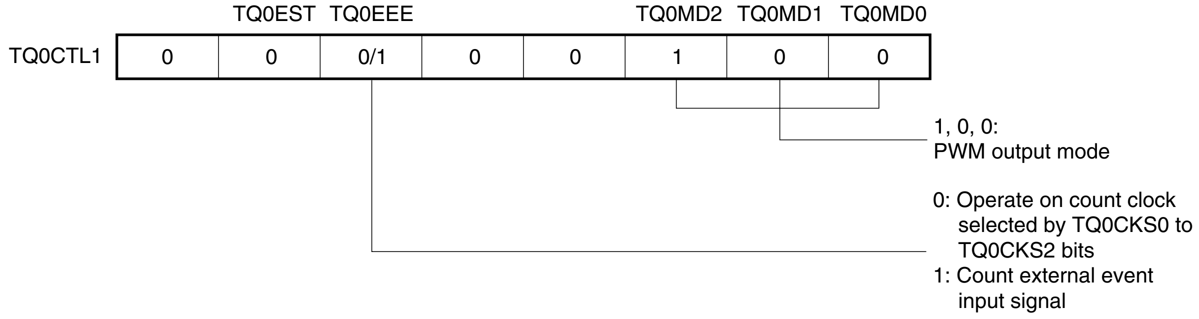
Remark k = 1 to 3
m = 0 to 3

Figure 8-26. Setting of Registers in PWM Output Mode (1/3)

(a) TMQ0 control register 0 (TQ0CTL0)



(b) TMQ0 control register 1 (TQ0CTL1)



Note The setting is invalid when the TQ0CTL1.TQ0EEE bit = 1.

Figure 8-26. Setting of Registers in PWM Output Mode (2/3)

(c) TMQ0 I/O control register 0 (TQ0IOC0)

	TQ0OL3	TQ0OE3	TQ0OL2	TQ0OE2	TQ0OL1	TQ0OE1	TQ0OL0	TQ0OE0
TQ0IOC0	0/1	0/1	0/1	0/1	0/1	0/1	0/1 Note	0/1 Note

0: Disable TOQ00 pin output
1: Enable TOQ00 pin output

Setting of output level while operation of TOQ00 pin is disabled
0: Low level
1: High level

0: Disable TOQ01 pin output
1: Enable TOQ01 pin output

Specification of active level of TOQ01 pin output
0: Active-high
1: Active-low

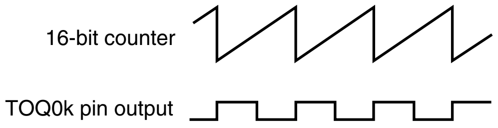
0: Disable TOQ02 pin output
1: Enable TOQ02 pin output

Specification of active level of TOQ02 pin output
0: Active-high
1: Active-low

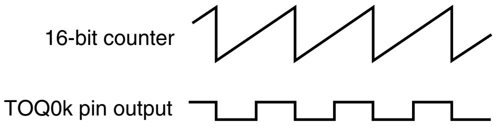
0: Disable TOQ03 pin output
1: Enable TOQ03 pin output

Specification of active level of TOQ03 pin output
0: Active-high
1: Active-low

- When TQ0OLk bit = 0



- When TQ0OLk bit = 1



(d) TMQ0 I/O control register 2 (TQ0IOC2)

					TQ0EES1	TQ0EES0	TQ0ETS1	TQ0ETS0
TQ0IOC2	0	0	0	0	0/1	0/1	0	0

Select valid edge of external event count input.

Note Clear this bit to 0 when the TOQ00 pin is not used in the PWM output mode.

Figure 8-26. Register Setting in PWM 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 and 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.

Cycle = $(D_0 + 1) \times$ Count clock cycle

Active level width = $D_k \times$ 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)

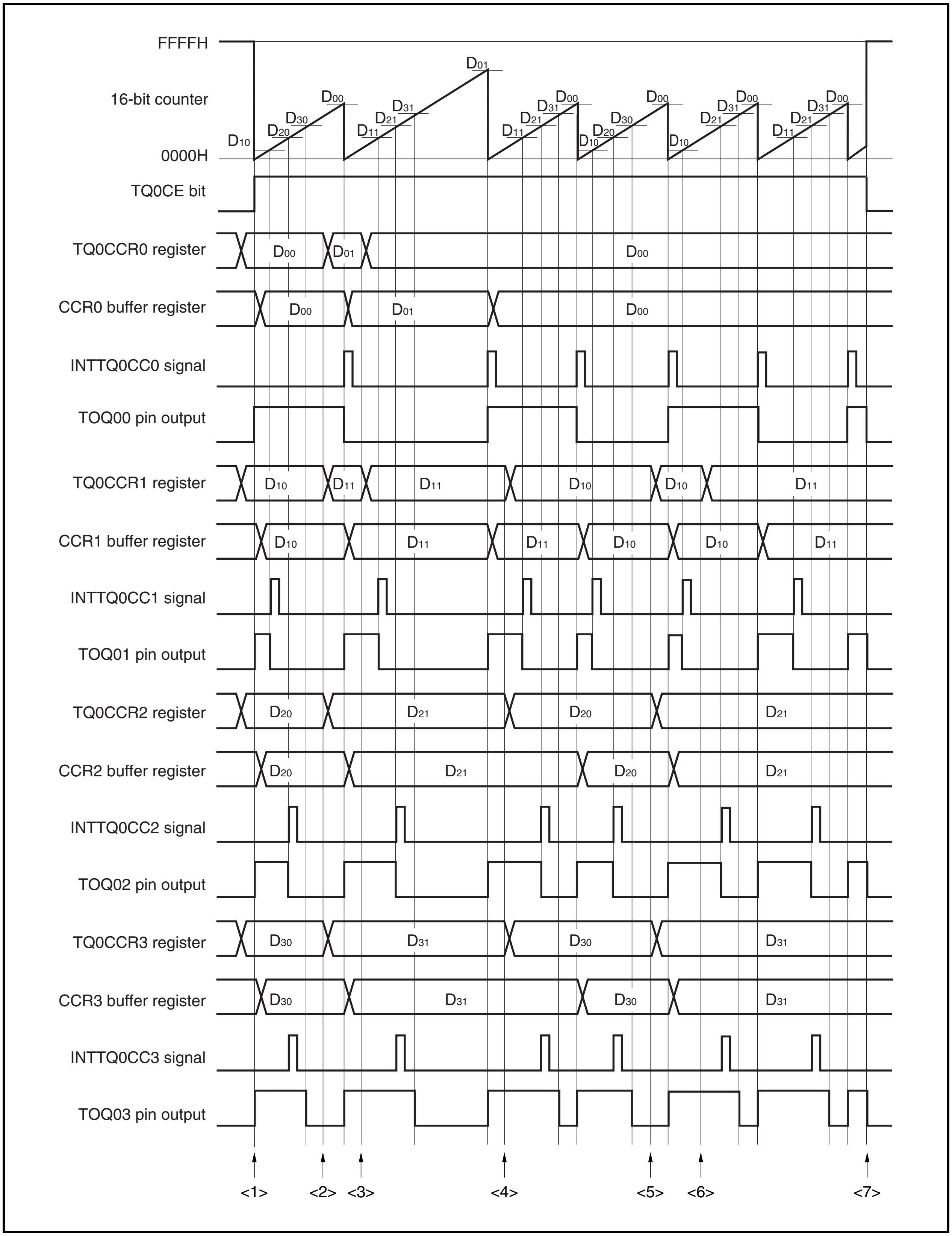
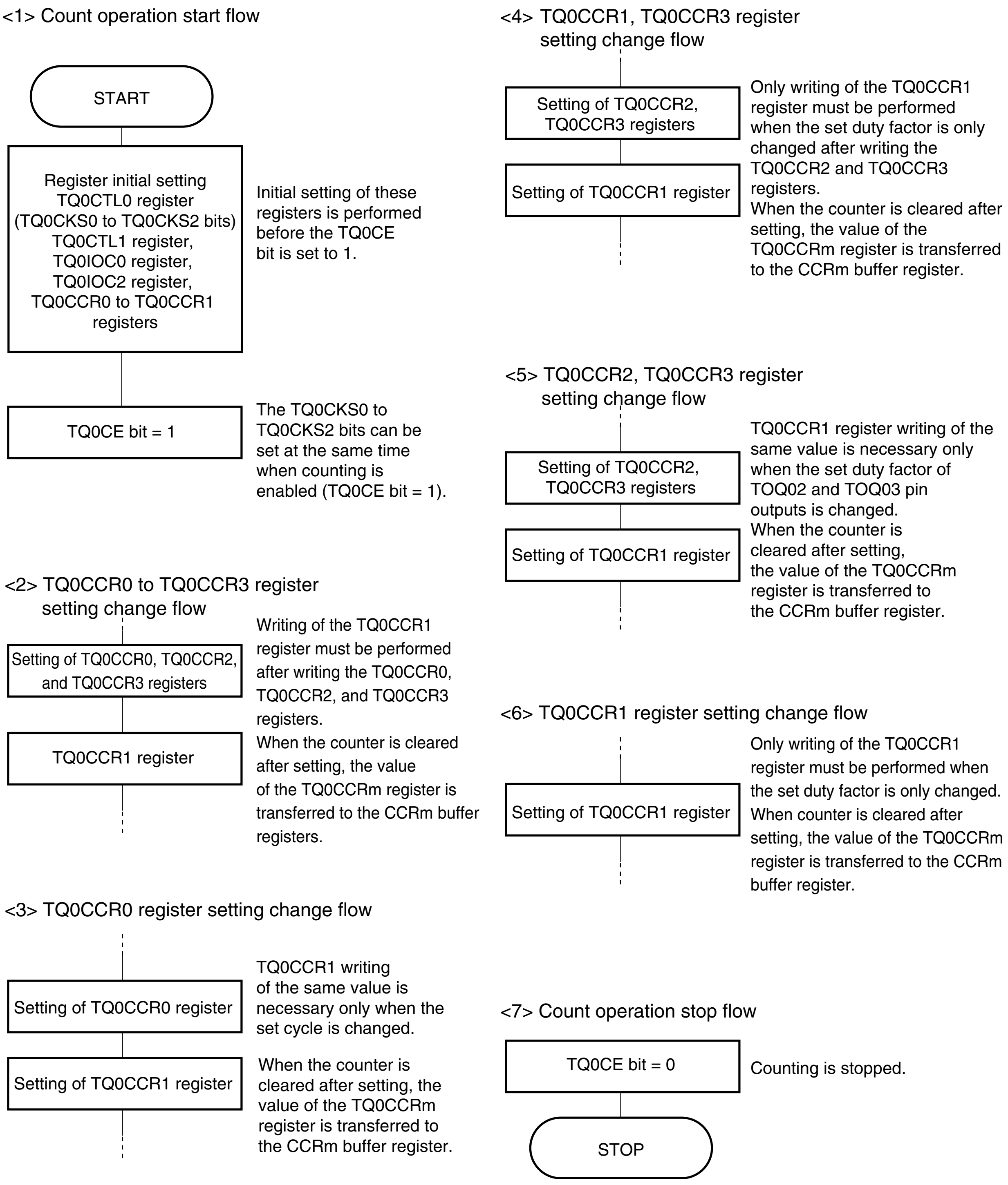


Figure 8-27. Software Processing Flow in PWM Output Mode (2/2)



<1> Count operation start flow

Initial setting of these registers is performed before the TQ0CE bit is set to 1.

The TQ0CKS0 to TQ0CKS2 bits can be set at the same time when counting is enabled (TQ0CE bit = 1).

<2> TQ0CCR0 to TQ0CCR3 register setting change flow

Writing of the TQ0CCR1 register must be performed after writing the TQ0CCR0, TQ0CCR2, and TQ0CCR3 registers.
When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer registers.

<3> TQ0CCR0 register setting change flow

TQ0CCR1 writing of the same value is necessary only when the set cycle is changed.

When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<4> TQ0CCR1, TQ0CCR3 register setting change flow

Only writing of the TQ0CCR1 register must be performed when the set duty factor is only changed after writing the TQ0CCR2 and TQ0CCR3 registers.
When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<5> TQ0CCR2, TQ0CCR3 register setting change flow

TQ0CCR1 register writing of the same value is necessary only when the set duty factor of TOQ02 and TOQ03 pin outputs is changed.
When the counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<6> TQ0CCR1 register setting change flow

Only writing of the TQ0CCR1 register must be performed when the set duty factor is only changed.
When counter is cleared after setting, the value of the TQ0CCRm register is transferred to the CCRm buffer register.

<7> Count operation stop flow

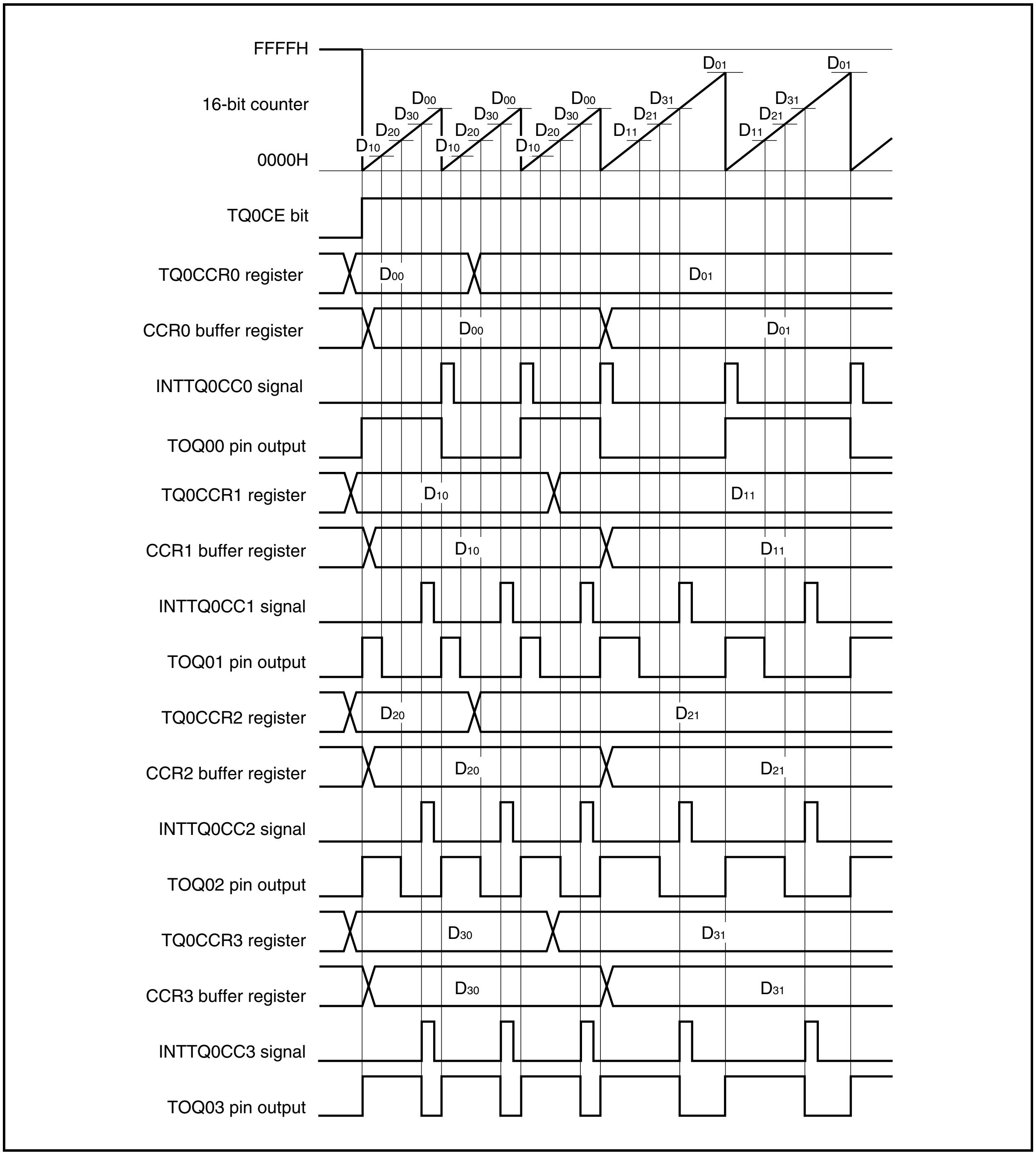
Counting is stopped.

Remark k = 1 to 3
m = 0 to 3

(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.

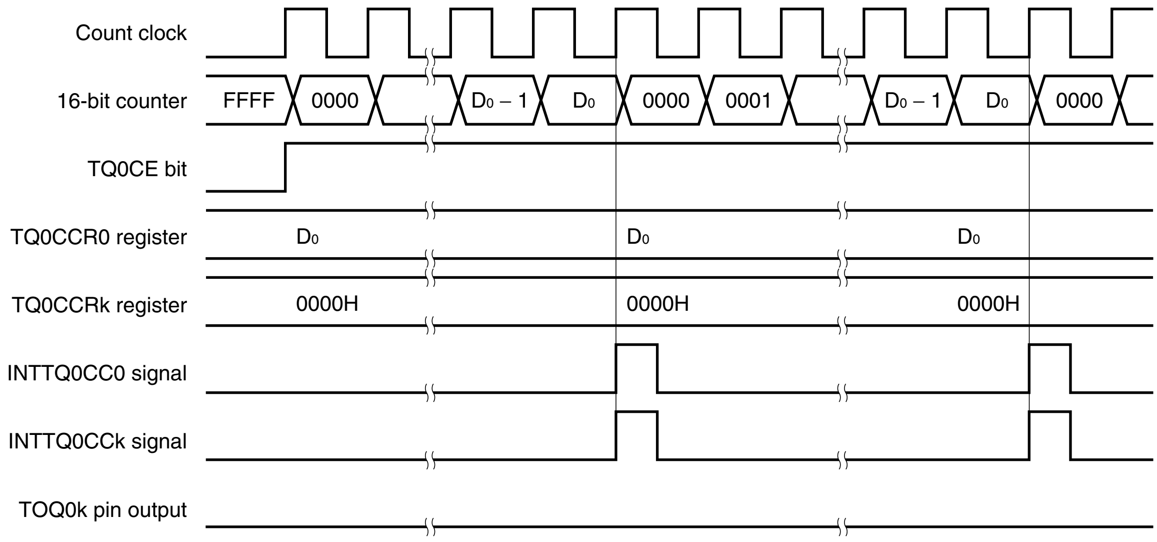
To change only the cycle of the PWM waveform, first set a cycle to the TQ0CCR0 register, and then write the same value to the TQ0CCR1 register.

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

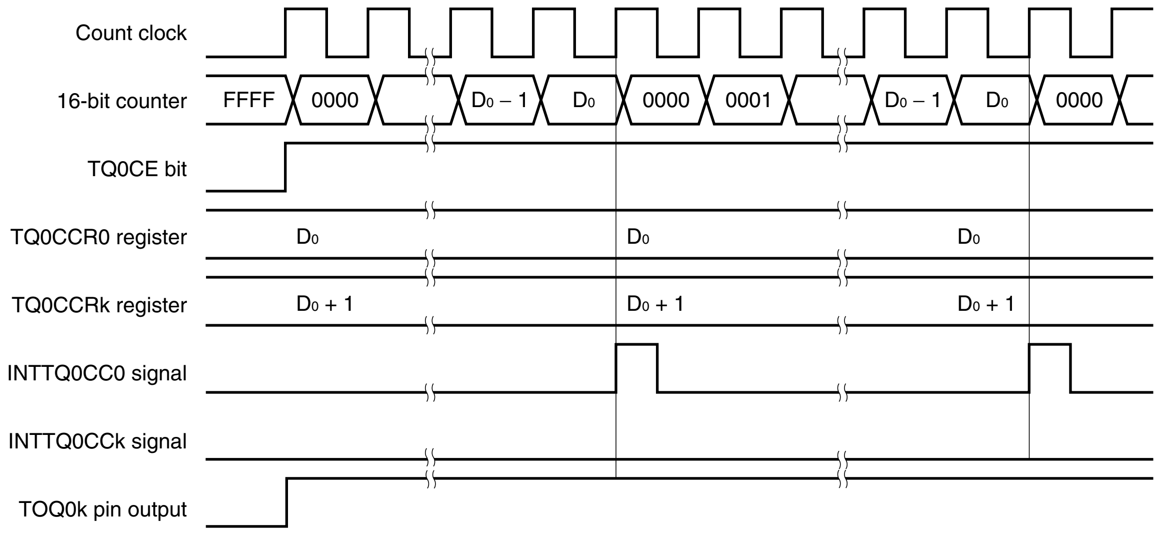
(b) 0%/100% output of PWM waveform

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.



Remark k = 1 to 3

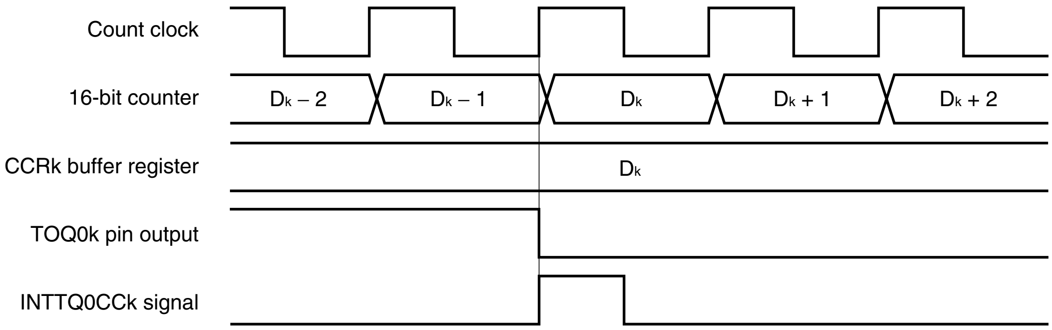
To output a 100% waveform, set a value of (set value of TQ0CCR0 register + 1) to the TQ0CCRk register. If the set value of the TQ0CCR0 register is FFFFH, 100% output cannot be produced.



Remark k = 1 to 3

(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.



Remark k = 1 to 3

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.

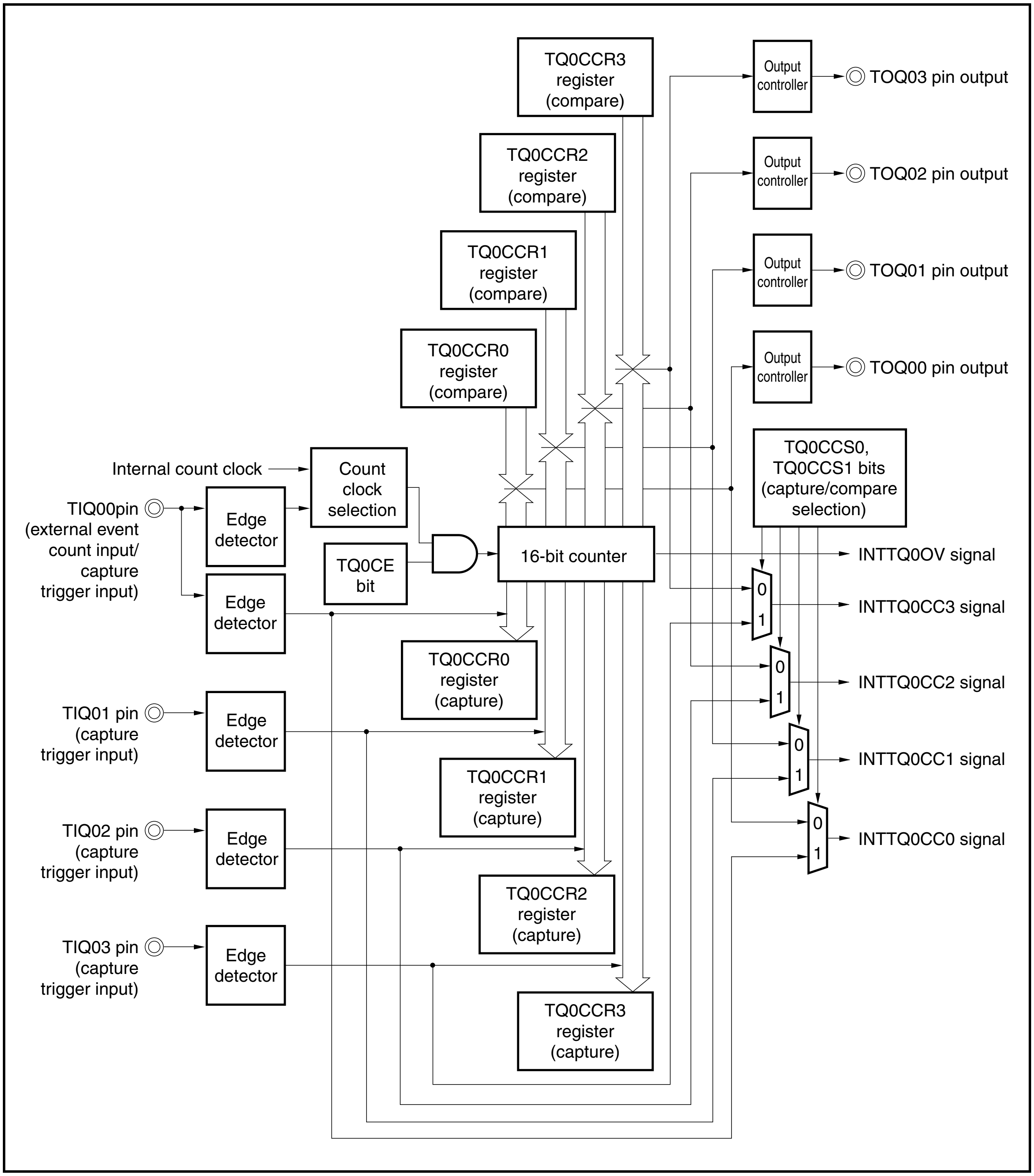
In the PWM output mode, however, it is generated one clock earlier. This is because the timing is changed to match the change timing of the output signal of the TOQ0k pin.

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

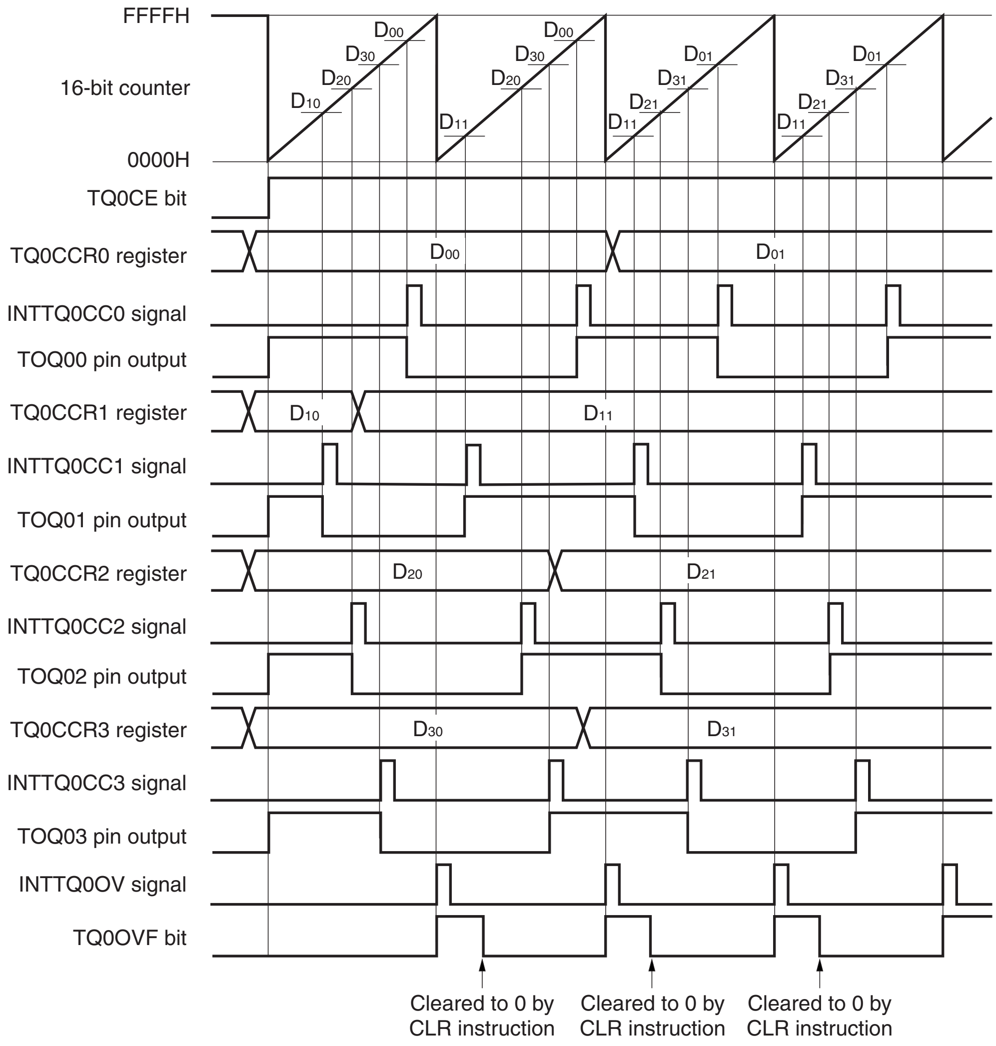


When the TQ0CE bit is set to 1, 16-bit timer/event counter Q starts counting, and the output signals of the TOQ00 to TOQ03 pins are inverted. When the count value of the 16-bit counter later matches the set value of the TQ0CCRm register, a compare match interrupt request signal (INTTQ0CCm) is generated, 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)

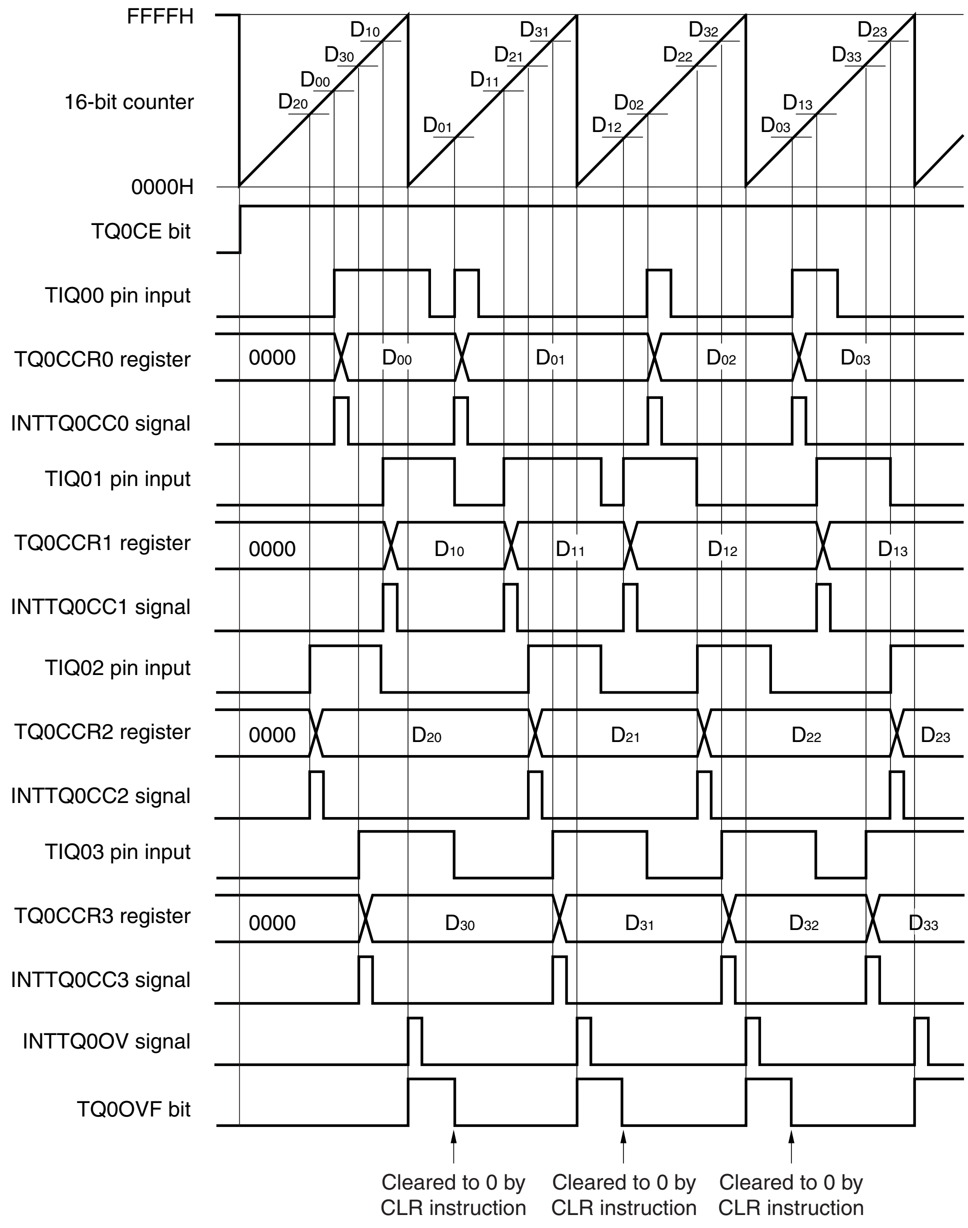
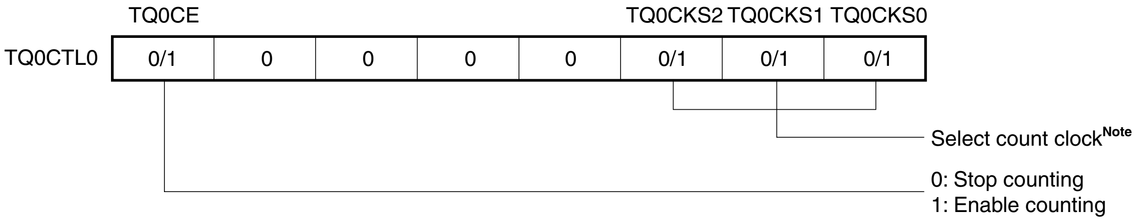


Figure 8-31. Register Setting in Free-Running Timer Mode (1/3)

(a) TMQ0 control register 0 (TQ0CTL0)



Note The setting is invalid when the TQ0CTL1.TQ0EEE bit = 1

(b) TMQ0 control register 1 (TQ0CTL1)

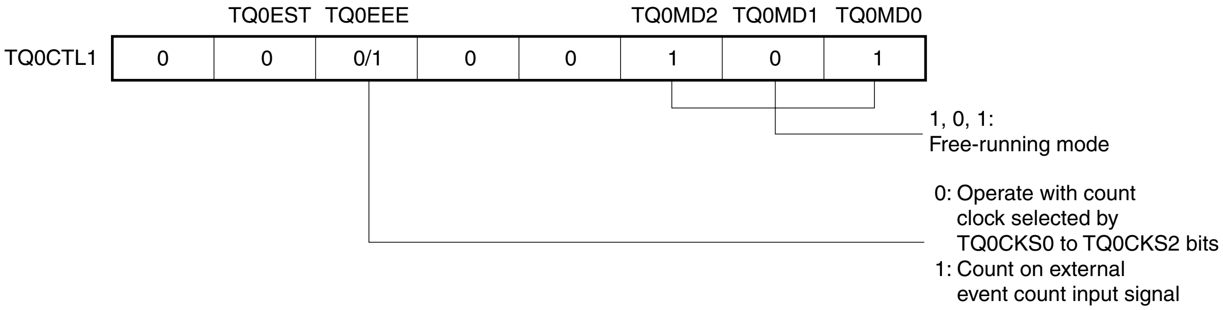
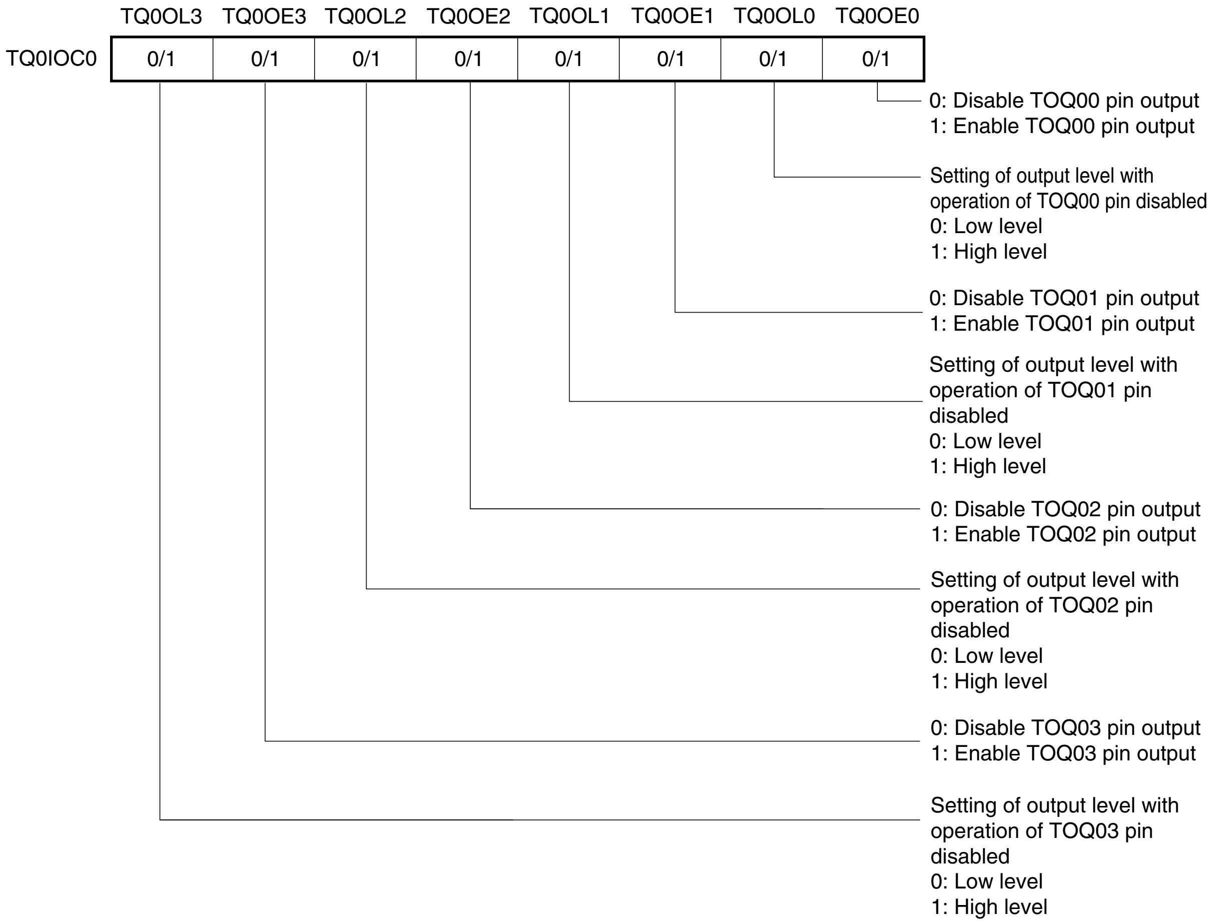


Figure 8-31. Register Setting in Free-Running Timer Mode (2/3)

(c) TMQ0 I/O control register 0 (TQ0IOC0)



(d) TMQ0 I/O control register 1 (TQ0IOC1)

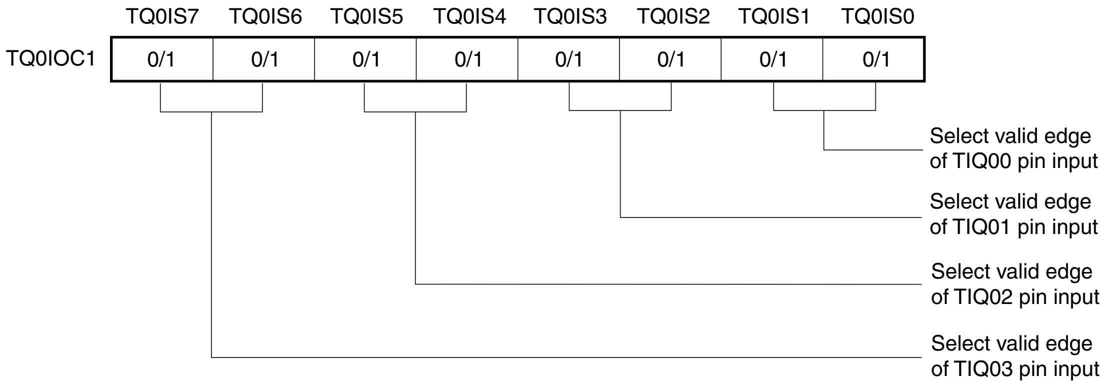
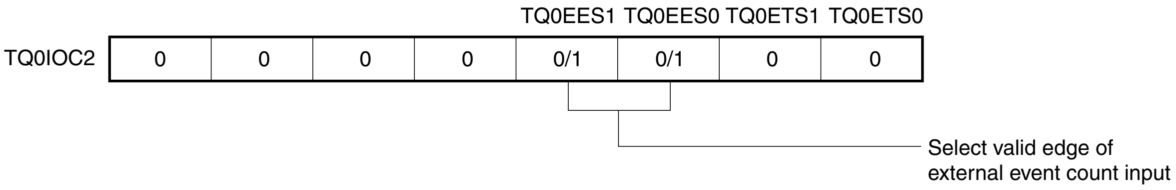
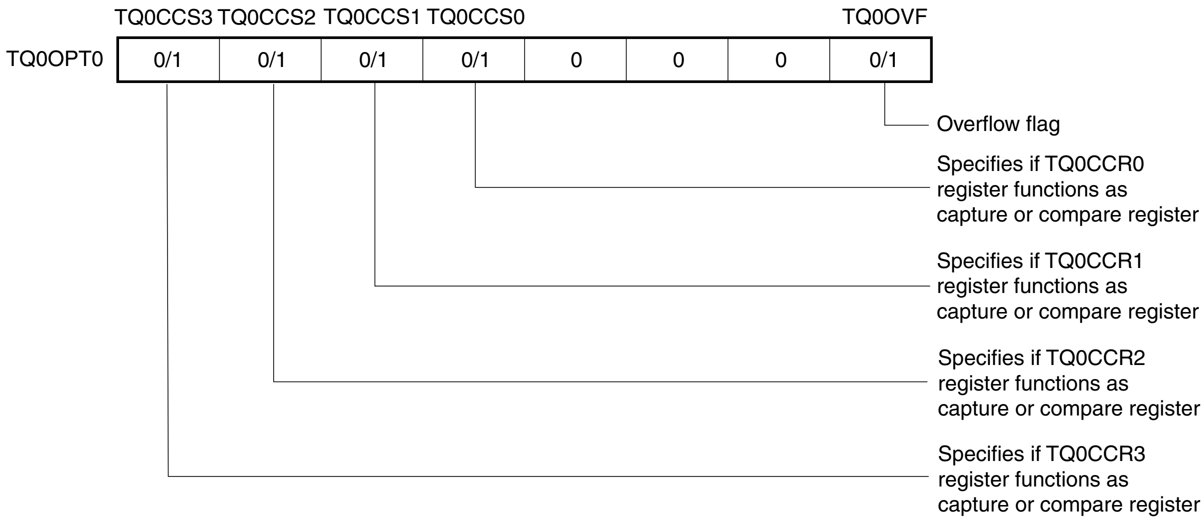


Figure 8-31. Register Setting in Free-Running Timer Mode (3/3)

(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_m is set to the TQ0CCRm register, the INTTQ0CCm signal is generated when the counter reaches (D_m + 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)

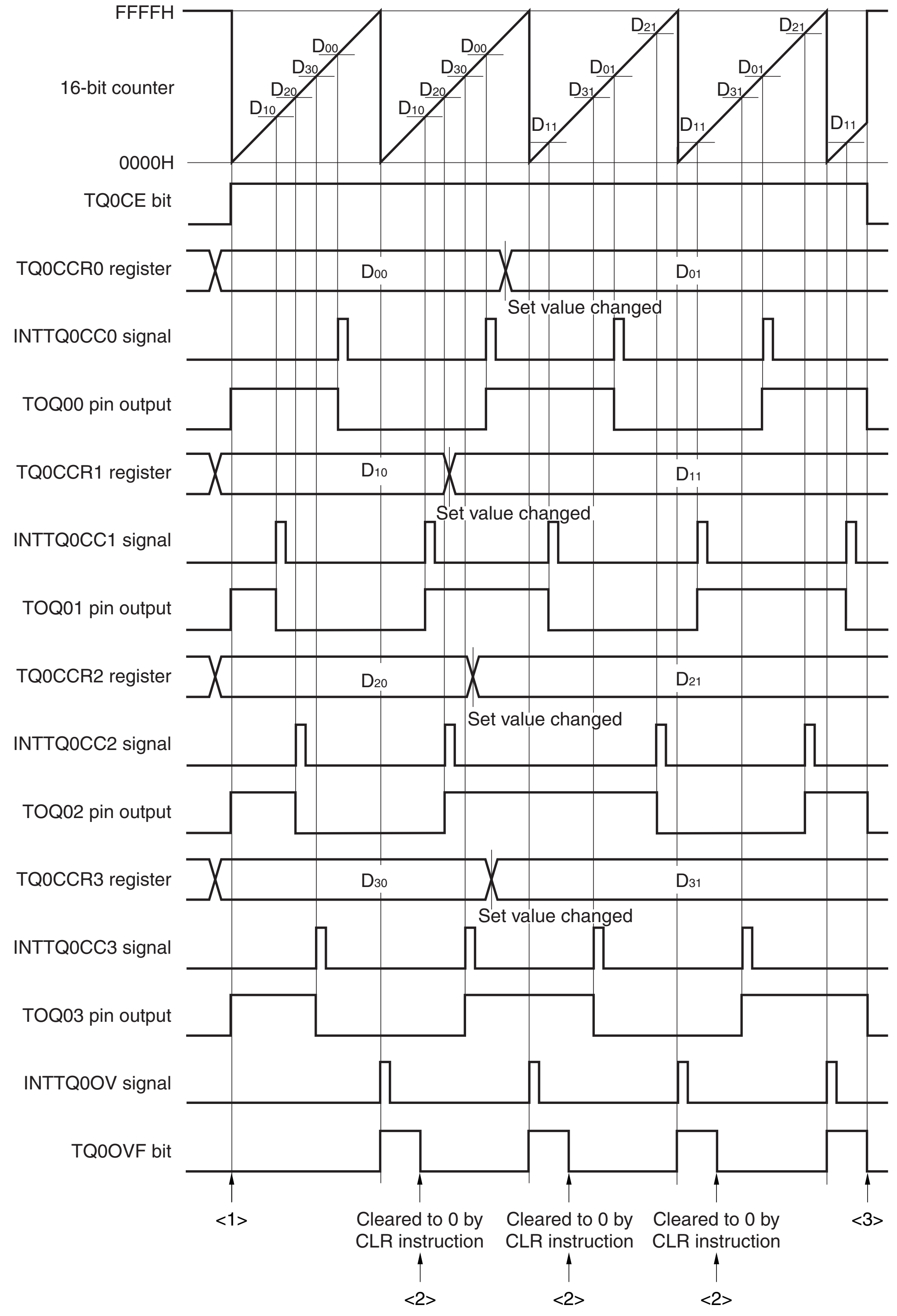
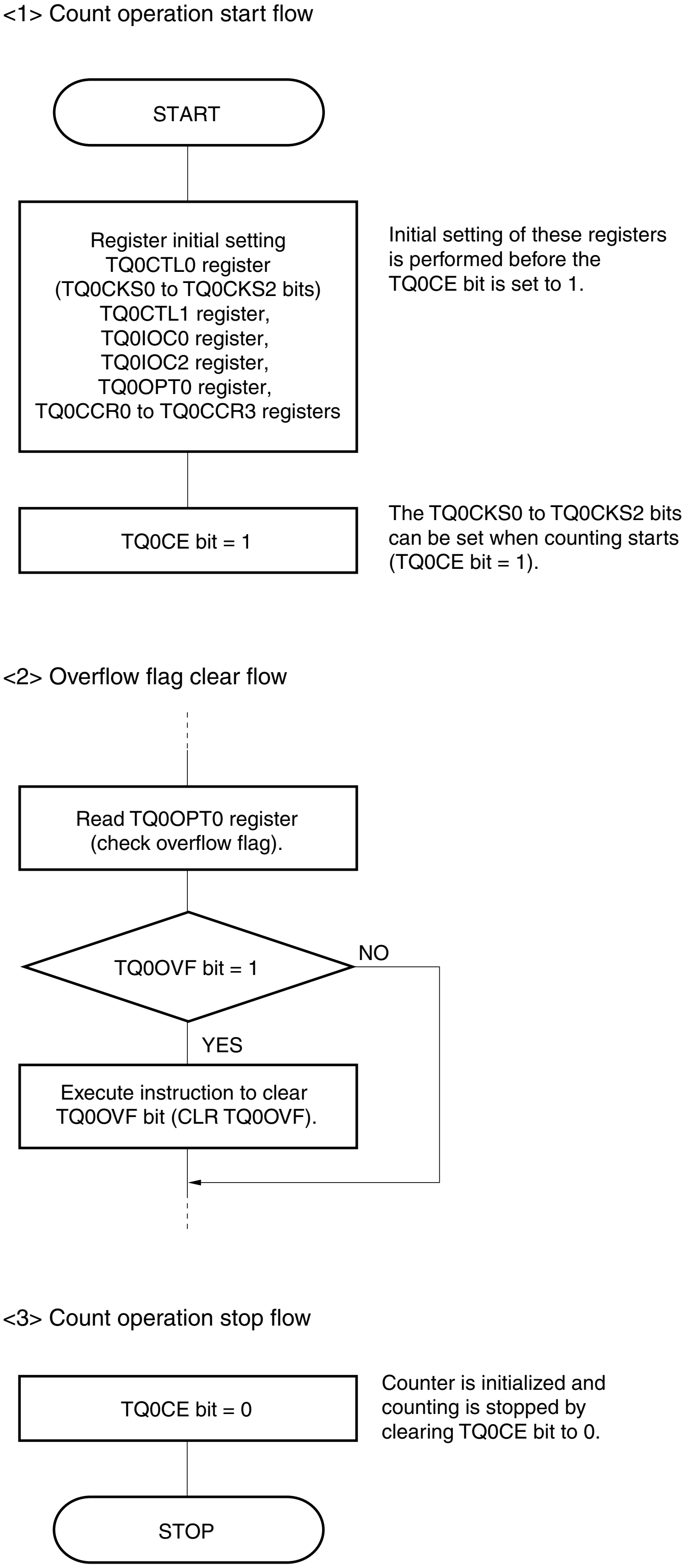


Figure 8-32. Software Processing Flow in Free-Running Timer Mode (Compare Function) (2/2)



Initial setting of these registers is performed before the TQ0CE bit is set to 1.

The TQ0CKS0 to TQ0CKS2 bits can be set when counting starts (TQ0CE bit = 1).

Counter is initialized and counting is stopped by clearing TQ0CE bit to 0.

(b) When using capture/compare register as capture register

Figure 8-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (1/2)

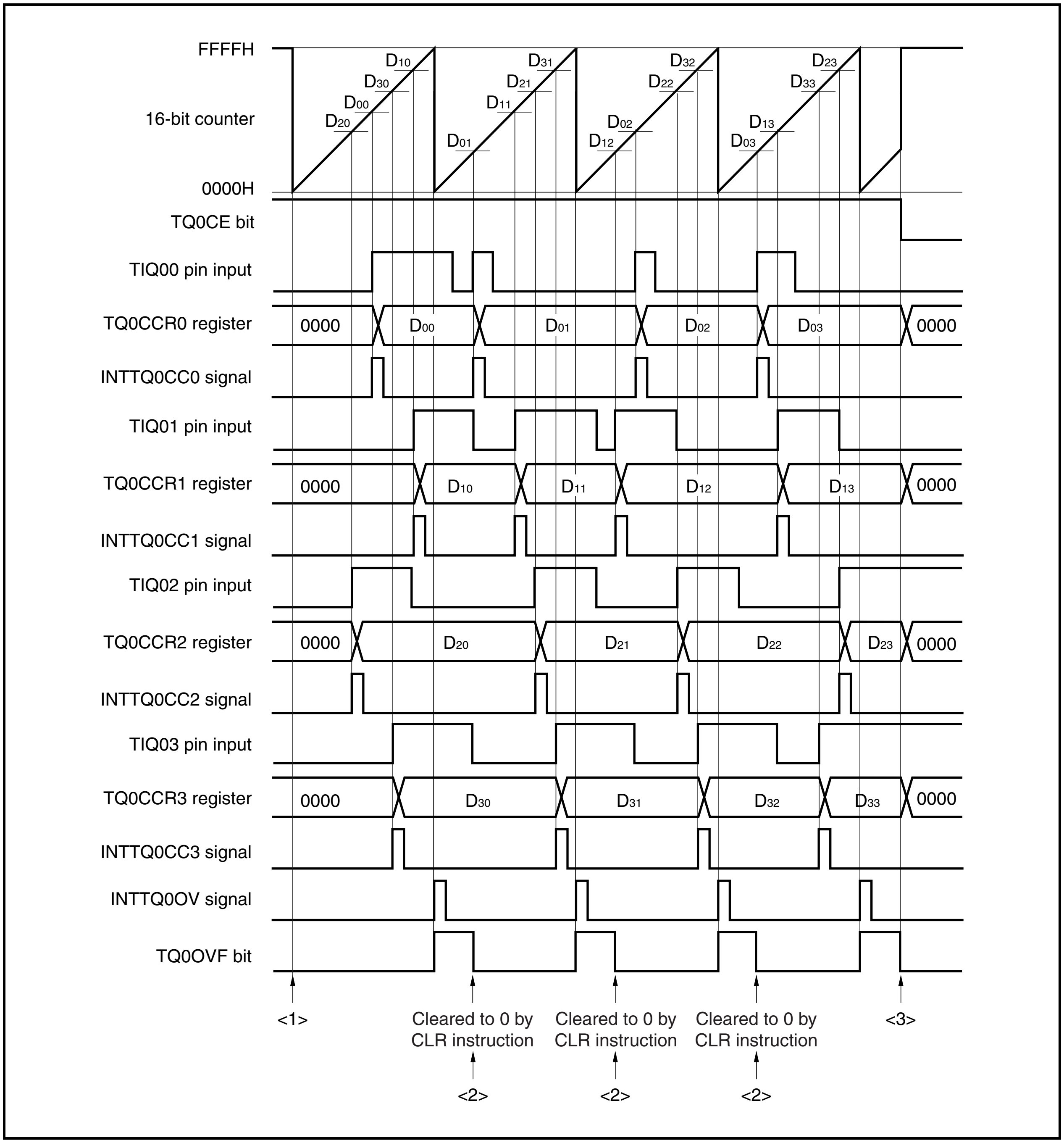
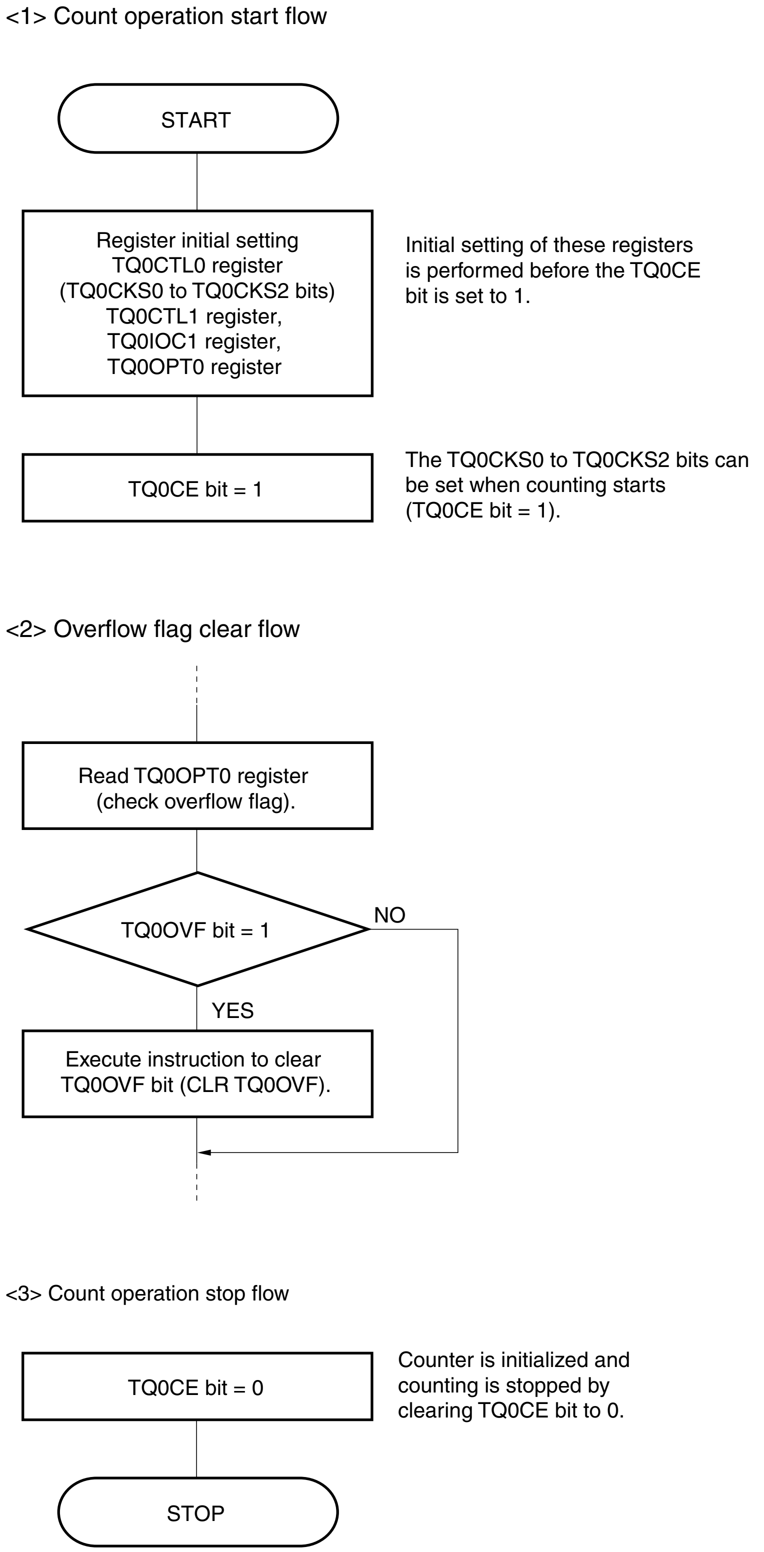


Figure 8-33. Software Processing Flow in Free-Running Timer Mode (Capture Function) (2/2)



Initial setting of these registers is performed before the TQ0CE bit is set to 1.

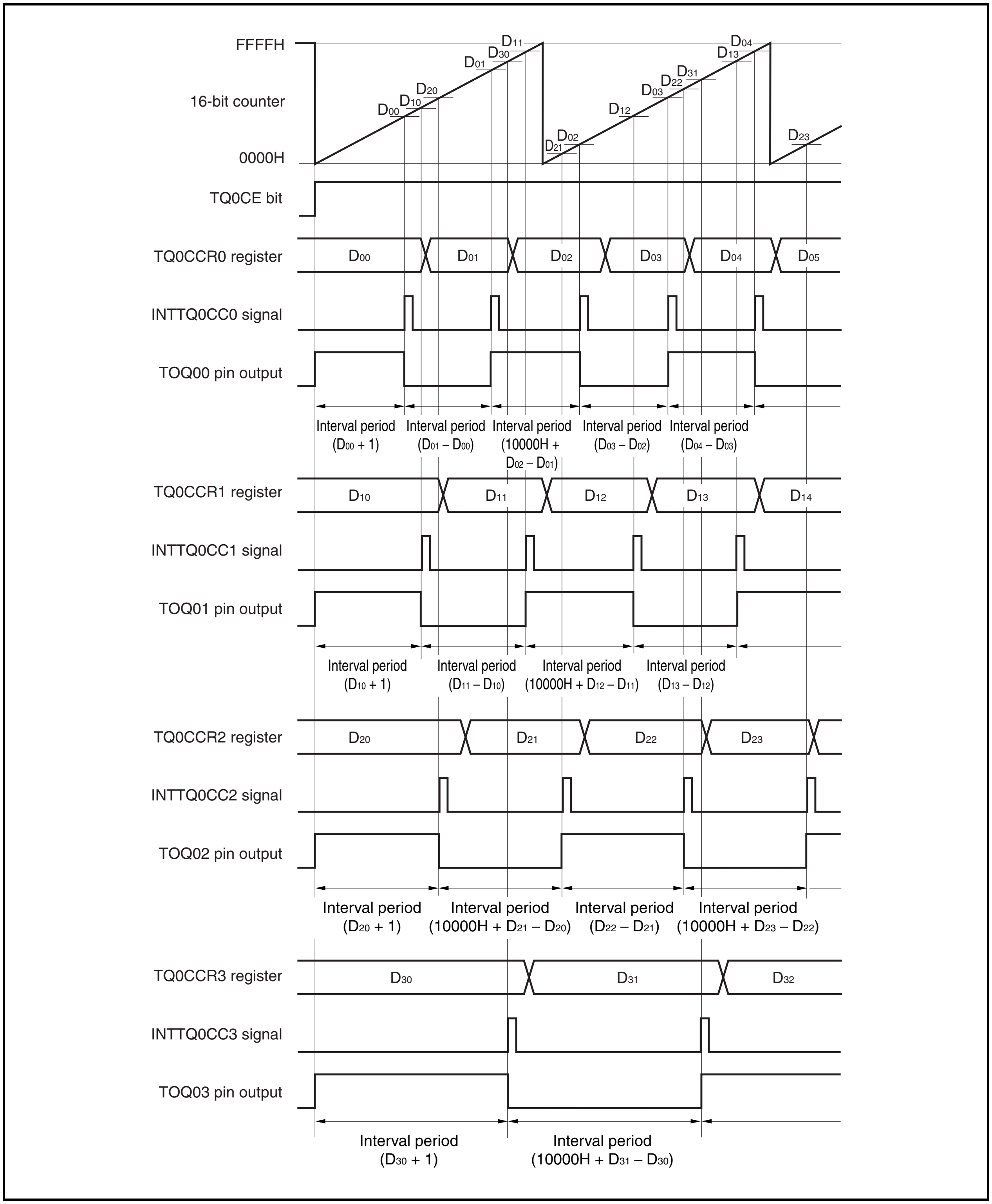
The TQ0CKS0 to TQ0CKS2 bits can be set when counting starts (TQ0CE bit = 1).

Counter is initialized and counting is stopped by clearing TQ0CE bit to 0.

(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.



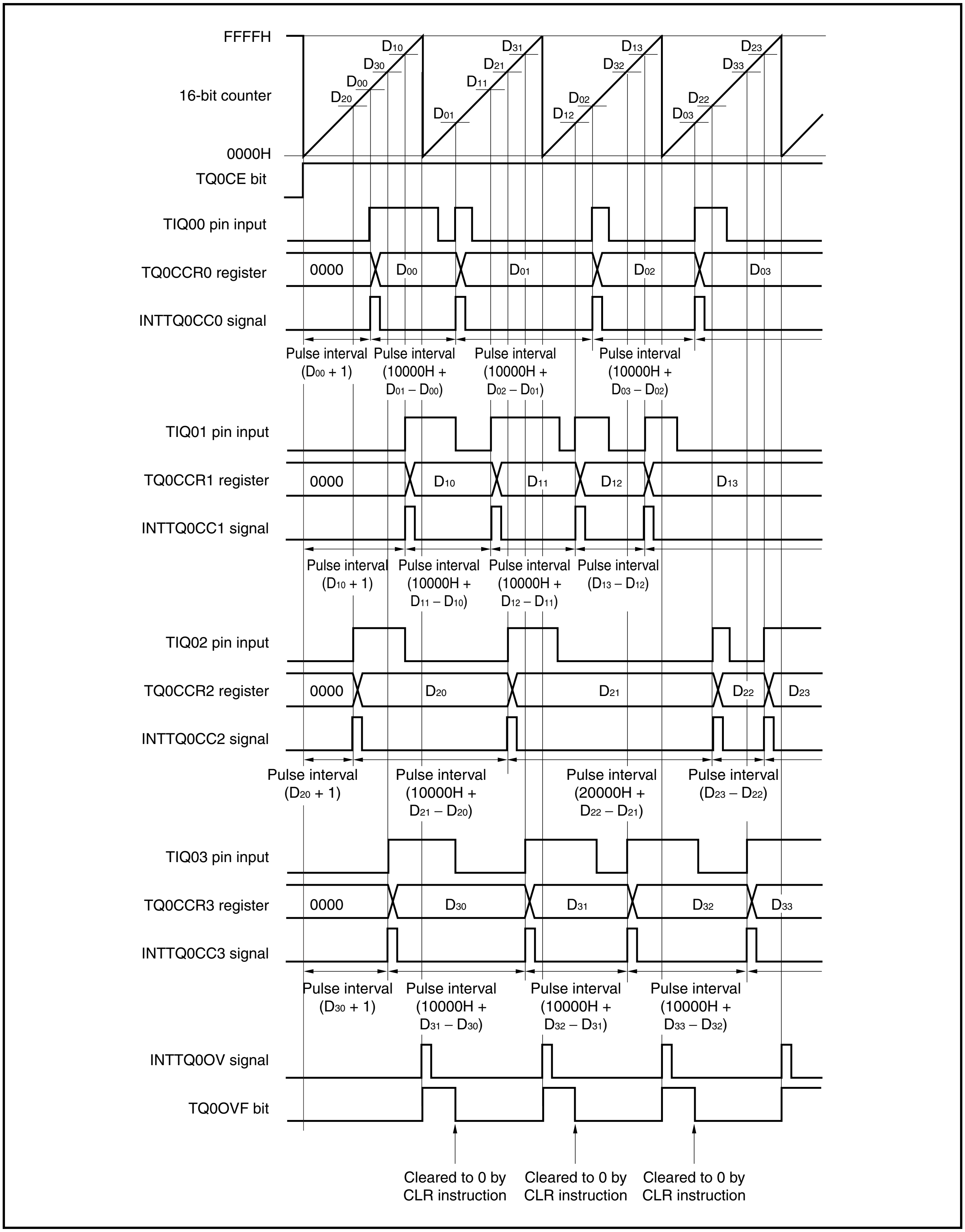
When performing an interval operation in the free-running timer mode, two intervals can be set with one channel.
To perform the interval operation, the value of the corresponding TQ0CCRm register must be re-set in the interrupt servicing that is executed when the INTTQ0CCm signal is detected.
The set value for re-setting the TQ0CCRm register can be calculated by the following expression, where "D_m" 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.

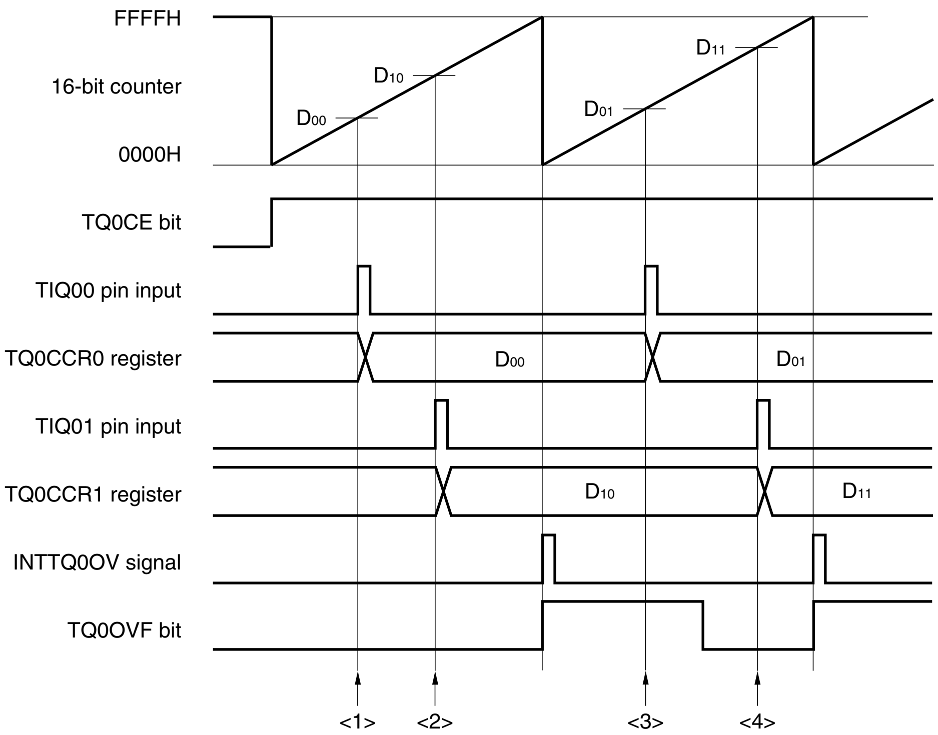
To measure a pulse width, the pulse width can be calculated by reading the value of the TQ0CCRm register in synchronization with the INTTQ0CCm signal, and calculating the difference between the read value and the previously read value.

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}).

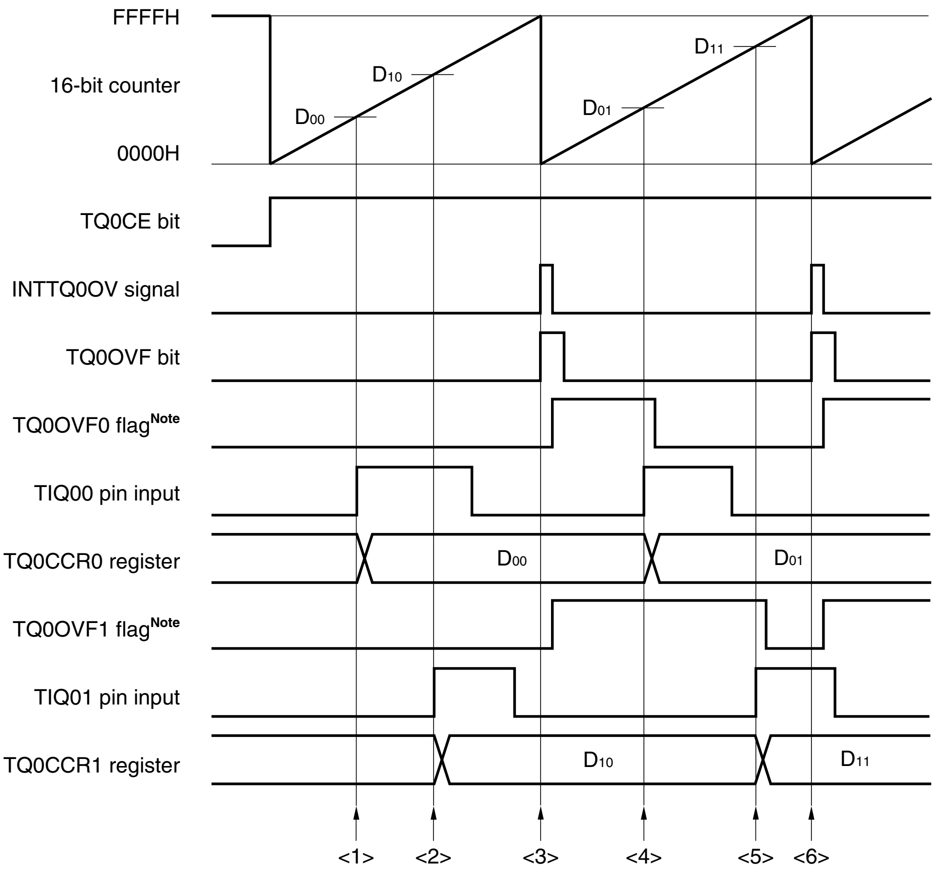
<4> Read the TQ0CCR1 register.
Read the overflow flag. Because the flag is cleared in <3>, 0 is read.
Because the overflow flag is 0, the pulse width can be calculated by (D_{11} – D_{10}) (incorrect).

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.

(1/2)

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.

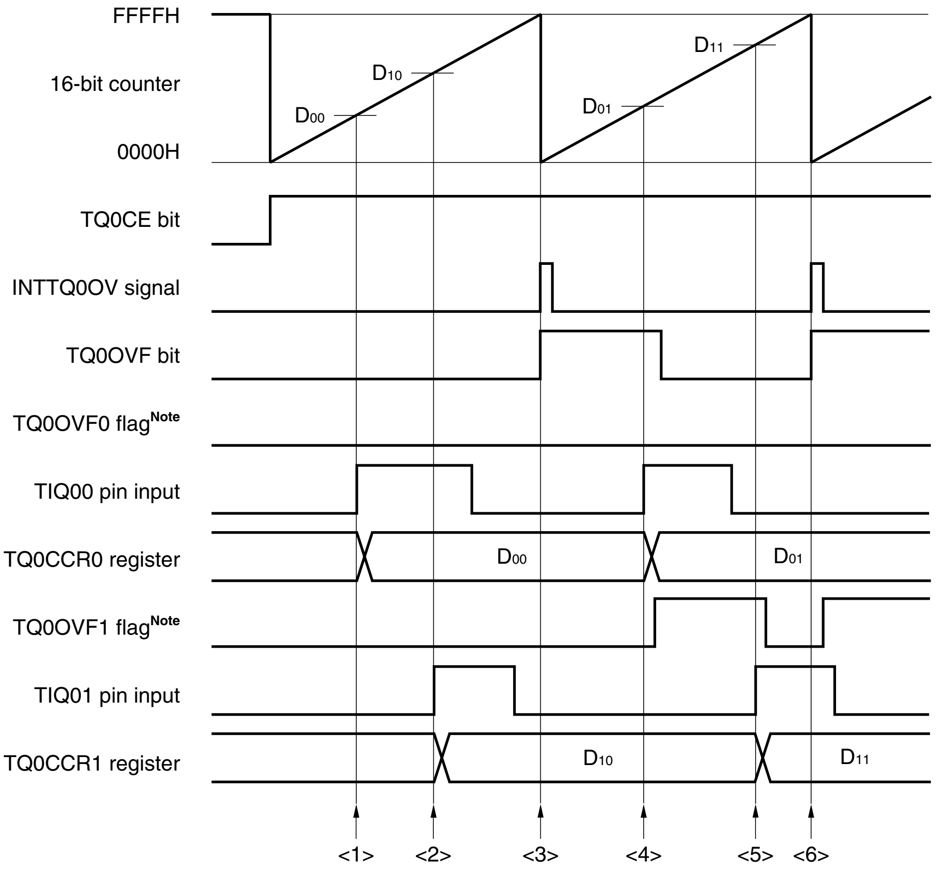
<4> Read the TQ0CCR0 register.
Read the TQ0OVF0 flag. If the TQ0OVF0 flag is 1, clear it to 0.
Because the TQ0OVF0 flag is 1, the pulse width can be calculated by (10000H + D_{01} – D_{00}).

<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>

(2/2)

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.

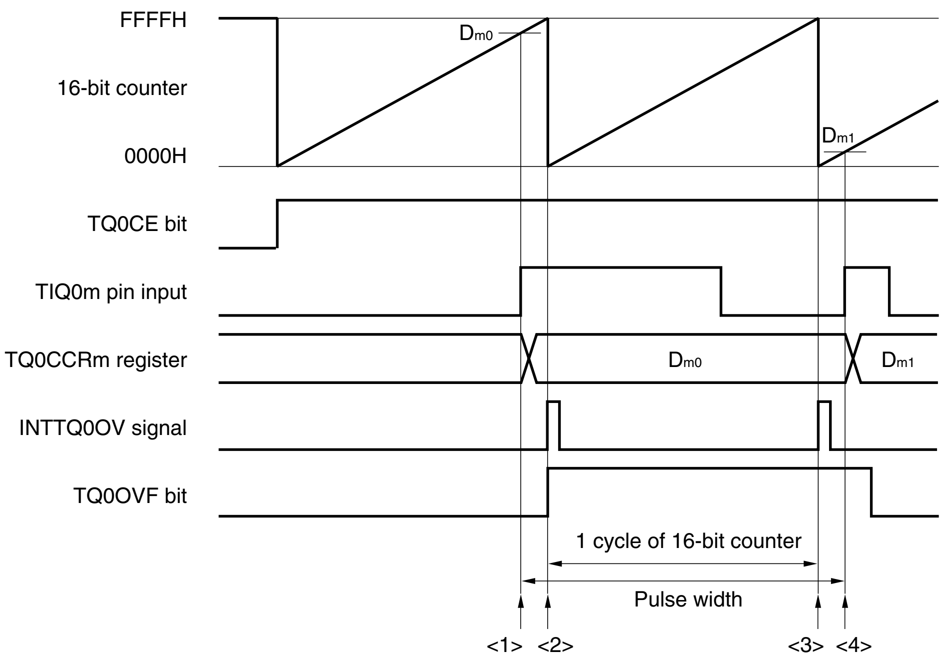
Because the TQ0OVF1 flag is 1, the pulse width can be calculated by (10000H + D_{11} – D_{10}) (correct).

<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.

Example of incorrect processing when capture trigger interval is long



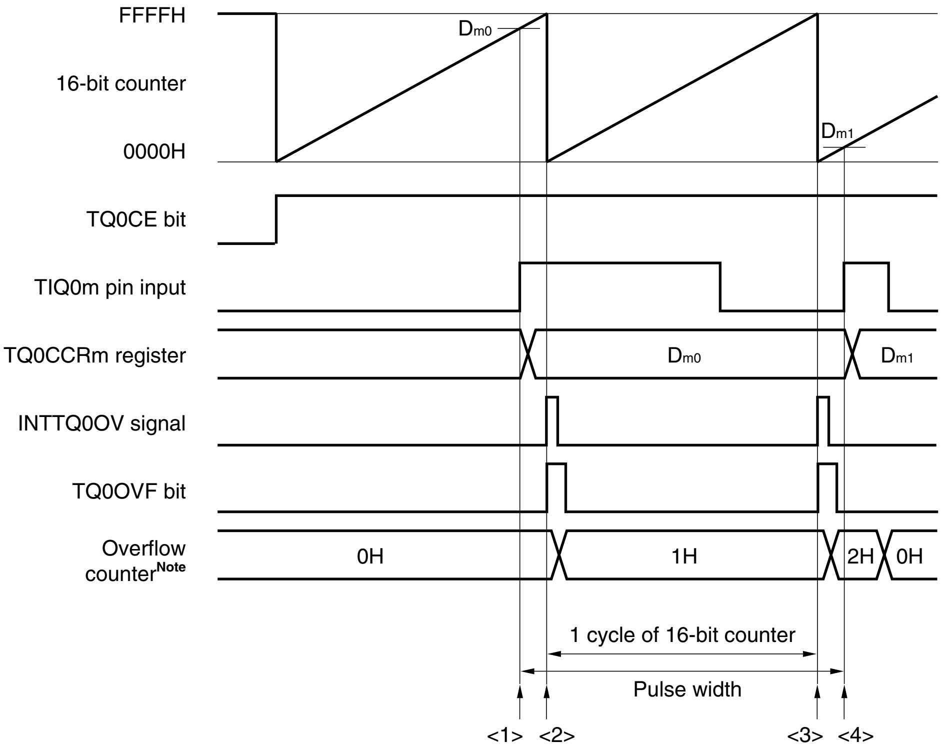
The following problem may occur when a long pulse width in the free-running timer mode.

<1> Read the TQ0CCRm register (setting of the default value of the TIQ0m pin input).
<2> An overflow occurs. Nothing is done by software.
<3> An overflow occurs a second time. Nothing is done by software.
<4> Read the TQ0CCRm 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_{m1} – D_{m0}) (incorrect).
Actually, the pulse width must be (20000H + D_{m1} – D_{m0}) because an overflow occurs twice.

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).

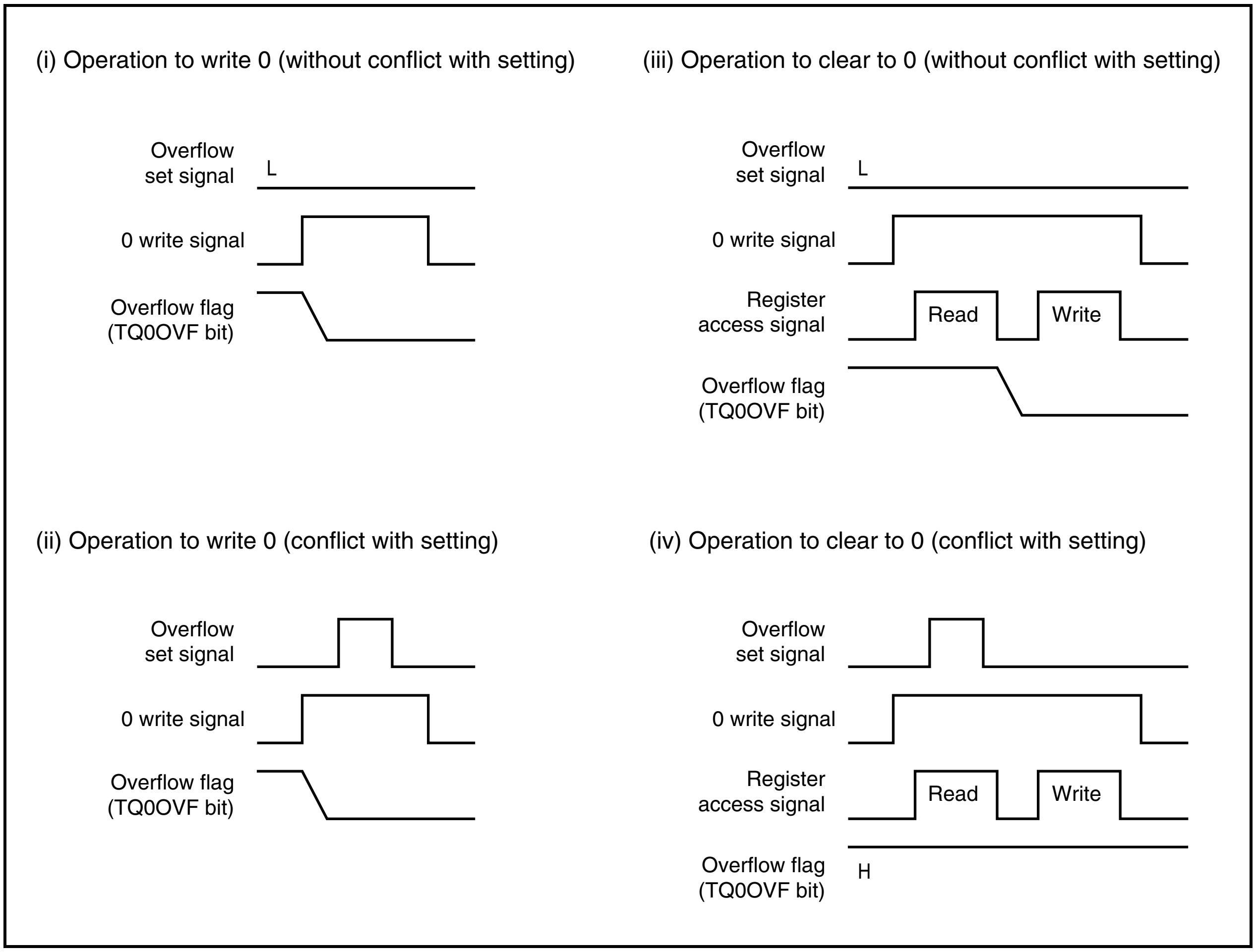
<2> An overflow occurs. Increment the overflow counter and clear the overflow flag to 0 in the overflow interrupt servicing.

<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 × 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

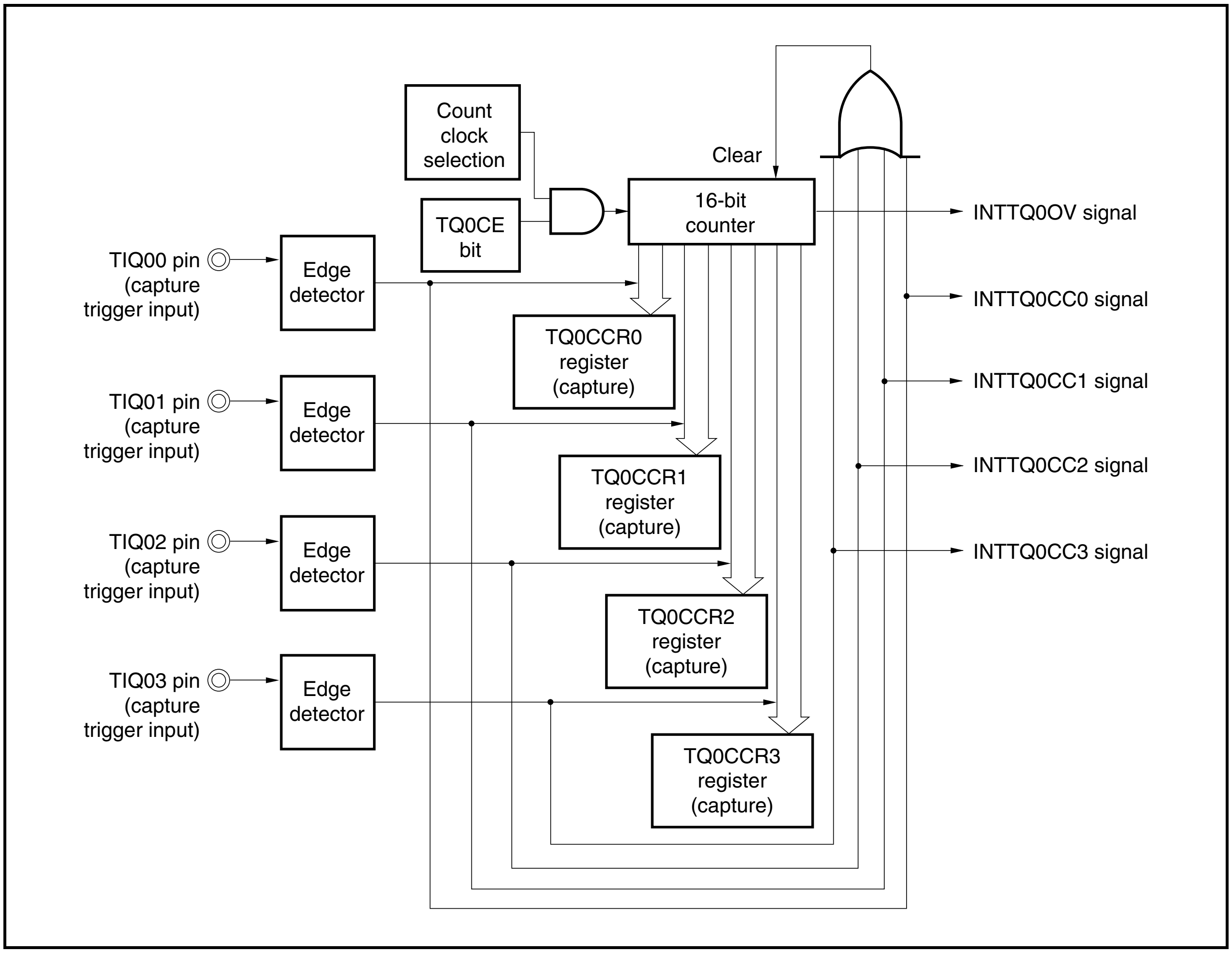
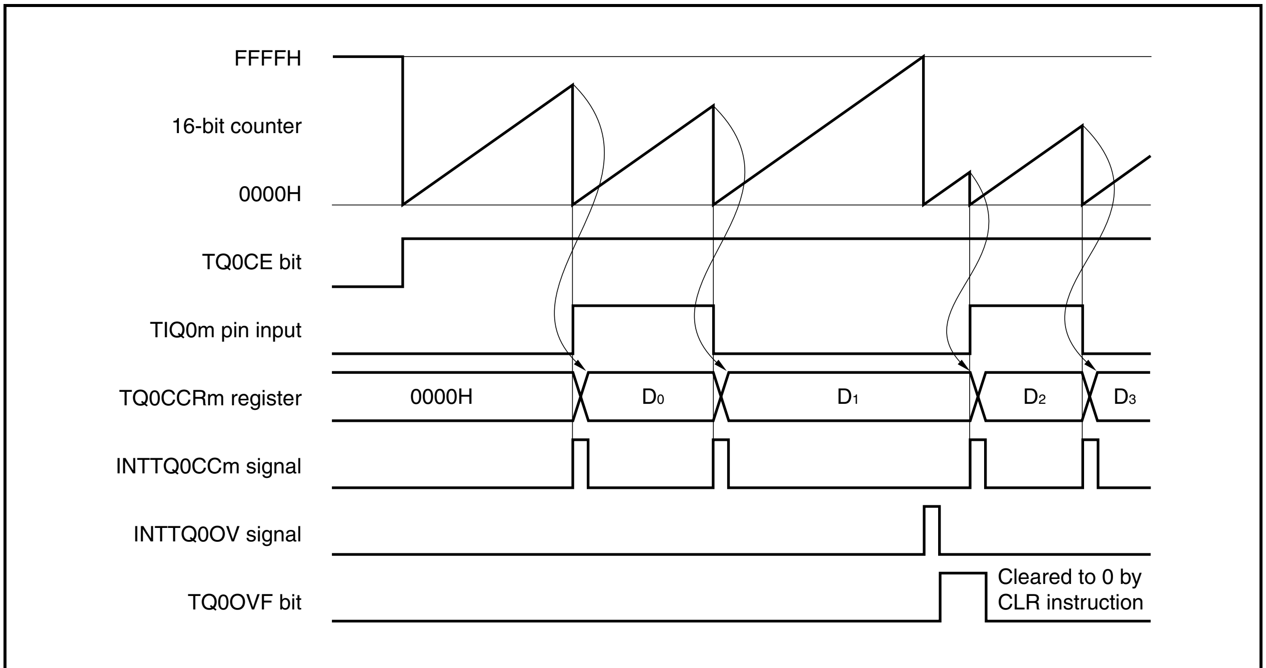


Figure 8-35. Basic Timing in Pulse Width Measurement Mode



Remark m = 0 to 3

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.

Pulse width = Captured value × 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.

Pulse width = (10000H × TQ0OVF bit set (1) count + Captured value) × Count clock cycle

Remark m = 0 to 3

Figure 8-36. Register Setting in Pulse Width Measurement Mode (1/2)

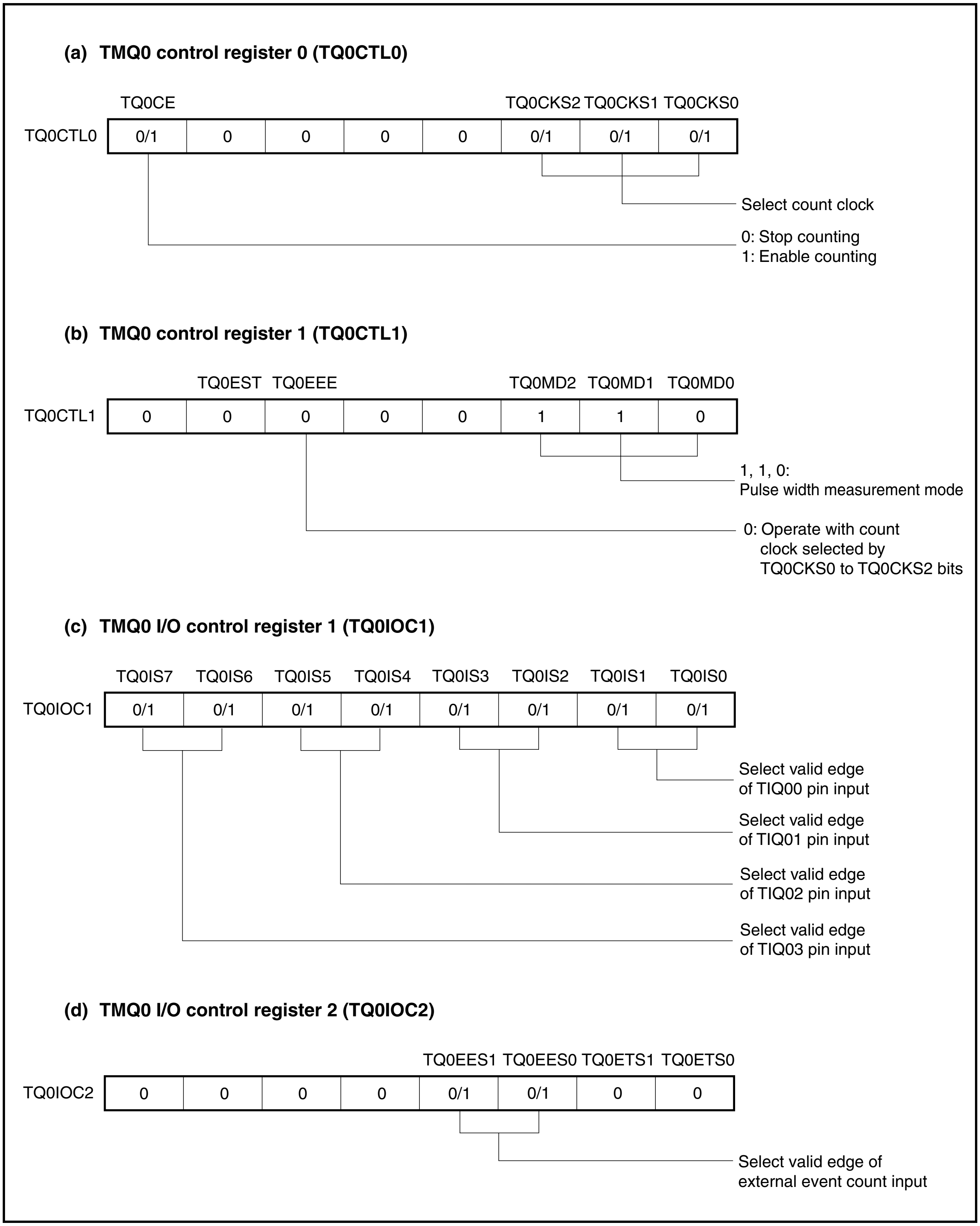


Figure 8-36. Register Setting in Pulse Width Measurement Mode (2/2)

(e) TMQ0 option register 0 (TQ0OPT0)

	TQ0CCS3	TQ0CCS2	TQ0CCS1	TQ0CCS0				TQ0OVF
TQ0OPT0	0	0	0	0	0	0	0	0/1

Overflow flag

(f) TMQ0 counter read buffer register (TQ0CNT)

The value of the 16-bit counter can be read by reading the TQ0CNT register.

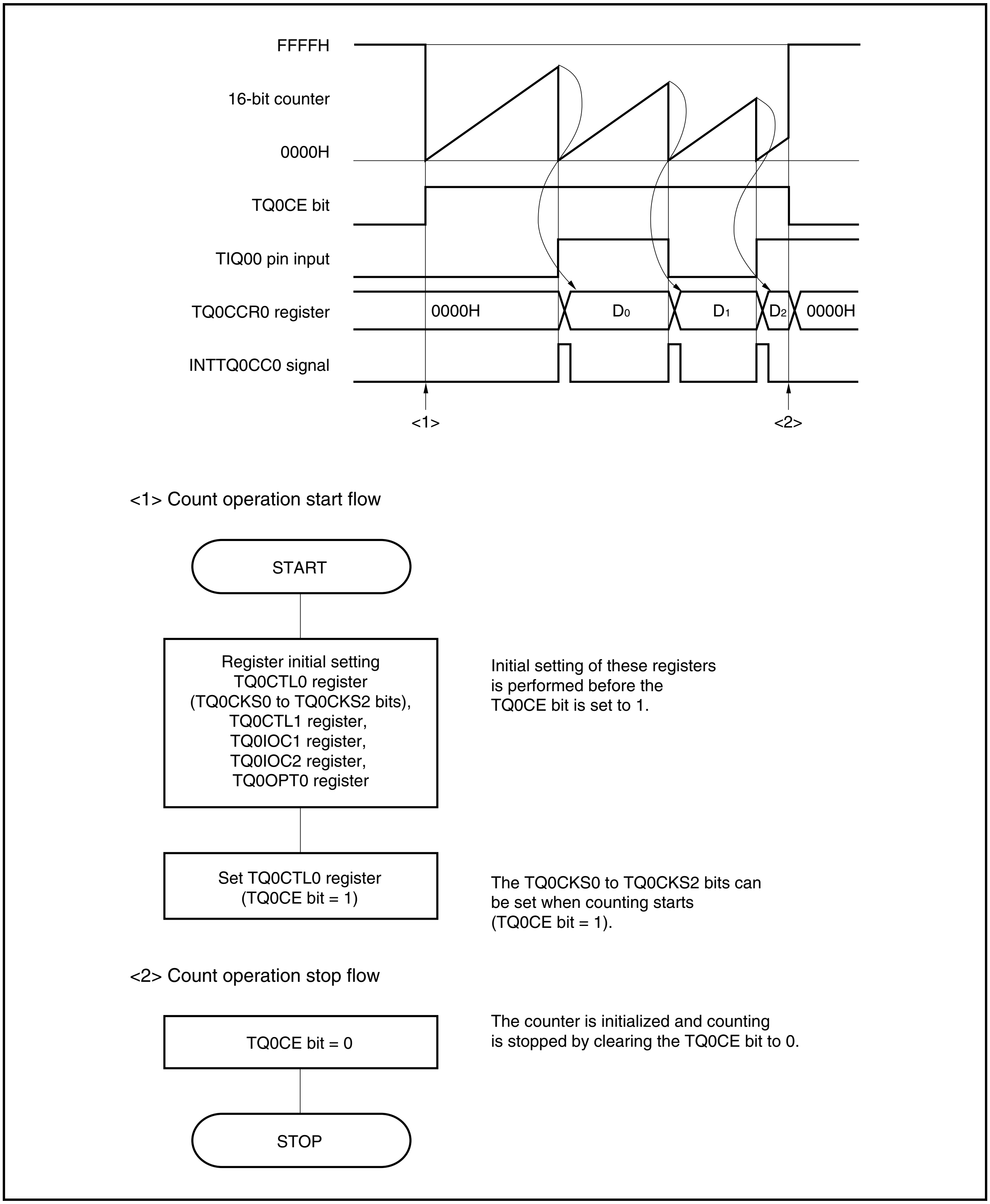
(g) TMQ0 capture/compare registers 0 to 3 (TQ0CCR0 to TQ0CCR3)

These registers store the count value of the 16-bit counter when the valid edge input to the TIQ0m pin is detected.

Remarks **1.** TMQ0 I/O control register 0 (TQ0IOC0) is not used in the pulse width measurement mode.
2. m = 0 to 3

(1) Operation flow in pulse width measurement mode

Figure 8-37. Software Processing Flow in Pulse Width Measurement Mode



Initial setting of these registers is performed before the TQ0CE bit is set to 1.

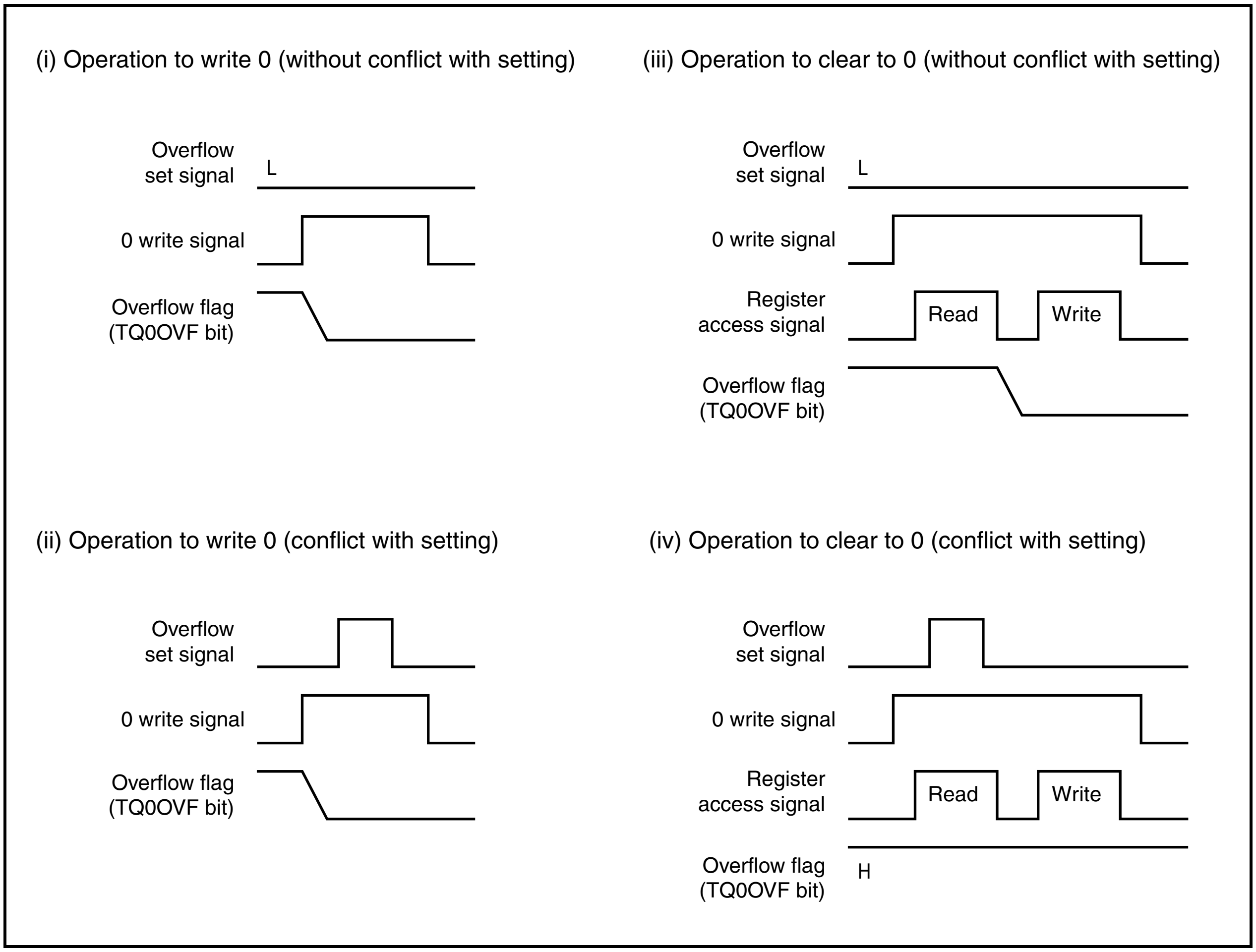
The TQ0CKS0 to TQ0CKS2 bits can be set when counting starts (TQ0CE bit = 1).

The counter is initialized and counting is stopped by clearing the TQ0CE bit to 0.

(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	–			
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

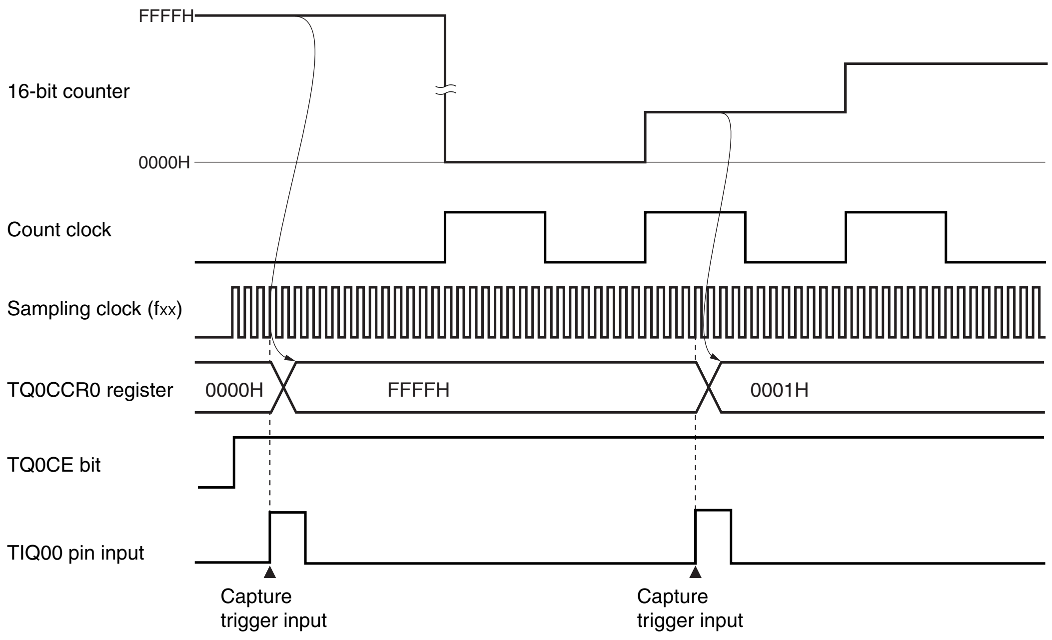
8.6 Cautions

(1) Capture operation

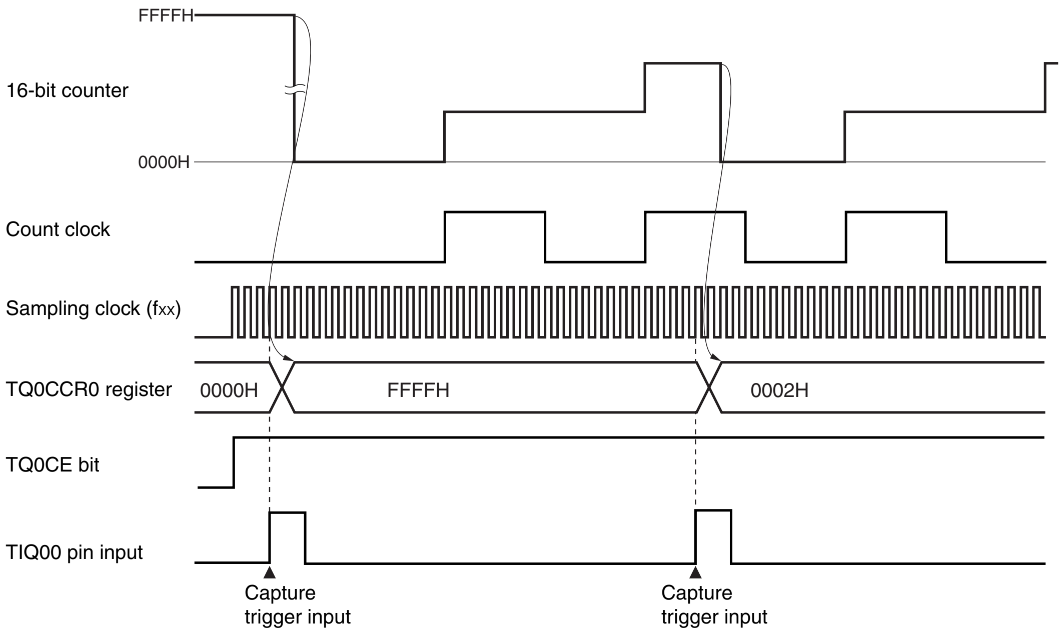
When the capture operation is used and a slow clock is selected as the count clock, FFFFH, not 0000H, may be captured in the TQ0CCR0, TQ0CCR1, TQ0CCR2, and TQ0CCR3 registers, or the capture operation may not be performed (capture interrupt does not occur) if the capture trigger is input immediately after the TQ0CE bit is set to 1.

The same operation results during the period in which no external event counts are input while the capture operation is used and an external event count input is used as a count clock.

(a) Free-running timer mode



(b) Pulse width measurement mode



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.

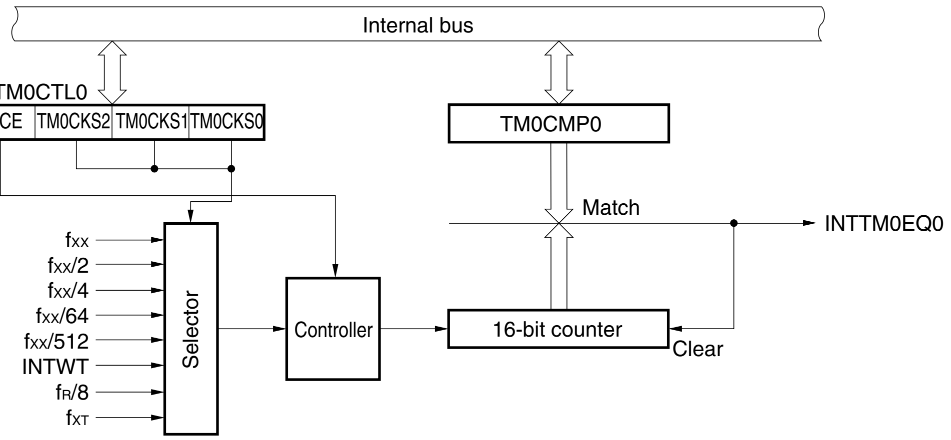
9.2 Configuration

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



Remark fXX: Main clock frequency
fR: Internal oscillation clock frequency
fXT: Subclock frequency
INTWT: Watch timer interrupt request signal

(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.

After reset: 0000H R/W Address: FFFFF694H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TM0CMP0																

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	TM0CE	0	0	0	0	TM0CKS2	TM0CKS1	TM0CKS0

TM0CE	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 TM0CE bit. When the TM0CE 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_{XX}
0	0	1	$f_{XX}/2$
0	1	0	$f_{XX}/4$
0	1	1	$f_{XX}/64$
1	0	0	$f_{XX}/512$
1	0	1	INTWT
1	1	0	$f_R/8$
1	1	1	f_{XT}

Cautions 1. Set the TM0CKS2 to TM0CKS0 bits when TM0CE bit = 0.
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.

2. Be sure to clear bits 3 to 6 to “0”.

Remark f_{XX}: Main clock frequency
f_R: Internal oscillation clock frequency
f_{XT}: 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 TM0CTL0.TM0CE bit is set to 1.

Figure 9-2. Configuration of Interval Timer

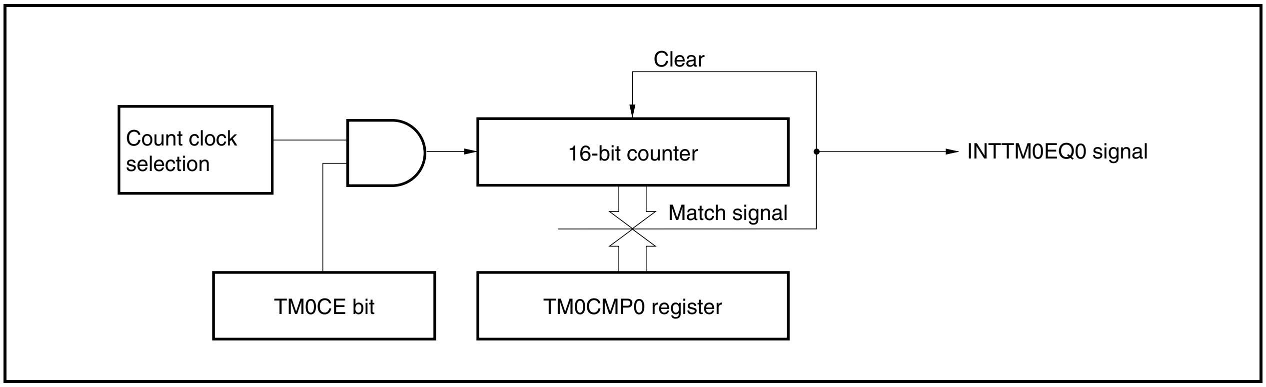
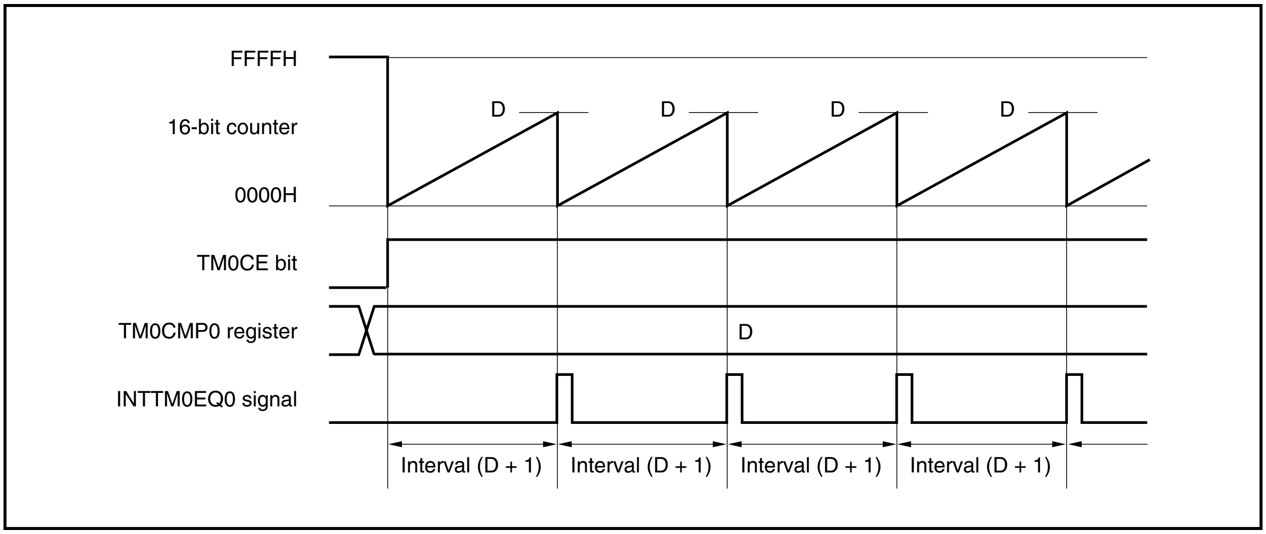


Figure 9-3. Basic Timing of Operation in Interval Timer Mode



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.

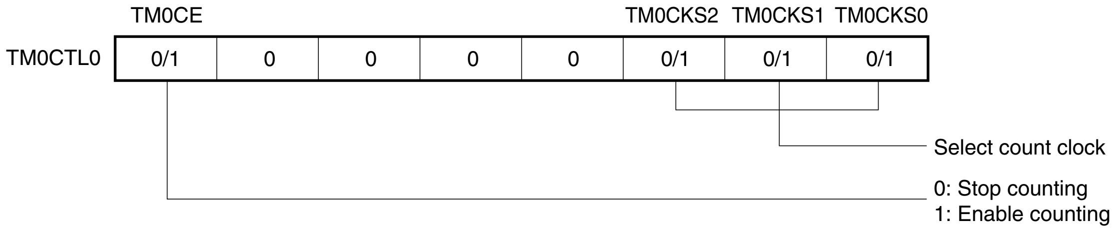
When the count value of the 16-bit counter matches the value of the TM0CMP0 register, the 16-bit counter is cleared to 0000H and a compare match interrupt request signal (INTTM0EQ0) is generated.

The interval can be calculated by the following expression.

Interval = (Set value of TM0CMP0 register + 1) × Count clock cycle

Figure 9-4. Register Setting for Interval Timer Mode Operation

(a) TMM0 control register 0 (TM0CTL0)



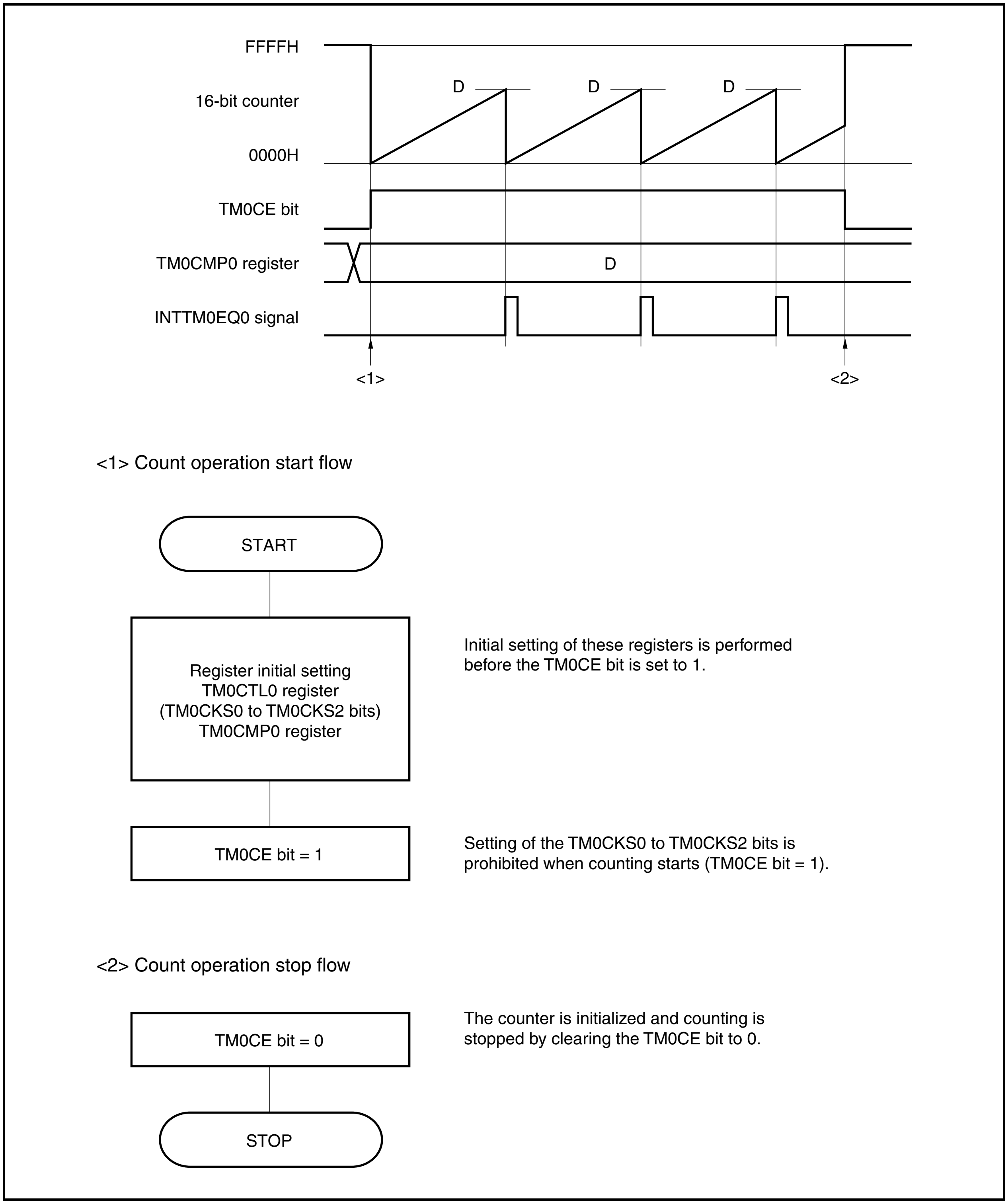
(b) TMM0 compare register 0 (TM0CMP0)

If the TM0CMP0 register is set to D, the interval is as follows.

Interval = (D + 1) × Count clock cycle

(1) Interval timer mode operation flow

Figure 9-5. Software Processing Flow in Interval Timer Mode



Initial setting of these registers is performed before the TM0CE bit is set to 1.

Setting of the TM0CKS0 to TM0CKS2 bits is prohibited when counting starts (TM0CE bit = 1).

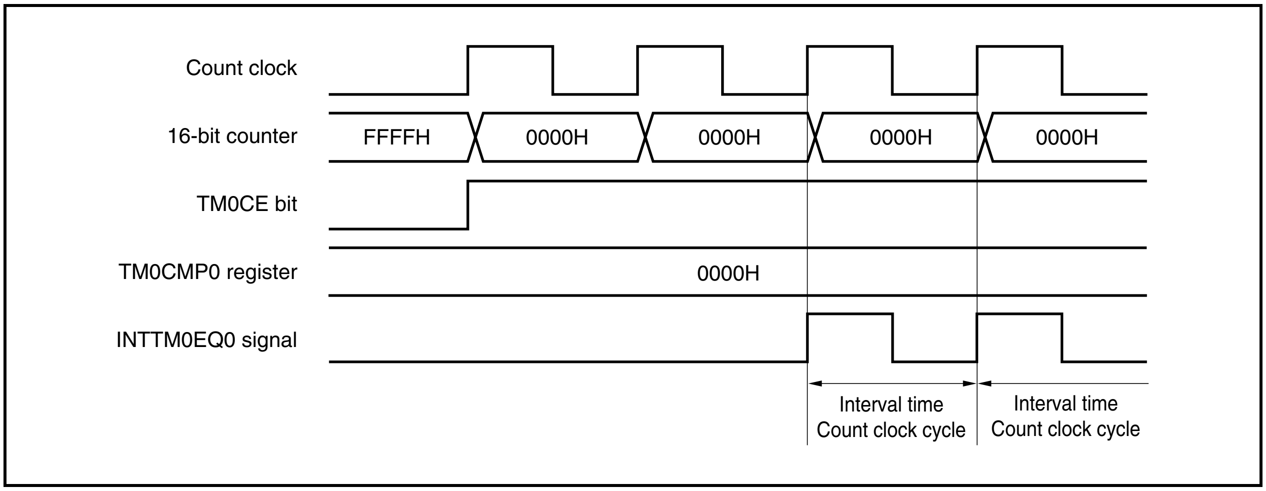
The counter is initialized and counting is stopped by clearing the TM0CE bit to 0.

(2) Interval timer mode operation timing

Caution **Do not set the TM0CMP0 register to FFFFH.**

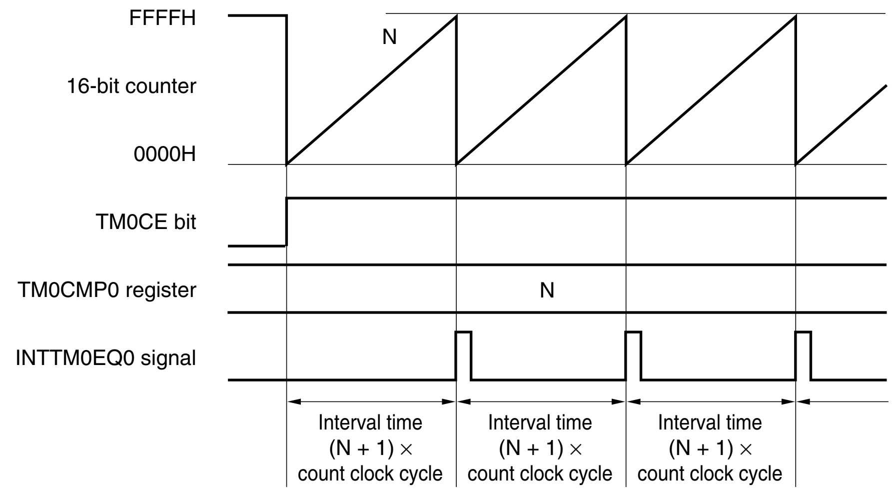
(a) Operation if TM0CMP0 register is set to 0000H

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.



Remark 0000H < N < FFFFH

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.

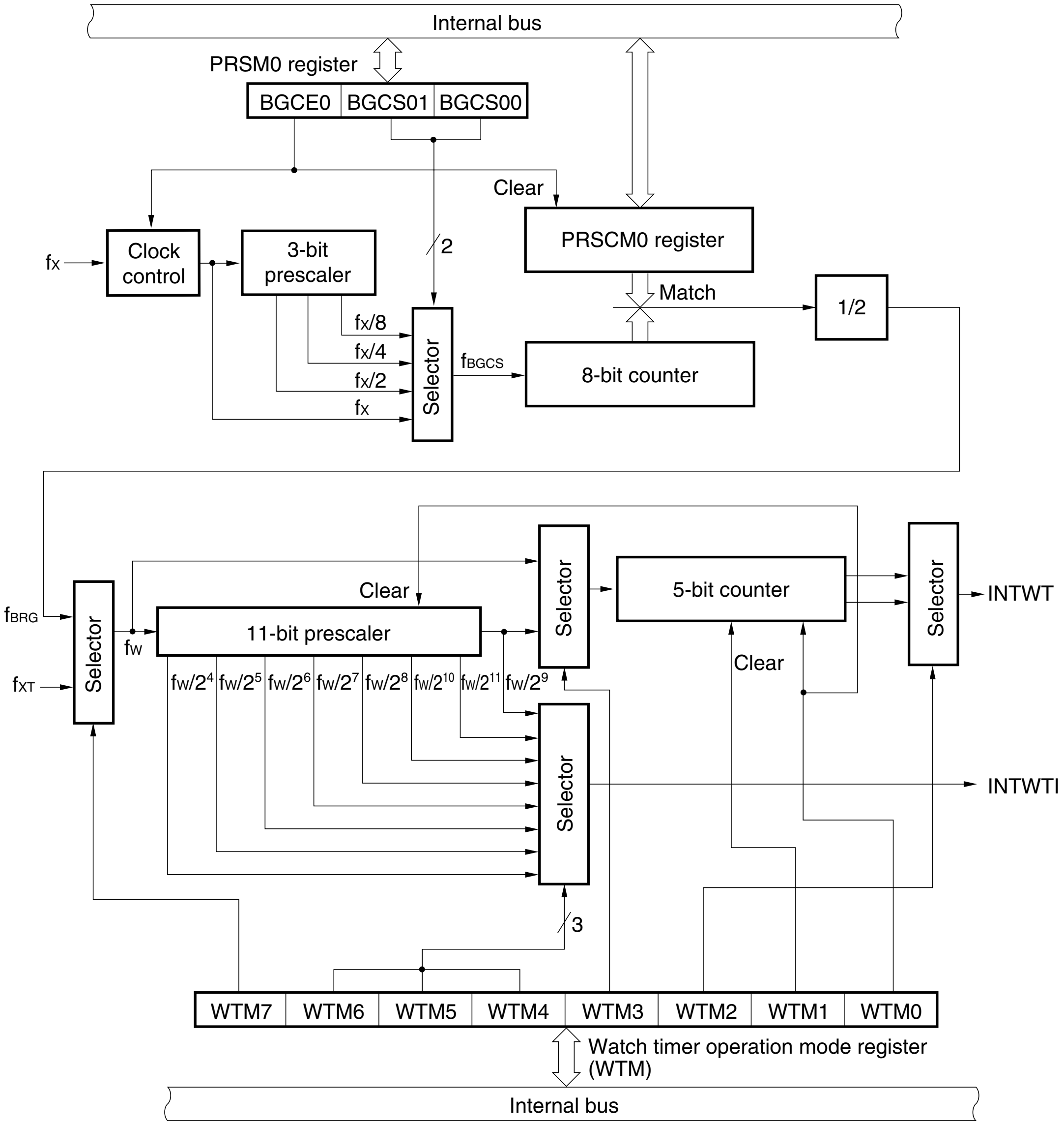
- Watch timer: An interrupt request signal (INTWT) is generated at intervals of 0.5 or 0.25 seconds by using the main clock or subclock.
- Interval timer: An interrupt request signal (INTWTI) is generated at set intervals.

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



Remark

f_X:	Main clock oscillation frequency
f_{BGCS}:	Watch timer source clock frequency
f_{BRG}:	Watch timer count clock frequency
f_{XT}:	Subclock frequency
f_W:	Watch timer clock frequency
INTWT:	Watch timer interrupt request signal
INTWTI:	Interval timer interrupt request signal

(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_{BGCS}).

(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 $2^4/f_W$, $2^{13}/f_W$, $2^5/f_W$, 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 μs
1	1	$f_X/8$	1.6 μs	2 μs

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: FFFFF8B1H

	7	6	5	4	3	2	1	0
PRSCM0	PRSCM07	PRSCM06	PRSCM05	PRSCM04	PRSCM03	PRSCM02	PRSCM01	PRSCM00

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 the PRSCM0 register = 1 to 256

However, N = 256 when the 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>
WTM	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 μs: $f_W = f_{XT}$)
0	0	0	1	$2^5/f_W$ (977 μs: $f_W = f_{XT}$)
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 μs: $f_W = f_{BRG}$)
1	0	0	1	$2^5/f_W$ (977 μs: $f_W = f_{BRG}$)
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: $f_W = f_{BRG}$)

(2/2)

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 μs: $f_W = f_{XT}$)
0	1	1	$2^{4}/f_W$ (488 μs: $f_W = f_{XT}$)
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 μs: $f_W = f_{BRG}$)
1	1	1	$2^{4}/f_W$ (488 μs: $f_W = f_{BRG}$)

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.

$$f_{BRG} = fx/(2^{m+1} \times N)$$

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 = fx/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 fx = 4.00 MHz

<1> N = 4,000,000/65,536 = 61.03…, 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.

$$f_{BRG} = fx/(2^{m+1} \times N) = 4{,}000{,}000/(2 \times 61)$$
$$= 32.787 \text{ kHz}$$

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 when PRSCM0 register is set to 00H.

fx: 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.

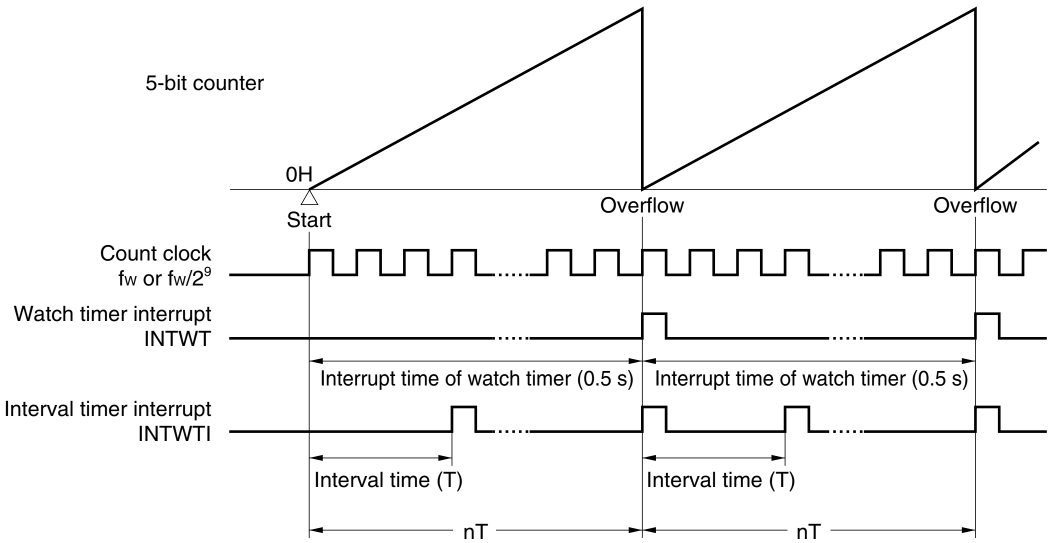
The interval time can be selected by the WTM4 to WTM7 bits of the WTM register.

Table 10-1. Interval Time of Interval Timer

WTM7	WTM6	WTM5	WTM4	Interval Time	
0	0	0	0	2^4 × 1/fw	488 μs (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	0	0	1	2^5 × 1/fw	977 μs (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	0	1	0	2^6 × 1/fw	1.95 ms (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	0	1	1	2^7 × 1/fw	3.91 ms (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	1	0	0	2^8 × 1/fw	7.81 ms (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	1	0	1	2^9 × 1/fw	15.6 ms (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	1	1	0	2^{10} × 1/fw	31.3 ms (operating at $f_W = f_{XT}$ = 32.768 kHz)
0	1	1	1	2^{11} × 1/fw	62.5 ms (operating at $f_W = f_{XT}$ = 32.768 kHz)
1	0	0	0	2^4 × 1/fw	488 μs (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	0	0	1	2^5 × 1/fw	977 μs (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	0	1	0	2^6 × 1/fw	1.95 ms (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	0	1	1	2^7 × 1/fw	3.91 ms (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	1	0	0	2^8 × 1/fw	7.81 ms (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	1	0	1	2^9 × 1/fw	15.6 ms (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	1	1	0	2^{10} × 1/fw	31.3 ms (operating at $f_W = f_{BRG}$ = 32.768 kHz)
1	1	1	1	2^{11} × 1/fw	62.5 ms (operating at $f_W = f_{BRG}$ = 32.768 kHz)

Remark f_W: Watch timer clock frequency

Figure 10-2. Operation Timing of Watch Timer/Interval Timer



Remarks 1. When 0.5 seconds of the watch timer interrupt time is set.

2. fw: Watch timer clock frequency

Values in parentheses apply to operation with fw = 32.768 kHz.

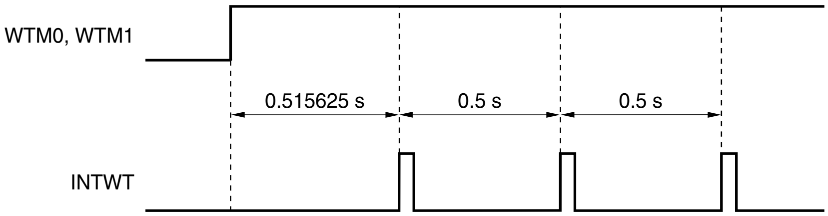
n: Number of interval timer operations

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)

It takes 0.515625 seconds (max.) for the first INTWT signal to be generated ($2^9 \times 1/32768 = 0.015625$ seconds longer (max.)). The INTWT signal is then generated every 0.5 seconds.



CHAPTER 11 FUNCTIONS OF WATCHDOG TIMER 2

11.1 Functions

Watchdog timer 2 has the following functions.

- Default-start watchdog timer[Note 1]
  → 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)[Note 2]
- Input selectable from main clock, internal oscillation clock, and subclock as the source clock

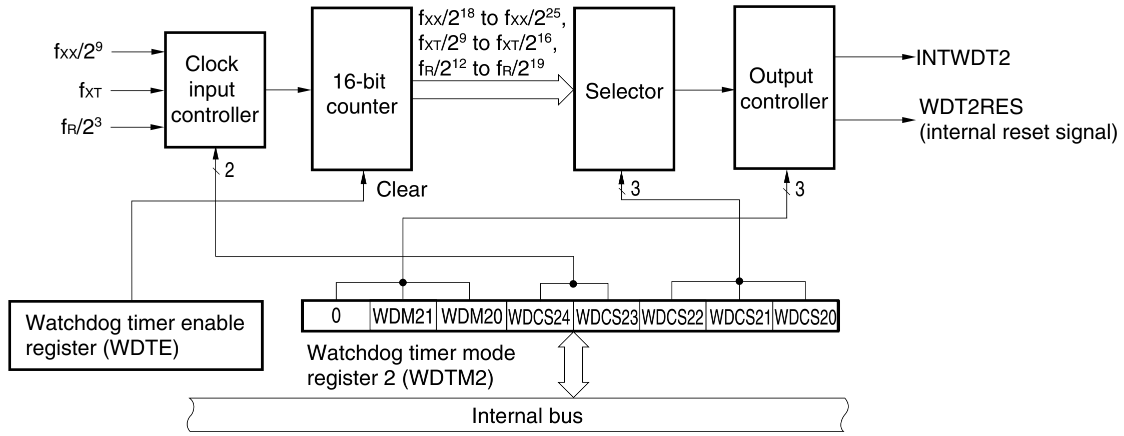
Notes 1. Watchdog timer 2 automatically starts in the reset mode following reset release.
When watchdog timer 2 is not used, either stop its operation before reset is executed via this function, or clear watchdog timer 2 once and stop it within the next interval time.
Also, write to the WDTM2 register 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



Remark f_{XX}: Main clock frequency

f_{XT}: Subclock frequency

f_R: Internal oscillation clock frequency

INTWDT2: Non-maskable interrupt request signal from watchdog timer 2

WDTRES2: Watchdog timer 2 reset signal

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) 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

	7	6	5	4	3	2	1	0
WDTM2	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 (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 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^n/fxx 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	1191.6 ms	655.4 ms
0	0	1	1	1	$2^{19}/f_R$	5,242.9 ms	2383.1 ms	1,310.7 ms
						f_{XX} = 20 MHz	f_{XX} = 16 MHz	f_{XX} = 10 MHz
0	1	0	0	0	$2^{18}/f_{XX}$	13.1 ms	16.4 ms	26.2 ms
0	1	0	0	1	$2^{19}/f_{XX}$	26.2 ms	32.8 ms	52.4 ms
0	1	0	1	0	$2^{20}/f_{XX}$	52.4 ms	65.5 ms	104.9 ms
0	1	0	1	1	$2^{21}/f_{XX}$	104.9 ms	131.1 ms	209.7 ms
0	1	1	0	0	$2^{22}/f_{XX}$	209.7 ms	262.1 ms	419.4 ms
0	1	1	0	1	$2^{23}/f_{XX}$	419.4 ms	524.3 ms	838.9 ms
0	1	1	1	0	$2^{24}/f_{XX}$	838.9 ms	1,048.6 ms	1,677.7 ms
0	1	1	1	1	$2^{25}/f_{XX}$	1,677.7 ms	2,097.2 ms	3,355.4 ms
						f_{XT} = 32.768 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.

After reset: 9AH R/W Address: FFFFF6D1H

	7	6	5	4	3	2	1	0
WDTE								

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 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 RTBL0 and RTBH0 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.

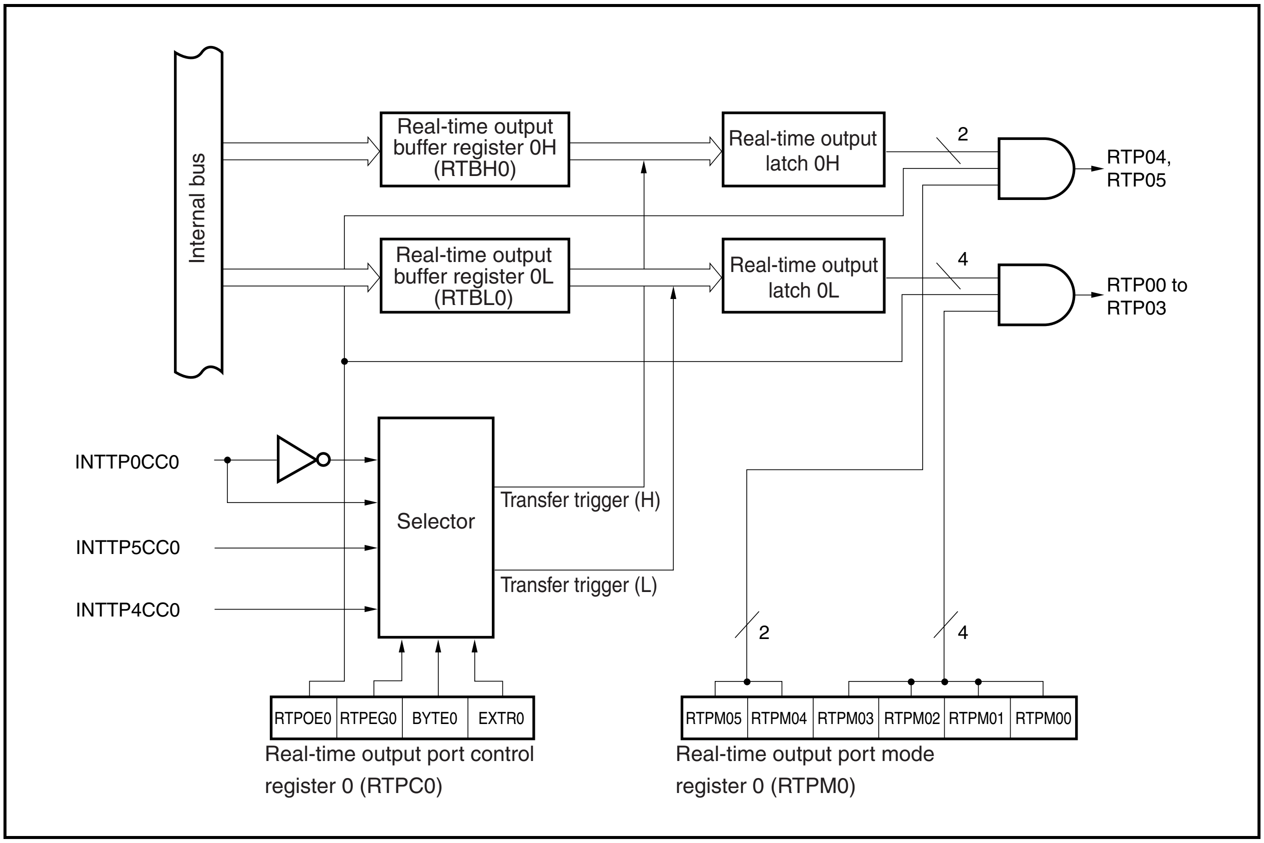
In the V850ES/JG3-L, one 6-bit real-time output port channel is provided.

The real-time output port can be set to the port mode or real-time output port mode in 1-bit units.

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 0L, 0H (RTBL0, RTBH0)
Control registers	Real-time output port mode register 0 (RTPM0) Real-time output port control register 0 (RTPC0)

(1) Real-time output buffer registers 0L, 0H (RTBL0, RTBH0)

The RTBL0 and RTBH0 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 (RTPC0.BYTE0 bit = 0), data can be individually set to the RTBL0 and RTBH0 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 (BYTE0 bit = 1), 8-bit data can be set to both the RTBL0 and RTBH0 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 RTBL0 and RTBH0 registers are manipulated.

After reset: 00H R/W Address: RTBL0 FFFFF6E0H, RTBH0 FFFFF6E2H

	7	6	5	4	3	2	1	0
RTBL0					RTBL03	RTBL02	RTBL01	RTBL00
RTBH0	0	0	RTBH05	RTBH04				

Cautions 1. When writing to bits 6 and 7 of the RTBH0 register, always set 0.

2. Accessing the RTBL0 and RTBH0 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**

Table 12-2. Operation During Manipulation of RTBL0 and RTBH0 Registers

Operation Mode	Register to Be Manipulated	Read		Write[Note]	
		Higher 4 Bits	Lower 4 Bits	Higher 4 Bits	Lower 4 Bits
4 bits × 1 channel, 2 bits × 1 channel	RTBL0	RTBH0	RTBL0	Invalid	RTBL0
	RTBH0	RTBH0	RTBL0	RTBH0	Invalid
6 bits × 1 channel	RTBL0	RTBH0	RTBL0	RTBH0	RTBL0
	RTBH0	RTBH0	RTBL0	RTBH0	RTBL0

Note After setting the real-time output port, set output data to the RTBL0 and RTBH0 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 0 (RTPM0)
- Real-time output port control register 0 (RTPC0)

(1) Real-time output port mode register 0 (RTPM0)

The RTPM0 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: FFFFF6E4H

	7	6	5	4	3	2	1	0
RTPM0	0	0	RTPM05	RTPM04	RTPM03	RTPM02	RTPM01	RTPM00

RTPM0m	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 (RTPC0.RTPOE0 bit = 1), the bits enabled to real-time output among the RTP00 to RTP05 signals perform real-time output, and the bits set to port mode output 0.

2. If real-time output is disabled (RTPOE0 bit = 0), the real-time output pins (RTP00 to RTP05) all output 0, regardless of the RTPM0 register setting.

3. In order to use this register as the real-time output pins (RTP00 to RTP05), set these pins as real-time output port pins using the PMC and PFC registers.

4. When writing to bits 6 and 7 of the RTPM0 register, always set 0.

(2) Real-time output port control register 0 (RTPC0)

The RTPC0 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 Table 12-3.

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: FFFFF6E5H

	<7>	6	5	4	3	2	1	0
RTPC0	RTPOE0	RTPEG0	BYTE0	EXTR0	0	0	0	0

RTPOE0	Control of real-time output operation
0	Disables operation^{Note 1}
1	Enables operation

RTPEG0	Valid edge of INTTP0CC0 signal
0	Falling edge^{Note 2}
1	Rising edge

BYTE0	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 (RTPOE0 bit = 0), all the bits of the real-time output signals (RTP00 to RTP05) output “0”.

2. The INTTP0CC0 signal is output for 1 clock of the count clock selected by TMP0.

Caution Set the RTPEG0, BYTE0, and EXTR0 bits only when RTPOE0 bit = 0.

Table 12-3. Operation Modes and Output Triggers of Real-Time Output Port

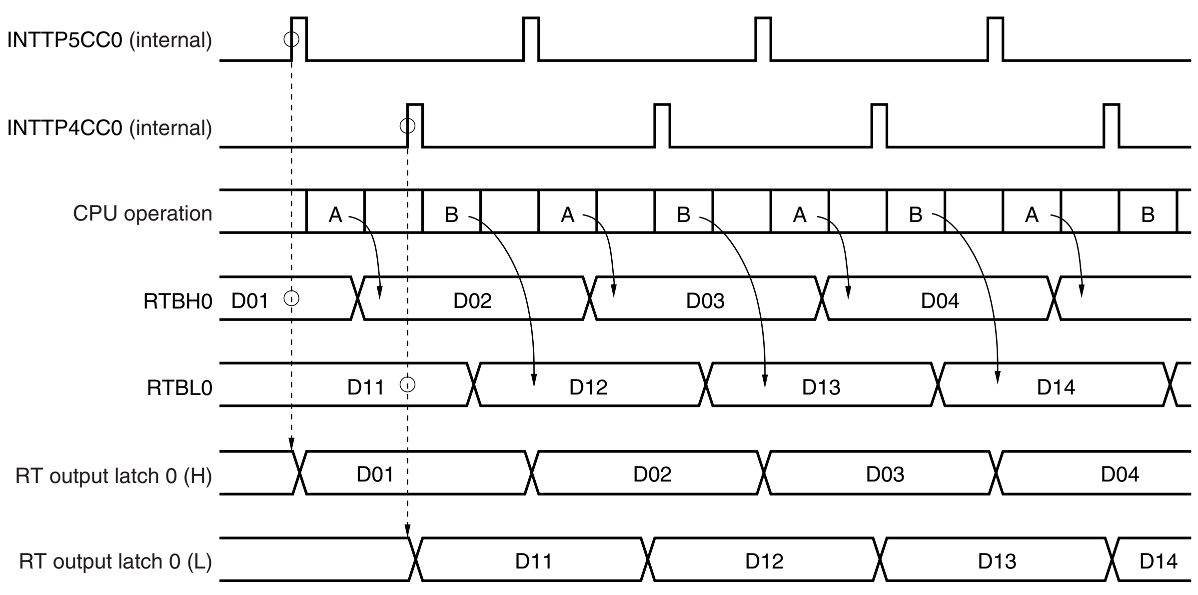
<table>
<tr><th>BYTE0</th><th>EXTR0</th><th>Operation Mode</th><th>RTBH0 (RTP04, RTP05)</th><th>RTBL0 (RTP00 to RTP03)</th></tr>
<tr><td rowspan="2">0</td><td>0</td><td rowspan="2">4 bits × 1 channel,
2 bits × 1 channel</td><td>INTTP5CC0</td><td>INTTP4CC0</td></tr>
<tr><td>1</td><td>INTTP4CC0</td><td>INTTP0CC0</td></tr>
<tr><td rowspan="2">1</td><td>0</td><td rowspan="2">6 bits × 1 channel</td><td colspan="2">INTTP4CC0</td></tr>
<tr><td>1</td><td colspan="2">INTTP0CC0</td></tr>
</table>

12.4 Operation

If the real-time output operation is enabled by setting the RTPC0.RTPOE0 bit to 1, the data of the RTBH0 and RTBL0 registers is transferred to the real-time output latch in synchronization with the generation of the selected transfer trigger (set by the RTPC0.EXTR0 and RTPC0.BYTE0 bits). Of the transferred data, only the data of the bits for which real-time output is enabled by the RTPM0 register is output from the RTP00 to RTP05 bits. The bits for which real-time output is disabled by the RTPM0 register output 0.

If the real-time output operation is disabled by clearing the RTPOE0 bit to 0, the RTP00 to RTP05 signals output 0 regardless of the setting of the RTPM0 register.

Figure 12-2. Example of Operation Timing of RTO0 (When EXTR0 Bit = 0, BYTE0 Bit = 0)



A: Software processing by INTTP5CC0 interrupt request (RTBH0 write)
B: Software processing by INTTP4CC0 interrupt request (RTBL0 write)

Remark For the operation during standby, see **CHAPTER 21 STANDBY FUNCTION**.

12.5 Usage

(1) Disable real-time output.
Clear the RTPC0.RTPOE0 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 RTPM0 register.
- Channel configuration: Select the trigger and valid edge.
  Set the RTPC0.EXTR0, RTPC0.BYTE0, and RTPC0.RTPEG0 bits.
- Set the initial values to the RTBH0 and RTBL0 registers[Note 1].

(3) Enable real-time output.
Set the RTPOE0 bit = 1.

(4) Set the next output value to the RTBH0 and RTBL0 registers by the time the selected transfer trigger is generated[Note 2].

(5) Set the next real-time output value to the RTBH0 and RTBL0 registers via interrupt servicing corresponding to the selected trigger.

Notes 1. If the RTBH0 and RTBL0 registers are written when the RTPOE0 bit = 0, that value is transferred to real-time output latches 0H and 0L, respectively.

2. Even if the RTBH0 and RTBL0 registers are written when the RTPOE0 bit = 1, data is not transferred to real-time output latches 0H and 0L.

12.6 Cautions

(1) Prevent the following conflicts by software.

- Conflict between real-time output disable/enable switching (RTPOE0 bit) and selected real-time output trigger.
- Conflict between writing to the RTBH0 and RTBL0 registers in the real-time output enabled status and the selected real-time output trigger.

(2) Before performing initialization, disable real-time output (RTPOE0 bit = 0).

(3) Once real-time output has been disabled (RTPOE0 bit = 0), be sure to initialize the RTBH0 and RTBL0 registers before enabling real-time output again (RTPOE0 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 12 analog input signal channels (ANI0 to ANI11).

The A/D converter has the following features.

- ○ 10-bit resolution
- ○ 12 channels
- ○ Successive approximation method
- ○ Operating voltage: AV_{REF0} = 2.7 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 ANI11, 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.

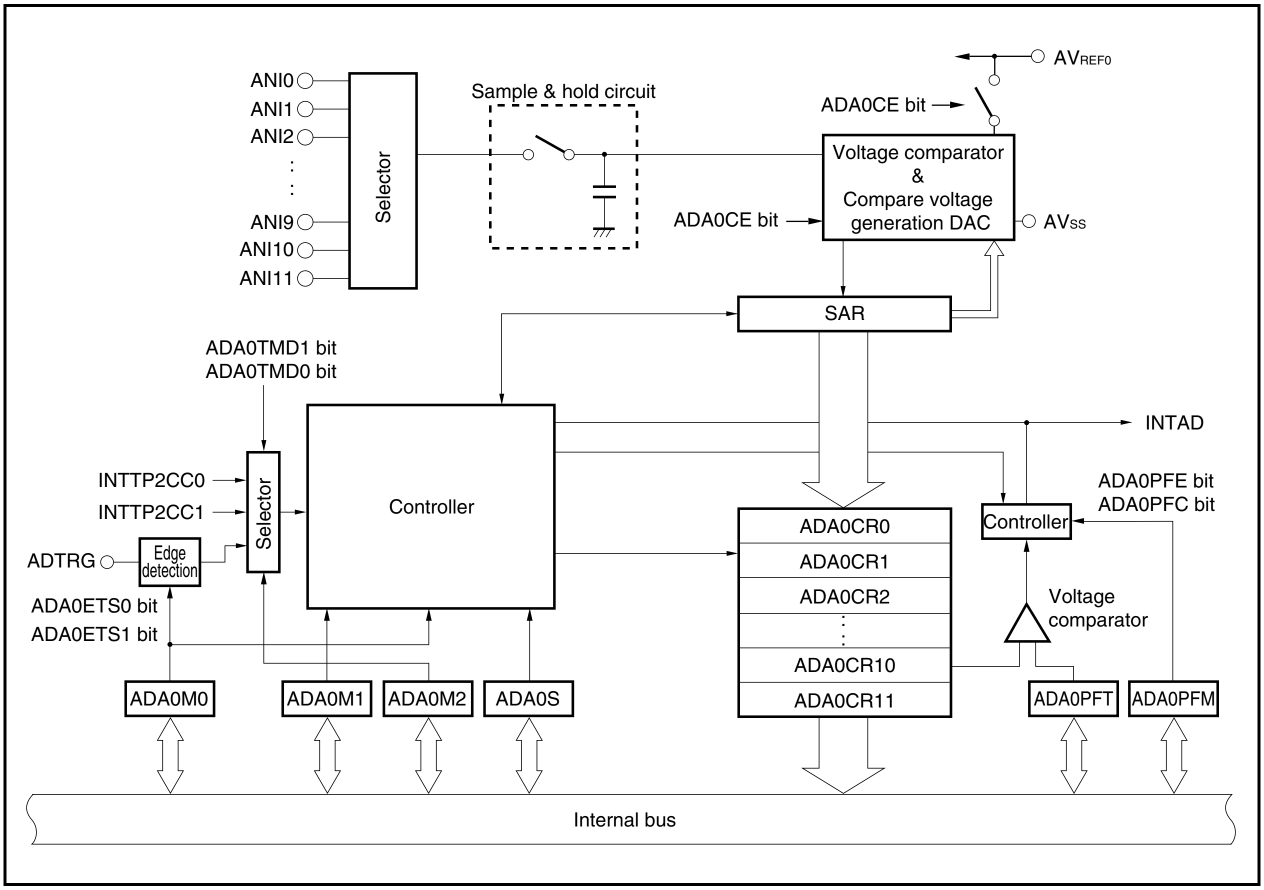
(2) Power-fail detection function

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 11).

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	12 channels (ANI0 to ANI11 pins)
Registers	Successive approximation register (SAR) A/D conversion result registers 0 to 11 (ADA0CR0 to ADA0CR11) A/D conversion result registers 0H to 11H (ADCR0H to ADCR11H): Only higher 8 bits can be read
Control registers	A/D converter mode registers 0 to 2 (ADA0M0 to ADA0M2) A/D converter channel specification register 0 (ADA0S) Power fail compare mode register (ADA0PFM) Power fail compare threshold value register (ADA0PFT)

(1) Successive approximation register (SAR)

The SAR register compares the voltage value of the analog input signal with the output voltage of the compare voltage generation DAC (compare voltage), 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 11

(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 12 registers and the A/D conversion result is stored in the 10 higher bits of the AD0CRn 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 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 ANI11 pins

These are analog input pins for the 12 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 ANI11 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 ANI11 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.

Caution 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**

(1/2)

After reset: 00H R/W Address: FFFFF200H

	<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

(2/2)

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. A write operation to bit 0 is ignored.

2. Changing the ADA0M1.ADA0FR2 to ADA0M1.ADA0FR0 bits is prohibited while A/D conversion is enabled (ADA0CE bit = 1).

3. In the following modes, write data to the ADA0M0, ADA0M2, ADA0S, ADA0PFM, or ADA0PFT registers while A/D conversion is stopped (ADA0CE bit = 0), and then enable the A/D conversion operation (ADA0CE bit = 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.

4. 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).

5. 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 bit to 00H.

After reset: 00H R/W Address: FFFFF201H

	7	6	5	4	3	2	1	0
ADA0M1	ADA0HS1	0	0	0	0	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 3 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)

ADA0 FR2	ADA0 FR1	ADA0 FR0	A/D Conversion Time						
			Stabilization Time + Conversion Time + Wait Time	fxx = 20 MHz	fxx = 16 MHz	fxx = 12 MHz	fxx = 10 MHz	fxx = 4 MHz	Trigger Response Time
0	0	0	66/fxx (13/fxx + 26/fxx + 27/fxx)	Setting prohibited	Setting prohibited	Setting prohibited	6.6 µs	16.5 µs	3/fxx
0	0	1	131/fxx (26/fxx + 52/fxx + 53/fxx)	6.55 µs[Note]	8.19 µs[Note]	10.92 µs	13.1 µs	Setting prohibited	3/fxx
0	1	0	196/fxx (39/fxx + 78/fxx + 79/fxx)	9.8 µs	12.25 µs	16.33 µs	19.6 µs	Setting prohibited	3/fxx
0	1	1	259/fxx (50/fxx + 104/fxx + 105/fxx)	12.95 µs	16.19 µs	21.58 µs	25.9 µs	Setting prohibited	3/fxx
1	0	0	311/fxx (50/fxx + 130/fxx + 131/fxx)	15.55 µs	19.44 µs	Setting prohibited	Setting prohibited	Setting prohibited	3/fxx
1	0	1	363/fxx (50/fxx + 156/fxx + 157/fxx)	18.15 µs	22.69 µs	Setting prohibited	Setting prohibited	Setting prohibited	3/fxx
1	1	0	415/fxx (50/fxx + 182/fxx + 183/fxx)	20.75 µs	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	3/fxx
1	1	1	467/fxx (50/fxx + 208/fxx + 209/fxx)	23.35 µs	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	3/fxx
Other than above			Setting prohibited						

Remark

Stabilization time:	A/D converter setup time (1 µs or longer)
Conversion time:	Actual A/D conversion time (2.6 to 10.4 µs)
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 µs). 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.

Note Setting prohibited when 2.7 V $\leq AV_{REF0} <$ 3.0 V

Cautions 1. Set as 2.6 µs ≤ conversion time ≤ 10.4 µs when 3.0 V ≤ AV_{REF0} ≤ 3.6 V.
Set as 3.9 µs ≤ conversion time ≤ 10.4 µs when 2.7 V ≤ AV_{REF0} < 3.0 V.

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)

ADA0 FR2	ADA0 FR1	ADA0 FR0	A/D Conversion Time						
			Conversion Time (+ Wait Time)	f_{XX} = 20 MHz	f_{XX} = 16 MHz	f_{XX} = 12 MHz	f_{XX} = 10 MHz	f_{XX} = 4 MHz	Trigger Response Time
0	0	0	26/f_{XX} (+ 13/f_{XX})	Setting prohibited	Setting prohibited	Setting prohibited	2.6 μs (+ 1.3 μs)	6.5 μs (+ 0 μs)	3/f_{XX}
0	0	1	52/f_{XX} (+ 26/f_{XX})	2.6 μs[Note] (+ 1.3 μs)	3.25 μs[Note] (+ 1.625 μs)	4.333 μs (+ 2.167 μs)	5.2 μs (+ 2.6 μs)	Setting prohibited	3/f_{XX}
0	1	0	78/f_{XX} (+ 39/f_{XX})	3.9 μs (+ 1.95 μs)	4.875 μs (+ 2.438 μs)	6.5 μs (+ 3.25 μs)	7.8 μs (+ 3.9 μs)	Setting prohibited	3/f_{XX}
0	1	1	104/f_{XX} (+ 50/f_{XX})	5.2 μs (+ 2.5 μs)	6.5 μs (+ 3.125 μs)	8.667 μs (+ 4.167 μs)	10.4 μs (+ 5 μs)	Setting prohibited	3/f_{XX}
1	0	0	130/f_{XX} (+ 50/f_{XX})	6.5 μs (+ 2.5 μs)	8.125 μs (+ 3.125 μs)	Setting prohibited	Setting prohibited	Setting prohibited	3/f_{XX}
1	0	1	156/f_{XX} (+ 50/f_{XX})	7.8 μs (+ 2.5 μs)	9.75 μs (+ 3.125 μs)	Setting prohibited	Setting prohibited	Setting prohibited	3/f_{XX}
1	1	0	182/f_{XX} (+ 50/f_{XX})	9.1 μs (+ 2.5 μs)	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	3/f_{XX}
1	1	1	208/f_{XX} (+ 50/f_{XX})	10.4 μs (+ 2.5 μs)	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	3/f_{XX}
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).

Note Setting prohibited when 2.7 V ≤ AV_{REF0} < 3.0 V

Cautions 1. Set as 2.6 μs ≤ conversion time ≤ 10.4 μs when 3.0 V ≤ AV_{REF0} ≤ 3.6 V.
Set as 3.9 μs ≤ conversion time ≤ 10.4 μs when 2.7 V ≤ AV_{REF0} < 3.0 V.

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. In the following modes, write data to the ADA0M2 register while A/D conversion is stopped (ADA0M0.ADA0CE bit = 0), and then enable the A/D conversion operation (ADA0CE bit = 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) Analog input 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	Setting prohibited	Setting prohibited
1	1	0	1	Setting prohibited	Setting prohibited
1	1	1	0	Setting prohibited	Setting prohibited
1	1	1	1	Setting prohibited	Setting prohibited

Cautions 1. In the following modes, write data to the ADA0S register while A/D conversion is stopped (ADA0M0.ADA0CE bit = 0), and then enable the A/D conversion operation (ADA0CE bit = 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 FFFFF210H, ADA0CR1 FFFFF212H,
ADA0CR2 FFFFF214H, ADA0CR3 FFFFF216H,
ADA0CR4 FFFFF218H, ADA0CR5 FFFFF21AH,
ADA0CR6 FFFFF21CH, ADA0CR7 FFFFF21EH,
ADA0CR8 FFFFF220H, ADA0CR9 FFFFF222H,
ADA0CR10 FFFFF224H, ADA0CR11 FFFFF226H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADA0CRn (n = 0 to 11)	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0	0	0	0	0	0	0

After reset: Undefined R Address: ADA0CR0H FFFFF211H, ADA0CR1H FFFFF213H,
ADA0CR2H FFFFF215H, ADA0CR3H FFFFF217H,
ADA0CR4H FFFFF219H, ADA0CR5H FFFFF21BH,
ADA0CR6H FFFFF21DH, ADA0CR7H FFFFF21FH,
ADA0CR8H FFFFF221H, ADA0CR9H FFFFF223H,
ADA0CR10H FFFFF225H, ADA0CR11H FFFFF227H

	7	6	5	4	3	2	1	0
ADA0CRnH (n = 0 to 11)	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2

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 ANI11) and the A/D conversion result (ADA0CRn register) is as follows.

$$\text{SAR} = \text{INT}\left(\frac{V_{IN}}{AV_{REF0}} \times 1{,}024 + 0.5\right)$$

$$\text{ADA0CR}^{\text{Note}} = \text{SAR} \times 64$$

Or,

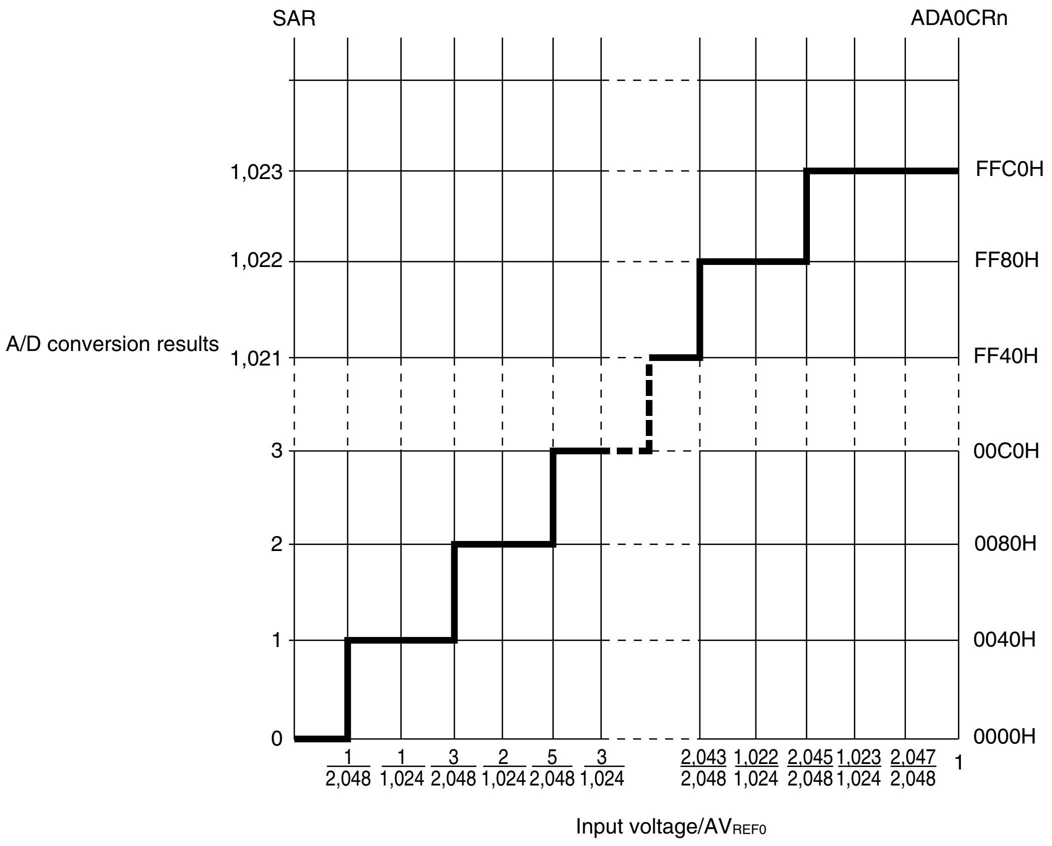
$$(\text{SAR} - 0.5) \times \frac{AV_{REF0}}{1{,}024} \leq V_{IN} < (\text{SAR} + 0.5) \times \frac{AV_{REF0}}{1{,}024}$$

INT( ):	Function that returns the integer of the value in ( )
V_{IN}:	Analog input voltage
AV_{REF0}:	AV_{REF0} 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 ≥ 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. In the following modes, write data to the ADA0PFM register while A/D conversion is stopped (ADA0M0.ADA0CE bit = 0), and then enable the A/D conversion operation (ADA0CE bit = 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.

After reset: 00H R/W Address: FFFFF205H

	7	6	5	4	3	2	1	0
ADA0PFT								

Caution In the following modes, write data to the ADA0PFT register while A/D conversion is stopped (ADA0M0.ADA0CE bit = 0), and then enable the A/D conversion operation (ADA0CE bit = 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). The tap selector selects (1/2) AV_{REF0} as the compare voltage generation DAC.

<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 voltage tap of 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 ≥ Compare voltage: Bit 8 = 1
Analog input voltage ≤ 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[Note]. In one-shot scan mode, conversion is stopped after scanning once[Note]. 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.

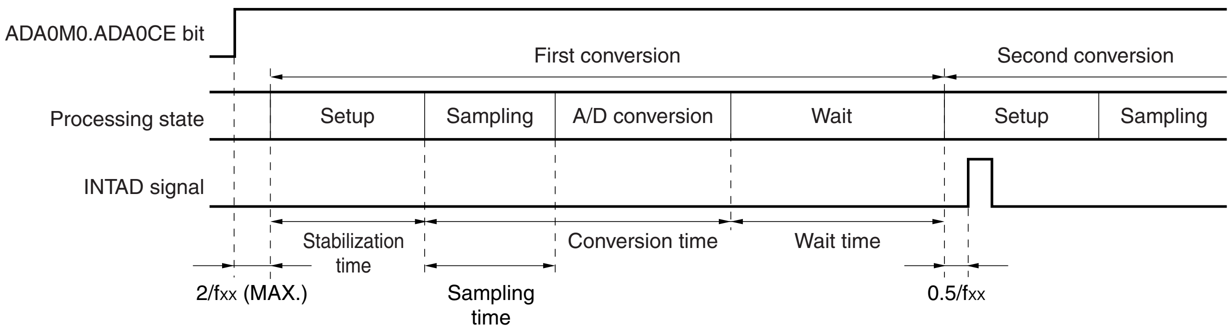
Note In the external trigger mode, timer trigger mode 0, or timer trigger mode 1, the trigger standby status is entered.

Remark The trigger standby status means the status after the stabilization time has passed.

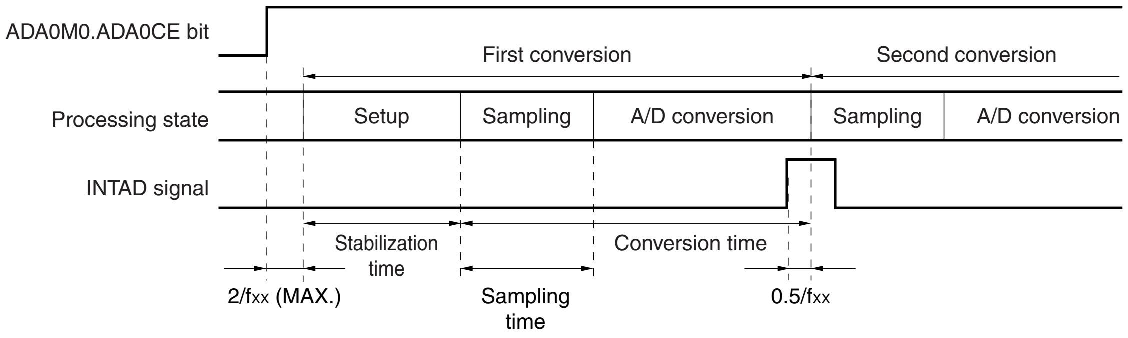
13.5.2 Conversion operation timing

Figure 13-3. Conversion Operation Timing (Continuous Conversion)

(1) Operation in normal conversion mode (ADA0HS1 bit = 0)



(2) Operation in high-speed conversion mode (ADA0HS1 bit = 1)



ADA0FR2 to ADA0FR0 Bits	Stabilization Time	Conversion Time (Sampling Time)	Wait Time	Trigger Response Time
000	13/fxx	26/fxx (8/fxx)	27/fxx	3/fxx
001	26/fxx	52/fxx (16/fxx)	53/fxx	3/fxx
010	39/fxx	78/fxx (24/fxx)	79/fxx	3/fxx
011	50/fxx	104/fxx (32/fxx)	105/fxx	3/fxx
100	50/fxx	130/fxx (40/fxx)	131/fxx	3/fxx
101	50/fxx	156/fxx (48/fxx)	157/fxx	3/fxx
110	50/fxx	182/fxx (56/fxx)	183/fxx	3/fxx
111	50/fxx	208/fxx (64/fxx)	209/fxx	3/fxx

Remark The above timings are when a trigger generates within the stabilization time. If the trigger generates after the stabilization time, a trigger response time is inserted.

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 ANI11 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 ANI11) 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 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 ANI11) 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 ANI11 pins: continuous select mode, continuous scan mode, one-shot select mode, and one-shot scan mode.

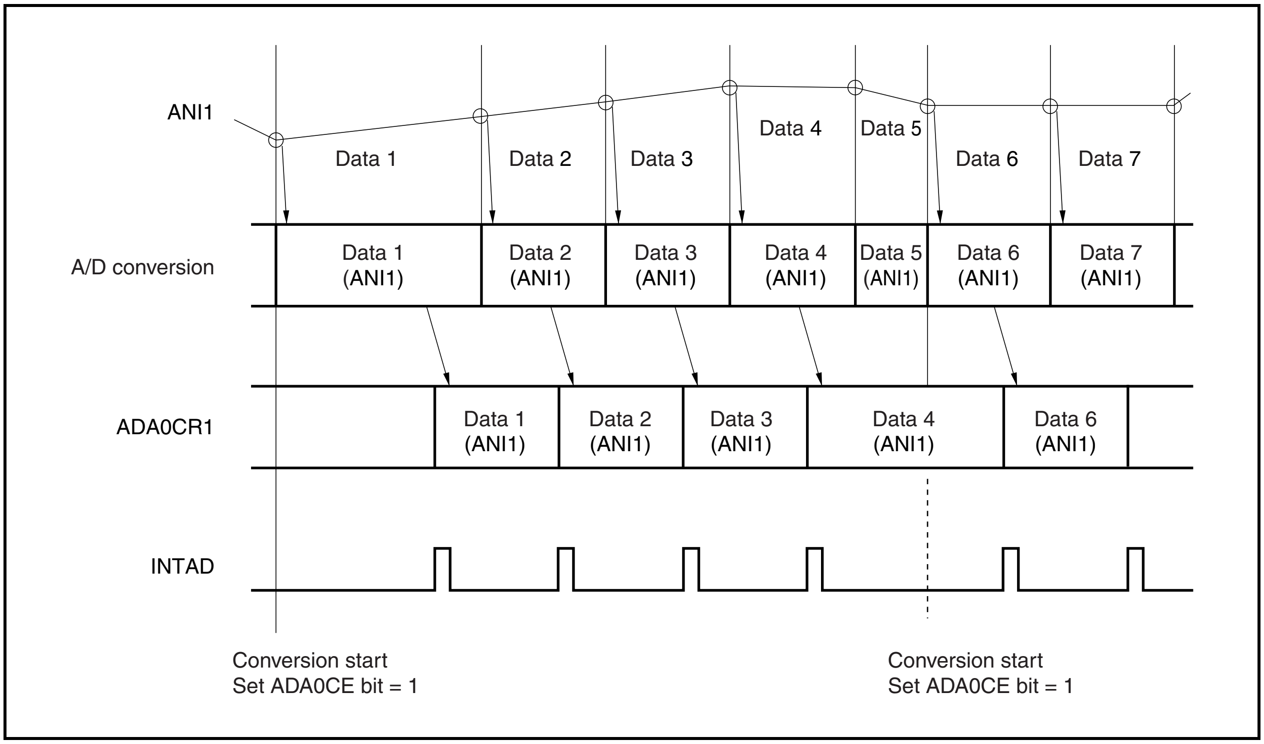
The operation mode is selected by the ADA0M0.ADA0MD1 and ADA0M0.ADA0MD0 bits.

(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 11).

Figure 13-4. Timing Example of Continuous Select Mode Operation (ADA0S Register = 01H)



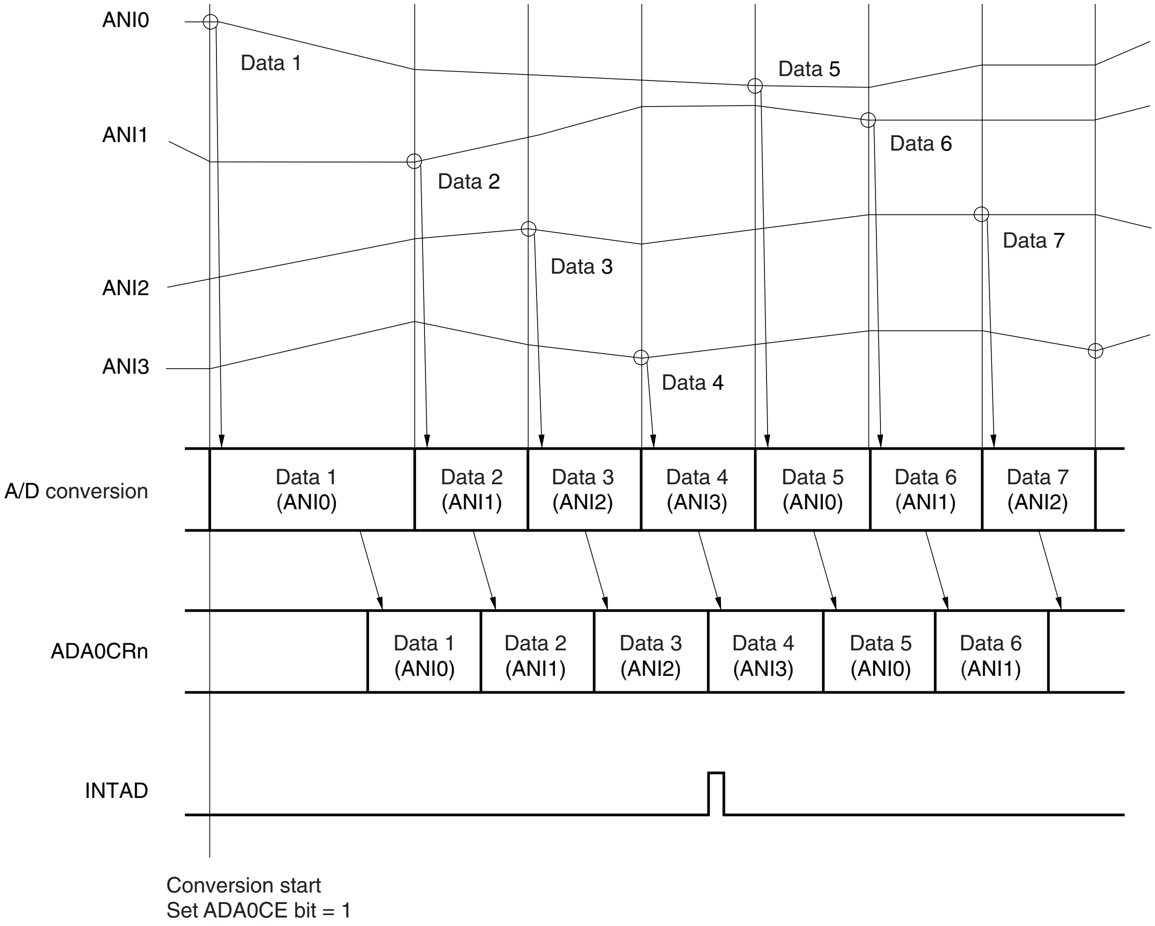
(2) Continuous scan mode

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.

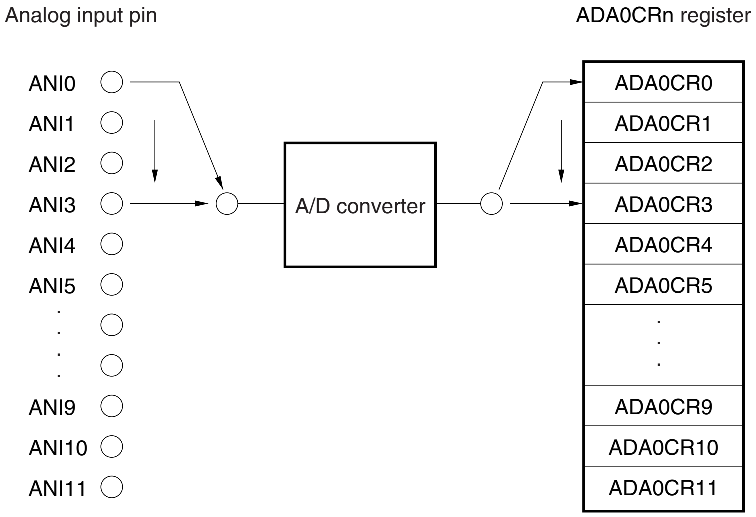
The result of each conversion is stored in the ADA0CRn register corresponding to the analog input pin. When conversion of the analog input pin specified by the ADA0S register is complete, the INTAD signal is generated, and A/D conversion is started again from the ANI0 pin, unless the ADA0CE bit is cleared to 0 (n = 0 to 11).

Figure 13-5. Timing Example of Continuous Scan Mode Operation (ADA0S Register = 03H)

(a) Timing example



(b) Block diagram

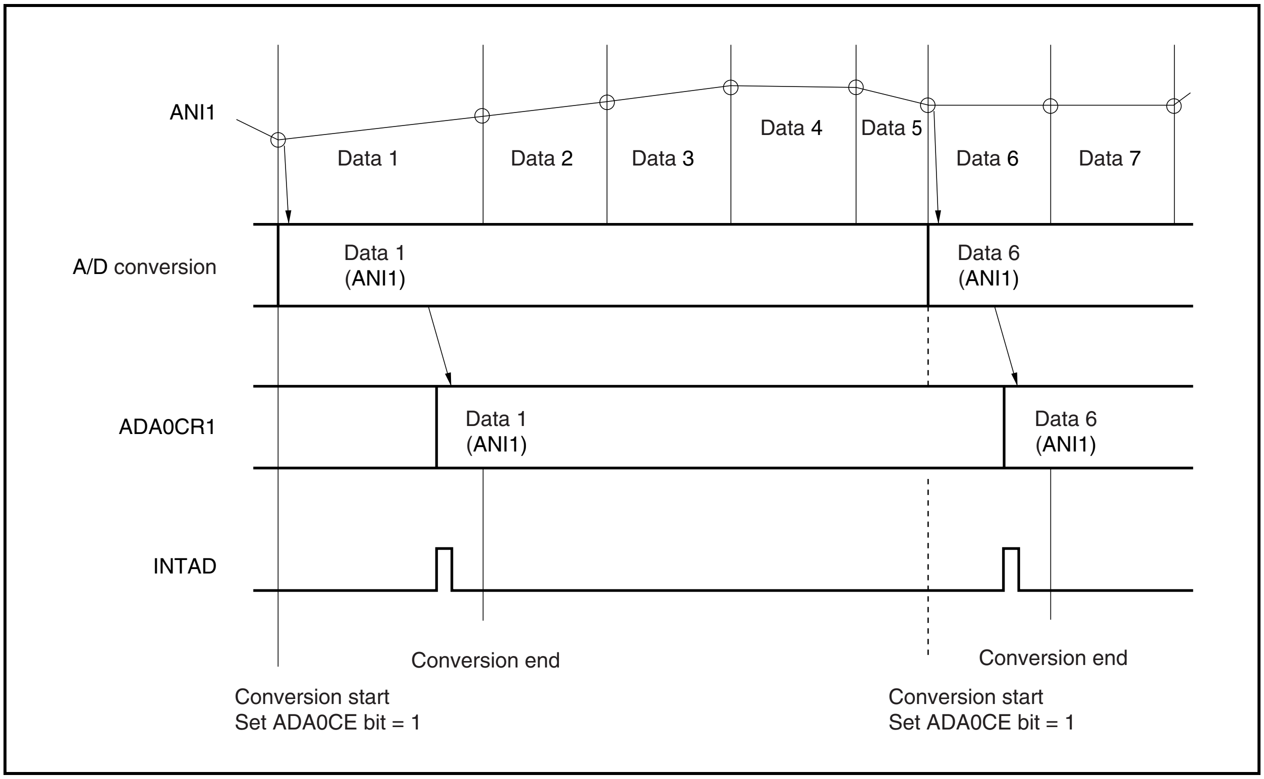


(3) One-shot select mode

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 11).

Figure 13-6. Timing Example of One-Shot Select Mode Operation (ADA0S Register = 01H)



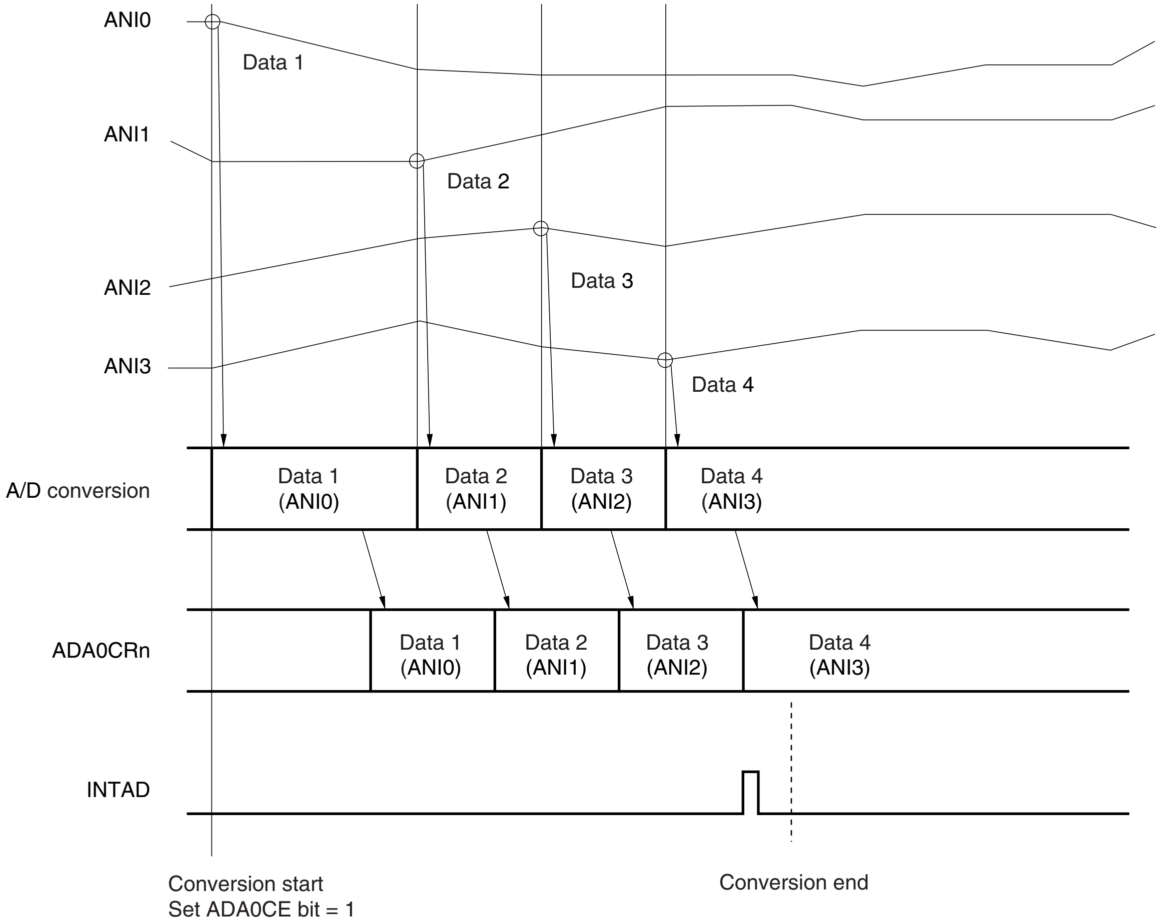
(4) One-shot scan mode

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 .

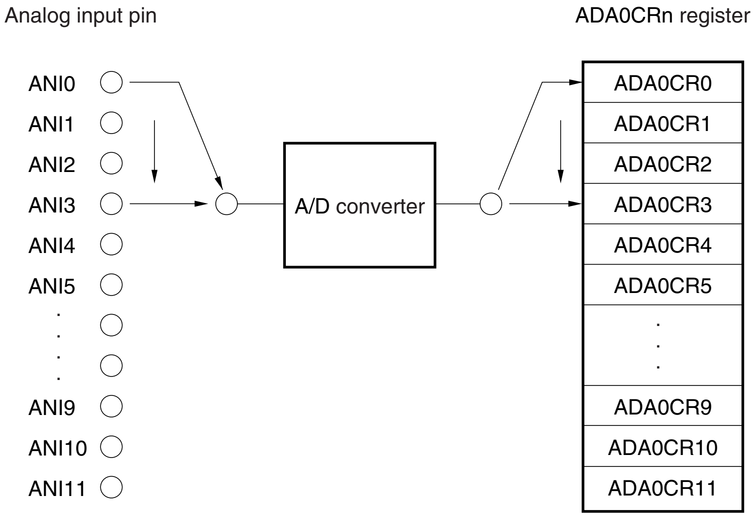
Each conversion result is stored in the ADA0CRn register corresponding to the analog input pin. When conversion of the analog input pin specified by the ADA0S register is complete, the INTAD signal is generated. A/D conversion is stopped after it has been completed (n = 0 to 11).

Figure 13-7. Timing Example of One-Shot Scan Mode Operation (ADA0S Register = 03H)

(a) Timing example



(b) Block diagram



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 ≥ 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.

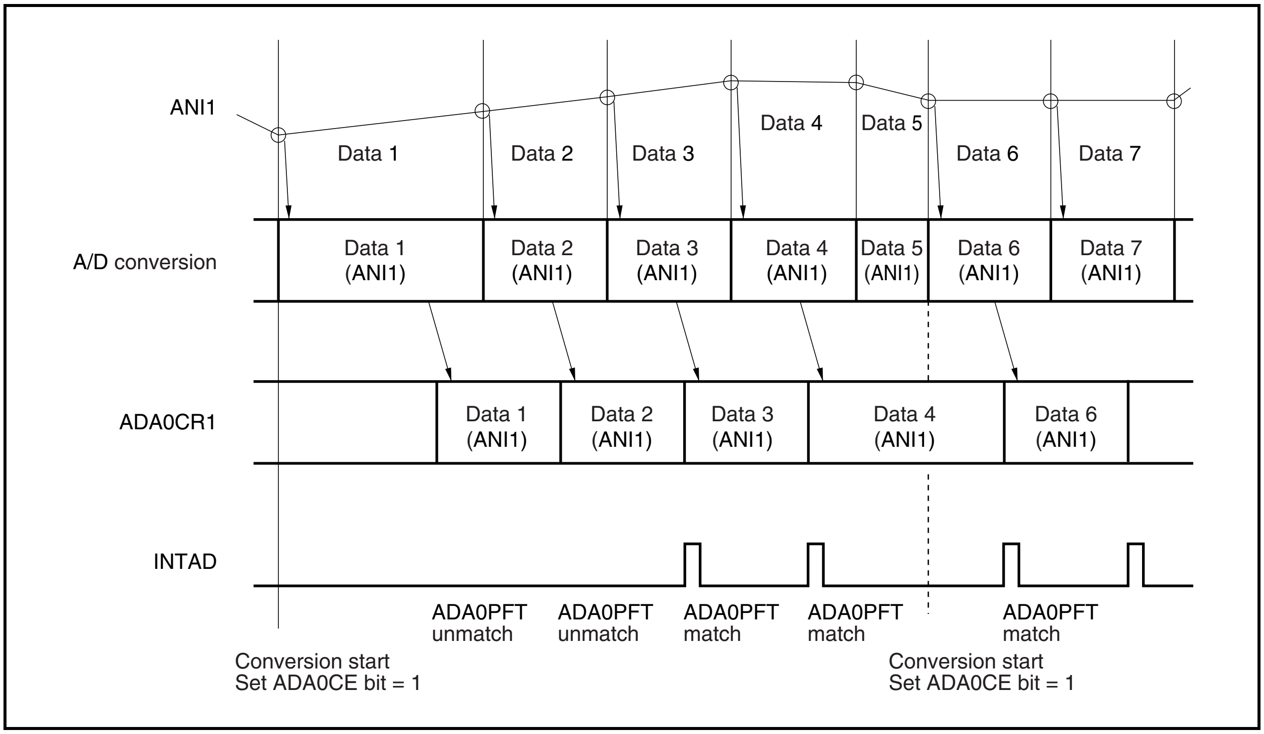
Remark n = 0 to 11

In the power-fail compare mode, four modes are available as modes in which to set the ANI0 to ANI11 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 11).

Figure 13-8. Timing Example of Continuous Select Mode Operation (When Power-Fail Comparison Is Made: ADA0S Register = 01H)



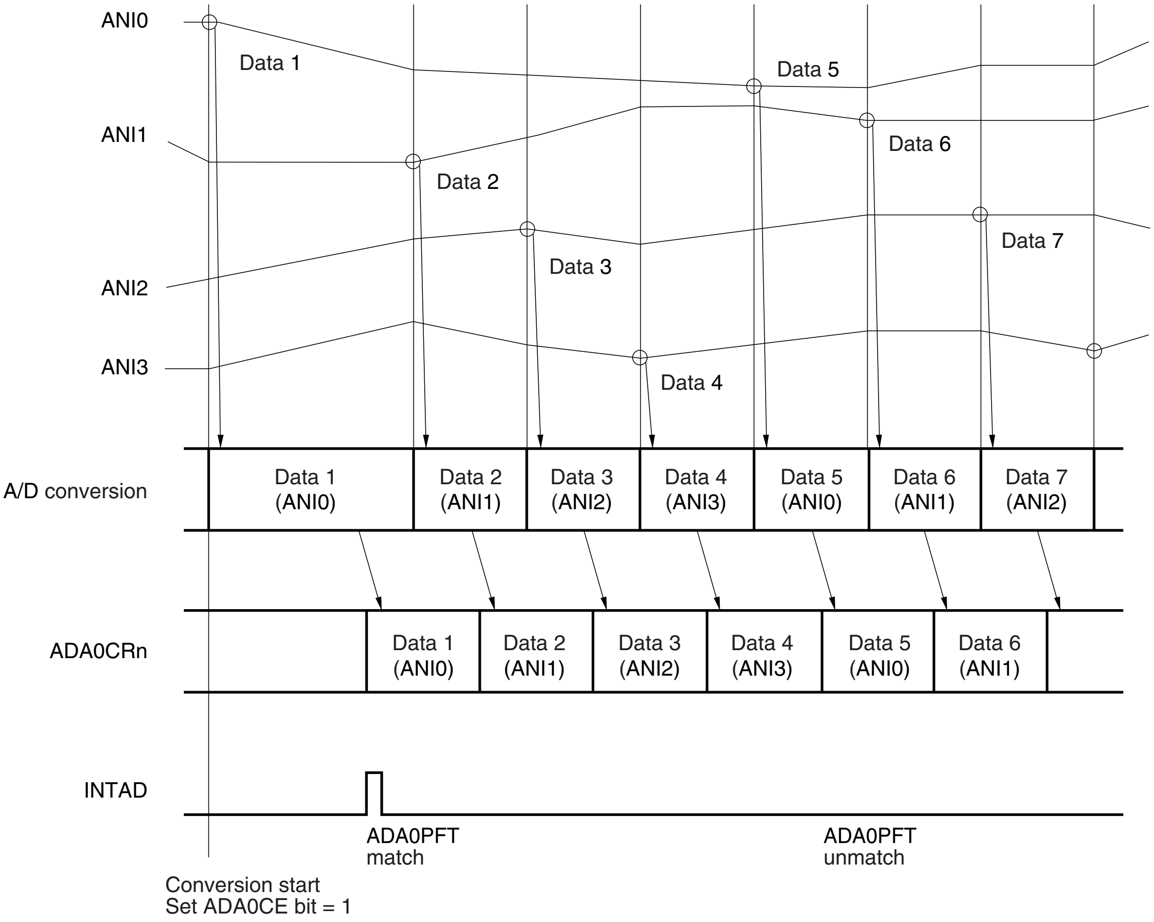
(2) Continuous scan mode

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.

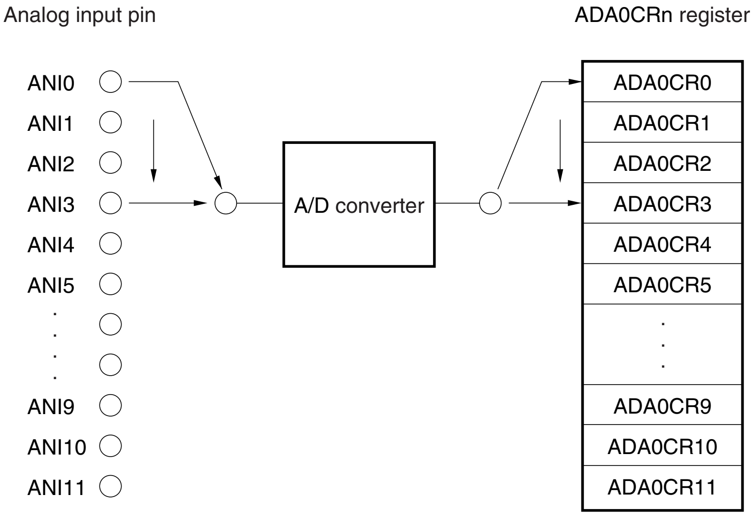
After the result of the first conversion has been stored in the ADA0CR0 register, the results of sequentially converting the voltages on the analog input pins up to the pin specified by the ADA0S register are continuously stored. After completion of conversion, the next conversion is started from the 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



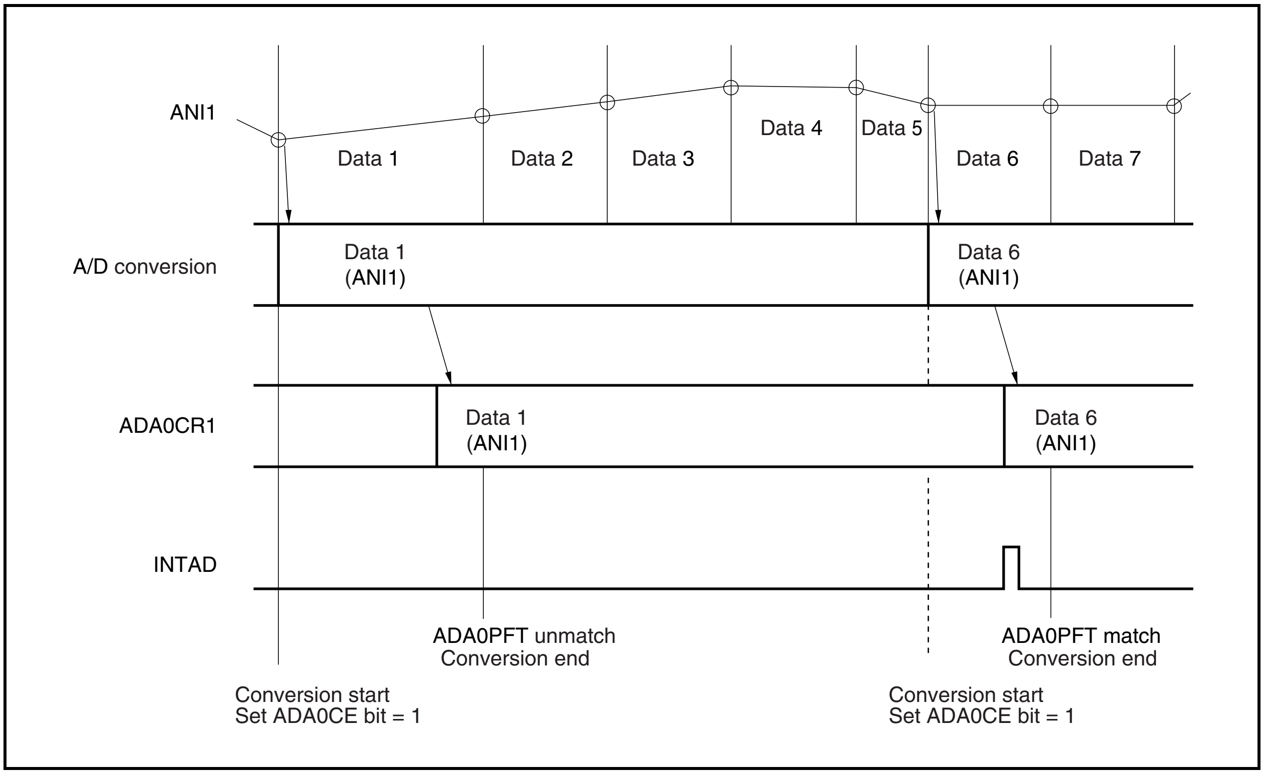
(b) Block diagram



(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)

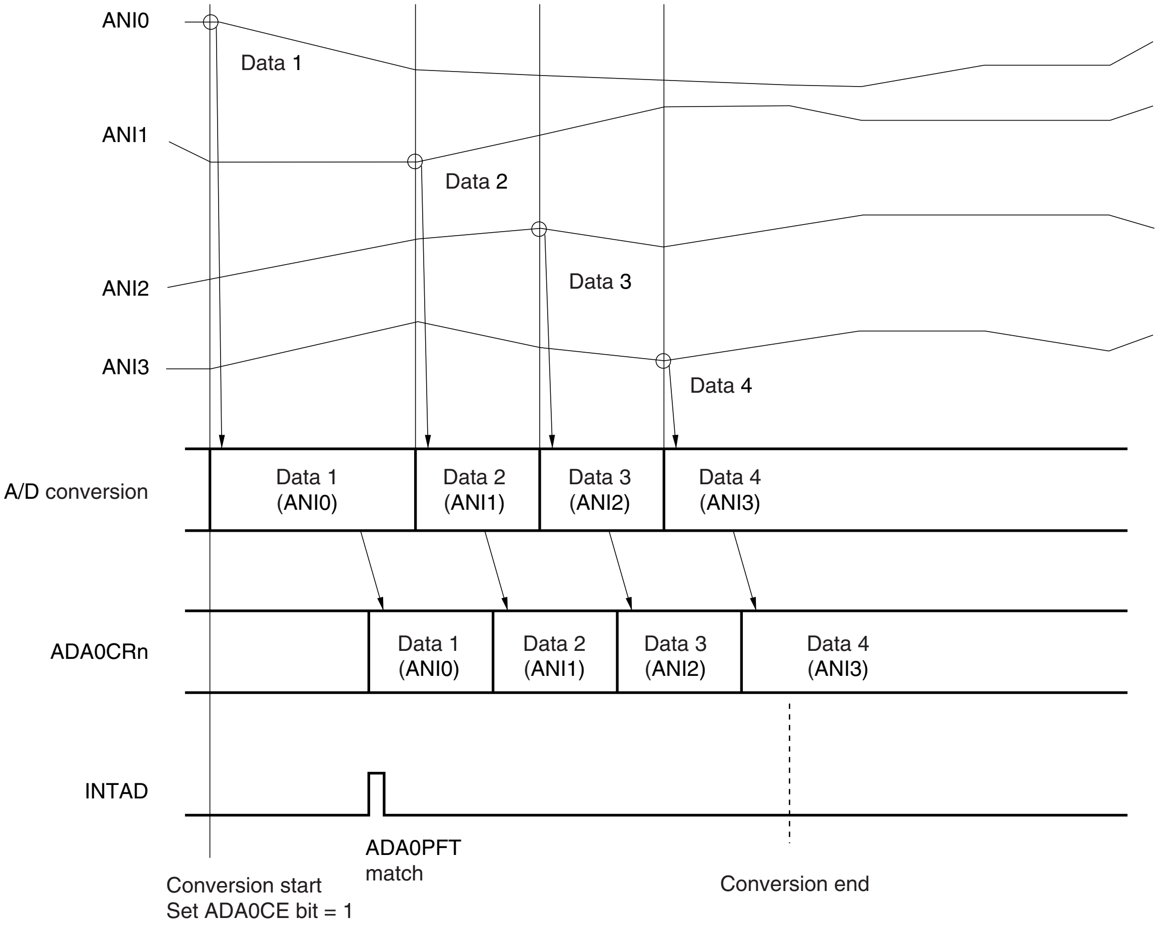


(4) One-shot scan mode

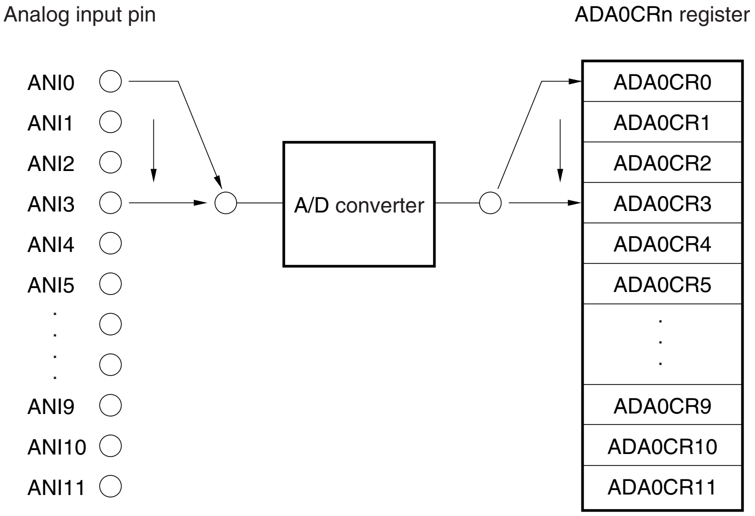
In this mode, the results of converting the voltages of the analog input pins sequentially selected from the ANI0 pin to the pin specified by the ADA0S register are stored, and the set value of the ADA0CR0H register of channel 0 is compared with the set value of the ADA0PFT register. If the result of 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)

(a) Timing example



(b) Block diagram



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.

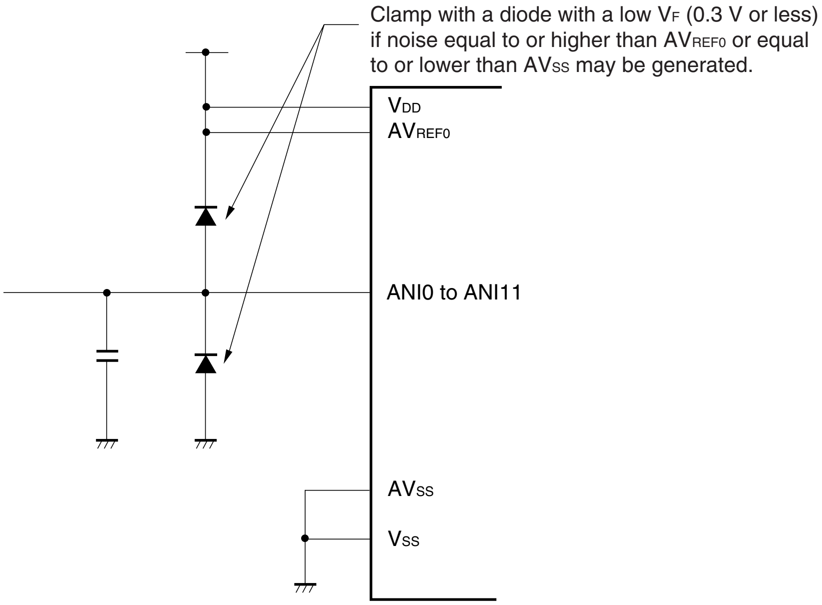
(2) Input range of ANI0 to ANI11 pins

Input the voltage within the specified range to the ANI0 to ANI11 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 ANI11 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 ANI11) function alternately as port pins. When selecting one of the ANI0 to ANI11 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.

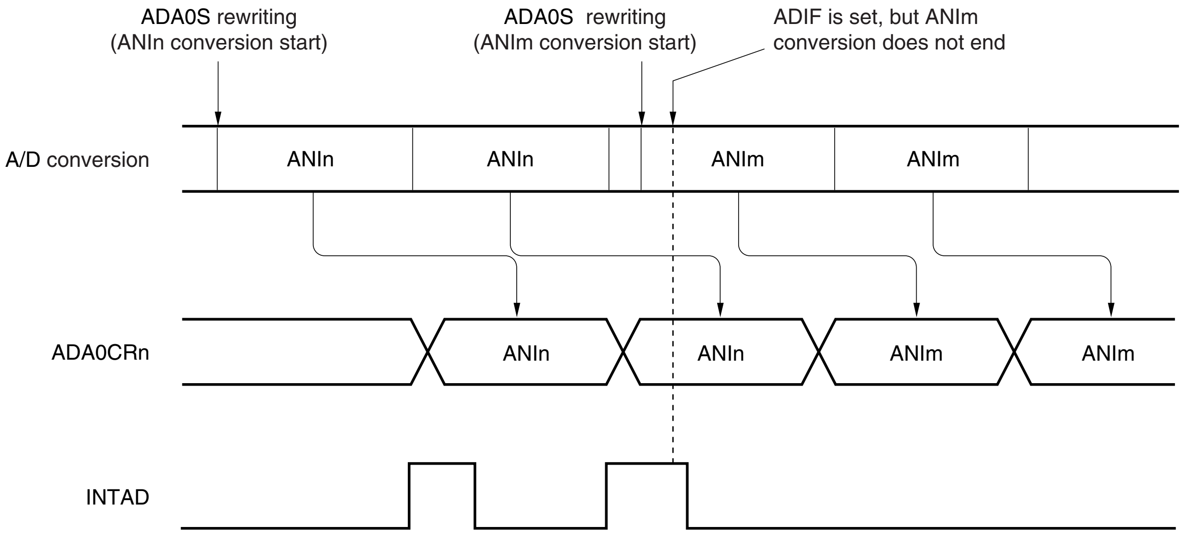
Also the conversion resolution may drop at the pins set as output port pins during A/D conversion if the output current fluctuates due to the effect of the external circuit connected to the port pins.

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

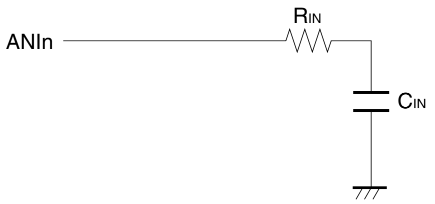


Remark n = 0 to 11
m = 0 to 11

(6) Internal equivalent circuit

The following shows the equivalent circuit of the analog input block.

Figure 13-14. Internal Equivalent Circuit of ANIn Pin



R_{IN}	C_{IN}
14 kΩ	8.0 pF

Remarks 1. The above values are reference values.

2. n = 0 to 11

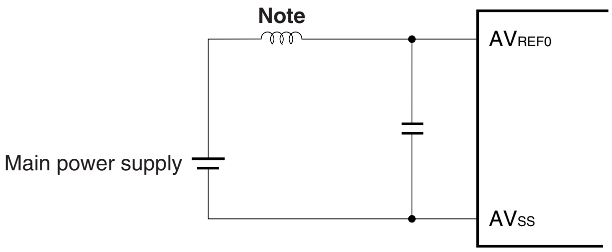
(7) AV_{REF0} pin

(a) The AV_{REF0} 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_{DD} to the AV_{REF0} pin as shown in Figure 13-15.

(b) The AV_{REF0} pin is also used as the reference voltage pin of the A/D converter. If the source supplying power to the AV_{REF0} 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_{REF0} and AV_{SS} pins to suppress the reference voltage fluctuation as shown in Figure 13-15.

(c) If the source supplying power to the AV_{REF0} 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_{REF0} Pin Processing Example



Note Parasitic inductance

(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.

1%FSR = (Maximum value of convertible analog input voltage – Minimum value of convertible analog input voltage)/100

= (AV_{REF0} – 0)/100

= AV_{REF0}/100

When the resolution is 10 bits, 1 LSB is as follows:

1 LSB = $1/2^{10}$ = 1/1,024

= 0.098%FSR

The accuracy is determined by the overall error, independently of the resolution.

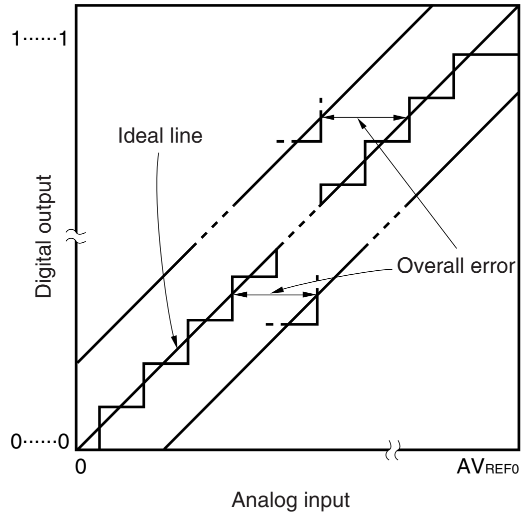
(2) Overall error

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

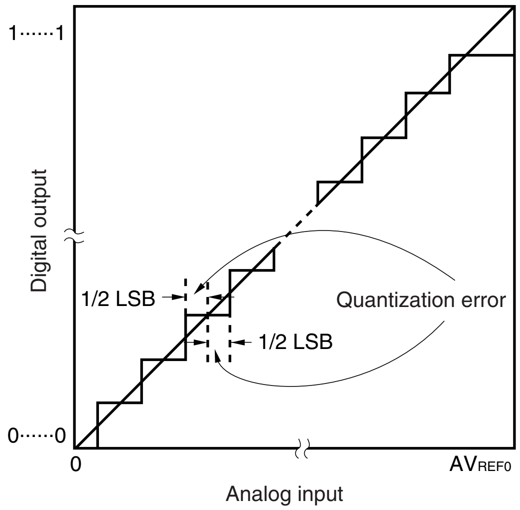


(3) Quantization error

This is an error of ±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 ±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.

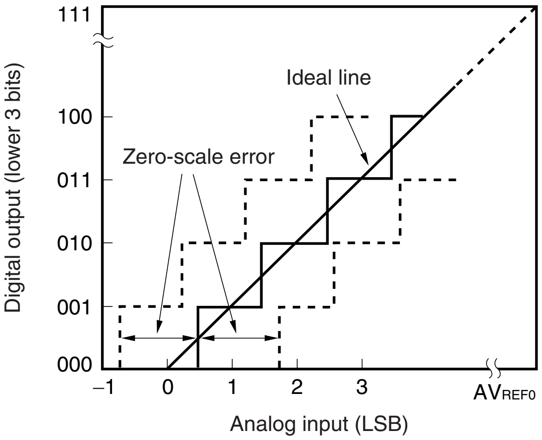
Figure 13-17. Quantization Error



(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).

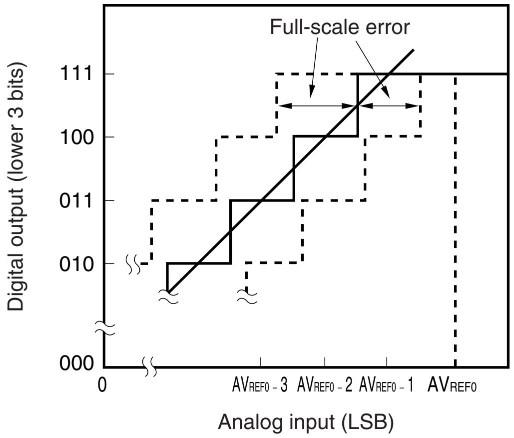
Figure 13-18. Zero-Scale Error



(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).

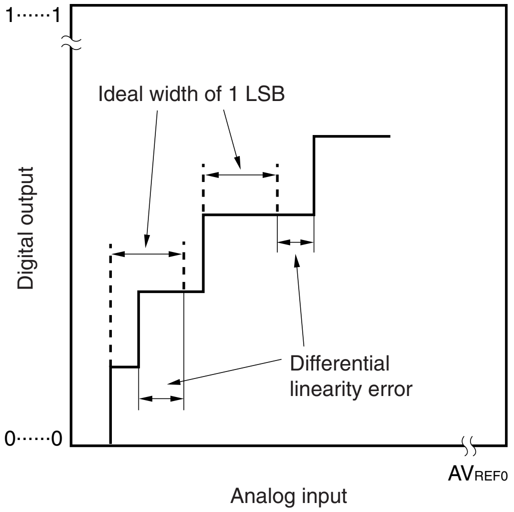
Figure 13-19. Full-Scale Error



(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**.

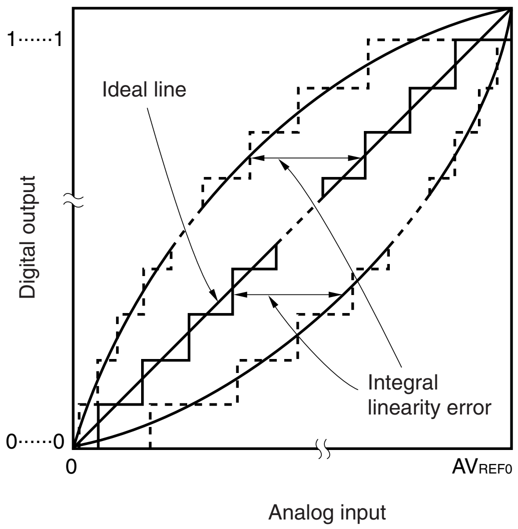
Figure 13-20. Differential Linearity Error



(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



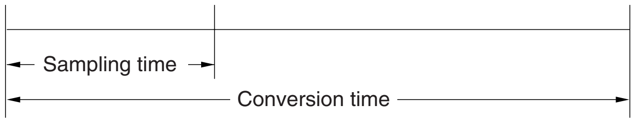
(8) Conversion time

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.

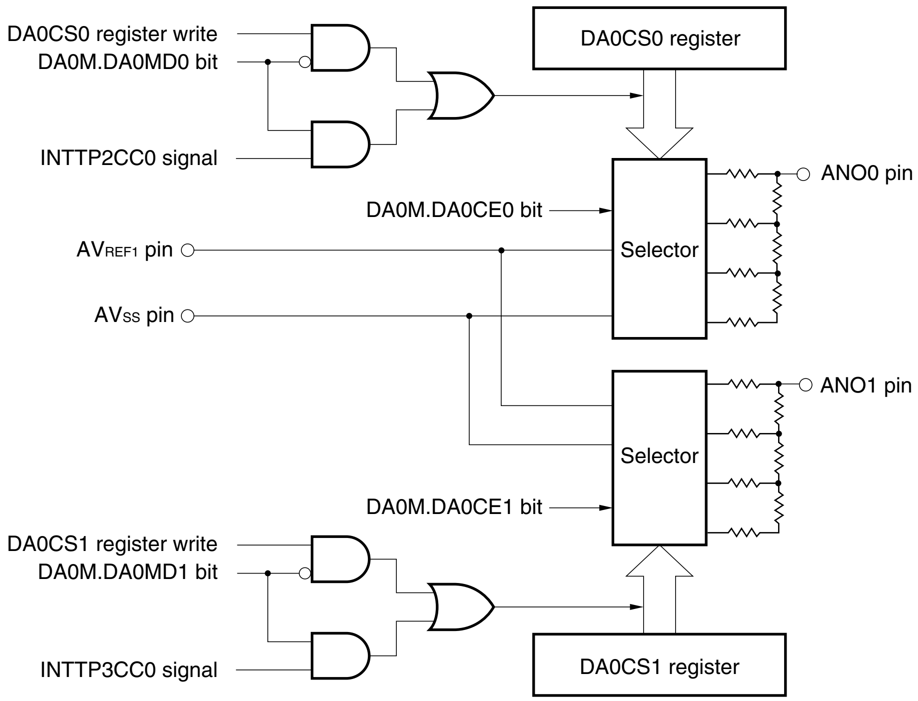
- ○ 8-bit resolution × 2 channels (DA0CS0, DA0CS1)
- ○ R-2R ladder method
- ○ Settling time: 3 µs max. (when AV_{REF1} is 2.7 to 3.6 V and external load is 20 pF)
- ○ Analog output voltage: $AV_{REF1} \times m/256$ (m = 0 to 255; value set to DA0CSn register)
- ○ Operation modes: Normal mode, real-time 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



Cautions 1. DAC0 and DAC1 share the AV_{REF1} pin.

2. DAC0 and DAC1 share the AV_{SS} pin. The AV_{SS} pin is also shared by the A/D 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) 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[Note]

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

	7	6	5	4	3	2	1	0
DA0CSn	DA0CSn7	DA0CSn6	DA0CSn5	DA0CSn4	DA0CSn3	DA0CSn2	DA0CSn1	DA0CSn0

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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

14.4.3 Cautions

Observe the following cautions when using the D/A converter of the V850ES/JG3-L.

(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.

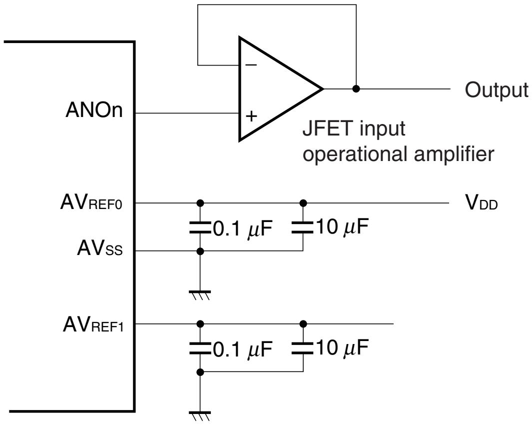
(3) When using one of the P10/AN00 and P11/AN01 pins as an I/O port and the other as a D/A output pin, do so in an application where the port I/O level does not change during D/A output.

(4) Make sure that $AV_{REF0} = V_{DD} = AV_{REF1}$ = 2.7 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 MΩ 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.

15.1 Mode Switching of UARTA and Other Serial Interfaces

15.1.1 CSIB4 and UARTA0 mode switching

In the V850ES/JG3-L, 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	$\overline{\text{SCKB4}}$ 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^{2}C00 mode switching

In the V850ES/JG3-L, UARTA2 and I^{2}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^{2}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^{2}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^{2}C00 mode

Remarks 1. n = 8, 9

2. × = don't care

15.1.3 UARTA1 and I^{2}C02 mode switching

In the V850ES/JG3-L, UARTA1 and I^{2}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^{2}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^{2}C02 Mode Switch Settings

After reset: 0000H R/W Address: FFFFF452H, FFFFF453H

	15	14	13	12	11	10	9	8
PMC9	PMC915	PMC914	PMC913	PMC912	PMC911	PMC910	PMC99	PMC98
	7	6	5	4	3	2	1	0
	PMC97	PMC96	PMC95	PMC94	PMC93	PMC92	PMC91	PMC90

After reset: 0000H R/W Address: FFFFF472H, FFFFF473H

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

After reset: 0000H R/W Address: FFFFF712H, FFFFF713H

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

PMC9n	PFCE9n	PFC9n	Operation mode
1	1	0	UARTA1 mode
1	1	1	I^{2}C02 mode

Remark n = 0, 1

15.2 Features

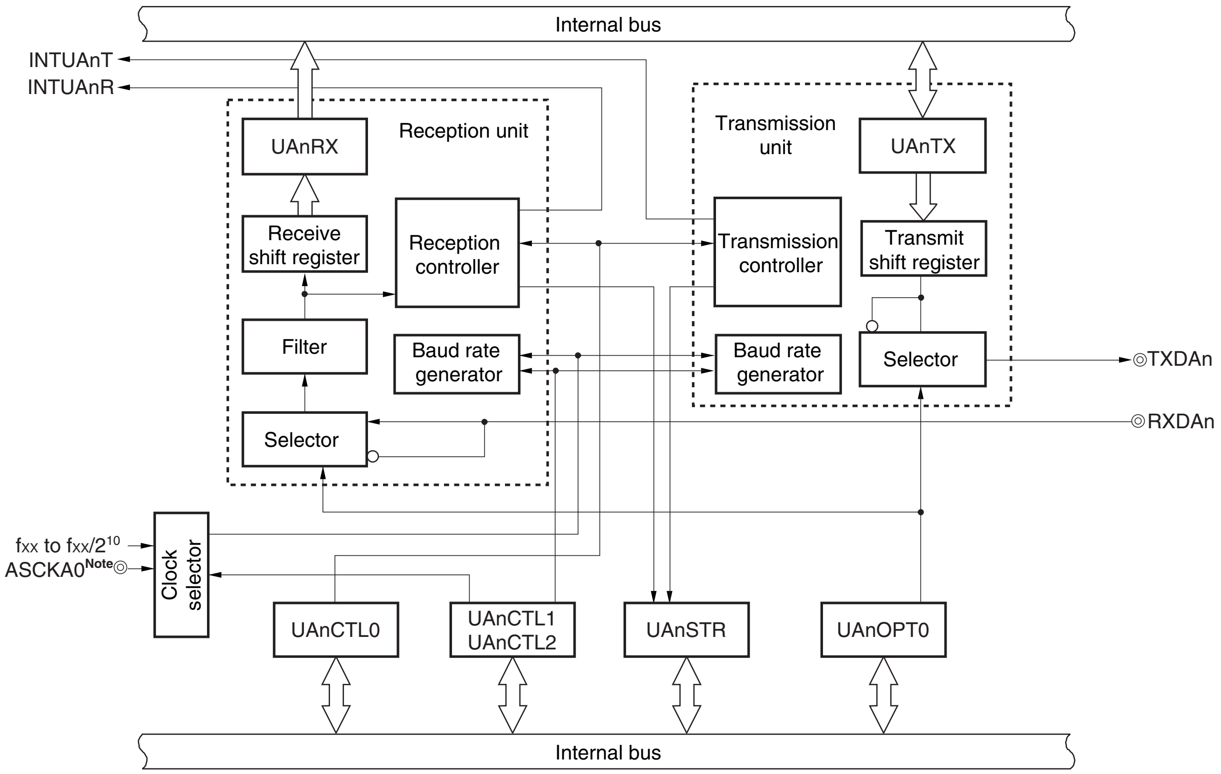
- ○ Transfer rate: 300 bps to 625 kbps (using internal system clock of 20 MHz and dedicated baud rate generator)
- ○ Full-duplex communication: Internal UARTAn receive data register (UAnRX)
  Internal UARTAn transmit data register (UAnTX)
- ○ 2-pin configuration: TXDAn: Transmit data output pin
  RXDAn: 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
  - 13 to 20 bits selectable for the SBF transmission
  - Recognition of 11 bits or more possible for SBF reception
  - SBF reception flag provided

Remark n = 0 to 2

15.3 Configuration

The block diagram of the UARTAn is shown below.

Figure 15-4. Block Diagram of Asynchronous Serial Interface An



Note UARTA0 only

Remarks 1. n = 0 to 2

2. For the configuration of the baud rate generator, see **Figure 15-16**.

UARTAn includes the following hardware.

Table 15-1. Configuration of UARTAn

Item	Configuration
Registers	UARTAn control register 0 (UAnCTL0) UARTAn control register 1 (UAnCTL1) UARTAn control register 2 (UAnCTL2) UARTAn option control register 0 (UAnOPT0) UARTAn status register (UAnSTR) UARTAn receive shift register UARTAn receive data register (UAnRX) UARTAn transmit shift register 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.

(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 FFFFFA00H, UA1CTL0 FFFFFA10H,
UA2CTL0 FFFFFA20H

	<7>	<6>	<5>	<4>	3	2	1	0
UAnCTL0 (n = 0 to 2)	UAnPWR	UAnTXE	UAnRXE	UAnDIR	UAnPS1	UAnPS0	UAnCL	UAnSL

UAnPWR	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).	

UAnTXE	Transmission operation enable
0	Disable transmission operation
1	Enable transmission operation
• 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. • 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 **15.7 (1) (a) Base clock**).	

UAnRXE	Reception operation enable
0	Disable reception operation
1	Enable reception operation
• 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. • 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 **15.7 (1) (a) Base clock**).	

(2/2)

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 FFFFFA03H, UA1OPT0 FFFFFA13H,
UA2OPT0 FFFFFA23H

	<7>	6	5	4	3	2	1	0
UAnOPT0 (n = 0 to 2)	UAnSRF	UAnSRT	UAnSTT	UAnSLS2	UAnSLS1	UAnSLS0	UAnTDL	UAnRDL

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

- SBF (Sync Brake Field) reception is judged during LIN communication.
- The UAnSRF bit is held at 1 when an SBF reception error occurs, and then SBF reception is started again.
- The UAnSRF bit is a read-only bit.

UAnSRT	SBF reception trigger
0	–
1	SBF reception trigger

- 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.
- Set the UAnSRT bit after setting the UAnPWR bit = UAnRXE bit = 1.

UAnSTT	SBF transmission trigger
0	–
1	SBF transmission trigger

- This is the SBF transmission trigger bit during LIN communication, and when read, “0” is always read.
- Set the UAnSTT bit after setting the UAnPWR bit = UAnTXE bit = 1.

Caution Do not set the UAnSRT and UAnSTT bits (to 1) during SBF reception (UAnSRF bit = 1).

(2/2)

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	• Reset • UAnCTL0.UAnPWR = 0
UAnTSF bit	• UAnCTL0.UAnTXE = 0
UAnPE, UAnFE, UAnOVE bits	• 0 write • UAnCTL0.UAnRXE = 0

After reset: 00H R/W Address: UA0STR FFFFFA04H, UA1STR FFFFFA14H,
UA2STR FFFFFA24H

	<7>	6	5	4	3	<2>	<1>	<0>
UAnSTR (n = 0 to 2)	UAnTSF	0	0	0	0	UAnPE	UAnFE	UAnOVE

UAnTSF	Transfer status flag
0	• When the UAnPWR bit = 0 or the UAnTXE bit = 0 has been set. • When, following transfer completion, there was no next data transfer from UAnTX register
1	Write to UAnTX register

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.

UAnPE	Parity error flag
0	• When the UAnPWR bit = 0 or the UAnRXE bit = 0 has been set. • When 0 has been written
1	When parity of data and parity bit do not match during reception.

- The operation of the UAnPE bit is controlled by the settings of the UAnCTL0.UAnPS1 and UAnCTL0.UAnPS0 bits.
- 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.

UAnFE	Framing error flag
0	• When the UAnPWR bit = 0 or the UAnRXE bit = 0 has been set • When 0 has been written
1	When no stop bit is detected during reception

- Only the first bit of the receive data stop bits is checked, regardless of the value of the UAnCTL0.UAnSL bit.
- 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.

UAnOVE	Overrun error flag
0	• When the UAnPWR bit = 0 or the UAnRXE bit = 0 has been set. • When 0 has been written
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

- When an overrun error occurs, the data is discarded without the next receive data being written to the receive buffer.
- 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.

(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.

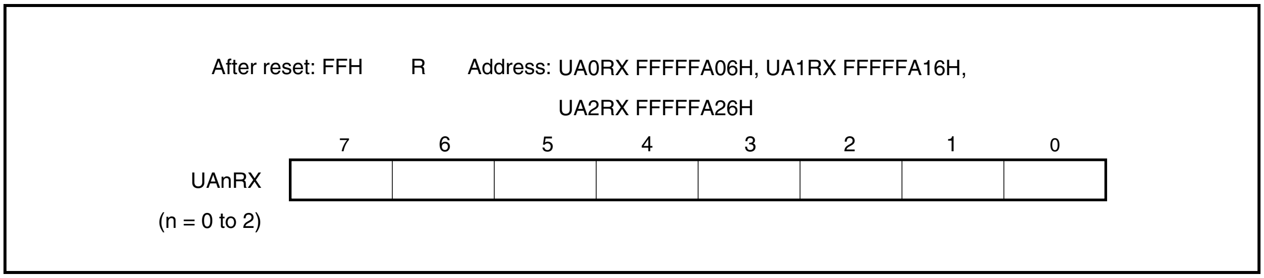
The data stored in the receive shift register is transferred to the UAnRX register upon completion of reception of 1 byte of data.

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.

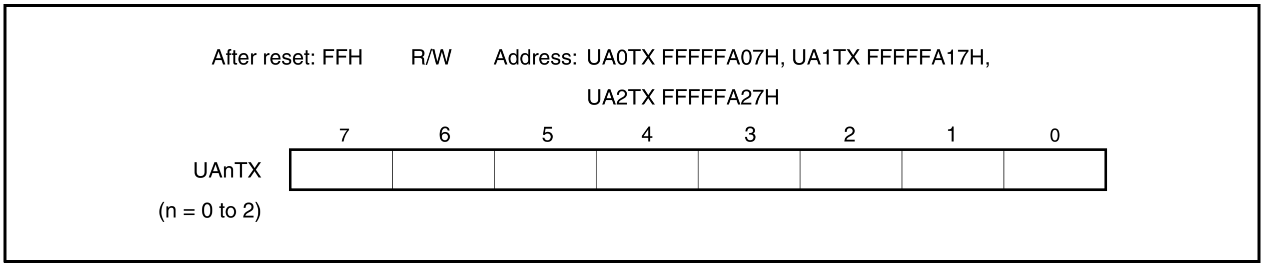


(7) UARTAn transmit data register (UAnTX)

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).

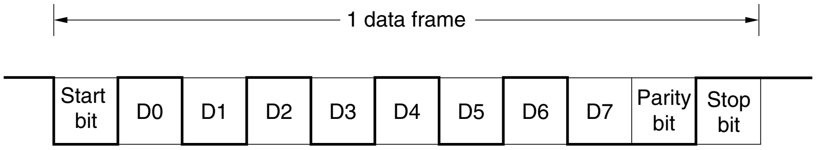
Specification of the character bit length within 1 data frame, parity selection, specification of the stop bit length, and specification of MSB/LSB-first transfer are performed using the UAnCTL0 register.

Moreover, control of UART output/inverted output for the TXDAn bit is performed using the UAnOPT0.UAnTDL bit.

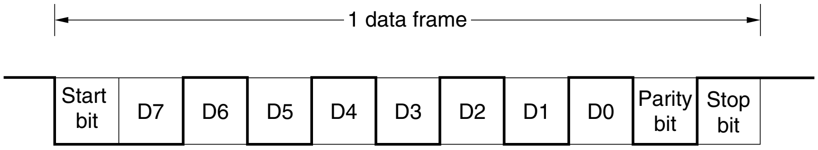
- Start bit.................. 1 bit
- Character bits........ 7 bits/8 bits
- Parity bit .... Even parity/odd parity/0 parity/no parity
- Stop bit .... 1 bit/2 bits

Figure 15-5. UARTA Transmit/Receive Data Format

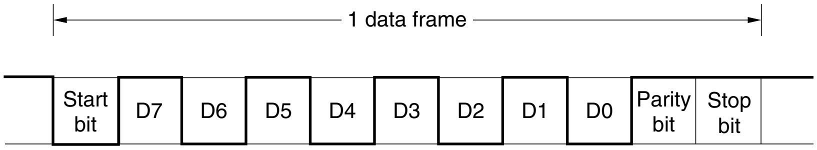
(a) 8-bit data length, LSB first, even parity, 1 stop bit, transfer data: 55H



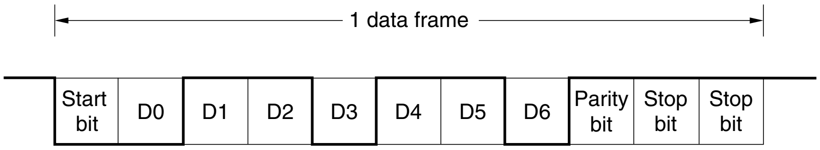
(b) 8-bit data length, MSB first, even parity, 1 stop bit, transfer data: 55H



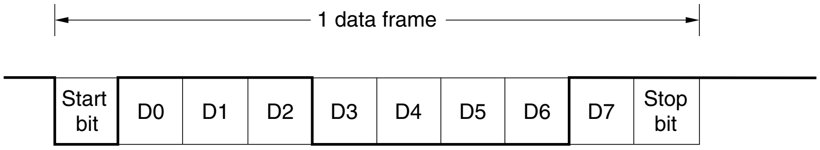
(c) 8-bit data length, MSB first, even parity, 1 stop bit, transfer data: 55H, TXDAn inversion



(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



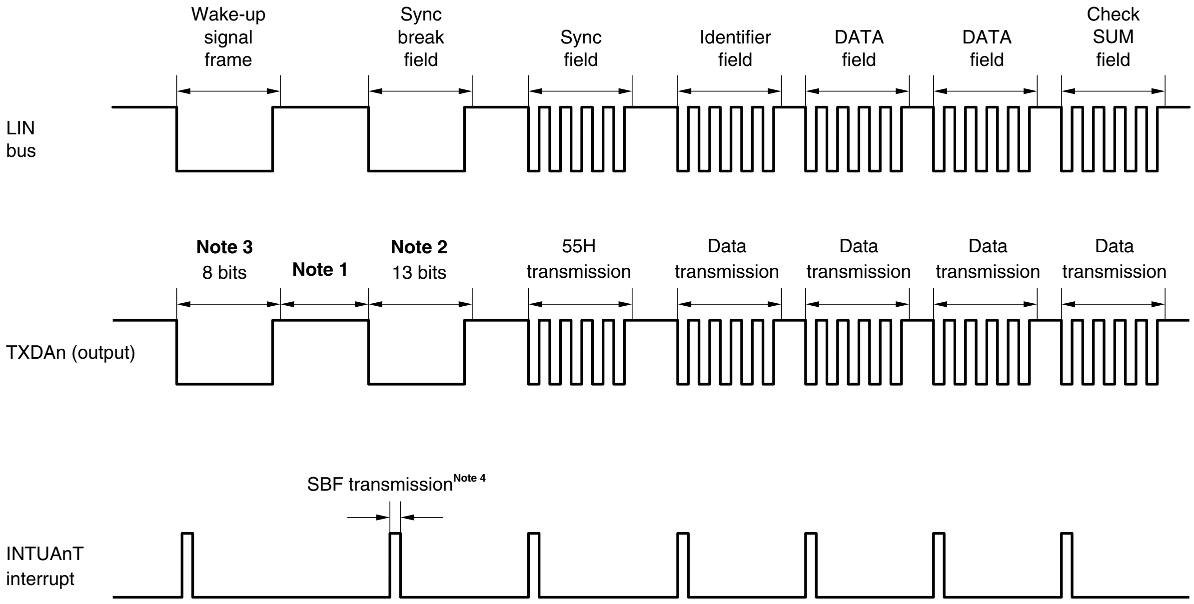
15.6.2 SBF transmission/reception format

The V850ES/JG3-L 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 ±15% or less.

Figures 15-6 and 15-7 outline the transmission and reception manipulations of LIN.

Figure 15-6. LIN Transmission Manipulation Outline



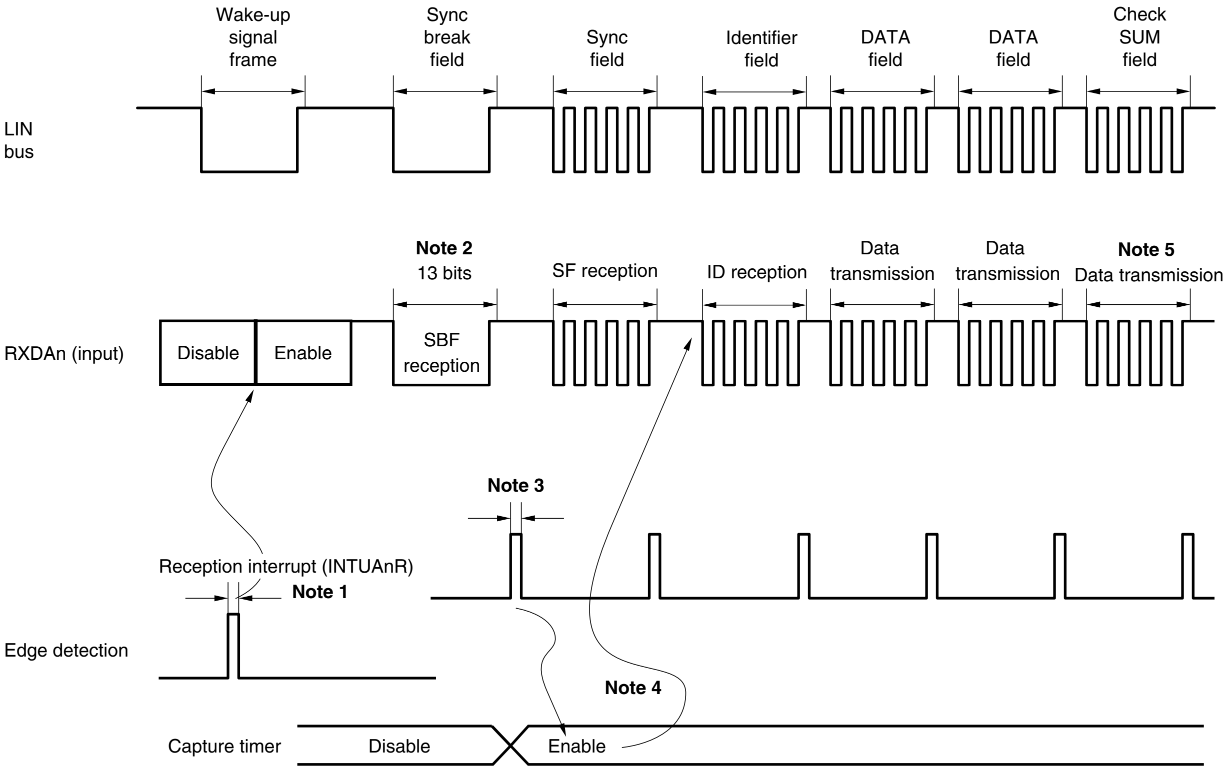
Notes 1. The interval between each field is controlled by software.

2. SBF output is performed by hardware. The output width is the bit length set by the UAnOPT0.UAnSBL2 to UAnOPT0.UAnSBL0 bits. If even finer output width adjustments are required, such adjustments can be performed using the UAnCTLn.UAnBRS7 to UAnCTLn.UAnBRS0 bits.

3. 80H transfer in the 8-bit mode is substituted for the wakeup signal frame.

4. A transmission enable interrupt request signal (INTUAnT) is output at the start of each transmission. The INTUAnT signal is also output at the start of each SBF transmission.

Figure 15-7. LIN Reception Manipulation Outline



Notes 1. The wakeup signal is sent by the pin edge detector, UARTAn is enabled, and the SBF reception mode is set.

2. The receive operation is performed until detection of the stop bit. Upon detection of SBF reception of 11 or more bits, normal SBF reception end is judged, and an interrupt signal is output. Upon detection of SBF reception of less than 11 bits, an SBF reception error is judged, no interrupt signal is output, and the mode returns to the SBF reception mode.

3. If SBF reception ends normally, an interrupt request signal is output. The timer is enabled by an SBF reception complete interrupt. Moreover, error detection for the UAnSTR.UAnOVE, UAnSTR.UAnPE, and UAnSTR.UAnFE bits is suppressed and UART communication error detection processing and UARTAn receive shift register and data transfer of the UAnRX register are not performed. The UARTAn receive shift register holds the initial value, FFH.

4. The RXDAn pin is connected to TI (capture input) of the timer, the transfer rate is calculated, and the baud rate error is calculated. The value of the UAnCTL2 register obtained by correcting the baud rate error after dropping UARTA enable is set again, causing the status to become the reception status.

5. Check-sum field distinctions are made by software. UARTAn is initialized following CSF reception, and the processing for setting the SBF reception mode again is performed by software.

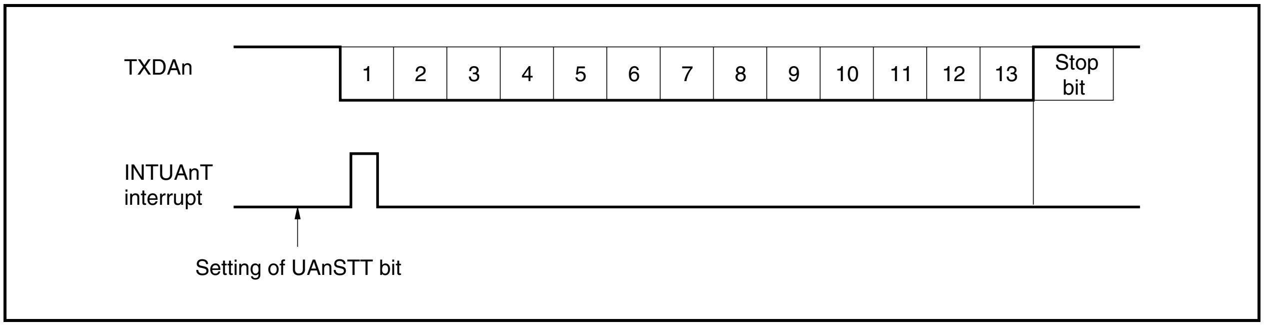
15.6.3 SBF transmission

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.

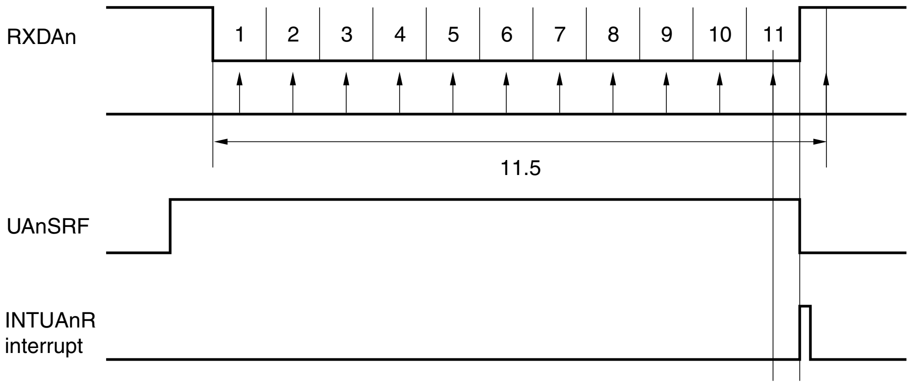
When a stop bit is received, if the SBF width is 11 or more bits, normal processing is judged and a reception complete interrupt request signal (INTUAnR) is output. The UAnOPT0.UAnSRF bit is automatically cleared and SBF reception ends. Error detection for the UAnSTR.UAnOVE, UAnSTR.UAnPE, and UAnSTR.UAnFE 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.

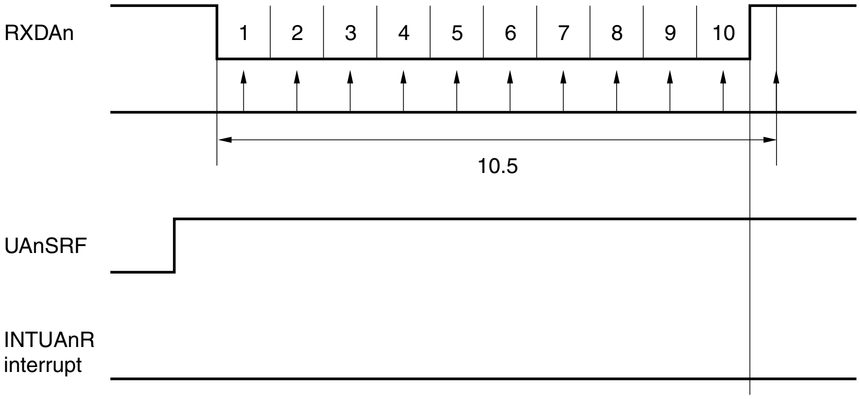
2. Do not set the SBF reception trigger bit (UAnSRT) and SBF transmission trigger bit (UAnSTT) to 1 during an SBF reception (UAnSRF = 1).

Figure 15-9. SBF Reception

(a) Normal SBF reception (detection of stop bit in more than 10.5 bits)



(b) SBF reception error (detection of stop bit in 10.5 or fewer bits)



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.

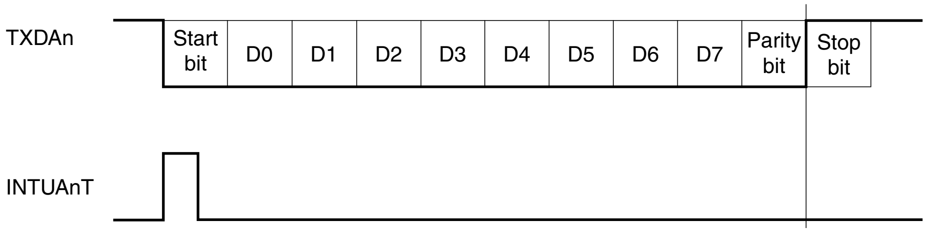
Since the CTS (transmit enable signal) input pin is not provided in UARTAn, use a port to check that reception is enabled at the transmit destination.

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



Remark LSB first

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

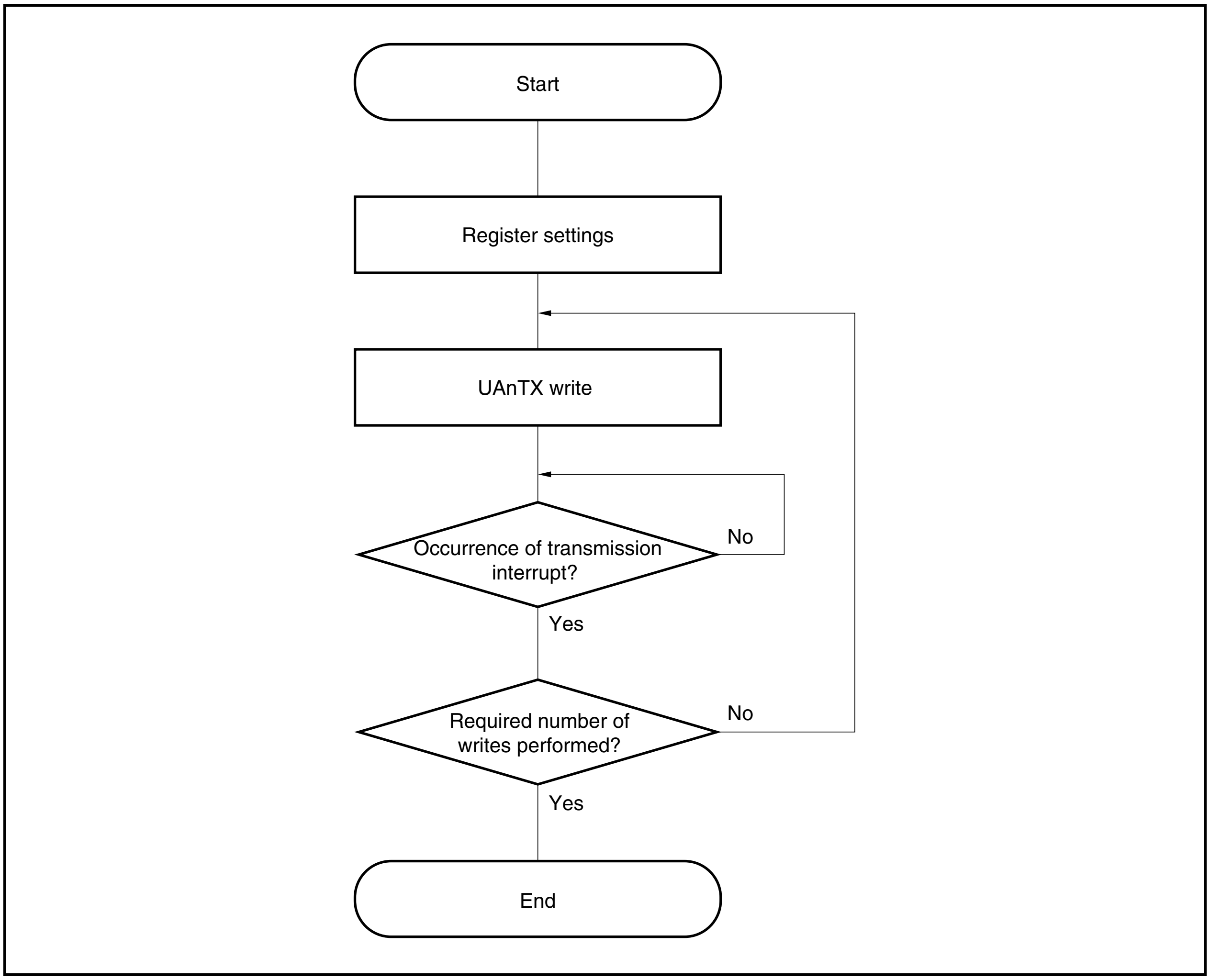
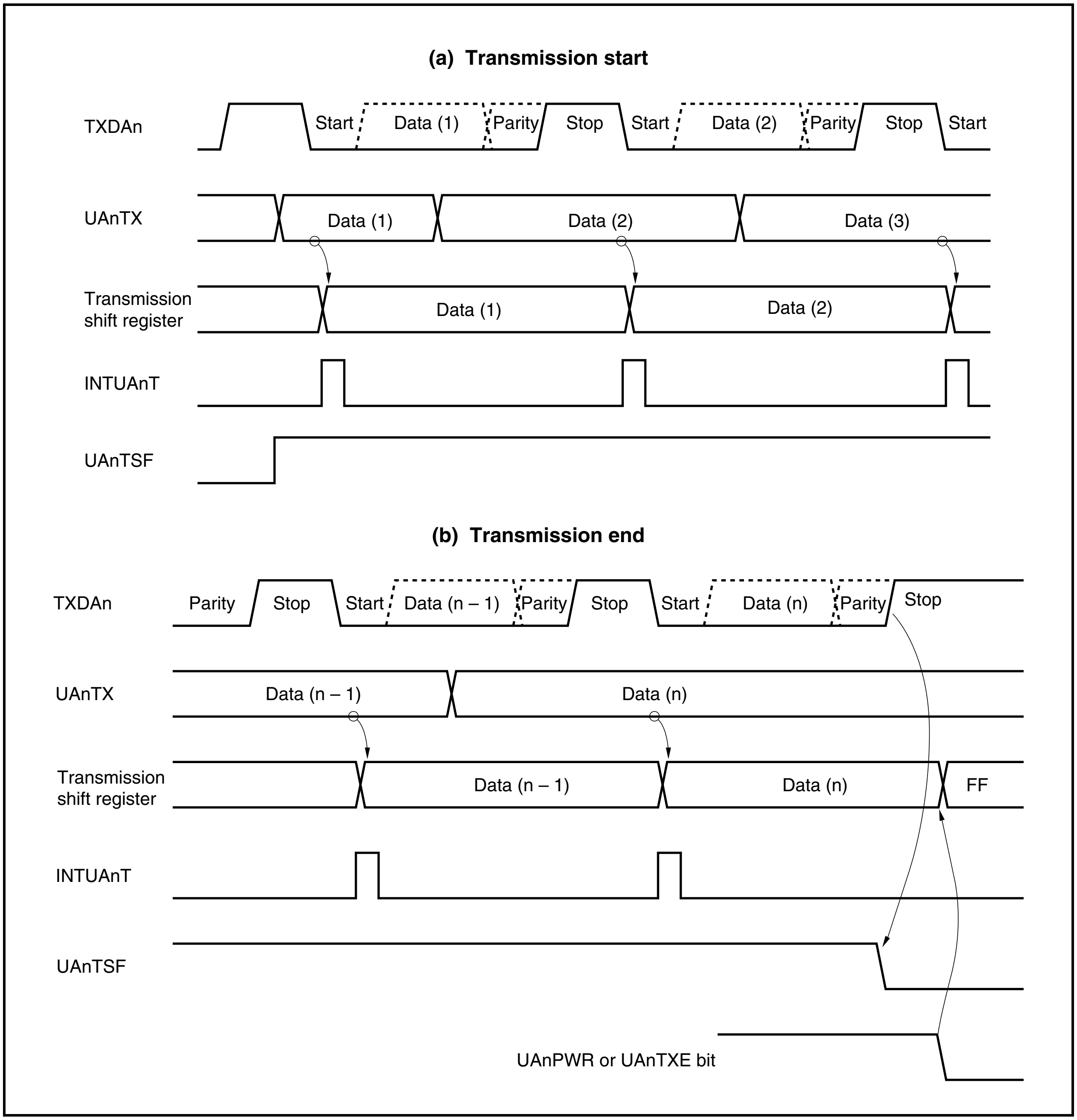


Figure 15-12. Continuous Transmission Operation Timing



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.

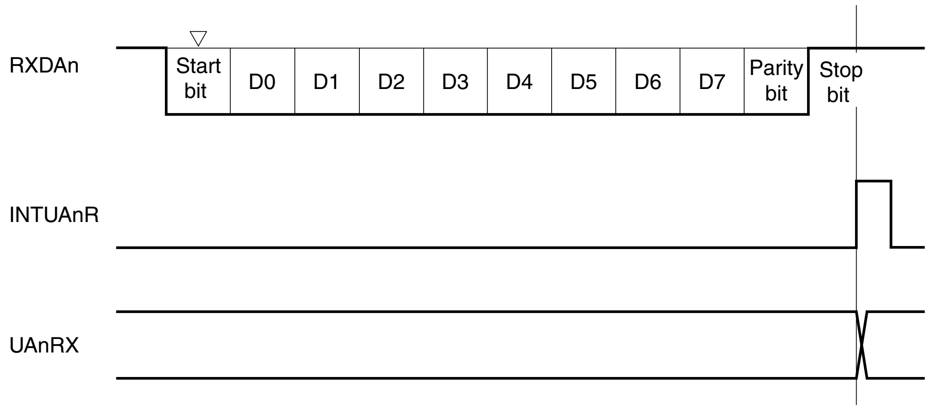
Start bit detection is performed using a two-step detection routine.

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 UARTAn 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 UARTAn 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.

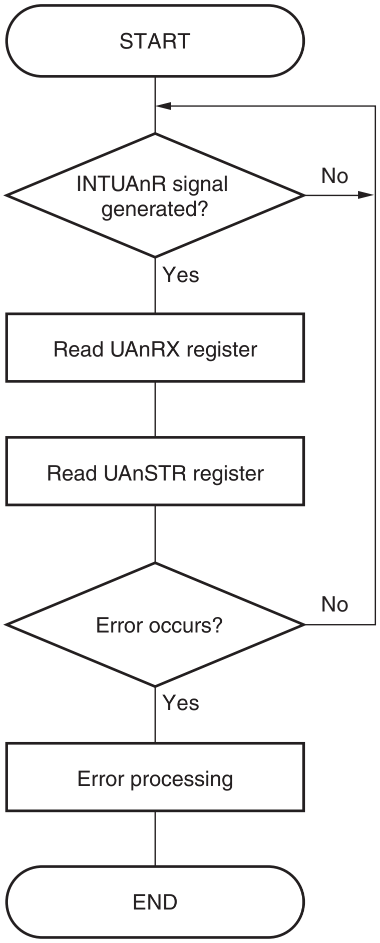
To complete reception without waiting INTUAnR signal generation, be sure to clear (0) the interrupt request flag (UAnRIF) of the UAnRIC register, after setting (1) the interrupt mask flag (UAnRMK) of the interrupt control register (UAnRIC) and then set (1) the UAnPWR bit = 0 or UAnRXE bit = 0.

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



Caution When an INTUAnR signal is generated, the UAnSTR register must be read to check for errors.

- 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

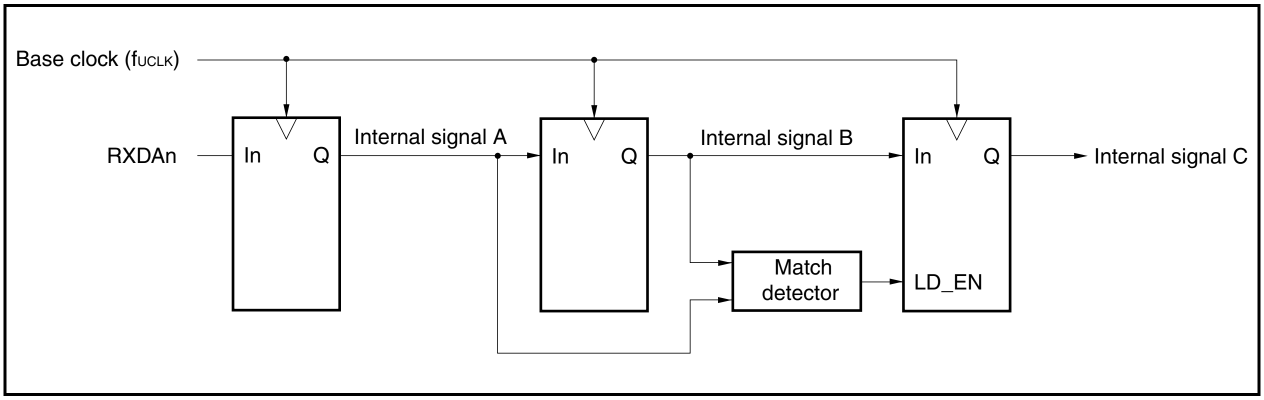
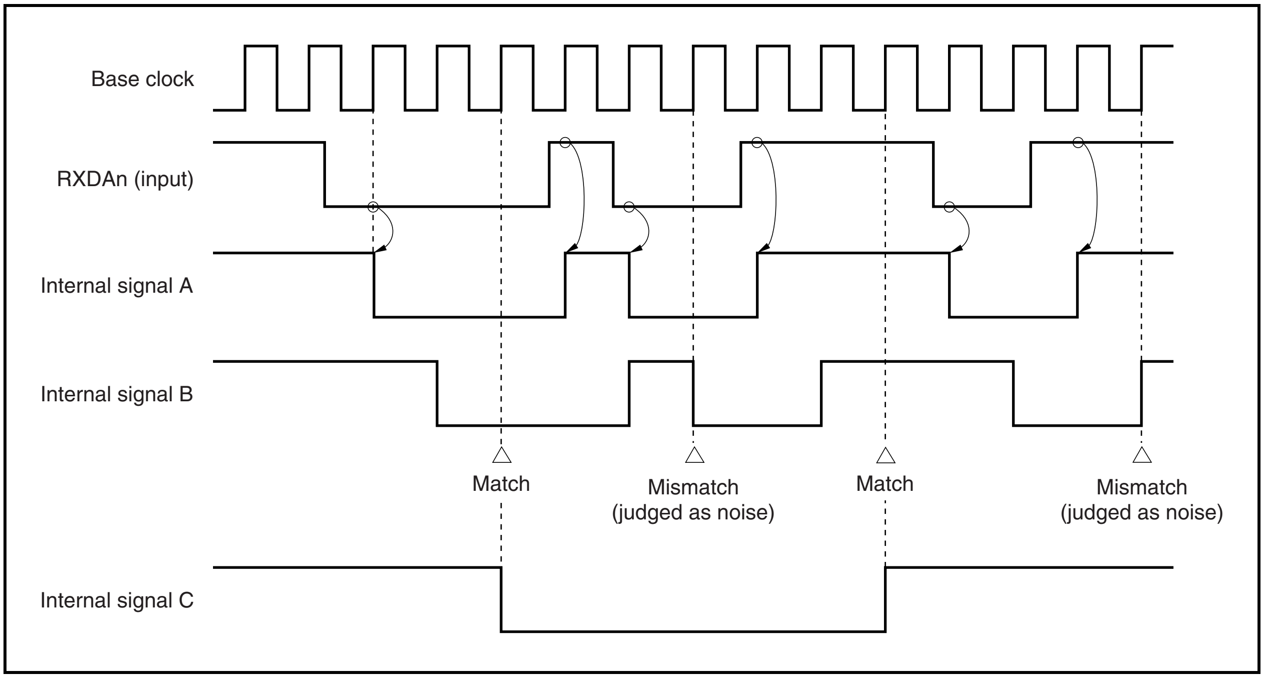


Figure 15-15. Timing of RXDAn Signal Judged as Noise



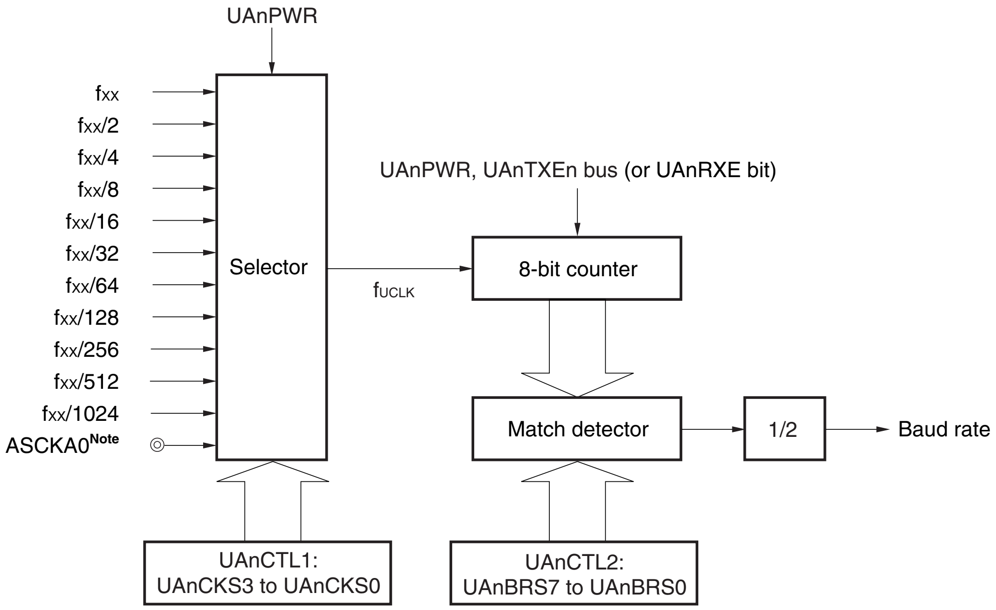
15.7 Dedicated Baud Rate Generator

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



Note Only UARTA0 is valid; setting UARTA1 and UARTA2 is prohibited.

Remarks 1. n = 0 to 2

2. f_{XX}: Main clock frequency

f_{UCLK}: Base clock frequency

(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 2).

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 FFFFFA01H, UA1CTL1 FFFFFA11H,
UA2CTL1 FFFFFA21H

	7	6	5	4	3	2	1	0
UAnCTL1 (n = 0 to 2)	0	0	0	0	UAnCKS3	UAnCKS2	UAnCKS1	UAnCKS0

UAnCKS3	UAnCKS2	UAnCKS1	UAnCKS0	Base clock (f_{UCLK}) 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[Note] (ASCKA0 pin)
Other than above				Setting prohibited

Note Only UARTA0 is valid; setting UARTA1 and UARTA2 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 FFFFFA02H, UA1CTL2 FFFFFA12H,
UA2CTL2 FFFFFA22H

	7	6	5	4	3	2	1	0
UAnCTL2 (n = 0 to 2)	UAnBRS7	UAnBRS6	UAnBRS5	UAnBRS4	UAnBRS3	UAnBRS2	UAnBRS1	UAnBRS0

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	$f_{UCLK}/4$
0	0	0	0	0	1	0	1	5	$f_{UCLK}/5$
0	0	0	0	0	1	1	0	6	$f_{UCLK}/6$
:	:	:	:	:	:	:	:	:	:
1	1	1	1	1	1	0	0	252	$f_{UCLK}/252$
1	1	1	1	1	1	0	1	253	$f_{UCLK}/253$
1	1	1	1	1	1	1	0	254	$f_{UCLK}/254$
1	1	1	1	1	1	1	1	255	$f_{UCLK}/255$

Remark f_{UCLK}: Clock frequency selected by the UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits

(4) Baud rate

The baud rate is obtained by the following equation.

$$\text{Baud rate} = \frac{f_{UCLK}}{2 \times k} \text{ [bps]}$$

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).

$$\text{Baud rate} = \frac{f_{XX}}{2^{m+1} \times k} \text{ [bps]}$$

Remark f_{UCLK} = Frequency of base clock selected by the UAnCTL1.UAnCKS3 to UAnCTL1.UAnCKS0 bits

f_{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.

$$\text{Error (\%)} = \left(\frac{\text{Actual baud rate (baud rate with error)}}{\text{Target baud rate (correct baud rate)}} - 1 \right) \times 100 \text{ [\%]}$$

$$= \left(\frac{f_{UCLK}}{2 \times k \times \text{Target baud rate}} - 1 \right) \times 100 \text{ [\%]}$$

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).

$$\text{Error (\%)} = \left(\frac{f_{XX}}{2^{m+1} \times k \times \text{Target baud rate}} - 1 \right) \times 100 \text{ [\%]}$$

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 × target baud rate) and m to 0.
<2> If k is 256 or greater (k ≥ 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} = 20 MHz and target baud rate = 153,600 bps
<1> k = 20,000,000/(2 × 153,600) = 65.10…, m = 0
<2>, <3> k = 65.10… < 256, m = 0
<4> Set value of UAnCTL2 register: k = 65 = 41H, set value of UAnCTL1 register: m = 0

Actual baud rate = 20,000,000/(2 × 65)
= 153,846 [bps]

Baud rate error = {20,000,000/(2 × 65 × 153,600) − 1} × 100
= 0.160 [%]

The representative examples of baud rate settings are shown below.

Table 15-3. Baud Rate Generator Setting Data

Baud Rate (bps)	f_{XX} = 20 MHz			f_{XX} = 16 MHz			f_{XX} = 10 MHz		
	UAnCTL1	UAnCTL2	ERR (%)	UAnCTL1	UAnCTL2	ERR (%)	UAnCTL1	UAnCTL2	ERR (%)
300	08H	82H	0.16	07H	D0H	0.16	07H	82H	0.16
600	07H	82H	0.16	06H	D0H	0.16	06H	82H	0.16
1200	06H	82H	0.16	05H	D0H	0.16	05H	82H	0.16
2400	05H	82H	0.16	04H	D0H	0.16	04H	82H	0.16
4800	04H	82H	0.16	03H	D0H	0.16	03H	82H	0.16
9600	03H	82H	0.16	02H	D0H	0.16	02H	82H	0.16
19200	02H	82H	0.16	01H	D0H	0.16	01H	82H	0.16
31250	01H	A0H	0	01H	80H	0	00H	A0H	0
38400	01H	82H	0.16	00H	D0H	0.16	00H	82H	0.16
76800	00H	82H	0.16	00H	68H	0.16	00H	41H	0.16
153600	00H	41H	0.16	00H	34H	0.16	00H	21H	−1.36
312500	00H	20H	0	00H	1AH	−1.54	00H	10H	0
625000	00H	10H	0	00H	0DH	−1.54	00H	08H	0

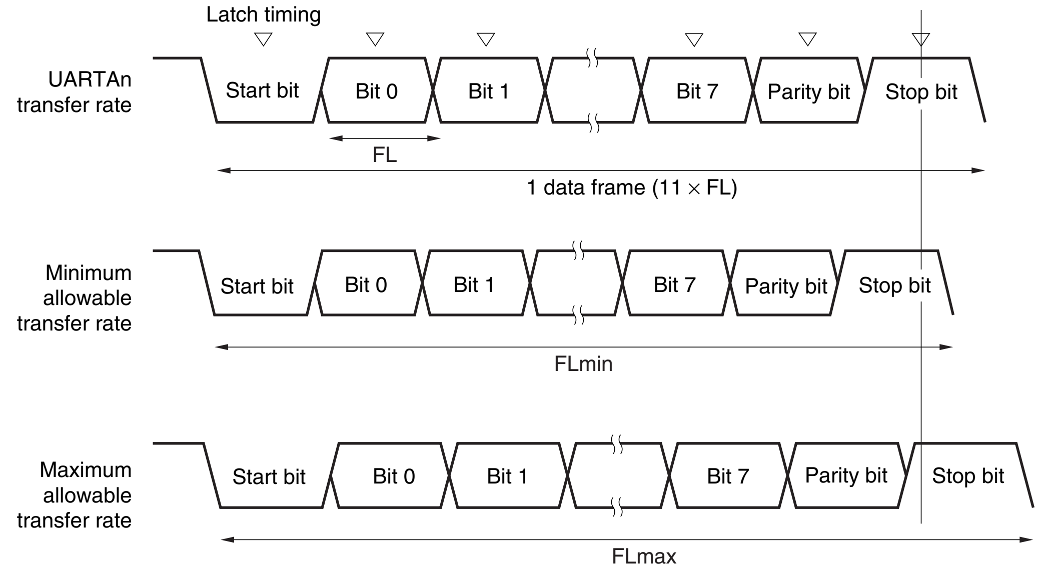
Remark f_{XX}: Main clock frequency
ERR: Baud rate error (%)

(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



Remark n = 0 to 2

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.

$FL = (Brate)^{-1}$

Brate: UARTAn baud rate (n = 0 to 2)
k: Setting value of UAnCTL2.UAnBRS7 to UAnCTL2.UAnBRS0 bits (n = 0 to 2)
FL: 1-bit data length
Latch timing margin: 2 clocks

Minimum allowable transfer rate: $FLmin = 11 \times FL - \frac{k-2}{2k} \times FL = \frac{21k+2}{2k} FL$

Therefore, the maximum baud rate that can be received by the destination is as follows.

$$\boxed{BRmax = (FLmin/11)^{-1} = \frac{22k}{21k + 2} \text{ Brate}}$$

Similarly, obtaining the following maximum allowable transfer rate yields the following.

$$\frac{10}{11} \times FLmax = 11 \times FL - \frac{k + 2}{2 \times k} \times FL = \frac{21k - 2}{2 \times k} FL$$

$$FLmax = \frac{21k - 2}{20\ k} FL \times 11$$

Therefore, the minimum baud rate that can be received by the destination is as follows.

$$\boxed{BRmin = (FLmax/11)^{-1} = \frac{20k}{21k - 2} \text{ Brate}}$$

Obtaining the allowable baud rate error for UARTAn 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%

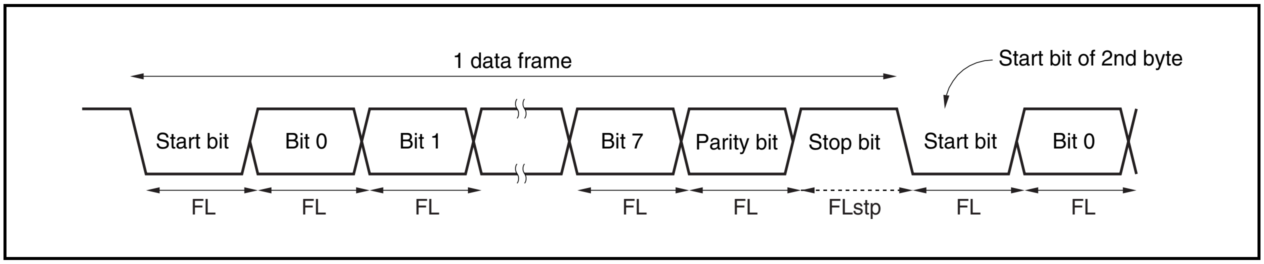
Remarks 1. The reception accuracy depends on the bit count in 1 frame, the input clock frequency, and the division ratio (k). The higher the input clock frequency and the larger the division ratio (k), the higher the accuracy.

2. k: Setting value of UAnCTL2.UAnBRS7 to UAnCTL2.UAnBRS0 bits (n = 0 to 2)

(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_{UCLK}, we obtain the following equation.

$$FLstp = FL + 2/f_{UCLK}$$

Therefore, the transfer rate during continuous transmission is as follows.

$$\text{Transfer rate} = 11 \times FL + (2/f_{UCLK})$$

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.

16.1 Mode Switching of CSIB and Other Serial Interfaces

16.1.1 CSIB4 and UARTA0 mode switching

In the V850ES/JG3-L, 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

After reset: 0000H R/W Address: FFFFF446H, FFFFF447H

PMC3

15	14	13	12	11	10	9	8
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

PFC3

15	14	13	12	11	10	9	8
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

PFCE3L

7	6	5	4	3	2	1	0
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	$\overline{\text{SCKB4}}$ 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

16.1.2 CSIB0 and I^{2}C01 mode switching

In the V850ES/JG3-L, CSIB0 and I^{2}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^{2}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^{2}C01 Mode Switch Settings

After reset: 00H R/W Address: FFFFF448H

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

After reset: 00H R/W Address: FFFFF468H

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

PMC4n	PFC4n	Operation mode
0	×	Port I/O mode
1	0	CSIB0 mode
1	1	I^{2}C01 mode

Remarks 1. n = 0, 1

2. × = don’t care

16.2 Features

○ Transfer rate: 5 Mbps max. (f_{XX} = 20 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)

○ 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

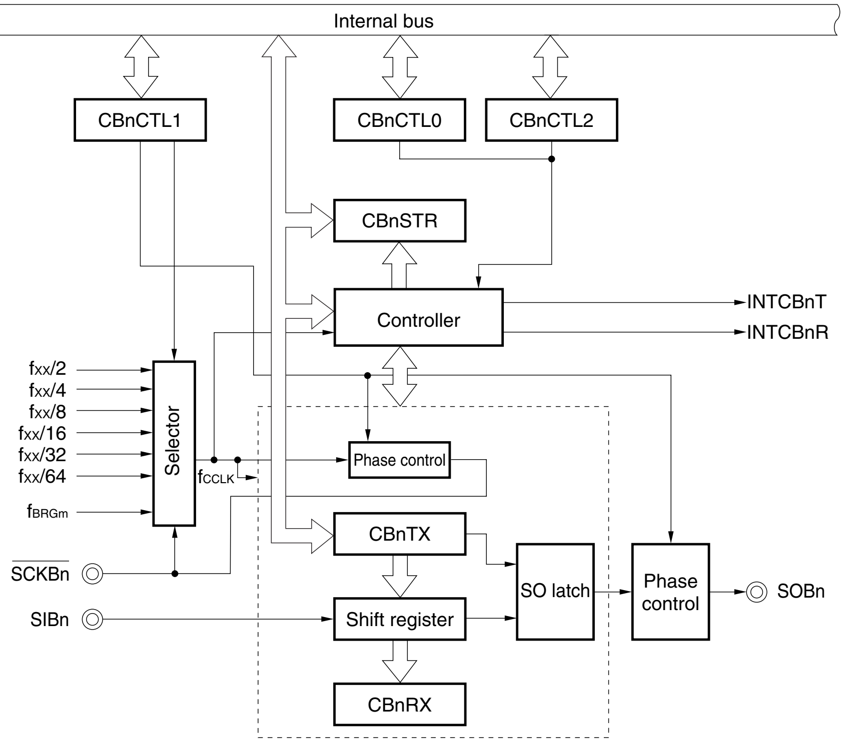
○ 3-wire transfer SOBn: Serial data output
SIBn: Serial data input
$\overline{\text{SCKBn}}$: Serial clock output
Transmission mode, reception mode, and transmission/reception mode specifiable

Remark n = 0 to 4

16.3 Configuration

The following shows the block diagram of CSIBn.

Figure 16-3. Block Diagram of CSIBn



Remarks f_{CCLK}: Communication clock

f_{XX}: Main clock frequency

f_{BRGm}: BRGm count clock

n = 0 to 4

m = 1 (n = 0, 1)

m = 2 (n = 2, 3)

m = 3 (n = 4)

CSIBn includes the following hardware.

Table 16-1. Configuration of CSIBn

Item	Configuration
Registers	CSIBn receive data register (CBnRX) CSIBn transmit data register (CBnTX)
Control registers	CSIBn control register 0 (CBnCTL0) CSIBn control register 1 (CBnCTL1) CSIBn control register 2 (CBnCTL2) 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.

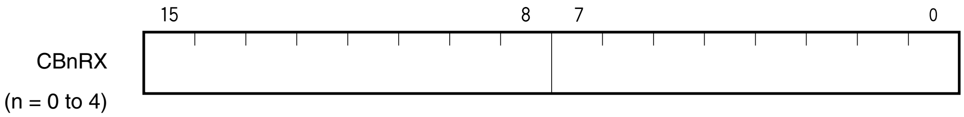
The receive operation is started by reading the CBnRX register in the reception enabled status.

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.

After reset: 0000H R Address: CB0RX FFFFFD04H, CB1RX FFFFFD14H,
CB2RX FFFFFD24H, CB3RX FFFFFD34H,
CB4RX FFFFFD44H



(2) CSIBn transmit data register (CBnTX)

The CBnTX register is a 16-bit buffer register used to write the CSIBn transfer data.

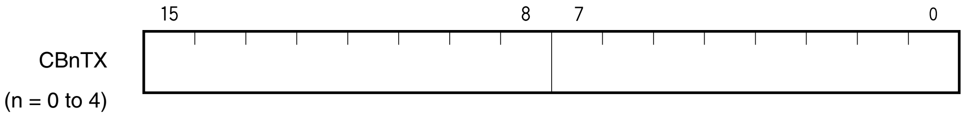
This register can be read or written in 16-bit units.

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.

After reset 0000H R/W Address: CB0TX FFFFFD06H, CB1TX FFFFFD16H,
CB2TX FFFFFD26H, CB3TX FFFFFD36H,
CB4TX FFFFFD46H



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 FFFFFD00H, CB1CTL0 FFFFFD10H,
CB2CTL0 FFFFFD20H, CB3CTL0 FFFFFD30H,
CB4CTL0 FFFFFD40H

	<7>	<6>	<5>	<4>	3	2	1	<0>
CBnCTL0 (n = 0 to 4)	CBnPWR	CBnTXE[Note]	CBnRXE[Note]	CBnDIR[Note]	0	0	CBnTMS[Note]	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[Note]	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[Note]	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.

(2/3)

CBnDIR[Note]	Specification of transfer direction mode (MSB/LSB)
0	MSB-first transfer
1	LSB-first transfer

CBnTMS[Note]	Transfer mode specification
0	Single transfer mode
1	Continuous transfer mode

[In single transfer mode]

The reception complete interrupt (INTCBnR) occurs when communication is complete.

Even if transmission is enabled (CBnTXE bit = 1), the transmission enable interrupt (INTCBnT) does not occur.

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. CBnTSF 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, the CBnPWR can be set to 1 at the same time as these bits are rewritten.

(3/3)

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[Note 1].
  (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[Note 2].
- 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 1. If the CBnSCE bit is read while it is 1, the next communication operation is started.

2. 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.

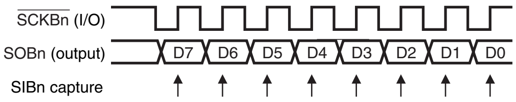
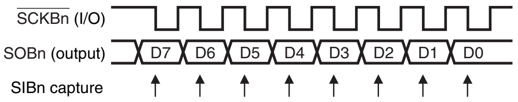
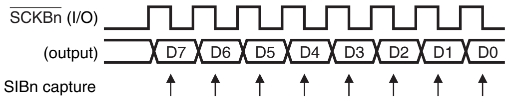
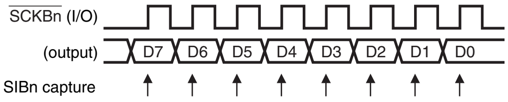
This register can be read or written in 8-bit or 1-bit units.

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 FFFFFD01H, CB1CTL1 FFFFFD11H,
CB2CTL1 FFFFFD21H, CB3CTL1 FFFFFD31H,
CB4CTL1 FFFFFD41H

	7	6	5	4	3	2	1	0
CBnCTL1 (n = 0 to 4)	0	0	0	CBnCKP	CBnDAP	CBnCKS2	CBnCKS1	CBnCKS0

	CBnCKP	CBnDAP	Specification of data transmission/ reception timing in relation to $\overline{\text{SCKBn}}$
Communication type 1	0	0	
Communication type 2	0	1	
Communication type 3	1	0	
Communication type 4	1	1	

CBnCKS2	CBnCKS1	CBnCKS0	Communication clock (f_{CCLK})[Note]	Mode
0	0	0	$f_{XX}/2$	Master mode
0	0	1	$f_{XX}/4$	Master mode
0	1	0	$f_{XX}/8$	Master mode
0	1	1	$f_{XX}/16$	Master mode
1	0	0	$f_{XX}/32$	Master mode
1	0	1	$f_{XX}/64$	Master mode
1	1	0	f_{BRGm}	Master mode
1	1	1	External clock ($\overline{\text{SCKBn}}$)	Slave mode

Note Set the communication clock (f_{CCLK}) to 5 MHz or lower.

Remark When n = 0, 1, m = 1
When n = 2, 3, m = 2
When n = 4, m = 3
For details of f_{BRGm}, 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 FFFFFD02H, CB1CTL2 FFFFFD12H,
CB2CTL2 FFFFFD22H, CB3CTL2 FFFFFD32H,
CB4CTL2 FFFFFD42H

	7	6	5	4	3	2	1	0
CBnCTL2 (n = 0 to 4)	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

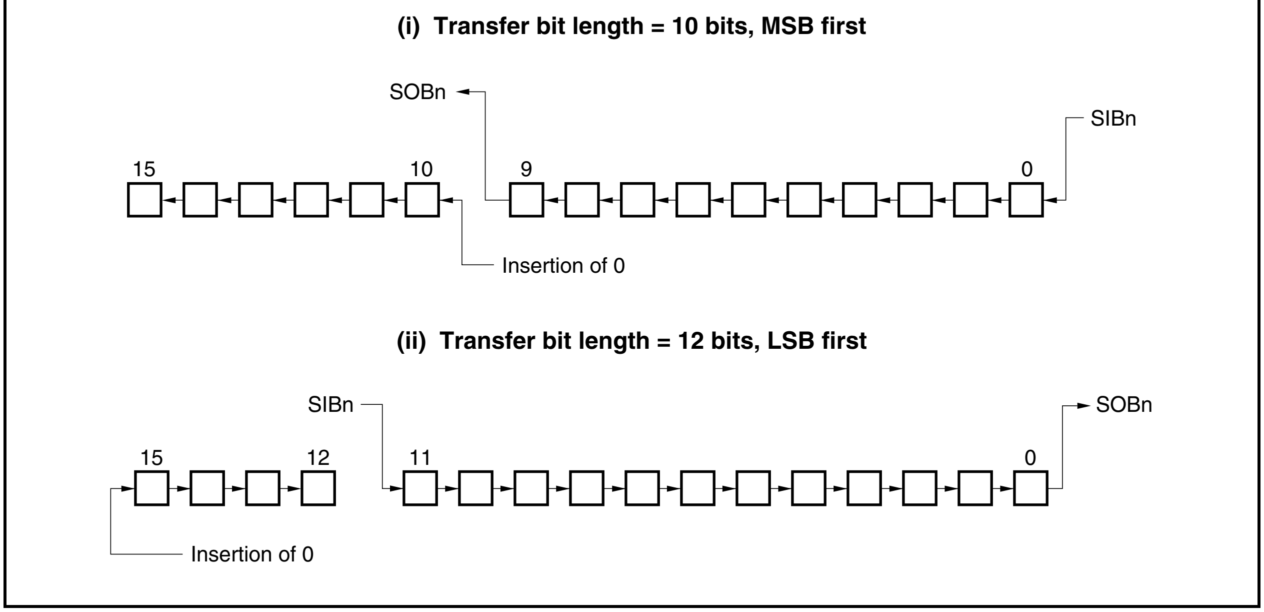
Remarks 1. If the number of transfer bits is other than 8 or 16, prepare and use data stuffed from the LSB of the CBnTX and CBnRX registers.

2. ×: don’t care

(a) Transfer data length change function

The CSIBn 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 FFFFFD03H, CB1STR FFFFFD13H,
CB2STR FFFFFD23H, CB3STR FFFFFD33H,
CB4STR FFFFFD43H

	<7>	6	5	4	3	2	1	<0>
CBnSTR (n = 0 to 4)	CBnTSF	0	0	0	0	0	0	CBnOVE

CBnTSF	Communication status flag
0	Communication stopped
1	Communicating

- 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.
  When transfer ends, this flag is cleared to 0 at the last edge of the clock.

CBnOVE	Overrun error flag
0	No overrun
1	Overrun

- 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.
- The CBnOVE bit is valid also in the single transfer mode. Therefore, when only using transmission, note the following.
  - Do not check the CBnOVE flag.
  - Read this bit even if reading the reception data is not required.
- The CBnOVE flag is cleared by writing 0 to it. It cannot be set even by writing 1 to it.

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.

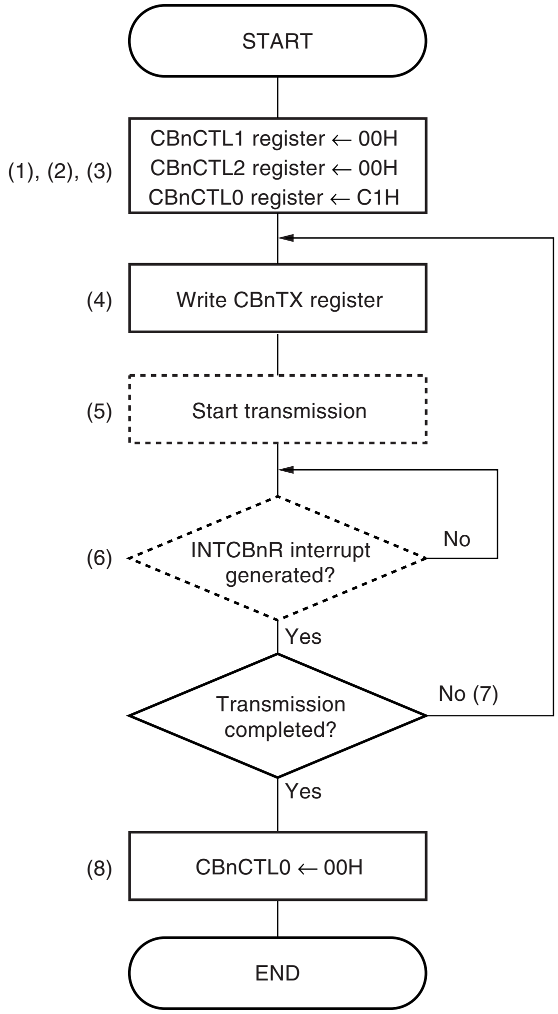
In the single transmission and single transmission/reception modes, the INTCBnT interrupt is not generated.

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_{CCLK}) = $f_{XX}/2$ (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow

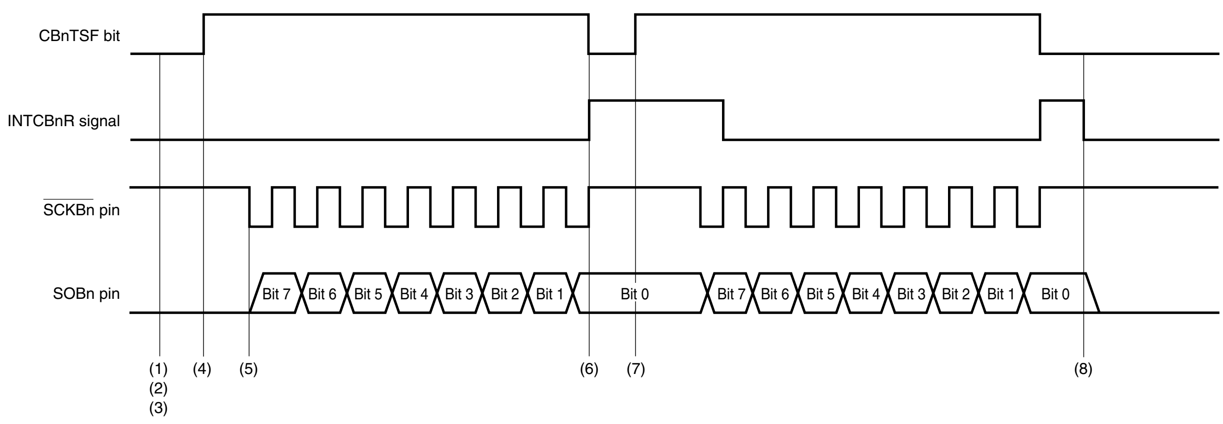


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(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 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_{CCLK}).

(4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and start transmission.

(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 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 (INTCBnR) at the last edge of the serial clock, and clear the CBnTSF bit to 0.

(7) To continue transmission, start the next transmission by writing the transmit data to the CBnTX register again after the INTCBnR signal is generated.

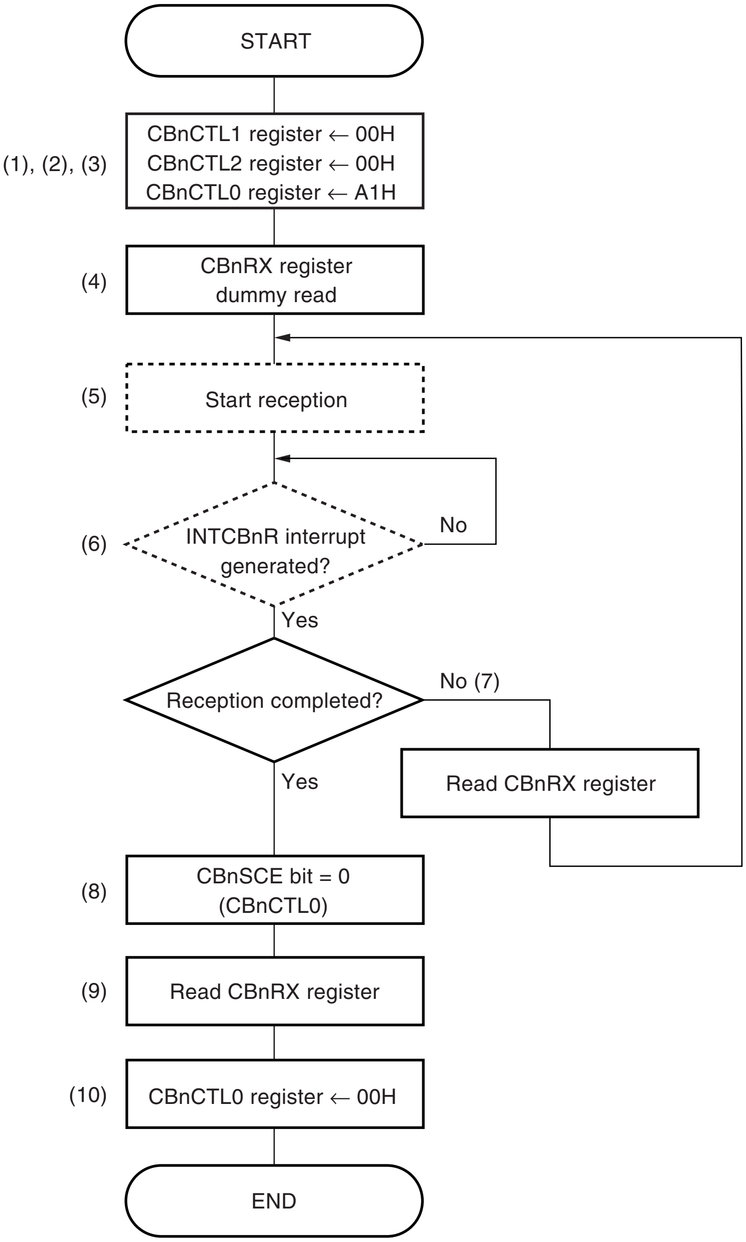
(8) To end transmission, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnTXE bit = 0.

Remark n = 0 to 4

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_{CCLK}) = $f_{XX}/2$ (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow

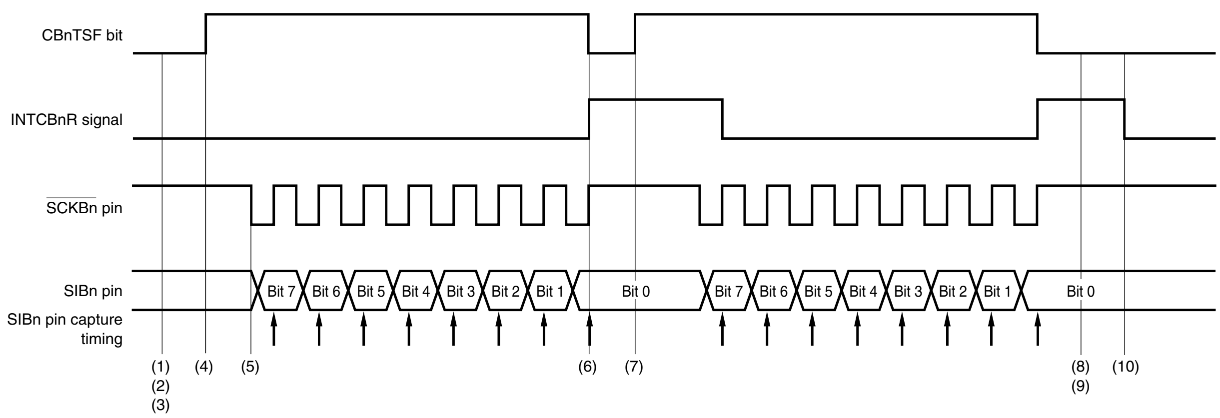


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(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 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_{CCLK}).

(4) The CBnSTR.CBnTSF bit is set to 1 by performing a dummy read of the CBnRX register, and start reception.

(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 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.

(8) To read the CBnRX register without starting the next reception, write the CBnSCE bit = 0.

(9) Read the CBnRX register.

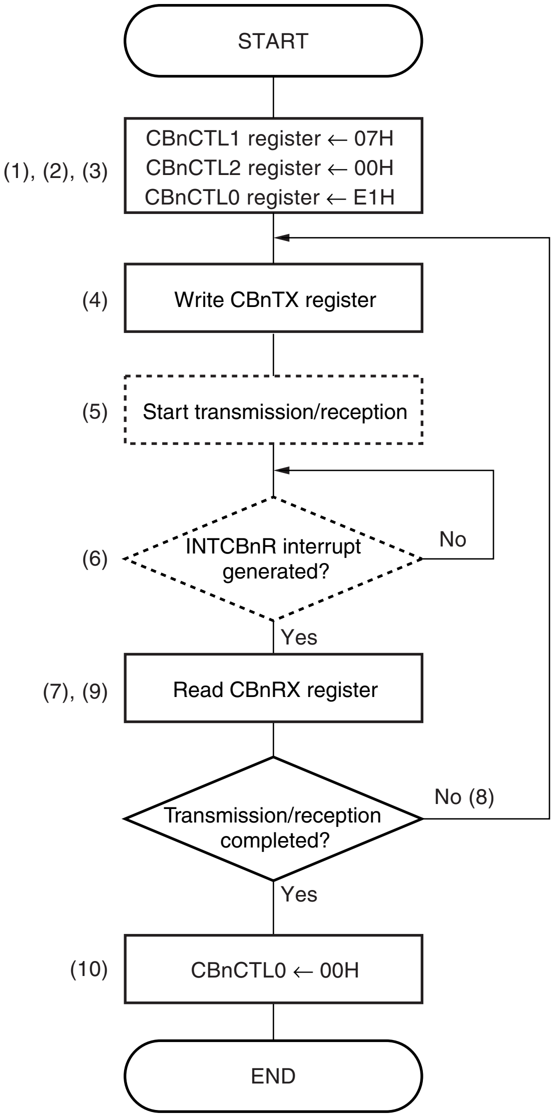
(10) To end reception, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnRXE bit = 0.

Remark n = 0 to 4

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_{CCLK}) = $f_{XX}/2$ (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow

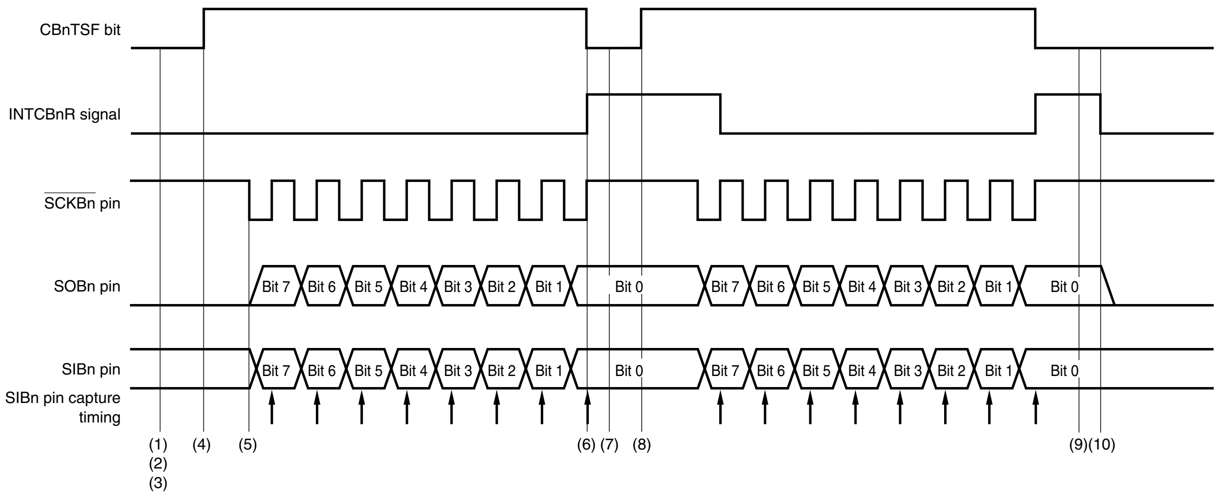


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(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 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_{CCLK}).

(4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and start transmission/reception.

(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.

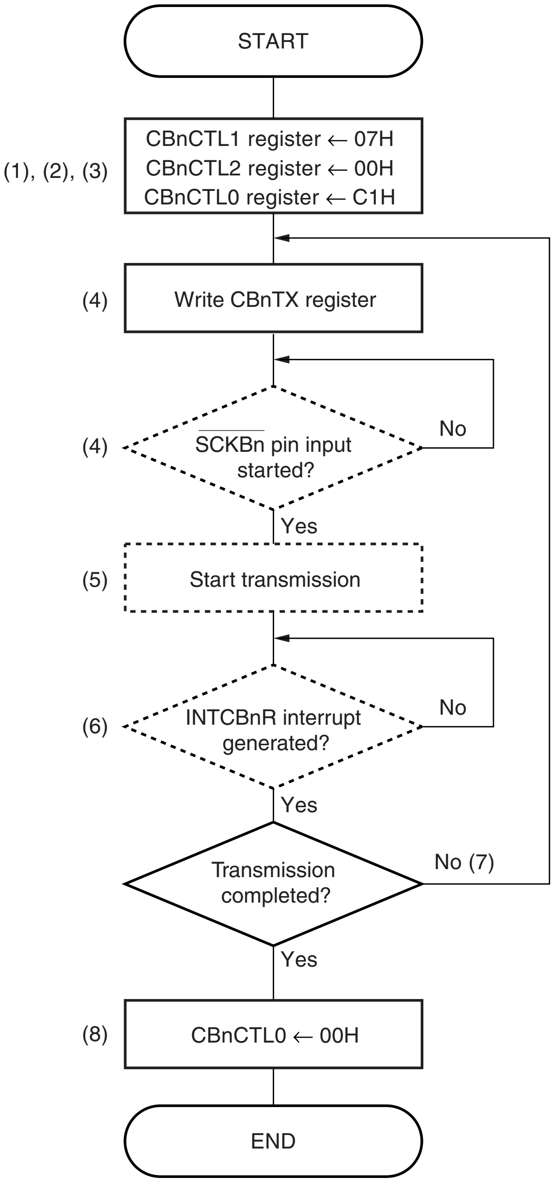
(10) To end transmission/reception, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0.

Remark n = 0 to 4

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_{CCLK}) = 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

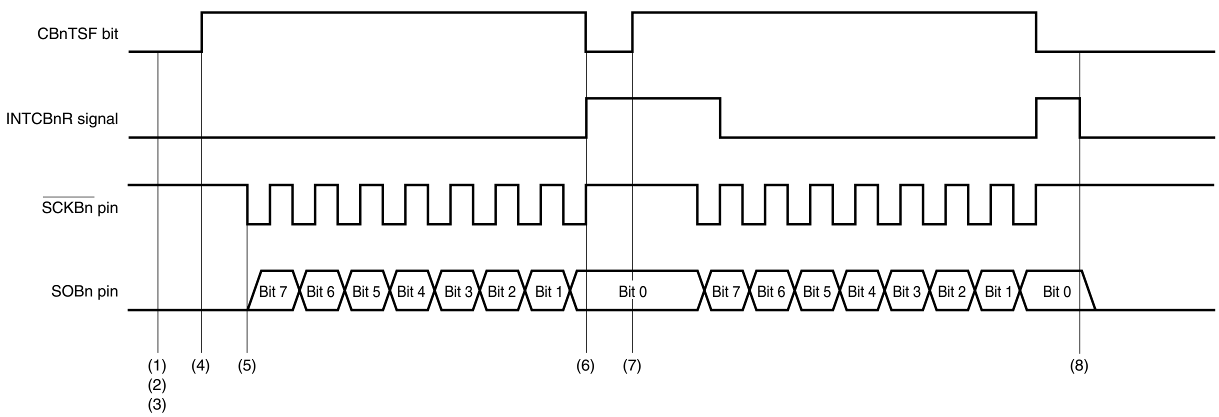


Remarks **1.** The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing



(1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock (f_{CCLK}) = external clock ($\overline{\text{SCKBn}}$), 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_{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 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.

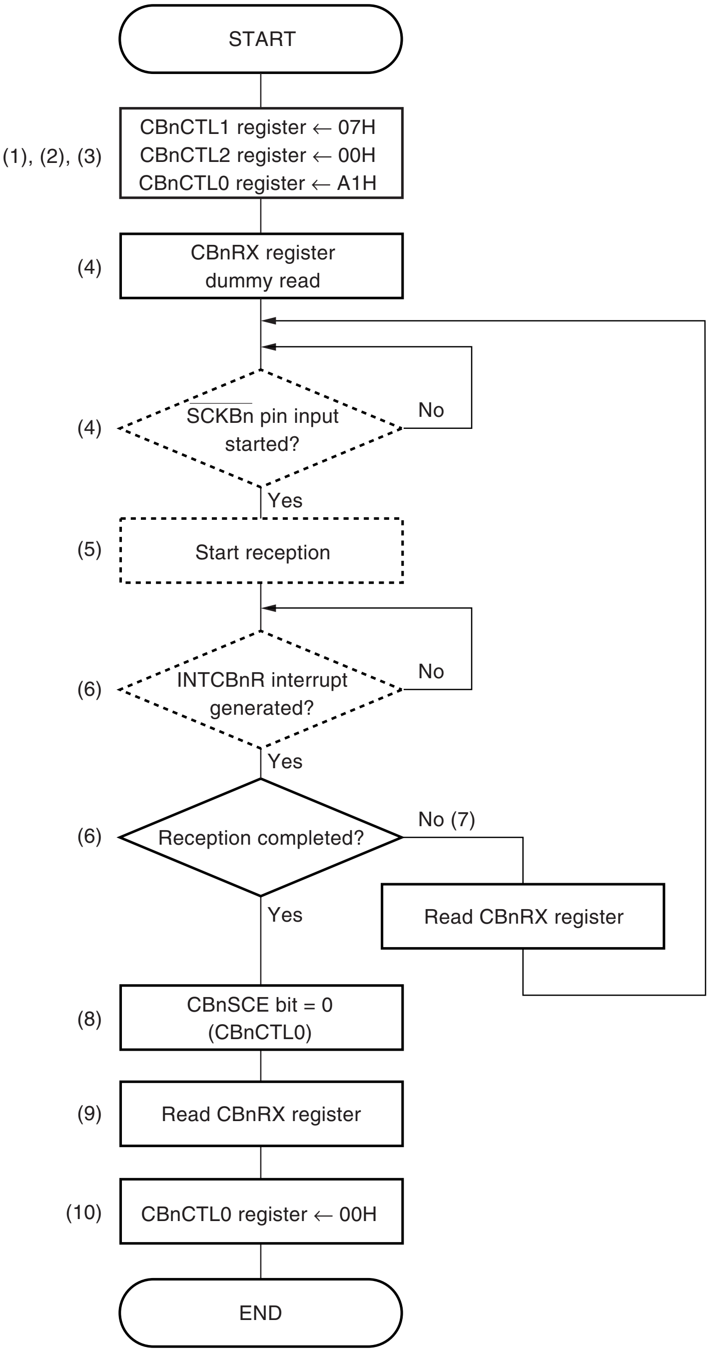
(8) To end transmission, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnTXE bit = 0.

Remark n = 0 to 4

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_{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

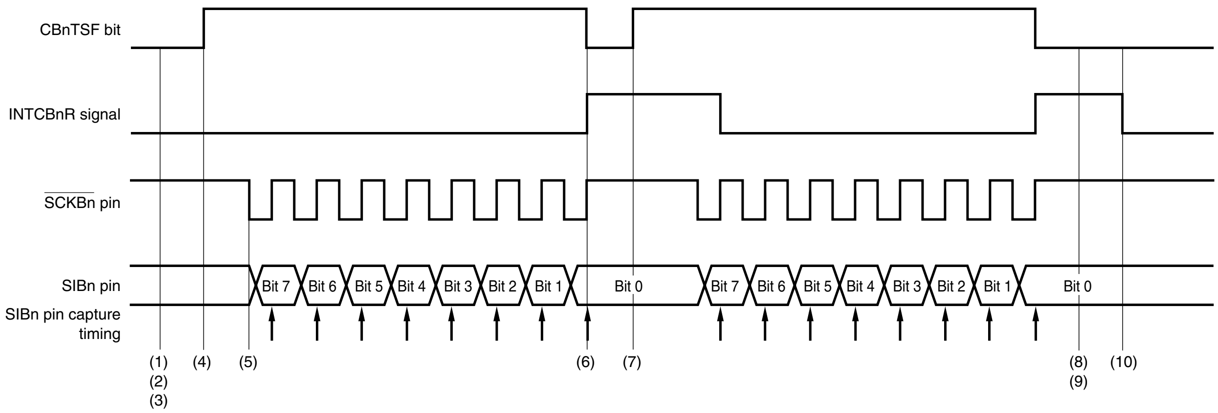


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing



(1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock (f_{CCLK}) = external clock ($\overline{\text{SCKBn}}$), 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_{CCLK}).

(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.

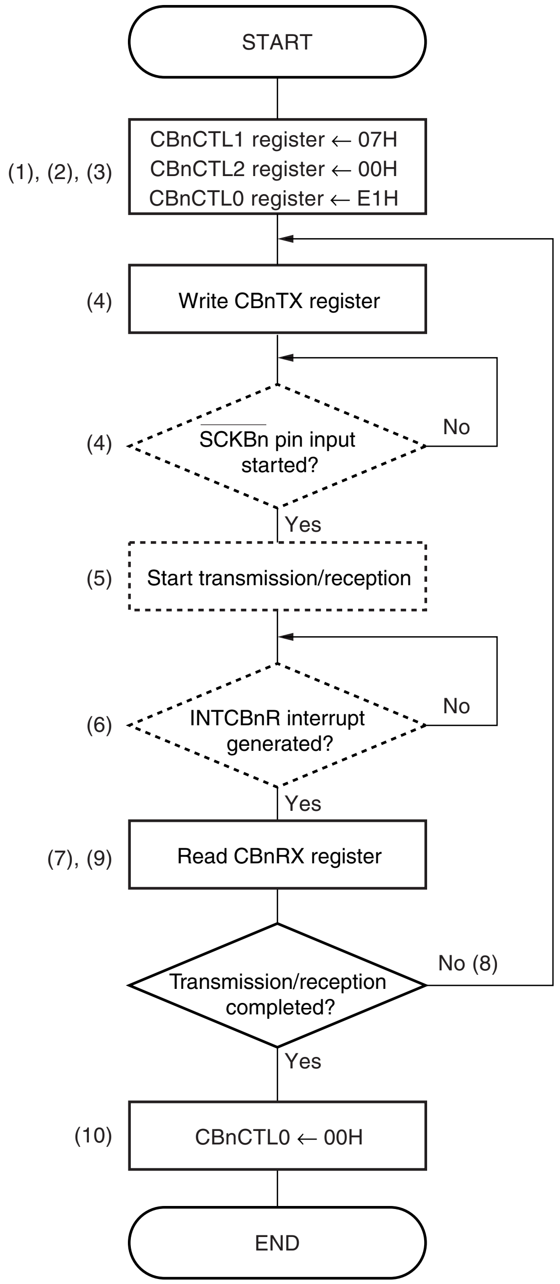
(10) To end reception, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnRXE bit = 0.

Remark n = 0 to 4

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_{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

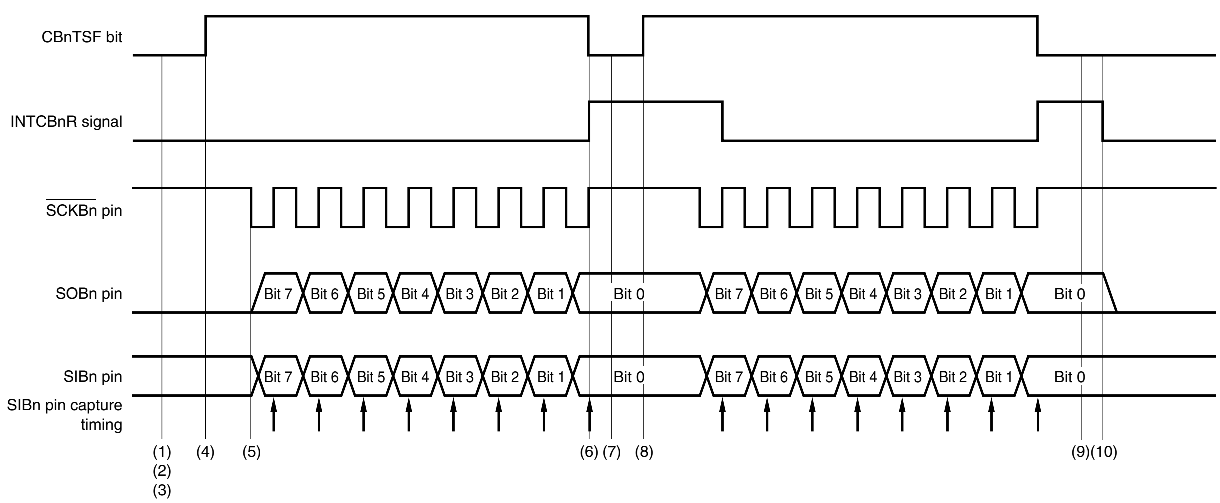


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing



(1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock (f_{CCLK}) = external clock ($\overline{SCKBn}$), 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_{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.

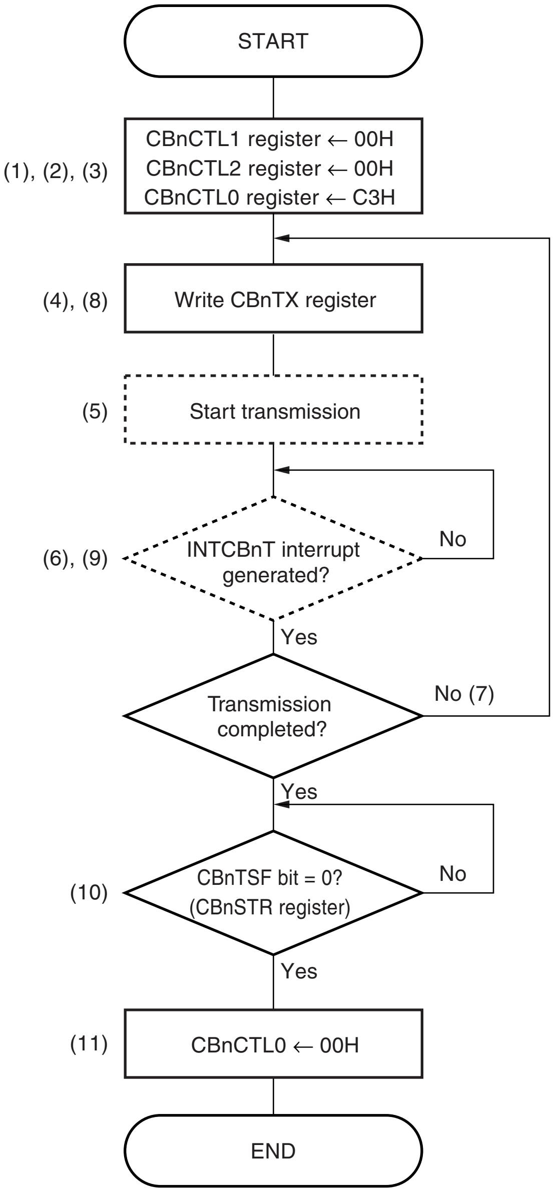
(10) To end transmission/reception, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0.

Remark n = 0 to 4

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_{CCLK}) = $f_{XX}/2$ (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow

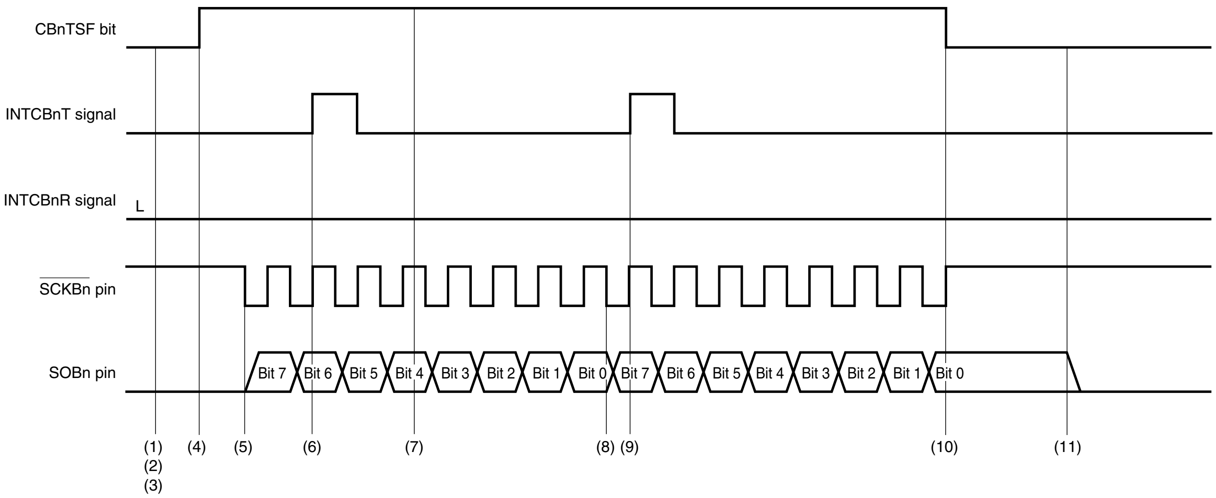


Remarks **1.** The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(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 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_{CCLK}).

(4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and start transmission.

(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 output to the $\overline{\text{SCKBn}}$ pin after transfer completion, and clear the CBnTSF 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 CBnTSF bit = 0.

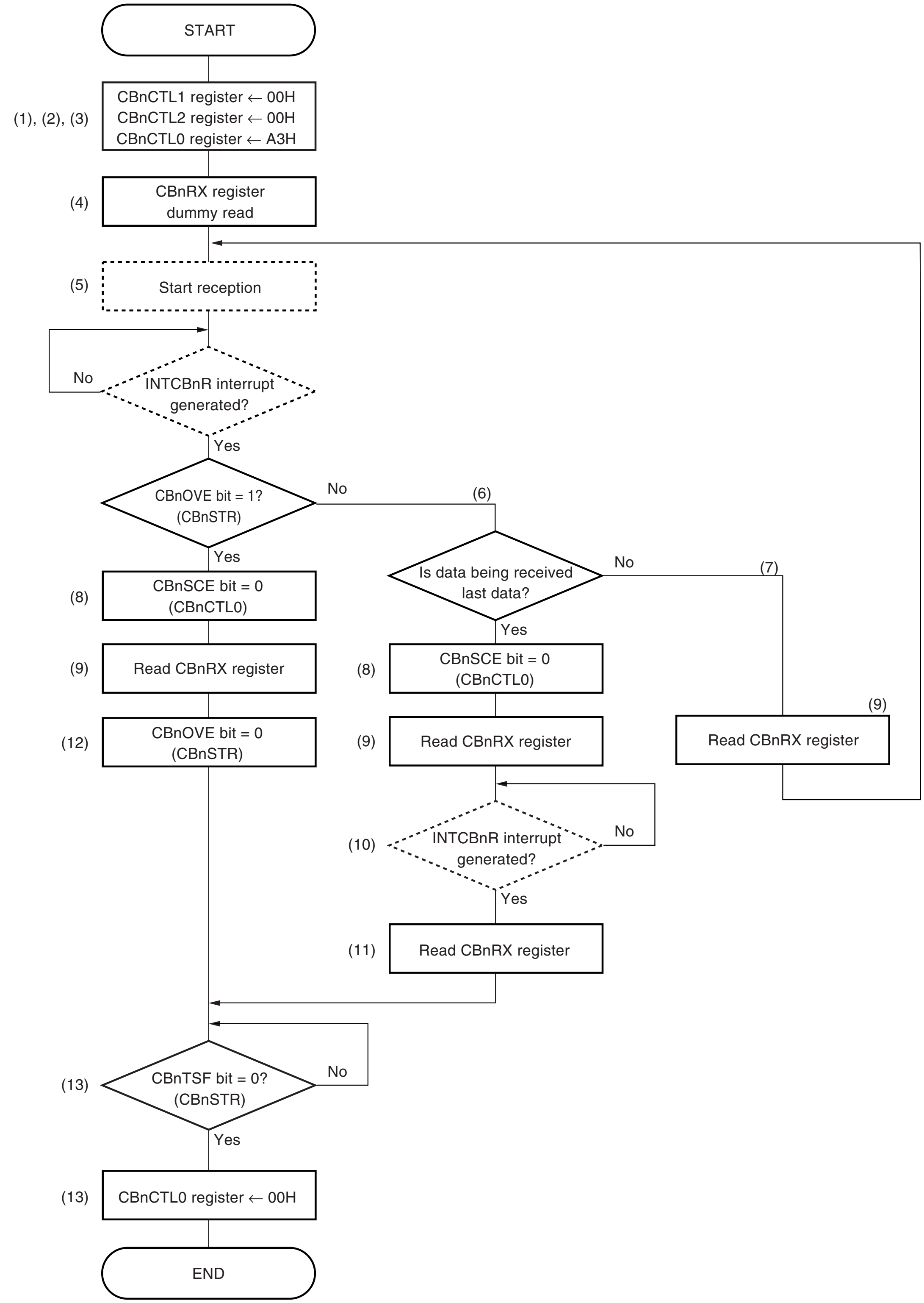
Caution In continuous transmission mode, the reception completion interrupt request signal (INTCBnR) is not generated.

Remark n = 0 to 4

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_{CCLK}) = $f_{XX}/2$ (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow

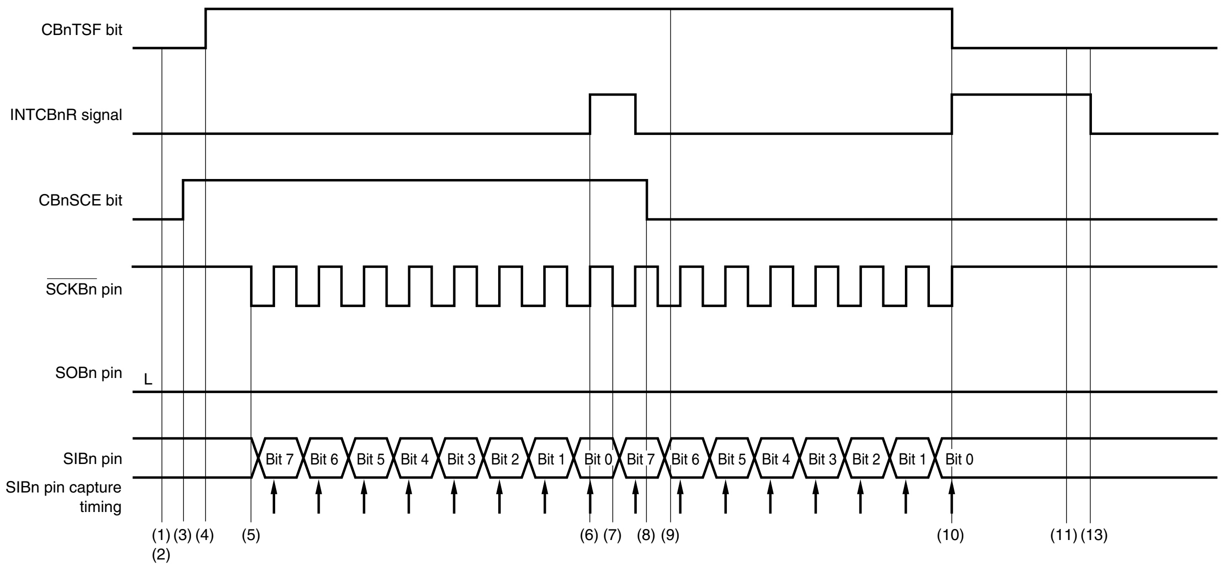


Remarks **1.** The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(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 start reception.

(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 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 $\overline{\text{SCKBn}}$ 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.

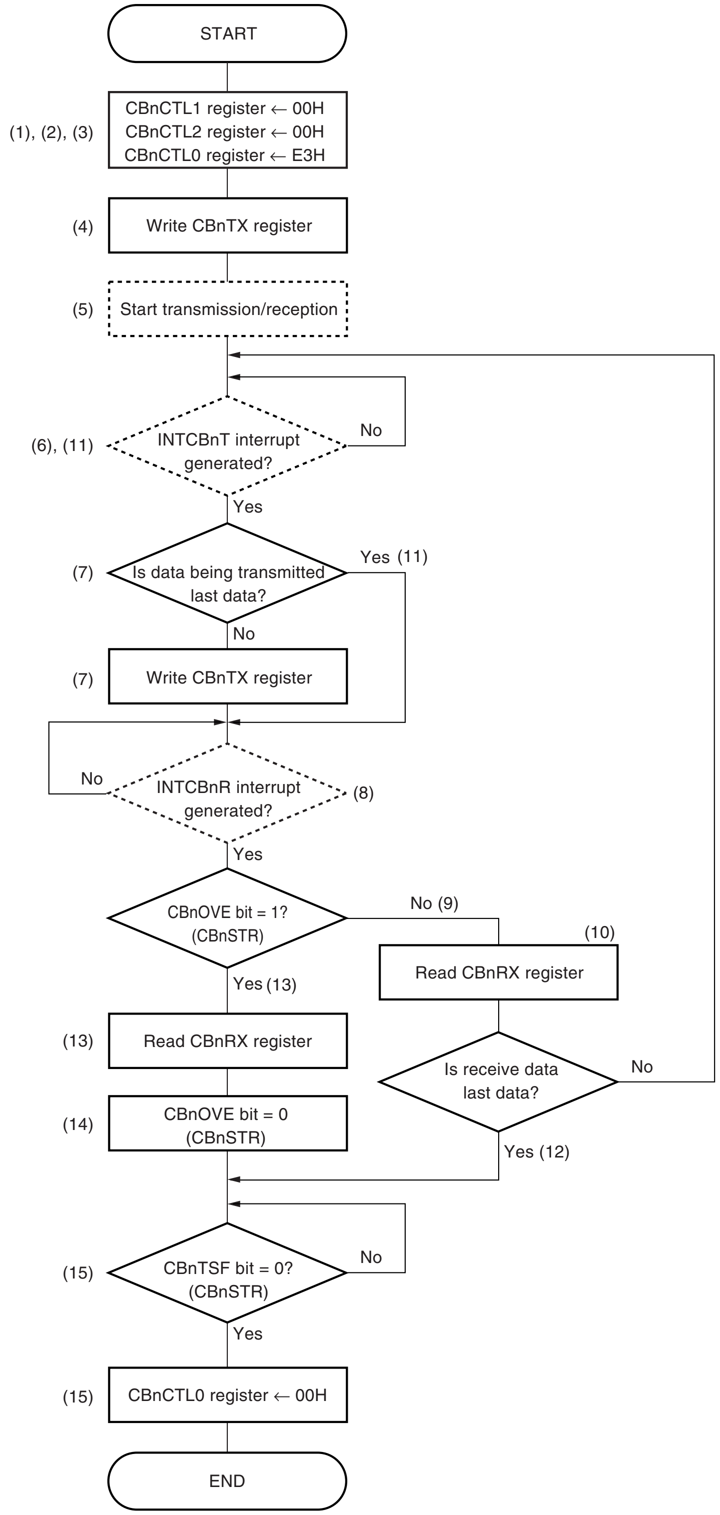
(13) To release the reception enable status, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnRXE bit = 0 after checking that the CBnTSF bit = 0.

Remark n = 0 to 4

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_{CCLK}) = $f_{XX}/2$ (CBnCTL1.CBnCKS2 to CBnCTL1.CBnCKS0 bits = 000), transfer data length = 8 bits (CBnCTL2.CBnCL3 to CBnCTL2.CBnCL0 bits = 0000)

(1) Operation flow



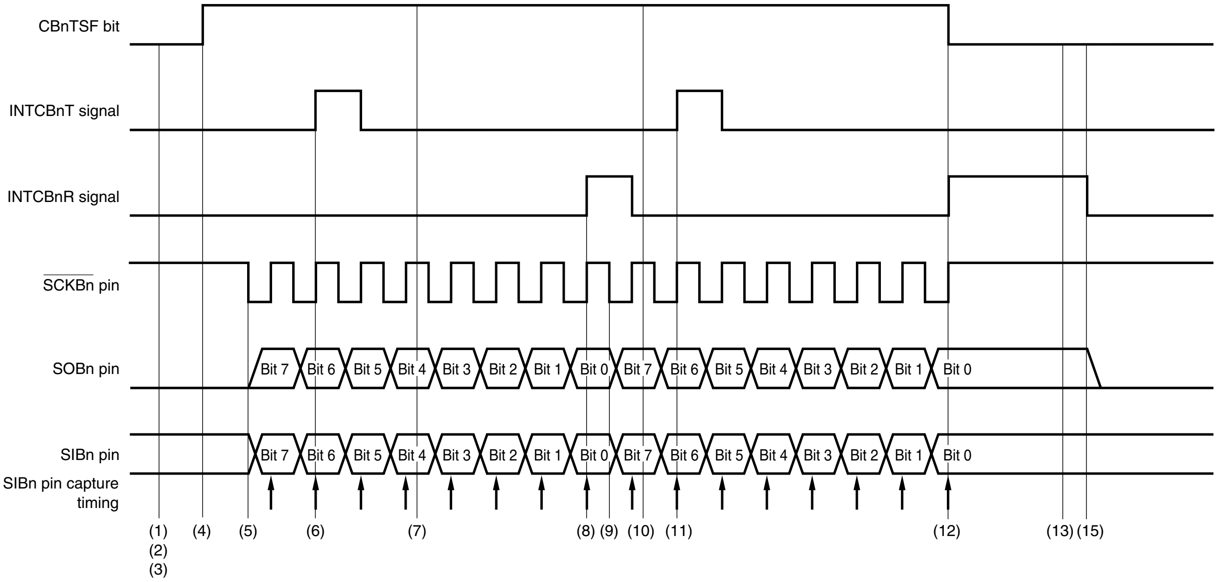
Remarks **1.** The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing

(1/2)



(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 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_{CCLK}).

(4) The CBnSTR.CBnTSF bit is set to 1 by writing the transmit data to the CBnTX register, and start transmission/reception.

(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 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 4

(2/2)

(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.

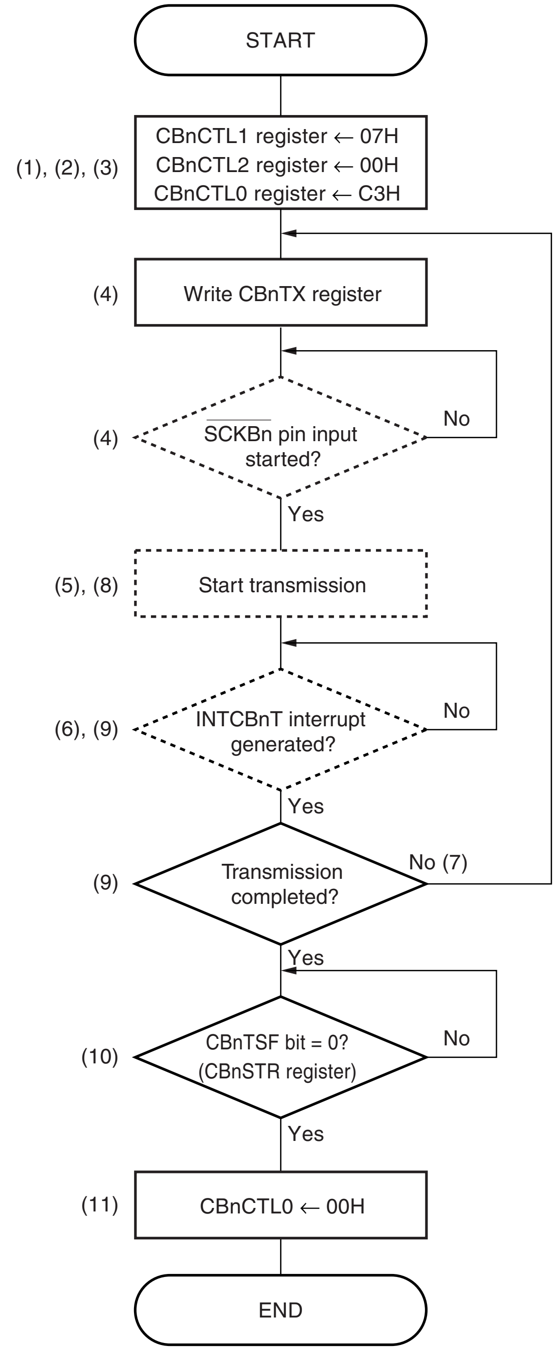
(15) To release the transmission/reception enable status, write the CBnCTL0.CBnPWR bit = 0, the CBnCTL0.CBnTXE bit = 0, and the CBnCTL0.CBnRXE bit = 0 after checking that the CBnTSF bit = 0.

Remark n = 0 to 4

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_{CCLK}) = 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

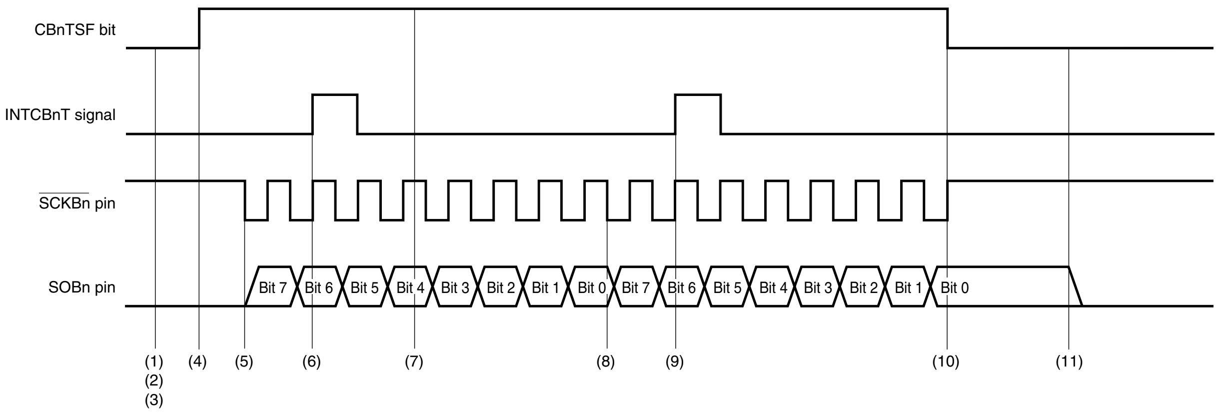


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing



(1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock (f_{CCLK}) = external clock ($\overline{\text{SCKBn}}$), 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_{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 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.

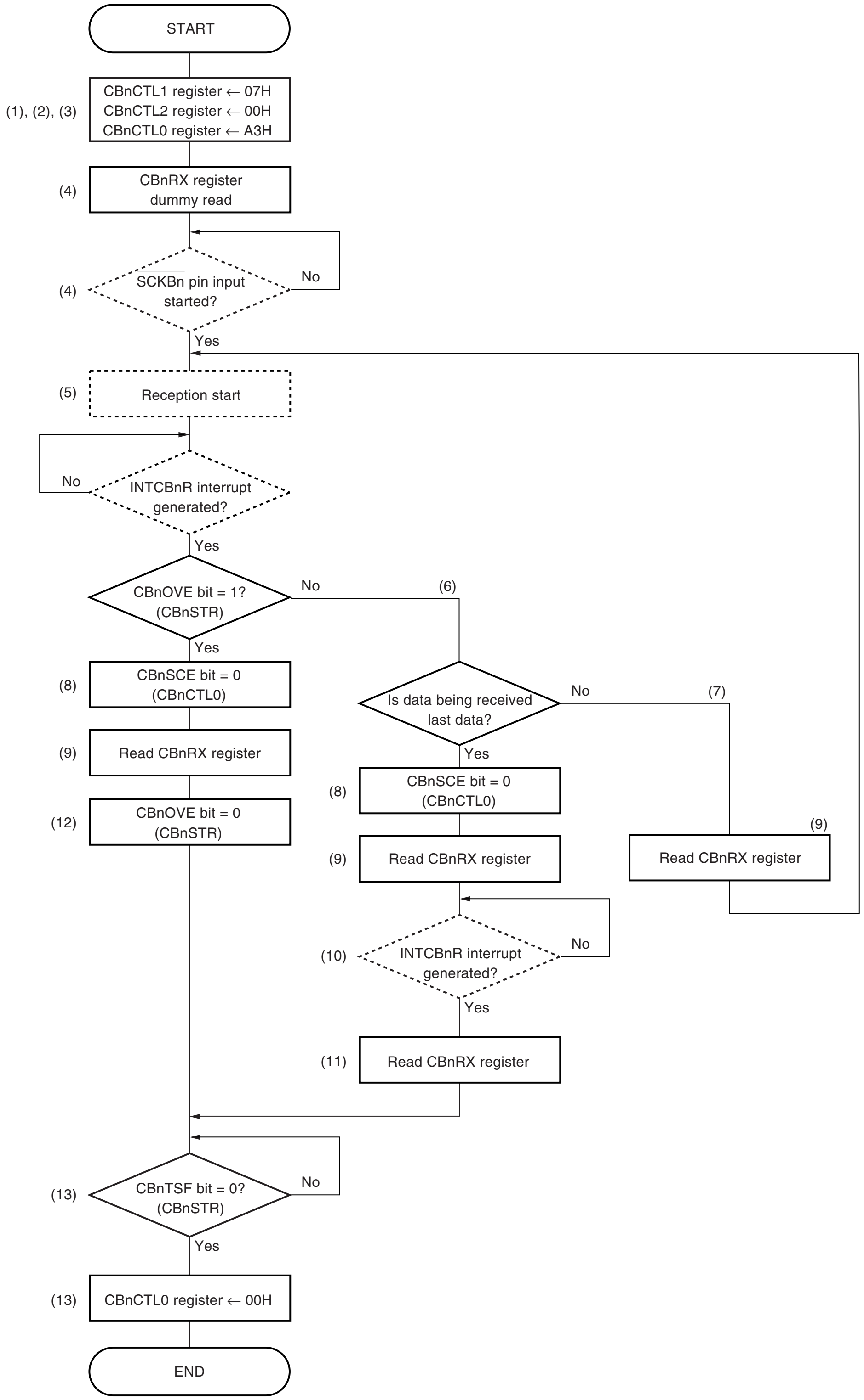
Caution In continuous transmission mode, the reception completion interrupt request signal (INTCBnR) is not generated.

Remark n = 0 to 4

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_{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

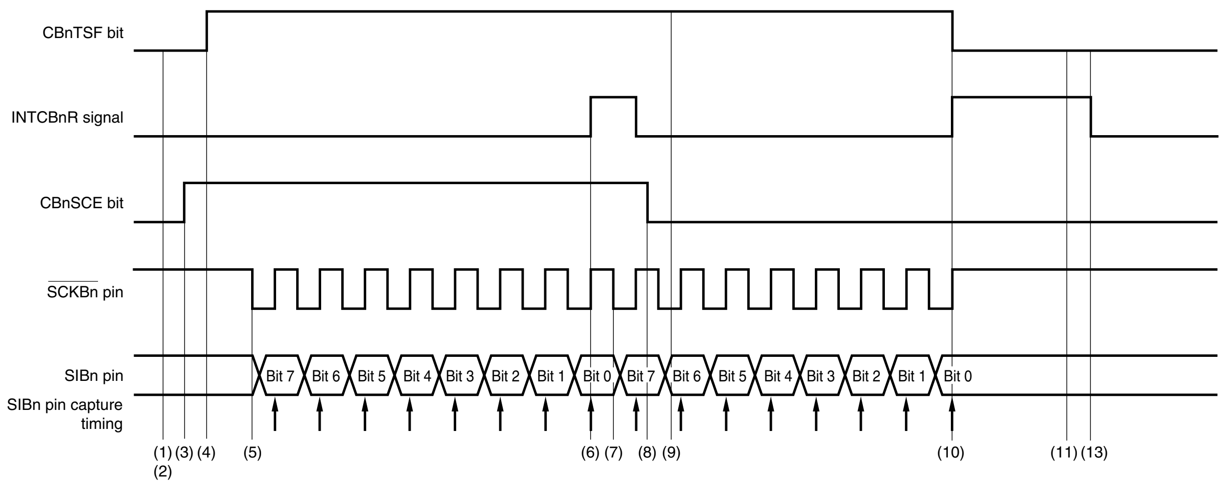


Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing



(1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock (f_{CCLK}) = external clock ($\overline{\text{SCKBn}}$), 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_{CCLK}).

(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.

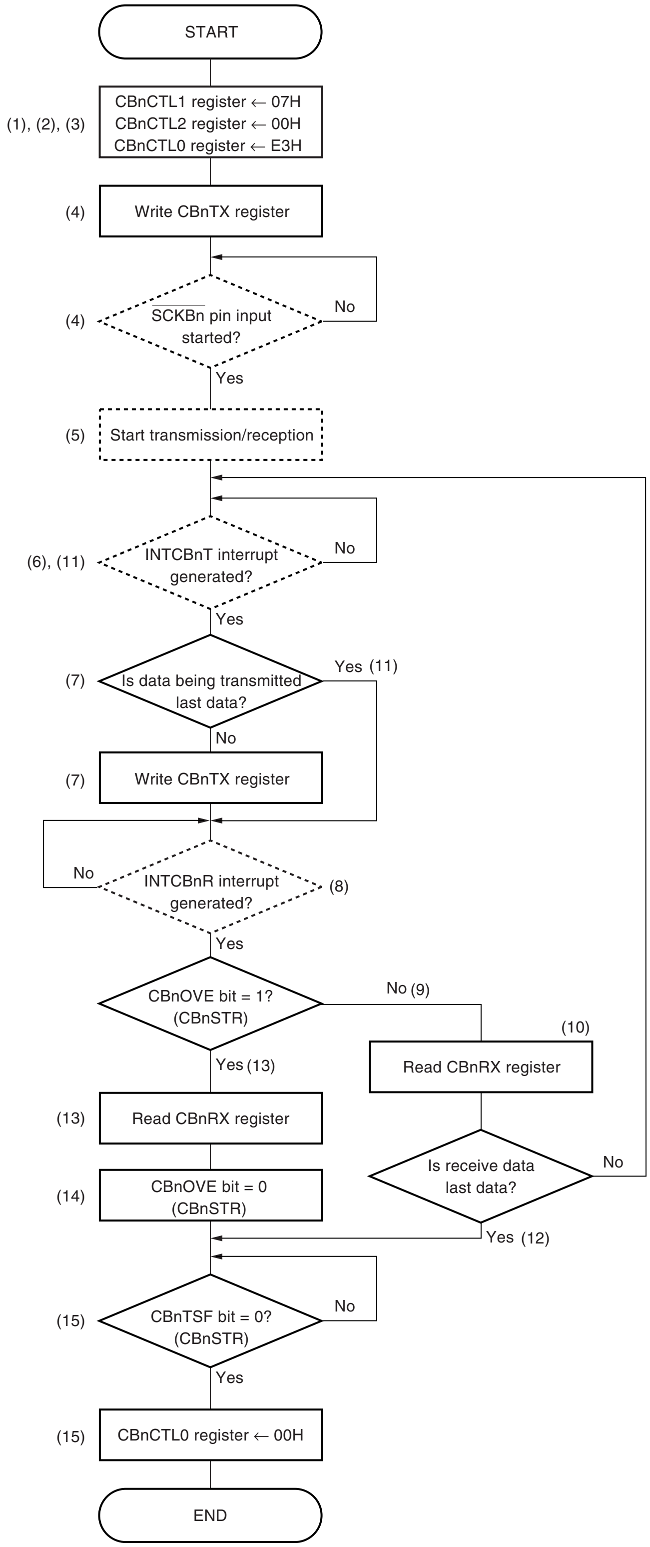
(13) To release the reception enable status, write the CBnCTL0.CBnPWR bit = 0 and the CBnCTL0.CBnRXE bit = 0 after checking that the CBnTSF bit = 0.

Remark n = 0 to 4

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_{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



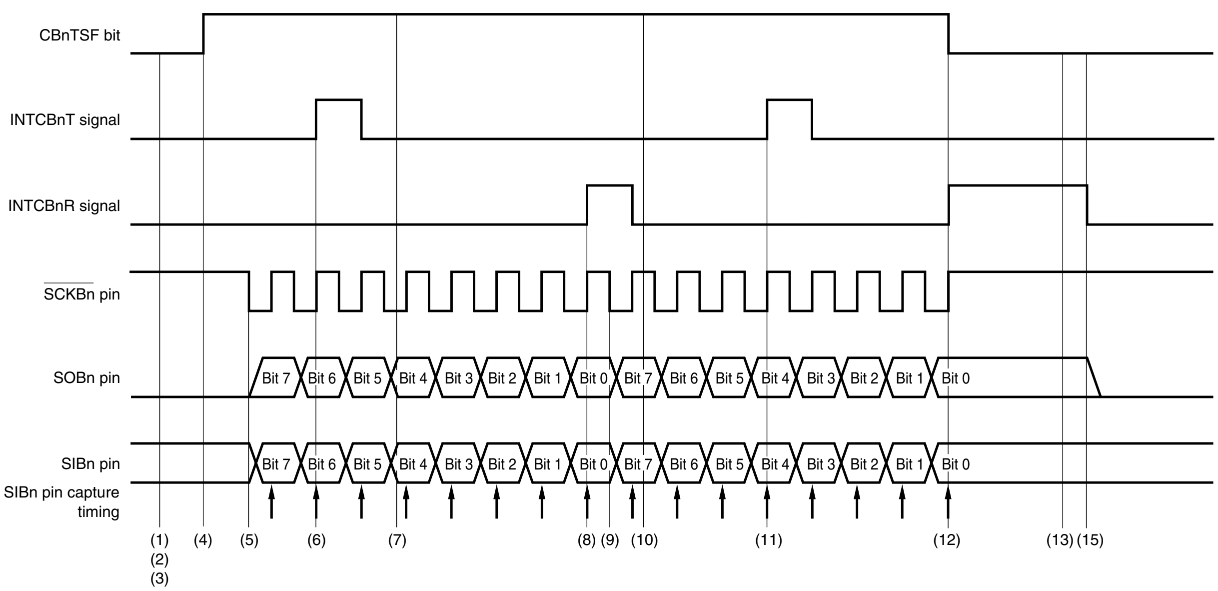
Remarks 1. The broken lines indicate the hardware processing.

2. The numbers in this figure correspond to the processing numbers in **(2) Operation timing**.

3. n = 0 to 4

(2) Operation timing

(1/2)



(1) Write 07H to the CBnCTL1 register, and select communication type 1, communication clock (f_{CCLK}) = external clock ($\overline{\text{SCKBn}}$), 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_{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 4

(2/2)

(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 4

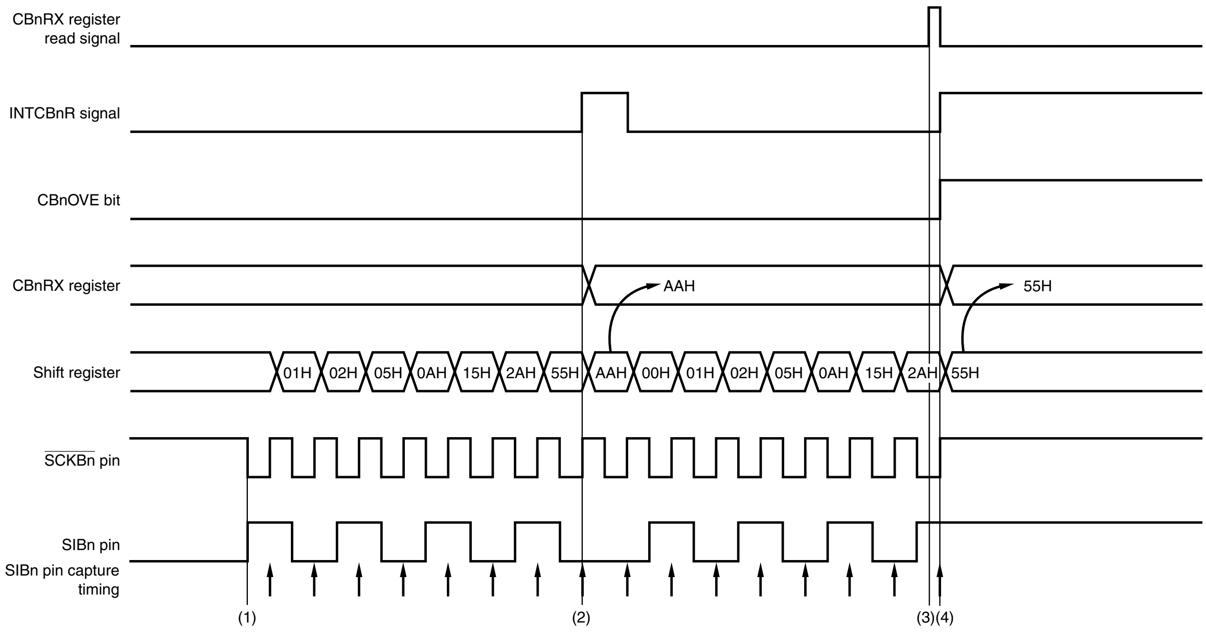
16.6.13 Reception error

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



(1) Start continuous transfer.

(2) Completion of the first transfer

(3) The CBnRX register cannot be read until one half clock before the completion of the second transfer.

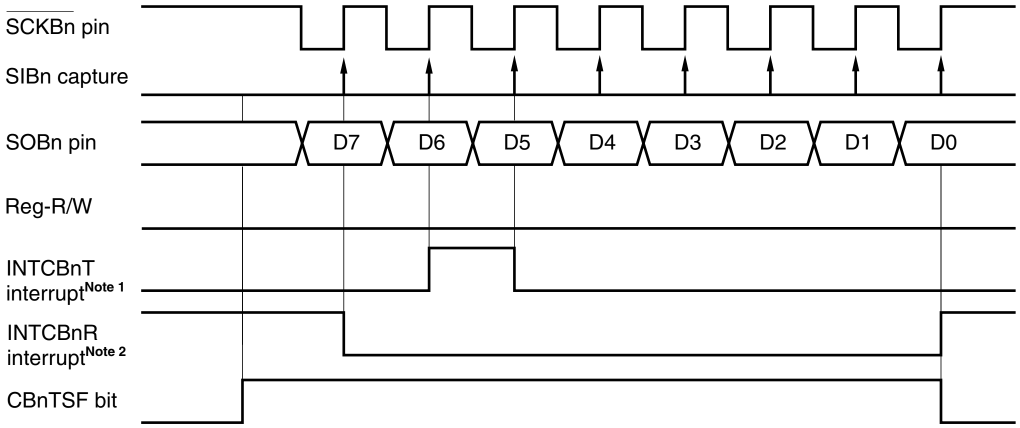
(4) An overrun error occurs, and the reception completion interrupt request signal (INTCBnR) is generated, and then the overrun error flag (CBnSTR.CBnOVE) is set to 1. The receive data is overwritten.

Remark n = 0 to 4

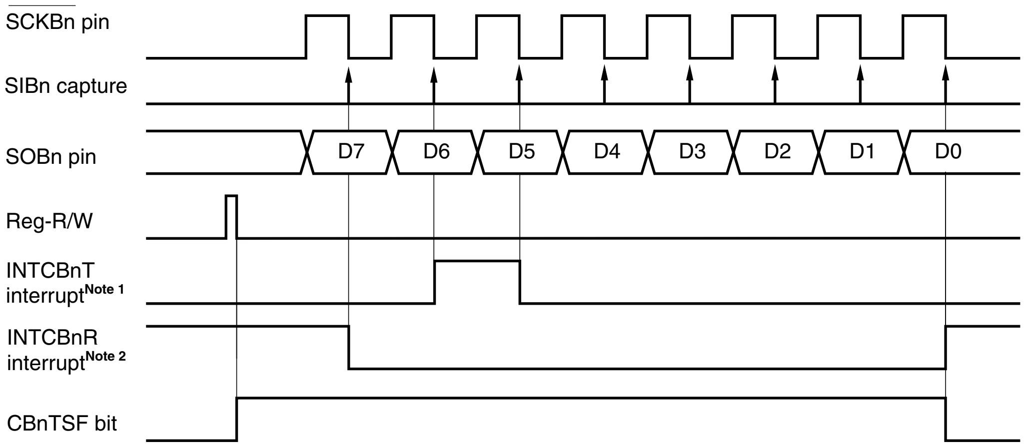
16.6.14 Clock timing

(1/2)

(i) **Communication type 1 (CBnCKP and CBnDAP bits = 00)**



(ii) **Communication type 3 (CBnCKP and CBnDAP bits = 10)**



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 mode. In the single transmission or single transmission/reception mode, 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.

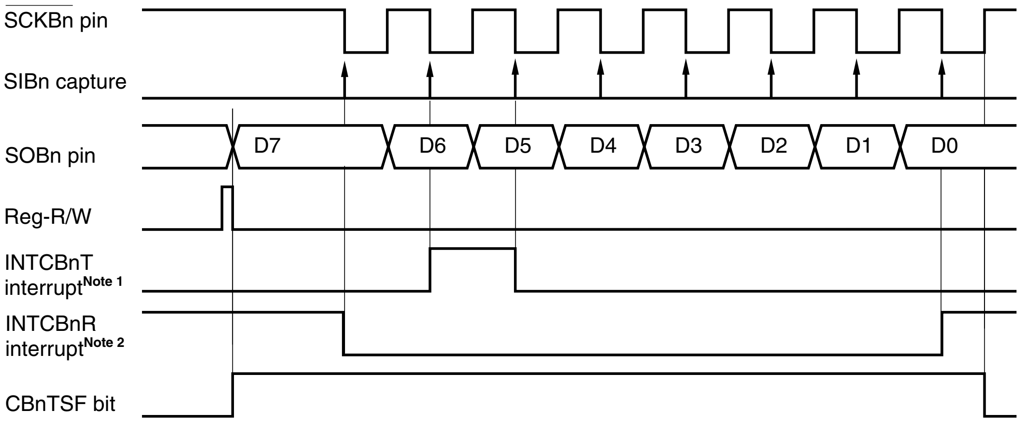
Caution **In single transfer mode, writing to the CBnTX register with the CBnTSF bit set to 1 is ignored. This has no influence on the operation during transfer.**

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.

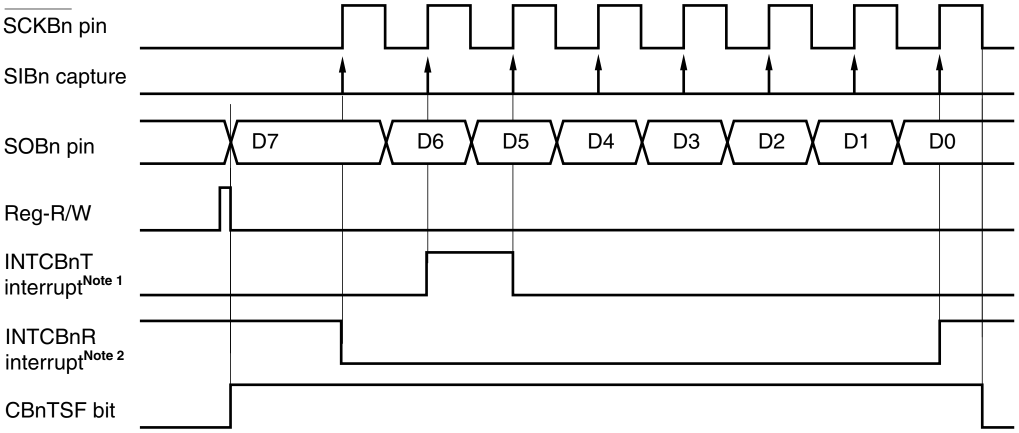
Use the continuous transfer mode, not the single transfer mode, for such applications.

(2/2)

(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 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.

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 4

(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)

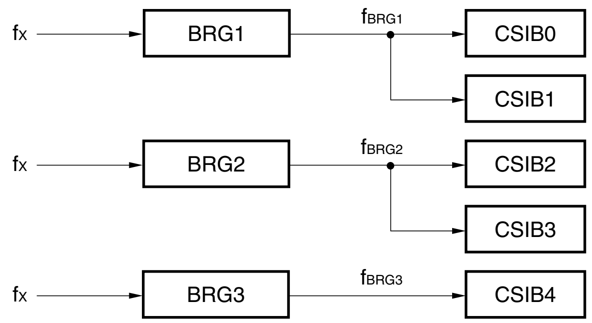
Remarks 1. The SOBn pin output changes when any one of the CBnCTL0.CBnTXE, CBnCTL0.CBnDIR bits, and CBnCTL1.CBnDAP bit is rewritten.

2. ×: Don’t care

3. n = 0 to 4

16.8 Baud Rate Generator

The BRG1 to BRG3 and CSIB0 to CSIB4 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 (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 (fBGCSm)	Setting value (k)
0	0	fxx	0
0	1	fxx/2	1
1	0	fxx/4	2
1	1	fxx/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 FFFFF321H, PRSCM2 FFFFF325H,
PRSCM3 FFFFF329H

	7	6	5	4	3	2	1	0
PRSCMm	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 5 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 or 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 4

CHAPTER 17 I^{2}C BUS

To use the I^{2}C bus function, set 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), and set them to N-ch open-drain output.

17.1 Mode Switching of I^{2}C Bus and Other Serial Interfaces

17.1.1 UARTA2 and I^{2}C00 mode switching

In the V850ES/JG3-L, UARTA2 and I^{2}C00 are alternate functions of the same pin and therefore cannot be used simultaneously. Set I^{2}C00 in advance, using the PMC3 and PFC3 registers, before use.

Caution The transmit/receive operation of UARTA2 and I^{2}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^{2}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^{2}C00 mode

Remarks 1. n = 8, 9

2. × = don’t care

17.1.2 CSIB0 and I^2C01 mode switching

In the V850ES/JG3-L, CSIB0 and I^2C01 are alternate functions of the same pin and therefore cannot be used simultaneously. Set I^2C01 in advance, using the PMC4 and PFC4 registers, before use.

Caution The transmit/receive operation of CSIB0 and I^2C01 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^2C01 Mode Switch Settings

After reset: 00H R/W Address: FFFFF448H

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

After reset: 00H R/W Address: FFFFF468H

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

PMC4n	PFC4n	Operation mode
0	×	Port I/O mode
1	0	CSIB0 mode
1	1	I^2C01 mode

Remarks 1. n = 0, 1

2. × = don't care

17.1.3 UARTA1 and I^{2}C02 mode switching

In the V850ES/JG3-L, UARTA1 and I^{2}C02 are alternate functions of the same pin and therefore cannot be used simultaneously. Set I^{2}C02 in advance, using the PMC9, PFC9, and PFCE9 registers, before use.

Caution The transmit/receive operation of UARTA1 and I^{2}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^{2}C02 Mode Switch Settings

After reset: 0000H R/W Address: FFFFF452H, FFFFF453H

PMC9

15	14	13	12	11	10	9	8
PMC915	PMC914	PMC913	PMC912	PMC911	PMC910	PMC99	PMC98

7	6	5	4	3	2	1	0
PMC97	PMC96	PMC95	PMC94	PMC93	PMC92	PMC91	PMC90

After reset: 0000H R/W Address: FFFFF472H, FFFFF473H

PFC9

15	14	13	12	11	10	9	8
PFC915	PFC914	PFC913	PFC912	PFC911	PFC910	PFC99	PFC98

7	6	5	4	3	2	1	0
PFC97	PFC96	PFC95	PFC94	PFC93	PFC92	PFC91	PFC90

After reset: 0000H R/W Address: FFFFF712H, FFFFF713H

PFCE9

15	14	13	12	11	10	9	8
PFCE915	PFCE914	0	0	0	0	0	0

7	6	5	4	3	2	1	0
PFCE97	PFCE96	PFCE95	PFCE94	PFCE93	PFCE92	PFCE91	PFCE90

PMC9n	PFCE9n	PFC9n	Operation mode
1	1	0	UARTA1 mode
1	1	1	I^{2}C02 mode

Remark n = 0, 1

17.2 Features

I^{2}C00 to I^{2}C02 have the following two modes.

- Operation stopped mode
- I^{2}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^{2}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^{2}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^{2}C bus.

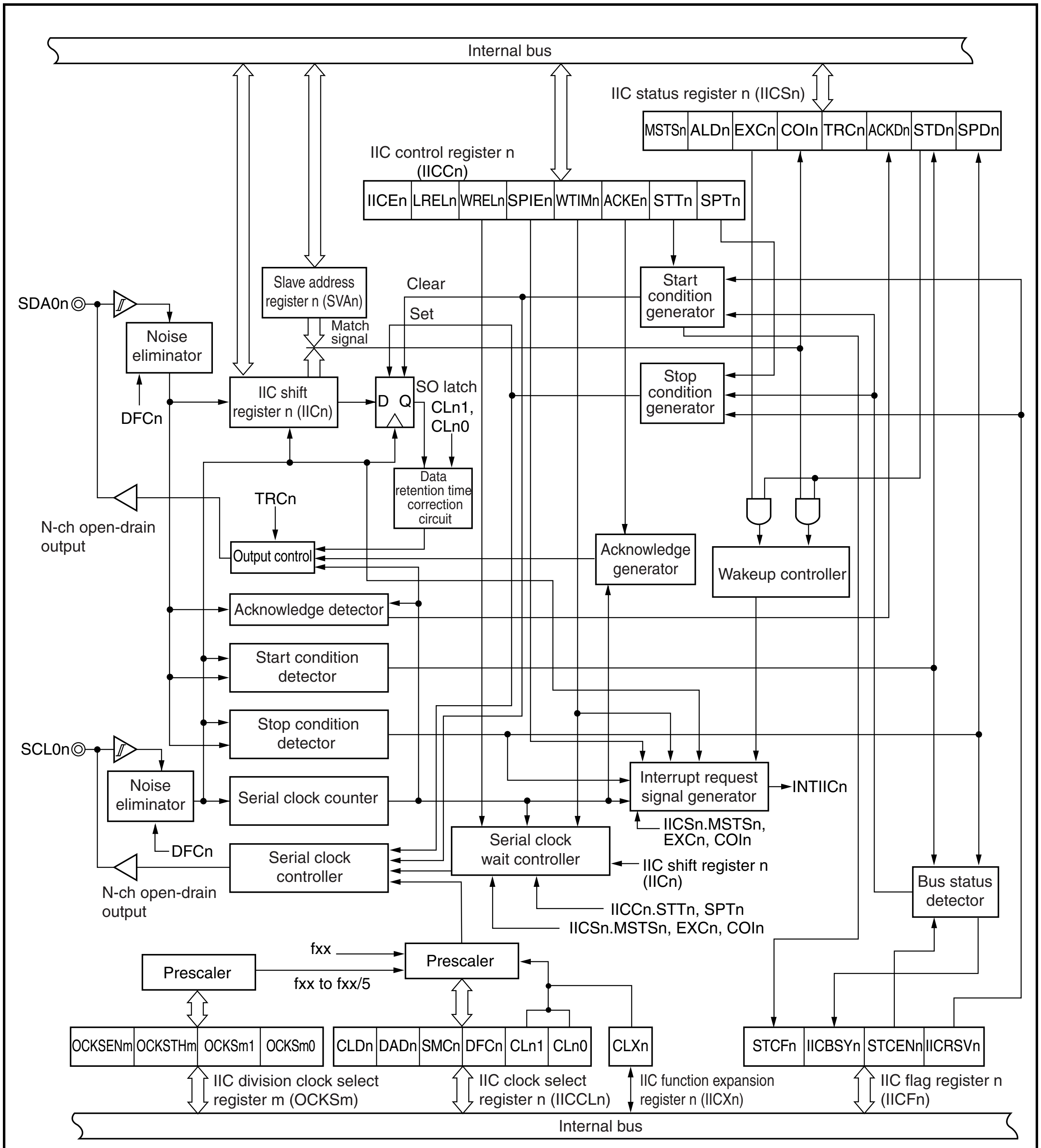
Since SCL0n and SDA0n pins are used for N-ch open-drain outputs, I^{2}C0n requires pull-up resistors for the serial clock line and the serial data bus line.

Remark n = 0 to 2

17.3 Configuration

The block diagram of the I^{2}C0n is shown below.

Figure 17-4. Block Diagram of I^{2}C0n

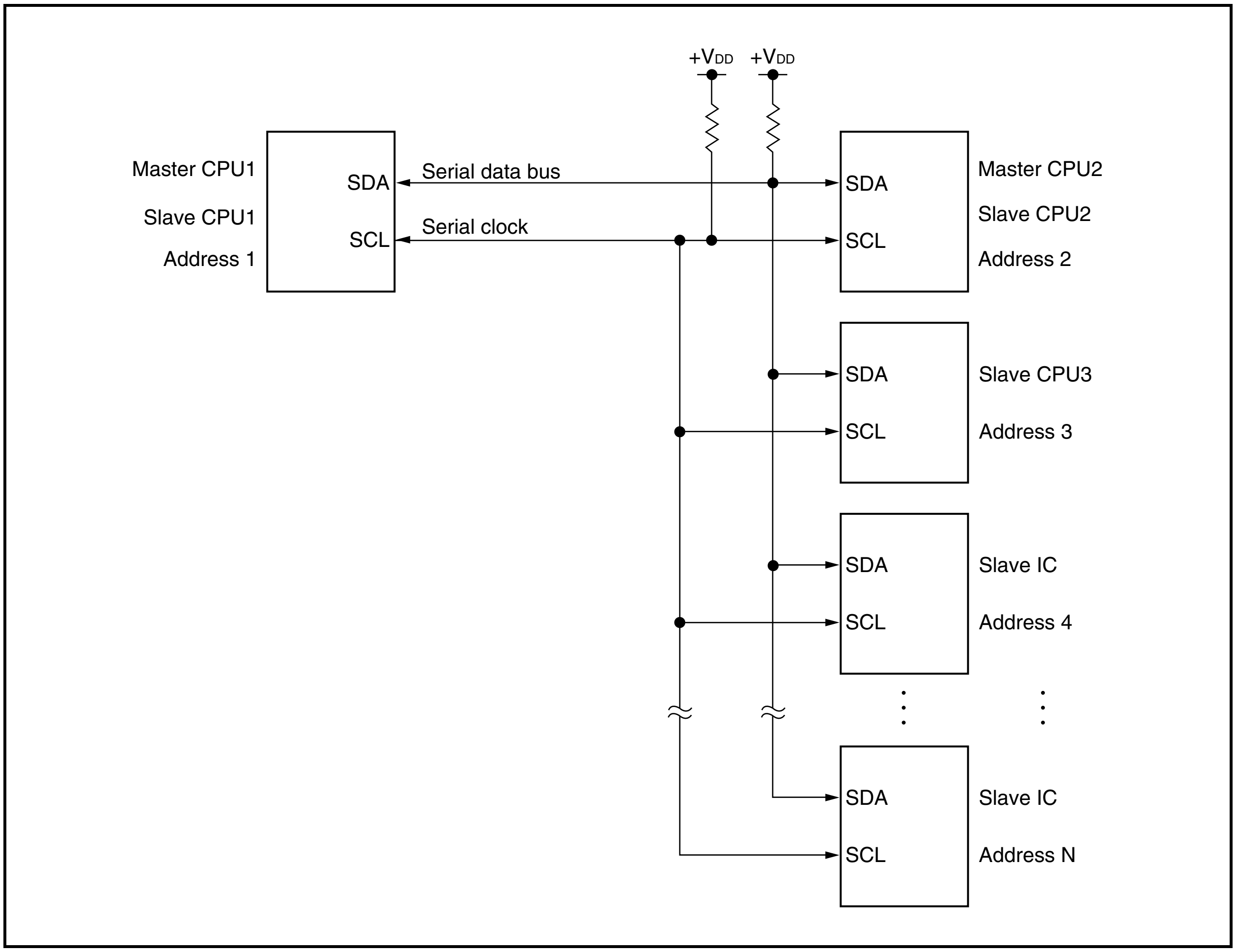


Remark n = 0 to 2

m = 0, 1

A serial bus configuration example is shown below.

Figure 17-5. Serial Bus Configuration Example Using I²C Bus



I^{2}C0n includes the following hardware (n = 0 to 2).

Table 17-1. Configuration of I^{2}C0n

Item	Configuration
Registers	IIC shift register n (IICn) Slave address register n (SVAn)
Control registers	IIC control register n (IICCn) IIC status register n (IICSn) IIC flag register n (IICF0n) IIC clock select register n (IICCLn) IIC function expansion register n (IICXn) 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^{2}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^{2}C00 to I^{2}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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

(1) IIC control registers 0 to 2 (IICC0 to IICC2)

The IICCn register enables/stops I^{2}C0n operations, sets the wait timing, and sets other I^{2}C operations (n = 0 to 2).

These registers 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 these registers to 00H.

(1/4)

After reset: 00H   R/W   Address: IICC0 FFFFFD82H, IICC1 FFFFFD92H, IICC2 FFFFFDA2H

	<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^{2}Cn operation enable/disable
0	Operation stopped. IICSn register reset[Note 1]. 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)	Condition for setting (IICEn bit = 1)
• Cleared by instruction • After reset	• Set by instruction

LRELn[Note 2]	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. The SCL0n and SDA0n lines are set to high impedance. 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. • After a stop condition is detected, restart is in master mode. • An address match occurs or an extension code is received after the start condition.	
Condition for clearing (LRELn bit = 0)	Condition for setting (LRELn bit = 1)
• Automatically cleared after execution • After reset	• Set by instruction

WRELn[Note 2]	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)	Condition for setting (WRELn bit = 1)
• Automatically cleared after execution • After reset	• Set by instruction

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^{2}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^{2}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.

(2/4)

<table>
<tr><th>SPIEn[Note]</th><th colspan="2">Enable/disable generation of interrupt request when stop condition is detected</th></tr>
<tr><td>0</td><td colspan="2">Disabled</td></tr>
<tr><td>1</td><td colspan="2">Enabled</td></tr>
<tr><td colspan="2">Condition for clearing (SPIEn bit = 0)</td><td>Condition for setting (SPIEn bit = 1)</td></tr>
<tr><td colspan="2">• Cleared by instruction
• After reset</td><td>• Set by instruction</td></tr>
</table>

<table>
<tr><th>WTIMn[Note]</th><th colspan="2">Control of wait state and interrupt request generation</th></tr>
<tr><td>0</td><td colspan="2">Interrupt request is generated at the eighth clock’s falling edge.
Master mode: After output of eight clocks, clock output is set to low level and the wait state is set.
Slave mode: After input of eight clocks, the clock is set to low level and the wait state is set for the master device.</td></tr>
<tr><td>1</td><td colspan="2">Interrupt request is generated at the ninth clock’s falling edge.
Master mode: After output of nine clocks, clock output is set to low level and the wait state is set.
Slave mode: After input of nine clocks, the clock is set to low level and the wait state is set for the master device.</td></tr>
<tr><td colspan="3">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 $\overline{\text{ACK}}$ 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.</td></tr>
<tr><td colspan="2">Condition for clearing (WTIMn bit = 0)</td><td>Condition for setting (WTIMn bit = 1)</td></tr>
<tr><td colspan="2">• Cleared by instruction
• After reset</td><td>• Set by instruction</td></tr>
</table>

<table>
<tr><th>ACKEn[Note]</th><th colspan="2">Acknowledgment control</th></tr>
<tr><td>0</td><td colspan="2">Acknowledgment disabled.</td></tr>
<tr><td>1</td><td colspan="2">Acknowledgment enabled. During the ninth clock period, the SDA0n line is set to low level.</td></tr>
<tr><td colspan="3">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.
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.</td></tr>
<tr><td colspan="2">Condition for clearing (ACKEn bit = 0)</td><td>Condition for setting (ACKEn bit = 1)</td></tr>
<tr><td colspan="2">• Cleared by instruction
• After reset</td><td>• Set by instruction</td></tr>
</table>

Note This flag’s signal is invalid when the IICEn bit = 0.

Remark n = 0 to 2

(3/4)

<table>
<tr><th>STTn</th><th colspan="2">Start condition trigger</th></tr>
<tr><td>0</td><td colspan="2">Start condition is not generated.</td></tr>
<tr><td>1</td><td colspan="2">When bus is released (in STOP mode):
A start condition is generated (for starting as master). The SDA0n line is changed from high level to low level while the SCLn 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.
During communication with a third party:
If the communication reservation function is enabled (IICFn.IICRSVn bit = 0)
• This trigger functions as a start condition reserve flag. When set to 1, it releases the bus and then automatically generates a start condition.
If the communication reservation function is disabled (IICRSVn = 1)
• The IICFn.STCFn bit is set to 1 and information set (1) to the STTn bit is cleared. This trigger does not generate a start condition.
In the wait state (when master device):
A restart condition is generated after the wait state is released.</td></tr>
<tr><td colspan="3">Cautions concerning set timing
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.
For master transmission: A start condition cannot be generated normally during the $\overline{\text{ACK}}$ period. Set to 1 during the wait period that follows output of the ninth clock.
For slave: Even when the communication reservation function is disabled (IICRSVn bit = 1), the communication reservation status is entered.
• Setting to 1 at the same time as the SPTn bit is prohibited.
• When the STTn bit is set to 1, setting the STTn bit to 1 again is disabled until the setting is cleared to 0.</td></tr>
<tr><td colspan="2">Condition for clearing (STTn bit = 0)</td><td>Condition for setting (STTn bit = 1)</td></tr>
<tr><td colspan="2">• When the STTn bit is set to 1 in the communication reservation disabled status
• Cleared by loss in arbitration
• Cleared after start condition is generated by master device
• When the LRELn bit = 1 (communication save)
• When the IICEn bit = 0 (operation stop)
• After reset</td><td>• Set by instruction</td></tr>
</table>

Remarks **1.** The STTn bit is 0 if it is read immediately after data setting.

2. n = 0 to 2

(4/4)

<table>
<tr><th>SPTn</th><th colspan="2">Stop condition trigger</th></tr>
<tr><td>0</td><td colspan="2">Stop condition is not generated.</td></tr>
<tr><td>1</td><td colspan="2">Stop condition is generated (termination of master device’s transfer).
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.</td></tr>
<tr><td colspan="3">Cautions concerning set timing
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 during the wait period after the slave has been notified of final reception.
For master transmission: A stop condition cannot be generated normally during the $\overline{\text{ACK}}$ reception period. Set to 1 during the wait period that follows output of the ninth clock.
• Cannot be set to 1 at the same time as the STTn bit.
• The SPTn bit can be set to 1 only when in master mode[Note].
• 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.
• When the SPTn bit is set to 1, setting the SPTn bit to 1 again is disabled until the setting is cleared to 0.</td></tr>
<tr><td colspan="2">Condition for clearing (SPTn bit = 0)</td><td>Condition for setting (SPTn bit = 1)</td></tr>
<tr><td colspan="2">• Cleared by loss in arbitration
• Automatically cleared after stop condition is detected
• When the LRELn bit = 1 (communication save)
• When the IICEn bit = 0 (operation stop)
• After reset</td><td>• Set by instruction</td></tr>
</table>

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 IICSn register indicates the status of I^2C0n (n = 0 to 2).

These registers are read-only, in 8-bit or 1-bit units. However, the IICSn register can only be read when the IICCn.STTn bit is 1 or during the wait period.

Reset sets these registers to 00H.

Caution Accessing the IICSn 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 FFFFFD86H, IICS1 FFFFFD96H, IICS2 FFFFFDA6H

	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IICSn	MSTSn	ALDn	EXCn	COIn	TRCn	ACKDn	STDn	SPDn

(n = 0 to 2)

MSTSn	Master device status
0	Slave device status or communication standby status
1	Master device communication status

Condition for clearing (MSTSn bit = 0)	Condition for setting (MSTSn bit = 1)
• When a stop condition is detected • When the ALDn bit = 1 (arbitration loss) • Cleared by LRELn bit = 1 (communication save) • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• When a start condition is generated

ALDn	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 MSTSn bit is cleared to 0.

Condition for clearing (ALDn bit = 0)	Condition for setting (ALDn bit = 1)
• Automatically cleared after the IICSn register is read^{Note} • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• When the arbitration result is a “loss”.

EXCn	Detection of extension code reception
0	Extension code was not received.
1	Extension code was received.

Condition for clearing (EXCn bit = 0)	Condition for setting (EXCn bit = 1)
• When a start condition is detected • When a stop condition is detected • Cleared by LRELn bit = 1 (communication save) • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• When the higher four bits of the received address data are either “0000” or “1111” (set at the rising edge of the eighth clock).

Note This bit is also cleared when a bit manipulation instruction is executed for another bit in the IICSn register.

(2/3)

COIn	Matching address detection
0	Addresses do not match.
1	Addresses match.
Condition for clearing (COIn bit = 0)	Condition for setting (COIn bit = 1)
• When a start condition is detected • When a stop condition is detected • Cleared by LRELn bit = 1 (communication save) • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• When the received address matches the local address (SVAn register) (set at the rising edge of the eighth clock).

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)
• When a stop condition is detected • Cleared by LRELn bit = 1 (communication save) • When the IICEn bit changes from 1 to 0 (operation stop) • Cleared by IICCn.WRELn bit = 1[Note] • When the ALDn bit changes from 0 to 1 (arbitration loss) • After reset Master • When "1" is output to the first byte's LSB (transfer direction specification bit) Slave • When a start condition is detected When not used for communication	Master • When a start condition is generated • When "0" is output to the first byte's LSB (transfer direction specification bit) Slave • When "1" is input by the first byte's LSB (transfer direction specification bit)

ACKDn	$\overline{\text{ACK}}$ detection
0	$\overline{\text{ACK}}$ was not detected.
1	$\overline{\text{ACK}}$ was detected.
Condition for clearing (ACKDn bit = 0)	Condition for setting (ACKD bit = 1)
• When a stop condition is detected • At the rising edge of the next byte's first clock • Cleared by LRELn bit = 1 (communication save) • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• After the SDA0n bit is set to low level at the rising edge of the SCL0n pin's ninth clock

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

(3/3)

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)
• When a stop condition is detected • At the rising edge of the next byte's first clock following address transfer • Cleared by LRELn bit = 1 (communication save) • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• When a start condition is detected

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)
• At the rising edge of the address transfer byte's first clock following setting of this bit and detection of a start condition • When the IICEn bit changes from 1 to 0 (operation stop) • After reset	• When a stop condition is detected

Remark n = 0 to 2

(3) IIC flag registers 0 to 2 (IICF0 to IICF2)

The IICFn register sets the I^{2}C0n operation mode and indicates the I^{2}C bus status.

These registers 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^{2}C0n is disabled (IICCn.IICEn bit = 0). After operation is enabled, IICFn can be read (n = 0 to 2).

Reset sets these registers to 00H.

After reset: 00H R/W[Note] Address: IICF0 FFFFFD8AH, IICF1 FFFFFD9AH, IICF2 FFFFFDAAH

	<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)		Condition for setting (STCFn bit = 1)
• Cleared by IICCn.STTn bit = 1 • When the IICCn.IICEn bit = 0 • After reset		• When start condition is not issued and STTn flag is cleared to 0 during communication reservation is disabled (IICRSVn bit = 1).

IICBSYn	I²C0n 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)		Condition for setting (IICBSYn bit = 1)
• When stop condition is detected • When the IICEn bit = 0 • After reset		• When start condition is detected • By setting the IICEn bit when the STCENn bit = 0

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)		Condition for setting (STCENn bit = 1)
• When start condition is detected • After reset		• Setting by instruction

IICRSVn	Communication reservation function disable bit	
0	Communication reservation enabled	
1	Communication reservation disabled	
Condition for clearing (IICRSVn bit = 0)		Condition for setting (IICRSVn bit = 1)
• Clearing by instruction • After reset		• Setting by instruction

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 I²Cn 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 I^2C0n.

These registers 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 IICCn.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^2C0n transfer clock setting method**) (n = 0 to 2, m = 0, 1).

Reset sets these registers to 00H.

After reset: 00H R/W[Note] Address: IICCL0 FFFFFD84H, IICCL1 FFFFFD94H, IICCL2 FFFFFDA4H

	7	6	<5>	<4>	3	2	1	0
IICCLn (n = 0 to 2)	0	0	CLDn	DADn	SMCn	DFCn	CLn1	CLn0

CLDn	Detection of SCL0n pin level (valid only when IICCn.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)
• When the SCL0n pin is at low level • When the IICEn bit = 0 (operation stop) • After reset	• When the SCL0n pin is at high level

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 (DAD0n bit = 1)
• When the SDA0n pin is at low level • When the IICEn bit = 0 (operation stop) • After reset	• When the SDA0n pin is at high level

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.

The digital filter can be used only in high-speed mode.
In high-speed mode, the transfer clock does not vary regardless of the DFCn bit setting (on/off).
The digital filter is used to eliminate noise in high-speed mode.

Note Bits 4 and 5 are read-only bits.

Caution Be sure to clear bits 7 and 6 to “0”.

Remark When the IICCn.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^{2}C0n function expansion (valid only in the high-speed mode).

These registers 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^{2}C0n transfer clock setting method**) (m = 0, 1).

Set the IICXn register when the IICCn.IICEn bit = 0.

Reset sets these registers to 00H.

After reset: 00H R/W Address: IICX0 FFFFFD85H, IICX1 FFFFFD95H, IICX2 FFFFFDA5H

	7	6	5	4	3	2	1	<0>
IICXn	0	0	0	0	0	0	0	CLXn

(n = 0 to 2)

(6) I^{2}C0n transfer clock setting method

The I^{2}C0n transfer clock frequency (f_{SCL}) 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**).

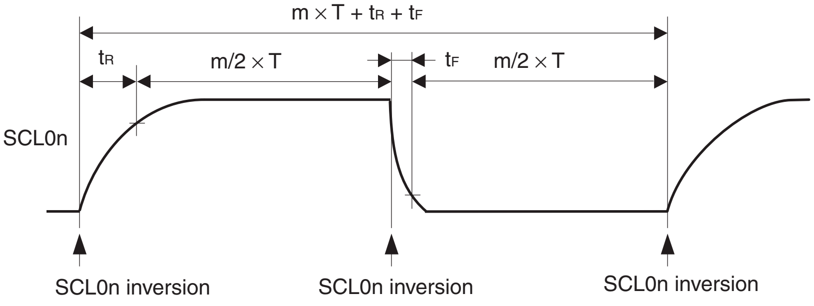
T: 1/f_{XX}

t_R: SCL0n pin rise time

t_F: SCL0n pin fall time

For example, the I^{2}C0n transfer clock frequency (f_{SCL}) when f_{XX} = 19.2 MHz, m = 198, t_R = 200 ns, and t_F = 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 (fxx) Range	Operating Mode
Bit 0	Bit 3	Bit 1	Bit 0				
CLX0	SMC0	CL01	CL00				
0	0	0	0	fxx (when OCKS0 = 18H set)	fxx/44	2.50 MHz ≤ fxx ≤ 4.19 MHz	Standard mode (SMC0 bit = 0)
				fxx/2 (when OCKS0 = 10H set)	fxx/88	4.00 MHz ≤ fxx ≤ 8.38 MHz	
				fxx/3 (when OCKS0 = 11H set)	fxx/132	6.00 MHz ≤ fxx ≤ 12.57 MHz	
				fxx/4 (when OCKS0 = 12H set)	fxx/176	8.00 MHz ≤ fxx ≤ 16.76 MHz	
				fxx/5 (when OCKS0 = 13H set)	fxx/220	10.00 MHz ≤ fxx ≤ 20.00 MHz	
0	0	0	1	fxx (when OCKS0 = 18H set)	fxx/86	4.19 MHz ≤ fxx ≤ 8.38 MHz	
				fxx/2 (when OCKS0 = 10H set)	fxx/172	8.38 MHz ≤ fxx ≤ 16.76 MHz	
				fxx/3 (when OCKS0 = 11H set)	fxx/258	12.57 MHz ≤ fxx ≤ 20.00 MHz	
				fxx/4 (when OCKS0 = 12H set)	fxx/344	16.76 MHz ≤ fxx ≤ 20.00 MHz	
0	0	1	0	fxx[Note]	fxx/86	4.19 MHz ≤ fxx ≤ 8.38 MHz	
0	0	1	1	fxx (when OCKS0 = 18H set)	fxx/66	fxx = 6.40 MHz	
				fxx/2 (when OCKS0 = 10H set)	fxx/132	fxx = 12.80 MHz	
				fxx/3 (when OCKS0 = 11H set)	fxx/198	fxx = 19.20 MHz	
0	1	0	×	fxx (when OCKS0 = 18H set)	fxx/24	4.19 MHz ≤ fxx ≤ 8.38 MHz	High-speed mode (SMC0 bit = 1)
				fxx/2 (when OCKS0 = 10H set)	fxx/48	8.00 MHz ≤ fxx ≤ 16.76 MHz	
				fxx/3 (when OCKS0 = 11H set)	fxx/72	12.00 MHz ≤ fxx ≤ 20.00 MHz	
				fxx/4 (when OCKS0 = 12H set)	fxx/96	16.00 MHz ≤ fxx ≤ 20.00 MHz	
0	1	1	0	fxx[Note]	fxx/24	4.00 MHz ≤ fxx ≤ 8.38 MHz	
0	1	1	1	fxx (when OCKS0 = 18H set)	fxx/18	fxx = 6.40 MHz	
				fxx/2 (when OCKS0 = 10H set)	fxx/36	fxx = 12.80 MHz	
				fxx/3 (when OCKS0 = 11H set)	fxx/54	fxx = 19.20 MHz	
1	1	0	×	fxx (when OCKS0 = 18H set)	fxx/12	4.00 MHz ≤ fxx ≤ 4.19 MHz	
				fxx/2 (when OCKS0 = 10H set)	fxx/24	8.00 MHz ≤ fxx ≤ 8.38 MHz	
				fxx/3 (when OCKS0 = 11H set)	fxx/36	12.00 MHz ≤ fxx ≤ 12.57 MHz	
				fxx/4 (when OCKS0 = 12H set)	fxx/48	16.00 MHz ≤ fxx ≤ 16.67 MHz	
				fxx/5 (when OCKS0 = 13H set)	fxx/60	fxx = 20.00 MHz	
1	1	1	0	fxx[Note]	fxx/12	4.00 MHz ≤ fxx ≤ 4.19 MHz	
Other than above				Setting prohibited	–	–	–

Note Since the selection clock is fxx regardless of the value set to the OCKS0 register, clear the OCKS0 register to 00H (I^{2}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 (fxx) Range	Operating Mode
Bit 0	Bit 3	Bit 1	Bit 0				
CLXm	SMCm	CLm1	CLm0				
0	0	0	0	fxx (when OCKS1 = 18H set)	fxx/44	2.50 MHz ≤ fxx ≤ 4.19 MHz	Standard mode (SMCm bit = 0)
				fxx/2 (when OCKS1 = 10H set)	fxx/88	4.00 MHz ≤ fxx ≤ 8.38 MHz	
				fxx/3 (when OCKS1 = 11H set)	fxx/132	6.00 MHz ≤ fxx ≤ 12.57 MHz	
				fxx/4 (when OCKS1 = 12H set)	fxx/176	8.00 MHz ≤ fxx ≤ 16.76 MHz	
				fxx/5 (when OCKS1 = 13H set)	fxx/220	10.00 MHz ≤ fxx ≤ 20.00 MHz	
0	0	0	1	fxx (when OCKS1 = 18H set)	fxx/86	4.19 MHz ≤ fxx ≤ 8.38 MHz	
				fxx/2 (when OCKS1 = 10H set)	fxx/172	8.38 MHz ≤ fxx ≤ 16.76 MHz	
				fxx/3 (when OCKS1 = 11H set)	fxx/258	12.57 MHz ≤ fxx ≤ 20.00 MHz	
				fxx/4 (when OCKS1 = 12H set)	fxx/344	16.76 MHz ≤ fxx ≤ 20.00 MHz	
0	0	1	0	fxx[Note]	fxx/86	4.19 MHz ≤ fxx ≤ 8.38 MHz	
0	0	1	1	fxx (when OCKS1 = 18H set)	fxx/66	fxx = 6.40 MHz	
				fxx/2 (when OCKS1 = 10H set)	fxx/132	fxx = 12.80 MHz	
				fxx/3 (when OCKS1 = 11H set)	fxx/198	fxx = 19.20 MHz	
0	1	0	×	fxx (when OCKS1 = 18H set)	fxx/24	4.19 MHz ≤ fxx ≤ 8.38 MHz	High-speed mode (SMCm bit = 1)
				fxx/2 (when OCKS1 = 10H set)	fxx/48	8.00 MHz ≤ fxx ≤ 16.76 MHz	
				fxx/3 (when OCKS1 = 11H set)	fxx/72	12.00 MHz ≤ fxx ≤ 20.00 MHz	
				fxx/4 (when OCKS1 = 12H set)	fxx/96	16.00 MHz ≤ fxx ≤ 20.00 MHz	
0	1	1	0	fxx[Note]	fxx/24	4.00 MHz ≤ fxx ≤ 8.38 MHz	
0	1	1	1	fxx (when OCKS1 = 18H set)	fxx/18	fxx = 6.40 MHz	
				fxx/2 (when OCKS1 = 10H set)	fxx/36	fxx = 12.80 MHz	
				fxx/3 (when OCKS1 = 11H set)	fxx/54	fxx = 19.20 MHz	
1	1	0	×	fxx (when OCKS1 = 18H set)	fxx/12	4.00 MHz ≤ fxx ≤ 4.19 MHz	
				fxx/2 (when OCKS1 = 10H set)	fxx/24	8.00 MHz ≤ fxx ≤ 8.38 MHz	
				fxx/3 (when OCKS1 = 11H set)	fxx/36	12.00 MHz ≤ fxx ≤ 12.57 MHz	
				fxx/4 (when OCKS1 = 12H set)	fxx/48	16.00 MHz ≤ fxx ≤ 16.67 MHz	
				fxx/5 (when OCKS1 = 13H set)	fxx/60	fxx = 20.00 MHz	
1	1	1	0	fxx[Note]	fxx/12	4.00 MHz ≤ fxx ≤ 4.19 MHz	
Other than above				Setting prohibited	–	–	–

Note Since the selection clock is fxx regardless of the value set to the OCKS1 register, clear the OCKS1 register to 00H (I^{2}C division clock stopped status).

Remarks 1. m = 1, 2

2. ×: don't care

(7) IIC division clock select registers 0, 1 (OCKS0, OCKS1)

The OCKSm register controls the I^{2}C0n division clock (n = 0 to 2, m = 0, 1).

These registers control the I^{2}C00 division clock via the OCKS0 register and the I^{2}C01 and I^{2}C02 division clocks via the OCKS1 register.

These registers can be read or written in 8-bit units.

Reset sets these registers to 00H.

After reset: 00H R/W Address: OCKS0 FFFFF340H, OCKS1 FFFFF344H

	7	6	5	4	3	2	1	0
OCKSm (m = 0, 1)	0	0	0	OCKSENm	OCKSTHm	0	OCKSm1	OCKSm0

OCKSENm	Operation setting of I^{2}C division clock
0	Disable I^{2}C division clock operation
1	Enable I^{2}C division clock operation

OCKSTHm	OCKSm1	OCKSm0	Selection of I^{2}C division clock
0	0	0	fxx/2
0	0	1	fxx/3
0	1	0	fxx/4
0	1	1	fxx/5
1	0	0	fxx
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. These registers 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 (IICCn.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 these registers 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^2C bus's slave address.

These registers 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 these registers to 00H.

After reset: 00H R/W Address: SVA0 FFFFFD83H, SVA1 FFFFFD93H, SVA2 FFFFFDA3H

	7	6	5	4	3	2	1	0
SVAn								0

(n = 0 to 2)

17.5 I^{2}C Bus Mode Functions

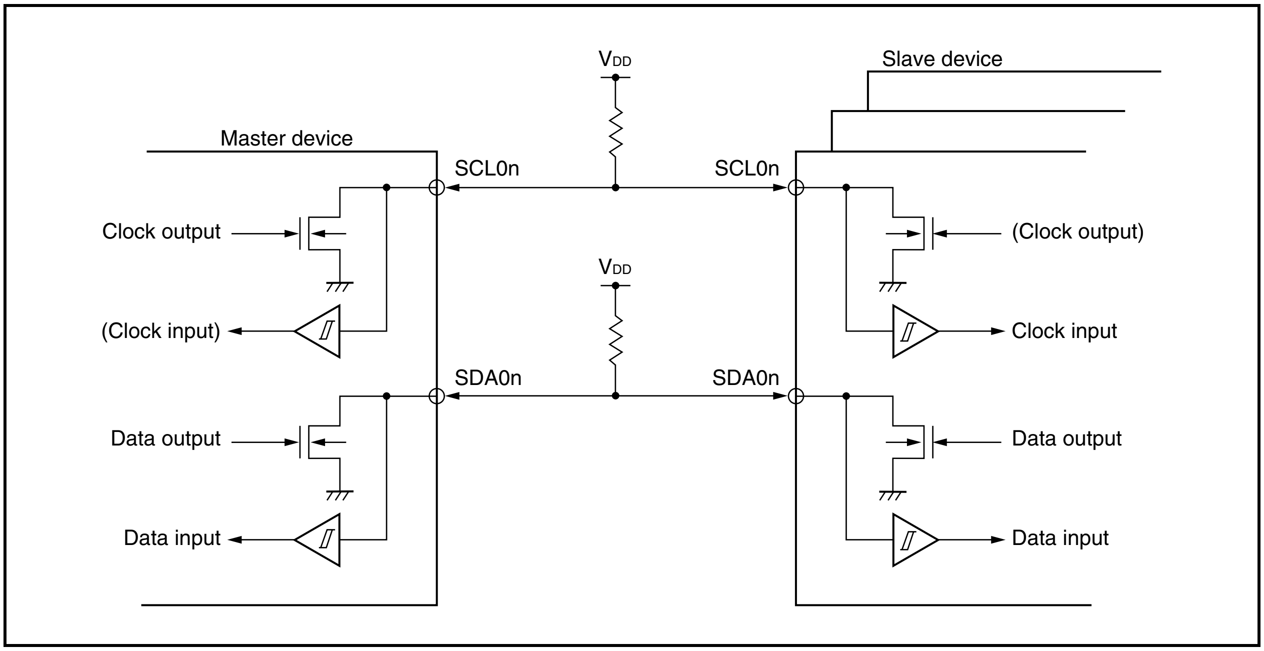
17.5.1 Pin configuration

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.

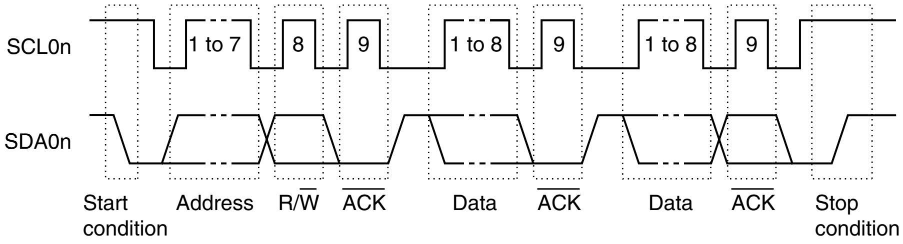
Figure 17-6. Pin Configuration Diagram



17.6 I²C Bus Definitions and Control Methods

The following section describes the I²C bus's serial data communication format and the signals used by the I²C bus. The transfer timing for the "start condition", "address", "transfer direction specification", "data", and "stop condition" generated on the I²C bus's serial data bus is shown below.

Figure 17-7. I²C Bus Serial Data Transfer Timing



The master device generates the start condition, slave address, and stop condition.

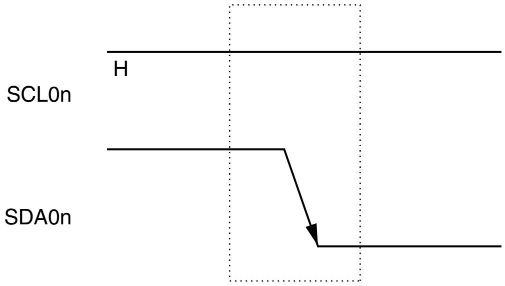
$\overline{ACK}$ can be generated by either the master or slave device (normally, it is generated by the device that receives 8-bit data).

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 defect the start condition (n = 0 to 2).

Figure 17-8. Start Condition



A start condition is output when the IICCn.STTn bit is set (1) after a stop condition has been detected (IICSn.SPDn bit = 1). When a start condition is detected, the IICSn.STDn bit is set (1) (n = 0 to 2).

Caution **When the IICCn.IICEn bit of the V850ES/JG3-L 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 IICCn.IICEn bit to 1 when the SCL0n and SDA0n lines are high level.**

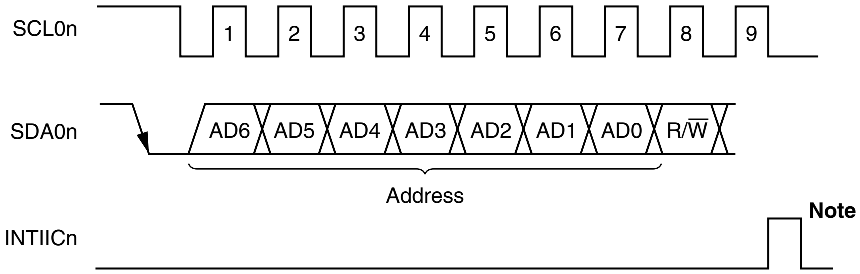
17.6.2 Addresses

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



Note The interrupt request signal (INTIICn) is generated if a local address or extension code is received during slave device operation.

Remark n = 0 to 2

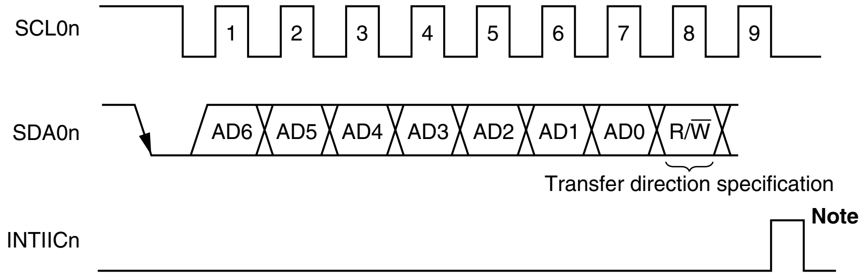
The slave address and the eighth bit, which specifies the transfer direction as described in **17.6.3 Transfer direction specification** below, are written together to IIC shift register n (IICn) and then output. Received addresses are written to the IICn register (n = 0 to 2).

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



Note The INTIICn signal is generated if a local address or extension code is received during slave device operation.

Remark n = 0 to 2

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.

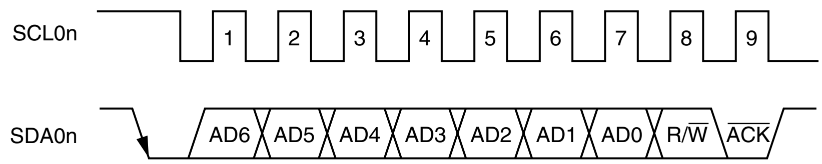
When the receiving device sets the SDA0n line to low level during the ninth clock, $\overline{\text{ACK}}$ is generated (normal reception).

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. $\overline{\text{ACK}}$



Remark n = 0 to 2

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.

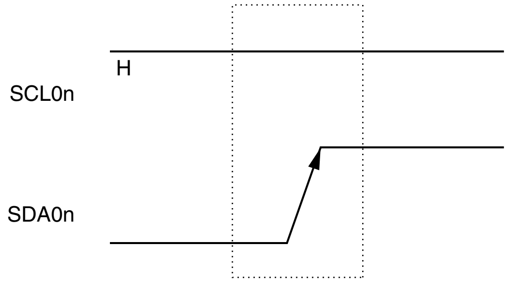
Remark n = 0 to 2

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 the master device outputs to the slave device when serial transfer has been completed. When used as the slave device, the start condition can be detected.

Figure 17-12. Stop Condition



Remark n = 0 to 2

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).

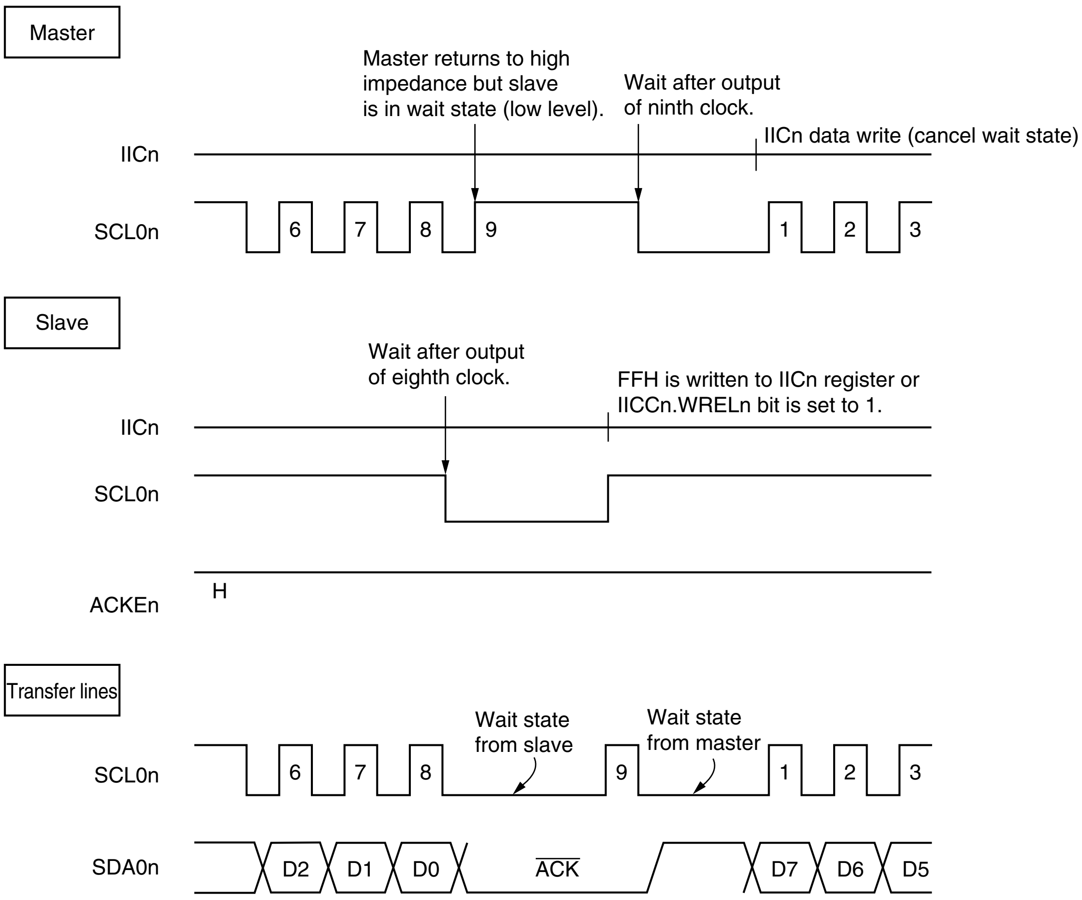
17.6.6 Wait state

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)

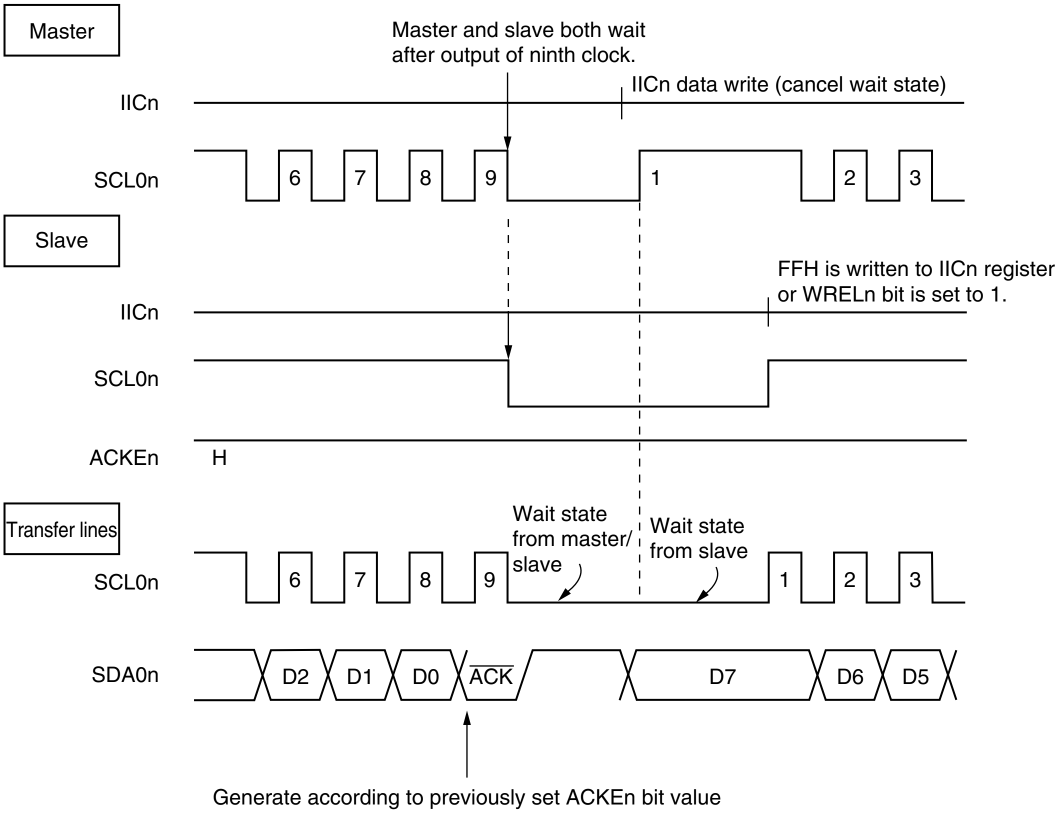
(a) When master device has a nine-clock wait and slave device has an eight-clock wait (master: transmission, slave: reception, and IICCn.ACKEn bit = 1)



Remark n = 0 to 2

Figure 17-13. Wait State (2/2)

(b) When master and slave devices both have a nine-clock wait (master: transmission, slave: reception, and ACKEn bit = 1)



Remark n = 0 to 2

A wait state may be automatically generated depending on the setting of the IICCn.WTIMn bit (n = 0 to 2).

Normally, when the IICCn.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 IICCn.STTn bit to 1
- By setting the IICCn.SPTn bit to 1

17.6.7 Wait state cancellation method

In the case of I^{2}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 IICCn.WRELn bit to 1 (wait state cancellation)
- By setting the IICCn.STTn bit to 1 (start condition generation)
- By setting the IICCn.SPTn bit to 1 (stop condition generation)

If any of these wait state cancellation actions is performed, I^{2}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 IICCn.IICEn bit to 0 will stop communication, enabling wait state to be cancelled.

If the I^{2}C bus dead-locks due to noise, etc., setting the IICCn.LRELn bit to 1 causes the communication operation to be exited, enabling wait state to be cancelled.

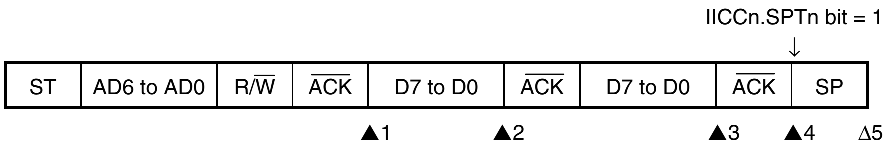
17.7 I^{2}C Interrupt Request Signals (INTIICn)

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 IICCn.WTIMn bit = 0



▲1: IICSn register = 1000X110B

▲2: IICSn register = 1000X000B

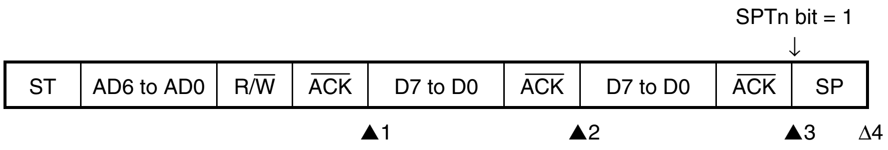
▲3: IICSn register = 1000X000B (WTIMn bit = 1)

▲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

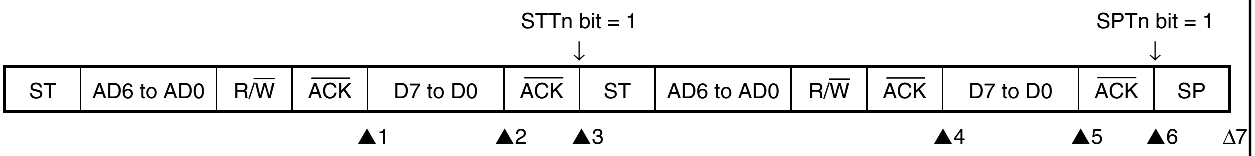
▲3: IICSn register = 1000XX00B

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)

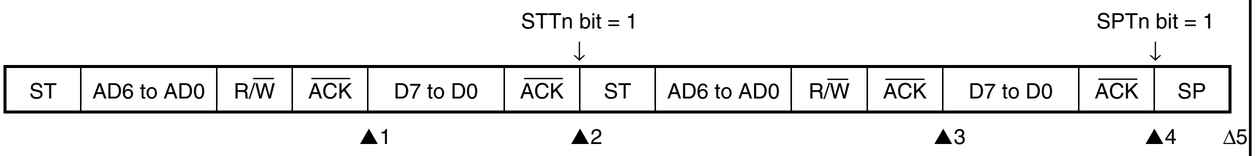
▲5: IICSn register = 1000X000B (WTIMn bit = 1)

▲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

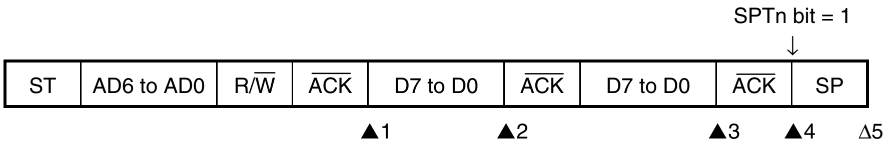
▲4: IICSn register = 1000XX00B

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)

<1> When WTIMn bit = 0



▲1: IICSn register = 1010X110B

▲2: IICSn register = 1010X000B

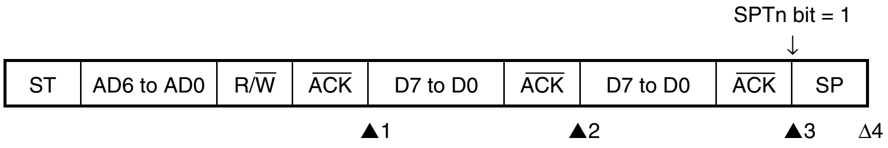
▲3: IICSn register = 1010X000B (WTIMn bit = 1)

▲4: IICSn register = 1010XX00B

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 = 1010X110B

▲2: IICSn register = 1010X100B

▲3: IICSn register = 1010XX00B

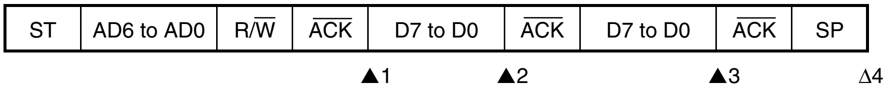
Δ 4: IICSn register = 00000001B

Remarks 1. ▲: Always generated
Δ: Generated only when SPIEn bit = 1
X: don't care
2. n = 0 to 2

17.7.2 Slave device operation (when receiving slave address data (address match))

(1) Start ~ Address ~ Data ~ Data ~ Stop

<1> When IICCn.WTIMn bit = 0



▲1: IICSn register = 0001X110B

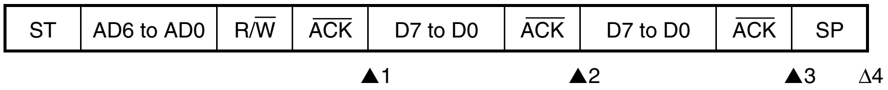
▲2: IICSn register = 0001X000B

▲3: IICSn register = 0001X000B

Δ 4: IICSn register = 00000001B

Remarks 1. ▲: Always generated
Δ: Generated only when IICCn.SPIEn bit = 1
X: don't care
2. n = 0 to 2

<2> When WTIMn bit = 1



▲1: IICSn register = 0001X110B

▲2: IICSn register = 0001X100B

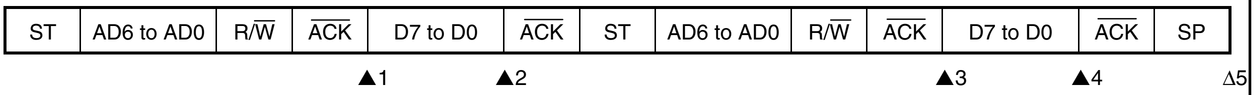
▲3: IICSn register = 0001XX00B

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

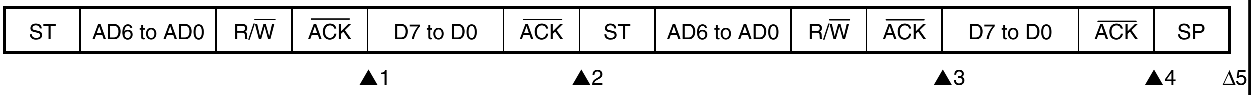
▲3: IICSn register = 0001X110B

▲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

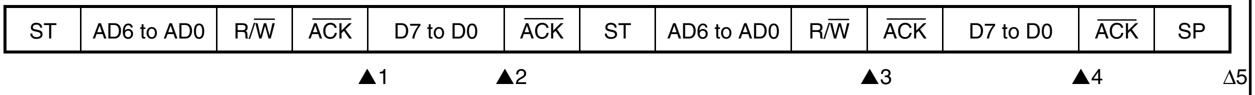
▲4: IICSn register = 0001XX00B

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

<1> When WTIMn bit = 0 (after restart, extension code reception)



▲1: IICSn register = 0001X110B

▲2: IICSn register = 0001X000B

▲3: IICSn register = 0010X010B

▲4: IICSn register = 0010X000B

Δ 5: IICSn register = 00000001B

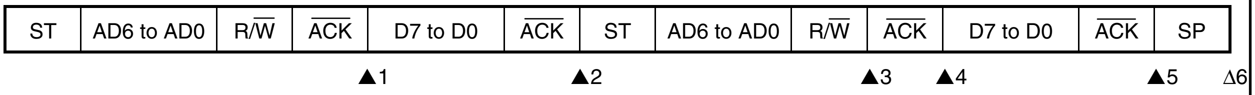
Remarks 1. ▲: Always generated

Δ: Generated only when SPIEn bit = 1

X: don’t care

2. n = 0 to 2

<2> When WTIMn bit = 1 (after restart, extension code reception)



▲1: IICSn register = 0001X110B

▲2: IICSn register = 0001XX00B

▲3: IICSn register = 0010X010B

▲4: IICSn register = 0010X110B

▲5: IICSn register = 0010XX00B

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

(4) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop

<1> When WTIMn bit = 0 (after restart, address mismatch (= not extension code))

ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	SP
			▲1	▲2					▲3			Δ4

▲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))

ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	SP
			▲1		▲2				▲3			Δ4

▲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

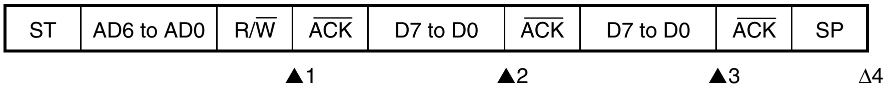
X: don’t care

2. n = 0 to 2

17.7.3 Slave device operation (when receiving extension code)

(1) Start ~ Code ~ Data ~ Data ~ Stop

<1> When IICCn.WTIMn bit = 0



▲1: IICSn register = 0010X010B

▲2: IICSn register = 0010X000B

▲3: IICSn register = 0010X000B

Δ 4: IICSn register = 00000001B

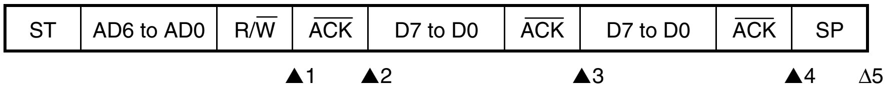
Remarks 1. ▲: Always generated

Δ: Generated only when IICCn.SPIEn bit = 1

X: don't care

2. n = 0 to 2

<2> When WTIMn bit = 1



▲1: IICSn register = 0010X010B

▲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

(2) Start ~ Code ~ Data ~ Start ~ Address ~ Data ~ Stop

<1> When WTIMn bit = 0 (after restart, address match)

ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	SP	
			▲1		▲2					▲3	▲4		Δ5

▲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)

ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	SP	
			▲1	▲2		▲3				▲4		▲5	Δ6

▲1: IICSn register = 0010X010B

▲2: IICSn register = 0010X110B

▲3: IICSn register = 0010XX00B

▲4: IICSn register = 0001X110B

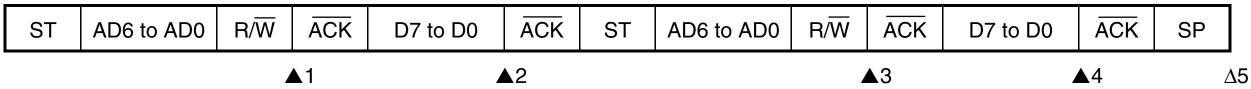
▲5: IICSn register = 0001XX00B

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)



▲1: IICSn register = 0010X010B

▲2: IICSn register = 0010X000B

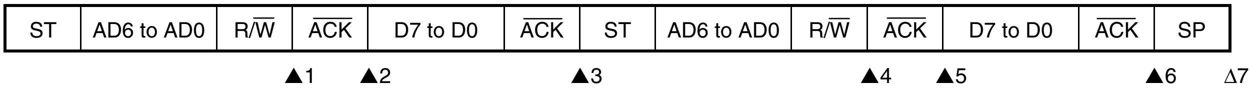
▲3: IICSn register = 0010X010B

▲4: IICSn register = 0010X000B

△ 5: IICSn register = 00000001B

Remarks 1. ▲: Always generated
△: 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)



▲1: IICSn register = 0010X010B

▲2: IICSn register = 0010X110B

▲3: IICSn register = 0010XX00B

▲4: IICSn register = 0010X010B

▲5: IICSn register = 0010X110B

▲6: IICSn register = 0010XX00B

△ 7: IICSn register = 00000001B

Remarks 1. ▲: Always generated
△: 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))

ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	SP
			▲1		▲2					▲3		Δ4

▲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))

ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	ST	AD6 to AD0	R/$\overline{\text{W}}$	$\overline{\text{ACK}}$	D7 to D0	$\overline{\text{ACK}}$	SP
			▲1	▲2		▲3				▲4		Δ5

▲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

ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	SP	
									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 IICCn.WTIMn bit = 0

ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	SP	
			▲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 IICCn.SPIEn bit = 1
X: don't care
2. n = 0 to 2

<2> When WTIMn bit = 1

ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	SP	
			▲1		▲2		▲3		Δ4

▲1: IICSn register = 0101X110B (Example: When ALDn bit is read during interrupt servicing)

▲2: IICSn register = 0001X100B

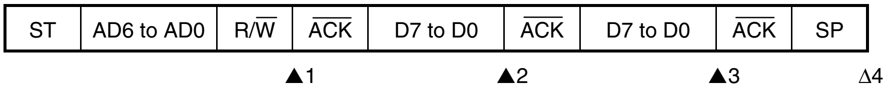
▲3: IICSn register = 0001XX00B

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

<1> When WTIMn bit = 0



▲1: IICSn register = 0110X010B (Example: When ALDn bit is read during interrupt servicing)

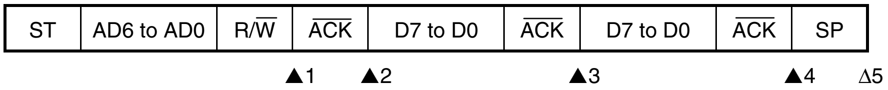
▲2: IICSn register = 0010X000B

▲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

<2> 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

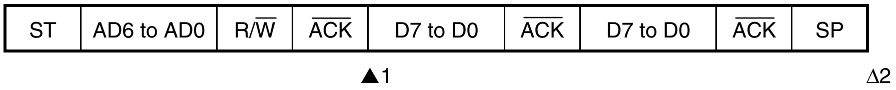
▲4: IICSn register = 0010XX00B

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: IICSn register = 01000110B (Example: When IICSn.ALDn bit is read during interrupt servicing)

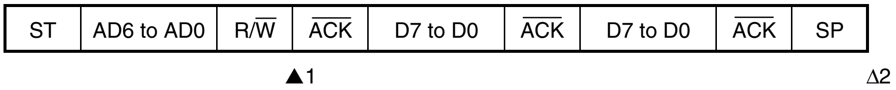
Δ 2: IICSn register = 00000001B

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: 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

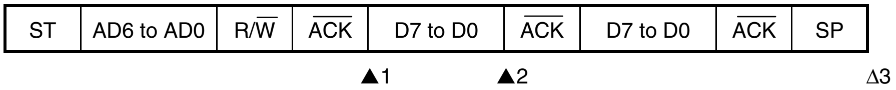
Δ: Generated only when SPIEn bit = 1

X: don't care

2. n = 0 to 2

(3) When arbitration loss occurs during data transfer

<1> When IICCn.WTIMn bit = 0



▲1: IICSn register = 10001110B

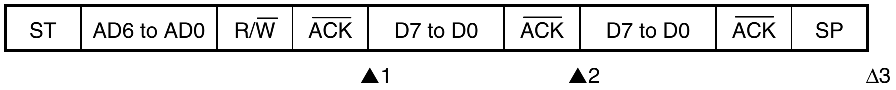
▲2: IICSn register = 01000000B (Example: When ALDn bit is read during interrupt servicing)

Δ 3: IICSn register = 00000001B

Remarks 1. ▲: Always generated
Δ: Generated only when SPIEn bit = 1

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)

Δ 3: 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)

ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to Dn	ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	SP
			▲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

ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to Dn	ST	AD6 to AD0	R/$\overline{W}$	$\overline{ACK}$	D7 to D0	$\overline{ACK}$	SP
			▲1					▲2			Δ3

▲1: IICSn register = 1000X110B

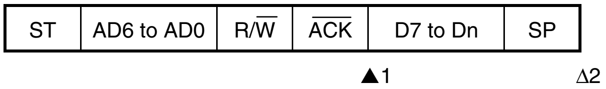
▲2: IICSn register = 0110X010B (Example: When ALDn bit is read during interrupt servicing)

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

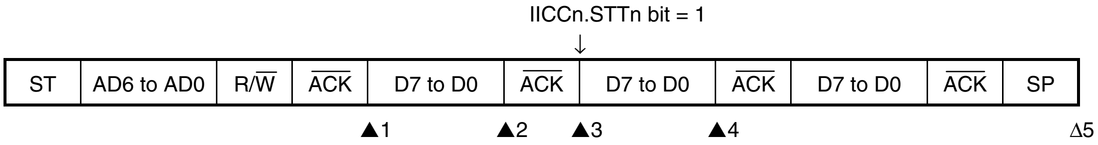
X: don’t care

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)

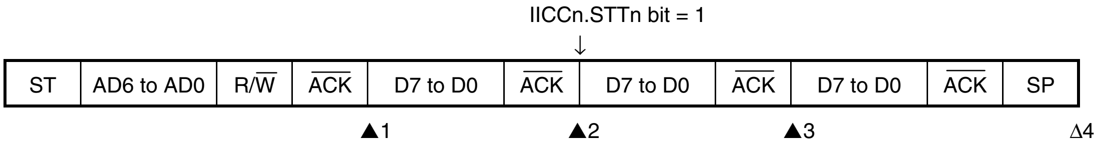
▲3: IICSn register = 1000XX00B (WTIMn bit = 0)

▲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

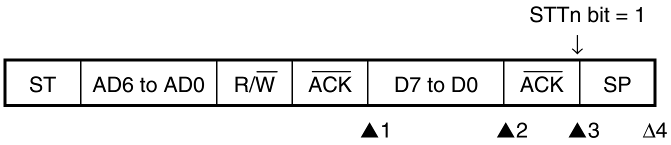
▲3: IICSn register = 01000100B (Example: When ALDn bit is read during interrupt servicing)

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

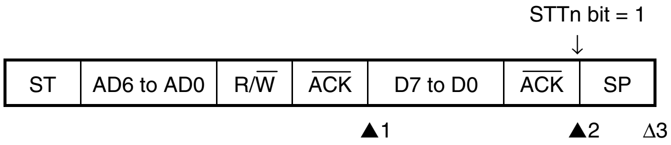
▲2: IICSn register = 1000X000B (WTIMn bit = 1)

▲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

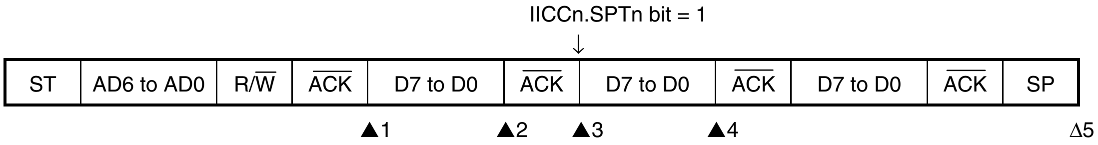
▲2: IICSn register = 1000XX00B

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)

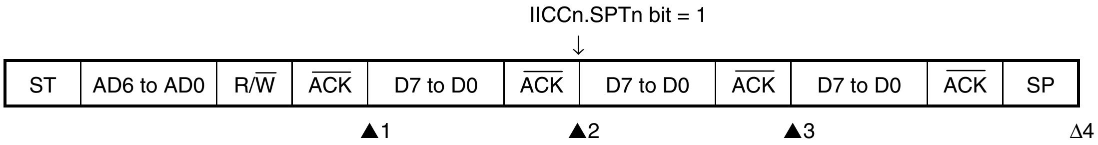
▲3: IICSn register = 1000XX00B (WTIMn bit = 0)

▲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 IICCn.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	9[Notes 1, 2]	8[Note 2]	8[Note 2]	9	8	8
1	9[Notes 1, 2]	9[Note 2]	9[Note 2]	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, the $\overline{\text{ACK}}$ is generated regardless of the value set to the IICCn.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 occurs.

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 cancellation method

The four wait cancellation methods are as follows.

- By setting the IICCn.WRELn bit to 1
- By writing to the IICn register
- By start condition setting (IICCn.STTn bit = 1)[Note]
- By stop condition setting (IICCn.SPTn bit = 1)[Note]

Note Master only

When an 8-clock wait has been selected (WTIMn bit = 0), whether or not the $\overline{\text{ACK}}$ 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^2C 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^2C 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 IICCn.LRELn bit to 1 and the CPU will enter the next communication wait state.

Table 17-4. Extension Code Bit Definitions

Slave Address	$R/\overline{W}$ 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

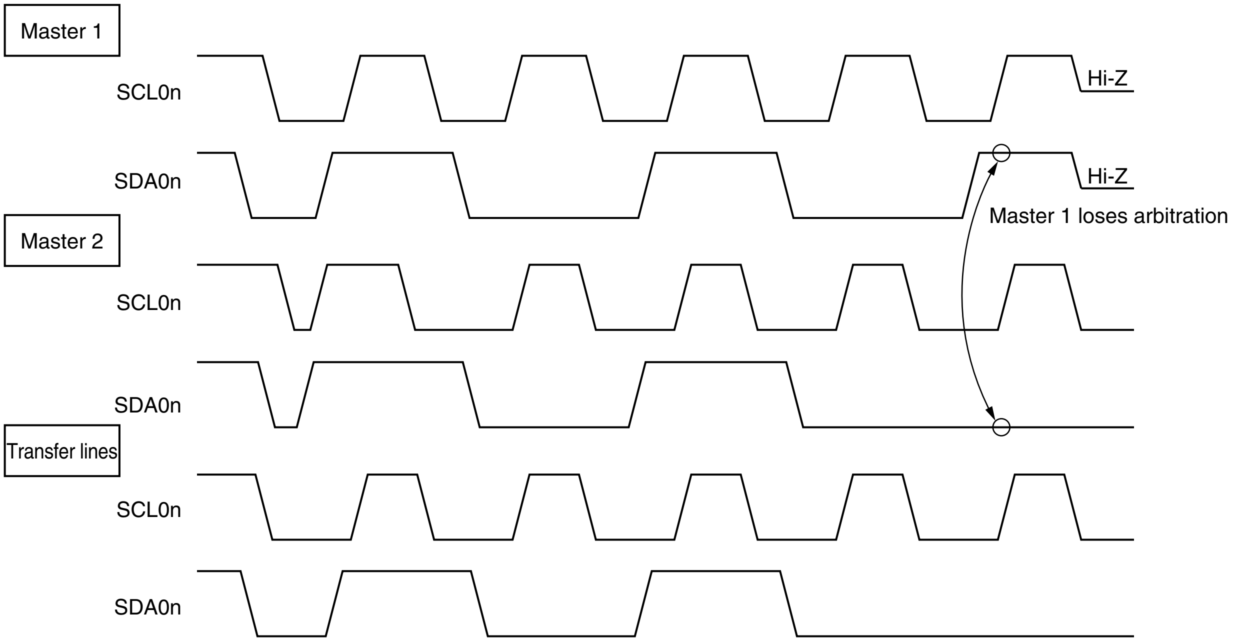
When several master devices simultaneously generate a start condition (when the IICCn.STTn bit is set to 1 before the IICSn.STDn bit is set to 1), communication between the master devices is performed while the number of clocks is adjusted until the data differs. This kind of operation is called arbitration (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 I²C Interrupt Request Signals (INTIICn)**.

Figure 17-14. Arbitration Timing Example



Remark n = 0 to 2

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[Note 1]
Read/write data after address transmission	
Transmitting extension code	
Read/write data after extension code transmission	
Transmitting data	
$\overline{\text{ACK}}$ 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)[Note 2]
When SDA0n pin is low level while attempting to generate restart condition	At falling edge of eighth or ninth clock following byte transfer[Note 1]
When stop condition is detected while attempting to generate restart condition	When stop condition is generated (when IICCn.SPIEn bit = 1)[Note 2]
When DSA0n pin is low level while attempting to generate stop condition	At falling edge of eighth or ninth clock following byte transfer[Note 1]
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^2C 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 IICCn.LRELn bit was set to 1) (n = 0 to 2).

If the IICCn.STTn bit is set to 1 while the bus is not used, a start condition is automatically generated and a wait status 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 IICn register causes master address transfer to start. At this point, the IICCn.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 IICSn.MSTSn 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 IICXn.CLXn bit (n = 0 to 2).

Table 17-6. Wait Periods

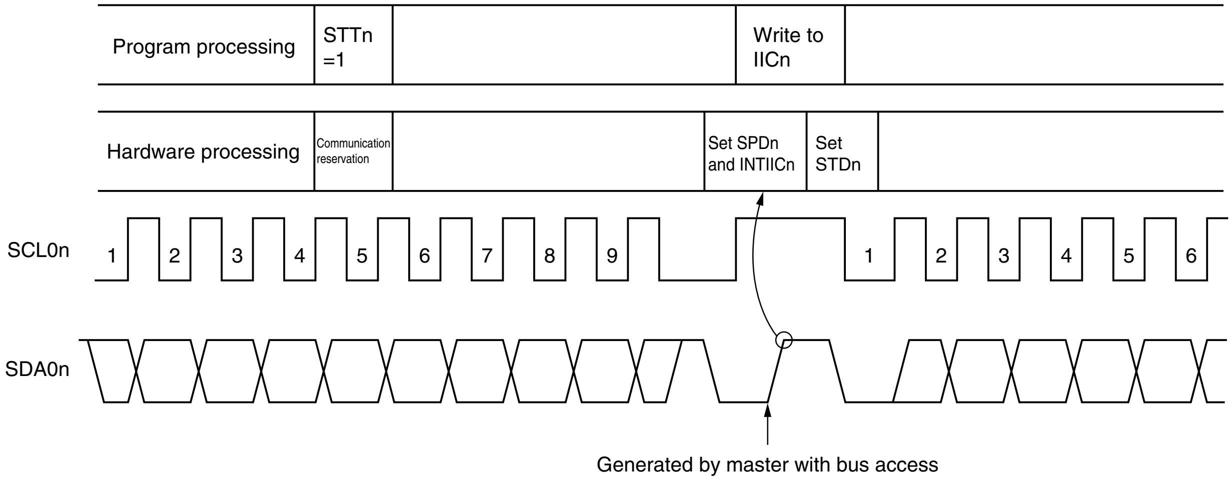
Clock Selection	CLXn	SMCn	CLn1	CLn0	Wait Period
fxx (when OCKSm = 18H set)	0	0	0	0	26 clocks
fxx/2 (when OCKSm = 10H set)	0	0	0	0	52 clocks
fxx/3 (when OCKSm = 11H set)	0	0	0	0	78 clocks
fxx/4 (when OCKSm = 12H set)	0	0	0	0	104 clocks
fxx/5 (when OCKSm = 13H set)	0	0	0	0	130 clocks
fxx (when OCKSm = 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	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 (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	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 (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



Remark n = 0 to 2

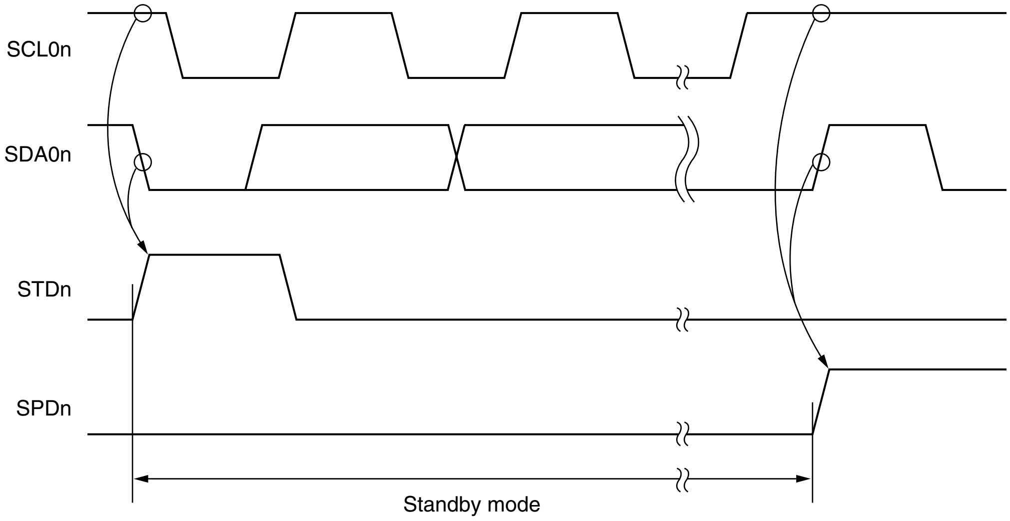
STTn: Bit of IICCn register

STDn: Bit of IICSn register

SPDn: Bit of IICSn register

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 IICCn.STTn bit to 1 before a stop condition is detected (n = 0 to 2).

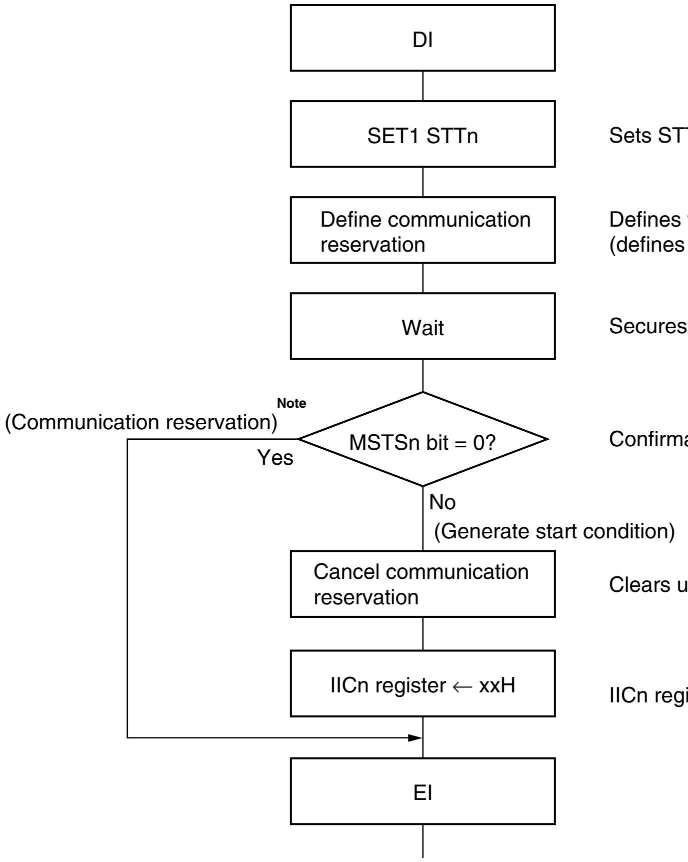
Figure 17-16. Timing for Accepting Communication Reservations



Remark n = 0 to 2

The communication reservation flowchart is illustrated below.

Figure 17-17. Communication Reservation Flowchart



Note The communication reservation operation executes a write to the IICn register when a stop condition interrupt request occurs.

Remark n = 0 to 2

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 I²C0n 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 I²C0n 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/JG3-L 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 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 status will be released by writing communication data to I²Cn, then transferring will begin. If an interrupt is not generated by the detection of a stop condition, transmission will halt in the wait status 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.MSTSn 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/JG3-L 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^{2}C0n bus multimaster system, whether the bus is released or used cannot be judged by the I^{2}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/JG3-L 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/JG3-L 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/JG3-L is used as the slave of the I^{2}C0n bus is shown below.

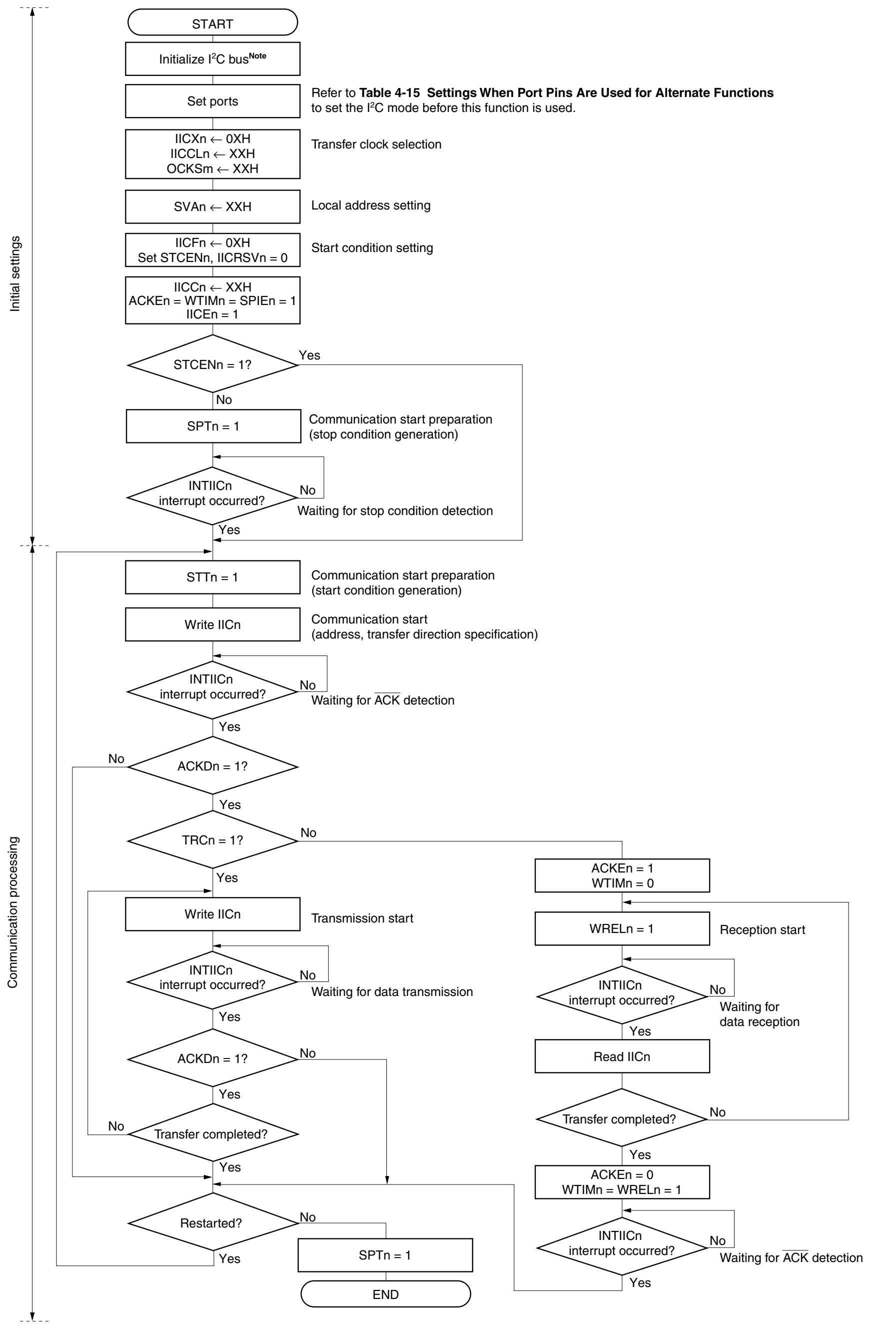
When used as the slave, operation is started by an interrupt. Execute the initial settings at startup, then wait for the INTIICn interrupt occurrence (communication waiting). When the INTIICn interrupt occurs, the communication status is judged and its result is passed as a flag over to the main processing.

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



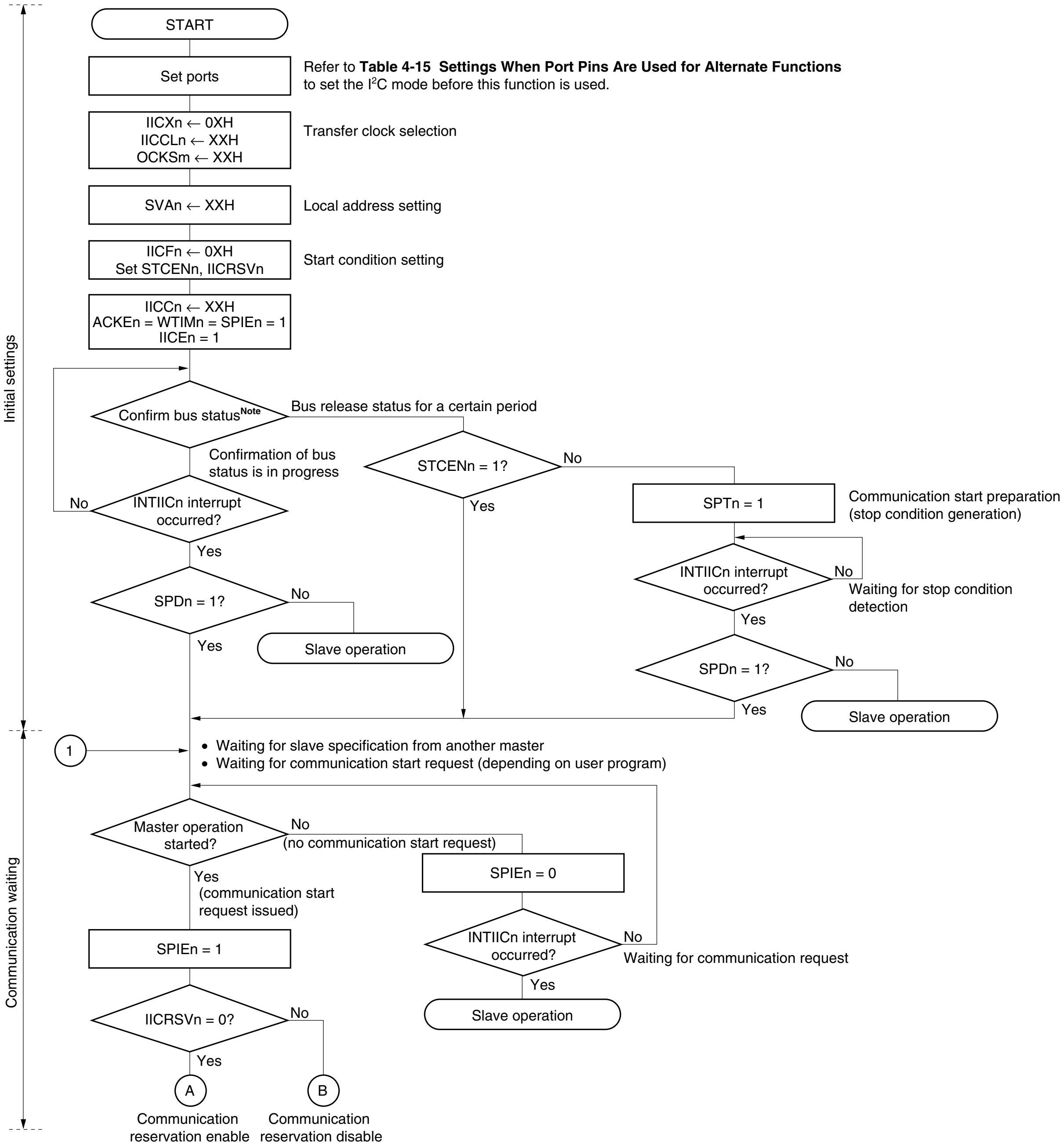
Note Release the I²C0n bus (SCL0n, SDA0n pins = high level) in conformity with the specifications of the product in communication.
For example, when the EEPROM™ outputs a low level to the SDA0n pin, set the SCL0n pin to the output port and output clock pulses from that output port until when the SDA0n pin is constantly high level.

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

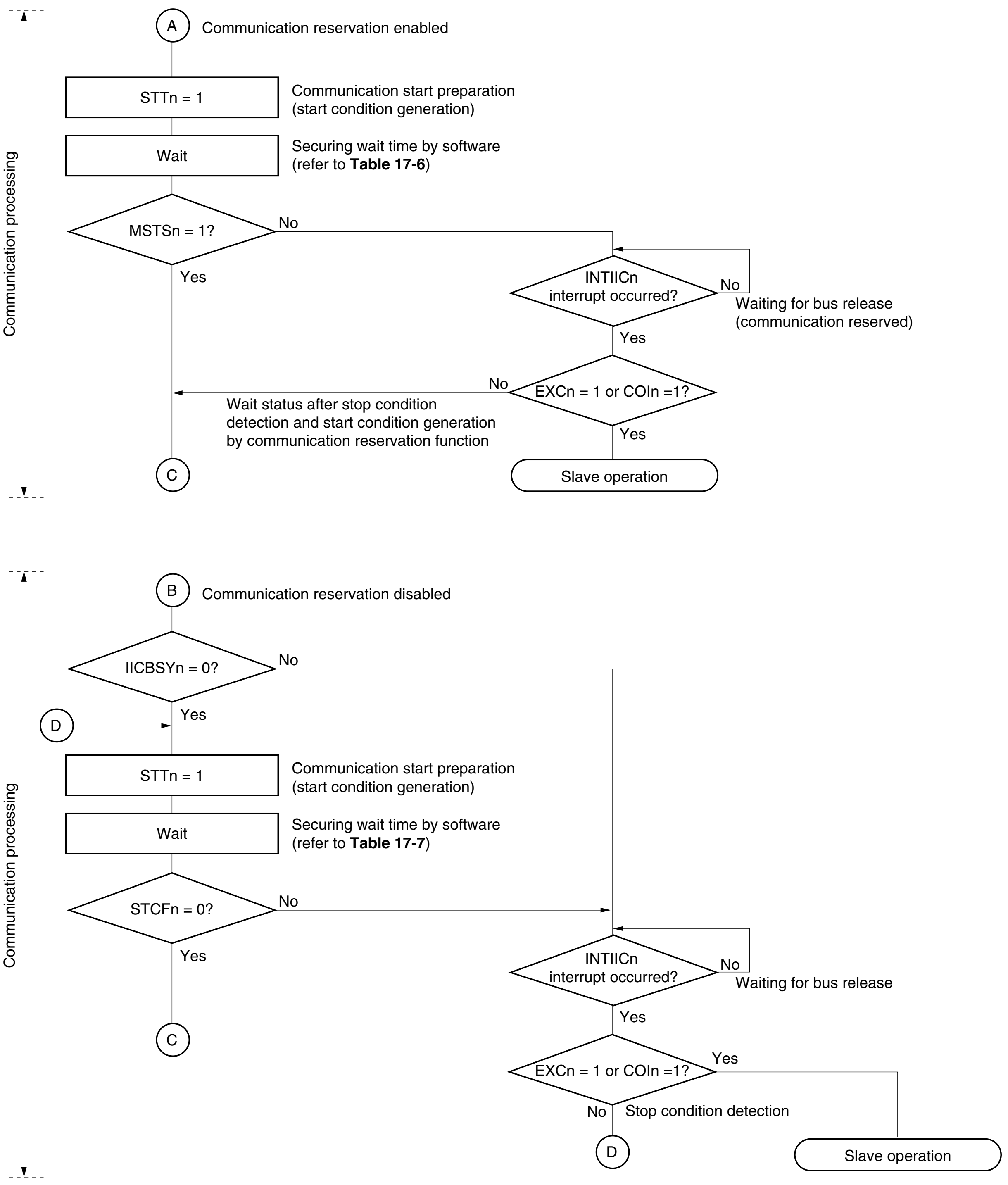
Figure 17-19. Master Operation in Multimaster System (1/3)



Note 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 I²C0n bus (SCL0n, SDA0n pins = high level) by referring to the specifications of the product in communication.

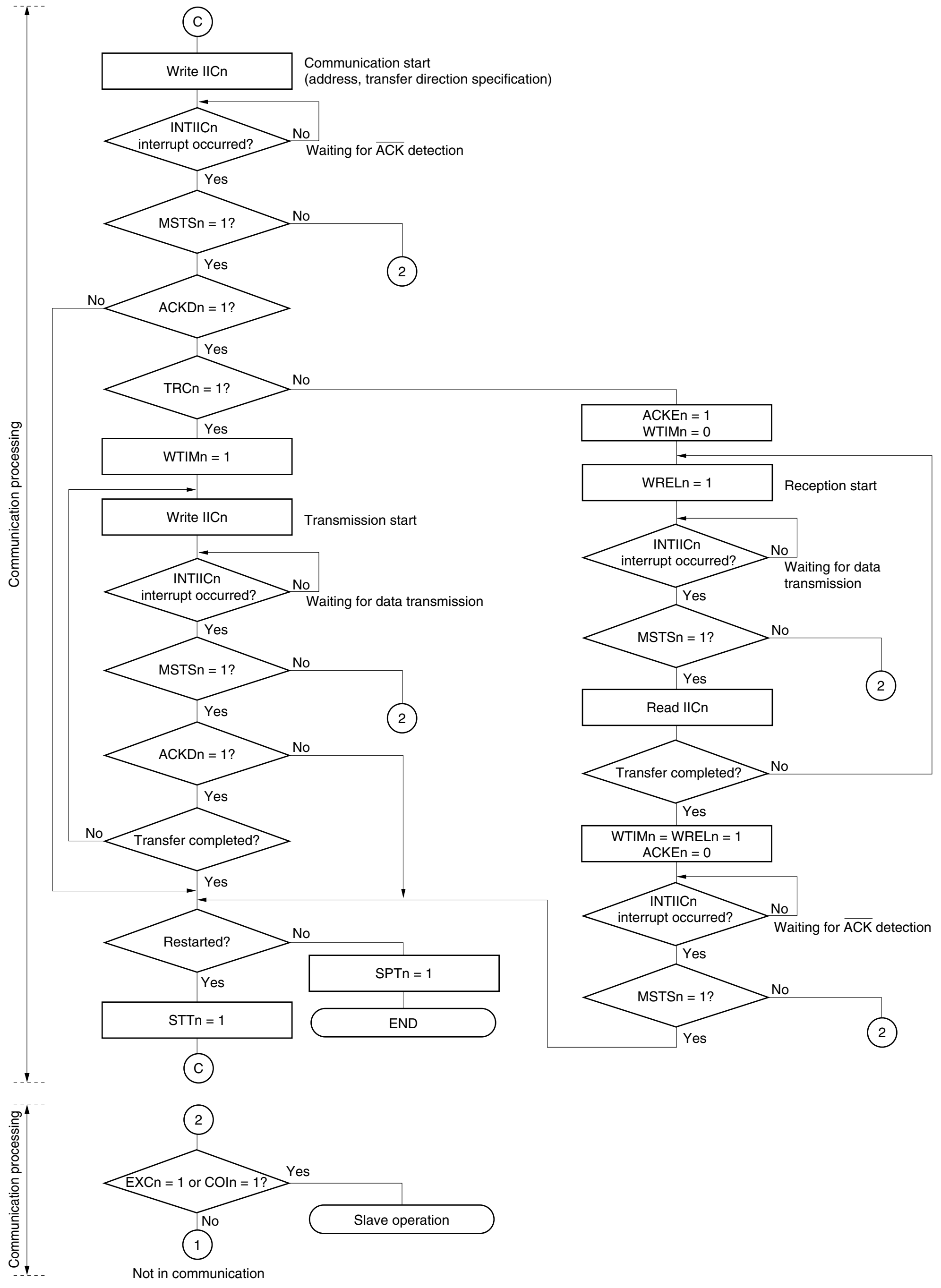
Remark n = 0 to 2, m = 0, 1

Figure 17-19. Master Operation in Multimaster System (2/3)



Remark n = 0 to 2

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/JG3-L 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/JG3-L 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

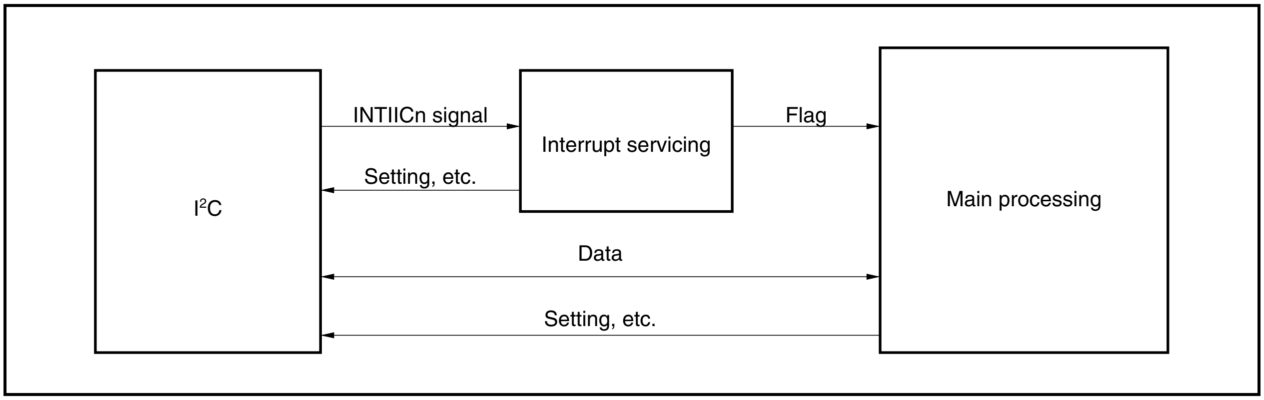
17.16.3 Slave operation

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.

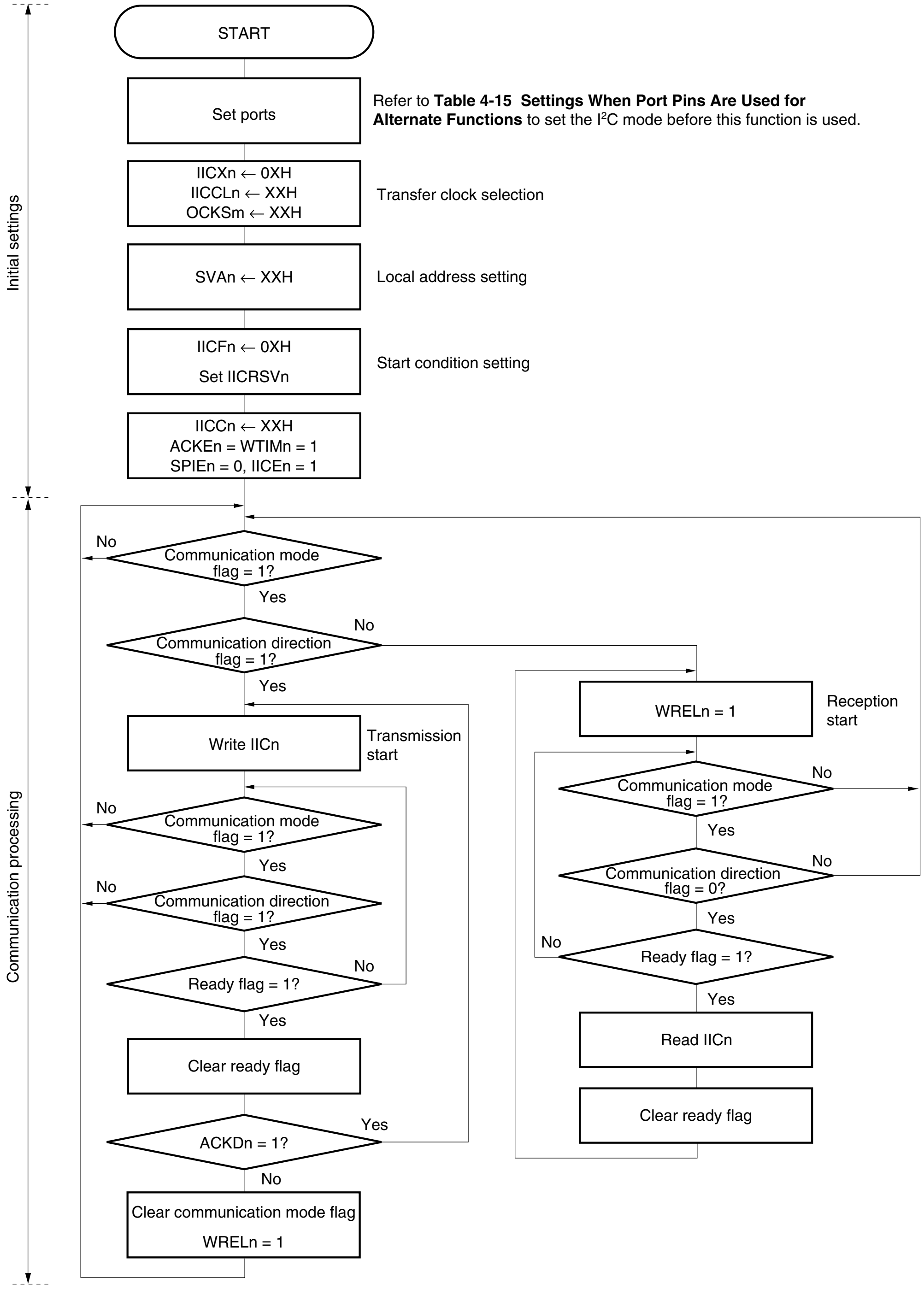
The following shows the operation of the main processing block during slave operation.

Start I²C0n 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)



Remark n = 0 to 2, m = 0, 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.

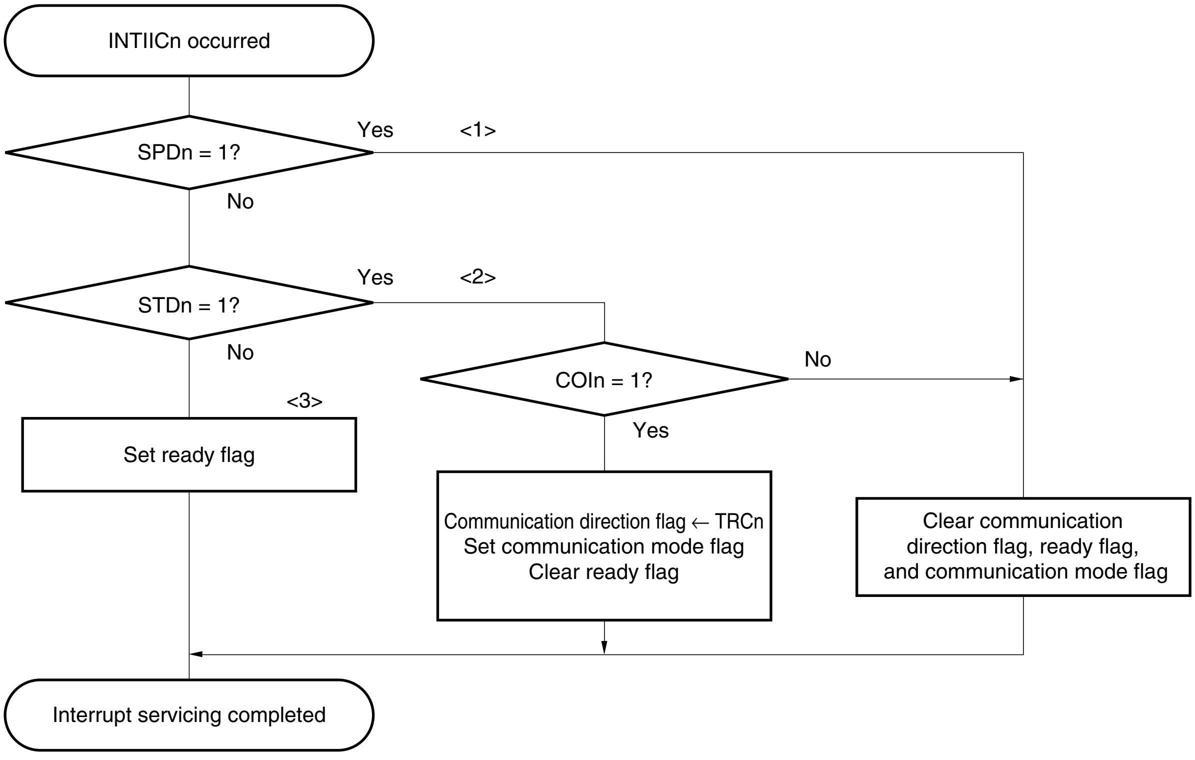
<1> When a stop condition is detected, communication is terminated.

<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 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^{2}C0n bus remains in the wait status.

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)



Remark n = 0 to 2

17.17 Timing of Data Communication

When using I^{2}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.

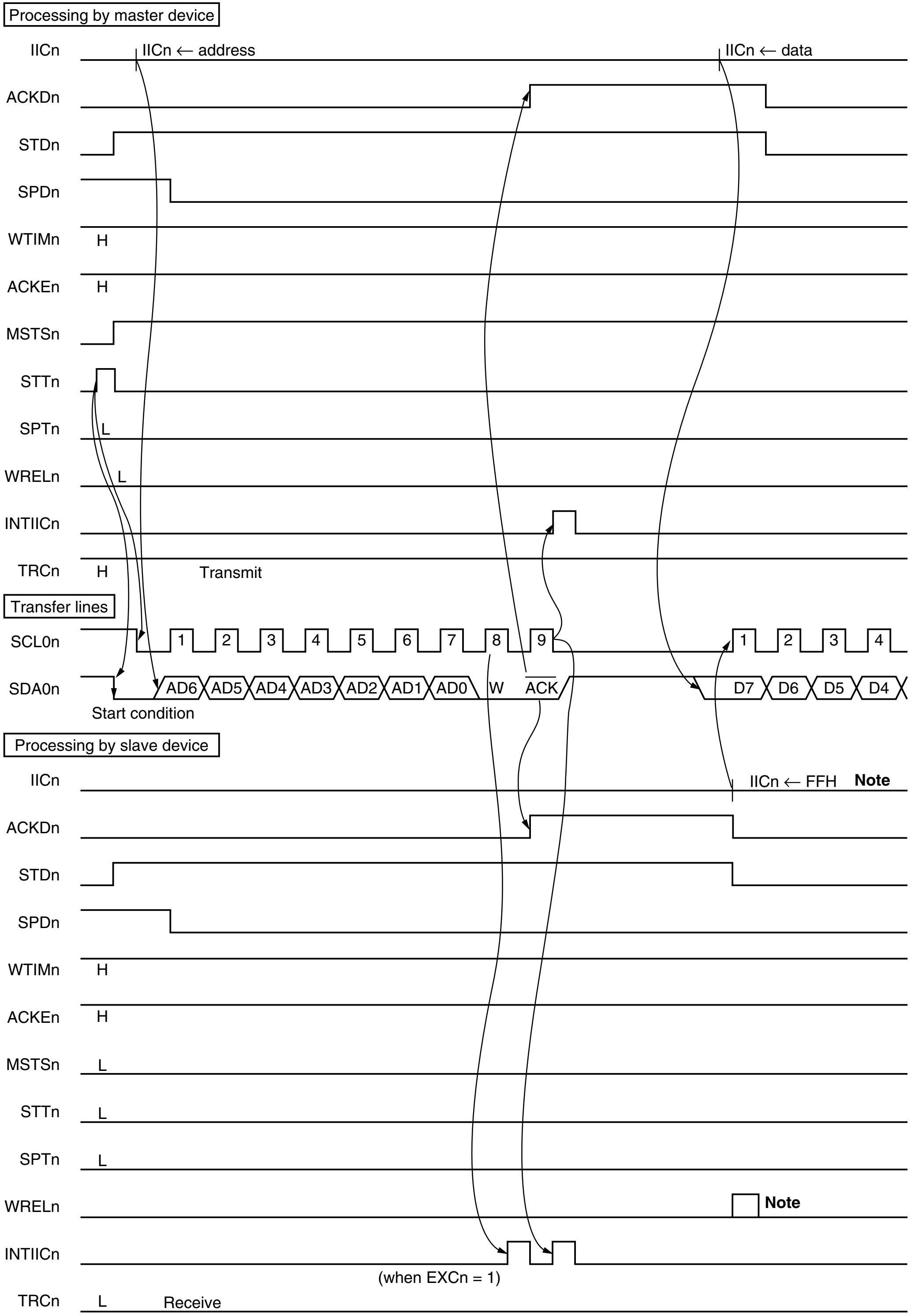
Data input via the SDA0n pin is captured by the IICn register at the rising edge of the SCL0n pin.

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)

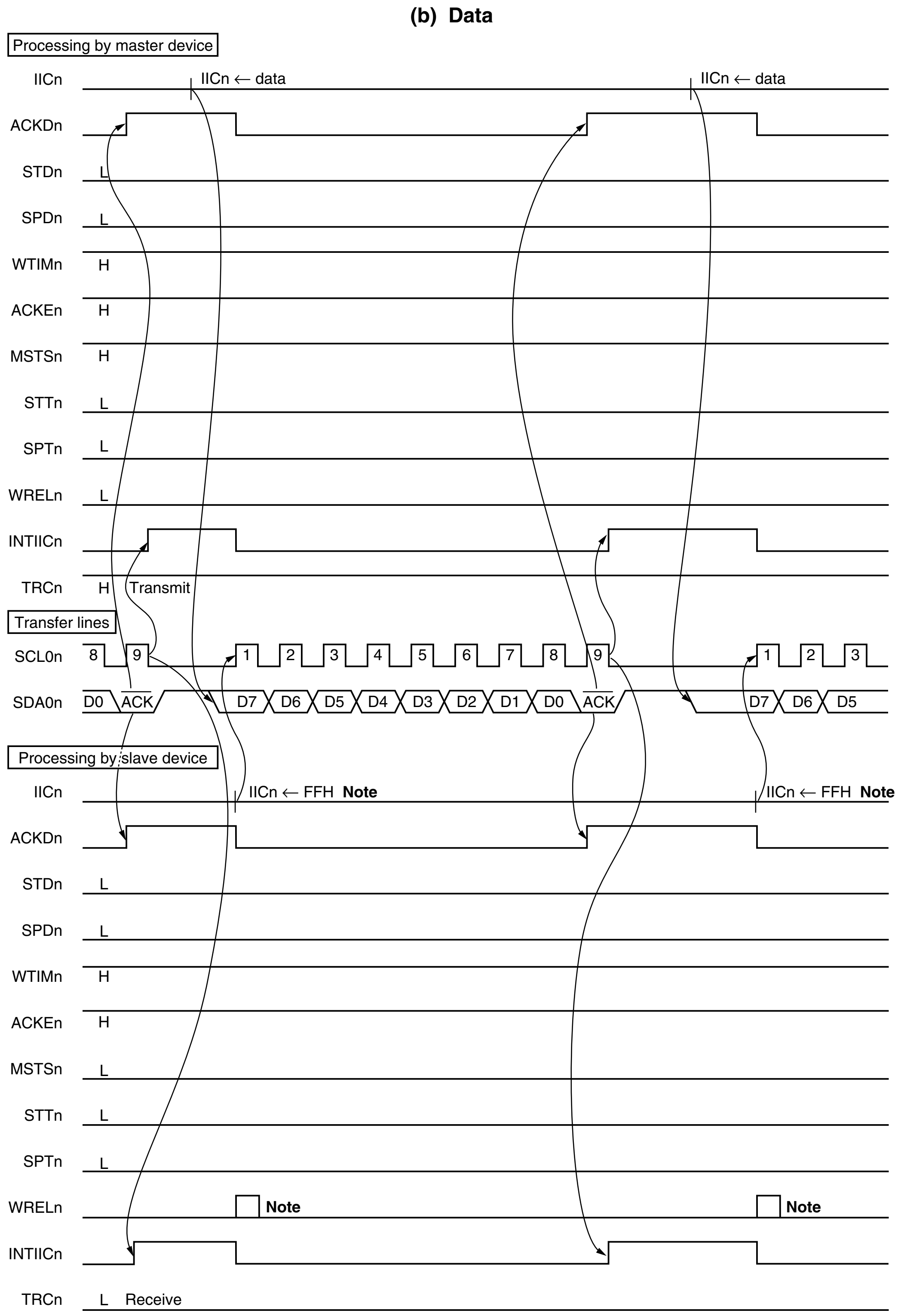
(a) Start condition ~ address



Note To cancel slave wait, write FFH to IICn or set WRELn.

Remark n = 0 to 2

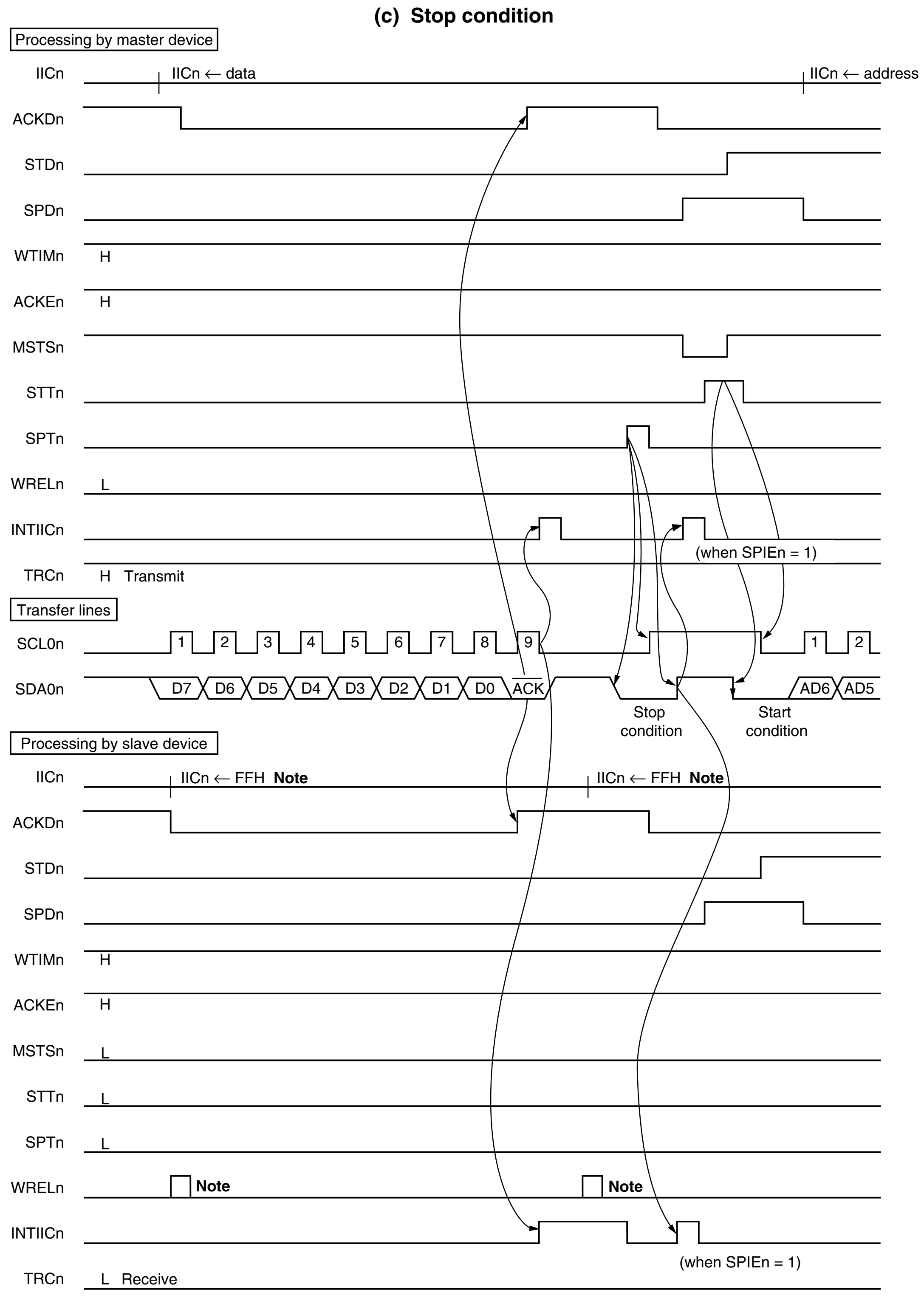
Figure 17-23. Example of Master to Slave Communication (When 9-Clock Wait Is Selected for Both Master and Slave) (2/3)



Note To cancel slave wait, write FFH to IICn or set WRELn.

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) (3/3)

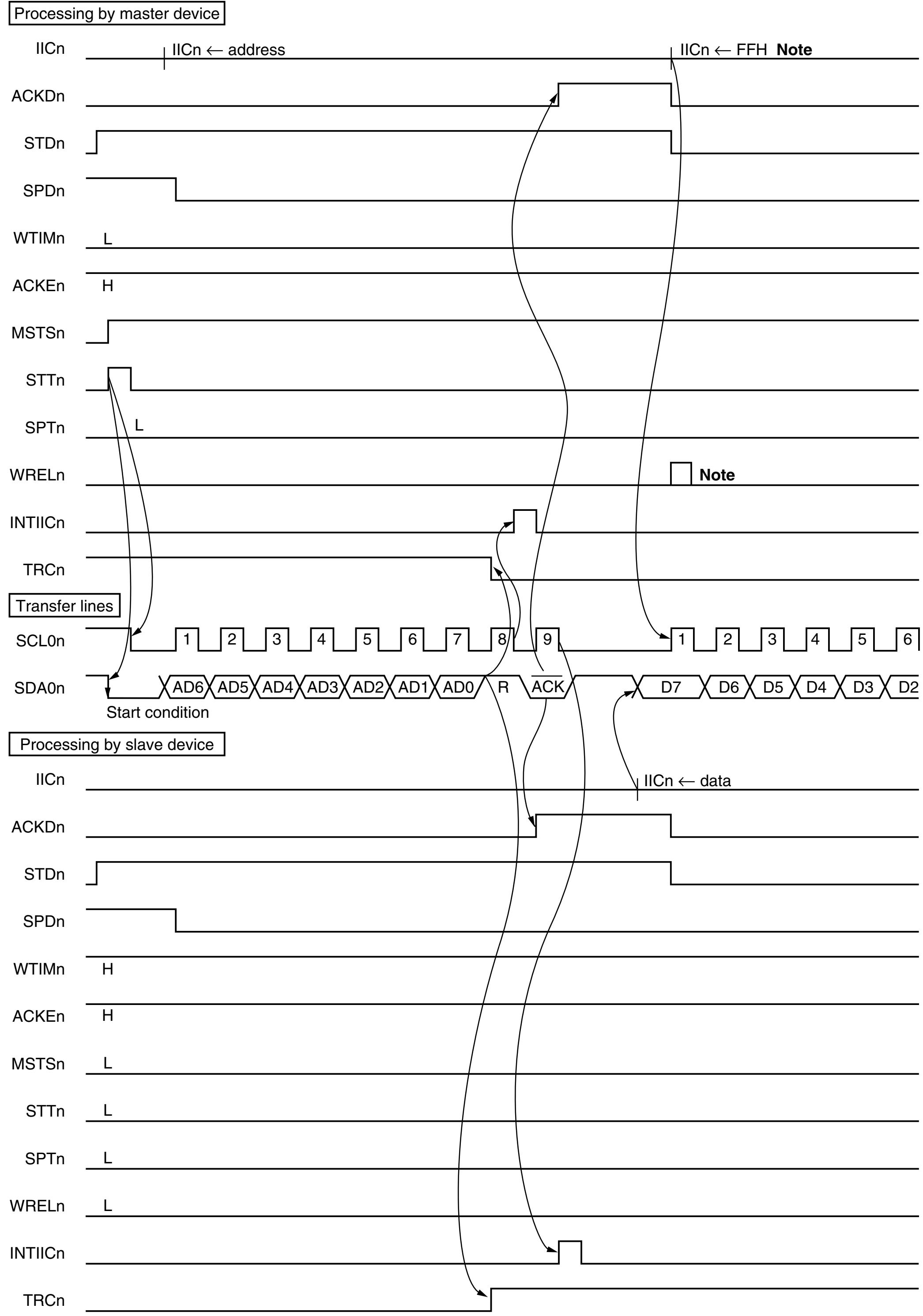


Note To cancel slave wait, write FFH to IICn or set WRELn.

Remark n = 0 to 2

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)

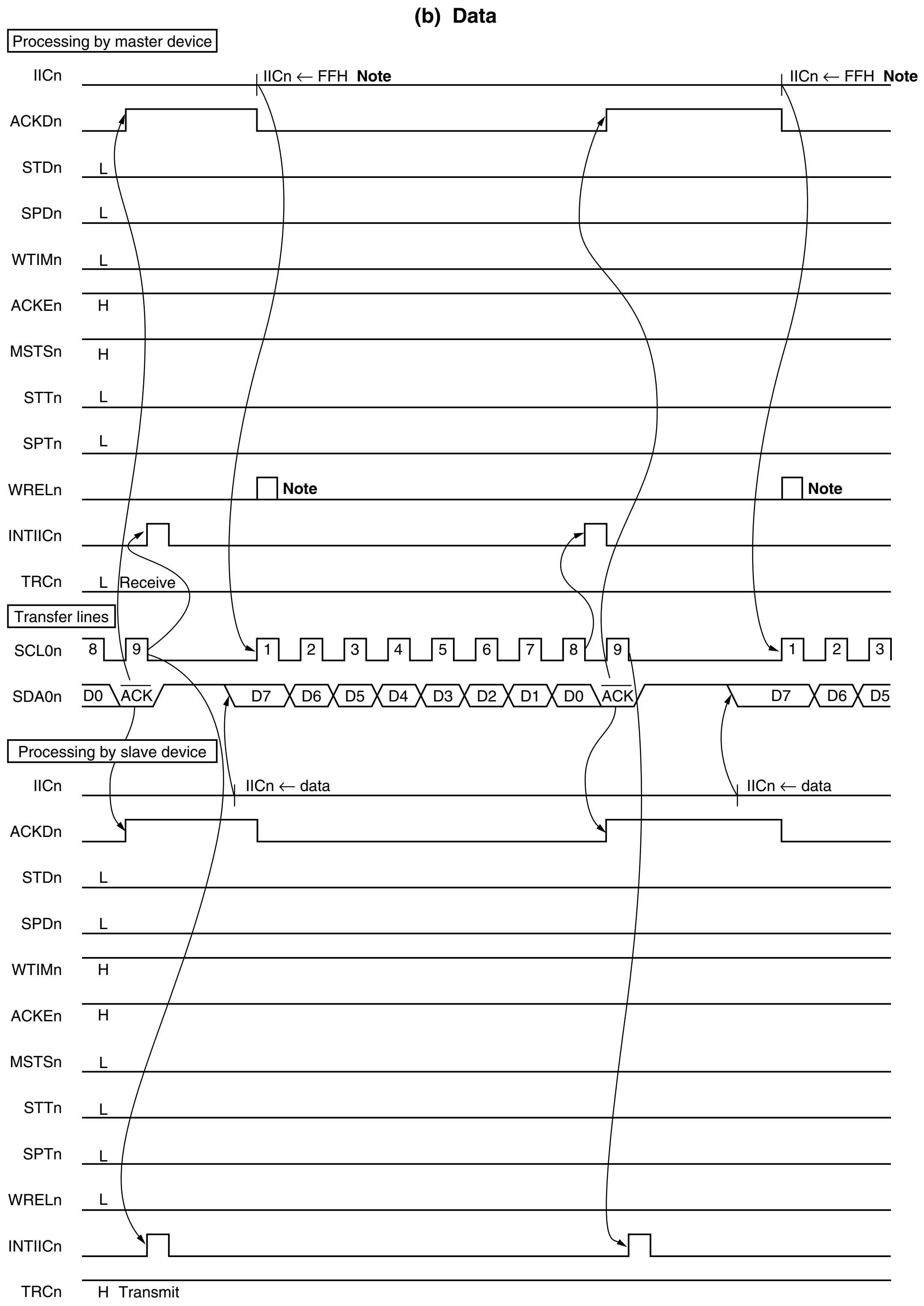
(a) Start condition ~ address



Note To cancel master wait, write FFH to IICn or set WRELn.

Remark n = 0 to 2

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)

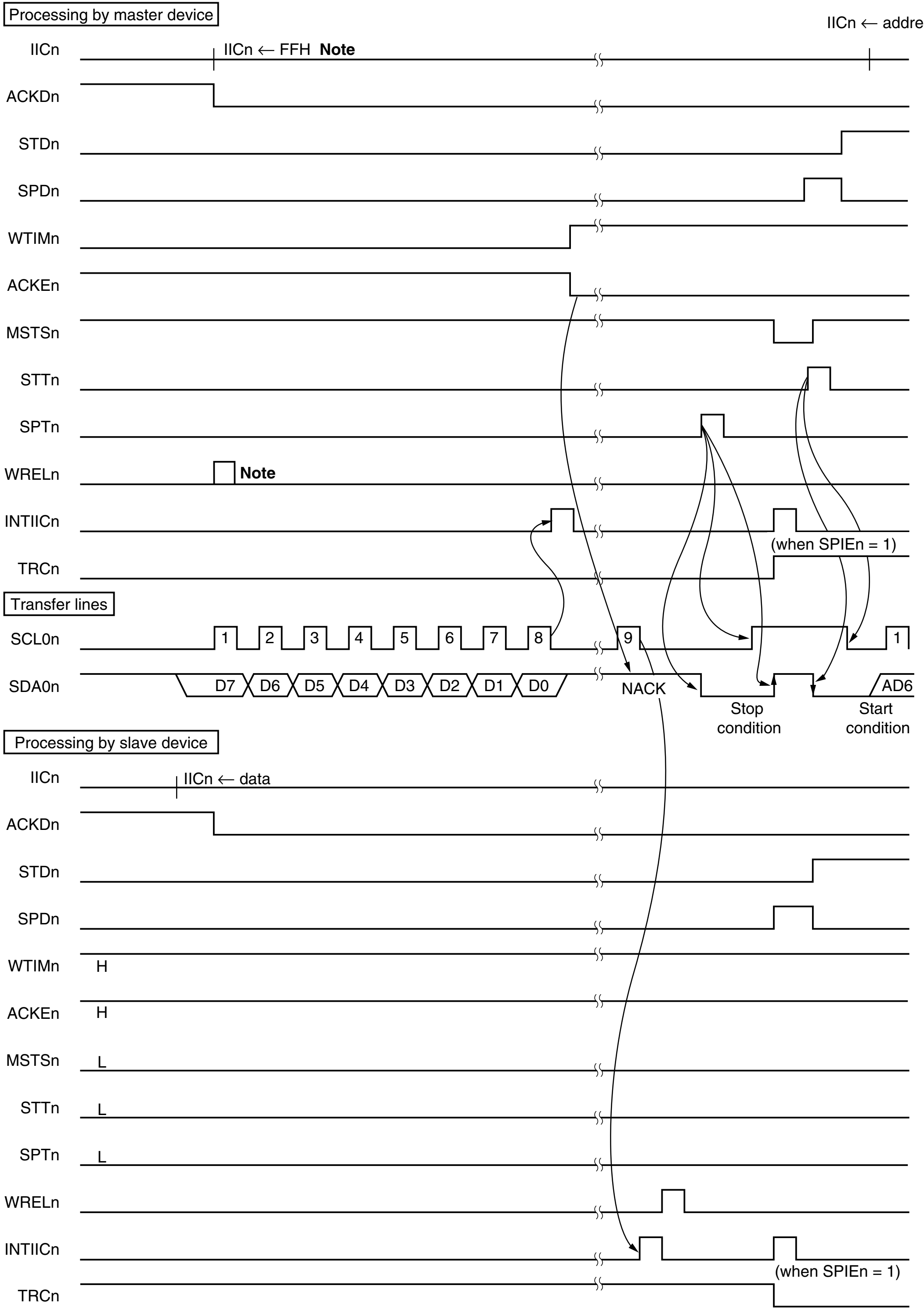


Note To cancel master wait, write FFH to IICn or set WRELn.

Remark n = 0 to 2

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)

(c) Stop condition



Note To cancel master wait, write FFH to IICn or set WRELn.

Remark n = 0 to 2

CHAPTER 18 DMA FUNCTION (DMA CONTROLLER)

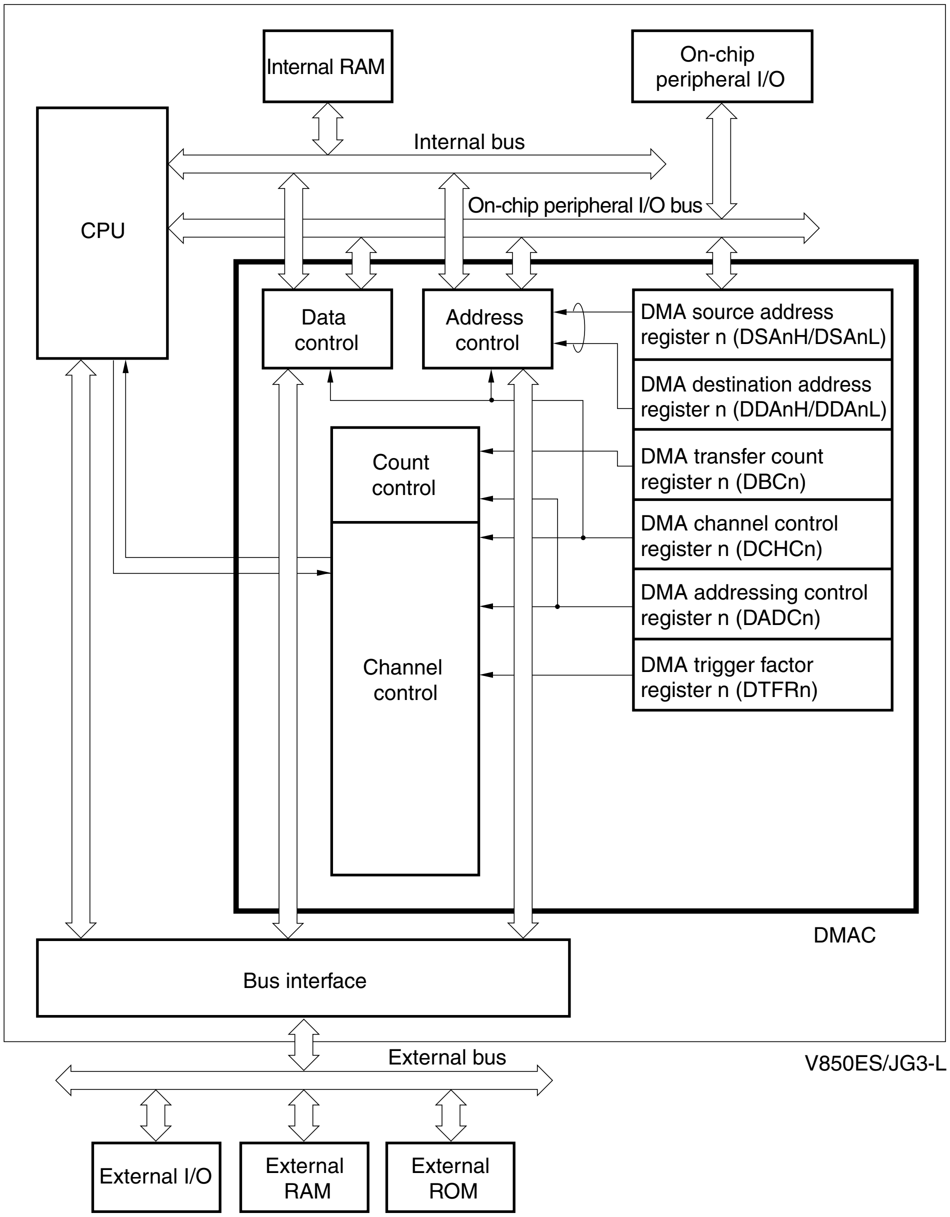
The V850ES/JG3-L includes a direct memory access (DMA) controller (DMAC) that executes and controls DMA transfer.

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



Remark n = 0 to 3

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, DSAnH and DSAnL.
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
DSAnH (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
DSAnL (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). During DMA transfer, the next DMA transfer source address is held. 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). During DMA transfer, the next DMA transfer source address is held. When DMA transfer is completed, the DMA address set first is held.

Cautions 1. Be sure to clear bits 14 to 10 of the DSAnH register to 0.

2. Set the DSAnH and DSAnL 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**

3. 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 18.13 Cautions).

4. 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.

(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

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DDAnH (n = 0 to 3)	IR	0	0	0	0	0	DA25	DA24	DA23	DA22	DA21	DA20	DA19	DA18	DA17	DA16

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DDAnL (n = 0 to 3)	DA15	DA14	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	DA5	DA4	DA3	DA2	DA1	DA0

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). 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). 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 1. Be sure to clear bits 14 to 10 of the DDAnH register to 0.

2. 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**

3. 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).

4. 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

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DBCn (n = 0 to 3)	BC15	BC14	BC13	BC12	BC11	BC10	BC9	BC8	BC7	BC6	BC5	BC4	BC3	BC2	BC1	BC0

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^{16}) 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 FFFFF0D0H, DADC1 FFFFF0D2H,
DADC2 FFFFF0D4H, DADC3 FFFFF0D6H

	15	14	13	12	11	10	9	8
DADCn (n = 0 to 3)	0	DS0	0	0	0	0	0	0

	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,
DCHC2 FFFFF0E4H, DCHC3 FFFFF0E6H

	<7>	6	5	4	3	<2>	<1>	<0>
DCHCn	TCn^Note 1^	0	0	0	0	INITn^Note 2^	STGn^Note 2^	Enn

(n = 0 to 3)

TCn^Note 1^	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^Note 2^	If the INITn bit is set to 1 with DMA transfer disabled (Enn bit = 0), the DMA transfer status can be initialized. 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. When initializing the DMA controller, however, be sure to observe the procedure described in **18.13 Cautions**.

STGn^Note 2^	This is a software startup trigger of DMA transfer. 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. When DMA transfer is completed (when a terminal count is generated), this bit is automatically cleared to 0. To abort DMA transfer, clear the Enn bit to 0 by software. To resume, set the Enn bit to 1 again. When aborting or resuming DMA transfer, however, be sure to observe the procedure described in **18.13 Cautions**.	

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, DFn 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
DTFRn	DFn	0	IFCn5	IFCn4	IFCn3	IFCn2	IFCn1	IFCn0

(n = 0 to 3)

DFn^{Note}	DMA transfer request status flag
0	No DMA transfer request
1	DMA transfer request

Note 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 IFCn5 to IFCn0 bits 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. 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).

3. 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.

Remark For the IFCn5 to IFCn0 bits, see **Table 18-1 DMA Start Factors**.

Table 18-1. DMA Start Factors

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
1	0	1	0	1	1	INTUA2T
1	0	1	1	0	0	INTAD
1	0	1	1	0	1	INTKR
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 "×" 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>) + 1Note 1 + Transfer destination memory access (<2>)

DMA Cycle		Minimum Number of Execution Clocks
<1> DMA request response time		4 clocks (MIN.) + Noise elimination timeNote 2
<2> Memory access	External memory access	Depends on connected memory.
	Internal RAM access	2 clocksNote 3
	Peripheral I/O register access	3 clocks + Number of wait cycles specified by VSWC registerNote 4

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 7).

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).

TCn bit = 0, Enn bit = 1
↓
STGn bit = 1 … Starts the first DMA transfer.
↓
Confirm that the contents of the DBCn register have been updated.
STGn bit = 1 … Starts the second DMA transfer.
↓
:
↓
Generation of terminal count … Enn bit = 0, TCn bit = 1, and INTDMAn signal is generated.

(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 1. 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.

2. 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).

3. 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

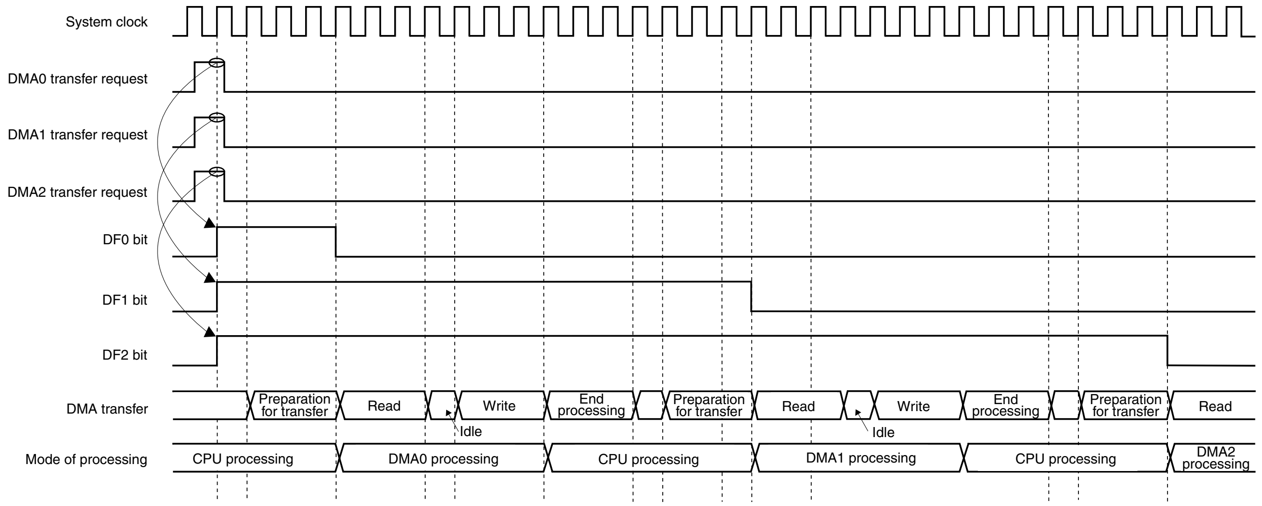
When DMA transfer has been completed the number of times set to the DBCn register and when the DCHCn.Enn bit is cleared to 0 and TCn bit is set to 1, a DMA transfer end interrupt request signal (INTDMAn) is generated for the interrupt controller (INTC) (n = 0 to 3).

The V850ES/JG3-L 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.

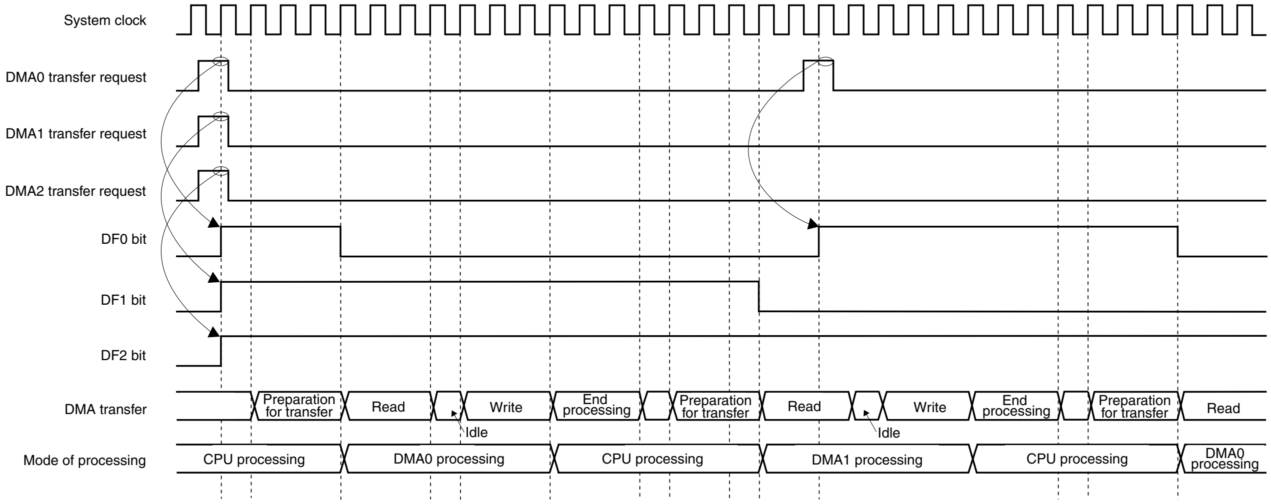
Figure 18-1. Priority of DMA (1)



Remarks 1. Transfer in the order of DMA0 → DMA1 → DMA2

2. In the case of transfer between external memory spaces (multiplexed bus, no wait)

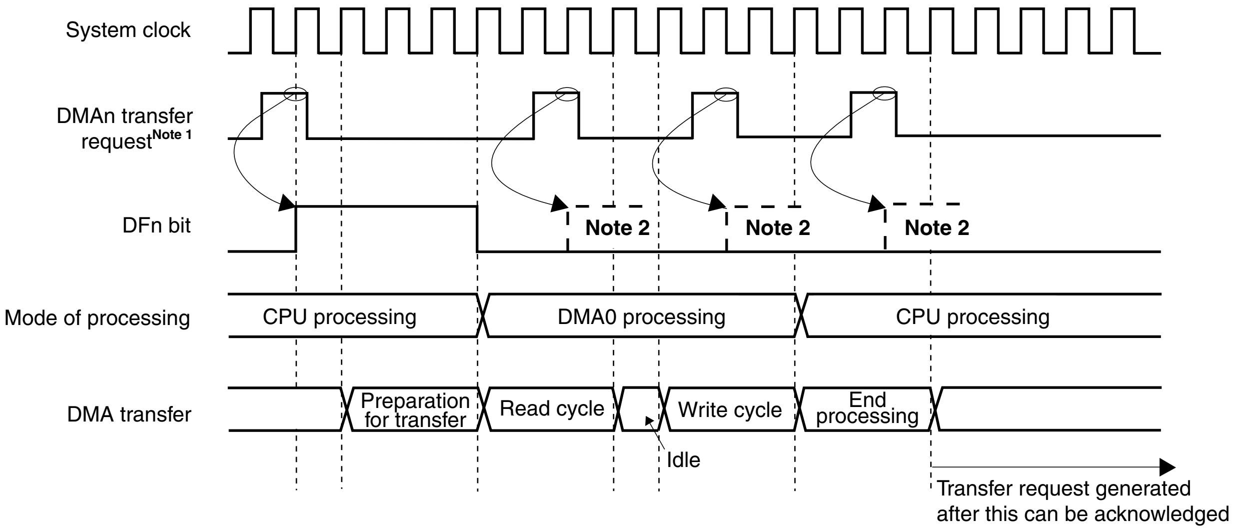
Figure 18-2. Priority of DMA (2)



Remarks 1. Transfer in the order of DMA0 → DMA1 → DMA0 (DMA2 is held pending.)

2. In the case of transfer between external memory spaces (multiplexed bus, no wait)

Figure 18-3. Period in Which DMA Transfer Request Is Ignored (1)

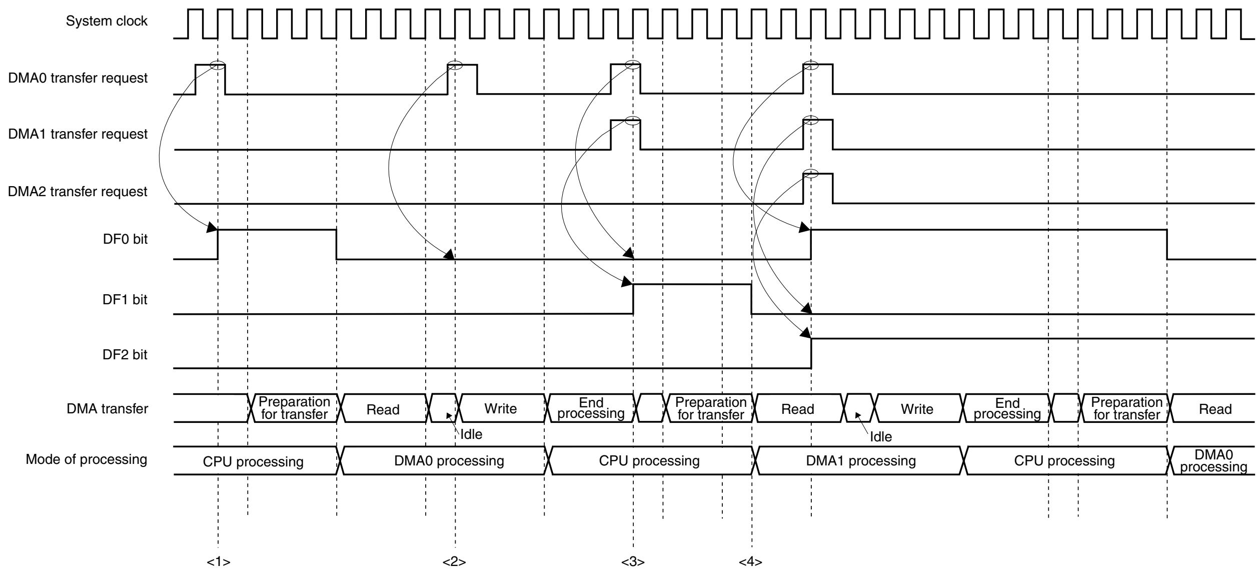


Notes 1. Interrupt from on-chip peripheral I/O, or software trigger (STGn bit)

2. New DMA request of the same channel is ignored between when the first request is generated and the end processing is complete.

Remark In the case of transfer between external memory spaces (multiplexed bus, no wait)

Figure 18-4. Period in Which DMA Transfer Request Is Ignored (2)



<1> DMA0 transfer request

<2> New DMA0 transfer request is generated during DMA0 transfer.

→ A DMA transfer request of the same channel is ignored during DMA transfer.

<3> Requests for DMA0 and DMA1 are generated at the same time.

→ DMA0 request is ignored (a DMA transfer request of the same channel during transfer is ignored).

→ DMA1 request is acknowledged.

<4> Requests for DMA0, DMA1, and DMA2 are generated at the same time.

→ DMA1 request is ignored (a DMA transfer request of the same channel during transfer is ignored).

→ DMA0 request is acknowledged according to priority. DMA2 request is held pending (transfer of DMA2 occurs next).

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 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.

(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 DCHCn.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 DCHC0.E00 bit to 0.
- Clear DCHC1.E11 bit to 0.
- Clear DCHC2.E22 bit to 0.
- Clear DCHC2.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 DCHCn 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 internal ROM and internal RAM to/from which DMA transfer is not being executed.

[Example]

- The CPU can access the internal ROM and internal RAM when DMA transfer is being executed between the external memory and on-chip peripheral I/O.
- The CPU can access the internal ROM when DMA transfer is being executed between the on-chip peripheral I/O and internal RAM.

(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/JG3-L is provided with a dedicated interrupt controller (INTC) for interrupt servicing and can process a total of 57 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/JG3-L 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: 8, Internal: 47 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)

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	$\overline{\text{RESET}}$ pin input Reset input 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	**Note 1**	–
Software exception	Exception	–	TRAP0n[Note 2]	TRAP instruction	–	004nH[Note 2]	00000040H	nextPC	–
		–	TRAP1n[Note 2]	TRAP instruction	–	005nH[Note 2]	00000050H	nextPC	–
Exception trap	Exception	–	ILGOP/ DBG0	Illegal opcode/ DBTRAP instruction	–	0060H	00000060H	nextPC	–
Maskable	Interrupt	0	INTLVI	Low voltage detection	POCLVI	0080H	00000080H	nextPC	LVIIC
		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

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	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
		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/ INTIIC1	CSIB0 reception completion/ CSIB0 reception error/ IIC1 transfer completion	CSIB0/ IIC1	0290H	00000290H	nextPC	CB0RIC/ IICIC1
		34	INTCB0T	CSIB0 consecutive transmission write enable	CSIB0	02A0H	000002A0H	nextPC	CB0TIC
		35	INTCB1R	CSIB1 reception completion/ CSIB1 reception error	CSIB1	02B0H	000002B0H	nextPC	CB1RIC
		36	INTCB1T	CSIB1 consecutive transmission write enable	CSIB1	02C0H	000002C0H	nextPC	CB1TIC
		37	INTCB2R	CSIB2 reception completion/ CSIB2 reception error	CSIB2	02D0H	000002D0H	nextPC	CB2RIC
		38	INTCB2T	CSIB2 consecutive transmission write enable	CSIB2	02E0H	000002E0H	nextPC	CB2TIC
		39	INTCB3R	CSIB3 reception completion/ CSIB3 reception error	CSIB3	02F0H	000002F0H	nextPC	CB3RIC
		40	INTCB3T	CSIB3 consecutive transmission write enable	CSIB3	0300H	00000300H	nextPC	CB3TIC
		41	INTUA0R/ INTCB4R	UARTA0 reception completion/ CSIB4 reception completion/ CSIB4 reception error	UARTA0/ CSIB4	0310H	00000310H	nextPC	UA0RIC/CB4RIC
		42	INTUA0T/ INTCB4T	UARTA0 consecutive transmission enable/CSIB4 consecutive transmission write enable	UARTA0/ CSIB4	0320H	00000320H	nextPC	UA0TIC/ CB4TIC
		43	INTUA1R/ INTIIC2	UARTA1 reception completion/ UARTA1 reception error/ IIC2 transfer completion	UARTA1/ IIC2	0330H	00000330H	nextPC	UA1RIC/ IICIC2
		44	INTUA1T	UARTA1 consecutive transmission enable	UARTA1	0340H	00000340H	nextPC	UA1TIC
		45	INTUA2R/ INTIIC0	UARTA2 reception completion/ IIC0 transfer completion	UARTA/ IIC0	0350H	00000350H	nextPC	UA2RIC/ IICIC0
		46	INTUA2T	UARTA2 consecutive transmission enable	UARTA2	0360H	00000360H	nextPC	UA2TIC
		47	INTAD	A/D conversion completion	A/D	0370H	00000370H	nextPC	ADIC

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	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

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)

(a) NMI and INTWDT2 request signals generated at the same time

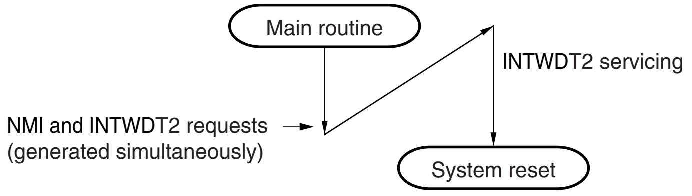
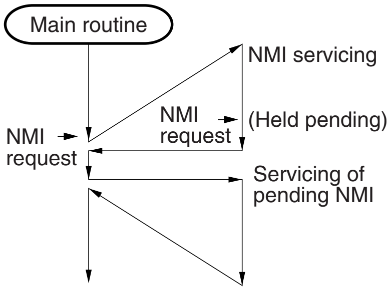
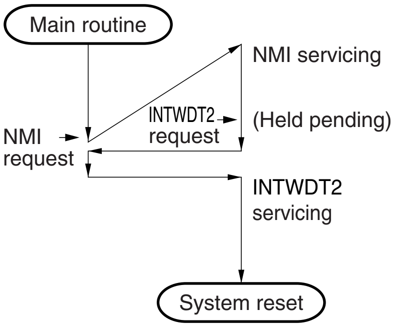
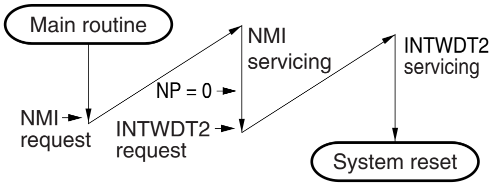
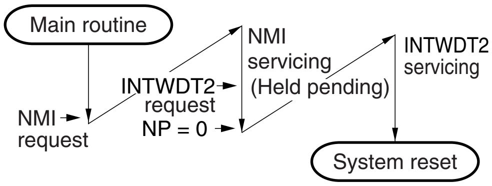
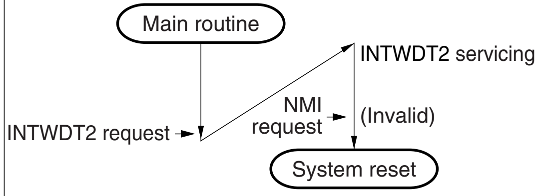
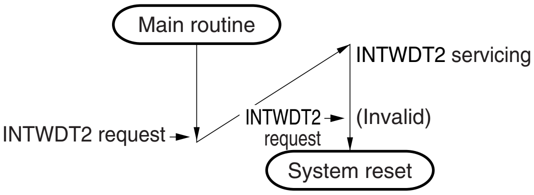


Figure 19-1. Non-Maskable Interrupt Request Signal Acknowledgment Operation (2/2)

(b) Non-maskable interrupt request signal generated during non-maskable interrupt servicing

Non-maskable interrupt being serviced	Non-maskable interrupt request signal generated during non-maskable interrupt servicing	
	NMI	INTWDT2
NMI	• NMI request generated during NMI servicing  	• INTWDT2 request generated during NMI servicing (NP bit = 1 retained before INTWDT2 request)  • INTWDT2 request generated during NMI servicing (NP bit = 0 set before INTWDT2 request)  • INTWDT2 request generated during NMI servicing (NP = 0 set after INTWDT2 request) 
INTWDT2	• NMI request generated during INTWDT2 servicing  	• INTWDT2 request generated during INTWDT2 servicing 

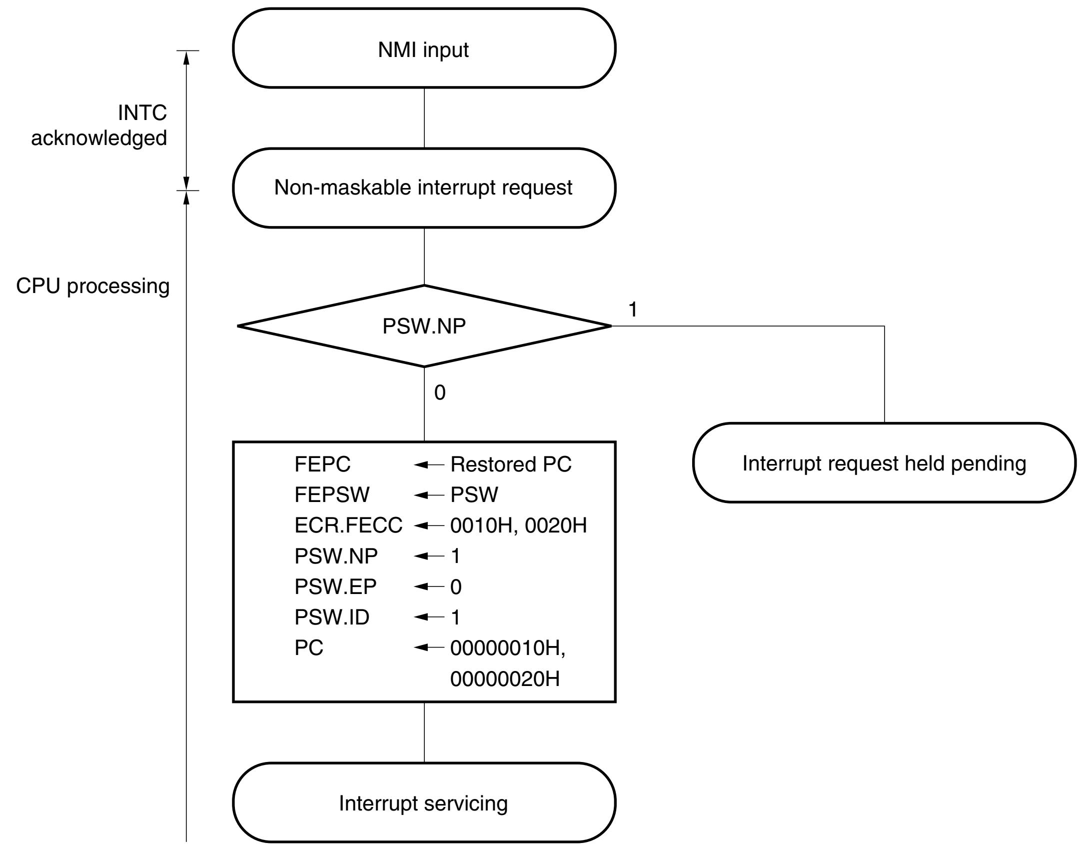
19.2.1 Operation

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.

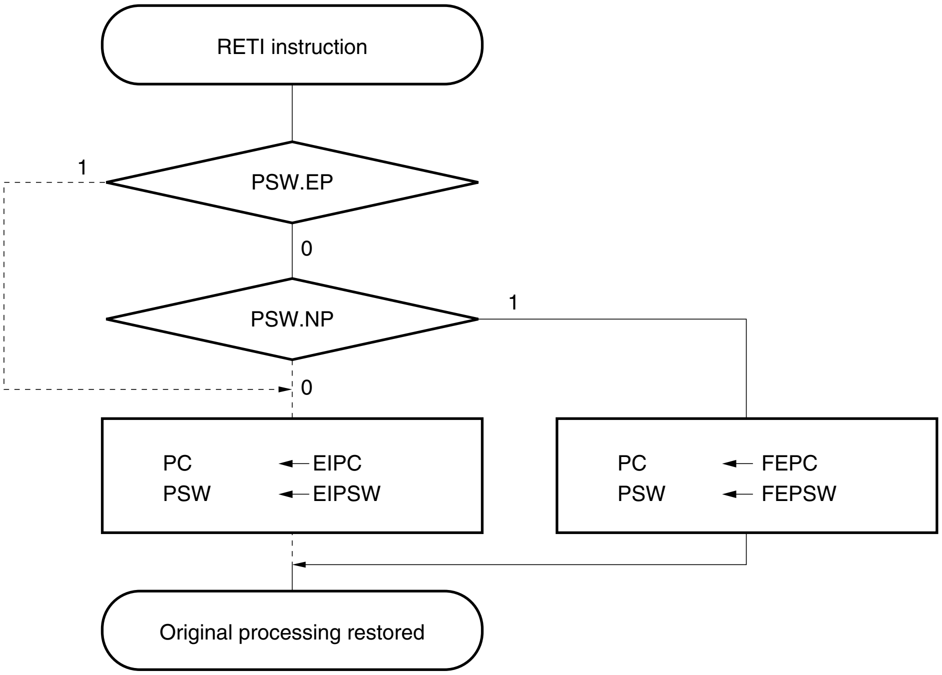
When the RETI instruction is executed, the CPU performs the following processing, and transfers control to the address of the restored PC.

<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



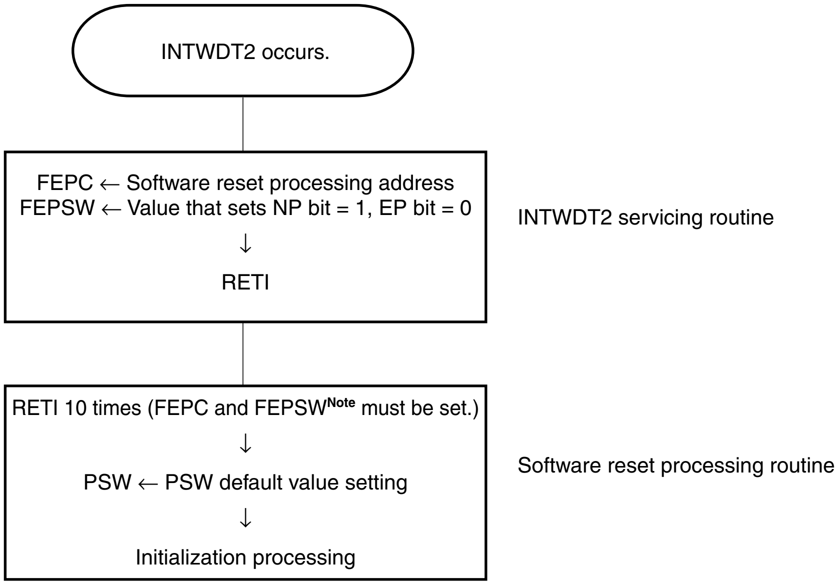
Caution When the EP and NP bits are changed by the LDSR instruction during non-maskable interrupt servicing, in order to restore the PC and PSW correctly during recovery by the RETI instruction, it is necessary to set the EP bit back to 0 and the NP bit back to 1 using the LDSR instruction immediately before the RETI instruction.

Remark The solid line shows the CPU processing flow.

(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



Note FEPSW ← Value that sets NP bit = 1, EP bit = 0

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.

After reset: 00000020H

	31 to 8	7	6	5	4	3	2	1	0
PSW	0	**NP**	EP	ID	SAT	CY	OV	S	Z

NP	NMI interrupt servicing status
0	No NMI interrupt servicing
1	NMI interrupt currently being serviced

19.3 Maskable Interrupts

Maskable interrupt request signals can be masked by interrupt control registers. The V850ES/JG3-L has 55 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

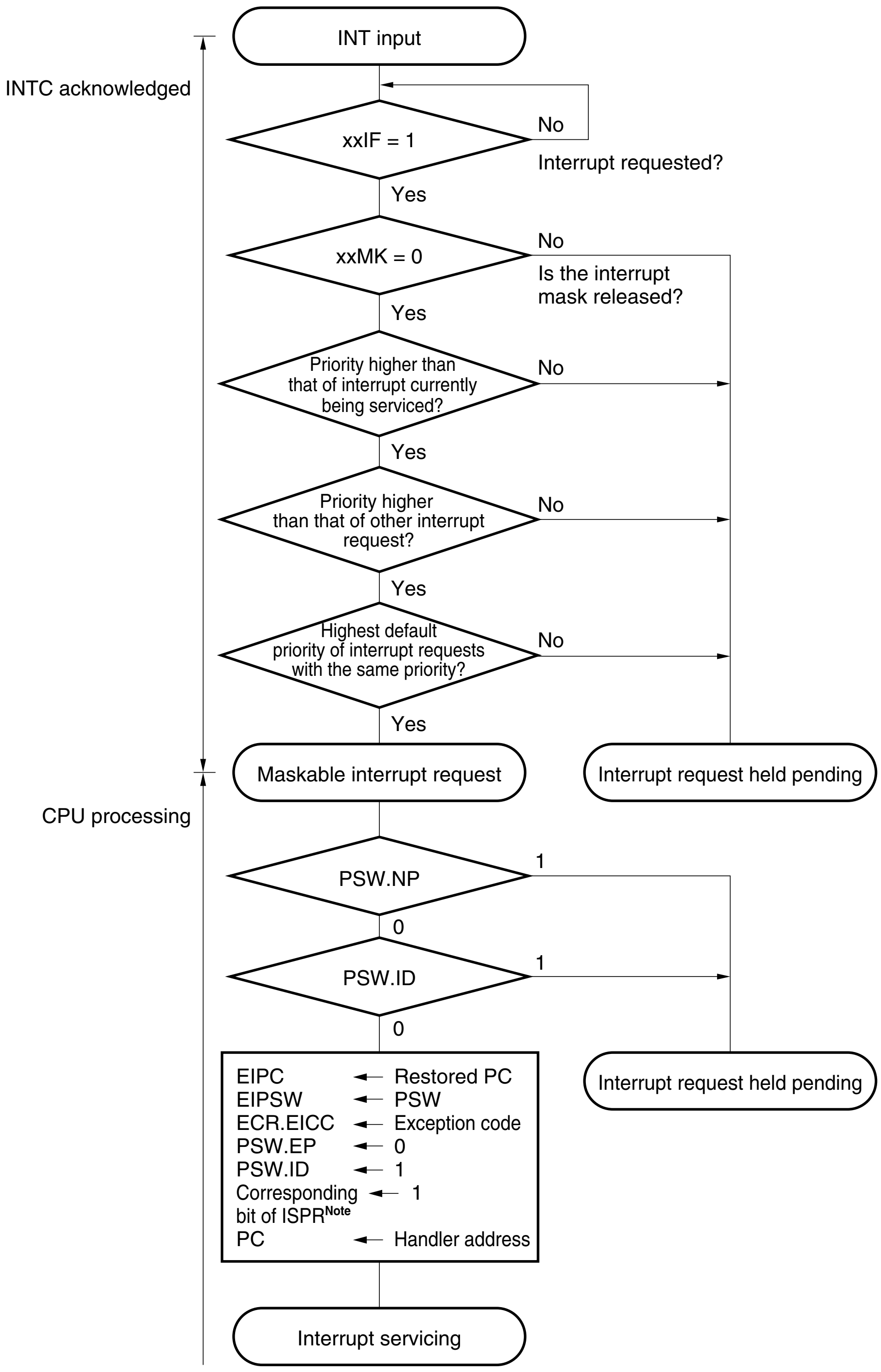
If a maskable interrupt occurs, the CPU performs the following processing, and transfers control to a handler routine.

<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



Note For the ISPR register, see **19.3.6 In-service priority register (ISPR)**.

19.3.2 Restore

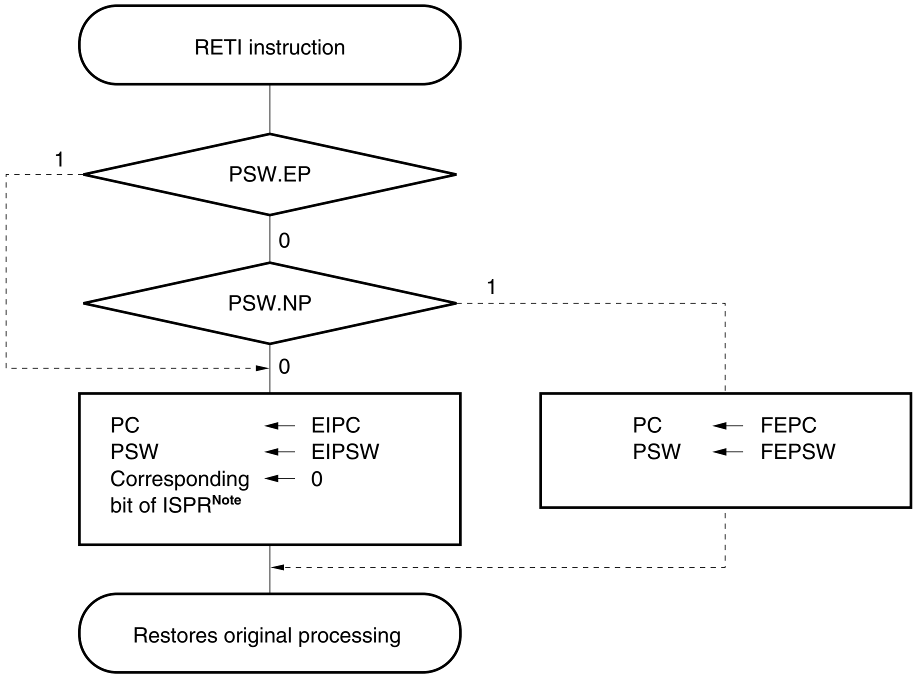
Recovery from maskable interrupt servicing is carried out by the RETI instruction.

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 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



Note For the ISPR register, see **19.3.6 In-service priority register (ISPR)**.

Caution 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.

Remark The solid line shows the CPU processing flow.

19.3.3 Priorities of maskable interrupts

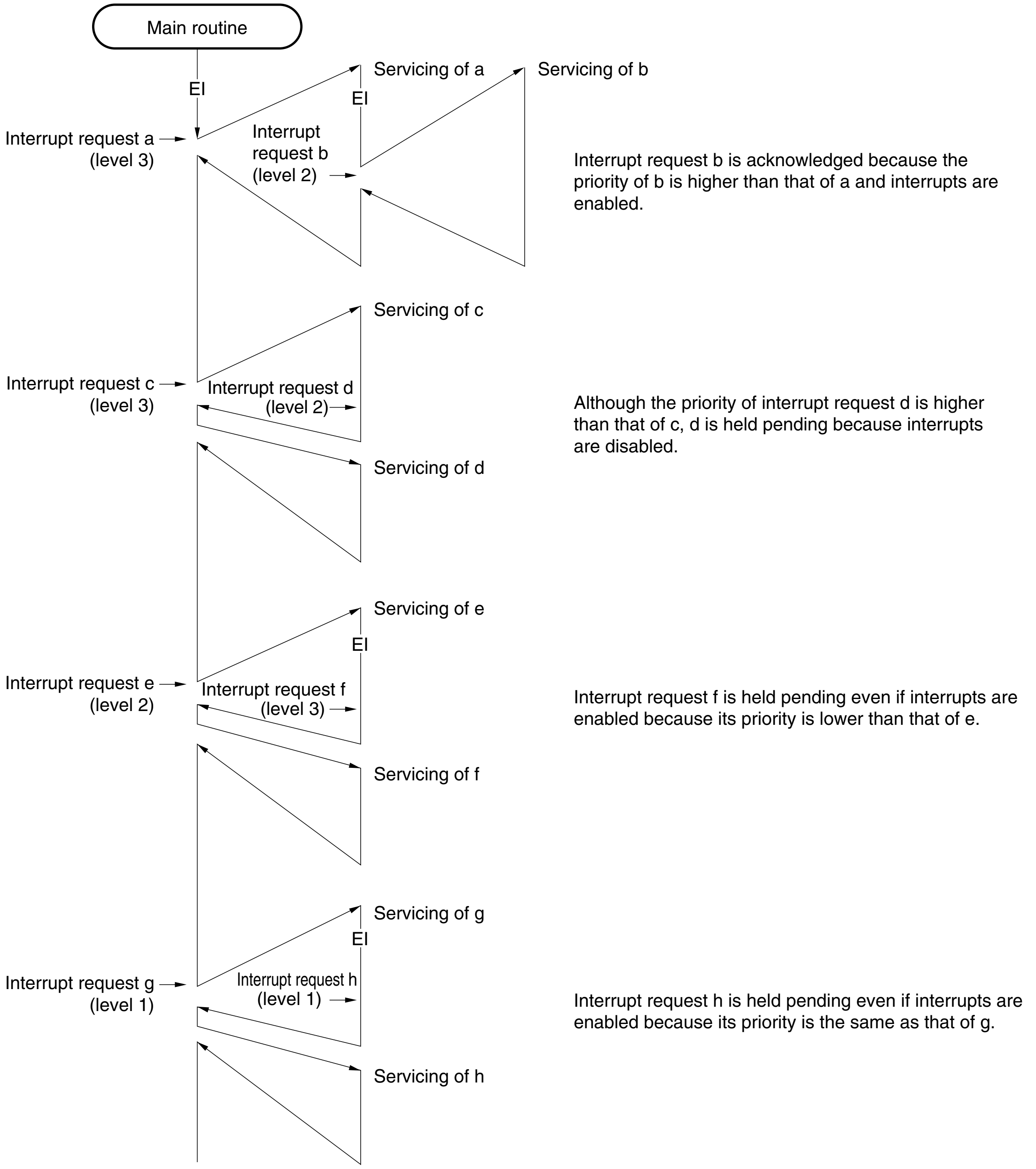
The INTC performs multiple interrupt servicing in which an interrupt is acknowledged while another interrupt is being serviced. Multiple interrupts can be controlled by priority levels.

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)

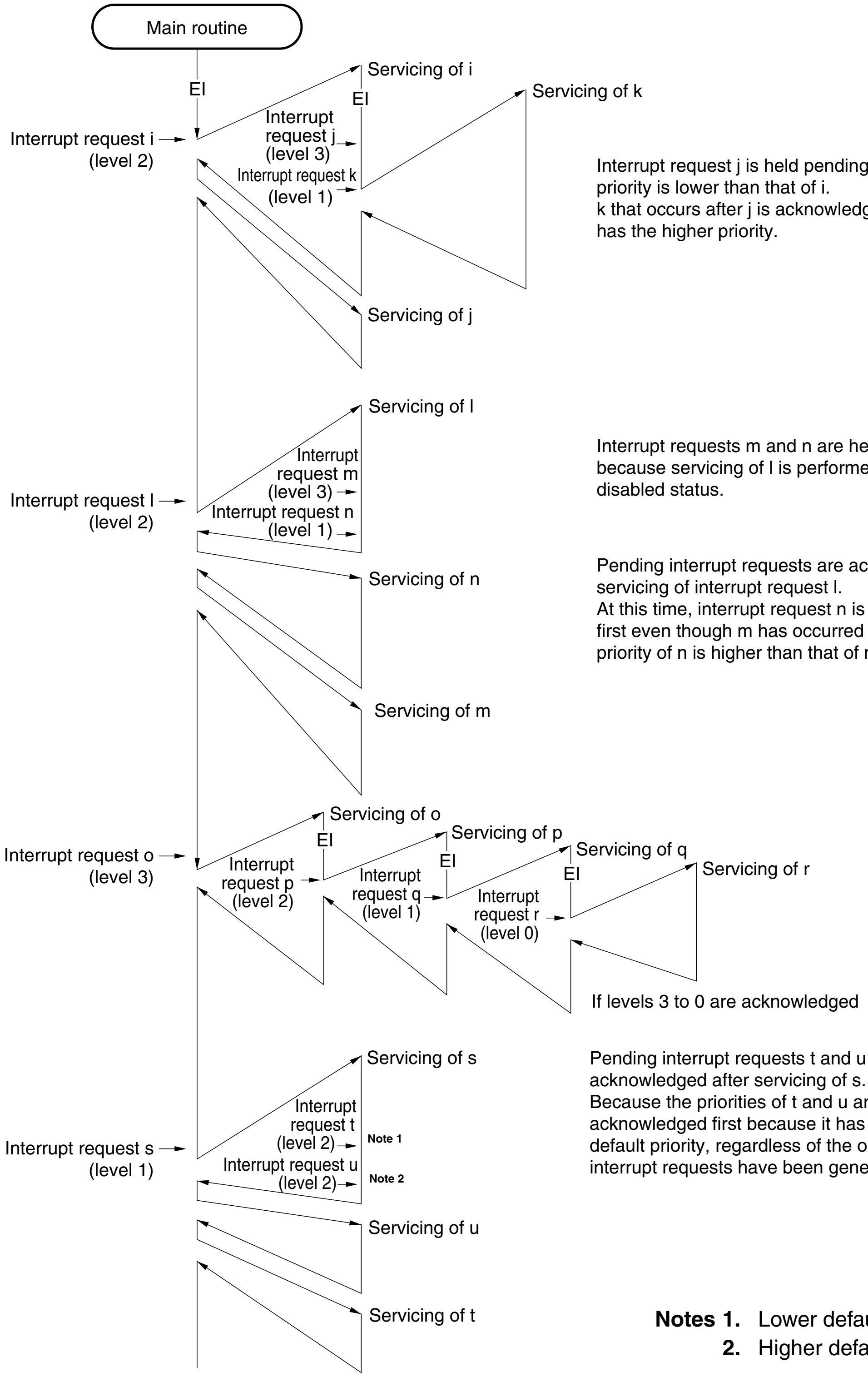


Caution **To perform multiple interrupt servicing, the values of the EIPC and EIPSW registers must be saved before executing the EI instruction. When returning from multiple interrupt servicing, restore the values of EIPC and EIPSW after executing the DI instruction.**

Remarks 1. a to u in the figure are the temporary names of interrupt request signals shown for the sake of explanation.

2. The default priority in the figure indicates the relative priority between two interrupt request signals.

Figure 19-7. Example of Processing in Which Another Interrupt Request Signal Is Issued While an Interrupt Is Being Serviced (2/2)



Interrupt request j is held pending because its priority is lower than that of i.
k that occurs after j is acknowledged because it has the higher priority.

Interrupt requests m and n are held pending because servicing of l is performed in the interrupt disabled status.

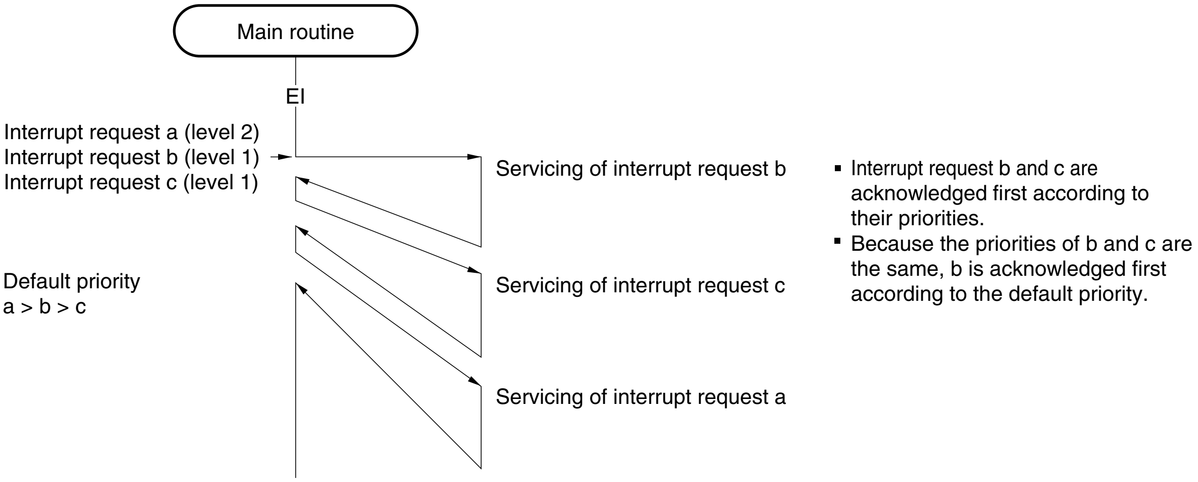
Pending interrupt requests are acknowledged after servicing of interrupt request l.
At this time, interrupt request n is acknowledged first even though m has occurred first because the priority of n is higher than that of m.

Pending interrupt requests t and u are acknowledged after servicing of s.
Because the priorities of t and u are the same, u is acknowledged first because it has the higher default priority, regardless of the order in which the interrupt requests have been generated.

Notes 1. Lower default priority
2. Higher default priority

Caution 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.

Figure 19-8. Example of Servicing Interrupt Request Signals Simultaneously Generated



Caution **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.**

Remarks **1.** a to c in the figure are the temporary names of interrupt request signals shown for the sake of explanation.

2. The default priority in the figure indicates the relative priority between two interrupt request signals.

19.3.4 Interrupt control register (xxICn)

The xxICn 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 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.

After reset: 47H R/W Address: FFFFF112H to FFFFF184H

	<7>	<6>	5	4	3	2	1	0
xxICn	xxIFn	xxMKn	0	0	0	xxPRn2	xxPRn1	xxPRn0

xxIFn	Interrupt request flag[Note]
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 (xxICn)**)
n: Peripheral unit number (see **Table 19-2 Interrupt Control Register (xxICn)**).

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	LVIIC	LVIIF	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/ IICIC1	CB0RIF/ IICIF1	CB0RMK/ IICMK1	0	0	0	CB0RPR2/ IICPR12	CB0RPR1/ IICPR11	CB0RPR0/ 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/ CB4RIC	UA0RIF/ CB4RIF	UA0RMK/ CB4RMK	0	0	0	UA0RPR2/ CB4RPR2	UA0RPR1/ CB4RPR1	UA0RPR0/ CB4RPR0
FFFFF164H	UA0TIC/ CB4TIC	UA0TIF/ CB4TIF	UA0TMK/ CB4TMK	0	0	0	UA0TPR2/ CB4TPR2	UA0TPR1/ CB4TPR1	UA0TPR0/ CB4TPR0
FFFFF166H	UA1RIC/ IICIC2	UA1RIF/ IICIF2	UA1RMK/ IICMK2	0	0	0	UA1RPR2/ IICPR22	UA1RPR1/ IICPR21	UA1RPR0/ IICPR20
FFFFF168H	UA1TIC	UA1TIF	UA1TMK	0	0	0	UA1TPR2	UA1TPR1	UA1TPR0
FFFFF16AH	UA2RIC/ IICIC0	UA2RIF/ IICIF0	UA2RMK/ IICMK0	0	0	0	UA2RPR2/ IICPR02	UA2RPR1/ IICPR01	UA2RPR0/ 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

19.3.5 Interrupt mask registers 0 to 3 (IMR0 to IMR3)

The IMR0 to IMR3 registers set the interrupt mask state for the maskable interrupts. The xxMKn bit of the IMR0 to IMR3 registers is equivalent to the xxICn.xxMKn bit.

The IMRm register can be read or written in 16-bit units (m = 0 to 3).

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 3).

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: IMR3 FFFFF106H,
IMR3L FFFFF106H, IMR3H FFFFF107H

	15	14	13	12	11	10	9	8
IMR3 (IMR3H[Note])	1	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[Note])	ADMK	UA2TMK	UA2RMK/ IICMK0	UA1TMK	UA1RMK/ IIC2MK	UA0TMK/ CB4TMK	UA0RMK/ CB4RMK	CB3TMK
	7	6	5	4	3	2	1	0
IMR2L	CB3RMK	CB2TMK	CB2RMK	CB1TMK	CB1RMK	CB0TMK	CB0RMK/ IICMK1	TM0EQMK0

After reset: FFFFH R/W Address: IMR1 FFFFF102H,
IMR1L FFFFF102H, IMR1H FFFFF103H

	15	14	13	12	11	10	9	8
IMR1 (IMR1H[Note])	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[Note])	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 IMR3 registers in 8-bit or 1-bit units, specify them as bits 0 to 7 of IMR0H to IMR3H registers.

Caution Set bits 7 to 15 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	**ID**	SAT	CY	OV	S	Z

ID	Specification of maskable interrupt servicing[Note]
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.

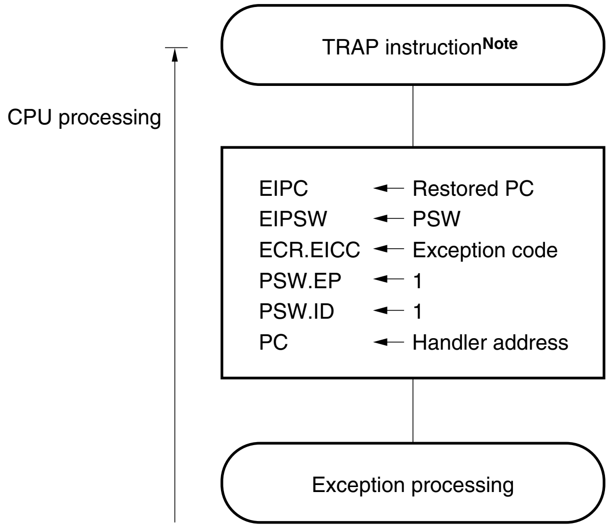
19.4.1 Operation

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



Note TRAP instruction format: TRAP vector (the vector is a value from 00H to 1FH.)

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

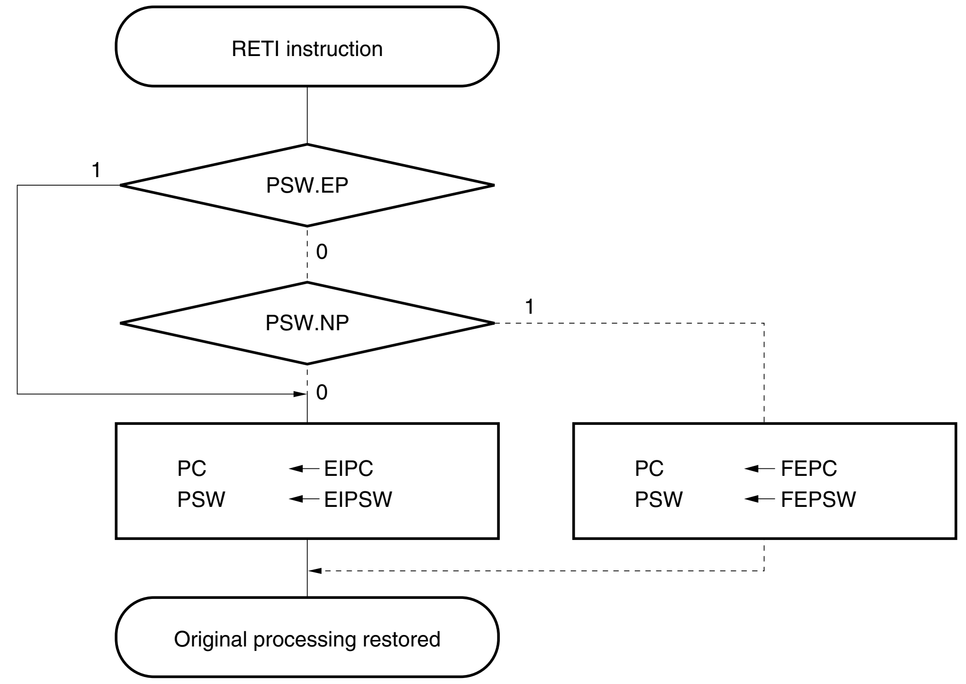
Restoration from software exception processing is carried out by the RETI instruction.

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



Caution **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.**

Remark The solid line shows the CPU processing flow.

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.

After reset: 00000020H

	31 8	7	6	5	4	3	2	1	0
PSW	0	NP	**EP**	ID	SAT	CY	OV	S	Z

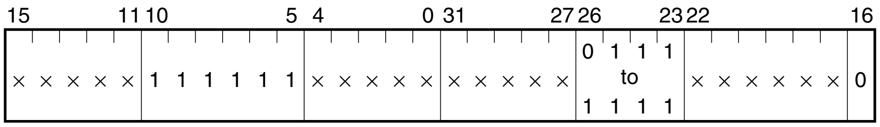
EP	Exception processing status
0	Exception processing not in progress.
1	Exception processing in progress.

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/JG3-L, an illegal opcode exception (ILGOP: Illegal Opcode Trap) is considered as an exception trap.

19.5.1 Illegal opcode

An illegal opcode is defined as an instruction with instruction opcode (bits 10 to 5) = 111111B, sub-opcode (bits 26 to 23) = 0111B to 1111B, and sub-opcode (bit 16) = 0B. When such an instruction is executed, an exception trap is generated.



×: Arbitrary

Caution It is recommended not to use an illegal opcode because instructions may newly be assigned in the future.

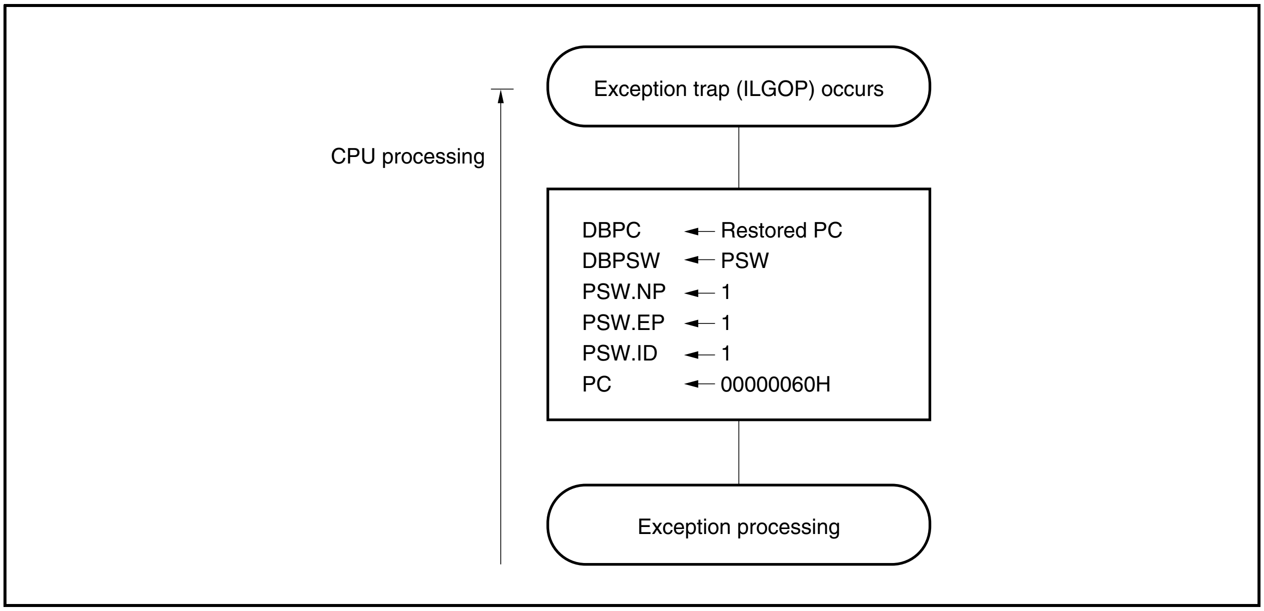
(1) Operation

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

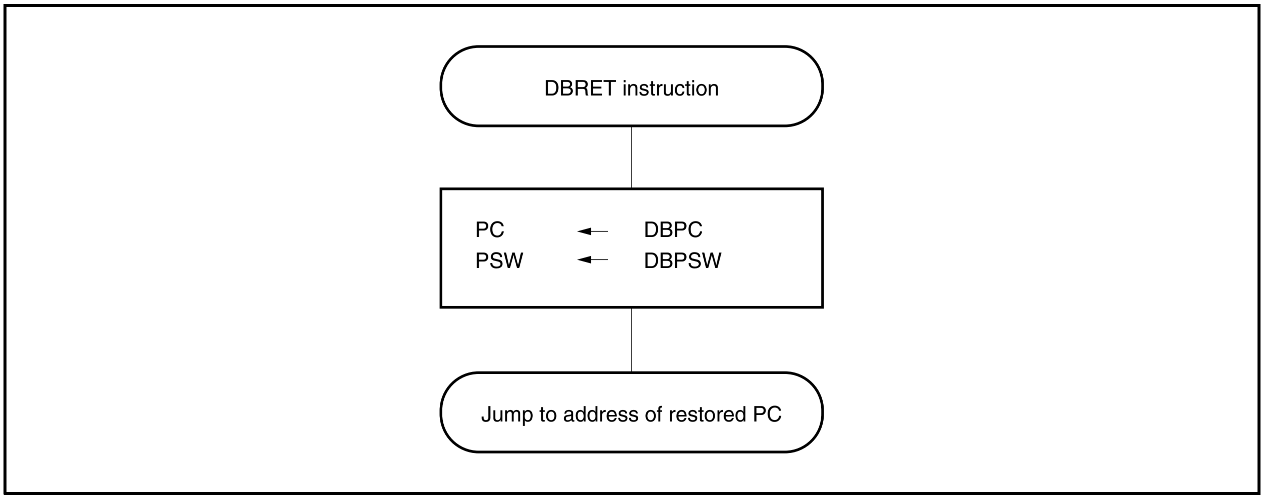
Restoration from an exception trap is carried out by the DBRET instruction. By executing the DBRET instruction, the CPU carries out the following processing and controls the address of the restored PC.

<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 DBRET instruction.

Processing for restoring from an exception trap is shown below.

Figure 19-12. Processing for Restoring 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.

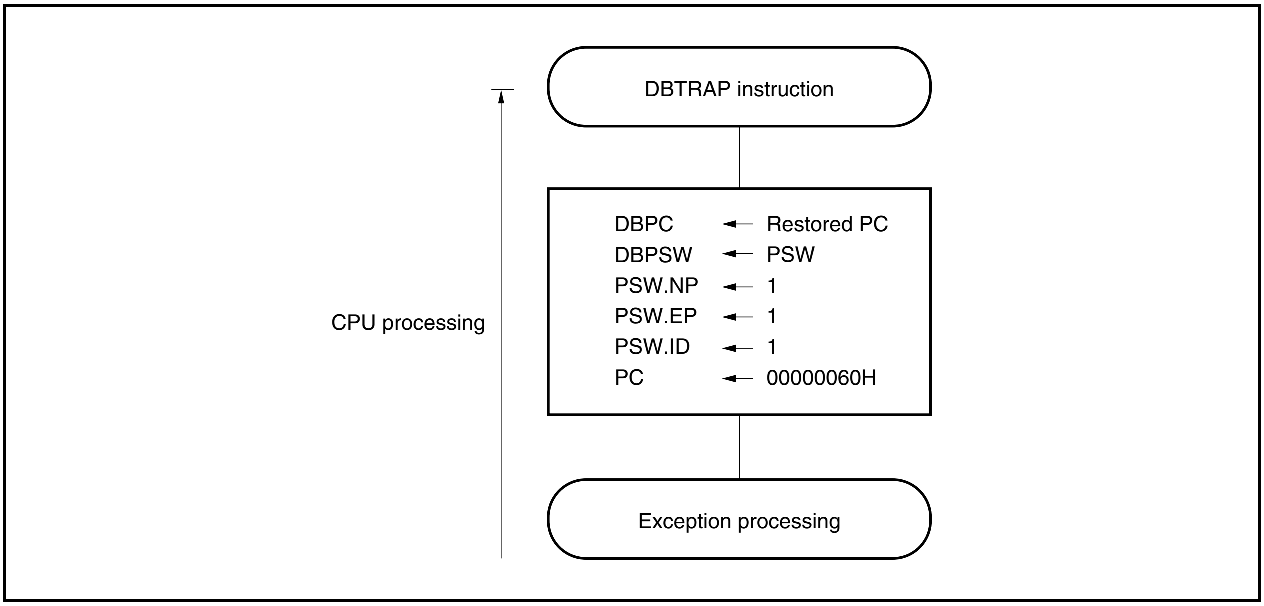
(1) Operation

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.

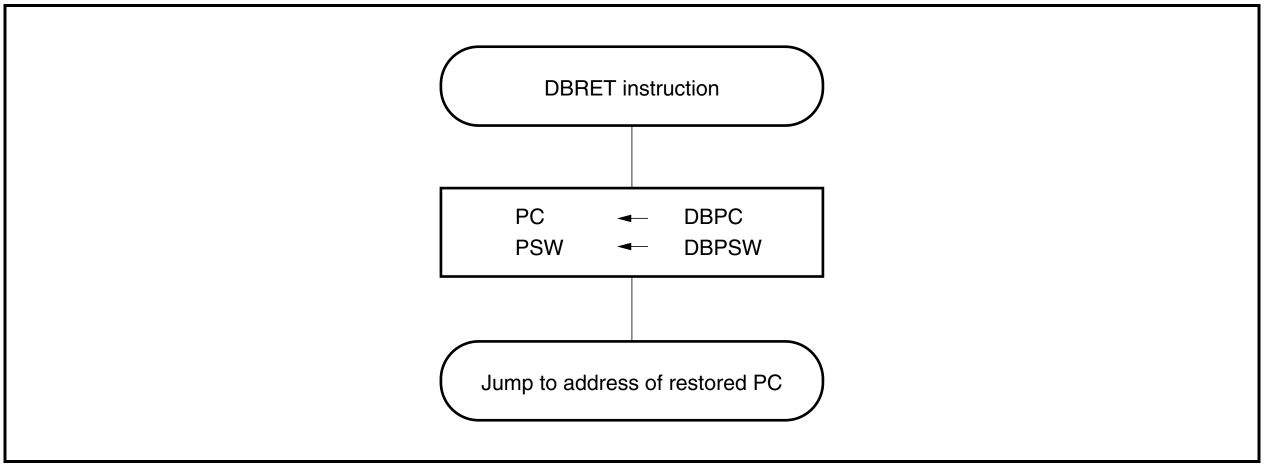
With the DBRET instruction, the CPU performs the following steps and transfers control to the address of the restored PC.

<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 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 INTP7)

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 INTP7 pins

The INTP0 to INTP7 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 INTP7 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.

After reset: 00H R/W Address: INTF0 FFFFFC00H, INTR0 FFFFFC20H

	7	6	5	4	3	2	1	0
INTF0	0	INTF06	INTF05	INTF04	INTF03	INTF02	0	0
		INTP3	INTP2	INTP1	INTP0	NMI		

	7	6	5	4	3	2	1	0
INTR0	0	INTR06	INTR05	INTR04	INTR03	INTR02	0	0
		INTP3	INTP2	INTP1	INTP0	NMI		

Remark For how to specify a valid edge, see **Table 19-3**.

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 INRT3.INTR31 bit to 0). When using the pin as the INTP7 pin, stop UARTA0 reception (clear the UA0CTL0.UA0RXE bit to 0).

After reset: 00H R/W Address: INTF3 FFFFFC06H, INTR3 FFFFFC26H

	7	6	5	4	3	2	1	0
INTF3	0	0	0	0	0	0	INTF31	0
							INTP7	

	7	6	5	4	3	2	1	0
INTR3	0	0	0	0	0	0	INTR31	0
							INTP7	

Remark For how to specify a valid edge, see **Table 19-4**.

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 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.

After reset: 00H R/W Address: INTF9H FFFFFC13H, INTR9H FFFFFC33H

	15	14	13	12	11	10	9	8
INTF9H	INTF915	INTF914	INTF913	0	0	0	0	0
	INTP6	INTP5	INTP4					

	15	14	13	12	11	10	9	8
INTR9H	INTR915	INTR914	INTR913	0	0	0	0	0
	INTP6	INTP5	INTP4					

Remark For how to specify a valid edge, see **Table 19-5**.

Table 19-5. 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

(4) 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 3 times.

Even when digital noise elimination is selected, using f_{XT} as the sampling clock makes it possible to use the INTP3 interrupt request signal to release the IDLE1, IDLE2, and STOP modes.

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 3 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.

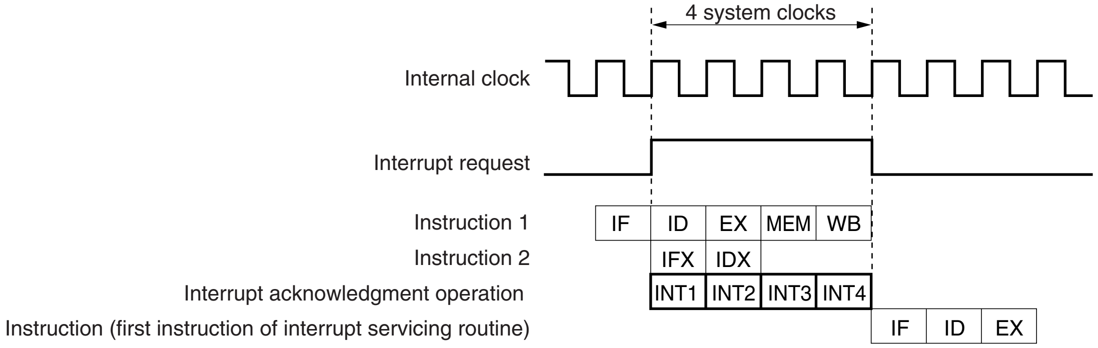
19.7 Interrupt Acknowledge Time of CPU

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.

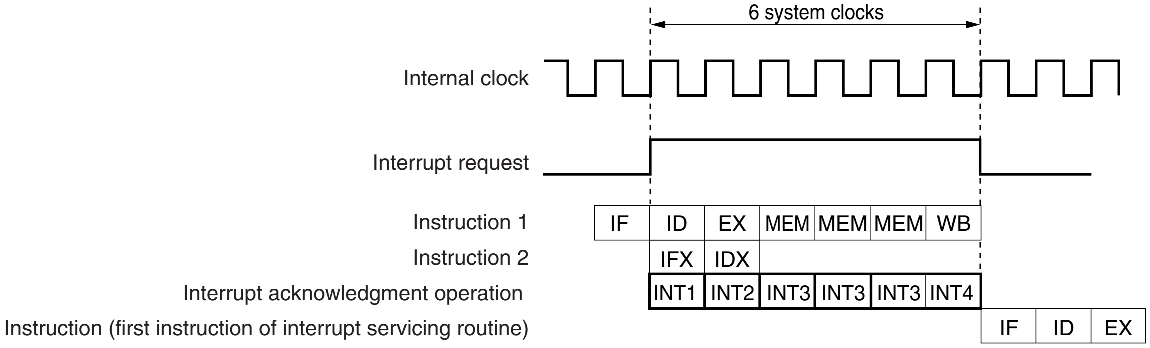
- In IDLE1/IDLE2/STOP mode
- When the external bus is accessed
- When interrupt request non-sampling instructions are successively executed (see **19.8 Periods in Which Interrupts Are Not Acknowledged by CPU**.)
- When the interrupt control register is accessed

Figure 19-15. Pipeline Operation at Interrupt Request Signal Acknowledgment (Outline)

(1) Minimum interrupt response time



(2) Maximum interrupt response time



Remark		
	INT1 to INT4:	Interrupt acknowledgment processing
	IFX:	Invalid instruction fetch
	IDX:	Invalid instruction decode

Interrupt acknowledge time (internal system clock)			Condition
	Internal interrupt	External interrupt	
Minimum	4	4 + Analog delay time	The following cases are exceptions. • In IDLE1/IDLE2/STOP mode • External bus access • Two or more interrupt request non-sample instructions are executed in succession • Access to peripheral I/O register
Maximum	6	6 + Analog delay time	

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 3 (IMR0 to IMR3)
  - 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 alternately functions as the P02 pin, and functions 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

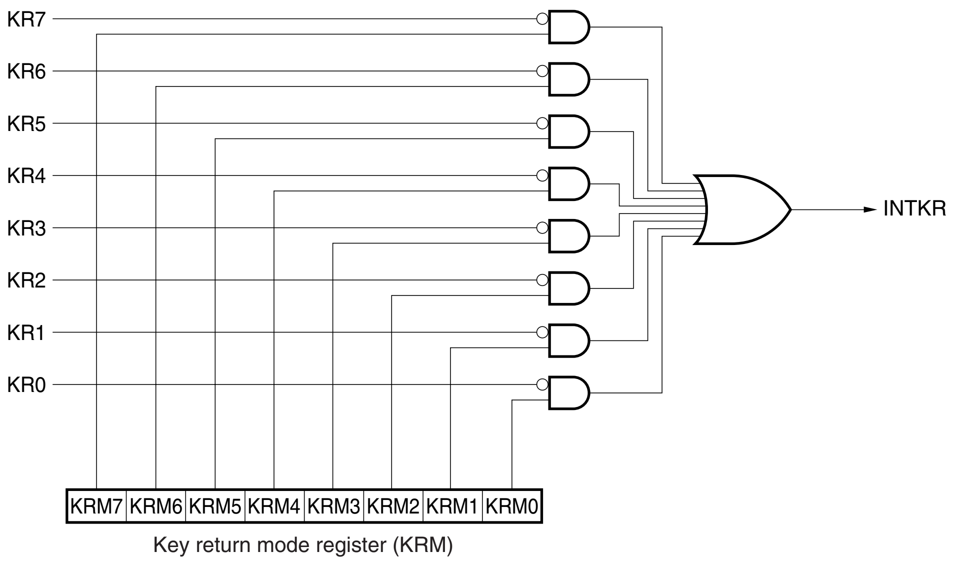
20.1 Function

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 4-15 Settings When Port Pins Are Used for Alternate Functions**.

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

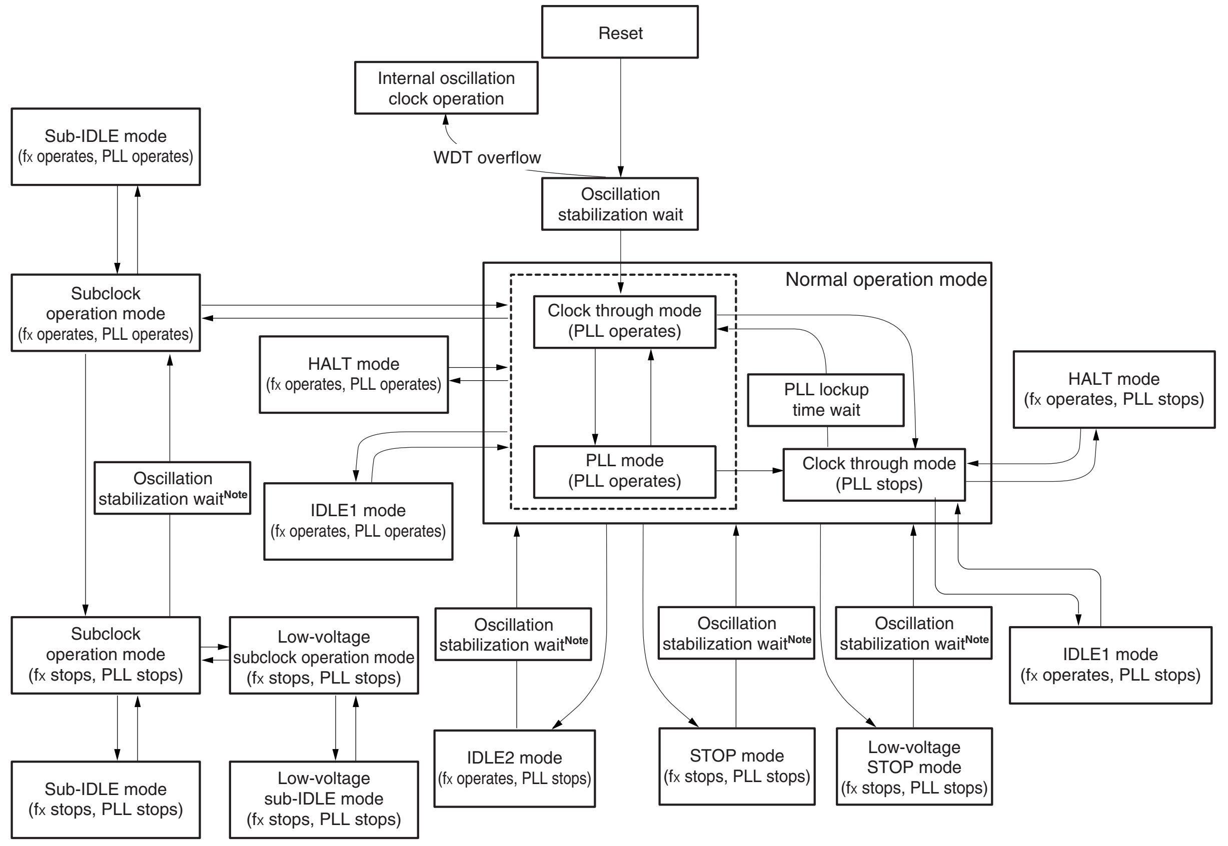
The power consumption of the system can be effectively reduced by using the standby modes in combination and selecting the appropriate mode for the application. The available standby modes are listed in Table 21-1.

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^{Note}, and flash memory are stopped
IDLE2 mode	Mode in which all the operations of the internal circuits except the oscillator are stopped
STOP mode	Mode in which all the operations of the internal circuits except the subclock oscillator are stopped. Two modes are available: STOP mode and low-voltage STOP mode.
Subclock operation mode	Mode in which the subclock is used as the internal system clock. Two modes are available: subclock operation mode and low-voltage subclock operation mode.
Sub-IDLE mode	Mode in which all the operations of the internal circuits except the oscillator, PLL operation^{Note}, and flash memory are stopped, in the subclock operation mode. Two modes are available: sub-IDLE mode and low-voltage sub-IDLE mode.

Note In the IDLE1 or sub-IDLE mode, the PLL retains the operating status immediately before mode transition. If the PLL operation is not necessary, stop the PLL to lower the power consumption. In the IDLE2 mode, mode transition causes the PLL to stop automatically.

Figure 21-1. Status Transition



Note If a WDT overflow occurs during an oscillation stabilization time, the CPU operates on the internal oscillation clock.

Remark fx: Main clock oscillation frequency

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	Standby mode release control upon occurrence of INTWDT2 signal
0	Standby mode release by INTWDT2 signal enabled
1	Standby mode release by INTWDT2 signal disabled

NMI0M	Standby mode release control by NMI pin input
0	Standby mode release by NMI pin input enabled
1	Standby mode release by NMI pin input disabled

INTM	Standby mode release control via maskable interrupt request signal
0	Standby mode release by maskable interrupt request signal enabled
1	Standby mode release by maskable interrupt request signal disabled

STP	Standby mode[Note] 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 mode
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 internal 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.

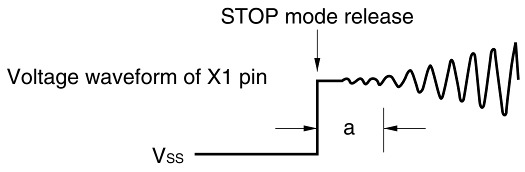
After reset: 06H R/W Address: FFFFF6C0H

	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[Note]		
				fx	
				4 MHz	5 MHz
0	0	0	2^{10}/fx	0.256 ms	0.205 ms
0	0	1	2^{11}/fx	0.512 ms	0.410 ms
0	1	0	2^{12}/fx	1.024 ms	0.819 ms
0	1	1	2^{13}/fx	2.048 ms	1.638 ms
1	0	0	2^{14}/fx	4.096 ms	3.277 ms
1	0	1	2^{15}/fx	8.192 ms	6.554 ms
1	1	0	2^{16}/fx	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 input 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 differs depending on the option byte. For details, see CHAPTER 27 OPTION BYTE.

Remark fx = Main clock oscillation frequency

(4) Regulator protection register (REGPR)

The REGPR register is used to protect the regulator output voltage level control register 0 (REGOVL0) so that illegal data is not written to REGOVL0. Data cannot be written to the REGOVL0 register unless enabling data (C9H) is written to the REGPR register. Only two types of data, C9H (enabling data) and 00H (protection data), can be written to the REGPR register. Writing any other value is prohibited. (If a value other than C9H or 00H is written to the REGPR register, the written value is set to prohibit a write access to the REGOVL0 register, but the operation is not guaranteed.)

This register can be read or written only in 8-bit units (accessing it in 1-bit units is prohibited).

Reset sets this register to 00H (protection data status).

After reset: 00H R/W Address: FFFFF331H

	7	6	5	4	3	2	1	0
REGPR	PR7	PR6	PR5	PR4	PR3	PR2	PR1	PR0

- **Protection data status: REGPR = 00H**

  In this status, the REGOVL0 register is protected from an illegal write access. In the protection data status, a value is not written to the REGOVL0 register even if an attempt is made to write it, and the REGOVL0 register holds the previous value.

  Be sure to set REGPR to 00H, except when changing the value of the REGOVL0 register, in order to avoid unexpected misoperation.

- **Enabling data status: REGPR = C9H**

  In this status, a write access to the REGOVL0 register is enabled.
  - Transition from normal mode → low-voltage STOP mode
    See **21.6.1 Setting and operation status.**
  - Transition of subclock operation mode → low-voltage subclock operation mode
    See **21.7.1 Setting and operation status.**
  - Transition of subclock operation mode → low-voltage sub-IDLE mode
    See **21.8.1 Setting and operation status.**

(5) Regulator output voltage level control register 0 (REGOVL0)

This register is used to select the low-voltage STOP mode, low-voltage subclock operation mode, or low-voltage sub-IDLE mode. The power consumption can be reduced by lowering the output voltage of the regulator.

This register can be read or written only in 8-bit units (accessing it in 1-bit units is prohibited).

Reset sets this register to 00H.

This register must be always written in pairs with the regulator protection register (REGPR).

After reset: 00H R/W Address: FFFFF332H

	7	6	5	4	3	2	1	0
REGOVL0	0	0	0	0	0	0	SUBMD	STPMD

SUBMD	Output mode selection of regulator in subclock operation mode/sub-IDLE mode
0	Subclock operation mode/sub-IDLE mode
1	Low-voltage subclock operation mode/low-voltage sub-IDLE mode

STPMD	Output mode selection of regulator in STOP mode
0	STOP mode
1	Low-voltage STOP mode

- **Write operation of REGOVL0 register**

  Writing the REGOVL0 register is enabled only when C9H is written to the REGPR register (see **21.2 (4) Regulator protection register (REGPR)**).

  This register can be set only to 00H, 01H, and 02H.

  Setting 03H is prohibited. If 03H is set, the operation is not guaranteed.

- **Read operation of REGOVL0 register**

  The default value of the REGOVL0 register is 00H. After a value has been written to this register in the correct procedure[Note], the written value is read. The procedure for reading this register is not restricted.

Note
- Transition from normal mode → low-voltage STOP mode
  See **21.6.1 Setting and operation status.**
- Transition of subclock operation mode → low-voltage subclock operation mode
  See **21.7.1 Setting and operation status.**
- Transition of subclock operation mode → low-voltage sub-IDLE mode
  See **21.8.1 Setting and operation status.**

Caution Be sure to stop the main clock and PLL when setting the low-voltage subclock mode and low-voltage sub-IDLE mode.

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 INTP7 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 or equal to 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 Item		Operating Status	
		When Subclock Is Not Used	When Subclock Is Used
LVI		Operable	
Main clock oscillator		Oscillates	
Subclock oscillator		–	Oscillates
Internal oscillator		Oscillation enabled	
PLL		Operable	
CPU		Stops operation	
DMA		Operable	
Interrupt controller		Operable	
Timer P (TMP0 to TMP5)		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 CSIB4	Operable	
	I^2C00 to I^2C02	Operable	
	UARTA0 to UARTA2	Operable	
A/D converter		Operable	
D/A converter		Operable	
Real-time output function (RTO)		Operable	
Key interrupt function (KR)		Operable	
CRC operation circuit		Operable (in the status in which data is not input to the CRCIN register to stop the CPU)	
External bus interface		See **2.2 Pin States**.	
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 INTP7 pin input), unmasked internal interrupt request signal from a peripheral function operable in the IDLE1 mode, or reset signal (reset by $\overline{\text{RESET}}$ 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 or equal to 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 Item		Operating Status	
		When Subclock Is Not Used	When Subclock Is Used
LVI		Operable	
Main clock oscillator		Oscillates	
Subclock oscillator		–	Oscillates
Internal oscillator		Oscillation enabled	
PLL		Operable	
CPU		Stops operation	
DMA		Stops operation	
Interrupt controller		Stops operation (but standby mode release enabled)	
Timer P (TMP0 to TMP5)		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 CSIB4	Operable when the $\overline{\text{SCKBn}}$ input clock is selected as the count clock (n = 0 to 4)	
	I^{2}C00 to I^{2}C02	Stops operation	
	UARTA0 to UARTA2	Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)	
A/D converter		Holds operation (conversion result held)[Note]	
D/A converter		Holds operation (output held [Note])	
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 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 INTP7 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 or equal to 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	
Item		When Subclock Is Not Used	When Subclock Is Used
LVI		Operable	
Main clock oscillator		Oscillates	
Subclock oscillator		–	Oscillates
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 TMP5)		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 CSIB4	Operable when the $\overline{\text{SCKBn}}$ input clock is selected as the count clock (n = 0 to 4)	
	I^{2}C00 to I^{2}C02	Stops operation	
	UARTA0 to UARTA2	Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)	
A/D converter		Holds operation (conversion result held)[Note]	
D/A converter		Holds operation (output held[Note])	
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.

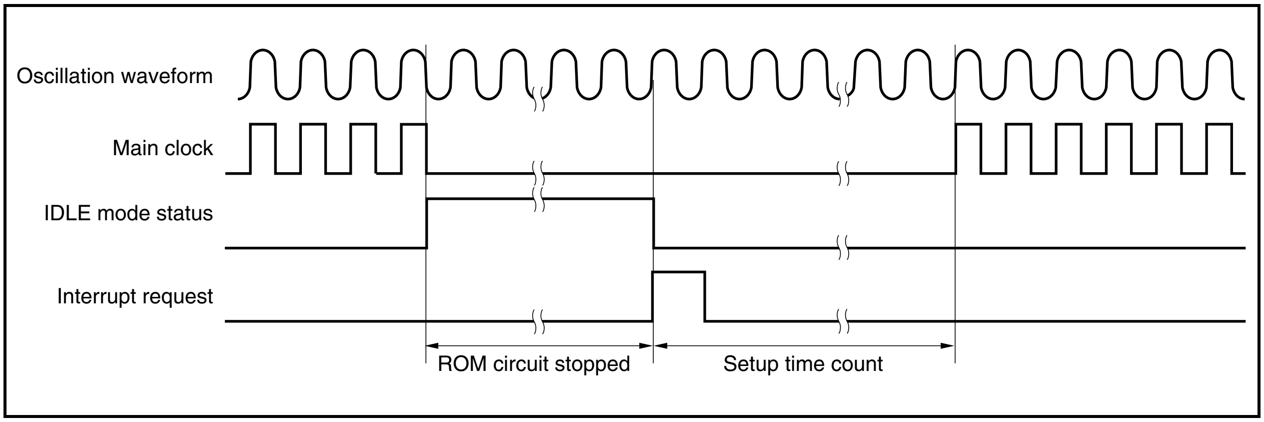
21.5.3 Securing setup time when releasing IDLE2 mode

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 differs depending on the option byte. For details, see **CHAPTER 27 OPTION BYTE**.

21.6 STOP Mode/Low-Voltage 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. The low-voltage 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 after setting the REGOVL0 register to 01H in 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. Clock supply to the CPU and the on-chip peripheral functions is stopped, but the subclock oscillator continues operating. In the STOP mode, CSIBn and UARTA0 that can operate with the external clock continue operating. In the low-voltage STOP mode, stop supply of the external clock to CSIBn and UARTA0 (n = 0 to 4).

Table 21-8 shows the operating status in the STOP mode and Table 21-9 shows the operating status in the low-voltage 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, low-voltage detector (LVI), and external clock are not used, the power consumption can be minimized with only leakage current flowing.

The power consumption decreases further in the low-voltage STOP mode because the voltage of the regulator is lowered.

Be sure to set the low-voltage STOP mode in the following procedure.

(1) Procedure for setting “normal mode” → “low-voltage STOP mode”

Make the following setting in the normal operation mode (while the main clock is operating).

<1> Stop the functions that are specified to be stopped in **Table 21-9 Operating Status in Low-Voltage STOP Mode**.

Be especially sure to stop the following functions, because they are signals from external sources.

- Stop the $\overline{\text{SCKBn}}$ input clock when the $\overline{\text{SCKBn}}$ input clock to CSIBn is selected (n = 0 to 4).
- Stop the ASCKA0 input clock when the ASCKA0 input clock to UARTA0 is selected.

<2> Disable the DMA operation.

<3>
- Disable the maskable interrupt by the DI instruction.
- Disable the NMI interrupt (INTF02 = 0, INTR02 = 0).
- Create a status in which the INTWDT2 signal is not generated (stop watchdog timer 2 or set a mode other than the INTWDT2 mode. Create a status in which the INTWDT2 signal is not generated immediately after watchdog timer 2 has been cleared).

<4> Write C9H (enabling data) to the REGPR register.

<5> Write 01H to the REGOVL0 register.

At this time, the output voltage of the regulator is at the normal level.

<6> Write 00H (protection data) to the REGPR register.

<7> As necessary, enable the maskable interrupt, NMI interrupt, or INTWDT2 interrupt by the EI instruction (restore the settings <2> and <3>, above).

<8> Set the STOP mode.

PSMR.PSM1, PSMR.PSM0 bits = 01 or 11
PSC.STP bit = 1

In the STOP mode, the output voltage of the regulator drops, decreasing the current consumption to an extremely low level.

Be sure to observe the above sequence.
Note, however, that step <7> may be performed at any time as long as it is done after step <6>. (The setting in step <7> may be made without problem, even after the low-voltage STOP mode has been released.)

Cautions 1, Insert five or more NOP instructions after the instruction that stores data in the PSC register to set the STOP mode/low-voltage STOP mode.

2. If the STOP mode/low-voltage STOP mode is set while an unmasked interrupt request signal is being held pending, the STOP mode/low-voltage STOP mode is released immediately by the pending interrupt request.

Table 21-8. Operating Status in STOP Mode

Setting of STOP Mode Item		Operating Status	
		When Subclock Is Not Used	When Subclock Is Used
LVI		Operable	
Main clock oscillator		Stops oscillation	
Subclock oscillator		–	Oscillates
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 TMP5)		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 CSIB4	Operable when the $\overline{\text{SCKBn}}$ input clock is selected as the count clock (n = 0 to 4)	
	I^{2}C00 to I^{2}C02	Stops operation	
	UARTA0 to UARTA2	Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)	
A/D converter		Stops operation (conversion result undefined)Notes 1, 2	
D/A converter		Stops operationNotes 3, 4 (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 **2.2 Pin States**.	
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.

Table 21-9. Operating Status in Low-Voltage STOP Mode

Setting of Low-Voltage STOP Mode / Item		Operating Status	
		When Subclock Is Not Used	When Subclock Is Used
LVI		Operable	
Main clock oscillator		Stops oscillation	
Subclock oscillator		–	Oscillates
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 TMP5)		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 $f_R/8$ is selected as the count clock	Operable when $f_R/8$ or f_{XT} is selected as the count clock
Serial interface	CSIB0 to CSIB4	Stops operation (When the $\overline{\text{SCKBn}}$ input clock is selected as the count clock, be sure to stop the $\overline{\text{SCKBn}}$ input clock (n = 0 to 4).)	
	I^{2}C00 to I^{2}C02	Stops operation	
	UARTA0 to UARTA2	Stops operation (When the ASCKA0 input clock to UARTA0 is selected, be sure to stop the ASCKA0 input clock.)	
A/D converter		Stops operation (conversion result undefined)$^{\text{Notes 1, 2}}$	
D/A converter		Stops operation$^{\text{Notes 3, 4}}$ (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 **2.2 Pin States**.	
Port function		Retains status before low-voltage 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 low-voltage STOP mode was set.	

Notes 1. If the low-voltage STOP mode is set while the A/D converter is operating, the A/D converter is automatically stopped and starts operating again after the low-voltage STOP mode is released. However, in that case, the A/D conversion results after the low-voltage STOP mode is released are invalid. All the A/D conversion results before the low-voltage STOP mode is set are invalid.

2. Even if the low-voltage 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 low-voltage STOP mode is set.

3. If the low-voltage STOP mode is set while the D/A converter is operating, the D/A converter is automatically stopped. After the low-voltage STOP mode is released, D/A conversion resumes, the setting time elapses, and the status returns to the output level before the low-voltage STOP mode was set.

4. Even if the low-voltage 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 low-voltage STOP mode is set.

21.6.2 Releasing STOP mode/low-voltage STOP mode

The STOP mode/low-voltage STOP mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP7 pin input), unmasked internal interrupt request signal from the peripheral functions operable in the STOP mode/low-voltage STOP mode, or reset signal (reset by $\overline{\text{RESET}}$ pin input, WDT2RES signal, or low-voltage detector (LVI)).

After the STOP mode/low-voltage STOP mode has been released, the normal operation mode is restored after the oscillation stabilization time has been secured.

For re-set after releasing the low-voltage STOP mode, see **21.6.3 Re-setting after release of low-voltage STOP mode**.

(1) Releasing STOP mode/low-voltage STOP mode by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The STOP mode/low-voltage 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/low-voltage 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/low-voltage 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/low-voltage 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/low-voltage STOP mode is not released.

Table 21-10. Operation After Releasing STOP Mode/Low-Voltage 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/low-voltage STOP mode by reset

The same operation as the normal reset operation is performed.

21.6.3 Re-setting after release of low-voltage STOP mode

(1) If low-voltage STOP mode is released by interrupt

The status after the low-voltage STOP mode has been released is as follows.

- Regulator: Automatically returns to the normal level.
  It is necessary to secure the recovery time within the oscillation stabilization time (set value of the OSTS register).
  Be sure to secure by using the OSTS register the time for the regulator to recover from low-voltage mode + PLL setup time + main oscillator stabilization time.
- REGOVL0 register = 01H (low-voltage STOP mode): Value described in 21.6.1 (1) <5> is retained.
- REGPR register = 00H (protection data): Value described in 21.6.1 (1) <6> is retained.

(a) To continuously use the REGOVL0 register = 01H (low-voltage STOP mode), the other registers do not have to be set again.

(b) Follow this procedure when returning the REGOVL0 register = 00H.

<1> Disable the DMA.

<2>
- Disable the maskable interrupt by the DI instruction.
- Disable the NMI interrupt (INTF02 = 0, INTR02 = 0).
- Create a status in which the INTWDT2 signal is not generated (stop watchdog timer 2 or set a mode other than the INTWDT2 mode. Create a status in which the INTWDT2 signal is not generated immediately after watchdog timer 2 has been cleared).

<3> Write C9H (enabling data) to the REGPR register.

<4> Write 00H to the REGOVL0 register.

<5> Write 00H (protection data) to the REGPR register.

<6> As necessary, enable the maskable interrupt, NMI interrupt, or INTWDT2 interrupt by enabling DMA or the EI instruction (restore the settings <1> and <2> above).

Be sure to observe the above sequence.

(2) If low-voltage STOP mode is released by reset

The CPU transits to the normal operation mode after it has been released from the reset status, and the REGOVL0 register is initialized to 00H and the REGPR register to 00H (protection data). Be sure by setting an option byte to secure the time necessary for setting up the regulator. For details, see **CHAPTER 27 OPTION BYTE**.

Caution The interrupt requests that are set to 1 (disabled) by the PSC.NMI1M, PSC.NMI0M, and PSC.INTM bits are disabled, and the low-voltage STOP mode is not released.

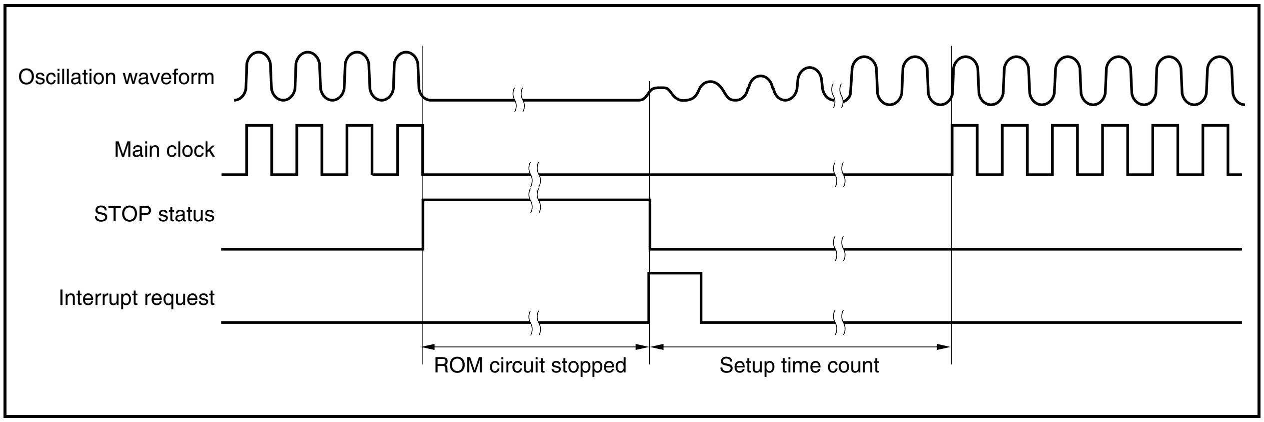
21.6.4 Securing oscillation stabilization time when releasing STOP mode

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 differs depending on the option byte. For details, see **CHAPTER 27 OPTION BYTE**.

21.7 Subclock Operation Mode/Low-Voltage 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. The low-voltage subclock operation mode is set by setting the REGOVL0 register to 02H in the subclock 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, 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, power consumption can be further reduced to the level of the STOP mode by stopping the operation of the main clock oscillator. Power consumption decreases further in the low-voltage subclock operation mode because the voltage of the regulator is lowered.

When the main clock oscillator is stopped in the subclock operation mode, CSIBn and UARTA0 can operate with the external clock continuing to operate, but stop supply of the external clock input to CSIBn and UARTA0 in the low-voltage subclock operation mode (n = 0 to 4).

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.

Internal system clock (f_{CLK}) > Subclock (f_{XT} = 32.768 kHz) × 4

Remark Internal system clock (f_{CLK}): Clock generated from main clock (f_{XX}) in accordance with the settings of the CK2 to CK0 bits

Be sure to set the low-voltage subclock operation mode in the following procedure.

(1) Procedure for setting “subclock operation mode” → “low-voltage subclock operation mode”

Make the following settings in the subclock operation mode.

<1> Stop the main clock and PLL.

<2> Stop the functions that are specified to be stopped in **Table 21-14 Operating Status in Low-Voltage Sub-IDLE Mode**.

Be especially sure to stop the following functions, because they are signals from external sources.

- Stop the $\overline{\text{SCKBn}}$ input clock when the $\overline{\text{SCKBn}}$ input clock to CSIBn is selected (n = 0 to 4).
- Stop the ASCKA0 input clock when the ASCKA0 input clock to UARTA0 is selected.

<3> Disable the DMA operation (if the DMA operation is enabled).

<4>
- Disable the maskable interrupt by the DI instruction.
- Disable the NMI interrupt (INTF02 = 0, INTR02 = 0).
- Create a status in which the INTWDT2 signal is not generated (create a status in which the INTWDT2 signal is not generated immediately after watchdog timer 2 has been cleared).

<5> Write C9H (enabling data) to the REGPR register.

<6> Write 02H to the REGOVL0 register.

At this time, the output voltage of the regulator is at the low level, decreasing power consumption to an extremely low level.

<7> Write 00H (protection data) to the REGPR register.

<8> As necessary, enable the maskable interrupt, NMI interrupt, or INTWDT2 interrupt by the EI instruction (restore the setting <4> above).

Be sure to observe the above sequence.

For the setting of the subclock operation mode, see **21.7.1 Setting and operation status**.

Table 21-11 shows the operating status in the subclock operation mode and Table 21-12 shows the operating status in the low-voltage subclock operation mode.

Table 21-11. Operating Status in Subclock Operation Mode

Setting of Subclock Operation Mode Item		Operating Status	
		When Main Clock Is Oscillating	When Main Clock Is Stopped
LVI		Operable	
Subclock oscillator		Oscillates	
Internal oscillator		Oscillation enabled	
PLL		Operable	Stops operation[Note]
CPU		Operable	
DMA		Operable	
Interrupt controller		Operable	
Timer P (TMP0 to TMP5)		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 CSIB4	Operable	Operable when the $\overline{\text{SCKBn}}$ input clock is selected as the count clock (n = 0 to 4)
	I^{2}C00 to I^{2}C02	Operable	Stops operation
	UARTA0 to UARTA2	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)).

Table 21-12. Operating Status in Low-Voltage Subclock Operation Mode

Setting of Low-Voltage Subclock Operation Mode Item		Operating Status
		Main Clock Is Stopped (Must Be Stopped)
LVI		Operable
Subclock oscillator		Oscillates
Internal oscillator		Oscillation enabled
PLL		Stops operation$^{\text{Note}}$
CPU		Operable
DMA		Stops operation (must stop)
Interrupt controller		Operable
Timer P (TMP0 to TMP5)		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		Operable when f_{XT} is selected as the count clock
Watchdog timer 2		Operable when $f_R/8$ or f_{XT} is selected as the count clock
Serial interface	CSIB0 to CSIB4	Stops operation (When the $\overline{\text{SCKBn}}$ input clock is selected as the count clock, be sure to stop the $\overline{\text{SCKBn}}$ input clock (n = 0 to 4).)
	I^{2}C00 to I^{2}C02	Stops operation
	UARTA0 to UARTA2	Stops operation (When the ASCKA0 input clock to UARTA0 is selected, be sure to stop the ASCKA0 input clock.)
A/D converter		Stops operation
D/A converter		Stops operation (must stop)
Real-time output function (RTO)		Stops operation (output held)
Key interrupt function (KR)		Operable
CRC operation circuit		Stops operation (must stop)
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).

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)).

21.7.2 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 set 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 set 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).

21.7.3 Releasing low-voltage subclock operation mode

In low-voltage subclock mode, the subclock operation mode is set by setting the REGOVL0 register to 00H. After that, transit to the normal mode according to **21.7.2 Releasing subclock operation mode**. Be sure to follow this procedure to transit the mode from the low-voltage subclock operation mode to the subclock operation mode.

(1) Procedure for setting “low-voltage subclock operation mode” → “subclock operation mode”

Make the following settings in the low-voltage subclock operation mode.

<1>
- Disable the maskable interrupt by the DI instruction.
- Disable the NMI interrupt (INTF02 = 0, INTR02 = 0).
- Create a status in which the INTWDT2 signal is not generated (stop watchdog timer 2 or set a mode other than the INTWDT2 mode. Create a status in which the INTWDT2 signal is not generated immediately after watchdog timer 2 has been cleared).

<2> Write C9H (enabling data) to the REGPR register.

<3> Write 00H to the REGOVL0 register (transit to the subclock operation mode).

<4> Write 00H (protection data) to the REGPR register.

<5> Wait for at least 800 μs by software.

<6> As necessary, enable the maskable interrupt, NMI interrupt, or INTWDT2 interrupt by the EI instruction (restore the setting <1> above).

<7> Enable the DMA if necessary.

<8> Start the functions to be used, from among those that have been stopped in steps <1> and <2> in section **21.7.1 (1) Procedure for setting “subclock operation mode” → “low-voltage subclock operation mode”**.

Be sure to observe the above sequence.

Note, however, that <6>, <7>, and <8> may be performed at any time as long as it is done after <5>.

(2) If low-voltage subclock operation mode is released by reset

When the low-voltage 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)), the CPU transits to the normal operation mode after it has been released from the reset status, and the REGOVL0 register is initialized to 00H and the REGPR register to 00H (protection data). Make sure by setting an option byte that the time necessary for setting up the regulator elapses. For details, see **CHAPTER 27 OPTION BYTE**.

21.8 Sub-IDLE Mode/Low-Voltage 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. The low-voltage 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 after setting the REGOVL0 register to 02H 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. In the subclock operation mode, CSIBn and UARTA0, which can operate with the external clock, continue operating. In the low-voltage subclock operation mode, stop supply of the external clock input to CSIBn and UARTA0 (n = 0 to 4).

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. The power consumption decreases further in the low-voltage sub-IDLE mode because the voltage of the regulator is lowered.

Table 21-13 shows the operating status in the sub-IDLE mode and Table 21-14 shows the operating status in the low-voltage sub-IDLE mode.

Be sure to set the low-voltage sub-IDLE mode in the following procedure.

(1) Procedure for setting "subclock operation mode" → "low-voltage subclock operation mode" → "low-voltage sub-IDLE mode"

Make the following settings in the subclock operation mode.

<1> Stop the main clock and PLL.

<2> Stop the functions that are specified to be stopped in **Table 21-14 Operating Status in Low-Voltage Sub-IDLE Mode**.

Be especially sure to stop the following functions, because they are signals from external sources.

- Stop $\overline{\text{SCKBn}}$ input clock when the $\overline{\text{SCKBn}}$ input clock to CSIBn is selected (n = 0 to 4).
- Stop ASCKA0 input clock when the ASCKA0 input clock to UARTA0 is selected.

<3> Disable the DMA operation (if the DMA operation is enabled).

<4>
- Disable the maskable interrupt by the DI instruction.
- Disable the NMI interrupt (INTF02 = 0, INTR02 = 0).
- Create a status in which the INTWDT2 signal is not generated (set a status in which the INTWDT2 signal is not generated immediately after watchdog timer 2 has been cleared).

<5> Write C9H (enabling data) to the REGPR register.

<6> Write 02H to the REGOVL0 register.

At this time, the output voltage of the regulator is at the low level, decreasing the power consumption to an extremely low level.

<7> Write 00H (protection data) to the REGPR register.

<8> As necessary, enable the maskable interrupt, NMI interrupt, or INTWDT2 interrupt by the EI instruction (restore the settings in step <4>).

<9> Set the sub-IDLE mode.

PSMR.PSM1, PSMR.PSM0 bits = 00 or 10
PSC.STP bit = 1

Be sure to observe the above sequence.

For the setting of the subclock operation mode, see **21.7.1 Setting and operation status**.

Cautions 1. Following the store instruction to the PSC register for setting the sub-IDLE mode/low-voltage sub-IDLE mode, insert the five or more NOP instructions.

2. If the sub-IDLE mode/low-voltage sub-IDLE mode is set while an unmasked interrupt request signal is being held pending, the sub-IDLE mode/low-voltage sub-IDLE mode is then released immediately by the pending interrupt request.

Table 21-13. Operating Status in Sub-IDLE Mode

Setting of Sub-IDLE Mode Item		Operating Status	
		When Main Clock Is Oscillating	When Main Clock Is Stopped
LVI		Operable	
Subclock oscillator		Oscillates	
Internal oscillator		Oscillation enabled	
PLL		Operable	Stops operation[Note 1]
CPU		Stops operation	
DMA		Stops operation	
Interrupt controller		Stops operation (but standby mode release is possible)	
Timer P (TMP0 to TMP5)		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		Operable	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 CSIB4	Operable when the $\overline{\text{SCKBn}}$ input clock is selected as the count clock (n = 0 to 4)	
	I^{2}C00 to I^{2}C02	Stops operation	
	UARTA0 to UARTA2	Stops operation (but UARTA0 is operable when the ASCKA0 input clock is selected)	
A/D converter		Holds operation (conversion result held)[Note 2]	
D/A converter		Holds operation (output held[Note 2])	
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** (same operation status as IDLE1 and IDLE2 modes).	
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.

Table 21-14. Operating Status in Low-Voltage Sub-IDLE Mode

Setting of Low-Voltage Sub-IDLE Mode Item		Operating Status
		Main Clock Is Stopped (Must Be Stopped)
LVI		Operable
Subclock oscillator		Oscillates
Internal oscillator		Oscillation enabled
PLL		Stops operation[Note]
CPU		Stops operation
DMA		Stops operation
Interrupt controller		Stops operation (but standby mode release is possible)
Timer P (TMP0 to TMP5)		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		Operable when f_{XT} is selected as the count clock
Watchdog timer 2		Operable when f_R/8 or f_{XT} is selected as the count clock
Serial interface	CSIB0 to CSIB4	Stops operation (When the $\overline{\text{SCKBn}}$ input clock is selected as the count clock, be sure to stop the $\overline{\text{SCKBn}}$ input clock (n = 0 to 4).)
	I^{2}C00 to I^{2}C02	Stops operation
	UARTA0 to UARTA2	Stops operation (When the ASCKA0 input clock to UARTA0 is selected, be sure to stop the ASCKA0 input clock.)
A/D converter		Stops operation
D/A converter		Stops operation (must stop)
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** (same operation status as IDLE1 and IDLE2 modes).
Port function		Retains status before low-voltage 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 low-voltage sub-IDLE mode was set.

Note Be sure to stop the PLL (PLLCTL.PLLON bit = 0).

21.8.2 Releasing sub-IDLE mode/low-voltage sub-IDLE mode

The sub-IDLE mode/low-voltage sub-IDLE mode is released by a non-maskable interrupt request signal (NMI pin input, INTWDT2 signal), unmasked external interrupt request signal (INTP0 to INTP7 pin input), unmasked internal interrupt request signal from the peripheral functions operable in the sub-IDLE mode/low-voltage 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. It returns to the stop status in the low-voltage sub-IDLE mode.

When the sub-IDLE mode is released by an interrupt request signal, the subclock operation mode is set.

When the low-voltage sub-IDLE mode is released by an interrupt request signal, the low-voltage subclock operation mode is set.

For releasing low-voltage subclock operation mode, see **21.7.3 Releasing low-voltage subclock operation mode**.

(1) Releasing sub-IDLE mode/low-voltage sub-IDLE by non-maskable interrupt request signal or unmasked maskable interrupt request signal

The sub-IDLE mode/low-voltage sub-IDLE 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/low-voltage sub-IDLE 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/low-voltage sub-IDLE 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/low-voltage 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/low-voltage sub-IDLE mode is not released.

2. When the sub-IDLE mode/low-voltage sub-IDLE mode is released, 12 cycles of the subclock (about 366 μs) elapse from when the interrupt request signal that releases the sub-IDLE mode/low-voltage sub-IDLE is generated to when the mode is released.

Table 21-11. Operation After Releasing Sub-IDLE Mode/Low-Voltage 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/low-voltage sub-IDLE by reset

The same operation as the normal reset operation is performed.

CHAPTER 22 RESET FUNCTIONS

22.1 Overview

The following reset functions are available.

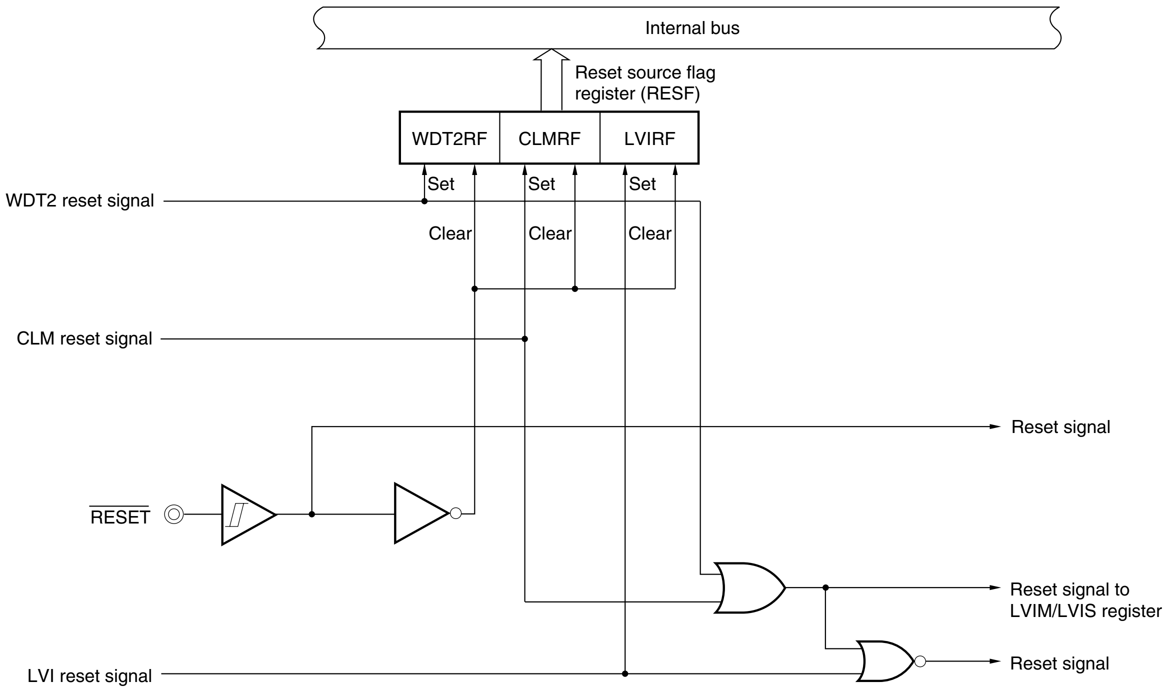
(1) Four kinds of reset sources
- External reset input via the $\overline{\text{RESET}}$ pin
- Reset via the watchdog timer 2 (WDT2) overflow (WDT2RES)
- System reset via the comparison of the low-voltage detector (LVI) supply voltage and detected voltage
- System reset via the detecting clock monitor (CLM) oscillation stop

After a reset is released, the source of the reset can be confirmed with the reset source flag register (RESF).

(2) Emergency operation mode
If the WDT2 overflows during the main clock oscillation stabilization time inserted after reset, a main clock oscillation anomaly is judged and the CPU starts operating on the internal oscillation clock.

Caution In the emergency operation mode, do not access the on-chip peripheral I/O registers other than those for the "interrupt function, port function, WDT2, and timer M" that can operate on the internal oscillation clock. In addition, operating CSIB0 to CSIB4 and UARTA0 by using an external clock is also prohibited.

Figure 22-1. Block Diagram of Reset Function



Caution An LVI circuit internal reset does not reset the LVI circuit.

Remarks 1. LVIM: Low-voltage detection register

2. LVIS: Low-voltage detection level select register

22.2 Registers to Check Reset Source

The V850ES/JG3-L 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[Note] R/W Address: FFFFF888H

	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}), 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). Otherwise value immediately after reset input is retained.	
I/O lines (ports/alternate-function pins)	High impedance[Note]	
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 pins may output an undefined level temporarily even during reset.

- P10/ANO0 pin
- P11/ANO1 pin
- 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 may be entered. For details, see CHAPTER 4 PORT FUNCTIONS.

Figure 22-2. Timing of Reset Operation by $\overline{\text{RESET}}$ Pin Input

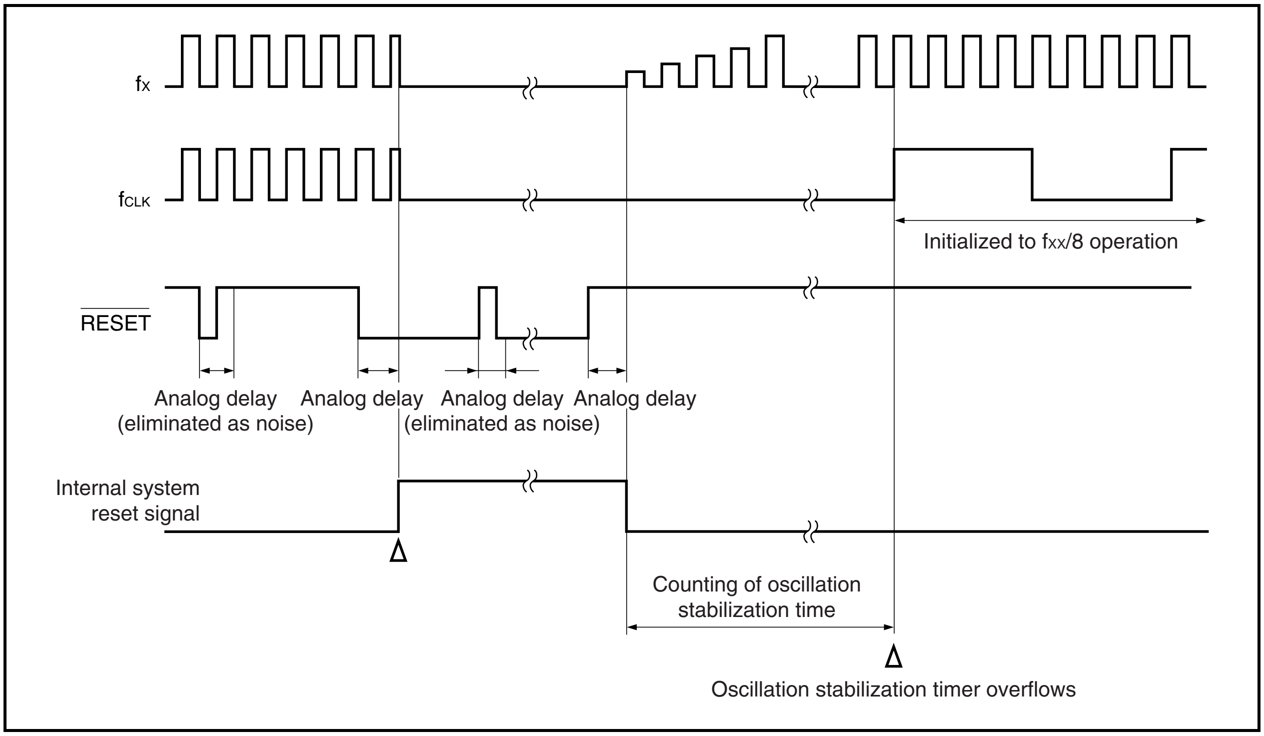
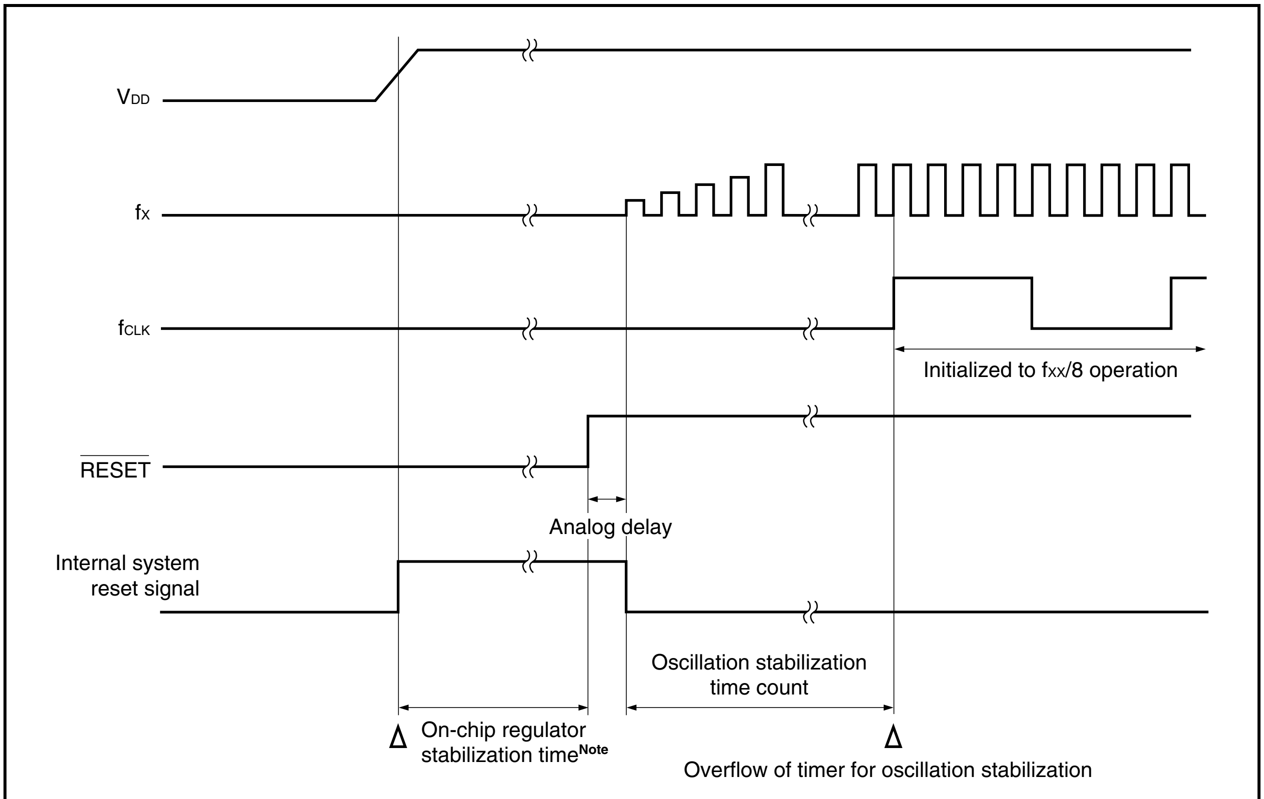


Figure 22-3. Timing of Power-on Reset Operation



Note Time after V_{DD} reaches 2.2 V: 3.5 ms (MAX.)
Time after V_{DD} reaches 2.7 V: 1.0 ms (MAX.)

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.

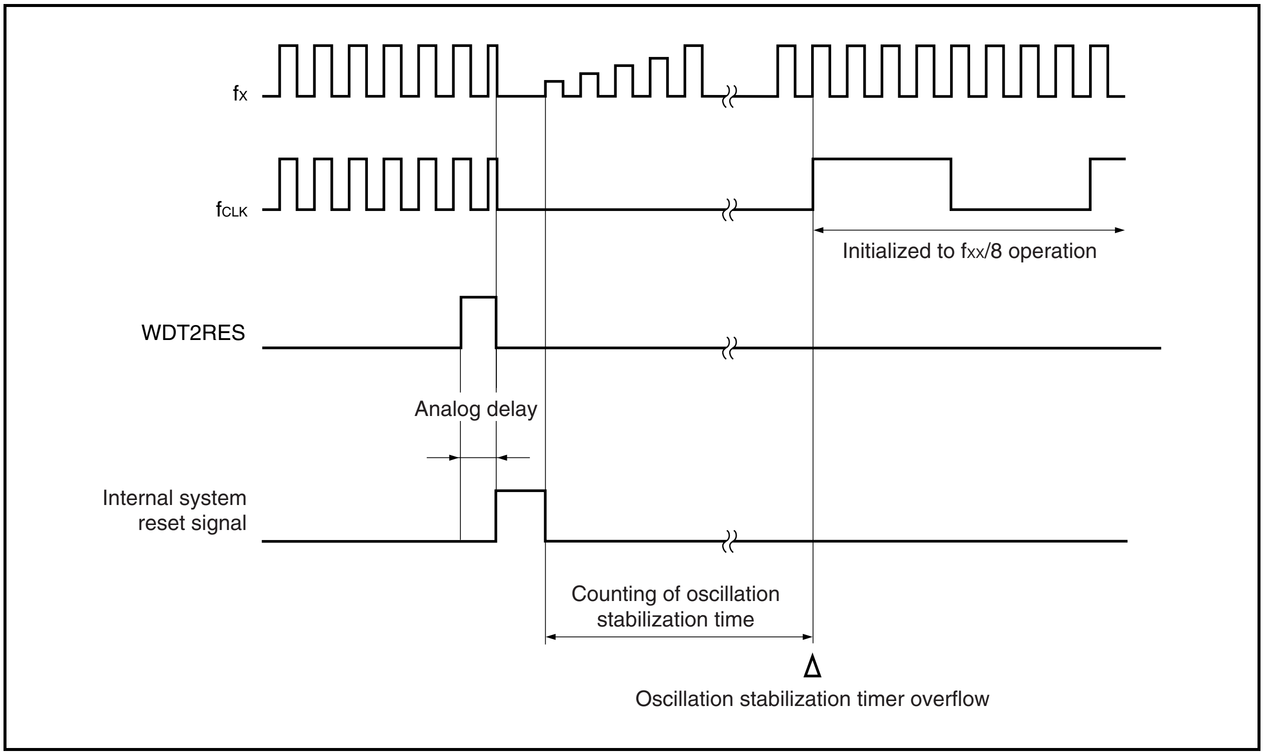
Following watchdog timer 2 overflow, the reset status is entered and lasts the predetermined time (analog delay), and the reset status is then automatically released.

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 (f_X)	Oscillation stops	Oscillation starts
Subclock oscillator (f_{XT})	Oscillation continues	
Internal oscillator	Oscillation stops	Oscillation starts
Peripheral clock (f_{XX} to f_{XX}/1,024)	Operation stops	Operation starts after securing oscillation stabilization time
Internal system clock (f_{XX}), CPU clock (f_{CPU})	Operation stops	Operation starts after securing oscillation stabilization time (initialized to f_{XX}/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}), 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). 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 stops	
On-chip peripheral functions other than above	Operation stops	Operation can be started after securing oscillation stabilization time.

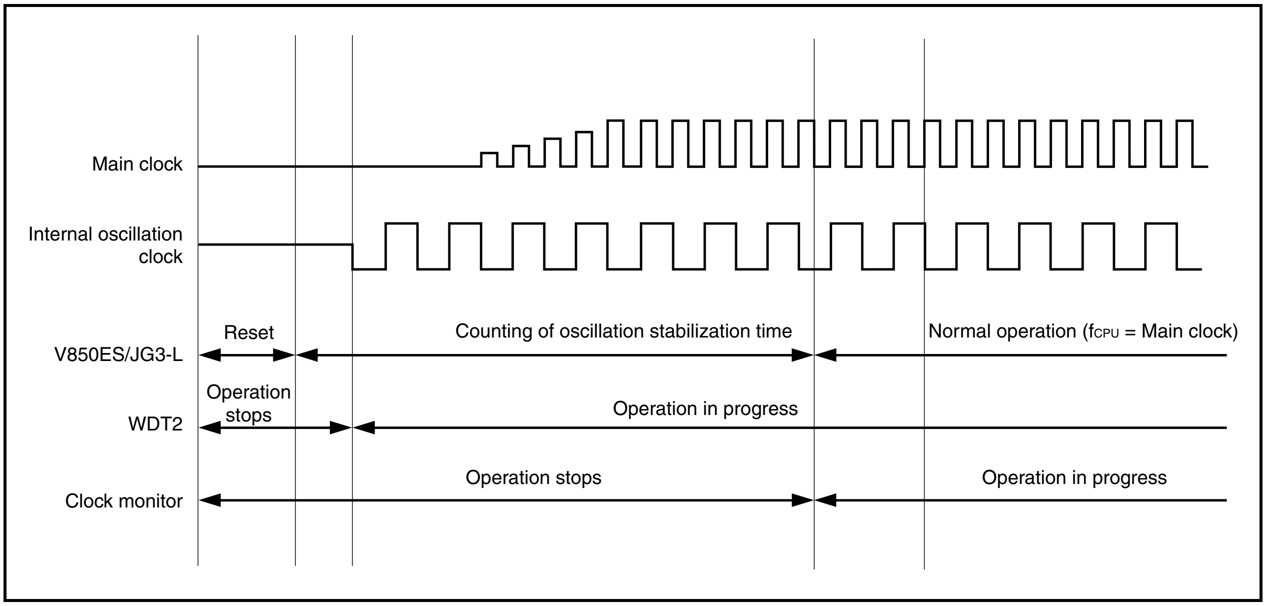
Remark For the reset timing of the low-voltage detector, see **CHAPTER 24 LOW-VOLTAGE DETECTOR (LVI)**.

22.3.4 Operation after reset release

After the reset is released, the main clock starts oscillation and oscillation stabilization time (differs depending on the option byte. For details, see **CHAPTER 27 OPTION BYTE**). 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.

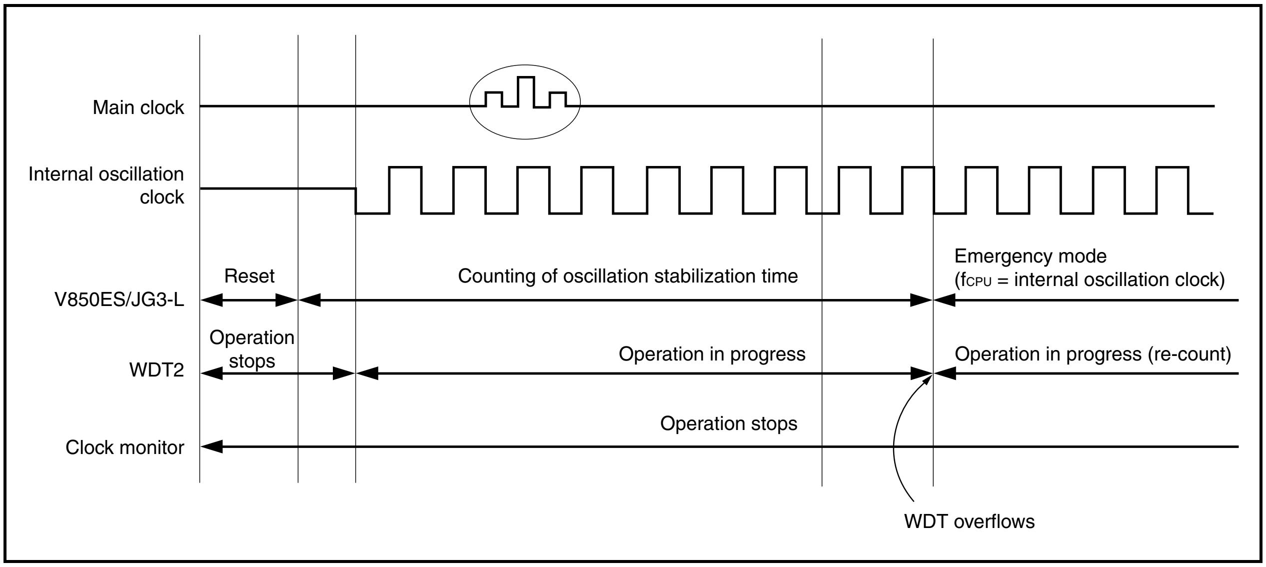
Figure 22-5. Operation After Reset Release



(1) Emergent operation mode

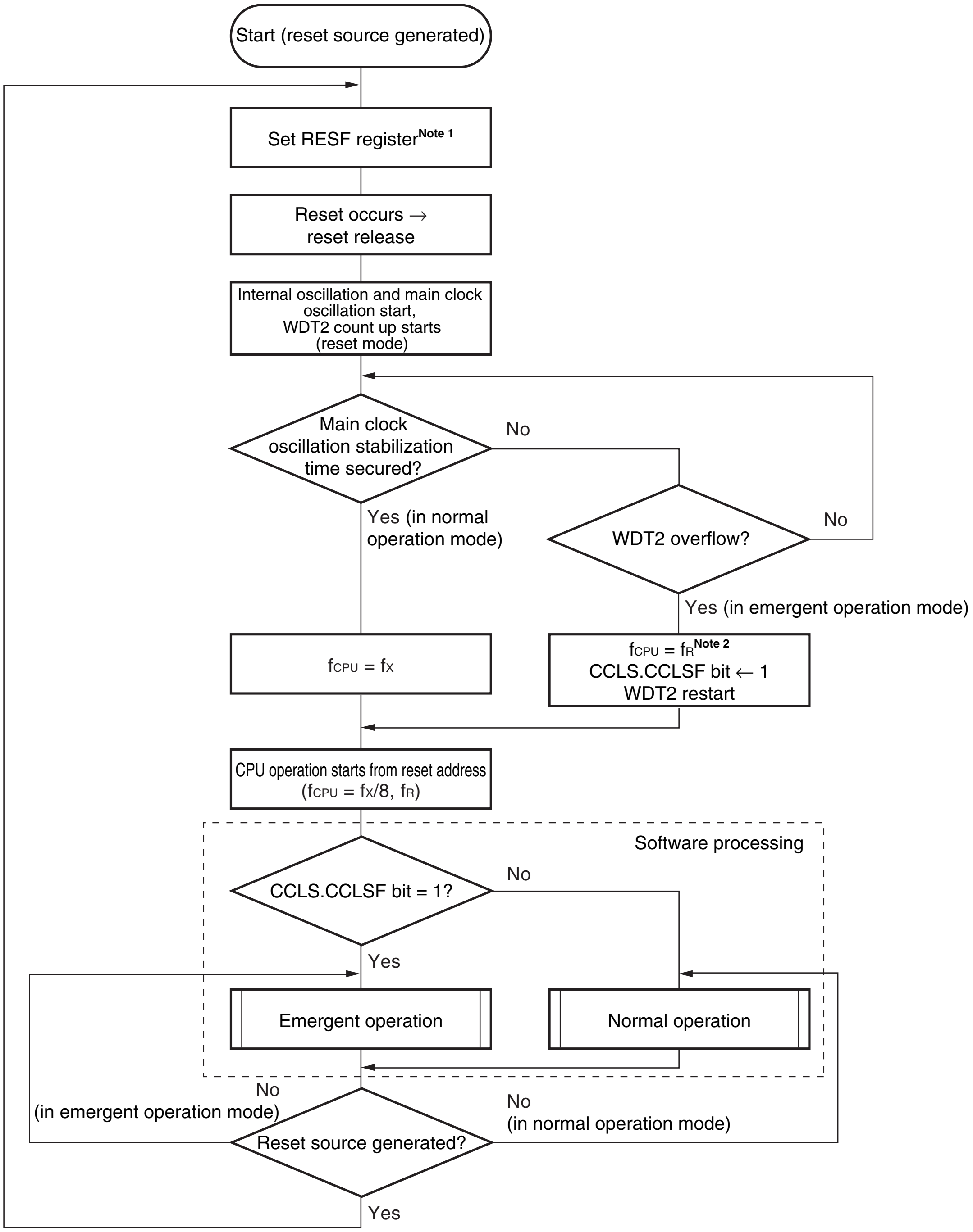
If an anomaly occurs in the main clock before oscillation stabilization time is secured, the WDT2 overflows before executing the CPU program. At this time, the CPU starts program execution by using the internal oscillation clock as the source clock.

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
$\overline{\text{RESET}}$ 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.

22.4 Cautions

When executing the power-on reset operation, the supply voltage must be within the guaranteed operating range when the reset status is released. The usable range of the supply voltage of the V850ES/JG3-L differs depending on the internal operating frequency (2.2 to 2.7 V @5 MHz (MAX.) or 2.7 to 3.6 V @20 MHz (MAX.)). Therefore, observe the following points.

(1) At less than 2.2 V when reset is released

Use prohibited

(2) At 2.2 V or more to less than 2.7 V when reset is released

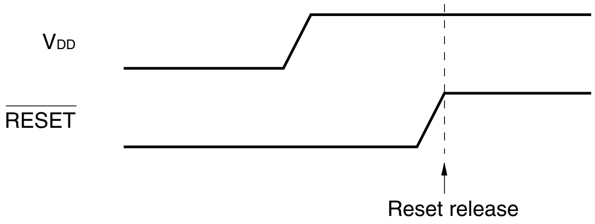
- Input f_X = 2.5 to 5 MHz to the main clock oscillator and set the clock through mode (PLLCTL.SELPLL = 0).
- Inputting 5 MHz or more to the main clock oscillator is prohibited.
- Be sure to stop PLL (PLLCTL.PLLON = 0) by the initialization routine.

(3) At 2.7 to 3.6 V when reset is released

- Both the clock through mode and PLL mode can be used.

Remarks 1. The voltage value (V) is the value of V_{DD}.

2. The reset status is released in the following timing. For the relationship between the rising of V_{DD} and releasing the reset status by the $\overline{\text{RESET}}$ pin, see **CHAPTER 30 ELECTRICAL SPECIFICATIONS (TARGET)**.



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

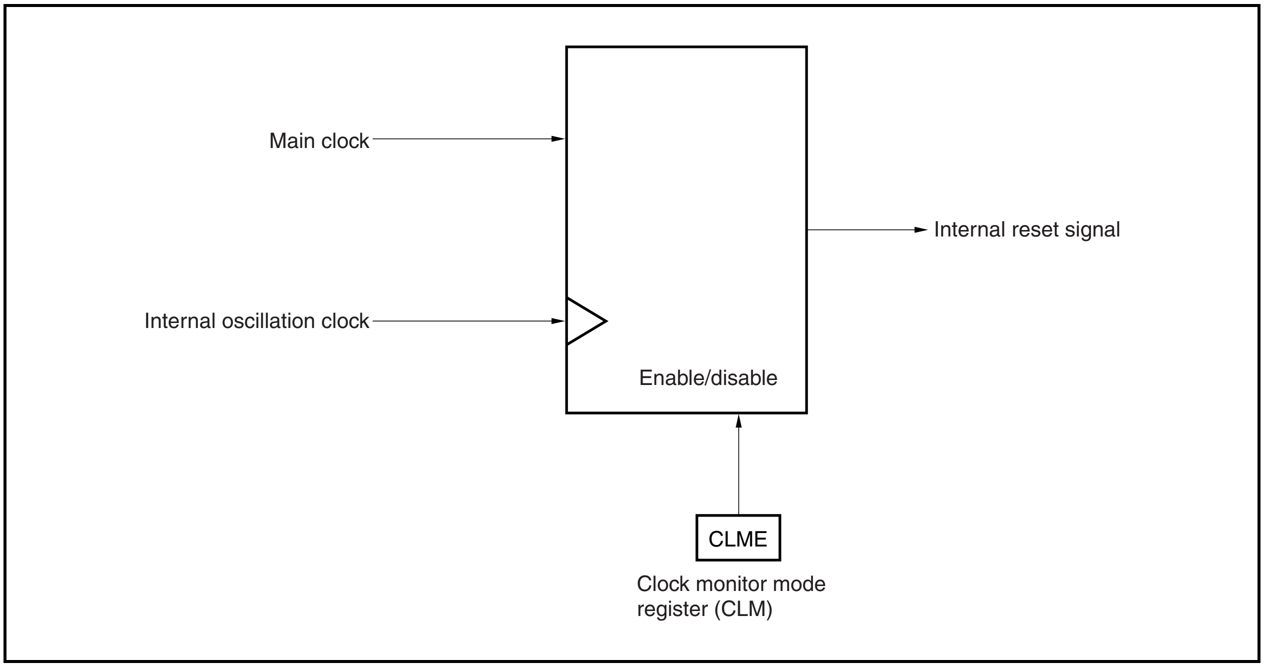
23.2 Configuration

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 with 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[Note 1]	Operates[Note 2]
	IDLE1, IDLE2 modes	Oscillates	Oscillates[Note 1]	Operates[Note 2]
	STOP mode	Stops	Oscillates[Note 1]	Stops
Subclock (MCK bit of PCC register = 0)	Sub-IDLE mode	Oscillates	Oscillates[Note 1]	Operates[Note 2]
Subclock (MCK bit of PCC register = 1)	Sub-IDLE mode	Stops	Oscillates[Note 1]	Stops
Internal oscillation clock	–	Stops	Oscillates[Note 3]	Stops
During reset	–	Stops	Stops	Stops

Notes 1. Internal oscillator can be stopped by setting the RCM.RSTOP bit to 1.

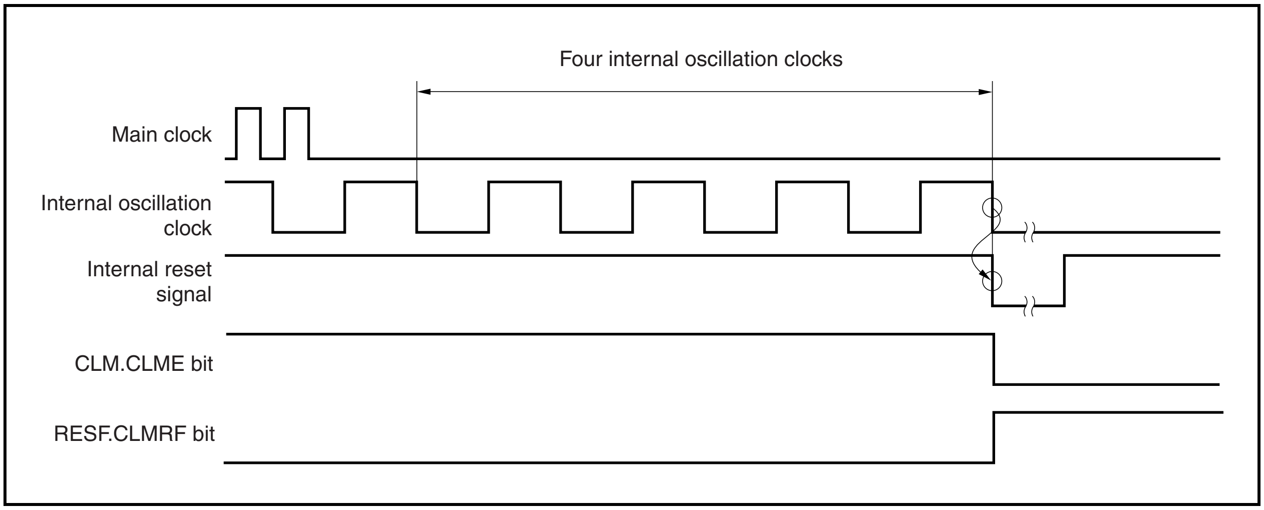
2. The clock monitor is stopped while internal oscillator is stopped.

3. 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.

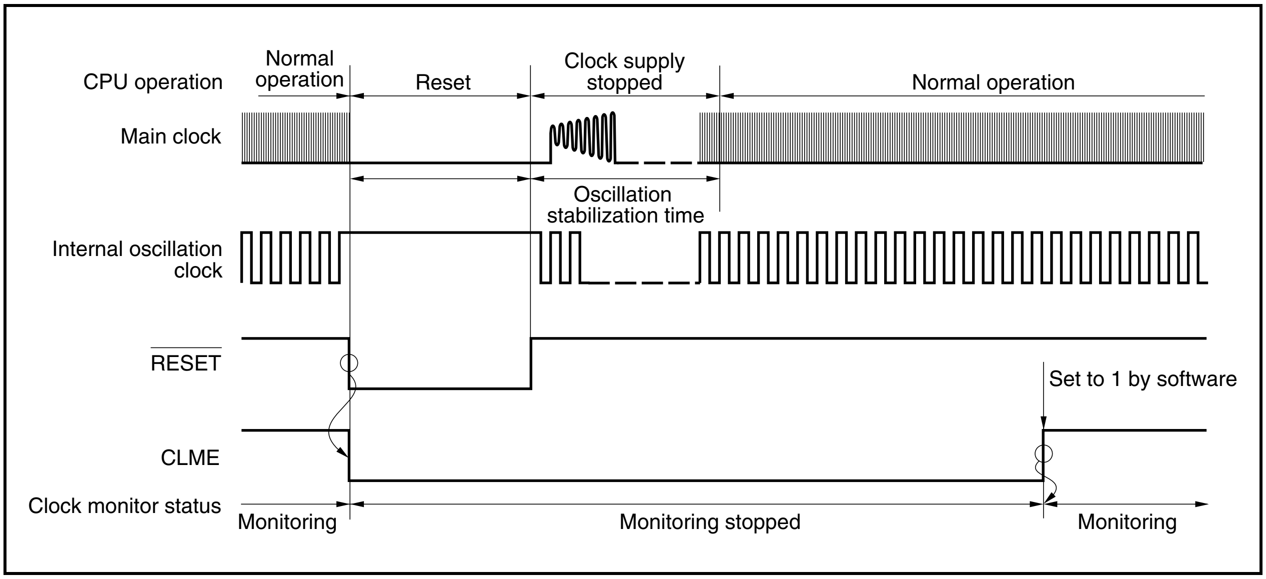
Figure 23-2. Reset Period Due to That Oscillation of Main Clock Is Stopped



(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.

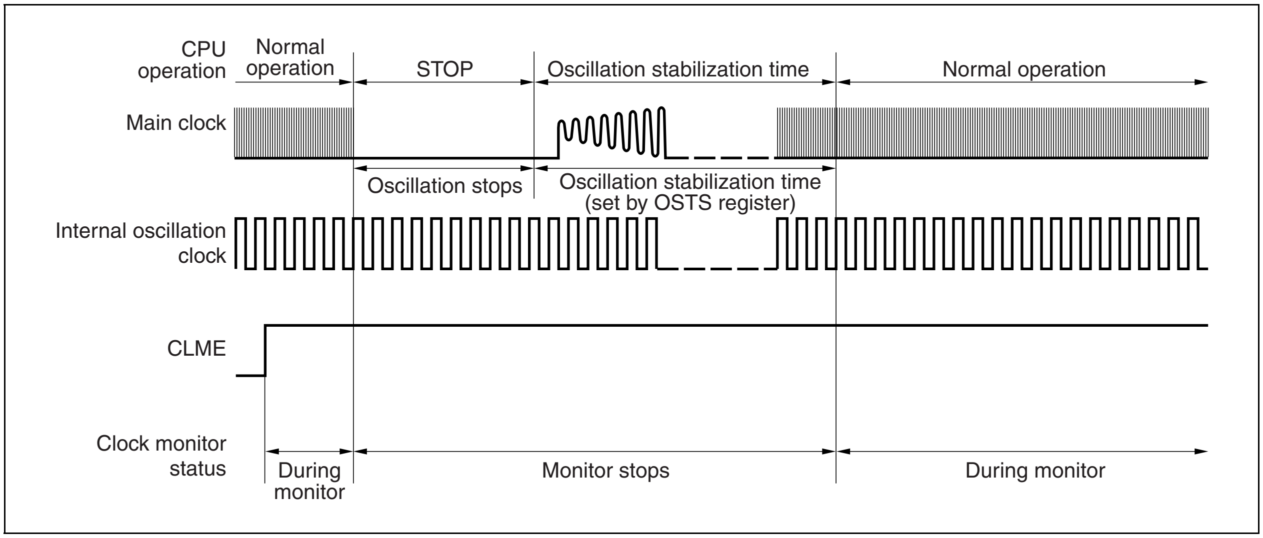
Figure 23-3. Clock Monitor Status After $\overline{\text{RESET}}$ Input
(CLM.CLME bit = 1 is set after $\overline{\text{RESET}}$ input and at the end of main clock oscillation stabilization time)



(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.

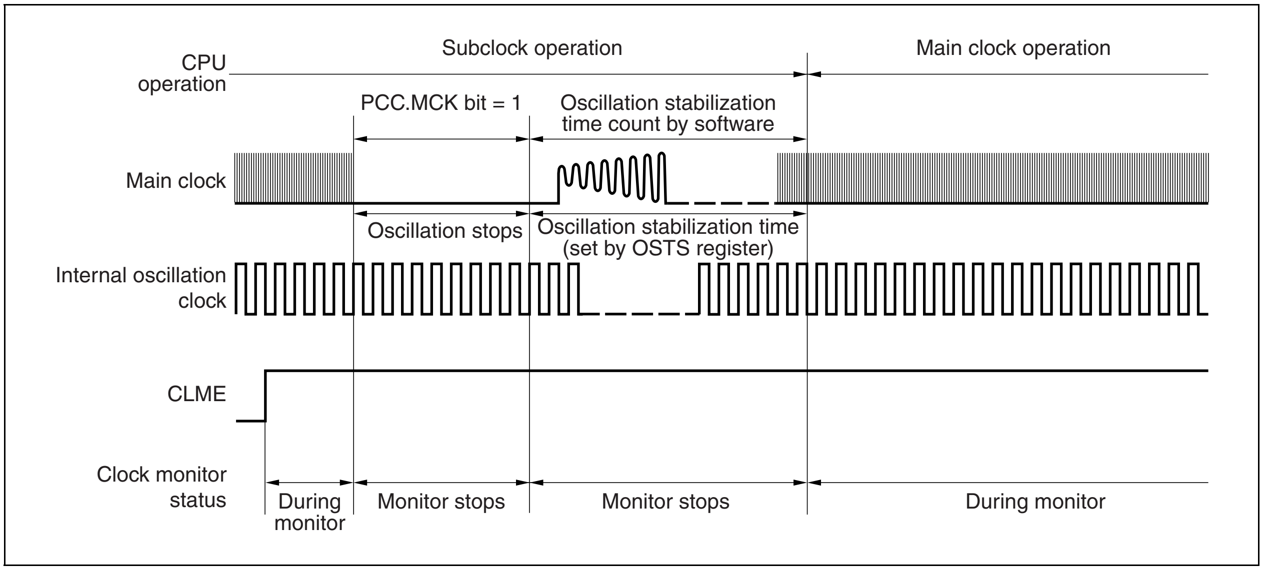
Figure 23-4. Operation in STOP Mode or After STOP Mode Is Released



(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.CCLSF bit = 1)

The monitor operation is not stopped when the CCLSF 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.

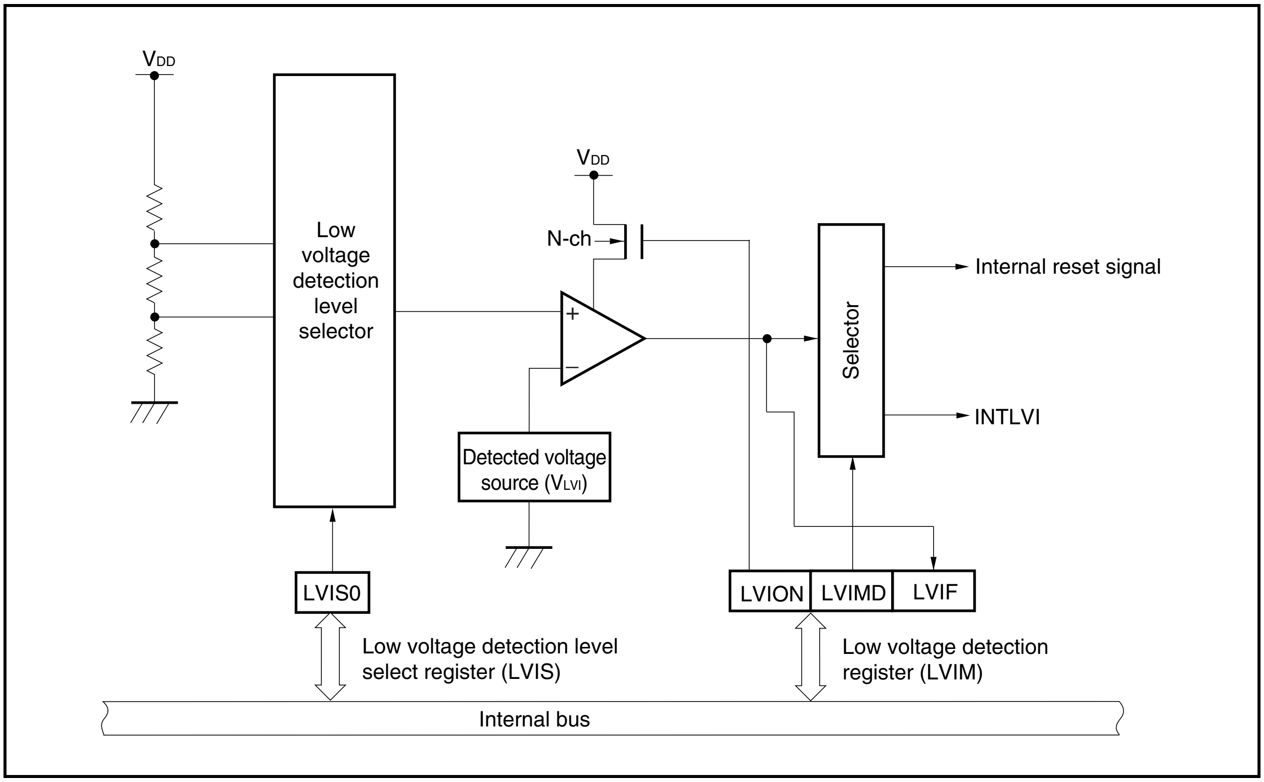
- If the interrupt occurrence at low-voltage detection is selected, the low-voltage detector compares the supply voltage (V_{DD}) and the detected voltage (V_{LVI}), and generates an internal interrupt signal when the supply voltage drops or rises across the detected voltage.
- If the reset occurrence 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})
- The level of the supply voltage to be detected can be changed by software (in two steps).
- 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: **Note 1** R/W Address: FFFFF890H

	<7>	6	5	4	3	2	<1>	<0>
LVIM	LVION	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 detected voltage.
1	Generate internal reset signal LVIRES when supply voltage < detected voltage.

LVIF[Notes 2, 3]	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. Do not change the LVION bit from 1 to 0 while the supply voltage (V_{DD}) is lower than the detected voltage (V_{LVI}) (LVIM.LVIF bit = 1).

3. After the LVI operation has started (LVION bit = 1) or when INTLVI has occurred, confirm the supply voltage state by 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 at least 0.2 ms by software before checking the voltage at the LVIF bit after the LVION bit is set.

3. Be sure to set 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 units.

After reset: **Note** 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	2.80 V (TYP.) (preliminary value)
1	2.30 V (TYP.) (preliminary value)

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”.

24.4 Operation

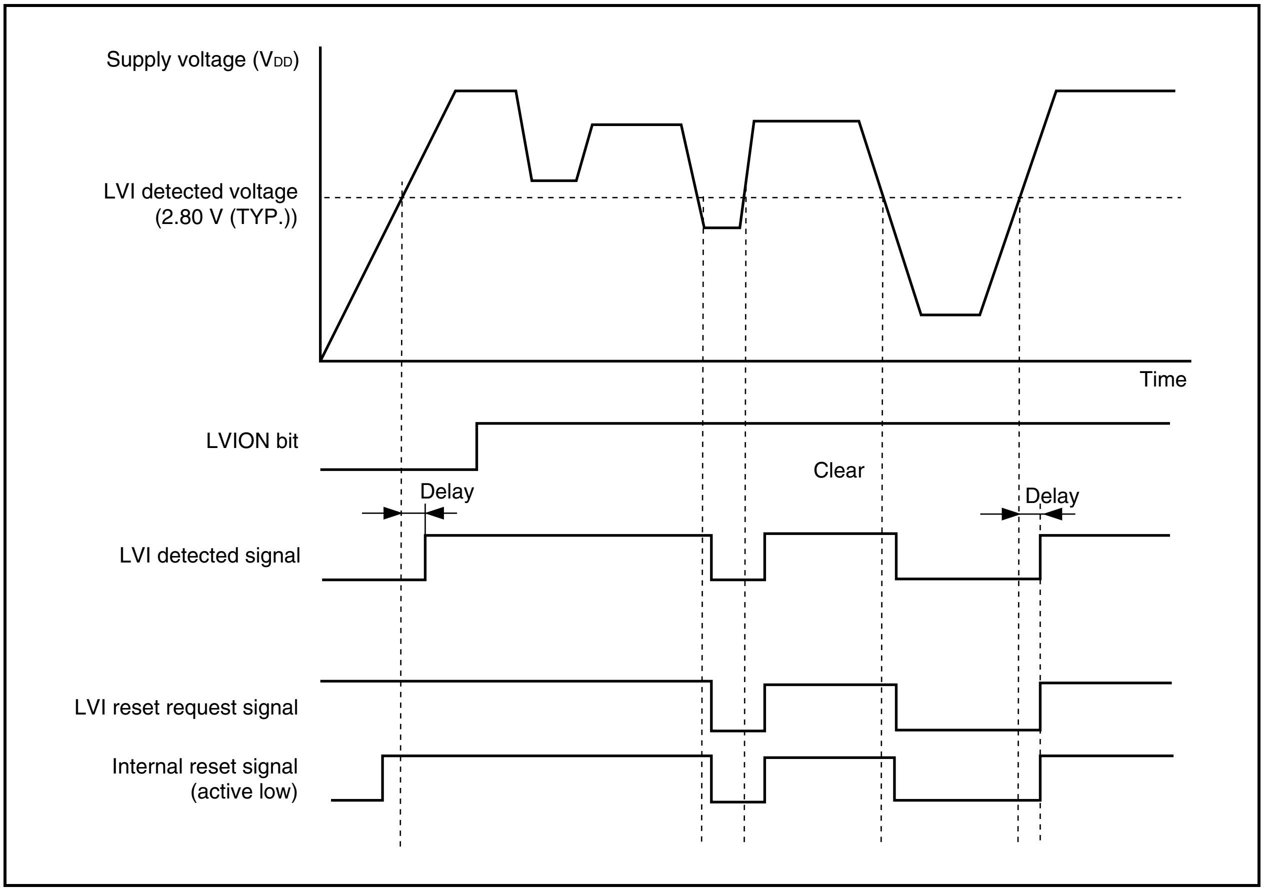
Depending on the setting of the LVIM.VIMD bit, an interrupt signal (INTLVI) or an internal reset signal is generated. How to specify each operation is described below, together with timing charts.

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 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)

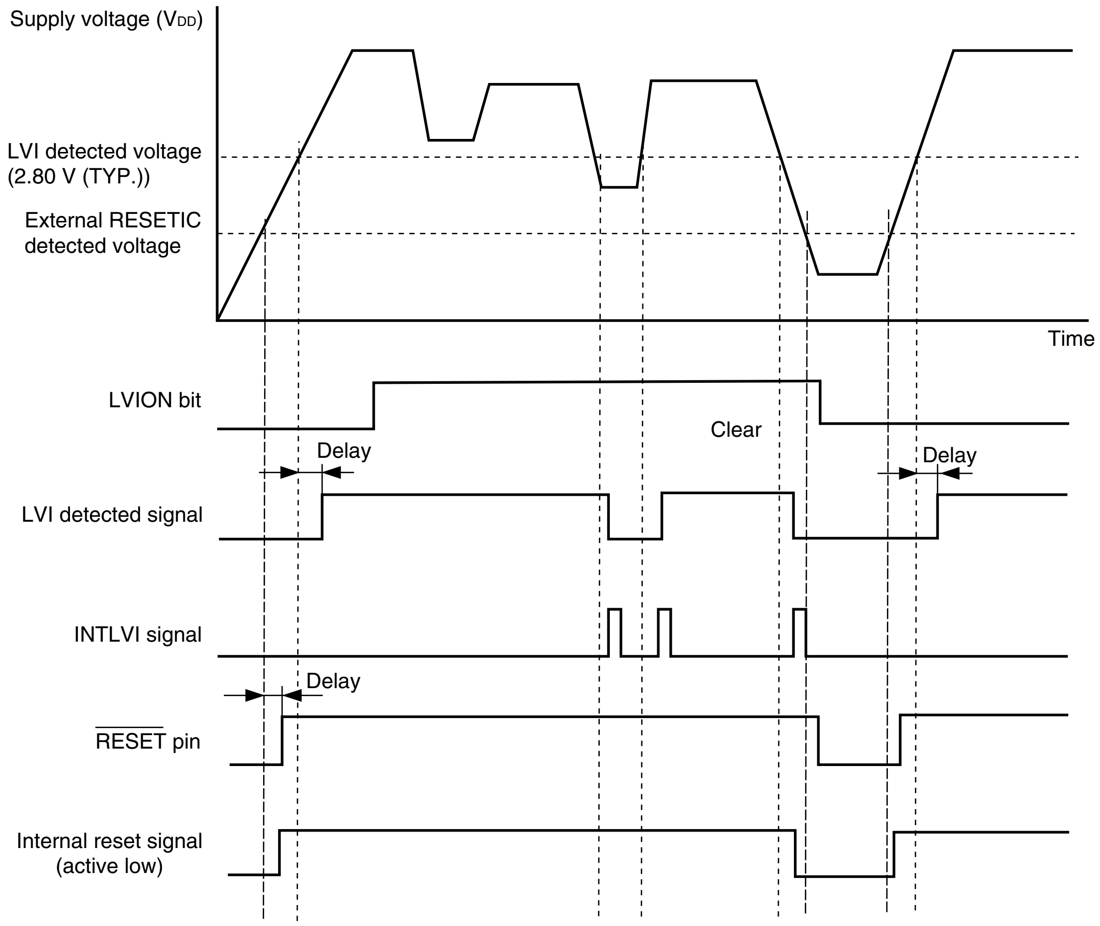


24.4.2 To use for interrupt

<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>
<1> By using the LVIM.LVIF bit, check if the supply voltage > detected voltage.
<2> Clear the LVION bit to 0.

Figure 24-3. Operation Timing of Low-Voltage Detector (LVIMD Bit = 0)



Caution **When the INTLVI signal is generated, confirm, by using the LVIM.LVIF bit, whether the INTLVI signal is generated due to a supply voltage drop or rise across the detected voltage.**

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.

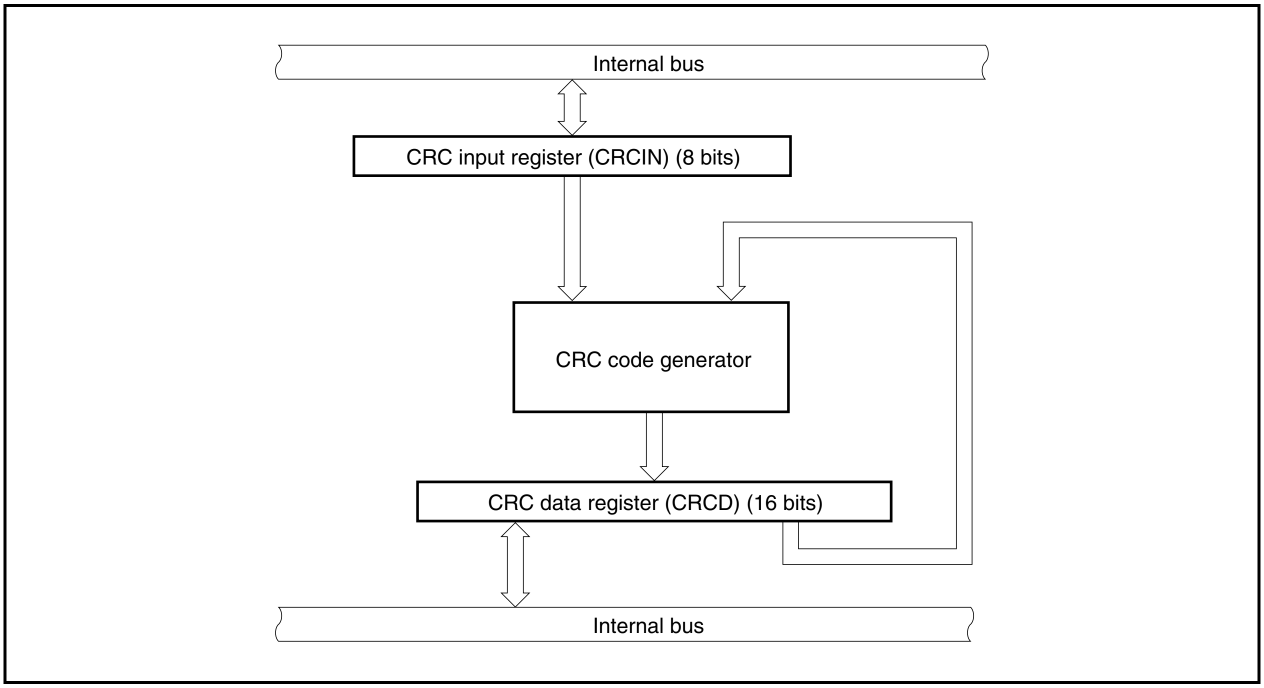
25.2 Configuration

The CRC function includes the following hardware.

Table 25-1. CRC Configuration

Item	Configuration
Control registers	CRC input register (CRCIN) 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.

After reset: 00H R/W Address: FFFFF310H

	7	6	5	4	3	2	1	0
CRCIN								

(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, 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**

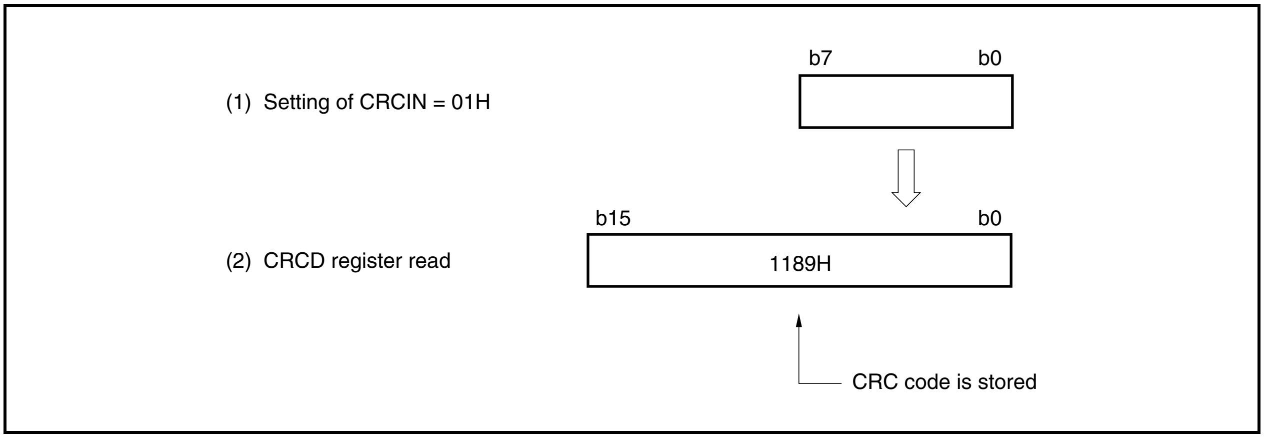
After reset: 0000H R/W Address: FFFFF312H

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRCD																

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.

$0 + 0 = 0$

$0 + 1 = 1$

$1 + 0 = 1$

$1 + 1 = 0$

$-1 = 1$

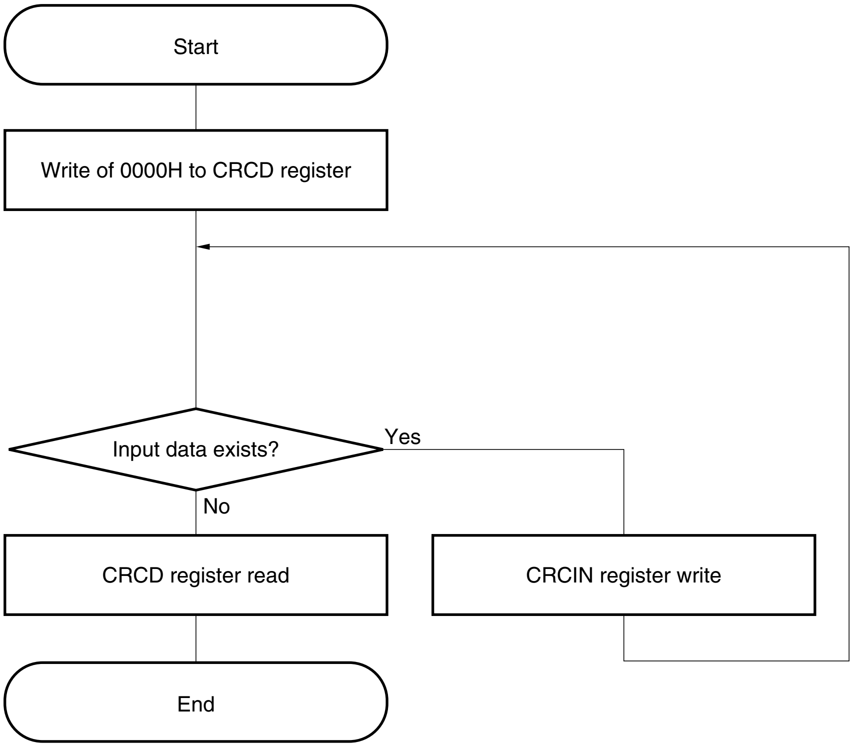
```
                          LSB
                             \                    1000  1000    MSB
1  0001  0000  0010  0001 / 1000  0000  0000  0000  0000  0000 /
                            1000  1000  0001  0000  1
                                  1000  0001  0000  1000  0
                                  1000  1000  0001  0000  1
                                        1001  0001  1000  1000
                                       /                      \
                                   LSB                          MSB
```

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



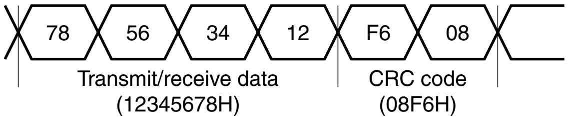
[Basic usage method]

<1> Write 0000H to the CRCD register.
<2> Write the required quantity of data to the CRCIN register.
<3> Read the CRCD register.

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.

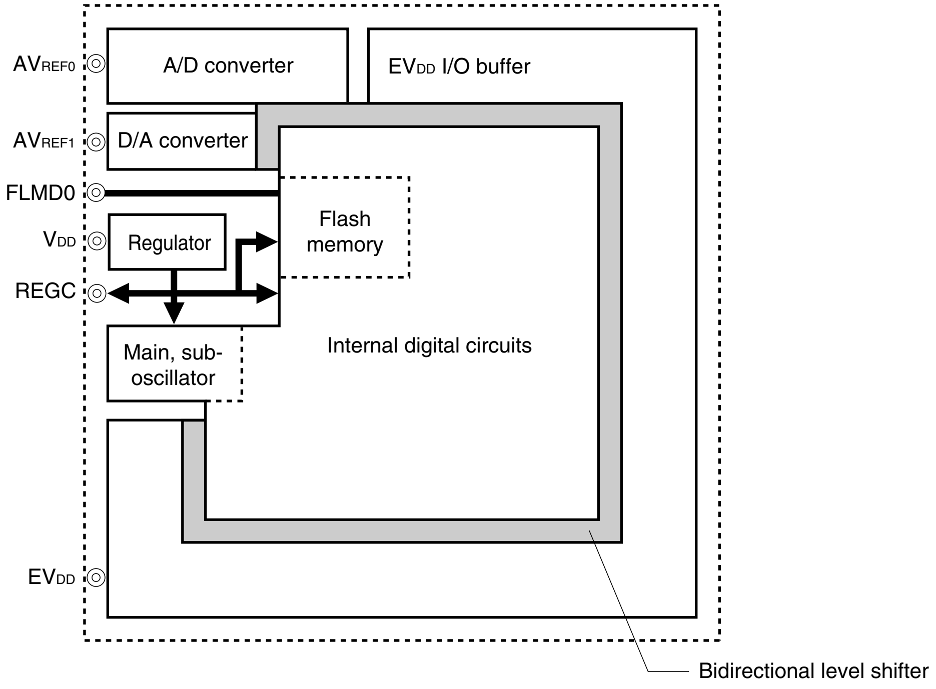
CHAPTER 26 REGULATOR

26.1 Outline

The V850ES/JG3-L 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).

Figure 26-1. Regulator



Caution Use the regulator with a setting of $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$.

26.2 Operation

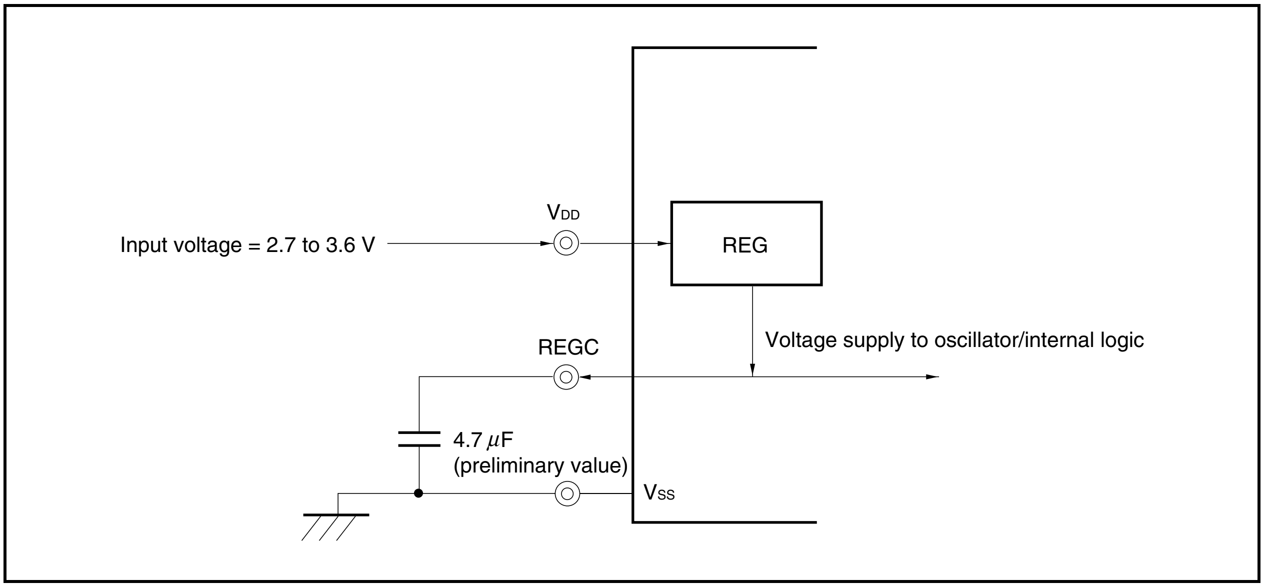
The regulator of the V850ES/JG3-L always operates in any mode (normal operation mode, HALT mode, IDLE1 mode, IDLE2 mode, STOP mode, subclock operation mode, sub-IDLE mode, or during reset).

The output voltage of the regulator can be lowered in the STOP mode, subclock operation mode, and sub-IDLE mode to reduce the power consumption. For details, see **CHAPTER 21 STANDBY FUNCTION**.

Be sure to connect a capacitor (4.7 μF (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 OPTION BYTE

The option byte is stored in address 000007AH of the internal flash memory (internal ROM area) as 8-bit data. This 8-bit data is used to set the oscillation stabilization time that elapses after the reset status is released. After the reset status is released, the oscillation stabilization time is ensured to pass by this set value.

When writing a program to the V850ES/JG3-L, be sure to set the option data in the program at address 000007AH. The data in this area cannot be rewritten during program execution.

Address: 0000007AH

7	6	5	4	3	2	1	0
0	0	0	0	0	RESOSTS2	RESOSTS1	RESOSTS0

RES OSTS2	RES OSTS1	RES OSTS0	Selection of oscillation stabilization time (theoretical value)			
				fx		
				2.5 MHz	5 MHz	10 MHz
0	0	0	2^{10}/fx	409.6 μs	Setting prohibited	Setting prohibited
0	0	1	2^{11}/fx	819.2 μs	409.6 μs	Setting prohibited
0	1	0	2^{12}/fx	1.638 ms	819.2 μs	409.6 μs
0	1	1	2^{13}/fx	3.277 ms	1.638 ms	819.2 μs
1	0	0	2^{14}/fx	6.554 ms	3.277 ms	1.638 ms
1	0	1	2^{15}/fx	13.11 ms	6.554 ms	3.277 ms
1	1	0	2^{16}/fx	26.21 ms	13.11 ms	6.554 ms
1	1	1	2^{16}/fx	26.21 ms	13.11 ms	6.554 ms

Remark The wait time after releasing the STOP mode or IDLE2 mode is set by the OSTS register. For details of the OSTS register, see **21.2 (3) Oscillation stabilization time select register (OSTS)**.

Cautions 1. The oscillation stabilization time shown above is longer than the theoretical value because the overhead time since power application is taken into consideration. The actual oscillation stabilization time is the time shown above, plus up to 260 μs.

2. Be sure to select an oscillation stabilization time (theoretical value) of 400 μs or longer. If it is set to less than 400 μs, the internal status becomes unstable and the operation cannot be guaranteed.

The following shows program examples when the CA850 is used.

[Program example]

```
#-------------------------------------------------------------
# OPTION_BYTES
#-------------------------------------------------------------
.section "OPTION_BYTES"
.byte 0b00000001 -- 0x7a
.byte 0b00000000 -- 0x7b
.byte 0b00000000 -- 0x7c
.byte 0b00000000 -- 0x7d
.byte 0b00000000 -- 0x7e
.byte 0b00000000 -- 0x7f
```

Caution Be sure to describe 6 bytes of this section. If it is less than 6 bytes, an error occurs when a linker is executed.

Error message: F4112: illegal "OPTION_BYTES" section size.

Remark Set 0x00 to addresses 007BH to 007FH.

CHAPTER 28 FLASH MEMORY

The V850ES/JG3-L incorporates a flash memory.

- μPD70F3737: 128 KB flash memory
- μPD70F3738: 256 KB flash memory

Flash memory versions offer the following advantages for development environments and mass production applications.

○ For altering software after the V850ES/JG3-L 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.

28.1 Features

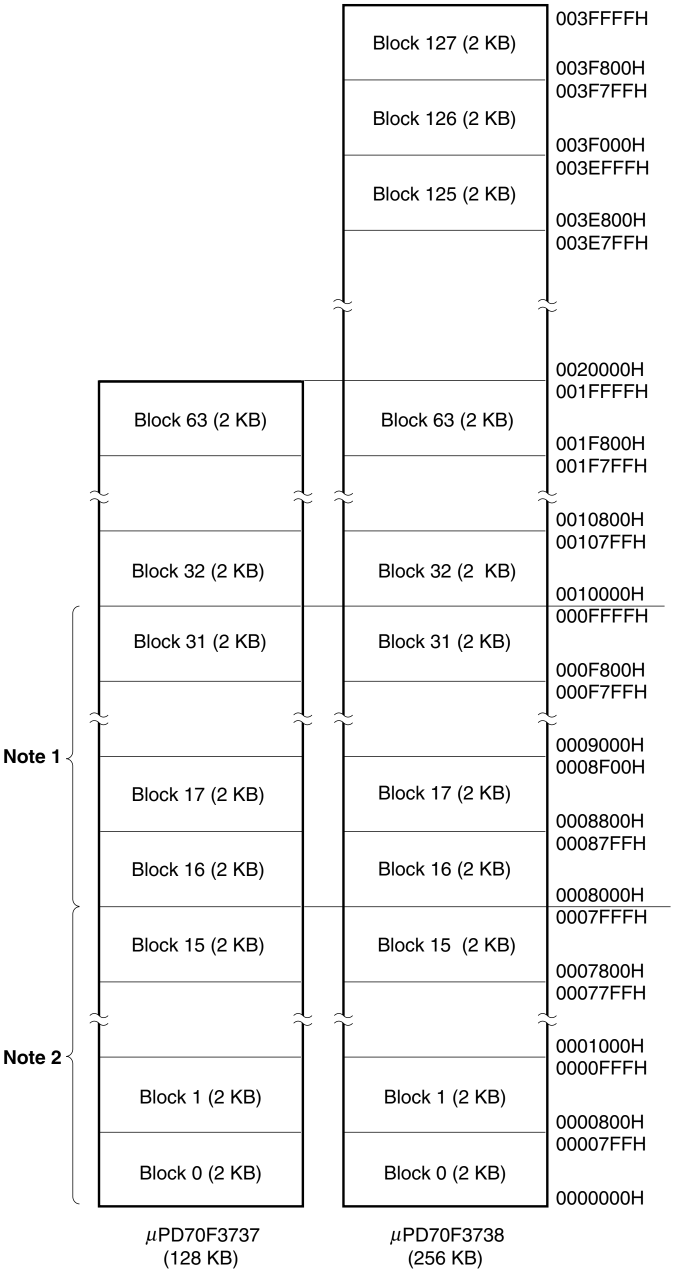
○ 4-byte/1-clock access (when instruction is fetched)
○ Capacity: 256/128 KB
○ Write voltage: Erase/write with a single power supply
○ Rewriting method
  - Rewriting by communication with dedicated flash programmer via serial interface (on-board/off-board programming)
  - Rewriting flash memory by user program (self programming)
○ Flash memory write prohibit function supported (security function)
○ Safe rewriting of entire flash memory area by self programming using boot swap function
○ Interrupts can be acknowledged during self programming.

28.2 Memory Configuration

The V850ES/JG3-L internal flash memory area is divided into 64 or 128 blocks and can be programmed/erased in block units. All the blocks can also be erased at once.

When the boot swap function is used, the physical memory located at the addresses of blocks 0 to 15 is replaced by the physical memory located at the addresses of blocks 16 to 31. For details of the boot swap function, see **28.5 Rewriting by Self Programming**.

Figure 28-1. Flash Memory Mapping



Notes 1. Area to be replaced with the boot area by the boot swap function

2. Boot area

28.3 Functional Outline

The internal flash memory of the V850ES/JG3-L can be rewritten by using the rewrite function of the dedicated flash programmer, regardless of whether the V850ES/JG3-L 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 28-1. 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 Densei Machida Mfg. Co., Ltd.

Table 28-2. 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.	√	× (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 is prohibited, and rewriting of the boot area is prohibited.	√	× (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 28-3. 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 a chip erase command.
Boot area rewrite prohibit	Execution of write, block erase, and chip erase commands on the boot area is prohibited. Setting of the prohibition of rewriting the boot area cannot be initialized after it is once set.

Table 28-4. Security Setting

Function	Erase, Write, Read Operations When Each Security Is Set (√: Executable, ×: Not Executable, –: Not Supported)		Notes on Security Setting	
	On-Board/ Off-Board Programming	Self Programming	On-Board/ Off-Board Programming	Self Programming
Block erase command prohibit	Block erase command: × Chip erase command: √ Program command: √ Read command: √	Block erasure (FlashBlockErase): √ Chip erasure: – Write (FlashWordWrite): √ 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: × Chip erase command: × Program command: √[Note 1] Read command: √	Block erasure (FlashBlockErase): √ Chip erasure: – Write (FlashWordWrite): √ Read (FlashWordRead): √	Setting of prohibition cannot be initialized.	
Program command prohibit	Block erase command: × Chip erase command: √ Program command: × Read command: √	Block erasure (FlashBlockErase): √ Chip erasure: – Write (FlashWordWrite): √ Read (FlashWordRead): √	Setting of prohibition can be initialized by chip erase command.	
Read command prohibit	Block erase command: √ Chip erase command: √ Program command: √ Read command: ×	Block erasure (FlashBlockErase): √ Chip erasure: – Write (FlashWordWrite): √ Read (FlashWordRead): √	Setting of prohibition can be initialized by chip erase command.	
Boot area rewrite prohibit	Block erase command: ×[Note 2] Chip erase command: × Program command: ×[Note 2] Read command: √	Block erasure (FlashBlockErase): ×[Note 2] Chip erasure: – Write (FlashWordWrite): ×[Note 2] Read (FlashWordRead): √	Setting of prohibition cannot be initialized.	Supported only when setting is changed from enable to prohibit[Note 3]

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.

3. The boot area rewrite prohibit function becomes effective after the reset input.

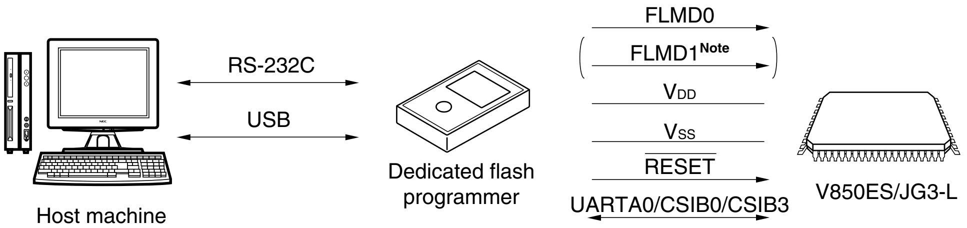
28.4 Rewriting by Dedicated Flash Programmer

The flash memory can be rewritten by using a dedicated flash programmer after the V850ES/JG3-L 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).

28.4.1 Programming environment

The following shows the environment required for writing programs to the flash memory of the V850ES/JG3-L.

Figure 28-2. Environment Required for Writing Programs to Flash Memory



Note Connect the FLMD1 pin to the flash programmer or connect to GND via a pull-down resistor on the board.

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/JG3-L to perform writing, erasing, etc. A dedicated program adapter (FA series) required for off-board writing.

- FA-70F3738GC-UEU-RX (GC-UEU type) (already wired)[Note]
- FA-70F3738GF-GAS-RX (GF-GAS type) (already wired)[Note]
- FA-100GC-UEU-B (GC-UEU type) (not wired: wiring required)
- FA-100GF-GAS-B (GF-GAS type) (not wired: wiring required)

Note Under development

Remark The FA series is a product of Naito Densei Machida Mfg. Co., Ltd.

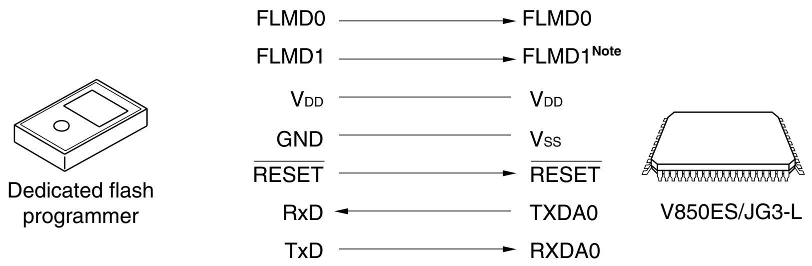
28.4.2 Communication mode

Communication between the dedicated flash programmer and the V850ES/JG3-L is performed by serial communication using the UARTA0, CSIB0, or CSIB3 interfaces of the V850ES/JG3-L.

(1) UARTA0

Transfer rate: 9,600 to 153,600 bps

Figure 28-3. Communication with Dedicated Flash Programmer (UARTA0)

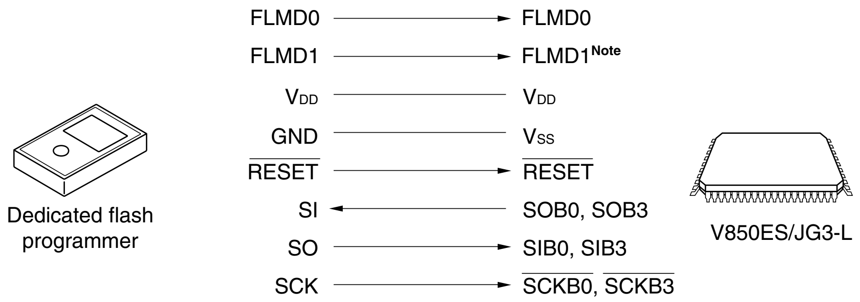


Note Connect the FLMD1 pin to the flash programmer or connect to GND via a pull-down resistor on the board.

(2) CSIB0, CSIB3

Serial clock: 2.4 kHz to 2.5 MHz (MSB first)

Figure 28-4. Communication with Dedicated Flash Programmer (CSIB0, CSIB3)

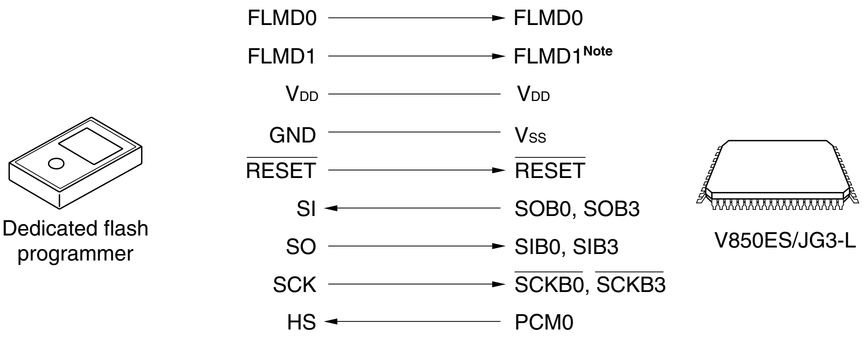


Note Connect the FLMD1 pin to the flash programmer or connect to GND via a pull-down resistor on the board.

(3) CSIB0 + HS, CSIB3 + HS

Serial clock: 2.4 kHz to 2.5 MHz (MSB first)

Figure 28-5. Communication with Dedicated Flash Programmer (CSIB0 + HS, CSIB3 + HS)



Note Connect the FLMD1 pin to the flash programmer or connect to GND via a pull-down resistor on the board.

The dedicated flash programmer outputs the transfer clock, and the V850ES/JG3-L operates as a slave.

When the PG-FP5 is used as the dedicated flash programmer, it generates the following signals to the V850ES/JG3-L. For details, refer to the **PG-FP5 User's Manual (U18865E)**.

Table 28-5. Signal Connections of Dedicated Flash Programmer (PG-FP5)

PG-FP5			V850ES/JG3-L	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	◎Note 1	◎Note 1	◎Note 1
VDD	–	VDD voltage generation/voltage monitor	VDD	◎	◎	◎
GND	–	Ground	VSS	◎	◎	◎
CLK	Output	Clock output to V850ES/JG3-L	X1, X2	×Note 2	×Note 2	×Note 2
RESET	Output	Reset signal	RESET	◎	◎	◎
SI/RxD	Input	Receive signal	SOB0, SOB3/ TXDA0	◎	◎	◎
SO/TxD	Output	Transmit signal	SIB0, SIB3/ 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 Figures 28-6 and 28-7, or connect then 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 28-6. Wiring of V850ES/JG3-L Flash Writing Adapters (FA-100GF-GAS-B, FA-100GC-UEU-B) (1/2)

Flash Programmer (FG-FP5) Connection Pin			Name of FA Board Pin	CSIB0 + HS Used			CSIB0 Used			UARTA0 Used		
Signal Name	I/O	Pin Function		Pin Name	Pin No.		Pin Name	Pin No.		Pin Name	Pin No.	
					GF	GC		GF	GC		GF	GC
SI/RxD	Input	Receive signal	SI	P41/SOB0/SCL01	25	23	P41/SOB0/SCL01	25	23	P30/TXDA0/SOB4	27	25
SO/TxD	Output	Transmit signal	SO	P40/SIB0/SDA01	24	22	P40/SIB0/SDA01	24	22	P31/RXDA0/INTP7/SIB4	28	26
SCK	Output	Transfer clock	SCK	P42/$\overline{\text{SCKB0}}$	26	24	P42/$\overline{\text{SCKB0}}$	26	24	Not needed	–	–
CLK	Output	Clock to V850ES/JG3-L	X1	Not needed	–	–	Not needed	–	–	Not needed	–	–
			X2	Not needed	–	–	Not needed	–	–	Not needed	–	–
/RESET	Output	Reset signal	/RESET	$\overline{\text{RESET}}$	16	14	$\overline{\text{RESET}}$	16	14	$\overline{\text{RESET}}$	16	14
FLMD0	Output	Write voltage	FLMD0	FLMD0	10	8	FLMD0	10	8	FLMD0	10	8
FLMD1	Output	Write voltage	FLMD1	PDL5/AD5/FLMD1	78	76	PDL5/AD5/FLMD1	78	76	PDL5/AD5/FLMD1	78	76
HS	Input	Handshake signal for CSI0 + HS communication	RESERVE/HS	PCM0/$\overline{\text{WAIT}}$	63	61	Not needed	–	–	Not needed	–	–
VDD	–	VDD voltage generation/ voltage monitor	VDD	V_{DD}	11	9	V_{DD}	11	9	V_{DD}	11	9
				EV_{DD}	36, 72	34, 70	EV_{DD}	36, 72	34, 70	EV_{DD}	36, 72	34, 70
				AV_{REF0}	3	1	AV_{REF0}	3	1	AV_{REF0}	3	1
				AV_{REF1}	7	5	AV_{REF1}	7	5	AV_{REF1}	7	5
GND	–	Ground	GND	V_{SS}	13	11	V_{SS}	13	11	V_{SS}	13	11
				AV_{SS}	4	2	AV_{SS}	4	2	AV_{SS}	4	2
				EV_{SS}	35, 71	33, 69	EV_{SS}	35, 71	33, 69	EV_{SS}	35, 71	33, 69

Cautions 1. Be sure to connect the REGC pin to GND via 4.7 μF (preliminary value) capacitor.

2. Clock cannot be supplied from the CLK pin of the flash programmer. Create an oscillator on the board and supply clock.

Remark GF: 100-pin plastic LQFP (14 × 20)

GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

Table 28-6. Wiring of V850ES/JG3-L Flash Writing Adapters (FA-100GF-GAS-B and FA-100GC-UEU-B) (2/2)

Flash Programmer (FG-FP5) Connection Pin			Name of FA Board Pin	CSIB3 + HS Used			CSIB3 Used		
Signal Name	I/O	Pin Function		Pin Name	Pin No.		Pin Name	Pin No.	
					GF	GC		GF	GC
SI/RxD	Input	Receive signal	SI	P911/A11/SOB3	56	54	P911/A11/SOB3	56	54
SO/TxD	Output	Transmit signal	SO	P910/A10/SIB3	55	53	P910/A10/SIB3	55	53
SCK	Output	Transfer clock	SCK	P912/A12/$\overline{\text{SCKB3}}$	57	55	P912/A12/$\overline{\text{SCKB3}}$	57	55
CLK	Output	Clock to V850ES/JG3-L	X1	Not needed	–	–	Not needed	–	–
			X2	Not needed	–	–	Not needed	–	–
/RESET	Output	Reset signal	/RESET	$\overline{\text{RESET}}$	16	14	$\overline{\text{RESET}}$	16	14
FLMD0	Output	Write voltage	FLMD0	FLMD0	10	8	FLMD0	10	8
FLMD1	Output	Write voltage	FLMD1	PDL5/AD5/FLMD1	78	76	PDL5/AD5/FLMD1	78	76
HS	Input	Handshake signal for CSI0 + HS communication	RESERVE/HS	PCM0/$\overline{\text{WAIT}}$	63	61	Not needed	–	–
VDD	–	VDD voltage generation/ voltage monitor	VDD	V_{DD}	11	9	V_{DD}	11	9
				EV_{DD}	36, 72	34, 70	EV_{DD}	36, 72	34, 70
				AV_{REF0}	3	1	AV_{REF0}	3	1
				AV_{REF1}	7	5	AV_{REF1}	7	5
GND	–	Ground	GND	V_{SS}	13	11	V_{SS}	13	11
				AV_{SS}	4	2	AV_{SS}	4	2
				EV_{SS}	35, 71	33, 69	EV_{SS}	35, 71	33, 69

Cautions 1. Be sure to connect the REGC pin to GND via 4.7 μF (preliminary value) capacitor.

2. Clock cannot be supplied from the CLK pin of the flash programmer.
Create an oscillator on the board and supply clock.

Remark GF: 100-pin plastic LQFP (14 × 20)
GC: 100-pin plastic LQFP (fine pitch) (14 × 14)

Figure 28-6. Wiring Example of V850ES/JG3-L Flash Writing Adapter (FA-100GF-GAS-B) (In CSIB0 + HS Mode) (1/2)

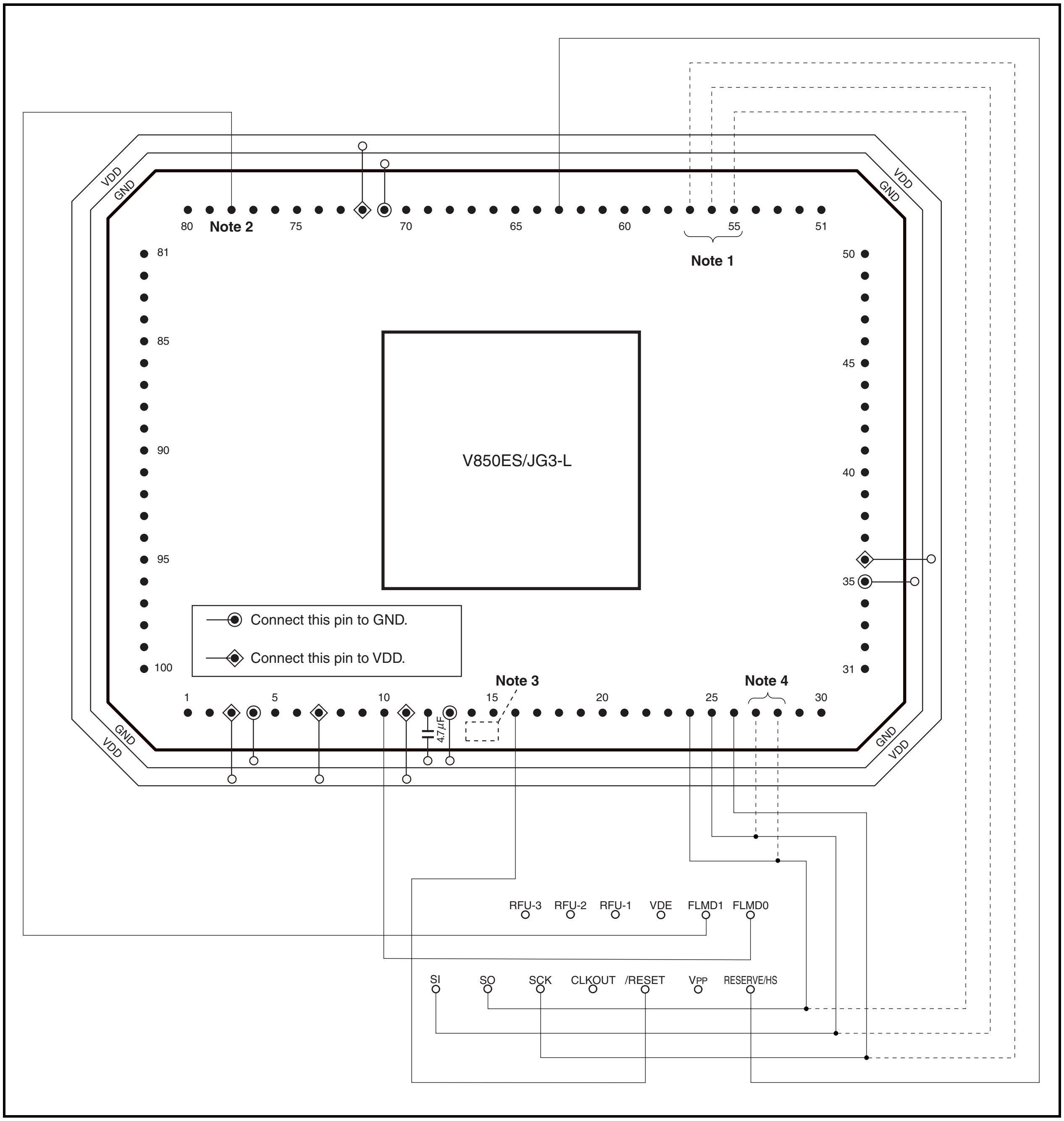


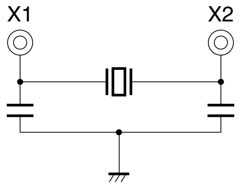
Figure 28-6. Wiring Example of V850ES/JG3-L Flash Writing Adapter (FA-100GF-GAS-B) (In CSIB0 + HS Mode) (2/2)

Notes 1. Corresponding pins when CSIB3 is used.

2. Wire the FLMD1 pin as shown below, or connect it to GND on board via a pull-down resistor.

3. Create an oscillator on the flash writing adapter (shown in broken lines) and supply a clock. Here is an example of the oscillator.

Example:



4. Corresponding pins 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 the handling of unused pins (see **2.3 Pin I/O Circuit Types, I/O Buffer Power Supplies, and Connection of Unused Pins**).

2. This adapter is for the 100-pin plastic LQFP package.

Figure 28-7. Wiring Example of V850ES/JG3-L Flash Writing Adapter (FA-100GC-UEU-B) (In CSIB0 + HS Mode) (1/2)

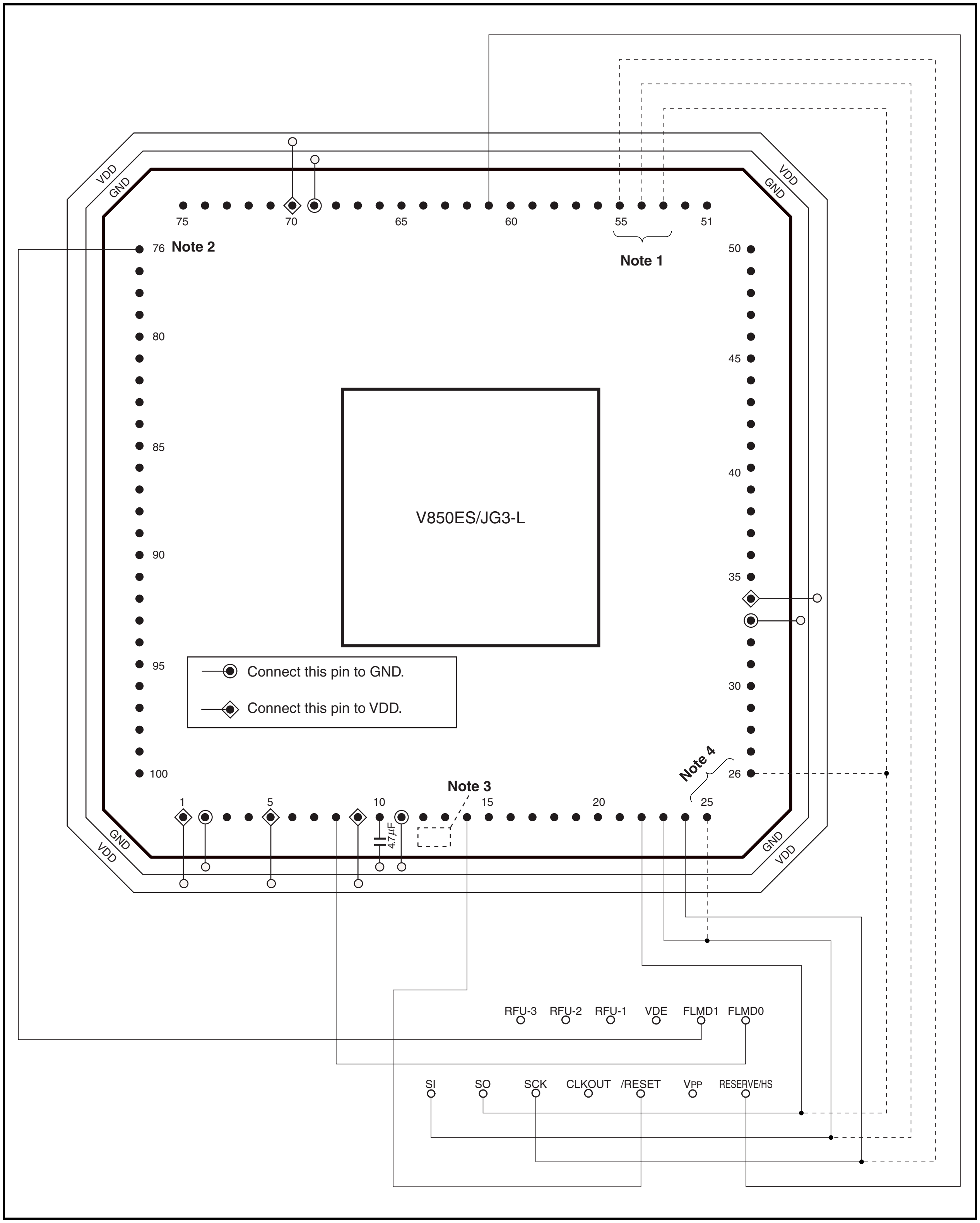


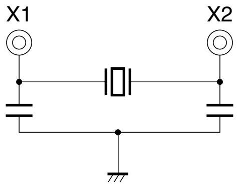
Figure 28-7. Wiring Example of V850ES/JG3-L Flash Writing Adapter (FA-100GC-UEU-B) (In CSIB0 + HS Mode) (2/2)

Notes 1. Corresponding pins when CSIB3 is used.

2. Wire the FLMD1 pin as shown below, or connect it to GND on board via a pull-down resistor.

3. Create an oscillator on the flash writing adapter (shown in broken lines) and supply a clock. Here is an example of the oscillator.

Example:



4. Corresponding pins when UARTA0 is used.

Caution Do not input a high level to the $\overline{\text{DRST}}$ pin.

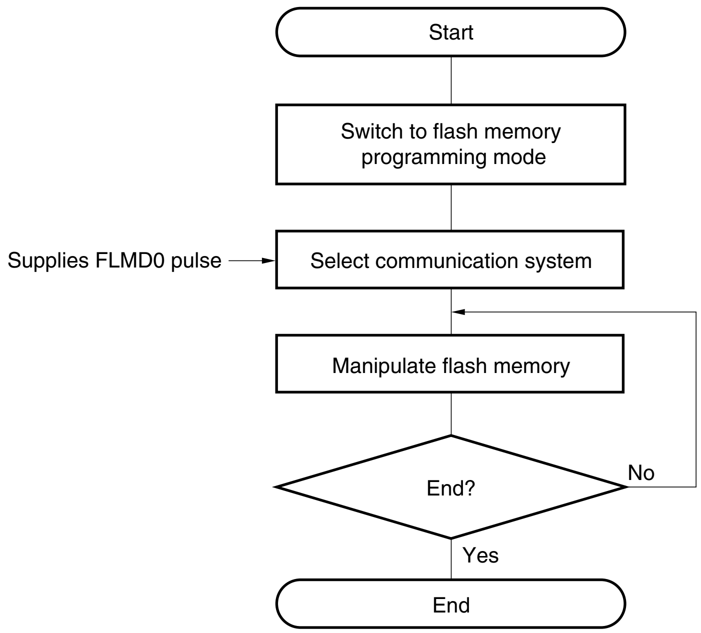
Remarks 1. Process the pins not shown in accordance with the handling of unused pins (see **2.3 Pin I/O Circuit Types, I/O Buffer Power Supplies, and Connection of Unused Pins**).

2. This adapter is for the 100-pin plastic LQFP package.

28.4.3 Flash memory control

The following shows the procedure for manipulating the flash memory.

Figure 28-8. Procedure for Manipulating Flash Memory

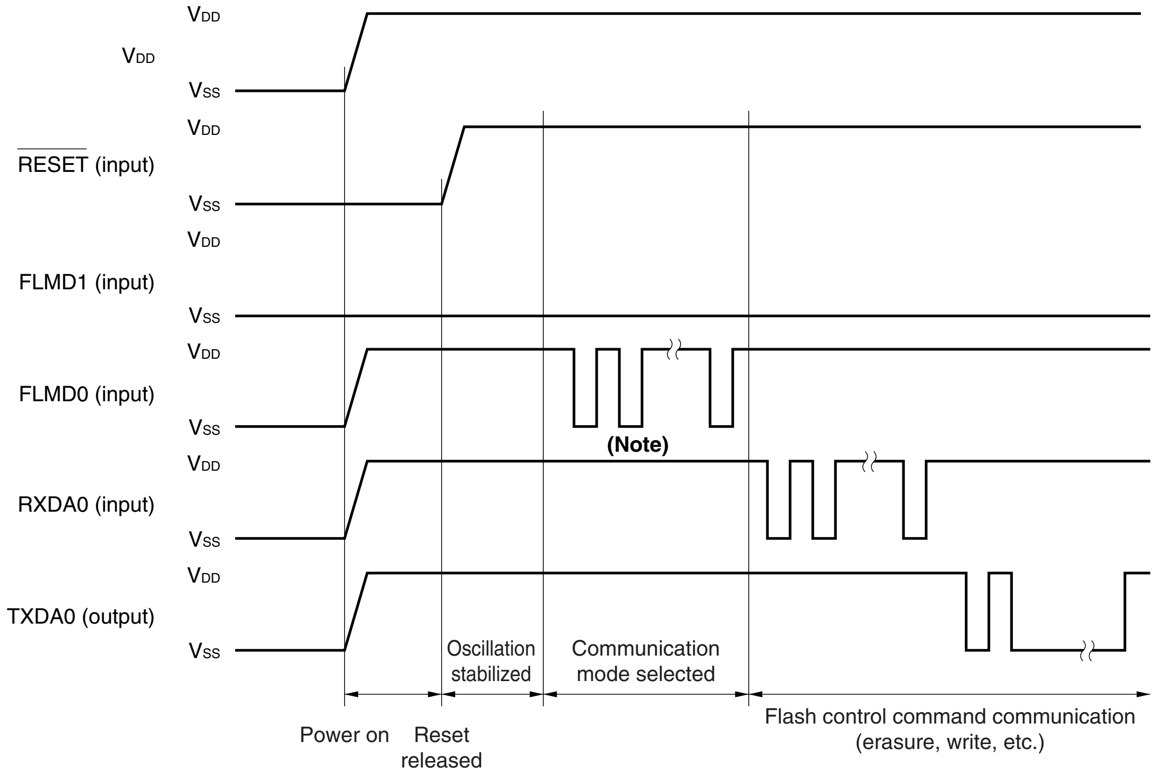


28.4.4 Selection of communication mode

In the V850ES/JG3-L, 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 28-9. Selection of Communication Mode



Note The number of clocks is as follows depending on the communication mode.

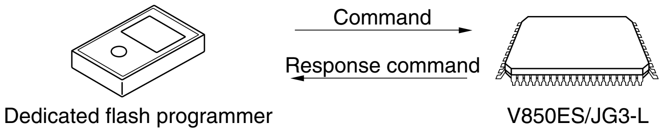
FLMD0 Pulse	Communication Mode	Remarks
0	UARTA0	Communication rate: 9,600 bps (after reset), LSB first
8	CSIB0	V850ES/JG3-L performs slave operation, MSB first
9	CSIB3	V850ES/JG3-L performs slave operation, MSB first
11	CSIB0 + HS	V850ES/JG3-L performs slave operation, MSB first
12	CSIB3 + HS	V850ES/JG3-L 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.**

28.4.5 Communication commands

The V850ES/JG3-L communicates with the dedicated flash programmer by means of commands. The signals sent from the dedicated flash programmer to the V850ES/JG3-L are called “commands”. The response signals sent from the V850ES/JG3-L to the dedicated flash programmer are called “response commands”.

Figure 28-10. Communication Commands



The following shows the commands for flash memory control in the V850ES/JG3-L. All of these commands are issued from the dedicated flash programmer, and the V850ES/JG3-L performs the processing corresponding to the commands.

Table 28-7. 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	√	√	√	Prohibits the chip erase command, block erase command, program command, read command, and boot area rewrite.

28.4.6 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.

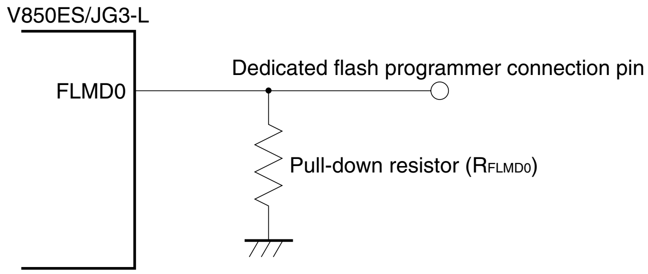
In the flash memory programming mode, all the pins not used for flash memory programming become the same status as that immediately after reset. Therefore, pin handling is required when the external device does not acknowledge the status immediately after a reset.

(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 **28.5.5 (1) FLMD0 pin**.

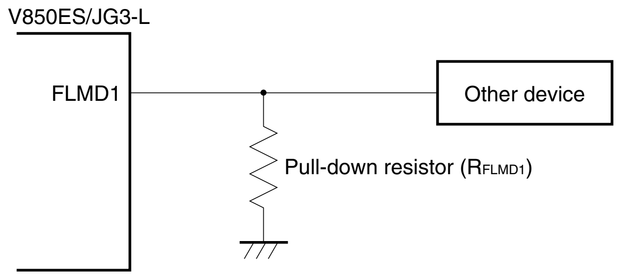
Figure 28-11. FLMD0 Pin Connection Example



(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 28-12. FLMD1 Pin Connection Example



Caution 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.

Table 28-8. 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_{DD}	0	Flash memory programming mode
V_{DD}	V_{DD}	Setting prohibited

(3) Serial interface pin

The following shows the pins used by each serial interface.

Table 28-9. Pins Used by Serial Interfaces

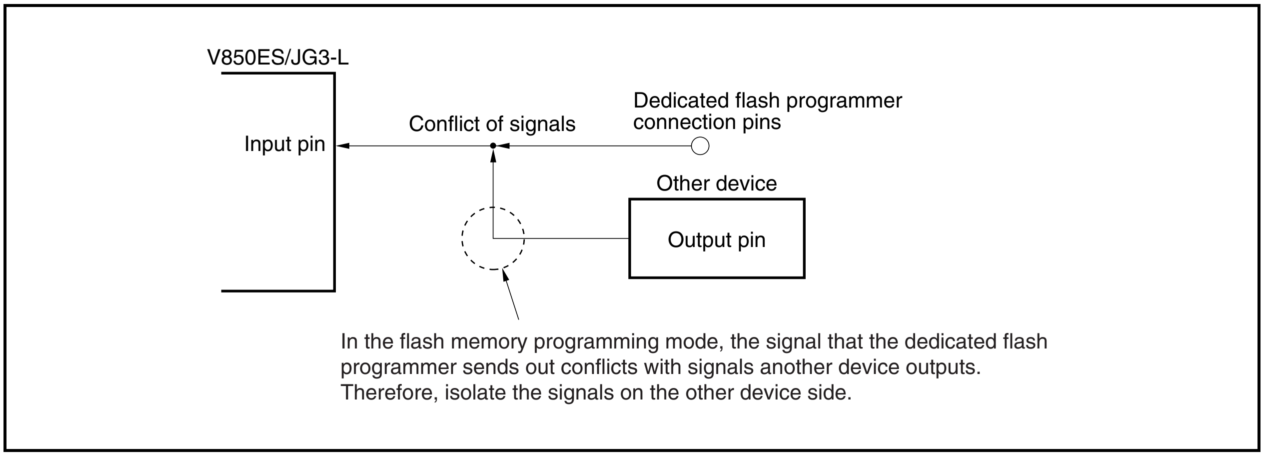
Serial Interface	Pins Used
UARTA0	TXDA0, RXDA0
CSIB0	SOB0, SIB0, $\overline{\text{SCKB0}}$
CSIB3	SOB3, SIB3, $\overline{\text{SCKB3}}$
CSIB0 + HS	SOB0, SIB0, $\overline{\text{SCKB0}}$, PCM0
CSIB3 + HS	SOB3, SIB3, $\overline{\text{SCKB3}}$, PCM0

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.

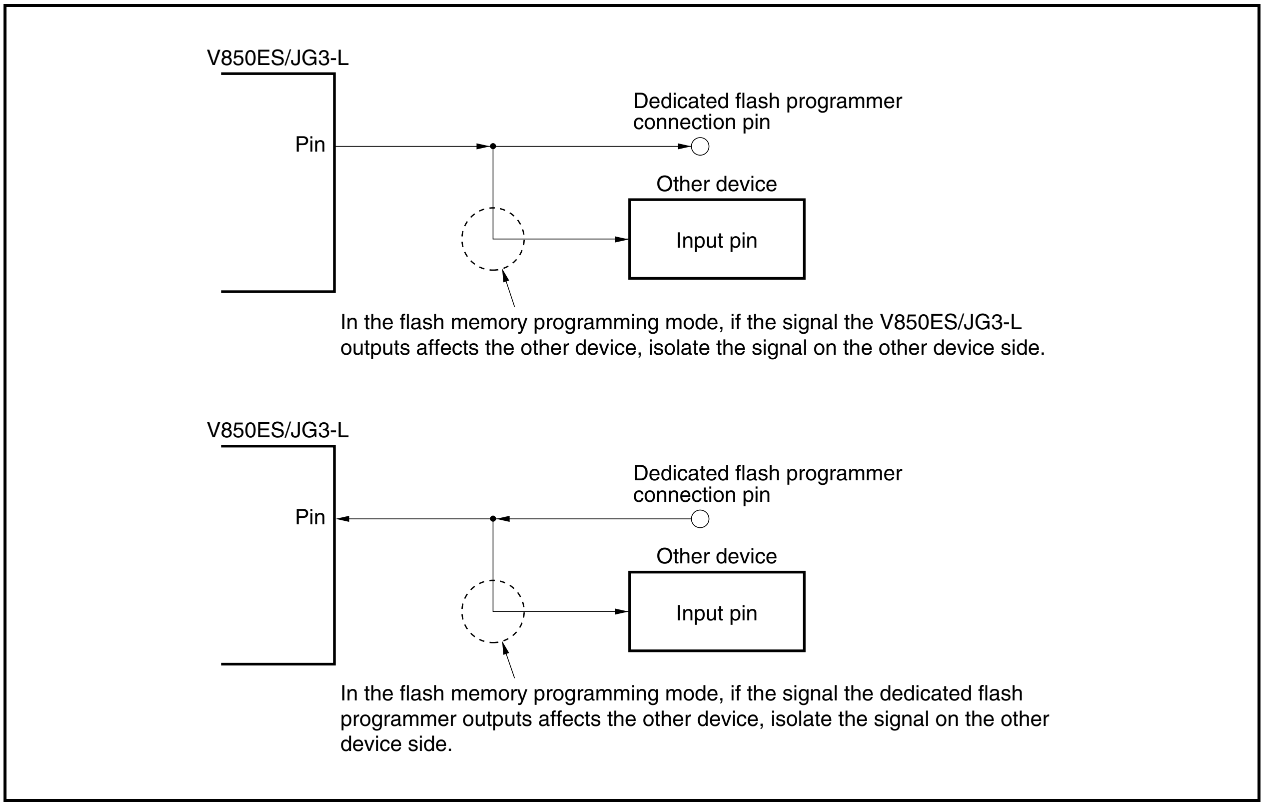
Figure 28-13. Conflict of Signals (Serial Interface Input Pin)



(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 28-14. Malfunction of Other Device



In the flash memory programming mode, if the signal the V850ES/JG3-L outputs affects the other device, isolate the signal on the other device side.

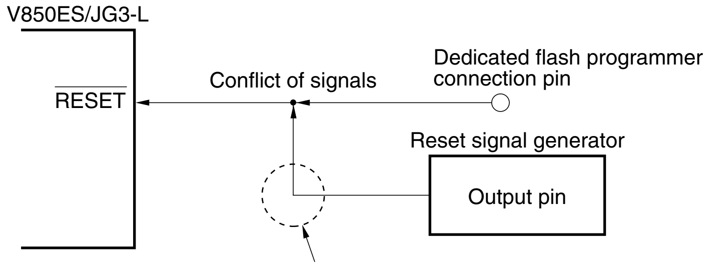
In the flash memory programming mode, if the signal the dedicated flash programmer outputs affects the other device, isolate the signal on the other device side.

(4) $\overline{\text{RESET}}$ 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 28-15. Conflict of Signals ($\overline{\text{RESET}}$ Pin)



In the flash memory programming mode, the signal the reset signal generator outputs conflicts with the signal the dedicated flash programmer outputs. Therefore, isolate the signals on the reset signal generator side.

(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.

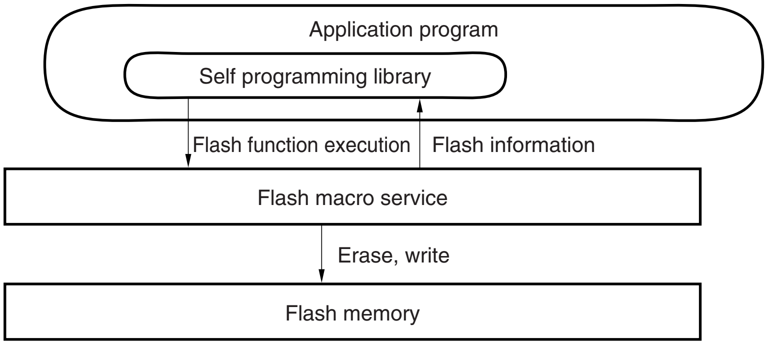
28.5 Rewriting by Self Programming

28.5.1 Overview

The V850ES/JG3-L 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[Note] can be rewritten in the field.

Note Be sure not to allocate the program code to the block where the constant data of rewriting target is allocated. See **28.2 Memory Configuration** for the block configuration.

Figure 28-16. Concept of Self Programming

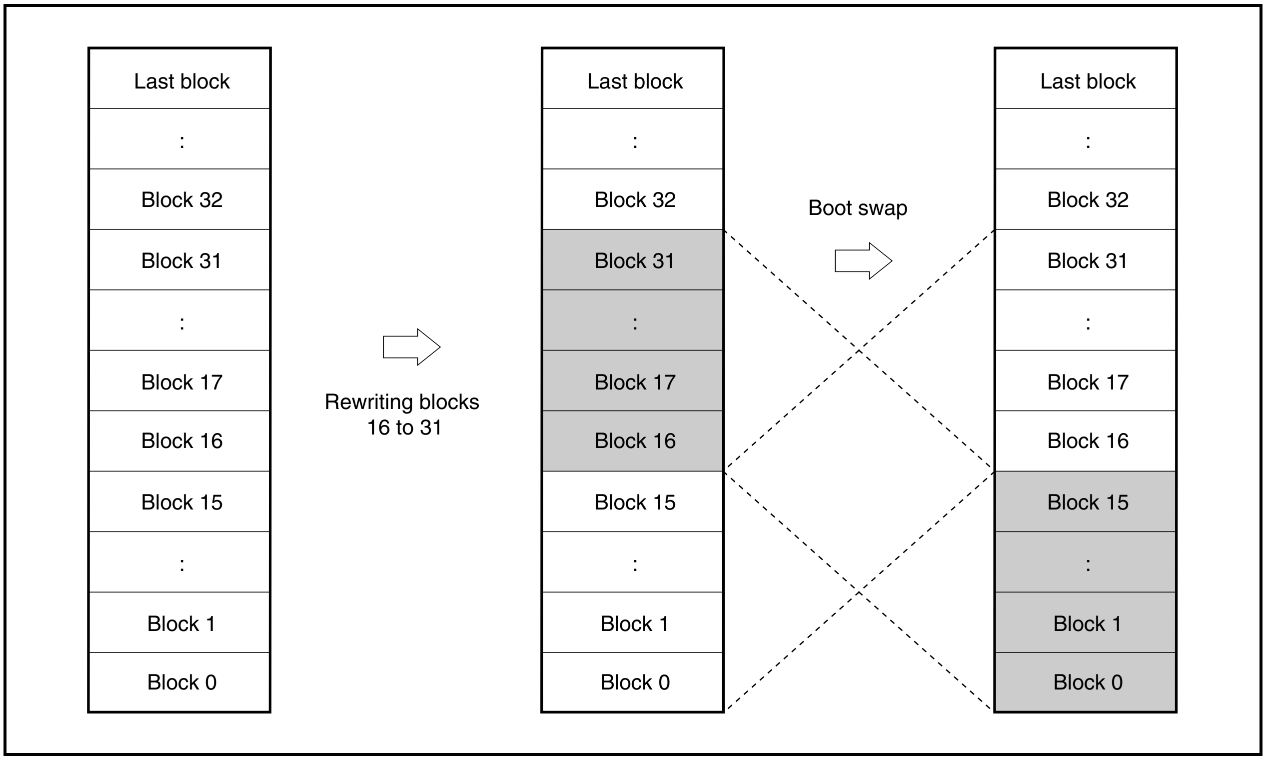


28.5.2 Features

(1) Secure self programming (boot swap function)

The V850ES/JG3-L 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 28-17. Rewriting Entire Memory Area (Boot Swap)



(2) Interrupt support

Instructions cannot be fetched from the flash memory during self-programming. Consequently, a user handler written to the flash memory could not be used even if an interrupt has occurred.

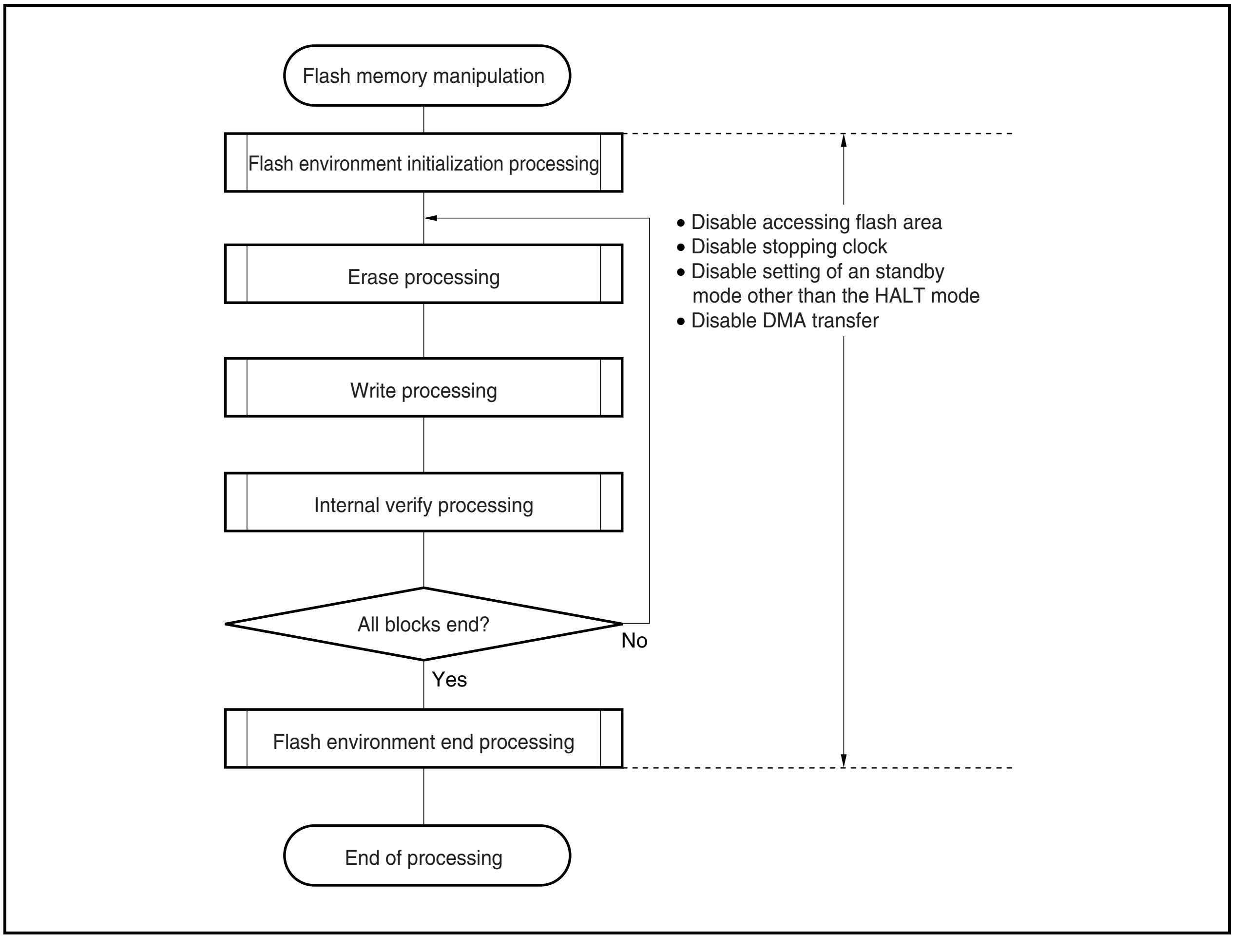
Therefore, in the V850ES/JG3-L, to use an interrupt during self-programming, processing transits to the specific address[Note] in the internal RAM. Allocate the jump instruction that transits processing to the user interrupt servicing at the specific address[Note] in the internal RAM.

Note NMI interrupt: Start address of internal RAM
Maskable interrupt: Start address of internal RAM + 4 addresses

28.5.3 Standard self programming flow

The entire processing to rewrite the flash memory by flash self programming is illustrated below.

Figure 28-18. Standard Self Programming Flow



28.5.4 Flash functions

Table 28-10. Flash Function List

Function Name	Outline	Support
FlashInit	Self-programming library initialization	√
FlashEnv	Flash environment start/end	√
FlashFLMDCheck	FLMD pin check	√
FlashStatusCheck	Hardware processing execution status check	√
FlashBlockErase	Block erase	√
FlashWordWrite	Data write	√
FlashBlockIVerify	Internal verification of block	√
FlashBlockBlankCheck	Blank check of block	√
FlashSetInfo	Flash information setting	√
FlashGetInfo	Flash information acquisition	√
FlashBootSwap	Boot swap execution	√

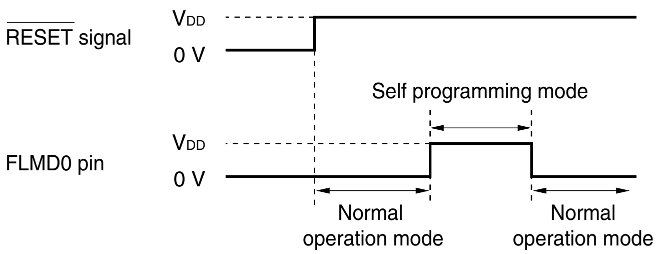
28.5.5 Pin processing

(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 28-19. Mode Change Timing



Caution Make sure that the FLMD0 pin is at 0 V when reset is released.

28.5.6 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 28-11. Internal Resources Used

Resource Name	Description
Stack area	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[Note]	Program entity of library (can be used anywhere other than the flash memory block to be manipulated).
Application program	Executed as user application. 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, since the processing transits to the address of the internal RAM start address + 4 addresses, allocate the jump instruction that transits the processing to the user interrupt servicing at the address of the internal RAM start address + 4 addresses in advance.
NMI interrupt	Can be used in the 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.

Note About resources used, refer to the **Flash Memory Self-Programming Library User's Manual**.

CHAPTER 29 ON-CHIP DEBUG FUNCTION

The V850ES/JG3-L 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/JG3-L, with using the $\overline{\mathrm{DRST}}$, 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 29-1. On-Chip Debug Function Features

		Debugging Using DCU	Debugging Without Using DCU
Debug interface pins		$\overline{\mathrm{DRST}}$, DCK, DMS, DDI, DDO	• When UARTA0 is used RXD0, TXD0 • When CSIB0 is used SIB0, SOB0, $\overline{\mathrm{SCKB0}}$, HS (PCM0) • When CSIB3 is used SIB3, SOB3, $\overline{\mathrm{SCKB3}}$, HS (PCM0)
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[Note 1]		Available	Available
Dynamic memory modification (DMM) function[Note 2]		Available	Available
Mask function		Reset, NMI, INTWDT2, $\overline{\mathrm{HLDRQ}}$, $\overline{\mathrm{WAIT}}$	$\overline{\mathrm{RESET}}$ pin
ROM security function		10-byte ID code authentication	10-byte ID code authentication
Hardware used		NINICUBE®, 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.

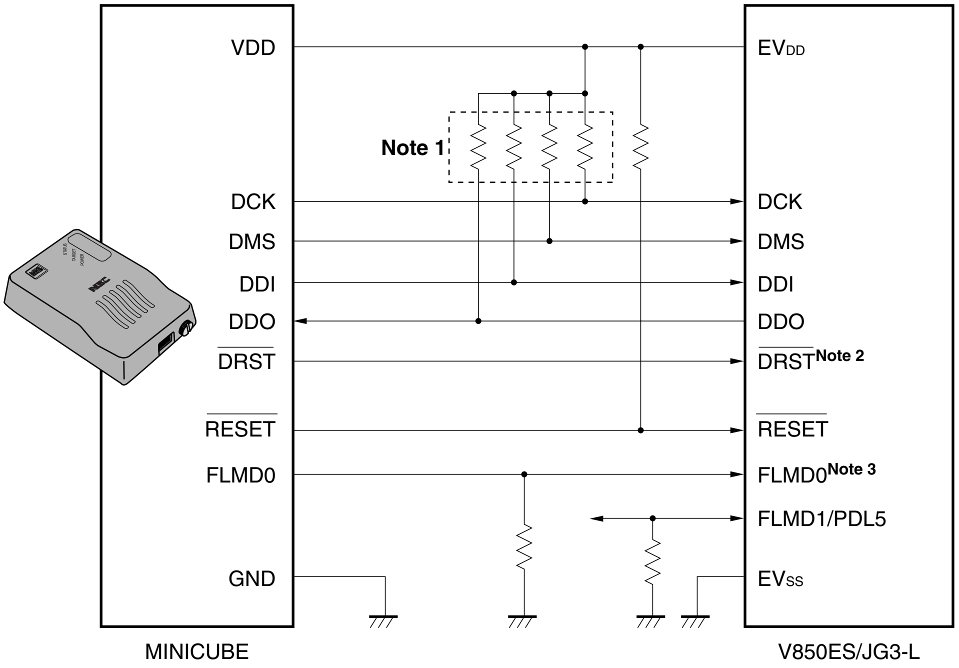
2. This is a function which rewrites RAM contents during program execution.

29.1 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).

29.1.1 Connection circuit example

Figure 29-1. Circuit Connection Example When Debug Interface Pins Are Used for Communication Interface



Notes 1. Example of pin connection when MINICUBE is not connected

2. A pull-down resistor is provided on chip.

3. For flash memory rewriting

29.1.2 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_{DD}

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. 3.40 Integrated Debugger Operation User's Manual (U18604E)**.

(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).

29.1.3 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/JG3-L functions are listed below.

Table 29-2. Maskable Functions

Maskable Functions with ID850QB	Corresponding V850ES/JG3-L 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

29.1.4 Register

(1) On-chip debug mode register (OCDM)

This register is 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.

This register is a special register and can be written only in a combination of specific sequences (see **3.4.7 Special registers**).

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[Note] R/W Address: FFFFF9FCH

	7	6	5	4	3	2	1	<0>
OCDM	0	0	0	0	0	0	0	OCDM0

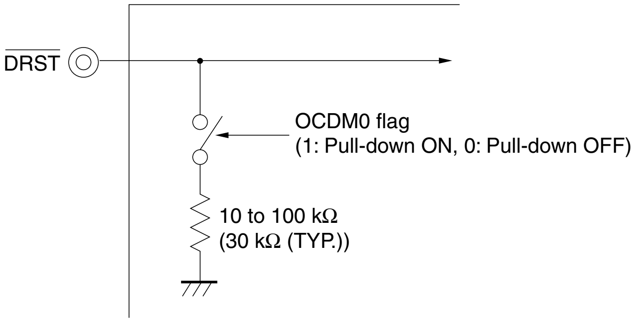
OCDM0	Operation mode
0	Selects normal operation mode (in which a pin that functions alternately as on-chip debug function pin is used as a port/peripheral function pin) and disconnects the on-chip pull-down resistor of the P05/INTP2/$\overline{\text{DRST}}$ pin.
1	When $\overline{\text{DRST}}$ pin is low: 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) When $\overline{\text{DRST}}$ pin is high: 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 OCDM 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.



29.1.5 Operation

The on-chip debug function is made invalid under the conditions shown in the table below.

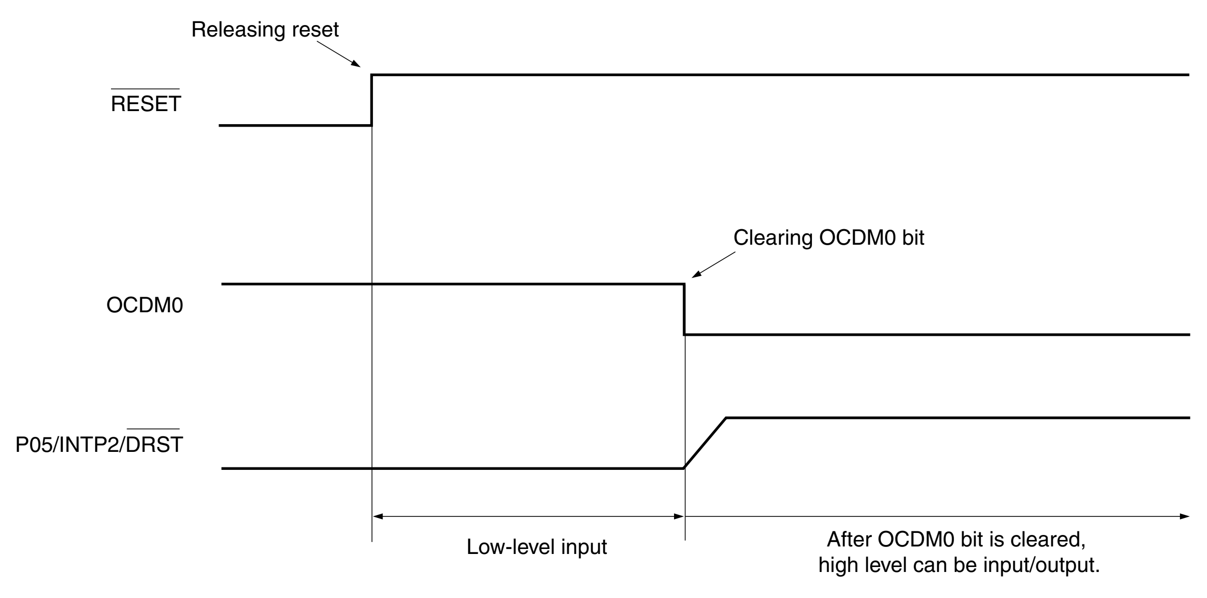
When this function is not used, keep the $\overline{\text{DRST}}$ pin low until the OCDM.OCDM0 flag is cleared to 0.

OCDM0 Flag $\overline{\text{DRST}}$ Pin	0	1
L	Invalid	Invalid
H	Invalid	Valid

Remark L: Low-level input

H: High-level input

Figure 29-2. Timing When On-Chip Debug Function Is Not Used



29.1.6 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.

(5) On-chip debugging can be used when the supply voltage (V_{DD}) is in a range of 2.7 to 3.6 V. It cannot be used at less than 2.7 V.

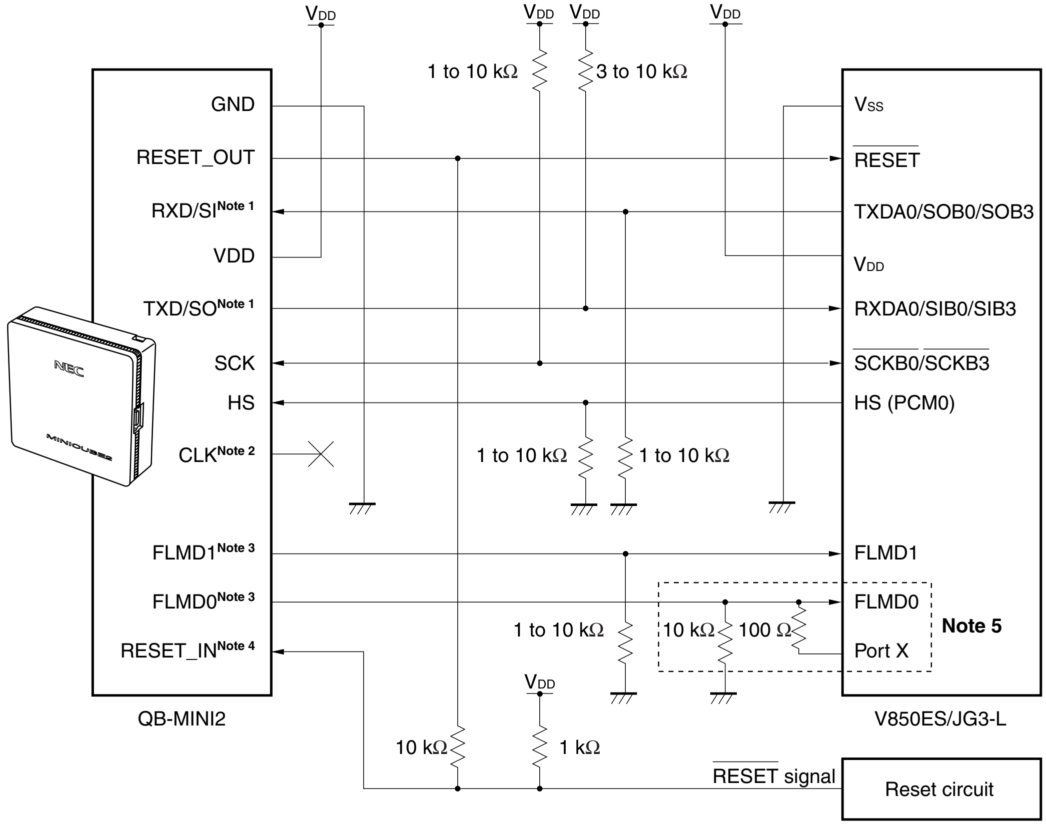
(6) In the on-chip debug mode, the output voltage of the regulator does not decrease even in the low-voltage STOP mode, low-voltage subclock operation mode, or low-voltage sub-IDLE mode

29.2 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, SCKB0, and HS (PMC0)), or pins for CSIB3 (SIB3, SOB3, SCKB3, and HS (PMC0)) as debug interfaces, without using the DCU.

29.2.1 Circuit connection examples

Figure 29-3. Circuit Connection Example When UARTA0/CSIB0/CSIB3 Is Used for Communication Interface



Notes 1. Connect TXDA0/SOB0/SOB3 (transmit side) of the V850ES/JG3-L to RXD/SI (receive side) of the target connector, and TXD/SO (transmit side) of the target connector to RXDA0/SIB0/SIB3 (receive side) of the V850ES/JG3-L.

2. This pin may be used to supply a clock from MINICUBE2 during flash memory programming. For details, see **CHAPTER 28 FLASH MEMORY**.

3. The V850ES/JG3-L-side pin connected to this pin (FLMD0, FLMD1) can be used as an alternate-function pin other than while the memory is rewritten during a break in debugging, because this pin is in Hi-Z state.

4. This connection is designed assuming that the RESET signal is output from the N-ch open-drain buffer (output resistance: 100 Ω or less).

5. The circuit enclosed by a dashed line is designed for flash self programming, which controls the FLMD0 pin via ports. Use the port for inputting or outputting the high level. When flash self programming is not performed, a pull-down resistance for the FLMD0 pin can be within 1 to 10 kΩ.

Remark See **Table 29-3** for pins used when UARTA0, CSIB0, or CSIB3 is used for communication interface.

Table 29-3. Wiring Between V850ES/JG3-L 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.	
				GC	GF		GC	GF		GC	GF
SI/RxD	Input	Pin to receive commands and data from V850ES/JG3-L	P41/SOB0	23	25	P911/SOB3	54	56	P30/TXDA0	25	27
SO/TxD	Output	Pin to transmit commands and data to V850ES/JG3-L	P40/SIB0	22	24	P910/SIB3	53	55	P31/RXDA0	26	28
SCK	Output	Clock output pin for 3-wire serial communication	P42/$\overline{\text{SCKB0}}$	24	26	P912/$\overline{\text{SCKB3}}$	55	57	Not needed	–	–
CLK[Note]	Output	Clock output pin to V850ES/JG3-L	Not needed[Note]	–	–	Not needed[Note]	–	–	Not needed[Note]	–	–
			Not needed[Note]	–	–	Not needed[Note]	–	–	Not needed[Note]	–	–
RESET_OUT	Output	Reset output pin to V850ES/JG3-L	$\overline{\text{RESET}}$	14	16	$\overline{\text{RESET}}$	14	16	$\overline{\text{RESET}}$	14	16
FLMD0	Output	Output pin to set V850ES/JG3-L to debug mode or programming mode	FLMD0	8	10	FLMD0	8	10	FLMD0	8	10
FLMD1	Output	Output pin to set programming mode	PDL5/FLMD1	76	78	PDL5/FLMD1	76	78	PDL5/FLMD1	76	78
HS	Input	Handshake signal for CSI0 + HS communication	PCM0/$\overline{\text{WAIT}}$	61	63	PCM0/$\overline{\text{WAIT}}$	61	63	Not needed	–	–
GND	–	Ground	V_{SS}	11	13	V_{SS}	11	13	V_{SS}	11	13
			AV_{SS}	2	4	AV_{SS}	2	4	AV_{SS}	2	4
			EV_{SS}	33, 69	35, 71	EV_{SS}	33, 69	35, 71	EV_{SS}	33, 69	35, 71
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, see **CHAPTER 28 FLASH MEMORY**.

Remark GC: 100-pin plastic LQFP (fine pitch) (14 × 14)
GF: 100-pin plastic LQFP (14 × 20)

29.2.2 Maskable functions

Only reset signals can be masked.

The maskable functions with the debugger (ID850QB) and the corresponding V850ES/JG3-L functions are listed below.

Table 29-4. Maskable Functions

Maskable Functions with ID850QB	Corresponding V850ES/JG3-L Functions
NMI0	–
NMI1	–
NMI2	–
STOP	–
HOLD	–
RESET	Reset signal generation by $\overline{\text{RESET}}$ pin input
WAIT	–

29.2.3 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.

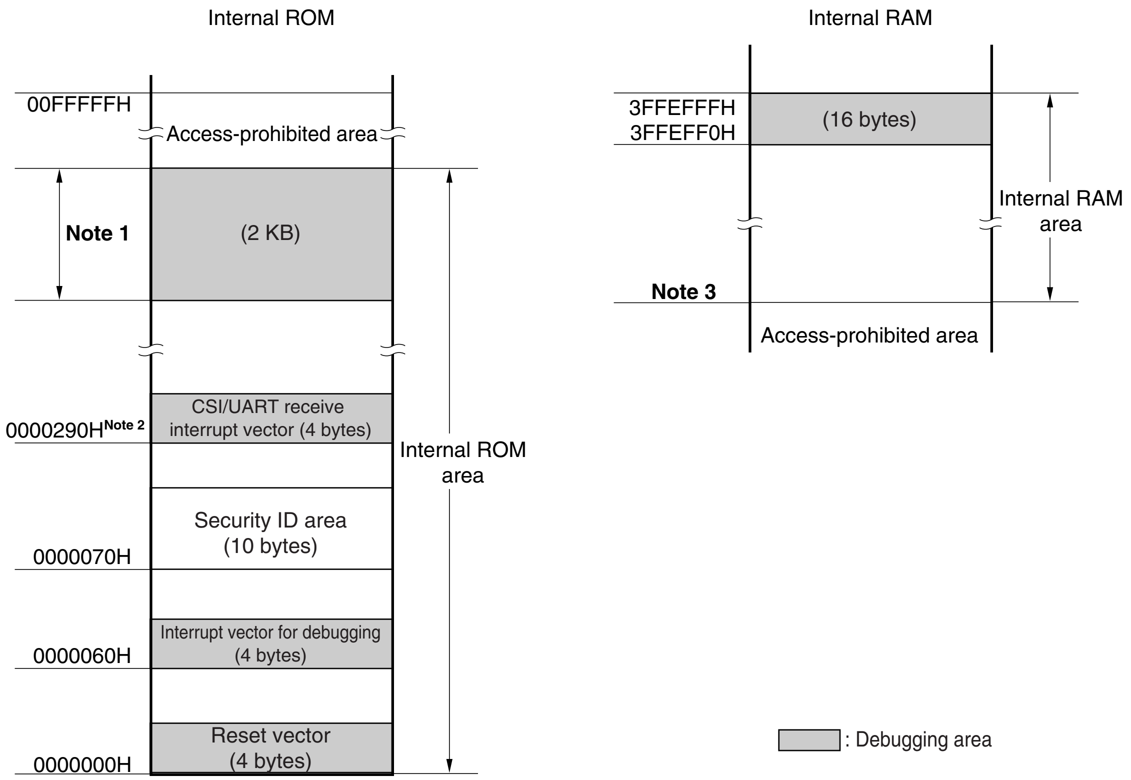
(1) Securement of memory space

The shaded portions in Figure 29-4 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 29-4, to prevent the memory from being read by an unauthorized person. For details, see **29.3 ROM Security Function**.

Figure 29-4. Memory Spaces Where Debug Monitor Programs Are Allocated



Notes 1. Address values vary depending on the product.

	Internal ROM Size	Address Value
μPD70F3737	128 KB	001F800H to 001FFFFH
μPD70F3738	256 KB	003F800H to 003FFFFH

2. This is the address when CSIB0 is used. It starts at 00002F0H when CSIB3 is used, and at 0000310H when UARTA0 is used.

3. Address values vary depending on the product.

	Internal RAM Size	Address Value
μPD70F3737	8 KB	3FFD000H
μPD70F3738	16 KB	3FFB000H

(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 (F0C34 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 29-4 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 256 KB (end address is 003FFFFH) and internal RAM has 16 KB (end address is 3FFEFFFH).

```
MROMSEG      : !LOAD ?R V0x03f800{
             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).

(a) When CSIB0 is used

	7	6	5	4	3	2	1	0
CB0RIC	×	0	×	×	×	×	×	×

(b) When CSIB3 is used

	7	6	5	4	3	2	1	0
CB3RIC	×	0	×	×	×	×	×	×

(C) When UARTA0 is used

	7	6	5	4	3	2	1	0
UA0RIC	×	0	×	×	×	×	×	×

Remark ×: 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	×	×	×	×	×	×	×	**Note**

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	×	×	×	×	×	×	×	**Note**

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

29.2.4 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.

(7) On-chip debugging can be used when the supply voltage (V_{DD}) is in a range of 2.7 to 3.6 V. It cannot be used at less than 2.7 V.

29.3 ROM Security Function

29.3.1 Security ID

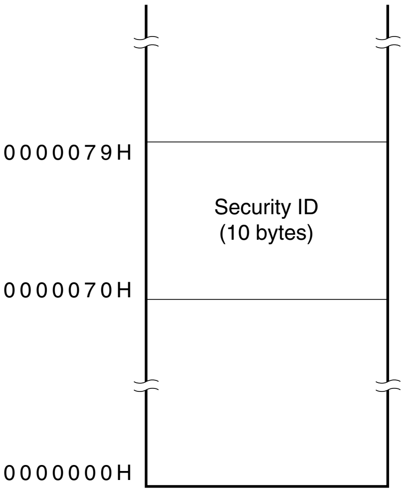
The flash memory versions of the V850ES/JG3-L perform authentication using a 10-byte ID code to prevent the contents of the flash memory from being read by an unauthorized person during on-chip debugging by the on-chip debug emulator.

Set the ID code in the 10-byte internal 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 29-5. Security ID Area



Caution After the flash memory is erased, 1 is written to the entire area.

29.3.2 Setting

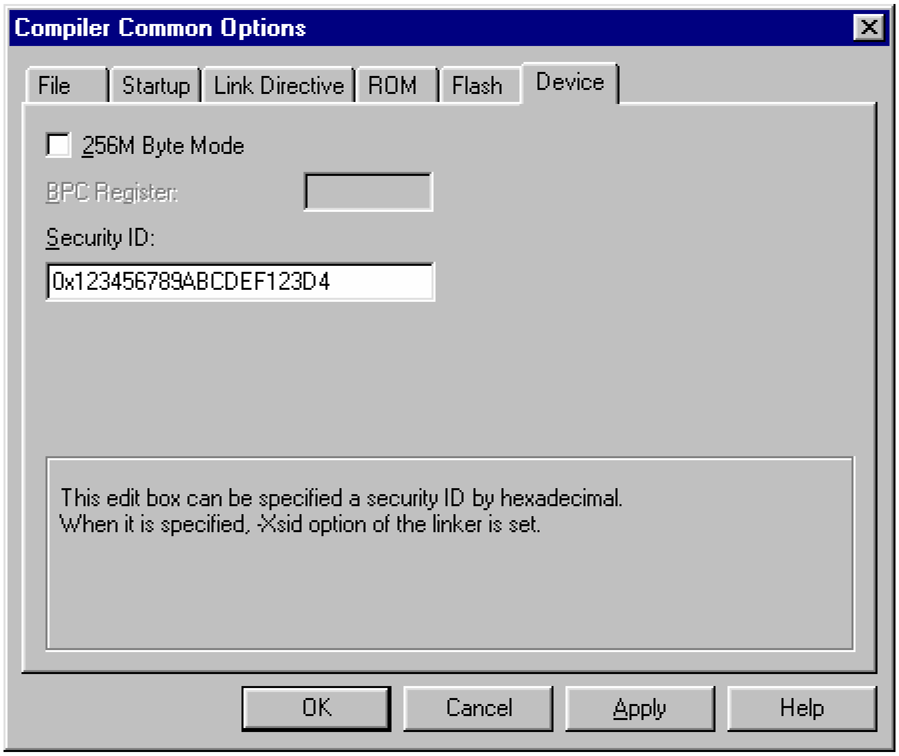
The following shows how to set the ID code as shown in Table 29-5.

When the ID code is set as shown in Table 29-5, the ID code input in the configuration dialog box of the ID850QB is “123456789ABCDEF123D4” (the ID code is case-insensitive).

Table 29-5. 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 by using the PM+ compiler common option setting.



☐ 256M Byte Mode

BPC Register:

Security ID:

0x123456789ABCDEF123D4

This edit box can be specified a security ID by hexadecimal.
When it is specified, -Xsid option of the linker is set.

Absolute Maximum Ratings (T_A = 25°C) (1/2)

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	V_{DD}	$V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$	–0.5 to +4.6	V
	EV_{DD}	$V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$	–0.5 to +4.6	V
	AV_{REF0}	$V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$	–0.5 to +4.6	V
	AV_{REF1}	$V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$	–0.5 to +4.6	V
	V_{SS}	$V_{SS} = EV_{SS} = AV_{SS}$	–0.5 to +0.5	V
	AV_{SS}	$V_{SS} = EV_{SS} = AV_{SS}$	–0.5 to +0.5	V
	EV_{SS}	$V_{SS} = EV_{SS} = AV_{SS}$	–0.5 to +0.5	V
Input voltage	V_{I1}	P97 to P915, PDH0 to PDH5, PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDL0 to PDL15, $\overline{\text{RESET}}$, FLMD0	–0.5 to EV_{DD} + 0.5$^{\text{Note 1}}$	V
	V_{I2}	P10, P11	–0.5 to AV_{REF1} + 0.5$^{\text{Note 1}}$	V
	V_{I3}	X1	–0.5 to V_{DD} + 0.5$^{\text{Note 1}}$	V
		X2	–0.5 to $V_{RO}{}^{\text{Note 2}}$ + 0.5$^{\text{Note 1}}$	
	V_{I4}	P02 to P06, P30 to P39, P40 to P42, P50 to P55, P90 to P96	–0.5 to +6.0	V
	V_{I5}	XT1, XT2	–0.5 to $V_{RO}{}^{\text{Note 2}}$ + 0.5	V
Analog input voltage	V_{IAN}	P70 to P711	–0.5 to AV_{REF0} + 0.5$^{\text{Note 1}}$	V

Notes 1. Be sure not to exceed the absolute maximum ratings (MAX. value) of each supply voltage.

2. On-chip regulator output voltage

Cautions 1. Do not directly connect the output (or I/O) pins of IC products to each other, or to V_{DD}, V_{CC}, 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.

Absolute Maximum Ratings (T_A = 25°C) (2/2)

Parameter	Symbol	Conditions		Ratings	Unit
Output current, low	I_{OL}	P02 to P06, P30 to P39, P40 to P42, P50 to P55, P90 to P915, PDH4, PDH5	Per pin	4	mA
			Total of all pins	50	mA
		PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDH0 to PDH3, 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 P711	Per pin	4	mA
			Total of all pins	20	mA
Output current, high	I_{OH}	P02 to P06, P30 to P39, P40 to P42, P50 to P55, P90 to P915, PDH4, PDH5	Per pin	–4	mA
			Total of all pins	–50	mA
		PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDH0 to PDH3, 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 P711	Per pin	–4	mA
			Total of all pins	–20	mA
Operating ambient temperature	T_A	Normal operation mode		–40 to +85	°C
		Flash memory programming mode		–40 to +85	°C
Storage temperature	T_{stg}			–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_{DD}, V_{CC}, 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 = 25°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = V_{SS} = EV_{SS} = AV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
I/O capacitance	C_{IO}	f_X = 1 MHz Unmeasured pins returned to 0 V			10	pF

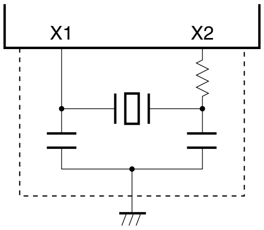
Operating Conditions

(T_A = −40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}, V_{SS} = EV_{SS} = AV_{SS} = 0 V)

Internal System Clock Frequency	Conditions	Supply Voltage			Unit
		V_{DD}	EV_{DD}	AV_{REF0}, AV_{REF1}	
f_{XX} = 2.5 to 20 MHz	C = 4.7 μF, A/D converter operating, D/A converter operating	2.7 to 3.6	2.7 to 3.6	2.7 to 3.6	V
f_{XX} = 2.5 to 5 MHz	C = 4.7 μF, A/D converter stopped, D/A converter stopped	2.2 to 3.6	2.2 to 3.6	2.2 to 3.6	V
f_{XT} = 32.768 kHz	C = 4.7 μF, A/D converter stopped, D/A converter stopped	2.2 to 3.6	2.2 to 3.6	2.2 to 3.6	V

Main Clock Oscillator Characteristics

(T_A = –40 to +85°C, $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ = 2.2 to 3.6 V, $V_{SS} = EV_{SS} = AV_{SS}$ = 0 V)

Resonator	Circuit Example	Parameter	Conditions		MIN.	TYP.	MAX.	Unit
Ceramic resonator/ Crystal resonator		Oscillation frequency (f_X)[Note 1]	Clock through mode		2.5		10	MHz
			PLL mode		2.5		5	MHz
		Oscillation stabilization time[Note 2]	After reset is released		**Note 3**	**Note 3**		s
			After STOP mode is released	Clock through mode	1[Note 5]	**Note 4**		ms
				PLL mode	1[Note 6]	**Note 4**		ms
			After IDLE2 mode is released	Clock through mode	350[Note 5]	**Note 4**		µs
				PLL mode	800[Note 6]	**Note 4**		µs

Notes 1. The oscillation frequency shown above indicates only oscillator characteristics. Use the V850ES/JG3-L 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 oscillation stabilization time differs depending on the set value of the option byte. For details, see **CHAPTER 27 OPTION BYTE**.

4. The value varies depending on the setting of the OSTS register.

5. Time required to set up the regulator and flash memory. Secure the setup time using the OSTS register.

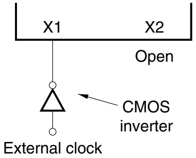
6. Time required to set up the regulator, flash memory, and PLL. Secure the setup time using the OSTS register.

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_{SS}.**
- **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.

(T_A = –40 to +85°C, $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ = 2.7 to 3.6 V, $V_{SS} = EV_{SS} = AV_{SS}$ = 0 V)

Resonator	Circuit Example	Parameter	Conditions	MIN.	TYP.	MAX.	Unit
External clock		Input frequency (f_X)[Note]	Clock through mode	2.5		5	MHz
			PLL mode	2.5		5	MHz
		V_{IH}	X1	2.3		V_{DD}	V
		V_{IL}	X1	V_{SS}		0.4	V

Note Keep the duty factor of the input waveform to within 45% to 55%.

Cautions 1. Be sure to disconnect the internal feedback resistor after reset (set PCC.MFRC = 1).

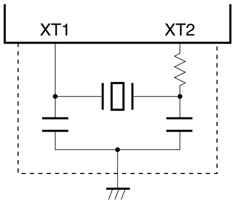
2. Leave the X2 pin open.

3. Make sure that the CMOS inverter is as close to the X1 pin as possible.

4. Thoroughly evaluate matching between the V850ES/JG3-L and CMOS inverter.

Subclock Oscillator Characteristics

(T_A = –40 to +85°C, $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$, $V_{SS} = EV_{SS} = AV_{SS}$ = 0 V)

Resonator	Circuit Example	Parameter	Conditions	MIN.	TYP.	MAX.	Unit
Crystal resonator		Oscillation frequency (f_{XT})[Note 1]		32	32.768	35	kHz
		Oscillation stabilization time[Note 2]				10	s

Notes 1. The oscillation frequency shown above indicates only oscillator characteristics. Use the V850ES/JG3-L 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 (2.2 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°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}, V_{SS} = EV_{SS} = AV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input frequency	f_X		2.5		5	MHz
Output frequency	f_{XX}		10		20	MHz
Lock time	t_{PLL}	After V_{DD} reaches 2.7 V (MIN.)			800	μs

Internal Oscillator Characteristics

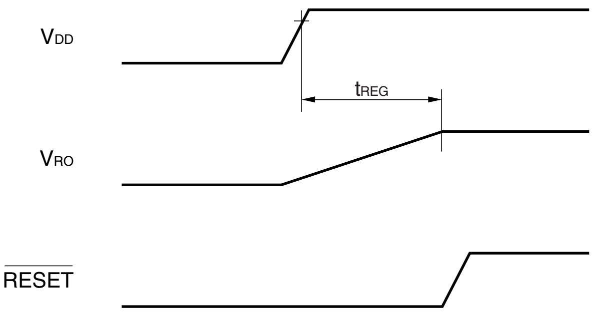
(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}, V_{SS} = EV_{SS} = AV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output frequency	f_R		100	220	400	kHz

Regulator Characteristics

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}, V_{SS} = EV_{SS} = AV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage	V_{DD}	f_{XX} = 20 MHz (MAX.)	2.7		3.6	V
		f_{XX} = 5 MHz (MAX.)	2.2		3.6	V
		Stops operation	1.9		3.6	V
Output voltage	V_{RO}	V_{DD} = 2.7 to 3.6 V		2.5		V
Regulator output stabilization time	t_{REG}	After V_{DD} reaches 2.7 V (MIN.), stabilization capacitance C = 4.7 μF (preliminary value) connected to REGC pin			1	ms
		After V_{DD} reaches 2.2 V (MIN.), stabilization capacitance C = 4.7 μF (preliminary value) connected to REGC pin			3.5	ms
External capacitance	REGC	Permissible error of external capacitance to be connected to REGC pin	3.76	4.70	5.64	μF



DC Characteristics

(T_A = –40 to +85°C, $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$, $V_{SS} = EV_{SS} = AV_{SS}$ = 0 V) (1/3)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage, high	V_{IH1}	$\overline{\text{RESET}}$, FLMD0, P97 to P915	$0.8EV_{DD}$		EV_{DD}	V
	V_{IH2}	P02 to P06, P30 to P37, P42, P50 to P55, P92 to P96	$0.8EV_{DD}$		5.5	V
	V_{IH3}	P38, P39, P40, P41, P90, P91	$0.7EV_{DD}$		5.5	V
	V_{IH4}	PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDH0 to PDH5, PDL0 to PDL15	$0.7EV_{DD}$		EV_{DD}	V
	V_{IH5}	P70 to P711	$0.7AV_{REF0}$		AV_{REF0}	V
	V_{IH6}	P10, P11	$0.7AV_{REF1}$		AV_{REF1}	V
Input voltage, low	V_{IL1}	$\overline{\text{RESET}}$, FLMD0, P97 to P915	EV_{SS}		$0.2EV_{DD}$	V
	V_{IL2}	P02 to P06, P30 to P37, P42, P50 to P55, P92 to P96	EV_{SS}		$0.2EV_{DD}$	V
	V_{IL3}	P38, P39, P40, P41, P90, P91	EV_{SS}		$0.3EV_{DD}$	V
	V_{IL4}	PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDH0 to PDH5, PDL0 to PDL15	EV_{SS}		$0.3EV_{DD}$	V
	V_{IL5}	P70 to P711	AV_{SS}		$0.3AV_{REF0}$	V
	V_{IL6}	P10, P11	AV_{SS}		$0.3AV_{REF1}$	V
Input leakage current, high	I_{LIH}	$V_I = V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$			5	μA
Input leakage current, low	I_{LIL}	V_I = 0 V			–5	μA
Output leakage current, high	I_{LOH}	$V_O = V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$			5	μA
Output leakage current, low	I_{LOL}	V_O = 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_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}, V_{SS} = EV_{SS} = AV_{SS} = 0 V) (2/3)

Parameter	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Output voltage, high	V_{OH1}	P02 to P06, P30 to P39, P40 to P42, P50 to P55, P90 to P915, PDH4, PDH5	Per pin I_{OH} = –1.0 mA	Total of all pins –20 mA	EV_{DD} – 1.0		EV_{DD}	V
			Per pin I_{OH} = –100 μA	Total of all pins –4.2 mA	EV_{DD} – 0.5		EV_{DD}	V
	V_{OH2}	PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDH0 to PDH3, PDL0 to PDL15	Per pin I_{OH} = –1.0 mA	Total of all pins –20 mA	EV_{DD} – 1.0		EV_{DD}	V
			Per pin I_{OH} = –100 μA	Total of all pins –2.8 mA	EV_{DD} – 0.5		EV_{DD}	V
	V_{OH3}	P70 to P711	Per pin I_{OH} = –0.4 mA	Total of all pins –4.8 mA	AV_{REF0} – 1.0		AV_{REF0}	V
			Per pin I_{OH} = –100 μA	Total of all pins –1.2 mA	AV_{REF0} – 0.5		AV_{REF0}	V
	V_{OH4}	P10, P11	Per pin I_{OH} = –0.4 mA	Total of all pins –0.8 mA	AV_{REF1} – 1.0		AV_{REF1}	V
			Per pin I_{OH} = –100 μA	Total of all pins –0.2 mA	AV_{REF1} – 0.5		AV_{REF1}	V
Output voltage, low	V_{OL1}	P02 to P06, P30 to P37, P42, P50 to P55, P92 to P915, PDH4, PDH5	Per pin I_{OL} = 1.0 mA	Total of all pins 20 mA	0		0.4	V
	V_{OL2}	P38, P39, P40, P41, P90, P91	Per pin I_{OL} = 3.0 mA		0		0.4	V
	V_{OL3}	PCM0 to PCM3, PCT0, PCT1, PCT4, PCT6, PDH0 to PDH3, PDL0 to PDL15	Per pin I_{OL} = 1.0 mA	Total of all pins 20 mA	0		0.4	V
	V_{OL4}	P10, P11, P70 to P711	Per pin I_{OL} = 0.4 mA	Total of all pins 5.6 mA	0		0.4	V
Software pull-down resistor[Note]	R_1	P05	V_I = V_{DD}		10	20	100	kΩ

Note $\overline{\text{DRST}}$ pin only (controlled by OCDM register)

Remarks 1. Unless specified otherwise, the characteristics of alternate-function pins are the same as those of port pins.

2. When the I_{OH} and I_{OL} 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_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}, V_{SS} = EV_{SS} = AV_{SS} = 0 V) (3/3)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Supply current[Note 1]	I_{DD1}	Normal operation	f_{XX} = 20 MHz (f_X = 5 MHz)[Note 4]		12[Note 5]	20	mA
			f_{XX} = 10 MHz (f_X = 10 MHz), PLL off[Note 4]		7[Note 5]	10	mA
	I_{DD2}	HALT mode	f_{XX} = 20 MHz (f_X = 5 MHz)[Note 4]		9	14	mA
	I_{DD3}	IDLE1 mode	f_{XX} = 5 MHz (f_X = 5 MHz), PLL off[Note 4]		0.6	1	mA
	I_{DD4}	IDLE2 mode	f_{XX} = 5 MHz (f_X = 5 MHz), PLL off[Note 4]		TBD	TBD	mA
	I_{DD5}	Subclock operation mode	f_{XT} = 32.768 kHz, main clock stopped, internal oscillator stopped, PLL off REGOVL0 = 02H (low-voltage subclock operation mode)		25		µA
	I_{DD6}	Sub-IDLE mode	f_{XT} = 32.768 kHz, main clock stopped, internal oscillator stopped, PLL off REGOVL0 = 02H (low-voltage sub-IDLE mode)		2.5	50	µA
	I_{DD7}	STOP mode	Subclock stopped, internal oscillator stopped REGOVL0 = 01H (low-voltage STOP mode) T_A = 25°C		1.5	3.0	µA
			Subclock stopped, internal oscillator stopped REGOVL0 = 01H (low-voltage STOP mode) T_A = 85°C			45	µA
			Subclock operating, internal oscillator stopped REGOVL0 = 01H (low-voltage STOP mode)		2.5	50	µA
	I_{DD8}	Flash memory programming mode	f_{XX} = 20 MHz (f_X = 5 MHz)		15	21	mA
LVI current	I_{LVI}				1.2	3	µA
WDT, internal oscillation current	I_{WDT}				5		µA

Notes 1. TYP. current is a value at V_{DD} = EV_{DD} = 3.3 V, T_A = 25°C.
The TYP. value is not a value guaranteed for each device.

2. MAX. current is a value at which the characteristic in question is at the worst-case value at V_{DD} = EV_{DD} = 3.6 V, T_A = –40 to +85°C.

3. Total of V_{DD} and EV_{DD} currents. Currents I_{LVI} and I_{WDT} flowing through the output buffers, A/D converter, D/A converter, and on-chip pull-down resistor are not included.

4. TYP. value indicates the current value when watch timer + TMM (count by watch timer interrupt) operate as peripheral functions.
MAX. value indicates the current value when all the functions operable in a range in which the pin status is not changed operate as peripheral functions.
However, I_{LVI} and I_{WDT} are excluded.

5. TYP. value of I_{DD1} is a value when all instructions are executed + RAM access 15%.

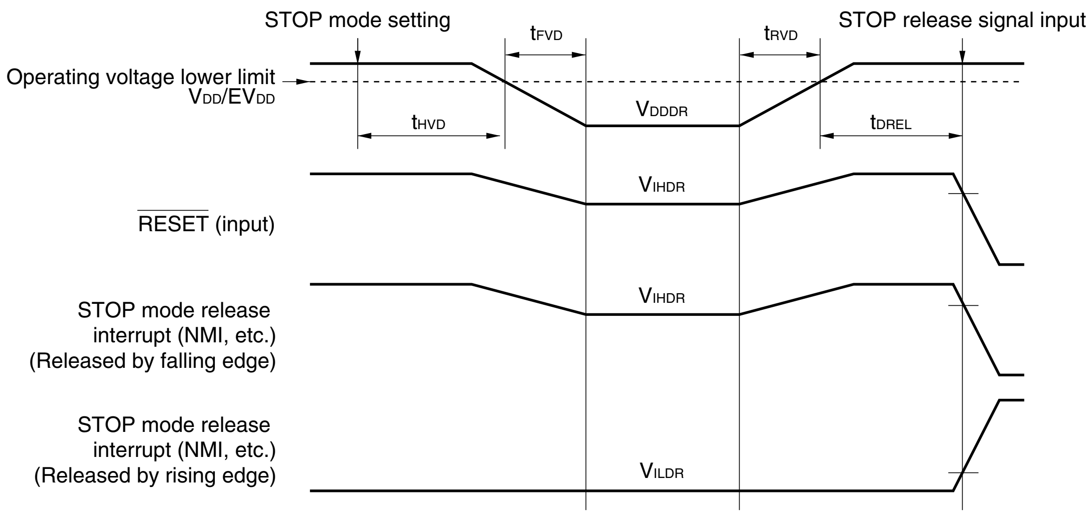
Data Retention Characteristics

In STOP mode

(T_A = –40 to +85°C, $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$, $V_{SS} = EV_{SS} = AV_{SS} = 0$ V)

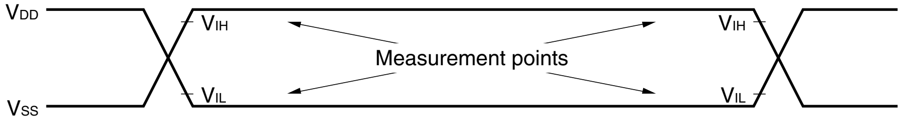
Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention voltage	V_{DDDR}	STOP mode (all functions stopped)	1.9		3.6	V
Data retention current	I_{DDDR}	Subclock stopped, internal oscillator stopped T_A = 85°C			45	μA
Supply voltage rise time	t_{RVD}		200			μs
Supply voltage fall time	t_{FVD}		200			μs
Supply voltage retention time	t_{HVD}	After STOP mode setting	0			ms
STOP release signal input time	t_{DREL}	After V_{DD} reaches 1.9 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.

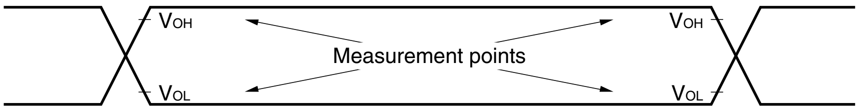


AC Characteristics

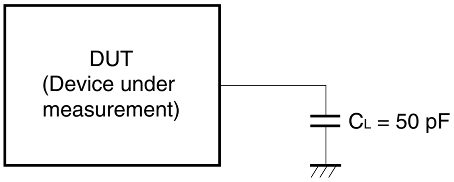
AC Test Input Measurement Points (V_{DD}, AV_{REF0}, EV_{DD})



AC Test Output Measurement Points



Load Conditions



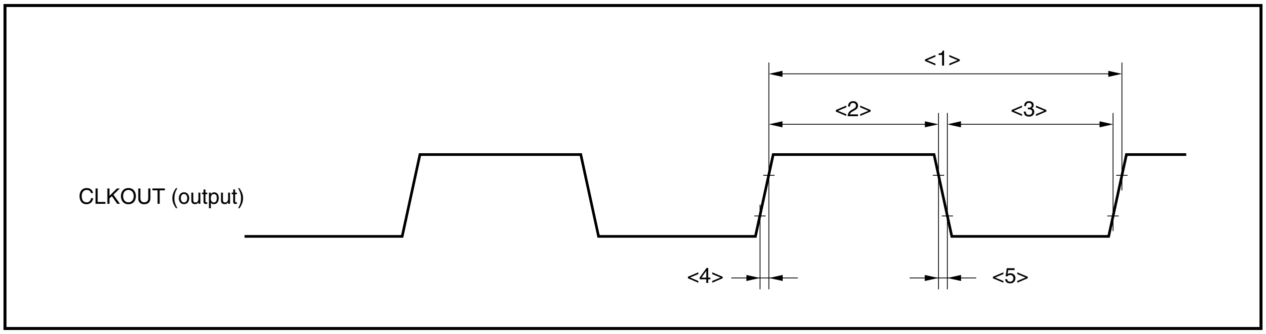
Caution If the load capacitance exceeds 50 pF due to the circuit configuration, bring the load capacitance of the device to 50 pF or less by inserting a buffer or by some other means.

CLKOUT Output Timing

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Output cycle	t_{CYK}	<1>		50 ns	31.25 μs	
High-level width	t_{WKH}	<2>		t_{CYK}/2 – 10		ns
Low-level width	t_{WKL}	<3>		t_{CYK}/2 – 10		ns
Rise time	t_{KR}	<4>			10	ns
Fall time	t_{KF}	<5>			10	ns

Clock Timing



Bus Timing

(1) In multiplexed bus mode

(a) Read/write cycle (CLKOUT asynchronous)

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Address setup time (to ASTB↓)	t_{SAST}	<6>		$(0.5 + t_{ASW})T - 20$		ns
Address hold time (from ASTB↓)	t_{HSTA}	<7>		$(0.5 + t_{AHW})T - 15$		ns
Delay time from $\overline{RD}$↓ 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 $\overline{RD}$↓	t_{SRID}	<10>			$(1 + n)T - 25$	ns
Delay time from ASTB↓ to $\overline{RD}$, $\overline{WRm}$↓	$t_{DSTRDWR}$	<11>		$(0.5 + t_{AHW})T - 15$		ns
Data input hold time (from $\overline{RD}$↑)	t_{HRDID}	<12>		0		ns
Address output time from $\overline{RD}$↑	t_{DRDA}	<13>		$(1 + i)T - 15$		ns
Delay time from $\overline{RD}$, $\overline{WRm}$↑ to ASTB↑	$t_{DRDWRST}$	<14>		$0.5T - 15$		ns
Delay time from $\overline{RD}$↑ to ASTB↓	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 $\overline{WRm}$↓	t_{DWROD}	<18>			15	ns
Data output setup time (to $\overline{WRm}$↑)	t_{SODWR}	<19>		$(1 + n)T - 20$		ns
Data output hold time (from $\overline{WRm}$↑)	t_{HWROD}	<20>		$T - 15$		ns
$\overline{WAIT}$ setup time (to address)	t_{SAWT1}	<21>	n ≥ 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 ≥ 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↓)	t_{SSTWT1}	<25>	n ≥ 1		$(1 + t_{AHW})T - 25$	ns
	t_{SSTWT2}	<26>			$(1 + n + t_{AHW})T - 25$	ns
$\overline{WAIT}$ hold time (from ASTB↓)	t_{HSTWT1}	<27>	n ≥ 1	$(n + t_{AHW})T$		ns
	t_{HSTWT2}	<28>		$(1 + n + t_{AHW})T$		ns
Address hold time from $\overline{RD}$↑	t_{HRDA2}	<29>		$(1 + i)T - 15$		ns
Address hold time from $\overline{WRm}$↑	t_{HWRA2}	<30>		$T - 15$		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

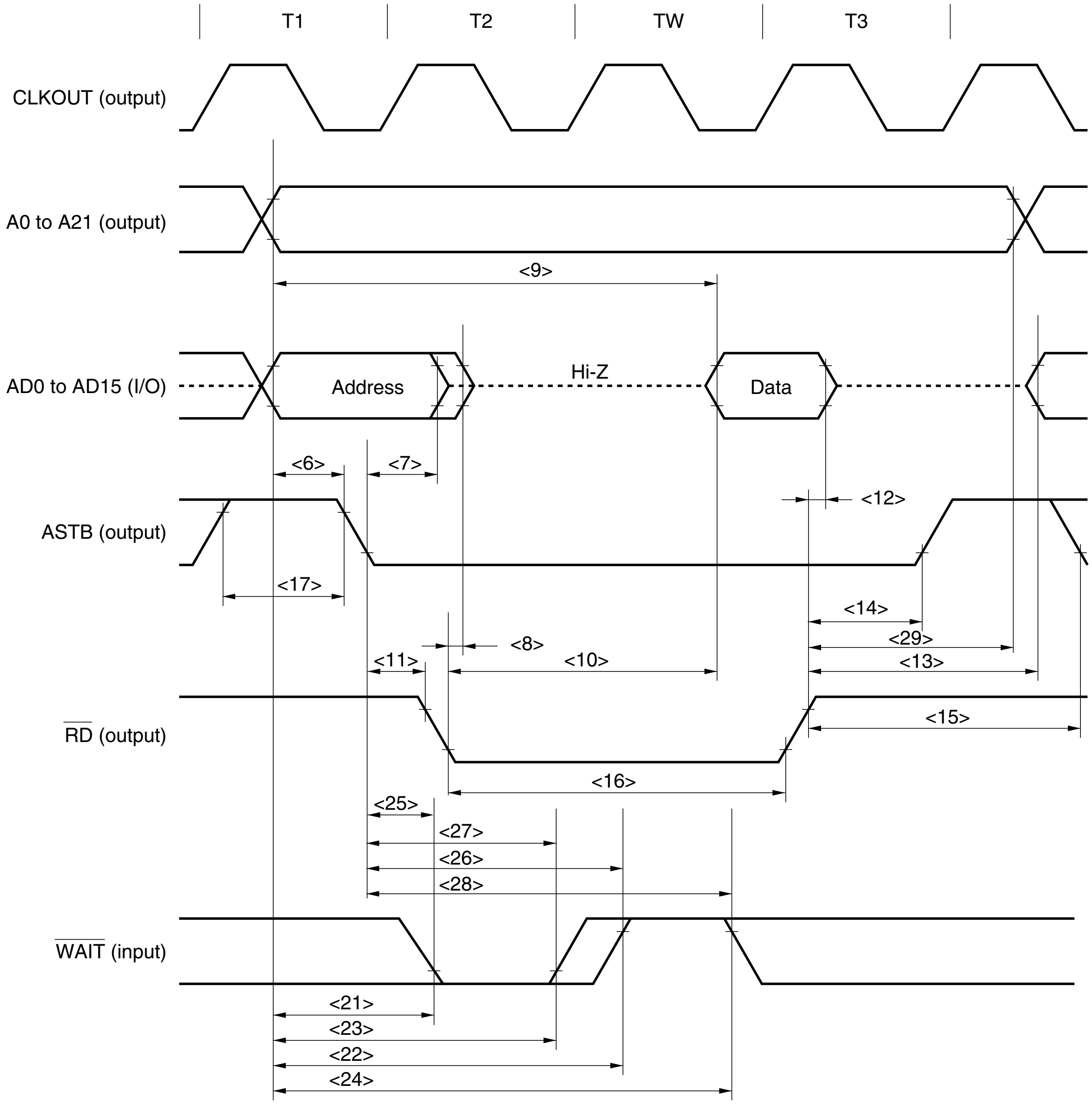
The sampling timing changes when a programmable wait is inserted.

4. m = 0, 1

5. i: Number of idle states inserted after a read cycle (0 or 1)

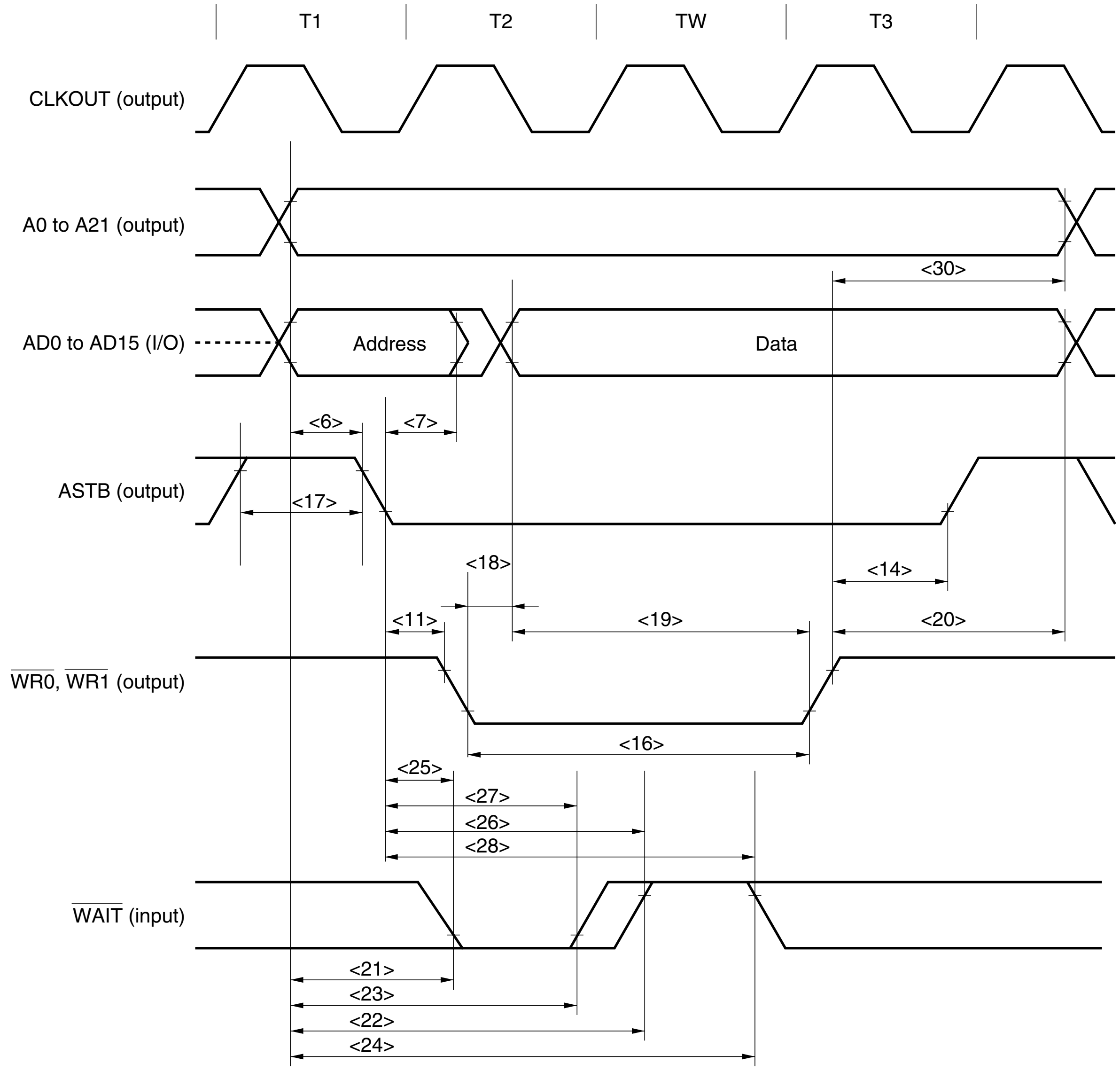
6. The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Read Cycle (CLKOUT Asynchronous): In Multiplexed Bus Mode



Remark $\overline{\text{WR0}}$ and $\overline{\text{WR1}}$ are high level.

Write Cycle (CLKOUT Asynchronous): In Multiplexed Bus Mode



Remark $\overline{\text{RD}}$ is high level.

(b) Read/write cycle (CLKOUT synchronous): In multiplexed bus mode

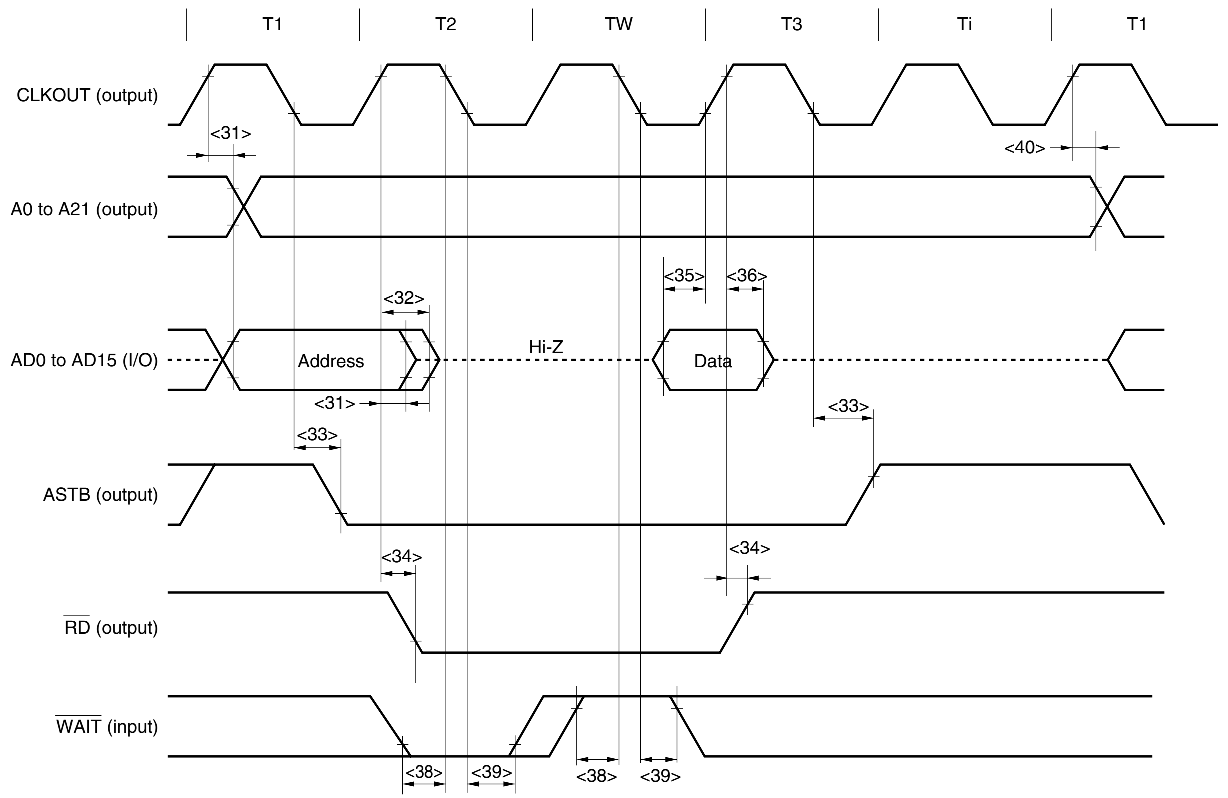
(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Delay time from CLKOUT↑ to address	t_{DKA}	<31>		0	25	ns
Delay time from CLKOUT↑ to address float	t_{FKA}	<32>		0	19	ns
Delay time from CLKOUT↓ to ASTB	t_{DKST}	<33>		–12	7	ns
Delay time from CLKOUT↑ to $\overline{\text{RD}}$, $\overline{\text{WRm}}$	t_{DKRDWR}	<34>		–5	14	ns
Data input setup time (to CLKOUT↑)	t_{SIDK}	<35>		15		ns
Data input hold time (from CLKOUT↑)	t_{HKID}	<36>		5		ns
Data output delay time from CLKOUT↑	t_{DKOD}	<37>			19	ns
$\overline{\text{WAIT}}$ setup time (to CLKOUT↓)	t_{SWTK}	<38>		20		ns
$\overline{\text{WAIT}}$ hold time (from CLKOUT↓)	t_{HKWT}	<39>		5		ns
Address hold time from CLKOUT↑	t_{HKA2}	<40>		0	25	ns
Data output hold time from $\overline{\text{WRm}}$↑	t_{HWROD2}	<41>		T – 15		ns
Address hold time from $\overline{\text{WRm}}$↑	t_{HWRA2}	<42>		T – 15		ns

Remarks 1. m = 0, 1

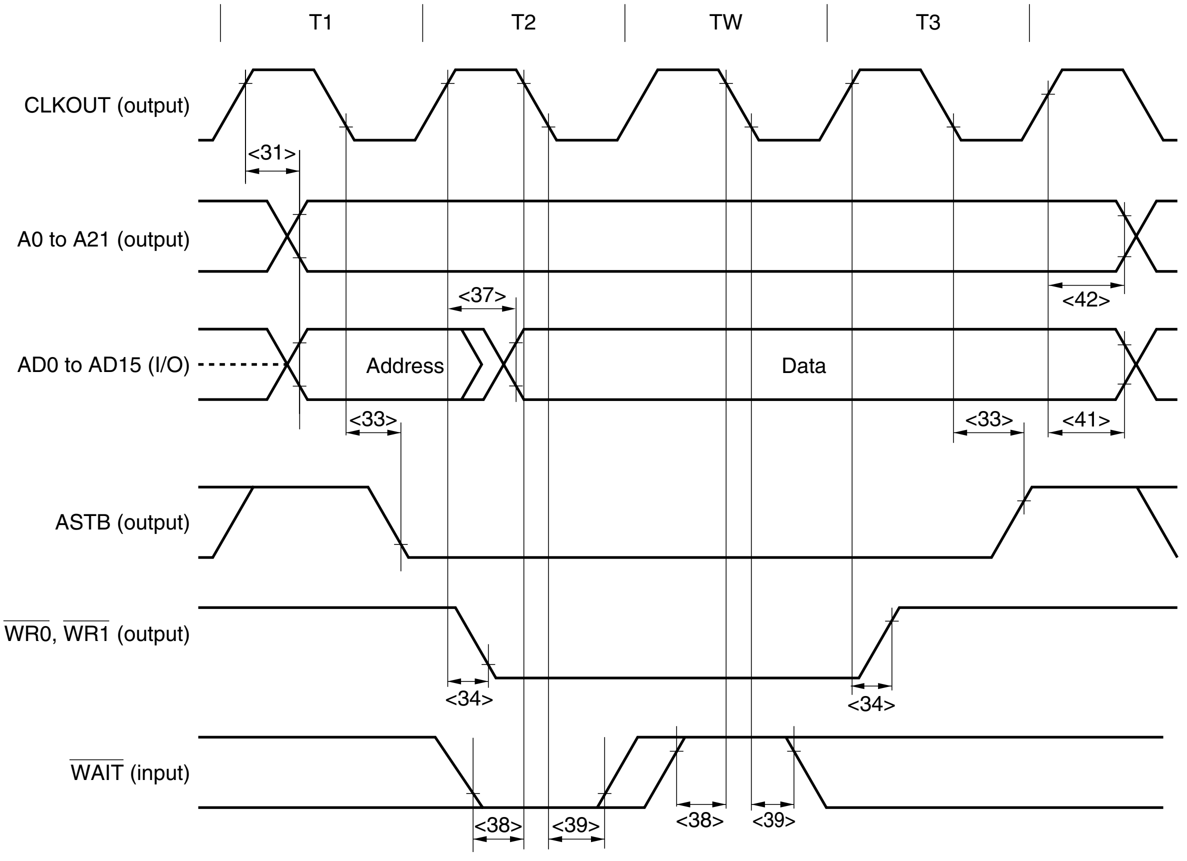
2. The values in the above specifications are values for when clocks with a 1:1 duty ratio are input from X1.

Read Cycle (CLKOUT Synchronous): In Multiplexed Bus Mode



Remark $\overline{\text{WR0}}$ and $\overline{\text{WR1}}$ are high level.

Write Cycle (CLKOUT Synchronous): In Multiplexed Bus Mode



Remark $\overline{\text{RD}}$ is high level.

(2) In separate bus mode

(a) Read cycle (CLKOUT asynchronous): In separate bus mode

(T_A = –40 to +85°C, $V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1}$ = 2.7 to 3.6 V, $V_{SS} = EV_{SS} = AV_{SS}$ = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Address setup time (to $\overline{\text{RD}}$↓)	t_{SARD}	<43>		$(0.5 + t_{ASW})T - 27$		ns
Address hold time (from $\overline{\text{RD}}$↑)	t_{HARD}	<44>		$iT + 2$		ns
$\overline{\text{RD}}$ low-level width	t_{WRDL}	<45>		$(1.5 + n + t_{AHW})T - 10$		ns
Data setup time (to $\overline{\text{RD}}$↑)	t_{SISD}	<46>		23		ns
Data hold time (from $\overline{\text{RD}}$↑)	t_{HISD}	<47>		2		ns
Data setup time (to address)	t_{SAID}	<48>			$(2 + n + t_{ASW} + t_{AHW})T - 40$	ns
$\overline{\text{WAIT}}$ setup time (to $\overline{\text{RD}}$↓)	t_{SRDWT1}	<49>			$(0.5 + t_{AHW})T - 25$	ns
	t_{SRDWT2}	<50>			$(0.5 + n + t_{AHW})T - 25$	ns
$\overline{\text{WAIT}}$ hold time (from $\overline{\text{RD}}$↓)	t_{HRDWT1}	<51>		$(n - 0.5 + t_{AHW})T$		ns
	t_{HRDWT2}	<52>		$(n + 0.5 + t_{AHW})T$		ns
$\overline{\text{WAIT}}$ setup time (to address)	t_{SAWT1}	<53>			$(1 + t_{ASW} + t_{AHW})T - 45$	ns
	t_{SAWT2}	<54>			$(1 + n + t_{ASW} + t_{AHW})T - 45$	ns
$\overline{\text{WAIT}}$ hold time (from address)	t_{HAWT1}	<55>		$(n + t_{ASW} + t_{AHW})T$		ns
	t_{HAWT2}	<56>		$(1 + n + t_{ASW} + t_{AHW})T$		ns
Data output delay time from $\overline{\text{RD}}$↑	t_{DRDOD1}	<57>		$(1 + i + t_{ASW})T - 15$		ns

Remarks 1. t_{ASW}: Number of address setup wait clocks
t_{AHW}: Number of address hold wait clocks

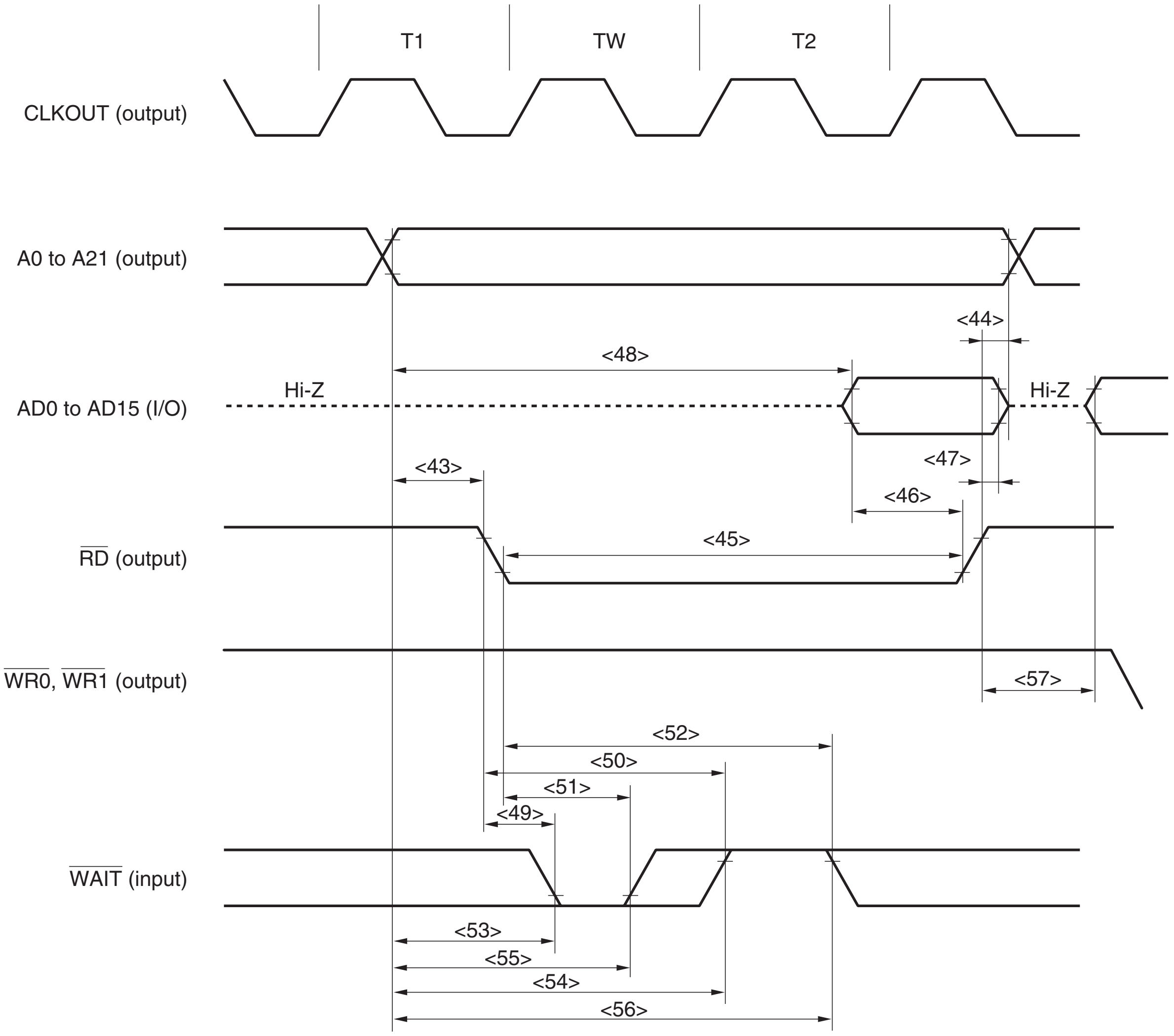
2. $T = 1/f_{CPU}$ (f_{CPU}: CPU operating clock frequency)

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



Remark $\overline{\text{WR0}}$ and $\overline{\text{WR1}}$ are high level.

(b) Write cycle (CLKOUT asynchronous): In separate bus mode

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Address setup time (to $\overline{\text{WRm}}$↓)	t_{SAWR}	<58>		$(1 + t_{ASW} + t_{AHW})T - 27$		ns
Address hold time (from $\overline{\text{WRm}}$↑)	t_{HAWR}	<59>		$0.5T - 6$		ns
$\overline{\text{WRm}}$ low-level width	t_{WWRL}	<60>		$(0.5 + n)T - 10$		ns
Data output time from $\overline{\text{WRm}}$↓	t_{DOSDW}	<61>		-5		ns
Data setup time (to $\overline{\text{WRm}}$↑)	t_{SOSDW}	<62>		$(0.5 + n)T - 20$		ns
Data hold time (from $\overline{\text{WRm}}$↑)	t_{HOSDW}	<63>		$0.5T - 7$		ns
Data setup time (to address)	t_{SAOD}	<64>		$(1 + t_{ASW} + t_{AHW})T - 25$		ns
$\overline{\text{WAIT}}$ setup time (to $\overline{\text{WRm}}$↓)	t_{SWRWT1}	<65>		22		ns
	t_{SWRWT2}	<66>			$nT - 22$	ns
$\overline{\text{WAIT}}$ hold time (from $\overline{\text{WRm}}$↓)	t_{HWRWT1}	<67>		0		ns
	t_{HWRWT2}	<68>		nT		ns
$\overline{\text{WAIT}}$ setup time (to address)	t_{SAWT1}	<69>			$(1 + t_{ASW} + t_{AHW})T - 45$	ns
	t_{SAWT2}	<70>			$(1 + n + t_{ASW} + t_{AHW})T - 45$	ns
$\overline{\text{WAIT}}$ hold time (from address)	t_{HAWT1}	<71>		$(n + t_{ASW} + t_{AHW})T$		ns
	t_{HAWT2}	<72>		$(1 + n + t_{ASW} + t_{AHW})T$		ns

Remarks 1. m = 0, 1

2. t_{ASW}: Number of address setup wait clocks

t_{AHW}: Number of address hold wait clocks

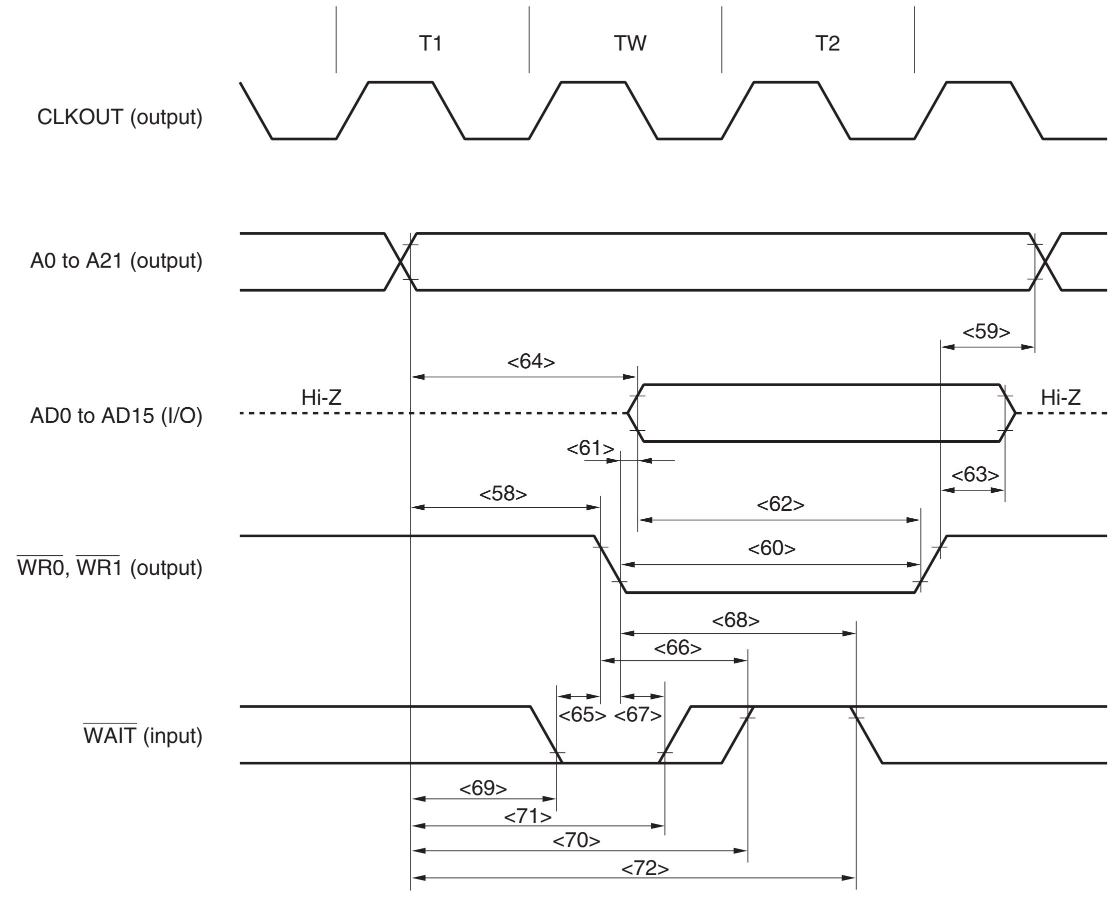
3. $T = 1/f_{CPU}$ (f_{CPU}: CPU operating clock frequency)

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



Remark RD is high level.

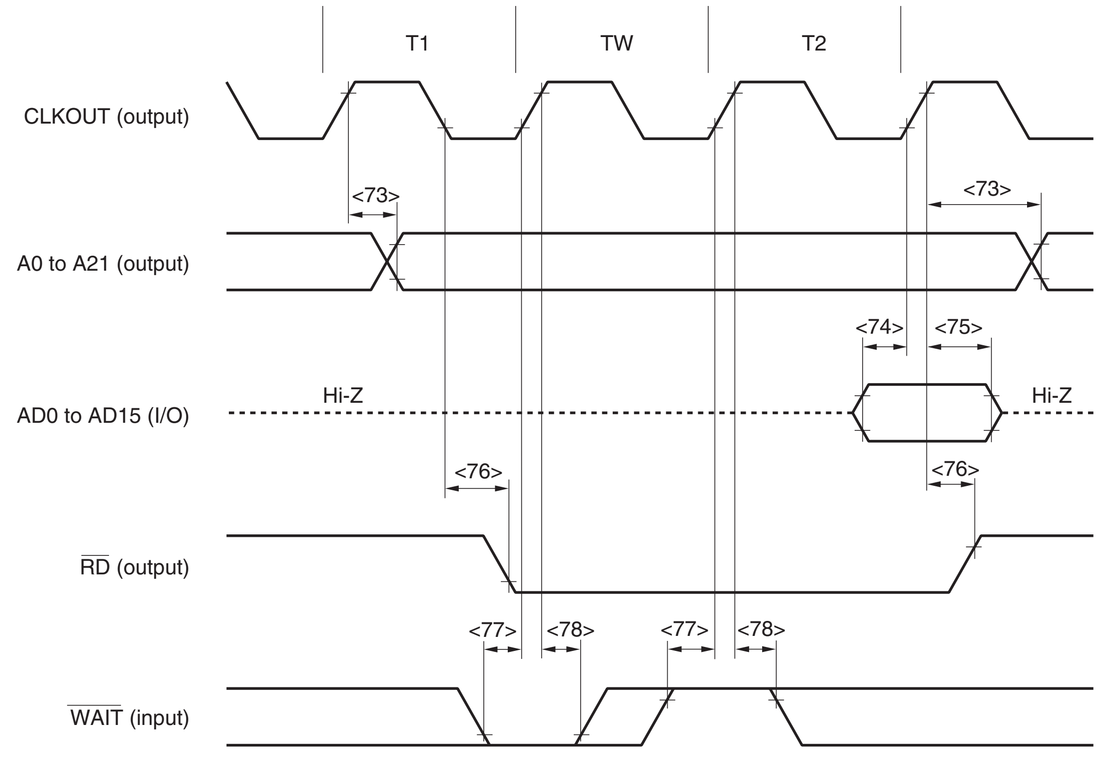
(c) Read cycle (CLKOUT synchronous): In separate bus mode

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Delay time from CLKOUT↑ to address	t_{DKSA}	<73>		0	27	ns
Data input setup time (to CLKOUT↑)	t_{SISDK}	<74>		20		ns
Data input hold time (from CLKOUT↑)	t_{HKISD}	<75>		0		ns
Delay time from CLKOUT↓↑ to $\overline{RD}$	t_{DKSR}	<76>		–2	12	ns
$\overline{WAIT}$ setup time (to CLKOUT↑)	t_{SWTK}	<77>		20		ns
$\overline{WAIT}$ hold time (from CLKOUT↑)	t_{HKWT}	<78>		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



Remark $\overline{WR0}$ and $\overline{WR1}$ are high level.

(d) Write cycle (CLKOUT synchronous): In separate bus mode

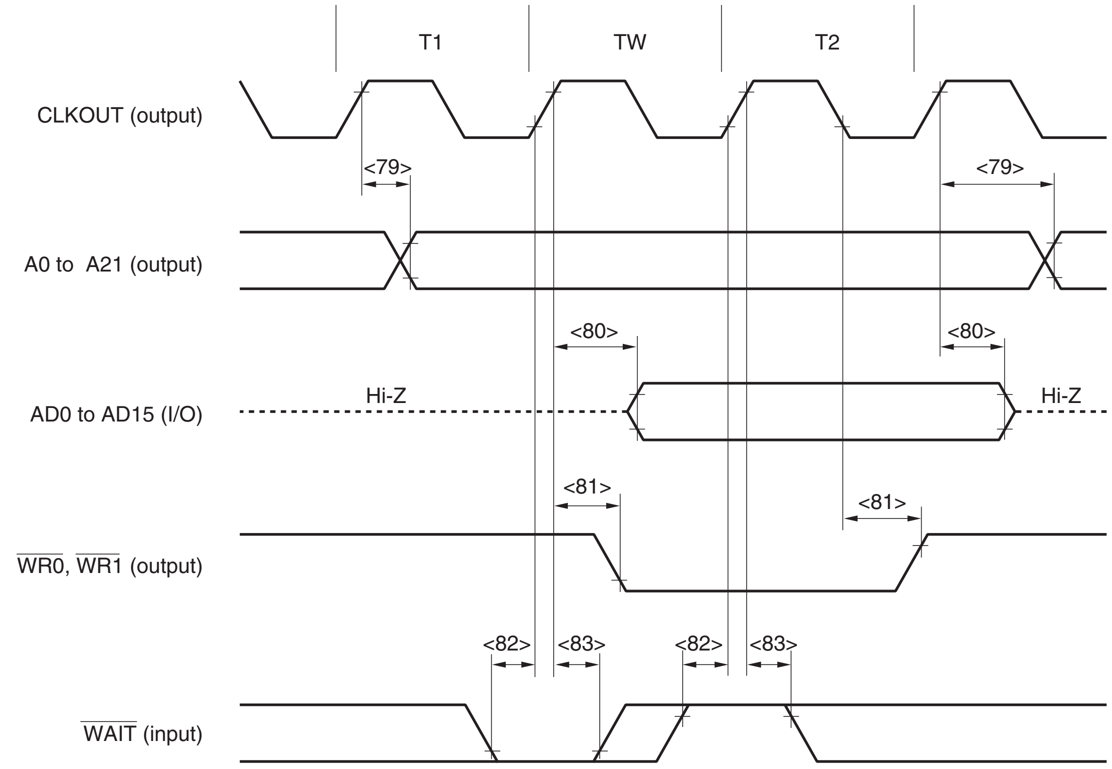
(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
Delay time from CLKOUT↑ to address	t_{DKSA}	<79>		0	27	ns
Delay time from CLKOUT↑ to data output	t_{DKSD}	<80>		0	18	ns
Delay time from CLKOUT↑↓ to $\overline{\text{WRm}}$	t_{DKSW}	<81>		–2	12	ns
$\overline{\text{WAIT}}$ setup time (to CLKOUT↑)	t_{SWTK}	<82>		20		ns
$\overline{\text{WAIT}}$ hold time (from CLKOUT↑)	t_{HKWT}	<83>		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



Remark $\overline{\text{RD}}$ is high level.

(3) Bus hold

(a) CLKOUT asynchronous

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

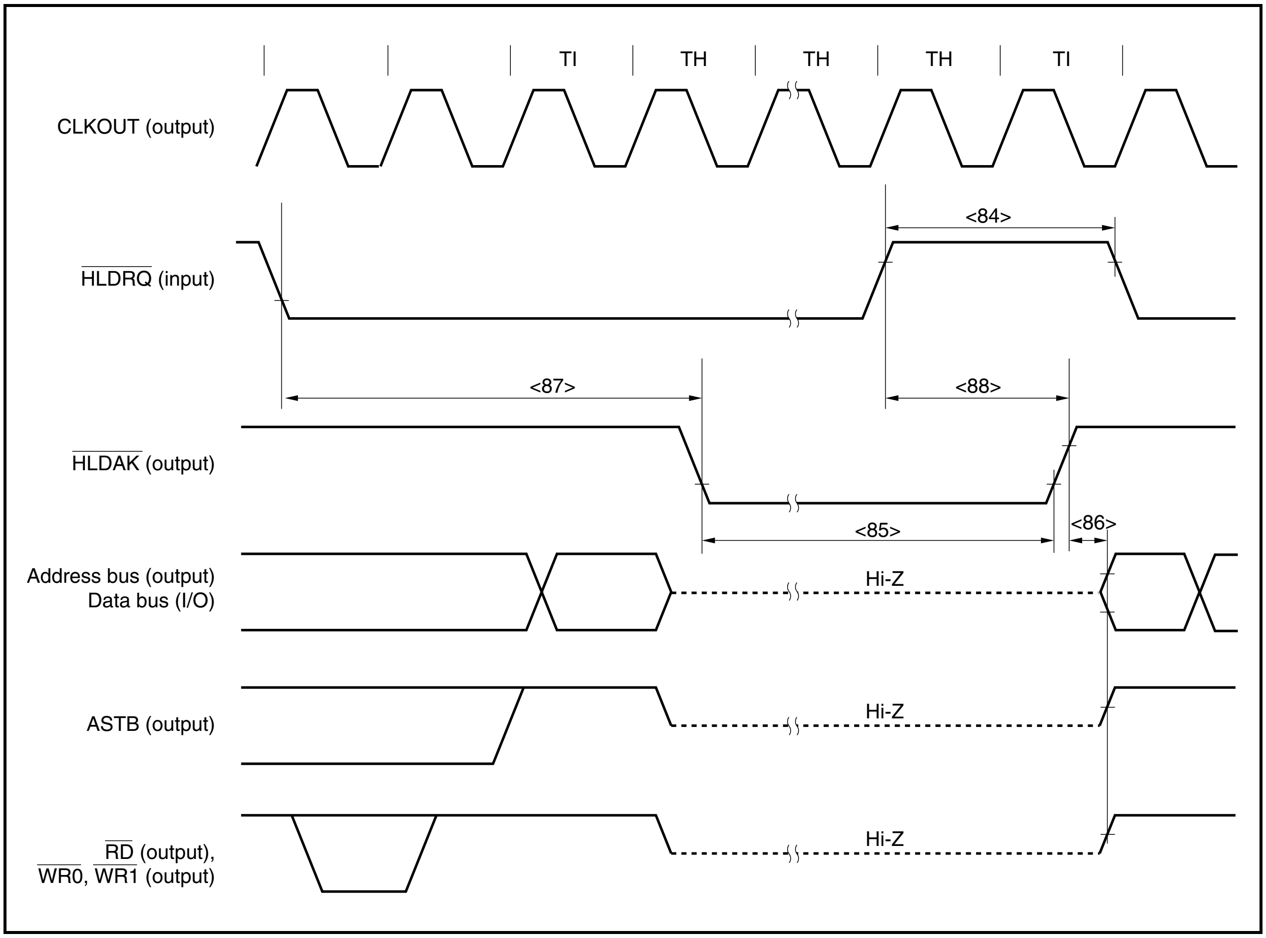
Parameter	Symbol		Conditions	MIN.	MAX.	Unit
$\overline{\text{HLDRQ}}$ high-level width	t_{WHQH}	<84>		T + 10		ns
$\overline{\text{HLDAK}}$ low-level width	t_{WHAL}	<85>		T – 15		ns
Delay time from $\overline{\text{HLDAK}}$↑ to bus output	t_{DHAC}	<86>		–3		ns
Delay time from $\overline{\text{HLDRQ}}$↓ to $\overline{\text{HLDAK}}$↓	t_{DHQHA1}	<87>			(2n + 7.5)T + 26	ns
Delay time from $\overline{\text{HLDRQ}}$↑ to $\overline{\text{HLDAK}}$↑	t_{DHQHA2}	<88>		0.5T	1.5T + 26	ns

Remarks 1. T = 1/f_{CPU} (f_{CPU}: CPU operating clock frequency)

2. n: Number of wait clocks inserted in the bus cycle
The sampling timing changes when a programmable wait is inserted.

3. 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)



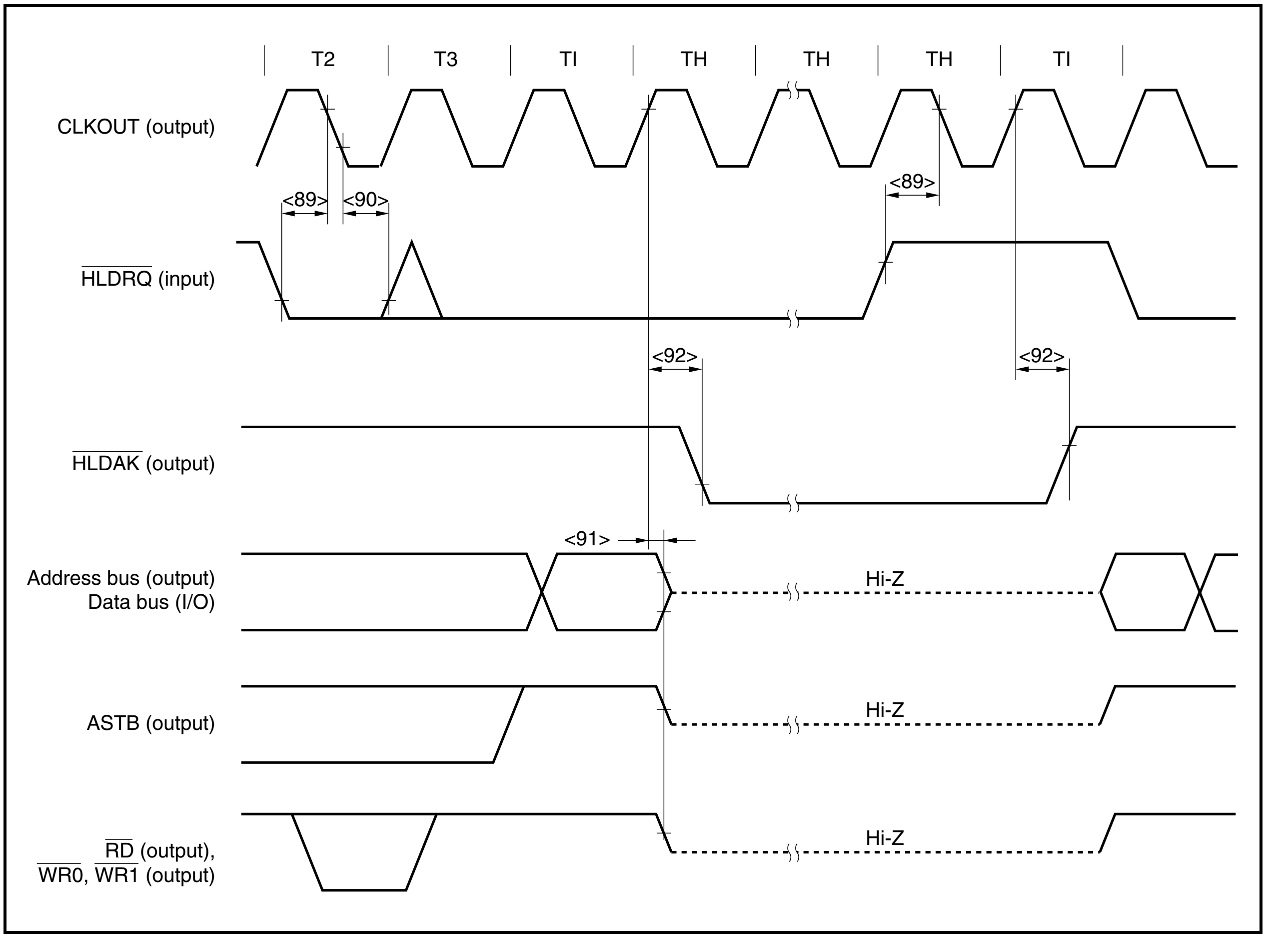
(b) CLKOUT synchronous

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, 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↓)	t_{SHQK}	<89>		20		ns
$\overline{\text{HLDRQ}}$ hold time (from CLKOUT↓)	t_{HKHQ}	<90>		5		ns
Delay time from CLKOUT↑ to bus float	t_{DKF}	<91>			19	ns
Delay time from CLKOUT↑ to $\overline{\text{HLDAK}}$	t_{DKHA}	<92>			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)

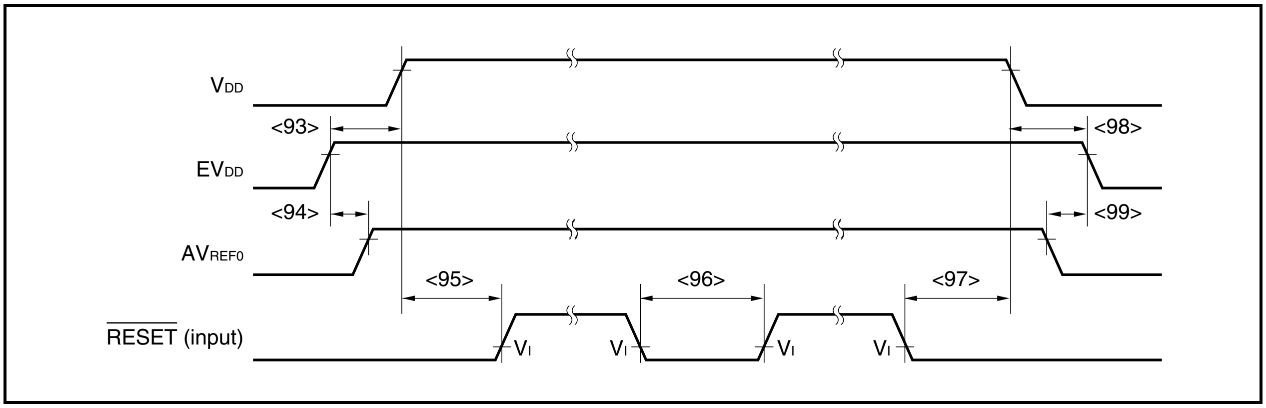


Power On/Power Off/Reset Timing

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol		Conditions	MIN.	MAX.	Unit
$EV_{DD}\uparrow \rightarrow V_{DD}\uparrow$	t_{REL}	<93>		0		ns
$EV_{DD}\uparrow \rightarrow AV_{REF0}, AV_{REF1}\uparrow$	t_{REA}	<94>		0	t_{REL}	ns
$V_{DD}\uparrow \rightarrow \overline{RESET}\uparrow$	t_{RER}	<95>		500 + t_{REG} Note		ns
$\overline{RESET}$ low-level width	t_{WRSL}	<96>	Analog noise elimination (during flash erase/writing)	500		ns
			Analog noise elimination	500		ns
$\overline{RESET}\downarrow \rightarrow V_{DD}\downarrow$	t_{FRE}	<97>		500		ns
$V_{DD}\downarrow \rightarrow EV_{DD}\downarrow$	t_{FEL}	<98>		0		ns
$AV_{REF0}\downarrow \rightarrow EV_{DD}\downarrow$	t_{FEA}	<99>		0	t_{FEL}	ns

Note Depends on the on-chip regulator characteristics.



$\overline{RESET}$ pin, Interrupt, FLMD0 Pin Timing

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol	Conditions	MIN.	MAX.	Unit
$\overline{RESET}$ low-level width	t_{WRSL}		500		ns
NMI high-level width	t_{WNIH}	Analog noise elimination	500		ns
NMI low-level width	t_{WNIL}	Analog noise elimination	500		ns
INTPn Note 1 high-level width	t_{WITH}	n = 0 to 7 (Analog noise elimination)	500		ns
		n = 3 (Digital noise elimination)	$3T_{SMP}$ + 20		ns
INTPn Note 1 low-level width	t_{WITL}	n = 0 to 7 (Analog noise elimination)	500		ns
		n = 3 (Digital noise elimination)	$3T_{SMP}$ + 20		ns
FLMD0 high-level width Note 2	t_{WMDH}		500		ns
FLMD0 low-level width Note 2	t_{WMDL}		500		ns

Notes 1. The characteristics of INTPn is the same as the $\overline{DRST}$ pin (P05/INTP2/$\overline{DRST}$).

2. Flash memory programming mode only

Remark T_{SMP}: Noise elimination sampling clock cycle

Key Return Timing

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, 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°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, 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, TIP30, TIP31, TIP40, TIP41, TIP50, TIP51, 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°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, 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		2.2 V ≤ V_{DD} < 2.7 V		5	MHz
		2.7 V ≤ V_{DD} < 3.6 V		10	MHz

CSIB Timing

(1) Master mode

(T_A = –40 to +85°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_{KCY1}	<100>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	200		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	800		ns
$\overline{\text{SCKBn}}$ high-level width	t_{KH1}	<101>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	$t_{KCY1}/2 - 8$		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	$t_{KCY1}/2 - 80$		ns
$\overline{\text{SCKBn}}$ low-level width	t_{KL1}	<102>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	$t_{KCY1}/2 - 8$		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	$t_{KCY1}/2 - 80$		ns
SIBn setup time (to $\overline{\text{SCKBn}}$↑)	t_{SIK1}	<103>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	27		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	100		ns
SIBn hold time (from $\overline{\text{SCKBn}}$↑)	t_{KSI1}	<104>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	27		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	100		ns
Delay time from $\overline{\text{SCKBn}}$↓ to SOBn output	t_{KSO1}	<105>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$		27	ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$		95	ns

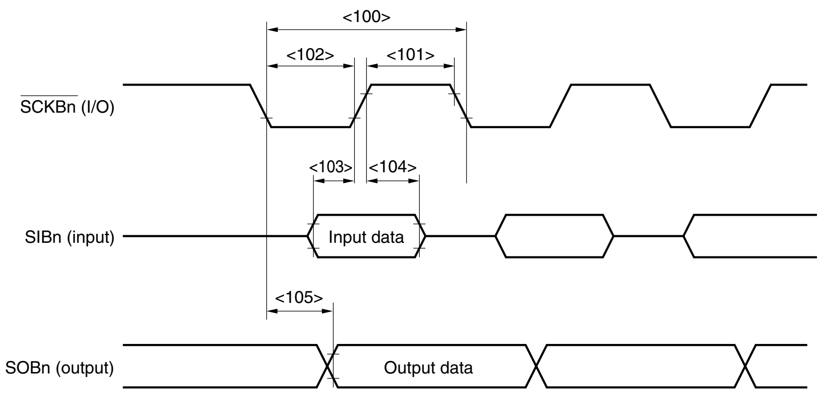
Remark n = 0 to 4

(2) Slave mode

(T_A = –40 to +85°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_{KCY2}	<100>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	200		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	800		ns
$\overline{\text{SCKBn}}$ high-level width	t_{KH2}	<101>		92		ns
$\overline{\text{SCKBn}}$ low-level width	t_{KL2}	<102>		92		ns
SIBn setup time (to $\overline{\text{SCKBn}}$↑)	t_{SIK2}	<103>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	27		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	100		ns
SIBn hold time (from $\overline{\text{SCKBn}}$↑)	t_{KSI2}	<104>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$	27		ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$	100		ns
Delay time from $\overline{\text{SCKBn}}$↓ to SOBn output	t_{KSO2}	<105>	$2.7\ \text{V} \le V_{DD} \le 3.6\ \text{V}$		27	ns
			$2.2\ \text{V} \le V_{DD} < 2.7\ \text{V}$		95	ns

Remark n = 0 to 4



Remark n = 0 to 4

I^{2}C Bus Mode

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V)

Parameter		Symbol		Normal Mode		High-Speed Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCL0n clock frequency		f_{CLK}		0	100	0	400	kHz
Bus free time (Between start and stop conditions)		t_{BUF}	<106>	4.7	–	1.3	–	μs
Hold time[Note 1]		$t_{HD:STA}$	<107>	4.0	–	0.6	–	μs
SCL0n clock low-level width		t_{LOW}	<108>	4.7	–	1.3	–	μs
SCL0n clock high-level width		t_{HIGH}	<109>	4.0	–	0.6	–	μs
Setup time for start/restart conditions		$t_{SU:STA}$	<110>	4.7	–	0.6	–	μs
Data hold time	CBUS compatible master	$t_{HD:DAT}$	<111>	5.0	–	–	–	μs
	I^{2}C mode			0[Note 2]	–	0[Note 2]	0.9[Note 3]	μs
Data setup time		$t_{SU:DAT}$	<112>	250	–	100[Note 4]	–	ns
SDA0n and SCL0n signal rise time		t_R	<113>	–	1000	20 + 0.1Cb[Note 5]	300	ns
SDA0n and SCL0n signal fall time		t_F	<114>	–	300	20 + 0.1Cb[Note 5]	300	ns
Stop condition setup time		$t_{SU:STO}$	<115>	4.0	–	0.6	–	μs
Pulse width of spike suppressed by input filter		t_{SP}	<116>	–	–	0	50	ns
Capacitance load of each bus line		Cb		–	400	–	400	pF

Notes 1. At the start condition, the first clock pulse is generated after the hold time.

2. 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.

3. 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.

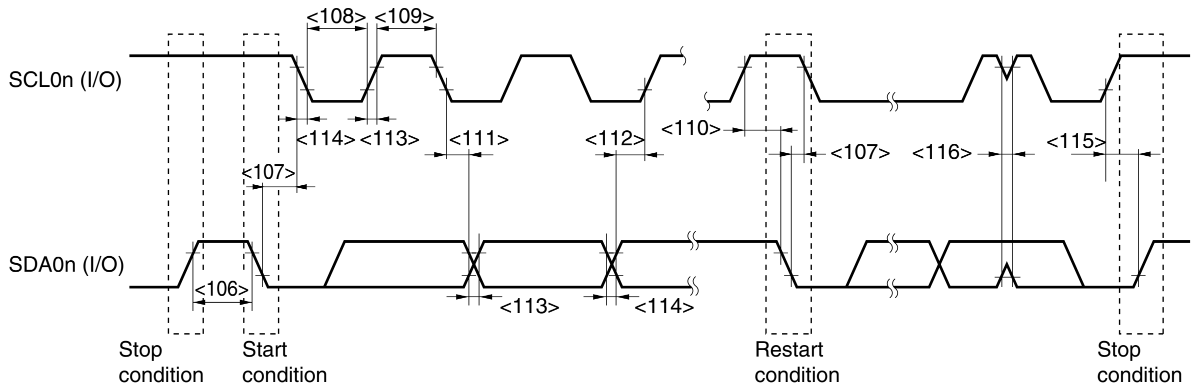
4. The high-speed mode I^{2}C bus can be used in the normal-mode I^{2}C bus system. In this case, set the high-speed mode I^{2}C bus so that it meets the following conditions.

- If the system does not extend the SCL0n signal's low state hold time:
  $t_{SU:DAT} \geq 250$ 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 ($t_{Rmax.} + t_{SU:DAT}$ = 1,000 + 250 = 1,250 ns: Normal mode I^{2}C bus specification).

5. Cb: Total capacitance of one bus line (unit: pF)

Remark n = 0 to 2

I^{2}C Bus Mode



Remark n = 0 to 2

A/D Converter

(T$_{A}$ = –40 to +85°C, V$_{DD}$ = EV$_{DD}$ = AV$_{REF0}$ = AV$_{REF1}$, 2.7 V ≤ AV$_{REF0}$ = AV$_{REF1}$ ≤ 3.6 V, V$_{SS}$ = EV$_{SS}$ = AV$_{SS}$ = 0 V, C$_{L}$ = 50 pF)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution					10	bit
Overall error[Note 1]		2.7 V ≤ AV$_{REF0}$ ≤ 3.6 V			±0.6	%FSR
Conversion time[Note 2]	t_{CONV}	3.0 V ≤ AV$_{REF0}$ ≤ 3.6 V	2.6		24	μs
		2.7 V ≤ AV$_{REF0}$ ≤ 3.0 V	3.9		24	μs
Zero scale error					±0.5	%FSR
Full scale error					±0.5	%FSR
Non-linearity error					±4.0	LSB
Differential linearity error					±4.0	LSB
Analog input voltage	V$_{IAN}$		AV$_{SS}$		AV$_{REF0}$	V
Reference voltage	AV$_{REF0}$		2.7		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	μA

Notes 1. Excluding quantization error (±0.05 %FSR).

2. This is the conversion time of only the analog blocks. The conversion time set by the ADA0M1.ADA0FR0 to ADA0M1.ADA0FR2 bits is this value plus the time to transfer data to the A/D controller block.

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°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.	TYP.	MAX.	Unit
Resolution					8	bit
Overall error		R = 2 MΩ			±1.2	%FSR
Settling time		C = 20 pF			3	μs
Output resistor	R_O	Output data 55H		6.42		kΩ
Reference voltage	AV_{REF1}		2.7		3.6	V
AV_{REF1} current^{Note}	AI_{REF1}	D/A conversion operating		1	2.5	mA
		D/A conversion stopped			5	μA

Note Value of 1 channel of D/A converter

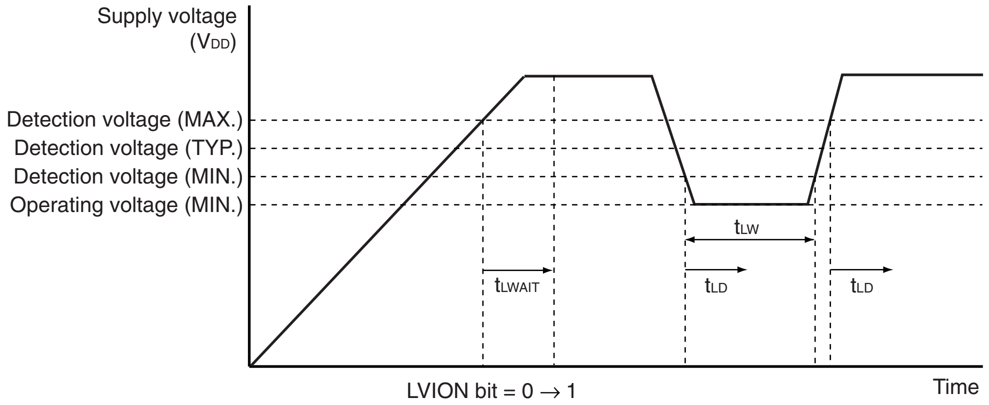
Remark R is the output pin load resistance and C is the output pin load capacitance.

LVI Circuit Characteristics

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.2 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V_{LVI0}		2.7	2.8	2.9	V
	V_{LVI1}		2.2	2.3	2.4	V
Response time^{Note}	t_{LD}	After V_{DD} reaches V_{LVI0}/V_{LVI1} (MAX.), or after V_{DD} has dropped to V_{LVI0}/V_{LVI1} (MIN.)		0.2	2.0	ms
Minimum pulse width	t_{LW}	V_{DD} = V_{LVI0}/V_{LVI1} (MIN.)	0.2			ms
Reference voltage stabilization wait time	t_{LWAIT}	After V_{DD} reaches V_{LVI0} or V_{LVI1} (MAX.)		0.1	0.2	ms

Note Time required to detect the detection voltage and output an interrupt or reset signal.



Flash Memory Programming Characteristics

(T_A = –40 to +85°C, V_{DD} = EV_{DD} = AV_{REF0} = AV_{REF1} = 2.7 to 3.6 V, V_{SS} = EV_{SS} = AV_{SS} = 0 V, C_L = 50 pF)

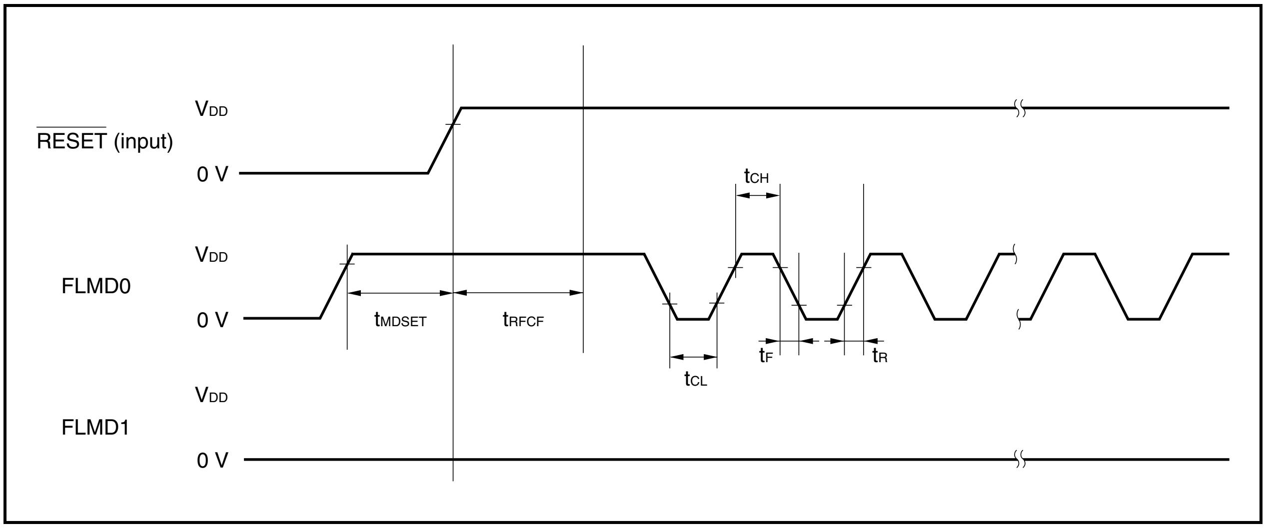
(1) Basic characteristics

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Operating frequency	f_{CPU}		2.5		20	MHz
Supply voltage	V_{DD}	2.5 MHz ≤ f_{XX} ≤ 20 MHz	2.7		3.6	V
Number of rewrites	C_{WRT}				100	times
Programming temperature	t_{PRG}		–40		+85	°C

(2) Serial write operation characteristics

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
FLMD0, FLMD1 setup time	t_{MDSET}		2		3000	ms
FLMD0 count start time from $\overline{\text{RESET}}$↑	t_{RFCF}	f_X = 2.5 to 10 MHz	800			μs
FLMD0 counter high-level width/ low-level width	t_{CH}/t_{CL}		10		100	μs
FLMD0 counter rise time/fall time	t_R/t_F				1	μs

Flash write mode setup timing



(3) Programming characteristics

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Chip erase time		f_{XX} = 20 MHz (batch processing)		105		ms
Write time per 256 bytes		f_{XX} = 20 MHz		2.0		ms
Block internal verify time		f_{XX} = 20 MHz		10		ms
Block blank check time		f_{XX} = 20 MHz		0.5		ms
Flash memory information setting time		f_{XX} = 20 MHz		30		ms

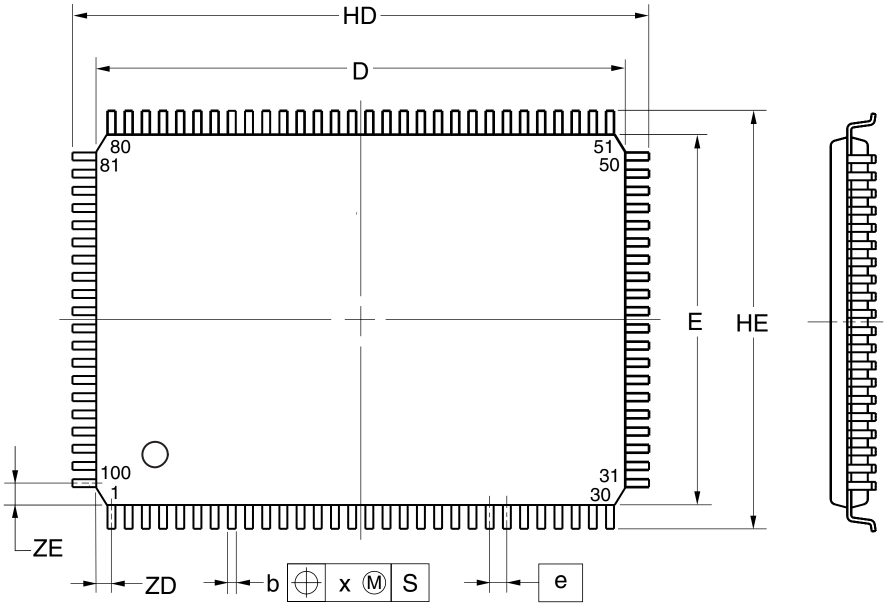
Remark Block size = 2 KB

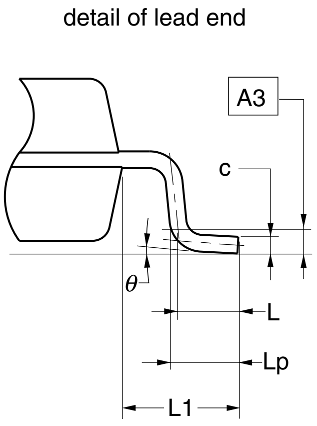
Caution When writing initially to shipped products, it is counted as one rewrite for both “erase to write” and “write only”.

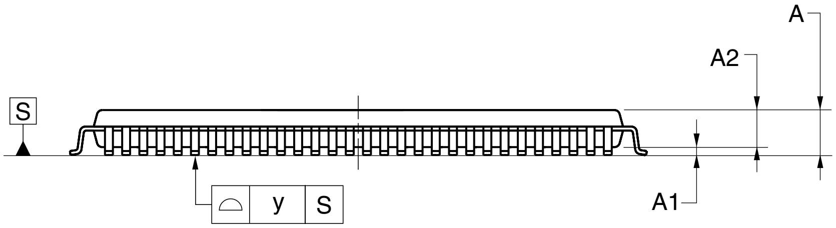
Example (P: Write, E: Erase)

Shipped product ⟶ P → E → P → E → P: 3 rewrites
Shipped product → E → P → E → P → E → P: 3 rewrites

100-PIN PLASTIC LQFP (14x20)







NOTE

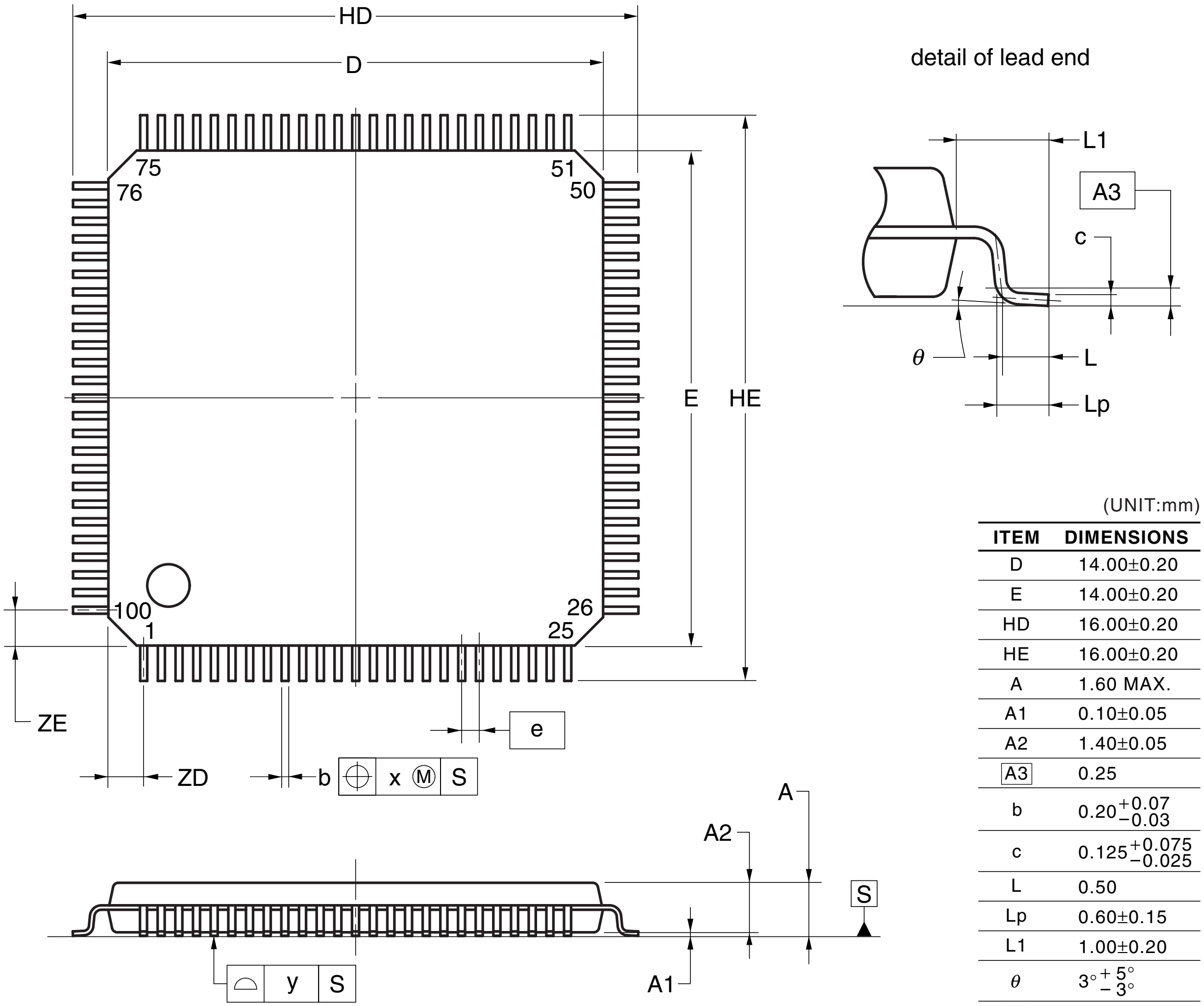
Each lead centerline is located within 0.13 mm of its true position at maximum material condition.

(UNIT:mm)

ITEM	DIMENSIONS
D	20.00±0.20
E	14.00±0.20
HD	22.00±0.20
HE	16.00±0.20
A	1.60 MAX.
A1	0.10±0.05
A2	1.40±0.05
$\boxed{\text{A3}}$	0.25
b	$0.30^{+0.08}_{-0.04}$
c	$0.125^{+0.075}_{-0.025}$
L	0.50
Lp	0.60±0.15
L1	1.00±0.20
θ	$3°^{+5°}_{-3°}$
$\boxed{\text{e}}$	0.65
x	0.13
y	0.10
ZD	0.575
ZE	0.825

P100GF-65-GAS

100-PIN PLASTIC LQFP (FINE PITCH) (14x14)



(UNIT:mm)

ITEM	DIMENSIONS
D	14.00±0.20
E	14.00±0.20
HD	16.00±0.20
HE	16.00±0.20
A	1.60 MAX.
A1	0.10±0.05
A2	1.40±0.05
$\boxed{\text{A3}}$	0.25
b	$0.20^{+0.07}_{-0.03}$
c	$0.125^{+0.075}_{-0.025}$
L	0.50
Lp	0.60±0.15
L1	1.00±0.20
θ	$3°^{+5°}_{-3°}$
$\boxed{\text{e}}$	0.50
x	0.08
y	0.08
ZD	1.00
ZE	1.00

P100GC-50-UEU-1

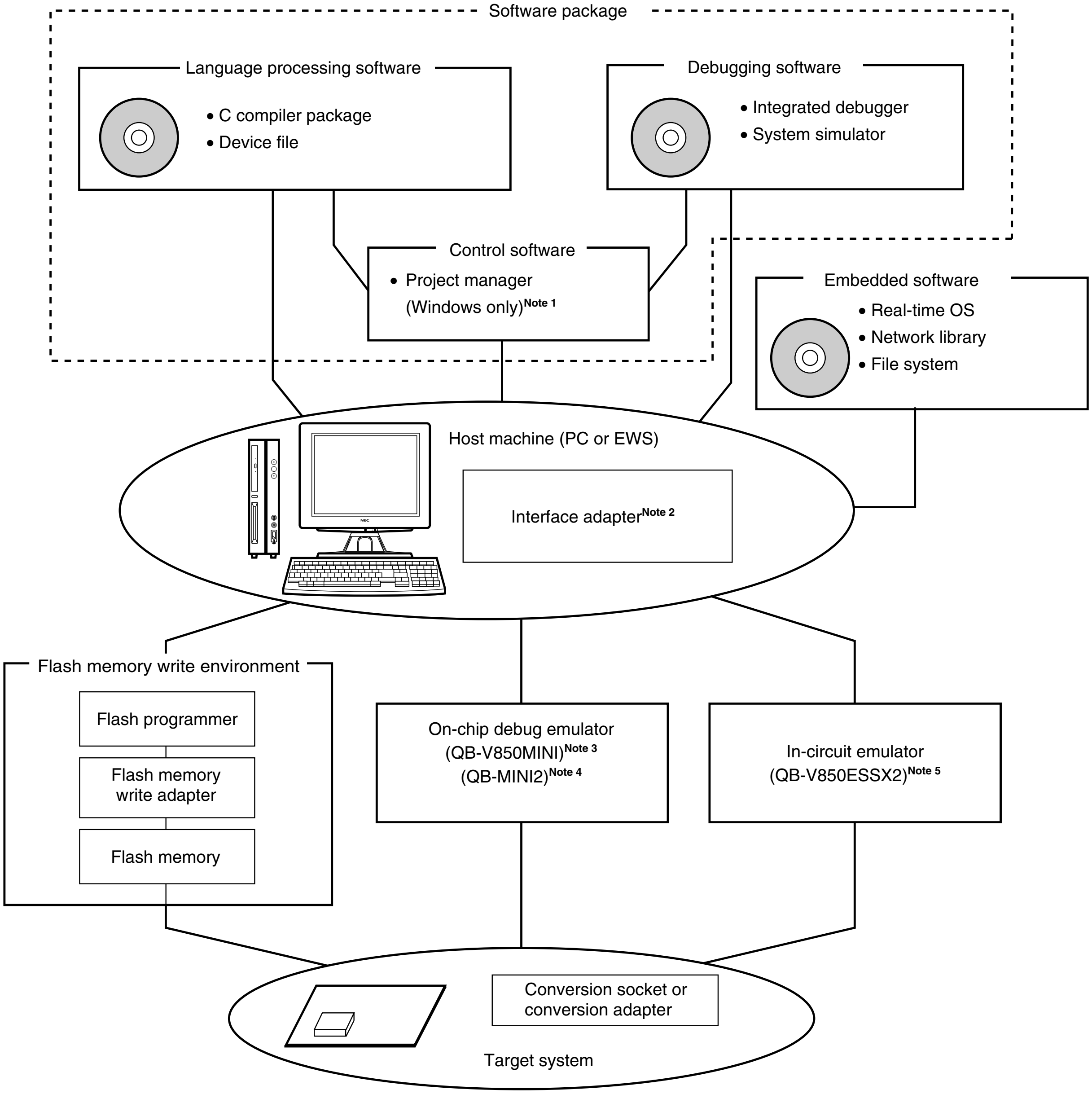
APPENDIX A DEVELOPMENT TOOLS

The following development tools are available for the development of systems that employ the V850ES/JG3-L.
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, flash memory programmer (MINICUBE2), power supply unit, and USB interface adapter. All other products are optional.

A.1 Software Package

SP850 Software package for V850 microcontrollers	Development tools (software) commonly used with V850 microcontrollers are included this package.
	Part number: μS××××SP850

Remark ×××× in the part number differs depending on the host machine and OS used.

μS××××SP850

××××	Host Machine	OS	Supply Medium
AB17	PC-9800 series, IBM PC/AT compatibles	Windows (Japanese version)	CD-ROM
BB17		Windows (English version)	

A.2 Language Processing Software

CA850 C compiler package	This compiler converts programs written in C into object codes executable with a microcontroller. This compiler is started from project manager PM+.
	Part number: μS××××CA703000
DF703738 Device file	This file contains information peculiar to the device. This device file should be used in combination with a tool (CA850 or ID850QB). The corresponding OS and host machine differ depending on the tool to be used.

Remark ×××× in the part number differs depending on the host machine and OS used.

μS××××CA703000

××××	Host Machine	OS	Supply Medium
AB17	PC-9800 series, IBM PC/AT compatibles	Windows (Japanese version)	CD-ROM
BB17		Windows (English version)	
3K17	SPARCstation™	SunOS™ (Rel. 4.1.4), Solaris™ (Rel. 2.5.1)	

A.3 Control Software

PM+ Project manager	This is control software designed to enable efficient user program development in the Windows environment. All operations used in development of a user program, such as starting the editor, building, and starting the debugger, can be performed from PM+. **<Caution>** PM+ is included in C compiler package CA850. 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)

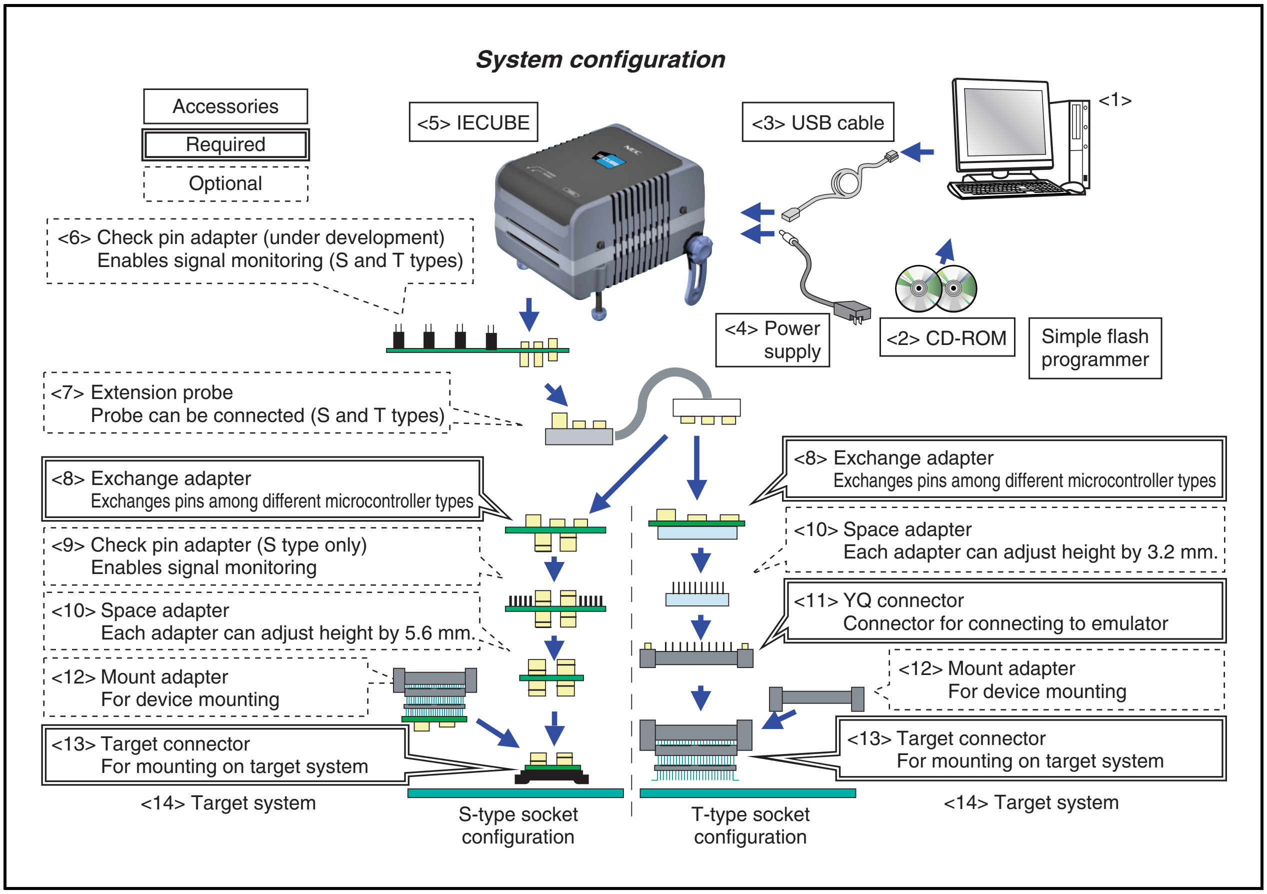


Figure A-2. System Configuration (When Using QB-V850ESSX2) (2/2)

<1> Host machine (PC-9821 series, IBM-PC/AT compatibles)
<2> Debugger, USB driver, manuals, etc. (ID850QB Disk, Accessory Disk[Note 1])
<3> USB interface cable
<4> AC adapter
<5> In-circuit emulator (QB-V850ESSX2)
<6> Check pin adapter (S and T types) (QB-144-CA-01[Note 2]) (optional)
<7> Extension probe (S and T types) (QB-144-EP-01S) (optional)
<8> Exchange adapter[Note 3] (S type: QB-100GC-EA-01S (GC package), QB-100GF-EA-01S (GF package), T type: QB-100GC-EA-01T (GC package), QB-100GF-EA-01T (GF package))
<9> Check pin adapter[Note 4] (S type only) (QB-100-CA-01S) (optional)
<10> Space adapter[Note 4] (S type: QB-100-SA-01S (GC/GF packages), T type: QB-100GC-YS-01T (GF package), QB-100GF-YS-01T (GF package) (optional)
<11> YQ connector[Note 3] (T type only) (QB-100GC-YQ-01T) (GC package), QB-100GF-YQ-01T (GF package)
<12> Mount adapter (S type: QB-100GC-MA-01S (GC package), QB-100GF-MA-01S (GF package), T type: QB-100GF-HQ-01T (GC package), QB-100GF-HQ-01T (GF package)) (optional)
<13> Target connector[Note 3] (S type: QB-100GC-TC-01S (GC package), QB-100GF-TC-01S (GF package), T type: QB-100GC-NQ-01T (GC package), QB-100GF-NQ-01T (GF package))
<14> Target system

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-S100GC is ordered
  The QB-100GC-EA-01S and QB-100GC-TC-01S are supplied.
- When QB-V850ESSX2-S100GF is ordered
  The QB-100GF-EA-01S and QB-100GF-TC-01S are supplied.
- When QB-V850ESSX2-T100GC is ordered
  The QB-100GC-EA-01T, QB-100GC-YQ-01T, and QB-100GC-NQ-01T are supplied.
- When QB-V850ESSX2-T100GF is ordered
  The QB-100GF-EA-01T, QB-100GF-YQ-01T, and QB-100GF-NQ-01T are supplied.

4. When using both <9> and <10>, the order between <9> and <10> is not cared.

<5> QB-V850ESSX2[Note] In-circuit emulator	The in-circuit emulator serves to debug hardware and software when developing application systems using the V850ES/JG3-L. It supports 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-100GC-EA-01S QB-100GF-EA-01S QB-100GC-EA-01T QB-100GF-EA-01T Exchange adapter	Adapter to perform pin conversion. • QB-100GC-EA-01S: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-EA-01S: 100-pin plastic LQFP (GF-GAS type) • QB-100GC-EA-01T: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-EA-01T: 100-pin plastic LQFP (GC-GAS type)
<9> QB-100-CA-01S (S type only) Check pin adapter	Adapter used in waveform monitoring using the oscilloscope, etc. • QB-100-CA-01S: GC-UEU/GF-GAS type
<10> QB-100-SA-01S QB-100GC-YS-01T QB-100GF-YS-01T Space adapter	Adapter to adjust the height. • QB-100GF-SA-01S: GC-UEU/GF-GAS type • QB-100GC-YS-01T: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-YS-01T: 100-pin plastic LQFP (GF-GAS type)
<11> QB-100GC-YQ-01T QB-100GF-YQ-01T (T type only) YQ connector	Conversion adapter to connect target connector and exchange adapter • QB-100GC-YQ-01T: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-YQ-01T: 100-pin plastic LQFP (GF-GAS type)
<12> QB-100GC-MA-01S QB-100GF-MA-01S QB-100GC-HQ-01T QB-100GF-HQ-01T Mount adapter	Adapter to mount the V850ES/JG3-L with socket. • QB-100GC-MA-01S: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-MA-01S: 100-pin plastic LQFP (GF-GAS type) • QB-100GC-HQ-01T: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-HQ-01T: 100-pin plastic LQFP (GF-GAS type)
<13> QB-100GC-TC-01S QB-100GF-TC-01S QB-100GC-NQ-01T QB-100GF-NQ-01T Target connector	Connector to solder on the target system. • QB-100GC-TC-01S: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-TC-01S: 100-pin plastic LQFP (GF-GAS type) • QB-100GC-NQ-01T: 100-pin plastic LQFP (GC-UEU type) • QB-100GF-NQ-01T: 100-pin plastic LQFP (GF-GAS type)

Note The QB-V850ESSX2 is supplied with a power supply unit, USB interface cable, and flash memory programmer (MINICUBE2). It is also supplied with integrated debugger ID850QB as control software.

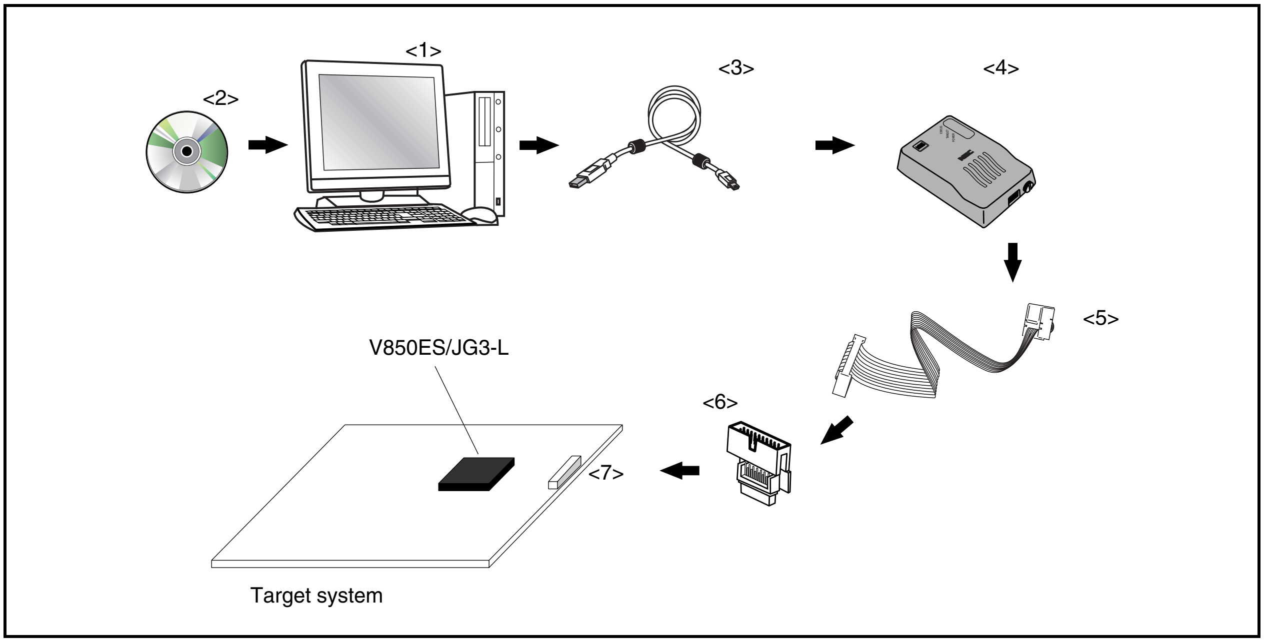
Remark The numbers in the angle brackets correspond to the numbers in Figure A-2.

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[Note 1]	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 On-chip debug emulator	This on-chip debug emulator serves to debug hardware and software when developing application systems using the V850ES/JG3-L. 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 KEL adapter	This conversion board is supplied with MINICUBE.
<7> MINICUBE connector KEL connector[Note 2]	8830E-026-170S (supplied with MINICUBE) 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

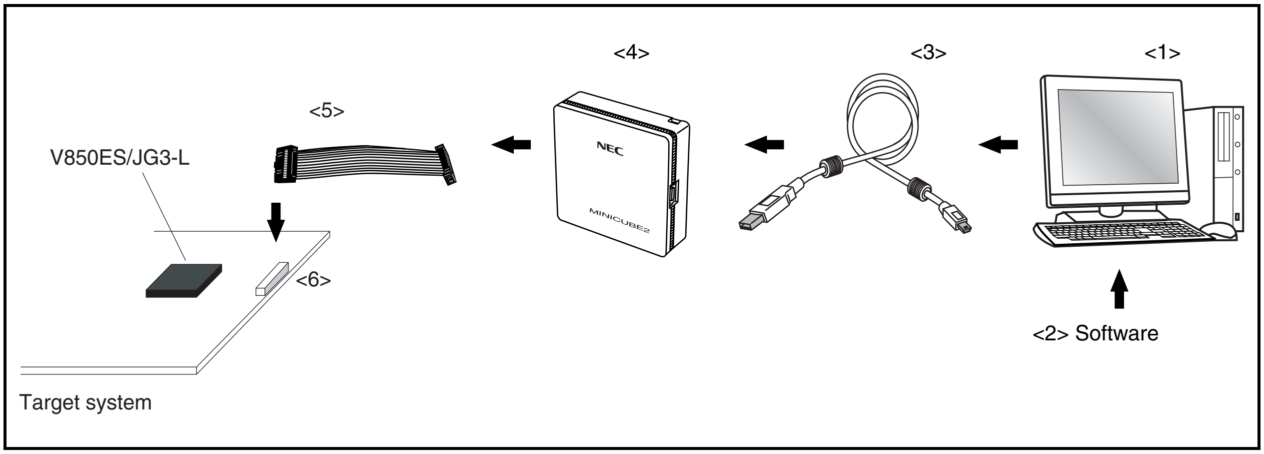
2. Product of KEL Corporation

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. Download the device file from the NEC Electronics website. http://www.necel.com/micro/ods/eng/
<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 On-chip debug emulator	This on-chip debug emulator serves to debug hardware and software when developing application systems using the V850ES/JG3-L. It supports integrated debugger ID850QB.
<5> 16-pin target cable	Cable to connect MINICUBE2 and the target system. 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)

ID850QB Integrated debugger	This debugger supports the in-circuit emulators for V850 microcontrollers. The ID850QB is Windows-based software. 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. It should be used in combination with the device file.
	Part number: μS×××× ID703000-QB (ID850QB)

Remark ×××× in the part number differs depending on the host machine and OS used.

μS××××ID703000-QB

××××	Host Machine	OS	Supply Medium
AB17	PC-9800 series, IBM PC/AT compatibles	Windows (Japanese version)	CD-ROM
BB17		Windows (English version)	

A.6 Embedded Software

RX850, RX850 Pro Real-time OS	The RX850 and RX850 Pro are real-time OSs conforming to μITRON 3.0 specifications. A tool (configurator) for generating multiple information tables is supplied. RX850 Pro has more functions than the RX850.
	Part number: μS××××RX703000-ΔΔΔΔ (RX850) μS××××RX703100-ΔΔΔΔ (RX850 Pro)
Applilet® (under development)	This is a driver configurator that automatically generates sample programs for the V850ES/JG3-L.
RX-FS850 (File system)	This is a FAT file system function. It is a file system that supports the CD-ROM file system function. 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 ×××× and ΔΔΔΔ in the part number differ depending on the host machine and OS used.

μS××××RX703000-ΔΔΔΔ
μS××××RX703100-ΔΔΔΔ

ΔΔΔΔ	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

××××	Host Machine	OS	Supply Medium
AB17	PC-9800 series, 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 (part number: PG-FP4) Flashpro V (part number: PG-FP5) Flash programmer	Flash programmer dedicated to microcontrollers with internal flash memory.
QB-MINI2 (MINICUBE2)	On-chip debug emulator with programming function.
FA-100GC-UEU-B FA-100GF-GAS-B Flash memory writing adapter	Flash memory writing adapter used connected to the Flashpro IV, Flashpro V, etc. (not wired). • FA-100GC-UEU-B: 100-pin plastic LQFP (GC-UEU type) • FA-100GF-GAS-B: 100-pin plastic LQFP (GF-GAS type)
FA-70F3738GC-UEU-RX (under development) FA-70F3738GF-GAS-RX (under development) Flash memory writing adapter	Flash memory writing adapter used connected to the Flashpro IV, Flashpro V, etc. (already wired). • FA-70F3738GC-UEU-RX: 100-pin plastic LQFP (GC-UEU type) • FA-70F3738GF-GAS-RX: 100-pin plastic LQFP (GF-GAS type)

Remark FA-100GC-UEU-B and FA-100GF-GAS-B are products of Naito Densei Machida Mfg. Co., Ltd.
TEL: +81-42-750-4172

APPENDIX B MAJOR DIFFERENCES BETWEEN V850ES/JG3-L AND V850ES/JG2

Table B-1. Major Differences Between V850ES/JG3-L and V850ES/JG2

Major Differences		V850ES/JG3-L	V850ES/JG2
Pin	BV_{DD}, BV_{SS} pins	Changed to EV_{DD}, EV_{SS}	Provided
	Port (5 V tolerant)	84 (31)	84 (40)
Memory	Internal flash memory	128/256 KB	128/256/384/512/640 KB
	Internal RAM	8/16 KB	12/24/32/40/48 KB
Supply voltage	V_{DD}, EV_{DD}	2.2 to 3.6 V @5 MHz 2.7 to 3.6 V @20 MHz	2.85 to 3.6 V @20 MHz
	A/D, D/A operating voltage	2.7 to 3.6 V	3.0 to 3.6 V
Low-voltage detector (LVI)	LVI	2 levels: 2.8 V (TYP.), 2.3 V (TYP.) Selectable by software	1 level: 3.0 V (TYP.)
	Interrupt condition at low-voltage detection	When supply voltage drops or rises across the detection voltage	When supply voltage drops below the detection voltage
	RAMF	None	Provided
Standby function	Low-voltage STOP/ low-voltage subclock operation/ low-voltage sub-IDLE mode	Provided	None
CRC circuit		Provided	None
Flash memory	Boot area	32 KB	56 KB
	Block configuration	Block 0 to last block: 2 KB each	Blocks 0 to 3: 28 KB each Blocks 4 to 7: 4 KB each Block 8 to last block: 64 KB each

APPENDIX C REGISTER INDEX

(1/10)

(2/10)

Symbol	Name	Unit	Page
CB0TX	CSIB0 transmit data register	CSI	505
CB0TXL	CSIB0 transmit data register L	CSI	505
CB1CTL0	CSIB1 control register 0	CSI	506
CB1CTL1	CSIB1 control register 1	CSI	509
CB1CTL2	CSIB1 control register 2	CSI	510
CB1RIC	Interrupt control register	INTC	670
CB1RX	CSIB1 receive data register	CSI	505
CB1RXL	CSIB1 receive data register L	CSI	505
CB1STR	CSIB1 status register	CSI	512
CB1TIC	Interrupt control register	INTC	670
CB1TX	CSIB1 transmit data register	CSI	505
CB1TXL	CSIB1 transmit data register L	CSI	505
CB2CTL0	CSIB2 control register 0	CSI	506
CB2CTL1	CSIB2 control register 1	CSI	509
CB2CTL2	CSIB2 control register 2	CSI	510
CB2RIC	Interrupt control register	INTC	670
CB2RX	CSIB2 receive data register	CSI	505
CB2RXL	CSIB2 receive data register L	CSI	505
CB2STR	CSIB2 status register	CSI	512
CB2TIC	Interrupt control register	INTC	670
CB2TX	CSIB2 transmit data register	CSI	505
CB2TXL	CSIB2 transmit data register L	CSI	505
CB3CTL0	CSIB3 control register 0	CSI	506
CB3CTL1	CSIB3 control register 1	CSI	509
CB3CTL2	CSIB3 control register 2	CSI	510
CB3RIC	Interrupt control register	INTC	670
CB3RX	CSIB3 receive data register	CSI	505
CB3RXL	CSIB3 receive data register L	CSI	505
CB3STR	CSIB3 status register	CSI	512
CB3TIC	Interrupt control register	INTC	670
CB3TX	CSIB3 transmit data register	CSI	505
CB3TXL	CSIB3 transmit data register L	CSI	505
CB4CTL0	CSIB4 control register 0	CSI	506
CB4CTL1	CSIB4 control register 1	CSI	509
CB4CTL2	CSIB4 control register 2	CSI	510
CB4RIC	Interrupt control register	INTC	671
CB4RX	CSIB4 receive data register	CSI	505
CB4RXL	CSIB4 receive data register L	CSI	505
CB4STR	CSIB4 status register	CSI	512
CB4TIC	Interrupt control register	INTC	671
CB4TX	CSIB4 transmit data register	CSI	505
CB4TXL	CSIB4 transmit data register L	CSI	505
CCLS	CPU operation clock status register	CG	200
CKC	Clock control register	CG	203
CLM	Clock monitor mode register	CLM	732

(3/10)

Symbol	Name	Unit	Page
CRCD	CRC data register	CRC	742
CRCIN	CRC input register	CRC	742
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	462
DA0CS1	D/A conversion value setting register 1	DAC	462
DA0M	D/A converter mode register	DAC	461
DADC0	DMA addressing control register 0	DMAC	635
DADC1	DMA addressing control register 1	DMAC	635
DADC2	DMA addressing control register 2	DMAC	635
DADC3	DMA addressing control register 3	DMAC	635
DBC0	DMA byte count register 0	DMAC	634
DBC1	DMA byte count register 1	DMAC	634
DBC2	DMA byte count register 2	DMAC	634
DBC3	DMA byte count register 3	DMAC	634
DBPC	Exception/debug trap status saving register	CPU	54
DBPSW	Exception/debug trap status saving register	CPU	54
DCHC0	DMA channel control register 0	DMAC	636
DCHC1	DMA channel control register 1	DMAC	636
DCHC2	DMA channel control register 2	DMAC	636
DCHC3	DMA channel control register 3	DMAC	636
DDA0H	DMA destination address register 0H	DMAC	633
DDA0L	DMA destination address register 0L	DMAC	633
DDA1H	DMA destination address register 1H	DMAC	633
DDA1L	DMA destination address register 1L	DMAC	633
DDA2H	DMA destination address register 2H	DMAC	633
DDA2L	DMA destination address register 2L	DMAC	633
DDA3H	DMA destination address register 3H	DMAC	633
DDA3L	DMA destination address register 3L	DMAC	633
DMAIC0	Interrupt control register	INTC	671
DMAIC1	Interrupt control register	INTC	671
DMAIC2	Interrupt control register	INTC	671
DMAIC3	Interrupt control register	INTC	671
DSA0H	DMA source address register 0H	DMAC	632
DSA0L	DMA source address register 0L	DMAC	632
DSA1H	DMA source address register 1H	DMAC	632
DSA1L	DMA source address register 1L	DMAC	632
DSA2H	DMA source address register 2H	DMAC	632
DSA2L	DMA source address register 2L	DMAC	632
DSA3H	DMA source address register 3H	DMAC	632
DSA3L	DMA source address register 3L	DMAC	632
DTFR0	DMA trigger factor register 0	DMAC	637
DTFR1	DMA trigger factor register 1	DMAC	637
DTFR2	DMA trigger factor register 2	DMAC	637

(4/10)

Symbol	Name	Unit	Page
DTFR3	DMA trigger factor register 3	DMAC	637
DWC0	Data wait control register 0	BCU	179
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	170
FEPC	NMI status saving register	CPU	51
FEPSW	NMI status saving register	CPU	51
IIC0	IIC shift register 0	I^2C	573
IIC1	IIC shift register 1	I^2C	573
IIC2	IIC shift register 2	I^2C	573
IICC0	IIC control register 0	I^2C	559
IICC1	IIC control register 1	I^2C	559
IICC2	IIC control register 2	I^2C	559
IICCL0	IIC clock select register 0	I^2C	569
IICCL1	IIC clock select register 1	I^2C	569
IICCL2	IIC clock select register 2	I^2C	569
IICF0	IIC flag register 0	I^2C	567
IICF1	IIC flag register 1	I^2C	567
IICF2	IIC flag register 2	I^2C	567
IICIC0	Interrupt control register	INTC	671
IICIC1	Interrupt control register	INTC	670
IICIC2	Interrupt control register	INTC	671
IICS0	IIC status register 0	I^2C	564
IICS1	IIC status register 1	I^2C	564
IICS2	IIC status register 2	I^2C	564
IICX0	IIC function expansion register 0	I^2C	570
IICX1	IIC function expansion register 1	I^2C	570
IICX2	IIC function expansion register 2	I^2C	570
IMR0	Interrupt mask register 0	INTC	671
IMR0H	Interrupt mask register 0H	INTC	671
IMR0L	Interrupt mask register 0L	INTC	671
IMR1	Interrupt mask register 1	INTC	671
IMR1H	Interrupt mask register 1H	INTC	671
IMR1L	Interrupt mask register 1L	INTC	671
IMR2	Interrupt mask register 2	INTC	671
IMR2H	Interrupt mask register 2H	INTC	671
IMR2L	Interrupt mask register 2L	INTC	671
IMR3	Interrupt mask register 3	INTC	671
IMR3H	Interrupt mask register 3H	INTC	671
IMR3L	Interrupt mask register 3L	INTC	671
INTF0	External interrupt falling edge specification register 0	INTC	683
INTF3	External interrupt falling edge specification register 3	INTC	684
INTF9H	External interrupt falling edge specification register 9H	INTC	685
INTR0	External interrupt rising edge specification register 0	INTC	683

(5/10)

Symbol	Name	Unit	Page
INTR3	External interrupt rising edge specification register 3	INTC	684
INTR9H	External interrupt rising edge specification register 9H	INTC	685
ISPR	In-service priority register	INTC	673
KRIC	Interrupt control register	INTC	671
KRM	Key return mode register	KR	690
LOCKR	Lock register	CG	204
LVIIC	Interrupt control register	INTC	670
LVIM	Low voltage detection register	LVI	737
LVIS	Low voltage detection level select register	LVI	738
NFC	Noise elimination control register	INTC	686
OCDM	On-chip debug mode register	DCU	780
OCKS0	IIC division clock select register 0	I^2C	573
OCKS1	IIC division clock select register 1	I^2C	573
OSTS	Oscillation stabilization time select register	Standby	695
P0	Port 0 register	Port	89
P1	Port 1 register	Port	92
P3	Port 3 register	Port	94
P3H	Port 3 register H	Port	94
P3L	Port 3 register L	Port	94
P4	Port 4 register	Port	99
P5	Port 5 register	Port	101
P7H	Port 7 register H	Port	106
P7L	Port 7 register L	Port	106
P9	Port 9 register	Port	108
P9H	Port 9 register H	Port	108
P9L	Port 9 register L	Port	108
PC	Program counter	CPU	48
PCC	Processor clock control register	CG	196
PCM	Port CM register	Port	115
PCT	Port CT register	Port	117
PDH	Port DH register	Port	119
PDL	Port DL register	Port	122
PDLH	Port DL register H	Port	122
PDLL	Port DL register L	Port	122
PF0	Port 0 function register	Port	91
PF3	Port 3 function register	Port	98
PF3H	Port 3 function register H	Port	98
PF3L	Port 3 function register L	Port	98
PF4	Port 4 function register	Port	100
PF5	Port 5 function register	Port	104
PF9	Port 9 function register	Port	114
PF9H	Port 9 function register H	Port	114
PF9L	Port 9 function register L	Port	114
PFC0	Port 0 function control register	Port	91
PFC3	Port 3 function control register	Port	96

(6/10)

(7/10)

Symbol	Name	Unit	Page
PMCDH	Port DH mode control register	Port	120
PMCDL	Port DL mode control register	Port	123
PMCDLH	Port DL mode control register H	Port	123
PMCDLL	Port DL mode control register L	Port	123
PMCM	Port CM mode register	Port	115
PMCT	Port CT mode register	Port	117
PMDH	Port DH mode register	Port	119
PMDL	Port DL mode register	Port	122
PMDLH	Port DL mode register H	Port	122
PMDLL	Port DL mode register L	Port	122
PRCMD	Command register	CPU	78
PRSCM0	Prescaler compare register 0	WT	406
PRSCM1	Prescaler compare register 1	BRG	549
PRSCM2	Prescaler compare register 2	BRG	549
PRSCM3	Prescaler compare register 3	BRG	549
PRSM0	Prescaler mode register 0	WT	405
PRSM1	Prescaler mode register 1	BRG	548
PRSM2	Prescaler mode register 2	BRG	548
PRSM3	Prescaler mode register 3	BRG	548
PSC	Power save control register	CG	693
PSMR	Power save mode register	CG	694
PSW	Program status word	CPU	52
r0 to r31	General-purpose registers	CPU	48
RCM	Internal oscillation mode register	CG	200
REGOVL0	Regulator output voltage level control register 0	REGC	697
REGPR	Regulator protection register	REGC	696
RESF	Reset source flag register	Reset	722
RTBH0	Real-time output buffer register 0H	RTP	419
RTBL0	Real-time output buffer register 0L	RTP	419
RTPC0	Real-time output port control register 0	RTP	421
RTPM0	Real-time output port mode register 0	RTP	420
SELCNT0	Selector operation control register 0	Timer	293
SVA0	Slave address register 0	I^{2}C	574
SVA1	Slave address register 1	I^{2}C	574
SVA2	Slave address register 2	I^{2}C	574
SYS	System status register	CPU	79
TM0CMP0	TMM0 compare register 0	Timer	395
TM0CTL0	TMM0 control register 0	Timer	396
TM0EQIC0	Interrupt control register	INTC	670
TP0CCIC0	Interrupt control register	INTC	670
TP0CCIC1	Interrupt control register	INTC	670
TP0CCR0	TMP0 capture/compare register 0	Timer	217
TP0CCR1	TMP0 capture/compare register 1	Timer	219
TP0CNT	TMP0 counter read buffer register	Timer	221
TP0CTL0	TMP0 control register 0	Timer	211

(8/10)

Symbol	Name	Unit	Page
TP0CTL1	TMP0 control register 1	Timer	211
TP0IOC0	TMP0 I/O control register 0	Timer	213
TP0IOC1	TMP0 I/O control register 1	Timer	214
TP0IOC2	TMP0 I/O control register 2	Timer	215
TP0OPT0	TMP0 option register 0	Timer	216
TP0OVIC	Interrupt control register	INTC	670
TP1CCIC0	Interrupt control register	INTC	670
TP1CCIC1	Interrupt control register	INTC	670
TP1CCR0	TMP1 capture/compare register 0	Timer	217
TP1CCR1	TMP1 capture/compare register 1	Timer	219
TP1CNT	TMP1 counter read buffer register	Timer	221
TP1CTL0	TMP1 control register 0	Timer	211
TP1CTL1	TMP1 control register 1	Timer	211
TP1IOC0	TMP1 I/O control register 0	Timer	213
TP1IOC1	TMP1 I/O control register 1	Timer	214
TP1IOC2	TMP1 I/O control register 2	Timer	215
TP1OPT0	TMP1 option register 0	Timer	216
TP1OVIC	Interrupt control register	INTC	670
TP2CCIC0	Interrupt control register	INTC	670
TP2CCIC1	Interrupt control register	INTC	670
TP2CCR0	TMP2 capture/compare register 0	Timer	217
TP2CCR1	TMP2 capture/compare register 1	Timer	219
TP2CNT	TMP2 counter read buffer register	Timer	221
TP2CTL0	TMP2 control register 0	Timer	211
TP2CTL1	TMP2 control register 1	Timer	211
TP2IOC0	TMP2 I/O control register 0	Timer	213
TP2IOC1	TMP2 I/O control register 1	Timer	214
TP2IOC2	TMP2 I/O control register 2	Timer	215
TP2OPT0	TMP2 option register 0	Timer	216
TP2OVIC	Interrupt control register	INTC	670
TP3CCIC0	Interrupt control register	INTC	670
TP3CCIC1	Interrupt control register	INTC	670
TP3CCR0	TMP3 capture/compare register 0	Timer	217
TP3CCR1	TMP3 capture/compare register 1	Timer	219
TP3CNT	TMP3 counter read buffer register	Timer	221
TP3CTL0	TMP3 control register 0	Timer	211
TP3CTL1	TMP3 control register 1	Timer	211
TP3IOC0	TMP3 I/O control register 0	Timer	213
TP3IOC1	TMP3 I/O control register 1	Timer	214
TP3IOC2	TMP3 I/O control register 2	Timer	215
TP3OPT0	TMP3 option register 0	Timer	216
TP3OVIC	Interrupt control register	INTC	670
TP4CCIC0	Interrupt control register	INTC	670
TP4CCIC1	Interrupt control register	INTC	670
TP4CCR0	TMP4 capture/compare register 0	Timer	217

(9/10)

Symbol	Name	Unit	Page
TP4CCR1	TMP4 capture/compare register 1	Timer	219
TP4CNT	TMP4 counter read buffer register	Timer	221
TP4CTL0	TMP4 control register 0	Timer	211
TP4CTL1	TMP4 control register 1	Timer	211
TP4IOC0	TMP4 I/O control register 0	Timer	213
TP4IOC1	TMP4 I/O control register 1	Timer	214
TP4IOC2	TMP4 I/O control register 2	Timer	215
TP4OPT0	TMP4 option register 0	Timer	216
TP4OVIC	Interrupt control register	INTC	670
TP5CCIC0	Interrupt control register	INTC	670
TP5CCIC1	Interrupt control register	INTC	670
TP5CCR0	TMP5 capture/compare register 0	Timer	217
TP5CCR1	TMP5 capture/compare register 1	Timer	219
TP5CNT	TMP5 counter read buffer register	Timer	221
TP5CTL0	TMP5 control register 0	Timer	211
TP5CTL1	TMP5 control register 1	Timer	211
TP5IOC0	TMP5 I/O control register 0	Timer	213
TP5IOC1	TMP5 I/O control register 1	Timer	214
TP5IOC2	TMP5 I/O control register 2	Timer	215
TP5OPT0	TMP5 option register 0	Timer	216
TP5OVIC	Interrupt control register	INTC	670
TQ0CCIC0	Interrupt control register	INTC	670
TQ0CCIC1	Interrupt control register	INTC	670
TQ0CCIC2	Interrupt control register	INTC	670
TQ0CCIC3	Interrupt control register	INTC	670
TQ0CCR0	TMQ0 capture/compare register 0	Timer	305
TQ0CCR1	TMQ0 capture/compare register 1	Timer	307
TQ0CCR2	TMQ0 capture/compare register 2	Timer	309
TQ0CCR3	TMQ0 capture/compare register 3	Timer	311
TQ0CNT	TMQ0 counter read buffer register	Timer	313
TQ0CTL0	TMQ0 control register 0	Timer	299
TQ0CTL1	TMQ0 control register 1	Timer	300
TQ0IOC0	TMQ0 I/O control register 0	Timer	301
TQ0IOC1	TMQ0 I/O control register 1	Timer	302
TQ0IOC2	TMQ0 I/O control register 2	Timer	303
TQ0OPT0	TMQ0 option register 0	Timer	304
TQ0OVIC	Interrupt control register	INTC	670
UA0CTL0	UARTA0 control register 0	UARTA	471
UA0CTL1	UARTA0 control register 1	UARTA	493
UA0CTL2	UARTA0 control register 2	UARTA	494
UA0OPT0	UARTA0 option control register 0	UARTA	473
UA0RIC	Interrupt control register	INTC	671
UA0RX	UARTA0 receive data register	UARTA	476
UA0STR	UARTA0 status register	UARTA	474
UA0TIC	Interrupt control register	INTC	671

(10/10)

Symbol	Name	Unit	Page
UA0TX	UARTA0 transmit data register	UARTA	476
UA1CTL0	UARTA1 control register 0	UARTA	471
UA1CTL1	UARTA1 control register 1	UARTA	493
UA1CTL2	UARTA1 control register 2	UARTA	494
UA1OPT0	UARTA1 option control register 0	UARTA	473
UA1RIC	Interrupt control register	INTC	671
UA1RX	UARTA1 receive data register	UARTA	476
UA1STR	UARTA1 status register	UARTA	474
UA1TIC	Interrupt control register	INTC	671
UA1TX	UARTA1 transmit data register	UARTA	476
UA2CTL0	UARTA2 control register 0	UARTA	471
UA2CTL1	UARTA2 control register 1	UARTA	493
UA2CTL2	UARTA2 control register 2	UARTA	494
UA2OPT0	UARTA2 option control register 0	UARTA	473
UA2RIC	Interrupt control register	INTC	671
UA2RX	UARTA2 receive data register	UARTA	476
UA2STR	UARTA2 status register	UARTA	474
UA2TIC	Interrupt control register	INTC	671
UA2TX	UARTA2 transmit data register	UARTA	476
VSWC	System wait control register	CPU	80
WDTE	Watchdog timer enable register	WDT	416
WDTM2	Watchdog timer mode register 2	WDT	414
WTIC	Interrupt control register	INTC	671
WTIIC	Interrupt control register	INTC	671
WTM	Watch timer operation mode register	WT	407

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
I	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). If, as a result of calculations, n ≥ 7FFFFFFFH, let it be 7FFFFFFFH. 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
ll	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 (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 Lower (Less than)
1 0 0 1	CY = 0	No carry 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 or Z) = 1	Not higher (Less than or equal)
1 0 1 1	(CY 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 xor OV) = 1	Less than signed
1 1 1 0	(S xor OV) = 0	Greater than or equal signed
0 1 1 1	((S xor OV) or Z) = 1	Less than or equal signed
1 1 1 1	((S xor OV) 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	×	×	×	×	
	imm5,reg2	rrrrr010010iiiii	GR[reg2]←GR[reg2]+sign-extend(imm5)	1	1	1	×	×	×	×	
ADDI	imm16,reg1,reg2	rrrrr110000RRRRR iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1]+sign-extend(imm16)	1	1	1	×	×	×	×	
AND	reg1,reg2	rrrrr001010RRRRR	GR[reg2]←GR[reg2]AND GR[reg1]	1	1	1		0	×	×	
ANDI	imm16,reg1,reg2	rrrrr110110RRRRR iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1]AND zero-extend(imm16)	1	1	1		0	×	×	
Bcond	disp9	ddddd1011dddcccc **Note 1**	if conditions are satisfied then PC←PC+sign-extend(disp9) When conditions are satisfied	2 Note 2	2 Note 2	2 Note 2					
			When conditions are not satisfied	1	1	1					
BSH	reg2,reg3	rrrrr11111100000 wwwww01101000010	GR[reg3]←GR[reg2] (23 : 16) ll GR[reg2] (31 : 24) ll GR[reg2] (7 : 0) ll GR[reg2] (15 : 8)	1	1	1	×	0	×	×	
BSW	reg2,reg3	rrrrr11111100000 wwwww01101000000	GR[reg3]←GR[reg2] (7 : 0) ll GR[reg2] (15 : 8) ll GR [reg2] (23 : 16) ll GR[reg2] (31 : 24)	1	1	1	×	0	×	×	
CALLT	imm6	0000001000iiiiii	CTPC←PC+2(return PC) CTPSW←PSW adr←CTBP+zero-extend(imm6 logically shift left by 1) PC←CTBP+zero-extend(Load-memory(adr,Halfword))	4	4	4					
CLR1	bit#3,disp16[reg1]	10bbb111110RRRRR dddddddddddddddd	adr←GR[reg1]+sign-extend(disp16) Z flag←Not(Load-memory-bit(adr,bit#3)) Store-memory-bit(adr,bit#3,0)	3 Note 3	3 Note 3	3 Note 3				×	
	reg2,[reg1]	rrrrr111111RRRRR 0000000011100100	adr←GR[reg1] Z flag←Not(Load-memory-bit(adr,reg2)) Store-memory-bit(adr,reg2,0)	3 Note 3	3 Note 3	3 Note 3				×	
CMOV	cccc,imm5,reg2,reg3	rrrrr111111iiiii wwwww011000cccc0	if conditions are satisfied then GR[reg3]←sign-extended(imm5) else GR[reg3]←GR[reg2]	1	1	1					
	cccc,reg1,reg2,reg3	rrrrr111111RRRR wwwww011001cccc0	if conditions are satisfied then GR[reg3]←GR[reg1] else GR[reg3]←GR[reg2]	1	1	1					
CMP	reg1,reg2	rrrrr001111RRRRR	result←GR[reg2]–GR[reg1]	1	1	1	×	×	×	×	
	imm5,reg2	rrrrr010011iiiii	result←GR[reg2]–sign-extend(imm5)	1	1	1	×	×	×	×	
CTRET		0000011111100000 0000000101000100	PC←CTPC PSW←CTPSW	3	3	3	R	R	R	R	R
DBRET		0000011111100000 0000000101000110	PC←DBPC PSW←DBPSW	3	3	3	R	R	R	R	R

(2/6)

Mnemonic	Operand	Opcode	Operation	Execution Clock			Flags				
				i	r	l	CY	OV	S	Z	SAT
DBTRAP		1111100001000000	DBPC←PC+2 (restored PC) DBPSW←PSW PSW.NP←1 PSW.EP←1 PSW.ID←1 PC←00000060H	3	3	3					
DI		0000011111100000 0000000101100000	PSW.ID←1	1	1	1					
DISPOSE	imm5,list12	0000011001iiiiiL LLLLLLLLLLL00000	sp←sp+zero-extend(imm5 logically shift left by 2) GR[reg in list12]←Load-memory(sp,Word) sp←sp+4 repeat 2 steps above until all regs in list12 is loaded	n+1 Note 4	n+1 Note 4	n+1 Note 4					
	imm5,list12,[reg1]	0000011001iiiiiL LLLLLLLLLLLRRRRR **Note 5**	sp←sp+zero-extend(imm5 logically shift left by 2) GR[reg in list12]←Load-memory(sp,Word) sp←sp+4 repeat 2 steps above until all regs in list12 is loaded PC←GR[reg1]	n+3 Note 4	n+3 Note 4	n+3 Note 4					
DIV	reg1,reg2,reg3	rrrrr111111RRRRR wwwww01011000000	GR[reg2]←GR[reg2]÷GR[reg1] GR[reg3]←GR[reg2]%GR[reg1]	35	35	35		×	×	×	
DIVH	reg1,reg2	rrrrr000010RRRRR	GR[reg2]←GR[reg2]÷GR[reg1]$^{\text{Note 6}}$	35	35	35		×	×	×	
	reg1,reg2,reg3	rrrrr111111RRRRR wwwww01010000000	GR[reg2]←GR[reg2]÷GR[reg1]$^{\text{Note 6}}$ GR[reg3]←GR[reg2]%GR[reg1]	35	35	35		×	×	×	
DIVHU	reg1,reg2,reg3	rrrrr111111RRRRR wwwww01010000010	GR[reg2]←GR[reg2]÷GR[reg1]$^{\text{Note 6}}$ GR[reg3]←GR[reg2]%GR[reg1]	34	34	34		×	×	×	
DIVU	reg1,reg2,reg3	rrrrr111111RRRRR wwwww01011000010	GR[reg2]←GR[reg2]÷GR[reg1] GR[reg3]←GR[reg2]%GR[reg1]	34	34	34		×	×	×	
EI		1000011111100000 0000000101100000	PSW.ID←0	1	1	1					
HALT		0000011111100000 0000000100100000	Stop	1	1	1					
HSW	reg2,reg3	rrrrr11111100000 wwwww01101000100	GR[reg3]←GR[reg2](15 : 0) ll GR[reg2] (31 : 16)	1	1	1	×	0	×	×	
JARL	disp22,reg2	rrrrr11110dddddd ddddddddddddddd0 **Note 7**	GR[reg2]←PC+4 PC←PC+sign-extend(disp22)	2	2	2					
JMP	[reg1]	00000000011RRRRR	PC←GR[reg1]	3	3	3					
JR	disp22	0000011110dddddd ddddddddddddddd0 **Note 7**	PC←PC+sign-extend(disp22)	2	2	2					
LD.B	disp16[reg1],reg2	rrrrr111000RRRRR dddddddddddddddd	adr←GR[reg1]+sign-extend(disp16) GR[reg2]←sign-extend(Load-memory(adr,Byte))	1	1	**Note 11**					
LD.BU	disp16[reg1],reg2	rrrrr11110bRRRRR dddddddddddddd1 **Notes 8, 10**	adr←GR[reg1]+sign-extend(disp16) GR[reg2]←zero-extend(Load-memory(adr,Byte))	1	1	**Note 11**					

(3/6)

Mnemonic	Operand	Opcode	Operation		Execution Clock			Flags				
					i	r	l	CY	OV	S	Z	SAT
LD.H	disp16[reg1],reg2	rrrrr111001RRRRR ddddddddddddddd0 **Note 8**	adr←GR[reg1]+sign-extend(disp16) GR[reg2]←sign-extend(Load-memory(adr,Halfword))		1	1	Note 11					
LDSR	reg2,regID	rrrrr111111RRRRR 0000000000100000 **Note 12**	SR[regID]←GR[reg2]	Other than regID = PSW	1	1	1					
				regID = PSW	1	1	1	×	×	×	×	×
LD.HU	disp16[reg1],reg2	rrrrr111111RRRRR ddddddddddddddd1 **Note 8**	adr←GR[reg1]+sign-extend(disp16) GR[reg2]←zero-extend(Load-memory(adr,Halfword))		1	1	Note 11					
LD.W	disp16[reg1],reg2	rrrrr111001RRRRR ddddddddddddddd1 **Note 8**	adr←GR[reg1]+sign-extend(disp16) GR[reg2]←Load-memory(adr,Word)		1	1	Note 11					
MOV	reg1,reg2	rrrrr000000RRRRR	GR[reg2]←GR[reg1]		1	1	1					
	imm5,reg2	rrrrr010000iiiii	GR[reg2]←sign-extend(imm5)		1	1	1					
	imm32,reg1	00000110001RRRRR iiiiiiiiiiiiiiii IIIIIIIIIIIIIIII	GR[reg1]←imm32		2	2	2					
MOVEA	imm16,reg1,reg2	rrrrr110001RRRRR iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1]+sign-extend(imm16)		1	1	1					
MOVHI	imm16,reg1,reg2	rrrrr110010RRRRR iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1]+(imm16 ll 0^{16})		1	1	1					
MUL	reg1,reg2,reg3	rrrrr111111RRRRR wwwww01000100000	GR[reg3] ll GR[reg2]←GR[reg2]xGR[reg1] **Note 14**		1	4	5					
	imm9,reg2,reg3	rrrrr111111iiiii wwwww01001IIII00 **Note 13**	GR[reg3] ll GR[reg2]←GR[reg2]xsign-extend(imm9)		1	4	5					
MULH	reg1,reg2	rrrrr000111RRRRR	GR[reg2]←GR[reg2]$^{\text{Note 6}}$xGR[reg1]$^{\text{Note 6}}$		1	1	2					
	imm5,reg2	rrrrr010111iiiii	GR[reg2]←GR[reg2]$^{\text{Note 6}}$xsign-extend(imm5)		1	1	2					
MULHI	imm16,reg1,reg2	rrrrr110111RRRRR iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1]$^{\text{Note 6}}$ximm16		1	1	2					
MULU	reg1,reg2,reg3	rrrrr111111RRRRR wwwww01000100010	GR[reg3] ll GR[reg2]←GR[reg2]xGR[reg1] **Note 14**		1	4	5					
	imm9,reg2,reg3	rrrrr111111iiiii wwwww01001IIII10 **Note 13**	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 dddddddddddddddd	adr←GR[reg1]+sign-extend(disp16) Z flag←Not(Load-memory-bit(adr,bit#3)) Store-memory-bit(adr,bit#3,Z flag)		3 Note 3	3 Note 3	3 Note 3				×	
	reg2,[reg1]	rrrrr111111RRRRR 0000000011100010	adr←GR[reg1] Z flag←Not(Load-memory-bit(adr,reg2)) Store-memory-bit(adr,reg2,Z flag)		3 Note 3	3 Note 3	3 Note 3				×	

(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 iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1]OR zero-extend(imm16)	1	1	1		0	×	×	
PREPARE	list12,imm5	0000011110iiiiiL LLLLLLLLLLL00001	Store-memory(sp–4,GR[reg in list12],Word) sp←sp–4 repeat 1 step above until all regs in list12 is stored sp←sp-zero-extend(imm5)	n+1 Note 4	n+1 Note 4	n+1 Note 4					
	list12,imm5, sp/imm[Note 15]	0000011110iiiiiL LLLLLLLLLLLff011 imm16/imm32 **Note 16**	Store-memory(sp–4,GR[reg in list12],Word) sp←sp+4 repeat 1 step above until all regs in list12 is stored sp←sp-zero-extend (imm5) ep←sp/imm	n+2 Note 4 Note 17	n+2 Note 4 Note 17	n+2 Note 4 Note 17					
RETI		0000011111100000 0000000101000000	if PSW.EP=1 then PC ←EIPC PSW ←EIPSW else if PSW.NP=1 then PC ←FEPC PSW ←FEPSW else PC ←EIPC PSW ←EIPSW	3	3	3	R	R	R	R	R
SAR	reg1,reg2	rrrrr111111RRRRR 0000000010100000	GR[reg2]←GR[reg2]arithmetically shift right by GR[reg1]	1	1	1	×	0	×	×	
	imm5,reg2	rrrrr010101iiiii	GR[reg2]←GR[reg2]arithmetically shift right by zero-extend (imm5)	1	1	1	×	0	×	×	
SASF	cccc,reg2	rrrrr1111110cccc 0000001000000000	if conditions are satisfied then GR[reg2]←(GR[reg2]Logically shift left by 1) OR 00000001H else GR[reg2]←(GR[reg2]Logically shift left by 1) OR 00000000H	1	1	1					
SATADD	reg1,reg2	rrrrr000110RRRRR	GR[reg2]←saturated(GR[reg2]+GR[reg1])	1	1	1	×	×	×	×	×
	imm5,reg2	rrrrr010001iiiii	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 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 0000000000000000	If conditions are satisfied then GR[reg2]←00000001H else GR[reg2]←00000000H	1	1	1					

(5/6)

Mnemonic	Operand	Opcode	Operation	Execution Clock			Flags				
				i	r	l	CY	OV	S	Z	SAT
SET1	bit#3,disp16[reg1]	00bbb111110RRRRR dddddddddddddddd	adr←GR[reg1]+sign-extend(disp16) Z flag←Not (Load-memory-bit(adr,bit#3)) Store-memory-bit(adr,bit#3,1)	3 Note 3	3 Note 3	3 Note 3				×	
	reg2,[reg1]	rrrrr111111RRRRR 0000000011100000	adr←GR[reg1] Z flag←Not(Load-memory-bit(adr,reg2)) Store-memory-bit(adr,reg2,1)	3 Note 3	3 Note 3	3 Note 3				×	
SHL	reg1,reg2	rrrrr111111RRRRR 0000000011000000	GR[reg2]←GR[reg2] logically shift left by GR[reg1]	1	1	1	×	0	×	×	
	imm5,reg2	rrrrr010110iiiii	GR[reg2]←GR[reg2] logically shift left by zero-extend(imm5)	1	1	1	×	0	×	×	
SHR	reg1,reg2	rrrrr111111RRRRR 0000000010000000	GR[reg2]←GR[reg2] logically shift right by GR[reg1]	1	1	1	×	0	×	×	
	imm5,reg2	rrrrr010100iiiii	GR[reg2]←GR[reg2] logically shift right by zero-extend(imm5)	1	1	1	×	0	×	×	
SLD.B	disp7[ep],reg2	rrrrr0110ddddddd	adr←ep+zero-extend(disp7) GR[reg2]←sign-extend(Load-memory(adr,Byte))	1	1	Note 9					
SLD.BU	disp4[ep],reg2	rrrrr0000110dddd **Note 18**	adr←ep+zero-extend(disp4) GR[reg2]←zero-extend(Load-memory(adr,Byte))	1	1	Note 9					
SLD.H	disp8[ep],reg2	rrrrr1000ddddddd **Note 19**	adr←ep+zero-extend(disp8) GR[reg2]←sign-extend(Load-memory(adr,Halfword))	1	1	Note 9					
SLD.HU	disp5[ep],reg2	rrrrr0000111dddd **Notes 18, 20**	adr←ep+zero-extend(disp5) GR[reg2]←zero-extend(Load-memory(adr,Halfword))	1	1	Note 9					
SLD.W	disp8[ep],reg2	rrrrr1010dddddd0 **Note 21**	adr←ep+zero-extend(disp8) GR[reg2]←Load-memory(adr,Word)	1	1	Note 9					
SST.B	reg2,disp7[ep]	rrrrr0111ddddddd	adr←ep+zero-extend(disp7) Store-memory(adr,GR[reg2],Byte)	1	1	1					
SST.H	reg2,disp8[ep]	rrrrr1001ddddddd **Note 19**	adr←ep+zero-extend(disp8) Store-memory(adr,GR[reg2],Halfword)	1	1	1					
SST.W	reg2,disp8[ep]	rrrrr1010dddddd1 **Note 21**	adr←ep+zero-extend(disp8) Store-memory(adr,GR[reg2],Word)	1	1	1					
ST.B	reg2,disp16[reg1]	rrrrr111010RRRRR dddddddddddddddd	adr←GR[reg1]+sign-extend(disp16) Store-memory(adr,GR[reg2],Byte)	1	1	1					
ST.H	reg2,disp16[reg1]	rrrrr111011RRRRR ddddddddddddddd0 **Note 8**	adr←GR[reg1]+sign-extend(disp16) Store-memory (adr,GR[reg2], Halfword)	1	1	1					
ST.W	reg2,disp16[reg1]	rrrrr111011RRRRR ddddddddddddddd1 **Note 8**	adr←GR[reg1]+sign-extend(disp16) Store-memory (adr,GR[reg2], Word)	1	1	1					
STSR	regID,reg2	rrrrr111111RRRRR 0000000001000000	GR[reg2]←SR[regID]	1	1	1					

(6/6)

Mnemonic	Operand	Opcode	Operation	Execution Clock			Flags				
				i	r	l	CY	OV	S	Z	SAT
SUB	reg1,reg2	rrrrr001101RRRRR	GR[reg2]←GR[reg2]–GR[reg1]	1	1	1	×	×	×	×	
SUBR	reg1,reg2	rrrrr001100RRRRR	GR[reg2]←GR[reg1]–GR[reg2]	1	1	1	×	×	×	×	
SWITCH	reg1	00000000010RRRRR	adr←(PC+2) + (GR [reg1] logically shift left by 1) PC←(PC+2) + (sign-extend (Load-memory (adr,Halfword)) logically shift left by 1	5	5	5					
SXB	reg1	00000000101RRRRR	GR[reg1]←sign-extend (GR[reg1] (7 : 0))	1	1	1					
SXH	reg1	00000000111RRRRR	GR[reg1]←sign-extend (GR[reg1] (15 : 0))	1	1	1					
TRAP	vector	00000111111iiiii 0000000100000000	EIPC ←PC+4 (Restored PC) EIPSW ←PSW ECR.EICC ←Interrupt code PSW.EP ←1 PSW.ID ←1 PC ←00000040H (when vector is 00H to 0FH) 00000050H (when vector is 10H to 1FH)	3	3	3					
TST	reg1,reg2	rrrrr001011RRRRR	result←GR[reg2] AND GR[reg1]	1	1	1		0	×	×	
TST1	bit#3,disp16[reg1]	11bbb111110RRRRR dddddddddddddddd	adr←GR[reg1]+sign-extend(disp16) Z flag←Not (Load-memory-bit (adr,bit#3))	3 Note 3	3 Note 3	3 Note 3				×	
	reg2, [reg1]	rrrrr111111RRRRR 0000000011100110	adr←GR[reg1] Z flag←Not (Load-memory-bit (adr,reg2))	3 Note 3	3 Note 3	3 Note 3				×	
XOR	reg1,reg2	rrrrr001001RRRRR	GR[reg2]←GR[reg2] XOR GR[reg1]	1	1	1		0	×	×	
XORI	imm16,reg1,reg2	rrrrr110101RRRRR iiiiiiiiiiiiiiii	GR[reg2]←GR[reg1] XOR zero-extend (imm16)	1	1	1		0	×	×	
ZXB	reg1	00000000100RRRRR	GR[reg1]←zero-extend (GR[reg1] (7 : 0))	1	1	1					
ZXH	reg1	00000000110RRRRR	GR[reg1]←zero-extend (GR[reg1] (15 : 0))	1	1	1					

Notes 1. dddddddd: Higher 8 bits of disp9.

2. 3 if there is an instruction that rewrites the contents of the PSW immediately before.

3. If there is no wait state (3 + the number of read access wait states).

4. n is the total number of list12 load registers. (According to the number of wait states. Also, if there are no wait states, n is the total number of list12 registers. If n = 0, same operation as when n = 1)

5. RRRRR: other than 00000.

6. The lower halfword data only are valid.

7. ddddddddddddddddddddd: The higher 21 bits of disp22.

8. ddddddddddddddd: The higher 15 bits of disp16.

9. According to the number of wait states (1 if there are no wait states).

10. b: bit 0 of disp16.

11. According to the number of wait states (2 if there are no wait states).

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. iiiii: 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. dddddd: Higher 6 bits of disp8.

For further information,
please contact:

NEC Electronics Corporation
1753, Shimonumabe, Nakahara-ku,
Kawasaki, Kanagawa 211-8668,
Japan
Tel: 044-435-5111
http://www.necel.com/

[America]

NEC Electronics America, Inc.
2880 Scott Blvd.
Santa Clara, CA 95050-2554, U.S.A.
Tel: 408-588-6000
800-366-9782
http://www.am.necel.com/

[Europe]

NEC Electronics (Europe) GmbH
Arcadiastrasse 10
40472 Düsseldorf, Germany
Tel: 0211-65030
http://www.eu.necel.com/

Hanover Office
Podbielskistrasse 166 B
30177 Hannover
Tel: 0 511 33 40 2-0

Munich Office
Werner-Eckert-Strasse 9
81829 München
Tel: 0 89 92 10 03-0

Stuttgart Office
Industriestrasse 3
70565 Stuttgart
Tel: 0 711 99 01 0-0

United Kingdom Branch
Cygnus House, Sunrise Parkway
Linford Wood, Milton Keynes
MK14 6NP, U.K.
Tel: 01908-691-133

Succursale Française
9, rue Paul Dautier, B.P. 52
78142 Velizy-Villacoublay Cédex
France
Tel: 01-3067-5800

Sucursal en España
Juan Esplandiu, 15
28007 Madrid, Spain
Tel: 091-504-2787

Tyskland Filial
Täby Centrum
Entrance S (7th floor)
18322 Täby, Sweden
Tel: 08 638 72 00

Filiale Italiana
Via Fabio Filzi, 25/A
20124 Milano, Italy
Tel: 02-667541

Branch The Netherlands
Steijgerweg 6
5616 HS Eindhoven
The Netherlands
Tel: 040 265 40 10

[Asia & Oceania]

NEC Electronics (China) Co., Ltd
7th Floor, Quantum Plaza, No. 27 ZhiChunLu Haidian
District, Beijing 100083, P.R.China
Tel: 010-8235-1155
http://www.cn.necel.com/

Shanghai Branch
Room 2509-2510, Bank of China Tower,
200 Yincheng Road Central,
Pudong New Area, Shanghai, P.R.China P.C:200120
Tel:021-5888-5400
http://www.cn.necel.com/

Shenzhen Branch
Unit 01, 39/F, Excellence Times Square Building,
No. 4068 Yi Tian Road, Futian District, Shenzhen,
P.R.China P.C:518048
Tel:0755-8282-9800
http://www.cn.necel.com/

NEC Electronics Hong Kong Ltd.
Unit 1601-1613, 16/F., Tower 2, Grand Century Place,
193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: 2886-9318
http://www.hk.necel.com/

NEC Electronics Taiwan Ltd.
7F, No. 363 Fu Shing North Road
Taipei, Taiwan, R. O. C.
Tel: 02-8175-9600
http://www.tw.necel.com/

NEC Electronics Singapore Pte. Ltd.
238A Thomson Road,
#12-08 Novena Square,
Singapore 307684
Tel: 6253-8311
http://www.sg.necel.com/

NEC Electronics Korea Ltd.
11F., Samik Lavied'or Bldg., 720-2,
Yeoksam-Dong, Kangnam-Ku,
Seoul, 135-080, Korea
Tel: 02-558-3737
http://www.kr.necel.com/

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