

RL78/G1A

User's Manual: Hardware

16-Bit Single-Chip Microcontrollers

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General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can 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 must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. 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. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. 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, for example, 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.).

7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

How to Use This Manual

Readers

This manual is intended for user engineers who wish to understand the functions of the RL78/G1A and design and develop application systems and programs for these devices. The target products are as follows.

- 25-pin: R5F10E8x (x = A, C, D, E)
- 32-pin: R5F10EBx (x = A, C, D, E)
- 48-pin: R5F10EGx (x = A, C, D, E)
- 64-pin: R5F10ELx (x = C, D, E)

Purpose

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

Organization

The RL78/G1A manual is separated into two parts: this manual and the instructions edition (common to the RL78 Microcontroller).

RL78/G1A User's Manual (This Manual)	RL78 family User's Manual: Software

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

How to Read This Manual

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

- To gain a general understanding of functions:
 - Read this manual in the order of the **CONTENTS**. The mark "<R>" shows major revised points. The revised points can be easily searched by copying an "<R>" in the PDF file and specifying it in the "Find what:" field.
- How to interpret the register format:
 - For a bit number enclosed in angle brackets, the bit name is defined as a reserved word in the assembler, and is defined as an sfr variable using the #pragma sfr directive in the compiler.
- To know details of the RL78G1A Microcontroller instructions:
 - Refer to the separate document **RL78 family User's Manual: Software (R01US0015E)**.

Conventions

Data significance: Higher digits on the left and lower digits on the right

Active low representations: $\overline{\text{xxx}}$ (overscore over pin and signal name)

Note: Footnote for item marked with **Note** in the text

Caution: Information requiring particular attention

Remark: Supplementary information

Numerical representations: Binary ...xxxx or xxxxB
Decimal ...xxxx
Hexadecimal ...xxxxH

Related Documents

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

Documents Related to Devices

Document Name	Document No.
RL78/G1A User's Manual Hardware	This manual
RL78 Family User's Manual: Software	R01US0015E

Documents Related to Flash Memory Programming

Document Name	Document No.
PG-FP5 Flash Memory Programmer User's Manual	R20UT0008E

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Other Documents

Document Name	Document No.
Renesas Microcontrollers RL78 Family	R01CP0003E
Semiconductor Package Mount Manual	R50ZZ0003E
Semiconductor Reliability Handbook	R51ZZ0001E

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CHAPTER 1 OUTLINE

1.1 Features

Ultra-low power consumption technology

- V_{DD} = single power supply voltage of 1.6 to 3.6 V which can operate a 1.8 V device at a low voltage
- HALT mode
- STOP mode
- SNOOZE mode

RL78 CPU core

- CISC architecture with 3-stage pipeline
- Minimum instruction execution time: Can be changed from high speed (0.03125 μ s: @ 32 MHz operation with high-speed on-chip oscillator) to ultra-low speed (30.5 μ s: @ 32.768 kHz operation with subsystem clock)
- Address space: 1 MB
- General-purpose registers: (8-bit register $\times$ 8) $\times$ 4 banks
- On-chip RAM: 2 to 4 KB

Code flash memory

- Code flash memory: 16 to 64 KB
- Block size: 1 KB
- Prohibition of block erase and rewriting (security function)
- On-chip debug function
- Self-programming (with boot swap function/flash shield window function)

Data flash memory

- Data flash memory: 4 KB
- Back ground operation (BGO): Instructions can be executed from the program memory while rewriting the data flash memory.
- Number of rewrites: 1,000,000 times (TYP.)
- Voltage of rewrites: V_{DD} = 1.8 to 3.6 V

High-speed on-chip oscillator

- Select from 32 MHz, 24 MHz, 16 MHz, 12 MHz, 8 MHz, 6 MHz, 4 MHz, 3 MHz, 2 MHz, and 1 MHz
- High accuracy ± 1.0 % (V_{DD} = 1.8 to 3.6 V, T_A = -20 to +85°C)

Operating ambient temperature

- T_A = -40 to +85°C (A: Consumer applications)
- T_A = -40 to +105°C (G: Industrial applications)

Power management and reset function

- On-chip power-on-reset (POR) circuit
- On-chip voltage detector (LVD) (Select interrupt and reset from 12 levels)

DMA (Direct Memory Access) controller

- 2 channels
- Number of clocks during transfer between 8/16-bit SFR and internal RAM: 2 clocks

Multiplier and divider/multiply-accumulator

- $16 \text{ bits} \times 16 \text{ bits} = 32 \text{ bits}$ (Unsigned or signed)
- $32 \text{ bits} \div 32 \text{ bits} = 32 \text{ bits}$ (Unsigned)
- $16 \text{ bits} \times 16 \text{ bits} + 32 \text{ bits} = 32 \text{ bits}$ (Unsigned or signed)

Serial interface

- Simplified SPI (CSI^{Note1}): 2 to 6 channels
- UART/UART (LIN-bus supported): 2 or 3 channels
- I²C/Simplified I²C communication: 2 to 7 channels

Timer

- 16-bit timer: 8 channels
- 12-bit interval timer: 1 channel
- Real-time clock: 1 channel (calendar for 99 years, alarm function, and clock correction function)
- Watchdog timer: 1 channel (operable with the dedicated low-speed on-chip oscillator)

A/D converter

- 8/12-bit resolution A/D converter ($V_{DD} = 1.6$ to 3.6 V)
- Analog input: 13 to 28 channels
- Internal reference voltage (1.45 V) and temperature sensor^{Note2}

I/O port

- I/O port: 19 to 56 (N-ch open drain I/O [withstand voltage of 6 V]: 2 to 4, N-ch open drain I/O [V_{DD} withstand voltage^{Note3}/EV V_{DD} withstand voltage^{Note4}]: 6 to 12)
- Can be set to N-ch open drain, TTL input buffer, and on-chip pull-up resistor
- Different potential interface: Can connect to a $1.8/2.5 \text{ V}$ device
- On-chip key interrupt function
- On-chip clock output/buzzer output controller

Others

- On-chip BCD (binary-coded decimal) correction circuit

Notes 1. Although the CSI function is generally called SPI, it is also called CSI in this product, so it is referred to as such in this manual.

2. Can be selected only in HS (high-speed main) mode

3. Products with 25 to 48 pins

4. Products with 64 pins

Remark The functions mounted depend on the product. See **1.6 Outline of Functions**.

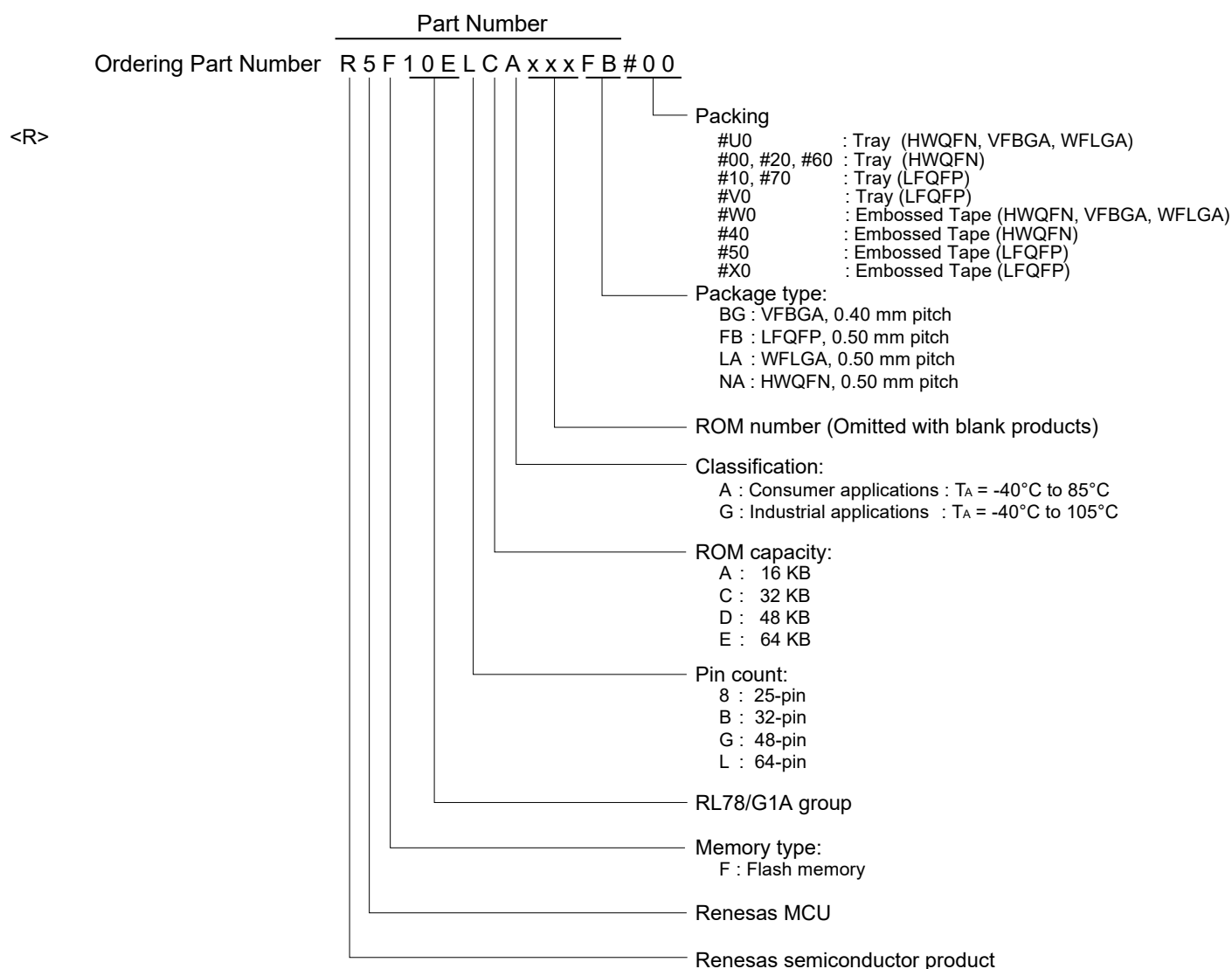
O ROM, RAM capacities

Flash ROM	Data flash	RAM	RL78/G1A			
			25 pins	32 pins	48 pins	64 pins
64 KB	4 KB	4 KB Note	R5F10E8E	R5F10EBE	R5F10EGE	R5F10ELE
48 KB	4 KB	3 KB	R5F10E8D	R5F10EBD	R5F10EGD	R5F10ELD
32 KB	4 KB	2 KB	R5F10E8C	R5F10EBC	R5F10EGC	R5F10ELC
16 KB	4 KB	2 KB	R5F10E8A	R5F10EBA	R5F10EGA	–

Note This is about 3 KB when the self-programming function and data flash function are used. (For details, see **CHAPTER 3**)

1.2 List of Part Numbers

Figure 1-1. Part Number, Memory Size, and Package of RL78/G1A



Caution The part number above is valid as of when this manual was issued. For the latest part number, see the web page of the target product on the Renesas Electronics website.

Table 1-1. List of Ordering Part Numbers

Pin count	Package	Fields of Application Note	Ordering Part Number		RENESAS Code
			Part Number	Packaging specification	
25 pins	25-pin plastic WFLGA (3 × 3 mm, 0.5 mm pitch)	A	R5F10E8AALA, R5F10E8CALA, R5F10E8DALA, R5F10E8EALA	#U0, #W0	PWLG0025KA-A
		G	R5F10E8AGLA, R5F10E8CGLA, R5F10E8DGLA, R5F10E8EGLA		
<R>	32 pins	A	R5F10EBAANA, R5F10EBCANA, R5F10EBDANA, R5F10EBEANA	#U0, #W0	PWQN0032KB-A
				#00, #20, #40, #60	PWQN0032KE-A PWQN0032KG-A
		G	R5F10EBAGNA, R5F10EBCGNA, R5F10EBDGNA, R5F10EBEGNA	#U0, #W0	PWQN0032KB-A
				#00, #20, #40, #60	PWQN0032KE-A PWQN0032KG-A
<R>	48 pins	A	R5F10EGAAFB, R5F10EGCAFB, R5F10EGDAFB, R5F10EGEAFB	#V0, #X0, #10, #50, #70	PLQP0048KF-A
		G	R5F10EGAGFB, R5F10EGCGFB, R5F10EGDGB, R5F10EGEGFB	#V0, #X0, #10, #50, #70	PLQP0048KF-A
	48-pin plastic HWQFN (7 × 7 mm, 0.5 mm pitch)	A	R5F10EGAANA, R5F10EGCANA, R5F10EGDANA, R5F10EGEANA	#U0, #W0	PWQN0048KB-A
				#00, #20, #40, #60	PWQN0048KE-A
		G	R5F10EGAGNA, R5F10EGCGNA, R5F10EGDGNA, R5F10EGEGNA	#U0, #W0	PWQN0048KB-A
				#00, #20, #40, #60	PWQN0048KE-A
<R>	64 pins	A	R5F10ELCAFB, R5F10ELDAFB, R5F10ELEAFB	#V0, #X0, #10, #50, #70	PLQP0064KF-A
		G	R5F10ELCGFB, R5F10ELDGFB, R5F10ELEGB	#V0, #X0, #10, #50, #70	PLQP0064KF-A
	64-pin plastic VFBGA (4 × 4 mm, 0.4 mm pitch)	A	R5F10ELCABG, R5F10ELDABG, R5F10ELEABG	#U0, #W0	PVBG0064LA-A
		G	R5F10ELCGBG, R5F10ELDGBG, R5F10ELEGBG		

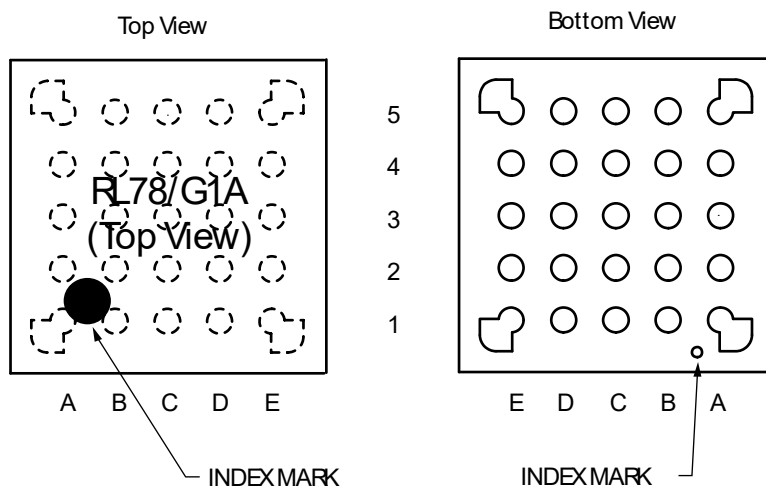
Note For the fields of application, see **Figure 1-1 Part Number, Memory Size, and Package of RL78/G1A**.

Caution The part number above is valid as of when this manual was issued. For the latest part number, see the web page of the target product on the Renesas Electronics website.

1.3 Pin Configuration (Top View)

1.3.1 25-pin products

- 25-pin plastic WFLGA (3 × 3 mm, 0.50 mm pitch)



	A	B	C	D	E	
5	P40/TOOL0	RESET	P03/ANI16/ RxD1/TO00/ (KR1)	P23/ANI3/ (KR3)	AV _{SS}	5
4	P122/X2/ EXCLK	P137/INTP0	P02/ANI17/ TxD1/TI00/ (KR0)	P22/ANI2/ (KR2)	AV _{DD}	4
3	P121/X1	V _{DD}	P21/ANI1/ AV _{REFM}	P11/ANI20/ SI00/SDA00/ RxD0/ TOOLRxD	P10/ANI18/ SCK00/SCL00	3
2	REGC	V _{SS}	P30/ANI27/ SCK11/SCL11/ INTP3	P51/ANI25/ SO11/INTP2	P50/ANI26/ SI11/SDA11 INTP1	2
1	P60/SCLA0	P61/SDAA0	P31/ANI29/TI03/ TO03/PCLBUZ0 /INTP4	P12/ANI21/ SO00/TxD0/ TOOLTxD	P20/ANI0/ AV _{REFP}	1
	A	B	C	D	E	

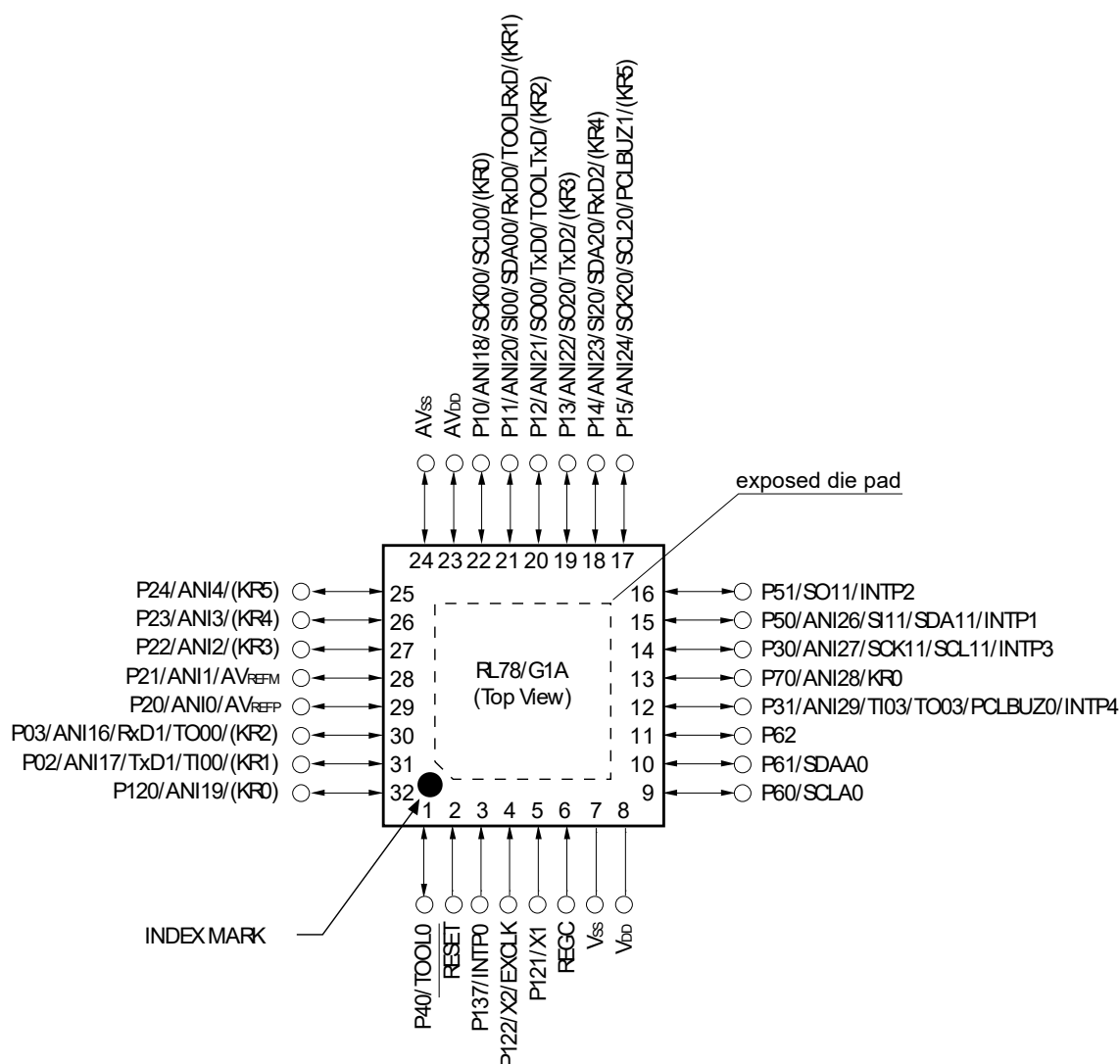
Caution Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μ F).

Remarks 1. For pin identification, see 1.4 Pin Identification.

2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

1.3.2 32-pin products

- 32-pin plastic HWQFN (5 × 5 mm, 0.5 mm pitch)



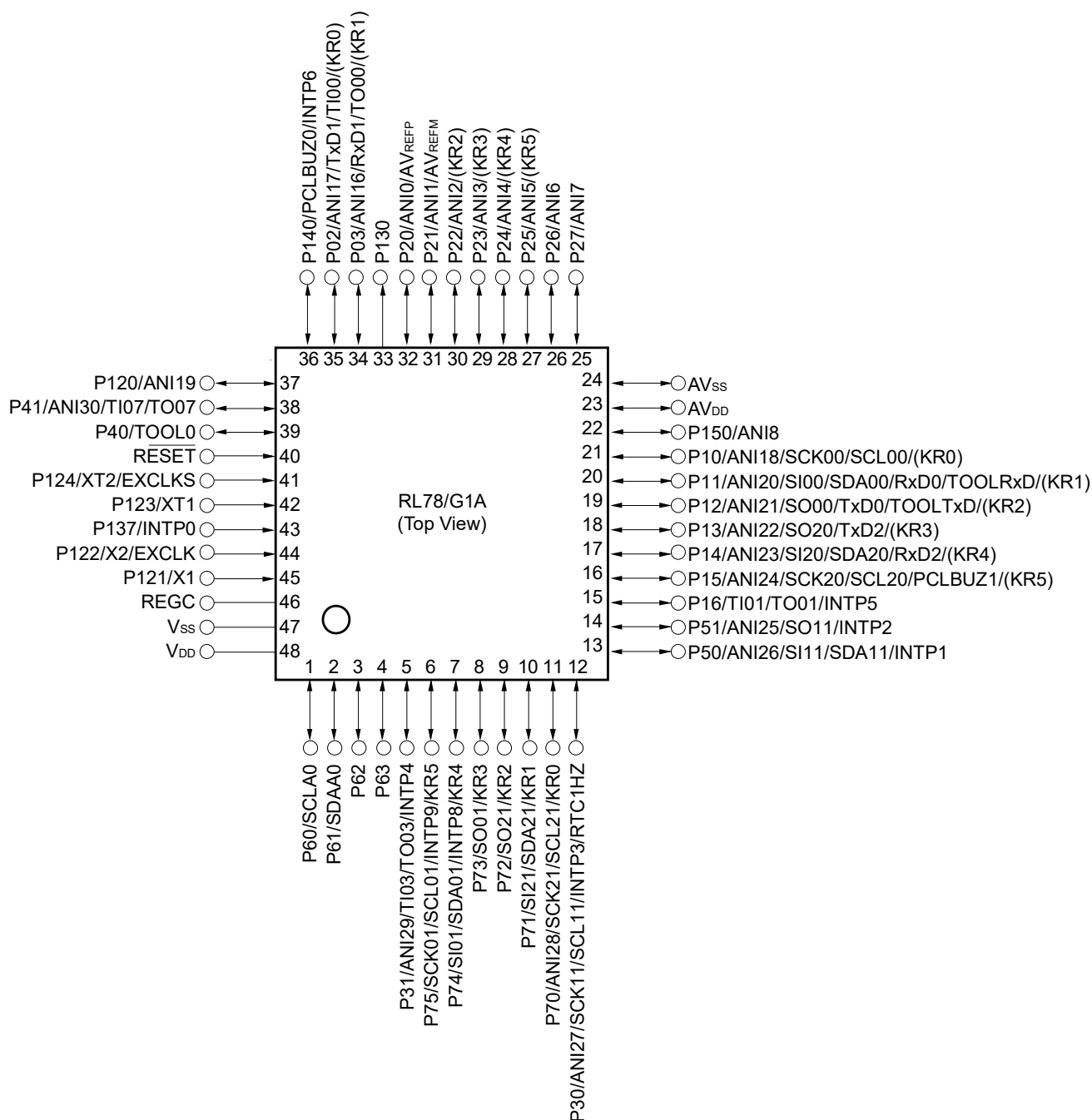
Caution Connect the REGC pin to Vss via a capacitor (0.47 to 1 μ F).

Remarks 1. For pin identification, see 1.4 Pin Identification.

- Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.
- It is recommended to connect an exposed die pad to Vss.

1.3.3 48-pin products

- 48-pin plastic LFQFP (7 × 7 mm, 0.5 mm pitch)

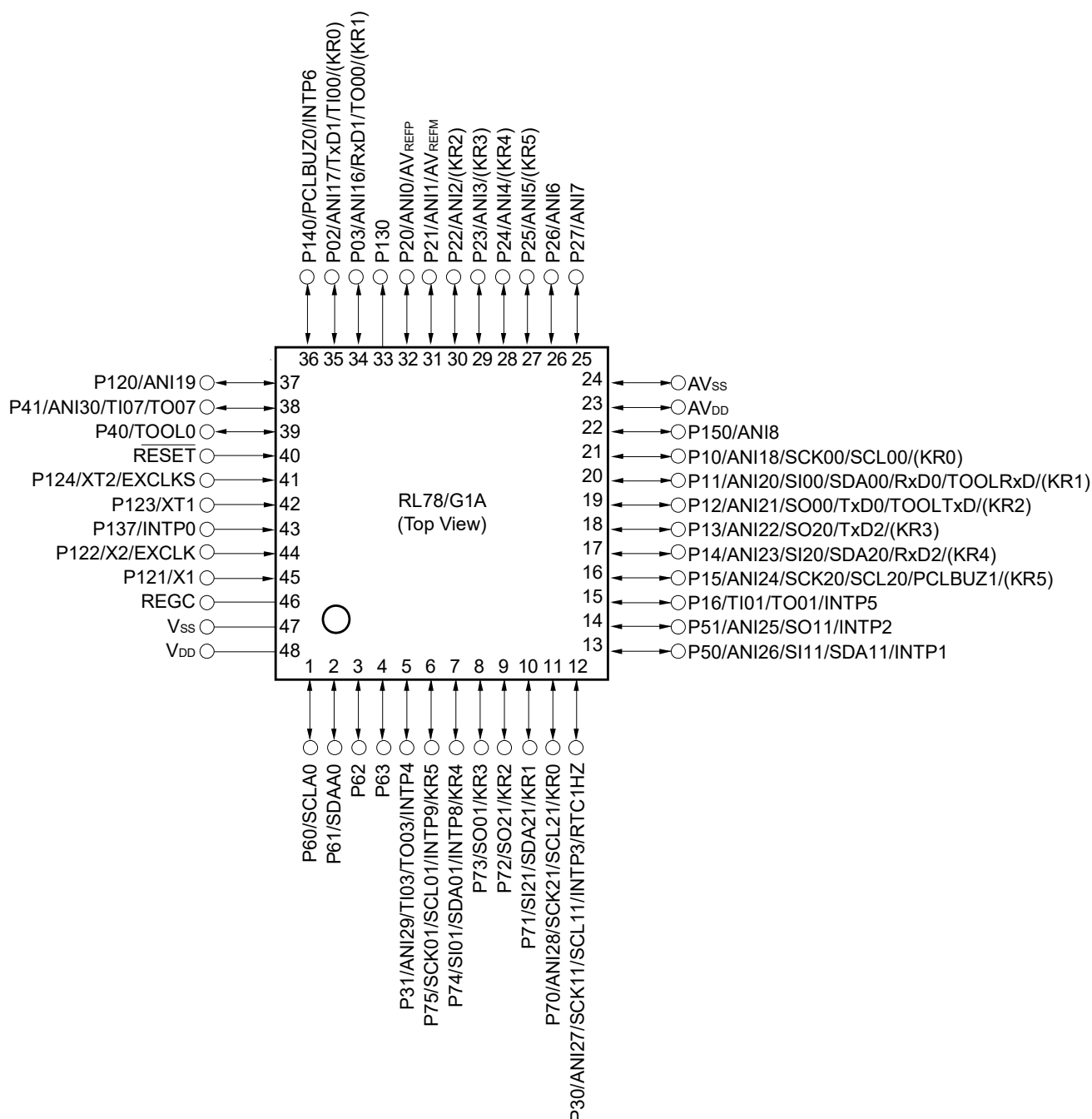


Caution Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF).

Remarks 1. For pin identification, see 1.4 Pin Identification.

2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR).

- 48-pin plastic HWQFN (7 × 7 mm, 0.5 mm pitch)



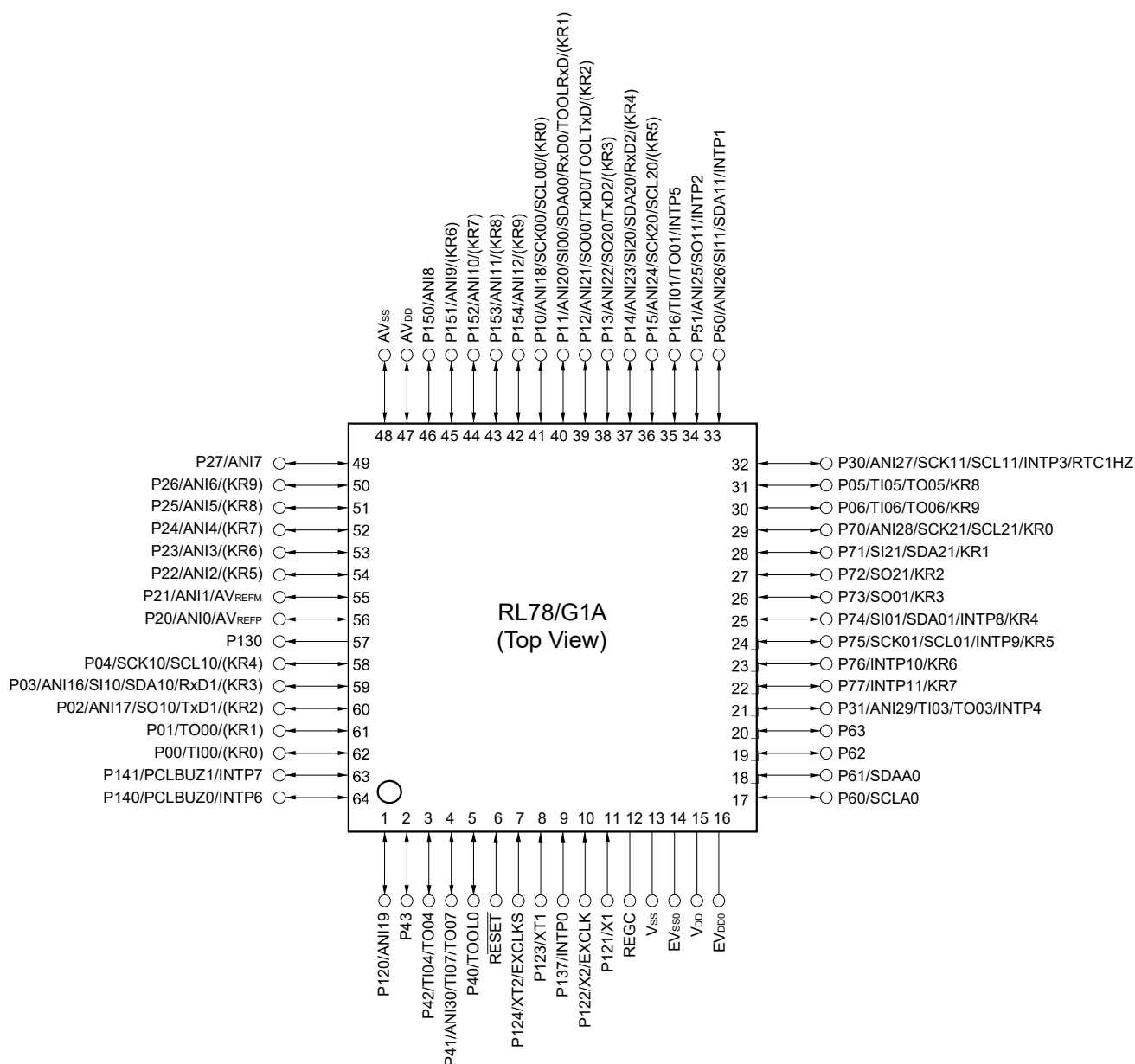
Caution Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μ F).

Remarks 1. For pin identification, see 1.4 Pin Identification.

- Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR).

1.3.4 64-pin products

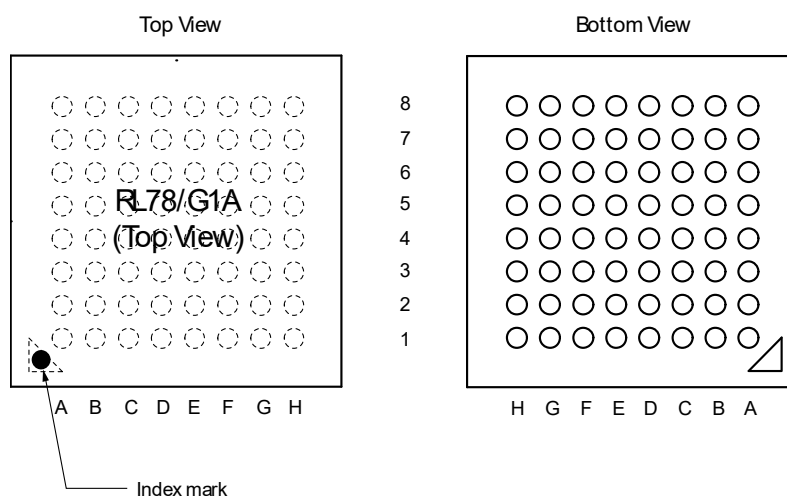
- 64-pin plastic LFQFP (10 × 10 mm, 0.5 mm pitch)



- Cautions 1.** Make EV_{SS0} pin the same potential as V_{SS} pin.
- 2.** Make V_{DD} pin the potential that is higher than EV_{DD0} pin.
- 3.** Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μ F).

- Remarks 1.** For pin identification, see 1.4 Pin Identification.
- 2.** When using the microcontroller for an application where the noise generated inside the microcontroller must be reduced, it is recommended to supply separate powers to the V_{DD} and EV_{DD0} pins and connect the V_{SS} and EV_{SS0} pins to separate ground lines.
- 3.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR).

- 64-pin plastic VFBGA (4 × 4 mm, 0.4 mm pitch)



Pin No.	Name	Pin No.	Name	Pin No.	Name	Pin No.	Name
A1	P05/TI05/TO05/KR8	C1	P51/ANI25/SO11/INTP2	E1	P153/ANI11/(KR8)	G1	AV _{DD}
A2	P30/ANI27/SCK11/SCL11/INTP3/RTC1HZ	C2	P71/SI21/SDA21/KR1	E2	P154/ANI12/(KR9)	G2	P25/ANI5/(KR8)
A3	P70/ANI28/SCK21/SCL21/KR0	C3	P74/SI01/SDA01/INTP8/KR4	E3	P10/ANI18/SCK00/SCL00/(KR0)	G3	P24/ANI4/(KR7)
A4	P75/SCK01/SCL01/INTP9/KR5	C4	P16/TI01/TO01/INTP5	E4	P11/ANI20/SI00/SDA00/RxD0/TOOLRxD/(KR1)	G4	P22/ANI2/(KR5)
A5	P77/INTP11/KR7	C5	P15/ANI24/SCK20/SCL20/(KR5)	E5	P03/ANI16/SI10/SDA10/RxD1/(KR3)	G5	P130
A6	P61/SDAA0	C6	P63	E6	P41/ANI30/TI07/TO07	G6	P02/ANI17/SO10/TxD1/(KR2)
A7	P60/SCLA0	C7	V _{SS}	E7	RESET	G7	P00/TI00/(KR0)
A8	EV _{DD0}	C8	P121/X1	E8	P137/INTP0	G8	P124/XT2/EXCLKS
B1	P50/ANI26/SI11/SDA11/INTP1	D1	P13/ANI22/SO20/TxD2/(KR3)	F1	P150/ANI8	H1	AV _{SS}
B2	P72/SO21/KR2	D2	P06/TI06/TO06/KR9	F2	P151/ANI9/(KR6)	H2	P27/ANI7
B3	P73/SO01/KR3	D3	P12/ANI21/SO00/TxD0/TOOLTxD/(KR2)	F3	P152/ANI10/(KR7)	H3	P26/ANI6/(KR9)
B4	P76/INTP10/KR6	D4	P14/ANI23/SI20/SDA20/RxD2/(KR4)	F4	P21/ANI1/AV _{REFM}	H4	P23/ANI3/(KR6)
B5	P31/ANI29/TI03/TO03/INTP4	D5	P42/TI04/TO04	F5	P04/SCK10/SCL10/(KR4)	H5	P20/ANI0/AV _{REFP}
B6	P62	D6	P40/TOOL0	F6	P43	H6	P141/PCLBUZ1/INTP7
B7	V _{DD}	D7	REGC	F7	P01/TO00/(KR1)	H7	P140/PCLBUZ0/INTP6
B8	EV _{SS0}	D8	P122/X2/EXCLK	F8	P123/XT1	H8	P120/ANI19

- Cautions**
1. Make EV_{SS0} pin the same potential as V_{SS} pin.
 2. Make V_{DD} pin the potential that is higher than EV_{DD0} pin.
 3. Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF).

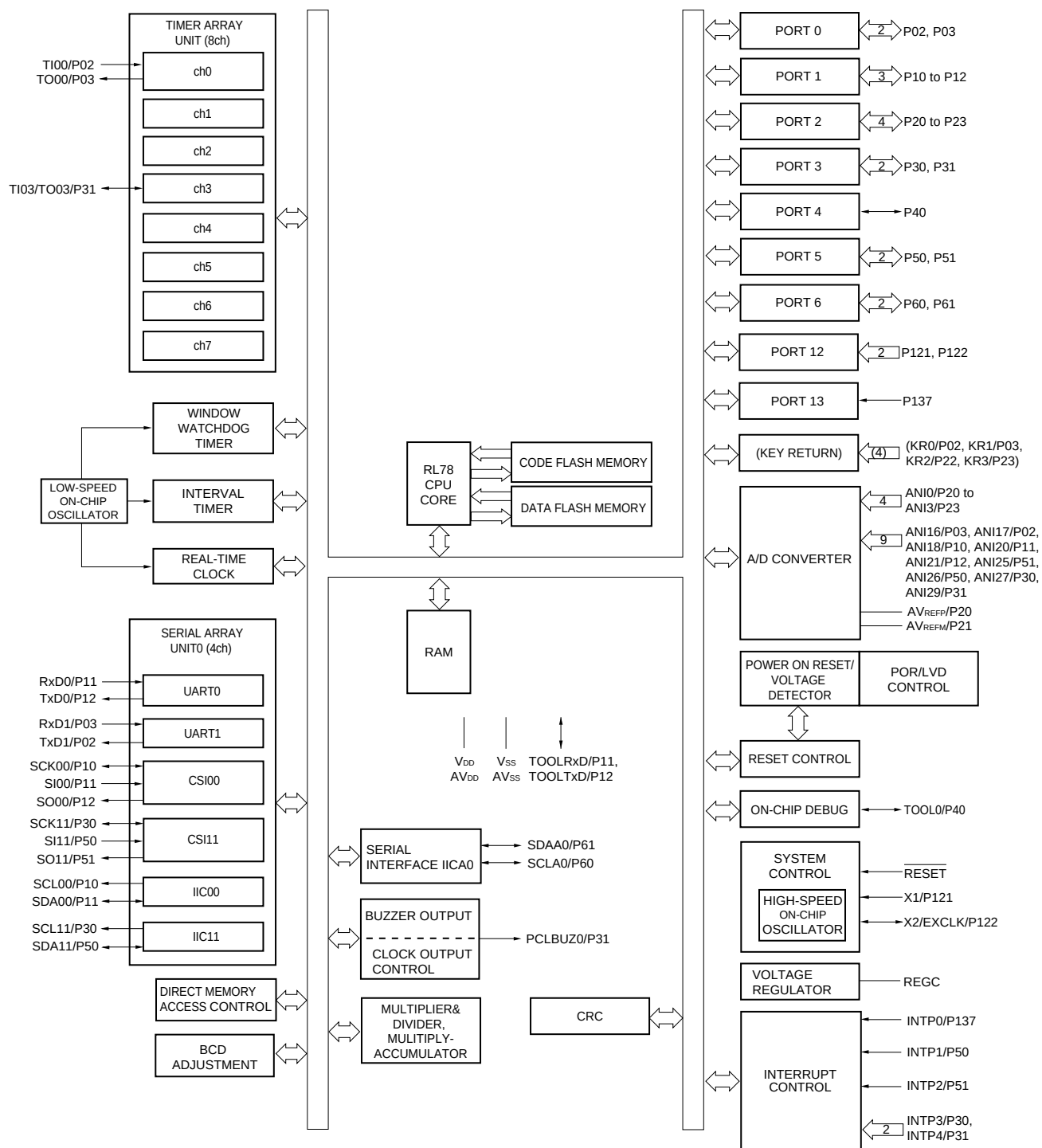
- Remarks**
1. For pin identification, see 1.4 Pin Identification.
 2. When using the microcontroller for an application where the noise generated inside the microcontroller must be reduced, it is recommended to supply separate powers to the V_{DD} and EV_{DD0} pins and connect the V_{SS} and EV_{SS0} pins to separate ground lines.
 3. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR).

1.4 Pin Identification

ANI0 to ANI12,		PCLBUZ0, PCLBUZ1:	Programmable clock output/buzzer output
ANI16 to ANI30:	Analog input	REGC:	Regulator capacitance
AV _{DD} :	Analog power supply	$\overline{\text{RESET}}$:	Reset
AV _{SS} :	Analog ground	RTC1HZ:	Real-time clock correction clock (1 Hz) output
AV _{REFM} :	A/D converter reference potential (– side) input	RxD0 to RxD2:	Receive data
AV _{REFP} :	A/D converter reference potential (+ side) input	SCK00, SCK01, SCK10,	
EV _{DD0} :	Power supply for port	SCK11, SCK20, SCK21:	Serial clock input/output
EV _{SS0} :	Ground for port	SCLA0, SCL00, SCL01,	
EXCLK:	External clock input (main system clock)	SCL10, SCL11, SCL20,	
EXCLKS:	External clock input (subsystem clock)	SCL21:	Serial clock output
INTP0 to INTP11:	Interrupt Request from External	SDAA0, SDA00, SDA01,	
KR0 to KR9:	Key return	SDA10, SDA11, SDA20,	
P00 to P06:	Port 0	SDA21:	Serial data input/output
P10 to P16:	Port 1	SI00, SI01, SI10, SI11,	
P20 to P27:	Port 2	SI20, SI21:	Serial data input
P30, P31:	Port 3	SO00, SO01, SO10,	
P40 to P43:	Port 4	SO11, SO20, SO21:	Serial data output
P50, P51:	Port 5	TI00, TI01, TI03 to TI07:	Timer input
P60 to P63:	Port 6	TO00, TO01,	
P70 to P77:	Port 7	TO03 to TO07:	Timer output
P120 to P124:	Port 12	TOOL0:	Data input/output for tool
P130, P137:	Port 13	TOOLRx _D , TOOLTx _D :	Data input/output for external device
P140, P141:	Port 14	TxD0 to TxD2:	Transmit data
P150 to P154:	Port 15	V _{DD} :	Power supply
		V _{SS} :	Ground
		X1, X2:	Crystal oscillator (main system clock)
		XT1, XT2:	Crystal oscillator (subsystem clock)

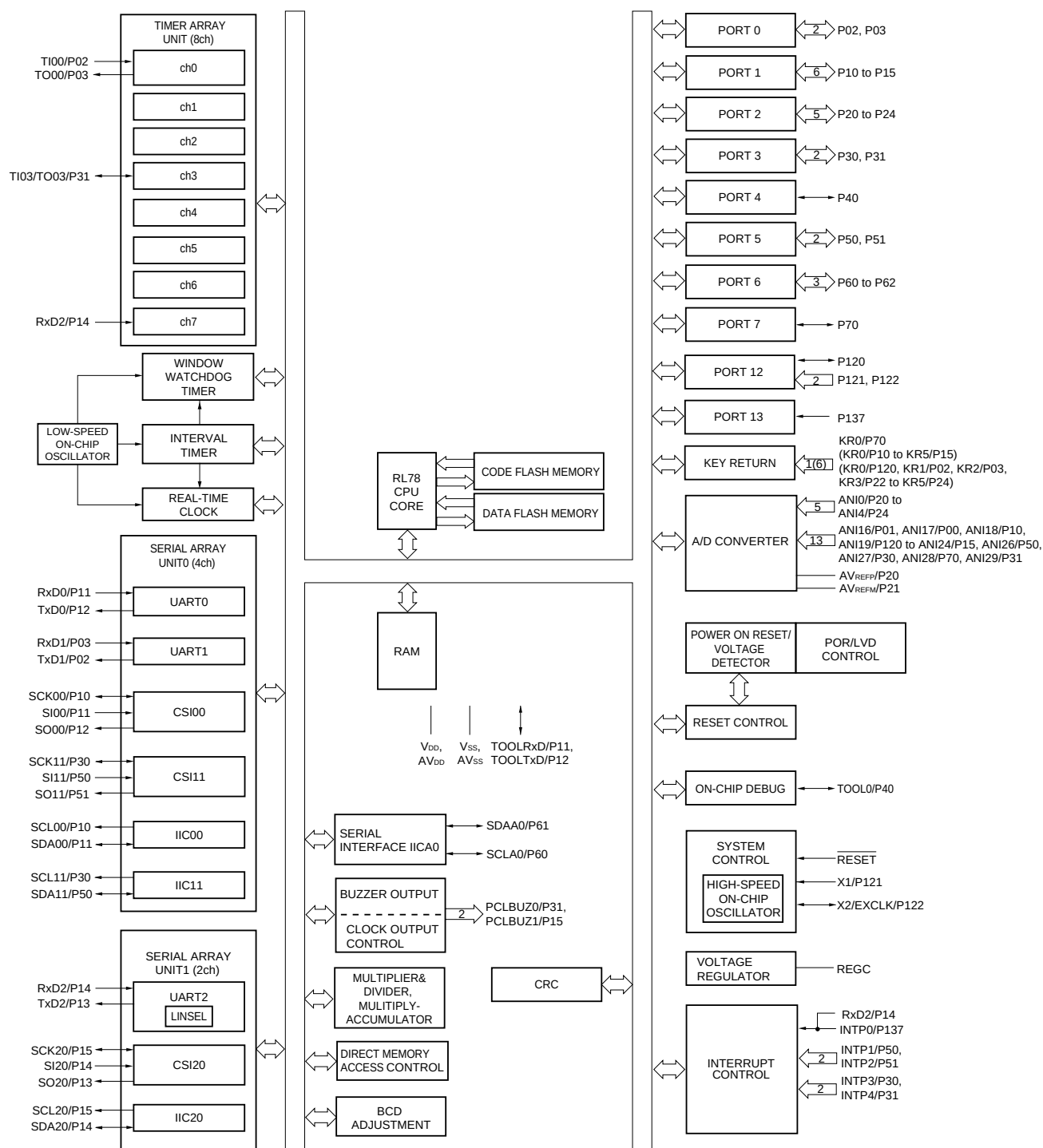
1.5 Block Diagram

1.5.1 25-pin products



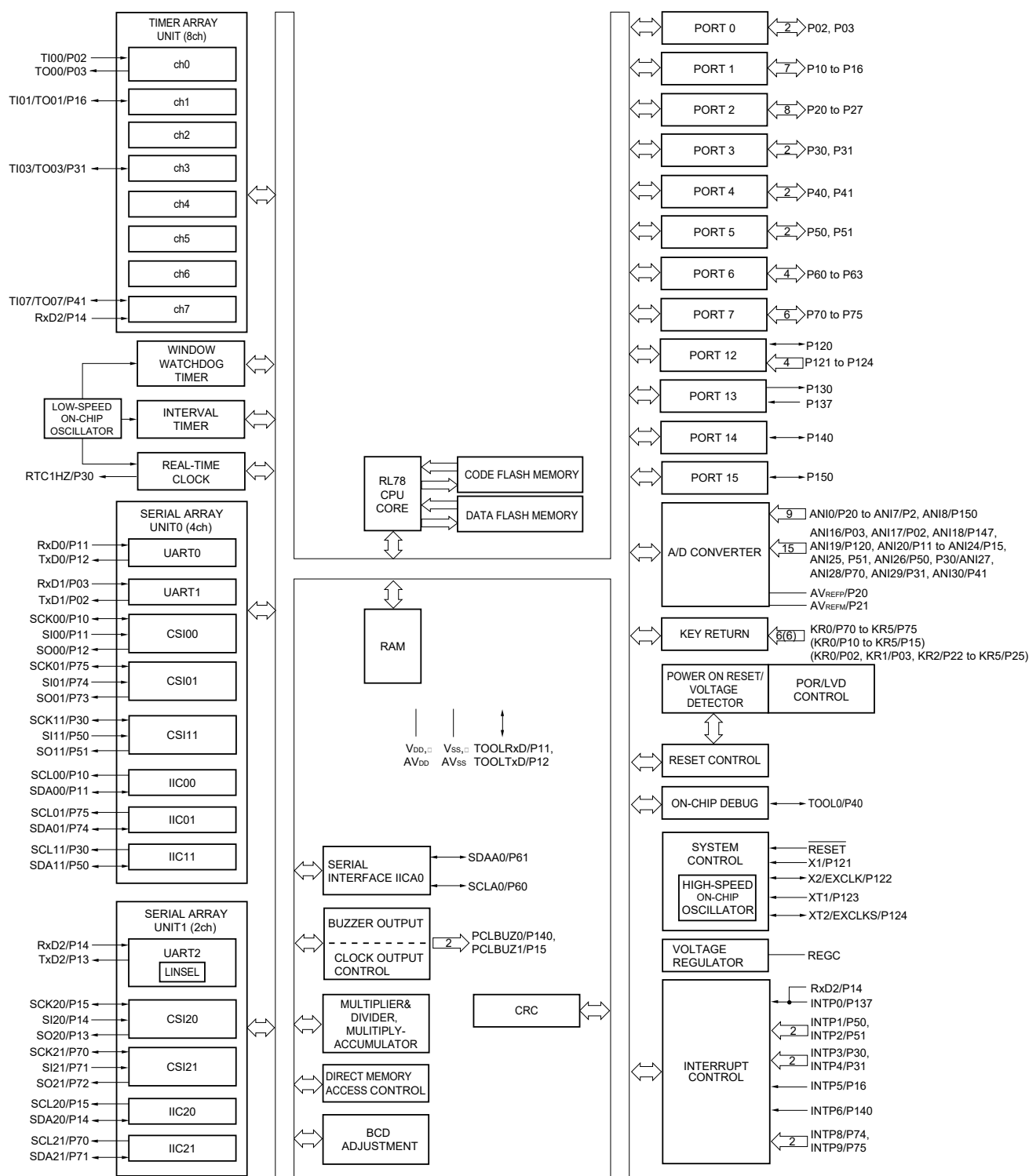
Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

1.5.2 32-pin products



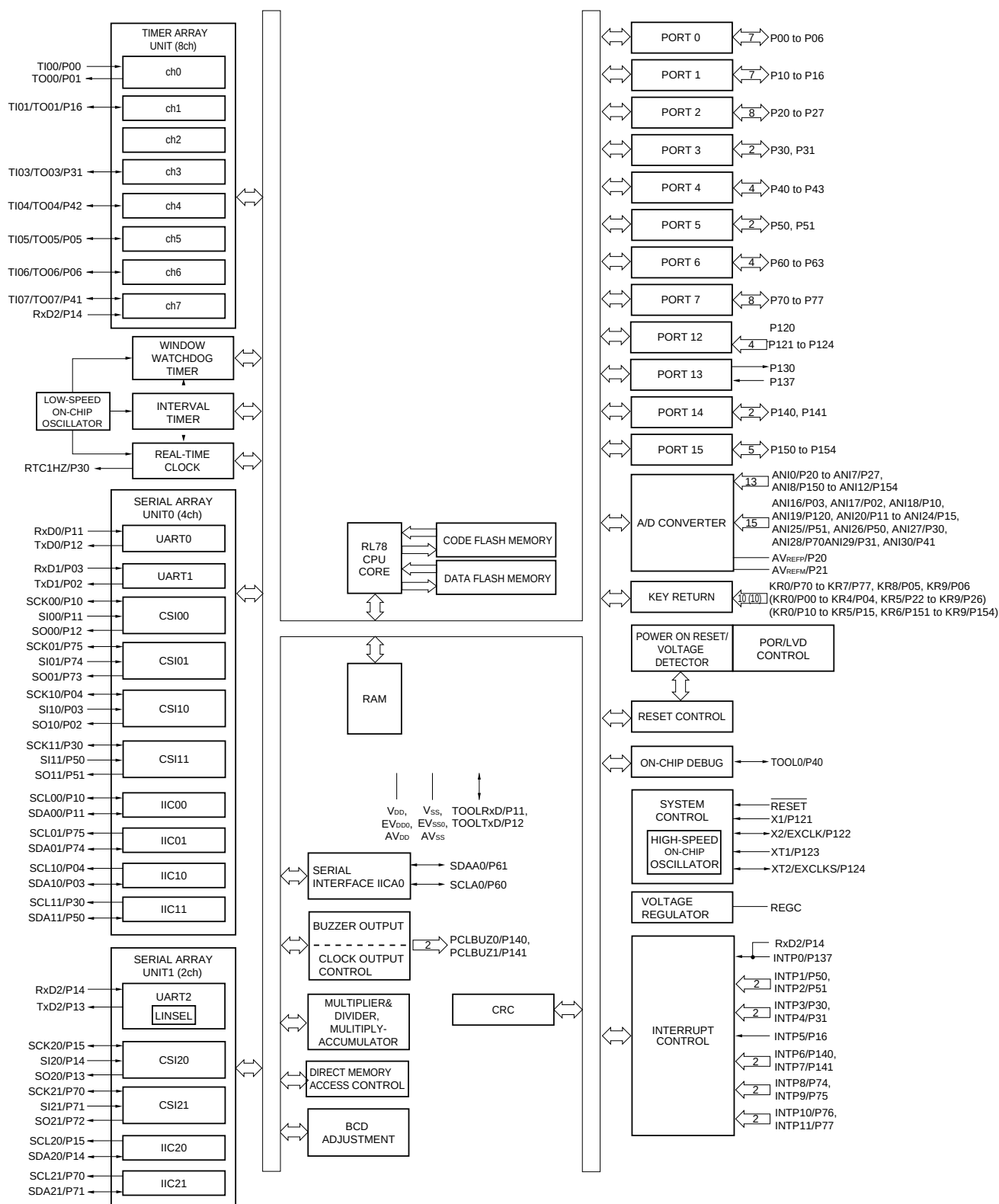
Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

1.5.3 48-pin products



Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

1.5.4 64-pin products



Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR).

1.6 Outline of Functions

(1/2)

Item		25-pin	32-pin	48-pin	64-pin
		R5F10E8x	R5F10EBx	R5F10EGx	R5F10ELx
Code flash memory (KB)		16 to 64	16 to 64	16 to 64	32 to 64
Data flash memory (KB)		4	4	4	4
RAM (KB)		2 to 4 ^{Note 1}	2 to 4 ^{Note 1}	2 to 4 ^{Note 1}	2 to 4 ^{Note 1}
Address space		1 MB			
Main system clock	High-speed system clock	X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK) HS (High-speed main) mode: 1 to 20 MHz (V _{DD} = 2.7 to 3.6 V), HS (High-speed main) mode: 1 to 16 MHz (V _{DD} = 2.4 to 3.6 V), LS (Low-speed main) mode: 1 to 8 MHz (V _{DD} = 1.8 to 3.6 V), LV (Low-voltage main) mode: 1 to 4 MHz (V _{DD} = 1.6 to 3.6 V)			
	High-speed on-chip oscillator	HS (High-speed main) mode : 1 to 32 MHz (V _{DD} = 2.7 to 3.6 V), HS (High-speed main) mode : 1 to 16 MHz (V _{DD} = 2.4 to 3.6 V), LS (Low-speed main) mode : 1 to 8 MHz (V _{DD} = 1.8 to 3.6 V), LV (Low-voltage main) mode : 1 to 4 MHz (V _{DD} = 1.6 to 3.6 V)			
Subsystem clock		–		XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz (TYP.)	
Low-speed on-chip oscillator		15 kHz (TYP.)			
General-purpose register		(8-bit register × 8) × 4 bank			
Minimum instruction execution time		0.03125 μs (High-speed on-chip oscillator: f _{IH} = 32 MHz operation)			
		0.05 μs (High-speed system clock: f _{MX} = 20 MHz operation)			
		–		30.5 μs (Subsystem clock: f _{SUB} = 32.768 kHz operation)	
Instruction set		• Data transfer (8/16 bits) • Adder and subtractor/logical operation (8/16 bits) • Multiplication (8 bits × 8 bits) • Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc.			
I/O port	Total	19	26	42	56
	CMOS I/O	14 (N-ch O.D. I/O [V _{DD} withstand voltage]: 6)	20 (N-ch O.D. I/O [V _{DD} withstand voltage]: 9)	32 (N-ch O.D. I/O [V _{DD} withstand voltage]: 11)	46 (N-ch O.D. I/O [V _{DD} withstand voltage]: 12)
	CMOS input	3	3	5	5
	CMOS output	–	–	1	1
	N-ch open-drain I/O (6 V tolerance)	2	3	4	4
Timer	16-bit timer	8 channels			
	Watchdog timer	1 channel			
	Real-time clock (RTC)	1 channel ^{Note 2}		1 channel	
	12-bit interval timer (IT)	1 channel			
	Timer output	2 channels (PWM outputs: 1 ^{Note 3})		4 channels (PWM outputs: 3 ^{Note 3})	7 channels (PWM outputs: 6 ^{Note 3})
	RTC output	–		1 • 1 Hz (subsystem clock: f _{SUB} = 32.768 kHz)	

- Notes**
1. In the case of the 4 KB, this is about 3 KB when the self-programming function and data flash function are used. (For details, see **CHAPTER 3**)
 2. Only the constant-period interrupt function when the low-speed on-chip oscillator clock (f_{IL}) is selected.
 3. The number of PWM outputs varies depending on the setting of channels in use (the number of masters and slaves). (**6.9.3 Operation as multiple PWM output function**).

(2/2)

Item				
	25-pin R5F10E8x	32-pin R5F10EBx	48-pin R5F10EGx	64-pin R5F10ELx
Clock output/buzzer output	1	2	2	2
	2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: $f_{MAIN} = 20$ MHz operation)		2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: $f_{MAIN} = 20$ MHz operation) 256 Hz, 512 Hz, 1.024 kHz, 2.048 kHz, 4.096 kHz, 8.192 kHz, 16.384 kHz, 32.768 kHz (Subsystem clock: $f_{SUB} = 32.768$ kHz operation)	
8/12-bit resolution A/D converter	13 channels	18 channels	24 channels	28 channels
Serial interface	[25-pin products] - Simplified SPI (CSI): 1 channel/simplified I²C: 1 channel/UART: 1 channel - Simplified SPI (CSI): 1 channel/simplified I²C: 1 channel/UART: 1 channel [32-pin products] - Simplified SPI (CSI): 1 channel/simplified I²C: 1 channel/UART: 1 channel - Simplified SPI (CSI): 1 channel/simplified I²C: 1 channel/UART: 1 channel - Simplified SPI (CSI): 1 channel/simplified I²C: 1 channel/UART (UART supporting LIN-bus): 1 channel [48-pin products] - Simplified SPI (CSI): 2 channels/simplified I²C: 2 channels/UART: 1 channel - Simplified SPI (CSI): 1 channel/simplified I²C: 1 channel/UART: 1 channel - Simplified SPI (CSI): 2 channels/simplified I²C: 2 channels/UART (UART supporting LIN-bus): 1 channel [64-pin products] - Simplified SPI (CSI): 2 channels/simplified I²C: 2 channels/UART: 1 channel - Simplified SPI (CSI): 2 channels/simplified I²C: 2 channels/UART: 1 channel - Simplified SPI (CSI): 2 channels/simplified I²C: 2 channels/UART (UART supporting LIN-bus): 1 channel			
	I ² C bus	1 channel	1 channel	1 channel
Multiplier and divider/multiply-accumulator	16 bits × 16 bits = 32 bits (Unsigned or signed) 32 bits ÷ 32 bits = 32 bits (Unsigned) 16 bits × 16 bits + 32 bits = 32 bits (Unsigned or signed)			
DMA controller	2 channels			
Vectored interrupt sources	Internal	24	27	27
	External	6	6	10
Key interrupt	0 ch (4 ch) ^{Note 1}	1 ch (6 ch) ^{Note 1}	6 ch	10 ch
Reset	- Reset by RESET pin - Internal reset by watchdog timer - Internal reset by power-on-reset - Internal reset by voltage detector - Internal reset by illegal instruction execution^{Note 2} - Internal reset by RAM parity error - Internal reset by illegal-memory access			
Power-on-reset circuit	- Power-on-reset: 1.51 V (TYP.) - Power-down-reset: 1.50 V (TYP.)			
Voltage detector	- Rising edge : 1.67 V to 3.14 V (12 stages) - Falling edge : 1.63 V to 3.06 V (12 stages)			
On-chip debug function	Provided			
Power supply voltage	$V_{DD} = 1.6$ to 3.6 V			
Operating ambient temperature	$T_A = -40$ to $+85^{\circ}\text{C}$ (A: Consumer application), $T_A = -40$ to $+105^{\circ}\text{C}$ (G: Industrial application)			

Notes 1. Can be used by the Peripheral I/O redirection register (PIOR).

2. The illegal instruction is generated when instruction code FFH is executed.

Reset by the illegal instruction execution not issued by emulation with the in-circuit emulator or on-chip debug emulator.

CHAPTER 2 PIN FUNCTIONS

2.1 Port Function

Pin I/O buffer power supplies depend on the product. The relationship between these power supplies and the pins is shown below.

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

(1) 25-pin products

Power Supply	Corresponding Pins
V_{DD}	Port pins other than P20 to P23 • $\overline{\text{RESET}}$, REGC
AV_{DD}	• P20 to P23

(2) 32-pin products

Power Supply	Corresponding Pins
V_{DD}	Port pins other than P20 to P24 • $\overline{\text{RESET}}$, REGC
AV_{DD}	• P20 to P24

(3) 48-pin products

Power Supply	Corresponding Pins
V_{DD}	Port pins other than P20 to P27, P150 • $\overline{\text{RESET}}$, REGC
AV_{DD}	• P20 to P27, P150

(4) 64-pin products

Power Supply	Corresponding Pins
EV_{DD0}	Port pins other than P20 to P27, P121 to P124, P137, and P150 to P154
V_{DD}	• P121 to P124, P137 • $\overline{\text{RESET}}$, REGC
AV_{DD}	• P20 to P27, and P150 to P154

Set in each port I/O, buffer, pull-up resistor is also valid for alternate functions.

2.1.1 25-pin products

(1/2)

Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P02	7-3-2	I/O	Analog input port	ANI17/TI00/TxD1/(KR0)	Port 0. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P03 can be set to TTL input buffer. Output of P02 and P03 can be set to N-ch open-drain output (V_{DD} tolerance). Can be set to analog input ^{Note 1} .
P03	8-3-2			ANI16/TO00/RxD1/(KR1)	
P10	8-3-2	I/O	Analog input port	ANI18/SCK00/SCL00	Port 1. 3-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P10 and P11 can be set to TTL input buffer. Output of P10 to P12 can be set to N-ch open-drain output (V_{DD} tolerance). Can be set to analog input ^{Note 1} .
P11				ANI20/SI00/RxD0/TOOLRxD/SDA00	
P12	7-3-2			ANI21/SO00/TxD0/TOOLTxD	
P20	4-3-1	I/O	Analog input port	ANI0/AV _{REFP}	Port 2. 4-bit I/O port. Input/output can be specified in 1-bit units. Can be set to analog input ^{Note 2} .
P21				ANI1/AV _{REFM}	
P22				ANI2/(KR2)	
P23				ANI3/(KR3)	
P30	7-3-1	I/O	Analog input port	ANI27/INTP3/SCK11/SCL11	Port 3. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Can be set to analog input ^{Note 1} .
P31				ANI29/TI03/TO03/INTP4/PCLBUZ0	
P40	7-1-1	I/O	Input port	TOOL0	Port 4. 1-bit I/O port. Input/output can be specified. Use of an on-chip pull-up resistor can be specified by a software setting at input port.
P50	7-3-2	I/O	Analog input port	ANI26/INTP1/SI11/SDA11	Port 5. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Output of P50 can be set to N-ch open-drain output (V_{DD} tolerance). Can be set to analog input ^{Note 1} .
P51	7-3-1			ANI25/INTP2/SO11	
P60	12-1-1	I/O	Input port	SCLA0	Port 6. 2-bit I/O port. Input/output can be specified in 1-bit units. Output of P60 and P61 can be set to N-ch open-drain output (6 V tolerance).
P61				SDAA0	

Notes 1. Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

2. Digital or analog for each pin can be selected with the A/D port configuration register (ADPC).

Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

(2/2)

Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P121	2-2-1	Input	Input port	X1	Port 12. 2-bit input only port.
P122				X2/EXCLK	
P137	2-1-2	Input	Input port	INTP0	Port 13. 1-bit input only port.
$\overline{\text{RESET}}$	2-1-1	Input	–	–	Input only pin for external reset When external reset is not used, connect this pin to V_{DD} directly or via a resistor.

2.1.2 32-pin products

(1/2)

Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P02	7-3-2	I/O	Analog input port	ANI17/TI00/TxD1/(KR1)	Port 0. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P03 can be set to TTL input buffer. Output of P02 and P03 can be set to N-ch open-drain output (V_{DD} tolerance). Can be set to analog input ^{Note 1} .
P03	8-3-2			ANI16/TO00/RxD1/(KR2)	
P10	8-3-2	I/O	Analog input port	ANI18/SCK00/SCL00/(KR0)	Port 1. 6-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P10, P11, P14, and P15 can be set to TTL input buffer. Output of P10 to P15 can be set to N-ch open-drain output (V_{DD} tolerance). Can be set to analog input.
P11				ANI20/SI00/RxD0/TOOLRxD/SDA00/(KR1)	
P12	7-3-2			ANI21/SO00/TxD0/TOOLTxD/(KR2)	
P13				ANI22/TxD2/SO20/(KR3)	
P14	8-3-2			ANI23/RxD2/SI20/SDA20/(KR4)	
P15				ANI24/PCLBUZ1/SCK20/SCL20/(KR5)	
P20	4-3-1	I/O	Analog input port	ANI0/AV _{REFP}	Port 2. 5-bit I/O port. Input/output can be specified in 1-bit units. Can be set to analog input ^{Note 2} .
P21				ANI1/AV _{REFM}	
P22				ANI2/(KR3)	
P23				ANI3/(KR4)	
P24				ANI4/(KR5)	
P30	7-3-1	I/O	Analog input port	ANI27/INTP3/SCK11/SCL11	Port 3. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Can be set to analog input ^{Note 1} .
P31				ANI29/TI03/TO03/INTP4/PCLBUZ0	
P40	7-1-1	I/O	Input port	TOOL0	Port 4. 1-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port.

Notes 1. Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

2. Digital or analog for each pin can be selected with the A/D port configuration register (ADPC).

Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

(2/2)

Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P50	7-3-2	I/O	Analog input port	ANI26/INTP1/SI11/SDA11	Port 5. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Output of P50 can be set to N-ch open-drain output (V_{DD} tolerance). P50 can be set to analog input ^{Note}
P51	7-1-1		Input port	INTP2/SO11	
P60	12-1-1	I/O	Input port	SCLA0	Port 6. 3-bit I/O port. Input/output can be specified in 1-bit units. Output of P60 to P62 can be set to N-ch open-drain output (6 V tolerance).
P61				SDAA0	
P62				—	
P70	7-3-1	I/O	Analog input port	ANI28/KR0	Port 7. 1-bit I/O port. Input/output can be specified. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Can be set to analog input ^{Note} .
P120	7-3-1	I/O	Analog input port	ANI19/(KR0)	Port 12. 1-bit I/O port and 2-bit input only port. P120 can be set to analog input ^{Note} . For only P120, input/output can be specified. For only P120, use of an on-chip pull-up resistor can be specified by a software setting at input port.
P121	2-2-1	Input	Input port	X1	
P122				X2/EXCLK	
P137	2-1-2	Input	Input port	INTP0	Port 13 1bit input only port.
RESET	2-1-1	Input	—	—	Input only pin for external reset When external reset is not used, connect this pin to V_{DD} directly or via a resistor.

Note Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

2.1.3 48-pin products

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Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P02	7-3-2	I/O	Analog input port	ANI17/TI00/TxD1/(KR0)	Port 0. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P03 can be set to TTL input buffer. Output of P02 and P03 can be set to N-ch open-drain output (V_{DD} tolerance). Can be set to analog input ^{Note 1} .
P03	8-3-2			ANI16TO00/RxD1/(KR1)	
P10	8-3-2	I/O	Analog input port	ANI18/SCK00/SCL00/(KR0)	Port 1. 7-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P10, P11, and P14 to P16 can be set to TTL input buffer. Output of P10 to P15 can be set to N-ch open-drain output (V_{DD} tolerance). P10 to P15 can be set to analog input ^{Note 1} .
P11				ANI20/SI00/RxD0/TOOLRxD/SDA00/(KR1)	
P12	7-3-2			ANI21/SO00/TxD0/TOOLTxD/(KR2)	
P13				ANI22/TxD2/SO20/(KR3)	
P14	8-3-2			ANI23/RxD2/SI20/SDA20/(KR4)	
P15				ANI24/PCLBUZ1/SCK20/SCL20/(KR5)	
P16	8-1-1		Input port	TI01/TO01/INTP5	
P20	4-3-1	I/O	Analog input port	ANI0/AV _{REFP}	Port 2. 8-bit I/O port. Input/output can be specified in 1-bit units. Can be set to analog input ^{Note 2} .
P21				ANI1/AV _{REFM}	
P22				ANI2/(KR2)	
P23				ANI3/(KR3)	
P24				ANI4/(KR4)	
P25				ANI5/(KR5)	
P26				ANI6	
P27				ANI7	
P30	7-3-1	I/O	Analog input port	ANI27/INTP3/RTC1HZ/SCK11/SCL11	Port 3. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Can be set to analog input ^{Note 1} .
P31				ANI29/TI03/TO03/INTP4	

Notes 1. Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

2. Digital or analog for each pin can be selected with the A/D port configuration register (ADPC).

Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

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Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P40	7-1-1	I/O	Input port	TOOL0	Port 4. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. P41 can be set to analog input ^{Note 1} .
P41	7-3-1		Analog input port	ANI30/TI07/TO07	
P50	7-3-2	I/O	Analog input port	ANI26/INTP1/SI11/SDA11	Port 5. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Output of P50 can be set to N-ch open-drain output (V _{DD} tolerance). Can be set to analog input ^{Note 1} .
P51	7-3-1			ANI25/INTP2/SO11	
P60	12-1-1	I/O	Input port	SCLA0	Port 6. 4-bit I/O port. Input/output can be specified in 1-bit units. N-ch open-drain output (6 V tolerance).
P61				SDAA0	
P62				–	
P63				–	
P70	7-3-1	I/O	Analog input port	ANI28/KR0/SCK21/SCL21	Port 7. 6-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Output of P71 and P74 can be set to N-ch open-drain output (V _{DD} tolerance). P70 can be set to analog input ^{Note 1} .
P71	7-1-2		Input port	KR1/SI21/SDA21	
P72	7-1-1			KR2/SO21	
P73				KR3/SO01	
P74	7-1-2			KR4/INTP8/SI01/SDA01	
P75	7-1-1			KR5/INTP9/SCK01/SCL01	
P120	7-3-1	I/O	Analog input port	ANI19	Port 12. 1-bit I/O port and 4-bit input only port. For only P120, input/output can be specified. For only P120, use of an on-chip pull-up resistor can be specified by a software setting at input port. P120 can be set to analog input ^{Note 1} .
P121	2-2-1		Input port	X1	
P122				X2/EXCLK	
P123				XT1	
P124				XT2/EXCLKS	
P130	1-1-1	Output	Output port	–	Port 13.
P137	2-1-2	Input	Input port	INTP0	1-bit output port and 1-bit input only port.
P140	7-1-1	I/O	Input port	PCLBUZ0/INTP6	Port 14. 1-bit I/O port. Input/output can be specified. Use of an on-chip pull-up resistor can be specified by a software setting at input port.
P150	4-3-1		Analog input port	ANI18	Port 15 1-bit I/O port. Input/output can be specified. Can be set to analog input ^{Note 2} .
RESET	2-1-1	Input	–	–	Input only pin for external reset When external reset is not used, connect this pin to V _{DD} directly or via a resistor.

Notes 1. Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

2. Digital or analog for each pin can be selected with the A/D port configuration register (ADPC).

2.1.4 64-pin products

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Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P00	8-1-1	I/O	Input port	TI00/(KR0)	Port 0. 7-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P00, P01, P03, and P04 can be set to TTL input buffer. Output of P02 to P04 can be set to N-ch open-drain output (V_{DD} tolerance). P02 and P03 can be set to analog input ^{Note 1} .
P01				TO00/(KR1)	
P02	7-3-2		Analog input port	ANI17/SO10/TxD1/(KR2)	
P03	8-3-2			ANI16/SI10/RxD1/SDA10/(KR3)	
P04	8-1-2		Input port	SCK10/SCL10/(KR4)	
P05	7-1-1			TI05/TO05/KR8	
P06				TI06/TO06/KR9	
P10	8-3-2	I/O	Analog input port	ANI18/SCK00/SCL00/(KR0)	Port 1. 7-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Input of P10, P11, and P14 to P16 can be set to TTL input buffer. Output of P10 to P15 can be set to N-ch open-drain output (V_{DD} tolerance). P10 to P15 can be set to analog input ^{Note 1} .
P11				ANI20/SI00/RxD0/TOOLRxD/SDA00/(KR1)	
P12	7-3-2			ANI21/SO00/TxD0/TOOLTxD/(KR2)	
P13				ANI22/TxD2/SO20/(KR3)	
P14	8-3-2			ANI23/RxD2/SI20/SDA20/(KR4)	
P15				ANI24/SCK20/SCL20/(KR5)	
P16	8-1-1		Input port	TI01/TO01/INTP5	
P20	4-3-1	I/O	Analog input port	ANI0/AV _{REFP}	Port 2. 8-bit I/O port. Input/output can be specified in 1-bit units. Can be set to analog input ^{Note 2} .
P21				ANI1/AV _{REFM}	
P22				ANI2/(KR5)	
P23				ANI3/(KR6)	
P24				ANI4/(KR7)	
P25				ANI5/(KR8)	
P26				ANI6/(KR9)	
P27				ANI7	
P30	7-3-2	I/O	Analog input port	ANI27/INTP3/RTC1HZ/SCK11/SCL11	Port 3. 2-bit I/O port. Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Can be set to analog input ^{Note 1} .
P31				ANI29/TI03/TO03/INTP4	

Notes 1. Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

2. Digital or analog for each pin can be selected with the A/D port configuration register (ADPC).

Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

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Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P40	7-1-1	I/O	Input port	TOOL0	Port 4.
P41	7-3-1		Analog input port	ANI30/8TI07/TO07	4-bit I/O port.
P42	7-1-1		Input port	TI04/TO04	Input/output can be specified in 1-bit units.
P43				—	Use of an on-chip pull-up resistor can be specified by a software setting at input port. P41 can be set to analog input ^{Note} .
P50	7-3-2	I/O	Analog input port	ANI26/INTP1/SI11/SDA11	Port 5.
P51	7-3-1			ANI25/INTP2/SO11	2-bit I/O port.
					Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port. Output of P50 can be set to N-ch open-drain output (V _{DD} tolerance). Can be set to analog input ^{Note} .
P60	12-1-1	I/O	Input port	SCLA0	Port 6.
P61				SDAA0	4-bit I/O port.
P62				—	Input/output can be specified in 1-bit units.
P63				—	N-ch open-drain output (6 V tolerance).
P70	7-3-1	I/O	Analog input port	ANI28/KR0/SCK21/SCL21	Port 7.
P71	7-1-2		Input port	KR1/SI21/SDA21	8-bit I/O port.
P72	7-1-1			KR2/SO21	Input/output can be specified in 1-bit units.
P73				KR3/SO01	Use of an on-chip pull-up resistor can be specified by a software setting at input port.
P74	7-1-2			KR4/INTP8/SI01/SDA01	Output of P71 and P74 can be set to N-ch open-drain output (V _{DD} tolerance).
P75	7-1-1			KR5/INTP9/SCK01/SCL01	P70 can be set to analog input ^{Note} .
P76				KR6/INTP10	
P77				KR7/INTP11	
P120	7-3-1	I/O	Analog input port	ANI19	Port 12.
P121	2-2-1		Input port	X1	1-bit I/O port and 4-bit input only port.
P122				X2/EXCLK	For only P120, input/output can be specified.
P123				XT1	For only P120, use of an on-chip pull-up resistor can be specified by a software setting at input port.
P124				XT2/EXCLKS	P120 can be set to analog input ^{Note} .
P130	1-1-1	Output	Output port	—	Port 13.
P137	2-1-2	Input	Input port	INTP0	1-bit output port and 1-bit input only port.
P140	7-1-1	I/O	Input port	PCLBUZ0/INTP6	Port 14.
P141				PCLBUZ1/INTP7	2-bit I/O port.
					Input/output can be specified in 1-bit units. Use of an on-chip pull-up resistor can be specified by a software setting at input port.

Note Digital or analog for each pin can be selected with the port mode control register x (PMCx) (can be set in 1-bit units).

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Function Name	Pin Type	I/O	After Reset Release	Alternate Function	Function
P150	4-3-1	I/O	Analog input port	ANI8	Port 15. 5-bit I/O port. Input/output can be specified in 1-bit units. Can be set to analog input ^{Note} .
P151				ANI9/(KR6)	
P152				ANI10/(KR7)	
P153				ANI11/(KR8)	
P154				ANI12/(KR9)	
RESET	2-1-1	Input	—	—	Input only pin for external reset When external reset is not used, connect this pin to V _{DD} directly or via a resistor.

Note Digital or analog for each pin can be selected with the A/D port configuration register (ADPC).

Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)**.

2.2 Functions Other than Port Pins

2.2.1 With functions for each product

(1/4)

Function Name	64-pin	48-pin	32-pin	25-pin
ANI0	√	√	√	√
ANI1	√	√	√	√
ANI2	√	√	√	√
ANI3	√	√	√	√
ANI4	√	√	√	–
ANI5	√	√	–	–
ANI6	√	√	–	–
ANI7	√	√	–	–
ANI8	√	√	–	–
ANI9	√	–	–	–
ANI10	√	–	–	–
ANI11	√	–	–	–
ANI12	√	–	–	–
ANI16	√	√	√	√
ANI17	√	√	√	√
ANI18	√	√	√	√
ANI19	√	√	√	–
ANI20	√	√	√	√
ANI21	√	√	√	√
ANI22	√	√	√	–
ANI23	√	√	√	–
ANI24	√	√	√	–
ANI25	√	√	–	√
ANI26	√	√	√	√
ANI27	√	√	√	√
ANI28	√	√	√	–
ANI29	√	√	√	√
ANI30	√	√	–	–
INTP0	√	√	√	√
INTP1	√	√	√	√
INTP2	√	√	√	√
INTP3	√	√	√	√
INTP4	√	√	√	√
INTP5	√	√	–	–
INTP6	√	√	–	–
INTP7	√	–	–	–
INTP8	√	√	–	–
INTP9	√	√	–	–
INTP10	√	–	–	–
INTP11	√	–	–	–

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Function Name	64-pin	48-pin	32-pin	25-pin
KR0	√	√	√	(√)
KR1	√	√	(√)	(√)
KR2	√	√	(√)	(√)
KR3	√	√	(√)	(√)
KR4	√	√	(√)	–
KR5	√	√	(√)	–
KR6	√	–	–	–
KR7	√	–	–	–
KR8	√	–	–	–
KR9	√	–	–	–
PCLBUZ0	√	√	√	√
PCLBUZ1	√	√	√	–
REGC	√	√	√	√
RTC1HZ	√	√	–	–
RESET	√	√	√	√
RxD0	√	√	√	√
RxD1	√	√	√	√
RxD2	√	√	√	–
SCK00	√	√	√	√
SCK01	√	√	–	–
SCK10	√	–	–	–
SCK11	√	√	√	√
SCK20	√	√	√	–
SCK21	√	√	–	–
SCLA0	√	√	√	√
SCL00	√	√	√	√
SCL01	√	√	–	–
SCL10	√	–	–	–
SCL11	√	√	√	√
SCL20	√	√	√	–
SCL21	√	√	–	–
SDAA0	√	√	√	√
SDA00	√	√	√	√
SDA01	√	√	–	–
SDA10	√	–	–	–
SDA11	√	√	√	√
SDA20	√	√	√	–
SDA21	√	√	–	–

Remark The checked function is available only when the bit corresponding to the function in the peripheral I/O redirection register (PIOR) is set to 1.

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Function Name	64-pin	48-pin	32-pin	25-pin
SI00	√	√	√	√
SI01	√	√	—	—
SI10	√	—	—	—
SI11	√	√	√	√
SI20	√	√	√	—
SI21	√	√	—	—
SO00	√	√	√	√
SO01	√	√	—	—
SO10	√	—	—	—
SO11	√	√	√	√
SO20	√	√	√	—
SO21	√	√	—	—
TI01	√	√	—	—
TI03	√	√	√	√
TI04	√	—	—	—
TI05	√	—	—	—
TI06	√	—	—	—
TI07	√	√	—	—
TO00	√	√	√	√
TO01	√	√	—	—
TO03	√	√	√	√
TO04	√	—	—	—
TO05	√	—	—	—
TO06	√	—	—	—
TO07	√	√	—	—
TxD0	√	√	√	√
TxD1	√	√	√	√
TxD2	√	√	√	—
X1	√	√	√	√
X2	√	√	√	√
EXCLK	√	√	√	√
EXCLKS	√	√	—	—
TI00	√	√	√	√
XT1	√	√	—	—
XT2	√	√	—	—

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Function Name	64-pin	48-pin	32-pin	25-pin
V _{DD}	√	√	√	√
EV _{DD0}	√	—	—	—
AV _{DD}	√	√	√	√
AV _{REFP}	√	√	√	√
AV _{REFM}	√	√	√	√
V _{SS}	√	√	√	√
EV _{SS0}	√	—	—	—
AV _{SS}	√	√	√	√
TOOLRxD	√	√	√	√
TOOLTxD	√	√	√	√
TOOL0	√	√	√	√

2.2.2 Explanation of function

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Function Name	I/O	Function
ANI0 to ANI12, ANI16 to ANI30	Input	A/D converter analog input (see Figure 11-44 Analog Input Pin Connection)
INTP0 to INTP11	Input	External interrupt request input The valid edge can be specified : Rising edge, falling edge, or both rising and falling edges)
KR0 to KR9	Input	Key interrupt input
PCLBUZ0, PCLBUZ1	Output	Clock output/buzzer output
REGC	–	Pin for connecting regulator output stabilization capacitance for internal operation. Connect this pin to V _{SS} via a capacitor (0.47 to 1 μ F). Also, use a capacitor with good characteristics, since it is used to stabilize internal voltage.
RTC1HZ	Output	Real-time clock correction clock (1 Hz) output
RESET	Input	This is the active-low system reset input pin. When the external reset is not used, connect this pin directly or via a resistor to V _{DD} .
RxD0 to RxD2	Input	Serial data input pins of serial interface UART0, UART1, and UART2
TxD0 to TxD2	Output	Serial data output pins of serial interface UART0, UART1, and UART2
SCK00, SCK01, SCK10, SCK11, SCK20, SCK21	I/O	Serial clock I/O pins of serial interface CSI00, CSI01, CSI10, CSI11, CSI20, and CSI21
SCL00, SCL01, SCL10, SCL11, SCL20, SCL21	Output	Serial clock output pins of serial interface IIC00, IIC01, IIC10, IIC11, IIC20, and IIC21
SDA00, SDA01, SDA10, SDA11, SDA20, SDA21	I/O	Serial data I/O pins of serial interface IIC00, IIC01, IIC10, IIC11, IIC20, and IIC21
SI00, SI01, SI10, SI11, SI20, SI21	Input	Serial data input pins of serial interface CSI00, CSI01, CSI10, CSI11, CSI20, and CSI21
SO00, SO01, SO10, SO11, SO20, SO21	Output	Serial data output pins of serial interface CSI00, CSI01, CSI10, CSI11, CSI20, and CSI21
SCLA0	I/O	Serial clock I/O pins of serial interface IICA0
SDAA0	I/O	Serial data I/O pins of serial interface IICA0
TI00, TI01, TI03 to TI07	Input	The pins for inputting an external count clock/capture trigger to 16-bit timers 00, 01, and 03 to 07
TO00, TO01, TO03 to TO07	Output	Timer output pins of 16-bit timers 00, 01, and 03 to 07
X1, X2	–	Resonator connection for main system clock
EXCLK	Input	External clock input for main system clock
XT1, XT2	–	Resonator connection for subsystem clock
EXCLKS	Input	External clock input for subsystem clock

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Function Name	I/O	Function
V _{DD}	–	<25-pin, 32-pin 48-pin> Positive power supply for port pin other than P20 to P27, P150 and $\overline{\text{RESET}}$, REGC pin. <64-pin > Positive power supply for P121 to P124, P137 and $\overline{\text{RESET}}$, REGC pin.
EV _{DD0}	–	Positive power supply for ports (other than P20 to P27, P121 to P124, P137, P150 to P154)
AV _{DD}	–	Positive power supply for P20 to P27, P150 to P154, and A/D converter
AV _{REFP}	Input	A/D converter reference potential (+ side) input
AV _{REFM}	Input	A/D converter reference potential (– side) input Make AV _{REFM} pin the same potential as AV _{SS} and V _{SS} pin.
V _{SS}	–	<25-pin, 32-pin, 48-pin> Ground potential for port pin other than P20 to P27, P150 and $\overline{\text{RESET}}$, REGC pin. <64-pin> Ground potential for P121 to P124, P137 and $\overline{\text{RESET}}$, REGC pin.
EV _{SS0}	–	Ground potential for ports (other than P20 to P27, P121 to P124, P137, P150 to P154) Make EV_{SS0} pin the same potential as V_{SS} pin.
AV _{SS}	–	Ground potential for A/D converter, P20 to P27, and P150 to P154. Use this pin with the same potential as EV _{SS0} , and V _{SS} .
TOOLRxD	Input	UART reception pin for the external device connection used during flash memory programming
TOOLTxD	Output	UART transmission pin for the external device connection used during flash memory programming
TOOL0	I/O	Data I/O for flash memory programmer/debugger

Caution After reset release, the relationships between P40/TOOL0 and the operating mode are as follows.

Table 2-2. Relationships Between P40/TOOL0 and Operation Mode After Reset Release

P40/TOOL0	Operating Mode
EV _{DD0}	Normal operation mode
0 V	Flash memory programming mode

For details, see 25.4 Serial Programming Method.

Remark Use bypass capacitors (about 0.1 μF) as noise and latch up countermeasures with relatively thick wires at the shortest distance to V_{DD} to V_{SS}, EV_{DD0} to EV_{SS0} lines.

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

Table 2-3 shows the connections of unused pins.

Remark The pins mounted depend on the product. See 1.3 Pin Configuration (Top View) and 2.1 Port Function.

Table 2-3. Connection of Unused Pins

Pin Name	I/O	Recommended Connection of Unused Pins
P00 to P06	I/O	Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Leave open.
P10 to P16		
P20 to P27		Input: Independently connect to AV _{DD} or AV _{SS} via a resistor. Output: Leave open.
P30, P31		Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Leave open.
P40/TOOL0		Input: Independently connect to EV _{DD0} or leave open. Output: Leave open.
P41 to P43		Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Leave open.
P50, P51		
P60 to P63		Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Set the port's output latch to 0 and leave the pins open, or set the port's output latch to 1 and independently connect the pins to EV _{DD0} or EV _{SS0} via a resistor.
P70 to P77		Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Leave open.
P120		Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Leave open.
P121 to P124	Input	Independently connect to V _{DD} or V _{SS} via a resistor.
P130	Output	Leave open.
P137	Input	Independently connect to V _{DD} or V _{SS} via a resistor.
P140, P141	I/O	Input: Independently connect to EV _{DD0} or EV _{SS0} via a resistor. Output: Leave open.
P150 to P154		Input: Independently connect to AV _{DD} or AV _{SS} via a resistor. Output: Leave open.
RESET	Input	Connect directly or via a resistor to V _{DD} .
REGC	–	Connect to V _{SS} via capacitor (0.47 to 1 μ F).

Remark With products not provided with an EV_{DD0}, or EV_{SS0} pin, replace EV_{DD0} with V_{DD}, or replace EV_{SS0} with V_{SS}.

2.4 Block Diagrams of Pins

Figures 2-1 to 2-13 show the block diagrams of the pins described in 2.1.1 25-pin products to 2.1.4 64-pin products.

Figure 2-1. Pin Block Diagram for Pin Type 1-1-1

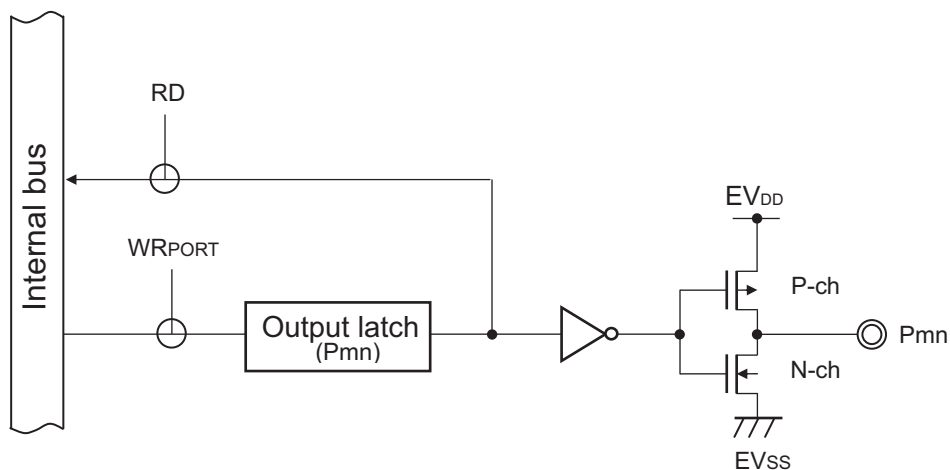


Figure 2-2. Pin Block Diagram for Pin Type 2-1-1

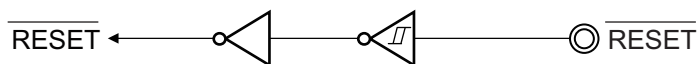
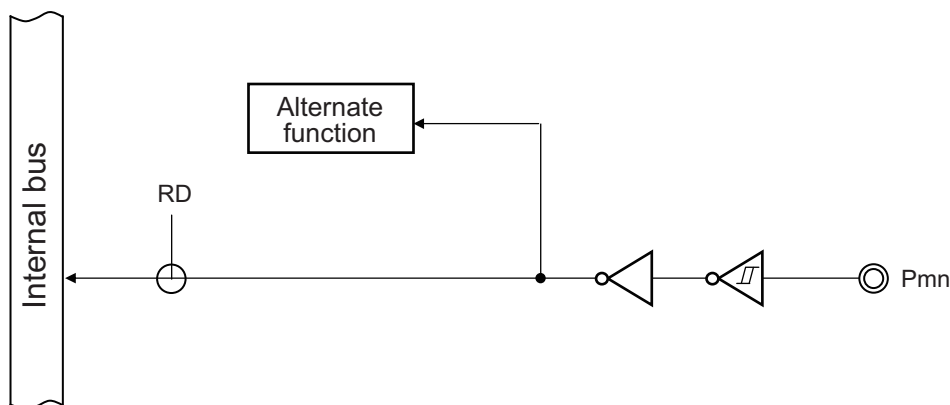
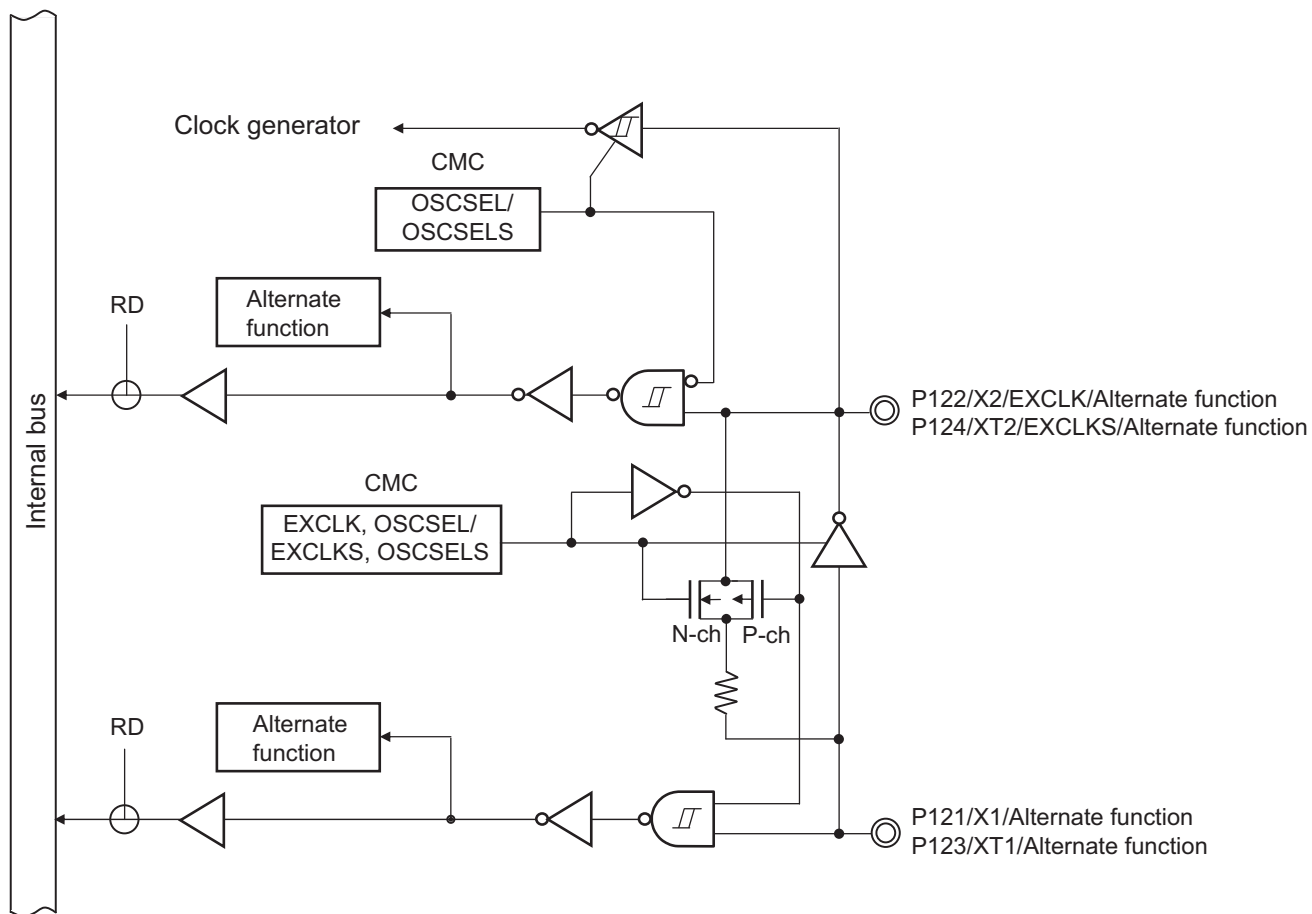


Figure 2-3. Pin Block Diagram for Pin Type 2-1-2



Remark For alternate functions, see 2.1 Port Function.

Figure 2-4. Pin Block Diagram for Pin Type 2-2-1



Remark For alternate functions, see **2.1 Port Function**.

Figure 2-5. Pin Block Diagram for Pin Type 4-3-1

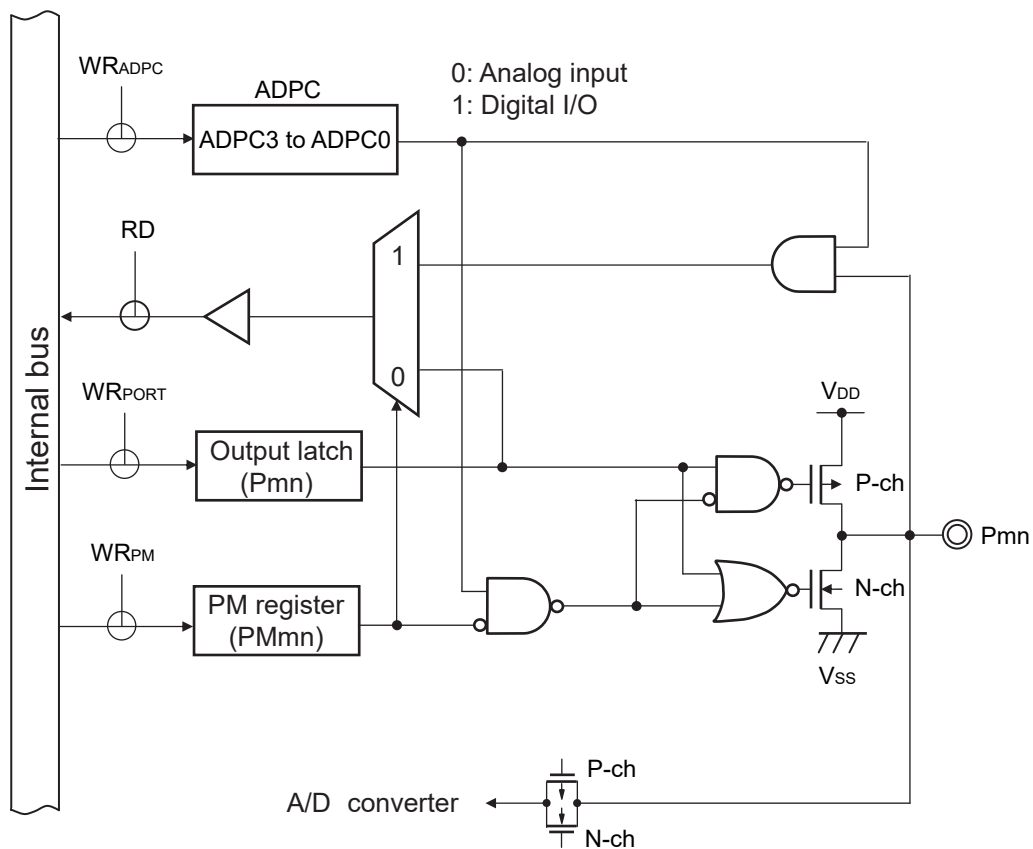
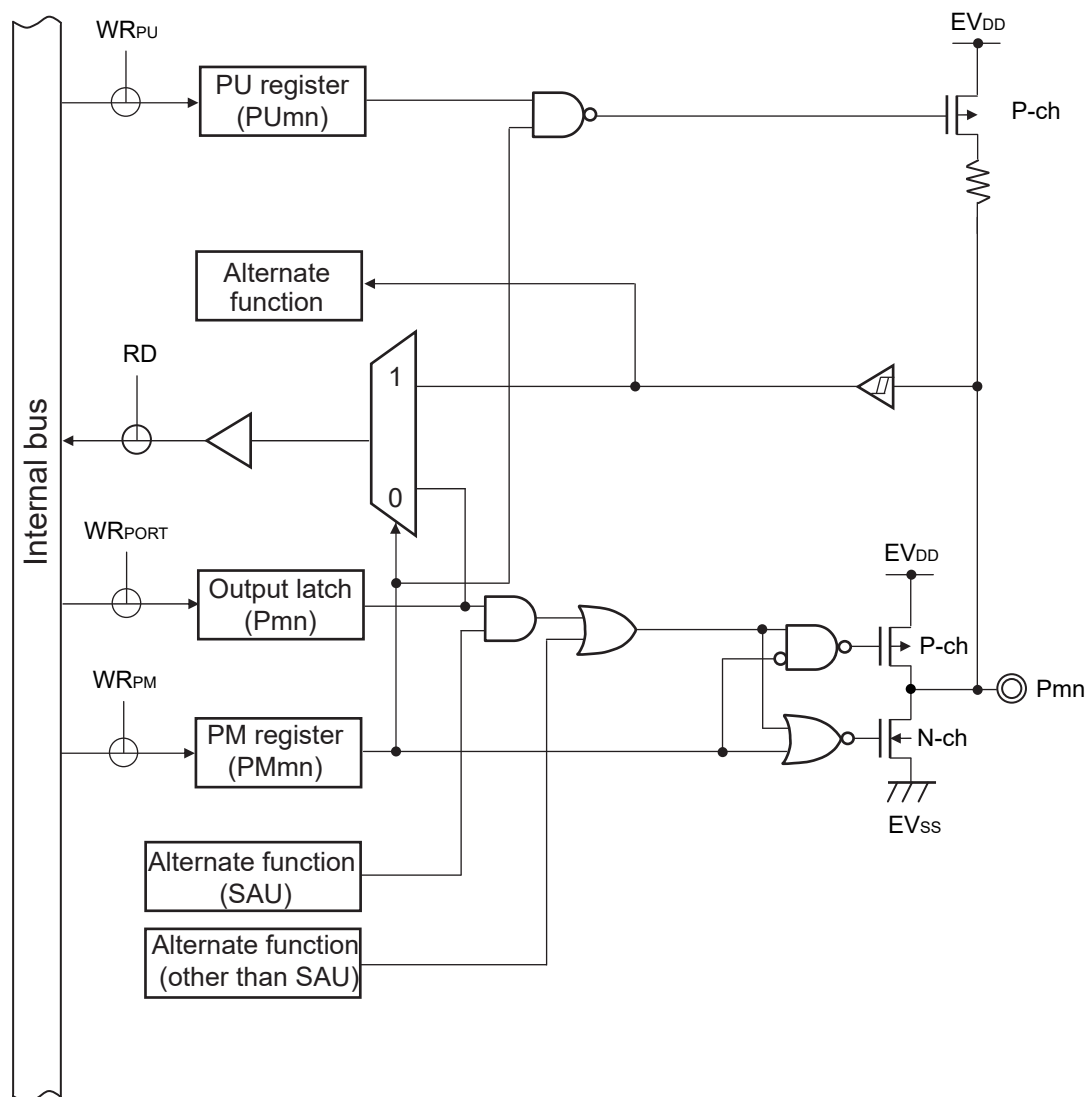
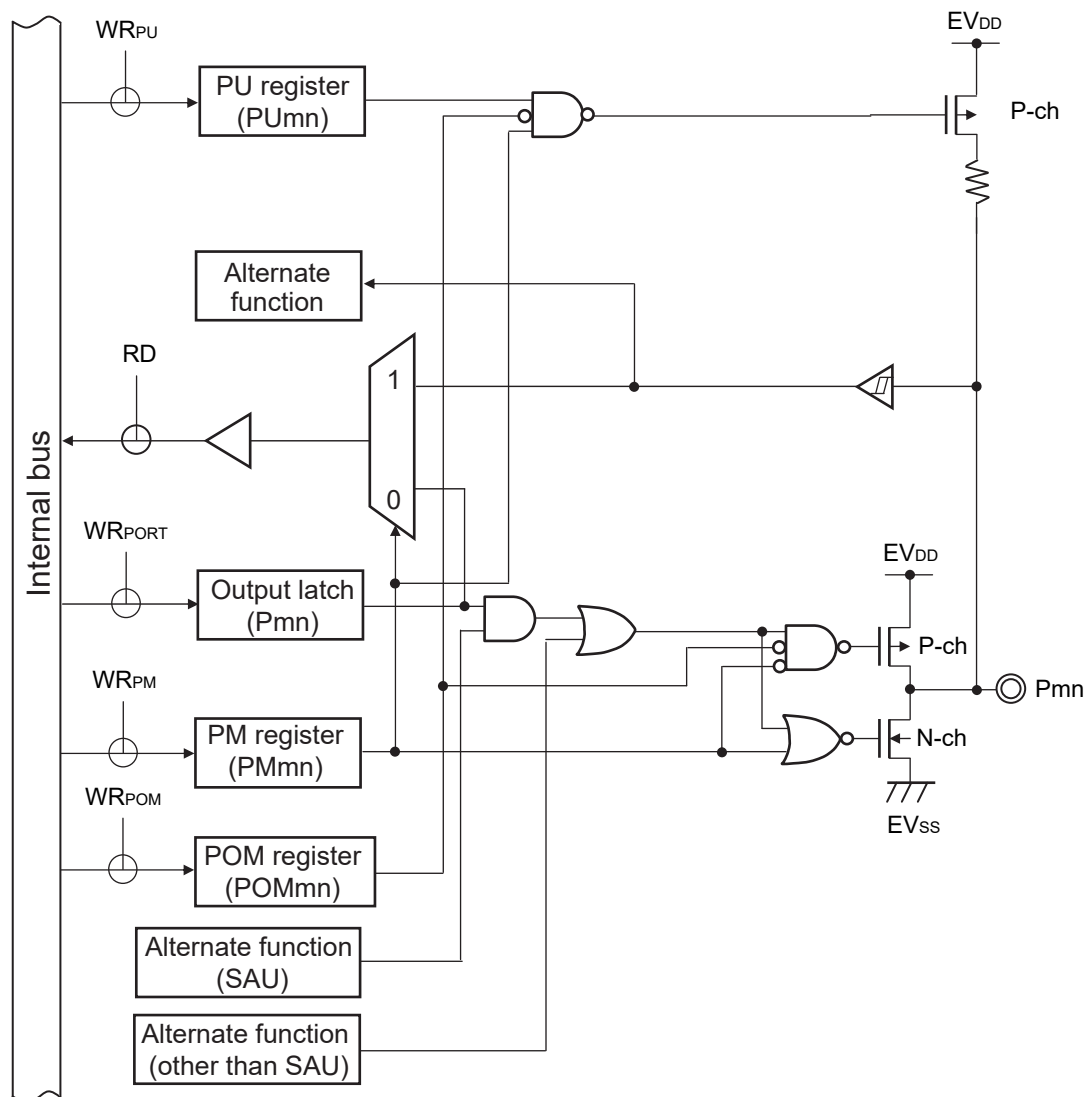


Figure 2-6. Pin Block Diagram for Pin Type 7-1-1



- Remarks**
1. For alternate functions, see 2.1 Port Function.
 2. SAU: Serial array unit

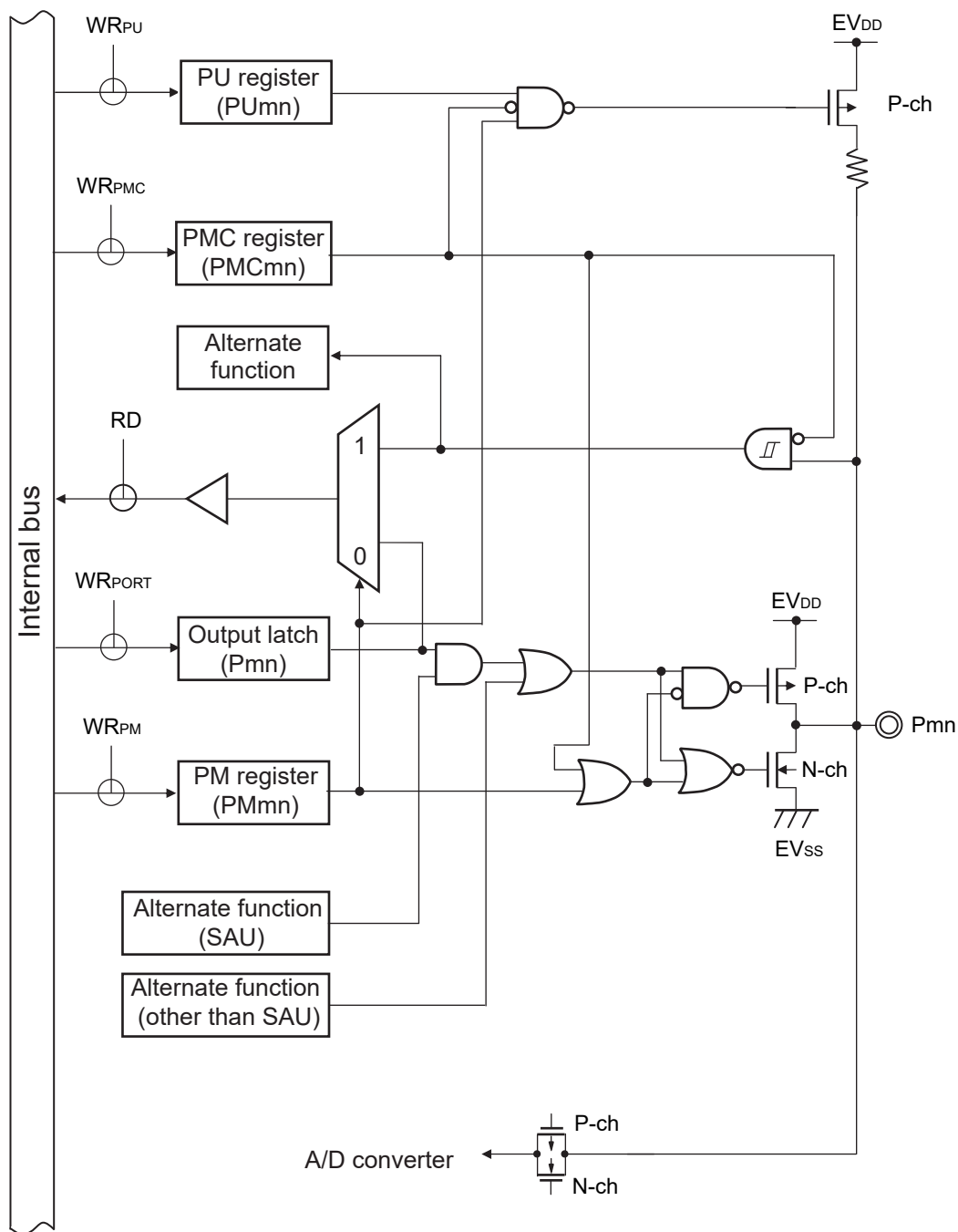
Figure 2-7. Pin Block Diagram for Pin Type 7-1-2



Caution A through current may flow through if the pin is in the intermediate potential, because the input buffer is also turned on when the pin is in N-ch open-drain output mode by port output mode register (POMx).

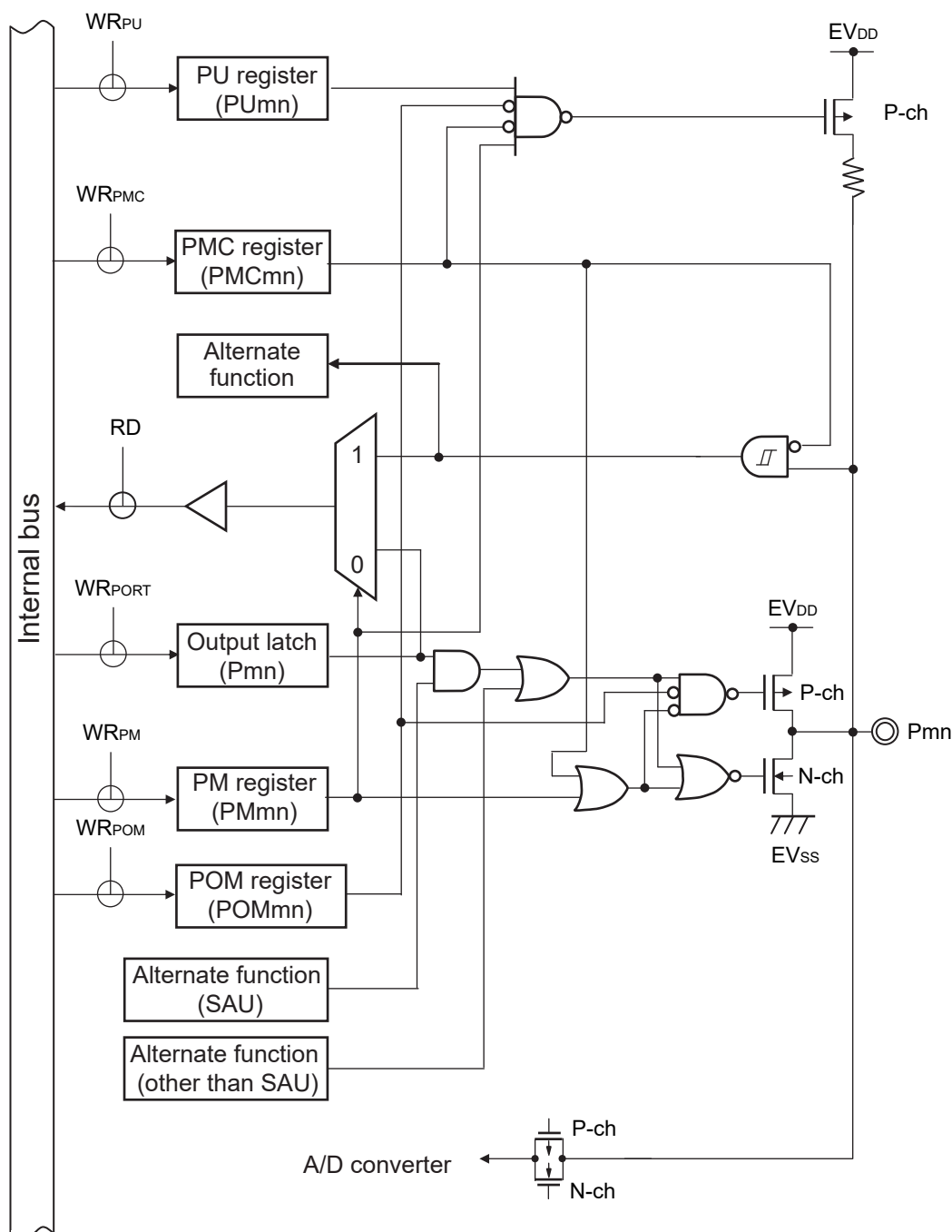
- Remarks**
1. For alternate functions, see 2.1 Port Function.
 2. SAU: Serial array unit

Figure 2-8. Pin Block Diagram for Pin Type 7-3-1



- Remarks**
1. For alternate functions, see **2.1 Port Function**.
 2. SAU: Serial array unit

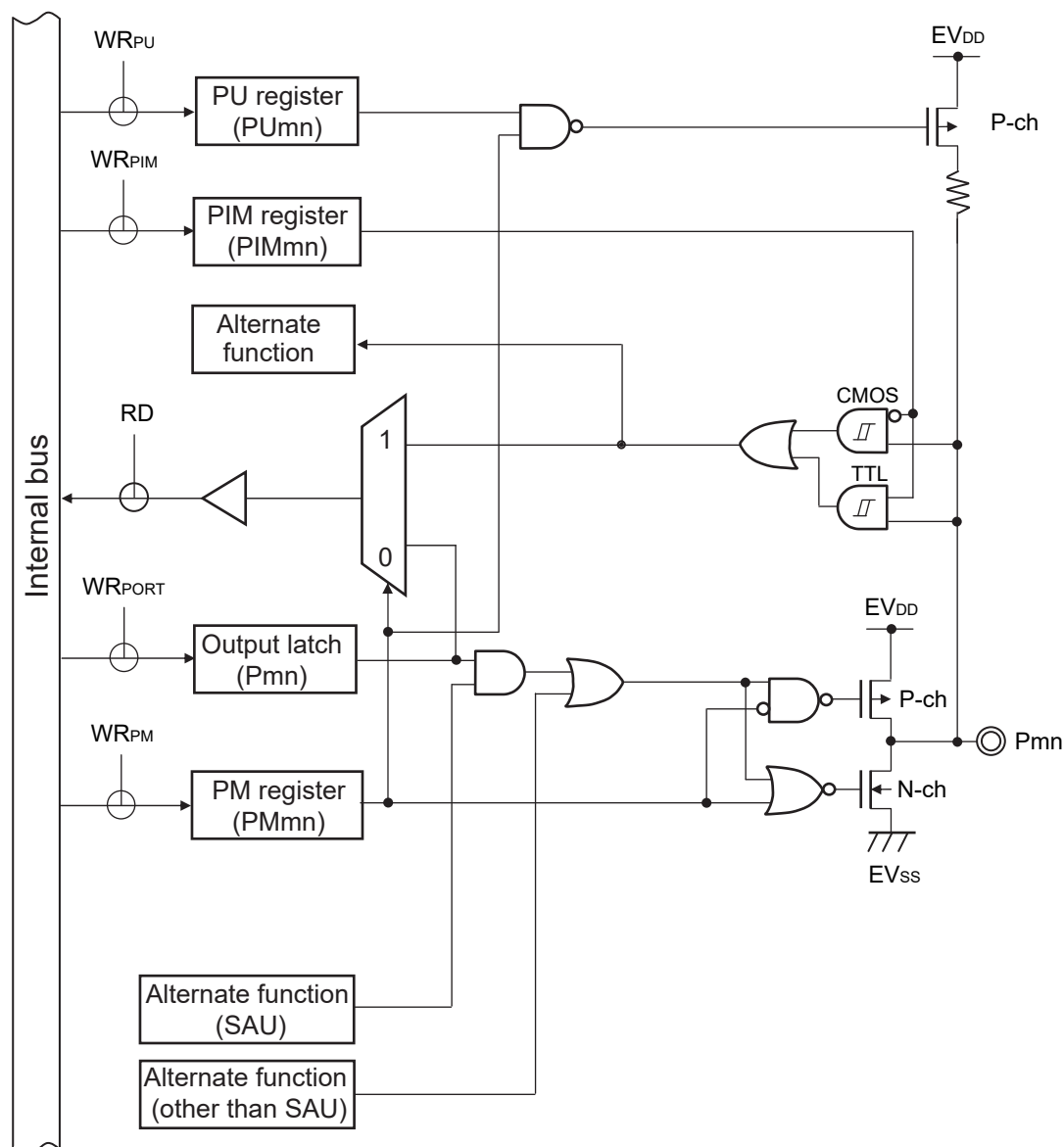
Figure 2-9. Pin Block Diagram for Pin Type 7-3-2



Caution A through current may flow through if the pin is in the intermediate potential, because the input buffer is also turned on when the pin is in N-ch open-drain output mode by port output mode register (POM_x).

- Remarks**
1. For alternate functions, see 2.1 Port Function.
 2. SAU: Serial array unit

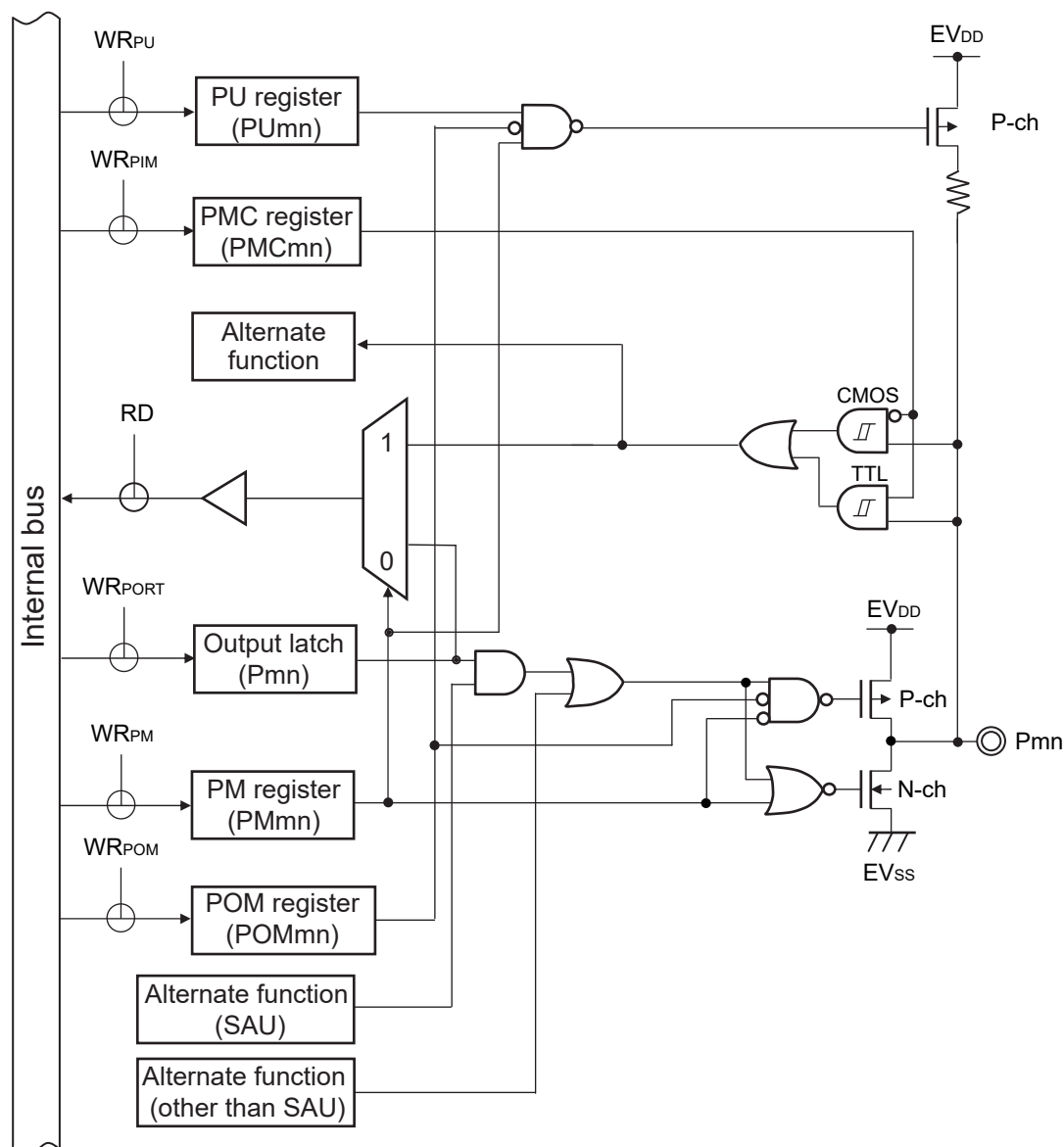
Figure 2-10. Pin Block Diagram for Pin Type 8-1-1



Caution Because of TTL input buffer structure, if the port input mode register (PIMx) is set in TTL input buffer, a through current may flow through in the case of high level input. It is recommended to input a low level to prevent a through current.

- Remarks**
1. For alternate functions, see 2.1 Port Function.
 2. SAU: Serial array unit

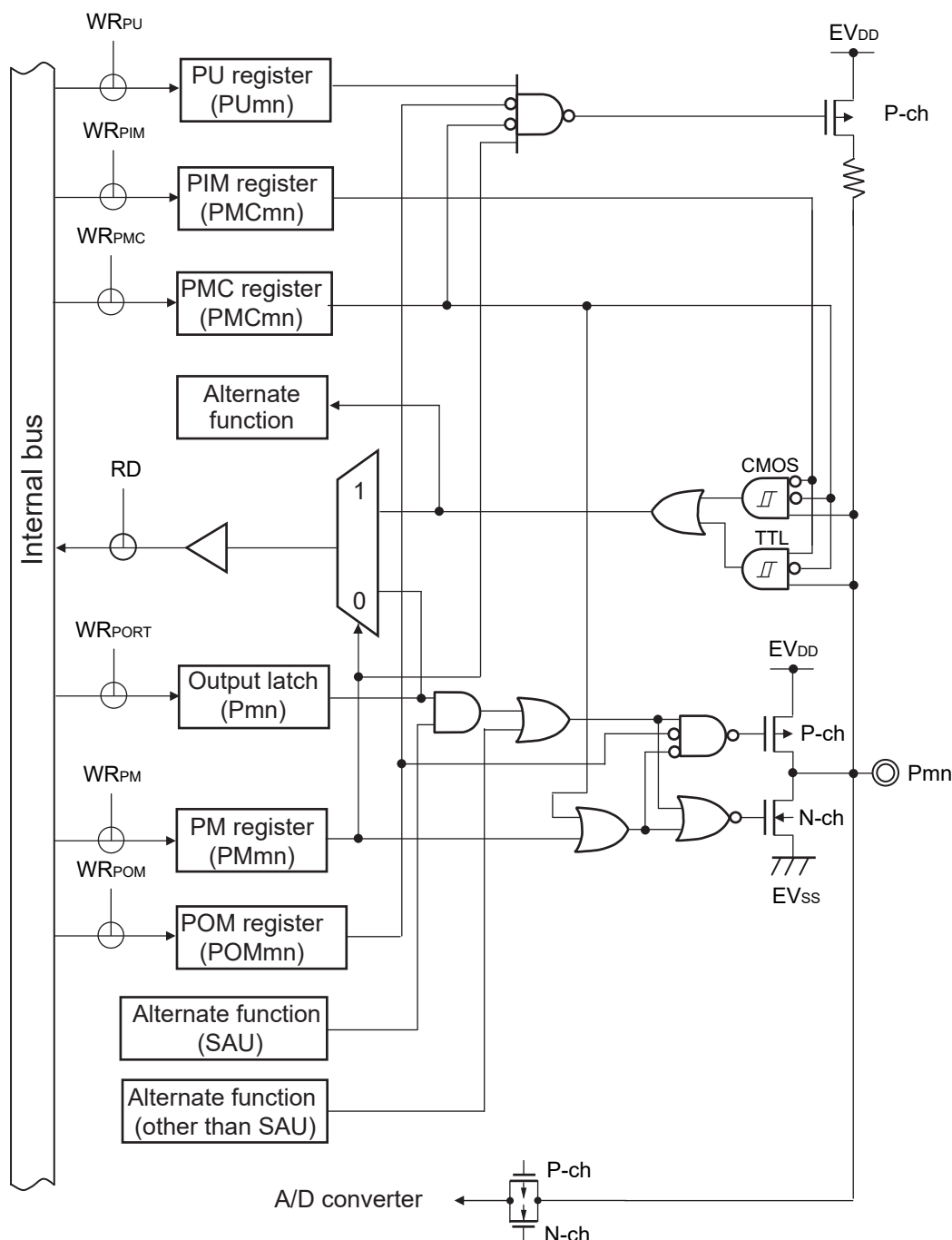
Figure 2-11. Pin Block Diagram for Pin Type 8-1-2



- Cautions**
1. A through current may flow through if the pin is in the intermediate potential, because the input buffer is also turned on when the pin is in N-ch open-drain output mode by port output mode register (POMx).
 2. Because of TTL input buffer structure, if the port input mode register (PIMx) is set in TTL input buffer, a through current may flow through in the case of high level input. It is recommended to input a low level to prevent a through current.

- Remarks**
1. For alternate functions, see 2.1 Port Function.
 2. SAU: Serial array unit

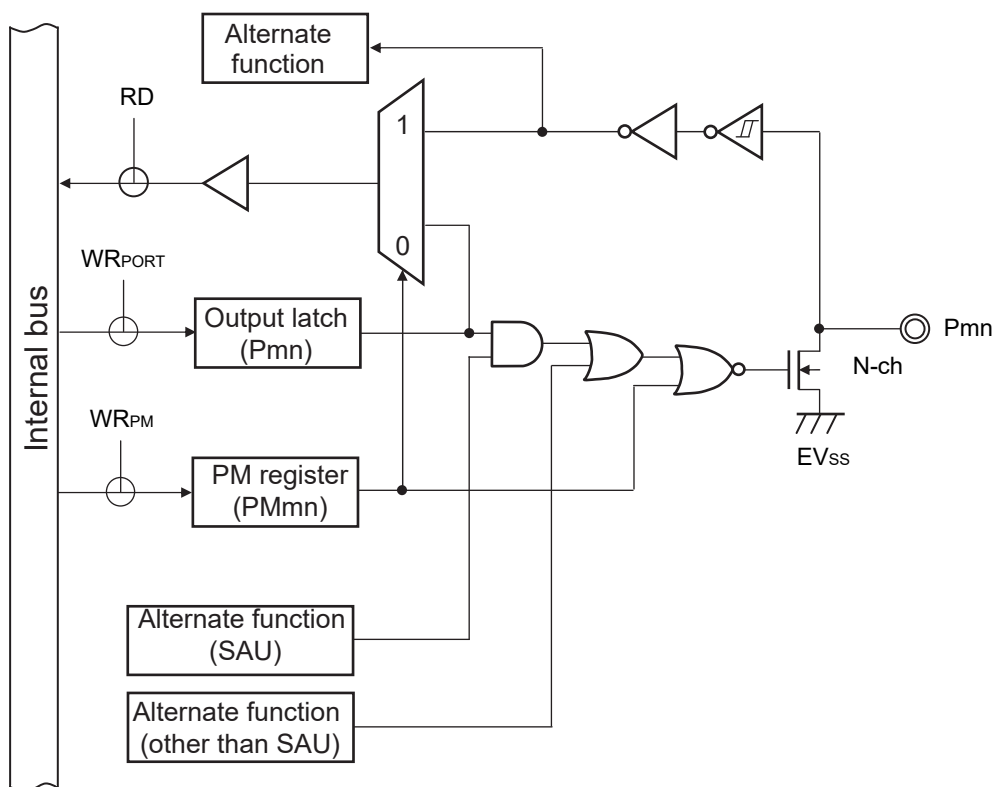
Figure 2-12. Pin Block Diagram for Pin Type 8-3-2



- Cautions**
1. A through current may flow through if the pin is in the intermediate potential, because the input buffer is also turned on when the pin is in N-ch open-drain output mode by port output mode register (POMx).
 2. Because of TTL input buffer structure, if the port input mode register (PIMx) is set in TTL input buffer, a through current may flow through in the case of high level input. It is recommended to input a low level to prevent a through current.

- Remarks**
1. For alternate functions, see **2.1 Port Function**.
 2. SAU: Serial array unit

Figure 2-13. Pin Block Diagram for Pin Type 12-1-1



Caution A through current may flow through if the pin is in the intermediate potential, because the input buffer is turned on when the pin is in output mode.

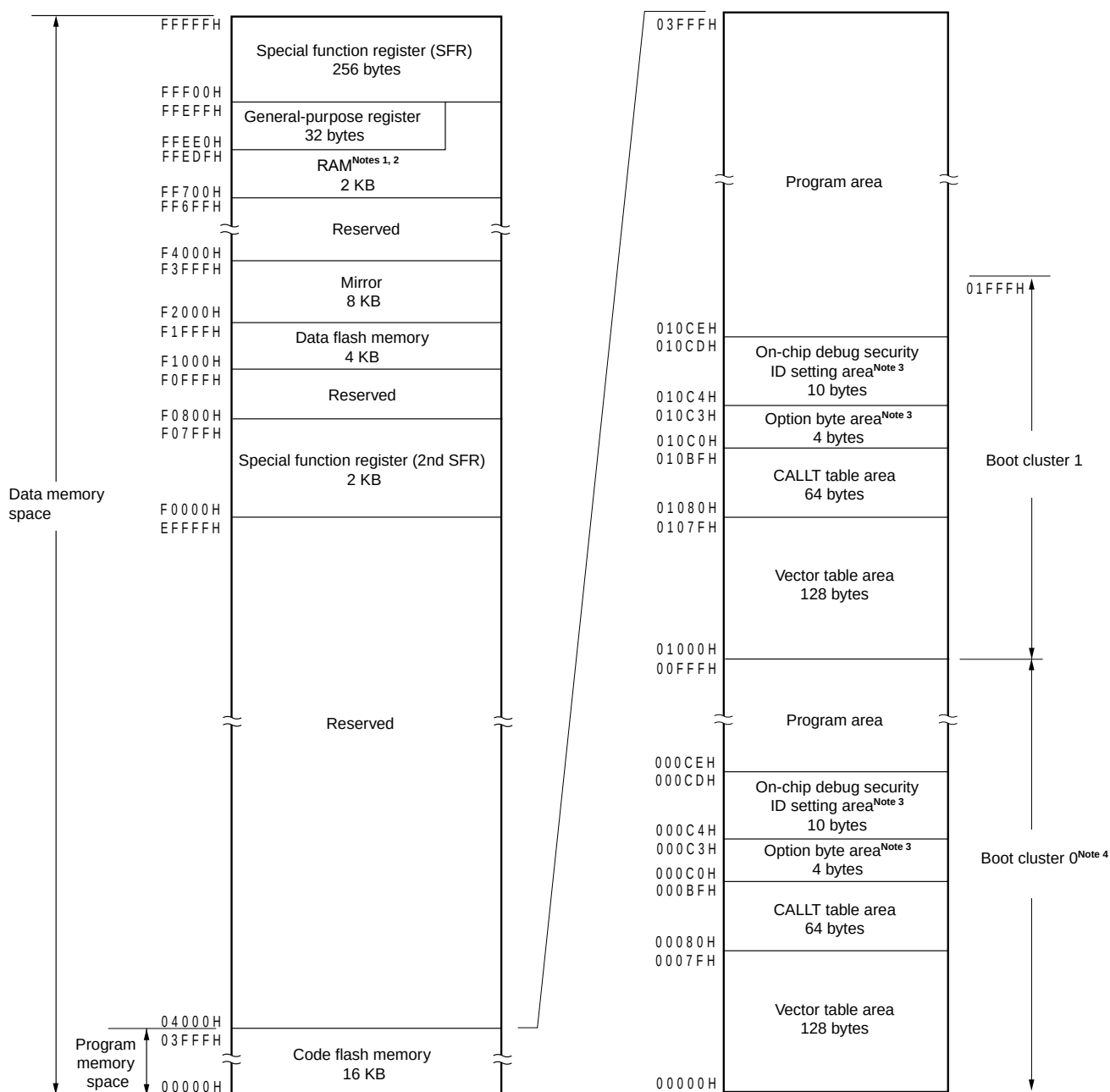
- Remarks**
1. For alternate functions, see 2.1 Port Function.
 2. SAU: Serial array unit

CHAPTER 3 CPU ARCHITECTURE

3.1 Memory Space

Products in the RL78/G1A can access a 1 MB address space. Figures 3-1 to 3-4 show the memory maps.

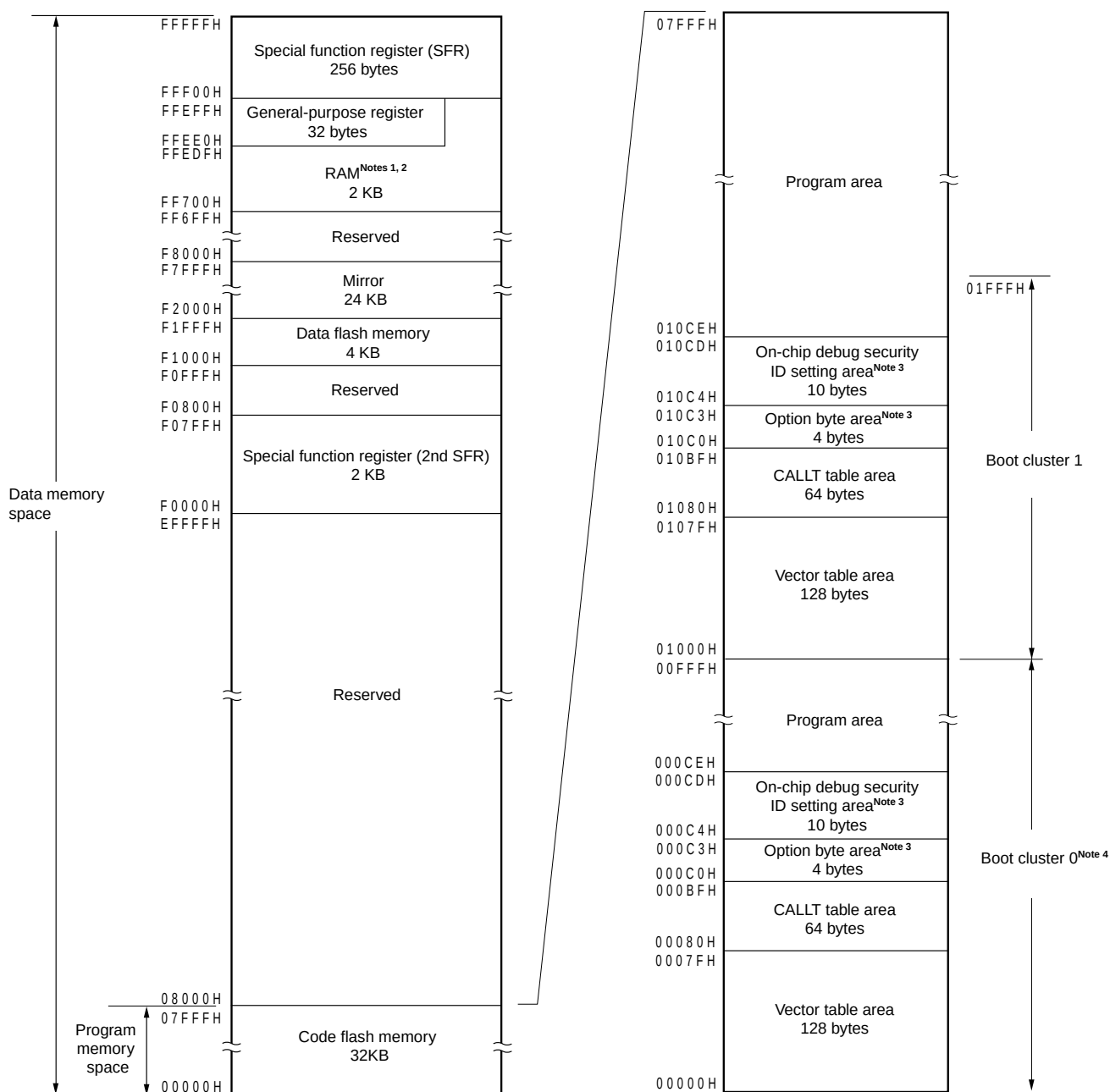
Figure 3-1. Memory Map (R5F10ExA (x = 8, B, G))



- Notes**
1. During self programming and data flash rewriting, the stack, data buffer, and RAM addresses used as branch destinations for vectored interrupts or as sources or destinations of DMA transfers must not be allocated to the area between addresses FFE20H and FFEDFH.
 2. Instructions can be executed from the RAM area excluding the general-purpose register area.
 3. When boot swap is not used: Set the option bytes to 000C0H to 000C3H, and the on-chip debug security IDs to 000C4H to 000CDH.
When boot swap is used: Set the option bytes to 000C0H to 000C3H and 010C0H to 010C3H, and the on-chip debug security IDs to 000C4H to 000CDH and 010C4H to 010CDH.
 4. Writing boot cluster 0 can be prohibited depending on the setting of security (see **25.7 Security Setting**).

Caution While RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize RAM areas where data access is to proceed and the RAM area + 10 bytes when instructions are fetched from RAM areas, respectively. Reset signal generation sets RAM parity error resets to enabled (RPERDIS = 0). For details, see **22.3.3 RAM parity error detection function**.

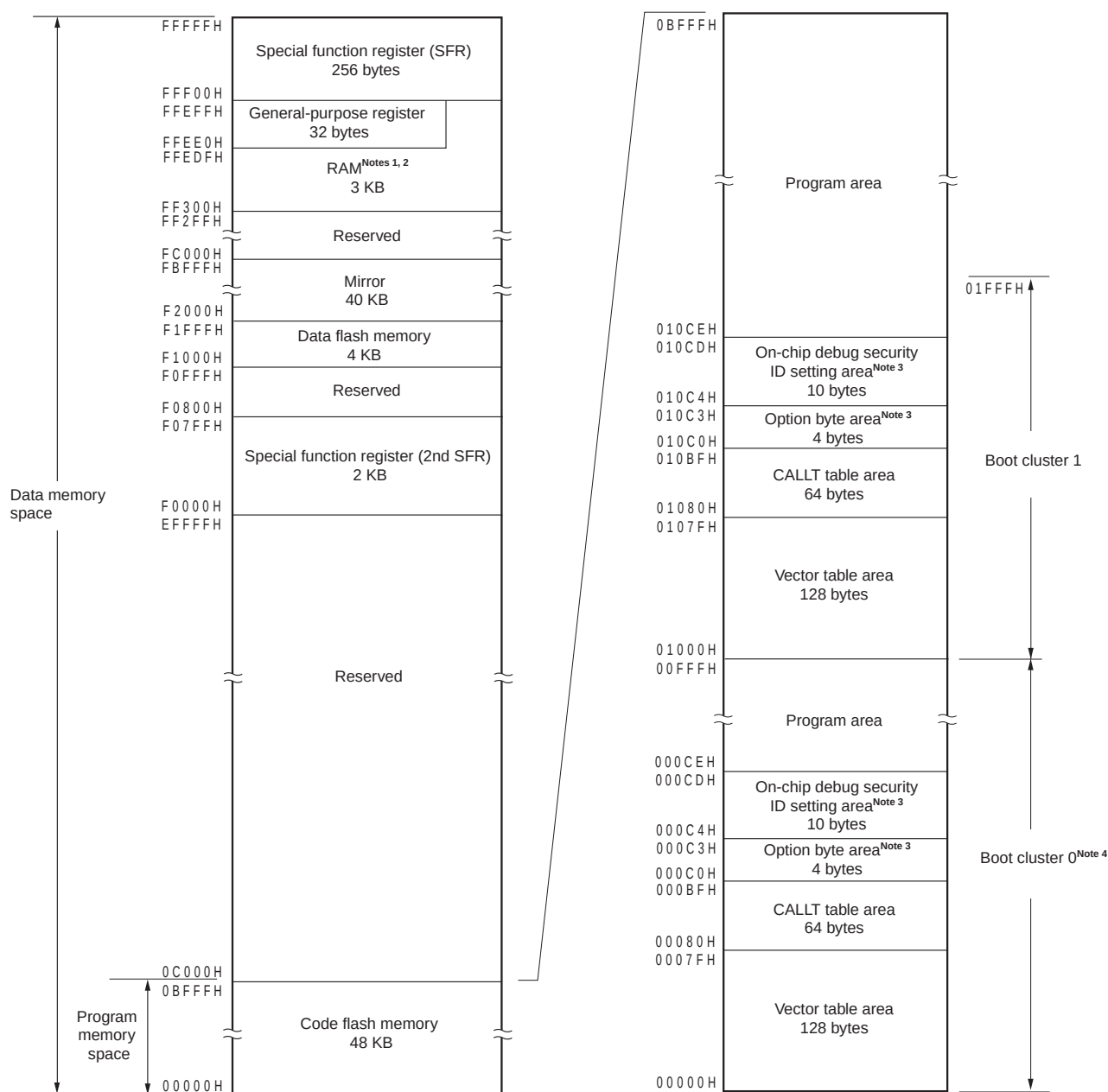
Figure 3-2. Memory Map (R5F10ExC (x = 8, B, G, L))



- Notes**
- During self programming and data flash rewriting, the stack, data buffer, and RAM addresses used as branch destinations for vectored interrupts or as sources or destinations of DMA transfers must not be allocated to the area between addresses FFE20H and FFEDFH.
 - Instructions can be executed from the RAM area excluding the general-purpose register area.
 - When boot swap is not used: Set the option bytes to 000C0H to 000C3H, and the on-chip debug security IDs to 000C4H to 000CDH.
When boot swap is used: Set the option bytes to 000C0H to 000C3H and 010C0H to 010C3H, and the on-chip debug security IDs to 000C4H to 000CDH and 010C4H to 010CDH.
 - Writing boot cluster 0 can be prohibited depending on the setting of security (see **25.7 Security Setting**).

Caution While RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize RAM areas where data access is to proceed and the RAM area + 10 bytes when instructions are fetched from RAM areas, respectively. Reset signal generation sets RAM parity error resets to enabled (RPERDIS = 0). For details, see **22.3.3 RAM parity error detection function**.

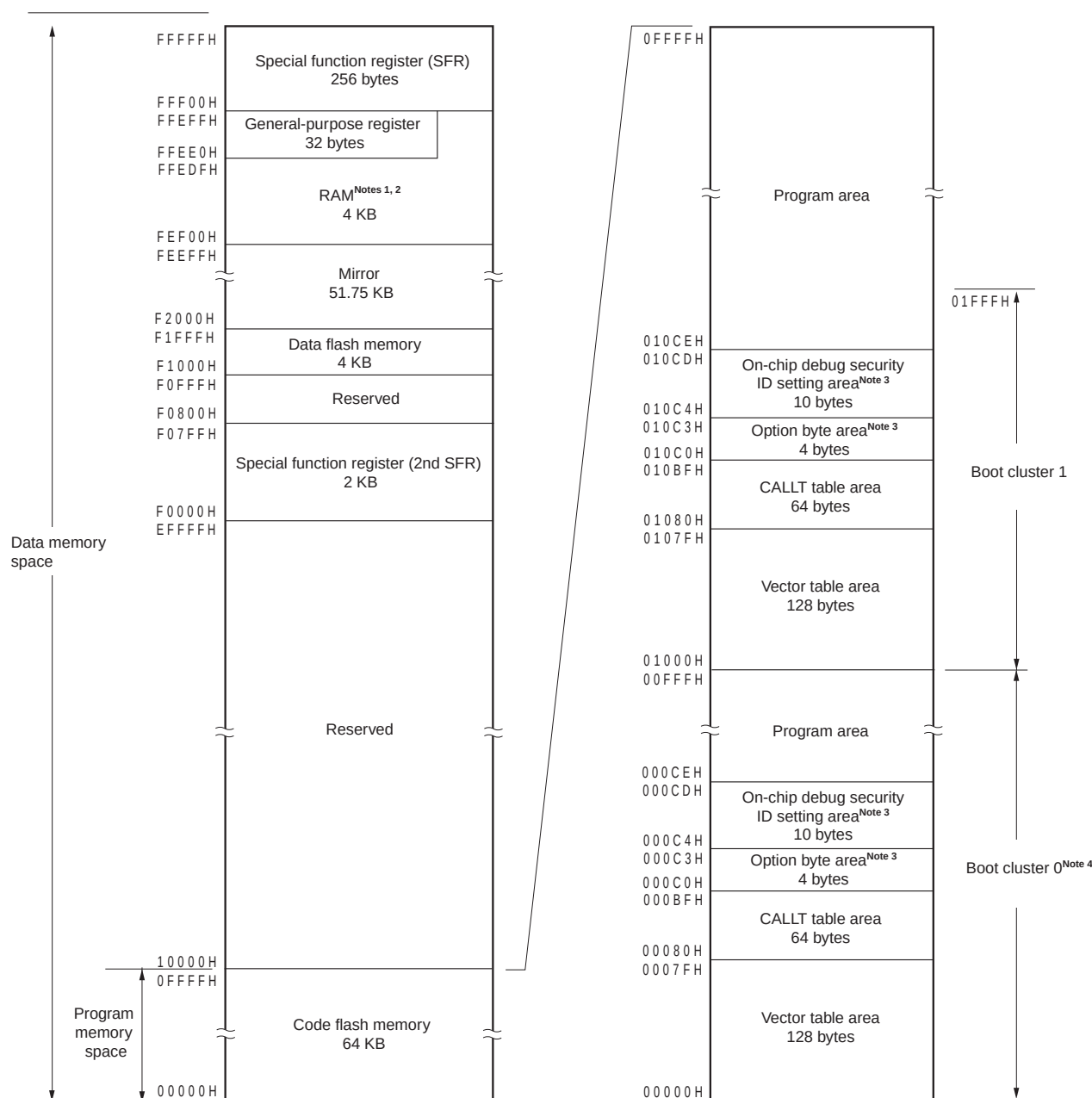
Figure 3-3. Memory Map (R5F10ExD (x = 8, B, G, L))



- Notes**
- During self programming and data flash rewriting, the stack, data buffer, and RAM addresses used as branch destinations for vectored interrupts or as sources or destinations of DMA transfers must not be allocated to the area between addresses FFE20H and FFEDFH. Also, use of the area FF300H to FF309H is prohibited, because this area is used for each library.
 - Instructions can be executed from the RAM area excluding the general-purpose register area.
 - When boot swap is not used: Set the option bytes to 000C0H to 000C3H, and the on-chip debug security IDs to 000C4H to 000CDH.
When boot swap is used: Set the option bytes to 000C0H to 000C3H and 010C0H to 010C3H, and the on-chip debug security IDs to 000C4H to 000CDH and 010C4H to 010CDH.
 - Writing boot cluster 0 can be prohibited depending on the setting of security (see **25.7 Security Setting**).

Caution While RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize RAM areas where data access is to proceed and the RAM area + 10 bytes when instructions are fetched from RAM areas, respectively. Reset signal generation sets RAM parity error resets to enabled (RPERDIS = 0). For details, see **22.3.3 RAM parity error detection function**.

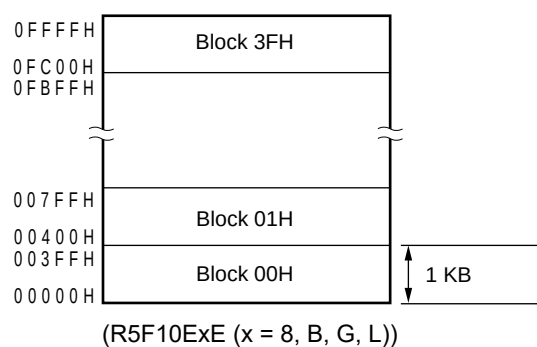
Figure 3-4. Memory Map (R5F10ExE (x = 8, B, G, L))



- Notes**
1. During self programming and data flash rewriting, the stack, data buffer, and RAM addresses used as branch destinations for vectored interrupts or as sources or destinations of DMA transfers must not be allocated to the area between addresses FFE20H and FFE00H. Also, use of the area FEF00H to FF309H is prohibited, because this area is used for each library.
 2. Instructions can be executed from the RAM area excluding the general-purpose register area.
 3. When boot swap is not used: Set the option bytes to 000C0H to 000C3H, and the on-chip debug security IDs to 000C4H to 000CDH.
When boot swap is used: Set the option bytes to 000C0H to 000C3H and 010C0H to 010C3H, and the on-chip debug security IDs to 000C4H to 000CDH and 010C4H to 010CDH.
 4. Writing boot cluster 0 can be prohibited depending on the setting of security (see **25.7 Security Setting**).

Caution While RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize RAM areas where data access is to proceed and the RAM area + 10 bytes when instructions are fetched from RAM areas, respectively. Reset signal generation sets RAM parity error resets to enabled (RPERDIS = 0). For details, see 22.3.3 RAM parity error detection function.

Remark The flash memory is divided into blocks (one block = 1 KB). For the address values and block numbers, see Table 3-1 Correspondence Between Address Values and Block Numbers in Flash Memory.



Correspondence between the address values and block numbers in the flash memory are shown below.

Table 3-1. Correspondence Between Address Values and Block Numbers in Flash Memory

Address Value	Block Number	Address Value	Block Number
00000H to 003FFH	00H	08000H to 083FFH	20H
00400H to 007FFH	01H	08400H to 087FFH	21H
00800H to 00BFFH	02H	08800H to 08BFFH	22H
00C00H to 00FFFH	03H	08C00H to 08FFFH	23H
01000H to 013FFH	04H	09000H to 093FFH	24H
01400H to 017FFH	05H	09400H to 097FFH	25H
01800H to 01BFFH	06H	09800H to 09BFFH	26H
01C00H to 01FFFH	07H	09C00H to 09FFFH	27H
02000H to 023FFH	08H	0A000H to 0A3FFH	28H
02400H to 027FFH	09H	0A400H to 0A7FFH	29H
02800H to 02BFFH	0AH	0A800H to 0ABFFH	2AH
02C00H to 02FFFH	0BH	0AC00H to 0AFFFH	2BH
03000H to 033FFH	0CH	0B000H to 0B3FFH	2CH
03400H to 037FFH	0DH	0B400H to 0B7FFH	2DH
03800H to 03BFFH	0EH	0B800H to 0BBFFH	2EH
03C00H to 03FFFH	0FH	0BC00H to 0BFFFH	2FH
04000H to 043FFH	10H	0C000H to 0C3FFH	30H
04400H to 047FFH	11H	0C400H to 0C7FFH	31H
04800H to 04BFFH	12H	0C800H to 0CBFFH	32H
04C00H to 04FFFH	13H	0CC00H to 0CFFFH	33H
05000H to 053FFH	14H	0D000H to 0D3FFH	34H
05400H to 057FFH	15H	0D400H to 0D7FFH	35H
05800H to 05BFFH	16H	0D800H to 0DBFFH	36H
05C00H to 05FFFH	17H	0DC00H to 0DFFFH	37H
06000H to 063FFH	18H	0E000H to 0E3FFH	38H
06400H to 067FFH	19H	0E400H to 0E7FFH	39H
06800H to 06BFFH	1AH	0E800H to 0EBFFH	3AH
06C00H to 06FFFH	1BH	0EC00H to 0EFFFH	3BH
07000H to 073FFH	1CH	0F000H to 0F3FFH	3CH
07400H to 077FFH	1DH	0F400H to 0F7FFH	3DH
07800H to 07BFFH	1EH	0F800H to 0FBFFH	3EH
07C00H to 07FFFH	1FH	0FC00H to 0FFFFH	3FH

Remark R5F10ExA (x = 8, B, G) : Block numbers 00H to 0FH
R5F10ExC (x = 8, B, G, L) : Block numbers 00H to 1FH
R5F10ExD (x = 8, B, G, L) : Block numbers 00H to 2FH
R5F10ExE (x = 8, B, G, L) : Block numbers 00H to 3FH

3.1.1 Internal program memory space

The internal program memory space stores the program and table data. The RL78/G1A products incorporate internal ROM (flash memory), as shown below.

Table 3-2. Internal ROM Capacity

Part Number	Internal ROM	
	Structure	Capacity
R5F10ExA (x = 8, B, G)	Flash memory	16384 × 8 bits (00000H to 03FFFFH)
R5F10ExC (x = 8, B, G, L)		32768 × 8 bits (00000H to 07FFFFH)
R5F10ExD (x = 8, B, G, L)		49152 × 8 bits (00000H to 0BFFFFH)
R5F10ExE (x = 8, B, G, L)		65536 × 8 bits (00000H to 0FFFFH)

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

(1) Vector table area

The 128-byte area 00000H to 0007FH is reserved as a vector table area. The program start addresses for branch upon reset or generation of each interrupt request are stored in the vector table area. Furthermore, the interrupt jump address is a 64 K address of 00000H to 0FFFFH, because the vector code is assumed to be 2 bytes.

Of the 16-bit address, the lower 8 bits are stored at even addresses and the higher 8 bits are stored at odd addresses. To use the boot swap function, set a vector table also at 01000H to 0107FH.

Table 3-3. Vector Table (1/2)

Vector Table Address	Interrupt Source	64-pin	48-pin	32-pin	25-pin
00000H	RESET, POR, LVD, WDT, TRAP, IAW, RPE	√	√	√	√
00004H	INTWDTI/INTSRO	√	√	√	√
00006H	INTLVI	√	√	√	√
00008H	INTP0	√	√	√	√
0000AH	INTP1	√	√	√	√
0000CH	INTP2	√	√	√	√
0000EH	INTP3	√	√	√	√
00010H	INTP4	√	√	√	√
00012H	INTP5	√	√	—	—
00014H	INTST2/INTCSI20/INTIIC20	√	√	√	—
00016H	INTSR2/INTCSI21/INTIIC21	√	√	Note 1	—
00018H	INTSRE2	√	√	√	—
0001AH	INTDMA0	√	√	√	√
0001CH	INTDMA1	√	√	√	√
0001EH	INTST0/INTCSI00/INTIIC00	√	√	√	√
00020H	INTSR0/INTCSI01/INTIIC01	√	√	Note 2	Note 2
00022H	INTSRE0	√	√	√	√
	INTTM01H	√	√	√	√
00024H	INTST1/INTCSI10/INTIIC10	√	Note 3	Note 3	Note 3
00026H	INTSR1/INTCSI11/INTIIC11	√	√	√	√
00028H	INTSRE1	√	√	√	√
	INTTM03H	√	√	√	√
0002AH	INTIICA0	√	√	√	√
0002CH	INTTM00	√	√	√	√
0002EH	INTTM01	√	√	√	√
00030H	INTTM02	√	√	√	√
00032H	INTTM03	√	√	√	√
00034H	INTAD	√	√	√	√
00036H	INTRTC	√	√	√	√
00038H	INTIT	√	√	√	√
0003AH	INTKR	√	√	√	Note 4

Notes 1. INTSR2 only.

2. INTSR0 only.

3. INTSR1 only.

4. When setting the peripheral I/O redirection register (PIOR).

Table 3-3. Vector Table (2/2)

Vector Table Address	Interrupt Source	64-pin	48-pin	32-pin	25-pin
00042H	INTTM04	√	√	√	√
00044H	INTTM05	√	√	√	√
00046H	INTTM06	√	√	√	√
00048H	INTTM07	√	√	√	√
0004AH	INTP6	√	√	–	–
0004CH	INTP7	√	–	–	–
0004EH	INTP8	√	√	–	–
00050H	INTP9	√	√	–	–
00052H	INTP10	√	–	–	–
00054H	INTP11	√	–	–	–
0005EH	INTMD	√	√	√	√
00062H	INTFL	√	√	√	√
0007EH	BRK	√	√	√	√

(2) CALLT instruction table area

The 64-byte area 00080H to 000BFH can store the subroutine entry address of a 2-byte call instruction (CALLT). Set the subroutine entry address to a value in a range of 00000H to 0FFFFH (because an address code is of 2 bytes).

To use the boot swap function, set a CALLT instruction table also at 01080H to 010BFH.

(3) Option byte area

A 4-byte area of 000C0H to 000C3H can be used as an option byte area. Set the option byte at 010C0H to 010C3H when the boot swap is used. For details, see **CHAPTER 24 OPTION BYTE**.

(4) On-chip debug security ID setting area

A 10-byte area of 000C4H to 000CDH and 010C4H to 010CDH can be used as an on-chip debug security ID setting area. Set the on-chip debug security ID of 10 bytes at 000C4H to 000CDH when the boot swap is not used and at 000C4H to 000CDH and 010C4H to 010CDH when the boot swap is used. For details, see **CHAPTER 26 ON-CHIP DEBUG FUNCTION**.

3.1.2 Mirror area

The RL78/G1A mirrors the code flash area of 00000H to 0FFFFH, to F0000H to FFFFFH. The products with 96 KB or more flash memory mirror the code flash area of 00000H to 0FFFFH or 10000H to 1FFFFH, to F0000H to FFFFFH (the code flash area to be mirrored is set by the processor mode control register (PMC)).

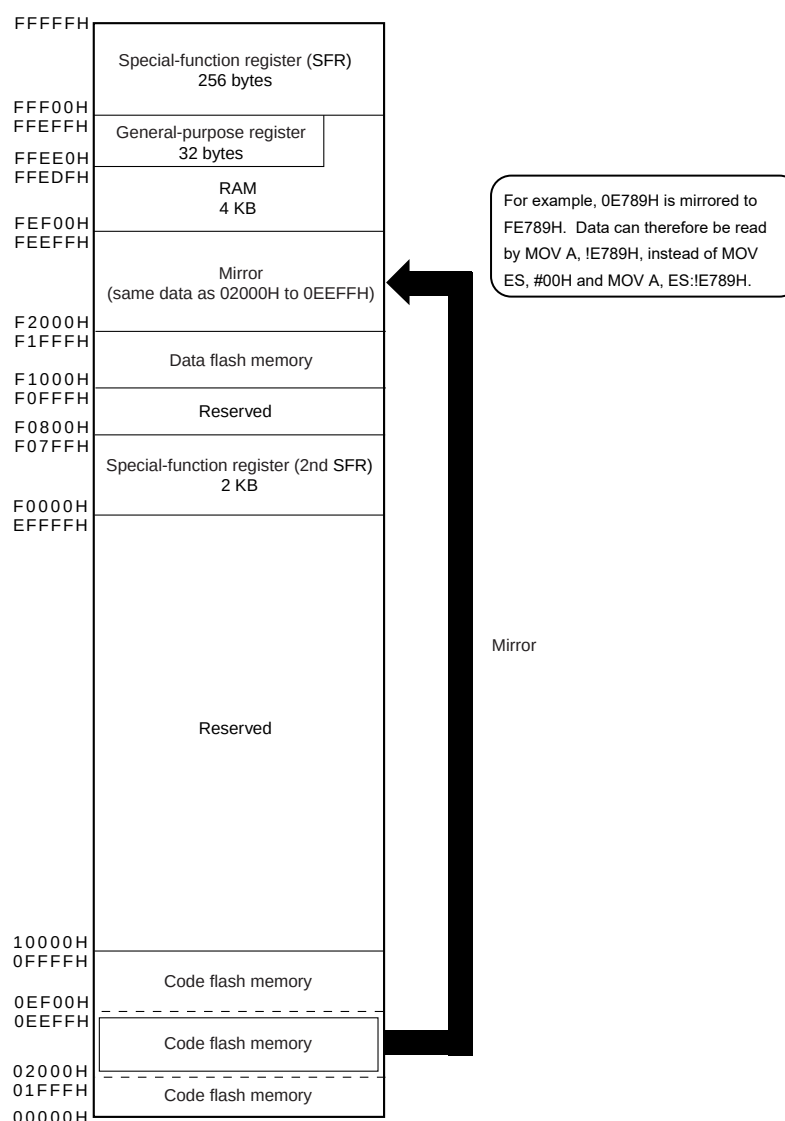
By reading data from F0000H to FFFFFH, an instruction that does not have the ES register as an operand can be used, and thus the contents of the code flash can be read with the shorter code. However, the code flash area is not mirrored to the SFR, extended SFR, RAM, and use prohibited areas.

See **3.1 Memory Space** for the mirror area of each product.

The mirror area can only be read and no instruction can be fetched from this area.

The following show examples.

Example R5F10ExE (x = 8, B, G, L) (Flash memory: 64 KB, RAM: 4 KB)



The PMC register is described below.

- **Processor mode control register (PMC)**

This register sets the flash memory space for mirroring to area from F0000H to FFFFFH.

The PMC register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 3-5. Format of Processor Mode Control Register (PMC)

Address: FFFFEH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	<0>
PMC	0	0	0	0	0	0	0	MAA

MAA	Selection of flash memory space for mirroring to area from F0000H to FFFFFH
0	00000H to 0FFFFH is mirrored to F0000H to FFFFFH
1	Setting is prohibited

- Cautions**
1. Be sure to clear bit 0 (MAA) of this register to 0 (default value).
 2. After setting the PMC register, wait for at least one instruction and access the mirror area.

3.1.3 Internal data memory space

The RL78/G1A products incorporate the following RAMs.

Table 3-4. Internal RAM Capacity

Part Number	Internal RAM
R5F10ExA (x = 8, B, G)	2048 × 8 bits (FF700H to FFEFFH)
R5F10ExC (x = 8, B, G, L)	
R5F10ExD (x = 8, B, G, L)	3072 × 8 bits (FF300H to FFEFFH)
R5F10ExE (x = 8, B, G, L)	4096 × 8 bits (FEF00H to FFEFFH)

The internal RAM can be used as a data area and a program area where instructions are fetched (it is prohibited to use the general-purpose register area for fetching instructions). Four general-purpose register banks consisting of eight 8-bit registers per bank are assigned to the 32-byte area of FFEE0H to FFEFFH of the internal RAM area.

The internal RAM is used as stack memory.

- Cautions**
1. It is prohibited to use the general-purpose register (FFEE0H to FFEFFH) space for fetching instructions or as a stack area.
 2. During self programming and data flash rewriting, the stack, data buffer, and RAM addresses used as branch destinations for vectored interrupts or as sources or destinations of DMA transfers must not be allocated to the area between addresses FFE20H and FFEDFH.
 3. During self programming and data flash rewriting, the RAM area in the products below is prohibited. Because this area is used for each library.

R5F10ExD (x = 8, B, G, L): FF300H to FF309H

R5F10ExE (x = 8, B, G, L): FEF00H to FF309H

3.1.4 Special function register (SFR) area

On-chip peripheral hardware special function registers (SFRs) are allocated in the area FFF00H to FFFFFH (see **Table 3-5** in **3.2.4 Special function registers (SFRs)**).

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

3.1.5 Extended special function register (2nd SFR: 2nd Special Function Register) area

On-chip peripheral hardware special function registers (2nd SFRs) are allocated in the area F0000H to F07FFH (see **Table 3-6** in **3.2.5 Extended Special function registers (2nd SFRs: 2nd Special Function Registers)**).

SFRs other than those in the SFR area (FFF00H to FFFFFH) are allocated to this area. An instruction that accesses the extended SFR area, however, is 1 byte longer than an instruction that accesses the SFR area.

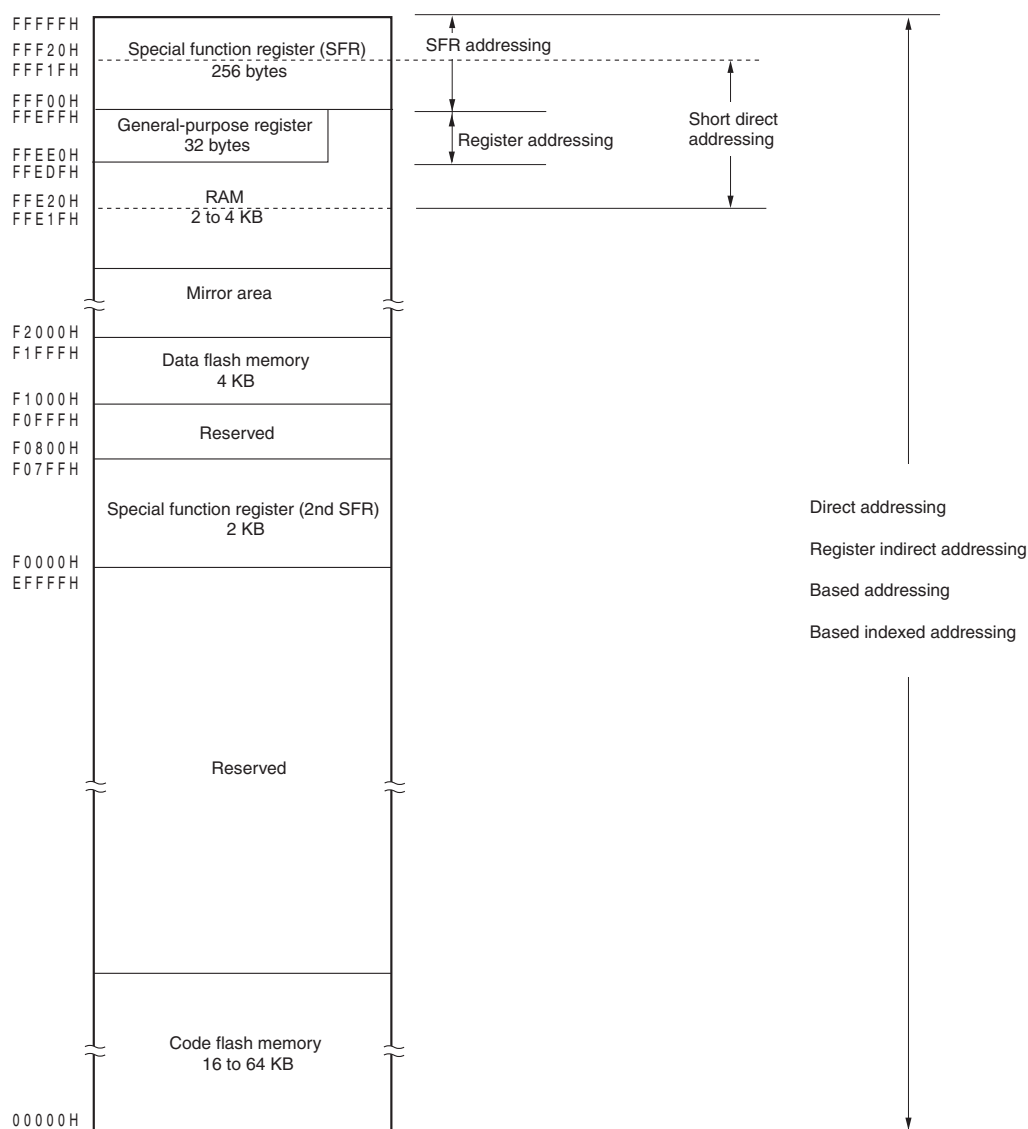
Caution Do not access addresses to which extended SFRs are not assigned.

3.1.6 Data memory addressing

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

Several addressing modes are provided for addressing the memory relevant to the execution of instructions for the RL78/G1A, based on operability and other considerations. In particular, special addressing methods designed for the functions of the special function registers (SFR) and general-purpose registers are available for use. Figure 3-6 shows correspondence between data memory and addressing. For details of each addressing, see **3.4 Addressing for Processing Data Addresses**.

Figure 3-6. Correspondence Between Data Memory and Addressing



3.2 Processor Registers

The RL78/G1A products incorporate the following processor registers.

3.2.1 Control registers

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

(1) Program counter (PC)

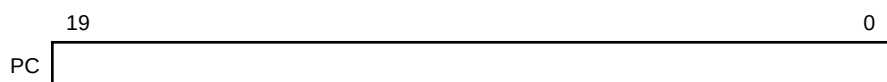
The program counter is a 20-bit register that holds the address information of the next program to be executed.

In normal operation, PC is automatically incremented according to the number of bytes of the instruction to be fetched.

When a branch instruction is executed, immediate data and register contents are set.

Reset signal generation sets the reset vector table values at addresses 00000H and 00001H to the 16 lower-order bits of the program counter. The four higher-order bits of the program counter are cleared to 0000.

Figure 3-7. Format of Program Counter

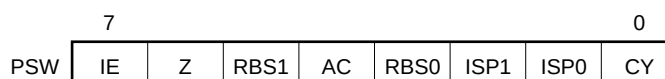


(2) Program status word (PSW)

The program status word is an 8-bit register consisting of various flags set/reset by instruction execution.

Program status word contents are stored in the stack area upon vectored interrupt request is acknowledged or PUSH PSW instruction execution and are restored upon execution of the RETB, RETI and POP PSW instructions. Reset signal generation sets the PSW register to 06H.

Figure 3-8. Format of Program Status Word



(a) Interrupt enable flag (IE)

This flag controls the interrupt request acknowledge operations of the CPU.

When 0, the IE flag is set to the interrupt disabled (DI) state, and all maskable interrupt requests are disabled.

When 1, the IE flag is set to the interrupt enabled (EI) state and maskable interrupt request acknowledgment is controlled with an in-service priority flag (ISP1, ISP0), an interrupt mask flag for various interrupt sources, and a priority specification flag.

The IE flag is reset (0) upon DI instruction execution or interrupt acknowledgment and is set (1) upon EI instruction execution.

(b) Zero flag (Z)

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

(c) Register bank select flags (RBS0, RBS1)

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

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

(d) Auxiliary carry flag (AC)

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

(e) In-service priority flags (ISP1, ISP0)

This flag manages the priority of acknowledgeable maskable vectored interrupts. Vectored interrupt requests specified lower than the value of ISP0 and ISP1 flags by the priority specification flag registers (PRn0L, PRn0H, PRn1L, PRn1H, PRn2L, PRn2H) (see **16.3.3**) can not be acknowledged. Actual vectored interrupt request acknowledgment is controlled by the interrupt enable flag (IE).

Remark n = 0, 1

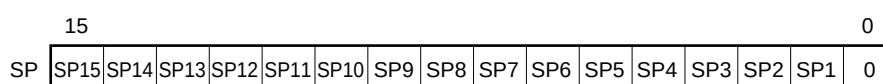
(f) Carry flag (CY)

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

(3) Stack pointer (SP)

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

Figure 3-9. Format of Stack Pointer



In stack addressing through a stack pointer, the SP is decremented ahead of write (save) to the stack memory and is incremented after read (restore) from the stack memory.

- Cautions**
1. Since reset signal generation makes the SP contents undefined, be sure to initialize the SP before using the stack.
 2. It is prohibited to use the general-purpose register (FFEE0H to FFEFFH) space for fetching instruction or a stack area.
 3. Do not allocate RAM addresses which are used as a stack area, a data buffer, a branch destination of vector interrupt processing, and a DMA transfer destination/transfer source to the area FFE20H to FFEDFH when performing self-programming and rewriting the data flash memory.
 4. Use of the RAM areas of the following products is prohibited when performing self-programming and rewriting the data flash memory, because these areas are used for each library.

R5F10ExA (x = 8, B, G): FFE20H to FFEDFH

R5F10ExC (x = 8, B, G, L): FFE20H to FFEDFH

R5F10ExD (x = 8, B, G, L): FFE20H to FFEDFH, FF300H to FF309H

R5F10ExE (x = 8, B, G, L): FFE20H to FFEDFH, FEF00H to FF309H

3.2.2 General-purpose registers

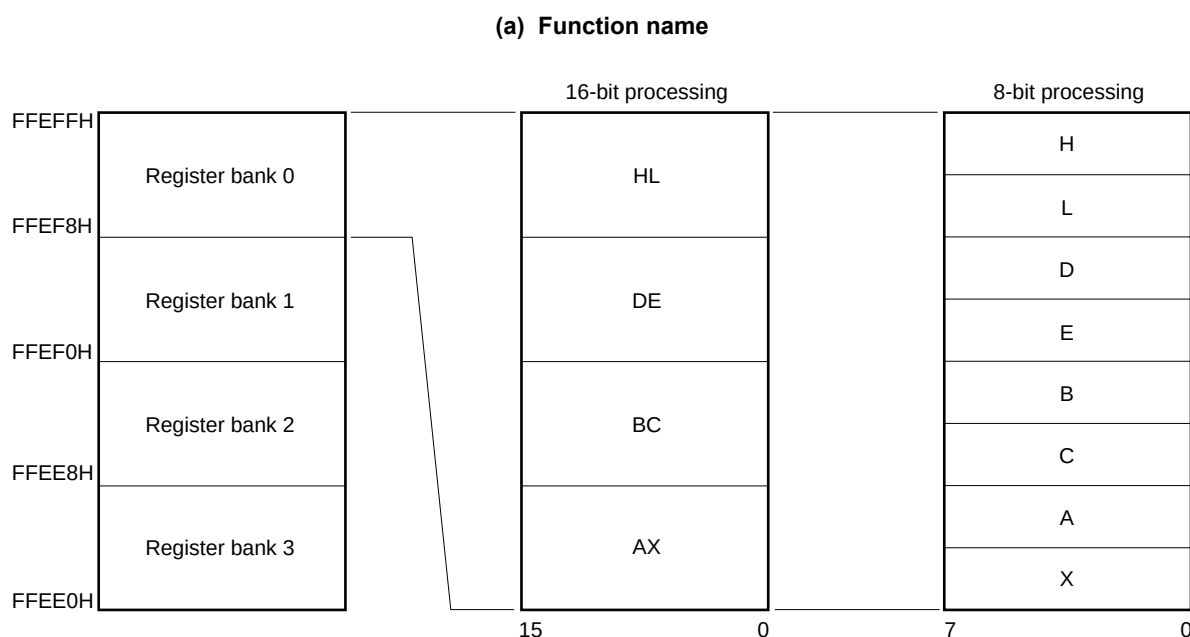
General-purpose registers are mapped at particular addresses (FFEE0H to FFEFFH) of the data memory. The general-purpose registers consists of 4 banks, each bank consisting of eight 8-bit registers (X, A, C, B, E, D, L, and H).

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

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

Caution It is prohibited to use the general-purpose register (FFEE0H to FFEFFH) space for fetching instructions or as a stack area.

Figure 3-10. Configuration of General-Purpose Registers



3.2.3 ES and CS registers

The ES register and CS register are used to specify the higher address for data access and when a branch instruction is executed (register direct addressing), respectively.

The default value of the ES register after reset is 0FH, and that of the CS register is 00H.

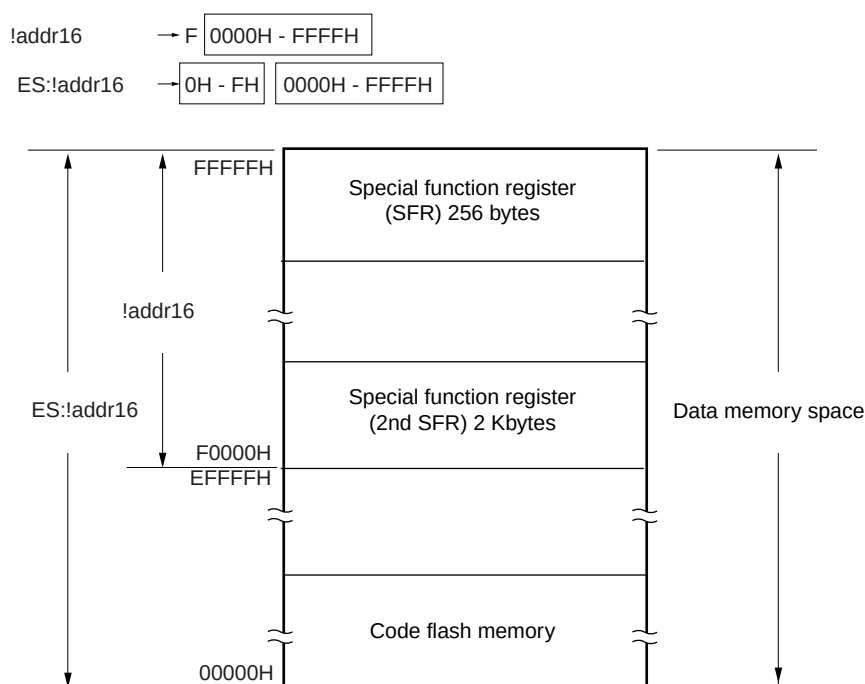
Figure 3-11. Configuration of ES and CS Registers

	7	6	5	4	3	2	1	0
ES	0	0	0	0	ES3	ES2	ES1	ES0

	7	6	5	4	3	2	1	0
CS	0	0	0	0	CS3	CS2	CS1	CS0

Though the data area which can be accessed with 16-bit addresses is the 64 KB from F0000H to FFFFFH, using the ES register as well extends this to the 1 MB from 00000H to FFFFFH.

Figure 3-12. Extension of Data Area Which Can Be Accessed



3.2.4 Special function registers (SFRs)

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

SFRs are allocated to the FFF00H to FFFFFH area.

SFRs can be manipulated like general-purpose registers, using operation, transfer, and bit manipulation instructions. The manipulable bit units, 1, 8, and 16, depend on the SFR type.

Each manipulation bit unit can be specified as follows.

- 1-bit manipulation

Describe as follows for the 1-bit manipulation instruction operand (sfr.bit).

When the bit name is defined: <Bit name>

When the bit name is not defined: <Register name>.<Bit number> or <Address>.<Bit number>

- 8-bit manipulation

Describe the symbol defined by the assembler for the 8-bit manipulation instruction operand (sfr). This manipulation can also be specified with an address.

- 16-bit manipulation

Describe the symbol defined by the assembler for the 16-bit manipulation instruction operand (sfrp). When specifying an address, describe an even address.

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

- Symbol

Symbol indicating the address of a special function register. It is a reserved word in the assembler, and is defined as an sfr variable using the #pragma sfr directive in the compiler. When using the assembler, debugger, and simulator, symbols can be written as an instruction operand.

- R/W

Indicates whether the corresponding SFR can be read or written.

R/W: Read/write enable

R: Read only

W: Write only

- Manipulable bit units

“√” indicates the manipulable bit unit (1, 8, or 16). “—” indicates a bit unit for which manipulation is not possible.

- After reset

Indicates each register status upon reset signal generation.

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

Remark For extended SFRs (2nd SFRs), see 3.2.5 Extended special function registers (2nd SFRs: 2nd Special Function Registers).

Table 3-5. SFR List (1/5)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
FFF00H	Port register 0	P0	R/W	√	√	–	00H
FFF01H	Port register 1	P1	R/W	√	√	–	00H
FFF02H	Port register 2	P2	R/W	√	√	–	00H
FFF03H	Port register 3	P3	R/W	√	√	–	00H
FFF04H	Port register 4	P4	R/W	√	√	–	00H
FFF05H	Port register 5	P5	R/W	√	√	–	00H
FFF06H	Port register 6	P6	R/W	√	√	–	00H
FFF07H	Port register 7	P7	R/W	√	√	–	00H
FFF0CH	Port register 12	P12	R/W	√	√	–	Undefined
FFF0DH	Port register 13	P13	R/W	√	√	–	Undefined
FFF0EH	Port register 14	P14	R/W	√	√	–	00H
FFF0FH	Port register 15	P15	R/W	√	√	–	00H
FFF10H	Serial data register 00	TXD0/ SIO00	R/W	–	√	√	0000H
FFF11H		–		–	–	–	
FFF12H	Serial data register 01	RXD0/ SIO01	R/W	–	√	√	0000H
FFF13H		–		–	–	–	
FFF18H	Timer data register 00	TDR00	R/W	–	–	√	0000H
FFF19H				–	–	–	
FFF1AH	Timer data register 01	TDR01L	R/W	–	√	√	00H
FFF1BH		TDR01H		–	√	–	00H
FFF1EH	12-bit A/D conversion result register	ADCR	R	–	–	√	0000H
FFF1FH	8-bit A/D conversion result register	ADCRH	R	–	√	–	00H
FFF20H	Port mode register 0	PM0	R/W	√	√	–	FFH
FFF21H	Port mode register 1	PM1	R/W	√	√	–	FFH
FFF22H	Port mode register 2	PM2	R/W	√	√	–	FFH
FFF23H	Port mode register 3	PM3	R/W	√	√	–	FFH
FFF24H	Port mode register 4	PM4	R/W	√	√	–	FFH
FFF25H	Port mode register 5	PM5	R/W	√	√	–	FFH
FFF26H	Port mode register 6	PM6	R/W	√	√	–	FFH
FFF27H	Port mode register 7	PM7	R/W	√	√	–	FFH
FFF2CH	Port mode register 12	PM12	R/W	√	√	–	FFH
FFF2EH	Port mode register 14	PM14	R/W	√	√	–	FFH
FFF2FH	Port mode register 15	PM15	R/W	√	√	–	FFH
FFF30H	A/D converter mode register 0	ADM0	R/W	√	√	–	00H
FFF31H	Analog input channel specification register	ADS	R/W	√	√	–	00H
FFF32H	A/D converter mode register 1	ADM1	R/W	√	√	–	00H

Table 3-5. SFR List (2/5)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
FFF34H	Key return control register	KRCTL	R/W	√	√	–	00H
FFF35H	Key return flag register	KRF	R/W	√	√	–	00H
FFF36H	Key return mode control register 1	KRM1	R/W	√	√	–	00H
FFF37H	Key return mode control register 0	KRM0	R/W	√	√	–	00H
FFF38H	External interrupt rising edge enable register 0	EGP0	R/W	√	√	–	00H
FFF39H	External interrupt falling edge enable register 0	EGN0	R/W	√	√	–	00H
FFF3AH	External interrupt rising edge enable register 1	EGP1	R/W	√	√	–	00H
FFF3BH	External interrupt falling edge enable register 1	EGN1	R/W	√	√	–	00H
FFF44H	Serial data register 02	TXD1/ SIO10	SDR02	R/W	–	√	0000H
FFF45H		–			–	–	
FFF46H	Serial data register 03	RXD1/ SIO11	SDR03	R/W	–	√	0000H
FFF47H		–			–	–	
FFF48H	Serial data register 10	TXD2/ SIO20	SDR10	R/W	–	√	0000H
FFF49H		–			–	–	
FFF4AH	Serial data register 11	RXD2/ SIO21	SDR11	R/W	–	√	0000H
FFF4BH		–			–	–	
FFF50H	IICA shift register 0	IICA0	R/W	–	√	–	00H
FFF51H	IICA status register 0	IICS0	R	√	√	–	00H
FFF52H	IICA flag register 0	IICF0	R/W	√	√	–	00H
FFF64H	Timer data register 02	TDR02	R/W	–	–	√	0000H
FFF65H				–	–	–	
FFF66H	Timer data register 03	TDR03L	TDR03	R/W	–	√	00H
FFF67H		TDR03H			–	√	00H
FFF68H	Timer data register 04	TDR04	R/W	–	–	√	0000H
FFF69H				–	–	–	
FFF6AH	Timer data register 05	TDR05	R/W	–	–	√	0000H
FFF6BH				–	–	–	
FFF6CH	Timer data register 06	TDR06	R/W	–	–	√	0000H
FFF6DH				–	–	–	
FFF6EH	Timer data register 07	TDR07	R/W	–	–	√	0000H
FFF6FH				–	–	–	

Table 3-5. SFR List (3/5)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
FFF90H	Interval timer control register	ITMC	R/W	–	–	√	0FFFH
FFF91H							
FFF92H	Second count register	SEC	R/W	–	√	–	00H
FFF93H	Minute count register	MIN	R/W	–	√	–	00H
FFF94H	Hour count register	HOURL	R/W	–	√	–	12H ^{Note}
FFF95H	Week count register	WEEK	R/W	–	√	–	00H
FFF96H	Day count register	DAY	R/W	–	√	–	01H
FFF97H	Month count register	MONTH	R/W	–	√	–	01H
FFF98H	Year count register	YEAR	R/W	–	√	–	00H
FFF99H	Watch error correction register	SUBCUD	R/W	–	√	–	00H
FFF9AH	Alarm minute register	ALARMWWM	R/W	–	√	–	00H
FFF9BH	Alarm hour register	ALARMWH	R/W	–	√	–	12H
FFF9CH	Alarm week register	ALARMWW	R/W	–	√	–	00H
FFF9DH	Real-time clock control register 0	RTCC0	R/W	√	√	–	00H
FFF9EH	Real-time clock control register 1	RTCC1	R/W	√	√	–	00H
FFFA0H	Clock operation mode control register	CMC	R/W	–	√	–	00H
FFFA1H	Clock operation status control register	CSC	R/W	√	√	–	C0H
FFFA2H	Oscillation stabilization time counter status register	OSTC	R	√	√	–	00H
FFFA3H	Oscillation stabilization time select register	OSTS	R/W	–	√	–	07H
FFFA4H	System clock control register	CKC	R/W	√	√	–	00H
FFFA5H	Clock output select register 0	CKS0	R/W	√	√	–	00H
FFFA6H	Clock output select register 1	CKS1	R/W	√	√	–	00H

Note The value of this register is 00H if the AMPM bit (bit 3 of real-time clock control register 0 (RTCC0)) is set to 1 after reset.

Table 3-5. SFR List (4/5)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
FFFA8H	Reset control flag register	RESF	R	–	√	–	Undefined ^{Note 1}
FFFA9H	Voltage detection register	LVIM	R/W	√	√	–	00H ^{Note 1}
FFFAAH	Voltage detection level register	LVIS	R/W	√	√	–	00H/01H/81H ^{Note 1}
FFFABH	Watchdog timer enable register	WDTE	R/W	–	√	–	1AH/9AH ^{Note 2}
FFFACH	CRC input register	CRCIN	R/W	–	√	–	00H
FFFB0H	DMA SFR address register 0	DSA0	R/W	–	√	–	00H
FFFB1H	DMA SFR address register 1	DSA1	R/W	–	√	–	00H
FFFB2H	DMA RAM address register 0	DRA0L	DRA0	R/W	–	√	00H
FFFB3H		DRA0H		R/W	–	√	00H
FFFB4H	DMA RAM address register 1	DRA1L	DRA1	R/W	–	√	00H
FFFB5H		DRA1H		R/W	–	√	00H
FFFB6H	DMA byte count register 0	DBC0L	DBC0	R/W	–	√	00H
FFFB7H		DBC0H		R/W	–	√	00H
FFFB8H	DMA byte count register 1	DBC1L	DBC1	R/W	–	√	00H
FFFB9H		DBC1H		R/W	–	√	00H
FFFBAH	DMA mode control register 0	DMC0	R/W	√	√	–	00H
FFFB BH	DMA mode control register 1	DMC1	R/W	√	√	–	00H
FFFBCH	DMA operation control register 0	DRC0	R/W	√	√	–	00H
FFFB DH	DMA operation control register 1	DRC1	R/W	√	√	–	00H

Notes 1. The reset values of the registers vary depending on the reset source as shown below.

Reset Source Register		RESET Input	Reset by POR	Reset by Execution of Illegal Instruction	Reset by WDT	Reset by RAM parity error	Reset by illegal- memory access	Reset by LVD
RESF	TRAP	Cleared (0)		Set (1)	Held			Held
	WDTRF			Held	Set (1)	Held		
	RPERF			Held		Set (1)	Held	
	IAWRF			Held			Set (1)	
	LVIRF			Held				
				Held				Set (1)
LVIM	LVISEN	Cleared (0)						Held
	LVIOMSK	Held						
	LVIF							
LVIS		Cleared (00H/01H/81H)						

2. The reset value of the WDTE register is determined by the setting of the option byte.

Table 3-5. SFR List (5/5)

Address	Special Function Register (SFR) Name	Symbol		R/W	Manipulable Bit Range			After Reset
					1-bit	8-bit	16-bit	
FFFD0H	Interrupt request flag register 2	IF2L	IF2	R/W	√	√	√	00H
FFFD1H		IF2H		R/W	√	√		00H
FFFD4H	Interrupt mask flag register 2	MK2L	MK2	R/W	√	√	√	FFH
FFFD5H		MK2H		R/W	√	√		FFH
FFFD8H	Priority specification flag register 02	PR02L	PR02	R/W	√	√	√	FFH
FFFD9H		PR02H		R/W	√	√		FFH
FFFDCH	Priority specification flag register 12	PR12L	PR12	R/W	√	√	√	FFH
FFDDH		PR12H		R/W	√	√		FFH
FFFE0H	Interrupt request flag register 0	IF0L	IF0	R/W	√	√	√	00H
FFFE1H		IF0H		R/W	√	√		00H
FFFE2H	Interrupt request flag register 1	IF1L	IF1	R/W	√	√	√	00H
FFFE3H		IF1H		R/W	√	√		00H
FFFE4H	Interrupt mask flag register 0	MK0L	MK0	R/W	√	√	√	FFH
FFFE5H		MK0H		R/W	√	√		FFH
FFFE6H	Interrupt mask flag register 1	MK1L	MK1	R/W	√	√	√	FFH
FFFE7H		MK1H		R/W	√	√		FFH
FFFE8H	Priority specification flag register 00	PR00L	PR00	R/W	√	√	√	FFH
FFFE9H		PR00H		R/W	√	√		FFH
FFFEAH	Priority specification flag register 01	PR01L	PR01	R/W	√	√	√	FFH
FFFEBH		PR01H		R/W	√	√		FFH
FFFECH	Priority specification flag register 10	PR10L	PR10	R/W	√	√	√	FFH
FF FEDH		PR10H		R/W	√	√		FFH
FFFEEH	Priority specification flag register 11	PR11L	PR11	R/W	√	√	√	FFH
FFFEFH		PR11H		R/W	√	√		FFH
FFFF0H	Multiplication/division data register A (L)	MDAL		R/W	–	–	√	0000H
FFFF1H								
FFFF2H	Multiplication/division data register A (H)	MDAH		R/W	–	–	√	0000H
FFFF3H								
FFFF4H	Multiplication/division data register B (H)	MDBH		R/W	–	–	√	0000H
FFFF5H								
FFFF6H	Multiplication/division data register B (L)	MDBL		R/W	–	–	√	0000H
FFFF7H								
FFFEH	Processor mode control register	PMC		R/W	√	√	–	00H

Remark For extended SFRs (2nd SFRs), see Table 3-6 Extended SFR (2nd SFR) List.

3.2.5 Extended special function registers (2nd SFRs)

Unlike a general-purpose register, each extended SFR (2nd SFR) has a special function.

Extended SFRs are allocated to the F0000H to F07FFH area. SFRs other than those in the SFR area (FFF00H to FFFFFH) are allocated to this area. An instruction that accesses the extended SFR area, however, is 1 byte longer than an instruction that accesses the SFR area.

Extended SFRs can be manipulated like general-purpose registers, using operation, transfer, and bit manipulation instructions. The manipulable bit units, 1, 8, and 16, depend on the SFR type.

Each manipulation bit unit can be specified as follows.

- 1-bit manipulation
Describe as follows for the 1-bit manipulation instruction operand (!addr16.bit)
When the bit name is defined: <Bit name>
When the bit name is not defined: <Register name>.<Bit number> or <Address>.<Bit number>
- 8-bit manipulation
Describe the symbol defined by the assembler for the 8-bit manipulation instruction operand (!addr16). This manipulation can also be specified with an address.
- 16-bit manipulation
Describe the symbol defined by the assembler for the 16-bit manipulation instruction operand (!addr16). When specifying an address, describe an even address.

Table 3-6 gives a list of the extended SFRs. The meanings of items in the table are as follows.

- Symbol
Symbol indicating the address of an extended SFR. It is a reserved word in the assembler, and is defined as an sfr variable using the #pragma sfr directive in the compiler. When using the assembler, debugger, and simulator, symbols can be written as an instruction operand.
- R/W
Indicates whether the corresponding extended SFR can be read or written.
R/W: Read/write enable
R: Read only
W: Write only
- Manipulable bit units
“√” indicates the manipulable bit unit (1, 8, or 16). “—” indicates a bit unit for which manipulation is not possible.
- After reset
Indicates each register status upon reset signal generation.

Caution Do not access addresses to which extended SFRs (2nd SFRs) are not assigned.

Remark For SFRs in the SFR area, see 3.2.4 Special function registers (SFRs).

Table 3-6. Extended SFR (2nd SFR) List (1/6)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
F0010H	A/D converter mode register 2	ADM2	R/W	√	√	–	00H
F0011H	Conversion result comparison upper limit setting register	ADUL	R/W	–	√	–	FFH
F0012H	Conversion result comparison lower limit setting register	ADLL	R/W	–	√	–	00H
F0013H	A/D test register	ADTES	R/W	–	√	–	00H
F0030H	Pull-up resistor option register 0	PU0	R/W	√	√	–	00H
F0031H	Pull-up resistor option register 1	PU1	R/W	√	√	–	00H
F0033H	Pull-up resistor option register 3	PU3	R/W	√	√	–	00H
F0034H	Pull-up resistor option register 4	PU4	R/W	√	√	–	01H
F0035H	Pull-up resistor option register 5	PU5	R/W	√	√	–	00H
F0037H	Pull-up resistor option register 7	PU7	R/W	√	√	–	00H
F003CH	Pull-up resistor option register 12	PU12	R/W	√	√	–	00H
F003EH	Pull-up resistor option register 14	PU14	R/W	√	√	–	00H
F0040H	Port input mode register 0	PIM0	R/W	√	√	–	00H
F0041H	Port input mode register 1	PIM1	R/W	√	√	–	00H
F0050H	Port output mode register 0	POM0	R/W	√	√	–	00H
F0051H	Port output mode register 1	POM1	R/W	√	√	–	00H
F0055H	Port output mode register 5	POM5	R/W	√	√	–	00H
F0057H	Port output mode register 7	POM7	R/W	√	√	–	00H
F0060H	Port mode control register 0	PMC0	R/W	√	√	–	FFH
F0061H	Port mode control register 1	PMC1	R/W	√	√	–	FFH
F0063H	Port mode control register 3	PMC3	R/W	√	√	–	FFH
F0064H	Port mode control register 4	PMC4	R/W	√	√	–	FFH
F0065H	Port mode control register 5	PMC5	R/W	√	√	–	FFH
F0067H	Port mode control register 7	PMC7	R/W	√	√	–	FFH
F006CH	Port mode control register 12	PMC12	R/W	√	√	–	FFH
F0070H	Noise filter enable register 0	NFEN0	R/W	√	√	–	00H
F0071H	Noise filter enable register 1	NFEN1	R/W	√	√	–	00H
F0073H	Input switch control register	ISC	R/W	√	√	–	00H
F0074H	Timer input select register 0	TIS0	R/W	–	√	–	00H
F0076H	A/D port configuration register	ADPC	R/W	–	√	–	00H
F0077H	Peripheral I/O redirection register	PIOR	R/W	–	√	–	00H
F0078H	Invalid memory access detection control register	IAWCTL	R/W	–	√	–	00H

Table 3-6. Extended SFR (2nd SFR) List (2/6)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
F007CH	Global analog input disable register	GAIDIS	R/W	√	√	–	00H
F007DH	Global digital input disable register	GDIDIS	R/W	√	√	–	00H
F0090H	Data flash control register	DFLCTL	R/W	√	√	–	00H
F00A0H	High-speed on-chip oscillator trimming register	HIOTRM	R/W	–	√	–	Undefined ^{Note 1}
F00A8H	High-speed on-chip oscillator frequency select register	HOCODIV	R/W	–	√	–	Undefined ^{Note 2}
F00E0H	Multiplication/division data register C (L)	MDCL	R/W	–	–	√	0000H
F00E2H	Multiplication/division data register C (H)	MDCH	R/W	–	–	√	0000H
F00E8H	Multiplication/division control register	MDUC	R/W	√	√	–	00H
F00F0H	Peripheral enable register 0	PER0	R/W	√	√	–	00H
F00F3H	Subsystem clock supply mode control register	OSMC	R/W	–	√	–	00H
F00F5H	RAM parity error control register	RPECTL	R/W	√	√	–	00H
F00FEH	BCD adjust result register	BCDADJ	R	–	√	–	Undefined
F0100H	Serial status register 00	SSR00L	SSR00	R	–	√	0000H
F0101H		–			–	–	
F0102H	Serial status register 01	SSR01L	SSR01	R	–	√	0000H
F0103H		–			–	–	
F0104H	Serial status register 02	SSR02L	SSR02	R	–	√	0000H
F0105H		–			–	–	
F0106H	Serial status register 03	SSR03L	SSR03	R	–	√	0000H
F0107H		–			–	–	
F0108H	Serial flag clear trigger register 00	SIR00L	SIR00	R/W	–	√	0000H
F0109H		–			–	–	
F010AH	Serial flag clear trigger register 01	SIR01L	SIR01	R/W	–	√	0000H
F010BH		–			–	–	
F010CH	Serial flag clear trigger register 02	SIR02L	SIR02	R/W	–	√	0000H
F010DH		–			–	–	
F010EH	Serial flag clear trigger register 03	SIR03L	SIR03	R/W	–	√	0000H
F010FH		–			–	–	

Notes 1. The value after a reset is adjusted at the time of shipment.

2. The value after a reset is a value set in FRQSEL2 to FRQSEL0 of the option byte (000C2H).

Table 3-6. Extended SFR (2nd SFR) List (3/6)

Address	Special Function Register (SFR) Name	Symbol		R/W	Manipulable Bit Range			After Reset
					1-bit	8-bit	16-bit	
F0110H	Serial mode register 00	SMR00		R/W	–	–	√	0020H
F0111H								
F0112H	Serial mode register 01	SMR01		R/W	–	–	√	0020H
F0113H								
F0114H	Serial mode register 02	SMR02		R/W	–	–	√	0020H
F0115H								
F0116H	Serial mode register 03	SMR03		R/W	–	–	√	0020H
F0117H								
F0118H	Serial communication operation setting register 00	SCR00		R/W	–	–	√	0087H
F0119H								
F011AH	Serial communication operation setting register 01	SCR01		R/W	–	–	√	0087H
F011BH								
F011CH	Serial communication operation setting register 02	SCR02		R/W	–	–	√	0087H
F011DH								
F011EH	Serial communication operation setting register 03	SCR03		R/W	–	–	√	0087H
F011FH								
F0120H	Serial channel enable status register 0	SE0L	SE0	R	√	√	√	0000H
F0121H		–			–	–		
F0122H	Serial channel start register 0	SS0L	SS0	R/W	√	√	√	0000H
F0123H		–			–	–		
F0124H	Serial channel stop register 0	ST0L	ST0	R/W	√	√	√	0000H
F0125H		–			–	–		
F0126H	Serial clock select register 0	SPS0L	SPS0	R/W	–	√	√	0000H
F0127H		–			–	–		
F0128H	Serial output register 0	SO0		R/W	–	–	√	0F0FH
F0129H								
F012AH	Serial output enable register 0	SOE0L	SOE0	R/W	√	√	√	0000H
F012BH		–			–	–		
F0134H	Serial output level register 0	SOL0L	SOL0	R/W	–	√	√	0000H
F0135H		–			–	–		
F0138H	Serial standby control register 0	SSC0L	SSC0	R/W	–	√	√	0000H
		–			–	–		
F0140H	Serial status register 10	SSR10L	SSR10	R	–	√	√	0000H
F0141H		–			–	–		
F0142H	Serial status register 11	SSR11L	SSR11	R	–	√	√	0000H
F0143H		–			–	–		
F0148H	Serial flag clear trigger register 10	SIR10L	SIR10	R/W	–	√	√	0000H
F0149H		–			–	–		
F014AH	Serial flag clear trigger register 11	SIR11L	SIR11	R/W	–	√	√	0000H
F014BH		–			–	–		

Table 3-6. Extended SFR (2nd SFR) List (4/6)

Address	Special Function Register (SFR) Name	Symbol		R/W	Manipulable Bit Range			After Reset
					1-bit	8-bit	16-bit	
F0150H	Serial mode register 10	SMR10		R/W	–	–	√	0020H
F0151H								
F0152H	Serial mode register 11	SMR11		R/W	–	–	√	0020H
F0153H								
F0158H	Serial communication operation setting register 10	SCR10		R/W	–	–	√	0087H
F0159H								
F015AH	Serial communication operation setting register 11	SCR11		R/W	–	–	√	0087H
F015BH								
F0160H	Serial channel enable status register 1	SE1L	SE1	R	√	√	√	0000H
F0161H		–			–	–		
F0162H	Serial channel start register 1	SS1L	SS1	R/W	√	√	√	0000H
F0163H		–			–	–		
F0164H	Serial channel stop register 1	ST1L	ST1	R/W	√	√	√	0000H
F0165H		–			–	–		
F0166H	Serial clock select register 1	SPS1L	SPS1	R/W	–	√	√	0000H
F0167H		–			–	–		
F0168H	Serial output register 1	SO1		R/W	–	–	√	0303H
F0169H								
F016AH	Serial output enable register 1	SOE1L	SOE1	R/W	√	√	√	0000H
F016BH		–			–	–		
F0174H	Serial output level register 1	SOL1L	SOL1	R/W	–	√	√	0000H
F0175H		–			–	–		
F0180H	Timer counter register 00	TCR00		R	–	–	√	FFFFH
F0181H								
F0182H	Timer counter register 01	TCR01		R	–	–	√	FFFFH
F0183H								
F0184H	Timer counter register 02	TCR02		R	–	–	√	FFFFH
F0185H								
F0186H	Timer counter register 03	TCR03		R	–	–	√	FFFFH
F0187H								
F0188H	Timer counter register 04	TCR04		R	–	–	√	FFFFH
F0189H								
F018AH	Timer counter register 05	TCR05		R	–	–	√	FFFFH
F018BH								
F018CH	Timer counter register 06	TCR06		R	–	–	√	FFFFH
F018DH								
F018EH	Timer counter register 07	TCR07		R	–	–	√	FFFFH
F018FH								

Table 3-6. Extended SFR (2nd SFR) List (5/6)

Address	Special Function Register (SFR) Name	Symbol	R/W	Manipulable Bit Range			After Reset
				1-bit	8-bit	16-bit	
F0190H	Timer mode register 00	TMR00	R/W	–	–	√	0000H
F0191H				–	–	–	
F0192H	Timer mode register 01	TMR01	R/W	–	–	√	0000H
F0193H				–	–	–	
F0194H	Timer mode register 02	TMR02	R/W	–	–	√	0000H
F0195H				–	–	–	
F0196H	Timer mode register 03	TMR03	R/W	–	–	√	0000H
F0197H				–	–	–	
F0198H	Timer mode register 04	TMR04	R/W	–	–	√	0000H
F0199H				–	–	–	
F019AH	Timer mode register 05	TMR05	R/W	–	–	√	0000H
F019BH				–	–	–	
F019CH	Timer mode register 06	TMR06	R/W	–	–	√	0000H
F019DH				–	–	–	
F019EH	Timer mode register 07	TMR07	R/W	–	–	√	0000H
F019FH				–	–	–	
F01A0H	Timer status register 00	TSR00L	R	–	√	√	0000H
F01A1H		–		–	–		
F01A2H	Timer status register 01	TSR01L	R	–	√	√	0000H
F01A3H		–		–	–		
F01A4H	Timer status register 02	TSR02L	R	–	√	√	0000H
F01A5H		–		–	–		
F01A6H	Timer status register 03	TSR03L	R	–	√	√	0000H
F01A7H		–		–	–		
F01A8H	Timer status register 04	TSR04L	R	–	√	√	0000H
F01A9H		–		–	–		
F01AAH	Timer status register 05	TSR05L	R	–	√	√	0000H
F01ABH		–		–	–		
F01ACH	Timer status register 06	TSR06L	R	–	√	√	0000H
F01ADH		–		–	–		
F01AEH	Timer status register 07	TSR07L	R	–	√	√	0000H
F01AFH		–		–	–		

Table 3-6. Extended SFR (2nd SFR) List (6/6)

Address	Special Function Register (SFR) Name	Symbol		R/W	Manipulable Bit Range			After Reset
					1-bit	8-bit	16-bit	
F01B0H	Timer channel enable status register 0	TE0L	TE0	R	√	√	√	0000H
F01B1H		—			—	—		
F01B2H	Timer channel start register 0	TS0L	TS0	R/W	√	√	√	0000H
F01B3H		—			—	—		
F01B4H	Timer channel stop register 0	TT0L	TT0	R/W	√	√	√	0000H
F01B5H		—			—	—		
F01B6H	Timer clock select register 0	TPS0		R/W	—	—	√	0000H
F01B7H								
F01B8H	Timer output register 0	TO0L	TO0	R/W	—	√	√	0000H
F01B9H		—			—	—		
F01BAH	Timer output enable register 0	TOE0L	TOE0	R/W	√	√	√	0000H
F01BBH		—			—	—		
F01BCH	Timer output level register 0	TOL0L	TOL0	R/W	—	√	√	0000H
F01BDH		—			—	—		
F01BEH	Timer output mode register 0	TOM0L	TOM0	R/W	—	√	√	0000H
F01BFH		—			—	—		
F0230H	IICA control register 00	IICCTL00	R/W	√	√	—	00H	F0230H
F0231H	IICA control register 01	IICCTL01	R/W	√	√	—	00H	F0231H
F0232H	IICA low-level width setting register 0	IICWL0	R/W	—	√	—	FFH	F0232H
F0233H	IICA high-level width setting register 0	IICWH0	R/W	—	√	—	FFH	F0233H
F0234H	Slave address register 0	SVA0	R/W	—	√	—	00H	F0234H
F02F0H	Flash memory CRC control register	CRC0 CTL	R/W	√	√	—	00H	F02F0H
F02F2H	Flash memory CRC operation result register	PGCR CL	R/W	—	—	√	0000H	F02F2H
F02FAH	CRC data register	CRCD	R/W	—	—	√	0000H	F02FAH

Remark For SFRs in the SFR area, see Table 3-5 SFR List.

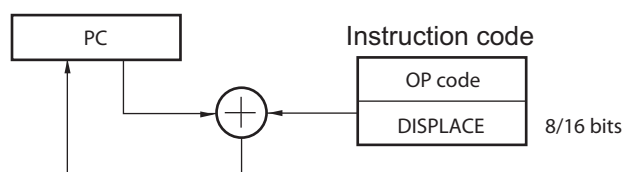
3.3 Instruction Address Addressing

3.3.1 Relative addressing

[Function]

Relative addressing stores in the program counter (PC) the result of adding a displacement value included in the instruction word (signed complement data: -128 to $+127$ or -32768 to $+32767$) to the program counter (PC)'s value (the start address of the next instruction), and specifies the program address to be used as the branch destination. Relative addressing is applied only to branch instructions.

Figure 3-13. Outline of Relative Addressing



3.3.2 Immediate addressing

[Function]

Immediate addressing stores immediate data of the instruction word in the program counter, and specifies the program address to be used as the branch destination.

For immediate addressing, CALL !!addr20 or BR !!addr20 is used to specify 20-bit addresses and CALL !addr16 or BR !addr16 is used to specify 16-bit addresses. 0000 is set to the higher 4 bits when specifying 16-bit addresses.

Figure 3-14. Example of CALL !!addr20/BR !!addr20

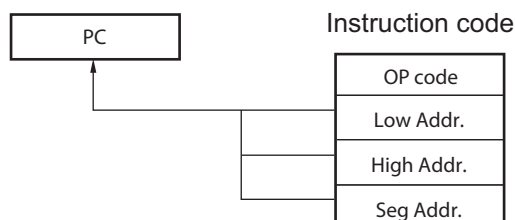
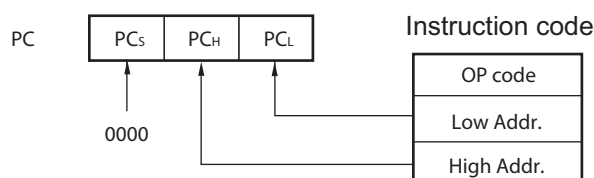


Figure 3-15. Example of CALL !addr16/BR !addr16



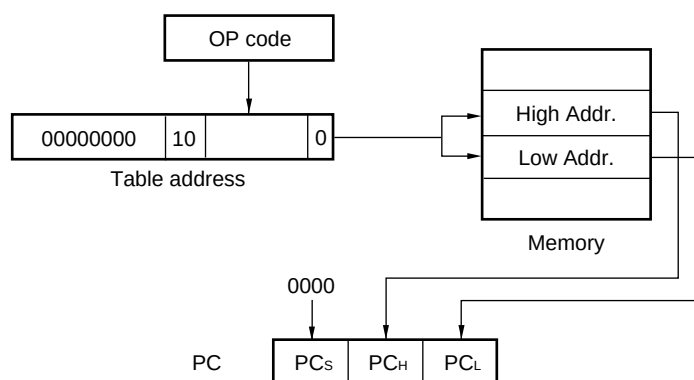
3.3.3 Table indirect addressing

[Function]

Table indirect addressing specifies a table address in the CALLT table area (0080H to 00BFH) with the 5-bit immediate data in the instruction word, stores the contents at that table address and the next address in the program counter (PC) as 16-bit data, and specifies the program address. Table indirect addressing is applied only for CALLT instructions.

In the RL78 microcontrollers, branching is enabled only to the 64 KB space from 00000H to 0FFFFH.

Figure 3-16. Outline of Table Indirect Addressing

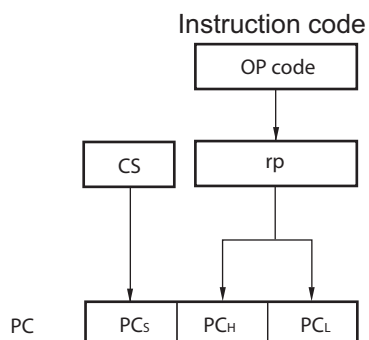


3.3.4 Register direct addressing

[Function]

Register direct addressing stores in the program counter (PC) the contents of a general-purpose register pair (AX/BC/DE/HL) and CS register of the current register bank specified with the instruction word as 20-bit data, and specifies the program address. Register direct addressing can be applied only to the CALL AX, BC, DE, HL, and BR AX instructions.

Figure 3-17. Outline of Register Direct Addressing



3.4 Addressing for Processing Data Addresses

3.4.1 Implied addressing

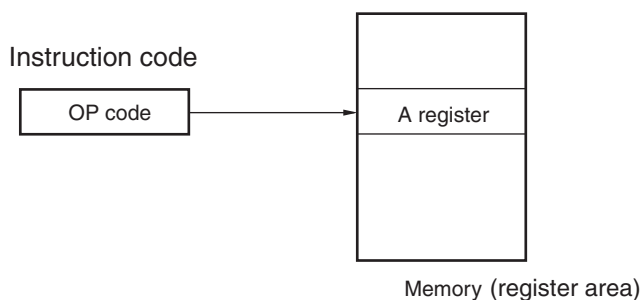
[Function]

Instructions for accessing registers (such as accumulators) that have special functions are directly specified with the instruction word, without using any register specification field in the instruction word.

[Operand format]

Implied addressing can be applied only to MULU X.

Figure 3-18. Outline of Implied Addressing



3.4.2 Register addressing

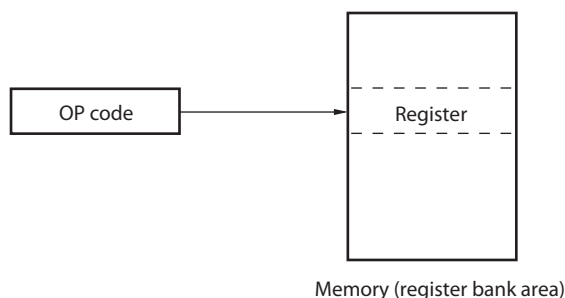
[Function]

Register addressing accesses a general-purpose register as an operand. The instruction word of 3-bit long is used to select an 8-bit register and the instruction word of 2-bit long is used to select a 16-bit register.

[Operand format]

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

Figure 3-19. Outline of Register Addressing



3.4.3 Direct addressing

[Function]

Direct addressing uses immediate data in the instruction word as an operand address to directly specify the target address.

[Operand format]

Identifier	Description
!addr16	Label or 16-bit immediate data (only the space from F0000H to FFFFFH is specifiable)
ES:!addr16	Label or 16-bit immediate data (higher 4-bit addresses are specified by the ES register)

Figure 3-20. Example of !addr16

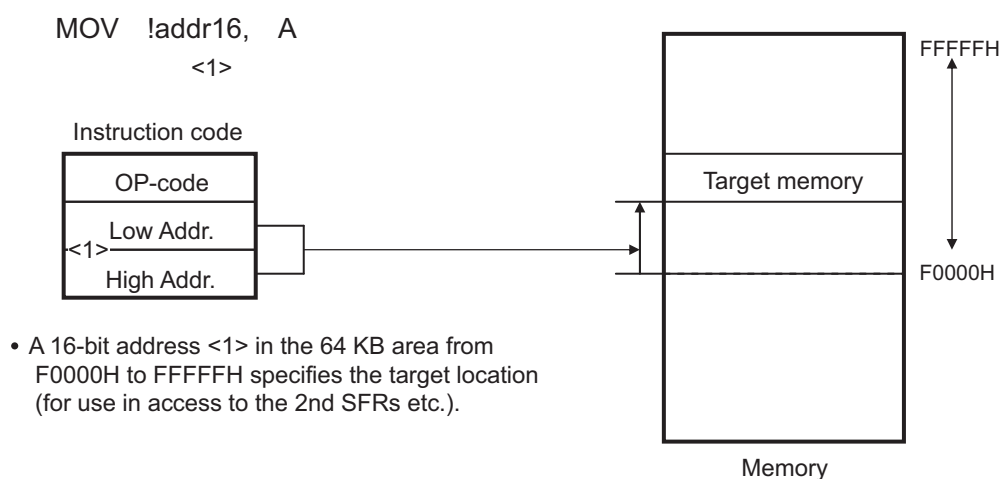
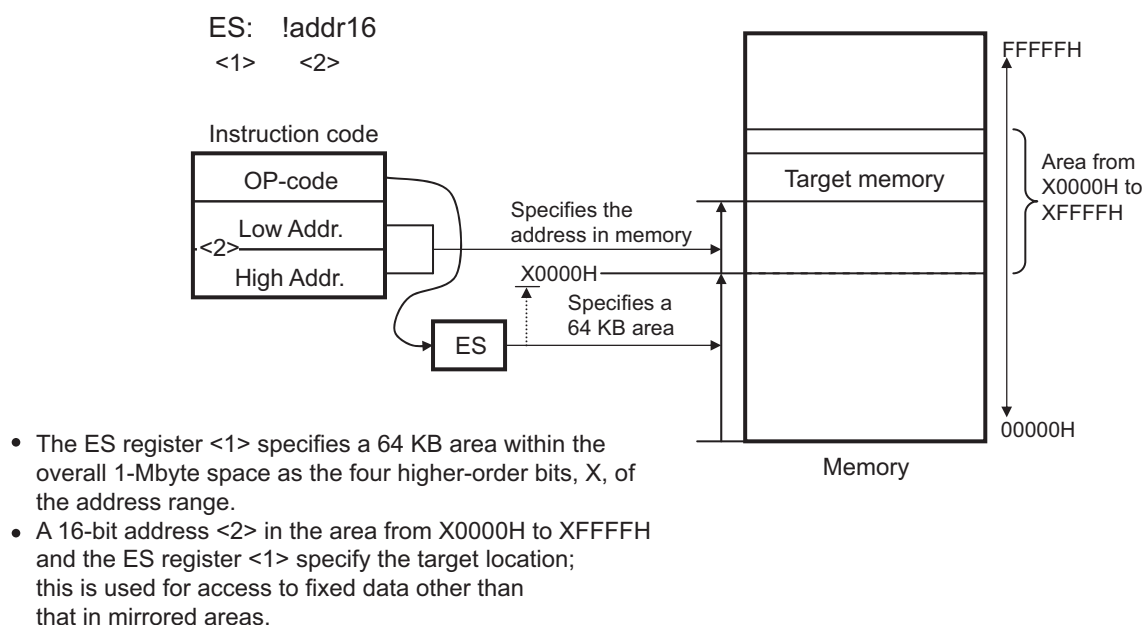


Figure 3-21. Example of ES:!addr16



3.4.4 Short direct addressing

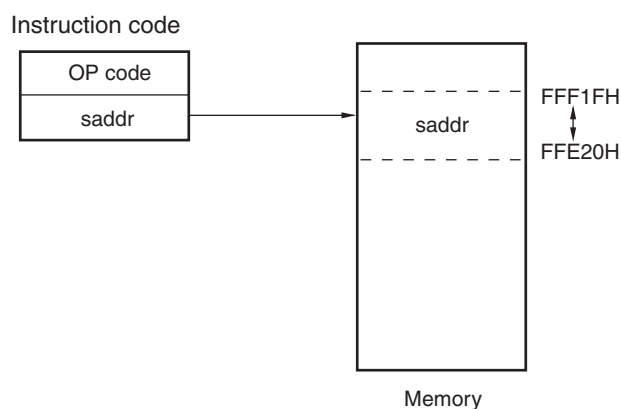
[Function]

Short direct addressing directly specifies the target addresses using 8-bit data in the instruction word. This type of addressing is applied only to the space from FFE20H to FFF1FH.

[Operand format]

Identifier	Description
SADDR	Label, FFE20H to FFF1FH immediate data, or 0FE20H to 0FF1FH immediate data (only the space from FFE20H to FFF1FH is specifiable)
SADDRP	Label, FFE20H to FFF1FH immediate data, or 0FE20H to 0FF1FH immediate data (even address only) (only the space from FFE20H to FFF1FH is specifiable)

Figure 3-22. Outline of Short Direct Addressing



Remark SADDR and SADDRP are used to describe the values of addresses FE20H to FF1FH with 16-bit immediate data (higher 4 bits of actual address are omitted), and the values of addresses FFE20H to FFF1FH with 20-bit immediate data.

Regardless of whether SADDR or SADDRP is used, addresses within the space from FFE20H to FFF1FH are specified for the memory.

3.4.5 SFR addressing

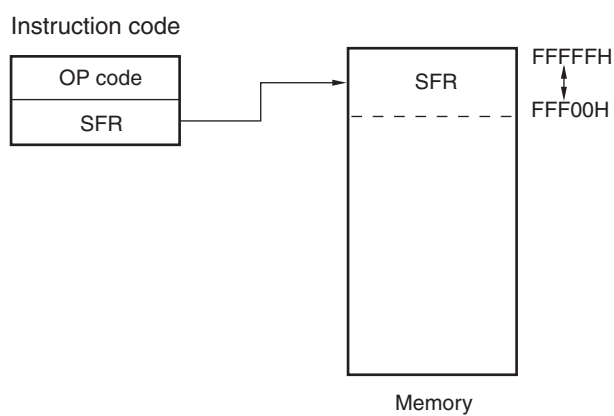
[Function]

SFR addressing directly specifies the target SFR addresses using 8-bit data in the instruction word. This type of addressing is applied only to the space from FFF00H to FFFFFH.

[Operand format]

Identifier	Description
SFR	SFR name
SFRP	16-bit-manipulatable SFR name (even address)

Figure 3-23. Outline of SFR Addressing



3.4.6 Register indirect addressing

[Function]

Register indirect addressing directly specifies the target addresses using the contents of the register pair specified with the instruction word as an operand address.

[Operand format]

Identifier	Description
–	[DE], [HL] (only the space from F0000H to FFFFFH is specifiable)
–	ES:[DE], ES:[HL] (higher 4-bit addresses are specified by the ES register)

Figure 3-24. Example of [DE], [HL]

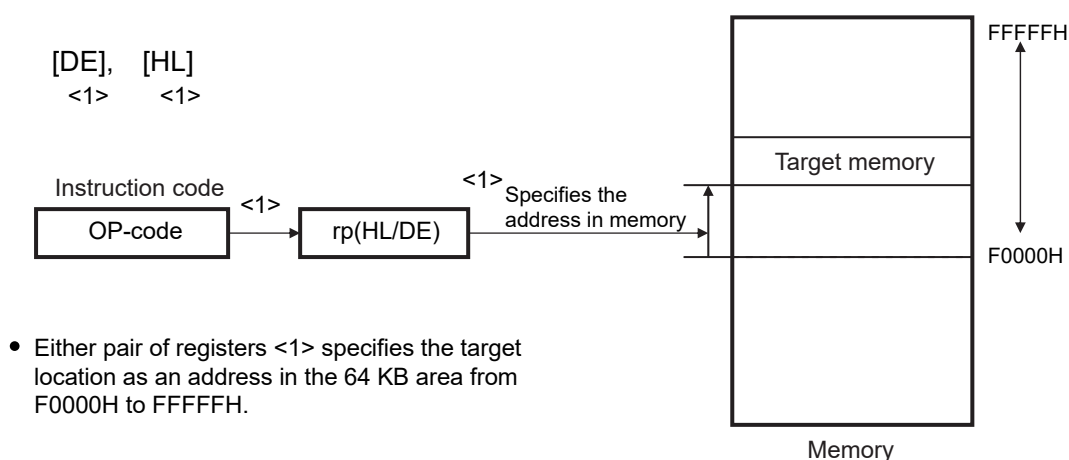
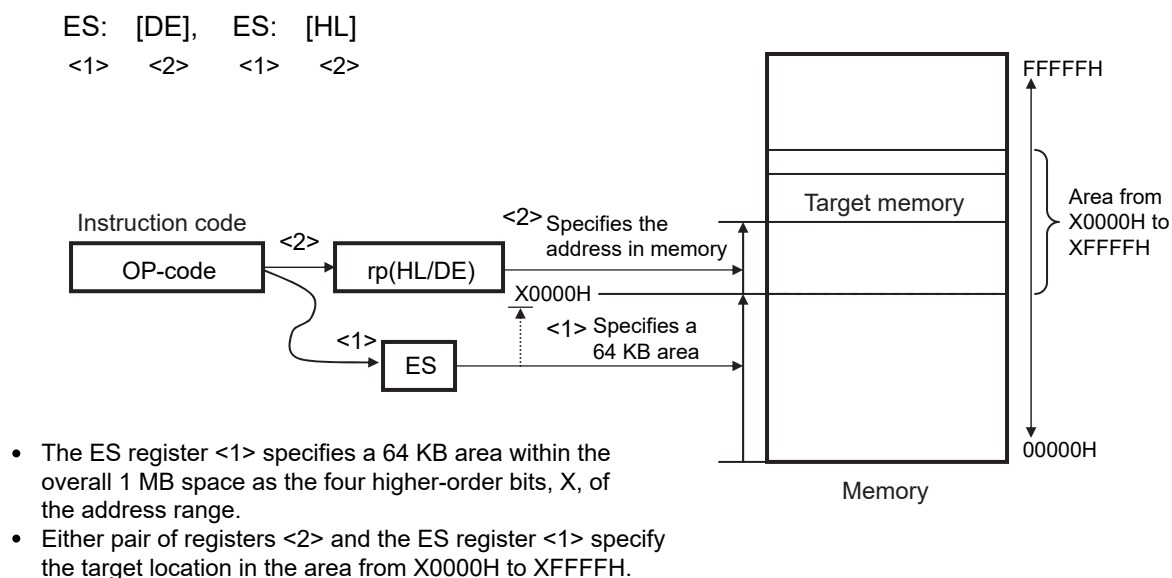


Figure 3-25. Example of ES:[DE], ES:[HL]



3.4.7 Based addressing

[Function]

Based addressing uses the contents of a register pair specified with the instruction word or 16-bit immediate data as a base address, and 8-bit immediate data or 16-bit immediate data as offset data. The sum of these values is used to specify the target address.

[Operand format]

Identifier	Description
–	[HL + byte], [DE + byte], [SP + byte] (only the space from F0000H to FFFFFH is specifiable)
–	word[B], word[C] (only the space from F0000H to FFFFFH is specifiable)
–	word[BC] (only the space from F0000H to FFFFFH is specifiable)
–	ES:[HL + byte], ES:[DE + byte] (higher 4-bit addresses are specified by the ES register)
–	ES:word[B], ES:word[C] (higher 4-bit addresses are specified by the ES register)
–	ES:word[BC] (higher 4-bit addresses are specified by the ES register)

Figure 3-26. Example of [SP+byte]

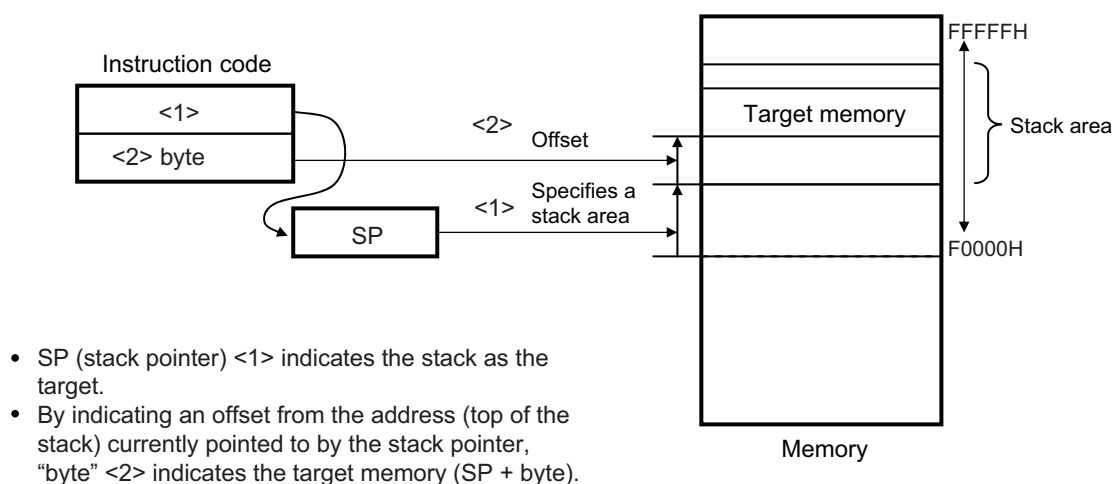


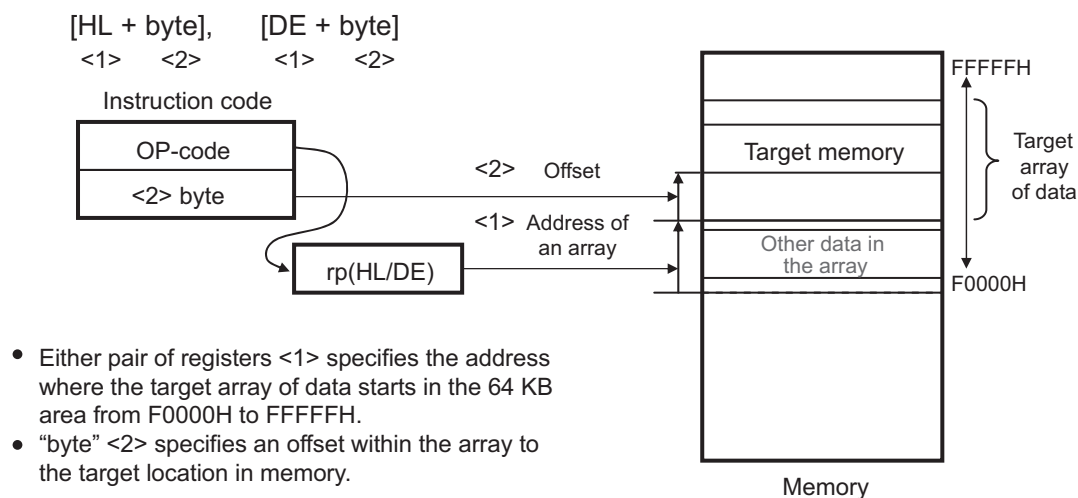
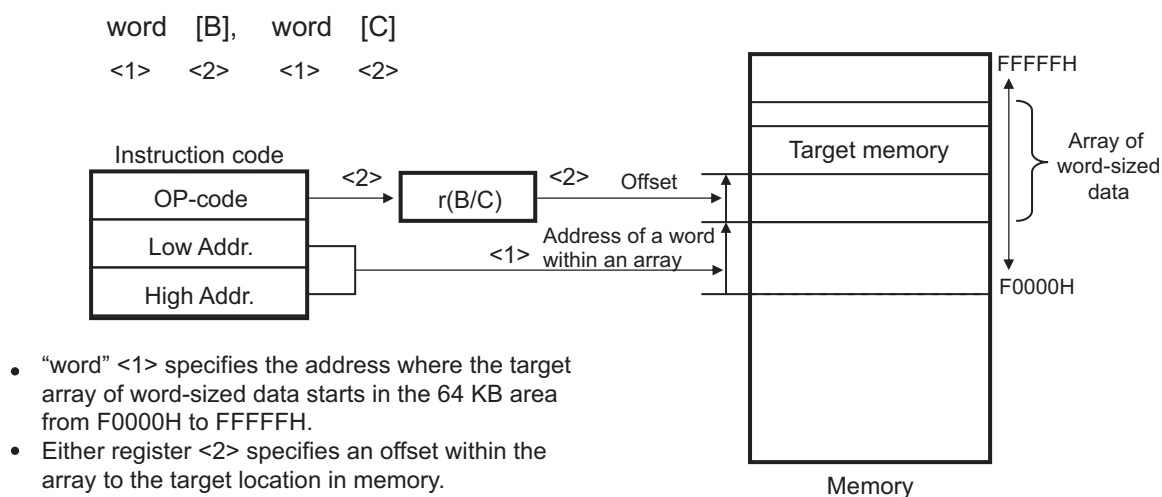
Figure 3-27. Example of [HL + byte], [DE + byte]**Figure 3-28. Example of word[B], word[C]**

Figure 3-29. Example of word[BC]

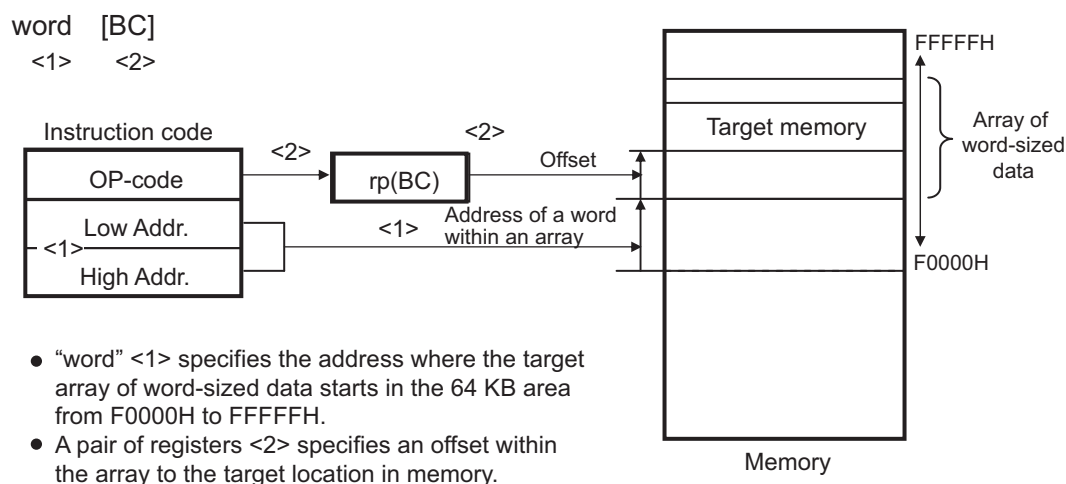


Figure 3-30. Example of ES:[HL + byte], ES:[DE + byte]

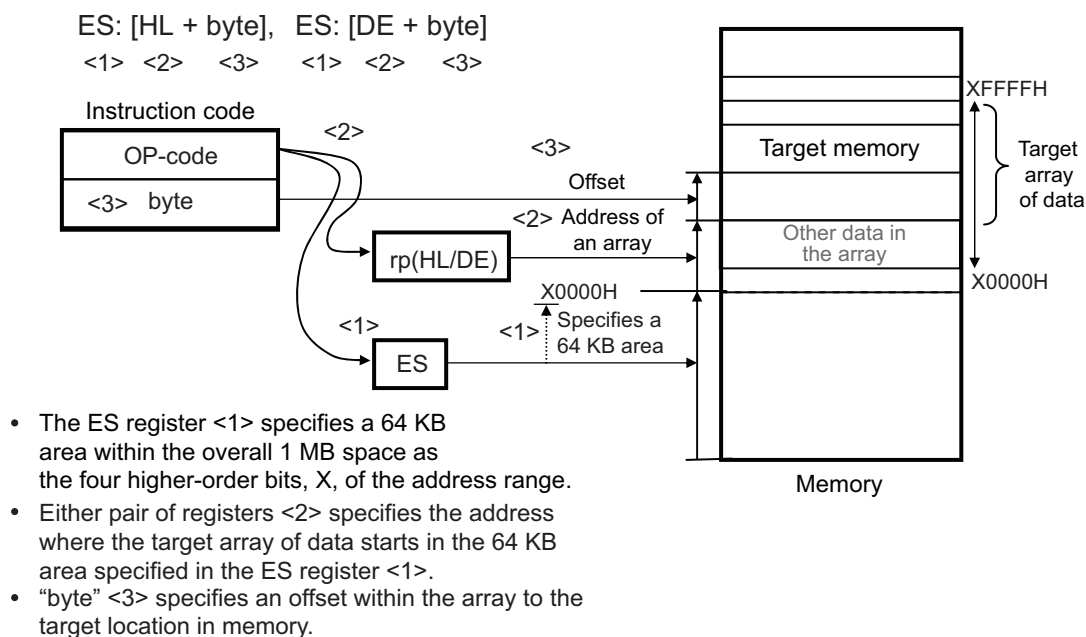
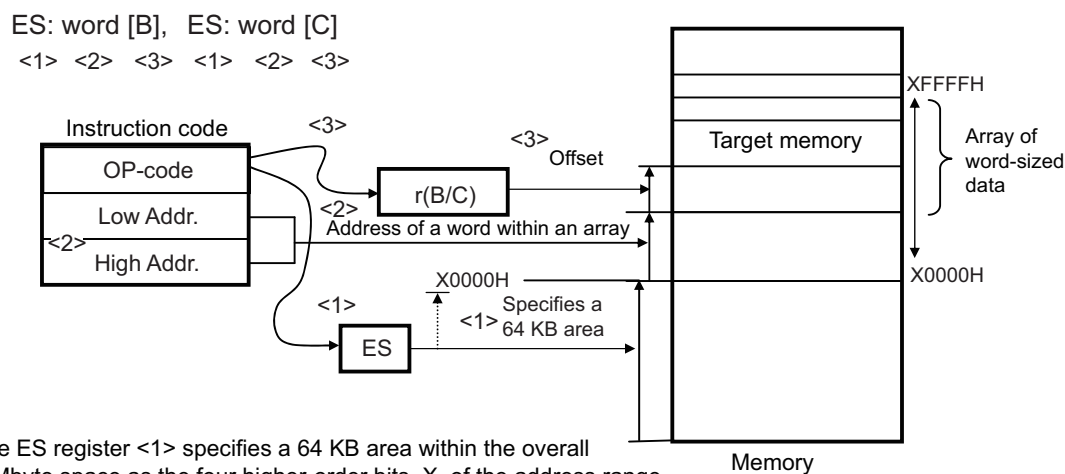
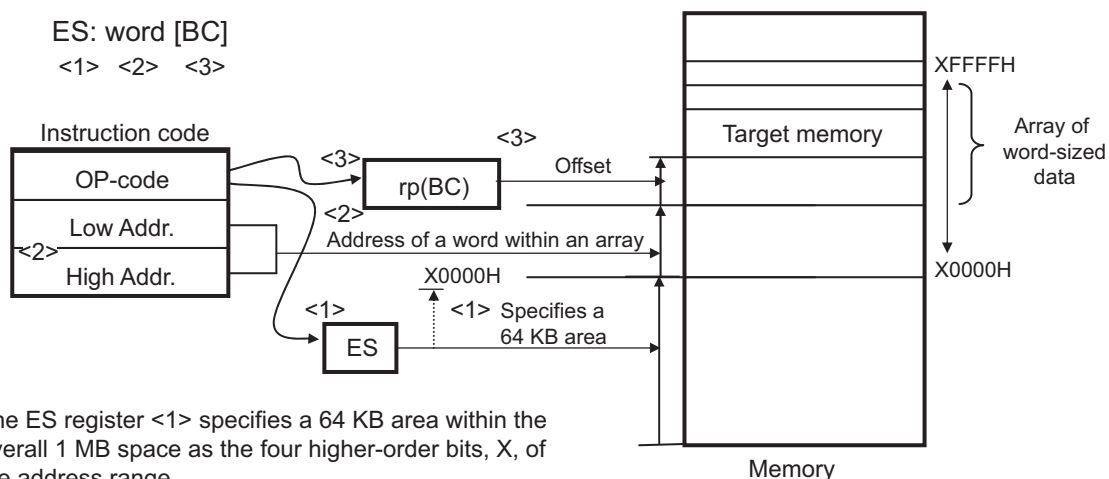


Figure 3-31. Example of ES:word[B], ES:word[C]

- The ES register <1> specifies a 64 KB area within the overall 1-Mbyte space as the four higher-order bits, X, of the address range.
- “word” <2> specifies the address where the target array of word-sized data starts in the 64 KB area specified in the ES register <1>.
- Either register <3> specifies an offset within the array to the target location in memory.

Figure 3-32. Example of ES:word[BC]

- The ES register <1> specifies a 64 KB area within the overall 1 MB space as the four higher-order bits, X, of the address range.
- “word” <2> specifies the address where the target array of word-sized data starts in the 64 KB area specified in the ES register <1>.
- A pair of registers <3> specifies an offset within the array to the target location in memory.

3.4.8 Based indexed addressing

[Function]

Based indexed addressing uses the contents of a register pair specified with the instruction word as the base address, and the content of the B register or C register similarly specified with the instruction word as offset address. The sum of these values is used to specify the target address.

[Operand format]

Identifier	Description
–	[HL+B], [HL+C] (only the space from F0000H to FFFFFH is specifiable)
–	ES:[HL+B], ES:[HL+C] (higher 4-bit addresses are specified by the ES register)

Figure 3-33. Example of [HL+B], [HL+C]

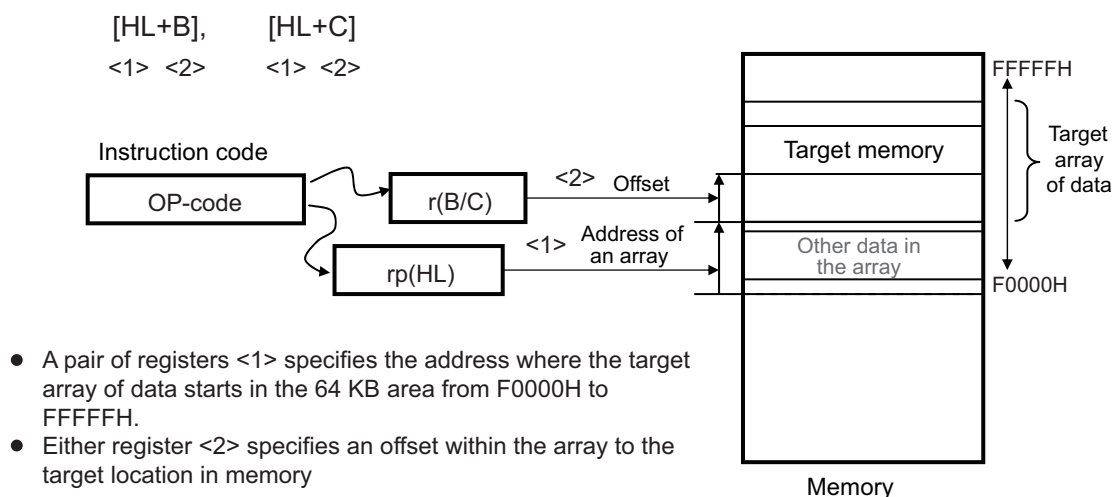
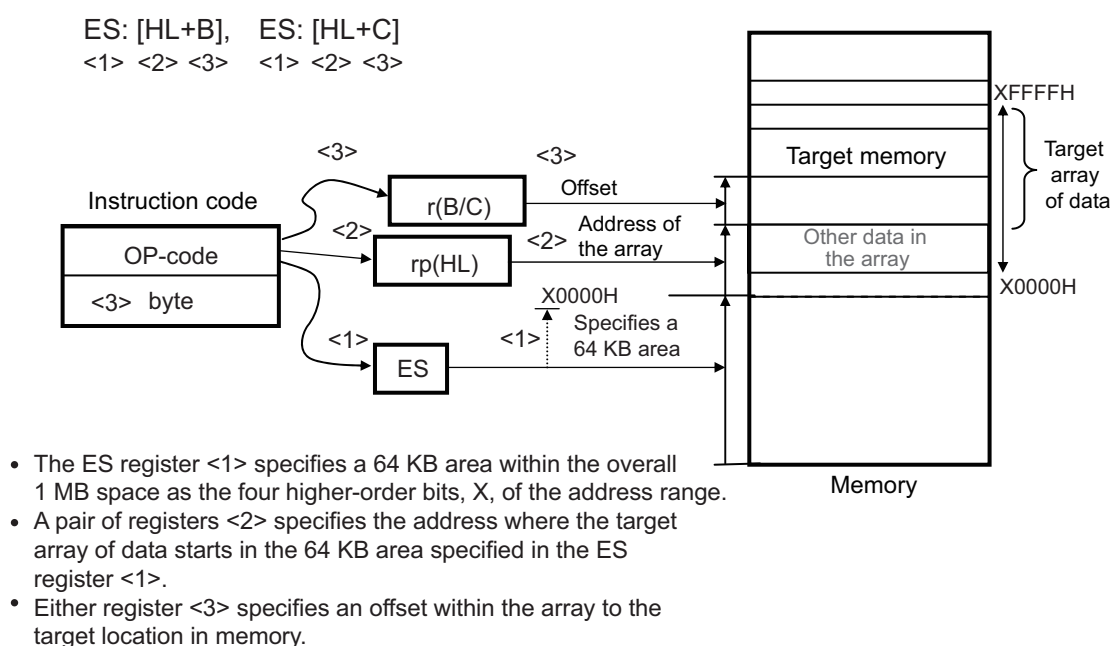


Figure 3-34. Example of ES:[HL+B], ES:[HL+C]



3.4.9 Stack addressing

[Function]

The stack area is indirectly addressed with the stack pointer (SP) values. This addressing is automatically employed when the PUSH, POP, subroutine call, and return instructions are executed or the register is saved/restored upon generation of an interrupt request.

Only the internal RAM area can be set as the stack area.

[Description format]

Identifier	Description
–	PUSH PSW AX/BC/DE/HL POP PSW AX/BC/DE/HL CALL/CALLT RET BRK RETB (Interrupt request generated) RETI

Each stack operation saves or restores data as shown in **Figures 3-35 to 3-40**.

Figure 3-35. Example of PUSH rp

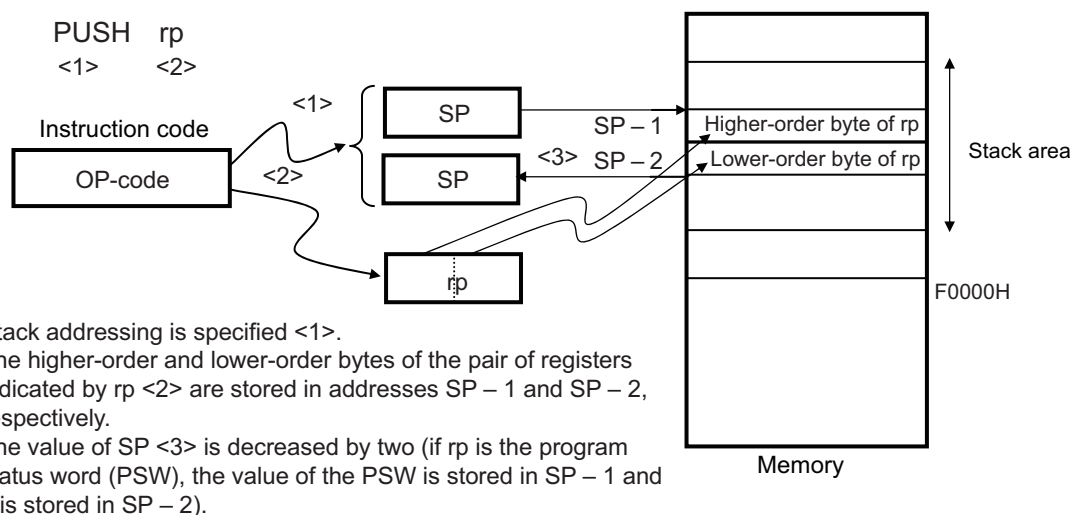
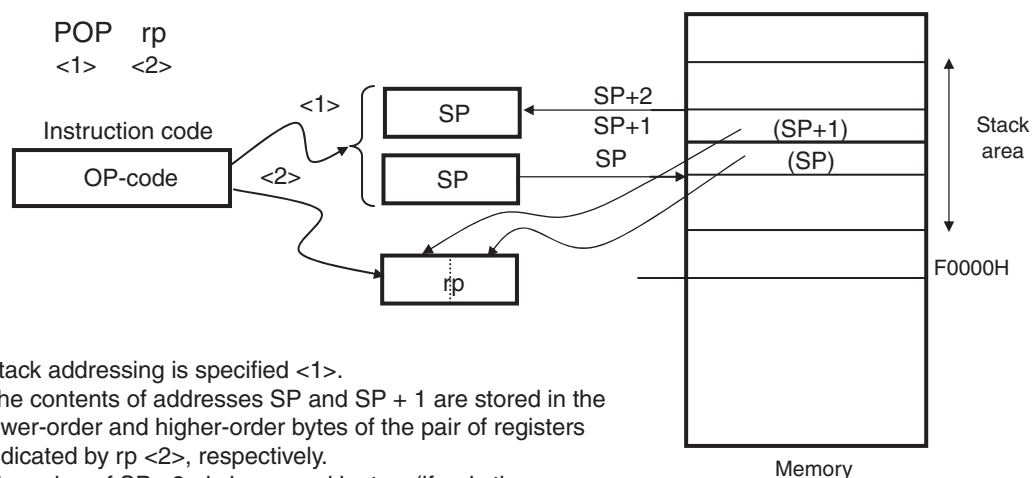
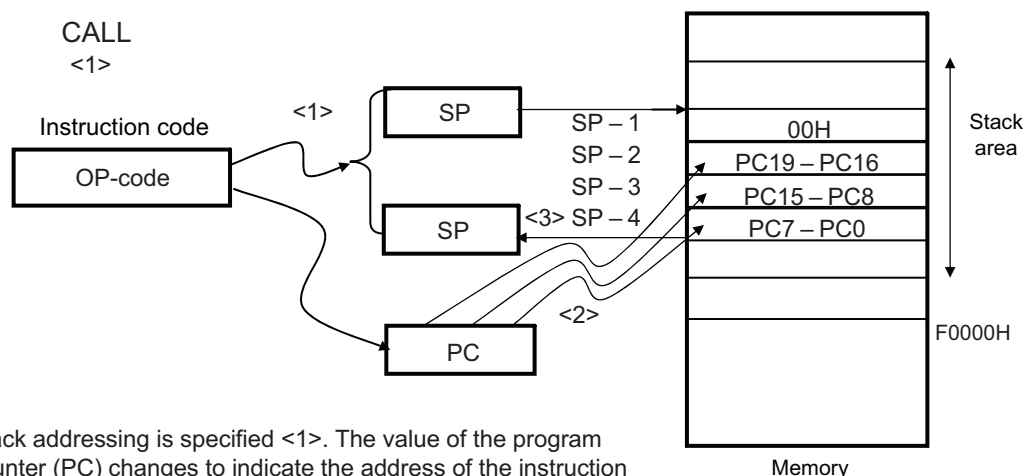


Figure 3-36. Example of POP



- Stack addressing is specified <1>.
- The contents of addresses SP and SP + 1 are stored in the lower-order and higher-order bytes of the pair of registers indicated by rp <2>, respectively.
- The value of SP <3> is increased by two (if rp is the program status word (PSW), the content of address SP + 1 is stored in the PSW).

Figure 3-37. Example of CALL, CALLT



- Stack addressing is specified <1>. The value of the program counter (PC) changes to indicate the address of the instruction following the CALL instruction.
- 00H, the values of PC bits 19 to 16, 15 to 8, and 7 to 0 are stored in addresses SP - 1, SP - 2, SP - 3, and SP - 4, respectively <2>.
- The value of the SP <3> is decreased by 4.

Figure 3-38. Example of RET

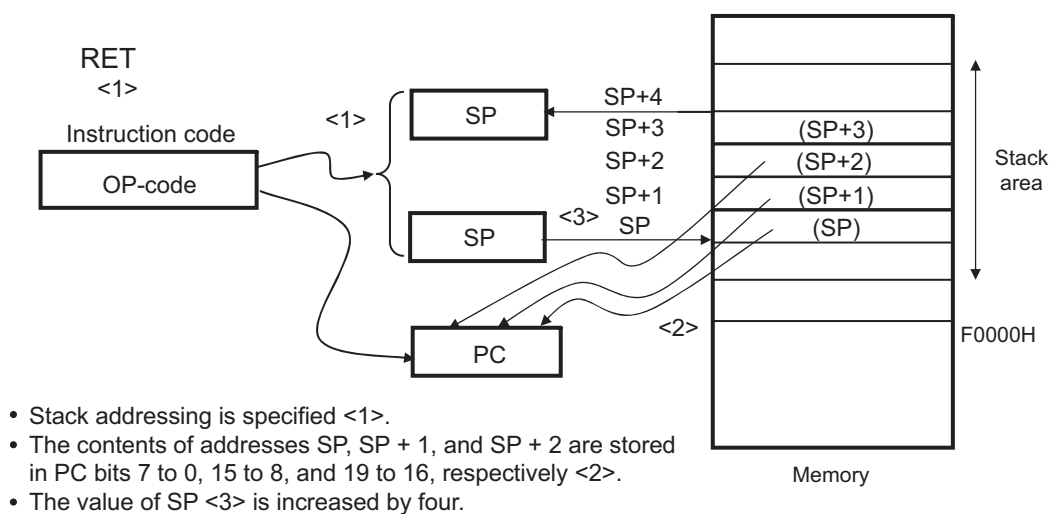


Figure 3-39. Example of Interrupt, BRK

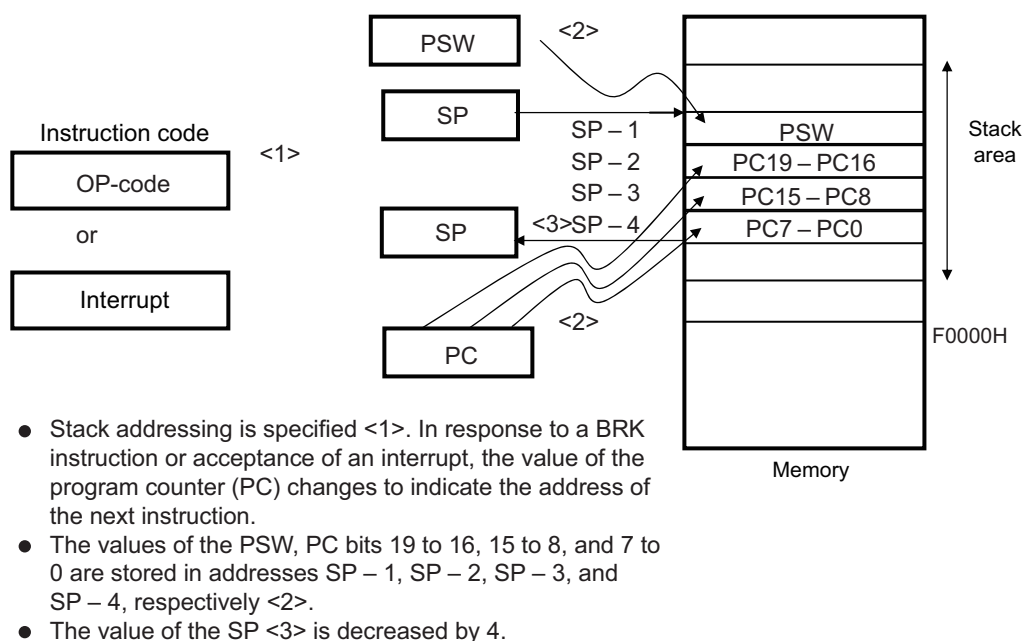
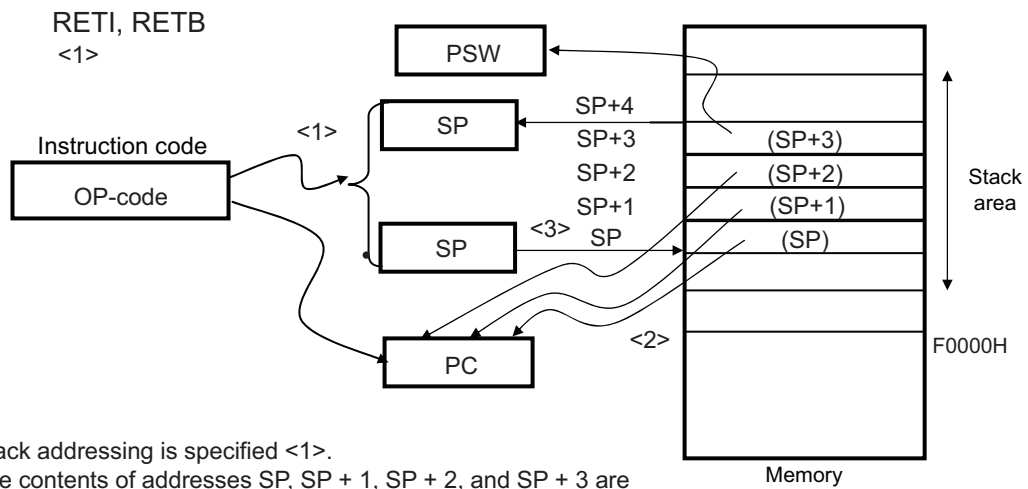


Figure 3-40. Example of RETI, RETB



- Stack addressing is specified <1>.
- The contents of addresses SP, SP + 1, SP + 2, and SP + 3 are stored in PC bits 7 to 0, 15 to 8, 19 to 16, and the PSW, respectively <2>.
- The value of SP <3> is increased by four.

CHAPTER 4 PORT FUNCTIONS

4.1 Port Functions

The RL78/G1A microcontrollers are provided with digital I/O ports, which enable variety of control operations.

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

4.2 Port Configuration

Ports include the following hardware.

Table 4-1. Port Configuration

Item	Configuration
Control registers	Port mode registers (PM0 to PM7, PM12, PM14, PM15) Port registers (P0 to P7, P12 to P15) Pull-up resistor option registers (PU0, PU1, PU3 to PU5, PU7, PU12, PU14) Port input mode registers (PIM0, PIM1) Port output mode registers (POM0, POM1, POM5, POM7) Port mode control registers (PMC0, PMC1, PMC3 to PMC5, PMC7, PMC12) A/D port configuration register (ADPC) Peripheral I/O redirection register (PIOR) Global digital input disable register (GDIDIS) Global analog input disable register (GAIDIS)
Port	• 25-pin products Total: 19 (CMOS I/O: 14 (N-ch open drain I/O [V_{DD} tolerance]: 6), CMOS input: 3, N-ch open drain I/O [6-V tolerance]: 2) • 32-pin products Total: 26 (CMOS I/O: 20 (N-ch open drain I/O [V_{DD} tolerance]: 9), CMOS input: 3, N-ch open drain I/O [6-V tolerance]: 3) • 48-pin products Total: 42 (CMOS I/O: 32 (N-ch open drain I/O [V_{DD} tolerance]: 11), CMOS input: 5, CMOS output: 1, N-ch open drain I/O [6-V tolerance]: 4) • 64-pin products Total: 56 (CMOS I/O: 46 (N-ch open drain I/O [V_{DD} tolerance]: 12), CMOS input: 5, CMOS output: 1, N-ch open drain I/O [6-V tolerance]: 4)
Pull-up resistor	• 25-pin products Total: 10 • 32-pin products Total: 15 • 48-pin products Total: 23 • 64-pin products Total: 33

4.2.1 Port 0

Port 0 is an I/O port with an output latch. Port 0 can be set to the input mode or output mode in 1-bit units using port mode register 0 (PM0). When the P00 to P06 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 0 (PU0).

Input to the P00, P01, P03 and P04 pins can be specified through a normal input buffer or a TTL input buffer in 1-bit units using port input mode register 0 (PIM0).

Output from the P02 to P04 pins can be specified as N-ch open-drain output (V_{DD} tolerance^{Note 1}/EV V_{DD} tolerance^{Note 2}) in 1-bit units using port output mode register 0 (POM0).

The P02 and P03 pins can be specified as digital input/output or analog input in 1-bit units, using port mode control register 0 (PMC0).

This port can also be used for timer I/O, A/D converter analog input, serial interface data I/O, clock I/O, and key interrupt input.

When reset signal is generated, the following configuration will be set.

- P00, P01 and P04 to P06 pins ... Input mode
- P02 and P03 pins ... Analog input

Notes 1. For 25- to 48-pin products

2. For 64-pin products

4.2.2 Port 1

Port 1 is an I/O port with an output latch. Port 1 can be set to the input mode or output mode in 1-bit units using port mode register 1 (PM1). When the P10 to P16 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 1 (PU1).

Input to the P10, P11, and P14 to P16 pins can be specified through a normal input buffer or a TTL input buffer in 1-bit units using port input mode register 1 (PIM1).

Output from the P10 to P15 pins can be specified as N-ch open-drain output (V_{DD} tolerance^{Note 1}/EV V_{DD} tolerance^{Note 2}) in 1-bit units using port output mode register 1 (POM1).

The P10 to P15 pins can be specified as digital input/output or analog input in 1-bit units, using port mode control register 1 (PMC1).

This port can also be used for A/D converter analog input, serial interface data I/O, clock I/O, programming UART I/O, timer I/O, and external interrupt request input.

When reset signal is generated, the following configuration will be set.

- P10 to P15 pins ... Analog input
- P16 pin ... Input mode

Notes 1. For 25- to 48-pin products

2. For 64-pin products

4.2.3 Port 2

Port 2 is an I/O port with an output latch. Port 2 can be set to the input mode or output mode in 1-bit units using port mode register 2 (PM2).

This port can also be used for A/D converter analog input and reference voltage input (+ side and – side).

To use P20/ANI0 to P27/ANI7 as digital I/O pins, set them in the digital I/O mode by using the A/D port configuration register (ADPC). Use these pins starting from the upper bit.

To use P20/ANI0 to P27/ANI7 as analog input pins, set them in the analog input mode by using the A/D port configuration register (ADPC) and in the input mode by using the PM2 register. Use these pins starting from the lower bit.

Table 4-2. Setting Functions of P20/ANI0 to P27/ANI7 Pins

ADPC Register	PM2 Register	ADS Register	P20/ANI0 to P27/ANI7 Pins
Digital I/O selection	Input mode	–	Digital input
	Output mode	–	Digital output
Analog input selection	Input mode	Selects ANI.	Analog input (to be converted)
		Does not select ANI.	Analog input (not to be converted)
	Output mode	Selects ANI.	Setting prohibited
		Does not select ANI.	

All P20/ANI0 to P27/ANI7 are set in the analog input mode when the reset signal is generated.

4.2.4 Port 3

Port 3 is an I/O port with an output latch. Port 3 can be set to the input mode or output mode in 1-bit units using port mode register 3 (PM3). When the P30, P31 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 3 (PU3).

The P30 and P31 pins can be specified as digital input/output or analog input in 1-bit units, using port mode control register 3 (PMC3).

This port can also be used for A/D converter analog input, external interrupt request input, real-time clock correction clock output, serial interface data I/O, clock I/O, and timer I/O.

Reset signal generation sets P30, P31 to analog input.

4.2.5 Port 4

Port 4 is an I/O port with an output latch. Port 4 can be set to the input mode or output mode in 1-bit units using port mode register 4 (PM4). When the P41 to P43 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 4 (PU4).

The P41 pin can be specified as digital input/output or analog input, using port mode control register 4 (PMC4).

This port can also be used for A/D converter analog input, timer I/O, data I/O for a flash memory programmer/debugger.

Reset signal generation sets port 4 to input mode.

4.2.6 Port 5

Port 5 is an I/O port with an output latch. Port 5 can be set to the input mode or output mode in 1-bit units using port mode register 5 (PM5). When the P50, P51 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 5 (PU5).

Output from the P50 pin can be set as N-ch open-drain output (V_{DD} tolerance^{Note 1}/ EV_{DD} tolerance^{Note 2}) in 1-bit units using port output mode register 5 (POM5).

The P50 and 51 pins can be specified as digital input/output or analog input in 1-bit units, using port mode control register 5 (PMC5).

This port can also be used for A/D converter analog input, external interrupt request input, serial interface data I/O.

Reset signal generation sets port 5 to input mode.

Notes 1. For 25- to 48-pin products

2. For 64-pin products

4.2.7 Port 6

Port 6 is an I/O port with an output latch. Port 6 can be set to the input mode or output mode in 1-bit units using port mode register 6 (PM6).

The output of the P60 to P63 pins is N-ch open-drain output (6 V tolerance).

This port can also be used for serial interface data I/O and clock I/O.

Reset signal generation sets port 6 to input mode.

4.2.8 Port 7

Port 7 is an I/O port with an output latch. Port 7 can be set to the input mode or output mode in 1-bit units using port mode register 7 (PM7). When used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 7 (PU7).

Output from the P71 and P74 pins can be specified as N-ch open-drain output (V_{DD} tolerance^{Note 1}/ EV_{DD} tolerance^{Note 2}) in 1-bit units using port output mode register 7 (POM7).

The P70 pin can be specified as digital input/output or analog input, using port mode control register 7 (PMC7).

This port can also be used for A/D converter analog input, key interrupt input, serial interface data I/O, clock I/O, and external interrupt request input.

Reset signal generation sets port 7 to input mode.

Notes 1. For 25- to 48-pin products

2. For 64-pin products

4.2.9 Port 12

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

P121 to P124 are 4-bit input only ports.

The P120 pin can be specified as digital input/output or analog input, using port mode control register 12 (PMC12).

This port can also be used for A/D converter analog input, connecting resonator for main system clock, connecting resonator for subsystem clock, external clock input for main system clock, and external clock input for subsystem clock.

Reset signal generation sets P120 to analog input, and sets P121 to P124 to input mode.

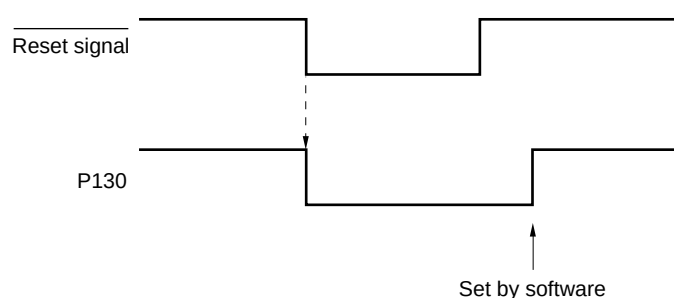
4.2.10 Port 13

P130 is a 1-bit output-only port with an output latch. P137 is a 1-bit input-only port.

P130 is fixed an output port, and P137 is fixed an input ports.

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

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



4.2.11 Port 14

Port 14 is an I/O port with an output latch. Port 14 can be set to the input mode or output mode in 1-bit units using port mode register 14 (PM14). When the P140, P141 pins are used as an input port, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option register 14 (PU14).

This port can also be used for clock/buzzer output, and external interrupt request input,

Reset signal generation sets P140, P141 to input mode.

4.2.12 Port 15

Port 15 is an I/O port with an output latch. Port 15 can be set to the input mode or output mode in 1-bit units using port mode register 15 (PM15).

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

To use P150/ANI8 to P154/ANI12 as digital input pins, set them in the digital I/O mode by using the A/D port configuration register (ADPC) and in the input mode by using the PM15 register. Use these pins starting from the upper bit.

To use P150/ANI8 to P154/ANI12 as digital output pins, set them in the digital I/O mode by using the A/D port configuration register (ADPC) and in the output mode by using the PM15 register. Use these pins starting from the upper bit.

To use P150/ANI8 to P154/ANI12 as analog input pins, set them in the analog input mode by using the A/D port configuration register (ADPC) and in the input mode by using the PM15 register. Use these pins starting from the lower bit.

Table 4-3. Setting Functions of P150/ANI8 to P154/ANI12 Pins

ADPC Register	PM15 Register	ADS Register	P150/ANI8 to P154/ANI12 Pins
Digital I/O selection	Input mode	–	Digital input
	Output mode	–	Digital output
Analog input selection	Input mode	Selects ANI.	Analog input (to be converted)
		Does not select ANI.	Analog input (not to be converted)
	Output mode	Selects ANI.	Setting prohibited
		Does not select ANI.	

All P150/ANI8 to P154/ANI12 are set in the analog input mode when the reset signal is generated.

4.3 Registers Controlling Port Function

Port functions are controlled by the following registers.

- Port mode registers (PMxx)
- Port registers (Pxx)
- Pull-up resistor option registers (PUxx)
- Port input mode registers (PIMxx)
- Port output mode registers (POMxx)
- Port mode control registers (PMCxx)
- A/D port configuration register (ADPC)
- Peripheral I/O redirection register (PIOR)
- Global digital input disable register (GDIDIS)
- Global analog input disable register (GAIDIS)

Caution Which registers and bits are included depends on the product. For registers and bits mounted on each product, see Table 4-4. Be sure to set bits that are not mounted to their initial values.

Table 4-4. PMxx, Pxx, PUxx, PIMxx, POMxx, PMCxx registers and the bits mounted on each product (1/2)

Port		Bit Name						64-pin	48-pin	32-pin	25-pin
		PMxx Register	Pxx Register	PUxx Register	PIMxx Register	POMxx Register	PMCxx Register				
Port 0	0	PM00	P00	PU00	PIM00	–	–	√	–	–	–
	1	PM01	P01	PU01	PIM01	–	–	√	–	–	–
	2	PM02	P02	PU02	–	POM02	PMC02	√	√	√	√
	3	PM03	P03	PU03	PIM03	POM03	PMC03	√	√	√	√
	4	PM04	P04	PU04	PIM04	POM04	–	√	–	–	–
	5	PM05	P05	PU05	–	–	–	√	–	–	–
	6	PM06	P06	PU06	–	–	–	√	–	–	–
Port 1	0	PM10	P10	PU10	PIM10	POM10	PMC10	√	√	√	√
	1	PM11	P11	PU11	PIM11	POM11	PMC11	√	√	√	√
	2	PM12	P12	PU12	–	POM12	PMC12	√	√	√	√
	3	PM13	P13	PU13	–	POM13	PMC13	√	√	√	–
	4	PM14	P14	PU14	PIM14	POM14	PMC14	√	√	√	–
	5	PM15	P15	PU15	PIM15	POM15	PMC15	√	√	√	–
	6	PM16	P16	PU16	PIM16	–	–	√	√	–	–
Port 2	0	PM20	P20	–	–	–	–	√	√	√	√
	1	PM21	P21	–	–	–	–	√	√	√	√
	2	PM22	P22	–	–	–	–	√	√	√	√
	3	PM23	P23	–	–	–	–	√	√	√	√
	4	PM24	P24	–	–	–	–	√	√	√	–
	5	PM25	P25	–	–	–	–	√	√	–	–
	6	PM26	P26	–	–	–	–	√	√	–	–
	7	PM27	P27	–	–	–	–	√	√	–	–

Remark √: Mounted, –: Not mounted

Table 4-4. PMxx, Pxx, PUxx, PIMxx, POMxx, PMCxx registers and the bits mounted on each product (2/2)

Port		Bit Name						64-pin	48-pin	32-pin	25-pin
		PMxx Register	Pxx Register	PUxx Register	PIMxx Register	POMxx Register	PMCxx Register				
Port 3	0	PM30	P30	PU30	–	–	PMC30	√	√	√	√
	1	PM31	P31	PU31	–	–	PMC31	√	√	√	√
Port 4	0	PM40	P40	PU40	–	–	–	√	√	√	√
	1	PM41	P41	PU41	–	–	PMC41	√	√	–	–
	2	PM42	P42	PU42	–	–	–	√	–	–	–
	3	PM43	P43	PU43	–	–	–	√	–	–	–
Port 5	0	PM50	P50	PU50	–	POM50	PMC50	√	√	√	√
	1	PM51	P51	PU51	–	–	PMC51	√	√	√	√
Port 6	0	PM60	P60	–	–	–	–	√	√	√	√
	1	PM61	P61	–	–	–	–	√	√	√	√
	2	PM62	P62	–	–	–	–	√	√	√	–
	3	PM63	P63	–	–	–	–	√	√	–	–
Port 7	0	PM70	P70	PU70	–	–	PMC70	√	√	√	–
	1	PM71	P71	PU71	–	POM71	–	√	√	–	–
	2	PM72	P72	PU72	–	–	–	√	√	–	–
	3	PM73	P73	PU73	–	–	–	√	√	–	–
	4	PM74	P74	PU74	–	POM74	–	√	√	–	–
	5	PM75	P75	PU75	–	–	–	√	√	–	–
	6	PM76	P76	PU76	–	–	–	√	–	–	–
	7	PM77	P77	PU77	–	–	–	√	–	–	–
Port 12	0	PM120	P120	PU120	–	–	PMC120	√	√	√	–
	1	–	P121	–	–	–	–	√	√	√	√
	2	–	P122	–	–	–	–	√	√	√	√
	3	–	P123	–	–	–	–	√	√	–	–
	4	–	P124	–	–	–	–	√	√	–	–
Port 13	0	–	P130	–	–	–	–	√	√	–	–
	7	–	P137	–	–	–	–	√	√	√	√
Port 14	0	PM140	P140	PU140	–	–	–	√	√	–	–
	1	PM141	P141	PU141	–	–	–	√	–	–	–
Port 15	–	PM150	P150	–	–	–	–	√	√	–	–
	–	PM151	P151	–	–	–	–	√	–	–	–
	–	PM152	P152	–	–	–	–	√	–	–	–
	–	PM153	P153	–	–	–	–	√	–	–	–
	–	PM154	P154	–	–	–	–	√	–	–	–

Remark √: Mounted, –: Not mounted

4.3.1 Port mode registers (PMxx)

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

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

Reset signal generation sets these registers to FFH.

When port pins are used as alternate-function pins, set the port mode register by referencing **4.5 Register Settings When Using Alternate Function**.

Figure 4-1. Format of Port Mode Register

Symbol	7	6	5	4	3	2	1	0	Address	After reset	R/W
PM0	1	PM06	PM05	PM04	PM03	PM02	PM01	PM00	FFF20H	FFH	R/W
PM1	1	PM16	PM15	PM14	PM13	PM12	PM11	PM10	FFF21H	FFH	R/W
PM2	PM27	PM26	PM25	PM24	PM23	PM22	PM21	PM20	FFF22H	FFH	R/W
PM3	1	1	1	1	1	1	PM31	PM30	FFF23H	FFH	R/W
PM4	1	1	1	1	PM43	PM42	PM41	PM40	FFF24H	FFH	R/W
PM5	1	1	1	1	1	1	PM51	PM50	FFF25H	FFH	R/W
PM6	1	1	1	1	PM63	PM62	PM61	PM60	FFF26H	FFH	R/W
PM7	PM77	PM76	PM75	PM74	PM73	PM72	PM71	PM70	FFF27H	FFH	R/W
PM12	1	1	1	1	1	1	1	PM120	FFF2CH	FFH	R/W
PM14	1	1	1	1	1	1	PM141	PM140	FFF2EH	FFH	R/W
PM15	1	1	1	PM154	PM153	PM152	PM151	PM150	FFF2FH	FFH	R/W
PMmn	Pmn pin I/O mode selection (m = 0 to 7, 12, 14, 15; n = 0 to 7)										
0	Output mode (output buffer on)										
1	Input mode (output buffer off)										

Caution Be sure to set bits that are not mounted to their initial values.

4.3.2 Port registers (Pxx)

These registers set the output latch value of a port.

If the data is read in the input mode, the pin level is read. If it is read in the output mode, the output latch value is read^{Note}.

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

Reset signal generation clears these registers to 00H.

Note If P02, P03, P10 to P15, P20 to P27, P30, P31, P41, P50, P51, P70, P120, and P150 to P154 are set up as analog inputs of the A/D converter, when a port is read while in the input mode, 0 is always returned, not the pin level.

Figure 4-2. Format of Port Register

Symbol	7	6	5	4	3	2	1	0	Address	After reset	R/W
P0	0	P06	P05	P04	P03	P02	P01	P00	FFF00H	00H (output latch)	R/W
P1	0	P16	P15	P14	P13	P12	P11	P10	FFF01H	00H (output latch)	R/W
P2	P27	P26	P25	P24	P23	P22	P21	P20	FFF02H	00H (output latch)	R/W
P3	0	0	0	0	0	0	P31	P30	FFF03H	00H (output latch)	R/W
P4	0	0	0	0	P43	P42	P41	P40	FFF04H	00H (output latch)	R/W
P5	0	0	0	0	0	0	P51	P50	FFF05H	00H (output latch)	R/W
P6	0	0	0	0	P63	P62	P61	P60	FFF06H	00H (output latch)	R/W
P7	P77	P76	P75	P74	P73	P72	P71	P70	FFF07H	00H (output latch)	R/W
P12	0	0	0	P124	P123	P122	P121	P120	FFF0CH	Undefined	R/W ^{Note 1}
P13	P137	0	0	0	0	0	0	P130	FFF0DH	Note 2	R/W ^{Note 1}
P14	0	0	0	0	0	0	P141	P140	FFF0EH	00H (output latch)	R/W
P15	0	0	0	P154	P153	P152	P151	P150	FFF0FH	00H (output latch)	R/W

Pmn	Output data control (in output mode)	Input data read (in input mode)
0	Output 0	Input low level
1	Output 1	Input high level

Notes 1. P121 to P124, and P137 are read-only.

2. P137 : Undefined

P130 : 0 (output latch)

Caution Be sure to set bits that are not mounted to their initial values.

Remark m = 0 to 7, 12 to 15; n = 0 to 7

4.3.3 Pull-up resistor option registers (PUxx)

These registers specify whether the on-chip pull-up resistors are to be used or not. On-chip pull-up resistors can be used in 1-bit units only for the bits set to both normal output mode (POMmn = 0) and input mode (PMmn = 1) for the pins to which the use of an on-chip pull-up resistor has been specified in these registers. On-chip pull-up resistors cannot be connected to bits set to output mode and bits used as alternate-function output pins and analog setting (PMC = 1, ADPC = 1), regardless of the settings of these registers.

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

Reset signal generation clears these registers to 00H (Only PU4 is set to 01H).

Caution When a port with the PIMn register is input from different potential device to the TTL buffer, pull up to the power supply of the different potential device via an external resistor by setting PUMn = 0.

Figure 4-3. Format of Pull-up Resistor Option Register

Symbol	7	6	5	4	3	2	1	0	Address	After reset	R/W
PU0	0	PU06	PU05	PU04	PU03	PU02	PU01	PU00	F0030H	00H	R/W
PU1	0	PU16	PU15	PU14	PU13	PU12	PU11	PU10	F0031H	00H	R/W
PU3	0	0	0	0	0	0	PU31	PU30	F0033H	00H	R/W
PU4	0	0	0	0	PU43	PU42	PU41	PU40	F0034H	01H	R/W
PU5	0	0	0	0	0	0	PU51	PU50	F0035H	00H	R/W
PU7	PU77	PU76	PU75	PU74	PU73	PU72	PU71	PU70	F0037H	00H	R/W
PU12	0	0	0	0	0	0	0	PU120	F003CH	00H	R/W
PU14	0	0	0	0	0	0	PU141	PU140	F003EH	00H	R/W
PUMn	Pmn pin on-chip pull-up resistor selection (m = 0, 1, 3 to 5, 7, 12, 14; n = 0 to 7)										
0	On-chip pull-up resistor not connected										
1	On-chip pull-up resistor connected										

Caution Be sure to set bits that are not mounted to their initial values.

4.3.4 Port input mode registers (PIMxx)

These registers set the input buffer in 1-bit units.

TTL input buffer can be selected during serial communication with an external device of the different potential.

Port input mode registers can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears these registers to 00H.

Figure 4-4. Format of Port Input Mode Register

Symbol	7	6	5	4	3	2	1	0	Address	After reset	R/W
PIM0	0	0	0	PIM04	PIM03	0	PIM01	PIM00	F0040H	00H	R/W
PIM1	0	PIM16	PIM15	PIM14	0	0	PIM11	PIM10	F0041H	00H	R/W
PIMmn	Pmn pin input buffer selection (m = 0, 1 ; n = 0, 1, 3 to 6)										
0	Normal input buffer										
1	TTL input buffer										

Caution Be sure to set bits that are not mounted to their initial values.

4.3.5 Port output mode registers (POMxx)

These registers set the output mode in 1-bit units.

N-ch open drain output (V_{DD} tolerance^{Note 1}/ EV_{DD} tolerance^{Note 2}) mode can be selected during serial communication with an external device of the different potential, and for the SDA00, SDA01, SDA10, SDA11, SDA20, and SDA21 pins during simplified I²C communication with an external device of the same potential.

In addition, POMxx register is set with PUxx register, whether or not to use the on-chip pull-up resistor.

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

Reset signal generation clears these registers to 00H.

Caution An on-chip pull-up resistor is not connected to a bit for which N-ch open drain output (V_{DD} tolerance^{Note 1}/ EV_{DD} tolerance^{Note 2}) mode (POMmn = 1) is set.

Figure 4-5. Format of Port Input Mode Register

Symbol	7	6	5	4	3	2	1	0	Address	After reset	R/W
POM0	0	0	0	POM04	POM03	POM02	0	0	F0050H	00H	R/W
POM1	0	0	POM15	POM14	POM13	POM12	POM11	POM10	F0051H	00H	R/W
POM5	0	0	0	0	0	0	0	POM50	F0055H	00H	R/W
POM7	0	0	0	POM74	0	0	POM71	0	F0057H	00H	R/W
POMmn	Pmn pin output mode selection (m = 0, 1, 5, 7; n = 0 to 5)										
0	Normal output mode										
1	N-ch open-drain output (V_{DD} tolerance ^{Note 1} / EV_{DD} tolerance ^{Note 2}) mode										

Notes 1. For 25- to 48-pin products

2. For 64-pin products

Caution Be sure to set bits that are not mounted to their initial values.

4.3.6 Port mode control registers (PMCxx)

These registers set the digital I/O/analog input in 1-bit units.

Port mode control registers can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears these registers to FFH.

Figure 4-6. Format of Port Mode Control Register

Symbol	7	6	5	4	3	2	1	0	Address	After reset	R/W
PMC0	1	1	1	1	PMC03	PMC02	1	1	F0060H	FFH	R/W
PMC1	1	1	PMC15	PMC14	PMC13	PMC12	PMC11	PMC10	F0061H	FFH	R/W
PMC3	1	1	1	1	1	1	PMC31	PMC30	F0063H	FFH	R/W
PMC4	1	1	1	1	1	1	PMC41	1	F0064H	FFH	R/W
PMC5	1	1	1	1	1	1	PMC51	PMC50	F0065H	FFH	R/W
PMC7	1	1	1	1	1	1	1	PMC70	F0067H	FFH	R/W
PMC12	1	1	1	1	1	1	1	PMC120	F006CH	FFH	R/W
PMCmn	Pmn pin digital I/O/analog input selection (m = 0, 1, 3 to 5, 7, 12; n = 0 to 5)										
0	Digital I/O (alternate function other than analog input)										
1	Analog input										

- Cautions 1.** Select input mode by using port mode registers 0, 1, 3 to 5, 7, 12 (PM0, PM1, PM3 to PM5, PM7, PM12) for the ports which are set by the PMCxx register as analog input.
- 2.** Do not set the pin set by the PMCxx register as digital I/O by the analog input channel specification register (ADS).
- 3.** Be sure to set bits that are not mounted to their initial values.

4.3.7 A/D port configuration register (ADPC)

This register switches the P20/ANI0 to P27/ANI7, and P150/ANI8 to P154/ANI12 pins to digital I/O of port or analog input of A/D converter.

The ADPC register can be set by an 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 4-7. Format of A/D Port Configuration Register (ADPC)

Address: F0076H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADPC	0	0	0	0	ADPC3	ADPC2	ADPC1	ADPC0

ADPC3	ADPC2	ADPC1	ADPC0	Analog input (A)/digital I/O (D) switching												
				ANI12/P154	ANI11/P153	ANI10/P152	ANI9/P151	ANI8/P150	ANI7/P27	ANI6/P26	ANI5/P25	ANI4/P24	ANI3/P23	ANI2/P22	ANI1/P21	ANI0/P20
0	0	0	0	A	A	A	A	A	A	A	A	A	A	A	A	A
0	0	0	1	D	D	D	D	D	D	D	D	D	D	D	D	D
0	0	1	0	D	D	D	D	D	D	D	D	D	D	D	D	A
0	0	1	1	D	D	D	D	D	D	D	D	D	D	D	A	A
0	1	0	0	D	D	D	D	D	D	D	D	D	D	A	A	A
0	1	0	1	D	D	D	D	D	D	D	D	D	A	A	A	A
0	1	1	0	D	D	D	D	D	D	D	D	A	A	A	A	A
0	1	1	1	D	D	D	D	D	D	D	A	A	A	A	A	A
1	0	0	0	D	D	D	D	D	D	A	A	A	A	A	A	A
1	0	0	1	D	D	D	D	D	A	A	A	A	A	A	A	A
1	0	1	0	D	D	D	D	A	A	A	A	A	A	A	A	A
1	0	1	1	D	D	D	A	A	A	A	A	A	A	A	A	A
1	1	0	0	D	D	A	A	A	A	A	A	A	A	A	A	A
1	1	0	1	D	A	A	A	A	A	A	A	A	A	A	A	A
1	1	1	0	A	A	A	A	A	A	A	A	A	A	A	A	A
1	1	1	1	A	A	A	A	A	A	A	A	A	A	A	A	A

- Cautions**
1. Set the port to analog input by ADPC register to the input mode by using port mode registers 2, 15 (PM2, PM15).
 2. Do not set the pin set by the ADPC register as digital I/O by the analog input channel specification register (ADS).
 3. When using AV_{REFP} and AV_{REFM} , set ANI0 and ANI1 to analog input and set the port mode register to the input mode.

4.3.8 Peripheral I/O redirection register (PIOR)

This register is used to specify whether to enable or disable the peripheral I/O redirect function.

This function is used to switch ports to which alternate functions are assigned.

Use the PIOR register to assign a port to the function to redirect and enable the function.

In addition, can be changed the settings for redirection until its function enable operation. The PIOR register can be set by an 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 4-8. Format of Peripheral I/O Redirection Register (PIOR)

Address: F0077H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
PIOR	0	0	0	0	0	0	PIOR1	PIOR0

Alternate function	64-pin				48-pin				32-pin				25-pin			
	Setting value of PIOR1, PIOR0				Setting value of PIOR1, PIOR0				Setting value of PIOR1, PIOR0				Setting value of PIOR1, PIOR0			
	0, 0	0, 1	1, 0	1, 1	0, 0	0, 1	1, 0	1, 1	0, 0	0, 1	1, 0	1, 1	0, 0	0, 1	1, 0	1, 1
KR0	P70	Setting prohibited	P00	P10	P70	Setting prohibited	P02	P10	P70	Setting prohibited	P120	P10	—	Setting prohibited	P02	Setting prohibited
KR1	P71		P01	P11	P71		P03	P11	—		P02	P11	—		P03	
KR2	P72		P02	P12	P72		P22	P12	—		P03	P12	—		P22	
KR3	P73		P03	P13	P73		P23	P13	—		P22	P13	—		P23	
KR4	P74		P04	P14	P74		P24	P14	—		P23	P14	—		—	
KR5	P75		P22	P15	P75		P25	P15	—		P24	P15	—		—	
KR6	P76		P23	P151	—		—	—	—		—	—	—		—	
KR7	P77		P24	P152	—		—	—	—		—	—	—		—	
KR8	P05		P25	P153	—		—	—	—		—	—	—		—	
KR9	P06		P26	P154	—		—	—	—		—	—	—		—	

Remark —: These functions are not available for use.

4.3.9 Global digital input disable register (GDIDIS)

This register is used to prevent through-current flowing to the input buffers of input ports which use EV_{DD0} as the power supply when the EV_{DD0} power supply is turned off.

When not all of the I/O ports using EV_{DD0} as the power supply are used, low power consumption can be achieved by setting the GDIDIS register (to 1) to turn off the EV_{DD0} power supply.

By setting the GDIDIS0 bit to 1, input to any input buffer using EV_{DD0} as the power supply is prohibited, preventing through-current from flowing when the EV_{DD0} power supply is turned off.

The GDIDIS register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Remark GDIDIS register is equipped with 64-pin products.

Figure 4-9. Format of Global Digital Input Disable Register (GDIDIS)

Address: F007DH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
GDIDIS	0	0	0	0	0	0	0	GDIDIS0

GDIDIS0	Setting of input buffers using EV _{DD0} power supply
0	Input to input buffers permitted (default)
1	Input to input buffers prohibited. No through-current flows to the input buffers.

Turn off the EV_{DD0} power supply with the following procedure.

- <1> Prohibit input to input buffers (set GDIDIS0 = 1).
- <2> Turn off the EV_{DD0} power supply.

Turn on again the EV_{DD0} power supply with the following procedure.

- <1> Turn on the EV_{DD0} power supply.
- <2> Permit input to input buffers (set GDIDIS0 = 0).

- Cautions**
1. Do not input an input voltage equal to or greater than EV_{DD0} to an input port that uses EV_{DD0} as the power supply.
 2. When input to input buffers is prohibited (GDIDIS0 = 1), the value read from the port register (Pxx) of a port that uses EV_{DD0} as the power supply is 1. When 1 is set in the port output mode register (POMxx) (N-ch open drain output (EV_{DD0} tolerance)), the value read from the port register (Pxx) is 0.

Remark Even when input to input buffers is prohibited (GDIDIS0 = 1), peripheral functions which do not use port functions having EV_{DD0} as the power supply can be used.

4.3.10 Global analog input disable register (GAIDIS)

This register is used to prevent through-current flowing from the input buffers of input ports which use AV_{DD} as the power supply when the AV_{DD} power supply is turned off.

When not all of the I/O ports using AV_{DD} as the power supply are used, low power consumption can be achieved by setting the GAIDIS register (to 1) to turn off the AV_{DD} power supply.

By setting the GAIDIS0 bit to 1, input to any input buffer using AV_{DD} as the power supply is prohibited, preventing through-current from flowing when the AV_{DD} power supply is turned off.

When using the GAIDIS register, set the GAIDIS0 bit to 1 while the AV_{DD} voltage is 1.6 V or higher, and then reduce the AV_{DD} voltage to 0 V.

Set GAIDIS0 to 0 after applying power to AV_{DD}.

The GAIDIS register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 4-10. Format of Global Analog Input Disable Register (GAIDIS)

Address: F007CH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
GAIDIS	0	0	0	0	0	0	0	GAIDIS0

GAIDIS0	Setting of input buffers using AV _{DD} power supply
0	Input to input buffers permitted (default)
1	Input to input buffers prohibited. No through-current flows to the input buffers.

Turn off the AV_{DD} power supply with the following procedure.

<1> Prohibit input to input buffers (set GAIDIS0 = 1).

<2> Turn off the AV_{DD} power supply.

Turn on again the AV_{DD} power supply with the following procedure.

<1> Turn on the AV_{DD} power supply.

<2> Permit input to input buffers (set GAIDIS0 = 0).

Cautions 1. Do not input an input voltage equal to or greater than AV_{DD} to an input port that uses AV_{DD} as the power supply.

2. When input to input buffers is prohibited (GAIDIS0 = 1), the value read from the port register (Pxx) of a port that uses AV_{DD} as the power supply is 1.

Remark Even when input to input buffers is prohibited (GAIDIS0 = 1), peripheral functions which do not use port functions having EV_{DD} as the power supply can be used.

4.4 Port Function Operations

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

4.4.1 Writing to I/O port

(1) Output mode

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

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

The data of the output latch is cleared when a reset signal is generated.

(2) Input mode

A value is written to the output latch by a transfer instruction, but since the output buffer is off, the pin status does not change. Therefore, byte data can be written to the ports used for both input and output.

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

The data of the output latch is cleared when a reset signal is generated.

4.4.2 Reading from I/O port

(1) Output mode

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

(2) Input mode

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

4.4.3 Operations on I/O port

(1) Output mode

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

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

The data of the output latch is cleared when a reset signal is generated.

(2) Input mode

The pin level is read and an operation is performed on its contents. The result of the operation is written to the output latch, but since the output buffer is off, the pin status does not change. Therefore, byte data can be written to the ports used for both input and output.

The data of the output latch is cleared when a reset signal is generated.

4.4.4 Handling different potential (1.8 V or 2.5 V) by using $EV_{DD} \leq V_{DD}$

When connecting an external device operating on a different potential (1.8 V or 2.5 V), it is possible to connect the I/O pins of general ports by changing EV_{DD} to accord with the power supply of the connected device.

4.4.5 Handling different potential (1.8 V or 2.5 V) by using I/O buffers

It is possible to connect an external device operating on a different potential (1.8 V or 2.5 V) by switching I/O buffers with the port input mode register (PIMxx) and port output mode register (POMxx).

When receiving input from an external device with a different potential (1.8 V or 2.5 V), set the port input mode registers 0 and 1 (PIM0 and PIM1) on a bit-by-bit basis to enable normal input (CMOS)/TTL input buffer switching.

When outputting data to an external device with a different potential (1.8 V or 2.5 V), set the port output mode registers 0, 1, and 7 (POM0, POM1, and POM7) on a bit-by-bit basis to enable normal output (CMOS)/N-ch open drain (V_{DD} tolerance^{Note 1}/ EV_{DD} tolerance^{Note 2}) switching.

Following, describes the connection of a serial interface.

Notes 1. For 25- to 48-pin products

2. For 64-pin products

(1) Setting procedure when using input ports of UART0 to UART2, CSI00, CSI10, and CSI20 functions for the TTL input buffer

In case of UART0:	P11
In case of UART1:	P03
In case of UART2:	P14
In case of CSI00:	P10, P11
In case of CSI10:	P03, P04
In case of CSI20:	P14, P15

<1> Using an external resistor, pull up externally the input pin to be used to the power supply of the target device (on-chip pull-up resistor cannot be used).

<2> Set the corresponding bit of the PIM0 and PIM1 registers to 1 to switch to the TTL input buffer. For V_{IH} and V_{IL} , refer to the DC characteristics when the TTL input buffer is selected.

<3> Enable the operation of the serial array unit and set the mode to the UART/Simplified SPI (CSI)^{Note} mode.

Note Although the CSI function is generally called SPI, it is also called CSI in this product, so it is referred to as such in this manual.

(2) Setting procedure when using output ports of UART0 to UART2, CSI00, CSI10, and CSI20 functions in N-ch open-drain output mode

In case of UART0:	P12
In case of UART1:	P02
In case of UART2:	P13
In case of CSI00:	P10, P12
In case of CSI10:	P02, P04
In case of CSI20:	P13, P15

- <1> Using an external resistor, pull up externally the output pin to be used to the power supply of the target device (on-chip pull-up resistor cannot be used).
- <2> After reset release, the port mode is the input mode (Hi-Z).
- <3> Set the output latch of the corresponding port to 1.
- <4> Set the corresponding bit of the POM0 and POM1 registers to 1 to set the N-ch open drain output (V_{DD} tolerance^{Note 1}/EV_{DD} tolerance^{Note 2}) mode.
- <5> Enable the operation of the serial array unit and set the mode to the UART/Simplified SPI (CSI) mode.
- <6> Set the output mode by manipulating the PM0 and PM1 registers. At this time, the output data is high level, so the pin is in the Hi-Z state.

- Notes**
1. For 25- to 48-pin products
 2. For 64-pin products

(3) Setting procedure when using I/O ports of IIC00, IIC10, and IIC20 functions with a different potential (1.8 V or 2.5 V)

In case of IIC00:	P10, P11
In case of IIC10:	P03, P04
In case of IIC20:	P14, P15

- <1> Using an external resistor, pull up externally the input pin to be used to the power supply of the target device (on-chip pull-up resistor cannot be used).
- <2> After reset release, the port mode is the input mode (Hi-Z).
- <3> Set the output latch of the corresponding port to 1.
- <4> Set the corresponding bit of the POM0 and POM1 registers to 1 to set the N-ch open drain output (V_{DD} tolerance^{Note 1}/EV_{DD} tolerance^{Note 2}) mode.
- <5> Set the corresponding bit of the PIM0 and PIM1 registers to 1 to switch to the TTL input buffer. For V_{IH} and V_{IL} , refer to the DC characteristics when the TTL input buffer is selected.
- <6> Enable the operation of the serial array unit and set the mode to the simplified I²C mode.
- <7> Set the corresponding bit of the PM0 and PM1 registers to the output mode (data I/O is possible in the output mode). At this time, the output data is high level, so the pin is in the Hi-Z state.

- Notes**
1. For 25- to 48-pin products
 2. For 64-pin products

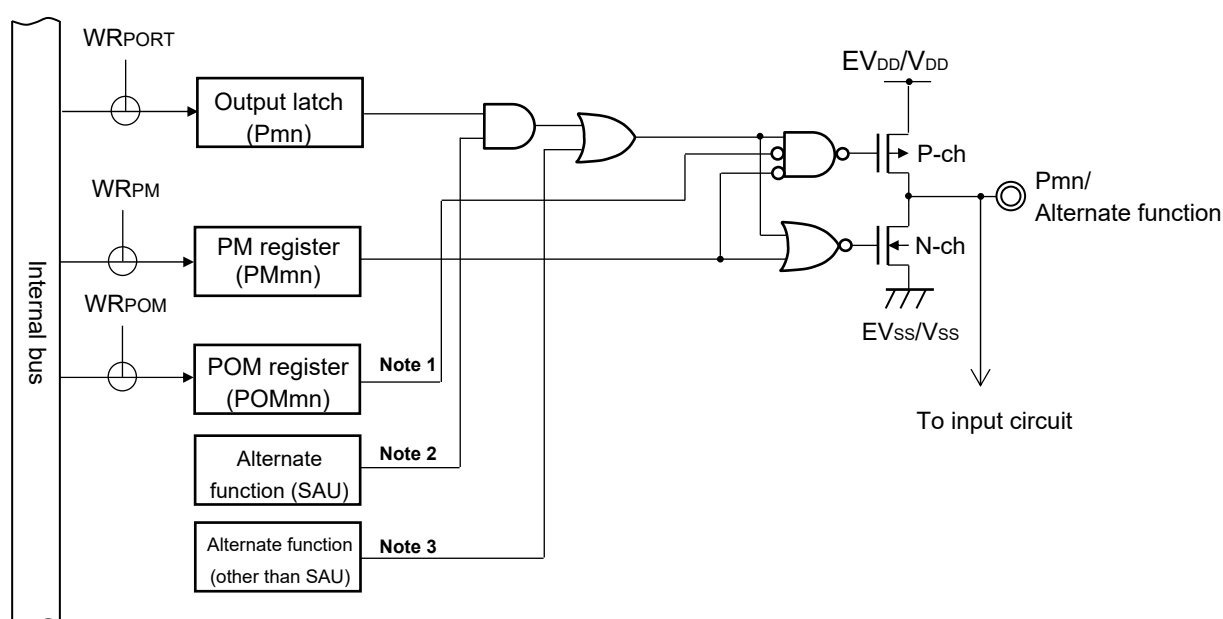
4.5 Register Settings When Using Alternate Function

4.5.1 Basic concept when using alternate function

In the beginning, for a pin also assigned to be used for analog input, use the ADPC register or port mode control register (PMCxx) to specify whether to use the pin for analog input or digital input/output.

Figure 4-11 shows the basic configuration of an output circuit for pins used for digital input/output. The output of the output latch for the port and the output of the alternate SAU function are input to an AND gate. The output of the AND gate is input to an OR gate. The output of an alternate function other than SAU (TAU, RTC, clock/buzzer output, IICA, etc.) is connected to the other input pin of the OR gate. When such kind of pins are used by the port function or an alternate function, the unused alternate function must not hinder the output of the function to be used. An idea of basic settings for this kind of case is shown in Table 4-5.

Figure 4-11. Basic Configuration of Output Circuit for Pins



- Notes**
1. When there is no POM register, this signal should be considered to be low level (0).
 2. When there is no alternate function, this signal should be considered to be high level (1).
 3. When there is no alternate function, this signal should be considered to be low level (0).

Remark m: Port number (m = 0 to 7, 12 to 15); n: Bit number (n = 0 to 7)

Table 4-5. Concept of Basic Settings

Output Function of Used Pin	Output Settings of Unused Alternate Function		
	Output Function for Port	Output Function for SAU	Output Function for other than SAU
Output function for port	–	Output is high (1)	Output is low (0)
Output function for SAU	High (1)	–	Output is low (0)
Output function for other than SAU	Low (0)	Output is high (1)	Output is low (0) ^{Note}

Note Since more than one output function other than SAU may be assigned to a single pin, the output of an unused alternate function must be set to low level (0). For details on the setting method, see **4.5.2 Register settings for alternate function whose output function is not used**.

4.5.2 Register settings for alternate function whose output function is not used

When the output of an alternate function of the pin is not used, the following settings should be made. Note that when the peripheral I/O redirection function is the target, the output can be switched to another pin by setting the peripheral I/O redirection register (PIOR). This allows usage of the port function or other alternate function assigned to the target pin.

(1) SOp = 1, TxDq = 1 (settings when the serial output (SOp/TxDq) of SAU is not used)

When the serial output (SOp/TxDq) is not used, such as, a case in which only the serial input of SAU is used, set the bit in serial output enable register m (SOEm) which corresponds to the unused output to 0 (output disabled) and set the SOMn bit in serial output register m (SOM) to 1 (high). These are the same settings as the initial state.

(2) SCKp = 1, SDAr = 1, SCLr = 1 (settings when channel n in SAU is not used)

When SAU is not used, set bit n (SEmn) in serial channel enable status register m (SEm) to 0 (operation stopped state), set the bit in serial output enable register m (SOEm) which corresponds to the unused output to 0 (output disabled), and set the SOMn and CKOMn bits in serial output register m (SOM) to 1 (high). These are the same settings as the initial state.

(3) TOMn = 0 (settings when the output of channel n in TAU is not used)

When the TOMn output of TAU is not used, set the bit in timer output enable register 0 (TOE0) which corresponds to the unused output to 0 (output disabled) and set the bit in timer output register 0 (TO0) to 0 (low). These are the same settings as the initial state.

(4) SDAA_n = 0, SCLAn = 0 (setting when IICA is not used)

When IICA is not used, set the IICEn bit in IICA control register n0 (IICCTLn0) to 0 (operation stopped). This is the same setting as the initial state.

(5) PCLBUZn = 0 (setting when clock/buzzer output is not used)

When the clock/buzzer output is not used, set the PCLOEn bit in clock output select register n (CKSn) to 0 (output disabled). This is the same setting as the initial state.

4.5.3 Register setting examples for used port and alternate functions

Register setting examples for used port and alternate functions are shown in Table 4-6. The registers used to control the port functions should be set as shown in Table 4-6. See the following remark for legends used in Table 4-6.

Remark —: Not supported
 ×: don't care
 PIORx: Peripheral I/O redirection register
 POMxx: Port output mode register
 PMCxx: Port mode control register
 PMxx: Port mode register
 Pxx: Port output latch
 Functions in parentheses can be assigned via settings in the peripheral I/O redirection register (PIOR).

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (1/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P00	P00	Input	–	–	–	1	×	–	–	×	×	×	√
		Output	–	–	–	0	0/1	–	–				
	TI00	Input	×	–	–	1	×	–	–	×	×	×	√
	(KR0)	Input	02H ^{Note 1}	–	–	1	×	–	–	×	×	×	√
P01	P01	Input	–	–	–	1	×	–	×	×	×	×	√
		Output	–	–	–	0	0/1	–	TO00 = 0				
	TO00	Output	×	–	–	0	0	–	×	×	×	×	√
	(KR1)	Input	02H ^{Note 1}	–	–	1	×	–	×	×	×	×	√
P02	P02	Input	–	–	0	1	×	×	–				
		Output	–	0	0	0	0/1	TxD1 = 1, SO10 = 1 ^{Note 1}	–	√	√	√	√
		N-ch open drain output	–	1	0	0	0/1		–				
	ANI17	Analog input	×	×	1	1	×	×	–	√	√	√	√
	TxD1	Output	×	0/1	0	0	1	×	–	√	√	√	√
	TI00	Input	×	×	0	1	×	×	–	√	√	√	×
	SO10	Output	×	0/1	0	0	1	×	–	×	×	×	√
	(KR0)	Input	02H ^{Note 2}	×	0	1	×	×	–	√	×	√	×
	(KR1)	Input	02H ^{Note 3}	×	0	1	×	×	–	×	√	×	×
	(KR2)	Input	02H ^{Note 1}	×	0	1	×	×	–	×	×	×	√

- Notes**
1. 64-pin products only
 2. 25- and 48-pin products only
 3. 32-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (2/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P03	P03	Input	–	–	0	1	×	–	×	√	√	√	√
		Output	–	0	0	0	0/1	–	SDA10 = 1 ^{Note 3} TO00 = 0 ^{Note 4}				
		N-ch open drain output	–	1	0	0	0/1	–	×				
	ANI16	Analog input	×	×	1	1	×	–	×	√	√	√	√
	SI10	Input	×	×	0	1	×	–	×	×	×	×	√
	RxD1	Input	×	×	0	1	×	–	×	√	√	√	√
	SDA10	I/O	×	1	0	0	1	–	×	×	×	×	√
	TO00	Output	×	0/1	0	0	1	–	×	√	√	√	×
	(KR1)	Input	02H ^{Note 4}	×	0	1	×	–	×	√	×	√	×
	(KR2)	Input	02H ^{Note 2}	×	0	1	×	–	×	×	√	×	×
	(KR3)	Input	02H ^{Note 3}	×	0	1	×	–	×	×	×	×	√
P04	P04	Input	–	–	–	1	×	×	–	×	×	×	√
		Output	–	0	–	0	0/1	SCK10 = 1, SCL10 = 1	–				
		N-ch open drain output	–	1	–	0	0/1						
	SCK10	Input	×	×	–	1	×	×	–	×	×	×	√
		Output	×	0/1	–	0	1	×	–	×	×	×	√
	SCL10	Output	×	0/1	–	0	1	×	–	×	×	×	√
	(KR4)	Input	02H ^{Note 3}	×	–	1	×	×	–	×	×	×	√
P05	P05	Input	–	–	–	1	×	–	×	×	×	×	√
		Output	–	–	–	0	0/1	–	TO05 = 0				
	TI05	Input	×	–	–	1	×	–	×	×	×	×	√
	TO05	Output	×	–	–	0	1	–	×	×	×	×	√
	KR8	Input	00H ^{Note 3}	–	–	1	×	–	×	×	×	×	√
P06	P06	Input	–	–	–	1	×	–	×	×	×	×	√
		Output	–	–	–	0	0/1	–	TO06 = 0				
	TI06	Input	×	–	–	1	×	–	×	×	×	×	√
	TO06	Output	×	–	–	0	1	–	×	×	×	×	√
	KR9	Input	00H ^{Note 3}	–	–	1	×	–	×	×	×	×	√

Notes 1. 25- and 48-pin products only

2. 32-pin products only

3. 64-pin products only

4. 25- to 48-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (3/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P10	P10	Input	–	×	–	1	×	×	–	√	√	√	√
		Output	–	0	–	0	0/1	SCK00 = 1, SCL00 = 1	–				
		N-ch open drain output	–	1	–	0	0/1	×	–				
	ANI18	Analog input	×	×	1	1	×	×	–	√	√	√	√
	SCK00	Input	×	×	0	1	×	×	–	√	√	√	√
		Output	×	0/1	0	0	1	×	–	√	√	√	√
	SCL00	Output	×	0/1	0	0	1	×	–	√	√	√	√
	(KR0)	Input	03H ^{Note}	×	0	1	×	×	–	×	√	√	√
P11	P11	Input	–	×	–	1	×	–	–	√	√	√	√
		Output	–	0	–	0	0/1	–	SDA00 = 0				
		N-ch open drain output	–	1	–	0	0/1						
	ANI20	Analog input	×	×	1	1	×	–	×	√	√	√	√
	SI00	Input	×	×	0	1	×	–	×	√	√	√	√
	SDA00	I/O	×	1	0	0	1	–	×	√	√	√	√
	RxD0	Input	×	×	0	1	×	–	×	√	√	√	√
	TOOLRxD	Input	×	×	0	1	×	–	×	√	√	√	√
(KR1)	Input	03H ^{Note}	×	0	1	×	–	×	×	√	√	√	
P12	P12	Input	–	×	–	1	×	×	×	√	√	√	√
		Output	–	0	–	0	0/1	SO00 = 1, Tx00 = 1	TOOLTxD = 0				
		N-ch open drain output	–	1	–	0	0/1	×	×				
	ANI21	Analog input	×	×	1	1	×	×	×	√	√	√	√
	SO00	Output	×	0/1	0	0	1	×	TOOLTxD = 0	√	√	√	√
	TxD0	Output	×	0/1	0	0	1	×	TOOLTxD = 0	√	√	√	√
	TOOLTxD	Output	×	0/1	0	0	1	SO00 = 1, Tx00 = 1	×	√	√	√	√
	(KR2)	Input	03H ^{Note}	×	0	1	×	×	×	×	√	√	√

Note 32- to 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (4/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P13	P13	Input	–	×	–	1	×	×	–	×	✓	✓	✓
		Output	–	0	–	0	0/1	SO20 = 1 TxD2 = 1	–				
		N-ch open drain output	–	1	–	0	0/1	×	–				
	ANI22	Analog input	×	×	1	1	×	×	–	×	✓	✓	✓
	SO20	Output	×	0/1	0	0	1	×	–	×	✓	✓	✓
	TxD2	Output	×	0/1	0	0	1	×	–	×	✓	✓	✓
	(KR3)	Input	03H ^{Note}	×	0	1	×	×	–	×	✓	✓	✓
P14	P14	Input	–	×	–	1	×	–	×	×	✓	✓	✓
		Output	–	0	–	0	0/1	–	SDA20 = 0				
		N-ch open drain output	–	1	–	0	0/1						
	ANI23	Analog input	×	×	1	1	×	–	×	×	✓	✓	✓
	SI20	Input	×	×	0	1	×	–	×	×	✓	✓	✓
	SDA20	I/O	×	1	0	0	1	–	×	×	✓	✓	✓
	RxD2	Input	×	×	0	1	×	–	×	×	✓	✓	✓
	(KR4)	Input	03H ^{Note}	×	0	1	×	–	×	×	✓	✓	✓

Note 32- to 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (5/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P15	P15	Input	–	×	–	1	×	×	×				
		Output	–	0	–	0	0/1	SCK20 = 1 ^{Note 1} SCL20 = 1 ^{Note 1}	PCLBUZ1 = 0 ^{Note 2}	×	√	√	√
		N-ch open drain output	–	1	–	0	0/1						
	ANI24	Analog input	×	×	1	1	×	×	×	×	√	√	√
	SCK20	Input	×	×	0	1	×	×	×	×	√	√	√
		Output	×	0/1	0	0	1	×	PCLBUZ1 = 0 ^{Note 2}	×	√	√	√
	SCL20	Output	×	0/1	0	0	1	×	PCLBUZ1 = 0 ^{Note 2}	×	√	√	√
	PCLBUZ1	Output	×	0	0	0	0	SCK20 = 1 ^{Note 1} SCL20 = 1 ^{Note 1}	×	×	√	√	×
P16	(KR5)	Input	03H ^{Note 1}	×	0	1	×	×	×	×	√	√	√
	P16	Input	–	×	–	1	×	–	×	×	×	√	√
		Output	–	0	–	0	0/1	–	TO01 = 0 ^{Note 3}				
	TI01	Input	×	–	–	1	×	–	×	×	×	√	√
	TO01	Output	×	–	–	0	0	–	×	×	×	√	√
	INTP5	Input	×	–	–	1	×	–	×	×	×	√	√

- Notes**
1. 32- to 64-pin products only
 2. 32- and 48-pin products only
 3. 48- and 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (6/17)

Pin Name	Used Function		ADPC	ADM2	PIOR	PMxx	Pxx	25-pin	32-pin	48-pin	64-pin
	Function Name	I/O									
P20	P20	Input	ADPC = 01H	×	—	1	×	√	√	√	√
		Output	ADPC = 01H	×	—	0	0/1				
	ANI0	Analog input	ADPC = 00H/02H to 0FH	00x0xx0x, 10x0xx0x	×	1	×	√	√	√	√
	AV _{REFP}	Reference voltage	ADPC = 00H/02H to 0FH	01x0xx0x	×	1	×	√	√	√	√
P21	P21	Input	ADPC = 01H/02H	×	—	1	×	√	√	√	√
		Output	ADPC = 01H/02H	×	—	0	0/1				
	ANI1	Analog input	ADPC = 00H/03H to 0FH	xx00xx0x	×	1	×	√	√	√	√
	AV _{REFM}	Reference voltage	ADPC = 00H/03H to 0FH	xx10xx0x	×	1	×	√	√	√	√
P22	P22	Input	ADPC = 01H to 03H	×	—	1	×	√	√	√	√
		Output	ADPC = 01H to 03H	×	—	0	0/1				
	ANI2	Analog input	ADPC = 00H/04H to 0FH	×	×	1	×	√	√	√	√
	(KR2)	Input	ADPC = 01H to 03H	×	02H ^{Note 1}	1	×	√	×	√	×
	(KR3)	Input	ADPC = 01H to 03H	×	02H ^{Note 2}	1	×	×	√	×	×
	(KR5)	Input	ADPC = 01H to 03H	×	02H ^{Note 3}	1	×	×	×	×	√
P23	P23	Input	ADPC = 01H to 04H	×	—	1	×	√	√	√	√
		Output	ADPC = 01H to 04H	×	—	0	0/1				
	ANI3	Analog input	ADPC = 00H/05H to 0FH	×	×	1	×	√	√	√	√
	(KR3)	Input	ADPC = 01H to 04H	×	02H ^{Note 1}	1	×	√	×	√	×
	(KR4)	Input	ADPC = 01H to 04H	×	02H ^{Note 2}	1	×	×	√	×	×
	(KR6)	Input	ADPC = 01H to 04H	×	02H ^{Note 3}	1	×	×	×	×	√

Notes 1. 25- and 48-pin products only

2. 32-pin products only

3. 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (7/17)

Pin Name	Used Function		ADPC	ADM2	PIOR	PMxx	Pxx	25-pin	32-pin	48-pin	64-pin
	Function Name	I/O									
P24	P24	Input	ADPC = 01H to 05H	×	–	1	×	×	√	√	√
		Output	ADPC = 01H to 05H	×	–	0	0/1				
	ANI4	Analog input	ADPC = 00H/06H to 0FH	×	×	1	×	×	√	√	√
	(KR4)	Input	ADPC = 01H to 05H	×	02H ^{Note 1}	1	×	×	×	√	×
	(KR5)	Input	ADPC = 01H to 05H	×	02H ^{Note 2}	1	×	×	√	×	×
	(KR7)	Input	ADPC = 01H to 05H	×	02H ^{Note 3}	1	×	×	×	×	√
P25	P25	Input	ADPC = 01H to 06H	×	–	1	×	×	×	√	√
		Output	ADPC = 01H to 06H	×	–	0	0/1				
	ANI5	Analog input	ADPC = 00H/07H to 0FH	×	×	1	×	×	×	√	√
	(KR5)	Input	ADPC = 01H to 06H	×	02H ^{Note 1}	1	×	×	×	√	×
	(KR8)	Input	ADPC = 01H to 06H	×	02H ^{Note 3}	1	×	×	×	×	√
P26	P26	Input	ADPC = 01H to 07H	×	–	1	×	×	×	√	√
		Output	ADPC = 01H to 07H	×	–	0	0/1				
	ANI6	Analog input	ADPC = 00H/08H to 0FH	×	×	1	×	×	×	√	√
	(KR9)	Input	ADPC = 01H to 07H	×	02H ^{Note 3}	1	×	×	×	×	√
P27	P27	Input	ADPC = 01H to 08H	×	–	1	×	×	×	√	√
		Output	ADPC = 01H to 08H	×	–	0	0/1				
	ANI7	Analog input	ADPC = 00H/09H to 0FH	×	×	1	×	×	×	√	√

- Notes**
1. 48-pin products only
 2. 32-pin products only
 3. 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (8/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P30	P30	Input	–	–	–	1	×	×	×				
		Output	–	–	–	0	0/1	SCK11 = 1, SCL11 = 1	RTC1HZ = 0 ^{Note 1}	√	√	√	√
	ANI27	Analog input	×	–	1	1	×	×	×	√	√	√	√
	SCK11	Input	×	–	0	1	×	×	×	√	√	√	√
		Output	×	–	0	0	1	×	RTC1HZ = 0 ^{Note 1}	√	√	√	√
	SCL11	Output	×	–	0	0	1	×	RTC1HZ = 0 ^{Note 1}	√	√	√	√
	INTP3	Input	×	–	0	1	×	×	×	√	√	√	√
P31	P31	Input	–	–	–	1	×	–	×				
		Output	–	–	–	0	0/1	–	TO03 = 0, PLCBUZ0 = 0 ^{Note 2}	√	√	√	√
	ANI29	Analog input	×	–	1	1	×	–	×	√	√	√	√
	TI03	Input	×	–	0	1	×	–	×	√	√	√	√
	TO03	Output	×	–	0	0	0	–	×	√	√	√	√
	PCLBUZ0	Output	×	–	0	0	0	–	×	√	√	×	×
	INTP4	Input	×	–	0	1	×	–	×	√	√	√	√

Notes 1. 48- and 64-pin products only

2. 25- and 32-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (9/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P40	P40	Input	–	–	–	1	×	–	–	√	√	√	√
		Output	–	–	–	0	0/1	–	TOOL0 = 1				
	TOOL0	I/O	×	–	–	×	×	–	×	√	√	√	√
P41	P41	Input	–	–	–	1	×	–	×	×	×	√	√
		Output	–	–	–	0	0/1	–	TO07 = 0				
	ANI30	Analog input	×	–	1	1	×	–	×	×	×	√	√
	TI07	Input	×	–	0	1	×	–	×	×	×	√	√
	TO07	Output	×	–	0	0	0	–	×	×	×	√	√
P42	P42	Input	–	–	–	1	×	–	×	×	×	×	√
		Output	–	–	–	0	0/1	–	TO04 = 0				
	TI04	Input	×	–	–	1	×	–	×	×	×	×	√
	TO04	Output	×	–	–	0	0	–	×	×	×	×	√
P43	P43	Input	–	–	–	1	×	–	–	×	×	×	√
		Output	–	–	–	0	0/1	–	–				

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (10/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P50	P50	Input	–	–	–	1	×	×	×				
		Output	–	0	–	0	0/1	–	SDA11 = 0	√	√	√	√
		N-ch open drain output	–	1	–	0	0/1						
	ANI26	Analog input	×	×	1	1	×	–	×	√	√	√	√
	SI11	Input	×	×	0	1	×	–	×	√	√	√	√
	SDA11	I/O	×	1	0	0	1	–	×	√	√	√	√
	INTP1	Input	×	×	0	1	×	–	×	√	√	√	√
P51	P51	Input	–	–	–	1	×	×	–	√	√	√	√
		Output	–	–	–	0	0/1	SO11 = 1	–				
	ANI25	Analog input	×	–	1	1	×	×	–	√	×	√	√
	SO11	Output	×	–	0	0	1	×	–	√	√	√	√
	INTP2	Input	×	–	0	1	×	×	–	√	√	√	√

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (11/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P60	P60	Input	–	–	–	1	×	–	×				
		N-ch open drain output (6-V tolerance)	–	–	–	0	0/1	–	SCLA0 = 0	√	√	√	√
	SCLA0	I/O	×	–	–	0	0	–	×	√	√	√	√
P61	P61	Input	–	–	–	1	×	–	×				
		N-ch open drain output (6-V tolerance)	–	–	–	0	0/1	–	SDAA0 = 0	√	√	√	√
	SDAA0	I/O	×	–	–	0	0	–	×	√	√	√	√
P62	P62	Input	–	–	–	1	×	–	–				
		N-ch open drain output (6-V tolerance)	–	–	–	0	0/1	–	–	×	√	√	√
P63	P63	Input	–	–	–	1	×	–	–				
		N-ch open drain output (6-V tolerance)	–	–	–	0	0/1	–	–	×	×	√	√

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (12/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P70	P70	Input	–	–	0	1	×	×	–				
		Output	–	–	0	0	0/1	SCK21 = 1 ^{Note 2} , SCL21 = 1 ^{Note 2}	–	×	√	√	√
	ANI28	Analog input	×	–	1	1	×	×	–	×	√	√	√
	SCK21	Input	×	–	0	1	×	×	–	×	×	√	√
		Output	×	–	0	0	1	×	–	×	×	√	√
	SCL21	Output	×	–	0	0	1	×	–	×	×	√	√
	KR0	Input	00H ^{Note 1}	–	0	1	×	×	–	×	√	√	√
P71	P71	Input	–	–	–	1	×	–	–				
		Output	–	0	–	0	0/1	–	SDA21 = 0	×	×	√	√
		N-ch open drain output	–	1	–	0	0/1						
	SI21	Input	×	×	–	1	×	–	×	×	×	√	√
	SDA21	I/O	×	1	–	0	1	–	×	×	×	√	√
	KR1	Input	00H ^{Note 2}	×	–	1	×	–	×	×	×	√	√
P72	P72	Input	–	–	–	1	×	×	–	×	×	√	√
		Output	–	–	–	0	0/1	SO21 = 1	–				
	SO21	Output	×	–	–	0	1	×	–	×	×	√	√
	KR2	Input	00H ^{Note 2}	–	–	1	×	×	–	×	×	√	√
P73	P73	Input	–	–	–	1	×	×	–	×	×	√	√
		Output	–	–	–	0	0/1	SO01 = 1	–				
	SO01	Output	×	–	–	0	1	×	–	×	×	√	√
	KR3	Input	00H ^{Note 2}	–	–	1	×	×	–	×	×	√	√

- Notes** 1. 32- to 64-pin products only
2. 48- and 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (13/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P74	P74	Input	–	–	–	1	×	–	×				
		Output	–	0	–	0	0/1	–	SDA01 = 0	×	×	√	√
		N-ch open drain output	–	1	–	0	0/1						
	SI01	Input	–	×	–	1	×	–	×	×	×	√	√
	SDA01	I/O	–	1	–	0	1	–	×	×	×	√	√
	INTP8	Input	×	×	–	1	×	–	×	×	×	√	√
	KR4	Input	00H ^{Note 1}	×	–	1	×	–	×	×	×	√	√
P75	P75	Input	–	–	–	1	×	×	–				
		Output	–	–	–	0	0/1	SCK01 = 1, SCL01 = 1	–	×	×	√	√
	SCK01	Input	×	–	–	1	×	×	–	×	×	√	√
		Output	×	–	–	0	1	×	–	×	×	√	√
	SCL01	Output	×	–	–	0	1	×	–	×	×	√	√
	INTP9	Input	×	–	–	1	×	×	–	×	×	√	√
	KR5	Input	00H ^{Note 1}	–	–	1	×	×	–	×	×	√	√
P76	P76	Input	–	–	–	1	×	–	–				
		Output	–	–	–	0	0/1	–	–	×	×	×	√
	INTP10	Input	×	–	–	1	×	–	–	×	×	×	√
	KR6	Input	00H ^{Note 2}	–	–	1	×	–	–	×	×	×	√
P77	P77	Input	–	–	–	1	×	–	–				
		Output	–	–	–	0	0/1	–	–	×	×	×	√
	INTP11	Input	×	–	–	1	×	–	–	×	×	×	√
	KR7	Input	00H ^{Note 2}	–	–	1	×	–	–	×	×	×	√

Notes 1. 48- and 64-pin products only

2. 64-pin products only

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (14/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P120	P120	Input	–	–	0	1	×	–	–	×	√	√	√
		Output	–	–	0	0	0/1	–	–	×	√	√	√
	ANI19	Analog input	–	–	1	1	×	–	–	×	√	√	√
	(KR0)	Input	02H ^{Note}	–	0	1	×	–	–	×	√	×	×

Note 32-pin products only**Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (15/17)**

Pin Name	Used Function		CMC (EXCLK, OSCSEL, EXCLKS, OSCSELS)	Pxx	25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						
P121	P121	Input	00xx/10 xx/11 xx	×	√	√	√	√
	X1	–	01 xx	–	√	√	√	√
P122	P122	Input	00 xx/10 xx	×	√	√	√	√
	X2	–	01 xx	–	√	√	√	√
	EXCLK	Input	11 xx	–	√	√	√	√
P123	P123	Input	xx 00/xx 10/xx11	×	×	×	√	√
	XT1	–	xx 01	–	×	×	√	√
P124	P123	Input	xx 00/xx 10	×	×	×	√	√
	XT2	–	xx 01	–	×	×	√	√
	EXCLKS	Input	xx 11	–	×	×	√	√

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (16/17)

Pin Name	Used Function		PIOR	POMxx	PMCxx	PMxx	Pxx	Alternate Function Output		25-pin	32-pin	48-pin	64-pin
	Function Name	I/O						SAU Output Function	Other than SAU				
P130	P130	Output	–	–	–	–	0/1	–	–	×	×	√	√
P137	P137	Input	–	–	–	–	×	–	–	√	√	√	√
	INTP0	Input	×	–	–	–	×	–	–	√	√	√	√
P140	P140	Input	–	–	–	1	×	–	×	×	×	√	√
		Output	–	–	–	0	0/1	–	PCLBUZ0 = 0				
	PCLBUZ0	Output	×	–	–	0	0	–	×	×	×	√	√
	INTP6	Input	×	–	–	1	×	–	×	×	×	√	√
P141	P141	Input	–	–	–	1	×	–	×	×	×	×	√
		Output	–	–	–	0	0/1	–	PCLBUZ1 = 0				
	PCLBUZ1	Output	×	–	–	0	0	–	×	×	×	×	√
	INTP7	Input	×	–	–	1	×	–	×	×	×	×	√

Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function (17/17)

Pin Name	Used Function		ADPC	PIOR	PMxx	Pxx	25-pin	32-pin	48-pin	64-pin
	Function Name	I/O								
P150	P150	Input	ADPC = 01H to 09H	–	1	×	×	×	√	√
		Output	ADPC = 01H to 09H	–	0	0/1				
	ANI8	Analog input	ADPC = 00H/0AH to 0FH	×	1	×	×	×	√	√
P151	P151	Input	ADPC = 01H to 0AH	–	1	×	×	×	×	√
		Output	ADPC = 01H to 0AH	–	0	0/1				
	ANI9	Analog input	ADPC = 00H/0BH to 0FH	×	1	×	×	×	×	√
	(KR6)	Input	ADPC = 01H to 0AH	03H ^{Note}	1	×	×	×	×	√
P152	P152	Input	ADPC = 01H to 0BH	–	1	×	×	×	×	√
		Output	ADPC = 01H to 0BH	–	0	0/1				
	ANI10	Analog input	ADPC = 00H/0CH to 0FH	×	1	×	×	×	×	√
	(KR7)	Input	ADPC = 01H to 0BH	03H ^{Note}	1	×	×	×	×	√
P153	P153	Input	ADPC = 01H to 0CH	–	1	×	×	×	×	√
		Output	ADPC = 01H to 0CH	–	0	0/1				
	ANI11	Analog input	ADPC = 00H/0DH to 0FH	×	1	×	×	×	×	√
	(KR8)	Input	ADPC = 01H to 0CH	03H ^{Note}	1	×	×	×	×	√
P154	P154	Input	ADPC = 01H to 0DH	–	1	×	×	×	×	√
		Output	ADPC = 01H to 0DH	–	0	0/1				
	ANI12	Analog input	ADPC = 00H/0EH/0FH	×	1	×	×	×	×	√
	(KR9)	Input	ADPC = 01H to 0DH	03H ^{Note}	1	×	×	×	×	√

Note 64-pin products only

4.6 Cautions When Using Port Function

4.6.1 Cautions on 1-bit manipulation instruction for port register n (Pn)

When a 1-bit manipulation instruction is executed on a port that provides both input and output functions, the output latch value 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 P10 is an output port, P11 to P16 are input ports (all pin statuses are high level), and the port latch value of port 1 is 00H, if the output of output port P10 is changed from low level to high level via a 1-bit manipulation instruction, the output latch value of port 1 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 1-bit manipulation instruction is executed in the following order in the RL78/G1A.

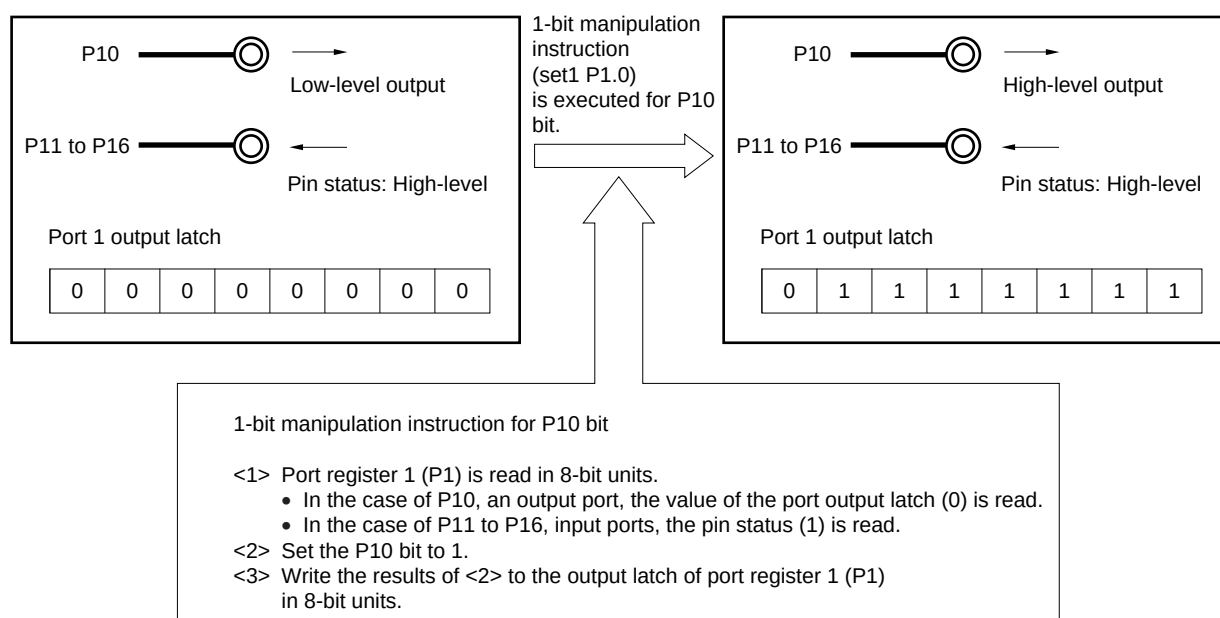
- <1> The Pn register is read in 8-bit units.
- <2> The targeted one bit is manipulated.
- <3> The Pn register is written in 8-bit units.

In step <1>, the output latch value (0) of P10, which is an output port, is read, while the pin statuses of P11 to P16, which are input ports, are read. If the pin statuses of P11 to P16 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 4-12. Bit Manipulation Instruction (P10)



4.6.2 Notes on specifying the pin settings

For an output pin to which multiple functions are assigned, the output of the unused alternate functions must be set to its initial state so as to prevent conflicting outputs. This also applies to the functions assigned by using the peripheral I/O redirection register (PIOR). For details about the alternate function output, see **4.5 Register Settings When Using Alternate Function**.

No specific setting is required for input pins because the output of their alternate functions is disabled (the buffer output is Hi-Z).

Disabling the unused functions, including blocks that are only used for input or do not have I/O, is recommended for lower power consumption.

CHAPTER 5 CLOCK GENERATOR

The presence or absence of connecting resonator pin for main system clock, connecting resonator pin for subsystem clock, external clock input pin for main system clock, and external clock input pin for subsystem clock, depends on the product.

Output pin	25, 32-pin	48, 64-pin
X1, X2 pins	√	√
EXCLK pin	√	√
XT1, XT2 pins	–	√
EXCLKS pin	–	√

5.1 Functions of Clock Generator

The clock generator generates the clock to be supplied to the CPU and peripheral hardware.

The following three kinds of system clocks and clock oscillators are selectable.

(1) Main system clock

<1> X1 oscillator

This circuit oscillates a clock of $f_x = 1$ to 20 MHz by connecting a resonator to X1 and X2 pins.

Oscillation can be stopped by executing the STOP instruction or setting of the MSTOP bit (bit 7 of the clock operation status control register (CSC)).

<2> High-speed on-chip oscillator

The frequency at which to oscillate can be selected from among $f_{IH} = 32, 24, 16, 12, 8, 6, 4, 3, 2$, or 1 MHz (typ.) by using the option byte (000C2H). After a reset release, the CPU always starts operating with this high-speed on-chip oscillator clock. Oscillation can be stopped by executing the STOP instruction or setting the HIOSTOP bit (bit 0 of the CSC register).

The frequency specified by using an option byte can be changed by using the high-speed on-chip oscillator frequency select register (HOCODIV). For details about the frequency, see Figure 5-9 Format of High-speed On-chip Oscillator Frequency Select Register (HOCODIV).

The frequencies that can be specified for the high-speed on-chip oscillator by using the option byte and the high-speed on-chip oscillator frequency select register (HOCODIV) are shown below.

Power Supply Voltage	Flash Operation Mode	Oscillation Frequency (MHz)									
		1	2	3	4	6	8	12	16	24	32
$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	HS (high-speed main) mode	√	√	√	√	√	√	√	√	√	√
$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$		√	√	√	√	√	√	√	√	–	–
$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	LS (low-speed main) mode	√	√	√	√	√	√	–	–	–	–
$1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	LV (low-voltage main) mode	√	√	√	√	–	–	–	–	–	–

An external main system clock ($f_{EX} = 1$ to 20 MHz) can also be supplied from the EXCLK/X2/P122 pin. An external main system clock input can be disabled by executing the STOP instruction or setting of the MSTOP bit.

As the main system clock, a high-speed system clock (X1 clock or external main system clock) or high-speed on-chip oscillator clock can be selected by setting of the MCM0 bit (bit 4 of the system clock control register (CKC)). However, note that the usable frequency range of the main system clock differs depending on the setting of the power supply voltage (V_{DD}). The operating voltage of the flash memory must be set by using the CMODE0 and CMODE1 bits of the option byte (000C2H) (see CHAPTER 24 OPTION BYTE).

(2) Subsystem clock**• XT1 clock oscillator**

This circuit oscillates a clock of $f_{XT} = 32.768$ kHz by connecting a 32.768 kHz resonator to XT1 and XT2 pins. Oscillation can be stopped by setting the XTSTOP bit (bit 6 of the clock operation status control register (CSC)).

An external subsystem clock ($f_{EXS} = 32.768$ KHz) can also be supplied from the EXCLKS/XT2/P124 pin. An external subsystem clock input can be disabled by the setting of the XTSTOP bit.

(3) Low-speed on-chip oscillator clock (Low-speed on-chip oscillator)

This circuit oscillates a clock of $f_{IL} = 15$ kHz (TYP.).

The low-speed on-chip oscillator clock cannot be used as the CPU clock.

Only the following peripheral hardware runs on the low-speed on-chip oscillator clock.

- Watchdog timer
- Real-time clock
- 12-bit interval timer

This clock operates when bit 4 (WDTON) of the option byte (000C0H), bit 4 (WUTMMCK0) of the subsystem clock supply mode control register (OSMC), or both are set to 1.

However, when WDTON = 1, WUTMMCK0 = 0, and bit 0 (WDSTBYON) of the option byte (000C0H) is 0, oscillation of the low-speed on-chip oscillator stops if the HALT or STOP instruction is executed.

Caution The low-speed on-chip oscillator clock (f_{IL}) can only be selected as the real-time clock count clock when the fixed-cycle interrupt function is used.

Remark

f_X :	X1 clock oscillation frequency
f_{IH} :	High-speed on-chip oscillator clock frequency
f_{EX} :	External main system clock frequency
f_{XT} :	XT1 clock oscillation frequency
f_{EXS} :	External subsystem clock frequency
f_{IL} :	Low-speed on-chip oscillator clock frequency

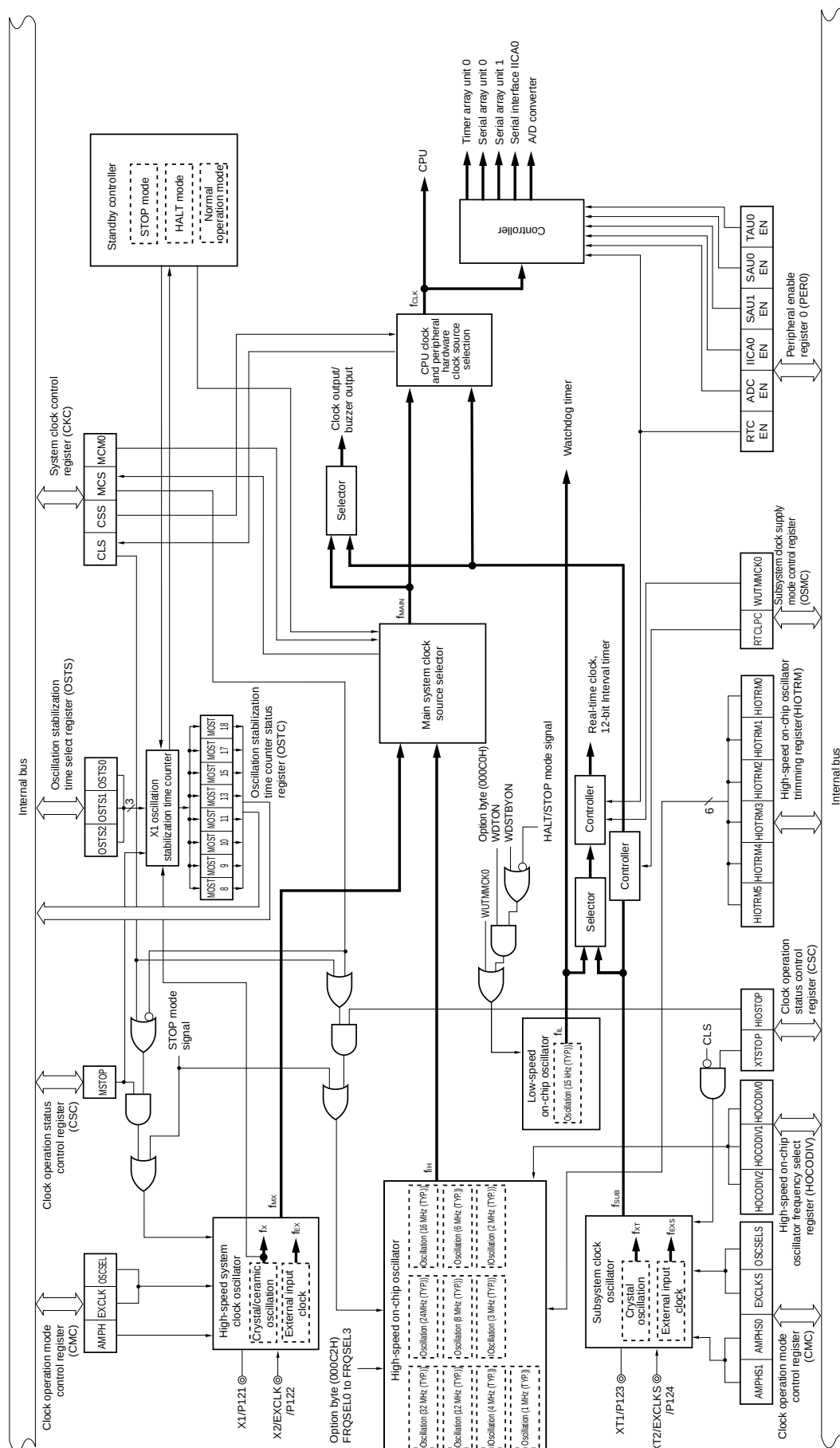
5.2 Configuration of Clock Generator

The clock generator includes the following hardware.

Table 5-1. Configuration of Clock Generator

Item	Configuration
Control registers	Clock operation mode control register (CMC) System clock control register (CKC) Clock operation status control register (CSC) Oscillation stabilization time counter status register (OSTC) Oscillation stabilization time select register (OSTS) Peripheral enable register 0 (PER0) Subsystem clock supply mode control register (OSMC) High-speed on-chip oscillator frequency select register (HOCODIV) High-speed on-chip oscillator trimming register (HIOTRM)
Oscillators	X1 oscillator XT1 oscillator High-speed on-chip oscillator Low-speed on-chip oscillator

Figure 5-1. Block Diagram of Clock Generator



(Remark is listed on the next page after next.)

Remark	fx:	X1 clock oscillation frequency
	f_{IH}:	High-speed on-chip oscillator clock frequency
	f_{EX}:	External main system clock frequency
	f_{MX}:	High-speed system clock frequency
	f_{MAIN}:	Main system clock frequency
	f_{XT}:	XT1 clock oscillation frequency
	f_{EXS}:	External subsystem clock frequency
	f_{SUB}:	Subsystem clock frequency
	f_{CLK}:	CPU/peripheral hardware clock frequency
	f_{IL}:	Low-speed on-chip oscillator clock frequency

5.3 Registers Controlling Clock Generator

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

- Clock operation mode control register (CMC)
- System clock control register (CKC)
- Clock operation status control register (CSC)
- Oscillation stabilization time counter status register (OSTC)
- Oscillation stabilization time select register (OSTS)
- Peripheral enable register 0 (PER0)
- Subsystem clock supply mode control register (OSMC)
- High-speed on-chip oscillator frequency select register (HOCODIV)
- High-speed on-chip oscillator trimming register (HIOTRM)

Caution Which registers and bits are included depends on the product. Be sure to set registers and bits that are not mounted in a product to their initial values.

5.3.1 Clock operation mode control register (CMC)

This register is used to set the operation mode of the X1/P121, X2/EXCLK/P122, XT1/P123, and XT2/EXCLKS/P124 pins, and to select a gain of the oscillator.

The CMC register can be written only once by an 8-bit memory manipulation instruction after reset release. This register can be read by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 5-2. Format of Clock Operation Mode Control Register (CMC)

Address: FFFA0H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
CMC	EXCLK	OSCSEL	EXCLKS	OSCSELS	0	AMPHS1	AMPHS0	AMPH
	EXCLK	OSCSEL	High-speed system clock pin operation mode		X1/P121 pin		X2/EXCLK/P122 pin	
	0	0	Input port mode		Input port			
	0	1	X1 oscillation mode		Crystal/ceramic resonator connection			
	1	0	Input port mode		Input port			
	1	1	External clock input mode		Input port		External clock input	
	EXCLKS	OSCSELS	Subsystem clock pin operation mode		XT1/P123 pin		XT2/EXCLKS/P124 pin	
	0	0	Input port mode		Input port			
	0	1	XT1 oscillation mode		Crystal resonator connection			
	1	0	Input port mode		Input port			
	1	1	External clock input mode		Input port		External clock input	
	AMPHS1	AMPHS0	XT1 oscillator oscillation mode selection					
	0	0	Low power consumption oscillation (default)					
	0	1	Normal oscillation					
	1	0	Ultra-low power consumption oscillation					
	1	1	Setting prohibited					
	AMPH	Control of X1 clock oscillation frequency						
	0	1 MHz ≤ f _x ≤ 10 MHz						
	1	10 MHz < f _x ≤ 20 MHz						

- Cautions 1.** The CMC register can be written only once after reset release, by an 8-bit memory manipulation instruction. When using the CMC register with its initial value (00H), be sure to set the register to 00H after a reset ends in order to prevent malfunction due to a program loop. Such a malfunction becomes unrecoverable when a value other than 00H is mistakenly written.
- After reset release, set the CMC register before X1 or XT1 oscillation is started as set by the clock operation status control register (CSC).
 - Be sure to set the AMPH bit to 1 if the X1 clock oscillation frequency exceeds 10 MHz.
 - Specify the settings for the AMPH, AMPHS1, and AMPHS0 bits while f_{IH} is selected as f_{CLK} after a reset ends (before f_{CLK} is switched to f_{MX} or f_{SUB}).
 - Oscillation stabilization time of f_{XT} , counting on the software.
 - Although the maximum system clock frequency is 32 MHz, the maximum frequency of the X1 oscillator is 20 MHz.

(Cautions and Remark are given on the next page.)

Cautions 7. The XT1 oscillator is a circuit with low amplification in order to achieve low-power consumption. Note the following points when designing the circuit.

- Pins and circuit boards include parasitic capacitance. Therefore, perform oscillation evaluation using a circuit board to be actually used and confirm that there are no problems.
- Before using the ultra-low power consumption oscillation (AMPHS1, AMPHS0 = 1, 0) as the mode of the XT1 oscillator, evaluate the resonators described in 5.7 Resonator and Oscillator Constants.
- Make the wiring between the XT1 and XT2 pins and the resonators as short as possible, and minimize the parasitic capacitance and wiring resistance. Note this particularly when the ultra-low power consumption oscillation (AMPHS1, AMPHS0 = 1, 0) is selected.
- Configure the circuit of the circuit board, using material with little wiring resistance.
- Place a ground pattern that has the same potential as V_{SS} as much as possible near the XT1 oscillator.
- Be sure that the signal lines between the XT1 and XT2 pins, and the resonators do not cross with the other signal lines. Do not route the wiring near a signal line through which a high fluctuating current flows.
- The impedance between the XT1 and XT2 pins may drop and oscillation may be disturbed due to moisture absorption of the circuit board in a high-humidity environment or dew condensation on the board. When using the circuit board in such an environment, take measures to damp-proof the circuit board, such as by coating.
- When coating the circuit board, use material that does not cause capacitance or leakage between the XT1 and XT2 pins.

Remark fx: X1 clock frequency

5.3.2 System clock control register (CKC)

This register is used to select a CPU/peripheral hardware clock and a main system clock.

The CKC register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 5-3. Format of System Clock Control Register (CKC)

Address: FFFA4H After reset: 00H R/W^{Note 1}

Symbol	<7>	<6>	<5>	<4>	3	2	1	0
CKC	CLS	CSS	MCS	MCM0	0	0	0	0
CLS	Status of CPU/peripheral hardware clock (f_{CLK})							
0	Main system clock (f_{MAIN})							
1	Subsystem clock (f_{SUB})							
CSS	Selection of CPU/peripheral hardware clock (f_{CLK})							
0	Main system clock (f_{MAIN})							
1 ^{Note 2}	Subsystem clock (f_{SUB})							
MCS	Status of Main system clock (f_{MAIN})							
0	High-speed on-chip oscillator clock (f_{IH})							
1	High-speed system clock (f_{MX})							
MCM0 ^{Note 2}	Main system clock (f_{MAIN}) operation control							
0	Selects the high-speed on-chip oscillator clock (f_{IH}) as the main system clock (f_{MAIN})							
1	Selects the high-speed system clock (f_{MX}) as the main system clock (f_{MAIN})							

Notes 1. Bits 7 and 5 are read-only.

2. Changing the value of the MCM0 bit is prohibited while the CSS bit is set to 1.

Cautions 1. Be sure to set bit 3 to 0 to 0.

- The clock set by the CSS bit is supplied to the CPU and peripheral hardware. If the CPU clock is changed, therefore, the clock supplied to peripheral hardware (except the real-time clock, 12-bit interval timer, clock output/buzzer output, and watchdog timer) is also changed at the same time. Consequently, stop each peripheral function when changing the CPU/peripheral hardware clock.
- If the subsystem clock is used as the peripheral hardware clock, the operations of the A/D converter and IICA are not guaranteed. For the operating characteristics of the peripheral hardware, refer to the chapters describing the various peripheral hardware as well as CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$), CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$).

Remark f_{IH} : High-speed on-chip oscillator clock frequency
 f_{MX} : High-speed system clock frequency
 f_{MAIN} : Main system clock frequency
 f_{SUB} : Subsystem clock frequency

5.3.3 Clock operation status control register (CSC)

This register is used to control the operations of the high-speed system clock, high-speed on-chip oscillator clock, and subsystem clock (except the low-speed on-chip oscillator clock).

The CSC register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to C0H.

Figure 5-4. Format of Clock Operation Status Control Register (CSC)

Address: FFA1H After reset: C0H R/W

Symbol	<7>	<6>	5	4	3	2	1	<0>
CSC	MSTOP	XTSTOP	0	0	0	0	0	HIOSTOP

MSTOP	High-speed system clock operation control		
	X1 oscillation mode	External clock input mode	Input port mode
0	X1 oscillator operating	External clock from EXCLK pin is valid	Input port
1	X1 oscillator stopped	External clock from EXCLK pin is invalid	

XTSTOP	Subsystem clock operation control		
	XT1 oscillation mode	External clock input mode	Input port mode
0	XT1 oscillator operating	External clock from EXCLKS pin is valid	Input port
1	XT1 oscillator stopped	External clock from EXCLKS pin is invalid	

HIOSTOP	High-speed on-chip oscillator clock operation control		
0	High-speed on-chip oscillator operating		
1	High-speed on-chip oscillator stopped		

- Cautions**
1. After reset release, set the clock operation mode control register (CMC) before setting the CSC register.
 2. Set the oscillation stabilization time select register (OSTS) before setting the MSTOP bit to 0 after releasing reset. Note that if the OSTS register is being used with its default settings, the OSTS register is not required to be set here.
 3. To start X1 oscillation as set by the MSTOP bit, check the oscillation stabilization time of the X1 clock by using the oscillation stabilization time counter status register (OSTC).
 4. When starting XT1 oscillation by setting the XTSTOP bit, wait for oscillation of the subsystem clock to stabilize by setting a wait time using software.
 5. Do not stop the clock selected for the CPU peripheral hardware clock (f_{CLK}) with the OSC register.
 6. The setting of the flags of the register to stop clock oscillation (invalidate the external clock input) and the condition before clock oscillation is to be stopped are as Table 5-2.
Before stopping the clock oscillation, check the conditions before the clock oscillation is stopped.

Table 5-2. Stopping Clock Method

Clock	Condition Before Stopping Clock (Invalidating External Clock Input)	Setting of CSC Register Flags
X1 clock	CPU and peripheral hardware clocks operate with a clock other than the high-speed system clock. (CLS = 0 and MCS = 0, or CLS = 1)	MSTOP = 1
External main system clock		
XT1 clock	CPU and peripheral hardware clocks operate with a clock other than the subsystem clock. (CLS = 0)	XTSTOP = 1
External subsystem clock		
High-speed on-chip oscillator clock	CPU and peripheral hardware clocks operate with a clock other than the high-speed on-chip oscillator clock. (CLS = 0 and MCS = 1, or CLS = 1)	HIOSTOP = 1

5.3.4 Oscillation stabilization time counter status register (OSTC)

This is the register that indicates the count status of the X1 clock oscillation stabilization time counter.

The X1 clock oscillation stabilization time can be checked in the following case,

- If the X1 clock starts oscillation while the high-speed on-chip oscillator clock or subsystem clock is being used as the CPU clock.
- If the STOP mode is entered and then released while the high-speed on-chip oscillator clock is being used as the CPU clock with the X1 clock oscillating.

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

When reset signal is generated, the STOP instruction and MSTOP (bit 7 of clock operation status control register (CSC)) = 1 clear the OSTC register to 00H.

Remark The oscillation stabilization time counter starts counting in the following cases.

- When oscillation of the X1 clock starts (EXCLK, OSCSEL = 0, 1 → MSTOP = 0)
- When the STOP mode is released

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

Address: FFFA2H After reset: 00H R

Symbol	7	6	5	4	3	2	1	0
OSTC	MOST 8	MOST 9	MOST 10	MOST 11	MOST 13	MOST 15	MOST 17	MOST 18

MOST 8	MOST 9	MOST 10	MOST 11	MOST 13	MOST 15	MOST 17	MOST 18	Oscillation stabilization time status		
									$f_x = 10 \text{ MHz}$	$f_x = 20 \text{ MHz}$
0	0	0	0	0	0	0	0	$2^8/f_x \text{ max.}$	$25.6 \mu\text{s max.}$	$12.8 \mu\text{s max.}$
1	0	0	0	0	0	0	0	$2^9/f_x \text{ min.}$	$25.6 \mu\text{s min.}$	$12.8 \mu\text{s min.}$
1	1	0	0	0	0	0	0	$2^9/f_x \text{ min.}$	$51.2 \mu\text{s min.}$	$25.6 \mu\text{s min.}$
1	1	1	0	0	0	0	0	$2^{10}/f_x \text{ min.}$	$102 \mu\text{s min.}$	$51.2 \mu\text{s min.}$
1	1	1	1	0	0	0	0	$2^{11}/f_x \text{ min.}$	$204 \mu\text{s min.}$	$102 \mu\text{s min.}$
1	1	1	1	1	0	0	0	$2^{13}/f_x \text{ min.}$	$819 \mu\text{s min.}$	$409 \mu\text{s min.}$
1	1	1	1	1	1	0	0	$2^{15}/f_x \text{ min.}$	3.27 ms min.	1.63 ms min.
1	1	1	1	1	1	1	0	$2^{17}/f_x \text{ min.}$	13.1 ms min.	6.55 ms min.
1	1	1	1	1	1	1	1	$2^{18}/f_x \text{ min.}$	26.2 ms min.	13.1 ms min.

Cautions 1. After the above time has elapsed, the bits are set to 1 in order from the MOST8 bit and remain 1.

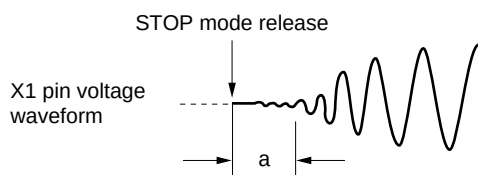
2. The oscillation stabilization time counter counts up to the oscillation stabilization time set by the oscillation stabilization time select register (OSTS).

In the following cases, set the oscillation stabilization time of the OSTS register to the value greater than the count value which is to be checked by the OSTC register.

- If the X1 clock starts oscillation while the high-speed on-chip oscillator clock or subsystem clock is being used as the CPU clock.
- If the STOP mode is entered and then released while the high-speed on-chip oscillator clock is being used as the CPU clock with the X1 clock oscillating.

(Note, therefore, that only the status up to the oscillation stabilization time set by the OSTS register is set to the OSTC register after the STOP mode is released.)

3. The X1 clock oscillation stabilization wait time does not include the time until clock oscillation starts ("a" below).



Remark f_x : X1 clock oscillation frequency

5.3.5 Oscillation stabilization time select register (OSTS)

This register is used to select the X1 clock oscillation stabilization wait time.

When the X1 clock is made to oscillate by clearing the MSTOP bit to start the X1 oscillation circuit operating, actual operation is automatically delayed for the time set in the OSTS register.

When switching the CPU clock from the high-speed on-chip oscillator clock or the subsystem clock to the X1 clock, and when using the high-speed on-chip oscillator clock for switching the X1 clock from the oscillating state to STOP mode, use the oscillation stabilization time counter status register (OSTC) to confirm that the desired oscillation stabilization time has elapsed after release from the STOP mode. That is, use the OSTC register to check that the oscillation stabilization time corresponding to its setting has been reached

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

Reset signal generation sets the OSTS register to 07H.

Figure 5-6. Format of Oscillation Stabilization Time Select Register (OSTS)

Address: FFFA3H After reset: 07H R/W

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

OSTS2	OSTS1	OSTS0	Oscillation stabilization time selection		
				$f_x = 10 \text{ MHz}$	$f_x = 20 \text{ MHz}$
0	0	0	$2^8/f_x$	25.6 μs	12.8 μs
0	0	1	$2^9/f_x$	51.2 μs	25.6 μs
0	1	0	$2^{10}/f_x$	102 μs	51.2 μs
0	1	1	$2^{11}/f_x$	204 μs	102 μs
1	0	0	$2^{13}/f_x$	819 μs	409 μs
1	0	1	$2^{15}/f_x$	3.27 ms	1.63 ms
1	1	0	$2^{17}/f_x$	13.1 ms	6.55 ms
1	1	1	$2^{18}/f_x$	26.2 ms	13.1 ms

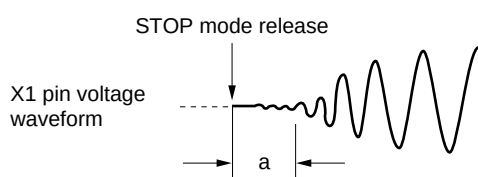
Cautions 1. Change the setting of the OSTS register before setting the MSTOP bit of the clock operation status control register (CSC) to 0.

2. The oscillation stabilization time counter counts up to the oscillation stabilization time set by the OSTS register.

In the following cases, set the oscillation stabilization time of the OSTS register to the value greater than the count value which is to be checked by the OSTC register after the oscillation starts.

- If the X1 clock starts oscillation while the high-speed on-chip oscillator clock or subsystem clock is being used as the CPU clock.
- If the STOP mode is entered and then released while the high-speed on-chip oscillator clock is being used as the CPU clock with the X1 clock oscillating. (Note, therefore, that only the status up to the oscillation stabilization time set by the OSTS register is set to the OSTC register after the STOP mode is released.)

3. The X1 clock oscillation stabilization wait time does not include the time until clock oscillation starts (“a” below).



Remark f_x : X1 clock oscillation frequency

5.3.6 Peripheral enable register 0 (PER0)

These registers are used to enable or disable supplying the clock to the peripheral hardware. Clock supply to the hardware that is not used is also stopped so as to decrease the power consumption and noise.

To use the peripheral functions below, which are controlled by this register, set (1) the bit corresponding to each function before specifying the initial settings of the peripheral functions.

- Real-time clock, 12-bit interval timer
- A/D converter
- Serial interface IICA0
- Serial array unit 1
- Serial array unit 0
- Timer array unit 0

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears these registers to 00H.

Figure 5-7. Format of Peripheral Enable Register 0 (PER0) (1/3)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN	SAU0EN	0	TAU0EN

RTCEN	Control of real-time clock (RTC) and 12-bit interval timer input clock supply
0	Stops input clock supply. • SFR used by the real-time clock (RTC) and 12-bit interval timer cannot be written. • The real-time clock (RTC) and 12-bit interval timer are in the reset status.
1	Enables input clock supply. • SFR used by the real-time clock (RTC) and 12-bit interval timer can be read and written.

Caution Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

Figure 5-7. Format of Peripheral Enable Register 0 (PER0) (2/3)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN	SAU0EN	0	TAU0EN

ADCEN	Control of A/D converter input clock supply
0	Stops input clock supply. - SFR used by the A/D converter cannot be written. - The A/D converter is in the reset status.
1	Enables input clock supply. SFR used by the A/D converter can be read and written.

IICA0EN	Control of serial interface IICA0 input clock supply
0	Stops input clock supply. - SFR used by the serial interface IICA0 cannot be written. - The serial interface IICA0 is in the reset status.
1	Enables input clock supply. SFR used by the serial interface IICA0 can be read and written.

SAU1EN	Control of serial array unit 1 input clock supply
0	Stops input clock supply. - SFR used by the serial array unit 1 cannot be written. - The serial array unit 1 is in the reset status.
1	Enables input clock supply. SFR used by the serial array unit 1 can be read and written.

Caution Be sure to clear the following bits to 0.**25-pin products: bits 1, 3, 6****32, 48, 64-pin products: bits 1, 6**

Figure 5-7. Format of Peripheral Enable Register 0 (PER0) (3/3)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN	SAU0EN	0	TAU0EN

SAU0EN	Control of serial array unit 0 input clock supply
0	Stops input clock supply. - SFR used by the serial array unit 0 cannot be written. - The serial array unit 0 is in the reset status.
1	Enables input clock supply. SFR used by the serial array unit 0 can be read and written.

TAU0EN	Control of timer array unit 0 input clock supply
0	Stops input clock supply. - SFR used by timer array unit 0 cannot be written. - Timer array unit 0 is in the reset status.
1	Enables input clock supply. SFR used by timer array unit 0 can be read and written.

Caution Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

5.3.7 Subsystem clock supply mode control register (OSMC)

This register is used to reduce power consumption by stopping unnecessary clock functions.

If the RTCLPC bit is set to 1, power consumption can be reduced, because clock supply to the peripheral functions, except the real-time clock and 12-bit interval timer, is stopped in STOP mode or HALT mode while subsystem clock is selected as CPU clock.

In addition, the OSMC register can be used to select the count clock of the real-time clock and 12-bit interval timer.

The OSMC register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 5-8. Format of Subsystem Clock Supply Mode Control Register (OSMC)

Address: F00F3H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
OSMC	RTCLPC	0	0	WUTMMCK0	0	0	0	0

RTCLPC	Setting in STOP mode or HALT mode while subsystem clock is selected as CPU clock
0	Enables supply of subsystem clock to peripheral functions (See Tables 18-1, 18-2, and 18-3 for peripheral functions whose operations are enabled.)
1	Stops supply of subsystem clock to peripheral functions other than real-time clock and 12-bit interval timer.

WUTMMCK0	Selection of count clock for real-time clock and 12-bit interval timer.
0	Subsystem clock (f_{SUB})
1	Low-speed on-chip oscillator clock (f_{L})

5.3.8 High-speed on-chip oscillator frequency select register (HOCODIV)

The frequency of the high-speed on-chip oscillator which is set by an option byte (000C2H) can be changed by using high-speed on-chip oscillator frequency select register (HOCODIV). However, the selectable frequency depends on the FRQSEL3 bit of the option byte (000C2H).

The HOCODIV register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to the value set by FRQSEL2 to FRQSEL0 of the option byte (000C2H).

Figure 5-9. Format of High-speed On-chip Oscillator Frequency Select Register (HOCODIV)

Address: F00A8H After reset: the value set by FRQSEL2 to FRQSEL0 of the option byte (000C2H) R/W

Symbol	7	6	5	4	3	2	1	0
HOCODIV	0	0	0	0	0	HOCODIV2	HOCODIV1	HOCODIV0

HOCODIV2	HOCODIV1	HOCODIV0	High-Speed On-Chip Oscillator Clock Frequency	
			FRQSEL3 Bit is 0	FRQSEL3 Bit is 1
0	0	0	24 MHz	32 MHz
0	0	1	12 MHz	16 MHz
0	1	0	6 MHz	8 MHz
0	1	1	3 MHz	4 MHz
1	0	0	Setting prohibited	2 MHz
1	0	1	Setting prohibited	1 MHz
Other than above			Setting prohibited	

Cautions 1. When changing the frequency by using the HOCODIV register, specify a frequency in the voltage range corresponding to the flash operating mode specified in the option byte (000C2H).

Option Byte (000C2H) Value		Flash Operation Mode	Operating Frequency Range	Operating Voltage Range
CMODE1	CMODE0			
0	0	LV (low-voltage main) mode	1 to 4 MHz	1.6 to 3.6 V
1	0	LS (low-speed main) mode	1 to 8 MHz	1.8 to 3.6 V
1	1	HS (high-speed main) mode	1 to 16 MHz	2.4 to 3.6 V
			1 to 32 MHz	2.7 to 3.6 V

2. Change the HOCODIV register value while the high-speed on-chip oscillator clock (f_{H}) is selected as the CPU/peripheral hardware clock (f_{CLK}).
3. After the frequency is changed using the HOCODIV register, the new frequency is applied after the period below has elapsed.
 - Operation for up to three clocks at the pre-change frequency
 - CPU/peripheral hardware clock wait at the post-change frequency for up to three clocks

5.3.9 High-speed on-chip oscillator trimming register (HIOTRM)

This register is used to adjust the accuracy of the high-speed on-chip oscillator.

With self-measurement of the high-speed on-chip oscillator frequency via a timer using high-accuracy external clock input (timer array unit), and so on, the accuracy can be adjusted.

The HIOTRM register can be set by an 8-bit memory manipulation instruction.

Caution The frequency will vary if the temperature and V_{DD} pin voltage change after accuracy adjustment. When the temperature and V_{DD} voltage change, accuracy adjustment must be executed regularly or before the frequency accuracy is required.

Figure 5-10. Format of High-Speed On-Chip Oscillator Trimming Register (HIOTRM)

Address: F00A0H After reset: Undefined^{Note} R/W

Symbol	7	6	5	4	3	2	1	0
HIOTRM	0	0	HIOTRM5	HIOTRM4	HIOTRM3	HIOTRM2	HIOTRM1	HIOTRM0

HIOTRM5	HIOTRM4	HIOTRM3	HIOTRM2	HIOTRM1	HIOTRM0	High-speed on-chip oscillator
0	0	0	0	0	0	Minimum speed
0	0	0	0	0	1	↑
0	0	0	0	1	0	
0	0	0	0	1	1	
0	0	0	1	0	0	
• • •						
1	1	1	1	1	0	↓
1	1	1	1	1	1	Maximum speed

Note The value after reset is the value adjusted at shipment.

- Remarks**
1. The HIOTRM register holds a six-bit value used to adjust the high-speed on-chip oscillator with an increment of 1 corresponding to an increase of frequency by about 0.05%.
 2. For the usage example of the HIOTRM register, see the application note for RL78 MCU series High-speed On-chip Oscillator (HOCO) Clock Frequency Correction (R01AN0464).

5.4 System Clock Oscillator

5.4.1 X1 oscillator

The X1 oscillator oscillates with a crystal resonator or ceramic resonator (1 to 20 MHz) connected to the X1 and X2 pins.

An external clock can also be input. In this case, input the clock signal to the EXCLK pin.

To use the X1 oscillator, set bits 7 and 6 (EXCLK, OSCSEL) of the clock operation mode control register (CMC) as follows.

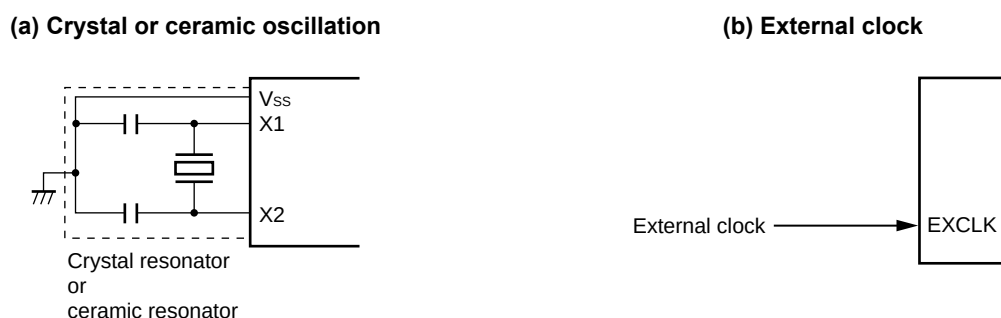
- Crystal or ceramic oscillation: EXCLK, OSCSEL = 0, 1
- External clock input: EXCLK, OSCSEL = 1, 1

When the X1 oscillator is not used, set the input port mode (EXCLK, OSCSEL = 0, 0).

When the pins are not used as input port pins, either, see **Table 2-3 Connection of Unused Pins (64-pin products)**.

Figure 5-11 shows an example of the external circuit of the X1 oscillator.

Figure 5-11. Example of External Circuit of X1 Oscillator



Cautions are listed on the next page.

5.4.2 XT1 oscillator

The XT1 oscillator oscillates with a crystal resonator (32.768 kHz (TYP.)) connected to the XT1 and XT2 pins.

To use the XT1 oscillator, set bit 4 (OSCSELS) of the clock operation mode control register (CMC) to 1.

An external clock can also be input. In this case, input the clock signal to the EXCLKS pin.

To use the XT1 oscillator, set bits 5 and 4 (EXCLKS, OSCSELS) of the clock operation mode control register (CMC) as follows.

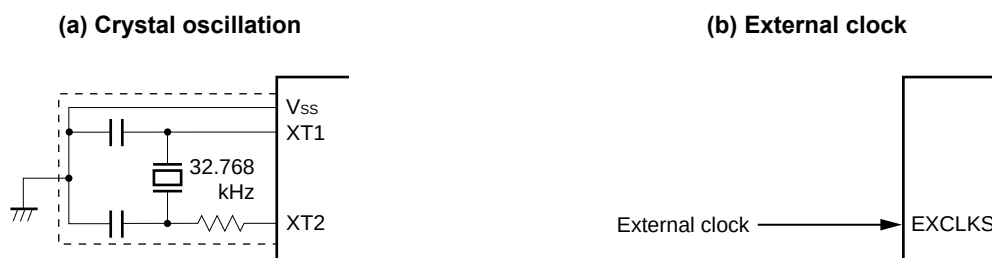
- Crystal or ceramic oscillation: EXCLKS, OSCSELS = 0, 1
- External clock input: EXCLKS, OSCSELS = 1, 1

When the XT1 oscillator is not used, set the input port mode (EXCLKS, OSCSELS = 0, 0).

When the pins are not used as input port pins, either, see **Table 2-3 Connection of Unused Pins (64-pin products)**.

Figure 5-12 shows an example of the external circuit of the XT1 oscillator.

Figure 5-12. Example of External Circuit of XT1 Oscillator



Caution When using the X1 oscillator and XT1 oscillator, wire as follows in the area enclosed by the broken lines in the Figures 5-11 and 5-12 to avoid an adverse effect from wiring capacitance.

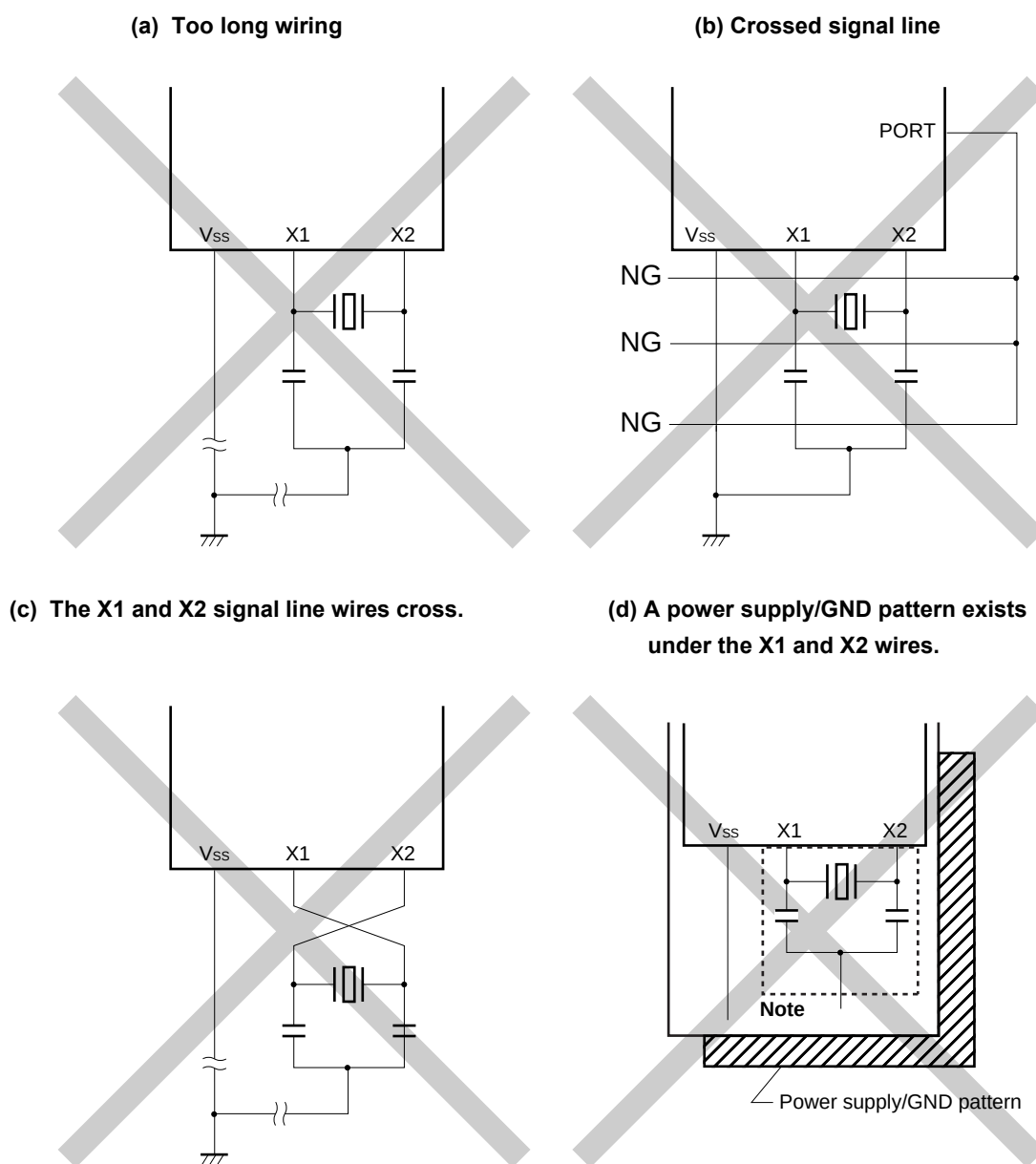
- Keep the wiring length as short as possible.
- Do not cross the wiring with the other signal lines. Do not route the wiring near a signal line through which a high fluctuating current flows.
- Always make the ground point of the oscillator capacitor the same potential as Vss. Do not ground the capacitor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

The XT1 oscillator is a circuit with low amplification in order to achieve low-power consumption. Note the following points when designing the circuit.

- Pins and circuit boards include parasitic capacitance. Therefore, perform oscillation evaluation using a circuit board to be actually used and confirm that there are no problems.
- Before using the ultra-low power consumption oscillation (AMPHS1, AMPHS0 = 1, 0) as the mode of the XT1 oscillator, evaluate the resonators described in 5.7 Resonator and Oscillator Constants.
- Make the wiring between the XT1 and XT2 pins and the resonators as short as possible, and minimize the parasitic capacitance and wiring resistance. Note this particularly when the ultra-low power consumption oscillation (AMPHS1, AMPHS0 = 1, 0) is selected.
- Configure the circuit of the circuit board, using material with little wiring resistance.
- Place a ground pattern that has the same potential as Vss as much as possible near the XT1 oscillator.
- Be sure that the signal lines between the XT1 and XT2 pins, and the resonators do not cross with the other signal lines. Do not route the wiring near a signal line through which a high fluctuating current flows.
- The impedance between the XT1 and XT2 pins may drop and oscillation may be disturbed due to moisture absorption of the circuit board in a high-humidity environment or dew condensation on the board. When using the circuit board in such an environment, take measures to damp-proof the circuit board, such as by coating.
- When coating the circuit board, use material that does not cause capacitance or leakage between the XT1 and XT2 pins.

Figure 5-13 shows examples of incorrect resonator connection.

Figure 5-13. Examples of Incorrect Resonator Connection (1/2)

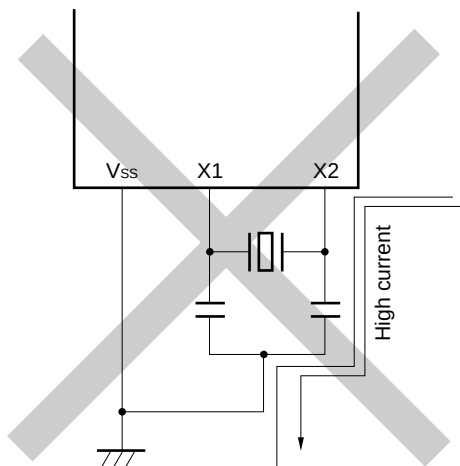


Note Do not place a power supply/GND pattern under the wiring section (section indicated by a broken line in the figure) of the X1 and X2 pins and the resonators in a multi-layer board or double-sided board.
Do not configure a layout that will cause capacitance elements and affect the oscillation characteristics.

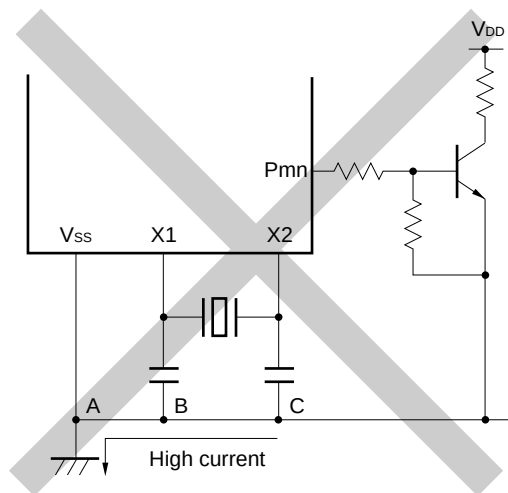
Remark When using the subsystem clock, replace X1 and X2 with XT1 and XT2, respectively. Also, insert resistors in series on the XT2 side.

Figure 5-13. Examples of Incorrect Resonator Connection (2/2)

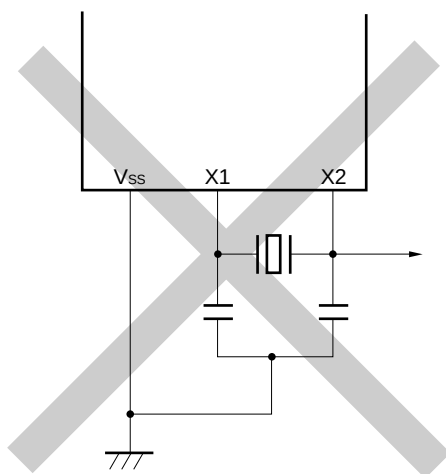
(e) Wiring near high alternating current



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



(g) Signals are fetched



Caution When X2 and XT1 are wired in parallel, the crosstalk noise of X2 may increase with XT1, resulting in malfunctioning.

Remark When using the subsystem clock, replace X1 and X2 with XT1 and XT2, respectively. Also, insert resistors in series on the XT2 side.

5.4.3 High-speed on-chip oscillator

The high-speed on-chip oscillator is incorporated in the RL78/G1A. The frequency can be selected from among 32, 24, 16, 12, 8, 6, 4, 3, 2, or 1 MHz by using the option byte (000C2H). Oscillation can be controlled by bit 0 (HIOSTOP) of the clock operation status control register (CSC). The high-speed on-chip oscillator automatically starts oscillating after reset release.

5.4.4 Low-speed on-chip oscillator

The low-speed on-chip oscillator is incorporated in the RL78/G1A.

The low-speed on-chip oscillator clock is used only as the watchdog timer, real-time clock, and 12-bit interval timer clock. The low-speed on-chip oscillator clock cannot be used as the CPU clock.

This clock operates when bit 4 (WDTON) of the option byte (000C0H), bit 4 (WUTMMCK0) of the subsystem clock supply mode control register (OSMC), or both are set to 1.

Unless the watchdog timer is stopped and WUTMMCK0 is a value other than zero, oscillation of the low-speed on-chip oscillator continues. Note that only when the watchdog timer is operating and the WUTMMCK0 bit is 0, oscillation of the low-speed on-chip oscillator will stop while the WDSTBYON bit is 0 and operation is in the HALT, STOP, or SNOOZE mode. While the watchdog timer operates, the low-speed on-chip oscillator clock does not stop even if the program freezes.

5.5 Clock Generator Operation

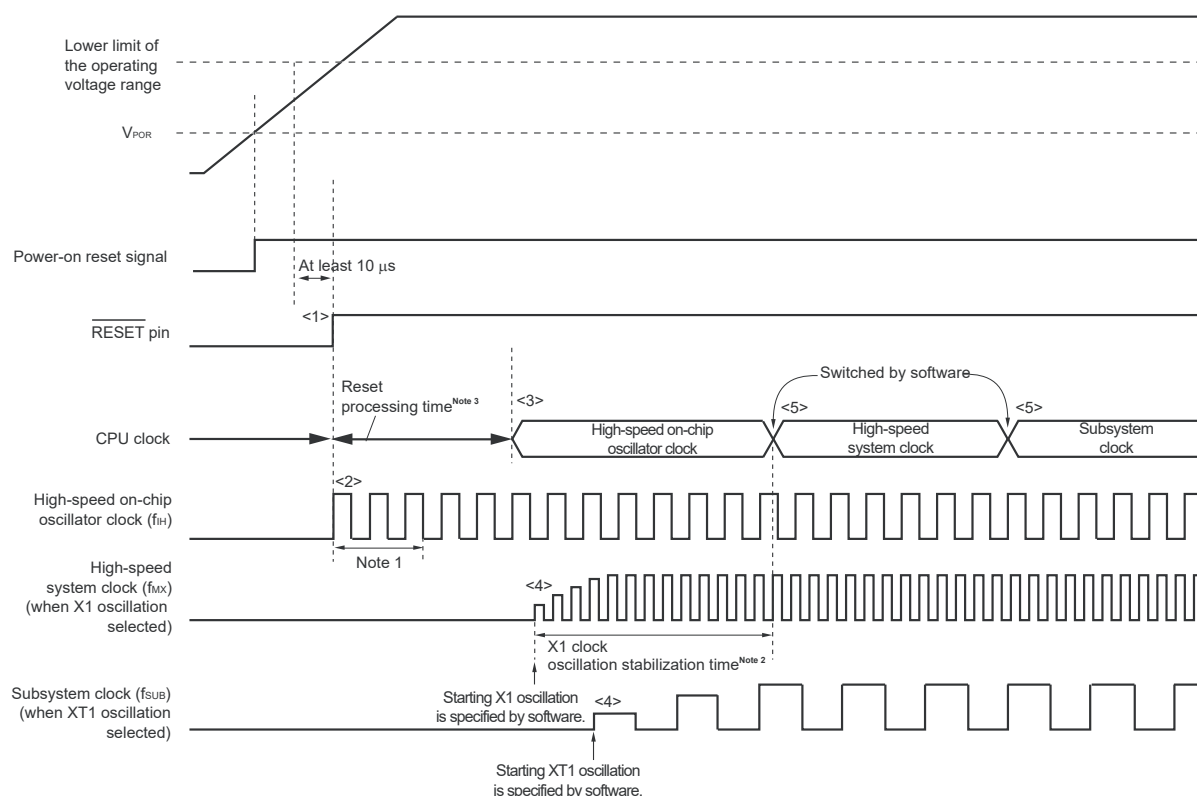
The clock generator generates the following clocks and controls the operation modes of the CPU, such as standby mode (see **Figure 5-1**).

- Main system clock f_{MAIN}
 - High-speed system clock f_{MX}
 - X1 clock f_{X}
 - External main system clock f_{EX}
 - High-speed on-chip oscillator clock f_{IH}
- Subsystem clock f_{SUB}
 - XT1 clock f_{XT}
 - External subsystem clock f_{EXS}
- Low-speed on-chip oscillator clock f_{IL}
- CPU/peripheral hardware clock f_{CLK}

The CPU starts operation when the high-speed on-chip oscillator starts outputting after a reset release in the RL78/G1A.

When the power supply voltage is turned on, the clock generator operation is shown in Figure 5-14.

Figure 5-14. Clock Generator Operation When Power Supply Voltage Is Turned On



- <1> When the power is turned on, an internal reset signal is generated by the power-on-reset (POR) circuit. Note that the reset state is maintained after a reset by the voltage detection circuit or an external reset until the voltage reaches the range of operating voltage described in **29.4 AC Characteristics** and **30.4 AC Characteristics** (the above figure is an example when the external reset is in use).
- <2> When the reset is released, the high-speed on-chip oscillator automatically starts oscillation.
- <3> The CPU starts operation on the high-speed on-chip oscillator clock after waiting for the voltage to stabilize and a reset processing have been performed after reset release.
- <4> Set the start of oscillation of the X1 or XT1 clock via software (see **5.6.2 Example of setting X1 oscillation clock** and **5.6.3 Example of setting XT1 oscillation clock**).
- <5> When switching the CPU clock to the X1 or XT1 clock, wait for the clock oscillation to stabilize, and then set switching via software (see **5.6.2 Example of setting X1 oscillation clock** and **5.6.3 Example of setting XT1 oscillation clock**).

- Notes**
1. The internal reset processing time includes the oscillation accuracy stabilization time of the high-speed on-chip oscillator clock.
 2. When releasing a reset, confirm the oscillation stabilization time for the X1 clock using the oscillation stabilization time counter status register (OSTC).
 3. For the reset processing time, see **CHAPTER 20 POWER-ON-RESET CIRCUIT**.

Caution It is not necessary to wait for the oscillation stabilization time when an external clock input from the EXCLK pin is used.

5.6 Controlling Clock

5.6.1 Example of setting high-speed on-chip oscillator

After a reset release, the CPU/peripheral hardware clock (f_{CLK}) always starts operating with the high-speed on-chip oscillator clock. The frequency of the high-speed on-chip oscillator can be selected from 32, 24, 16, 12, 8, 6, 4, 3, 2, and 1 MHz by using FRQSEL0 to FRQSEL3 of the option byte (000C2H).

[Option byte setting]

Address: 000C2H

Option byte (000C2H)	7	6	5	4	3	2	1	0
	CMODE1	CMODE0			FRQSEL3	FRQSEL2	FRQSEL1	FRQSEL0
	0/1	0/1	1	0	0/1	0/1	0/1	0/1

CMODE1	CMODE0	Setting of flash operation mode	
0	0	LV (low voltage main) mode	$V_{DD} = 1.6\text{ V to }3.6\text{ V @ }1\text{ MHz to }4\text{ MHz}$
1	0	LS (low speed main) mode	$V_{DD} = 1.8\text{ V to }3.6\text{ V @ }1\text{ MHz to }8\text{ MHz}$
1	1	HS (high speed main) mode	$V_{DD} = 2.4\text{ V to }3.6\text{ V @ }1\text{ MHz to }16\text{ MHz}$ $V_{DD} = 2.7\text{ V to }3.6\text{ V @ }1\text{ MHz to }32\text{ MHz}$
Other than above		Setting prohibited	

FRQSEL3	FRQSEL2	FRQSEL1	FRQSEL0	Frequency of the high-speed on-chip oscillator
1	0	0	0	32 MHz
0	0	0	0	24 MHz
1	0	0	1	16 MHz
0	0	0	1	12 MHz
1	0	1	0	8 MHz
0	0	1	0	6 MHz
1	0	1	1	4 MHz
0	0	1	1	3 MHz
1	1	0	0	2 MHz
1	1	0	1	1 MHz
Other than above				Setting prohibited

[High-speed on-chip oscillator frequency select register (HOCODIV) setting]

Address: F00A8H

	7	6	5	4	3	2	1	0
HOCODIV	0	0	0	0	0	HOCODIV2	HOCODIV1	HOCODIV0

HOCODIV2	HOCODIV1	HOCODIV0	Selection of high-speed on-chip oscillator clock frequency	
			FRQSEL3 Bit is 0	FRQSEL3 Bit is 1
0	0	0	24 MHz	32 MHz
0	0	1	12 MHz	16 MHz
0	1	0	6 MHz	8 MHz
0	1	1	3 MHz	4 MHz
1	0	0	Setting prohibited	2 MHz
1	0	1	Setting prohibited	1 MHz
Other than above			Setting prohibited	

5.6.2 Example of setting X1 oscillation clock

After a reset release, the CPU/peripheral hardware clock (f_{CLK}) always starts operating with the high-speed on-chip oscillator clock. To subsequently change the clock to the X1 oscillation clock, set the oscillator and start oscillation by using the oscillation stabilization time select register (OSTS) and clock operation mode control register (CMC) and clock operation status control register (CSC) and wait for oscillation to stabilize by using the oscillation stabilization time counter status register (OSTC). After the oscillation stabilizes, set the X1 oscillation clock to f_{CLK} by using the system clock control register (CKC).

[Register settings] Set the register in the order of <1> to <5> below.

<1> Set (1) the OSCSEL bit of the CMC register, except for the cases where $f_x > 10$ MHz, in such cases set (1) the AMPH bit, to operate the X1 oscillator.

	7	6	5	4	3	2	1	0
CMC	EXCLK	OSCSEL	EXCLKS	OSCSELS		AMPHS1	AMPHS0	AMPH
	0	1	0	0	0	0	0	0/1

<2> Using the OSTS register, select the oscillation stabilization time of the X1 oscillator at releasing of the STOP mode.

Example: Setting values when a wait of at least 102 μ s is set based on a 10 MHz resonator.

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

<3> Clear (0) the MSTOP bit of the CSC register to start oscillating the X1 oscillator.

	7	6	5	4	3	2	1	0
CSC	MSTOP	XTSTOP						HIOSTOP
	0	1	0	0	0	0	0	0

<4> Use the OSTC register to wait for oscillation of the X1 oscillator to stabilize.

Example: Wait until the bits reach the following values when a wait of at least 102 μ s is set based on a 10 MHz resonator.

	7	6	5	4	3	2	1	0
OSTC	MOST8	MOST9	MOST10	MOST11	MOST13	MOST15	MOST17	MOST18
	1	1	1	0	0	0	0	0

<5> Use the MCM0 bit of the CKC register to specify the X1 oscillation clock as the CPU/peripheral hardware clock.

	7	6	5	4	3	2	1	0
CKC	CLS	CSS	MCS	MCM0				
	0	0	0	1	0	0	0	0

Caution Keep the operating voltage within the range that allows operation of the flash memory as set in an option byte (000C2H) before and after changes to the main system clock (f_{MAIN}) by using the system clock control register (CKC).

Option Byte (000C2H) Value		Flash Operation Mode	Operating Frequency Range	Operating Voltage Range
CMODE1	CMODE0			
0	0	LV (low-voltage main) mode	1 MHz to 4 MHz	1.6 V to 3.6 V
1	0	LS (low-speed main) mode	1 MHz to 8 MHz	1.8 V to 3.6 V
1	1	HS (high-speed main) mode	1 MHz to 16 MHz	2.4 V to 3.6 V
			1 MHz to 32 MHz	2.7 V to 3.6 V

5.6.3 Example of setting XT1 oscillation clock

After a reset release, the CPU/peripheral hardware clock (f_{CLK}) always starts operating with the high-speed on-chip oscillator clock. To subsequently change the clock to the XT1 oscillation clock, set the oscillator and start oscillation by using the subsystem clock supply mode control register (OSMC), clock operation mode control register (CMC), and clock operation status control register (CSC), set the XT1 oscillation clock to f_{CLK} by using the system clock control register (CKC).

[Register settings] Set the register in the order of <1> to <5> below.

<1> To run only the real-time clock and 12-bit interval timer on the subsystem clock (ultra-low current consumption) when in the STOP mode or HALT mode during CPU operation on the subsystem clock, set the RTCLPC bit to 1.

	7	6	5	4	3	2	1	0
OSMC	RTCLPC 0/1	0	0	WUTMMCK0 0	0	0	0	0

<2> Set (1) the OSCSELS bit of the CMC register to operate the XT1 oscillator.

	7	6	5	4	3	2	1	0
CMC	EXCLK 0	OSCSEL 0	EXCLKS 0	OSCSELS 1	0	AMPHS1 0/1	AMPHS0 0/1	AMPH 0

AMPHS0 and AMPHS1 bits: These bits are used to specify the oscillation mode of the XT1 oscillator.

<3> Clear (0) the XTSTOP bit of the CSC register to start oscillating the XT1 oscillator.

	7	6	5	4	3	2	1	0
CSC	MSTOP 1	XTSTOP 0	0	0	0	0	0	HIOSTOP 0

<4> Use the timer function or another function to wait for oscillation of the subsystem clock to stabilize by using software.

<5> Use the CSS bit of the CKC register to specify the XT1 oscillation clock as the CPU/peripheral hardware clock.

	7	6	5	4	3	2	1	0
CKC	CLS 0	CSS 1	MCS 0	MCM0 0	0	0	0	0

5.6.4 CPU clock status transition diagram

Figure 5-15 shows the CPU clock status transition diagram of this product.

Figure 5-15. CPU Clock Status Transition Diagram

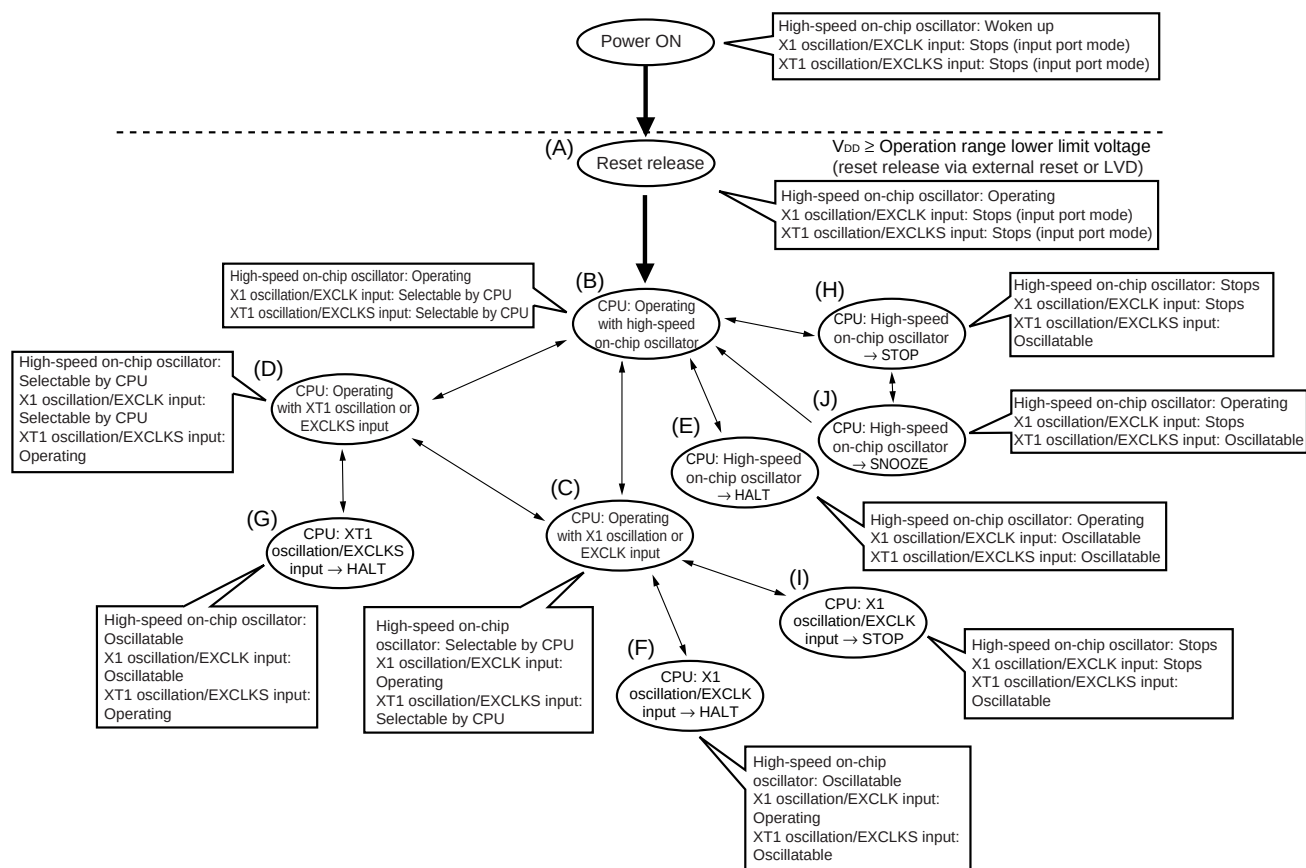


Table 5-3 shows transition of the CPU clock and examples of setting the SFR registers.

Table 5-3. CPU Clock Transition and SFR Register Setting Examples (1/5)

(1) CPU operating with high-speed on-chip oscillator clock (B) after reset release (A)

Status Transition	SFR Register Setting
(A) → (B)	SFR registers do not have to be set (default status after reset release).

(2) CPU operating with high-speed system clock (C) after reset release (A)

(The CPU operates with the high-speed on-chip oscillator clock immediately after a reset release (B).)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CMC Register ^{Note}			OSTS Register	CSC Register	OSTC Register	CKC Register
	EXCLK	OSCSEL	AMPH		MSTOP		MCM0
(A) → (B) → (C) (X1 clock: 1 MHz ≤ f _x ≤ 10 MHz)	0	1	0	Note 2	0	Must be checked	1
(A) → (B) → (C) (X1 clock: 10 MHz < f _x ≤ 20 MHz)	0	1	1	Note 2	0	Must be checked	1
(A) → (B) → (C) (external main clock)	1	1	×	Note 2	0	Must not be checked	1

- Notes**
- The clock operation mode control register (CMC) can be written only once by an 8-bit memory manipulation instruction after reset release.
 - Set the oscillation stabilization time as follows.
 - Desired the oscillation stabilization time counter status register (OSTC) oscillation stabilization time ≤ Oscillation stabilization time set by the oscillation stabilization time select register (OSTS)

Caution Set the clock after the supply voltage has reached the operable voltage of the clock to be set (see CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = −40 to +85°C), CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS T_A = −40 to + 105°C).

(3) CPU operating with subsystem clock (D) after reset release (A)

(The CPU operates with the high-speed on-chip oscillator clock immediately after a reset release (B).)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CMC Register ^{Note}				CSC Register	Waiting for Oscillation Stabilization	CKC Register
	EXCLKS	OSCSELS	AMPHS1	AMPHS0	XTSTOP		CSS
(A) → (B) → (D) (XT1 clock)	0	1	0/1	0/1	0	Necessary	1
(A) → (B) → (D) (external sub clock)	1	1	×	×	0	Necessary	1

Note The clock operation mode control register (CMC) can be written only once by an 8-bit memory manipulation instruction after reset release.

Remarks 1. ×: don't care

2. (A) to (J) in Table 5-3 correspond to (A) to (J) in Figure 5-15.

Table 5-3. CPU Clock Transition and SFR Register Setting Examples (2/5)

(4) CPU clock changing from high-speed on-chip oscillator clock (B) to high-speed system clock (C)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CMC Register ^{Note 1}			OSTS Register	CSC Register	OSTC Register	CKC Register
	EXCLK	OSCSEL	AMPH		MSTOP		MCM0
(B) → (C) (X1 clock: 1 MHz ≤ fX ≤ 10 MHz)	0	1	0	Note 2	0	Must be checked	1
(B) → (C) (X1 clock: 10 MHz < fX ≤ 20 MHz)	0	1	1	Note 2	0	Must be checked	1
(B) → (C) (external main clock)	1	1	×	Note 2	0	Must not be checked	1

Unnecessary if these registers are already set Unnecessary if the CPU is operating with the high-speed system clock

Notes 1. The clock operation mode control register (CMC) can be written only once by an 8-bit memory manipulation instruction after reset release.

This setting is not necessary if it has already been set.

2. Set the oscillation stabilization time as follows.

- Desired the oscillation stabilization time counter status register (OSTC) oscillation stabilization time ≤ Oscillation stabilization time set by the oscillation stabilization time select register (OSTS)

Caution Set the clock after the supply voltage has reached the operable voltage of the clock to be set (see CHAPTER 29 ELECTRICAL SPECIFICATIONS (TA = −40 to +85°C), CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS TA = −40 to + 105°C).

(5) CPU clock changing from high-speed on-chip oscillator clock (B) to subsystem clock (D)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CMC Register ^{Note}			CSC Register	Waiting for Oscillation Stabilization	CKC Register
	EXCLKS	OSCSELS	AMPHS1, AMPHS0	XTSTOP		CSS
(B) → (D) (XT1 clock)	0	1	00: Low power consumption oscillation 01: Normal oscillation 10: Ultra-low power consumption oscillation	0		1
(B) → (D) (external sub clock)	1	1	×	0	Necessary	1

Unnecessary if these registers are already set Unnecessary if the CPU is operating with the subsystem clock

Note The clock operation mode control register (CMC) can be written only once by an 8-bit memory manipulation instruction after reset release.

This setting is not necessary if it has already been set.

Remarks 1. ×: don't care

2. (A) to (J) in Table 5-3 correspond to (A) to (J) in Figure 5-15.

Table 5-3. CPU Clock Transition and SFR Register Setting Examples (3/5)

(6) CPU clock changing from high-speed system clock (C) to high-speed on-chip oscillator clock (B)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CSC Register	Oscillation accuracy stabilization time	CKC Register
	HIOSTOP		MCM0
(C) → (B)	0	18 μ s to 65 μ s	0

Unnecessary if the CPU is operating with the
high-speed on-chip oscillator clock

Remark The oscillation accuracy stabilization time changes according to the temperature conditions and the STOP mode period.

(7) CPU clock changing from high-speed system clock (C) to subsystem clock (D)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CSC Register	Waiting for Oscillation Stabilization	CKC Register
	XTSTOP		CSS
(C) → (D)	0	Necessary	1

Unnecessary if the CPU is operating with the
subsystem clock

(8) CPU clock changing from subsystem clock (D) to high-speed on-chip oscillator clock (B)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	CSC Register	Oscillation accuracy stabilization time	CKC Register
	HIOSTOP		CSS
(D) → (B)	0	18 μ s to 65 μ s	0

Unnecessary if the CPU is operating with the high-
speed on-chip oscillator clock

- Remarks**
- (A) to (J) in Table 5-3 correspond to (A) to (J) in Figure 5-15.
 - The oscillation accuracy stabilization time changes according to the temperature conditions and the STOP mode period.

Table 5-3. CPU Clock Transition and SFR Register Setting Examples (4/5)

(9) CPU clock changing from subsystem clock (D) to high-speed system clock (C)

(Setting sequence of SFR registers) →

Setting Flag of SFR Register Status Transition	OSTS Register	CSC Register	OSTC Register	CKC Register
		MSTOP		CSS
(D) → (C) (X1 clock: 1 MHz ≤ f _x ≤ 10 MHz)	Note	0	Must be checked	0
(D) → (C) (X1 clock: 10 MHz < f _x ≤ 20 MHz)	Note	0	Must be checked	0
(D) → (C) (external main clock)	Note	0	Must not be checked	0

Unnecessary if the CPU is operating
with the high-speed system clock

Note Set the oscillation stabilization time as follows.

- Desired the oscillation stabilization time counter status register (OSTC) oscillation stabilization time ≤ Oscillation stabilization time set by the oscillation stabilization time select register (OSTS)

Caution Set the clock after the supply voltage has reached the operable voltage of the clock to be set (see CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = −40 to +85°C), CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS T_A = −40 to +105°C).

(10) • HALT mode (E) set while CPU is operating with high-speed on-chip oscillator clock (B)

- HALT mode (F) set while CPU is operating with high-speed system clock (C)
- HALT mode (G) set while CPU is operating with subsystem clock (D)

Status Transition	Setting
(B) → (E) (C) → (F) (D) → (G)	Executing HALT instruction

Remark (A) to (J) in Table 5-3 correspond to (A) to (J) in Figure 5-15.

Table 5-3. CPU Clock Transition and SFR Register Setting Examples (5/5)

- (11) • STOP mode (H) set while CPU is operating with high-speed on-chip oscillator clock (B)
 • STOP mode (I) set while CPU is operating with high-speed system clock (C)

(Setting sequence) →

Status Transition		Setting		
(B) → (H)		Stopping peripheral functions that are disabled in STOP mode	–	Executing STOP instruction
(C) → (I)	In X1 oscillation		Sets the OSTS register	
	External main system clock		–	

(12) CPU changing from STOP mode (H) to SNOOZE mode (J)

For details about the setting for switching from the STOP mode to the SNOOZE mode, see **11.8 SNOOZE Mode Function**, **12.5.7 SNOOZE mode function** and **12.6.3 SNOOZE mode function**.

Remark (A) to (J) in Table 5-3 correspond to (A) to (J) in Figure 5-15.

5.6.5 Condition before changing CPU clock and processing after changing CPU clock

Condition before changing the CPU clock and processing after changing the CPU clock are shown below.

Table 5-4. Changing CPU Clock (1/2)

CPU Clock		Condition Before Change	Processing After Change
Before Change	After Change		
High-speed on-chip oscillator clock	X1 clock	Stabilization of X1 oscillation • OSCSEL = 1, EXCLK = 0, MSTOP = 0 • After elapse of oscillation stabilization time	The operating current can be reduced by stopping the high-speed on-chip oscillator (HIOSTOP = 1) after checking that the CPU clock is changed.
	External main system clock	Enabling input of external clock from the EXCLK pin • OSCSEL = 1, EXCLK = 1, MSTOP = 0	
	XT1 clock	Stabilization of XT1 oscillation • OSCSELS = 1, EXCLKS = 0, XTSTOP = 0 • After elapse of oscillation stabilization time	
	External subsystem clock	Enabling input of external clock from the EXCLKS pin • OSCSELS = 1, EXCLKS = 1, XTSTOP = 0	
X1 clock	High-speed on-chip oscillator clock	Enabling oscillation of high-speed on-chip oscillator • HIOSTOP = 0 • After elapse of oscillation accuracy stabilization time	X1 oscillation can be stopped (MSTOP = 1) after checking that the CPU clock is changed.
	External main system clock	Transition not possible	—
	XT1 clock	Stabilization of XT1 oscillation • OSCSELS = 1, EXCLKS = 0, XTSTOP = 0 • After elapse of oscillation stabilization time	X1 oscillation can be stopped (MSTOP = 1) after checking that the CPU clock is changed.
	External subsystem clock	Enabling input of external clock from the EXCLKS pin • OSCSELS = 1, EXCLKS = 1, XTSTOP = 0	X1 oscillation can be stopped (MSTOP = 1) after checking that the CPU clock is changed.
External main system clock	High-speed on-chip oscillator clock	Enabling oscillation of high-speed on-chip oscillator • HIOSTOP = 0 • After elapse of oscillation accuracy stabilization time	External main system clock input can be disabled (MSTOP = 1) after checking that the CPU clock is changed.
	X1 clock	Transition not possible	—
	XT1 clock	Stabilization of XT1 oscillation • OSCSELS = 1, EXCLKS = 0, XTSTOP = 0 • After elapse of oscillation stabilization time	External main system clock input can be disabled (MSTOP = 1) after checking that the CPU clock is changed.
	External subsystem clock	Enabling input of external clock from the EXCLKS pin • OSCSELS = 1, EXCLKS = 1, XTSTOP = 0	External main system clock input can be disabled (MSTOP = 1) after checking that the CPU clock is changed.

Table 5-5. Changing CPU Clock (2/2)

CPU Clock		Condition Before Change	Processing After Change
Before Change	After Change		
XT1 clock	High-speed on-chip oscillator clock	Oscillation of high-speed on-chip oscillator and selection of high-speed on-chip oscillator clock as main system clock • HIOSTOP = 0, MCS = 0	XT1 oscillation can be stopped (XTSTOP = 1) after checking that the CPU clock is changed.
	X1 clock	Stabilization of X1 oscillation and selection of high-speed system clock as main system clock • OSCSEL = 1, EXCLK = 0, MSTOP = 0 • After elapse of oscillation stabilization time • MCS = 1	
	External main system clock	Enabling input of external clock from the EXCLK pin and selection of high-speed system clock as main system clock • OSCSEL = 1, EXCLK = 1, MSTOP = 0 • MCS = 1	
	External subsystem clock	Transition not possible	—
External subsystem clock	High-speed on-chip oscillator clock	Oscillation of high-speed on-chip oscillator and selection of high-speed on-chip oscillator clock as main system clock • HIOSTOP = 0, MCS = 0	External subsystem clock input can be disabled (XTSTOP = 1) after checking that the CPU clock is changed.
	X1 clock	Stabilization of X1 oscillation and selection of high-speed system clock as main system clock • OSCSEL = 1, EXCLK = 0, MSTOP = 0 • After elapse of oscillation stabilization time • MCS = 1	
	External main system clock	Enabling input of external clock from the EXCLK pin and selection of high-speed system clock as main system clock • OSCSEL = 1, EXCLK = 1, MSTOP = 0 • MCS = 1	
	XT1 clock	Transition not possible	—

5.6.6 Time required for switchover of CPU clock and system clock

By setting bits 4 and 6 (MCM0, CSS) of the system clock control register (CKC), the CPU clock can be switched (between the main system clock and the subsystem clock), and main system clock can be switched (between the high-speed on-chip oscillator clock and the high-speed system clock).

The actual switchover operation is not performed immediately after rewriting to the CKC register; operation continues on the pre-switchover clock for several clocks (see Table 5-5 to Table 5-7).

Whether the CPU is operating on the main system clock or the subsystem clock can be ascertained using bit 7 (CLS) of the CKC register. Whether the main system clock is operating on the high-speed system clock or high-speed on-chip oscillator clock can be ascertained using bit 5 (MCS) of the CKC register.

When the CPU clock is switched, the peripheral hardware clock is also switched.

Table 5-5. Maximum Time Required for System Clock Switchover

Clock A	Switching directions	Clock B	Remark
f_{IH}	$\longleftrightarrow$	f_{MX}	See Table 5-6
f_{MAIN}	$\longleftrightarrow$	f_{SUB}	See Table 5-7

Table 5-6. Maximum Number of Clocks Required for $f_{IH} \leftrightarrow f_{MX}$

Set Value Before Switchover		Set Value After Switchover	
MCM0		MCM0	
		0 ($f_{MAIN} = f_{IH}$)	1 ($f_{MAIN} = f_{MX}$)
0 ($f_{MAIN} = f_{IH}$)	$f_{MX} \geq f_{IH}$		2 clocks
	$f_{MX} < f_{IH}$		$2f_{IH}/f_{MX}$ clocks
1 ($f_{MAIN} = f_{MX}$)	$f_{MX} \geq f_{IH}$	$2f_{MX}/f_{IH}$ clocks	
	$f_{MX} < f_{IH}$	2 clocks	

Table 5-7. Maximum Number of Clocks Required for $f_{MAIN} \leftrightarrow f_{SUB}$

Set Value Before Switchover		Set Value After Switchover	
CSS		CSS	
		0 ($f_{CLK} = f_{MAIN}$)	1 ($f_{CLK} = f_{SUB}$)
0 ($f_{CLK} = f_{MAIN}$)			$1 + 2f_{MAIN}/f_{SUB}$ clocks
1 ($f_{CLK} = f_{SUB}$)		3 clocks	

Remarks 1. The number of clocks listed in Table 5-6 and Table 5-7 is the number of CPU clocks before switchover.

2. Calculate the number of clocks in **Table 5-6** and **Table 5-7** by removing the decimal portion.

Example When switching the main system clock from the high-speed system clock to the high-speed on-chip oscillator clock (@ oscillation with $f_{IH} = 8$ MHz, $f_{MX} = 10$ MHz)

$$2f_{MX}/f_{IH} = 2 (10/8) = 2.5 \rightarrow 3 \text{ clocks}$$

5.6.7 Conditions before clock oscillation is stopped

The following lists the register flag settings for stopping the clock oscillation (disabling external clock input) and conditions before the clock oscillation is stopped.

Before stopping the clock oscillation, check the conditions before the clock oscillation is stopped.

Table 5-7. Conditions Before the Clock Oscillation Is Stopped and Flag Settings

Clock	Conditions Before Clock Oscillation Is Stopped (External Clock Input Disabled)	Flag Settings of SFR Register
High-speed on-chip oscillator clock	MCS = 1 or CLS = 1 (The CPU is operating on a clock other than the high-speed on-chip oscillator clock.)	HIOSTOP = 1
X1 clock	MCS = 0 or CLS = 1 (The CPU is operating on a clock other than the high-speed system clock.)	MSTOP = 1
External main system clock		
XT1 clock	CLS = 0 (The CPU is operating on a clock other than the subsystem clock.)	XTSTOP = 1
External subsystem clock		

5.7 Resonator and Oscillator Constants

The resonators for which the operation is verified and their oscillator constants are shown below.

- Cautions**
1. The oscillator constants shown above are reference values based on evaluation in a specific environment by the resonator manufacturer. Be sure to apply to the resonator manufacturer for evaluation on the actual circuit before using these constants for your application. Also apply to the resonator manufacturer for re-evaluation on the actual circuit if you have changed the make of the microcontroller or the board.
 2. The oscillation voltage and oscillation frequency only indicate the oscillator characteristic. Use the RL78 microcontroller so that the internal operation conditions are within the specifications of the DC and AC characteristics.

Figure 5-16. External Oscillation Circuit Example



(1) X1 oscillation:

As of February, 2013 (1/3)

Manufacturer	Resonator	Part Number ^{Note 1}	SMD/ Lead	Frequency (MHz)	Flash operation mode ^{Note 2}	Recommended Circuit Constants ^{Note 3} (reference)			Oscillation Voltage Range (V)	
						C1 (pF)	C2 (pF)	Rd (kΩ)	MIN.	MAX.
Murata Manufacturing Co., Ltd. ^{Note 4}	Ceramic resonator	CSTCC2M00G56-R0	SMD	2.0	LV	(47)	(47)	0	1.6	3.6
		CSTCR4M00G55-R0	SMD	4.0		(39)	(39)	0		
		CSTLS4M00G53-B0	Lead			(15)	(15)	0		
		CSTCC2M00G56-R0	SMD	2.0	LS	(47)	(47)	0	1.8	3.6
		CSTCR4M00G55-R0	SMD	4.0		(39)	(39)	0		
		CSTLS4M00G53-B0	Lead			(15)	(15)	0		
		CSTCR4M19G55-R0	SMD	4.194		(39)	(39)	0		
		CSTLS4M19G53-B0	Lead			(15)	(15)	0		
		CSTCR4M91G53-R0	SMD	4.915		(15)	(15)	0		
		CSTLS4M91G53-B0	Lead			(15)	(15)	0		
		CSTCR5M00G53-R0	SMD	5.0		(15)	(15)	0		
		CSTLS5M00G53-B0	Lead			(15)	(15)	0		
		CSTCR6M00G53-R0	SMD	6.0		(15)	(15)	0		
		CSTLS6M00G53-B0	Lead			(15)	(15)	0		
		CSTCE8M00G52-R0	SMD	8.0		(10)	(10)	0		
		CSTLS8M00G53-B0	Lead			(15)	(15)	0		

- Notes 1.** The part numbers of the products that can operate at up to 105°C differ from those listed in the above table. For details, contact Murata Manufacturing Co., Ltd.
- 2.** Set the flash operation mode by using CMODE1 and CMODE0 bits of the option byte (000C2H/010C2H).
- 3.** Values in parentheses in the C1, C2 columns indicate an internal capacitance.
- 4.** When using these oscillators, contact Murata Manufacturing Co., Ltd. (<http://www.murata.com/index.html>).

- Remarks 1.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
- HS (High speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$ (When X1 oscillation: 1 MHz to 20 MHz)
- $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
- LS (Low speed main) mode: $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
- LV (Low voltage main) mode: $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$
- 2.** A list of the resonators for which the operation has most recently been verified and their oscillation constants (for reference) is provided on the page for the corresponding product at the Renesas Web site (<http://www.renesas.com>).

(1) X1 oscillation:

As of February, 2013 (2/3)

Manufacturer	Resonator	Part Number ^{Note 1}	SMD/ Lead	Frequency (MHz)	Flash operation mode ^{Note 2}	Recommended Circuit Constants ^{Note 3} (reference)			Oscillation Voltage Range (V)	
						C1 (pF)	C2 (pF)	Rd (kΩ)	MIN.	MAX.
Murata Manufacturing Co., Ltd. ^{Note 4}	Ceramic resonator	CSTCC2M00G56-R0	SMD	2.0	HS	(47)	(47)	0	2.4	3.6
		CSTCR4M00G55-R0	SMD	4.0		(39)	(39)	0		
		CSTLS4M00G53-B0	Lead			(15)	(15)	0		
		CSTCR4M19G55-R0	SMD	4.194		(39)	(39)	0		
		CSTLS4M19G53-B0	Lead			(15)	(15)	0		
		CSTCR4M91G53-R0	SMD	4.915		(15)	(15)	0		
		CSTLS4M91G53-B0	Lead			(15)	(15)	0		
		CSTCR5M00G53-R0	SMD	5.0		(15)	(15)	0		
		CSTLS5M00G53-B0	Lead			(15)	(15)	0		
		CSTCR6M00G53-R0	SMD	6.0		(15)	(15)	0		
		CSTLS6M00G53-B0	Lead			(15)	(15)	0		
		CSTCE8M00G52-R0	SMD	8.0		(10)	(10)	0		
		CSTLS8M00G53-B0	Lead			(15)	(15)	0		
		CSTCE8M38G52-R0	SMD	8.388		(10)	(10)	0		
		CSTLS8M38G53-B0	Lead			(15)	(15)	0		
		CSTCE10M0G52-R0	SMD	10.0		(10)	(10)	0		
		CSTLS10M0G53-B0	Lead			(15)	(15)	0		
		CSTCE12M0G52-R0	SMD	12.0		(10)	(10)	0		
		CSTCE16M0V53-R0	SMD	16.0		(15)	(15)	0		
		CSTLS16M0X51-B0	Lead			(5)	(5)	0		
		CSTCE20M0V51-R0	SMD	20.0		(5)	(5)	0	2.7	3.6
		CSTLS20M0X51-B0	Lead			(5)	(5)	0		

- Notes 1.** The part numbers of the products that can operate at up to 105°C differ from those listed in the above table. For details, contact Murata Manufacturing Co., Ltd.
- 2.** Set the flash operation mode by using CMODE1 and CMODE0 bits of the option byte (000C2H/010C2H).
- 3.** Values in parentheses in the C1, C2 columns indicate an internal capacitance.
- 4.** When using these oscillators, contact Murata Manufacturing Co., Ltd. (<http://www.murata.com/index.html>).

- Remarks 1.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
- HS (High speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$ (When X1 oscillation: 1 MHz to 20 MHz)
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
- LS (Low speed main) mode: $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
- LV (Low voltage main) mode: $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$
- 2.** A list of the resonators for which the operation has most recently been verified and their oscillation constants (for reference) is provided on the page for the corresponding product at the Renesas Web site (<http://www.renesas.com>).

(1) X1 oscillation:

As of February, 2013 (3/3)

Manufacturer	Resonator	Part Number	SMD/ Lead	Frequency (MHz)	Flash operation mode ^{Note 1}	Recommended Circuit Constants (reference)			Oscillation Voltage Range (V)	
						C1 (pF)	C2 (pF)	Rd (kΩ)	MIN.	MAX.
KYOCERA Corporation ^{Note 2}	Ceramic resonator	PBRV4.00MR50Y000	SMD	4.0	LV	15	15	0	1.6	3.6
		PBRV4.00MR50Y000	SMD	4.0	LS	15	15	0	1.8	3.6
		PRQV8.00CR5010Y000	SMD	8.0		10	10	0		
		PRQV8.00CR5010Y000	SMD	8.0	HS	10	10	0	2.4	3.6
Nihon Dempa Kogyo Co., Ltd. ^{Note 3}	Crystal resonator	NX8045GE	SMD	4.0	LV	6	6	0	1.6	3.6
		NX8045GE	SMD	4.0	LS	6	6	0	1.8	3.6
		NX8045GB	SMD	8.0		0	0	0		
		NX8045GB	SMD	8.0	HS	0	0	0	2.4	3.6
		NX3225GB	SMD	16.0		1	1	0		
		NX2520SA ^{Note 4}	SMD	20.0		0	0	0		

- Notes 1.** Set the flash operation mode by using CMODE1 and CMODE0 bits of the option byte (000C2H/010C2H).
- 2.** When using these oscillators, contact KYOCERA Corporation (<http://global.kyocera.com/>).
- 3.** When using these oscillators, contact Nihon Dempa Kogyo Co., Ltd. (<http://www.ndk.com/en/index.html>).
- 4.** This resonator can operate at up to 85°C. For details about the products that can operate at up to 105°C, contact the manufacturer of the resonator.

- Remark 1.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
- HS (High speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$ (When X1 oscillation: 1 MHz to 20 MHz)
- $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
- LS (Low speed main) mode: $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
- LV (Low voltage main) mode: $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$
- 2.** A list of the resonators for which the operation has most recently been verified and their oscillation constants (for reference) is provided on the page for the corresponding product at the Renesas Web site (<http://www.renesas.com>).

CHAPTER 6 TIMER ARRAY UNIT

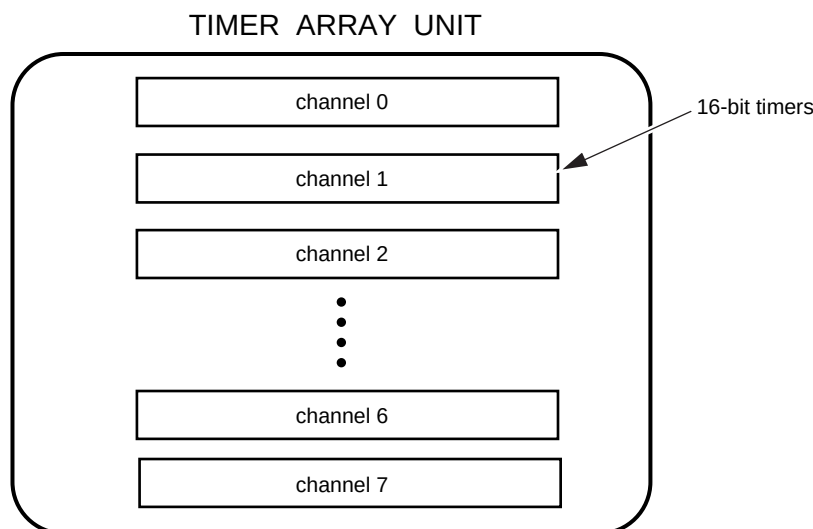
The timer array unit is provided in all products (Unit 0, Channels 0 to 7).

Units	Channels	25, 32, 48, 64-pin
Unit 0	Channel 0	√
	Channel 1	√
	Channel 2	√
	Channel 3	√
	Channel 4	√
	Channel 5	√
	Channel 6	√
	Channel 7	√

- Cautions**
1. The presence or absence of timer I/O pins depends on the product. See Table 6-2 Timer I/O Pins provided in Each Product for details.
 2. Most of the following descriptions in this chapter use the 64-pin products as an example.

The timer array unit has eight 16-bit timers.

Each 16-bit timer is called a channel and can be used as an independent timer. In addition, two or more “channels” can be used to create a high-accuracy timer.



For details about each function, see the table below.

Independent channel operation function	Simultaneous channel operation function
• Interval timer (→ see 6.8.1) • Square wave output (→ see 6.8.1) • External event counter (→ see 6.8.2) • Divider^{Note} (→ see 6.8.3) • Input pulse interval measurement (→ see 6.8.4) • Measurement of high-/low-level width of input signal (→ see 6.8.5) • Delay counter (→ see 6.8.6)	• One-shot pulse output(→ see 6.9.1) • PWM output(→ see 6.9.2) • Multiple PWM output(→ see 6.9.3)

Note Only channel 0 of unit 0.

It is possible to use the 16-bit timer of channels 1 and 3 of the units 0 as two 8-bit timers (higher and lower). The functions that can use channels 1 and 3 as 8-bit timers are as follows:

- Interval timer (higher/lower 8-bit timer only)/square wave output (lower 8-bit timer only)
- External event counter (lower 8-bit timer only)
- Delay counter (lower 8-bit timer only)

Channel 7 of unit 0 can be used to realize LIN-bus communication operating in combination with UART2 of the serial array unit (32, 48, and 64-pin products only).

6.1 Functions of Timer Array Unit

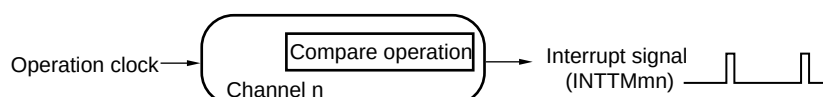
Timer array unit has the following functions.

6.1.1 Independent channel operation function

By operating a channel independently, it can be used for the following purposes without being affected by the operation mode of other channels.

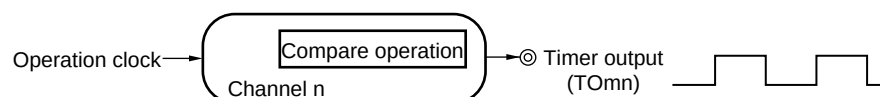
(1) Interval timer

Each timer of a unit can be used as a reference timer that generates an interrupt (INTTMmn) at fixed intervals.



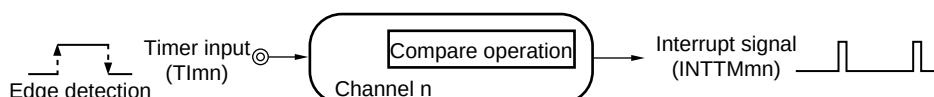
(2) Square wave output

A toggle operation is performed each time INTTMmn interrupt is generated and a square wave with a duty factor of 50% is output from a timer output pin (TOMn).



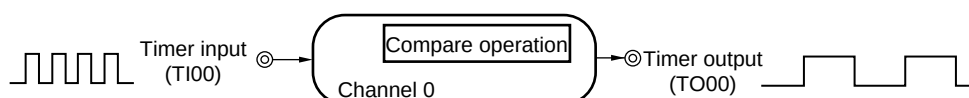
(3) External event counter

Each timer of a unit can be used as an event counter that generates an interrupt when the number of the valid edges of a signal input to the timer input pin (TIMn) has reached a specific value.



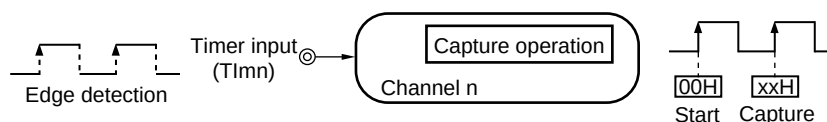
(4) Divider function (channel 0 only)

A clock input from a timer input pin (TI00) is divided and output from an output pin (TOM0).



(5) Input pulse interval measurement

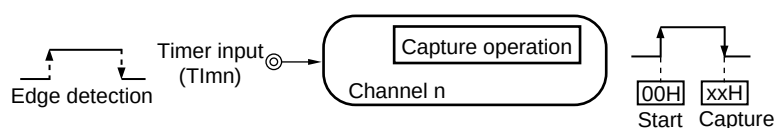
Counting is started by the valid edge of a pulse signal input to a timer input pin (TIMn). The count value of the timer is captured at the valid edge of the next pulse. In this way, the interval of the input pulse can be measured.



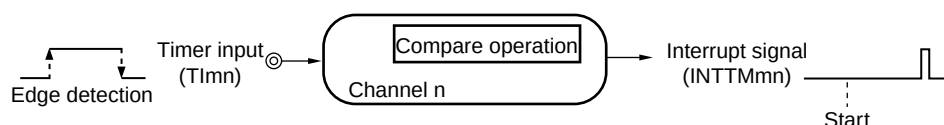
(Note, Caution, and Remark are listed on the next page.)

(6) Measurement of high-/low-level width of input signal

Counting is started by a single edge of the signal input to the timer input pin (TImn), and the count value is captured at the other edge. In this way, the high-level or low-level width of the input signal can be measured.

**(7) Delay counter**

Counting is started at the valid edge of the signal input to the timer input pin (TImn), and an interrupt is generated after any delay period.



Remarks 1 m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

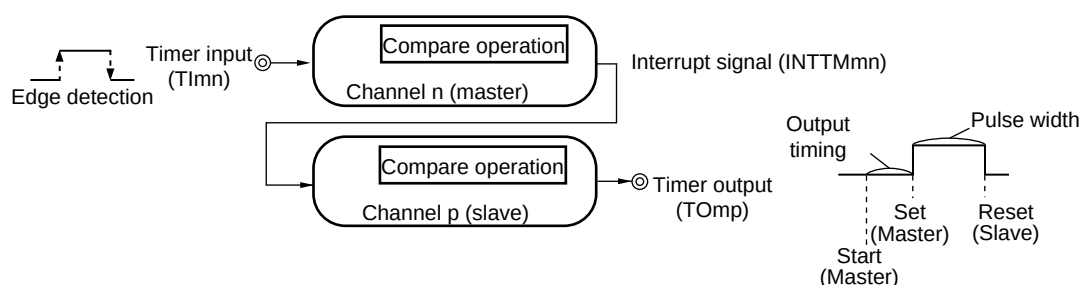
2. The presence or absence of timer I/O pins of channel 0 to 7 depends on the product. See **Table 6-2 Timer I/O Pins provided in Each Product** for details.

6.1.2 Simultaneous channel operation function

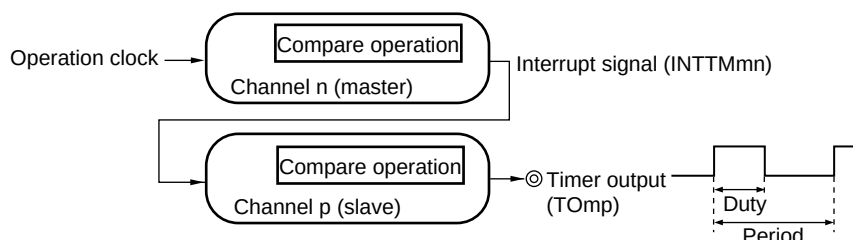
By using the combination of a master channel (a reference timer mainly controlling the cycle) and slave channels (timers operating according to the master channel), channels can be used for the following purposes.

(1) One-shot pulse output

Two channels are used as a set to generate a one-shot pulse with a specified output timing and a specified pulse width.

**(2) PWM (Pulse Width Modulation) output**

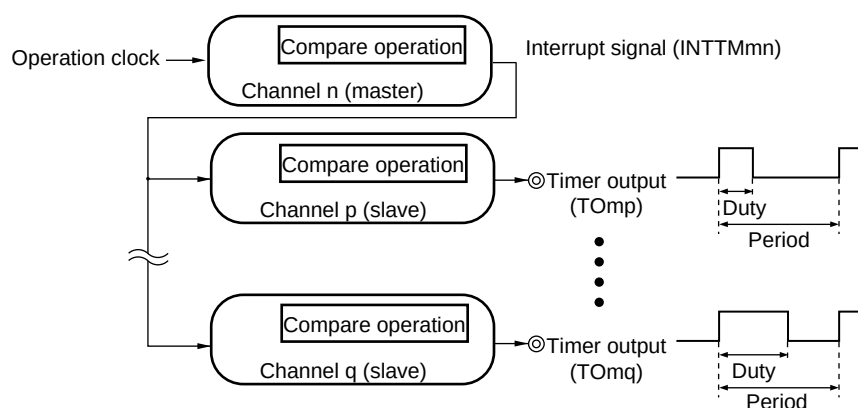
Two channels are used as a set to generate a pulse with a specified period and a specified duty factor.



(Caution is listed on the next page.)

(3) Multiple PWM (Pulse Width Modulation) output

By extending the PWM function and using one master channel and two or more slave channels, up to seven types of PWM signals that have a specific period and a specified duty factor can be generated.



Caution For details about the rules of simultaneous channel operation function, see 6.4.1 Basic rules of simultaneous channel operation function.

Remark m: Unit number ($m = 0$), n: Channel number ($n = 0$ to 7(however, timer input pin (TImn), timer output pin (TOMn) : $n = 0, 1, 3$ to 7)), p, q: Slave channel number ($n < p < q \leq 7$)

6.1.3 8-bit timer operation function (channels 1 and 3 only)

The 8-bit timer operation function makes it possible to use a 16-bit timer channel in a configuration consisting of two 8-bit timer channels. This function can only be used for channels 1 and 3.

Caution There are several rules for using 8-bit timer operation function.
For details, see 6.4.2 Basic rules of 8-bit timer operation function (channels 1 and 3 only).

6.1.4 LIN-bus supporting function (channel 7 of unit 0 only)

Timer array unit is used to check whether signals received in LIN-bus communication match the LIN-bus communication format.

(1) Detection of wakeup signal

The timer starts counting at the falling edge of a signal input to the serial data input pin (RxD2) of UART2 and the count value of the timer is captured at the rising edge. In this way, a low-level width can be measured. If the low-level width is greater than a specific value, it is recognized as a wakeup signal.

(2) Detection of break field

The timer starts counting at the falling edge of a signal input to the serial data input pin (RxD2) of UART2 after a wakeup signal is detected, and the count value of the timer is captured at the rising edge. In this way, a low-level width is measured. If the low-level width is greater than a specific value, it is recognized as a break field.

(3) Measurement of pulse width of sync field

After a break field is detected, the low-level width and high-level width of the signal input to the serial data input pin (RxD2) of UART2 are measured. From the bit interval of the sync field measured in this way, a baud rate is calculated.

Remark For details about setting up the operations used to implement the LIN-bus, see **6.3.13 Input switch control register (ISC)** and **6.8.5 Operation as input signal high-/low-level width measurement**.

6.2 Configuration of Timer Array Unit

Timer array unit includes the following hardware.

Table 6-1. Configuration of Timer Array Unit

Item	Configuration
Timer/counter	Timer count register mn (TCRmn)
Register	Timer data register mn (TDRmn)
Timer input	TI00, TI01, TI03 to TI07 ^{Note 1} , RxD2 pin (for LIN-bus)
Timer output	TO00, TO01, TO03 to TO07 ^{Note 1} , output controller
Control registers	<Registers of unit setting block> • Peripheral enable register 0 (PER0) • Timer clock select register m (TPSm) • Timer channel enable status register m (TEm) • Timer channel start register m (TSM) • Timer channel stop register m (TTm) • Timer input select register 0 (TIS0) • Timer output enable register m (TOEm) • Timer output register m (TOM) • Timer output level register m (TOLm) • Timer output mode register m (TOMm) <Registers of each channel> • Timer mode register mn (TMRmn) • Timer status register mn (TSRmn) • Input switch control register (ISC) • Noise filter enable registers 1 (NFEN1) • Port mode control register (PMCxx)^{Note 2} • Port mode register (PMxx)^{Note 2} • Port register (Pxx)^{Note 2}

Notes 1. The presence or absence of timer I/O pins of channel 0 to 7 depends on the product. See **Table 6-2 Timer I/O Pins provided in Each Product** for details.

2. The Port mode control register (PMCxx), port mode registers (PMxx) and port registers (Pxx) to be set differ depending on the product. for details, see **4.5.3 Register setting examples for used port and alternate functions**.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7)

The presence or absence of timer I/O pins in each timer array unit channel depends on the product.

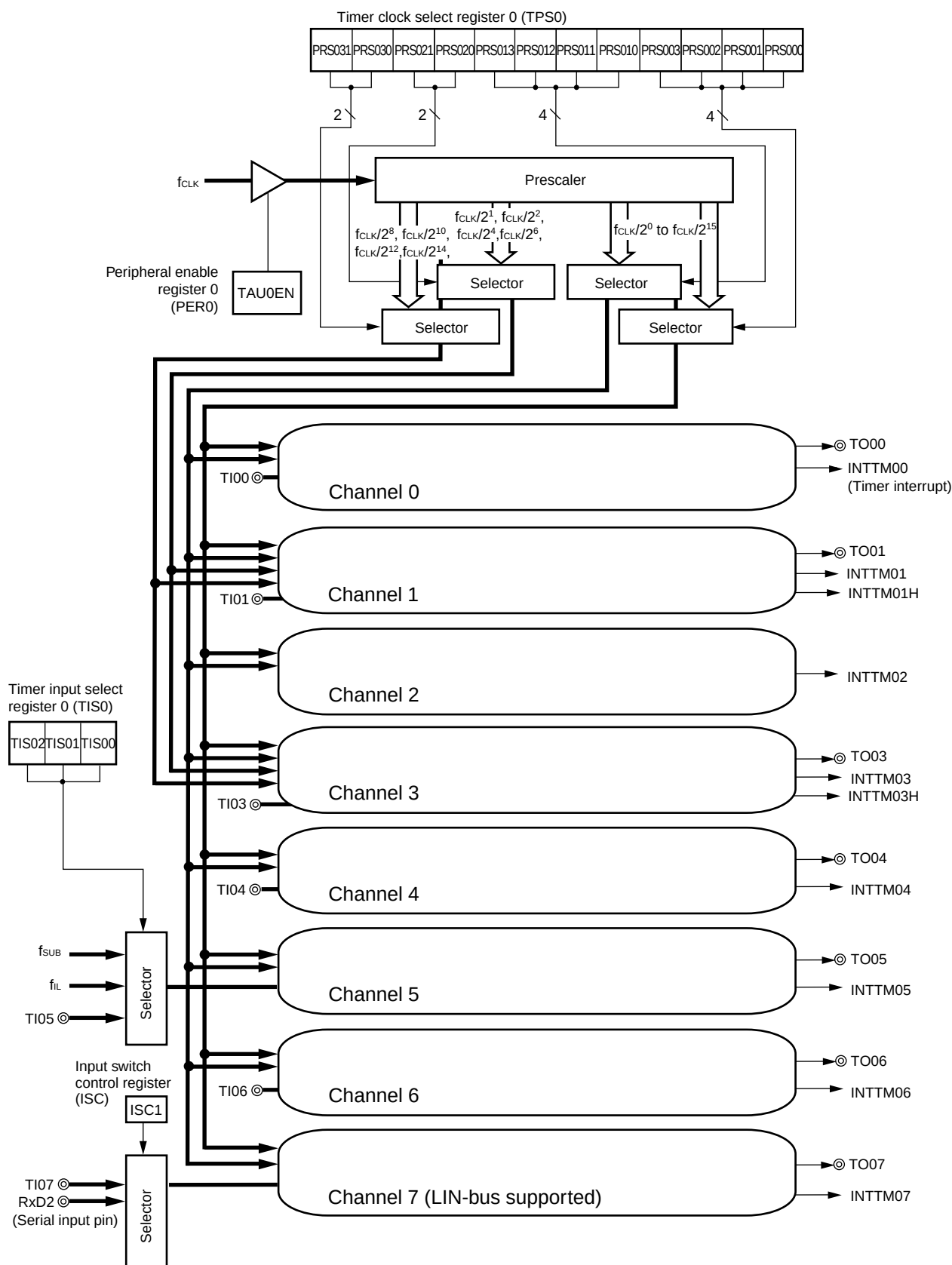
Table 6-2. Timer I/O Pins provided in Each Product

Timer array unit channels		I/O Pins of Each Product			
		64-pin	48-pin	32-pin	25-pin
Unit 0	Channel 0	TI00, TO00			
	Channel 1	TI01/TO01		–	
	Channel 2	–			
	Channel 3	TI03/TO03			
	Channel 4	TI04/TO04	–		
	Channel 5	TI05/TO05	–		
	Channel 6	TI06/TO06	–		
	Channel 7	TI07/TO07		–	

- Remarks**
1. When timer input and timer output are shared by the same pin, either only timer input or only timer output can be used.
 2. –: There is no timer I/O pin, but the channel is available. (However, the channel can only be used as an interval timer.)
 ×: The channel is not available.

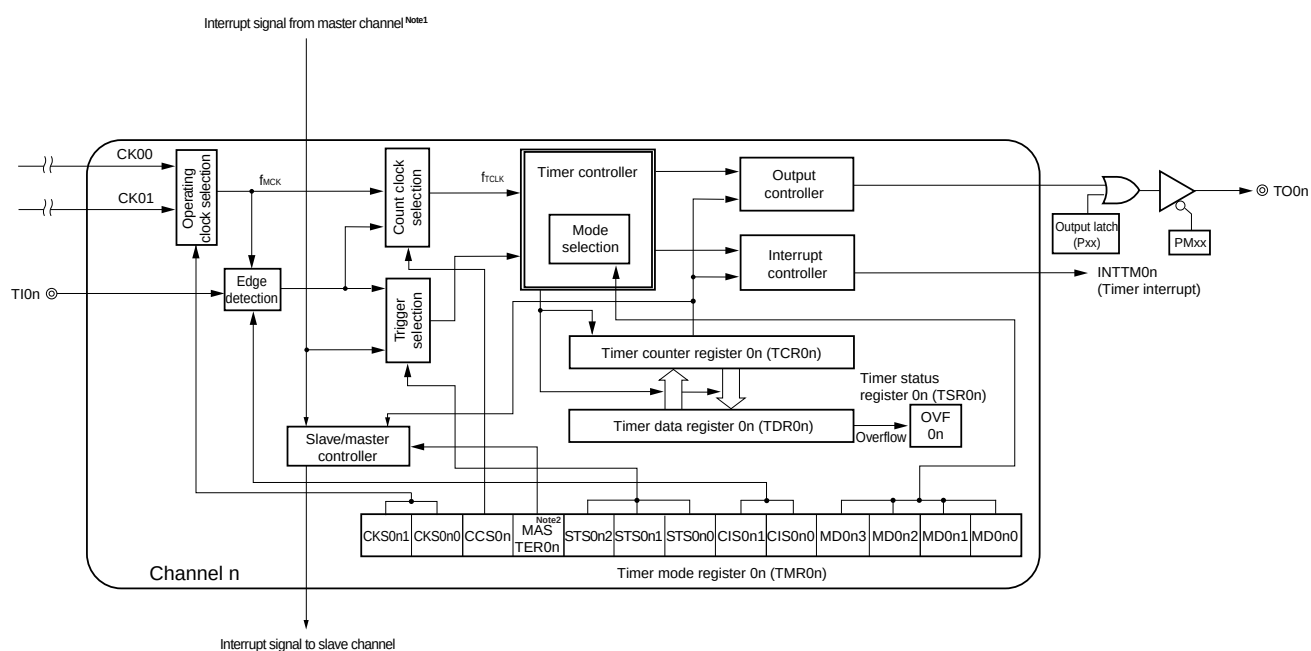
Figure 6-1 shows the block diagrams of the timer array unit.

Figure 6-1. Entire Configuration of Timer Array Unit 0 (Example: 64-pin products)



Remark f_{SUB}: Subsystem clock frequency
 f_{IL}: Low-speed on-chip oscillator clock frequency

Figure 6-2. Internal Block Diagram of Channel 0, 2, 4, 6 of Timer Array Unit 0

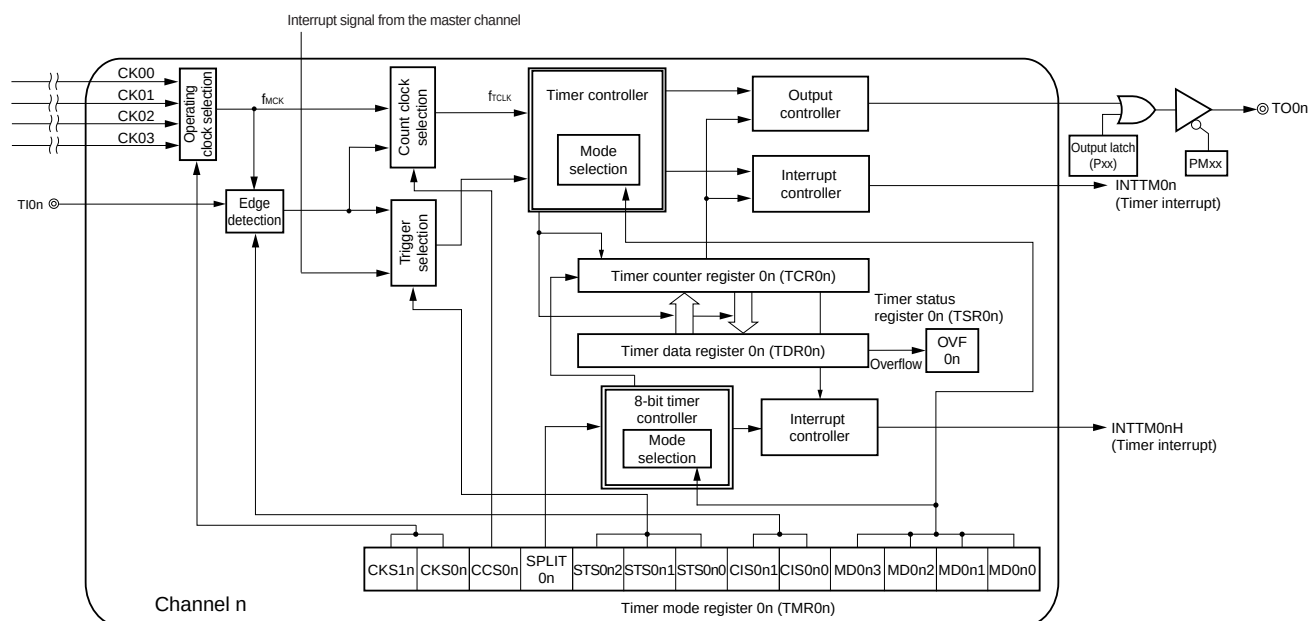


Notes 1. Channels 2, 4, 6 only

2. n = 2, 4, 6 only

Remark n = 0, 2, 4, 6

Figure 6-3. Internal Block Diagram of Channels 1 and 3 of Timer Array Unit 0



Remark n = 1, 3

Figure 6-4. Internal Block Diagram of Channel 5 of Timer Array Unit 0

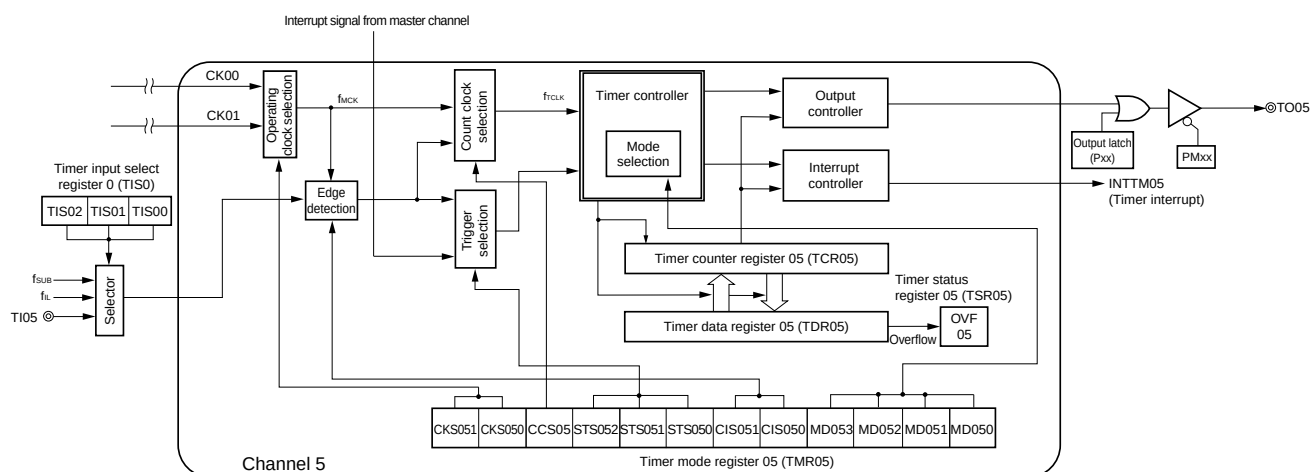
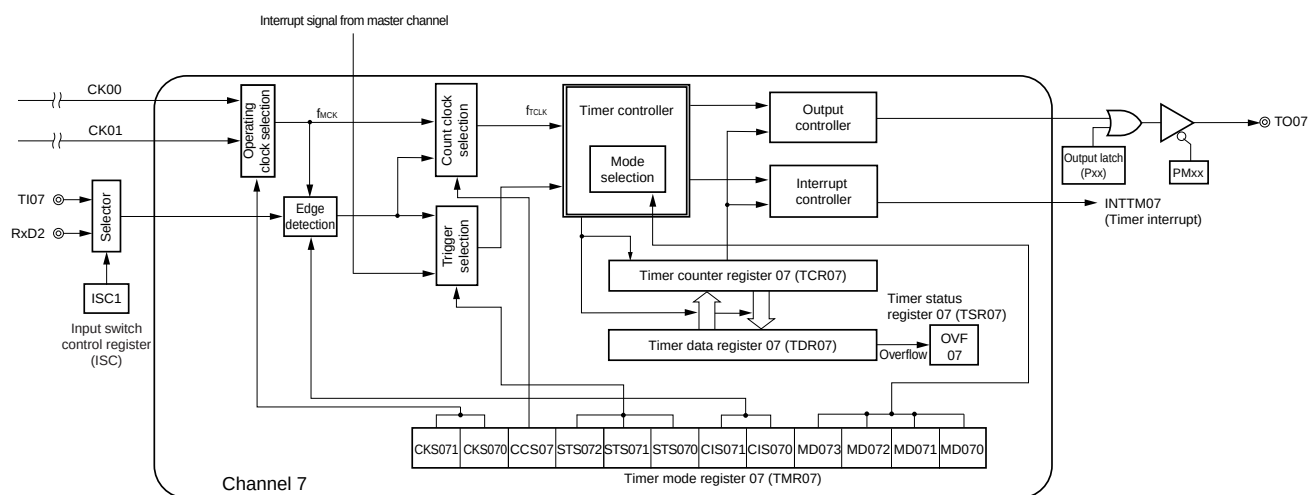


Figure 6-5. Internal Block Diagram of Channel 7 of Timer Array Unit 0



6.2.1 Timer count register mn (TCRmn)

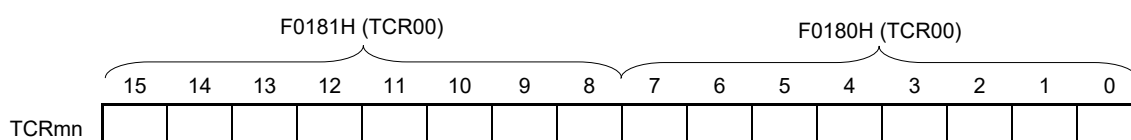
The TCRmn register is a 16-bit read-only register and is used to count clocks.

The value of this counter is incremented or decremented in synchronization with the rising edge of a count clock.

Whether the counter is incremented or decremented depends on the operation mode that is selected by the MDmn3 to MDmn0 bits of timer mode register mn (TMRmn) (see **6.3.3 Timer mode register mn (TMRmn)**).

Figure 6-6. Format of Timer Count Register mn (TCRmn)

Address: F0180H, F0181H (TCR00) to F018EH, F018FH (TCR07), After reset: FFFFH R
F01C0H, F01C1H (TCR10) to F01CEH, F01CFH (TCR17)



Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7)

The count value can be read by reading timer count register mn (TCRmn).

The count value is set to FFFFH in the following cases.

- When the reset signal is generated
- When the TAUmEN bit of peripheral enable register 0 (PER0) is cleared
- When counting of the slave channel has been completed in the PWM output mode
- When counting of the slave channel has been completed in the delay count mode
- When counting of the master/slave channel has been completed in the one-shot pulse output mode
- When counting of the slave channel has been completed in the multiple PWM output mode

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

- When the start trigger is input in the capture mode
- When capturing has been completed in the capture mode

Caution The count value is not captured to timer data register mn (TDRmn) even when the TCRmn register is read.

The TCRmn register read value differs as follows according to operation mode changes and the operating status.

Table 6-3. Timer Count Register mn (TCRmn) Read Value in Various Operation Modes

Operation Mode	Count Mode	Timer count register mn (TCRmn) Read Value ^{Note}			
		Value if the operation mode was changed after releasing reset	Value if the operation was count operation paused (TTmn = 1)	Value if the operation mode was changed after count operation paused (TTmn = 1)	Value when waiting for a start trigger after one count
Interval timer mode	Count down	FFFFH	Value if stop	Undefined	–
Capture mode	Count up	0000H	Value if stop	Undefined	–
Event counter mode	Count down	FFFFH	Value if stop	Undefined	–
One-count mode	Count down	FFFFH	Value if stop	Undefined	FFFFH
Capture & one-count mode	Count up	0000H	Value if stop	Undefined	Capture value of TDRmn register + 1

Note This indicates the value read from the TCRmn register when channel n has stopped operating as a timer (TEmn = 0) and has been enabled to operate as a counter (TSmn = 1). The read value is held in the TCRmn register until the count operation starts.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7)

6.2.2 Timer data register mn (TDRmn)

This is a 16-bit register from which a capture function and a compare function can be selected.

The capture or compare function can be switched by selecting an operation mode by using the MDmn3 to MDmn0 bits of timer mode register mn (TMRmn).

The value of the TDRmn register can be changed at any time.

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

In addition, for the TDRm1 and TDRm3 registers, while in the 8-bit timer mode (when the SPLITm1, SPLITm3 bits of timer mode registers m1 and m3 (TMRm1, TMRm3) are 1), it is possible to read or write the data in 8-bit units, with TDRm1H and TDRm3H used as the higher 8 bits, and TDRm1L and TDRm3L used as the lower 8 bits.

Reset signal generation clears this register to 0000H.

Figure 6-7. Format of Timer Data Register mn (TDRmn) (n = 0, 2, 4 to 7)

Address: FFF18H, FFF19H (TDR00), FFF64H, FFF65H (TDR02), After reset: 0000H R/W
 FFF68H, FFF69H (TDR04) to FFF6EH, FFF6FH (TDR07)

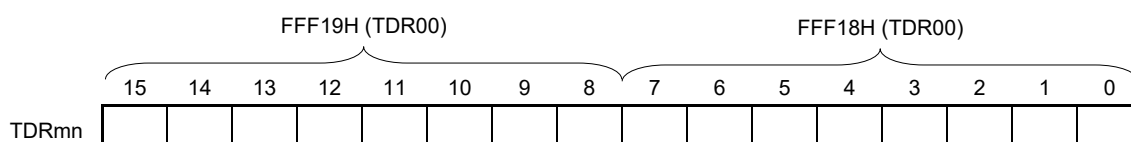
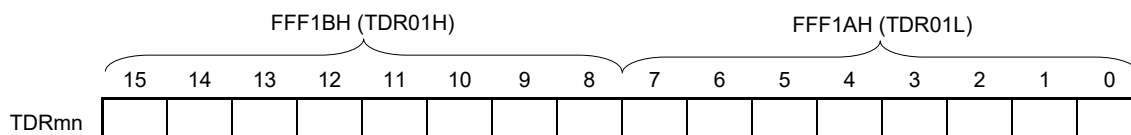


Figure 6-8. Format of Timer Data Register mn (TDRmn) (n = 1, 3)

Address: FFF1AH, FFF1BH (TDR01), FFF65H, FFF67H (TDR03) After reset: 0000H R/W



(i) When timer data register mn (TDRmn) is used as compare register

Counting down is started from the value set to the TDRmn register. When the count value reaches 0000H, an interrupt signal (INTTMmn) is generated. The TDRmn register holds its value until it is rewritten.

Caution The TDRmn register does not perform a capture operation even if a capture trigger is input, when it is set to the compare function.

(ii) When timer data register mn (TDRmn) is used as capture register

The count value of timer count register mn (TCRmn) is captured to the TDRmn register when the capture trigger is input.

A valid edge of the TImn pin can be selected as the capture trigger. This selection is made by timer mode register mn (TMRmn).

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

6.3 Registers Controlling Timer Array Unit

Timer array unit is controlled by the following registers.

- Peripheral enable register 0 (PER0)
- Timer clock select register m (TPSm)
- Timer mode register mn (TMRmn)
- Timer status register mn (TSRmn)
- Timer channel enable status register m (TEm)
- Timer channel start register m (TSm)
- Timer channel stop register m (TTm)
- Timer input select register 0 (TIS0)
- Timer output enable register m (TOEm)
- Timer output register m (TOM)
- Timer output level register m (TOLm)
- Timer output mode register m (TOMm)
- Input switch control register (ISC)
- Noise filter enable registers 1 (NFEN1)
- Port mode control register (PMCxx)
- Port mode register (PMxx)
- Port register (Pxx)

Caution Which registers and bits are included depends on the product. Be sure to set bits that are not mounted to their initial values.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7)

6.3.1 Peripheral enable register 0 (PER0)

This registers is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

When the timer array unit 0 is used, be sure to set bit 0 (TAU0EN) of this register to 1.

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 6-9. Format of Peripheral Enable Register 0 (PER0)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN ^{Note}	SAU0EN	0	TAU0EN

TAU0EN	Control of timer array 0 unit input clock
0	Stops supply of input clock. • SFR used by the timer array unit 0 cannot be written. • The timer array unit 0 is in the reset status.
1	Supplies input clock. • SFR used by the timer array unit 0 can be read/written.

Notes 32, 48, and 64-pin products only.

Cautions 1. When setting the timer array unit, be sure to set the TAUmEN bit to 1 first. If TAUmEN = 0, writing to a control register of timer array unit is ignored, and all read values are default values (except for the timer input select register 0 (TIS0), input switch control register (ISC), noise filter enable register 1 (NFEN1), port mode control registers 0, 1, 3, 4 (PMC0, PMC1, PMC3, PMC4), port mode registers 0, 1, 3, 4 (PM0, PM1, PM3, PM4), and port registers 0, 1, 3, 4 (P0, P1, P3, P4)).

- Timer clock select register m (TPSm)
- Timer mode register mn (TMRmn)
- Timer status register mn (TSRmn)
- Timer channel enable status register m (TEm)
- Timer channel start register m (TSM)
- Timer channel stop register m (TTm)
- Timer output enable register m (TOEm)
- Timer output register m (TOM)
- Timer output level register m (TOLm)
- Timer output mode register m (TOMm)

2. Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

6.3.2 Timer clock select register m (TPSm)

The TPSm register is a 16-bit register that is used to select two types or four types of operation clocks (CKm0, CKm1, CKm2, CKm3) that are commonly supplied to each channel. CKm0 is selected by using bits 3 to 0 of the TPSm register, and CKm1 is selected by using bits 7 to 4 of the TPSm register. In addition, only for channel 1 and 3, CKm2 and CKm3 can be also selected. CKm2 is selected by using bits 9 and 8 of the TPSm register, and CKm3 is selected by using bits 13 and 12 of the TPSm register.

Rewriting of the TPSm register during timer operation is possible only in the following cases.

If the PRSm00 to PRSm03 bits can be rewritten ($n = 0$ to 7):

All channels for which CKm0 is selected as the operation clock ($CKSmn1, CKSmn0 = 0, 0$) are stopped ($TEmn = 0$).

If the PRSm10 to PRSm13 bits can be rewritten ($n = 0$ to 7):

All channels for which CKm1 is selected as the operation clock ($CKSmn1, CKSmn0 = 0, 1$) are stopped ($TEmn = 0$).

If the PRSm20 and PRSm21 bits can be rewritten ($n = 1, 3$):

All channels for which CKm2 is selected as the operation clock ($CKSmn1, CKSmn0 = 1, 0$) are stopped ($TEmn = 0$).

If the PRSm30 and PRSm31 bits can be rewritten ($n = 1, 3$):

All channels for which CKm3 is selected as the operation clock ($CKSmn1, CKSmn0 = 1, 1$) are stopped ($TEmn = 0$).

The TPSm register can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears this register to 0000H.

Figure 6-10. Format of Timer Clock Select register m (TPSm) (1/2)

Address: F01B6H, F01B7H (TPS0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TPSm	0	0	PRS m31	PRS m30	0	0	PRS m21	PRS m20	PRS m13	PRS m12	PRS m11	PRS m10	PRS m03	PRS m02	PRS m01	PRS m00

PRS mk3	PRS mk2	PRS mk1	PRS mk0		Selection of operation clock (CKmk) ^{Note} (k = 0, 1)				
					f _{CLK} = 2 MHz	f _{CLK} = 5 MHz	f _{CLK} = 10 MHz	f _{CLK} = 20 MHz	f _{CLK} = 32 MHz
0	0	0	0	f _{CLK}	2 MHz	5 MHz	10 MHz	20 MHz	32 MHz
0	0	0	1	f _{CLK} /2	1 MHz	2.5 MHz	5 MHz	10 MHz	16 MHz
0	0	1	0	f _{CLK} /2 ²	500 kHz	1.25 MHz	2.5 MHz	5 MHz	8 MHz
0	0	1	1	f _{CLK} /2 ³	250 kHz	625 kHz	1.25 MHz	2.5 MHz	4 MHz
0	1	0	0	f _{CLK} /2 ⁴	125 kHz	313 kHz	625 kHz	1.25 MHz	2 MHz
0	1	0	1	f _{CLK} /2 ⁵	62.5 kHz	156 kHz	313 kHz	625 kHz	1 MHz
0	1	1	0	f _{CLK} /2 ⁶	31.3 kHz	78.1 kHz	156 kHz	313 kHz	500 kHz
0	1	1	1	f _{CLK} /2 ⁷	15.6 kHz	39.1 kHz	78.1 kHz	156 kHz	250 kHz
1	0	0	0	f _{CLK} /2 ⁸	7.81 kHz	19.5 kHz	39.1 kHz	78.1 kHz	125 kHz
1	0	0	1	f _{CLK} /2 ⁹	3.91 kHz	9.77 kHz	19.5 kHz	39.1 kHz	62.5 kHz
1	0	1	0	f _{CLK} /2 ¹⁰	1.95 kHz	4.88 kHz	9.77 kHz	19.5 kHz	31.3 kHz
1	0	1	1	f _{CLK} /2 ¹¹	977 Hz	2.44 kHz	4.88 kHz	9.77 kHz	15.6 kHz
1	1	0	0	f _{CLK} /2 ¹²	488 Hz	1.22 kHz	2.44 kHz	4.88 kHz	7.81 kHz
1	1	0	1	f _{CLK} /2 ¹³	244 Hz	610 Hz	1.22 kHz	2.44 kHz	3.91 kHz
1	1	1	0	f _{CLK} /2 ¹⁴	122 Hz	305 Hz	610 Hz	1.22 kHz	1.95 kHz
1	1	1	1	f _{CLK} /2 ¹⁵	61.0 Hz	153 Hz	305 Hz	610 Hz	977 Hz

Note When changing the clock selected for f_{CLK} (by changing the system clock control register (CKC) value), stop timer array unit (TTm = 00FFH).

Cautions 1. Be sure to clear bits 15, 14, 11, 10 to “0”.

2. If f_{CLK} (undivided) is selected as the operation clock (CKmk) and TDRnm is set to 0000H (n = 0 or 1, m = 0 to 7), interrupt requests output from timer array units cannot be used.

Remarks 1. f_{CLK}: CPU/peripheral hardware clock frequency

2. Waveform of the clock to be selected in the TPSm register which becomes high level for one period of f_{CLK} from its rising edge (m = 1 to 15). For details, see **6.5.1 Count clock (f_{CLK})**.

Figure 6-10. Format of Timer Clock Select register m (TPSm) (2/2)

Address: F01B6H, F01B7H (TPS0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TPSm	0	0	PRS m31	PRS m30	0	0	PRS m21	PRS m20	PRS m13	PRS m12	PRS m11	PRS m10	PRS m03	PRS m02	PRS m01	PRS m00

PRS m21	PRS m20		Selection of operation clock (CKm2) ^{ote}				
			f _{CLK} = 2 MHz	f _{CLK} = 5 MHz	f _{CLK} = 10 MHz	f _{CLK} = 20 MHz	f _{CLK} = 32 MHz
0	0	f _{CLK} /2	1 MHz	2.5 MHz	5 MHz	10 MHz	16 MHz
0	1	f _{CLK} /2 ²	500 kHz	1.25 MHz	2.5 MHz	5 MHz	8 MHz
1	0	f _{CLK} /2 ⁴	125 kHz	313 kHz	625 MHz	1.25 MHz	2 MHz
1	1	f _{CLK} /2 ⁶	31.3 kHz	78.1 kHz	156 kHz	313 kHz	500 kHz

PRS m31	PRS m30		Selection of operation clock (CKm3) ^{Note}				
			f _{CLK} = 2 MHz	f _{CLK} = 5 MHz	f _{CLK} = 10 MHz	f _{CLK} = 20 MHz	f _{CLK} = 32 MHz
0	0	f _{CLK} /2 ⁸	7.81 kHz	19.5 kHz	39.1 kHz	78.1 kHz	125 kHz
0	1	f _{CLK} /2 ¹⁰	1.95 kHz	4.88 kHz	9.77 kHz	19.5 kHz	31.3 kHz
1	0	f _{CLK} /2 ¹²	488 Hz	1.22 kHz	2.44 kHz	4.88 kHz	7.81 kHz
1	1	f _{CLK} /2 ¹⁴	122 Hz	305 Hz	610 Hz	1.22 kHz	1.95 kHz

Note When changing the clock selected for f_{CLK} (by changing the system clock control register (CKC) value), stop timer array unit (TTm = 00FFH).

The timer array unit must also be stopped if the operating clock (f_{MCK}) or the valid edge of the signal input from the TImn pin is selected.

Caution Be sure to clear bits 15, 14, 11, 10 to “0”.

By using channels 1 and 3 in the 8-bit timer mode and specifying CKm2 or CKm3 as the operation clock, the interval times shown in Table 6-4 can be achieved by using the interval timer function.

Table 6-4. Interval Times Available for Operation Clock CKSm2 or CKSm3

Clock		Interval time ^{Note} (f _{CLK} = 32 MHz)			
		10 μs	100 μs	1 ms	10 ms
CKm2	f _{CLK} /2	√	—	—	—
	f _{CLK} /2 ²	√	—	—	—
	f _{CLK} /2 ⁴	√	√	—	—
	f _{CLK} /2 ⁶	√	√	—	—
CKm3	f _{CLK} /2 ⁸	—	√	√	—
	f _{CLK} /2 ¹⁰	—	√	√	—
	f _{CLK} /2 ¹²	—	—	√	√
	f _{CLK} /2 ¹⁴	—	—	√	√

Note The margin is within 5 %.

Remarks 1. f_{CLK}: CPU/peripheral hardware clock frequency

2. For details of asignal of f_{CLK}/2^j selected with the TPSm register, see **6.5.1 Count clock (f_{CLK})**.

6.3.3 Timer mode register mn (TMRmn)

The TMRmn register sets an operation mode of channel n. This register is used to select the operation clock (f_{MCK}), select the count clock, select the master/slave, select the 16 or 8-bit timer (only for channels 1 and 3), specify the start trigger and capture trigger, select the valid edge of the timer input, and specify the operation mode (interval, capture, event counter, one-count, or capture and one-count).

Rewriting the TMRmn register is prohibited when the register is in operation (when TEMn = 1). However, bits 7 and 6 (CISmn1, CISmn0) can be rewritten even while the register is operating with some functions (when TEMn = 1) (for details, see **6.8 Independent Channel Operation Function of Timer Array Unit** and **6.9 Simultaneous Channel Operation Function of Timer Array Unit**).

The TMRmn register can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears this register to 0000H.

Caution The bits mounted depend on the channels in the bit 11 of TMRmn register.

TMRm2, TMRm4, TMRm6: MASTERmn bit (n = 2, 4, 6)

TMRm1, TMRm3: SPLITmn bit (n = 1, 3)

TMRm0, TMRm5, TMRm7: Fixed to 0

Figure 6-11. Format of Timer Mode Register mn (TMRmn) (1/4)

Address: F0190H, F0191H (TMR00) to F019EH, F019FH (TMR07) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 2, 4, 6)	CKS mn1	CKS mn0	0	CCS mn	MAST ERmn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 1, 3)	CKS mn1	CKS mn0	0	CCS mn	SPLIT mn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 0, 5, 7)	CKS mn1	CKS mn0	0	CCS mn	0 ^{Note}	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

CKS mn1	CKS mn0	Selection of operation clock (f_{MCK}) of channel n
0	0	Operation clock CKm0 set by timer clock select register m (TPSm)
0	1	Operation clock CKm2 set by timer clock select register m (TPSm)
1	0	Operation clock CKm1 set by timer clock select register m (TPSm)
1	1	Operation clock CKm3 set by timer clock select register m (TPSm)
Operation clock (f_{MCK}) is used by the edge detector. A count clock (f_{CLK}) and a sampling clock are generated depending on the setting of the CCSmn bit.		
The operation clocks CKm2 and CKm3 can only be selected for channels 1 and 3.		

CCS mn	Selection of count clock (f_{CLK}) of channel n
0	Operation clock (f_{MCK}) specified by the CKSmn0 and CKSmn1 bits
1	Valid edge of input signal input from the TImn pin • When unit 0 In channel 5, Valid edge of input signal selected by TIS0 In channel 7, Valid edge of input signal selected by ISC
Count clock (f_{CLK}) is used for the counter, output controller, and interrupt controller.	

Note Bit 11 is fixed at 0 of read only, write is ignored.**Cautions 1.** Be sure to clear bits 13, 5, and 4 to “0”.

2. The timer array unit must be stopped (TTm = 00FFH) if the clock selected for f_{CLK} is changed (by changing the value of the system clock control register (CKC)), even if the operating clock specified by using the CKSmn0 and CKSmn1 bits (f_{MCK}) or the valid edge of the signal input from the TImn pin is selected as the count clock (f_{CLK}).

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-11. Format of Timer Mode Register mn (TMRmn) (2/4)

Address: F0190H, F0191H (TMR00) to F019EH, F019FH (TMR07) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 2, 4, 6)	CKS mn1	CKS mn0	0	CCS mn	MAST ERmn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 1, 3)	CKS mn1	CKS mn0	0	CCS mn	SPLIT mn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 0, 5, 7)	CKS mn1	CKS mn0	0	CCS mn	0 ^{Note}	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

(Bit 11 of TMRmn (n = 2, 4, 6))

Bit 11 of MASTERmn (n = 2, 4, 6)

MAS TER mn	Selection between using channel n independently or simultaneously with another channel(as a slave or master)
0	Operates in independent channel operation function or as slave channel in simultaneous channel operation function.
1	Operates as master channel in simultaneous channel operation function.

Only the channel 2, 4, 6 can be set as a master channel (MASTERmn = 1).
Be sure to use channel 0, 5, 7 are fixed to 0 (Regardless of the bit setting, channel 0 operates as master, because it is the highest channel).
Clear the MASTERmn bit to 0 for a channel that is used with the independent channel operation function.

(Bit 11 of TMRmn (n = 1, 3))

SPLI Tmn	Selection of 8 or 16-bit timer operation for channels 1 and 3														
0	Operates as 16-bit timer. (Operates in independent channel operation function or as slave channel in simultaneous channel operation function.)														
1	Operates as 8-bit timer.														

STS mn2	STS mn1	STS mn0	Setting of start trigger or capture trigger of channel n												
0	0	0	Only software trigger start is valid (other trigger sources are unselected).												
0	0	1	Valid edge of the TImn pin input is used as both the start trigger and capture trigger.												
0	1	0	Both the edges of the TImn pin input are used as a start trigger and a capture trigger.												
1	0	0	Interrupt signal of the master channel is used (when the channel is used as a slave channel with the simultaneous channel operation function).												
Other than above			Setting prohibited												

Note Bit 11 is fixed at 0 of read only, write is ignored.**Remark** m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-11. Format of Timer Mode Register mn (TMRmn) (3/4)

Address: F0190H, F0191H (TMR00) to F019EH, F019FH (TMR07) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 2, 4, 6)	CKS mn1	CKS mn0	0	CCS mn	MAST ERmn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 1, 3)	CKS mn1	CKS mn0	0	CCS mn	SPLIT mn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 0, 5, 7)	CKS mn1	CKS mn0	0	CCS mn	0 ^{Note}	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

CIS mn1	CIS mn0	Selection of TImn pin input valid edge
0	0	Falling edge
0	1	Rising edge
1	0	Both edges (when low-level width is measured) Start trigger: Falling edge, Capture trigger: Rising edge
1	1	Both edges (when high-level width is measured) Start trigger: Rising edge, Capture trigger: Falling edge
If both the edges are specified when the value of the STSmn2 to STSmn0 bits is other than 010B, set the CISmn1 to CISmn0 bits to 10B.		

MD mn3	MD mn2	MD mn1	Operation mode of channel n	Corresponding function	Count operation of TCR
0	0	0	Interval timer mode	Interval timer / Square wave output / Divider function / PWM output (master)	Counting down
0	1	0	Capture mode	Input pulse interval measurement	Counting up
0	1	1	Event counter mode	External event counter	Counting down
1	0	0	One-count mode	Delay counter / One-shot pulse output / PWM output (slave)	Counting down
1	1	0	Capture & one-count mode	Measurement of high-/low-level width of input signal	Counting up
Other than above			Setting prohibited		
The operation of each mode varies depending on MDmn0 bit (see next table).					

Note Bit 11 is fixed at 0 of read only, write is ignored.**Remark** m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-11. Format of Timer Mode Register mn (TMRmn) (4/4)

Address: F0190H, F0191H (TMR00) to F019EH, F019FH (TMR07) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 2, 4, 6)	CKS mn1	CKS mn0	0	CCS mn	MAST ERmn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 1, 3)	CKS mn1	CKS mn0	0	CCS mn	SPLIT mn	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TMRmn (n = 0, 5, 7)	CKS mn1	CKS mn0	0	CCS mn	0 ^{Note}	STS mn2	STS mn1	STS mn0	CIS mn1	CIS mn0	0	0	MD mn3	MD mn2	MD mn1	MD mn0

Operation mode (Value set by the MDmn3 to MDmn1 bits (see table shown in the previous page))	MD mn0	Setting of starting counting and interrupt
• Interval timer mode (0, 0, 0)	0	Timer interrupt is not generated when counting is started (timer output does not change, either).
• Capture mode (0, 1, 0)	1	Timer interrupt is generated when counting is started (timer output also changes).
• Event counter mode (0, 1, 1)	0	Timer interrupt is not generated when counting is started (timer output does not change, either).
• One-count mode ^{Note 1} (1, 0, 0)	0	Start trigger is invalid during counting operation. At that time, interrupt is not generated.
	1	Start trigger is valid during counting operation ^{Note 2} . At that time, interrupt is not generated.
• Capture & one-count mode (1, 1, 0)	0	Timer interrupt is not generated when counting is started (timer output does not change, either). Start trigger is invalid during counting operation. At that time interrupt is not generated.
Other than above		Setting prohibited

Notes 1. Bit 11 is fixed at 0 of read only, write is ignored.**2.** In one-count mode, interrupt output (INTTmn) when starting a count operation and TOn output are not controlled.**3.** If the start trigger (TSmn = 1) is issued during operation, the counter is initialized, and recounting is started (does not occur the interrupt request).**Remark** m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOn) : n = 0, 1, 3 to 7))

6.3.4 Timer status register mn (TSRmn)

The TSRmn register indicates the overflow status of the counter of channel n.

The TSRmn register is valid only in the capture mode (MDmn3 to MDmn1 = 010B) and capture & one-count mode (MDmn3 to MDmn1 = 110B). See Table 6-5 for the operation of the OVF bit in each operation mode and set/clear conditions.

The TSRmn register can be read by a 16-bit memory manipulation instruction.

The lower 8 bits of the TSRmn register can be set with an 8-bit memory manipulation instruction with TSRmnL.

Reset signal generation clears this register to 0000H.

Figure 6-12. Format of Timer Status Register mn (TSRmn)

Address: F01A0H, F01A1H (TSR00) to F01AEH, F01AFH (TSR07) After reset: 0000H R

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

OVF	Counter overflow status of channel n
0	Overflow does not occur.
1	Overflow occurs.
When OVF = 1, this flag is cleared (OVF = 0) when the next value is captured without overflow.	

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7)

Table 6-5. OVF Bit Operation and Set/Clear Conditions in Each Operation Mode

Timer operation mode	OVF bit	Set/clear conditions
• Capture mode	clear	When no overflow has occurred upon capturing
• Capture & one-count mode	set	When an overflow has occurred upon capturing
• Interval timer mode	clear	— (Use prohibited)
• Event counter mode		
• One-count mode	set	

Remark The OVF bit does not change immediately after the counter has overflowed, but changes upon the subsequent capture.

6.3.5 Timer channel enable status register m (TE_m)

The TE_m register is used to enable or stop the timer operation of each channel.

Each bit of the TE_m register corresponds to each bit of the timer channel start register m (TSM) and the timer channel stop register m (TTM). When a bit of the TSM register is set to 1, the corresponding bit of this register is set to 1. When a bit of the TTM register is set to 1, the corresponding bit of this register is cleared to 0.

The TE_m register can be read by a 16-bit memory manipulation instruction.

The lower 8 bits of the TE_m register can be set with a 1-bit or 8-bit memory manipulation instruction with TE_mL.

Reset signal generation clears this register to 0000H.

Figure 6-13. Format of Timer Channel Enable Status register m (TE_m)

Address: F01B0H, F01B1H (TE₀) After reset: 0000H R

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TE _m	0	0	0	0	TEH _m 3	0	TEH _m 1	0	TE _m 7	TE _m 6	TE _m 5	TE _m 4	TE _m 3	TE _m 2	TE _m 1	TE _m 0

TEH 03	Indication of whether operation of the higher 8-bit timer is enabled or stopped when channel 3 is in the 8-bit timer mode
0	Operation is stopped.
1	Operation is enabled.

TEH 01	Indication of whether operation of the higher 8-bit timer is enabled or stopped when channel 1 is in the 8-bit timer mode
0	Operation is stopped.
1	Operation is enabled.

TE _m n	Indication of operation enable/stop status of channel n
0	Operation is stopped.
1	Operation is enabled.
This bit displays whether operation of the lower 8-bit timer for TE _m 1 and TE _m 3 is enabled or stopped when channel 1 or 3 is in the 8-bit timer mode.	

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7)

6.3.6 Timer channel start register m (TSm)

The TSm register is a trigger register that is used to initialize timer count register mn (TCRmn) and start the counting operation of each channel.

When a bit of this register is set to 1, the corresponding bit of timer channel enable status register m (TEm) is set to 1. The TSmn, TSHm1, TSHm3 bits are immediately cleared when operation is enabled (TEmn, TEHm1, TEHm3 = 1), because they are trigger bits.

The TSm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the TSm register can be set with a 1-bit or 8-bit memory manipulation instruction with TSmL.

Reset signal generation clears this register to 0000H.

Figure 6-14. Format of Timer Channel Start register m (TSm)

Address: F01B2H, F01B3H (TS0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TSm	0	0	0	0	TSHm3	0	TSHm1	0	TSm7	TSm6	TSm5	TSm4	TSm3	TSm2	TSm1	TSm0

TSHm3	Trigger to enable operation (start operation) of the higher 8-bit timer when channel 3 is in the 8-bit timer mode
0	No trigger operation
1	The TEHm3 bit is set to 1 and the count operation becomes enabled. The TCRm3 register count operation start in the interval timer mode in the count operation enabled state (see Table 6-6 in 6.5.2 Start timing of counter).

TSHm1	Trigger to enable operation (start operation) of the higher 8-bit timer when channel 1 is in the 8-bit timer mode
0	No trigger operation
1	The TEHm1 bit is set to 1 and the count operation becomes enabled. The TCRm1 register count operation start in the interval timer mode in the count operation enabled state (see Table 6-6 in 6.5.2 Start timing of counter).

TSmn	Operation enable (start) trigger of channel n
0	No trigger operation
1	The TEMn bit is set to 1 and the count operation becomes enabled. The TCRmn register count operation start in the count operation enabled state varies depending on each operation mode (see Table 6-6 in 6.5.2 Start timing of counter). This bit is the trigger to enable operation (start operation) of the lower 8-bit timer for TSm1 and TSm3 when channel 1 or 3 is in the 8-bit timer mode.

Cautions 1. Be sure to clear bits 15 to 12, 10, 8 to “0”

2. When switching from a function that does not use TImn pin input to one that does, the following wait period is required from when timer mode register mn (TMRmn) is set until the TSmn (TSHm1, TSHm3) bit is set to 1.

When the TImn pin noise filter is enabled (TNFENmn = 1): Four cycles of the operation clock (f_{MCK})

When the TImn pin noise filter is disabled (TNFENmn = 0): Two cycles of the operation clock (f_{MCK})

Remarks 1. When the TSm register is read, 0 is always read.

2. m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

6.3.7 Timer channel stop register m (TTm)

The TTm register is a trigger register that is used to stop the counting operation of each channel.

When a bit of this register is set to 1, the corresponding bit of timer channel enable status register m (TEm) is cleared to 0. The TTmn, TTHm1, TTHm3 bits are immediately cleared when operation is stopped (TEmn, TEHm1, TEHm3 = 0), because they are trigger bits.

The TTm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the TTm register can be set with a 1-bit or 8-bit memory manipulation instruction with TTmL.

Reset signal generation clears this register to 0000H.

Figure 6-15. Format of Timer Channel Stop register m (TTm)

Address: F01B4H, F01B5H (TT0) After reset: 0000H R/W

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

TTH m3	Trigger to stop operation of the higher 8-bit timer when channel 3 is in the 8-bit timer mode
0	No trigger operation
1	TEHm3 bit clear to 0, to be count operation stop status.

TTH m1	Trigger to stop operation of the higher 8-bit timer when channel 1 is in the 8-bit timer mode
0	No trigger operation
1	TEHm1 bit clear to 0, to be count operation stop status.

TTm n	Operation stop trigger of channel n
0	No trigger operation
1	TEmn bit clear to 0, to be count operation stop status. This bit is the trigger to stop operation of the lower 8-bit timer for TTm1 and TTm3 when channel 1 or 3 is in the 8-bit timer mode.

Caution Be sure to clear bits 15 to 12, 10, 8 of the TTm register to “0”.

Remarks 1. When the TTm register is read, 0 is always read.

2. m: Unit number (m = 0), n: Channel number (n = 0 to 7)

6.3.8 Timer input select register 0 (TIS0)

The TIS0 register is used to select the channel 5 of unit 0 timer input..

The TIS0 register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 6-16. Format of Timer Input Select register 0 (TIS0)

Address: F0074H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
TIS0	0	0	0	0	0	TIS02	TIS01	TIS00

TIS02	TIS01	TIS00	Selection of timer input used with channel 5
0	0	0	Input signal of timer input pin (TI05)
0	0	1	
0	1	0	
0	1	1	
1	0	0	Low-speed on-chip oscillator clock (f_{IL})
1	0	1	Subsystem clock (f_{SUB})
Other than above			Setting prohibited

Caution High-level width, low-level width of timer input is selected, will require more than $1/f_{MCK} + 10$ ns.
Therefore, when selecting f_{SUB} to f_{CLK} (CSS bit of CKC register = 1), can not TIS02 bit set to 1.

6.3.9 Timer output enable register m (TOEm)

The TOEm register is used to enable or disable timer output of each channel.

Channel n for which timer output has been enabled becomes unable to rewrite the value of the TOmn bit of timer output register m (TOM) described later by software, and the value reflecting the setting of the timer output function through the count operation is output from the timer output pin (TOMn).

The TOEm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the TOEm register can be set with a 1-bit or 8-bit memory manipulation instruction with TOEmL.

Reset signal generation clears this register to 0000H.

Figure 6-17. Format of Timer Output Enable register m (TOEm)

Address: F01BAH, F01BBH (TOE0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TOEm	0	0	0	0	0	0	0	0	TOE _{m7}	TOE _{m6}	TOE _{m5}	TOE _{m4}	TOE _{m3}	0	TOE _{m1}	TOE _{m0}

TOE _{mn}	Timer output enable/disable of channel n
0	Disable output of timer. Without reflecting on TOMn bit timer operation, to fixed the output. Writing to the TOMn bit is enabled, and level set to TOMn bit is output from the TOMn pin.
1	Enable output of timer. Reflected in the TOMn bit timer operation, to generate the output waveform. Writing to the TOMn bit is disabled (writing is ignored).

Caution Be sure to clear bits 15 to 8 to “0”.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.3.10 Timer output register m (TOM)

The TOM register is a buffer register of timer output of each channel.

The value of each bit in this register is output from the timer output pin (TOMn) of each channel.

The TOMn bit of this register can be rewritten by software only when timer output is disabled (TOEmn = 0). When timer output is enabled (TOEmn = 1), rewriting this register by software is ignored, and the value is changed only by the timer operation.

To use the P00/TI00, P01/TO00, P16/TI01/TO01, P31/TI03/TO03, P42/TI04/TO04, P05/TI05/TO05, P06/TI06/TO06, P41/TI07/TO07 pin as a port function pin, set the corresponding TOMn bit to "0".

The TOM register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the TOM register can be set with an 8-bit memory manipulation instruction with TOML.

Reset signal generation clears this register to 0000H.

Figure 6-18. Format of Timer Output register m (TOM)

Address: F01B8H, F01B9H (TO0) After reset: 0000H R/W

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

TOM _n	Timer output of channel n
0	Timer output value is "0".
1	Timer output value is "1".

Caution Be sure to clear bits 15 to 8 to "0".

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TIMn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.3.11 Timer output level register m (TOLm)

The TOLm register is a register that controls the timer output level of each channel.

The setting of the inverted output of channel n by this register is reflected at the timing of set or reset of the timer output signal while the timer output is enabled (TOEmn = 1) in the Slave channel output mode (TOMmn = 1). In the master channel output mode (TOMmn = 0), this register setting is invalid.

The TOLm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the TOLm register can be set with an 8-bit memory manipulation instruction with TOLmL.

Reset signal generation clears this register to 0000H.

Figure 6-19. Format of Timer Output Level register m (TOLm)

Address: F01BCH, F01BDH (TOL0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TOLm	0	0	0	0	0	0	0	0	TOL m7	TOL m6	TOL m5	TOL m4	TOL m3	0	TOL m1	0

TOL mn	Control of timer output level of channel n
0	Positive logic output (active-high)
1	Negative logic output (active-low)

Caution Be sure to clear bits 15 to 8, and 0 to “0”.

- Remarks 1.** If the value of this register is rewritten during timer operation, the timer output logic is inverted when the timer output signal changes next, instead of immediately after the register value is rewritten.
- 2.** m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.3.12 Timer output mode register m (TOMm)

The TOMm register is used to control the timer output mode of each channel.

When a channel is used for the independent channel operation function, set the corresponding bit of the channel to be used to 0.

When a channel is used for the simultaneous channel operation function (PWM output, one-shot pulse output, or multiple PWM output), set the corresponding bit of the master channel to 0 and the corresponding bit of the slave channel to 1.

The setting of each channel n by this register is reflected at the timing when the timer output signal is set or reset while the timer output is enabled ($TOEmn = 1$).

The TOMm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the TOMm register can be set with an 8-bit memory manipulation instruction with TOMmL.

Reset signal generation clears this register to 0000H.

Figure 6-20. Format of Timer Output Mode register m (TOMm)

Address: F01BEH, F01BFH (TOM0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TOMm	0	0	0	0	0	0	0	0	TOM _{m7}	TOM _{m6}	TOM _{m5}	TOM _{m4}	TOM _{m3}	0	TOM _{m1}	0

TOM _{mn}	Control of timer output mode of channel n
0	Master channel output mode (to produce toggle output by timer interrupt request signal (INTTMmn))
1	Slave channel output mode (output is set by the timer interrupt request signal (INTTMmn) of the master channel, and reset by the timer interrupt request signal (INTTM0p) of the slave channel)

Caution Be sure to clear bits 15 to 8, and 0 to “0”.

Remark m: Unit number (m = 0)

n: Channel number

n = 0 to 7 (n = 0, 2, 4, 6 for master channel)

p: Slave channel number

n < p ≤ 7

(For details of the relation between the master channel and slave channel, see **6.4.1 Basic rules of simultaneous channel operation function.**)

6.3.13 Input switch control register (ISC)

The ISC1 and ISC0 bits of the ISC register are used to implement LIN-bus communication operation by using channel 7 in association with the serial array unit. When the ISC1 bit is set to 1, the input signal of the serial data input pin (RxD2) is selected as a timer input signal.

The ISC register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 6-21. Format of Input Switch Control Register (ISC)

Address: F0073H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ISC	0	0	0	0	0	0	ISC1	ISC0

ISC1	Switching channel 7 input of timer array unit
0	48 and 64-pin products: Uses the input signal of the TI07 pin as a timer input (normal operation). 25 and 32-pin products: Do not use a timer input signal for channel 7.
1	Input signal of the RxD2 pin is used as timer input (detects the wakeup signal and measures the low width of the break field and the pulse width of the sync field). Setting is prohibited in the 25-pin products.

ISC0	Switching external interrupt (INTP0) input
0	Uses the input signal of the INTP0 pin as an external interrupt (normal operation).
1	Uses the input signal of the RxD2 pin as an external interrupt (wakeup signal detection).

Caution Be sure to clear bits 7 to 2 to “0”.

Remark When the LIN-bus communication function is used, select the input signal of the RxD2 pin by setting ISC1 to 1.

6.3.14 Noise filter enable register 1 (NFEN1)

The NFEN1 register is used to set whether the noise filter can be used for the timer input signal to each channel.

Enable the noise filter by setting the corresponding bits to 1 on the pins in need of noise removal.

When the noise filter is enabled, after synchronization with the operating clock (f_{MCK}) for the target channel, whether the signal keeps the same value for two clock cycles is detected. When the noise filter is disabled, the input signal is only synchronized with the operating clock (f_{MCK}) for the target channel^{Note}.

The NFEN1 registers can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Note For details, see **6.5.1 (2) When valid edge of input signal via the TImn pin is selected (CCSmn = 1)**, **6.5.2 Start timing of counter** and **6.7 Timer Input (TImn) Control**.

Figure 6-22. Format of Noise Filter Enable Register 1 (NFEN1)

Address: F0071H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
NFEN1	TNFEN07	TNFEN06	TNFEN05	TNFEN04	TNFEN03	0	TNFEN01	TNFEN00

TNFEN07	Enable/disable using noise filter of TI07 pin ^{Note}
0	Noise filter OFF
1	Noise filter ON

TNFEN06	Enable/disable using noise filter of TI06 pin
0	Noise filter OFF
1	Noise filter ON

TNFEN05	Enable/disable using noise filter of TI05 pin
0	Noise filter OFF
1	Noise filter ON

TNFEN04	Enable/disable using noise filter of TI04 pin
0	Noise filter OFF
1	Noise filter ON

TNFEN03	Enable/disable using noise filter of TI03 pin
0	Noise filter OFF
1	Noise filter ON

TNFEN01	Enable/disable using noise filter of TI01 pin
0	Noise filter OFF
1	Noise filter ON

TNFEN00	Enable/disable using noise filter of TI00 pin
0	Noise filter OFF
1	Noise filter ON

Note The applicable pin can be switched by setting the ISC1 bit of the ISC register.
 ISC1 = 0: Whether or not to use the noise filter of the TI07 pin can be selected.
 ISC1 = 1: Whether or not to use the noise filter of the RxD2 pin can be selected.

Caution Be sure to clear bit 2 to “0”.

Remark The presence or absence of timer I/O pins of channel 0 to 7 depends on the product. See **Table 6-2 Timer I/O Pins provided in Each Product** for details.

6.3.15 Registers controlling port functions of pins to be used for timer I/O

Using port pins for the timer array unit functions requires setting of the registers that control the port functions multiplexed on the target pins (port mode register (PMxx), port register (Pxx), and port mode control register (PMCxx)). For details, see **4.3.1 Port mode registers (PMxx)**, **4.3.2 Port registers (Pxx)**, and **4.3.6 Port mode control registers (PMCxx)**.

The port mode register (PMxx), port register (Pxx), and port mode control register (PMCxx) to be set depend on the product. For details, see **4.5.3 Register setting examples for used port and alternate functions**.

When using the ports (such as P31/TI03/TO03) to be shared with the timer output pin for timer output, set the port mode control register (PMCxx) bit, port mode register (PMxx) bit and port register (Pxx) bit corresponding to each port to 0.

Example: When using P31/TI03/TO03 for timer output

- Set the PMC31 bit of port mode control register 3 to 0.
- Set the PM31 bit of port mode register 3 to 0.
- Set the P31 bit of port register 3 to 0.

When using the ports (such as P31/TI03/TO03) to be shared with the timer input pin for timer input, set the port mode register (PMxx) bit corresponding to each port to 1. And set the port mode control register (PMCxx) bit corresponding to each port to 0. At this time, the port register (Pxx) bit may be 0 or 1.

Example: When using P31/TI03/TO03 for timer input

- Set the PMC31 bit of port mode control register 3 to 0.
- Set the PM31 bit of port mode register 3 to 1.
- Set the P31 bit of port register 3 to 0 or 1.

6.4 Basic Rules of Timer Array Unit

6.4.1 Basic rules of simultaneous channel operation function

When simultaneously using multiple channels, namely, a combination of a master channel (a reference timer mainly counting the cycle) and slave channels (timers operating according to the master channel), the following rules apply.

- (1) Only an even channel (channel 0, 2, 4, etc.) can be set as a master channel.
- (2) Any channel, except channel 0, can be set as a slave channel.
- (3) The slave channel must be lower than the master channel.

Example: If channel 2 is set as a master channel, channel 3 or those that follow (channels 3, 4, 5, etc.) can be set as a slave channel.

- (4) Two or more slave channels can be set for one master channel.
- (5) When two or more master channels are to be used, slave channels with a master channel between them may not be set.

Example: If channels 0 and 4 are set as master channels, channels 1 to 3 can be set as the slave channels of master channel 0. Channels 5 to 7 cannot be set as the slave channels of master channel 0.

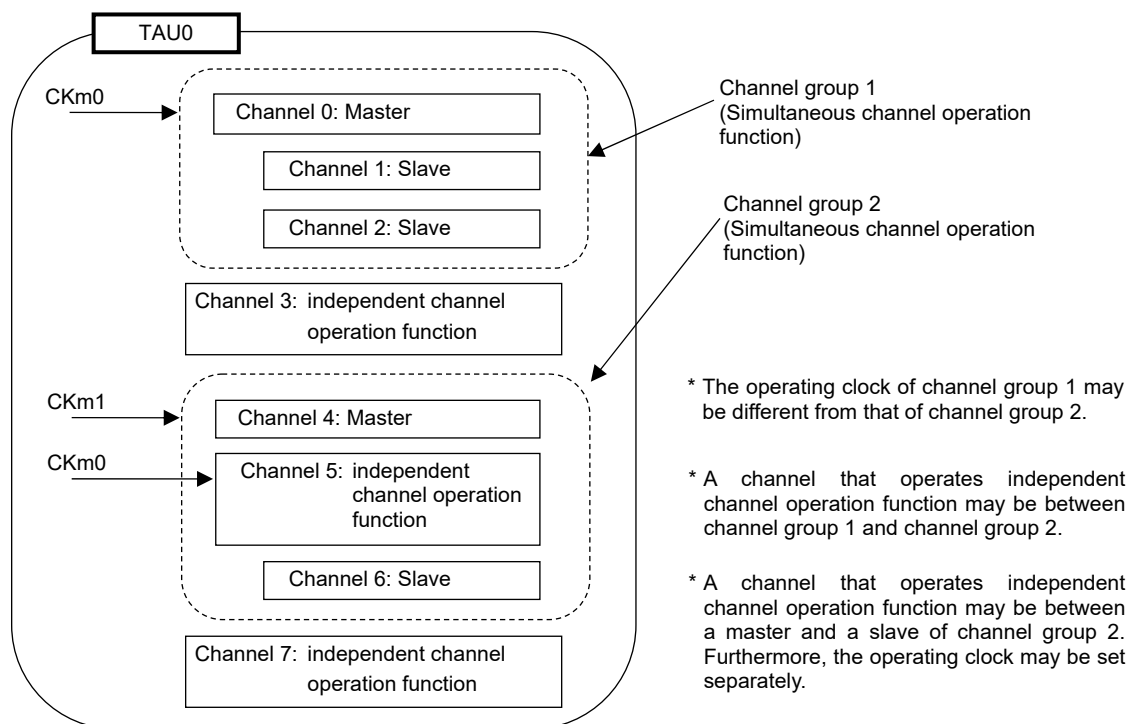
- (6) The operating clock for a slave channel in combination with a master channel must be the same as that of the master channel. The CKSmn0, CKSmn1 bits (bit 15, 14 of timer mode register mn (TMRmn)) of the slave channel that operates in combination with the master channel must be the same value as that of the master channel.
- (7) A master channel can transmit INTTMmn (interrupt), start software trigger, and count clock to the lower channels.
- (8) A slave channel can use INTTMmn (interrupt), a start software trigger, or the count clock of the master channel as a source clock, but cannot transmit its own INTTMmn (interrupt), start software trigger, or count clock to channels with lower channel numbers.
- (9) A master channel cannot use INTTMmn (interrupt), a start software trigger, or the count clock from the other higher master channel as a source clock.
- (10) To simultaneously start channels that operate in combination, the channel start trigger bit (TSMn) of the channels in combination must be set at the same time.
- (11) During the counting operation, a TSMn bit of a master channel or TSMn bits of all channels which are operating simultaneously can be set. It cannot be applied to TSMn bits of slave channels alone.
- (12) To stop the channels in combination simultaneously, the channel stop trigger bit (TTmn) of the channels in combination must be set at the same time.
- (13) CKm2/CKm3 cannot be selected while channels are operating simultaneously, because the operating clocks of master channels and slave channels have to be synchronized.
- (14) Timer mode register m0 (TMRm0) has no master bit (it is fixed as "0"). However, as channel 0 is the highest channel, it can be used as a master channel during simultaneous operation.

The rules of the simultaneous channel operation function are applied in a channel group (a master channel and slave channels forming one simultaneous channel operation function).

If two or more channel groups that do not operate in combination are specified, the basic rules of the simultaneous channel operation function in **6.4.1 Basic rules of simultaneous channel operation function** do not apply to the channel groups.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

Example



6.4.2 Basic rules of 8-bit timer operation function (channels 1 and 3 only)

The 8-bit timer operation function makes it possible to use a 16-bit timer channel in a configuration consisting of two 8-bit timer channels.

This function can only be used for channels 1 and 3, and there are several rules for using it.

The basic rules for this function are as follows:

- (1) The 8-bit timer operation function applies only to channels 1 and 3.
- (2) When using 8-bit timers, set the SPLITmn bit of timer mode register mn (TMRmn) to 1.
- (3) The higher 8 bits can be operated as the interval timer function.
- (4) At the start of operation, the higher 8 bits output INTTMm1H/INTTMm3H (an interrupt) (which is the same operation performed when MDmn0 is set to 1).
- (5) The operation clock of the higher 8 bits is selected according to the CKSmn1 and CKSmn0 bits of the lower-bit TMRmn register.
- (6) For the higher 8 bits, the TSHm1/TSHm3 bit is manipulated to start channel operation and the TTHm1/TTHm3 bit is manipulated to stop channel operation. The channel status can be checked using the TEHm1/TEHm3 bit.
- (7) The lower 8 bits operate according to the TMRmn register settings. The following three functions support operation of the lower 8 bits:
 - Interval timer function/Square wave output function
 - External event counter function
 - Delay count function
- (8) For the lower 8 bits, the TSm1/TSm3 bit is manipulated to start channel operation and the TTm1/TTm3 bit is manipulated to stop channel operation. The channel status can be checked using the TEM1/TEM3 bit.
- (9) During 16-bit operation, manipulating the TSHm1, TSHm3, TTHm1, and TTHm3 bits is invalid. The TSm1, TSm3, TTm1, and TTm3 bits are manipulated to operate channels 1 and 3. The TEHm3 and TEHm1 bits are not changed.
- (10) For the 8-bit timer function, the simultaneous operation functions (one-shot pulse, PWM, and multiple PWM) cannot be used.

Remark m: Unit number (m = 0), n: Channel number (n = 1, 3)

6.5 Operation of Counter

6.5.1 Count clock (f_{CLK})

The count clock (f_{CLK}) of the timer array unit can be selected between following by CCSmn bit of timer mode register mn (TMRmn).

- Operation clock (f_{MCK}) specified by the CKSmn0 and CKSmn1 bits
- Valid edge of input signal input from the TImn pin

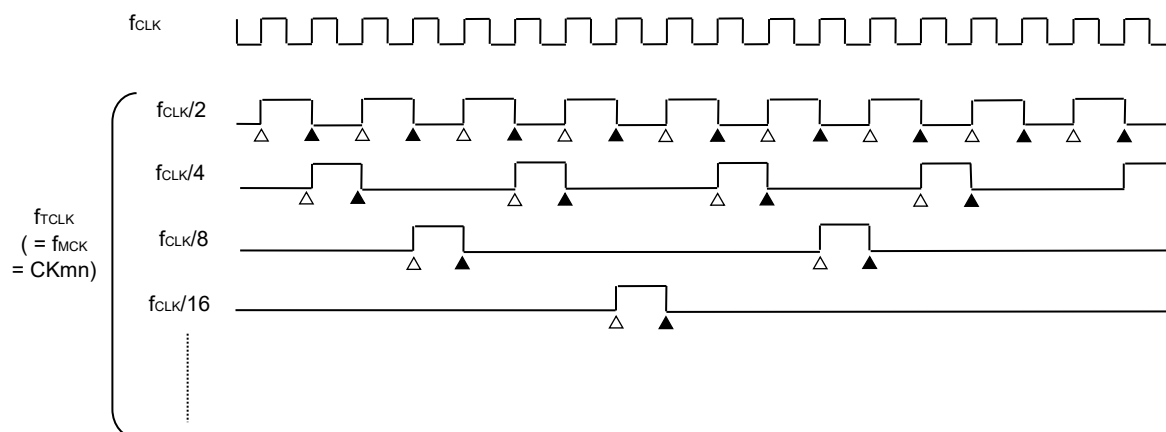
Because the timer array unit is designed to operate in synchronization with f_{CLK} , the timings of the count clock (f_{CLK}) are shown below.

(1) When operation clock (f_{MCK}) specified by the CKSmn0 and CKSmn1 bits is selected (CCSmn = 0)

The count clock (f_{CLK}) is between f_{CLK} to $f_{\text{CLK}}/2^{15}$ by setting of timer clock select register m (TPSm). When a divided f_{CLK} is selected, however, the clock selected in TPSmn register, but a signal which becomes high level for one period of f_{CLK} from its rising edge. When a f_{CLK} is selected, fixed to high level.

Counting of timer count register mn (TCRmn) delayed by one period of f_{CLK} from rising edge of the count clock, because of synchronization with f_{CLK} . But, this is described as “counting at rising edge of the count clock”, as a matter of convenience.

Figure 6-23. Timing of f_{CLK} and count clock (f_{CLK}) (When Ccsmn = 0)



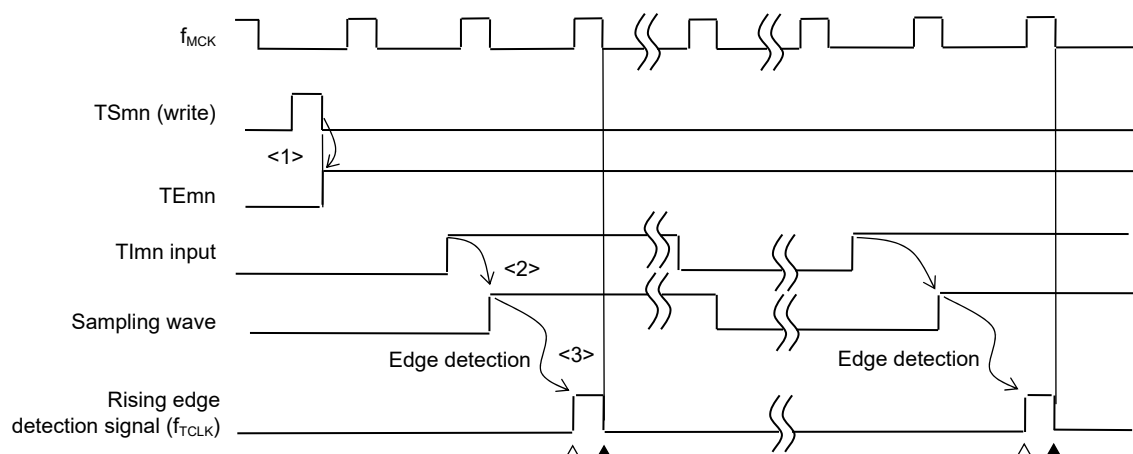
- Remarks**
1. Δ : Rising edge of the count clock
 $\blacktriangle$: Synchronization, increment/decrement of counter
 2. f_{CLK} : CPU/peripheral hardware clock
 3. m: Unit number ($m = 0$), n: Channel number ($n = 0$ to 7 (however, timer input pin (TImn), timer output pin (TOmn) : $n = 0, 1, 3$ to 7))

(2) When valid edge of input signal via the TImn pin is selected (CCSmn = 1)

The count clock (f_{TCLK}) becomes the signal that detects valid edge of input signal via the TImn pin and synchronizes next rising f_{MCK} . The count clock (f_{TCLK}) is delayed for 1 to 2 period of f_{MCK} from the input signal via the TImn pin (when a noise filter is used, the delay becomes 3 to 4 clock).

Counting of timer count register mn (TCRmn) delayed by one period of f_{CLK} from rising edge of the count clock, because of synchronization with f_{CLK} . But, this is described as “counting at valid edge of input signal via the TImn pin”, as a matter of convenience.

Figure 6-24. Timing of f_{CLK} and count clock (f_{TCLK}) (When CCSmn = 1, noise filter unused)



<1> Setting TSMn bit to 1 enables the timer to be started and to become wait state for valid edge of input signal via the TImn pin.

<2> The rise of input signal via the TImn pin is sampled by f_{MCK} .

<3> The edge is detected by the rising of the sampled signal and the detection signal (count clock) is output.

Remarks 1. Δ : Rising edge of the count clock

▲ : Synchronization, increment/decrement of counter

2. f_{CLK} : CPU/peripheral hardware clock

f_{MCK} : Operation clock of channel n

3. The waveform of the input signal via TImn pin of the input pulse interval measurement, the measurement of high/low width of input signal, and the delay counter, the one-shot pulse output are the same as that shown in Figure 6-22.

4. m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

6.5.2 Start timing of counter

Operation of timer count register mn (TCRmn) is enabled by setting of TSmn bit of timer channel start register m (TSM).
Operation from when counting is enabled to when timer count register mn (TCRmn) starts counting is shown in Table 6-6.

Table 6-6. Operations from Count Operation Enabled State to Timer count Register mn (TCRmn) Count Start

Timer operation mode	Operation when TSmn = 1 is set
Interval timer mode	No operation is carried out from start trigger detection (TSmn=1) until count clock generation. The first count clock loads the value of the TDRmn register to the TCRmn register and the subsequent count clock performs count down operation (see 6.5.3 (1) Operation of interval timer mode).
Event counter mode	Writing 1 to the TSmn bit loads the value of the TDRmn register to the TCRmn register. If detect edge of TImn input. The subsequent count clock performs count down operation (see 6.5.3 (2) Operation of event counter mode).
Capture mode	No operation is carried out from start trigger detection (TSmn = 1) until count clock generation. The first count clock loads 0000H to the TCRmn register and the subsequent count clock performs count up operation (see 6.5.3 (3) Operation of capture mode (input pulse interval measurement)).
One-count mode	The waiting-for-start-trigger state is entered by writing 1 to the TSmn bit while the timer is stopped (TEmn = 0). No operation is carried out from start trigger detection until count clock generation. The first count clock loads the value of the TDRmn register to the TCRmn register and the subsequent count clock performs count down operation (see 6.5.3 (4) Operation of one-count mode).
Capture & one-count mode	The waiting-for-start-trigger state is entered by writing 1 to the TSmn bit while the timer is stopped (TEmn = 0). No operation is carried out from start trigger detection until count clock generation. The first count clock loads 0000H to the TCRmn register and the subsequent count clock performs count up operation (see 6.5.3 (5) Operation of capture & one-count mode (high-level interval measurement)).

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn): n = 0, 1, 3 to 7))

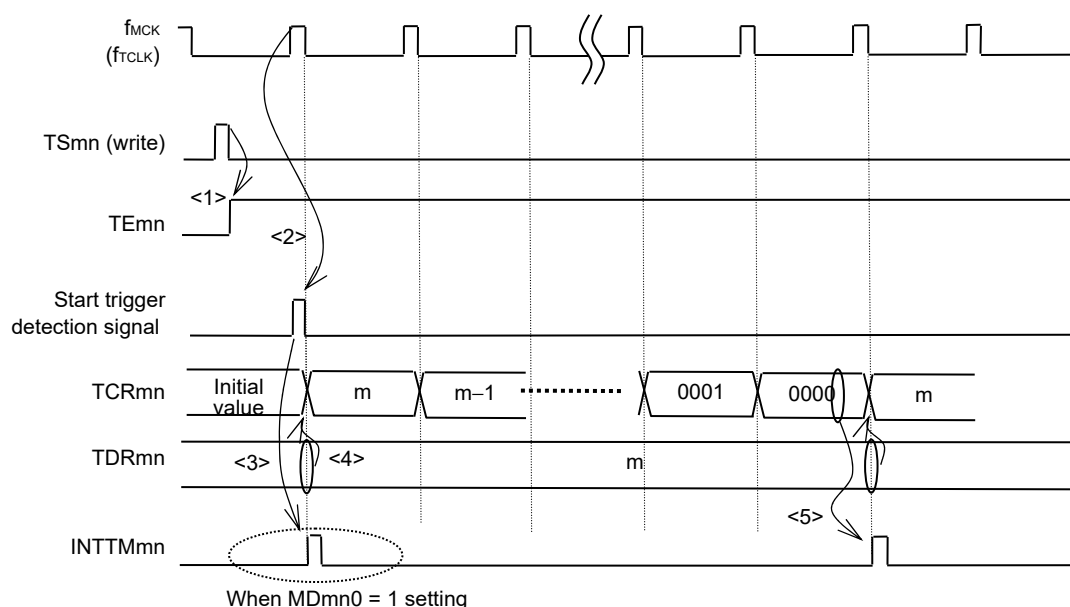
6.5.3 Operation of counter

Here, the counter operation in each mode is explained.

(1) Operation of interval timer mode

- <1> Operation is enabled ($TE_{mn} = 1$) by writing 1 to the TS_{mn} bit. Timer count register mn (TCR_{mn}) holds the initial value until count clock generation.
- <2> A start trigger is generated at the first count clock after operation is enabled.
- <3> When the MD_{mn0} bit is set to 1, $INTTM_{mn}$ is generated by the start trigger.
- <4> By the first count clock after the operation enable, the value of timer data register mn (TDR_{mn}) is loaded to the TCR_{mn} register and counting starts in the interval timer mode.
- <5> When the TCR_{mn} register counts down and its count value is 0000H, $INTTM_{mn}$ is generated and the value of timer data register mn (TDR_{mn}) is loaded to the TCR_{mn} register and counting keeps on.

Figure 6-25. Operation Timing (In Interval Timer Mode)

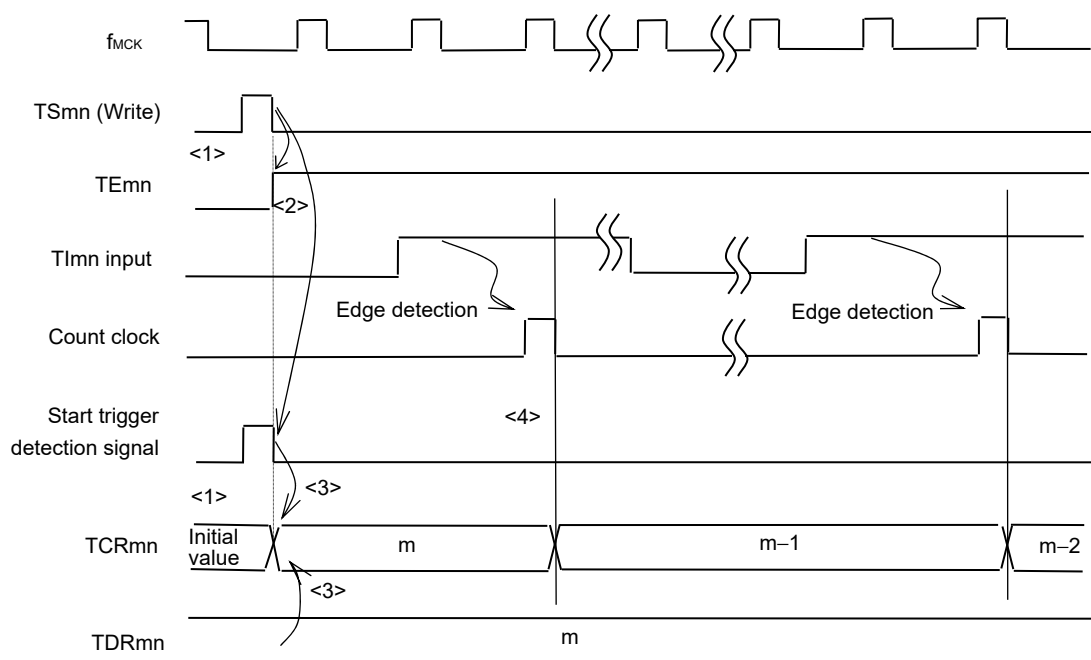


Caution In the operation in the first count clock cycle after writing the TS_{mn} bit, an error at a maximum of one count clock cycle occurs since count start delays until count clock has been generated. When the information on count start timing is necessary, an interrupt can be generated when counting is started by setting $MD_{mn0} = 1$.

- Remarks**
- f_{MCK} , the start trigger detection signal, and $INTTM_{mn}$ become active between one clock in synchronization with f_{CLK} .
 - m : Unit number ($m = 0$), n : Channel number ($n = 0$ to 7 (however, timer input pin (TI_{mn}), timer output pin (TO_{mn}): $n = 0, 1, 3$ to 7))

(2) Operation of event counter mode

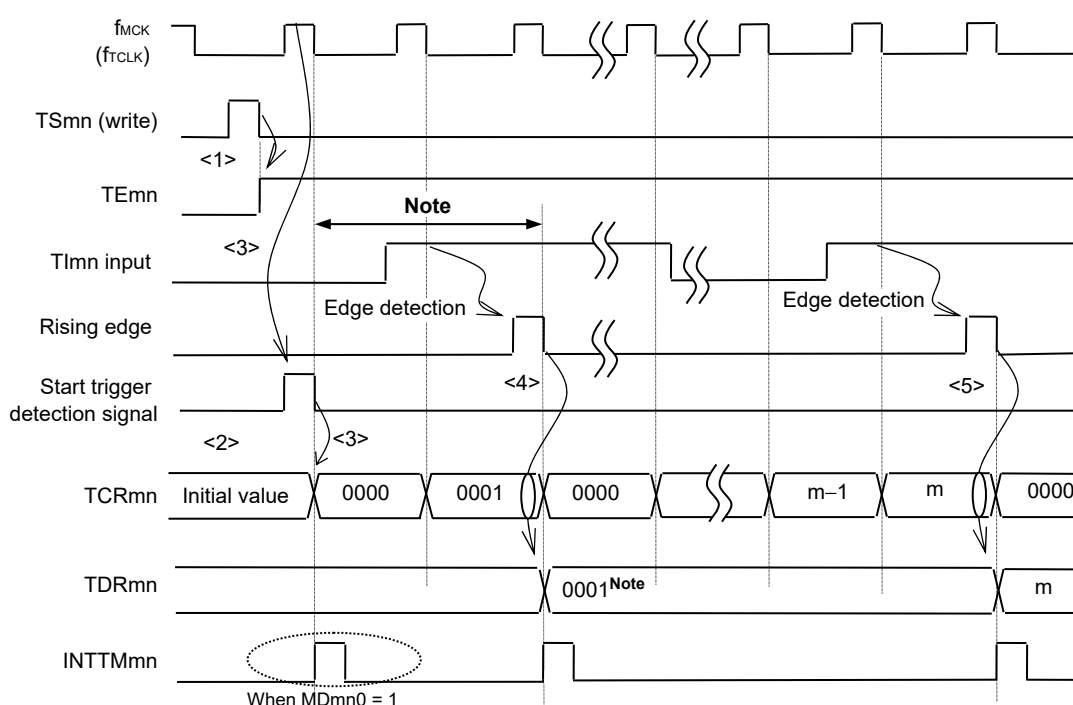
- <1> Timer count register mn (TCRmn) holds its initial value while operation is stopped (TEmn = 0).
- <2> Operation is enabled (TEmn = 1) by writing 1 to the TSmn bit.
- <3> As soon as 1 has been written to the TSmn bit and 1 has been set to the TE mn bit, the value of timer data register mn (TDRmn) is loaded to the TCRmn register to start counting.
- <4> After that, the TCRmn register value is counted down according to the count clock of the valid edge of the TImn input.

Figure 6-26. Operation Timing (In Event Counter Mode)

- Remarks 1.** Figure 6-26 shows the timing when the noise filter is not used. By making the noise filter on-state, the edge detection becomes 2 f_{MCK} cycles (it sums up to 3 to 4 cycles) later than the normal cycle of TImn input. The error per one period occurs by the asynchronous between the period of the TImn input and that of the count clock (f_{MCK}).
- 2.** m: Unit number ($m = 0$), n: Channel number ($n = 0$ to 7 (however, timer input pin (TImn), timer output pin (TOmn) : $n = 0, 1, 3$ to 7))

(3) Operation of capture mode (input pulse interval measurement)

- <1> Operation is enabled ($TE_{mn} = 1$) by writing 1 to the TS_{mn} bit.
- <2> Timer count register mn (TCR_{mn}) holds the initial value until count clock generation.
- <3> A start trigger is generated at the first count clock after operation is enabled. And the value of 0000H is loaded to the TCR_{mn} register and counting starts in the capture mode. (When the MD_{mn0} bit is set to 1, $INTTM_{mn}$ is generated by the start trigger.)
- <4> On detection of the valid edge of the TI_{mn} input, the value of the TCR_{mn} register is captured to timer data register mn (TDR_{mn}) and $INTTM_{mn}$ is generated. However, this capture value is no meaning. The TCR_{mn} register keeps on counting from 0000H.
- <5> On next detection of the valid edge of the TI_{mn} input, the value of the TCR_{mn} register is captured to timer data register mn (TDR_{mn}) and $INTTM_{mn}$ is generated.

Figure 6-27. Operation Timing (In Capture Mode : Input Pulse Interval Measurement)

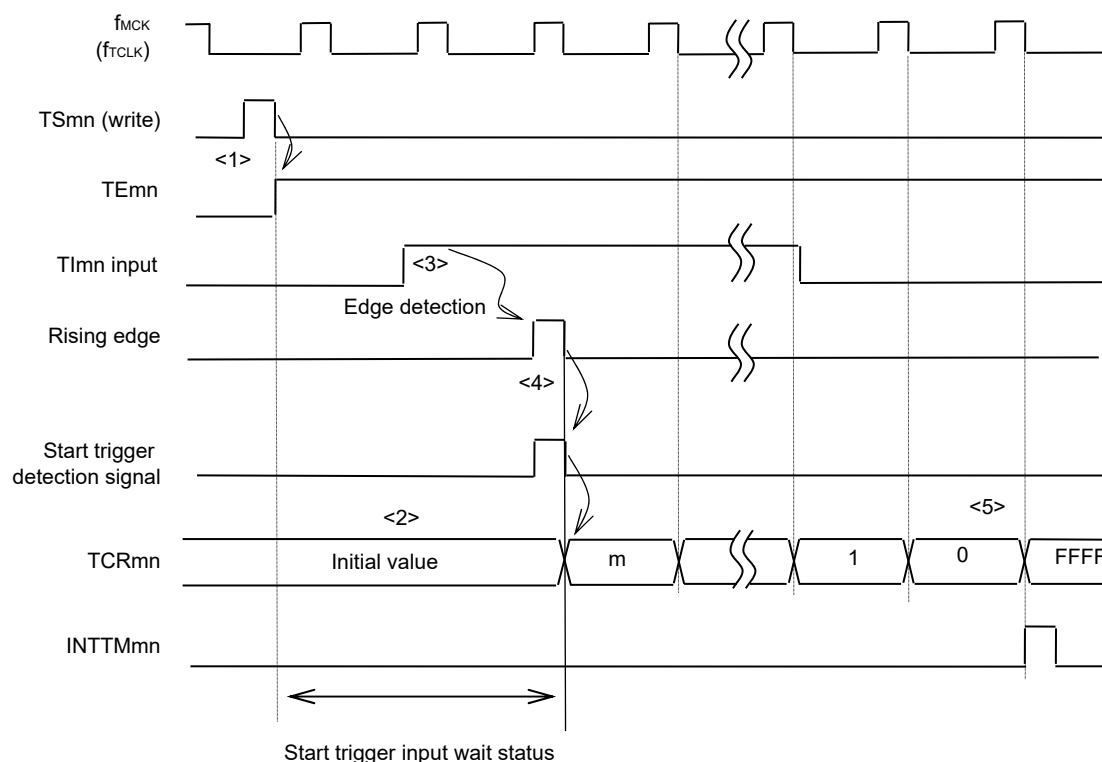
Note If a clock has been input to TI_{mn} (the trigger exists) when capturing starts, counting starts when a trigger is detected, even if no edge is detected. Therefore, the first captured value (<4>) does not determine a pulse interval (in the above figure, 0001 just indicates two clock cycles but does not determine the pulse interval) and so the user can ignore it.

Caution In the first cycle operation of count clock after writing the TS_{mn} bit, an error at a maximum of one clock is generated since count start delays until count clock has been generated. When the information on count start timing is necessary, an interrupt can be generated at count start by setting $MD_{mn0} = 1$.

- Remarks 1.** Figure 6-27 shows the timing when the noise filter is not used. By making the noise filter on-state, the edge detection becomes 2 f_{MCK} cycles (it sums up to 3 to 4 cycles) later than the normal cycle of TI_{mn} input. The error per one period occurs by the asynchronous between the period of the TI_{mn} input and that of the count clock (f_{MCK}).
- 2.** m : Unit number ($m = 0$), n : Channel number ($n = 0$ to 7 (however, timer input pin (TI_{mn}), timer output pin (TO_{mn}) : $n = 0, 1, 3$ to 7))

(4) Operation of one-count mode

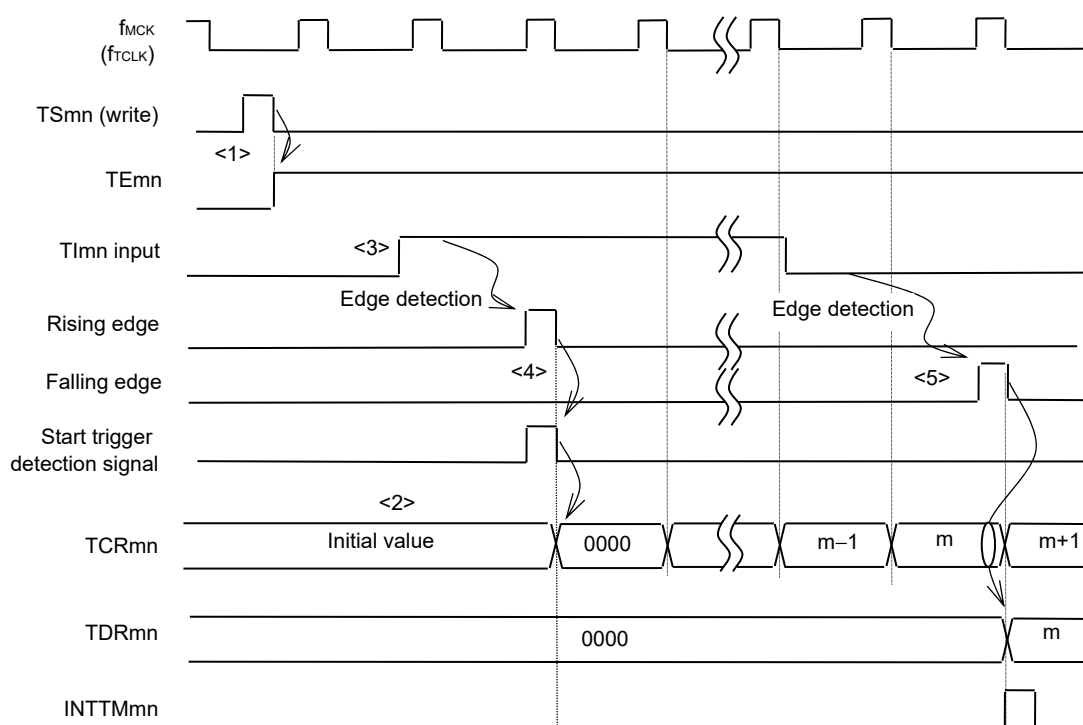
- <1> Operation is enabled ($TE_{mn} = 1$) by writing 1 to the TS_{mn} bit.
- <2> Timer count register mn (TCR_{mn}) holds the initial value until start trigger generation.
- <3> Rising edge of the TI_{mn} input is detected.
- <4> On start trigger detection, the value of timer data register mn (TDR_{mn}) is loaded to the TCR_{mn} register and count starts.
- <5> When the TCR_{mn} register counts down and its count value is 0000H, $INTTM_{mn}$ is generated and the value of the TCR_{mn} register becomes FFFFH and counting stops.

Figure 6-28. Operation Timing (In One-count Mode)

- Remarks 1.** Figure 6-28 shows the timing when the noise filter is not used. By making the noise filter on-state, the edge detection becomes $2 f_{MCK}$ cycles (it sums up to 3 to 4 cycles) later than the normal cycle of TI_{mn} input. The error per one period occurs by the asynchronous between the period of the TI_{mn} input and that of the count clock (f_{MCK}).
- 2.** m : Unit number ($m = 0$), n : Channel number ($n = 0$ to 7 (however, timer input pin (TI_{mn}), timer output pin (TO_{mn}): $n = 0, 1, 3$ to 7))

(5) Operation of capture & one-count mode (high-level width measurement)

- <1> Operation is enabled ($TE_{mn} = 1$) by writing 1 to the TS_{mn} bit of timer channel start register m (TS_m).
- <2> Timer count register mn (TCR_{mn}) holds the initial value until start trigger generation.
- <3> Rising edge of the TI_{mn} input is detected.
- <4> On start trigger detection, the value of 0000H is loaded to the TCR_{mn} register and count starts.
- <5> On detection of the falling edge of the TI_{mn} input, the value of the TCR_{mn} register is captured to timer data register mn (TDR_{mn}) and $INTT_{mn}$ is generated.

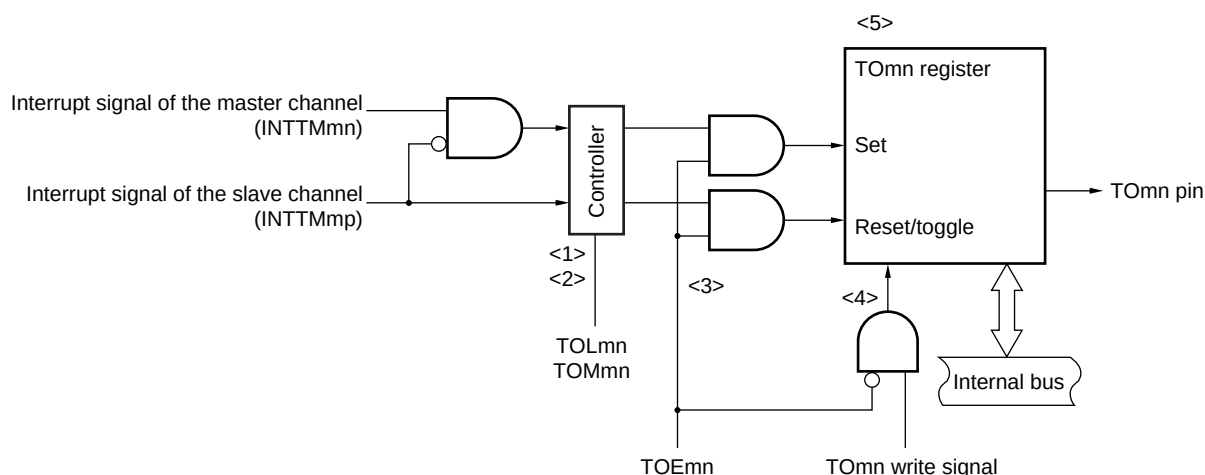
Figure 6-29. Operation Timing (In Capture & One-count Mode : High-level Width Measurement)

- Remarks 1.** Figure 6-29 shows the timing when the noise filter is not used. By making the noise filter on-state, the edge detection becomes 2 f_{MCK} cycles (it sums up to 3 to 4 cycles) later than the normal cycle of TI_{mn} input. The error per one period occurs by the asynchronous between the period of the TI_{mn} input and that of the count clock (f_{MCK}).
- 2.** m: Unit number ($m = 0$), n: Channel number ($n = 0$ to 7 (however, timer input pin (TI_{mn}), timer output pin (TO_{mn}) : $n = 0, 1, 3$ to 7))

6.6 Channel Output (TOMn Pin) Control

6.6.1 TOMn pin output circuit configuration

Figure 6-30. Output Circuit Configuration



The following describes the TOMn pin output circuit.

- <1> When $TOMmn = 0$ (master channel output mode), the set value of timer output level register m ($TOLm$) is ignored and only $INTTM0p$ (slave channel timer interrupt) is transmitted to timer output register m (TOm).
- <2> When $TOMmn = 1$ (slave channel output mode), both $INTTMmn$ (master channel timer interrupt) and $INTTM0p$ (slave channel timer interrupt) are transmitted to the TOm register.
At this time, the $TOLm$ register becomes valid and the signals are controlled as follows:

When $TOLmn = 0$: Positive logic output ($INTTMmn \rightarrow \text{set}$, $INTTM0p \rightarrow \text{reset}$)

When $TOLmn = 1$: Negative logic output ($INTTMmn \rightarrow \text{reset}$, $INTTM0p \rightarrow \text{set}$)

When $INTTMmn$ and $INTTM0p$ are simultaneously generated, (0% output of PWM), $INTTM0p$ (reset signal) takes priority, and $INTTMmn$ (set signal) is masked.

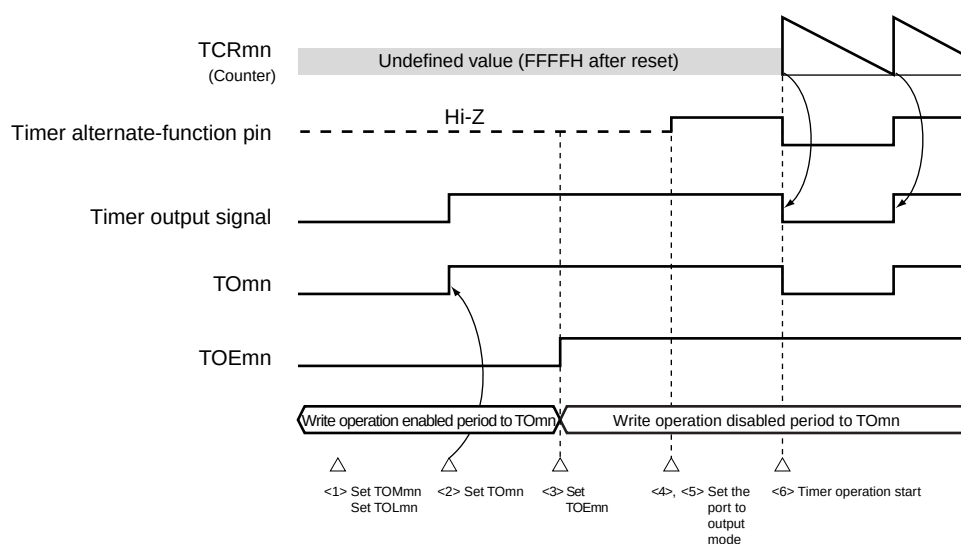
- <3> While timer output is enabled ($TOEmn = 1$), $INTTMmn$ (master channel timer interrupt) and $INTTM0p$ (slave channel timer interrupt) are transmitted to the TOm register. Writing to the TOm register ($TOMn$ write signal) becomes invalid.
When $TOEmn = 1$, the $TOMn$ pin output never changes with signals other than interrupt signals.
To initialize the $TOMn$ pin output level, it is necessary to set timer operation is stopped ($TOEmn = 0$) and to write a value to the TOm register.
- <4> While timer output is disabled ($TOEmn = 0$), writing to the $TOMn$ bit to the target channel ($TOMn$ write signal) becomes valid. When timer output is disabled ($TOEmn = 0$), neither $INTTMmn$ (master channel timer interrupt) nor $INTTM0p$ (slave channel timer interrupt) is transmitted to the TOm register.
- <5> The TOm register can always be read, and the $TOMn$ pin output level can be checked.

Remark m : Unit number ($m = 0$)
 n : Channel number
 $n = 0, 1, 3$ to 7
 p : Slave channel number
 $n < p \leq 7$

6.6.2 TOMn pin output setting

The following figure shows the procedure and status transition of the TOMn output pin from initial setting to timer operation start.

Figure 6-31. Status Transition from Timer Output Setting to Operation Start



<1> The operation mode of timer output is set.

- TOMmn bit (0: Master channel output mode, 1: Slave channel output mode)
- TOLmn bit (0: Positive logic output, 1: Negative logic output)

<2> The timer output signal is set to the initial status by setting timer output register m (TOM).

<3> The timer output operation is enabled by writing 1 to the TOEmn bit (writing to the TOM register is disabled).

<4> The port is set to digital I/O by port mode control register (PMCxx) (see **6.3.15 Registers controlling port functions of pins to be used for timer I/O**).

<5> The port I/O setting is set to output (see **6.3.15 Registers controlling port functions of pins to be used for timer I/O**).

<6> The timer operation is enabled (TSmn = 1).

Remark m: Unit number (m = 0), n: Channel number (n = 0, 1, 3 to 7)

6.6.3 Cautions on channel output operation

(1) Changing values set in the registers TOM, TOEm, and TOLm during timer operation

Since the timer operations (operations of timer count register mn (TCRmn) and timer data register mn (TDRmn)) are independent of the TOMn output circuit and changing the values set in timer output register m (TOM), timer output enable register m (TOEm), and timer output level register m (TOLm) does not affect the timer operation, the values can be changed during timer operation. To output an expected waveform from the TOMn pin by timer operation, however, set the TOM, TOEm, TOLm, and TOMm registers to the values stated in the register setting example of each operation shown in **6.8 Independent Channel Operation Function of Timer Array Unit** and **6.9 Simultaneous Channel Operation Function of Timer Array Unit**.

When the values set to the TOEm, and TOLm registers (but not the TOM register) are changed close to the occurrence of the timer interrupt (INTTMmn) of each channel, the waveform output to the TOMn pin might differ, depending on whether the values are changed immediately before or immediately after the timer interrupt (INTTMmn) occurs.

Remark m: Unit number (m = 0), n: Channel number (n = 0, 1, 3 to 7)

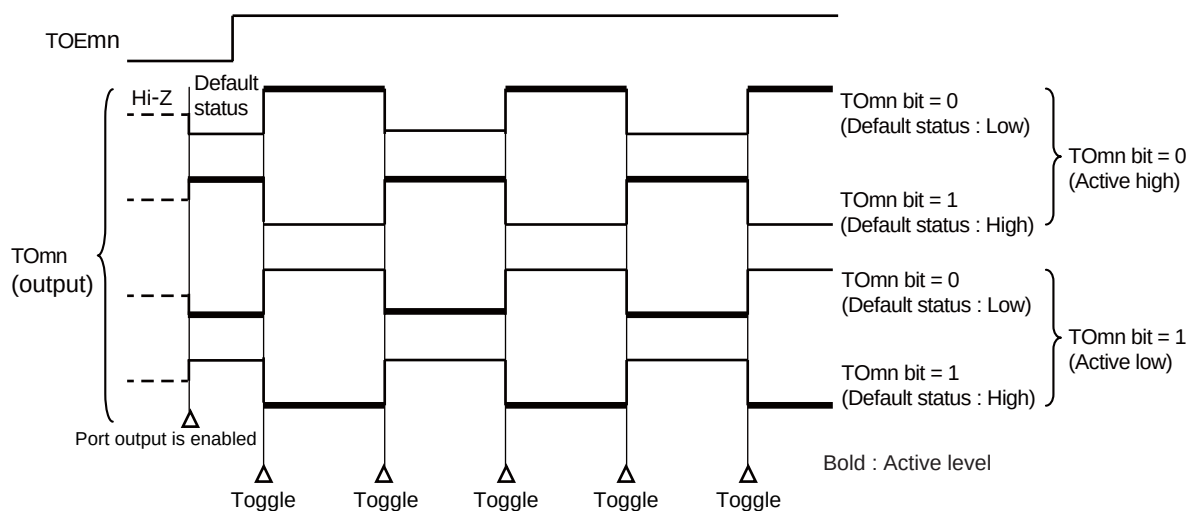
(2) Default level of TOMn pin and output level after timer operation start

The change in the output level of the TOMn pin when timer output register m (TOM) is written while timer output is disabled (TOEmn = 0), the initial level is changed, and then timer output is enabled (TOEmn = 1) before port output is enabled, is shown below.

(a) When operation starts with master channel output mode (TOMmn = 0) setting

The setting of timer output level register m (TOLm) is invalid when master channel output mode (TOMmn = 0). When the timer operation starts after setting the default level, the toggle signal is generated and the output level of the TOMn pin is reversed.

Figure 6-32. TOMn Pin Output Status at Toggle Output (TOMmn = 0)

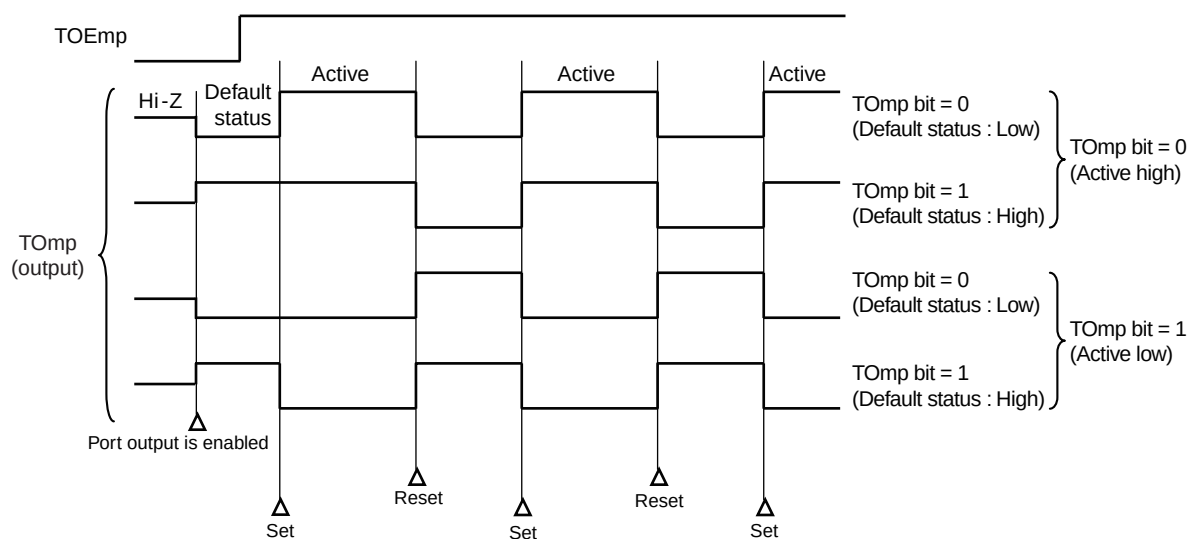


Remarks 1. Toggle: Reverse TOMn pin output status

2. m: Unit number (m = 0), n: Channel number (n = 0, 1, 3 to 7)

(b) When operation starts with slave channel output mode (TOMmp = 1) setting (PWM output))

When slave channel output mode (TOMmp = 1), the active level is determined by timer output level register m (TOLm) setting.

Figure 6-33. TOmp Pin Output Status at PWM Output (TOMmp = 1)

Remarks 1. Set: The output signal of the TOmp pin changes from inactive level to active level.

Reset: The output signal of the TOmp pin changes from active level to inactive level.

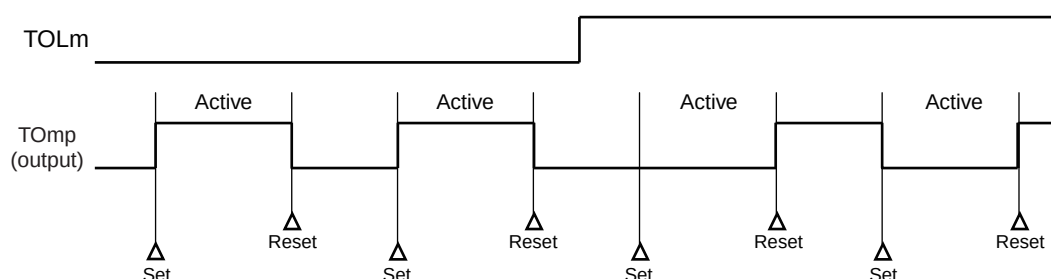
2. m: Unit number (m = 0), p: Channel number (p = 1, 3 to 7)

(3) Operation of TOMn pin in slave channel output mode (TOMmn = 1)**(a) When timer output level register m (TOLm) setting has been changed during timer operation**

When the TOLm register setting has been changed during timer operation, the setting becomes valid at the generation timing of the TOMn pin change condition. Rewriting the TOLm register does not change the output level of the TOMn pin.

The operation when TOMmn is set to 1 and the value of the TOLm register is changed while the timer is operating (TEmn = 1) is shown below.

Figure 6-34. Operation when TOLm Register Has Been Changed Contents during Timer Operation



Remarks 1. Set: The output signal of the TOMn pin changes from inactive level to active level.

Reset: The output signal of the TOMn pin changes from active level to inactive level.

2. m: Unit number (m = 0), n: Channel number (n = 0, 1, 3 to 7)

(b) Set/reset timing

To realize 0%/100% output at PWM output, the TOMn pin/TOMn bit set timing at master channel timer interrupt (INTTMmn) generation is delayed by 1 count clock by the slave channel.

If the set condition and reset condition are generated at the same time, a higher priority is given to the latter.

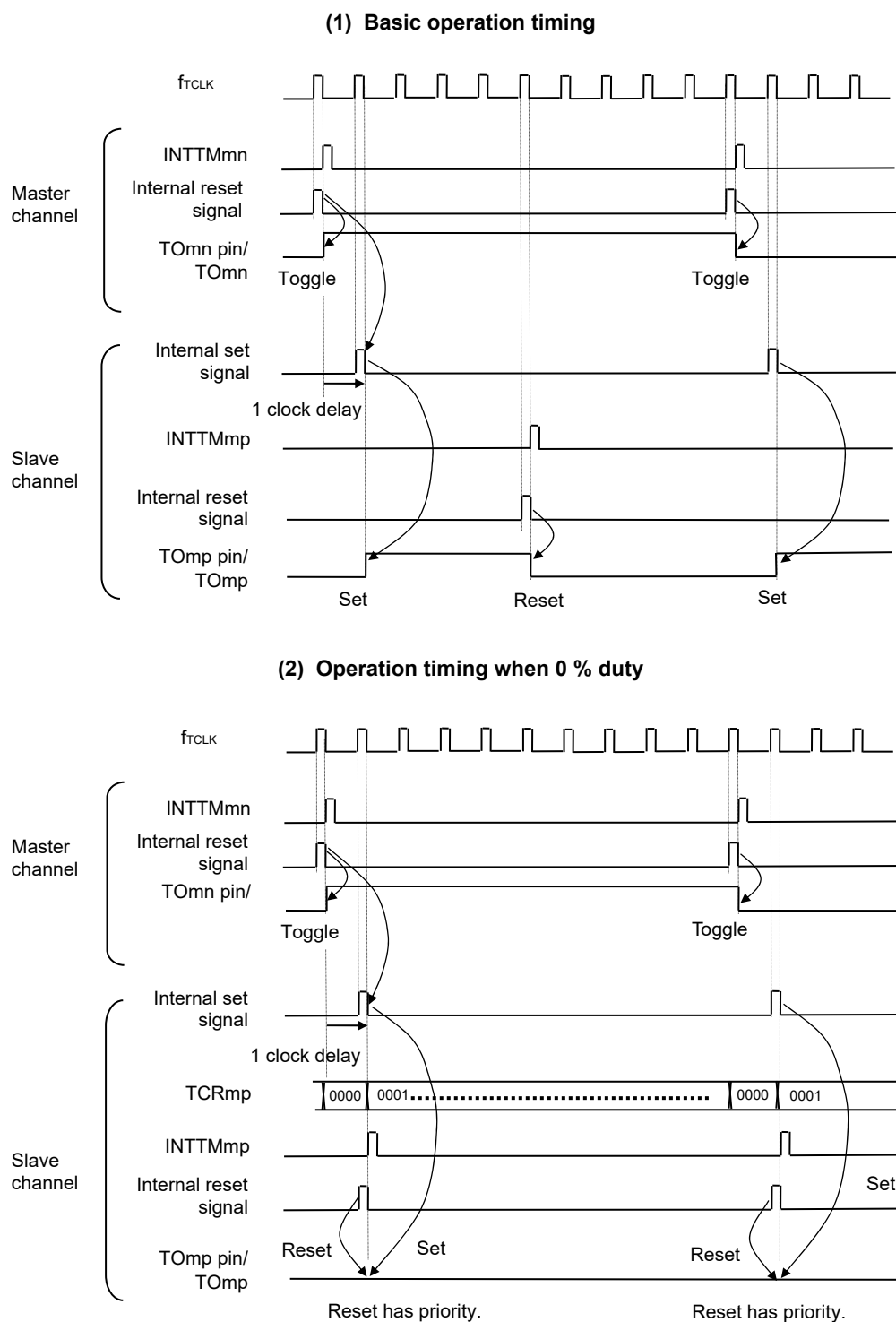
Figure 6-35 shows the set/reset operating statuses where the master/slave channels are set as follows.

Master channel: TOEmn = 1, TOMmn = 0, TOLmn = 0

Slave channel: TOEmp = 1, TOMmp = 1, TOLmp = 0

Remark m: Unit number (m = 0), n: Channel number (n = 0, 1, 3 to 7)

Figure 6-35. Set/Reset Timing Operating Statuses



Remarks 1. Internal reset signal: TOmn pin reset/toggle signal

Internal set signal: TOmn pin set signal

2. m: Unit number (m = 0)

n: Channel number

n = 0, 1, 3 to 7 (n = 0, 4, 6 for master channel)

p: Slave channel number

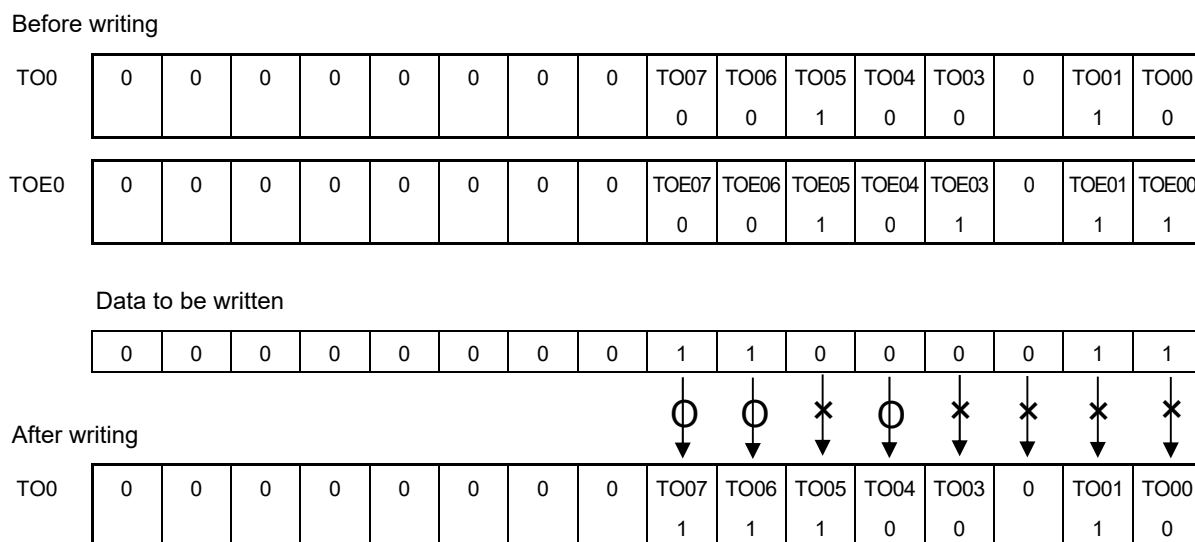
n < p ≤ 7

6.6.4 Collective manipulation of TOMn bit

In timer output register m (TOM), the setting bits for all the channels are located in one register in the same way as timer channel start register m (TSM). Therefore, the TOMn bit of all the channels can be manipulated collectively.

Only the desired bits can also be manipulated by enabling writing only to the TOMn bits (TOEmn = 0) that correspond to the relevant bits of the channel used to perform output (TOMn).

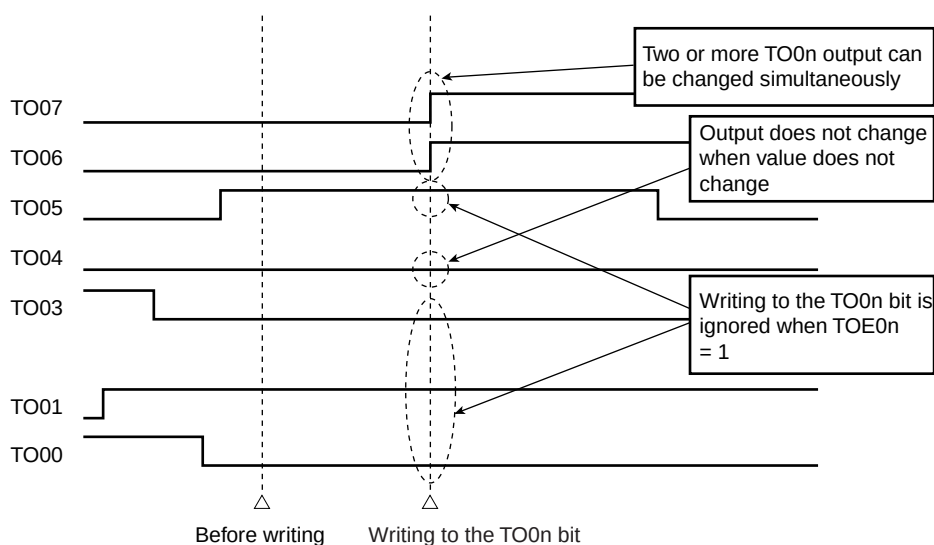
Figure 6-36. Example of TO0n Bit Collective Manipulation



Writing is done only to the TOMn bit with TOEmn = 0, and writing to the TOMn bit with TOEmn = 1 is ignored.

TOMn (channel output) to which TOEmn = 1 is set is not affected by the write operation. Even if the write operation is done to the TOMn bit, it is ignored and the output change by timer operation is normally done.

Figure 6-37. TO0n Pin Statuses by Collective Manipulation of TO0n Bit



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 1, 3 to 7)

6.6.5 Timer interrupt and TOMn pin output at operation start

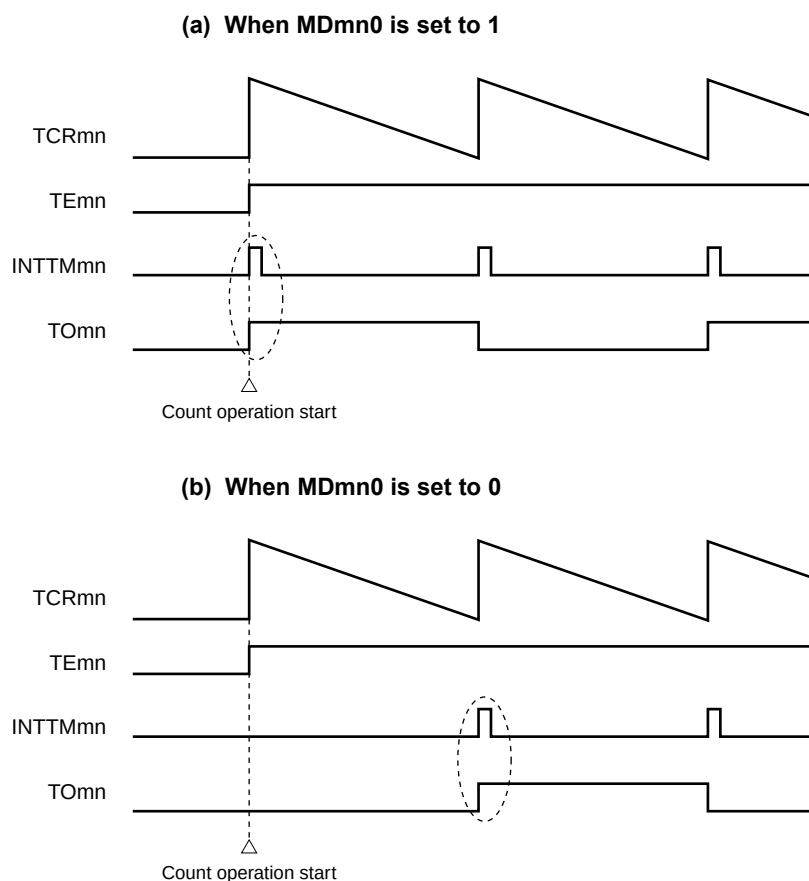
In the interval timer mode or capture mode, the MDmn0 bit in timer mode register mn (TMRmn) sets whether or not to generate a timer interrupt at count start.

When MDmn0 is set to 1, the count operation start timing can be known by the timer interrupt (INTTMmn) generation.

In the other modes, neither timer interrupt at count operation start nor TOMn output is controlled.

Figure 6-38 shows operation examples when the interval timer mode (TOEmn = 1, TOMmn = 0) is set.

Figure 6-38. Operation Examples of Timer Interrupt at Count Operation Start and TOMn Output



When MDmn0 is set to 1, a timer interrupt (INTTMmn) is output at count operation start, and TOMn performs a toggle operation.

When MDmn0 is set to 0, a timer interrupt (INTTMmn) is not output at count operation start, and TOMn does not change either. After counting one cycle, INTTMmn is output and TOMn performs a toggle operation.

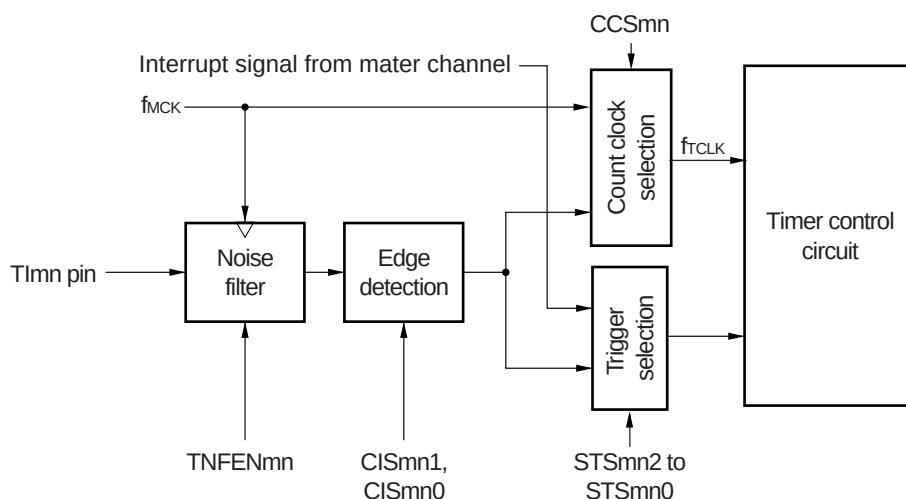
Remark m: Unit number (m = 0), n: Channel number (n = 0, 1, 3 to 7)

6.7 Timer Input (TImn) Control

6.7.1 TImn pin input circuit configuration

The signal input from a timer input pin passes through a noise filter and edge detector, and is then input to the timer controller. If it is necessary to eliminate noise at the pin in question, enable its noise filter. The configuration of the input circuit is shown below.

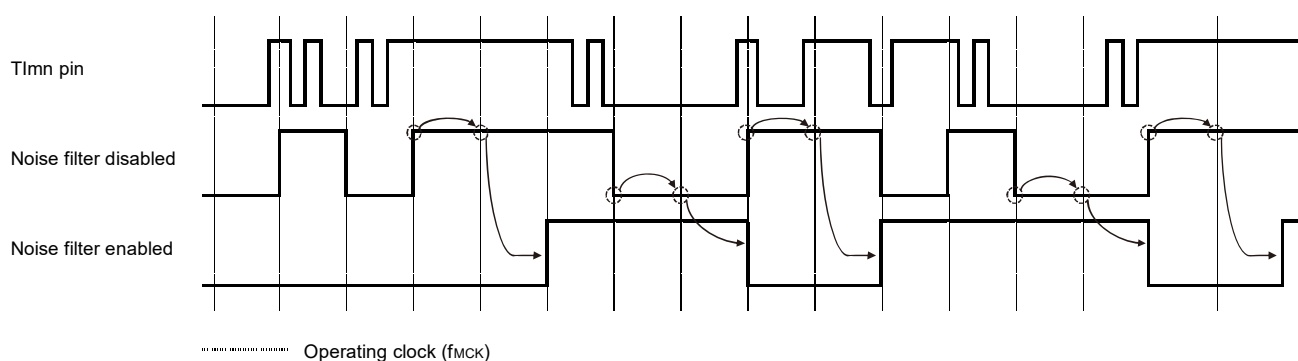
Figure 6-39. Input Circuit Configuration



6.7.2 Noise filter

If the noise filter is disabled, only synchronization is performed, based on the operating clock of channel n (f_{MCK}). If the noise filter is enabled, synchronization is performed based on the operating clock of channel n (f_{MCK}), and then two-clock match detection is performed. The following shows the waveforms of a signal after passing through a noise filter when the noise filter is enabled and disabled.

Figure 6-40. Waveform of Sampling Signal Input to TImn Pin When Noise Filter Is Enabled and Disabled



6.7.3 Cautions on channel input

When timer input pins are not used, the operating clock is not supplied to the noise filters. When use of a timer input pin is specified, therefore, the system must wait for the time shown below until the channel operation enable trigger flag for the channel corresponding to the timer input pin is set.

(1) When the noise filter is disabled

If bit 12 (CCSmn), bit 9 (STSmn1), or bit 8 (STSmn0) of timer mode register mn (TMRmn) is set when all of these bits are 0, wait for at least two cycles of the operating clock (f_{MCK}), and then set the corresponding timer operation enable trigger flag of the timer channel start register (TSm).

(2) When the noise filter is enabled

If bit 12 (CCSmn), bit 9 (STSmn1), or bit 8 (STSmn0) of timer mode register mn (TMRmn) is set when all of these bits are 0, wait for at least four cycles of the operating clock (f_{MCK}), and then set the corresponding timer operation enable trigger flag of the timer channel start register (TSm).

6.8 Independent Channel Operation Function of Timer Array Unit

6.8.1 Operation as interval timer/square wave output

(1) Interval timer

The timer array unit can be used as a reference timer that generates INTTMmn (timer interrupt) at fixed intervals. The interrupt generation period can be calculated by the following expression.

$$\text{Generation period of INTTMmn (timer interrupt)} = \text{Period of count clock} \times (\text{Set value of TDRmn} + 1)$$

(2) Operation as square wave output

TOMn performs a toggle operation as soon as INTTMmn has been generated, and outputs a square wave with a duty factor of 50%.

The period and frequency for outputting a square wave from TOMn can be calculated by the following expressions.

$$\bullet \text{ Period of square wave output from TOMn} = \text{Period of count clock} \times (\text{Set value of TDRmn} + 1) \times 2$$

$$\bullet \text{ Frequency of square wave output from TOMn} = \text{Frequency of count clock} / \{(\text{Set value of TDRmn} + 1) \times 2\}$$

Timer count register mn (TCRmn) operates as a down counter in the interval timer mode.

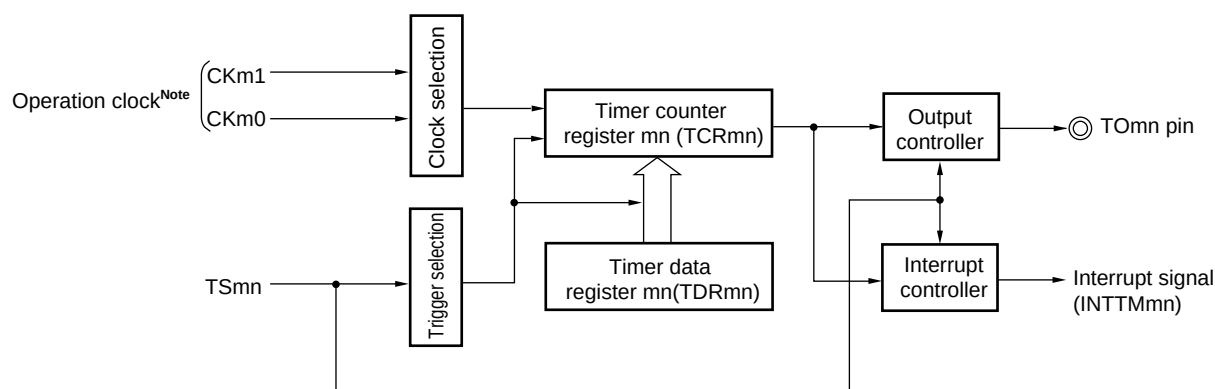
The TCRmn register loads the value of timer data register mn (TDRmn) at the first count clock after the channel start trigger bit (TSMn, TSHm1, TSHm3) of timer channel start register m (TSM) is set to 1. If the MDmn0 bit of timer mode register mn (TMRmn) is 0 at this time, INTTMmn is not output and TOMn is not toggled. If the MDmn0 bit of the TMRmn register is 1, INTTMmn is output and TOMn is toggled.

After that, the TCRmn register count down in synchronization with the count clock.

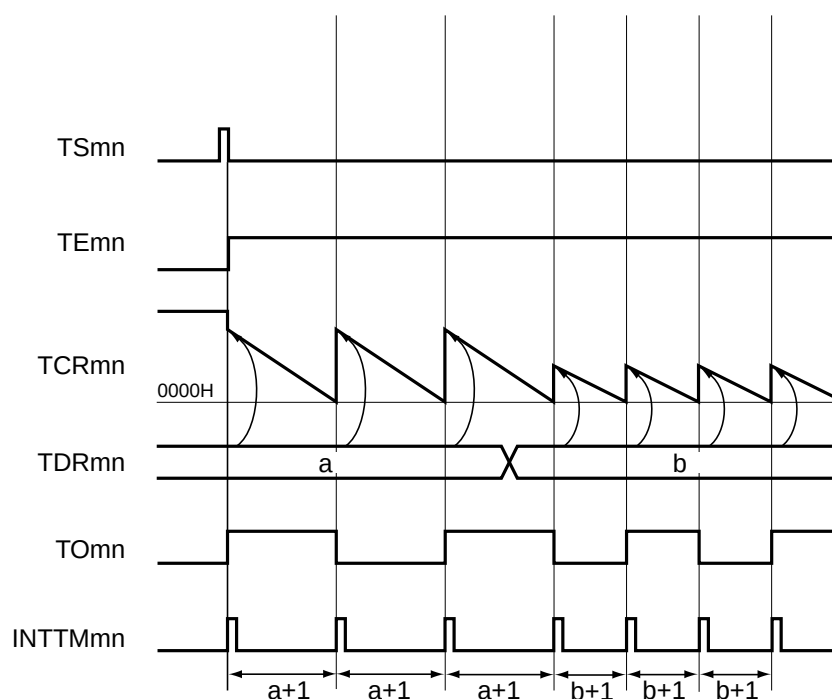
When TCRmn = 0000H, INTTMmn is output and TOMn is toggled at the next count clock. At the same time, the TCRmn register loads the value of the TDRmn register again. After that, the same operation is repeated.

The TDRmn register can be rewritten at any time. The new value of the TDRmn register becomes valid from the next period.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

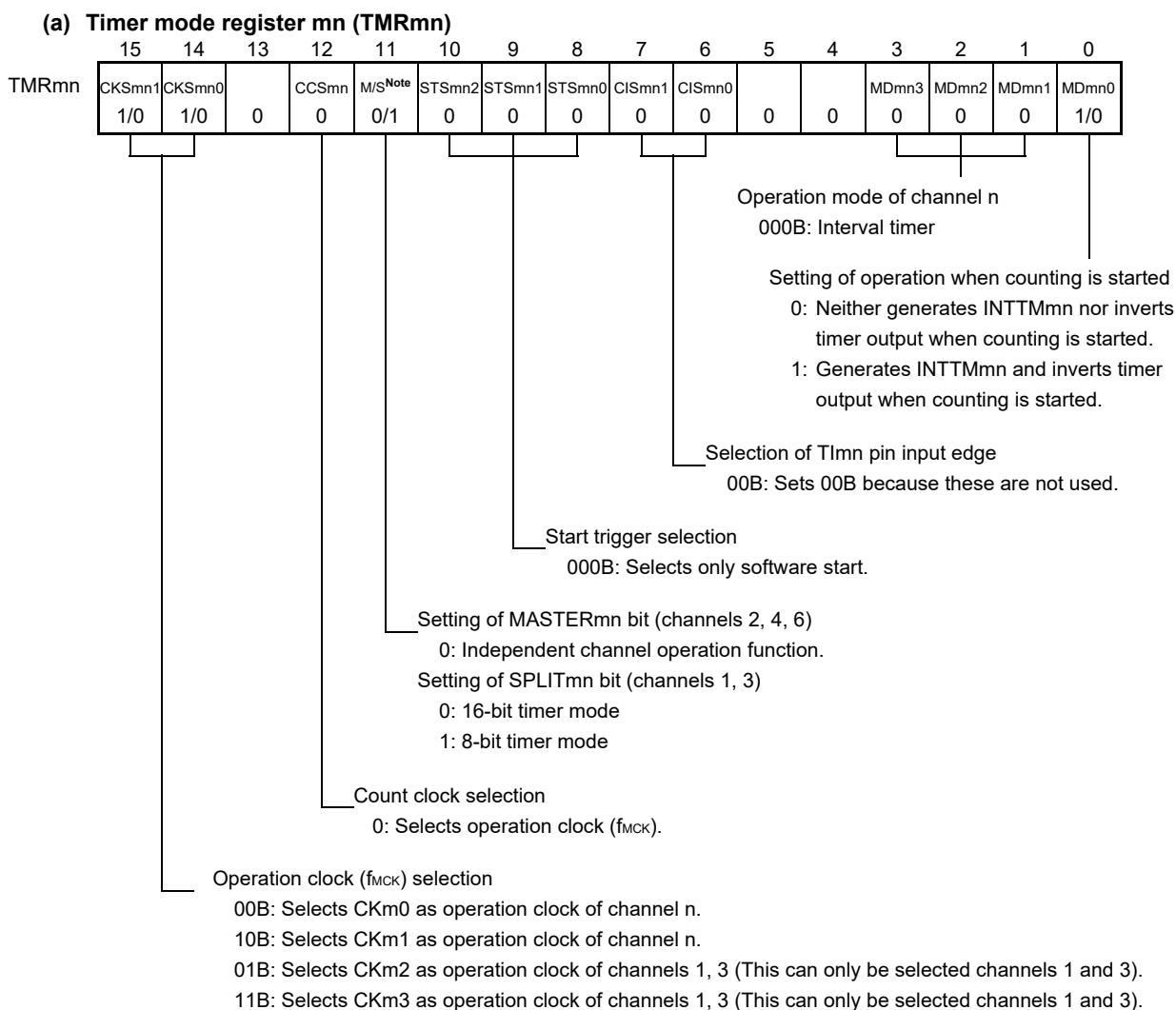
Figure 6-41. Block Diagram of Operation as Interval Timer/Square Wave Output

Note When channels 1 and 3, the clock can be selected from CKm0, CKm1, CKm2 and CKm3.

Figure 6-42. Example of Basic Timing of Operation as Interval Timer/Square Wave Output (MDmn0 = 1)

- Remarks**
1. m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TIMn), timer output pin (TOMn) : n = 0, 1, 3 to 7))
 2. TSmn: Bit n of timer channel start register m (TSM)
 TEMn: Bit n of timer channel enable status register m (TEM)
 TCRmn: Timer count register mn (TCRmn)
 TDRmn: Timer data register mn (TDRmn)
 TOMn: TOMn pin output signal

Figure 6-43. Example of Set Contents of Registers During Operation as Interval Timer/Square Wave Output (1/2)



(b) Timer output register m (TOM)

TOM	Bit n	
	TOMn	0: Outputs 0 from TOMn. 1: Outputs 1 from TOMn.
	1/0	

(c) Timer output enable register m (TOEm)

TOEm	Bit n	
	TOEmn	0: Stops the TOMn output operation by counting operation. 1: Enables the TOMn output operation by counting operation.
	1/0	

Note TMRm2, TMRm4, TMRm6: MASTERmn bit
 TMRm1, TMRm3: SPLITmn bit
 TMRm0, TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-43. Example of Set Contents of Registers During Operation as Interval Timer/Square Wave Output (2/2)**(d) Timer output level register m (TOLm)**

TOLm

Bit n
TOLmn
0

 0: Cleared to 0 when TOMmn = 0 (master channel output mode)

(e) Timer output mode register m (TOMm)

TOMm

Bit n
TOMmn
0

 0: Sets master channel output mode.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

Figure 6-44. Operation Procedure of Interval Timer/Square Wave Output Function (1/2)

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1.	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 to CKm3.	
Channel default setting	Sets timer mode register mn (TMRmn) (determines operation mode of channel). Sets interval (period) value to timer data register mn (TDRmn).	Channel stops operating. (Clock is supplied and some power is consumed.)
	To use the TOMn output Clears the TOMmn bit of timer output mode register m (TOMm) to 0 (master channel output mode). Clears the TOLmn bit to 0. Sets the TOMn bit and determines default level of the TOMn output.	The TOMn pin goes into Hi-Z output state.
	Sets the TOEmn bit to 1 and enables operation of TOMn. Clears the port register and port mode register to 0.	The TOMn default setting level is output when the port mode register is in the output mode and the port register is 0. TOMn does not change because channel stops operating. The TOMn pin outputs the TOMn set level.
Operation start	(Sets the TOEmn bit to 1 only if using TOMn output and resuming operation.). Sets the TSmn (TSHm1, TSHm3) bit to 1. The TSmn (TSHm1, TSHm3) bit automatically returns to 0 because it is a trigger bit.	TEmn (TEHm1, TEHm3) = 1, and count operation starts. Value of the TDRmn register is loaded to timer count register mn (TCRmn). INTTMmn is generated and TOMn performs toggle operation if the MDmn0 bit of the TMRmn register is 1.
During operation	Set value of the TDRmn register can be changed. The TCRmn register can always be read. The TSRmn register is not used. Set values of the TOM and TOEm registers can be changed. Set values of the TMRmn register, TOMmn, and TOLmn bits cannot be changed.	Counter (TCRmn) counts down. When count value reaches 0000H, the value of the TDRmn register is loaded to the TCRmn register again and the count operation is continued. By detecting TCRmn = 0000H, INTTMmn is generated and TOMn performs toggle operation. After that, the above operation is repeated.
Operation stop	The TTmn (TTHm1, TTHm3) bit is set to 1. The TTmn (TTHm1, TTHm3) bit automatically returns to 0 because it is a trigger bit.	TEmn (TEHm1, TEHm3), and count operation stops. The TCRmn register holds count value and stops. The TOMn output is not initialized but holds current status.
	The TOEmn bit is cleared to 0 and value is set to the TOMn bit.	The TOMn pin outputs the TOMn bit set level.

Operation is resumed.

(Remark is listed on the next page.)

Figure 6-44. Operation Procedure of Interval Timer/Square Wave Output Function (2/2)

	Software Operation	Hardware Status
TAU stop	To hold the TOMn pin output level Clears the TOMn bit to 0 after the value to be held is set to the port register. —————→	The TOMn pin output level is held by port function.
	When holding the TOMn pin output level is not necessary Setting not required. ----- The TAUmEN bit of the PER0 register is cleared to 0. —→	Power-off status All circuits are initialized and SFR of each channel is also initialized. (The TOMn bit is cleared to 0 and the TOMn pin is set to port mode.)

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.8.2 Operation as external event counter

The timer array unit can be used as an external event counter that counts the number of times the valid input edge (external event) is detected in the TImn pin. When a specified count value is reached, the event counter generates an interrupt. The specified number of counts can be calculated by the following expression.

$$\text{Specified number of counts} = \text{Set value of TDRmn} + 1$$

Timer count register mn (TCRmn) operates as a down counter in the event counter mode.

The TCRmn register loads the value of timer data register mn (TDRmn) by setting any channel start trigger bit (TSMn, TSHm1, TSHm3) of timer channel start register m (TSM) to 1.

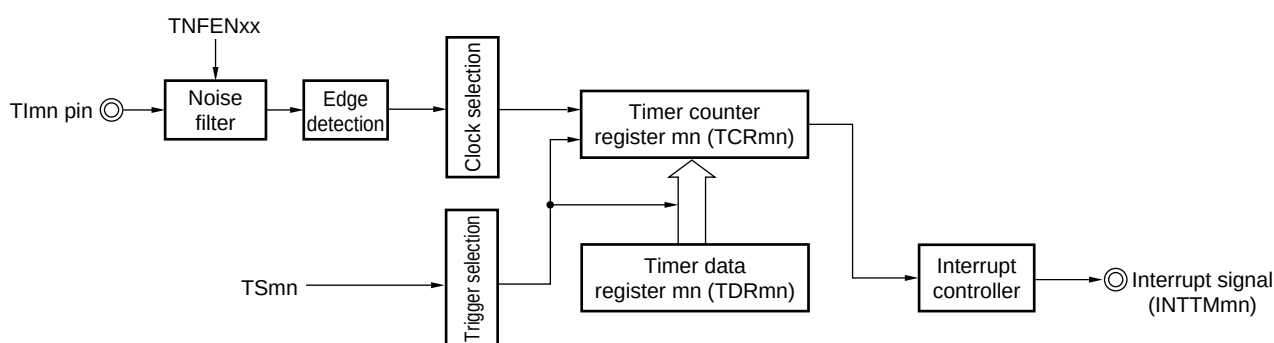
The TCRmn register counts down each time the valid input edge of the TImn pin has been detected. When TCRmn = 0000H, the TCRmn register loads the value of the TDRmn register again, and outputs INTTMmn.

After that, the above operation is repeated.

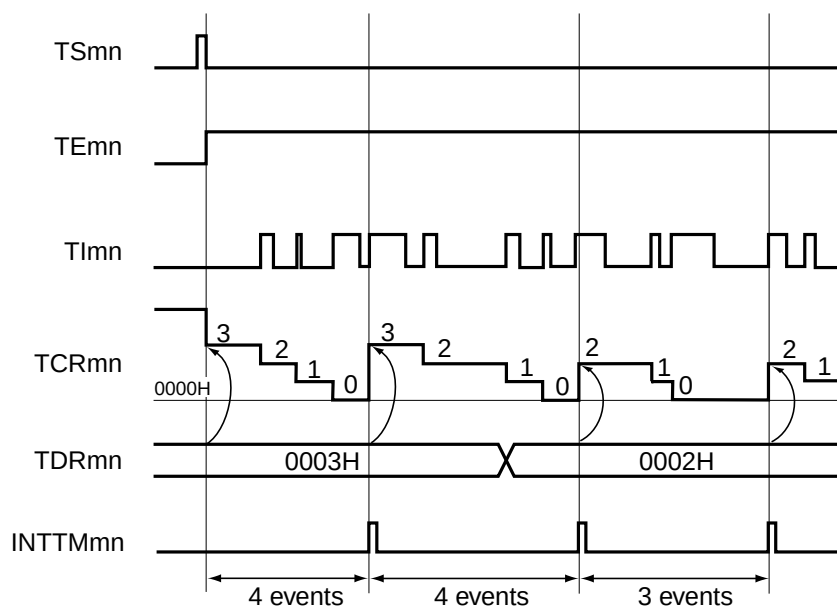
An irregular waveform that depends on external events is output from the TOmn pin. Stop the output by setting the TOEmn bit of timer output enable register m (TOEm) to 0.

The TDRmn register can be rewritten at any time. The new value of the TDRmn register becomes valid during the next count period.

Figure 6-45. Block Diagram of Operation as External Event Counter

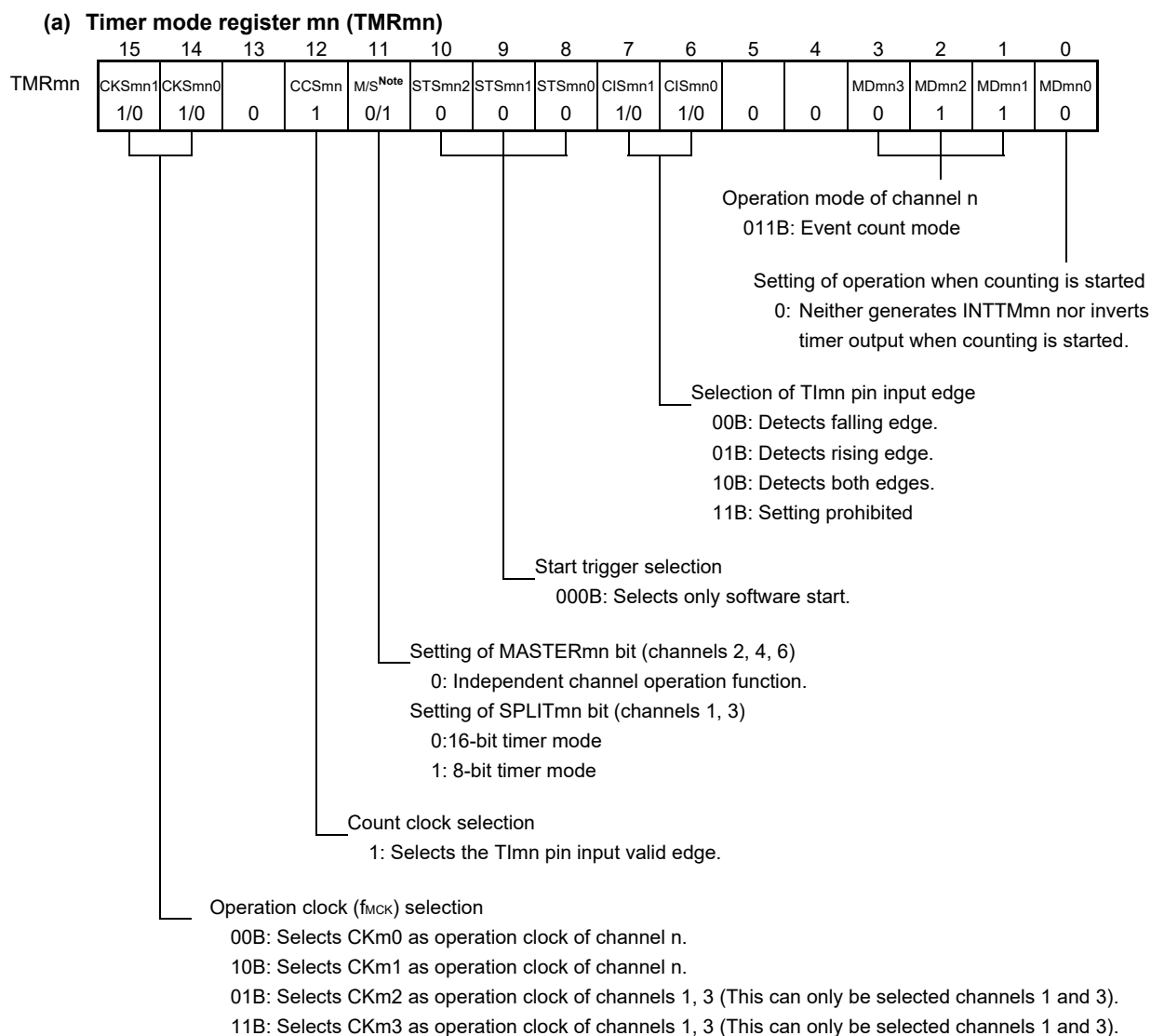


Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

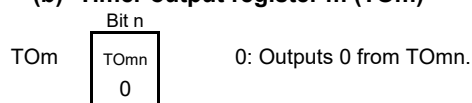
Figure 6-46. Example of Basic Timing of Operation as External Event Counter

- Remarks 1.** m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))
- 2.** TSmn: Bit n of timer channel start register m (TSM)
 TEmn: Bit n of timer channel enable status register m (TEM)
 TImn: TImn pin input signal
 TCRmn: Timer count register mn (TCRmn)
 TDRmn: Timer data register mn (TDRmn)

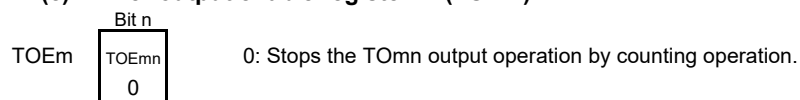
Figure 6-47. Example of Set Contents of Registers in External Event Counter Mode (1/2)



(b) Timer output register m (TOM)



(c) Timer output enable register m (TOEm)



Note TMRm2, TMRm4, TMRm6: MASTERmn bit
 TMRm1, TMRm3: SPLITmn bit
 TMRm0, TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-47. Example of Set Contents of Registers in External Event Counter Mode (2/2)**(d) Timer output level register m (TOLm)**

	Bit n	
TOLm	TOLmn 0	0: Cleared to 0 when TOMmn = 0 (master channel output mode).

(e) Timer output mode register m (TOMm)

	Bit n	
TOMm	TOMmn 0	0: Sets master channel output mode.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-48. Operation Procedure When External Event Counter Function Is Used

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1. —————→	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 to CKm3.	
Channel default setting	Sets corresponding bit of noise filter enable register 1 (NFEN1) to 0 (OFF) or 1 (ON). Sets timer mode register mn (TMRmn) (determines operation mode of channel). Sets number of counts to timer data register mn (TDRmn). Clears the TOEmn bit of timer output enable register m (TOEm) to 0.	Channel stops operating. (Clock is supplied and some power is consumed.)
Operation start	Sets the TSmn bit to 1. —————→ The TSmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 1, and count operation starts. Value of the TDRmn register is loaded to timer count register mn (TCRmn) and detection of the TImn pin input edge is awaited.
During operation	Set value of the TDRmn register can be changed. The TCRmn register can always be read. The TSRmn register is not used. Set values of the TMRmn register, TOMmn, TOLmn, TOMn, and TOEmn bits cannot be changed.	Counter (TCRmn) counts down each time input edge of the TImn pin has been detected. When count value reaches 0000H, the value of the TDRmn register is loaded to the TCRmn register again, and the count operation is continued. By detecting TCRmn = 0000H, the INTTMmn output is generated. After that, the above operation is repeated.
Operation stop	The TTmn bit is set to 1. —————→ The TTmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 0, and count operation stops. The TCRmn register holds count value and stops.
TAU stop	The TAUmEN bit of the PER0 register is cleared to 0. —————→	Power-off status All circuits are initialized and SFR of each channel is also initialized.

Operation is resumed.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

6.8.3 Operation as frequency divider (channel 0 of unit 0 only)

The timer array unit can be used as a frequency divider that divides a clock input to the TI00 pin and outputs the result from the TO00 pin.

The divided clock frequency output from TO00 can be calculated by the following expression.

- When rising edge/falling edge is selected:

$$\text{Divided clock frequency} = \text{Input clock frequency} / \{(\text{Set value of TDR00} + 1) \times 2\}$$
- When both edges are selected:

$$\text{Divided clock frequency} \cong \text{Input clock frequency} / (\text{Set value of TDR00} + 1)$$

Timer count register 00 (TCR00) operates as a down counter in the interval timer mode.

After the channel start trigger bit (TS00) of timer channel start register 0 (TS0) is set to 1, the TCR00 register loads the value of timer data register 00 (TDR00) when the TI00 valid edge is detected.

If the MD000 bit of timer mode register 00 (TMR00) is 0 at this time, INTTM00 is not output and TO00 is not toggled. If the MD000 bit of timer mode register 00 (TMR00) is 1, INTTM00 is output and TO00 is toggled.

After that, the TCR00 register counts down at the valid edge of the TI00 pin. When TCR00 = 0000H, it toggles TO00. At the same time, the TCR00 register loads the value of the TDR00 register again, and continues counting.

If detection of both the edges of the TI00 pin is selected, the duty factor error of the input clock affects the divided clock period of the TO00 output.

The period of the TO00 output clock includes a sampling error of one period of the operation clock.

$$\text{Clock period of TO00 output} = \text{Ideal TO00 output clock period} \pm \text{Operation clock period (error)}$$

The TDR00 register can be rewritten at any time. The new value of the TDR00 register becomes valid during the next count period.

Figure 6-49. Block Diagram of Operation as Frequency Divider

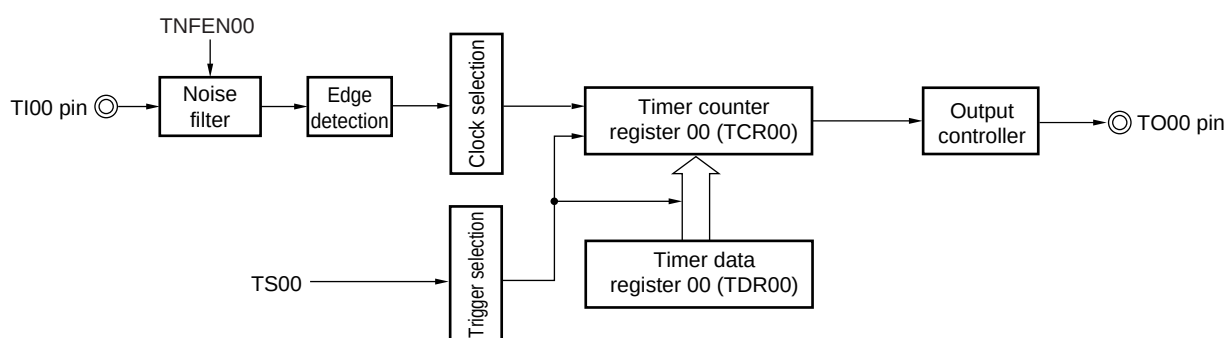
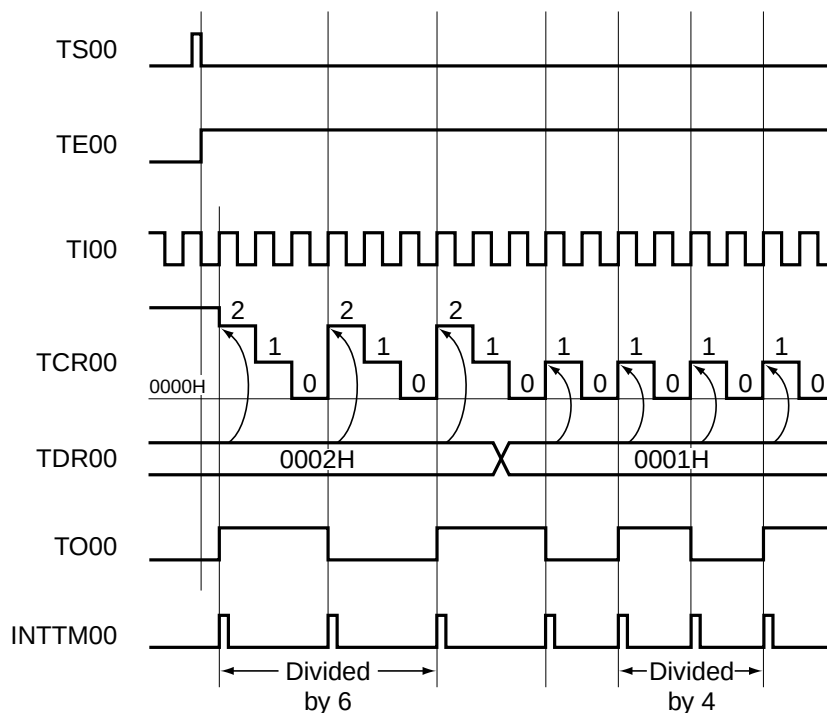
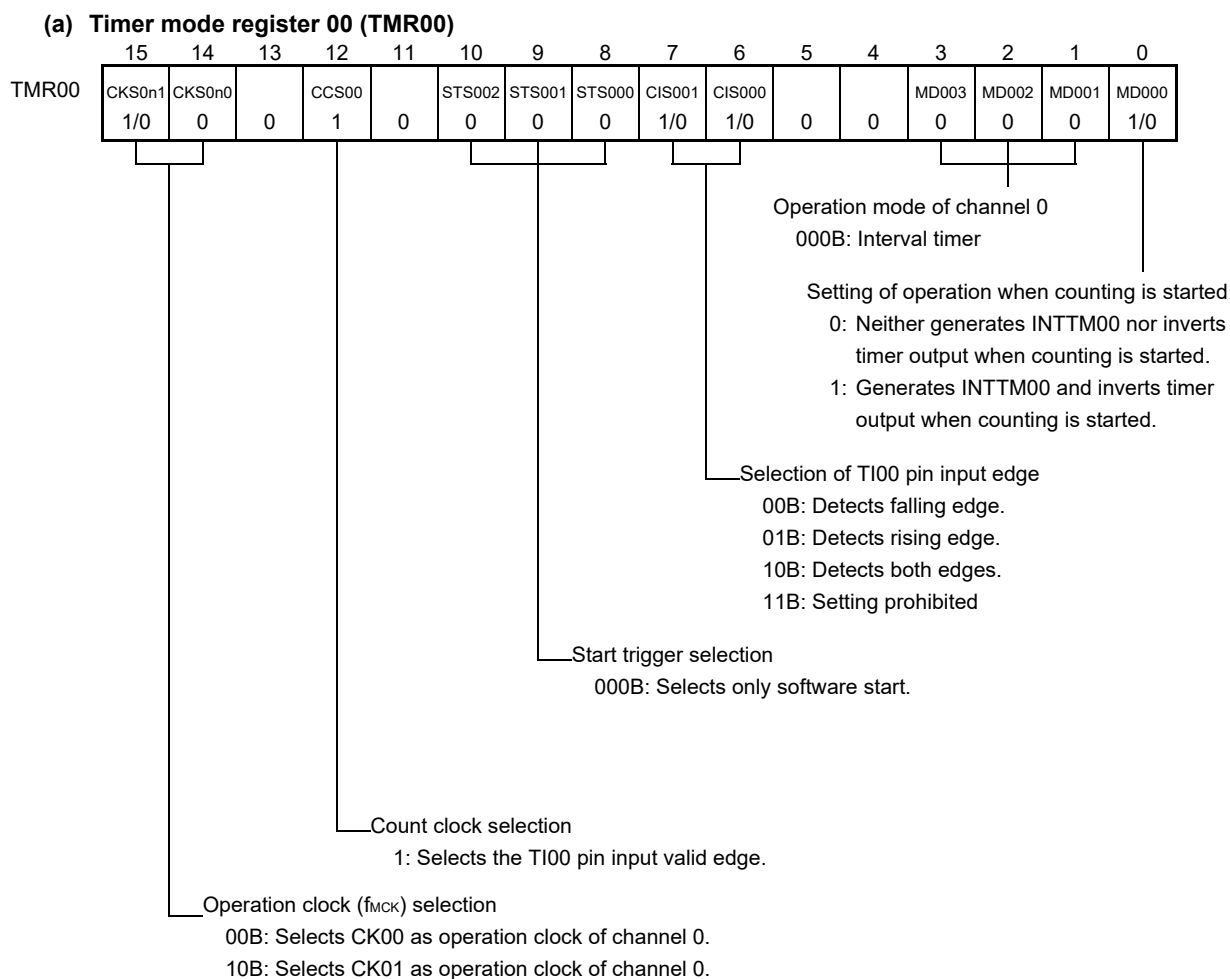


Figure 6-50. Example of Basic Timing of Operation as Frequency Divider (MD000 = 1)

Remark

- TS00: Bit n of timer channel start register 0 (TS0)
- TE00: Bit n of timer channel enable status register 0 (TE0)
- TI00: TI00 pin input signal
- TCR00: Timer count register 00 (TCR00)
- TDR00: Timer data register 00 (TDR00)
- TO00: TO00 pin output signal

Figure 6-51. Example of Set Contents of Registers During Operation as Frequency Divider**(b) Timer output register 0 (TO0)**

TO0	Bit 0	
	TO00	0: Outputs 0 from TO00. 1: Outputs 1 from TO00.

(c) Timer output enable register 0 (TOE0)

TOE0	Bit 0	
	TOE00	0: Stops the TO00 output operation by counting operation. 1: Enables the TO00 output operation by counting operation.

(d) Timer output level register 0 (TOL0)

TOL0	Bit 0	
	TOL00	0: Cleared to 0 when TOM00 = 0 (master channel output mode)

(e) Timer output mode register 0 (TOM0)

TOM0	Bit 0	
	TOM00	0: Sets master channel output mode.

Figure 6-52. Operation Procedure When Frequency Divider Function Is Used

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAU0EN bit of peripheral enable register 0 (PER0) to 1.	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register 0 (TPS0). Determines clock frequencies of CK00 to CK03.	
Channel default setting	Sets corresponding bit of noise filter enable register 1 (NFEN1) to 0 (OFF) or 1 (ON). Sets timer mode register 0n (TMR0n) (determines operation mode of channel and selects the detection edge). Sets interval (period) value to timer data register 00 (TDR00).	Channel stops operating. (Clock is supplied and some power is consumed.)
	Clears the TOM00 bit of timer output mode register 0 (TOM0) to 0 (master channel output mode). Clears the TOL00 bit to 0. Sets the TO00 bit and determines default level of the TO00 output.	The TO00 pin goes into Hi-Z output state.
	Sets the TOE00 bit to 1 and enables operation of TO00.	The TO00 default setting level is output when the port mode register is in output mode and the port register is 0.
	Clears the port register and port mode register to 0.	TO00 does not change because channel stops operating. The TO00 pin outputs the TO00 set level.
Operation start	Sets the TOE00 bit to 1 (only when operation is resumed). Sets the TS00 bit to 1. The TS00 bit automatically returns to 0 because it is a trigger bit.	TE00 = 1, and count operation starts. Value of the TDR00 register is loaded to timer count register 00 (TCR00). INTTM00 is generated and TO00 performs toggle operation if the MD000 bit of the TMR00 register is 1.
During operation	Set value of the TDR00 register can be changed. The TCR00 register can always be read. The TSR00 register is not used. Set values of the TO0 and TOE0 registers can be changed. Set values of the TMR00 register, TOM00, and TOL00 bits cannot be changed.	Counter (TCR00) counts down. When count value reaches 0000H, the value of the TDR00 register is loaded to the TCR00 register again, and the count operation is continued. By detecting TCR00 = 0000H, INTTM00 is generated and TO00 performs toggle operation. After that, the above operation is repeated.
Operation stop	The TT00 bit is set to 1. The TT00 bit automatically returns to 0 because it is a trigger bit.	TE00 = 0, and count operation stops. The TCR00 register holds count value and stops. The TO00 output is not initialized but holds current status.
	The TOE00 bit is cleared to 0 and value is set to the TO00 bit.	The TO00 pin outputs the TO00 set level.
TAU stop	To hold the TO00 pin output level Clears the TO00 bit to 0 after the value to be held is set to the port register. When holding the TO00 pin output level is not necessary Setting not required.	The TO00 pin output level is held by port function.
	The TAU0EN bit of the PER0 register is cleared to 0.	Power-off status All circuits are initialized and SFR of each channel is also initialized. (The TO00 bit is cleared to 0 and the TO00 pin is set to port mode).

Operation is resumed.

6.8.4 Operation as input pulse interval measurement

The count value can be captured at the Tl_{mn} valid edge and the interval of the pulse input to Tl_{mn} can be measured. In addition, the count value can be captured by using software operation (TS_{mn} = 1) as a capture trigger while the TE_{mn} bit is set to 1.

The pulse interval can be calculated by the following expression.

$$\text{Tl}_{mn} \text{ input pulse interval} = \text{Period of count clock} \times ((10000\text{H} \times \text{TSR}_{mn}:\text{OVF}) + (\text{Capture value of TDR}_{mn} + 1))$$

Caution The Tl_{mn} pin input is sampled using the operating clock selected with the CKS_{mn} bit of timer mode register mn (TMR_{mn}), so an error of up to one operating clock cycle occurs.

Timer count register mn (TCR_{mn}) operates as an up counter in the capture mode.

When the channel start trigger bit (TS_{mn}) of timer channel start register m (TS_m) is set to 1, the TCR_{mn} register counts up from 0000H in synchronization with the count clock.

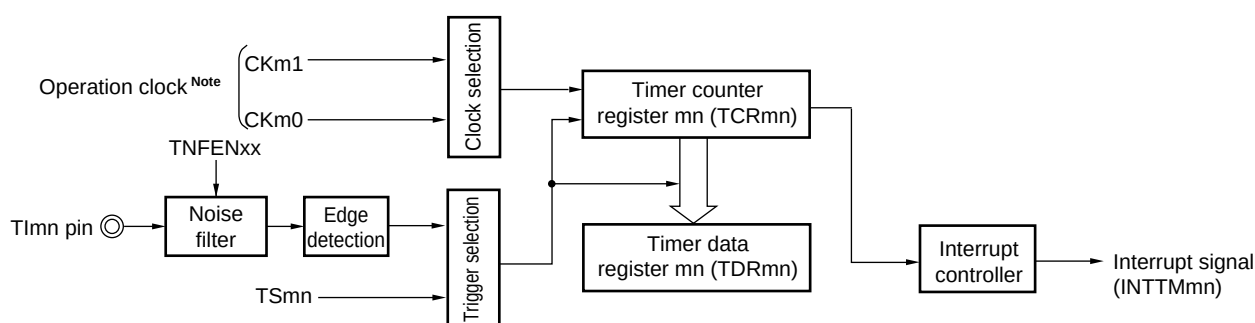
When the Tl_{mn} pin input valid edge is detected, the count value of the TCR_{mn} register is transferred (captured) to timer data register mn (TDR_{mn}) and, at the same time, the TCR_{mn} register is cleared to 0000H, and the INTTM_{mn} is output. If the counter overflows at this time, the OVF bit of timer status register mn (TSR_{mn}) is set to 1. If the counter does not overflow, the OVF bit is cleared. After that, the above operation is repeated.

As soon as the count value has been captured to the TDR_{mn} register, the OVF bit of the TSR_{mn} register is updated depending on whether the counter overflows during the measurement period. Therefore, the overflow status of the captured value can be checked.

If the counter reaches a full count for two or more periods, it is judged to be an overflow occurrence, and the OVF bit of the TSR_{mn} register is set to 1. However, a normal interval value cannot be measured for the OVF bit, if two or more overflows occur.

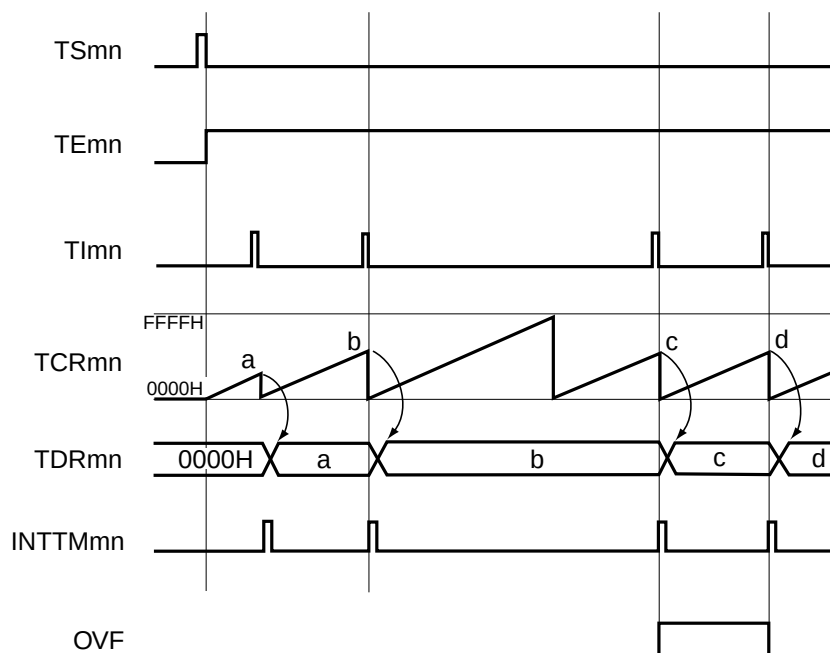
Set the STS_{mn2} to STS_{mn0} bits of the TMR_{mn} register to 001B to use the valid edges of Tl_{mn} as a start trigger and a capture trigger.

Figure 6-53. Block Diagram of Operation as Input Pulse Interval Measurement



Note When channels 1 and 3, the clock can be selected from CK_{m0}, CK_{m1}, CK_{m2} and CK_{m3}.

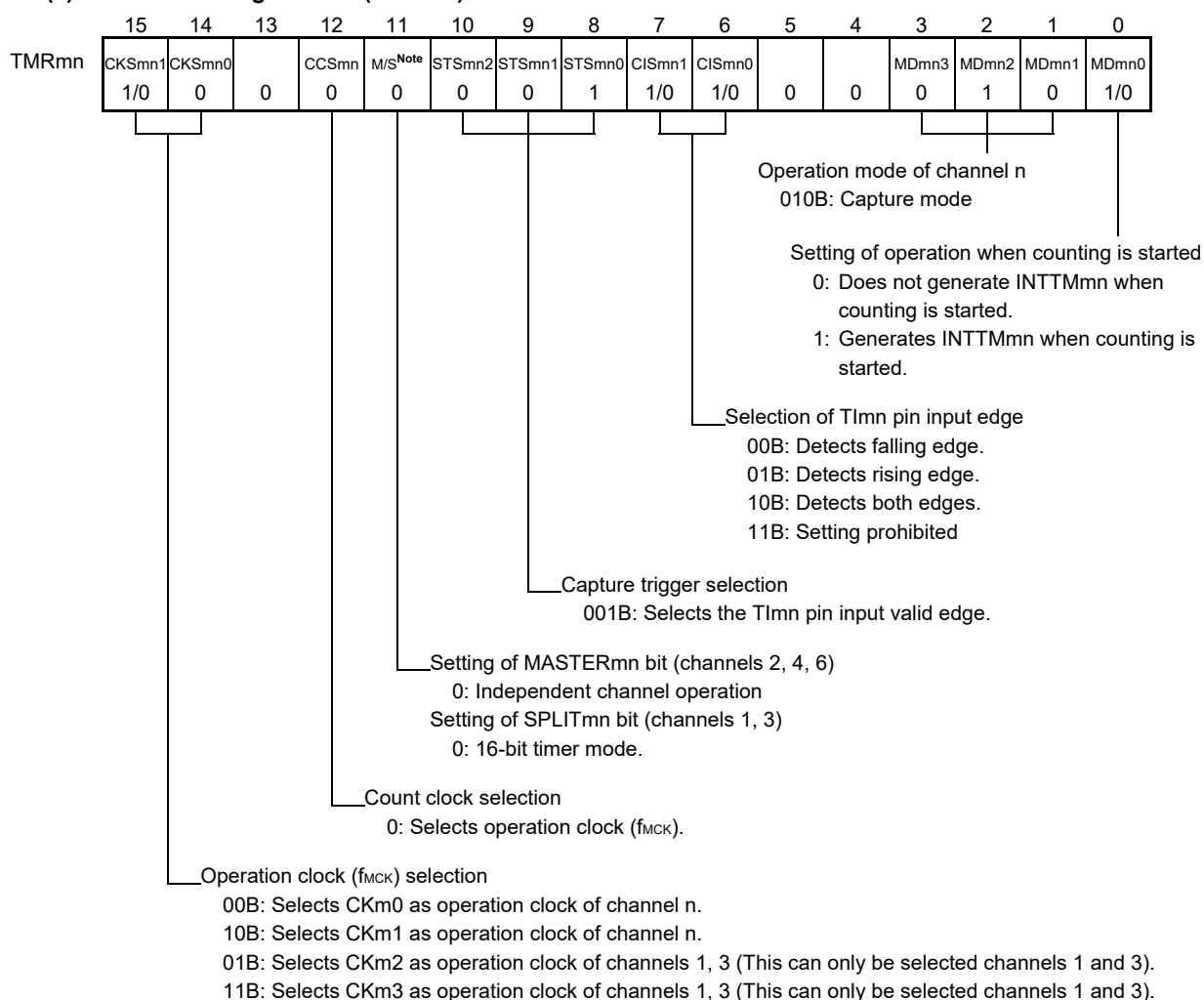
Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (Tl_{mn}), timer output pin (TO_{mn}) : n = 0, 1, 3 to 7))

Figure 6-54. Example of Basic Timing of Operation as Input Pulse Interval Measurement (MDmn0 = 0)

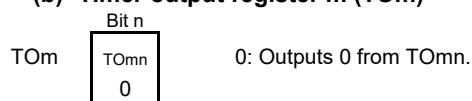
- Remarks**
1. m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))
 2. TSmn: Bit n of timer channel start register m (TSM)
 TE mn: Bit n of timer channel enable status register m (TEM)
 TImn: TImn pin input signal
 TCRmn: Timer count register mn (TCRmn)
 TDRmn: Timer data register mn (TDRmn)
 OVf: Bit 0 of timer status register mn (TSRmn)

Figure 6-55. Example of Set Contents of Registers to Measure Input Pulse Interval

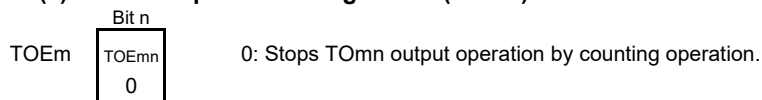
(a) Timer mode register mn (TMRmn)



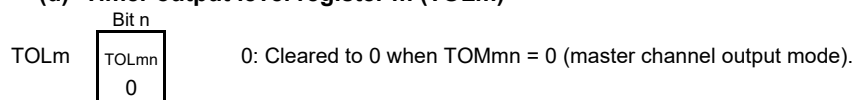
(b) Timer output register m (TOM)



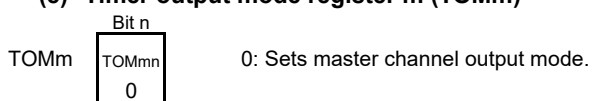
(c) Timer output enable register m (TOEm)



(d) Timer output level register m (TOLm)



(e) Timer output mode register m (TOMm)



Note TMRm2, TMRm4, TMRm6: MASTERmn bit
 TMRm1, TMRm3: SPLITmn bit
 TMRm0, TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-56. Operation Procedure When Input Pulse Interval Measurement Function Is Used

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1.	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 to CKm3.	
Channel default setting	Sets corresponding bit of noise filter enable register 1 (NFEN1) to 0 (OFF) or 1 (ON). Sets timer mode register mn (TMRmn) (determines operation mode of channel).	Channel stops operating. (Clock is supplied and some power is consumed.)
Operation start	Sets TSmn bit to 1. The TSmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 1, and count operation starts. Timer count register mn (TCRmn) is cleared to 0000H. When the MDmn0 bit of the TMRmn register is 1, INTTMmn is generated.
During operation	Set values of only the CISmn1 and CISmn0 bits of the TMRmn register can be changed. The TDRmn register can always be read. The TCRmn register can always be read. The TSRmn register can always be read. Set values of the TOMmn, TOLmn, TOMn, and TOEmn bits cannot be changed.	Counter (TCRmn) counts up from 0000H. When the valid edge of the TImn pin input is detected or the TSmn bit is set to 1, the count value is transferred (captured) to timer data register mn (TDRmn). At the same time, the TCRmn register is cleared to 0000H, and the INTTMmn signal is generated. If an overflow occurs at this time, the OVF bit of timer status register mn (TSRmn) is set; if an overflow does not occur, the OVF bit is cleared. After that, the above operation is repeated.
Operation stop	The TTmn bit is set to 1. The TTmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 0, and count operation stops. The TCRmn register holds count value and stops. The OVF bit of the TSRmn register is also held.
TAU stop	The TAUmEN bit of the PER0 register is cleared to 0.	Power-off status All circuits are initialized and SFR of each channel is also initialized.

Operation is resumed.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.8.5 Operation as input signal high-/low-level width measurement

Caution When using a channel to implement the LIN-bus, set bit 1 (ISC1) of the input switch control register (ISC) to 1. In the following descriptions, read TImn as RxD2.

By starting counting at one edge of the TImn pin input and capturing the number of counts at another edge, the signal width (high-level width/low-level width) of TImn can be measured. The signal width of TImn can be calculated by the following expression.

$$\text{Signal width of TImn input} = \text{Period of count clock} \times ((10000\text{H} \times \text{TSRmn: OVF}) + (\text{Capture value of TDRmn} + 1))$$

Caution The TImn pin input is sampled using the operating clock selected with the CKSmn bit of timer mode register mn (TMRmn), so an error equivalent to one operation clock occurs.

Timer count register mn (TCRmn) operates as an up counter in the capture & one-count mode.

When the channel start trigger bit (TSmn) of timer channel start register m (TSM) is set to 1, the TEmn bit is set to 1 and the TImn pin start edge detection wait status is set.

When the TImn pin input start edge (rising edge of the TImn pin input when the high-level width is to be measured) is detected, the counter counts up from 0000H in synchronization with the count clock. When the valid capture edge (falling edge of the TImn pin input when the high-level width is to be measured) is detected later, the count value is transferred to timer data register mn (TDRmn) and, at the same time, INTTMmn is output. If the counter overflows at this time, the OVF bit of timer status register mn (TSRmn) is set to 1. If the counter does not overflow, the OVF bit is cleared. The TCRmn register stops at the value "value transferred to the TDRmn register + 1", and the TImn pin start edge detection wait status is set. After that, the above operation is repeated.

As soon as the count value has been captured to the TDRmn register, the OVF bit of the TSRmn register is updated depending on whether the counter overflows during the measurement period. Therefore, the overflow status of the captured value can be checked.

If the counter reaches a full count for two or more periods, it is judged to be an overflow occurrence, and the OVF bit of the TSRmn register is set to 1. However, a normal interval value cannot be measured for the OVF bit, if two or more overflows occur.

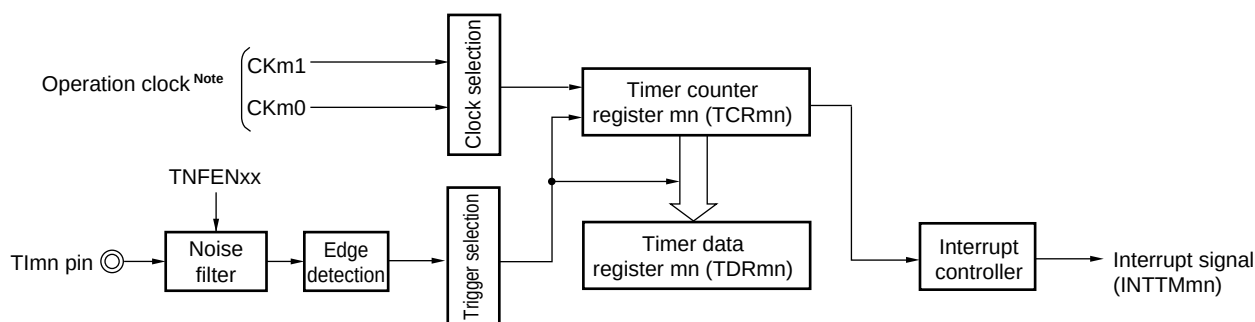
Whether the high-level width or low-level width of the TImn pin is to be measured can be selected by using the CISmn1 and CISmn0 bits of the TMRmn register.

Because this function is used to measure the signal width of the TImn pin input, the TSmn bit cannot be set to 1 while the TEmn bit is 1.

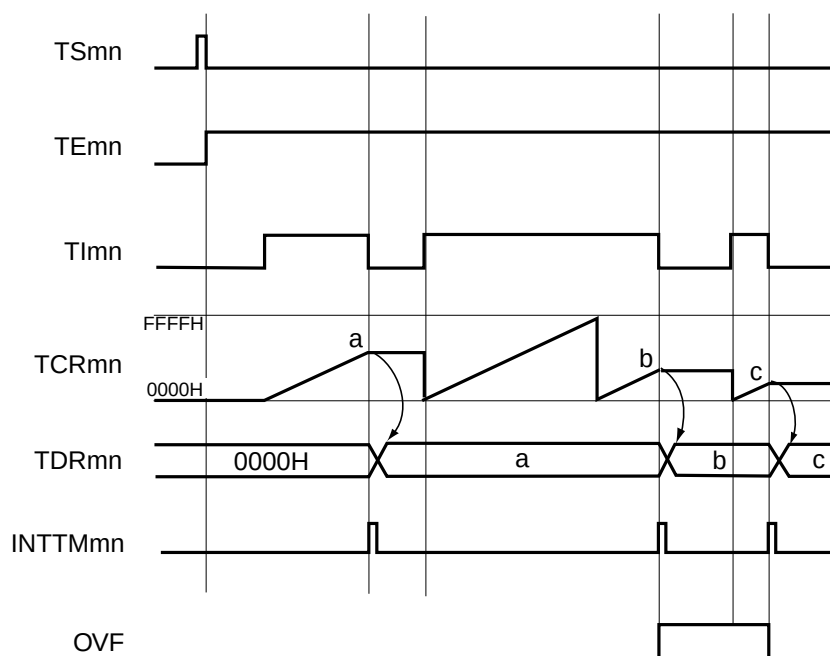
CISmn1, CISmn0 of TMRmn register = 10B: Low-level width is measured.

CISmn1, CISmn0 of TMRmn register = 11B: High-level width is measured.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

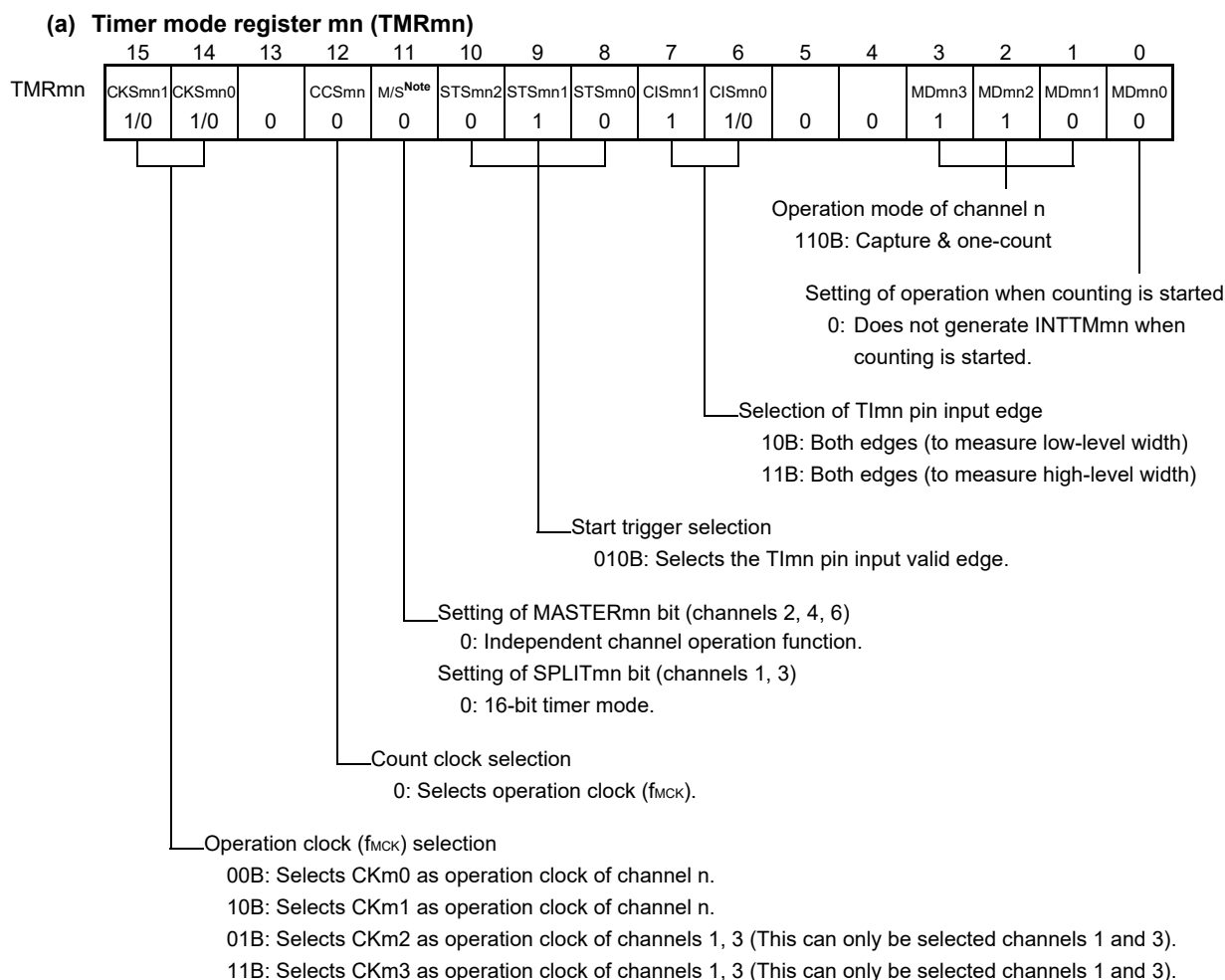
Figure 6-57. Block Diagram of Operation as Input Signal High-/Low-Level Width Measurement

Note For channels 1 and 3, the clock can be selected from CKm0, CKm1, CKm2 and CKm3.

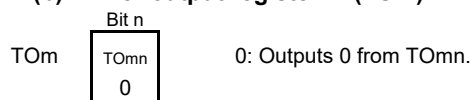
Figure 6-58. Example of Basic Timing of Operation as Input Signal High-/Low-Level Width Measurement

- Remarks**
1. m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))
 2. TSmn: Bit n of timer channel start register m (TSM)
 TEmn: Bit n of timer channel enable status register m (TEM)
 TImn: TImn pin input signal
 TCRmn: Timer count register mn (TCRmn)
 TDRmn: Timer data register mn (TDRmn)
 OVF: Bit 0 of timer status register mn (TSRmn)

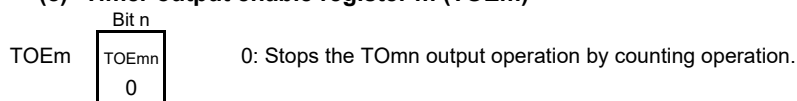
Figure 6-59. Example of Set Contents of Registers to Measure Input Signal High-/Low-Level Width



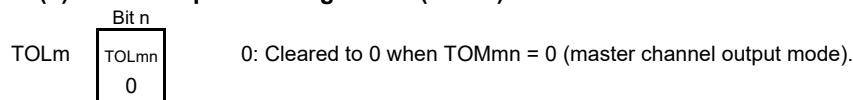
(b) Timer output register m (TOM)



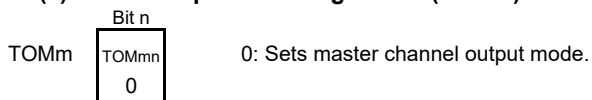
(c) Timer output enable register m (TOEm)



(d) Timer output level register m (TOLm)



(e) Timer output mode register m (TOMm)



Note TMRm2, TMRm4, TMRm6: MASTERmn bit
 TMRm1, TMRm3: SPLITmn bit
 TMRm0, TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-60. Operation Procedure When Input Signal High-/Low-Level Width Measurement Function Is Used

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1.	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 to CKm3.	
Channel default setting	Sets corresponding bit of noise filter enable register 1 (NFEN1) to 0 (OFF) or 1 (ON). Sets timer mode register mn (TMRmn) (determines operation mode of channel). Clears the TOEmn bit to 0 and stops operation of TOMn.	Channel stops operating. (Clock is supplied and some power is consumed.)
Operation start	Sets the TSmn bit to 1. The TSmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 1, and the TImn pin start edge detection wait status is set.
	Detects the TImn pin input count start valid edge.	Clears timer count register mn (TCRmn) to 0000H and starts counting up.
During operation	The TDRmn register can always be read. The TCRmn register can always be read. The TSRmn register can always be read. Set values of the TMRmn register, TOMmn, TOLmn, TOMn, and TOEmn bits cannot be changed.	When the TImn pin start edge is detected, the counter (TCRmn) counts up from 0000H. If a capture edge of the TImn pin is detected, the count value is transferred to timer data register mn (TDRmn) and INTTMmn is generated. If an overflow occurs at this time, the OVF bit of timer status register mn (TSRmn) is set; if an overflow does not occur, the OVF bit is cleared. The TCRmn register stops the count operation until the next TImn pin start edge is detected.
Operation stop	The TTmn bit is set to 1. The TTmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 0, and count operation stops. The TCRmn register holds count value and stops. The OVF bit of the TSRmn register is also held.
TAU stop	The TAUmEN bit of the PER0 register is cleared to 0.	Power-off status All circuits are initialized and SFR of each channel is also initialized.

Operation is resumed.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.8.6 Operation as delay counter

It is possible to start counting down when the valid edge of the TImn pin input is detected (an external event), and then generate INTTMmn (a timer interrupt) after any specified interval.

It is also possible to start counting down and generate INTTMmn (timer interrupt) at any interval by setting TSmn to 1 by software while TEMn = 1.

The interrupt generation period can be calculated by the following expression.

$$\text{Generation period of INTTMmn (timer interrupt)} = \text{Period of count clock} \times (\text{Set value of TDRmn} + 1)$$

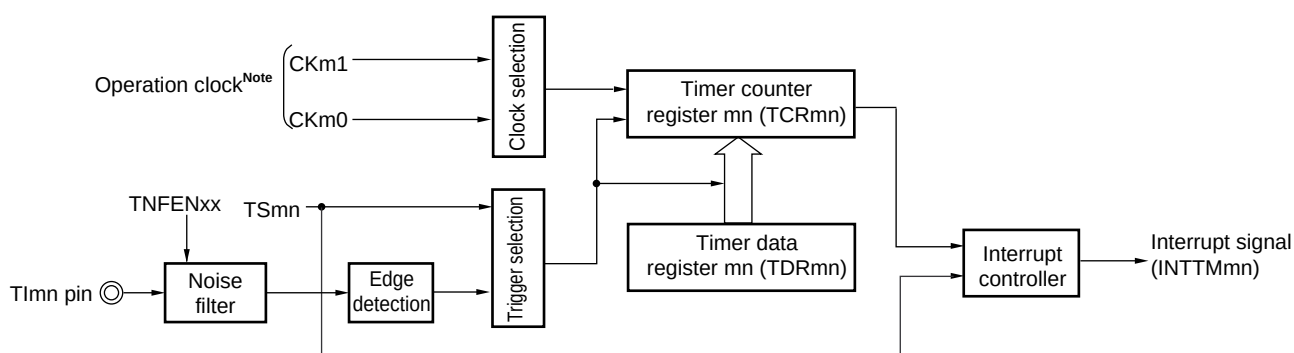
Timer count register mn (TCRmn) operates as a down counter in the one-count mode.

When the channel start trigger bit (TSmn, TSHm1, TSHm3) of timer channel start register m (TSM) is set to 1, the TEMn, TEHm1, TEHm3 bits are set to 1 and the TImn pin input valid edge detection wait status is set.

Timer count register mn (TCRmn) starts operating upon TImn pin input valid edge detection and loads the value of timer data register mn (TDRmn). The TCRmn register counts down from the value of the TDRmn register it has loaded, in synchronization with the count clock. When TCRmn = 0000H, it outputs INTTMmn and stops counting until the next TImn pin input valid edge is detected.

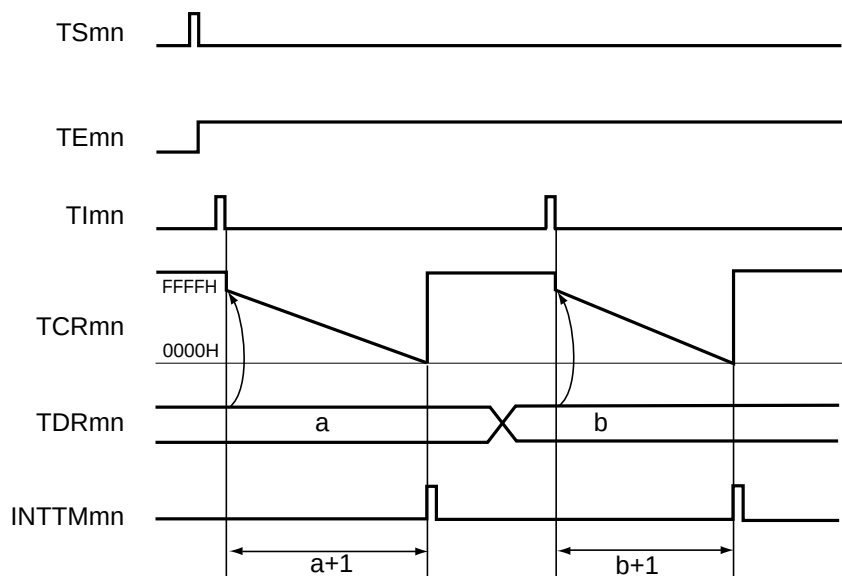
The TDRmn register can be rewritten at any time. The new value of the TDRmn register becomes valid from the next period.

Figure 6-61. Block Diagram of Operation as Delay Counter



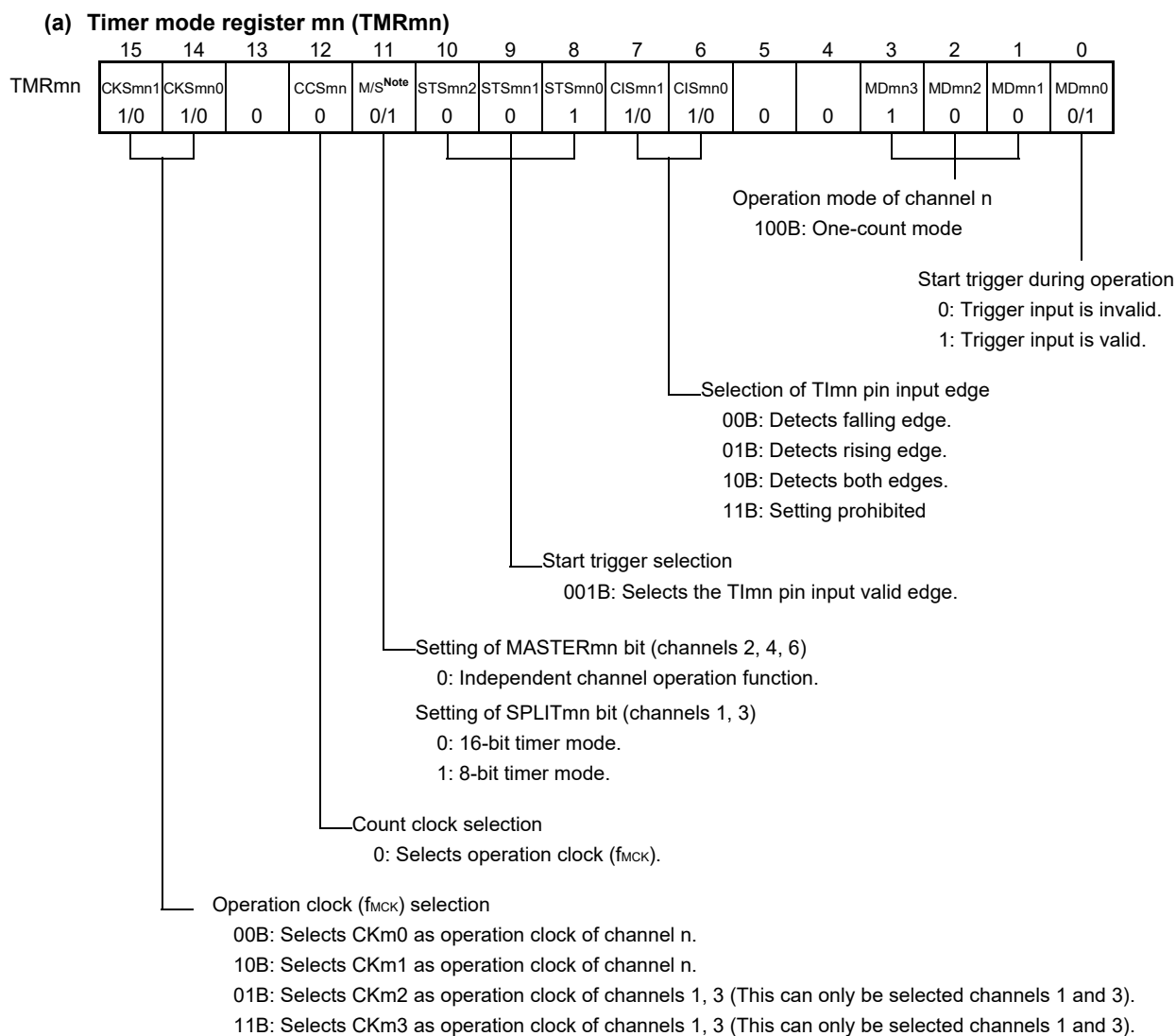
Note For using channels 1 and 3, the clock can be selected from CKm0, CKm1, CKm2 and CKm3.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOmn) : n = 0, 1, 3 to 7))

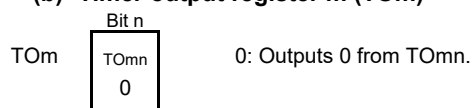
Figure 6-62. Example of Basic Timing of Operation as Delay Counter

- Remarks 1.** m: Unit number ($m = 0$), n: Channel number ($n = 0$ to 7 (however, timer input pin (TImn), timer output pin (TOMn) : $n = 0, 1, 3$ to 7))
- 2.** TSmn: Bit n of timer channel start register m (TSm)
 TEmn: Bit n of timer channel enable status register m (TEm)
 TImn: TImn pin input signal
 TCRmn: Timer count register mn (TCRmn)
 TDRmn: Timer data register mn (TDRmn)

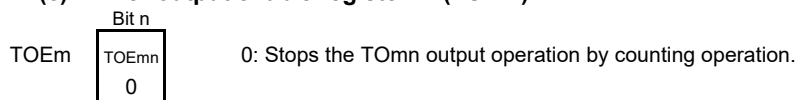
Figure 6-63. Example of Set Contents of Registers to Delay Counter (1/2)



(b) Timer output register m (TOM)



(c) Timer output enable register m (TOEm)



Note TMRm2, TMRm4, TMRm6: MASTERmn bit
 TMRm1, TMRm3: SPLITmn bit
 TMRm0, TMRm5, TMRm7: Fixed to 0

Remark m: Unit number ($m = 0$), n: Channel number ($n = 0$ to 7 (however, timer input pin (TImn), timer output pin (TOMn) : $n = 0, 1, 3$ to 7))

Figure 6-63. Example of Set Contents of Registers to Delay Counter (2/2)**(d) Timer output level register m (TOLm)**

TOLm

Bit n
TOLmn
0

 0: Cleared to 0 when TOMmn = 0 (master channel output mode).

(e) Timer output mode register m (TOMm)

TOMm

Bit n
TOMmn
0

 0: Sets master channel output mode.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

Figure 6-64. Operation Procedure When Delay Counter Function Is Used

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1.	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 to CKm3.	
Channel default setting	Sets corresponding bit of noise filter enable register 1 (NFEN1) to 0 (OFF) or 1 (ON). Sets timer mode register mn (TMRmn) (determines operation mode of channel). INTTMmn output delay is set to timer data register mn (TDRmn). Clears the TOEmn bit to 0 and stops operation of TOMn.	Channel stops operating. (Clock is supplied and some power is consumed.)
Operation start	Sets the TSmn bit to 1. The TSmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 1, and the start trigger detection (the valid edge of the TImn pin input is detected or the TSmn bit is set to 1) wait status is set.
	The counter starts counting down by the next start trigger detection. • Detects the TImn pin input valid edge. • Sets the TSmn bit to 1 by the software.	Value of the TDRmn register is loaded to the timer count register mn (TCRmn).
During operation	Set value of the TDRmn register can be changed. The TCRmn register can always be read. The TSRmn register is not used.	The counter (TCRmn) counts down. When the count value of TCRmn reaches 0000H, the INTTMmn output is generated, and the count operation stops until the next start trigger detection (the valid edge of the TImn pin input is detected or the TSmn bit is set to 1).
Operation stop	The TTmn bit is set to 1. The TTmn bit automatically returns to 0 because it is a trigger bit.	TEmn = 0, and count operation stops. The TCRmn register holds count value and stops.
TAU stop	The TAUmEN bit of the PER0 register is cleared to 0.	Power-off status All circuits are initialized and SFR of each channel is also initialized.

Operation is resumed.

Remark m: Unit number (m = 0), n: Channel number (n = 0 to 7 (however, timer input pin (TImn), timer output pin (TOMn) : n = 0, 1, 3 to 7))

6.9 Simultaneous Channel Operation Function of Timer Array Unit

6.9.1 Operation as one-shot pulse output function

By using two channels as a set, a one-shot pulse having any delay pulse width can be generated from the signal input to the TImn pin.

The delay time and pulse width can be calculated by the following expressions.

$\text{Delay time} = \{\text{Set value of TDRmn (master)} + 2\} \times \text{Count clock period}$ $\text{Pulse width} = \{\text{Set value of TDRmp (slave)}\} \times \text{Count clock period}$

The master channel operates in the one-count mode and counts the delays. Timer count register mn (TCRmn) of the master channel starts operating upon start trigger detection and loads the value of timer data register mn (TDRmn).

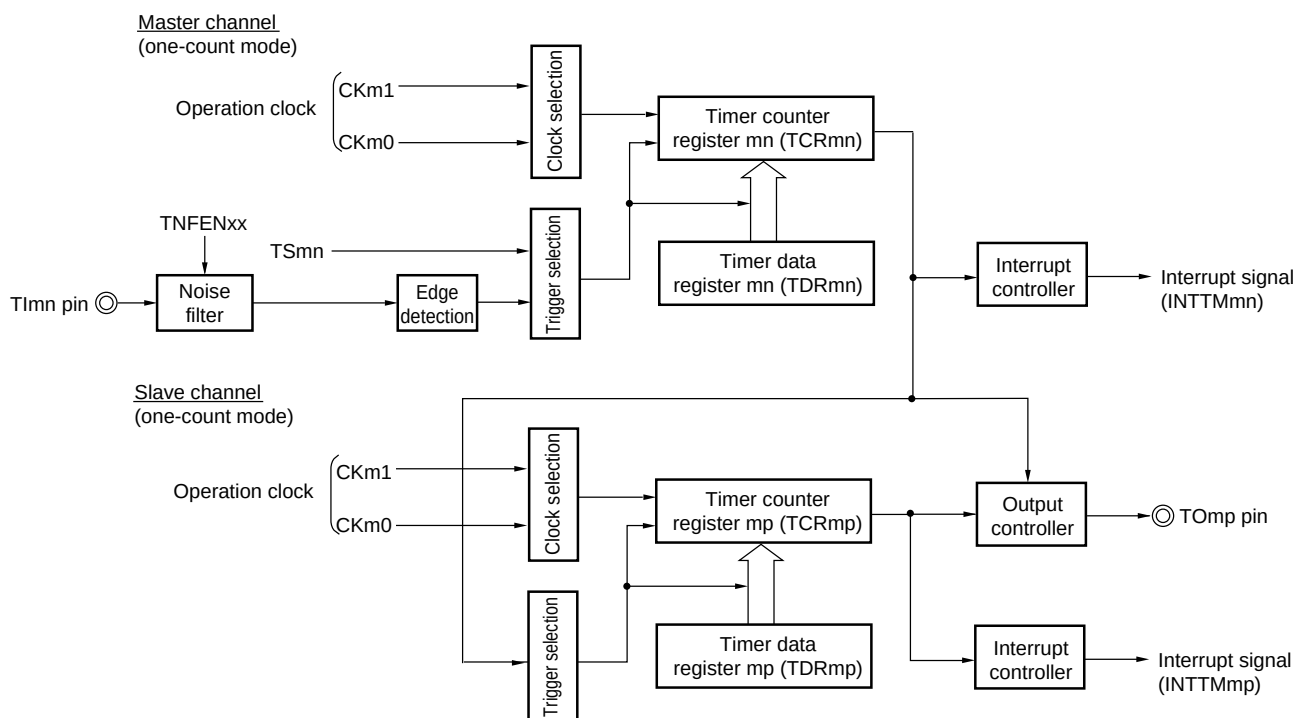
The TCRmn register counts down from the value of the TDRmn register it has loaded, in synchronization with the count clock. When TCRmn = 0000H, it outputs INTTMmn and stops counting until the next start trigger is detected.

The slave channel operates in the one-count mode and counts the pulse width. The TCRmp register of the slave channel starts operation using INTTMmn of the master channel as a start trigger, and loads the value of the TDRmp register. The TCRmp register counts down from the value of the TDRmp register it has loaded, in synchronization with the count value. When count value = 0000H, it outputs INTTMmp and stops counting until the next start trigger (INTTMmn of the master channel) is detected. The output level of TOmp becomes active one count clock after generation of INTTMmn from the master channel, and inactive when TCRmp = 0000H.

Instead of using the TImn pin input, a one-shot pulse can also be output using the software operation (TSmn = 1) as a start trigger.

Caution The timing of loading of timer data register mn (TDRmn) of the master channel is different from that of the TDRmp register of the slave channel. If the TDRmn and TDRmp registers are rewritten during counting, therefore, an illegal waveform may be output in conflict with the timing of loading. Rewrite the TDRmn register after INTTMmn is generated and the TDRmp register after INTTMmp is generated.

Remark m: Unit number (m = 0), n: Channel number (n = 0, 4, 6)
 p: Slave channel number (n < p ≤ 7)
 However, timer output pin (TOmp) : p = 1, 3 to 7

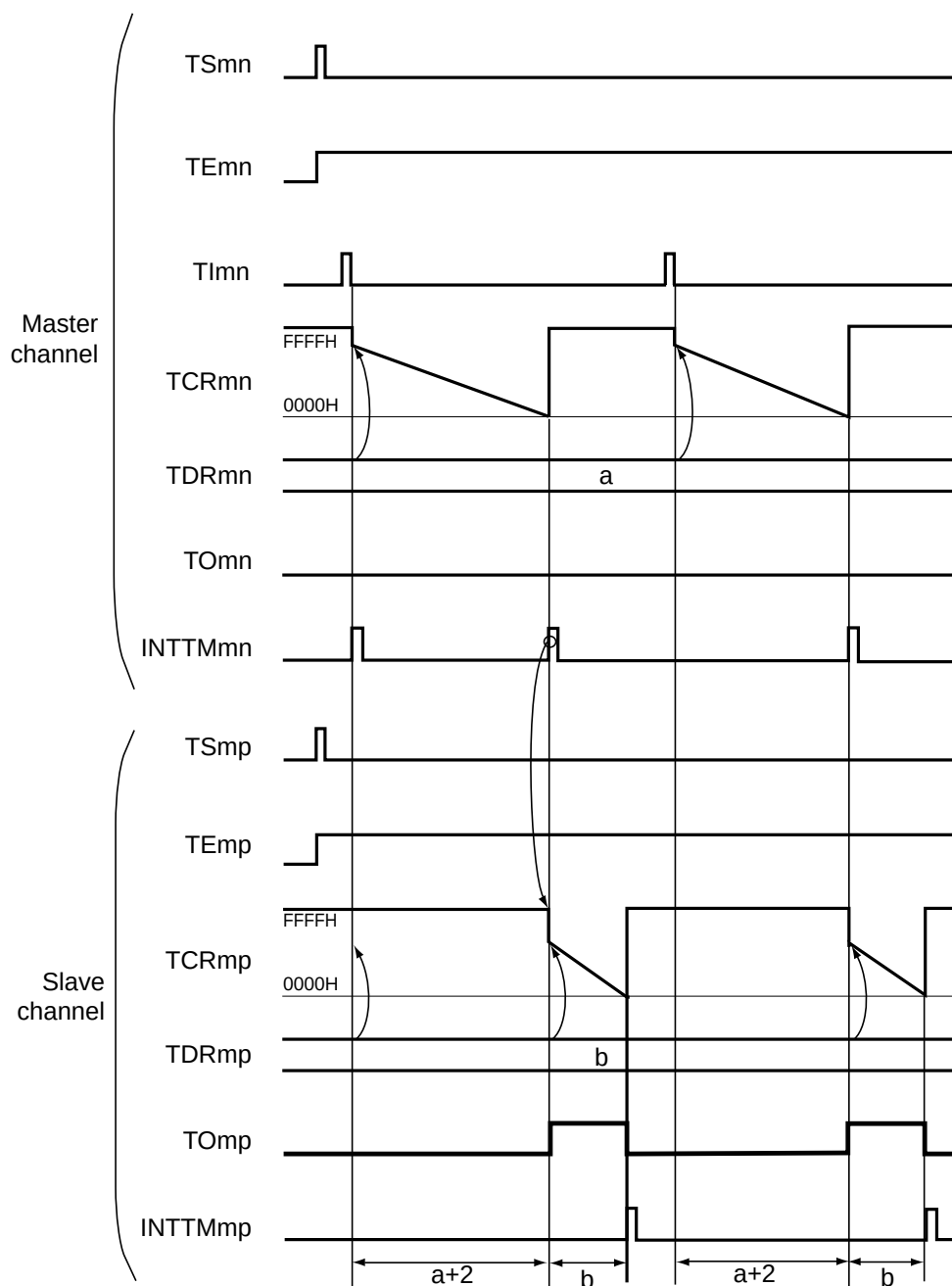
Figure 6-65. Block Diagram of Operation as One-Shot Pulse Output Function

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

p: Slave channel number (n < p ≤ 7)

However, timer output pin (TOmp) : p = 1, 3 to 7

**Figure 6-66. Example of Basic Timing of Operation as One-Shot Pulse Output Function
(Start Trigger: TImn Pin Input Valid Edge.)**



- Remarks**
- m: Unit number ($m = 0$), n: Channel number ($n = 0, 2, 4, 6$)

p: Slave channel number ($n < p \leq 7$)

However, timer output pin (TOMP) : $p = 1, 3$ to 7
 - TSmn, TSmp: Bit n, p of timer channel start register m (TSM)

TEmn, TEmp: Bit n, p of timer channel enable status register m (TEM)

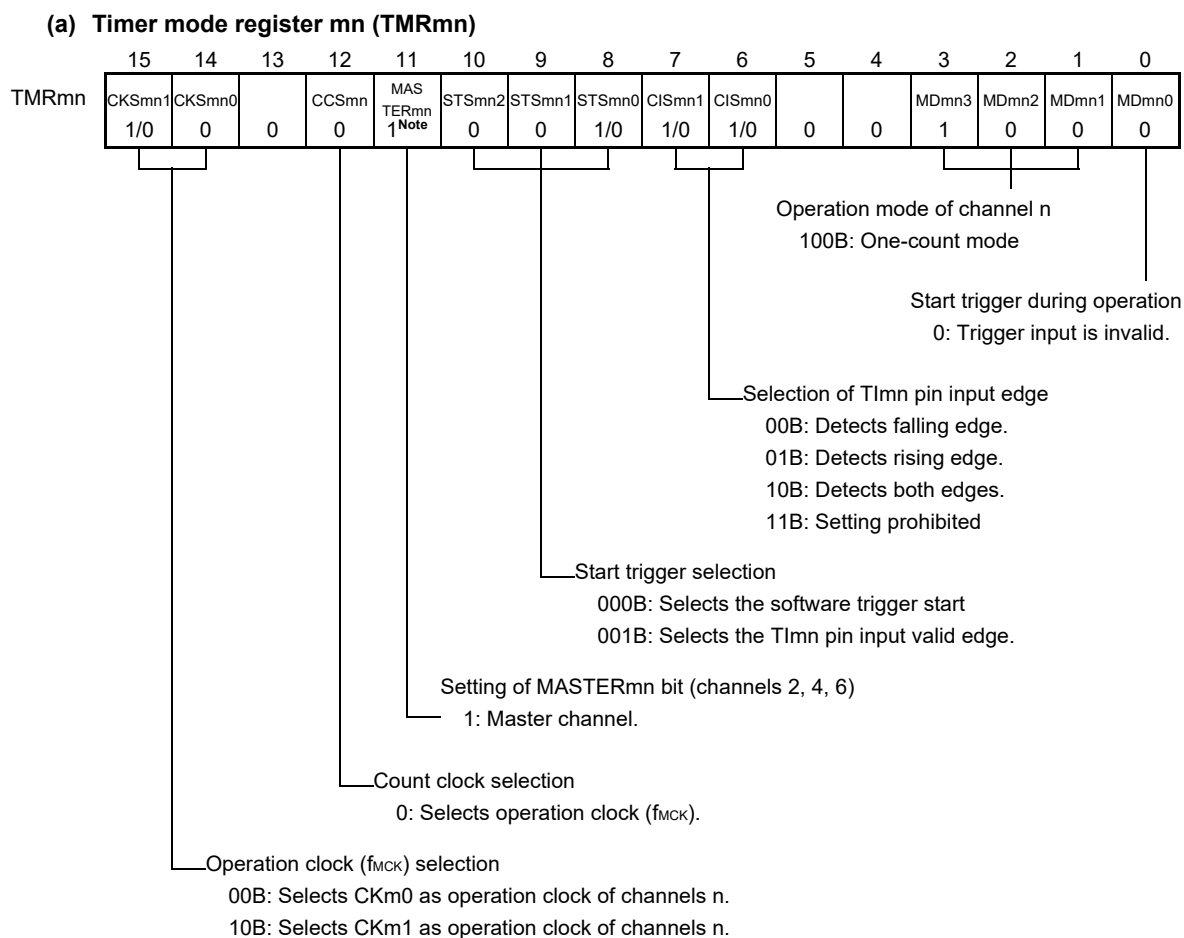
TImn, TImp: TImn and TImp pins input signal

TCRmn, TCRmp: Timer count registers mn, mp (TCRmn, TCRmp)

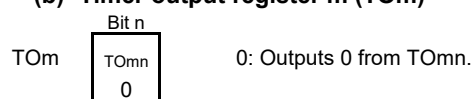
TDRmn, TDRmp: Timer data registers mn, mp (TDRmn, TDRmp)

TOMn, TOMP: TOMn and TOMP pins output signal

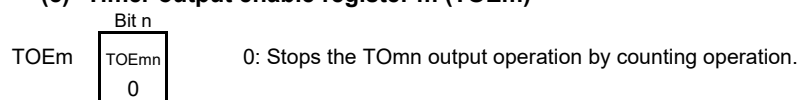
Figure 6-67. Example of Set Contents of Registers When One-Shot Pulse Output Function Is Used (Master Channel)



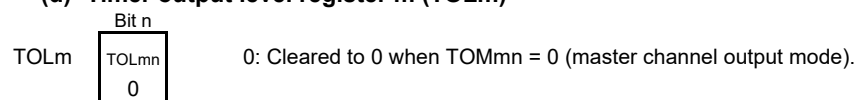
(b) Timer output register m (TOM)



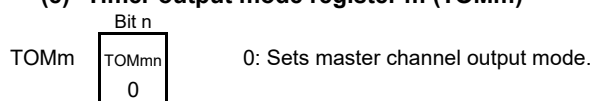
(c) Timer output enable register m (TOEm)



(d) Timer output level register m (TOLm)

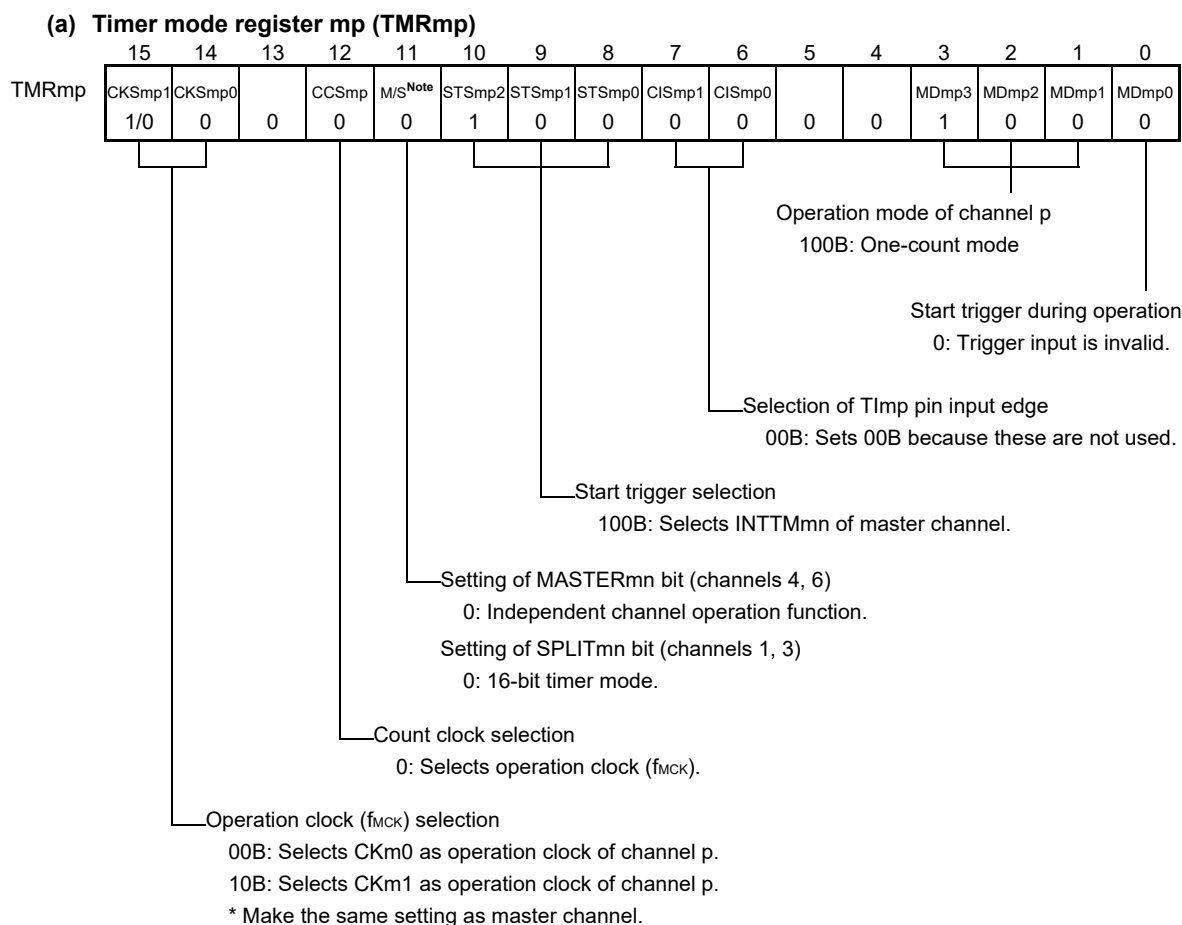


(e) Timer output mode register m (TOMm)



Note TMRm2, TMRm4, TMRm6: MASTERmn = 1
TMRm0: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

Figure 6-68. Example of Set Contents of Registers When One-Shot Pulse Output Function Is Used (Slave Channel)**(b) Timer output register m (TOM)**

TOM	Bit p	
	TOMp	0: Outputs 0 from TOMp. 1: Outputs 1 from TOMp.
	1/0	

(c) Timer output enable register m (TOEm)

TOEm	Bit p	
	TOEmp	0: Stops the TOMp output operation by counting operation. 1: Enables the TOMp output operation by counting operation.
	1/0	

(d) Timer output level register m (TOLm)

TOLm	Bit p	
	TOLmp	0: Positive logic output (active-high) 1: Negative logic output (active-low)
	1/0	

(e) Timer output mode register m (TOMm)

TOMm	Bit p	
	TOMmp	1: Sets the slave channel output mode.
	1	

Note TMRm4, TMRm6: MASTERmn bit
 TMRm1, TMRm3: SPLITmp bit
 TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)
 p: Slave channel number (n < p ≤ 7)
 However, timer output pin (TOMp) : p = 1, 3 to 7

Figure 6-69. Operation Procedure of One-Shot Pulse Output Function (1/2)

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable registers 0 (PER0) to 1.	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 and CKm1.	
Channel default setting	Sets corresponding bit of noise filter enable register 1 (NFEN1) to 0 (OFF) or 1 (ON). Sets timer mode register mn, mp (TMRmn, TMRmp) of two channels to be used (determines operation mode of channels). An output delay is set to timer data register mn (TDRmn) of the master channel, and a pulse width is set to the TDRmp register of the slave channel.	Channel stops operating. (Clock is supplied and some power is consumed.)
	Sets slave channel. The TOMmp bit of timer output mode register m (TOMm) is set to 1 (slave channel output mode). Sets the TOLmp bit. Sets the TOmp bit and determines default level of the TOmp output.	The TOmp pin goes into Hi-Z output state.
	Sets the TOEmp bit to 1 and enables operation of TOmp. Clears the port register and port mode register to 0.	The TOmp default setting level is output when the port mode register is in output mode and the port register is 0. TOmp does not change because channel stops operating. The TOmp pin outputs the TOmp set level.

(Note and Remark are listed on the next page.)

Figure 6-69. Operation Procedure of One-Shot Pulse Output Function (2/2)

	Software Operation	Hardware Status
Operation start	Sets the TOEmp bit (slave) to 1 (only when operation is resumed). The TSmn (master) and TSmp (slave) bits of timer channel start register m (TSM) are set to 1 at the same time. The TSmn and TSmp bits automatically return to 0 because they are trigger bits.	The TEMn and TEm bits are set to 1 and the master channel enters the start trigger detection (the valid edge of the TImn pin input is detected or the TSmn bit of the master channel is set to 1) wait status. Counter stops operating.
	Count operation of the master channel is started by start trigger detection of the master channel. • Detects the TImn pin input valid edge. • Sets the TSmn bit of the master channel to 1 by software^{Note}. Note Do not set the TSmn bit of the slave channel to 1.	Master channel starts counting.
During operation	Set values of only the CISmn1 and CISmn0 bits of the TMRmn register can be changed. Set values of the TMRmp, TDRmn, TDRmp registers, TOMmn, TOMmp, TOLmn, and TOLmp bits cannot be changed. The TCRmn and TCRmp registers can always be read. The TSRmn and TSRmp registers are not used. Set values of the TOM and TOEm registers by slave channel can be changed.	Master channel loads the value of the TDRmn register to timer count register mn (TCRmn) by the start trigger detection (the valid edge of the TImn pin input is detected or the TSmn bit of the master channel is set to 1), and the counter starts counting down. When the count value reaches TCRmn = 0000H, the INTTMmn output is generated, and the counter stops until the next start trigger detection. The slave channel, triggered by INTTMmn of the master channel, loads the value of the TDRmp register to the TCRmp register, and the counter starts counting down. The output level of TOMp becomes active one count clock after generation of INTTMmn from the master channel. It becomes inactive when TCRmp = 0000H, and the counting operation is stopped. After that, the above operation is repeated.
Operation stop	The TTmn (master) and TTmp (slave) bits are set to 1 at the same time. The TTmn and TTmp bits automatically return to 0 because they are trigger bits.	TEMn, TEm = 0, and count operation stops. The TCRmn and TCRmp registers hold count value and stop. The TOMp output is not initialized but holds current status.
	The TOEmp bit of slave channel is cleared to 0 and value is set to the TOMp bit.	The TOMp pin outputs the TOMp set level.
TAU stop	To hold the TOMp pin output level Clears the TOMp bit to 0 after the value to be held is set to the port register.	The TOMp pin output level is held by port function.
	When holding the TOMp pin output level is not necessary Setting not required. The TAUMEN bit of the PER0 register is cleared to 0.	Power-off status All circuits are initialized and SFR of each channel is also initialized. (The TOMp bit is cleared to 0 and the TOMp pin is set to port mode.)

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

p: Slave channel number (n < p ≤ 7)

However, timer output pin (TOMP) : p = 1, 3 to 7

6.9.2 Operation as PWM function

Two channels can be used as a set to generate a pulse of any period and duty factor.

The period and duty factor of the output pulse can be calculated by the following expressions.

Pulse period = {Set value of TDRmn (master) + 1} × Count clock period
 Duty factor [%] = {Set value of TDRmp (slave)} / {Set value of TDRmn (master) + 1} × 100
 0% output: Set value of TDRmp (slave) = 0000H
 100% output: Set value of TDRmp (slave) ≥ {Set value of TDRmn (master) + 1}

Remark The duty factor exceeds 100% if the set value of TDRmp (slave) > (set value of TDRmn (master) + 1), it summarizes to 100% output.

The master channel operates in the interval timer mode. If the channel start trigger bit (TSmn) of timer channel start register m (TSm) is set to 1, an interrupt (INTTMmn) is output, the value set to timer data register mn (TDRmn) is loaded to timer count register mn (TCRmn), and the counter counts down in synchronization with the count clock. When the counter reaches 0000H, INTTMmn is output, the value of the TDRmn register is loaded again to the TCRmn register, and the counter counts down. This operation is repeated until the channel stop trigger bit (TTmn) of timer channel stop register m (TTm) is set to 1.

If two channels are used to output a PWM waveform, the period until the master channel counts down to 0000H is the PWM output (TOmp) cycle.

The slave channel operates in one-count mode. By using INTTMmn from the master channel as a start trigger, the TCRmp register loads the value of the TDRmp register and the counter counts down to 0000H. When the counter reaches 0000H, it outputs INTTMmp and waits until the next start trigger (INTTMmn from the master channel) is generated.

If two channels are used to output a PWM waveform, the period until the slave channel counts down to 0000H is the PWM output (TOmp) duty.

PWM output (TOmp) goes to the active level one clock after the master channel generates INTTMmn and goes to the inactive level when the TCRmp register of the slave channel becomes 0000H.

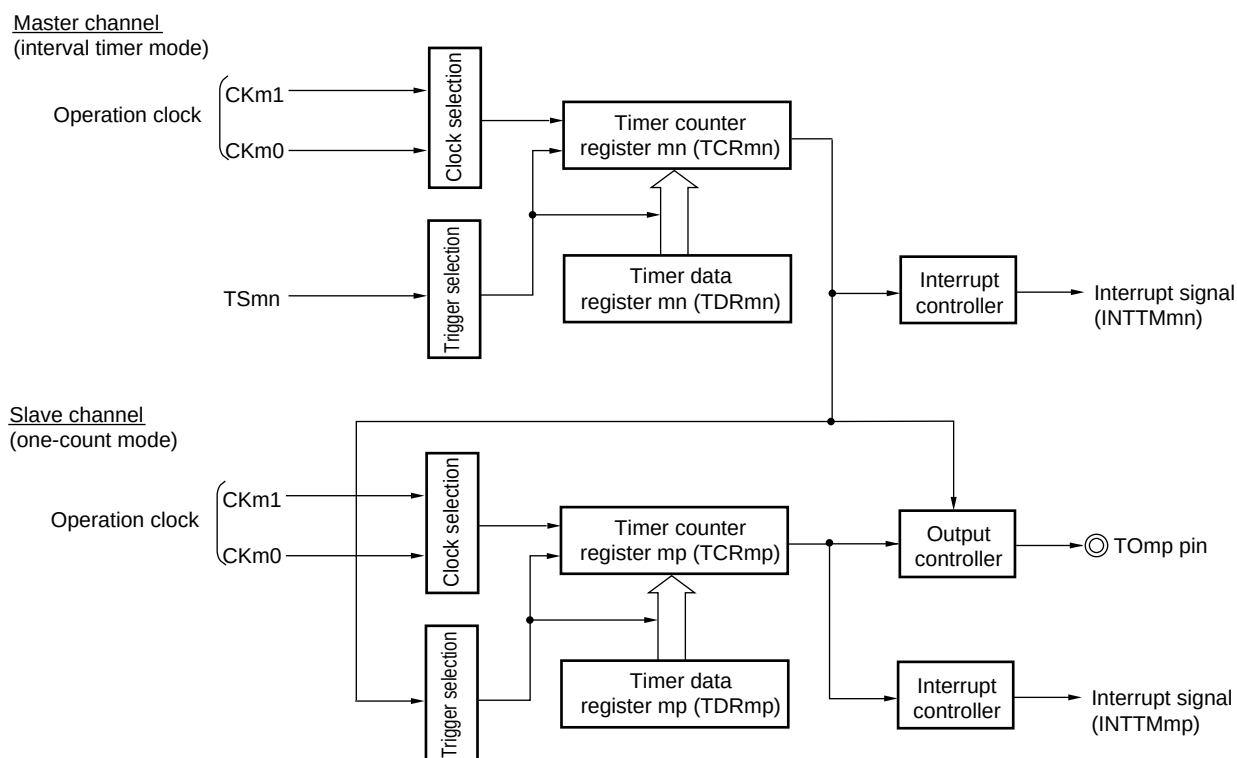
Caution To rewrite both timer data register mn (TDRmn) of the master channel and the TDRmp register of the slave channel, a write access is necessary two times. The timing at which the values of the TDRmn and TDRmp registers are loaded to the TCRmn and TCRmp registers is upon occurrence of INTTMmn of the master channel. Thus, when rewriting is performed split before and after occurrence of INTTMmn of the master channel, the TOmp pin cannot output the expected waveform. To rewrite both the TDRmn register of the master and the TDRmp register of the slave, therefore, be sure to rewrite both the registers immediately after INTTMmn is generated from the master channel.

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

p: Slave channel number (n < p ≤ 7)

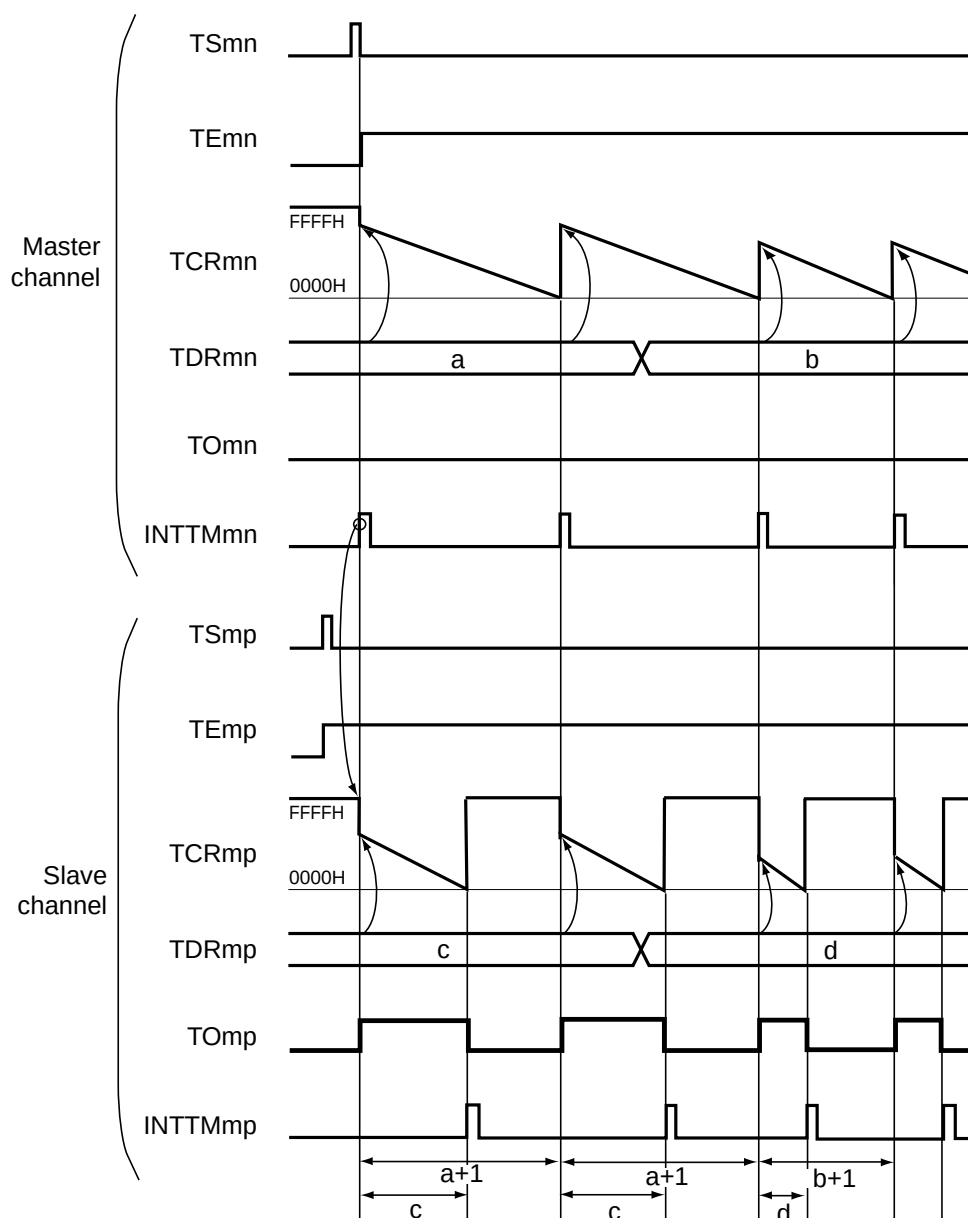
However, timer output pin (TOmp) : p = 1, 3 to 7

Figure 6-70. Block Diagram of Operation as PWM Function



Remark m: Unit number ($m = 0$), n: Channel number ($n = 0, 2, 4, 6$)
 p: Slave channel number ($n < p \leq 7$)
 However, timer output pin (TOMP) : $p = 1, 3$ to 7

Figure 6-71. Example of Basic Timing of Operation as PWM Function



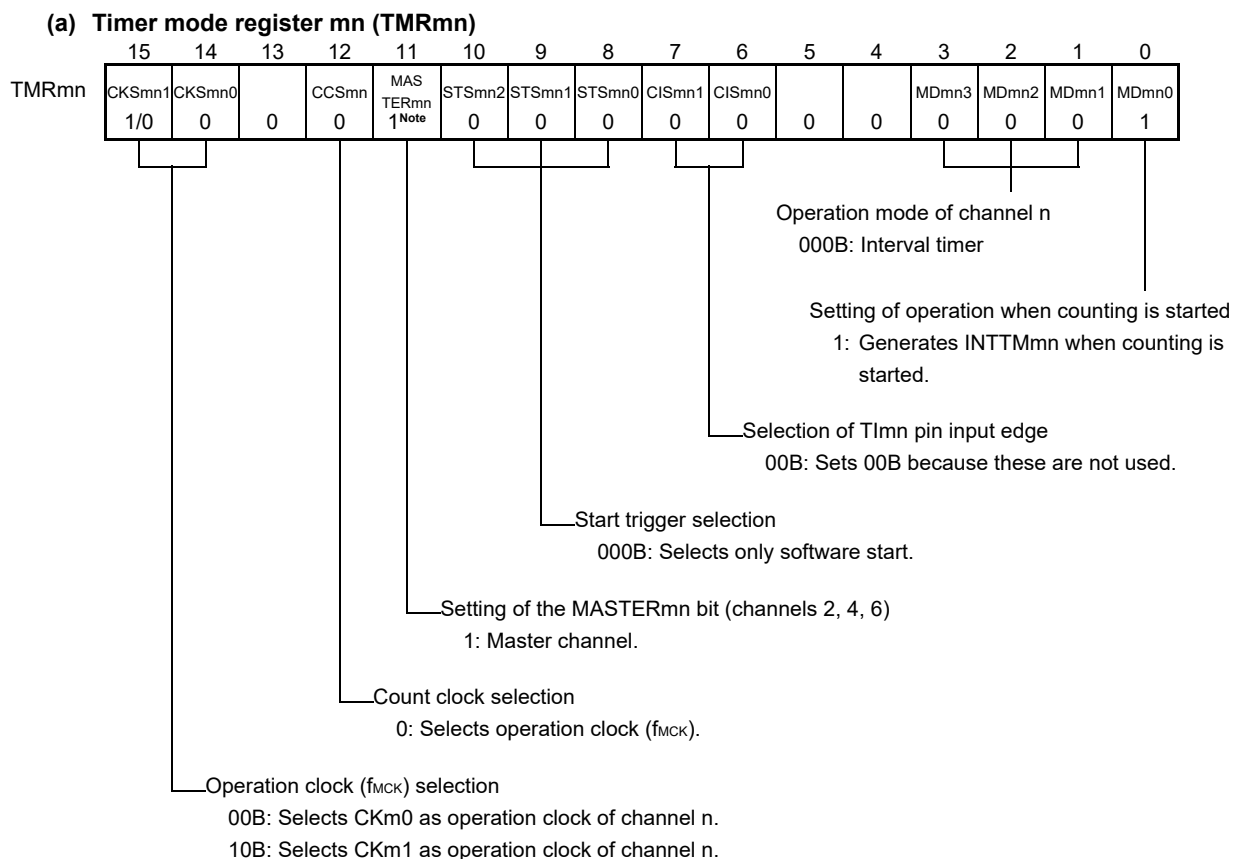
Remark 1. m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

p: Slave channel number (n < p ≤ 7)

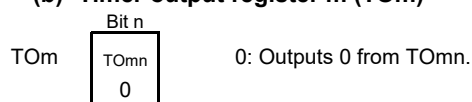
However, timer output pin (TOmp) : p = 1, 3 to 7

2. TSmn, TSmp: Bit n, p of timer channel start register m (TSm)
- TEmn, TEmp: Bit n, p of timer channel enable status register m (TEm)
- TCRmn, TCRmp: Timer count registers mn, mp (TCRmn, TCRmp)
- TDRmn, TDRmp: Timer data registers mn, mp (TDRmn, TDRmp)
- TOmn, TOmp: TOmn and TOmp pins output signal

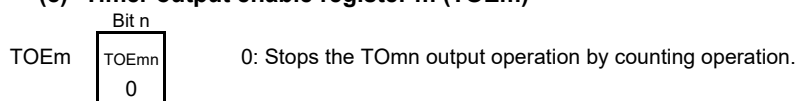
Figure 6-72. Example of Set Contents of Registers When PWM Function (Master Channel) Is Used



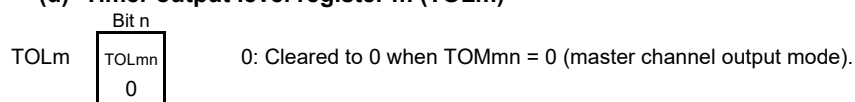
(b) Timer output register m (TOM)



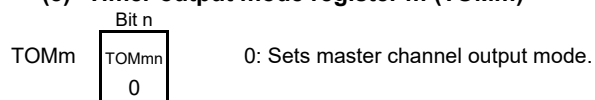
(c) Timer output enable register m (TOEm)



(d) Timer output level register m (TOLm)

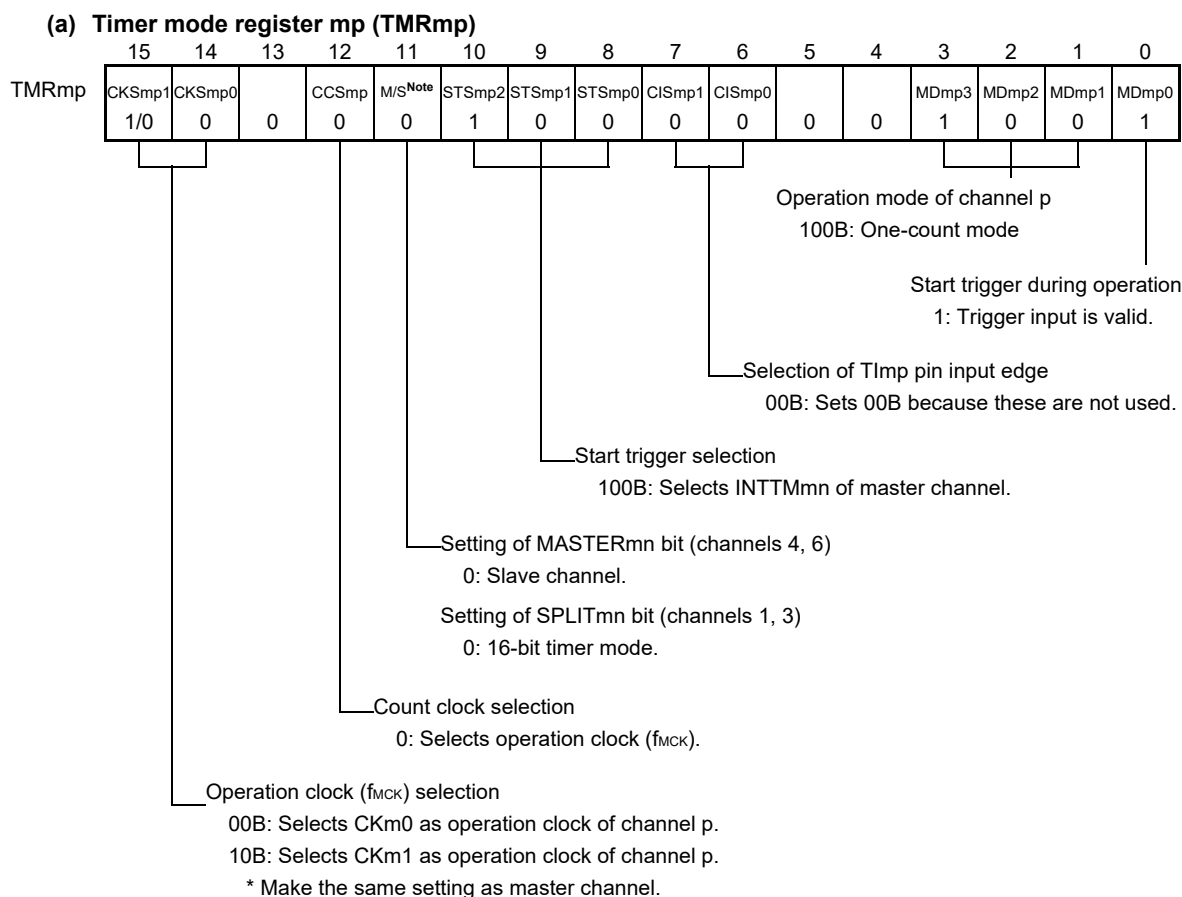


(e) Timer output mode register m (TOMm)



Note TMRm2, TMRm4, TMRm6: MASTERmn = 1
TMRm0 :Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

Figure 6-73. Example of Set Contents of Registers When PWM Function (Slave Channel) Is Used**(b) Timer output register m (TOM)**

TOM	Bit p	
	TOMp	
	1/0	0: Outputs 0 from TOMp. 1: Outputs 1 from TOMp.

(c) Timer output enable register m (TOEm)

TOEm	Bit p	
	TOEmp	
	1/0	0: Stops the TOMp output operation by counting operation. 1: Enables the TOMp output operation by counting operation.

(d) Timer output level register m (TOLm)

TOLm	Bit p	
	TOLmp	
	1/0	0: Positive logic output (active-high) 1: Negative logic output (active-low)

(e) Timer output mode register m (TOMm)

TOMm	Bit p	
	TOMmp	
	1	1: Sets the slave channel output mode.

Note TMRm4, TMRm6: MASTERmn bit

TMRm1, TMRm3: SPLITmp bit

TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

p: Slave channel number (n < p ≤ 7)

However, timer output pin (TOMp) : p = 1, 3 to 7

Figure 6-74. Operation Procedure When PWM Function Is Used (1/2)

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1. →	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 and CKm1.	
Channel default setting	Sets timer mode registers mn, mp (TMRmn, TMRmp) of two channels to be used (determines operation mode of channels). An interval (period) value is set to timer data register mn (TDRmn) of the master channel, and a duty factor is set to the TDRmp register of the slave channel.	Channel stops operating. (Clock is supplied and some power is consumed.)
	Sets slave channel. The TOMmp bit of timer output mode register m (TOMm) is set to 1 (slave channel output mode). Sets the TOLmp bit. Sets the TOmp bit and determines default level of the TOmp output. →	The TOmp pin goes into Hi-Z output state.
	Sets the TOEmp bit to 1 and enables operation of TOmp. →	The TOmp default setting level is output when the port mode register is in output mode and the port register is 0.
	Clears the port register and port mode register to 0. →	TOmp does not change because channel stops operating. The TOmp pin outputs the TOmp set level.

Figure 6-74. Operation Procedure When PWM Function Is Used (2/2)

	Software Operation	Hardware Status
Operation start	Sets the TOEmp bit (slave) to 1 (only when operation is resumed). The TSmn (master) and TSmp (slave) bits of timer channel start register m (TSM) are set to 1 at the same time. The TSmn and TSmp bits automatically return to 0 because they are trigger bits.	TEmn = 1, TEmn = 1 ► When the master channel starts counting, INTTMmn is generated. Triggered by this interrupt, the slave channel also starts counting.
During operation	Set values of the TMRmn and TMRmp registers, TOMmn, TOMmp, TOLmn, and TOLmp bits cannot be changed. Set values of the TDRmn and TDRmp registers can be changed after INTTMmn of the master channel is generated. The TCRmn and TCRmp registers can always be read. The TSRmn and TSRmp registers are not used.	The counter of the master channel loads the TDRmn register value to timer count register mn (TCRmn), and counts down. When the count value reaches TCRmn = 0000H, INTTMmn output is generated. At the same time, the value of the TDRmn register is loaded to the TCRmn register, and the counter starts counting down again. At the slave channel, the value of the TDRmp register is loaded to the TCRmp register, triggered by INTTMmn of the master channel, and the counter starts counting down. The output level of TOmp becomes active one count clock after generation of the INTTMmn output from the master channel. It becomes inactive when TCRmp = 0000H, and the counting operation is stopped. After that, the above operation is repeated.
Operation stop	The TTmn (master) and TTmp (slave) bits are set to 1 at the same time. The TTmn and TTmp bits automatically return to 0 because they are trigger bits. The TOEmp bit of slave channel is cleared to 0 and value is set to the TOmp bit.	TEmn, TEmn = 0, and count operation stops. The TCRmn and TCRmp registers hold count value and stop. The TOmp output is not initialized but holds current status. ----- ► The TOmp pin outputs the TOmp set level.
TAU stop	To hold the TOmp pin output level Clears the TOmp bit to 0 after the value to be held is set to the port register. When holding the TOmp pin output level is not necessary Setting not required. The TAUmEN bit of the PER0 register is cleared to 0.	► The TOmp pin output level is held by port function. ----- ► Power-off status All circuits are initialized and SFR of each channel is also initialized. (The TOmp bit is cleared to 0 and the TOmp pin is set to port mode.)

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4, 6)

p: Slave channel number (n < p ≤ 7)

However, timer output pin (TOmp) : p = 1, 3 to 7

6.9.3 Operation as multiple PWM output function

By extending the PWM function and using multiple slave channels, many PWM waveforms with different duty values can be output.

For example, when using two slave channels, the period and duty factor of an output pulse can be calculated by the following expressions.

$$\begin{aligned}\text{Pulse period} &= \{\text{Set value of TDRmn (master)} + 1\} \times \text{Count clock period} \\ \text{Duty factor 1 [\%]} &= \{\text{Set value of TDRmp (slave 1)}\} / \{\text{Set value of TDRmn (master)} + 1\} \times 100 \\ \text{Duty factor 2 [\%]} &= \{\text{Set value of TDRmq (slave 2)}\} / \{\text{Set value of TDRmn (master)} + 1\} \times 100\end{aligned}$$

Remark Although the duty factor exceeds 100% if the set value of TDRmp (slave 1) > {set value of TDRmn (master) + 1} or if the {set value of TDRmq (slave 2)} > {set value of TDRmn (master) + 1}, it is summarized into 100% output.

Timer count register mn (TCRmn) of the master channel operates in the interval timer mode and counts the periods.

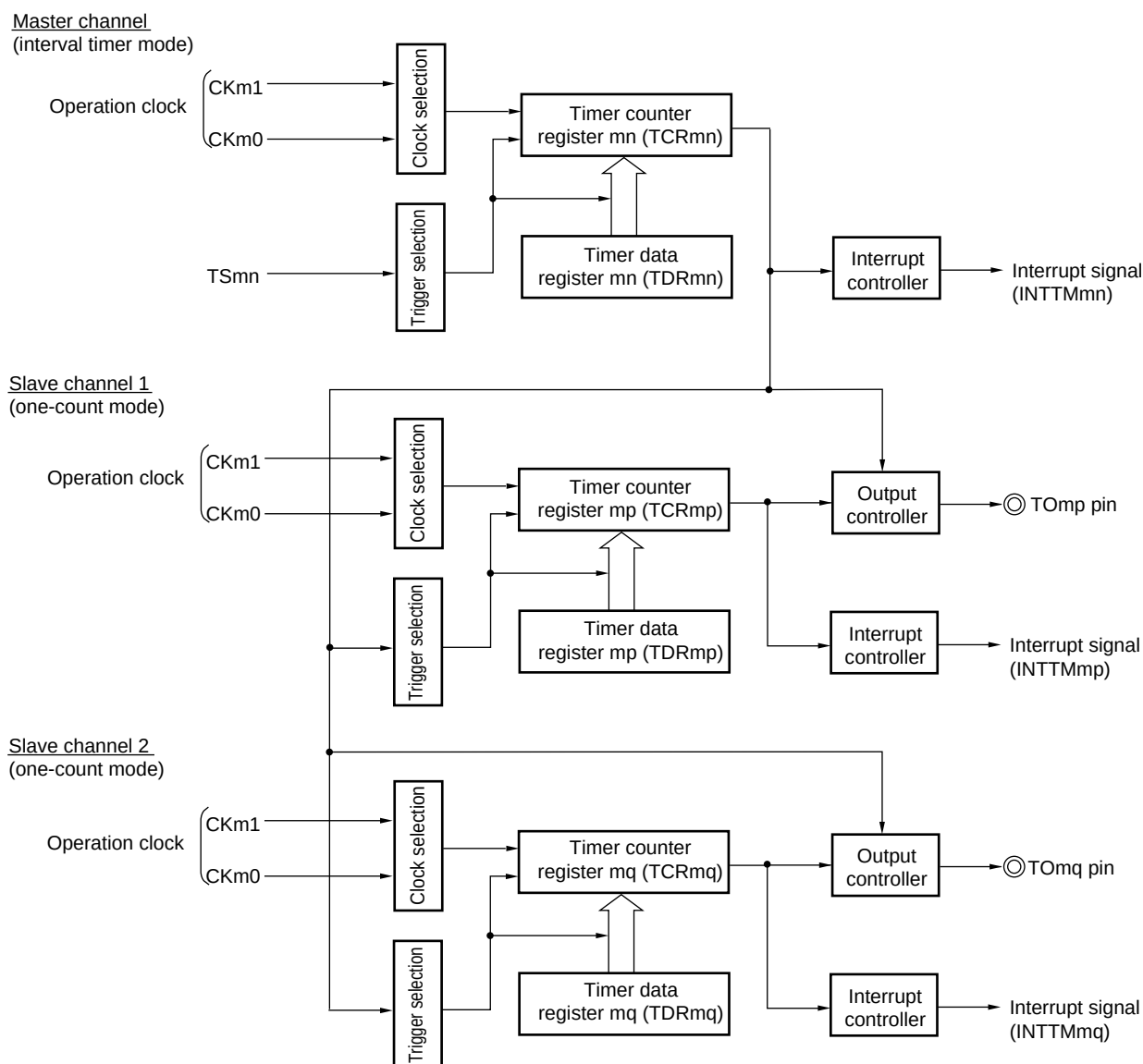
The TCRmp register of the slave channel 1 operates in one-count mode, counts the duty factor, and outputs a PWM waveform from the TOmp pin. The TCRmp register loads the value of timer data register mp (TDRmp), using INTTMmn of the master channel as a start trigger, and starts counting down. When TCRmp = 0000H, TCRmp outputs INTTMmp and stops counting until the next start trigger (INTTMmn of the master channel) has been input. The output level of TOmp becomes active one count clock after generation of INTTMmn from the master channel, and inactive when TCRmp = 0000H.

In the same way as the TCRmp register of the slave channel 1, the TCRmq register of the slave channel 2 operates in one-count mode, counts the duty factor, and outputs a PWM waveform from the TOMq pin. The TCRmq register loads the value of the TDRmq register, using INTTMmn of the master channel as a start trigger, and starts counting down. When TCRmq = 0000H, the TCRmq register outputs INTTMmq and stops counting until the next start trigger (INTTMmn of the master channel) has been input. The output level of TOMq becomes active one count clock after generation of INTTMmn from the master channel, and inactive when TCRmq = 0000H.

When channel 0 is used as the master channel as above, up to six types of PWM signals can be output at the same time.

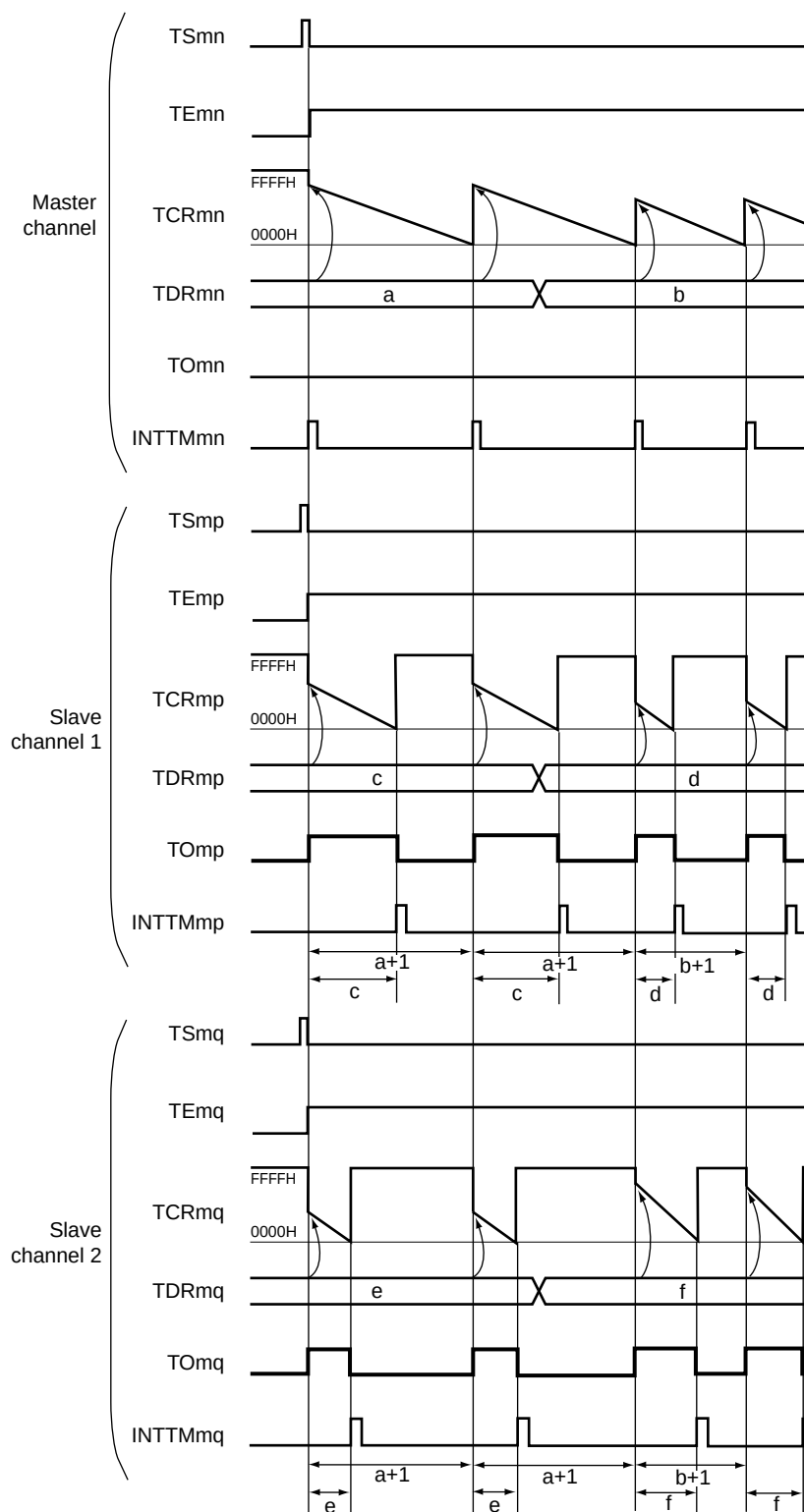
Caution To rewrite both timer data register mn (TDRmn) of the master channel and the TDRmp register of the slave channel 1, write access is necessary at least twice. Since the values of the TDRmn and TDRmp registers are loaded to the TCRmn and TCRmp registers after INTTMmn is generated from the master channel, if rewriting is performed separately before and after generation of INTTMmn from the master channel, the TOmp pin cannot output the expected waveform. To rewrite both the TDRmn register of the master and the TDRmp register of the slave, be sure to rewrite both the registers immediately after INTTMmn is generated from the master channel (This applies also to the TDRmq register of the slave channel 2).

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4)
 p: Slave channel number 1, q: Slave channel number 2
 $n < p < q \leq 7$
 However, timer output pin (TOmp, TOMq) : p = 1, 3 to 6, q = 3 to 7

Figure 6-75. Block Diagram of Operation as Multiple PWM Output Function (output two types of PWMs)

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4)
 p: Slave channel number 1, q: Slave channel number 2
 $n < p < q \leq 7$
 However, timer output pin (TOmp, TOMq) : p = 1, 3 to 6, q = 3 to 7

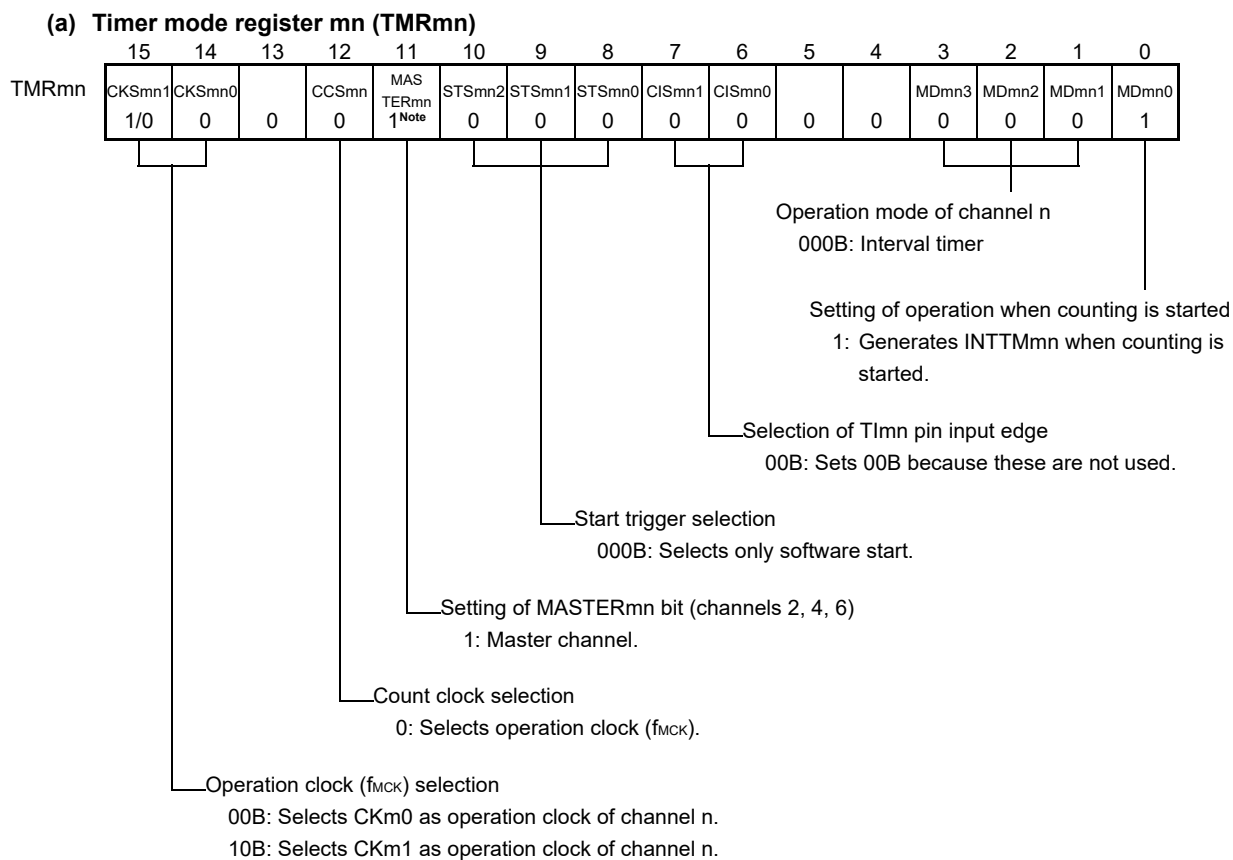
**Figure 6-76. Example of Basic Timing of Operation as Multiple PWM Output Function
(Output two types of PWMs)**



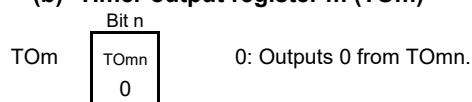
(Remark is listed on the next page.)

- Remarks1.** m: Unit number (m = 0), n: Channel number (n = 0, 2, 4)
p: Slave channel number 1, q: Slave channel number 2
 $n < p < q \leq 7$
However, timer output pin (TOmp, TOmq) : p = 1, 3 to 6, q = 3 to 7
- 2.** TSmn, TSmp, TSmq: Bit n, p, q of timer channel start register m (TSM)
TEmn, TEmq, TEMq: Bit n, p, q of timer channel enable status register m (TEM)
TCRmn, TCRmp, TCRmq: Timer count registers mn, mp, mq (TCRmn, TCRmp, TCRmq)
TDRmn, TDRmp, TDRmq: Timer data registers mn, mp, mq (TDRmn, TDRmp, TDRmq)
TOmn, TOmp, TOmq: TOmn, TOmp, and TOmq pins output signal

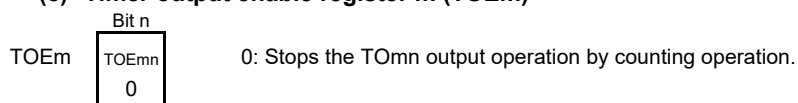
**Figure 6-77. Example of Set Contents of Registers
When Multiple PWM Output Function (Master Channel) Is Used**



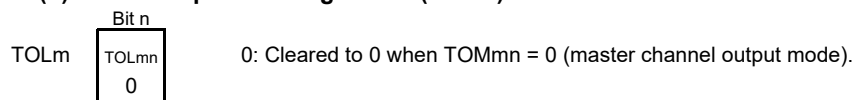
(b) Timer output register m (TOM)



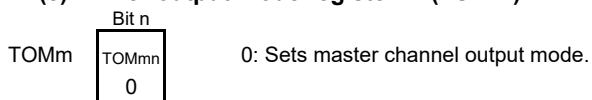
(c) Timer output enable register m (TOEm)



(d) Timer output level register m (TOLm)



(e) Timer output mode register m (TOMm)

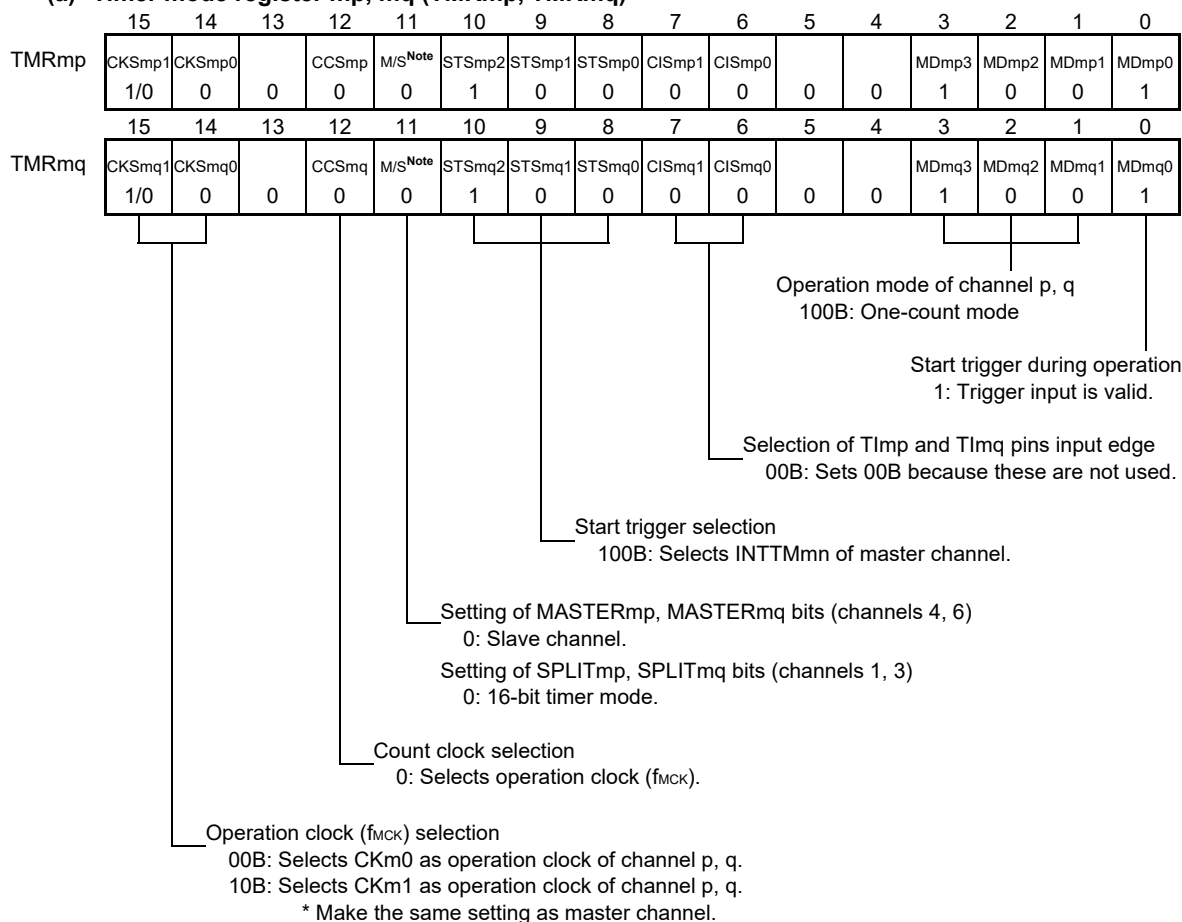


Note TMRm2, TMRm4, TMRm6: MASTERmn = 1
 TMRm0 :Fixed to 0

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4)

Figure 6-78. Example of Set Contents of Registers
When Multiple PWM Output Function (Slave Channel) Is Used (output two types of PWMs)

(a) Timer mode register mp, mq (TMRmp, TMRmq)



(b) Timer output register m (TOM)

	Bit q	Bit p
TOM	TOmq	TOmp
	1/0	1/0

0: Outputs 0 from TOmp or TOmq.
 1: Outputs 1 from TOmp or TOmq.

(c) Timer output enable register m (TOEm)

	Bit q	Bit p
TOEm	TOEmq	TOEmp
	1/0	1/0

0: Stops the TOmp or TOmq output operation by counting operation.
 1: Enables the TOmp or TOmq output operation by counting operation.

(d) Timer output level register m (TOLm)

	Bit q	Bit p
TOLm	TOLmq	TOLmp
	1/0	1/0

0: Positive logic output (active-high)
 1: Negative logic output (active-low)

(e) Timer output mode register m (TOMm)

	Bit q	Bit p
TOMm	TOMmq	TOMmp
	1	1

1: Sets the slave channel output mode.

Note TMRm4, TMRm6: MASTERmp, MASTERmq bit
 TMRm1, TMRm3: SPLITmp, SPLITmq bit
 TMRm5, TMRm7: Fixed to 0

Remark m: Unit number (m = 0, n: Channel number (n = 0, 2, 4)
 p: Slave channel number 1, q: Slave channel number 2
 n < p < q ≤ 7
 However, timer output pin (TOmp, TOmq) : p = 1, 3 to 6, q = 3 to 7

Figure 6-79. Operation Procedure When Multiple PWM Output Function Is Used (1/2)

	Software Operation	Hardware Status
TAU default setting		Power-off status (Clock supply is stopped and writing to each register is disabled.)
	Sets the TAUmEN bit of peripheral enable register 0 (PER0) to 1. →	Power-on status. Each channel stops operating. (Clock supply is started and writing to each register is enabled.)
	Sets timer clock select register m (TPSm). Determines clock frequencies of CKm0 and CKm1.	
Channel default setting	Sets timer mode registers mn, mp, 0q (TMRmn, TMRmp, TMRmq) of each channel to be used (determines operation mode of channels). An interval (period) value is set to timer data register mn (TDRmn) of the master channel, and a duty factor is set to the TDRmp and TDRmq registers of the slave channels.	Channel stops operating. (Clock is supplied and some power is consumed.)
	Sets slave channels. The TOMmp and TOMmq bits of timer output mode register m (TOMm) are set to 1 (slave channel output mode). Clears the TOLmp and TOLmq bits to 0. Sets the TOMP and TOMq bits and determines default level of the TOMP and TOMq outputs. →	The TOMP and TOMq pins go into Hi-Z output state.
	Sets the TOEmp and TOEmq bits to 1 and enables operation of TOMP and TOMq. →	The TOMP and TOMq default setting levels are output when the port mode register is in output mode and the port register is 0.
	Clears the port register and port mode register to 0. →	TOMP and TOMq do not change because channels stop operating.
		The TOMP and TOMq pins output the TOMP and TOMq set levels.

(Note and Remark are listed on the next page.)

Figure 6-79. Operation Procedure When Multiple PWM Output Function Is Used (2/2)

	Software Operation	Hardware Status
Operation start	(Sets the TOEmp and TOEmq (slave) bits to 1 only when resuming operation.) The TSmn bit (master), and TSmp and TSmq (slave) bits of timer channel start register m (TSM) are set to 1 at the same time. The TSmn, TSmp, and TSmq bits automatically return to 0 because they are trigger bits.	TEmn = 1, TEmq = 1 When the master channel starts counting, INTTMmn is generated. Triggered by this interrupt, the slave channel also starts counting.
During operation	Set values of the TMRmn, TMRmp, TMRmq registers, TOMmn, TOMmp, TOMmq, TOLmn, TOLmp, and TOLmq bits cannot be changed. Set values of the TDRmn, TDRmp, and TDRmq registers can be changed after INTTMmn of the master channel is generated. The TCRmn, TCRmp, and TCRmq registers can always be read. The TSRmn, TSRmp, and TSR0q registers are not used.	The counter of the master channel loads the TDRmn register value to timer count register mn (TCRmn) and counts down. When the count value reaches TCRmn = 0000H, INTTMmn output is generated. At the same time, the value of the TDRmn register is loaded to the TCRmn register, and the counter starts counting down again. At the slave channel 1, the values of the TDRmp register are transferred to the TCRmp register, triggered by INTTMmn of the master channel, and the counter starts counting down. The output levels of TOmp become active one count clock after generation of the INTTMmn output from the master channel. It becomes inactive when TCRmp = 0000H, and the counting operation is stopped. At the slave channel 2, the values of the TDRmq register are transferred to TCRmq register, triggered by INTTMmn of the master channel, and the counter starts counting down. The output levels of TOMq become active one count clock after generation of the INTTMmn output from the master channel. It becomes inactive when TCRmq = 0000H, and the counting operation is stopped. After that, the above operation is repeated.
Operation stop	The TTmn bit (master), TTmp, and TTmq (slave) bits are set to 1 at the same time. The TTmn, TTmp, and TTmq bits automatically return to 0 because they are trigger bits.	TEmn, TEmq = 0, and count operation stops. The TCRmn, TCRmp, and TCRmq registers hold count value and stop. The TOmp and TOMq output are not initialized but hold current status.
	The TOEmp and TOEmq bits of slave channels are cleared to 0 and value is set to the TOmp and TOMq bits.	The TOmp and TOMq pins output the TOmp and TOMq set levels.
TAU stop	To hold the TOmp and TOMq pin output levels Clears the TOmp and TOMq bits to 0 after the value to be held is set to the port register. When holding the TOmp and TOMq pin output levels are not necessary Setting not required	The TOmp and TOMq pin output levels are held by port function.
	The TAUmEN bit of the PER0 register is cleared to 0.	Power-off status All circuits are initialized and SFR of each channel is also initialized. (The TOmp and TOMq bits are cleared to 0 and the TOmp and TOMq pins are set to port mode.)

Remark m: Unit number (m = 0), n: Channel number (n = 0, 2, 4)

p: Slave channel number 1, q: Slave channel number 2

$n < p < q \leq 7$

However, timer output pin (TOmp, TOMq) : p = 1, 3 to 6, q = 3 to 7

6.10 Cautions When Using Timer Array Unit

6.10.1 Cautions when using timer output

Depends on products, a pin is assigned a timer output and other alternate functions. In this case, outputs of the other alternate functions must be set in initial status.

For details, see **4.5 Register Settings When Using Alternate Function**.

CHAPTER 7 REAL-TIME CLOCK

7.1 Functions of Real-time Clock

The real-time clock has the following features.

- Having counters of year, month, week, day, hour, minute, and second, and can count up to 99 years.
- Constant-period interrupt function (period: 0.5 seconds, 1 second, 1 minute, 1 hour, 1 day, 1 month)
- Alarm interrupt function (alarm: week, hour, minute)
- Pin output function of 1 Hz (48 and 64-pin products only)

The real-time clock interrupt signal (INTRTC) can be utilized for wakeup from STOP mode and triggering an A/D converter's SNOOZE mode.

Caution The count of year, month, week, day, hour, minutes and second can only be performed when a subsystem clock ($f_{\text{SUB}} = 32.768 \text{ kHz}$) is selected as the operation clock of the real-time clock. When the low-speed oscillation clock ($f_{\text{IL}} = 15 \text{ kHz (TYP.)}$) is selected, only the constant-period interrupt function is available. The 25- to 32-pin products have the constant-period interrupt function only, because these products have no subsystem clock. However, the constant-period interrupt interval when f_{IL} is selected will be calculated with the constant-period (the value selected with RTCC0 register) $\times f_{\text{SUB}}/f_{\text{IL}}$.

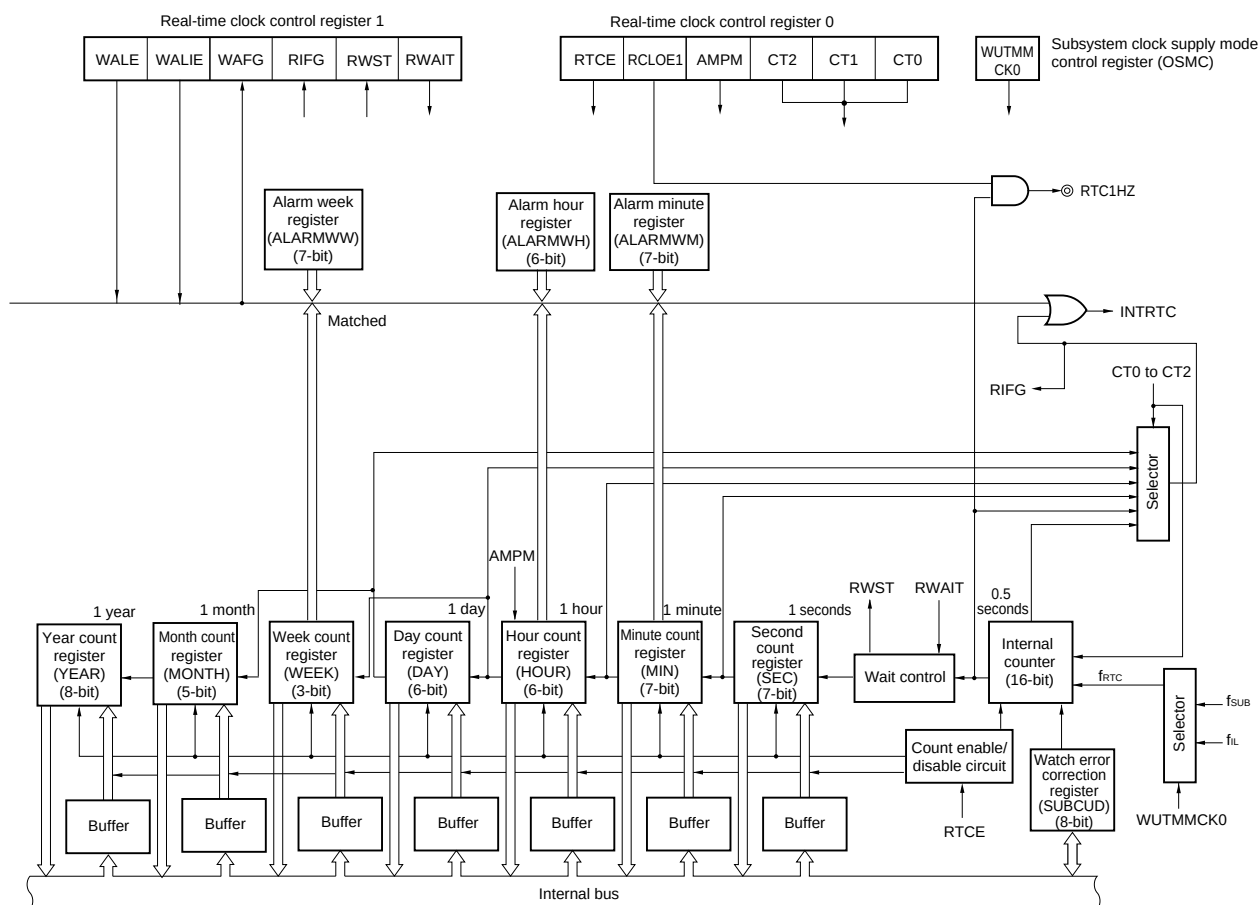
7.2 Configuration of Real-time Clock

The real-time clock includes the following hardware.

Table 7-1. Configuration of Real-time Clock

Item	Configuration
Counter	Internal counter (16-bit)
Control registers	Peripheral enable register 0 (PER0)
	Subsystem clock supply mode control register (OSMC)
	Real-time clock control register 0 (RTCC0)
	Real-time clock control register 1 (RTCC1)
	Second count register (SEC)
	Minute count register (MIN)
	Hour count register (HOUR)
	Day count register (DAY)
	Week count register (WEEK)
	Month count register (MONTH)
	Year count register (YEAR)
	Watch error correction register (SUBCUD)
	Alarm minute register (ALARMWM)
	Alarm hour register (ALARMWH)
	Alarm week register (ALARMWW)

Figure 7-1. Block Diagram of Real-time Clock



Caution The count of year, month, week, day, hour, minutes and second can only be performed when a subsystem clock ($f_{SUB} = 32.768 \text{ kHz}$) is selected as the operation clock of the real-time clock. When the low-speed oscillation clock ($f_{IL} = 15 \text{ kHz (TYP.)}$) is selected, only the constant-period interrupt function is available. The 25- to 32-pin products have the constant-period interrupt function only, because these products have no subsystem clock. However, the constant-period interrupt interval when f_{IL} is selected will be calculated with the constant-period (the value selected with RTCC0 register) $\times f_{SUB}/f_{IL}$.

7.3 Registers Controlling Real-time Clock

The real-time clock is controlled by the following registers.

- Peripheral enable register 0 (PER0)
- Subsystem clock supply mode control register (OSMC)
- Real-time clock control register 0 (RTCC0)
- Real-time clock control register 1 (RTCC1)
- Second count register (SEC)
- Minute count register (MIN)
- Hour count register (HOUR)
- Day count register (DAY)
- Week count register (WEEK)
- Month count register (MONTH)
- Year count register (YEAR)
- Watch error correction register (SUBCUD)
- Alarm minute register (ALARMWM)
- Alarm hour register (ALARMWH)
- Alarm week register (ALARMWW)
- Port mode register 3 (PM3)
- Port register 3 (P3)

7.3.1 Peripheral enable register 0 (PER0)

This register is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

When the real-time clock is used, be sure to set bit 7 (RTCEN) of this register to 1.

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-2. Format of Peripheral Enable Register 0 (PER0)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN ^{Not} _e	SAU0EN	0	TAU0EN

RTCEN	Control of real-time clock (RTC) and 12-bit interval timer input clock supply
0	Stops input clock supply. - SFR used by the real-time clock (RTC) and 12-bit interval timer cannot be written. - The real-time clock (RTC) and 12-bit interval timer are in the reset status.
1	Enables input clock supply. SFR used by the real-time clock (RTC) and 12-bit interval timer can be read and written.

Note 32, 48, and 64-pin products only.

Cautions 1. When using the real-time clock, first set the RTCEN bit to 1 and then set the following registers, while oscillation of the count clock (f_{RTC}) is stable. If RTCEN = 0, writing to the control registers of the real-time clock is ignored, and, even if the registers are read, only the default values are read (except for the subsystem clock supply mode control register (OSMC), port mode register 3 (PM3), port register 3 (P3)).

- Real-time clock control register 0 (RTCC0)
- Real-time clock control register 1 (RTCC1)
- Second count register (SEC)
- Minute count register (MIN)
- Hour count register (HOUR)
- Day count register (DAY)
- Week count register (WEEK)
- Month count register (MONTH)
- Year count register (YEAR)
- Watch error correction register (SUBCUD)
- Alarm minute register (ALARMWM)
- Alarm hour register (ALARMWH)
- Alarm week register (ALARMWW)

2. The subsystem clock supply to peripheral functions other than the real-time clock and 12-bit interval timer can be stopped in STOP mode or HALT mode when the subsystem clock is used, by setting the RTCLPC bit of the subsystem clock supply mode control register (OSMC) to 1.
3. Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

7.3.2 Subsystem clock supply mode control register (OSMC)

The WUTMMCK0 bit can be used to select the count clock (f_{RTC}) of the real-time clock.

In addition, by stopping clock functions that are unnecessary, the RTCLPC bit can be used to reduce power consumption. For details about setting the RTCLPC bit, see **CHAPTER 5 CLOCK GENERATOR**.

The OSMC register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-3. Format of Subsystem Clock Supply Mode Control Register (OSMC)

Address: F00F3H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
OSMC	RTCLPC	0	0	WUTMMCK0	0	0	0	0

WUTMMCK0	Selection of operation clock (f_{RTC}) for real-time clock and 12-bit interval timer.
0	Subsystem clock (f_{SUB})
1	Low-speed on-chip oscillator clock (f_{IL})

Caution The count of year, month, week, day, hour, minutes and second can only be performed when a subsystem clock ($f_{SUB} = 32.768$ kHz) is selected as the operation clock of the real-time clock. When the low-speed oscillation clock ($f_{IL} = 15$ kHz (TYP.)) is selected, only the constant-period interrupt function is available. The 25- to 32-pin products have the constant-period interrupt function only, because these products have no subsystem clock. However, the constant-period interrupt interval when f_{IL} is selected will be calculated with the constant-period (the value selected with RTCC0 register) $\times f_{SUB}/f_{IL}$.

7.3.3 Real-time clock control register 0 (RTCC0)

The RTCC0 register is an 8-bit register that is used to start or stop the real-time clock operation, control the RTC1HZ pin, and set a 12- or 24-hour system and the constant-period interrupt function.

The RTCC0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-4. Format of Real-time Clock Control Register 0 (RTCC0)

Address: FFF9DH After reset: 00H R/W

Symbol	<7>	6	<5>	4	3	2	1	0
RTCC0	RTCE	0	RCLOE1 ^{Note}	0	AMPM	CT2	CT1	CT0

RTCE	Real-time clock operation control
0	Stops counter operation.
1	Starts counter operation.

RCLOE1	RTC1HZ pin output control
0	Disables output of the RTC1HZ pin (1 Hz).
1	Enables output of the RTC1HZ pin (1 Hz).

AMPM	Selection of 12-/24-hour system
0	12-hour system (a.m. and p.m. are displayed.)
1	24-hour system
• Rewrite the AMPM bit value after setting the RWAIT bit (bit 0 of real-time clock control register 1 (RTCC1)) to 1. If the AMPM bit value is changed, the values of the hour count register (HOUR) change according to the specified time system. • Table 7-2 shows the displayed time digits that are displayed.	

CT2	CT1	CT0	Constant-period interrupt (INTRTC) selection
0	0	0	Does not use constant-period interrupt function.
0	0	1	Once per 0.5 s (synchronized with second count up)
0	1	0	Once per 1 s (same time as second count up)
0	1	1	Once per 1 m (second 00 of every minute)
1	0	0	Once per 1 hour (minute 00 and second 00 of every hour)
1	0	1	Once per 1 day (hour 00, minute 00, and second 00 of every day)
1	1	×	Once per 1 month (Day 1, hour 00 a.m., minute 00, and second 00 of every month)
When changing the values of the CT2 to CT0 bits while the counter operates (RTCE = 1), rewrite the values of the CT2 to CT0 bits after disabling interrupt servicing INTRTC by using the interrupt mask flag register. Furthermore, after rewriting the values of the CT2 to CT0 bits, enable interrupt servicing after clearing the RIFG and RTCIF flags.			

Note Set the RCLOE1 bit to 0 in the 25- and 32-pin products.

- Cautions**
1. Do not change the value of the RCLOE1 bit when RTCE = 1.
 2. 1 Hz is not output even if RCCOE1 is set to 1 when RTCE = 0.

Remark ×: don't care

7.3.4 Real-time clock control register 1 (RTCC1)

The RTCC1 register is an 8-bit register that is used to control the alarm interrupt function and the wait time of the counter.

The RTCC1 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-5. Format of Real-time Clock Control Register 1 (RTCC1) (1/2)

Address: FFF9EH After reset: 00H R/W

Symbol	<7>	<6>	5	<4>	<3>	2	<1>	<0>
RTCC1	WALE	WALIE	0	WAFG	RIFG	0	RWST	RWAIT

WALE	Alarm operation control
0	Match operation is invalid.
1	Match operation is valid.
When setting a value to the WALE bit while the counter operates (RTCE = 1) and WALIE = 1, rewrite the WALE bit after disabling interrupt servicing INTRTC by using the interrupt mask flag register. Furthermore, clear the WAFG and RTCIF flags after rewriting the WALE bit. When setting each alarm register (WALIE flag of real-time clock control register 1 (RTCC1), the alarm minute register (ALARMWM), the alarm hour register (ALARMWH), and the alarm week register (ALARMWW)), set match operation to be invalid ("0") for the WALE bit.	

WALIE	Control of alarm interrupt (INTRTC) function operation
0	Does not generate interrupt on matching of alarm.
1	Generates interrupt on matching of alarm.

WAFG	Alarm detection status flag
0	Alarm mismatch
1	Detection of matching of alarm
This is a status flag that indicates detection of matching with the alarm. It is valid only when WALE = 1 and is set to "1" one cycle of f_{RTC} after matching of the alarm is detected. This flag is cleared when "0" is written to it. Writing "1" to it is invalid.	

RIFG	Constant-period interrupt status flag
0	Constant-period interrupt is not generated.
1	Constant-period interrupt is generated.
This flag indicates the status of generation of the constant-period interrupt. When the constant-period interrupt is generated, it is set to "1". This flag is cleared when "0" is written to it. Writing "1" to it is invalid.	

Figure 7-5. Format of Real-time Clock Control Register 1 (RTCC1) (2/2)

Address: FFF9EH After reset: 00H R/W

Symbol	<7>	<6>	5	<4>	<3>	2	<1>	<0>
RTCC1	WALE	WALIE	0	WAFG	RIFG	0	RWST	RWAIT

RWST	Wait status flag of real-time clock
0	Counter is operating.
1	Mode to read or write counter value
This status flag indicates whether the setting of the RWAIT bit is valid. Before reading or writing the counter value, confirm that the value of this flag is 1.	

RWAIT	Wait control of real-time clock
0	Sets counter operation.
1	Stops SEC to YEAR counters. Mode to read or write counter value
This bit controls the operation of the counter. Be sure to write "1" to it to read or write the counter value. As the internal counter (16-bit) is continuing to run, complete reading or writing within one second and turn back to 0. When reading or writing to the counter is required while generation of the alarm interrupt is enabled, first set the CT2 to CT0 bits to 010B (generating the constant-period interrupt once per 1 second). Then, complete the processing from setting the RWAIT bit to 1 to setting it to 0 before generation of the next constant-period interrupt. When RWAIT = 1, it takes up to one cycle of f_{RTC} until the counter value can be read or written (RWST = 1).^{Notes 1, 2} When the internal counter (16-bit) overflowed while RWAIT = 1, it keeps the event of overflow until RWAIT = 0, then counts up. However, when it wrote a value to second count register, it will not keep the overflow event.	

- Notes**
1. When setting RWAIT = 1 during 1 operating clock (f_{RTC}), after setting RTCE = 1, it may take two clock time of the operation clock (f_{RTC}), until RWST bit is set to "1".
 2. When setting RWAIT = 1 during 1 operating clock (f_{RTC}), after returning from a stand-by (HALT mode, STOP mode and SNOOZE mode), it may take two clock time of the operation clock (f_{RTC}), until RWST bit is set to "1".

Caution If writing is performed to the RTCC1 register with a 1-bit manipulation instruction, the RIFG flag and WAFG flag may be cleared. Therefore, to perform writing to the RTCC1 register, be sure to use an 8-bit manipulation instruction. To prevent the RIFG flag and WAFG flag from being cleared during writing, disable writing by setting 1 to the corresponding bit. If the RIFG flag and WAFG flag are not used and the value may be changed, the RTCC1 register may be written by using a 1-bit manipulation instruction.

- Remarks**
1. Fixed-cycle interrupts and alarm match interrupts use the same interrupt source (INTRTC). When using these two types of interrupts at the same time, which interrupt occurred can be judged by checking the fixed-cycle interrupt status flag (RIFG) and the alarm detection status flag (WAFG) upon INTRTC occurrence.
 2. The internal counter (16 bits) is cleared when the second count register (SEC) is written.

7.3.5 Second count register (SEC)

The SEC register is an 8-bit register that takes a value of 0 to 59 (decimal) and indicates the count value of seconds. It counts up when the internal counter (16-bit) overflows.

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of f_{RTC} later. Set a decimal value of 00 to 59 to this register in BCD code.

The SEC register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Remark The internal counter (16 bits) is cleared when the second count register (SEC) is written.

Figure 7-6. Format of Second Count Register (SEC)

Address: FFF92H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
SEC	0	SEC40	SEC20	SEC10	SEC8	SEC4	SEC2	SEC1

Caution When it reads or writes from/to the register while the counter is in operation (RTCE = 1), follow the procedures described in 7.4.3 Reading/writing real-time clock.

7.3.6 Minute count register (MIN)

The MIN register is an 8-bit register that takes a value of 0 to 59 (decimal) and indicates the count value of minutes. It counts up when the second counter overflows.

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of f_{RTC} later. Even if the second count register overflows while this register is being written, this register ignores the overflow and is set to the value written. Set a decimal value of 00 to 59 to this register in BCD code.

The MIN register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-7. Format of Minute Count Register (MIN)

Address: FFF93H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
MIN	0	MIN40	MIN20	MIN10	MIN8	MIN4	MIN2	MIN1

Caution When it reads or writes from/to the register while the counter is in operation (RTCE = 1), follow the procedures described in 7.4.3 Reading/writing real-time clock.

7.3.7 Hour count register (HOUR)

The HOUR register is an 8-bit register that takes a value of 00 to 23 or 01 to 12 and 21 to 32 (decimal) and indicates the count value of hours.

It counts up when the minute counter overflows.

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of f_{RTC} later. Even if the minute count register overflows while this register is being written, this register ignores the overflow and is set to the value written. Specify a decimal value of 00 to 23, 01 to 12, or 21 to 32 by using BCD code according to the time system specified using bit 3 (AMPM) of real-time clock control register 0 (RTCC0).

If the AMPM bit value is changed, the values of the HOUR register change according to the specified time system.

The HOUR register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 12H.

However, the value of this register is 00H if the AMPM bit is set to 1 after reset.

Figure 7-8. Format of Hour Count Register (HOUR)

Address: FFF94H After reset: 12H R/W

Symbol	7	6	5	4	3	2	1	0
HOUR	0	0	HOUR20	HOUR10	HOUR8	HOUR4	HOUR2	HOUR1

- Cautions**
1. Bit 5 (HOUR20) of the HOUR register indicates AM(0)/PM(1) if AMPM = 0 (if the 12-hour system is selected).
 2. When it reads or writes from/to the register while the counter is in operation (RTCE = 1), follow the procedures described in 7.4.3 Reading/writing real-time clock.

Table 7-2 shows the relationship between the setting value of the AMPM bit, the hour count register (HOUR) value, and time.

Table 7-2. Displayed Time Digits

24-Hour Display (AMPM = 1)		12-Hour Display (AMPM = 1)	
Time	HOUR Register	Time	HOUR Register
0	00H	12 a.m.	12H
1	01H	1 a.m.	01H
2	02H	2 a.m.	02H
3	03H	3 a.m.	03H
4	04H	4 a.m.	04H
5	05H	5 a.m.	05H
6	06H	6 a.m.	06H
7	07H	7 a.m.	07H
8	08H	8 a.m.	08H
9	09H	9 a.m.	09H
10	10H	10 a.m.	10H
11	11H	11 a.m.	11H
12	12H	12 p.m.	32H
13	13H	1 p.m.	21H
14	14H	2 p.m.	22H
15	15H	3 p.m.	23H
16	16H	4 p.m.	24H
17	17H	5 p.m.	25H
18	18H	6 p.m.	26H
19	19H	7 p.m.	27H
20	20H	8 p.m.	28H
21	21H	9 p.m.	29H
22	22H	10 p.m.	30H
23	23H	11 p.m.	31H

The HOUR register value is set to 12-hour display when the AMPM bit is “0” and to 24-hour display when the AMPM bit is “1”.

In 12-hour display, the fifth bit of the HOUR register displays 0 for AM and 1 for PM.

7.3.8 Day count register (DAY)

The DAY register is an 8-bit register that takes a value of 1 to 31 (decimal) and indicates the count value of days.

It counts up when the hour counter overflows.

This counter counts as follows.

- 01 to 31 (January, March, May, July, August, October, December)
- 01 to 30 (April, June, September, November)
- 01 to 29 (February, leap year)
- 01 to 28 (February, normal year)

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of `RTC` later. Even if the hour count register overflows while this register is being written, this register ignores the overflow and is set to the value written. Set a decimal value of 01 to 31 to this register in BCD code.

The DAY register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 01H.

Figure 7-9. Format of Day Count Register (DAY)

Address: FFF96H After reset: 01H R/W

Symbol	7	6	5	4	3	2	1	0
DAY	0	0	DAY20	DAY10	DAY8	DAY4	DAY2	DAY1

Caution When it reads or writes from/to the register while the counter is in operation (`RTCE = 1`), follow the procedures described in 7.4.3 Reading/writing real-time clock.

7.3.9 Week count register (WEEK)

The WEEK register is an 8-bit register that takes a value of 0 to 6 (decimal) and indicates the count value of weekdays. It counts up in synchronization with the day counter.

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of f_{RTC} later. Set a decimal value of 00 to 06 to this register in BCD code.

The WEEK register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-10. Format of Week Count Register (WEEK)

Address: FFF95H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
WEEK	0	0	0	0	0	WEEK4	WEEK2	WEEK1

Cautions 1. The value corresponding to the month count register (MONTH) or the day count register (DAY) is not stored in the week count register (WEEK) automatically. After reset release, set the week count register as follow.

Day	WEEK
Sunday	00H
Monday	01H
Tuesday	02H
Wednesday	03H
Thursday	04H
Friday	05H
Saturday	06H

2. When it reads or writes from/to the register while the counter is in operation ($RTCE = 1$), follow the procedures described in 7.4.3 Reading/writing real-time clock.

7.3.10 Month count register (MONTH)

The MONTH register is an 8-bit register that takes a value of 1 to 12 (decimal) and indicates the count value of months. It counts up when the day counter overflows.

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of f_{RTC} later. Even if the day count register overflows while this register is being written, this register ignores the overflow and is set to the value written. Set a decimal value of 01 to 12 to this register in BCD code.

The MONTH register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 01H.

Figure 7-11. Format of Month Count Register (MONTH)

Address: FFF97H After reset: 01H R/W

Symbol	7	6	5	4	3	2	1	0
MONTH	0	0	0	MONTH10	MONTH8	MONTH4	MONTH2	MONTH1

Caution When it reads or writes from/to the register while the counter is in operation (RTCE = 1), follow the procedures described in 7.4.3 Reading/writing real-time clock.

7.3.11 Year count register (YEAR)

The YEAR register is an 8-bit register that takes a value of 0 to 99 (decimal) and indicates the count value of years. It counts up when the month count register (MONTH) overflows.

Values 00, 04, 08, ..., 92, and 96 indicate a leap year.

When data is written to this register, it is written to a buffer and then to the counter up to two cycles of f_{RTC} later. Even if the MONTH register overflows while this register is being written, this register ignores the overflow and is set to the value written. Set a decimal value of 00 to 99 to this register in BCD code.

The YEAR register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-12. Format of Year Count Register (YEAR)

Address: FFF98H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
YEAR	YEAR80	YEAR40	YEAR20	YEAR10	YEAR8	YEAR4	YEAR2	YEAR1

Caution When it reads or writes from/to the register while the counter is in operation (RTCE = 1), follow the procedures described in 7.4.3 Reading/writing real-time clock.

7.3.12 Watch error correction register (SUBCUD)

This register is used to correct the watch with high accuracy when it is slow or fast by changing the value that overflows from the internal counter (16-bit) to the second count register (SEC) (reference value: 7FFFH).

The SUBCUD register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-13. Format of Watch Error Correction Register (SUBCUD)

Address: FFF99H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
SUBCUD	DEV	F6	F5	F4	F3	F2	F1	F0

DEV	Setting of watch error correction timing
0	Corrects watch error when the second digits are at 00, 20, or 40 (every 20 seconds).
1	Corrects watch error only when the second digits are at 00 (every 60 seconds).
Writing to the SUBCUD register at the following timing is prohibited.	
- When DEV = 0 is set: For a period of SEC = 00H, 20H, 40H - When DEV = 1 is set: For a period of SEC = 00H	

F6	Setting of watch error correction value
0	Increases by $\{(F5, F4, F3, F2, F1, F0) - 1\} \times 2$.
1	Decreases by $\{((F5, /F4, /F3, /F2, /F1, /F0) + 1) \times 2$.
When (F6, F5, F4, F3, F2, F1, F0) = (*, 0, 0, 0, 0, 0, *), the watch error is not corrected. * is 0 or 1. /F5 to /F0 are the inverted values of the corresponding bits (000011 when 111100).	
Range of correction value: (when F6 = 0) 2, 4, 6, 8, ..., 120, 122, 124 (when F6 = 1) -2, -4, -6, -8, ..., -120, -122, -124	

The range of value that can be corrected by using the watch error correction register (SUBCUD) is shown below.

	DEV = 0 (correction every 20 seconds)	DEV = 1 (correction every 60 seconds)
Correctable range	-189.2 ppm to 189.2 ppm	-63.1 ppm to 63.1 ppm
Maximum excludes quantization error	± 1.53 ppm	± 0.51 ppm
Minimum resolution	± 3.05 ppm	± 1.02 ppm

Remark If a correctable range is -63.1 ppm or lower and 63.1 ppm or higher, set 0 to DEV.

7.3.13 Alarm minute register (ALARMWM)

This register is used to set minutes of alarm.

The ALARMWM register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Caution Set a decimal value of 00 to 59 to this register in BCD code. If a value outside the range is set, the alarm is not detected.

Figure 7-14. Format of Alarm Minute Register (ALARMWM)

Address: FFF9AH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ALARMWM	0	WM40	WM20	WM10	WM8	WM4	WM2	WM1

7.3.14 Alarm hour register (ALARMWH)

This register is used to set hours of alarm.

The ALARMWH register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 12H.

However, the value of this register is 00H if the AMPM bit is set to 1 after reset.

Caution Set a decimal value of 00 to 23, 01 to 12, or 21 to 32 to this register in BCD code. If a value outside the range is set, the alarm is not detected.

Figure 7-15. Format of Alarm Hour Register (ALARMWH)

Address: FFF9BH After reset: 12H R/W

Symbol	7	6	5	4	3	2	1	0
ALARMWH	0	0	WH20	WH10	WH8	WH4	WH2	WH1

Caution Bit 5 (WH20) of the ALARMWH register indicates AM(0)/PM(1) if AMPM = 0 (if the 12-hour system is selected).

7.3.15 Alarm week register (ALARMWW)

This register is used to set date of alarm.

The ALARMWW register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 7-16. Format of Alarm Week Register (ALARMWW)

Address: FFF9CH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ALARMWW	0	WW6	WW5	WW4	WW3	WW2	WW1	WW0

Here is an example of setting the alarm.

Time of Alarm	Day							12-Hour Display				24-Hour Display			
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Hour 10	Hour 1	Minute 10	Minute 1	Hour 10	Hour 1	Minute 10	Minute 1
	W W 0	W W 1	W W 2	W W 3	W W 4	W W 5	W W 6								
Every day, 0:00 a.m.	1	1	1	1	1	1	1	1	2	0	0	0	0	0	0
Every day, 1:30 a.m.	1	1	1	1	1	1	1	0	1	3	0	0	1	3	0
Every day, 11:59 a.m.	1	1	1	1	1	1	1	1	1	5	9	1	1	5	9
Monday through Friday, 0:00 p.m.	0	1	1	1	1	1	0	3	2	0	0	1	2	0	0
Sunday, 1:30 p.m.	1	0	0	0	0	0	0	2	1	3	0	1	3	3	0
Monday, Wednesday, Friday, 11:59 p.m.	0	1	0	1	0	1	0	3	1	5	9	2	3	5	9

7.3.16 Port mode register 3 (PM3)

The PM3 register can be set by a 1-bit or 8-bit manipulation instruction.

Reset signal generation sets this register to FFH.

When using the port 3 as the RTC1HZ pin for output of 1 Hz, set the PM30 bit to 0.

Figure 7-17. Format of Port Mode Register 3 (PM3)

Address: FFF23H After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
PM3	1	1	1	1	1	1	PM31	PM30

7.3.17 Port register 3 (P3)

The P3 register can be set by a 1-bit or 8-bit manipulation instruction.

Reset signal generation sets this register to 00H.

When using the port 3 as 1-Hz output to the RTC1Hz pin, set the P30 bit to 0.

Figure 7-18. Format of Port Register 3 (P3)

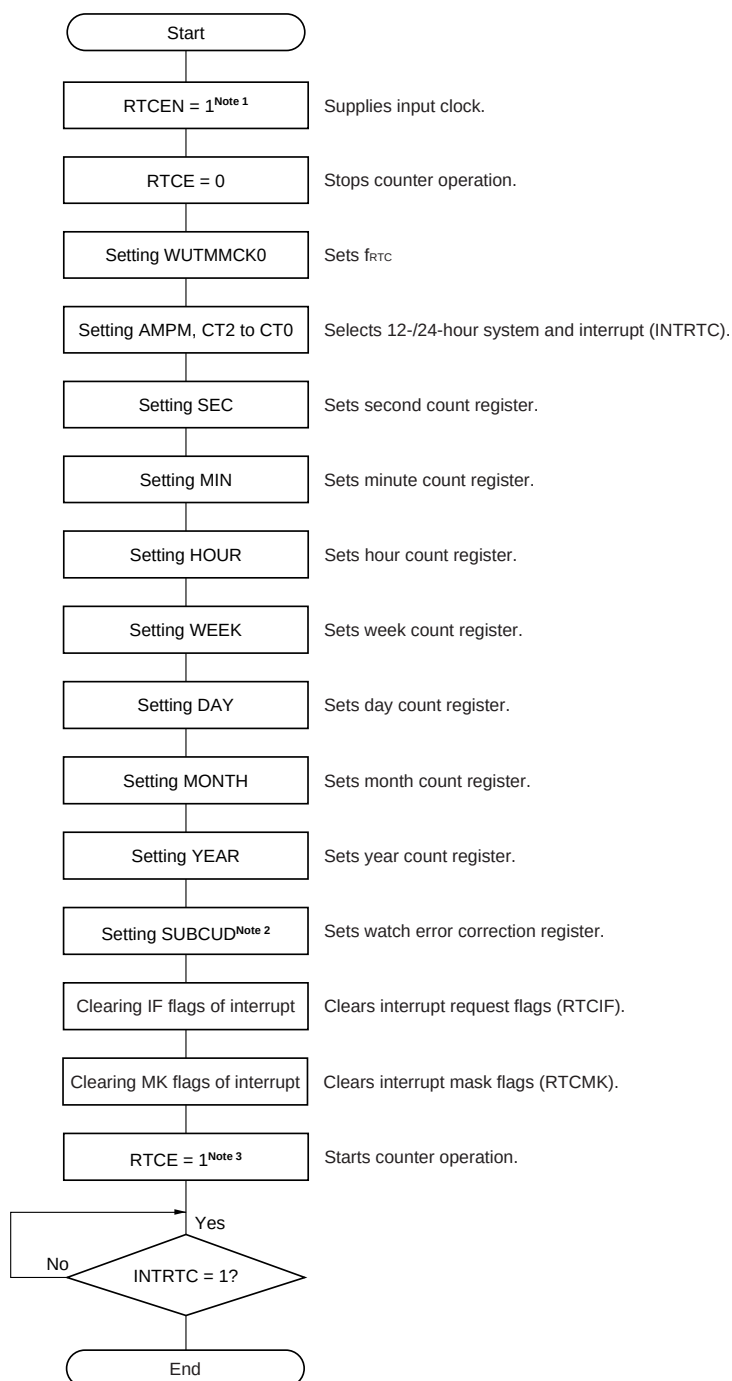
Address: FFF03H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
P3	0	0	0	0	0	0	P31	P30

7.4 Real-time Clock Operation

7.4.1 Starting operation of real-time clock

Figure 7-19. Procedure for Starting Operation of Real-time Clock



Notes 1. First set the $RTCEN$ bit to 1, while oscillation of the count clock (f_{RTC}) is stable.

2. Set up the $SUBCUD$ register only if the watch error must be corrected. For details about how to calculate the correction value, see **7.4.6 Example of watch error correction of real-time clock**.

3. Confirm the procedure described in **7.4.2 Shifting to HALT/STOP mode after starting operation** when shifting to HALT/STOP mode without waiting for $INTRTC = 1$ after $RTCE = 1$.

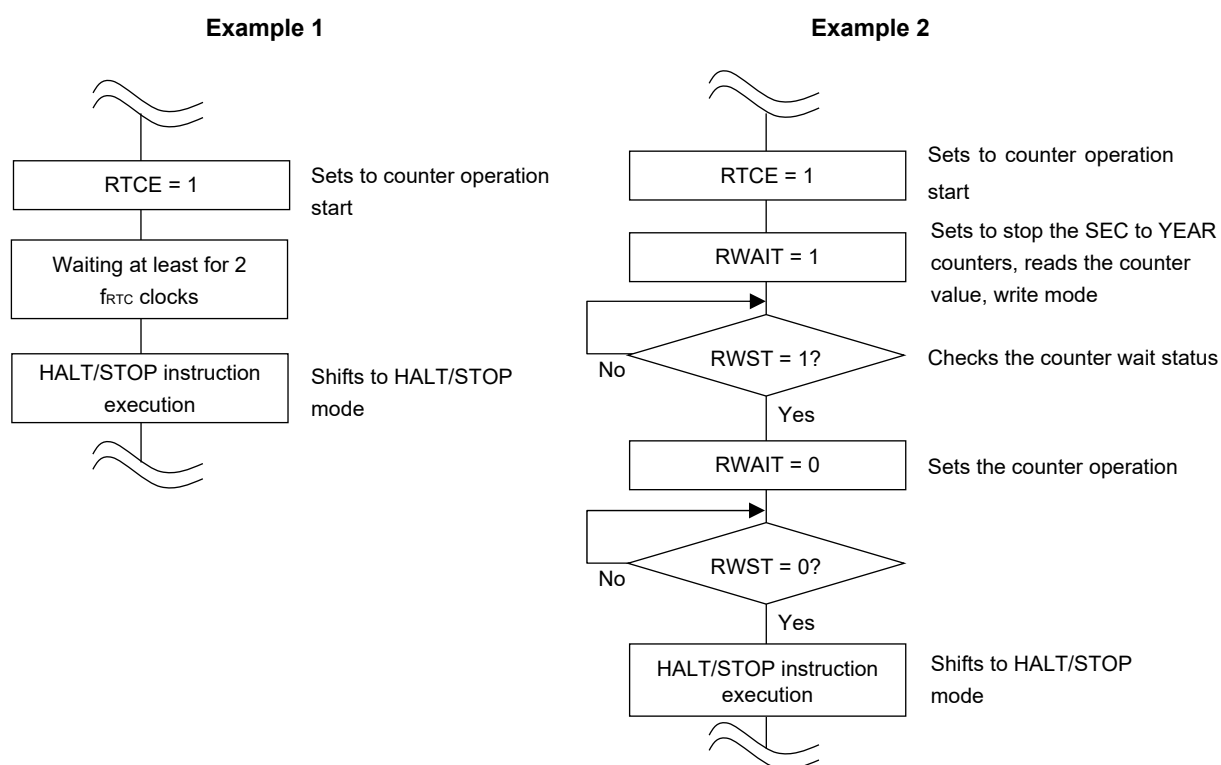
7.4.2 Shifting to HALT/STOP mode after starting operation

Perform one of the following processing when shifting to HALT/STOP mode immediately after setting the RTCE bit to 1.

However, after setting the RTCE bit to 1, this processing is not required when shifting to HALT/STOP mode after the INTRTC interrupt has occurred.

- Shifting to HALT/STOP mode when at least two count clocks (f_{RTC}) have elapsed after setting the RTCE bit to 1 (see **Figure 7-20, Example 1**).
- Checking by polling the RWST bit to become 1, after setting the RTCE bit to 1 and then setting the RWAIT bit to 1. Afterward, setting the RWAIT bit to 0 and shifting to HALT/STOP mode after checking again by polling that the RWST bit has become 0 (see **Figure 7-20, Example 2**).

Figure 7-20. Procedure for Shifting to HALT/STOP Mode After Setting RTCE bit to 1

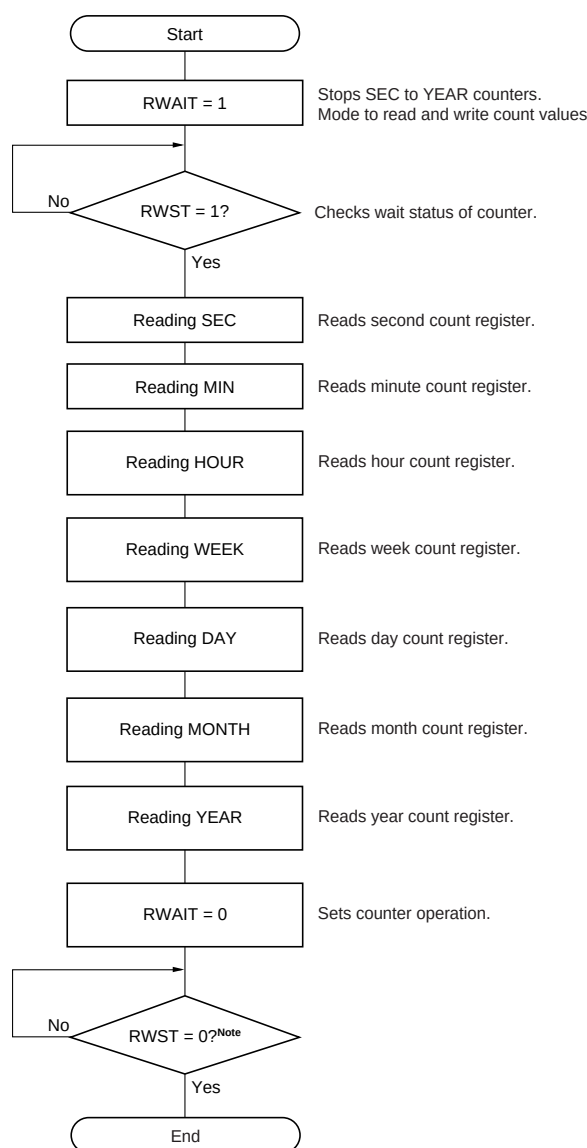


7.4.3 Reading/writing real-time clock

Read or write the counter after setting 1 to RWAIT first.

Set RWAIT to 0 after completion of reading or writing the counter.

Figure 7-21. Procedure for Reading Real-time Clock

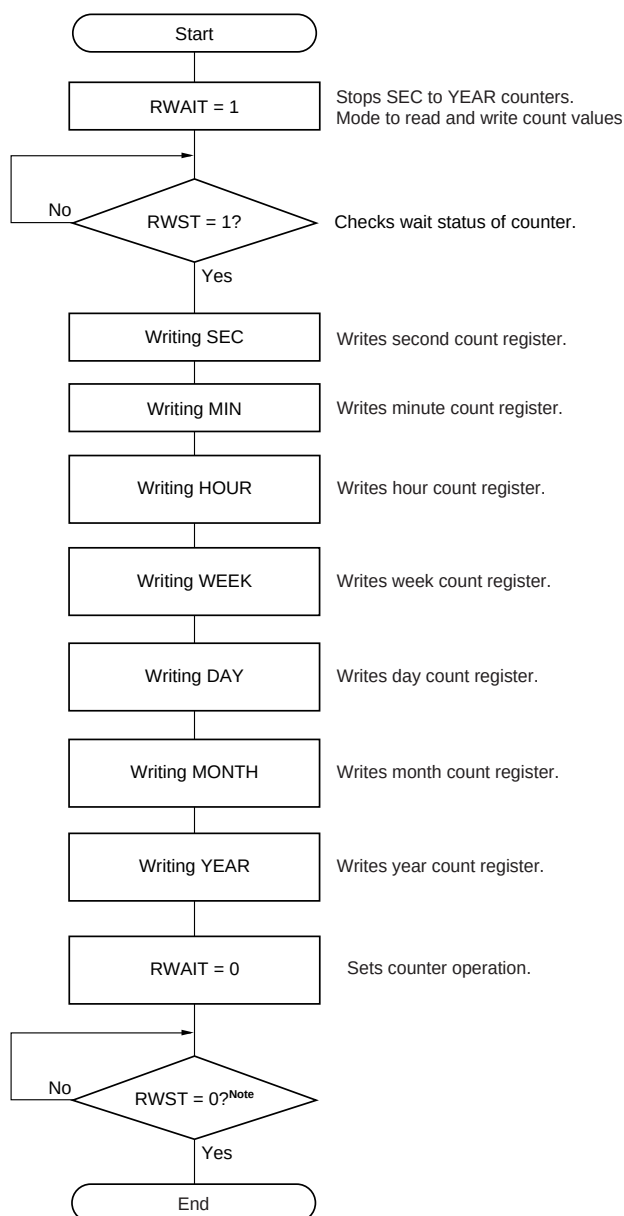


Note Be sure to confirm that RWST = 0 before setting STOP mode.

Caution Complete the series of process of setting the RWAIT bit to 1 to clearing the RWAIT bit to 0 within 1 second. When reading to the counter is required while generation of the alarm interrupt is enabled, first set the CT2 to CT0 bits to 010B (generating the constant-period interrupt once per 1 second). Then, complete the processing from setting the RWAIT bit to 1 to setting it to 0 before generation of the next constant-period interrupt.

Remark The second count register (SEC), minute count register (MIN), hour count register (HOUR), week count register (WEEK), day count register (DAY), month count register (MONTH), and year count register (YEAR) may be read in any sequence.
All the registers do not have to read and only some registers may be read.

Figure 7-22. Procedure for Writing Real-time Clock



Note Be sure to confirm that RWST = 0 before setting STOP mode.

- Cautions**
1. Complete the series of operations of setting the RWAIT bit to 1 to clearing the RWAIT bit to 0 within 1 second. When writing to the counter is required while generation of the alarm interrupt is enabled, first set the CT2 to CT0 bits to 010B (generating the constant-period interrupt once per 1 second). Then, complete the processing from setting the RWAIT bit to 1 to setting it to 0 before generation of the next constant-period interrupt.
 2. When changing the values of the SEC, MIN, HOUR, WEEK, DAY, MONTH, and YEAR register while the counter operates (RTCE = 1), rewrite the values of the MIN register after disabling interrupt servicing INTRTC by using the interrupt mask flag register. Furthermore, clear the WAFG, RIFG and RTCIF flags after rewriting the MIN register.

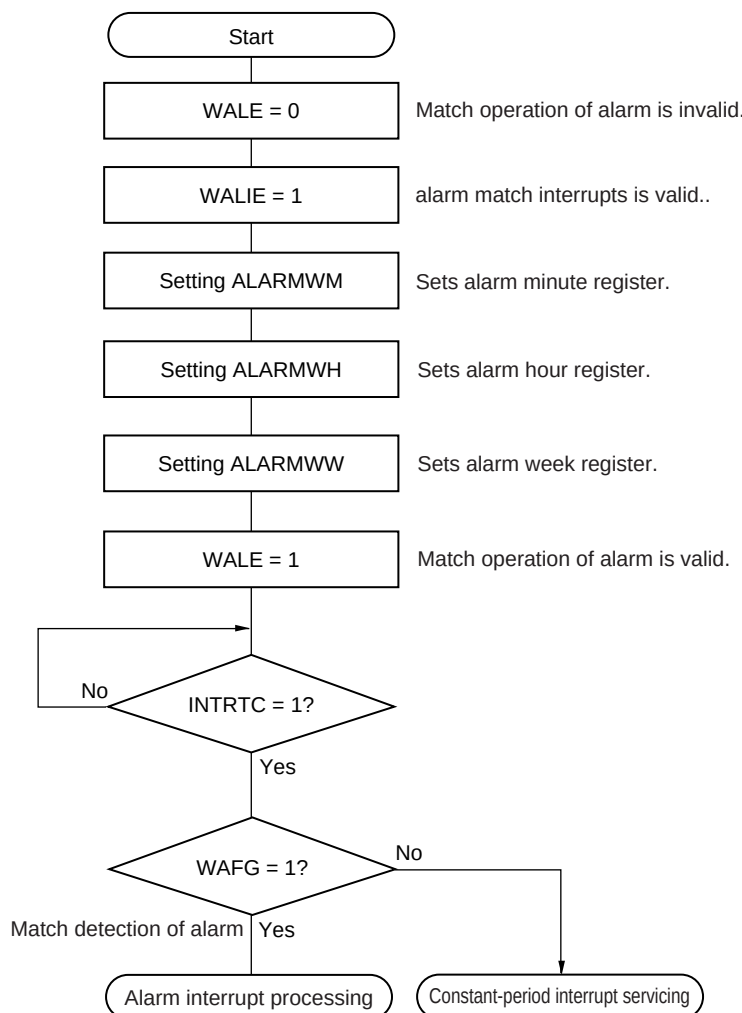
Remark The second count register (SEC), minute count register (MIN), hour count register (HOUR), week count register (WEEK), day count register (DAY), month count register (MONTH), and year count register (YEAR) may be written in any sequence.

All the registers do not have to be set and only some registers may be written.

7.4.4 Setting alarm of real-time clock

Set time of alarm after setting 0 to WALE (alarm operation invalid.) first.

Figure 7-23. Alarm processing Procedure

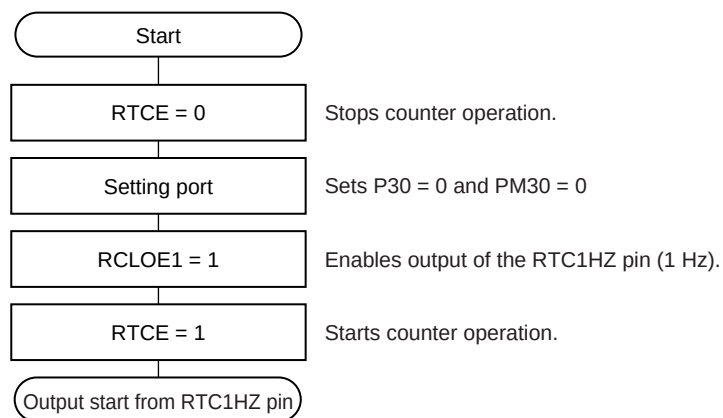


Remarks 1. The alarm week register (ALARMWW), alarm hour register (ALARMWH), and alarm week register (ALARMWW) may be written in any sequence.

- Fixed-cycle interrupts and alarm match interrupts use the same interrupt source (INTRTC). When using these two types of interrupts at the same time, which interrupt occurred can be judged by checking the fixed-cycle interrupt status flag (RIFG) and the alarm detection status flag (WAFG) upon INTRTC occurrence.

7.4.5 1 Hz output of real-time clock

Figure 7-24. 1 Hz Output Setting Procedure



- Cautions**
1. First set the `RTCEN` bit to 1, while oscillation of the count clock (f_{SUB}) is stable.
 2. 1 Hz output function of real-time clock is not available in the 25- and 32-pin products.

7.4.6 Example of watch error correction of real-time clock

The watch can be corrected with high accuracy when it is slow or fast, by setting a value to the watch error correction register.

Example of calculating the correction value

The correction value used when correcting the count value of the internal counter (16-bit) is calculated by using the following expression.

Set the DEV bit to 0 when the correction range is –63.1 ppm or less, or 63.1 ppm or more.

(When DEV = 0)

$$\text{Correction value}^{\text{Note}} = \text{Number of correction counts in 1 minute} \div 3 = (\text{Oscillation frequency} \div \text{Target frequency} - 1) \times 32768 \times 60 \div 3$$

(When DEV = 1)

$$\text{Correction value}^{\text{Note}} = \text{Number of correction counts in 1 minute} = (\text{Oscillation frequency} \div \text{Target frequency} - 1) \times 32768 \times 60$$

Note The correction value is the watch error correction value calculated by using bits 6 to 0 of the watch error correction register (SUBCUD).

(When F6 = 0) Correction value = $\{(F5, F4, F3, F2, F1, F0) - 1\} \times 2$

(When F6 = 1) Correction value = $-\{(/F5, /F4, /F3, /F2, /F1, /F0) + 1\} \times 2$

When (F6, F5, F4, F3, F2, F1, F0) is (*, 0, 0, 0, 0, 0, *), watch error correction is not performed. “*” is 0 or 1. /F5 to /F0 are bit-inverted values (000011 when 111100).

- Remarks**
1. The correction value is 2, 4, 6, 8, ... 120, 122, 124 or –2, –4, –6, –8, ... –120, –122, –124.
 2. The oscillation frequency is a value of the count clock (f_{RTC}).
It can be calculated from the output frequency of the RTC1HZ pin $\times$ 32768 when the watch error correction register is set to its initial value (00H).
 3. The target frequency is the frequency resulting after correction performed by using the watch error correction register.

Correction example 1

Example of correcting from 32772.3 Hz to 32768 Hz (32772.3 Hz – 131.2 ppm)

[Measuring the oscillation frequency]

The oscillation frequency^{Note} of each product is measured by outputting about 32.768 kHz from the PCLBUZ0 pin, or by outputting about 1 Hz from the RTC1HZ pin when the watch error correction register (SUBCUD) is set to its initial value (00H).

Note See **7.4.5 1 Hz output of real-time clock** for the setting procedure of the RTC1Hz output, and see **9.4 Operations of Clock Output/Buzzer Output Controller** for the setting procedure of outputting about 32 kHz from the PCLBUZ0 pin.

[Calculating the correction value]

(When the output frequency from the PCLBUZ0 pin is 32772.3 Hz)

Assume the target frequency to be 32768 Hz (32772.3 Hz–131.2 ppm) and DEV to be 0, because the correctable range of –131.2 ppm is –63.1 ppm or lower.

The expression for calculating the correction value when DEV is 0 is applied.

$$\begin{aligned}
 \text{Correction value} &= \text{Number of correction counts in 1 minute} \div 3 \\
 &= (\text{Oscillation frequency} \div \text{target frequency} - 1) \times 32768 \times 60 \div 3 \\
 &= (32772.3 \div 32768 - 1) \times 32768 \times 60 \div 3 \\
 &= 86
 \end{aligned}$$

[Calculating the values to be set to (F6 to F0)]

(When the correction value is 86)

If the correction value is 0 or larger (when slowing), assume F6 to be 0.

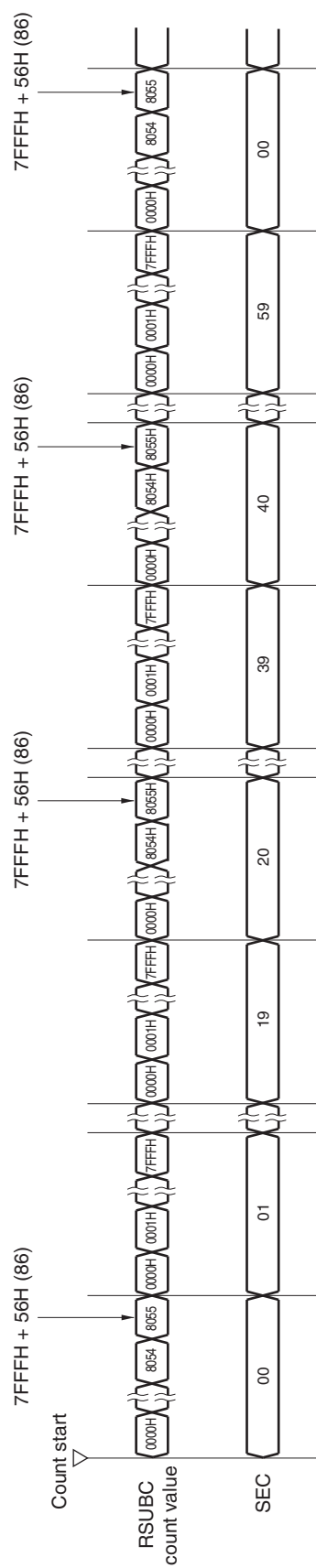
Calculate (F5, F4, F3, F2, F1, F0) from the correction value.

$$\begin{aligned}
 \{ (F5, F4, F3, F2, F1, F0) - 1 \} \times 2 &= 86 \\
 (F5, F4, F3, F2, F1, F0) &= 44 \\
 (F5, F4, F3, F2, F1, F0) &= (1, 0, 1, 1, 0, 0)
 \end{aligned}$$

Consequently, when correcting from 32772.3 Hz to 32768 Hz (32772.3 Hz – 131.2 ppm), setting the correction register such that DEV is 0 and the correction value is 86 (bits 6 to 0 of the SUBCUD register: 0101100) results in 32768 Hz (0 ppm).

Figure 7-25 shows the operation when (DEV, F6, F5, F4, F3, F2, F1, F0) is (0, 0, 1, 0, 1, 1, 0, 0).

Figure 7-25. Correction Operation when (DEV, F6, F5, F4, F3, F2, F1, F0) = (0, 0, 1, 0, 1, 1, 0, 0)



Correction example 2

Example of correcting from 32767.4 Hz to 32768 Hz (32767.4 Hz + 18.3 ppm)

[Measuring the oscillation frequency]

The oscillation frequency^{Note} of each product is measured by outputting about 1 Hz from the RTC1HZ pin when the watch error correction register (SUBCUD) is set to its initial value (00H).

Note See 7.4.5 1 Hz output of real-time clock for the setting procedure of outputting about 1 Hz from the RTC1HZ pin.

[Calculating the correction value]

(When the output frequency from the RTCCL pin is 0.9999817 Hz)

Oscillation frequency = $32768 \times 0.9999817 \approx 32767.4$ Hz

Assume the target frequency to be 32768 Hz (32767.4 Hz + 18.3 ppm) and DEV to be 1.

The expression for calculating the correction value when DEV is 1 is applied.

$$\begin{aligned} \text{Correction value} &= \text{Number of correction counts in 1 minute} \\ &= (\text{Oscillation frequency} \div \text{Target frequency} - 1) \times 32768 \times 60 \\ &= (32767.4 \div 32768 - 1) \times 32768 \times 60 \\ &= -36 \end{aligned}$$

[Calculating the values to be set to (F6 to F0)]

(When the correction value is -36)

If the correction value is 0 or less (when quickening), assume F6 to be 1.

Calculate (F5, F4, F3, F2, F1, F0) from the correction value.

$$\begin{aligned} -\{(\text{F5}, \text{F4}, \text{F3}, \text{F2}, \text{F1}, \text{F0}) - 1\} \times 2 &= -36 \\ (\text{F5}, \text{F4}, \text{F3}, \text{F2}, \text{F1}, \text{F0}) &= 17 \\ (\text{F5}, \text{F4}, \text{F3}, \text{F2}, \text{F1}, \text{F0}) &= (0, 1, 0, 0, 0, 1) \\ (\text{F5}, \text{F4}, \text{F3}, \text{F2}, \text{F1}, \text{F0}) &= (1, 0, 1, 1, 1, 0) \end{aligned}$$

Consequently, when correcting from 32767.4 Hz to 32768 Hz (32767.4 Hz + 18.3 ppm), setting the correction register such that DEV is 1 and the correction value is -36 (bits 6 to 0 of the SUBCUD register: 1101110) results in 32768 Hz (0 ppm).

Figure 7-26 shows the operation when (DEV, F6, F5, F4, F3, F2, F1, F0) is (1, 1, 1, 0, 1, 1, 1, 0).

CHAPTER 8 12-BIT INTERVAL TIMER

8.1 Functions of 12-bit Interval Timer

An interrupt (INTIT) is generated at any previously specified time interval. It can be utilized for wakeup from STOP mode and triggering an A/D converter's SNOOZE mode.

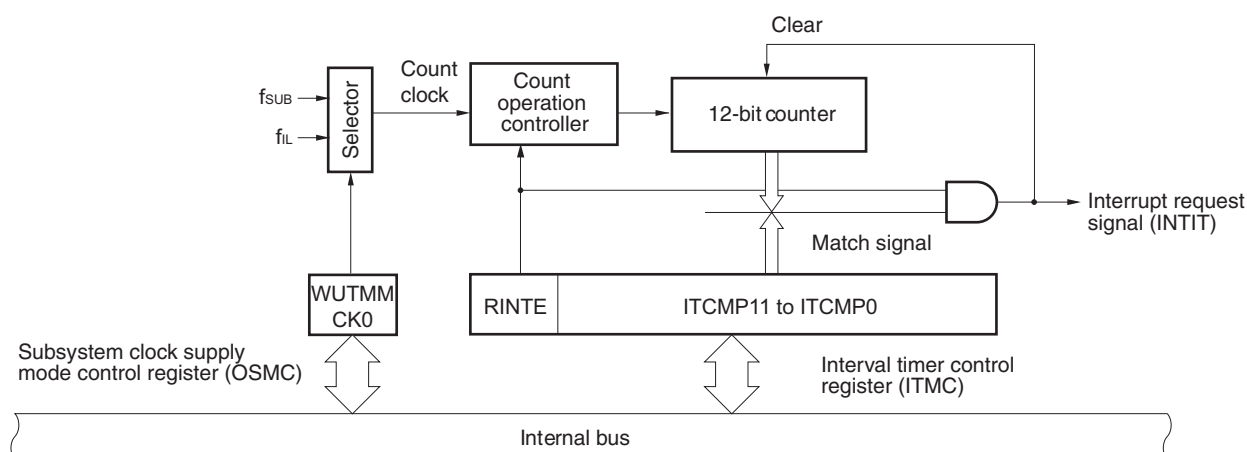
8.2 Configuration of 12-bit Interval Timer

The interval timer includes the following hardware.

Table 8-1. Configuration of 12-bit Interval Timer

Item	Configuration
Counter	12-bit counter
Control registers	Peripheral enable register 0 (PER0)
	Subsystem clock supply mode control register (OSMC)
	Interval timer control register (ITMC)

Figure 8-1. Block Diagram of 12-bit Interval Timer



Caution The subsystem clock (f_{SUB}) is selectable as a count clock in the 48- and 64-pin products.

8.3 Registers Controlling 12-bit Interval Timer

The 12-bit interval timer is controlled by the following registers.

- Peripheral enable register 0 (PER0)
- Subsystem clock supply mode control register (OSMC)
- Interval timer control register (ITMC)

8.3.1 Peripheral enable register 0 (PER0)

This register is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

When the 12-bit interval timer is used, be sure to set bit 7 (RTCEN) of this register to 1.

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 8-2. Format of Peripheral Enable Register 0 (PER0)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN ^{Note}	SAU0EN	0	TAU0EN

RTCEN	Control of real-time clock (RTC) and 12-bit interval timer input clock supply
0	Stops clock supply. • SFR used by the real-time clock (RTC) and 12-bit interval timer cannot be written. • The real-time clock (RTC) and 12-bit interval timer are in the reset status.
1	Enables clock supply. • SFR used by the real-time clock (RTC) and 12-bit interval timer can be read and written.

Note 32, 48, and 64-pin products only.

- Cautions**
1. When using the 12-bit interval timer, be sure to first set the RTCEN bit to 1 and then set the interval timer control register (ITMC), while oscillation of the count clock is stable. If RTCEN = 0, writing to the registers controlling the 12-bit interval timer is ignored, and, even if the register is read, only the default value is read (except the subsystem clock supply mode control register (OSMC)).
 2. Clock supply to peripheral functions other than the real-time clock and 12-bit interval timer can be stopped in STOP mode or HALT mode when the subsystem clock is used, by setting the RTCLPC bit of the subsystem clock supply mode control register (OSMC) to 1.
 3. Be sure to clear the following bits to 0.
 - 25-pin products: bits 1, 3, 6
 - 32, 48, 64-pin products: bits 1, 6

8.3.2 Subsystem clock supply mode control register (OSMC)

The WUTMMCK0 bit can be used to select the 12-bit interval timer and real-time clock operation clock.

In addition, by stopping clock functions that are unnecessary, the RTCLPC bit can be used to reduce power consumption. For details about setting the RTCLPC bit, see **CHAPTER 5 CLOCK GENERATOR**.

The OSMC register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 8-3. Format of Subsystem Clock Supply Mode Control Register (OSMC)

Address: F00F3H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
OSMC	RTCLPC	0	0	WUTMMCK0	0	0	0	0

WUTMMCK0	Selection of operation clock for real-time clock and 12-bit interval timer.
0	Subsystem clock (f_{SUB})
1	Low-speed on-chip oscillator clock (f_{IL})

8.3.3 Interval timer control register (ITMC)

This register is used to set up the starting and stopping of the 12-bit interval timer operation and to specify the timer compare value.

The ITMC register can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears this register to 0FFFH.

Figure 8-4. Format of 12-bit Interval Timer Control Register (ITMC)

Address: FFF90H After reset: 0FFFH R/W

Symbol	15	14	13	12	11 to 0
ITMC	RINTE	0	0	0	ITCMP11 to ITCMP0

RINTE	12-bit interval timer operation control
0	Count operation stopped (count clear)
1	Count operation started

ITCMP11 to ITCMP0	Specification of the 12-bit interval timer compare value
001H	These bits generate an interrupt at the fixed cycle (count clock cycles x (ITCMP setting + 1)).
.	
.	
FFFH	Setting prohibit
000H	

Example interrupt cycles when 001H or FFFH is specified for ITCMP11 to ITCMP0	
- ITCMP11 to ITCMP0 = 001H, count clock: when $f_{SUB} = 32.768 \text{ kHz}$ $1/32.768 \text{ [kHz]} \times (1 + 1) = 0.06103515625 \text{ [ms]} \cong 61.03 \text{ [}\mu\text{s]}$ - ITCMP11 to ITCMP0 = FFFH, count clock: when $f_{SUB} = 32.768 \text{ kHz}$ $1/32.768 \text{ [kHz]} \times (4095 + 1) = 125 \text{ [ms]}$	

- Cautions**
- Before changing the RINTE bit from 1 to 0, use the interrupt mask flag register to disable the INTIT interrupt servicing. When the operation starts (from 0 to 1) again, clear the ITIF flag, and then enable the interrupt servicing.
 - The value read from the RINTE bit is applied one count clock cycle after setting the RINTE bit.
 - When setting the RINTE bit to start operation of the counter after returning from a standby mode and then shifting to a standby mode again, either confirm that the value written to the RINTE bit has been applied, or make sure that at least one count clock cycle elapses between returning from a standby mode and shifting to a standby mode again.
 - Only change the setting of the ITCMP11 to ITCMP0 bits when RINTE = 0.
However, it is possible to change the settings of the ITCMP11 to ITCMP0 bits at the same time as when changing RINTE from 0 to 1 or 1 to 0.

8.4 12-bit Interval Timer Operation

8.4.1 12-bit interval timer operation timing

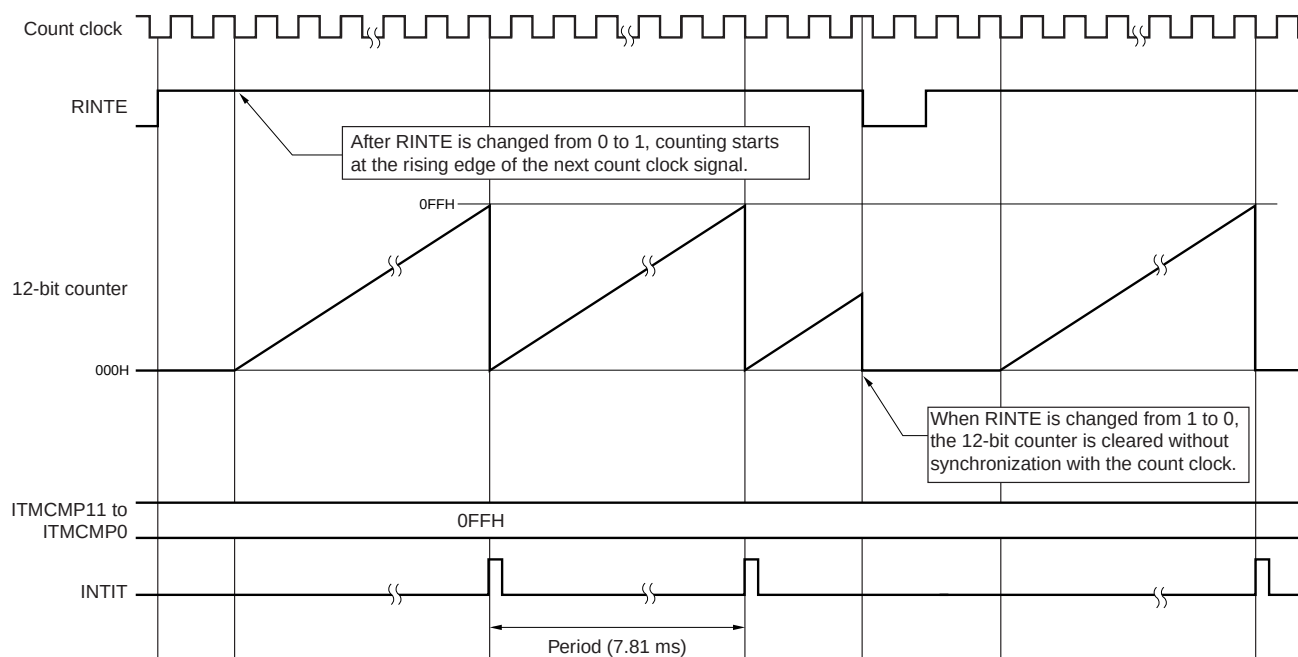
The count value specified for the ITCMP11 to ITCMP0 bits is used as an interval to operate as a 12-bit interval timer that repeatedly generates interrupt requests (INTIT).

When the RINTE bit is set to 1, the 12-bit counter starts counting.

When the 12-bit counter value matches the value specified for the ITCMP11 to ITCMP0 bits, the 12-bit counter value is cleared to 0, counting continues, and an interrupt request signal (INTIT) is generated at the same time.

The basic operation of the 12-bit interval timer is as follows.

Figure 8-5. 12-bit Interval Timer Operation Timing (ITCMP11 to ITCMP0 = 0FFH, count clock: $f_{SUB} = 32.768$ kHz)

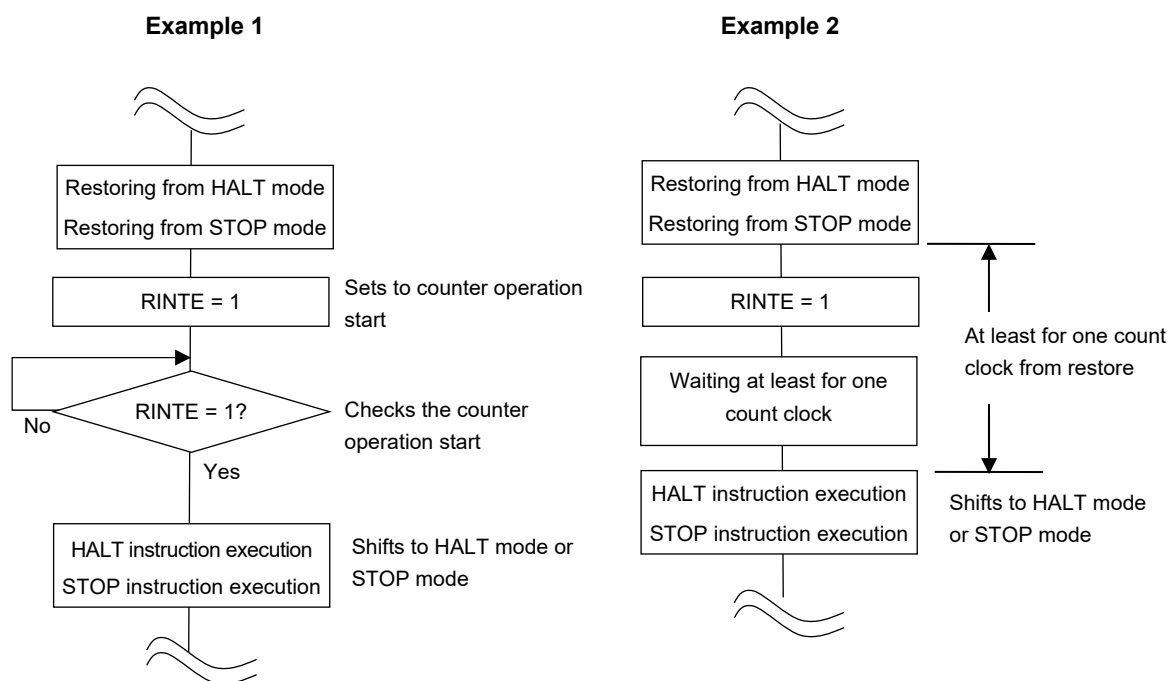


8.4.2 Starting counter operation after returning from HALT or STOP mode and then shifting to HALT or STOP mode again

When setting the RINTE bit to 1 to start operation of the counter after returning from the HALT or STOP mode and then shifting to the HALT or STOP mode again, either confirm that the value written to the RINTE bit (1) has been applied, or make sure that at least one count clock cycle elapses between returning from HALT or STOP mode and shifting to HALT or STOP mode again.

- After setting RINTE to 1, confirm that the RINTE bit value is actually 1 by polling the bit, and then shift to the HALT or STOP mode (see **Example 1** in **Figure 8-6**).
- After setting RINTE to 1, wait for at least one cycle of the count clock to elapse before shifting to the HALT or STOP mode (see **Example 2** in **Figure 8-6**).

Figure 8-6. Shifting to HALT or STOP Mode after Setting RINTE to 1



CHAPTER 9 CLOCK OUTPUT/BUZZER OUTPUT CONTROLLER

The number of output pins of the clock output and buzzer output controllers differs, depending on the product.

Output pin	25-pin	32, 48, 64-pin
PCLBUZ0	√	√
PCLBUZ1	—	√

Caution Most of the following descriptions in this chapter use the 64-pin as an example.

9.1 Functions of Clock Output/Buzzer Output Controller

The clock output controller is intended for clock output for supply to peripheral ICs. Buzzer output is a function to output a square wave of buzzer frequency.

One pin can be used to output a clock or buzzer sound.

Two output pins, PCLBUZ0 and PCLBUZ1, are available.

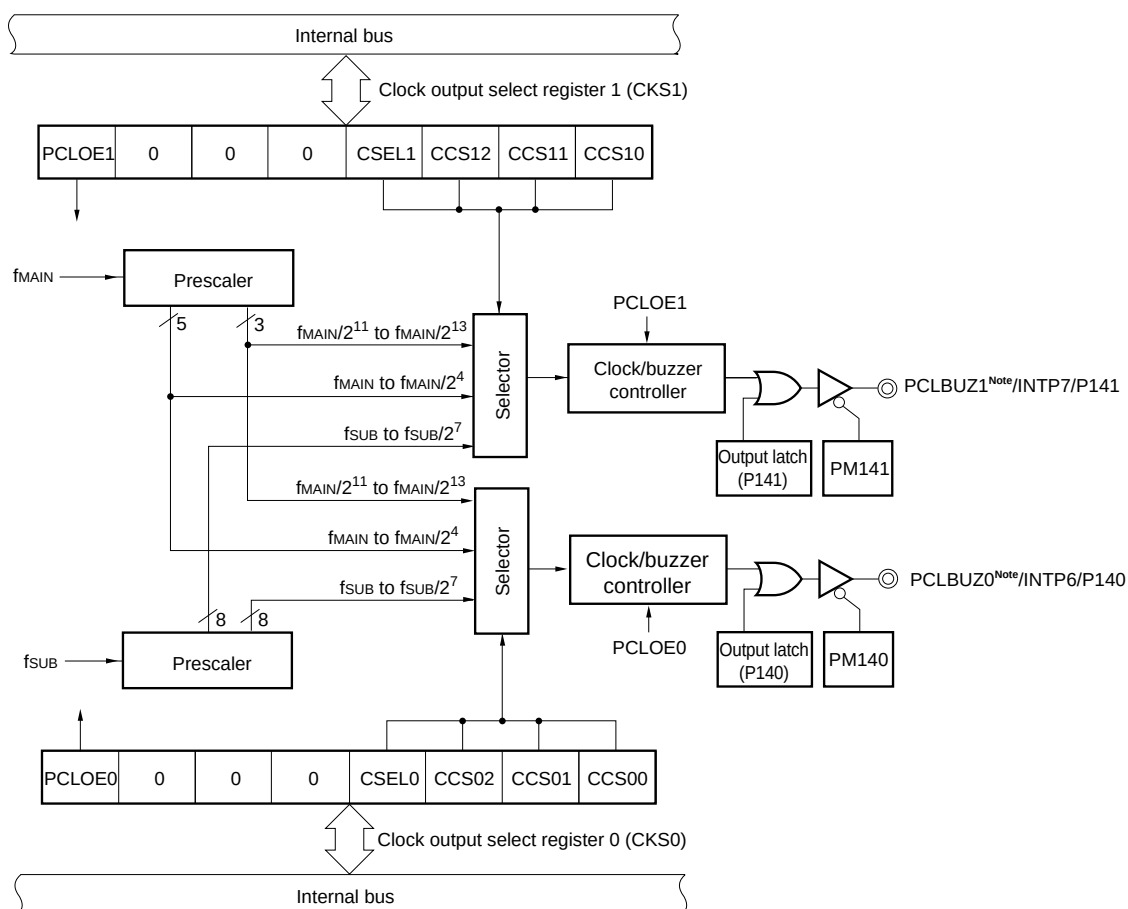
The PCLBUZn pin outputs a clock selected by clock output select register n (CKSn).

Figure 9-1 shows the block diagram of clock output/buzzer output controller.

Caution It is not possible to output the subsystem clock (f_{SUB}) from the PCLBUZn pin while the RTCLPC bit of the subsystem clock supply mode control register (OSMC), which controls the supply of the subsystem clock, is set to 1 and moreover while HALT mode is set with the subsystem clock (f_{SUB}) selected as CPU clock.

Remark n = 0, 1

Figure 9-1. Block Diagram of Clock Output/Buzzer Output Controller



Note For output frequencies available from PCLBUZ0 and PCLBUZ1, see **29.4** or **30.4 AC Characteristics**.

Remark The clock output/buzzer output pins in above diagram shows the information of 64-pins products.

9.2 Configuration of Clock Output/Buzzer Output Controller

The clock output/buzzer output controller includes the following hardware.

Table 9-1. Configuration of Clock Output/Buzzer Output Controller

Item	Configuration
Control registers	Clock output select registers n (CKSn) Port mode register 14 (PM14) Port register 14 (P14)

9.3 Registers Controlling Clock Output/Buzzer Output Controller

The following two registers are used to control the clock output/buzzer output controller.

- Clock output select registers n (CKSn)
- Port mode register 14 (PM14)
- Port register 14 (P14)

9.3.1 Clock output select registers n (CKSn)

These registers set output enable/disable for clock output or for the buzzer frequency output pin (PCLBUZn), and set the output clock.

Select the clock to be output from the PCLBUZn pin by using the CKSn register.

The CKSn register are set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears these registers to 00H.

Figure 9-2. Format of Clock Output Select Register n (CKSn)

Address: FFFA5H (CKS0), FFFA6H (CKS1) After reset: 00H R/W

Symbol	<7>	6	5	4	3	2	1	0
CKSn	PCLOEn	0	0	0	CSELn	CCSn2	CCSn1	CCSn0

PCLOEn	PCLBUZn pin output enable/disable specification
0	Output disable (default)
1	Output enable

CSELn	CCSn2	CCSn1	CCSn0		PCLBUZn pin output clock selection			
					f _{MAIN} = 5 MHz	f _{MAIN} = 10 MHz	f _{MAIN} = 20 MHz	f _{MAIN} = 32 MHz
0	0	0	0	f _{MAIN}	5 MHz	Setting prohibited ^{Note} _e	Setting prohibited ^{Note} _e	Setting prohibited ^{Note} _e
0	0	0	1	f _{MAIN} /2	2.5 MHz	5 MHz	Setting prohibited ^{Note} _e	Setting prohibited ^{Note} _e
0	0	1	0	f _{MAIN} /2 ²	1.25 MHz	2.5 MHz	5 MHz	8 MHz ^{Note}
0	0	1	1	f _{MAIN} /2 ³	625 kHz	1.25 MHz	2.5 MHz	4 MHz
0	1	0	0	f _{MAIN} /2 ⁴	312.5 kHz	625 kHz	1.25 MHz	2 MHz
0	1	0	1	f _{MAIN} /2 ¹¹	2.44 kHz	4.88 kHz	9.76 kHz	15.63 kHz
0	1	1	0	f _{MAIN} /2 ¹²	1.22 kHz	2.44 kHz	4.88 kHz	7.81 kHz
0	1	1	1	f _{MAIN} /2 ¹³	610 Hz	1.22 kHz	2.44 kHz	3.91 kHz
1	0	0	0	f _{SUB}	32.768 kHz			
1	0	0	1	f _{SUB} /2	16.384 kHz			
1	0	1	0	f _{SUB} /2 ²	8.192 kHz			
1	0	1	1	f _{SUB} /2 ³	4.096 kHz			
1	1	0	0	f _{SUB} /2 ⁴	2.048 kHz			
1	1	0	1	f _{SUB} /2 ⁵	1.024 kHz			
1	1	1	0	f _{SUB} /2 ⁶	512 Hz			
1	1	1	1	f _{SUB} /2 ⁷	256 Hz			

Note Use the output clock within a range of 8 MHz. Furthermore, when using the output clock at $2.7\text{ V} \leq V_{DD} < 4.0\text{ V}$, can be use it within 8 MHz only. See 29.4 or 30.4 AC Characteristics for details.

- Cautions**
1. Change the output clock after disabling clock output (PCLOEn = 0).
 2. To shift to STOP mode when the main system clock is selected (CSELn = 0), set PCLOEn = 0 before executing the STOP instruction. When the subsystem clock is selected (CSELn = 1), PCLOEn = 1 can be set because the clock can be output while the RTCLPC bit of the subsystem clock supply mode control register (OSMC) is set to 0 and moreover while STOP mode is set.
 3. It is not possible to output the subsystem clock (f_{SUB}) from the PCLBUZn pin while the RTCLPC bit of the subsystem clock supply mode control register (OSMC), which controls the supply of the subsystem clock, is set to 1 and moreover while HALT mode is set with the subsystem clock (f_{SUB}) selected as CPU clock.

Remarks 1. n = 0, 1

2. f_{MAIN}: Main system clock frequency
- f_{SUB}: Subsystem clock frequency

9.3.2 Registers controlling port functions of pins to be used for clock or buzzer output

Using a port pin for clock or buzzer output requires setting of the registers that control the port functions multiplexed on the target pin (port mode register (PMxx), port register (Pxx)). For details, see **4.3.1 Port mode registers (PMxx)** and **4.3.2 Port registers (Pxx)**.

Specifically, using a port pin with a multiplexed clock or buzzer output function (e.g. P140/INTP6/PCLBUZ0, P141/INTP7/PCLBUZ1) for clock or buzzer output, requires setting the corresponding bits in the port mode register (PMxx) and port register (Pxx) to 0.

Example: When P140/INTP6/PCLBUZ0 is to be used for clock or buzzer output

Set the PM140 bit of port mode register 14 to 0.

Set the P140 bit of port register 14 to 0.

9.4 Operations of Clock Output/Buzzer Output Controller

One pin can be used to output a clock or buzzer sound.

The PCLBUZ0 pin outputs a clock/buzzer selected by the clock output select register 0 (CKS0).

The PCLBUZ1 pin outputs a clock/buzzer selected by the clock output select register 1 (CKS1).

9.4.1 Operation as output pin

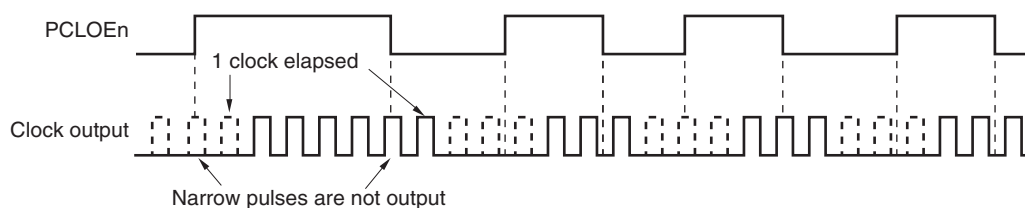
The PCLBUZn pin is output as the following procedure.

- <1> Set 0 in the bit of the port mode register (PMxx) and port register (Pxx) which correspond to the port which has a pin used as the PCLBUZn pin.
- <2> Select the output frequency with bits 0 to 3 (CCSn0 to CCSn2, CSELn) of the clock output select register (CKSn) of the PCLBUZn pin (output in disabled status).
- <3> Set bit 7 (PCLOEn) of the CKSn register to 1 to enable clock/buzzer output.

Remarks 1. The controller used for outputting the clock starts or stops outputting the clock one clock after enabling or disabling clock output (PCLOEn bit) is switched. At this time, pulses with a narrow width are not output. Figure 9-3 shows enabling or stopping output using the PCLOEn bit and the timing of outputting the clock.

2. n = 0, 1

Figure 9-3. Timing of Outputting Clock from PCLBUZn Pin



9.5 Cautions of Clock Output/Buzzer Output Controller

When the main system clock is selected for the PCLBUZn output (CSEL = 0), if STOP or HALT mode is entered within 1.5 clock cycles output from the PCLBUZn pin after the output is disabled (PCLOEn = 0), the PCLBUZn output width becomes shorter.

CHAPTER 10 WATCHDOG TIMER

10.1 Functions of Watchdog Timer

The counting operation of the watchdog timer is set by the option byte (000C0H).

The watchdog timer operates on the low-speed on-chip oscillator clock (f_{IL}).

The watchdog timer is used to detect an inadvertent program loop. If a program loop is detected, an internal reset signal is generated.

Program loop is detected in the following cases.

- If the watchdog timer counter overflows
- If a 1-bit manipulation instruction is executed on the watchdog timer enable register (WDTE)
- If data other than "ACH" is written to the WDTE register
- If data is written to the WDTE register during a window close period

When a reset occurs due to the watchdog timer, bit 4 (WDTRF) of the reset control flag register (RESF) is set to 1. For details of the RESF register, see **CHAPTER 19 RESET FUNCTION**.

When $75\% + 1/2/f_{IL}$ of the overflow time is reached, an interval interrupt can be generated.

10.2 Configuration of Watchdog Timer

The watchdog timer includes the following hardware.

Table 10-1. Configuration of Watchdog Timer

Item	Configuration
Counter	Internal counter (17 bits)
Control register	Watchdog timer enable register (WDTE)

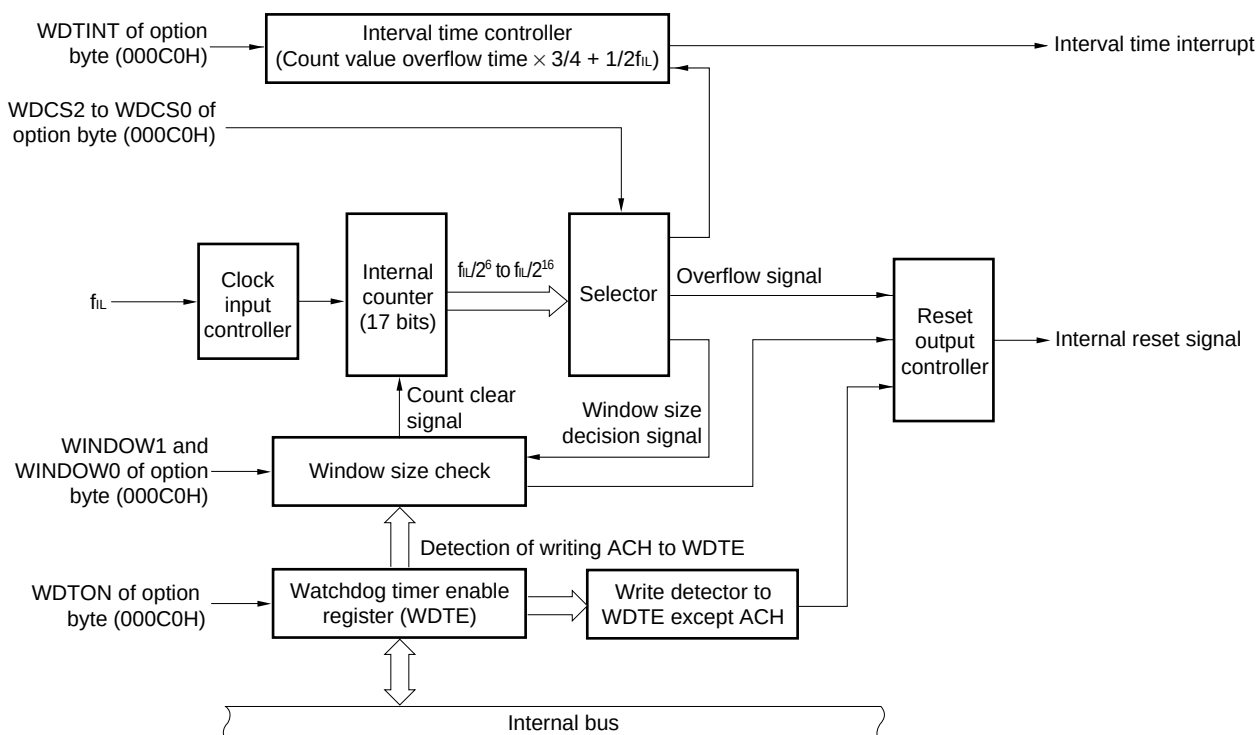
How the counter operation is controlled, overflow time, window open period, and interval interrupt are set by the option byte.

Table 10-2. Setting of Option Bytes and Watchdog Timer

Setting of Watchdog Timer	Option Byte (000C0H)
Watchdog timer interval interrupt	Bit 7 (WDTINT)
Window open period	Bits 6 and 5 (WINDOW1, WINDOW0)
Controlling counter operation of watchdog timer	Bit 4 (WDTON)
Overflow time of watchdog timer	Bits 3 to 1 (WDCS2 to WDCS0)
Controlling counter operation of watchdog timer (in HALT/STOP mode)	Bit 0 (WDSTBYON)

Remark For the option byte, see **CHAPTER 24 OPTION BYTE**.

Figure 10-1. Block Diagram of Watchdog Timer



Remark f_{IL} : Low-speed on-chip oscillator clock

10.3 Register Controlling Watchdog Timer

The watchdog timer is controlled by the watchdog timer enable register (WDTE).

10.3.1 Watchdog timer enable register (WDTE)

Writing “ACH” to the WDTE register clears the watchdog timer counter and starts counting again.

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

Reset signal generation sets this register to 9AH or 1AH^{Note}.

Figure 10-2. Format of Watchdog Timer Enable Register (WDTE)

Address: FFFABH	After reset: 9AH/1AH ^{Note}	R/W						
Symbol	7	6	5	4	3	2	1	0
WDTE								

Note The WDTE register reset value differs depending on the WDTON bit setting value of the option byte (000C0H). To operate watchdog timer, set the WDTON bit to 1.

WDTON Bit Setting Value	WDTE Register Reset Value
0 (watchdog timer count operation disabled)	1AH
1 (watchdog timer count operation enabled)	9AH

- Cautions**
1. If a value other than “ACH” is written to the WDTE register, an internal reset signal is generated.
 2. If a 1-bit memory manipulation instruction is executed for the WDTE register, an internal reset signal is generated.
 3. The value read from the WDTE register is 9AH/1AH (this differs from the written value (ACH)).

10.4 Operation of Watchdog Timer

10.4.1 Controlling operation of watchdog timer

- When the watchdog timer is used, its operation is specified by the option byte (000C0H).
 - Enable counting operation of the watchdog timer by setting bit 4 (WDTON) of the option byte (000C0H) to 1 (the counter starts operating after a reset release) (for details, see **CHAPTER 24**).

WDTON	Watchdog Timer Counter
0	Counter operation disabled (counting stopped after reset)
1	Counter operation enabled (counting started after reset)

- Set an overflow time by using bits 3 to 1 (WDCS2 to WDCS0) of the option byte (000C0H) (for details, see **10.4.2** and **CHAPTER 24**).
 - Set a window open period by using bits 6 and 5 (WINDOW1 and WINDOW0) of the option byte (000C0H) (for details, see **10.4.3** and **CHAPTER 24**).
- After a reset release, the watchdog timer starts counting.
 - By writing "ACH" to the watchdog timer enable register (WDTE) after the watchdog timer starts counting and before the overflow time set by the option byte, the watchdog timer is cleared and starts counting again.
 - After that, write the WDTE register the second time or later after a reset release during the window open period. If the WDTE register is written during a window close period, an internal reset signal is generated.
 - If the overflow time expires without "ACH" written to the WDTE register, an internal reset signal is generated. An internal reset signal is generated in the following cases.
 - If a 1-bit manipulation instruction is executed on the WDTE register
 - If data other than "ACH" is written to the WDTE register

- Cautions**
- When data is written to the watchdog timer enable register (WDTE) for the first time after reset release, the watchdog timer is cleared in any timing regardless of the window open time, as long as the register is written before the overflow time, and the watchdog timer starts counting again.
 - After "ACH" is written to the WDTE register, an error of up to 2 clocks (f_{IL}) may occur before the watchdog timer is cleared.
 - The watchdog timer can be cleared immediately before the count value overflows.

Cautions 4. The operation of the watchdog timer in the HALT, STOP, and SNOOZE modes differs as follows depending on the set value of bit 0 (WDSTBYON) of the option byte (000C0H).

	WDSTBYON = 0	WDSTBYON = 1
In HALT mode	Watchdog timer operation stops.	Watchdog timer operation continues.
In STOP mode		
In SNOOZE mode		

If WDSTBYON = 0, the watchdog timer resumes counting after the HALT or STOP mode is released. At this time, the counter is cleared to 0 and counting starts.

When operating with the X1 oscillation clock after releasing the STOP mode, the CPU starts operating after the oscillation stabilization time has elapsed.

Therefore, if the period between the STOP mode release and the watchdog timer overflow is short, an overflow occurs during the oscillation stabilization time, causing a reset.

Consequently, set the overflow time in consideration of the oscillation stabilization time when operating with the X1 oscillation clock and when the watchdog timer is to be cleared after the STOP mode release by an interval interrupt.

10.4.2 Setting overflow time of watchdog timer

Set the overflow time of the watchdog timer by using bits 3 to 1 (WDCS2 to WDCS0) of the option byte (000C0H).

If an overflow occurs, an internal reset signal is generated. The present count is cleared and the watchdog timer starts counting again by writing "ACH" to the watchdog timer enable register (WDTE) during the window open period before the overflow time.

The following overflow times can be set.

Table 10-3. Setting of Overflow Time of Watchdog Timer

WDCS2	WDCS1	WDCS0	Overflow Time of Watchdog Timer ($f_{IL} = 17.25 \text{ kHz (MAX.)}$)
0	0	0	$2^6/f_{IL}$ (3.71 ms)
0	0	1	$2^7/f_{IL}$ (7.42 ms)
0	1	0	$2^8/f_{IL}$ (14.84 ms)
0	1	1	$2^9/f_{IL}$ (29.68 ms)
1	0	0	$2^{11}/f_{IL}$ (118.72 ms)
1	0	1	$2^{13}/f_{IL}$ (474.89 ms) ^{Note}
1	1	0	$2^{14}/f_{IL}$ (949.79 ms) ^{Note}
1	1	1	$2^{16}/f_{IL}$ (3799.18 ms) ^{Note}

Note Using the watchdog timer under the following conditions may lead to the generation of an interval interrupt (INTWDTI) after one cycle of the watchdog timer clock once the watchdog timer counter has been cleared.

Usage conditions that may lead to the generation of an interval interrupt:

- The overflow time of the watchdog timer is set to $2^{13}/f_{IL}$, $2^{14}/f_{IL}$, or $2^{16}/f_{IL}$.
- The interval interrupt is in use (the setting of the WDTINT bit of the relevant option byte is 1).
- ACH is written to the WDTE register (FFFABH) when the watchdog timer counter has reached or exceeded 75% of the overflow time.

This interrupt can be masked by clearing the watchdog timer counter through steps 1 to 5 below.

1. Set the WDTIMK bit of the interrupt mask flag register 0 (MK0L) to 1 before clearing the watchdog timer counter.
2. Clear the watchdog timer counter.
3. Wait for at least 80 μs .
4. Clear the WDTIIF bit of the interrupt request flag register (IF0L) to 0.
5. Clear the WDTIMK bit of the interrupt mask flag register 0 (MK0L) to 0.

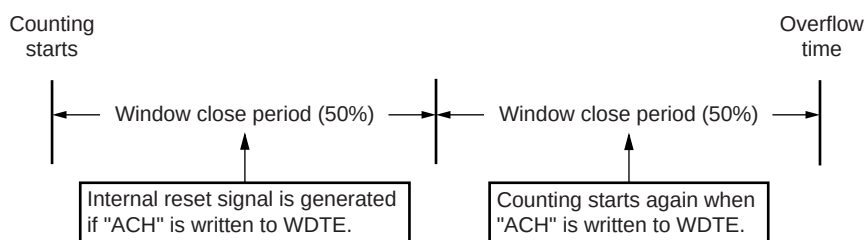
Remark f_{IL} : Low-speed on-chip oscillator clock frequency

10.4.3 Setting window open period of watchdog timer

Set the window open period of the watchdog timer by using bits 6 and 5 (WINDOW1, WINDOW0) of the option byte (000C0H). The outline of the window is as follows.

- If "ACH" is written to the watchdog timer enable register (WDTE) during the window open period, the watchdog timer is cleared and starts counting again.
- Even if "ACH" is written to the WDTE register during the window close period, an abnormality is detected and an internal reset signal is generated.

Example: If the window open period is 50%



Caution When data is written to the WDTE register for the first time after reset release, the watchdog timer is cleared in any timing regardless of the window open time, as long as the register is written before the overflow time, and the watchdog timer starts counting again.

The window open period can be set as follows.

Table 10-4. Setting Window Open Period of Watchdog Timer

WINDOW1	WINDOW0	Window Open Period of Watchdog Timer
0	0	Setting prohibited
0	1	50%
1	0	75%
1	1	100%

<R>

Note When the window open period is set to 75%, clearing the counter of the watchdog timer (writing ACH to WDTE) must proceed outside the corresponding period from among those listed below, over which clearing of the counter is prohibited (for example, confirming that the interval timer interrupt request flag (WDTIIF) of the watchdog timer is set).

WDCS2	WDCS1	WDCS0	Watchdog timer overflow time ($f_{IL} = 17.25 \text{ kHz (MAX.)}$)	Period over which clearing the counter is prohibited when the window open period is set to 75%
0	0	0	$2^6/f_{IL}$ (3.71 ms)	1.85 ms to 2.51 ms
0	0	1	$2^7/f_{IL}$ (7.42 ms)	3.71 ms to 5.02 ms
0	1	0	$2^8/f_{IL}$ (14.84 ms)	7.42 ms to 10.04 ms
0	1	1	$2^9/f_{IL}$ (29.68 ms)	14.84 ms to 20.08 ms
1	0	0	$2^{11}/f_{IL}$ (118.72 ms)	56.36 ms to 80.32 ms
1	0	1	$2^{13}/f_{IL}$ (474.89 ms)	237.44 ms to 321.26 ms
1	1	0	$2^{14}/f_{IL}$ (949.79 ms)	474.89 ms to 642.51 ms
1	1	1	$2^{16}/f_{IL}$ (3799.18 ms)	1899.59 ms to 2570.04 ms

Caution When bit 0 (WDSTBYON) of the option byte (000C0H) = 0, the window open period is 100% regardless of the values of the WINDOW1 and WINDOW0 bits.

Remark If the overflow time is set to $2^9/f_{IL}$, the window close time and open time are as follows.

	Setting of Window Open Period		
	50%	75%	100%
Window close time	0 to 20.08 ms	0 to 10.04 ms	None
Window open time	20.08 to 29.68 ms	10.04 to 29.68 ms	0 to 29.68 ms

<When window open period is 50%>

- Overflow time:
 $2^9/f_{IL} \text{ (MAX.)} = 2^9/17.25 \text{ kHz} = 29.68 \text{ ms}$
- Window close time:
 $0 \text{ to } 2^9/f_{IL} \text{ (MIN.)} \times (1 - 0.5) = 0 \text{ to } 2^9/12.75 \text{ kHz} \times 0.5 = 0 \text{ to } 20.08 \text{ ms}$
- Window open time:
 $2^9/f_{IL} \text{ (MIN.)} \times (1 - 0.5) \text{ to } 2^9/f_{IL} \text{ (MAX.)} = 2^9/12.75 \text{ kHz} \times 0.5 \text{ to } 2^9/17.25 \text{ kHz} = 20.08 \text{ to } 29.68 \text{ ms}$

10.4.4 Setting watchdog timer interval interrupt

Depending on the setting of bit 7 (WDTINT) of an option byte (000C0H), an interval interrupt (INTWDTI) can be generated when $75\% + 1/2f_{IL}$ of the overflow time is reached.

Table 10-5. Setting of Watchdog Timer Interval Interrupt

WDTINT	Use of Watchdog Timer Interval Interrupt
0	Interval interrupt is used.
1	Interval interrupt is generated when $75\% + 1/2f_{IL}$ of overflow time is reached.

Caution When operating with the X1 oscillation clock after releasing the STOP mode, the CPU starts operating after the oscillation stabilization time has elapsed. Therefore, if the period between the STOP mode release and the watchdog timer overflow is short, an overflow occurs during the oscillation stabilization time, causing a reset. Consequently, set the overflow time in consideration of the oscillation stabilization time when operating with the X1 oscillation clock and when the watchdog timer is to be cleared after the STOP mode release by an interval interrupt.

Remark The watchdog timer continues counting even after INTWDTI is generated (until ACH is written to the watchdog timer enable register (WDTE)). If ACH is not written to the WDTE register before the overflow time, an internal reset signal is generated.

CHAPTER 11 A/D CONVERTER

The number of analog input channels of the A/D converter differs, depending on the product.

			25-pin	32-pin	48-pin	64-pin
Analog input channels	Total		13 ch	18 ch	24 ch	28 ch
	High accuracy channel	Pins based on input buffer power supply AV_{DD}	4 ch (ANI0 to ANI3)	5 ch (ANI0 to ANI4)	9 ch (ANI0 to ANI8)	13 ch (ANI0 to ANI12)
	Standard channel	Pins based on input buffer power supply V_{DD}	9 ch (ANI16 to ANI18, ANI20, ANI21, ANI25 to ANI27, ANI29)	13 ch (ANI16 to ANI24, ANI26 to ANI29)	15 ch (ANI16 to ANI30)	—
		Pins based on input buffer power supply EV_{DD0}	—	—	—	15 ch (ANI16 to ANI30)

Remark Most of the following descriptions in this chapter use the 64-pin products as an example. With 25 to 48-pin products, replace EV_{DD0} with V_{DD} , or replace EV_{SS0} with V_{SS} .

11.1 Function of A/D Converter

The A/D converter converts analog input signals into digital values, and is configured to control analog inputs, including up to 28 channels of A/D converter analog inputs (ANI0 to ANI12 and ANI16 to ANI30). 12-bit resolution mode or 8-bit resolution mode can also be selected by using the ADTYP bit of A/D converter mode register 2 (ADM2).

The A/D converter has the following function.

- **12-bit/8-bit resolution A/D conversion**

A/D conversion is carried out repeatedly for one analog input channel selected from ANI0 to ANI12 and ANI16 to ANI30. Each time an A/D conversion operation ends, an interrupt request signal (INTAD) is generated (when in the select mode).

Caution The valid resolution differs depending on the voltage conditions of AV_{DD} and AV_{REFP} .
For details, see 29.6.1 A/D converter characteristics.

Remark When using the converter with a resolution of 10 bits, select the 12-bit resolution mode (ADTYP = 0). Use the higher 10 bits of the conversion result. Do not use the lower 2 bits.

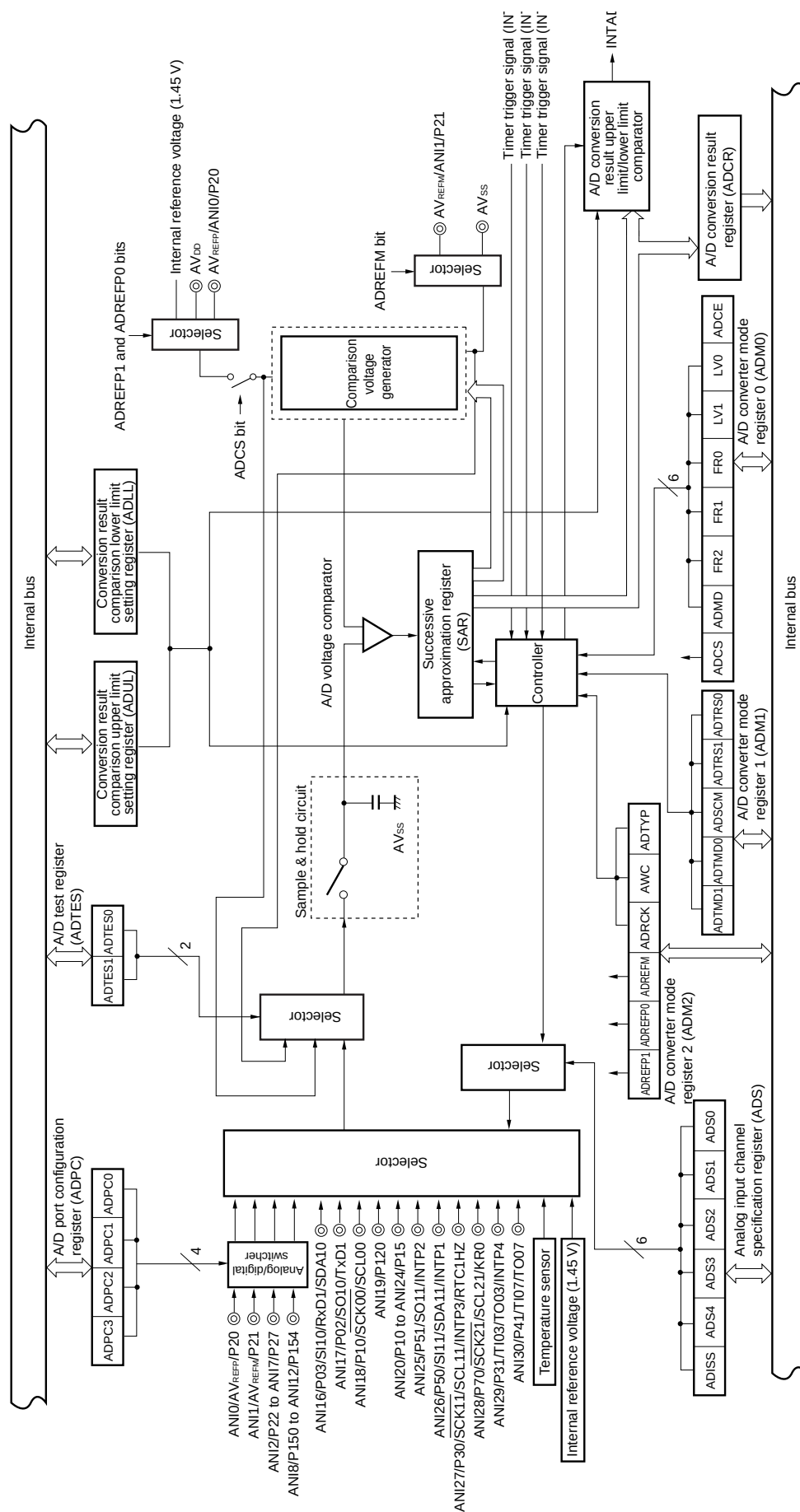
Various A/D conversion modes can be specified by using the mode combinations below.

Trigger mode	Software trigger	Conversion is started by software manipulation.
	Hardware trigger no-wait mode	Conversion is started by detecting a hardware trigger.
	Hardware trigger wait mode	The power is turned on by detecting a hardware trigger while the system is off and in the conversion standby state, and conversion is then started automatically after the A/D power supply stabilization wait time passes. When using the SNOOZE mode function, specify the hardware trigger wait mode.
Channel selection mode	Select mode	A/D conversion is performed on the analog input of one selected channel.
	Scan mode	A/D conversion is performed on the analog input of four channels in order. Four consecutive channels can be selected from ANI0 to ANI12 as analog input channels.
Conversion operation mode	One-shot conversion mode	A/D conversion is performed on the selected channel once.
	Sequential conversion mode	A/D conversion is sequentially performed on the selected channels until it is stopped by software.

Operation Mode ^{Note}	Number of Sampling Clock	
Normal 1	11 f_{AD}	Set a value to the number of sampling clocks, at which the sampling capacitor is fully charged, depending on the output impedance of the analog input source.
Normal 2	23 f_{AD}	
Low-voltage 1	33 f_{AD}	
Low-voltage 2	187 f_{AD}	

Note The operation modes selectable differ depending on the analog input channel, AV_{DD} voltage, trigger mode, and f_{CLK} . For details, **Table 11-3 A/D Conversion Time Selection**.

Figure 11-1. Block Diagram of A/D Converter



Remark Analog input pins in figure 11-1 when a 64-pin product is used.

11.2 Configuration of A/D Converter

The A/D converter includes the following hardware.

(1) ANI0 to ANI12 and ANI16 to ANI30 pins

These are the analog input pins of the 28 channels of the A/D converter. They input analog signals to be converted into digital signals. Pins other than the one selected as the analog input pin can be used as I/O port pins.

(2) Sample & hold circuit

The sample & hold circuit samples each of the analog input voltages sequentially sent from the input circuit, and sends them to the A/D voltage comparator. This circuit also holds the sampled analog input voltage during A/D conversion.

(3) A/D voltage comparator

This A/D voltage comparator compares output from the voltage tap of the comparison voltage generator with the sampled voltage value.

If the analog input voltage is found to be greater than the reference voltage ($1/2 AV_{REF}$) as a result of the comparison, the most significant bit (MSB) of the successive approximation register (SAR) is set. If the analog input voltage is less than the reference voltage ($1/2 AV_{REF}$), the MSB bit of the SAR is reset.

After that, bit 10 of the SAR register is automatically set, and the next comparison is made. The voltage tap of the comparison voltage generator is selected by the value of bit 11, to which the result has been already set.

Bit 11 = 0: ($1/4 AV_{REF}$)

Bit 11 = 1: ($3/4 AV_{REF}$)

The voltage tap of the comparison voltage generator and the analog input voltage are compared and bit 10 of the SAR register is manipulated according to the result of the comparison.

Analog input voltage $\geq$ Voltage tap of comparison voltage generator: Bit 10 = 1

Analog input voltage $\leq$ Voltage tap of comparison voltage generator: Bit 10 = 0

Comparison is continued like this to bit 0 of the SAR register.

When performing A/D conversion at a resolution of 8 bits, the comparison continues until bit 4 of the SAR register.

Remark AV_{REF} : The + side reference voltage of the A/D converter.

(This can be selected from AV_{REFP} , the internal reference voltage (1.45 V), and AV_{DD} .)

(4) Comparison voltage generator

The comparison voltage generator generates the comparison voltage input from an analog input pin.

(5) Successive approximation register (SAR)

The SAR register is a register that sets voltage tap data whose values from the comparison voltage generator match the voltage values of the analog input pins, 1 bit at a time starting from the most significant bit (MSB).

If data is set in the SAR register all the way to the least significant bit (LSB) (end of A/D conversion), the contents of the SAR register (conversion results) are held in the A/D conversion result register (ADCR). When all the specified A/D conversion operations have ended, an A/D conversion end interrupt request signal (INTAD) is generated.

(6) 12-bit A/D conversion result register (ADCR)

The A/D conversion result is loaded from the successive approximation register to this register each time A/D conversion is completed, and the ADCR register holds the A/D conversion result in its lower 12 bits (the higher 4 bits are fixed to 0).

(7) 8-bit A/D conversion result register (ADCRH)

The A/D conversion result is loaded from the successive approximation register to this register each time A/D conversion is completed, and the ADCRH register stores the higher 8 bits of the A/D conversion result.

(8) Controller

This circuit controls the conversion time of an input analog signal that is to be converted into a digital signal, as well as starting and stopping of the conversion operation. When A/D conversion has been completed, this controller generates an interrupt request signal (INTAD) through the A/D conversion result upper limit/lower limit comparator.

(9) AV_{REFP} pin

This pin inputs an external reference voltage (AV_{REFP}).

If using AV_{REFP} as the + side reference voltage of the A/D converter, set the ADREFP1 and ADREFP0 bits of A/D converter mode register 2 (ADM2) to 0 and 1, respectively.

The analog signals input to ANI2 to ANI12 and ANI16 to ANI30 are converted to digital signals based on the voltage applied between AV_{REFP} and the – side reference voltage (AV_{REFM}/AV_{SS}).

In addition to AV_{REFP}, it is possible to select AV_{DD}, or the internal reference voltage (1.45 V) as the + side reference voltage of the A/D converter.

(10) AV_{REFM} pin

This pin inputs an external reference voltage (AV_{REFM}). If using AV_{REFM} as the – side reference voltage of the A/D converter, set the ADREFM bit of the ADM2 register to 1.

In addition to AV_{REFM}, it is possible to select AV_{SS} as the – side reference voltage of the A/D converter.

11.3 Registers Used in A/D Converter

The A/D converter is controlled by the following registers.

- Peripheral enable register 0 (PER0)
- A/D converter mode register 0 (ADM0)
- A/D converter mode register 1 (ADM1)
- A/D converter mode register 2 (ADM2)
- 12-bit A/D conversion result register (ADCR)
- 8-bit A/D conversion result register (ADCRH)
- Analog input channel specification register (ADS)
- Conversion result comparison upper limit setting register (ADUL)
- Conversion result comparison lower limit setting register (ADLL)
- A/D test register (ADTES)
- A/D port configuration register (ADPC)
- Port mode control registers 0, 1, 3 to 5, 7, and 12 (PMC0, PMC1, PMC3 to PMC5, PMC7, PMC12)
- Port mode registers 0 to 5, 7, 12, and 15 (PM0 to PM5, PM7, PM12, PM15)

11.3.1 Peripheral enable register 0 (PER0)

This register is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

When the A/D converter is used, be sure to set bit 5 (ADCEN) of this register to 1.

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-2. Format of Peripheral Enable Register 0 (PER0)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN ^{Note}	SAU0EN	0	TAU0EN

ADCEN	Control of A/D converter input clock supply
0	Stops input clock supply. - SFR used by the A/D converter cannot be written. - The A/D converter is in the reset status.
1	Enables input clock supply. SFR used by the A/D converter can be read/written.

Note 32-, 48-, 64-pin products only

Cautions 1. When setting the A/D converter, be sure to set the following registers first while the ADCEN bit is set to 1. If ADCEN = 0, the values of the A/D converter control registers are cleared to their initial values and writing to them is ignored (except for port mode registers 0 to 5, 7, 12, and 15 (PM0 to PM5, PM7, PM12, PM15), port mode control registers 0, 1, 3 to 5, 7, and 12 (PMC0, PMC1, PMC3 to PMC5, PMC7, PMC12), and A/D port configuration register (ADPC)).

- A/D converter mode register 0 (ADM0)
- A/D converter mode register 1 (ADM1)
- A/D converter mode register 2 (ADM2)
- 12-bit A/D conversion result register (ADCR)
- 8-bit A/D conversion result register (ADCRH)
- Analog input channel specification register (ADS)
- Conversion result comparison upper limit setting register (ADUL)
- Conversion result comparison lower limit setting register (ADLL)
- A/D test register (ADTES)

2. Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

11.3.2 A/D converter mode register 0 (ADM0)

This register sets the conversion time for analog input to be A/D converted, and starts/stops conversion.

The ADM0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-3. Format of A/D Converter Mode Register 0 (ADM0)

Address: FFF30H After reset: 00H R/W

Symbol	<7>	6	5	4	3	2	1	<0>
ADM0	ADCS	ADMD	FR2 ^{Note 1}	FR1 ^{Note 1}	FR0 ^{Note 1}	LV1 ^{Note 1}	LV0 ^{Note 1}	ADCE

ADCS	A/D conversion operation control
0	Stops conversion operation [When read] Conversion stopped/standby status
1	Enables conversion operation [When read] While in the software trigger mode: Conversion operation status While in the hardware trigger wait mode: A/D power supply stabilization wait status + conversion operation status

ADMD	Specification of the A/D conversion channel selection mode
0	Select mode
1	Scan mode

ADCE	A/D voltage comparator operation control ^{Note 2}
0	Stops A/D voltage comparator operation
1	Enables A/D voltage comparator operation

Notes 1. For details of the FR2 to FR0, LV1, LV0 bits, and A/D conversion, see **Table 11-3 A/D Conversion Time Selection**.

- 2.** While in the software trigger mode or hardware trigger no-wait mode, the operation of the A/D voltage comparator is controlled by the ADCS and ADCE bits, and it takes stabilization wait status from the start of operation for the operation to stabilize. Therefore, when the ADCS bit is set to 1 after stabilization wait status or more has elapsed from the time ADCE bit is set to 1, the conversion result at that time has priority over the first conversion result. If the ADCS bit was set to 1 before the stabilization time elapsed, ignore the first conversion data.

[Stabilization wait status]

If a high-accuracy channel is selected as the analog input channel: 0.5 μ s

If a test mode setting (ADTES1 bit of ADTES register = 1) is selected: 0.5 μ s

If a standard channel is selected as the analog input channel: 2 μ s

If a temperature sensor output/internal reference voltage output are selected as the analog input channel: (ADISS bit of ADS register = 1): 2 μ s

Cautions 1. Change the ADMD, FR2 to FR0, LV1, and LV0 bits while in the conversion stopped status (ADCS = 0, ADCE = 0).

2. Setting ADCS = 1, ADCE = 0 is prohibited.

3. Do not change the ADCS and ADCE bits from 0 to 1 at the same time by using an 8-bit manipulation instruction. Be sure to set these bits in the order described in **11.7 A/D Converter Setup Flowchart**.

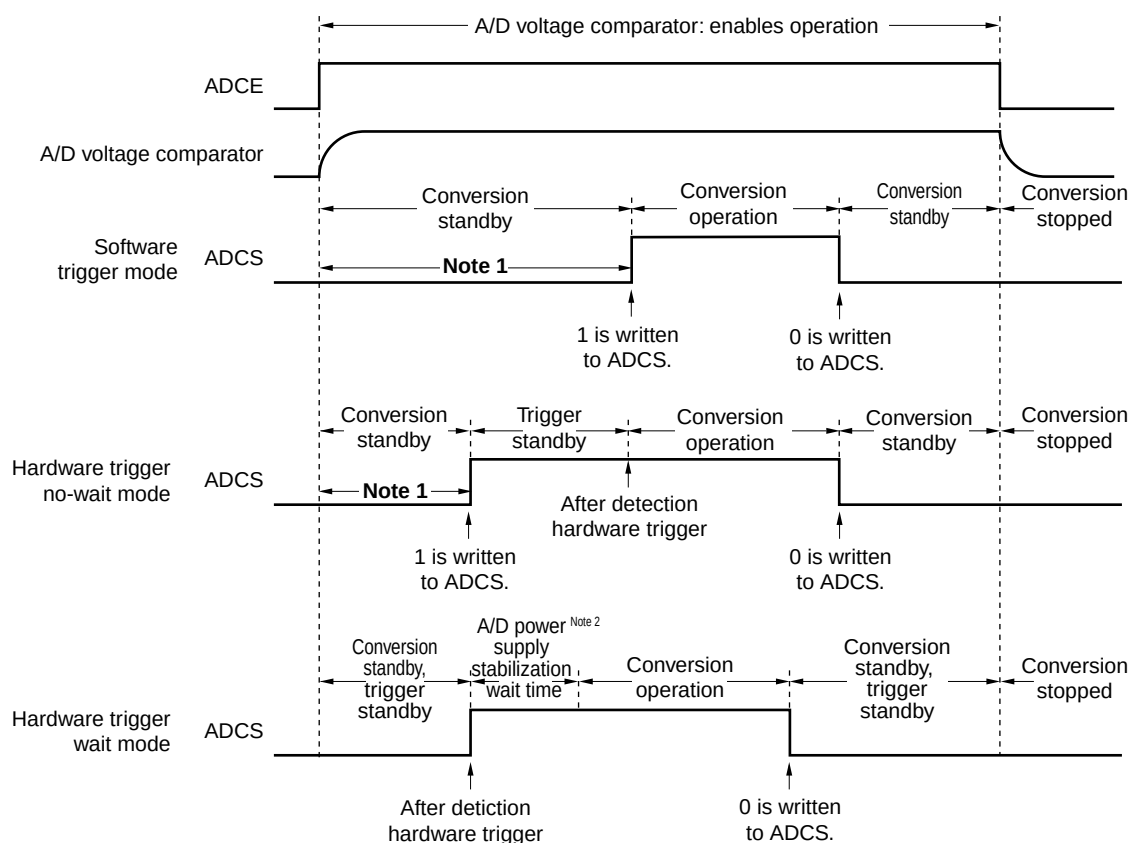
Table 11-1. Settings of ADCS and ADCE Bits

ADCS	ADCE	A/D Conversion Operation
0	0	Conversion stopped state
0	1	Conversion standby state
1	0	Setting prohibited
1	1	Conversion-in-progress state

Table 11-2. Setting and Clearing Conditions for ADCS Bit

A/D Conversion Mode			Set Conditions	Clear Conditions
Software trigger	Select mode	Sequential conversion mode	When 1 is written to ADCE and ADCS	When 0 is written to ADCS
		One-shot conversion mode		- When 0 is written to ADCS - The bit is automatically cleared to 0 when A/D conversion ends.
	Scan mode	Sequential conversion mode		When 0 is written to ADCS
		One-shot conversion mode		- When 0 is written to ADCS - The bit is automatically cleared to 0 when conversion ends on the specified four channels.
Hardware trigger no-wait mode	Select mode	Sequential conversion mode		When 0 is written to ADCS
		One-shot conversion mode		When 0 is written to ADCS
	Scan mode	Sequential conversion mode		When 0 is written to ADCS
		One-shot conversion mode		When 0 is written to ADCS
Hardware trigger wait mode	Select mode	Sequential conversion mode	When 1 is written to ADCE and a hardware trigger is input	When 0 is written to ADCS
		One-shot conversion mode		- When 0 is written to ADCS - The bit is automatically cleared to 0 when A/D conversion ends.
	Scan mode	Sequential conversion mode		When 0 is written to ADCS
		One-shot conversion mode		- When 0 is written to ADCS - The bit is automatically cleared to 0 when conversion ends on the specified four channels.

Figure 11-4. Timing Chart When A/D Voltage Comparator Is Used



Notes 1. While in the software trigger mode or hardware trigger no-wait mode, the time from the rising of the ADCE bit to the falling of the ADCS bit must be following time or longer to stabilize the internal circuit.

[Stabilization wait status]

If a high-accuracy channel is selected as the analog input channel: $0.5 \mu\text{s}$

If a test mode setting (ADTES1 bit of ADTES register = 1) is selected: $0.5 \mu\text{s}$

If a standard channel is selected as the analog input channel: $2 \mu\text{s}$

If a temperature sensor output/internal reference voltage output are selected as the analog input channel: (ADISS bit of ADS register = 1): $2 \mu\text{s}$

- 2.** For the second and subsequent conversion in sequential conversion mode and for conversion of the channel specified by scan 1, 2, and 3 in scan mode, the A/D power supply stabilization wait time do not occur after a hardware trigger is detected.

Cautions 1. If using the hardware trigger wait mode, setting the ADCS bit to 1 is prohibited (but the bit is automatically switched to 1 when the hardware trigger signal is detected). However, it is possible to clear the ADCS bit to 0 to specify the A/D conversion standby status.

2. While in the one-shot conversion mode of the hardware trigger no-wait mode, the ADCS flag is not automatically cleared to 0 when A/D conversion ends. Instead, 1 is retained.

3 Only rewrite the value of the ADCE bit when ADCS = 0 (while in the conversion stopped/conversion standby status).

4. To complete A/D conversion, specify at least the following time as the hardware trigger interval:

Hardware trigger no wait mode: $2 f_{\text{CLK}} \text{ clock} + \text{A/D conversion time}$

Hardware trigger wait mode: $2 f_{\text{CLK}} \text{ clock} + \text{A/D power supply stabilization wait time} + \text{A/D conversion time}$

Remark f_{CLK} : CPU/peripheral hardware clock frequency

Table 11-3. A/D Conversion Time Selection (1/4)

(1) 12-bit resolution mode (ADTYP = 0) When there is no stabilization wait time
(software trigger mode/hardware trigger no-wait mode)

A/D Converter Mode Register 0 (ADM0)					Mode	Conversion Clock (f _{CLK})	Number of Conversion Clock	Conversion Time	Conversion Time Selection				
FR2	FR1	FR0	LV1	LV0					AV _{DD} = 1.6 to 3.6 V f _{CLK} = 1 MHz	AV _{DD} = 1.6 to 3.6 V f _{CLK} = 4 MHz	AV _{DD} = 1.8 to 3.6 V f _{CLK} = 8 MHz	AV _{DD} = 2.4 to 3.6 V f _{CLK} = 16 MHz	AV _{DD} = 2.7 to 3.6 V f _{CLK} = 32 MHz
0	0	0	0	0	Normal 1	f _{CLK} /32	54 f _{AD} (number of sampling clock: 11 f _{AD})	1728/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	54 μs ^{Note}
0	0	1				f _{CLK} /16		864/f _{CLK}					54 μs ^{Note}
0	1	0				f _{CLK} /8		432/f _{CLK}					27 μs ^{Note}
0	1	1				f _{CLK} /6		324/f _{CLK}					13.5 μs ^{Note}
1	0	0				f _{CLK} /5		270/f _{CLK}					10.125 μs ^{Note}
1	0	1				f _{CLK} /4		216/f _{CLK}					8.4375 μs ^{Note}
1	1	0				f _{CLK} /2		108/f _{CLK}					6.75 μs ^{Note}
1	1	1				f _{CLK} /1		54/f _{CLK}					3.375 μs ^{Note}
0	0	0	0	1	Normal 2	f _{CLK} /32	66 f _{AD} (number of sampling clock: 23 f _{AD})	2112/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	66 μs
0	0	1				f _{CLK} /16		1056/f _{CLK}					33 μs
0	1	0				f _{CLK} /8		528/f _{CLK}					16.5 μs
0	1	1				f _{CLK} /6		396/f _{CLK}					12.375 μs
1	0	0				f _{CLK} /5		330/f _{CLK}					10.3125 μs
1	0	1				f _{CLK} /4		264/f _{CLK}					8.25 μs
1	1	0				f _{CLK} /2		132/f _{CLK}					4.125 μs
1	1	1				f _{CLK} /1		66/f _{CLK}					Setting prohibited
0	0	0	1	0	Low-voltage 1	f _{CLK} /32	76 f _{AD} (number of sampling clock: 33 f _{AD})	2432/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	76 μs
0	0	1				f _{CLK} /16		1216/f _{CLK}					38 μs
0	1	0				f _{CLK} /8		608/f _{CLK}					19 μs
0	1	1				f _{CLK} /6		456/f _{CLK}					14.25 μs
1	0	0				f _{CLK} /5		380/f _{CLK}					11.875 μs
1	0	1				f _{CLK} /4		304/f _{CLK}					9.5 μs
1	1	0				f _{CLK} /2		152/f _{CLK}					4.75 μs
1	1	1				f _{CLK} /1		76/f _{CLK}					Setting prohibited
0	0	0	1	1	Low-voltage 2	f _{CLK} /32	230 f _{AD} (number of sampling clock: 187 f _{AD})	7360/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	230 μs
0	0	1				f _{CLK} /16		3680/f _{CLK}					115 μs
0	1	0				f _{CLK} /8		1840/f _{CLK}					57.5 μs
0	1	1				f _{CLK} /6		1380/f _{CLK}					43.125 μs
1	0	0				f _{CLK} /5		1150/f _{CLK}					35.9375 μs
1	0	1				f _{CLK} /4		920/f _{CLK}					28.75 μs
1	1	0				f _{CLK} /2		460/f _{CLK}					14.375 μs
1	1	1				f _{CLK} /1		230/f _{CLK}					Setting prohibited

Note When using ANI16 to ANI30, setting this value is prohibited.

(Cautions and Remark are listed on the next page.)

- Cautions**
1. The A/D conversion time must also be within the relevant range of conversion times (t_{CONV}) described in 29.6.1 or 30.6.1 A/D converter characteristics.
 2. When rewriting the FR2 to FR0, LV1, and LV0 bits to other than the same data, while in the conversion stopped ($\text{ADCS} = 0$, $\text{ADCE} = 0$).
 3. The above conversion time does not include clock frequency errors. Select conversion time, taking clock frequency errors into consideration.
 4. When software trigger mode/hardware trigger no-wait mode, specify the conversion time so that the following conditions are satisfied:
 - f_{AD} is used within a range of 1 to 16 MHz.
 - When using ANI16 to ANI30, the A/D converter is used in the following range of AV_{DD} , in accordance with the settings of the LV1 and LV0 bits:

When LV1 = 0, LV0 = 0:	Setting prohibit
When LV1 = 0, LV0 = 1:	$2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
When LV1 = 1, LV0 = 0:	$1.8 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
When LV1 = 1, LV0 = 1:	$1.6 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
 - Condition when temperature sensor or internal reference voltage (ADISS bit of ADS register = 1) is set for the analog input channel:

When LV1 = 0, LV0 = 0:	Setting prohibit
When other than LV1 = 0, LV0 = 0:	$2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$

Remark f_{CLK} : CPU/peripheral hardware clock frequency

Table 11-3. A/D Conversion Time Selection (2/4)

(2) 12-bit resolution mode (ADTYP = 0) When there is A/D power supply stabilization wait time
(hardware trigger wait mode (except second and subsequent conversion in sequential conversion mode and conversion of channel specified by scan 1, 2, and 3 in scan mode^{Note 1}))

A/D Converter Mode Register 0 (ADM0)					Mode	Conversion Clock (f _{AD})	Number of A/D Power Supply Stabilization Wait Clock	Number of Conversion Clock	A/D Power Supply Stabilization Wait Time + Conversion Time	A/D Power Supply Stabilization Wait Time + Conversion Time Selection							
										AV _{DD} = 1.6 to 3.6 V	AV _{DD} = 1.6 to 3.6 V	AV _{DD} = 1.8 to 3.6 V	AV _{DD} = 2.4 to 3.6 V	AV _{DD} = 2.7 to 3.6 V			
FR2	FR1	FR0	LV1	LV0						f _{CLK} = 1 MHz	f _{CLK} = 4 MHz	f _{CLK} = 8 MHz	f _{CLK} = 16 MHz	f _{CLK} = 32 MHz			
0	0	0	0	0	Normal 1	f _{CLK} /32	4 f _{CLK}	54 f _{AD} (number of sampling clock: 11 f _{AD})	1732/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	54.125 μs ^{Note 2}			
0	0	1				f _{CLK} /16			868/f _{CLK}					54.25 μs ^{Note 2}	27.125 μs ^{Note 2}		
0	1	0				f _{CLK} /8			436/f _{CLK}					54.5 μs ^{Note 2}	27.25 μs ^{Note 2}	13.625 μs ^{Note 2}	
0	1	1				f _{CLK} /6			328/f _{CLK}					41 μs ^{Note 2}	20.5 μs ^{Note 2}	10.25 μs ^{Note 2}	
1	0	0				f _{CLK} /5			274/f _{CLK}					34.25 μs ^{Note 2}	17.125 μs ^{Note 2}	8.5625 μs ^{Note 2}	
1	0	1				f _{CLK} /4			220/f _{CLK}					55 μs ^{Note 2}	27.5 μs ^{Note 2}	13.75 μs ^{Note 2}	6.875 μs ^{Note 2}
1	1	0				f _{CLK} /2			112/f _{CLK}					28 μs ^{Note 2}	14 μs ^{Note 2}	7 μs ^{Note 2}	3.5 μs ^{Note 2}
1	1	1				f _{CLK} /1	2 f _{CLK}	56/f _{CLK}	56 μs ^{Note 2}					14 μs ^{Note 2}	7 μs ^{Note 2}	3.5 μs ^{Note 2}	Setting prohibited
0	0	0	0	1	Normal 2	f _{CLK} /32	58 f _{CLK}	66 f _{AD} (number of sampling clock: 23 f _{AD})	2170/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	67.8125 μs			
0	0	1				f _{CLK} /16			1114/f _{CLK}					69.625 μs	34.8125 μs		
0	1	0				f _{CLK} /8			586/f _{CLK}					73.25 μs ^{Note 2}	36.625 μs	18.3125 μs	
0	1	1				f _{CLK} /6			454/f _{CLK}					56.75 μs ^{Note 2}	28.375 μs	14.1875 μs	
1	0	0				f _{CLK} /5			388/f _{CLK}					48.5 μs ^{Note 2}	24.25 μs	12.125 μs	
1	0	1				f _{CLK} /4			322/f _{CLK}					80.5 μs ^{Note 2}	40.25 μs ^{Note 2}	20.125 μs	10.0625 μs
1	1	0				f _{CLK} /2			190/f _{CLK}					47.5 μs ^{Note 2}	23.75 μs ^{Note 2}	11.875 μs	5.9375 μs
1	1	1				f _{CLK} /1	29 f _{CLK}	95/f _{CLK}	95 μs ^{Note 2}					23.75 μs ^{Note 2}	11.875 μs ^{Note 2}	5.9375 μs	Setting prohibited
0	0	0	1	0	Low-voltage 1	f _{CLK} /32	15 f _{CLK}	76 f _{AD} (number of sampling clock: 33 f _{AD})	2447/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	76.46875 μs ^{Note 2}			
0	0	1				f _{CLK} /16			1231/f _{CLK}					76.9375 μs ^{Note 2}	38.46875 μs ^{Note 2}		
0	1	0				f _{CLK} /8			623/f _{CLK}					77.875 μs	38.9375 μs ^{Note 2}	19.46875 μs ^{Note 2}	
0	1	1				f _{CLK} /6			471/f _{CLK}					58.875 μs	29.4375 μs ^{Note 2}	14.71875 μs ^{Note 2}	
1	0	0				f _{CLK} /5			395/f _{CLK}					49.375 μs	24.6875 μs ^{Note 2}	12.34375 μs ^{Note 2}	
1	0	1				f _{CLK} /4			319/f _{CLK}					79.75 μs ^{Note 2}	39.875 μs	19.9375 μs ^{Note 2}	9.96875 μs ^{Note 2}
1	1	0				f _{CLK} /2			167/f _{CLK}					41.75 μs ^{Note 2}	20.875 μs	10.4375 μs ^{Note 2}	5.21875 μs ^{Note 2}
1	1	1				f _{CLK} /1	91/f _{CLK}	91 μs ^{Note 2}	22.75 μs ^{Note 2}					11.375 μs	5.6875 μs ^{Note}	Setting prohibited	
0	0	0	1	1	Low-voltage 2	f _{CLK} /32	8 f _{CLK}	230 f _{AD} (number of sampling clock: 187 f _{AD})	7368/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	230.25 μs ^{Note 2}			
0	0	1				f _{CLK} /16			3688/f _{CLK}					230.5 μs ^{Note 2}	115.25 μs ^{Note 2}		
0	1	0				f _{CLK} /8			1848/f _{CLK}					231 μs ^{Note 2}	115.5 μs ^{Note 2}	57.75 μs ^{Note 2}	
0	1	1				f _{CLK} /6			1388/f _{CLK}					173.5 μs ^{Note 2}	86.75 μs ^{Note 2}	43.375 μs ^{Note 2}	
1	0	0				f _{CLK} /5			1158/f _{CLK}					144.75 μs ^{Note 2}	72.375 μs ^{Note 2}	36.1875 μs ^{Note 2}	
1	0	1				f _{CLK} /4			928/f _{CLK}					232 μs	116 μs ^{Note 2}	58 μs ^{Note 2}	29 μs ^{Note 2}
1	1	0				f _{CLK} /2			468/f _{CLK}					117 μs	58.5 μs ^{Note 2}	29.25 μs ^{Note 2}	14.625 μs ^{Note 2}
1	1	1				f _{CLK} /1	238/f _{CLK}	238 μs	59.5 μs					29.75 μs ^{Note 2}	14.875 μs ^{Note 2}	Setting prohibited	

(Notes, Cautions and Remark are listed on the next page.)

- Notes**
1. For the second and subsequent conversion in sequential conversion mode and for conversion of the channel specified by scan 1, 2, and 3 in scan mode, the conversion start time and stabilization wait time for A/D power supply do not occur after a hardware trigger is detected (see **Table 11-3 (1/4)**).
 2. When using ANI16 to ANI30, setting this value is prohibited.

- Cautions**
1. The A/D conversion time must also be within the relevant range of conversion times (t_{CONV}) described in 29.6.1 or 30.6.1 A/D converter characteristics.
 2. When rewriting the FR2 to FR0, LV1, and LV0 bits to other than the same data, while in the conversion stopped (ADCS = 0, ADCE = 0).
 3. The above conversion time does not include clock frequency errors. Select conversion time, taking clock frequency errors into consideration.
 4. When hardware trigger wait mode, specify the conversion time so that the following conditions are satisfied:
 - f_{AD} is used within a range of 1 to 16 MHz.
 - When using ANI16 to ANI30, the A/D converter is used in the following conditions:
 - When LV1 = 0, LV0 = 0: Setting prohibit
 - When LV1 = 0, LV0 = 1: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
 - When LV1 = 1, LV0 = 0: $1.8 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 8 \text{ MHz}$
 - When LV1 = 1, LV0 = 1: $1.6 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 4 \text{ MHz}$
 - Condition when temperature sensor or internal reference voltage (ADISS bit of ADS register = 1) is set for the analog input channel:
 - When LV1 = 0, LV0 = 0: Setting prohibit
 - When LV1 = 0, LV0 = 1: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
 - When LV1 = 1, LV0 = 0: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 8 \text{ MHz}$
 - When LV1 = 1, LV0 = 1: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 4 \text{ MHz}$

Remark f_{CLK} : CPU/peripheral hardware clock frequency

Table 11-3. A/D Conversion Time Selection (3/4)

(3) 8-bit resolution mode (ADTYP = 1) When there is no stabilization wait time
(software trigger mode/hardware trigger no-wait mode)

A/D Converter Mode Register 0 (ADM0)					Mode	Conversion Clock (f _{CLK})	Number of Conversion Clock	Conversion Time	Conversion Time Selection				
FR2	FR1	FR0	LV1	LV0					AV _{DD} = 1.6 to 3.6 V f _{CLK} = 1 MHz	AV _{DD} = 1.6 to 3.6 V f _{CLK} = 4 MHz	AV _{DD} = 1.8 to 3.6 V f _{CLK} = 8 MHz	AV _{DD} = 2.4 to 3.6 V f _{CLK} = 16 MHz	AV _{DD} = 2.7 to 3.6 V f _{CLK} = 32 MHz
0	0	0	0	0	Normal 1	f _{CLK} /32	41 f _{AD} (number of sampling clock: 11 f _{AD})	1312/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	41 μs ^{Note}
0	0	1				f _{CLK} /16		656/f _{CLK}					41 μs ^{Note}
0	1	0				f _{CLK} /8		328/f _{CLK}					20.5 μs ^{Note}
0	1	1				f _{CLK} /6		246/f _{CLK}					10.25 μs ^{Note}
1	0	0				f _{CLK} /5		205/f _{CLK}					7.6875 μs ^{Note}
1	0	1				f _{CLK} /4		164/f _{CLK}					6.40625 μs ^{Note}
1	1	0				f _{CLK} /2		82/f _{CLK}					5.125 μs ^{Note}
1	1	1				f _{CLK} /1		41/f _{CLK}					2.5625 μs ^{Note}
0	0	0	0	1	Normal 2	f _{CLK} /32	53 f _{AD} (number of sampling clock: 23 f _{AD})	1696/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	53 μs
0	0	1				f _{CLK} /16		848/f _{CLK}					26.5 μs
0	1	0				f _{CLK} /8		424/f _{CLK}					13.25 μs
0	1	1				f _{CLK} /6		318/f _{CLK}					9.9375 μs
1	0	0				f _{CLK} /5		265/f _{CLK}					8.28125 μs
1	0	1				f _{CLK} /4		212/f _{CLK}					6.625 μs
1	1	0				f _{CLK} /2		106/f _{CLK}					3.3125 μs
1	1	1				f _{CLK} /1		53/f _{CLK}					Setting prohibited
0	0	0	1	0	Low-voltage 1	f _{CLK} /32	63 f _{AD} (number of sampling clock: 33 f _{AD})	2016/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	63 μs
0	0	1				f _{CLK} /16		1008/f _{CLK}					31.5 μs
0	1	0				f _{CLK} /8		504/f _{CLK}					15.75 μs
0	1	1				f _{CLK} /6		378/f _{CLK}					11.8125 μs
1	0	0				f _{CLK} /5		315/f _{CLK}					9.84375 μs
1	0	1				f _{CLK} /4		252/f _{CLK}					7.875 μs
1	1	0				f _{CLK} /2		126/f _{CLK}					3.9375 μs
1	1	1				f _{CLK} /1		63/f _{CLK}					Setting prohibited
0	0	0	1	1	Low-voltage 2	f _{CLK} /32	217 f _{AD} (number of sampling clock: 187 f _{AD})	6944/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	217 μs
0	0	1				f _{CLK} /16		3472/f _{CLK}					108.5 μs
0	1	0				f _{CLK} /8		1736/f _{CLK}					54.25 μs
0	1	1				f _{CLK} /6		1302/f _{CLK}					40.6875 μs
1	0	0				f _{CLK} /5		1085/f _{CLK}					33.90625 μs
1	0	1				f _{CLK} /4		868/f _{CLK}					27.125 μs
1	1	0				f _{CLK} /2		434/f _{CLK}					13.5625 μs
1	1	1				f _{CLK} /1		217/f _{CLK}					Setting prohibited

Note When using ANI16 to ANI30, setting this value is prohibited.

(Cautions and Remark are listed on the next page.)

- Cautions**
1. The A/D conversion time must also be within the relevant range of conversion times (t_{CONV}) described in 29.6.1 or 30.6.1 A/D converter characteristics.
 2. When rewriting the FR2 to FR0, LV1, and LV0 bits to other than the same data, while in the conversion stopped ($\text{ADCS} = 0$, $\text{ADCE} = 0$).
 3. The above conversion time does not include clock frequency errors. Select conversion time, taking clock frequency errors into consideration.
 4. When software trigger mode/hardware trigger no-wait mode, specify the conversion time so that the following conditions are satisfied:
 - f_{AD} is used within a range of 1 to 16 MHz.
 - When using ANI16 to ANI30, the A/D converter is used in the following range of AV_{DD} , in accordance with the settings of the LV1 and LV0 bits:

When LV1 = 0, LV0 = 0:	Setting prohibit
When LV1 = 0, LV0 = 1:	$2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
When LV1 = 1, LV0 = 0:	$1.8 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
When LV1 = 1, LV0 = 1:	$1.6 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
 - Condition when temperature sensor or internal reference voltage (ADISS bit of ADS register = 1) is set for the analog input channel:

When LV1 = 0, LV0 = 0:	Setting prohibit
When other than LV1 = 0, LV0 = 0:	$2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$

Remark f_{CLK} : CPU/peripheral hardware clock frequency

Table 11-3. A/D Conversion Time Selection (4/4)

(4) 8-bit resolution mode (ADTYP = 1) When there is A/D power supply stabilization wait time
(hardware trigger wait mode (except second and subsequent conversion in sequential conversion mode and conversion of channel specified by scan 1, 2, and 3 in scan mode^{Note 1}))

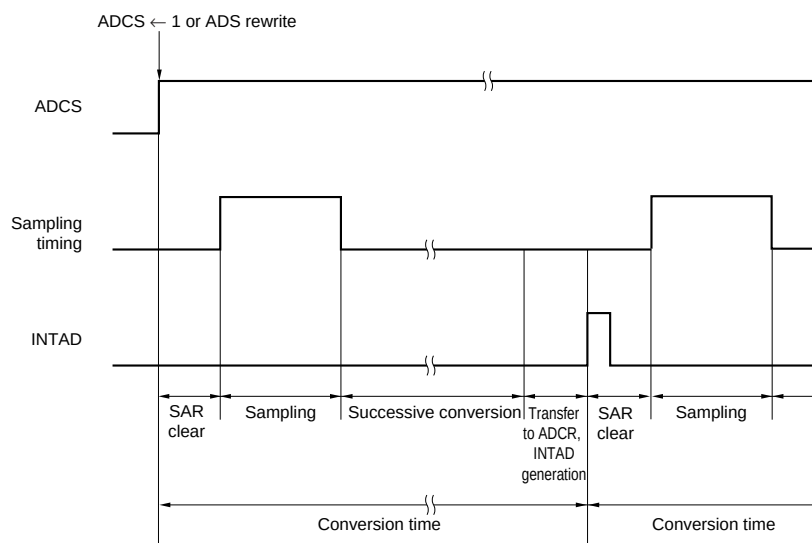
A/D Converter Mode Register 0 (ADM0)					Mode	Conversion Clock (f _{AD})	Number of A/D Power Supply Stabilization Wait Clock	Number of Conversion Clock	A/D Power Supply Stabilization Wait Time +Conversion Time	A/D Power Supply Stabilization Wait Time + Conversion Time Selection						
										AV _{DD} = 1.6 to 3.6 V f _{CLK} = 1 MHz	AV _{DD} = 1.6 to 3.6 V f _{CLK} = 4 MHz	AV _{DD} = 1.8 to 3.6 V f _{CLK} = 8 MHz	AV _{DD} = 2.4 to 3.6 V f _{CLK} = 16 MHz	AV _{DD} = 2.7 to 3.6 V f _{CLK} = 32 MHz		
FR2	FR1	FR0	LV1	LV0												
0	0	0	0	0	Normal 1	f _{CLK} /32	4 f _{CLK}	41 f _{AD} (number of sampling clock: 11 f _{AD})	1316/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	41.125 μs ^{Note 2}		
0	0	1				f _{CLK} /16			660/f _{CLK}					41.25 μs ^{Note 2}	20.625 μs ^{Note 2}	
0	1	0				f _{CLK} /8			332/f _{CLK}					41.5 μs ^{Note 2}	20.75 μs ^{Note 2}	10.375 μs ^{Note 2}
0	1	1				f _{CLK} /6			250/f _{CLK}					31.25 μs ^{Note 2}	15.625 μs ^{Note 2}	7.8125 μs ^{Note 2}
1	0	0				f _{CLK} /5			209/f _{CLK}					25.125 μs ^{Note 2}	13.0625 μs ^{Note 2}	6.53125 μs ^{Note 2}
1	0	1				f _{CLK} /4			168/f _{CLK}			42 μs ^{Note 2}	21 μs ^{Note 2}	10.5 μs ^{Note 2}	5.25 μs ^{Note 2}	
1	1	0				f _{CLK} /2			86/f _{CLK}			21.5 μs ^{Note 2}	10.75 μs ^{Note 2}	5.375 μs ^{Note 2}	2.6875 μs ^{Note 2}	
1	1	1				f _{CLK} /1	2 f _{CLK}	43/f _{CLK}	43 μs ^{Note 2}	10.75 μs ^{Note 2}	5.375 μs ^{Note 2}	2.6875 μs ^{Note 2}	Setting prohibited			
0	0	0	0	1	Normal 2	f _{CLK} /32	58 f _{CLK}	53 f _{AD} (number of sampling clock: 23 f _{AD})	1754/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	54.8125 μs		
0	0	1				f _{CLK} /16			906/f _{CLK}					56.625 μs	28.3125 μs	
0	1	0				f _{CLK} /8			482/f _{CLK}					60.25 μs ^{Note 2}	30.125 μs	15.0625 μs
0	1	1				f _{CLK} /6			376/f _{CLK}					47 μs ^{Note 2}	23.5 μs	11.75 μs
1	0	0				f _{CLK} /5			323/f _{CLK}					40.375 μs ^{Note 2}	20.1875 μs	10.09375 μs
1	0	1				f _{CLK} /4			270/f _{CLK}			67.5 μs ^{Note 2}	33.75 μs ^{Note 2}	16.875 μs	8.4375 μs	
1	1	0				f _{CLK} /2			164/f _{CLK}			41 μs ^{Note 2}	20.5 μs ^{Note 2}	10.25 μs	5.125 μs	
1	1	1				f _{CLK} /1	29 f _{CLK}	82/f _{CLK}	82 μs ^{Note 2}	20.5 μs ^{Note 2}	10.25 μs ^{Note 2}	5.125 μs	Setting prohibited			
0	0	0	1	0	Low- voltage 1	f _{CLK} /32	15 f _{CLK}	63 f _{AD} (number of sampling clock: 33 f _{AD})	2031/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	63.46875 μs ^{Note 2}		
0	0	1				f _{CLK} /16			1023/f _{CLK}					63.9375 μs ^{Note 2}	31.96875 μs ^{Note 2}	
0	1	0				f _{CLK} /8			519/f _{CLK}					64.875 μs	32.4375 μs ^{Note 2}	16.21875 μs ^{Note 2}
0	1	1				f _{CLK} /6			393/f _{CLK}					49.125 μs	24.5625 μs ^{Note 2}	12.28125 μs ^{Note 2}
1	0	0				f _{CLK} /5			330/f _{CLK}					41.25 μs	20.625 μs ^{Note 2}	10.3125 μs ^{Note 2}
1	0	1				f _{CLK} /4			267/f _{CLK}			66.75 μs ^{Note 2}	33.375 μs	16.6875 μs ^{Note 2}	8.34375 μs ^{Note 2}	
1	1	0				f _{CLK} /2			141/f _{CLK}			35.25 μs ^{Note 2}	17.625 μs	8.8125 μs ^{Note 2}	4.40625 μs ^{Note 2}	
1	1	1				f _{CLK} /1		78/f _{CLK}	78 μs ^{Note 2}	19.5 μs ^{Note 2}	9.75 μs	4.875 μs ^{Note 2}	Setting prohibited			
0	0	0	1	1	Low- voltage 2	f _{CLK} /32	8 f _{CLK}	217 f _{AD} (number of sampling clock: 187 f _{AD})	6952/f _{CLK}	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	217.25 μs ^{Note 2}		
0	0	1				f _{CLK} /16			3480/f _{CLK}					217.5 μs ^{Note 2}	108.75 μs ^{Note 2}	
0	1	0				f _{CLK} /8			1744/f _{CLK}					218 μs	109 μs ^{Note 2}	54.5 μs ^{Note 2}
0	1	1				f _{CLK} /6			1310/f _{CLK}					163.75 μs ^{Note 2}	81.875 μs ^{Note 2}	40.9375 μs ^{Note 2}
1	0	0				f _{CLK} /5			1093/f _{CLK}					136.625 μs ^{Note 2}	68.3125 μs ^{Note 2}	34.15625 μs ^{Note 2}
1	0	1				f _{CLK} /4			876/f _{CLK}			219 μs	109.5 μs ^{Note 2}	54.75 μs ^{Note 2}	27.375 μs ^{Note 2}	
1	1	0				f _{CLK} /2			442/f _{CLK}			110.5 μs	55.25 μs ^{Note 2}	27.625 μs ^{Note 2}	13.8125 μs ^{Note 2}	
1	1	1				f _{CLK} /1		225/f _{CLK}	225 μs	56.25 μs	28.125 μs ^{Note 2}	14.0625 μs ^{Note 2}	Setting prohibited			

(Notes, Cautions and Remark are listed on the next page.)

- Notes**
1. For the second and subsequent conversion in sequential conversion mode and for conversion of the channel specified by scan 1, 2, and 3 in scan mode, the conversion start time and stabilization wait time for A/D power supply do not occur after a hardware trigger is detected (see **Table 11-3 (3/4)**).
 2. When using ANI16 to ANI30, setting this value is prohibited.

- Cautions**
1. The A/D conversion time must also be within the relevant range of conversion times (t_{CONV}) described in 29.6.1 or 30.6.1 A/D converter characteristics.
 2. When rewriting the FR2 to FR0, LV1, and LV0 bits to other than the same data, while in the conversion stopped (ADCS = 0, ADCE = 0).
 3. The above conversion time does not include clock frequency errors. Select conversion time, taking clock frequency errors into consideration.
 4. When hardware trigger wait mode, specify the conversion time so that the following conditions are satisfied:
 - f_{AD} is used within a range of 1 to 16 MHz.
 - When using ANI16 to ANI30, the A/D converter is used in the following conditions:
 - When LV1 = 0, LV0 = 0: Setting prohibit
 - When LV1 = 0, LV0 = 1: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
 - When LV1 = 1, LV0 = 0: $1.8 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 8 \text{ MHz}$
 - When LV1 = 1, LV0 = 1: $1.6 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 4 \text{ MHz}$
 - Condition when temperature sensor or internal reference voltage (ADISS bit of ADS register = 1) is set for the analog input channel:
 - When LV1 = 0, LV0 = 0: Setting prohibit
 - When LV1 = 0, LV0 = 1: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$
 - When LV1 = 1, LV0 = 0: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 8 \text{ MHz}$
 - When LV1 = 1, LV0 = 1: $2.4 \text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6 \text{ V}$, $1 \text{ MHz} \leq f_{\text{CLK}} \leq 4 \text{ MHz}$

Remark f_{CLK} : CPU/peripheral hardware clock frequency

Figure 11-5. A/D Converter Sampling and A/D Conversion Timing (Example for Software Trigger Mode)

11.3.3 A/D converter mode register 1 (ADM1)

This register is used to specify the A/D conversion trigger, conversion mode, and hardware trigger signal.

The ADM1 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-6. Format of A/D Converter Mode Register 1 (ADM1)

Address: FFF32H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADM1	ADTMD1	ADTMD0	ADSCM	0	0	0	ADTRS1	ADTRS0

ADTMD1	ADTMD0	Selection of the A/D conversion trigger mode
0	×	Software trigger mode
1	0	Hardware trigger no-wait mode
1	1	Hardware trigger wait mode

ADSCM	Specification of the A/D conversion mode
0	Sequential conversion mode
1	One-shot conversion mode

ADTRS1	ADTRS0	Selection of the hardware trigger signal
0	0	End of timer channel 01 count or capture interrupt signal (INTTM01)
0	1	Setting prohibited
1	0	Real-time clock interrupt signal (INTRTC)
1	1	Interval timer interrupt signal (INTIT)

- Cautions**
1. Rewrite the value of the ADM1 register while conversion is stopped (ADCS = 0, ADCE = 0).
 2. To complete A/D conversion, specify at least the following time as the hardware trigger interval:
 Hardware trigger no wait mode: $2 f_{CLK} \text{ clock} + \text{A/D conversion time}$
 Hardware trigger wait mode: $2 f_{CLK} \text{ clock} + \text{A/D power supply stabilization wait time} + \text{A/D conversion time}$
 3. In modes other than SNOOZE mode, input of the next INTRTC or INTIT will not be recognized as a valid hardware trigger for up to four f_{CLK} cycles after the first INTRTC or INTIT is input.

- Remarks**
1. ×: don't care
 2. f_{CLK} : CPU/peripheral hardware clock frequency

11.3.4 A/D converter mode register 2 (ADM2)

This register is used to select the + side or - side reference voltage of the A/D converter, check the upper limit and lower limit A/D conversion result values, select the resolution, and specify whether to use the SNOOZE mode.

The ADM2 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-7. Format of A/D Converter Mode Register 2 (ADM2) (1/2)

Address: F0010H After reset: 00H R/W

Symbol	7	6	5	4	<3>	<2>	1	<0>
ADM2	ADREFP1	ADREFP0	ADREFM	0	ADRCK	AWC	0	ADTYP

ADREFP1	ADREFP0	Selection of the + side reference voltage of the A/D converter
0	0	Supplied from AV _{DD}
0	1	Supplied from P20/AV _{REFP} /ANI0
1	0	Supplied from the internal reference voltage (1.45 V) ^{Note}
1	1	Setting prohibited

- When ADREFP1 or ADREFP0 bit is rewritten, this must be configured in accordance with the following procedures.
 - (1) Set ADCE = 0
 - (2) Change the values of ADREFP1 and ADREFP0
 - (3) Reference voltage stabilization wait time (A)
 - (4) Set ADCE = 1
 - (5) Reference voltage stabilization wait time (B)

The stabilization wait time indicated by (3) is required when the value of the ADREFP1 and ADREFP0 bits is changed.

When ADREFP1 and ADREFP0 are changed to 1 and 0: A = 10 μ s

When ADREFP1 and ADREFP0 are changed to 0 and 0 or 0 and 1: A = 1 μ s

The stabilization wait time indicated by (5) is required when the value of the ADCE bit is changed to 1.

If a high-accuracy channel is selected as the analog input channel: B = 0.5 μ s

If a test mode setting (ADTES1 bit of ADTES register = 1) is selected: B = 0.5 μ s

If a standard channel is selected as the analog input channel: B = 2 μ s

If a temperature sensor/internal reference voltage are selected as the analog input channel: (ADISS bit of ADS register = 1): B = 2 μ s

After (5) stabilization time, start the A/D conversion.
- When ADREFP1 and ADREFP0 are set to 1 and 0, respectively, A/D conversion cannot be performed on the temperature sensor output voltage and internal reference voltage (1.45 V).
Be sure to perform A/D conversion while ADISS = 0.

ADREFM	Selection of the – side reference voltage of the A/D converter
0	Supplied from AV _{SS}
1	Supplied from P21/AV _{REFM} /ANI1

Note This setting can be used only in HS (high-speed main) mode. For detail, see Figure 24-3 Format of User Option Byte (000C2H/010C2H).

- Cautions**
1. Rewrite the value of the ADM2 register while conversion is stopped (ADCS = 0, ADCE = 0).
 2. Do not set the ADREFP1 bit to 1 when shifting to STOP mode, or to HALT mode while the CPU is operating on the subsystem clock. Also, if the ADREFP1 bit is set to 1, the A/D converter reference voltage current (I_{ADREF}) indicated in 29.3.2 or 30.3.2 Supply current characteristics will be added to the current consumption when shifting to HALT mode while the CPU is operating on the main system clock.
 3. When using AV_{REFP} and AV_{REFM}, specify ANI0 and ANI1 as the analog input channels and specify input mode by using the port mode register.

Figure 11-7. Format of A/D Converter Mode Register 2 (ADM2) (2/2)

Address: F0010H After reset: 00H R/W

Symbol	7	6	5	4	<3>	<2>	1	<0>
ADM2	ADREFP1	ADREFP0	ADREFM	0	ADRCK	AWC	0	ADTYP

ADRCK	Checking the upper limit and lower limit conversion result values
0	The A/D conversion end interrupt request signal (INTAD) is output when the ADLL register $\leq$ the ADCR register $\leq$ the ADUL register (AREA1).
1	The A/D conversion end interrupt request signal (INTAD) is output when the ADCR register $<$ the ADLL register (AREA2) or the ADUL register $<$ the ADCR register (AREA3).

Figure 11-8 shows the generation range of the A/D conversion end interrupt request signal (INTAD) for AREA1 to AREA3.

AWC	Specification of the SNOOZE mode
0	Do not use the SNOOZE mode function.
1	Use the SNOOZE mode function.

When there is a hardware trigger signal in the STOP mode, the STOP mode is exited, and A/D conversion is performed without operating the CPU (the SNOOZE mode).

- The SNOOZE mode function can only be specified when the high-speed on-chip oscillator clock is selected for the CPU/peripheral hardware clock (f_{CLK}). If any other clock is selected, specifying this mode is prohibited.
- Using the SNOOZE mode function in the software trigger mode or hardware trigger no-wait mode is prohibited.
- Using the SNOOZE mode function in the sequential conversion mode is prohibited.
- When using the SNOOZE mode function, specify a hardware trigger interval of at least “shift time to SNOOZE mode^{Note 1} + A/D power supply stabilization wait time + A/D conversion time + 2 f_{CLK} clock”
- Even when using SNOOZE mode, be sure to set the AWC bit to 0 in normal operation and change it to 1 just before shifting to STOP mode.

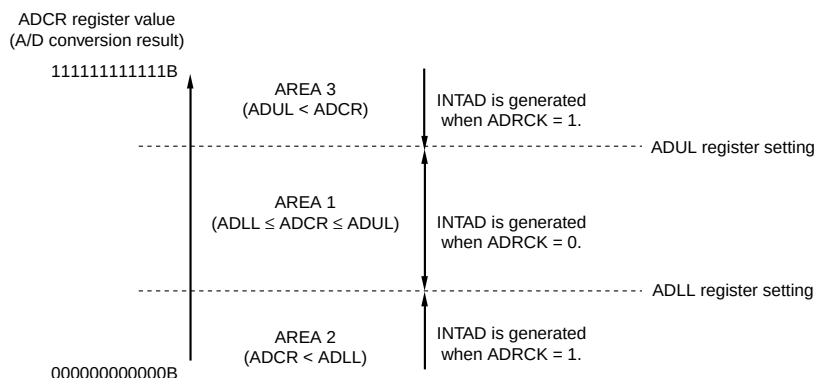
Also, be sure to change the AWC bit to 0 after returning from STOP mode to normal operation.

If the AWC bit is left set to 1, A/D conversion will not start normally in spite of the subsequent SNOOZE or normal operation.

ADTYP	Selection of the A/D conversion resolution
0	12-bit resolution ^{Note 2}
1	8-bit resolution

- Notes**
1. Refer to “Transition time from STOP mode to SNOOZE mode:” in **18.3.3 SNOOZE mode**
 2. The valid resolution differs depending on the voltage conditions of AV_{DD} and AV_{REFP} .
For details, see **29.6.1 A/D converter characteristics**.

Caution Rewrite the value of the ADM2 register while conversion operation is stopped ($ADCS = 0$, $ADCE = 0$).

Figure 11-8. ADRCK Bit Interrupt Signal Generation Range

Remark If INTAD does not occur, the A/D conversion result is not stored in the ADCR or ADCRH register.

11.3.5 12-bit A/D conversion result register (ADCR)

This register is a 16-bit register that stores the A/D conversion result. The higher 4 bits are fixed to 0. Each time A/D conversion ends, the value of ADSAR [11:0] is stored in the A/D conversion result register (note that whether to store this value is determined by the setting of the ADRCK bit of the ADM2 register and by the settings of the ADUL and ADLL registers). The higher 4 bits of the conversion result are stored in FFF1FH and the lower 8 bits are stored in the lower 4 bits of FFF1EH^{Note}.

The ADCR register can be read by a 16-bit memory manipulation instruction.

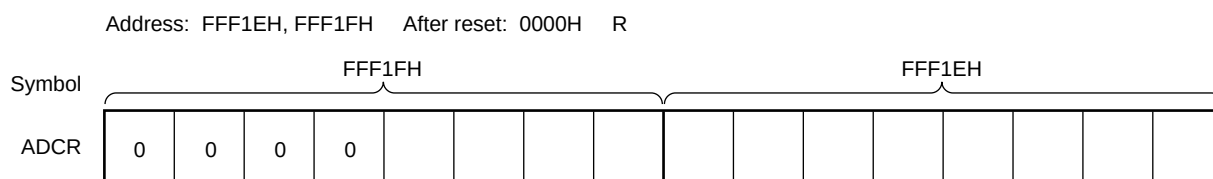
Reset signal generation clears this register to 0000H.

Note If the A/D conversion result is outside the range specified by using the A/D conversion comparison function (the value specified by the ADRCK bit of the ADM2 register and ADUL/ADLL registers; see **Figure 11-8**), the result is not stored.

Caution The valid resolution differs depending on the voltage conditions of AV_{DD} and AV_{REFP}.
For details, see 29.6.1 A/D converter characteristics.

Remarks 1. When using the converter with a resolution of 10 bits, select the 12-bit resolution mode (ADTYP = 0). Use the higher 10 bits of the conversion result. Do not use the lower 2 bits.
2. When using the converter with a resolution of 8 bits, select the 8-bit resolution mode (ADTYP = 1). Do not use the lower 4 bits of the ADCR register.
The higher 8 bits of the conversion result can be read by using the ADCRH register.

Figure 11-9. Format of 12-bit A/D Conversion Result Register (ADCR)



- Cautions** 1. When writing to the A/D converter mode register 0 (ADM0), analog input channel specification register (ADS), and A/D port configuration register (ADPC), the contents of the ADCR register may become undefined. Read the conversion result following conversion completion before writing to the ADM0, ADS, and ADPC registers. Using timing other than the above may cause an incorrect conversion result to be read.
2. If INTAD does not occur, the A/D conversion result is not stored in the ADCR register.

11.3.6 8-bit A/D conversion result register (ADCRH)

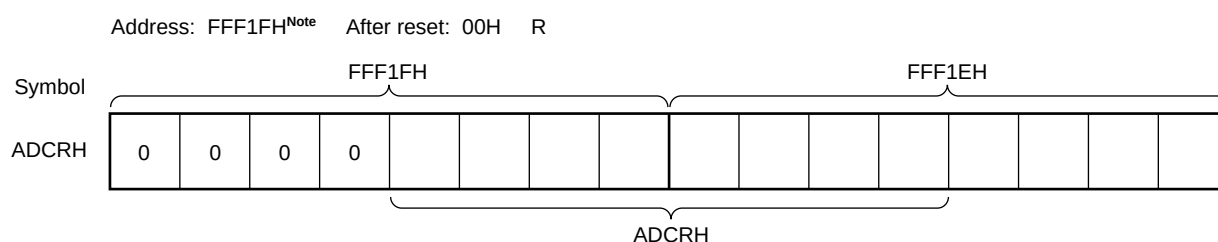
This register is an 8-bit register that indicate [11:4] bits of ADCR register. The higher 8 bits of 12-bit resolution are stored^{Note}.

The ADCRH register can be read by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Note If the A/D conversion result is outside the range specified by using the A/D conversion comparison function (the value specified by the ADRCK bit of the ADM2 register and ADUL/ADLL registers; see **Figure 11-8**), the result is not stored.

Figure 11-10. Format of 8-bit A/D Conversion Result Register (ADCRH)



Note The ADCRH data (the lower 4 bits of FFF1FH + the higher 4 bits of FFF1EH) is to be read as a FFF1FH address.

Cautions 1. When writing to the A/D converter mode register 0 (ADM0), analog input channel specification register (ADS), and A/D port configuration register (ADPC), the contents of the ADCRH register may become undefined. Read the conversion result following conversion completion before writing to the ADM0, ADS, and ADPC registers. Using timing other than the above may cause an incorrect conversion result to be read.

2. If INTAD does not occur, the A/D conversion result is not stored in the ADCRH register.

11.3.7 Analog input channel specification register (ADS)

This register specifies the input channel of the analog voltage to be A/D converted.

The ADS register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-11. Format of Analog Input Channel Specification Register (ADS) (1/2)

Address: FFF31H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADS	ADISS	0	0	ADS4	ADS3	ADS2	ADS1	ADS0

○ Select mode (ADMD = 0)

ADISS	ADS4	ADS3	ADS2	ADS1	ADS0	Analog input channel	Input source
0	0	0	0	0	0	ANI0	P20/ANI0/AV _{REFP} pin
0	0	0	0	0	1	ANI1	P21/ANI1/AV _{REFM} pin
0	0	0	0	1	0	ANI2	P22/ANI2 pin
0	0	0	0	1	1	ANI3	P23/ANI3 pin
0	0	0	1	0	0	ANI4	P24/ANI4 pin
0	0	0	1	0	1	ANI5	P25/ANI5 pin
0	0	0	1	1	0	ANI6	P26/ANI6 pin
0	0	0	1	1	1	ANI7	P27/ANI7 pin
0	0	1	0	0	0	ANI8	P150/ANI8 pin
0	0	1	0	0	1	ANI9	P151/ANI9 pin
0	0	1	0	1	0	ANI10	P152/ANI10 pin
0	0	1	0	1	1	ANI11	P153/ANI11 pin
0	0	1	1	0	0	ANI12	P154/ANI12 pin
0	0	1	1	0	1	Setting prohibited	
0	0	1	1	1	0	Setting prohibited	
0	0	1	1	1	1	Setting prohibited	
0	1	0	0	0	0	ANI16	P03/ANI16 pin
0	1	0	0	0	1	ANI17	P02/ANI17 pin
0	1	0	0	1	0	ANI18	P10/ANI18 pin
0	1	0	0	1	1	ANI19	P120/ANI19 pin
0	1	0	1	0	0	ANI20	P11/ANI20 pin
0	1	0	1	0	1	ANI21	P12/ANI21 pin
0	1	0	1	1	0	ANI22	P13/ANI22 pin
0	1	0	1	1	1	ANI23	P14/ANI23 pin
0	1	1	0	0	0	ANI24	P15/ANI24 pin
0	1	1	0	0	1	ANI25	P51/ANI25 pin
0	1	1	0	1	0	ANI26	P50/ANI26 pin
0	1	1	0	1	1	ANI27	P30/ANI27 pin
0	1	1	1	0	0	ANI28	P70/ANI28 pin
0	1	1	1	0	1	ANI29	P31/ANI29 pin
0	1	1	1	1	0	ANI30	P41/ANI30 pin
0	1	1	1	1	1	Setting prohibited	
1	0	0	0	0	0	–	Temperature sensor output voltage ^{Note}
1	0	0	0	0	1	–	Internal reference voltage (1.45 V) ^{Note}
Other than above						Setting prohibited	

Note This setting can be used only in HS (high-speed main) mode. For detail, see **Figure 24-3 Format of User Option Byte (000C2H/010C2H)**.

Figure 11-11. Format of Analog Input Channel Specification Register (ADS) (2/2)

Address: FFF31H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADS	ADISS	0	0	ADS4	ADS3	ADS2	ADS1	ADS0

○ Scan mode (ADMD = 1)

ADISS	ADS4	ADS3	ADS2	ADS1	ADS0	Analog input channel			
						Scan 0	Scan 1	Scan 2	Scan 3
0	0	0	0	0	0	ANI0	ANI1	ANI2	ANI3
0	0	0	0	0	1	ANI1	ANI2	ANI3	ANI4
0	0	0	0	1	0	ANI2	ANI3	ANI4	ANI5
0	0	0	0	1	1	ANI3	ANI4	ANI5	ANI6
0	0	0	1	0	0	ANI4	ANI5	ANI6	ANI7
0	0	0	1	0	1	ANI5	ANI6	ANI7	ANI8
0	0	0	1	1	0	ANI6	ANI7	ANI8	ANI9
0	0	0	1	1	1	ANI7	ANI8	ANI9	ANI10
0	0	1	0	0	0	ANI8	ANI9	ANI10	ANI11
0	0	1	0	0	1	ANI9	ANI10	ANI11	ANI12
0	1	0	0	0	0	ANI16	ANI17	ANI18	ANI19
0	1	0	0	0	1	ANI17	ANI18	ANI19	ANI20
0	1	0	0	1	0	ANI18	ANI19	ANI20	ANI21
0	1	0	0	1	1	ANI19	ANI20	ANI21	ANI22
0	1	0	1	0	0	ANI20	ANI21	ANI22	ANI23
0	1	0	1	0	1	ANI21	ANI22	ANI23	ANI24
0	1	0	1	1	0	ANI22	ANI23	ANI24	ANI25
0	1	0	1	1	1	ANI23	ANI24	ANI25	ANI26
0	1	1	0	0	0	ANI24	ANI25	ANI26	ANI27
0	1	1	0	0	1	ANI25	ANI26	ANI27	ANI28
0	1	1	0	1	0	ANI26	ANI27	ANI28	ANI29
0	1	1	0	1	1	ANI27	ANI28	ANI29	ANI30
Other than above						Setting prohibited			

- Cautions**
1. Be sure to clear bits 5 and 6 to 0.
 2. Set a channel to be set the analog input by ADPC and PMCx registers in the input mode by using port mode registers 0 to 5, 7, 12, or 15 (PM0 to PM5, PM7, PM12, PM15).
 3. Do not set the pin that is set by the A/D port configuration register (ADPC) as digital I/O by the ADS register.
 4. Do not set the pin that is set by port mode control register 0, 1, 3 to 5, 7, or 12 (PMC0, PMC1, PMC3 to PMC5, PMC7, PMC12) as digital I/O by the ADS register.
 5. Rewrite the value of the ADISS bit while conversion operation is stopped (ADCS = 0, ADCE = 0).
 6. If using AV_{REFP} as the + side reference voltage of the A/D converter, do not select ANI0 as an A/D conversion channel.
 7. If using AV_{REFM} as the – side reference voltage of the A/D converter, do not select ANI1 as an A/D conversion channel.
 8. If ADISS is set to 1, the internal reference voltage (1.45 V) cannot be used for the + side reference voltage. Also, after setting the ADISS to 1, the result of the first conversion cannot be used. For details about the setting flow, see 11.7.4 Setup when temperature sensor output voltage/internal reference voltage is selected (example for software trigger mode and one-shot conversion mode).
 9. Do not set the ADISS bit to 1 when shifting to STOP mode, or to HALT mode while the CPU is operating on the subsystem clock. When the ADISS bit is set to 1, the current value of the temperature sensor operating current (I_{TMPS}) and A/D converter reference voltage current (I_{ADREF}) indicated in 29.3.2 or 30.3.2 Supply current characteristics will be added.
 10. Ignore the conversion result if the corresponding ANI pin does not exist depending on the product (number of pins).

11.3.8 Conversion result comparison upper limit setting register (ADUL)

This register is used to specify the setting for checking the upper limit of the A/D conversion results.

The A/D conversion results and ADUL register value are compared, and A/D conversion end interrupt request signal (INTAD) generation is controlled in the range specified for the ADRCK bit of A/D converter mode register 2 (ADM2) (shown in **Figure 11-8**).

The ADUL register can be set by an 8-bit memory manipulation instruction.

Reset signal generation sets this register to FFH.

Figure 11-12. Format of Conversion Result Comparison Upper Limit Setting Register (ADUL)

Address: F0011H After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
ADUL	ADUL7	ADUL6	ADUL5	ADUL4	ADUL3	ADUL2	ADUL1	ADUL0

11.3.9 Conversion result comparison lower limit setting register (ADLL)

This register is used to specify the setting for checking the lower limit of the A/D conversion results.

The A/D conversion results and ADLL register value are compared, and A/D conversion end interrupt request signal (INTAD) generation is controlled in the range specified for the ADRCK bit of A/D converter mode register 2 (ADM2) (shown in **Figure 11-8**).

The ADLL register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-13. Format of Conversion Result Comparison Lower Limit Setting Register (ADLL)

Address: F0012H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADLL	ADLL7	ADLL6	ADLL5	ADLL4	ADLL3	ADLL2	ADLL1	ADLL0

- Cautions**
1. When 12-bit resolution A/D conversion is selected, the higher eight bits of the 12-bit A/D conversion result register (ADCR) are compared with the ADUL register and ADLL register.
 2. Only rewrite the value of the ADUL register and ADLL register while conversion operation is stopped (which is indicated by the ADCE bit of A/D converter mode register 0 (ADM0) being 0).
 3. Make sure that ADUL > ADLL when setting these registers.

11.3.10 A/D test register (ADTES)

This register is used to select the + side reference voltage or – side reference voltage for the A/D converter, an analog input channel (ANlxx), the temperature sensor output voltage, or the internal reference voltage (1.45 V) as the target for A/D conversion. When using as the A/D test function, set as follows.

- For zero-scale measurement, select the – side reference voltage as the target for conversion.
- For full-scale measurement, select the + side reference voltage as the target for conversion.

The ADTES register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 11-14. Format of A/D Test Register (ADTES)

Address: F0013H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADTES	0	0	0	0	0	0	ADTES1	ADTES0

ADTES1	ADTES0	A/D conversion target
0	0	ANlxx/temperature sensor output voltage ^{Note} /internal reference voltage (1.45 V) ^{Note} (This is specified using the analog input channel specification register (ADS).)
1	0	– side reference voltage (Setting at ADREFM bit of ADM2 register)
1	1	+ side reference voltage (Setting at ADREFP1, ADREFP0 bits of ADM2 register)
Other than above		Setting prohibited

Note Temperature sensor output/internal reference voltage (1.45 V) can be used only in HS (high-speed main) mode. For detail, see **Figure 24-3 Format of User Option Byte (000C2H/010C2H)**.

Caution For details of the A/D test function, see **CHAPTER 22 SAFETY FUNCTIONS**.

11.3.11 Registers controlling port function of analog input pins

Set up the registers for controlling the functions of the ports shared with the analog input pins of the A/D converter (port mode registers (PMxx), port mode control registers (PMCxx), and A/D port configuration register (ADPC)).

For details, see as follows.

- **4.3.1 Port mode registers (PMxx)**
- **4.3.6 Port mode control registers (PMCxx)**
- **4.3.7 A/D port configuration register (ADPC).**

When using the ANI0 to ANI12 pins for analog input of the A/D converter, set the port mode register (PMxx) bit corresponding to each port to 1 and select analog input through the A/D port configuration register (ADPC).

When using the ANI16 to ANI30 pins for analog input of the A/D converter, set the port mode register (PMxx) bit and port mode control register (PMCxx) bit corresponding to each port to 1.

11.4 A/D Converter Conversion Operations

The A/D converter conversion operations are described below.

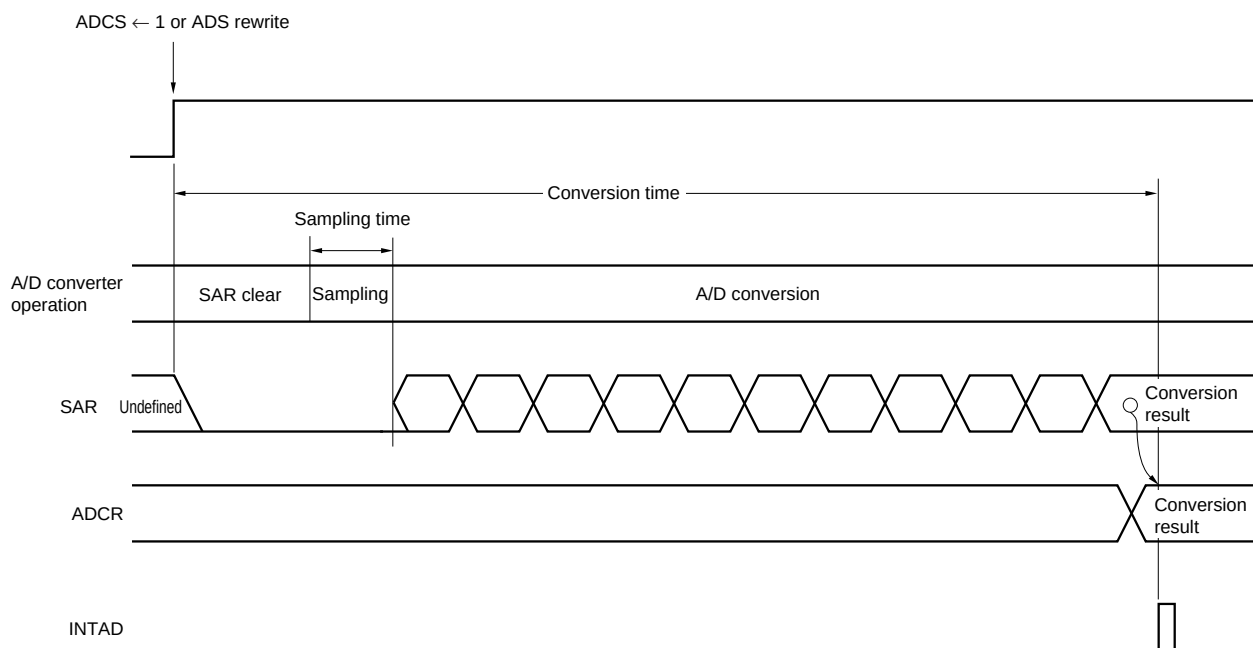
- <1> The voltage input to the selected analog input channel is sampled by the sample & hold circuit.
- <2> When sampling has been done for a certain time, the sample & hold circuit is placed in the hold state and the sampled voltage is held until the A/D conversion operation has ended.
- <3> Bit 11 of the successive approximation register (SAR) is set. The series resistor string voltage tap is set to $(1/2) AV_{REF}$ by the tap selector.
- <4> The voltage difference between the series resistor string voltage tap and sampled voltage is compared by the voltage comparator. If the analog input is greater than $(1/2) AV_{REF}$, the MSB bit of the SAR register remains set to 1. If the analog input is smaller than $(1/2) AV_{REF}$, the MSB bit is reset to 0.
- <5> Next, bit 10 of the SAR register is automatically set to 1, and the operation proceeds to the next comparison. The series resistor string voltage tap is selected according to the preset value of bit 11, as described below.
 - Bit 11 = 1: $(3/4) AV_{REF}$
 - Bit 11 = 0: $(1/4) AV_{REF}$

The voltage tap and sampled voltage are compared and bit 10 of the SAR register is manipulated as follows.

 - Sampled voltage $\geq$ Voltage tap: Bit 10 = 1
 - Sampled voltage $<$ Voltage tap: Bit 10 = 0
- <6> Comparison is continued in this way up to bit 0 of the SAR register.
- <7> Upon completion of the comparison of 12 bits, an effective digital result value remains in the SAR register, and the result value is transferred to the A/D conversion result register (ADCR, ADCRH) and then latched^{Note 1}.
At the same time, the A/D conversion end interrupt request signal (INTAD) can also be generated^{Note 1}.
- <8> Repeat steps <1> to <7>, until the ADCS bit is cleared to 0^{Note 2}.
To stop the A/D converter, clear the ADCS bit to 0.

- Notes**
1. If the A/D conversion result is outside the A/D conversion result range specified by the ADRCK bit and the ADUL and ADLL registers (see **Figure 11-8**), the A/D conversion result interrupt request signal is not generated and no A/D conversion results are stored in the ADCR and ADCRH registers.
 2. While in the sequential conversion mode, the ADCS flag is not automatically cleared to 0. This flag is not automatically cleared to 0 while in the one-shot conversion mode of the hardware trigger no-wait mode, either. Instead, 1 is retained.

- Remarks**
1. Two types of the A/D conversion result registers are available.
 - ADCR register (16 bits): Store 12-bit A/D conversion value
 - ADCRH register (8 bits): Store 8-bit A/D conversion value
 2. AV_{REF} : The + side reference voltage of the A/D converter. This can be selected from AV_{REFP} , the internal reference voltage (1.45 V), and AV_{DD} .

Figure 11-15. Conversion Operation of A/D Converter (Software Trigger Mode)

In one-shot conversion mode, the ADCS bit is automatically cleared to 0 after completion of A/D conversion.

In sequential conversion mode, A/D conversion operations proceed continuously until the software clears bit 7 (ADCS) of the A/D converter mode register 0 (ADM0) to 0.

Rewriting and overwriting to the analog input channel specification register (ADS) during A/D conversion interrupts the current conversion after which A/D conversion of the analog input specified by the ADS register proceeds. Data from the A/D conversion that was in progress are discarded.

Reset signal generation clears the A/D conversion result register (ADCR, ADCRH) to 0000H or 00H.

11.5 Input Voltage and Conversion Results

The relationship between the analog input voltage input to the analog input pins (ANI0 to ANI12, ANI16 to ANI30) and the theoretical A/D conversion result (stored in the 12-bit A/D conversion result register (ADCR)) is shown by the following expression.

$$\text{ADCR} = \text{INT} \left(\frac{V_{\text{AIN}}}{V_{\text{REF}}} \times 4096 + 0.5 \right)$$

or

$$(\text{ADCR} - 0.5) \times \frac{V_{\text{REF}}}{4096} \leq V_{\text{AIN}} < (\text{ADCR} + 0.5) \times \frac{V_{\text{REF}}}{4096}$$

where, INT(): Function which returns integer part of value in parentheses

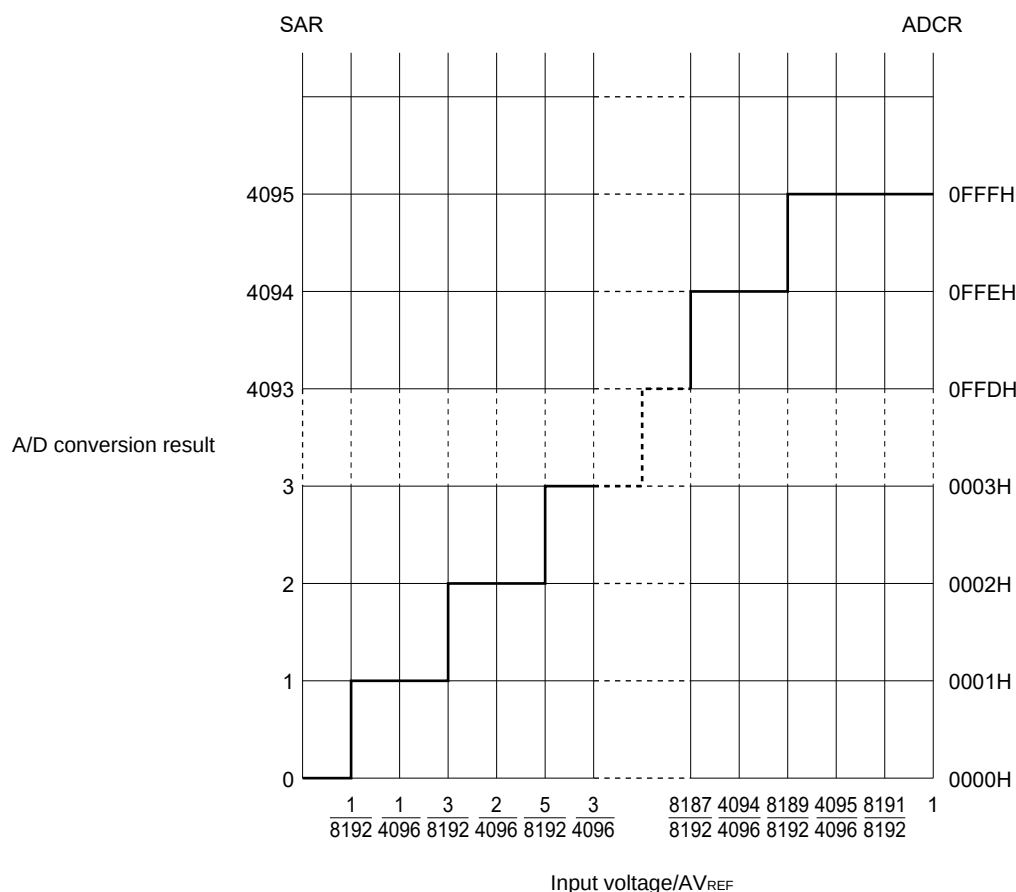
V_{AIN} : Analog input voltage

V_{REF} : V_{REF} pin voltage

ADCR: A/D conversion result register (ADCR) value

Figure 11-16 shows the relationship between the analog input voltage and the A/D conversion result.

Figure 11-16. Relationship Between Analog Input Voltage and A/D Conversion Result



Remark V_{REF} : The + side reference voltage of the A/D converter. This can be selected from V_{REFP} , the internal reference voltage (1.45 V), and V_{DD} .

11.6 A/D Converter Operation Modes

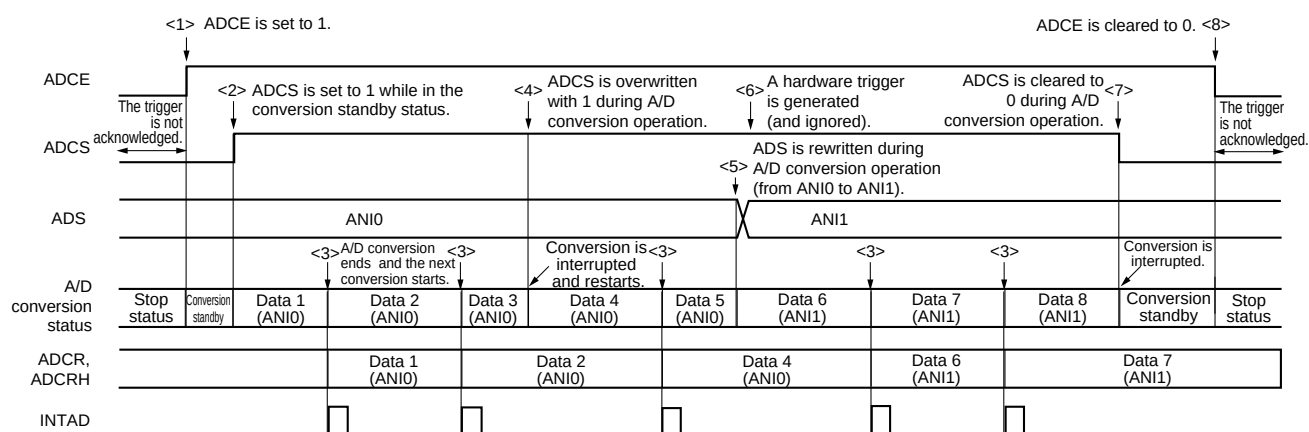
The operation of each A/D converter mode is described below. In addition, the procedure for specifying each mode is described in **11.7 A/D Converter Setup Flowchart**.

11.6.1 Software trigger mode (select mode, sequential conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to perform the A/D conversion of the analog input specified by the analog input channel specification register (ADS).
- <3> When A/D conversion ends, the conversion result is stored in the A/D conversion result register (ADCR, ADCRH), and the A/D conversion end interrupt request signal (INTAD) is generated. After A/D conversion ends, the next A/D conversion immediately starts.
- <4> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <5> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the analog input respecified by the ADS register. The partially converted data is discarded.
- <6> Even if a hardware trigger is input during conversion operation, A/D conversion does not start.
- <7> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status.
- <8> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCE = 0, specifying 1 for ADCS is ignored and A/D conversion does not start.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

Figure 11-17. Example of Software Trigger Mode (Select Mode, Sequential Conversion Mode) Operation Timing

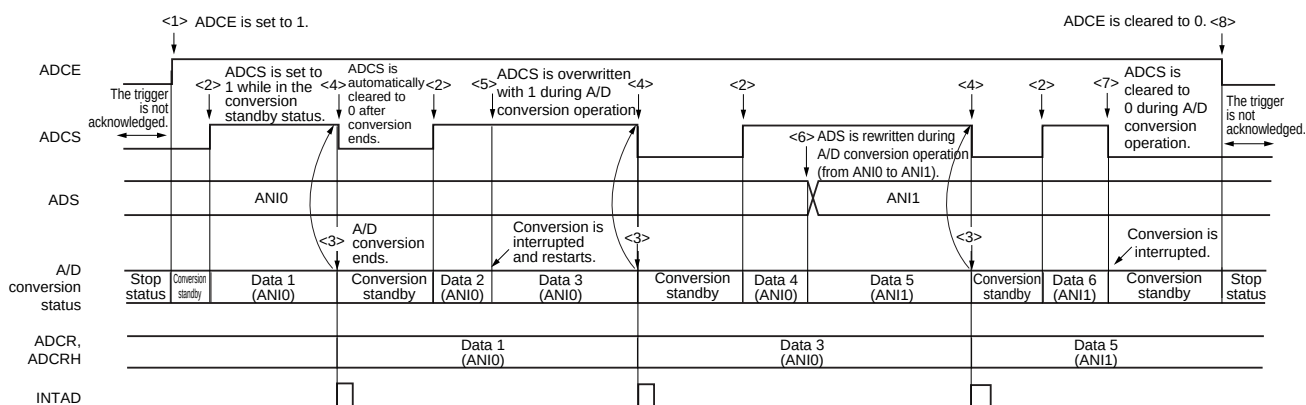


11.6.2 Software trigger mode (select mode, one-shot conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to perform the A/D conversion of the analog input specified by the analog input channel specification register (ADS).
- <3> When A/D conversion ends, the conversion result is stored in the A/D conversion result register (ADCR, ADCRH), and the A/D conversion end interrupt request signal (INTAD) is generated.
- <4> After A/D conversion ends, the ADCS bit is automatically cleared to 0, and the system enters the A/D conversion standby status.
- <5> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <6> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the analog input respecified by the ADS register. The partially converted data is discarded.
- <7> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status.
- <8> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCE = 0, specifying 1 for ADCS is ignored and A/D conversion does not start. In addition, A/D conversion does not start even if a hardware trigger is input while in the A/D conversion standby status.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

Figure 11-18. Example of Software Trigger Mode (Select Mode, One-Shot Conversion Mode) Operation Timing

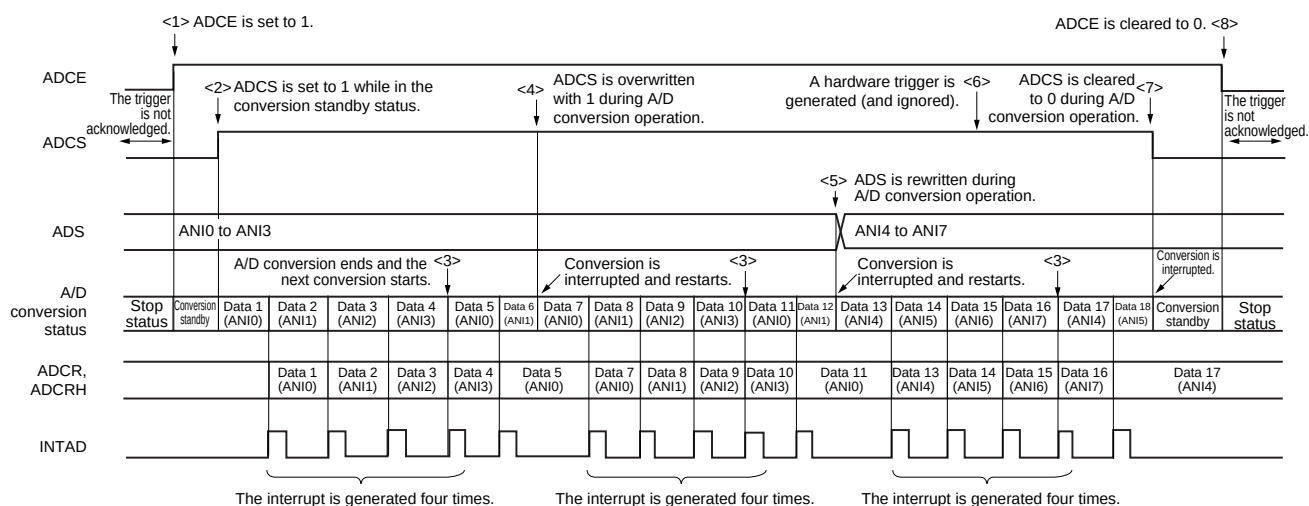


11.6.3 Software trigger mode (scan mode, sequential conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to perform A/D conversion on the four analog input channels specified by scan 0 to scan 3, which are specified by the analog input channel specification register (ADS). A/D conversion is performed on the analog input channels in order, starting with that specified by scan 0.
- <3> A/D conversion is sequentially performed on the four analog input channels, the conversion results are stored in the A/D conversion result register (ADCR, ADCRH) each time conversion ends, and the A/D conversion end interrupt request signal (INTAD) is generated. After A/D conversion of the four channels ends, the A/D conversion of the channel following the specified channel automatically starts (until all four channels are finished).
- <4> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <5> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the first channel respecified by the ADS register. The partially converted data is discarded.
- <6> Even if a hardware trigger is input during conversion operation, A/D conversion does not start.
- <7> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status.
- <8> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCE = 0, specifying 1 for ADCS is ignored and A/D conversion does not start.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

Figure 11-19. Example of Software Trigger Mode (Scan Mode, Sequential Conversion Mode) Operation Timing

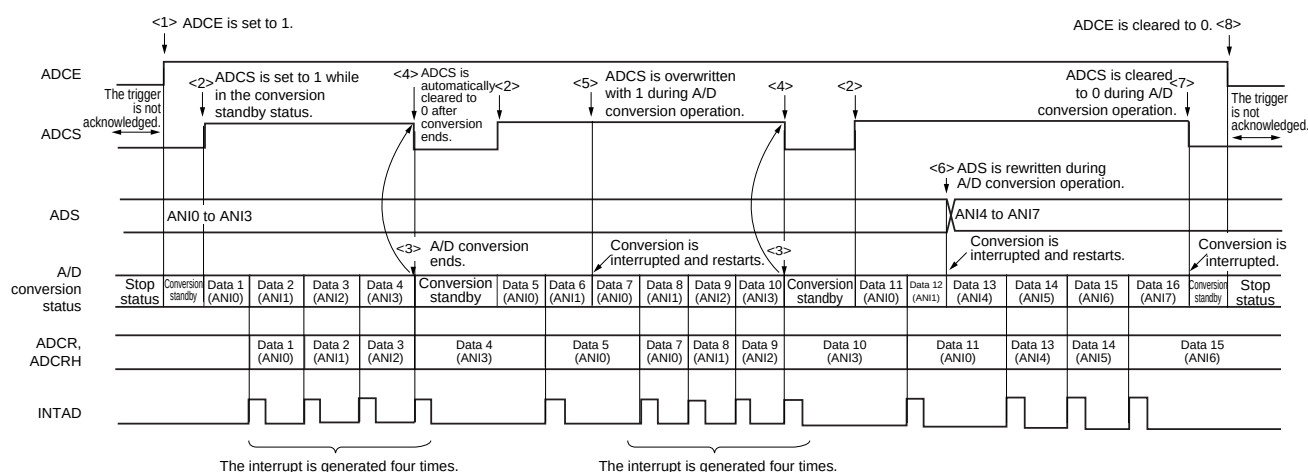


11.6.4 Software trigger mode (scan mode, one-shot conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to perform A/D conversion on the four analog input channels specified by scan 0 to scan 3, which are specified by the analog input channel specification register (ADS). A/D conversion is performed on the analog input channels in order, starting with that specified by scan 0.
- <3> A/D conversion is sequentially performed on the four analog input channels, the conversion results are stored in the A/D conversion result register (ADCR, ADCRH) each time conversion ends, and the A/D conversion end interrupt request signal (INTAD) is generated.
- <4> After A/D conversion of the four channels ends, the ADCS bit is automatically cleared to 0, and the system enters the A/D conversion standby status.
- <5> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <6> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the first channel respecified by the ADS register. The partially converted data is discarded.
- <7> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status.
- <8> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCE = 0, specifying 1 for ADCS is ignored and A/D conversion does not start. In addition, A/D conversion does not start even if a hardware trigger is input while in the A/D conversion standby status.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

Figure 11-20. Example of Software Trigger Mode (Scan Mode, One-Shot Conversion Mode) Operation Timing

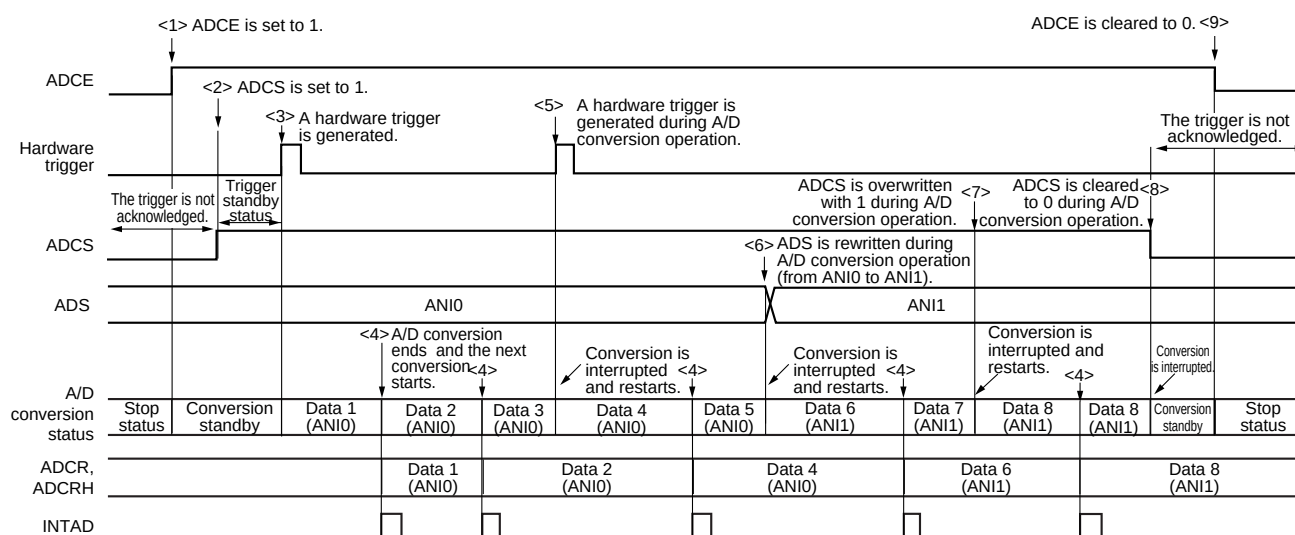


11.6.5 Hardware trigger no-wait mode (select mode, sequential conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to place the system in the hardware trigger standby status (and conversion does not start at this stage). Note that, while in this status, A/D conversion does not start even if ADCS is set to 1.
- <3> If a hardware trigger is input while ADCS = 1, A/D conversion is performed on the analog input specified by the analog input channel specification register (ADS).
- <4> When A/D conversion ends, the conversion result is stored in the A/D conversion result register (ADCR, ADCRH), and the A/D conversion end interrupt request signal (INTAD) is generated. After A/D conversion ends, the next A/D conversion immediately starts.
- <5> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <6> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the analog input respecified by the ADS register. The partially converted data is discarded.
- <7> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <8> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status. However, the A/D converter does not stop in this status.
- <9> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCS = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

**Figure 11-21. Example of Hardware Trigger No-Wait Mode (Select Mode, Sequential Conversion Mode)
Operation Timing**

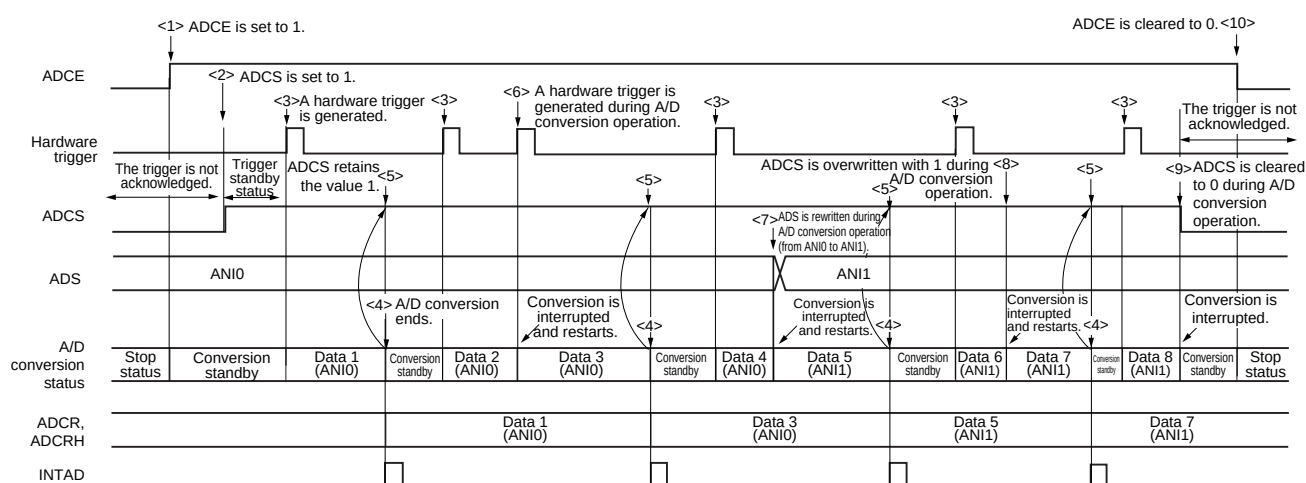


11.6.6 Hardware trigger no-wait mode (select mode, one-shot conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to place the system in the hardware trigger standby status (and conversion does not start at this stage). Note that, while in this status, A/D conversion does not start even if ADCS is set to 1.
- <3> If a hardware trigger is input while ADCS = 1, A/D conversion is performed on the analog input specified by the analog input channel specification register (ADS).
- <4> When A/D conversion ends, the conversion result is stored in the A/D conversion result register (ADCR, ADCRH), and the A/D conversion end interrupt request signal (INTAD) is generated.
- <5> After A/D conversion ends, the ADCS bit remains set to 1, and the system enters the A/D conversion standby status.
- <6> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <7> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the analog input respecified by the ADS register. The partially converted data is discarded.
- <8> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <9> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status. However, the A/D converter does not stop in this status.
- <10> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCS = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

Figure 11-22. Example of Hardware Trigger No-Wait Mode (Select Mode, One-Shot Conversion Mode) Operation Timing

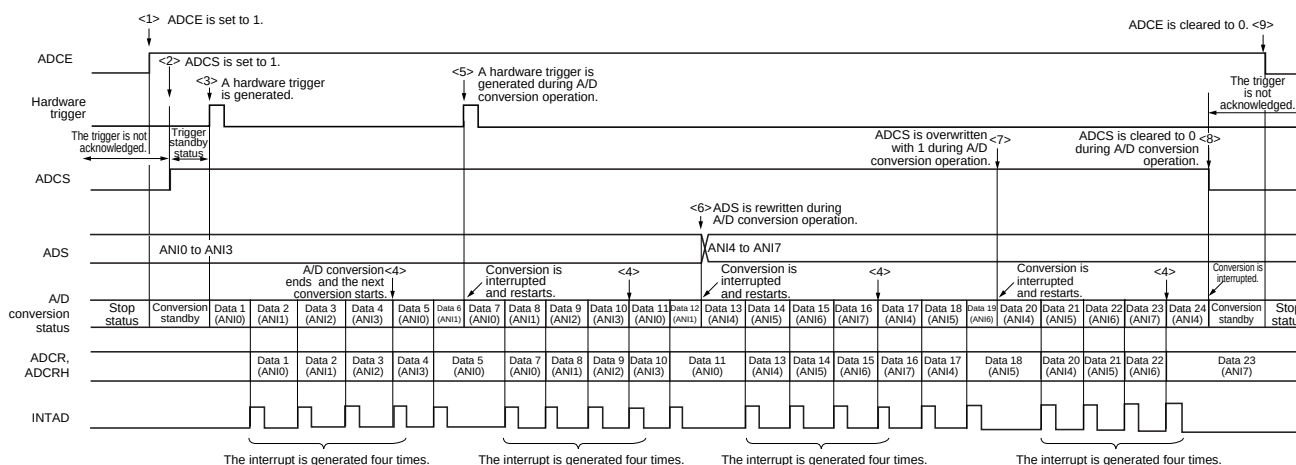


11.6.7 Hardware trigger no-wait mode (scan mode, sequential conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to place the system in the hardware trigger standby status (and conversion does not start at this stage). Note that, while in this status, A/D conversion does not start even if ADCS is set to 1.
- <3> If a hardware trigger is input while ADCS = 1, A/D conversion is performed on the four analog input channels specified by scan 0 to scan 3, which are specified by the analog input channel specification register (ADS). A/D conversion is performed on the analog input channels in order, starting with that specified by scan 0.
- <4> A/D conversion is sequentially performed on the four analog input channels, the conversion results are stored in the A/D conversion result register (ADCR, ADCRH) each time conversion ends, and the A/D conversion end interrupt request signal (INTAD) is generated. After A/D conversion of the four channels ends, the A/D conversion of the channel following the specified channel automatically starts.
- <5> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <6> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the first channel respecified by the ADS register. The partially converted data is discarded.
- <7> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <8> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status. However, the A/D converter does not stop in this status.
- <9> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCE = 0, specifying 1 for ADCS is ignored and A/D conversion does not start.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

Figure 11-23. Example of Hardware Trigger No-Wait Mode (Scan Mode, Sequential Conversion Mode) Operation Timing

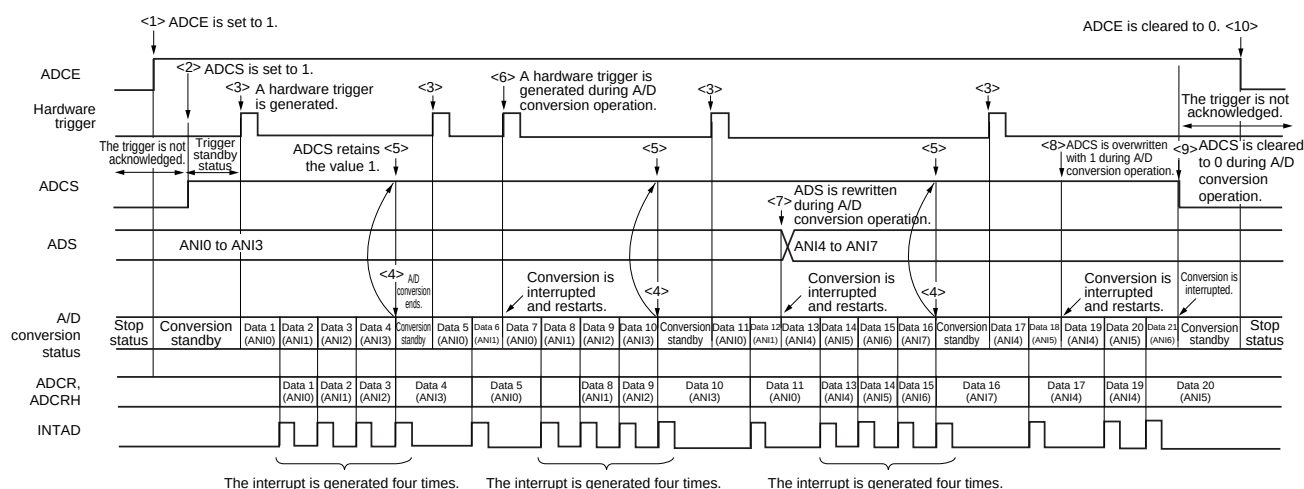


11.6.8 Hardware trigger no-wait mode (scan mode, one-shot conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> After the software counts up to the stabilization wait time^{Note}, the ADCS bit of the ADM0 register is set to 1 to place the system in the hardware trigger standby status (and conversion does not start at this stage). Note that, while in this status, A/D conversion does not start even if ADCS is set to 1.
- <3> If a hardware trigger is input while ADCS = 1, A/D conversion is performed on the four analog input channels specified by scan 0 to scan 3, which are specified by the analog input channel specification register (ADS). A/D conversion is performed on the analog input channels in order, starting with that specified by scan 0.
- <4> A/D conversion is sequentially performed on the four analog input channels, the conversion results are stored in the A/D conversion result register (ADCR, ADCRH) each time conversion ends, and the A/D conversion end interrupt request signal (INTAD) is generated.
- <5> After A/D conversion of the four channels ends, the ADCS bit remains set to 1, and the system enters the A/D conversion standby status.
- <6> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <7> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the first channel respecified by the ADS register. The partially converted data is discarded.
- <8> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <9> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, and the system enters the A/D conversion standby status. However, the A/D converter does not stop in this status.
- <10> When ADCE is cleared to 0 while in the A/D conversion standby status, the A/D converter enters the stop status. When ADCS = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

Note If a high-accuracy channel is selected as the analog input channel: Stabilization wait time = 0.5 μ s
 If a standard channel is selected as the analog input channel: Stabilization wait time = 2 μ s

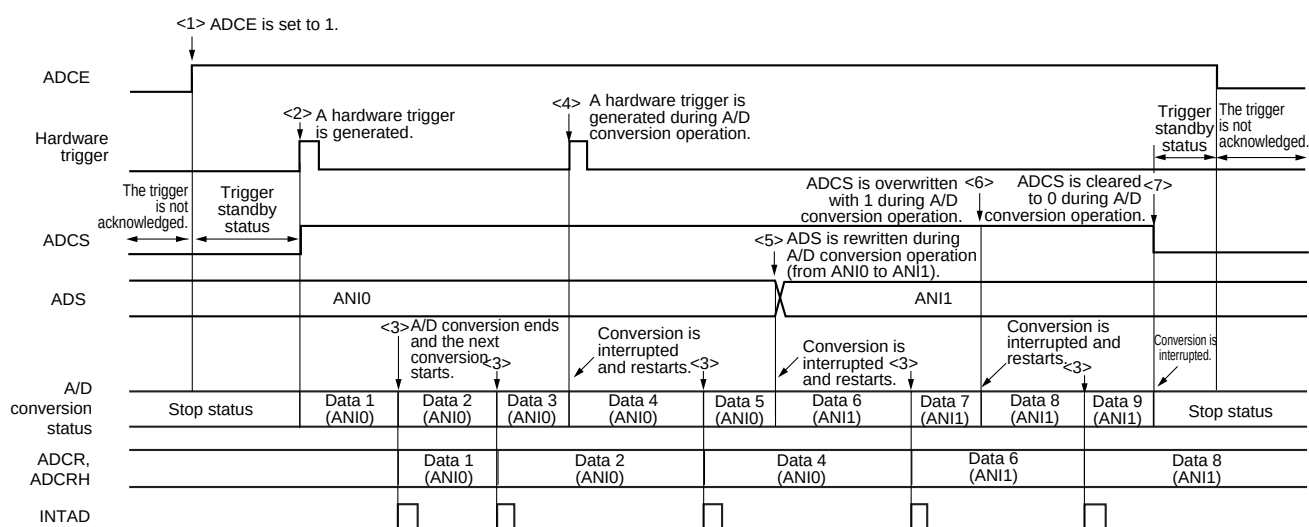
Figure 11-24. Example of Hardware Trigger No-Wait Mode (Scan Mode, One-Shot Conversion Mode)
Operation Timing



11.6.9 Hardware trigger wait mode (select mode, sequential conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the hardware trigger standby status.
- <2> If a hardware trigger is input while in the hardware trigger standby status, A/D conversion is performed on the analog input specified by the analog input channel specification register (ADS). The ADCS bit of the ADM0 register is automatically set to 1 according to the hardware trigger input.
- <3> When A/D conversion ends, the conversion result is stored in the A/D conversion result register (ADCR, ADCRH), and the A/D conversion end interrupt request signal (INTAD) is generated. After A/D conversion ends, the next A/D conversion immediately starts. (At this time, no hardware trigger is necessary.)
- <4> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <5> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the analog input respecified by the ADS register. The partially converted data is discarded.
- <6> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <7> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, the system enters the hardware trigger standby status, and the A/D converter enters the stop status. When ADCE = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

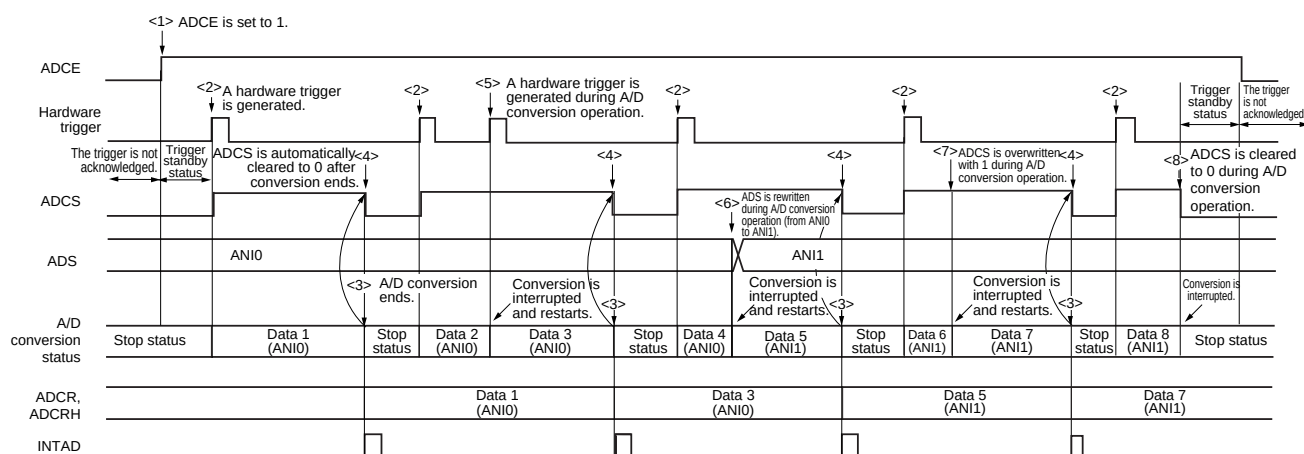
**Figure 11-25. Example of Hardware Trigger Wait Mode (Select Mode, Sequential Conversion Mode)
Operation Timing**



11.6.10 Hardware trigger wait mode (select mode, one-shot conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the hardware trigger standby status.
- <2> If a hardware trigger is input while in the hardware trigger standby status, A/D conversion is performed on the analog input specified by the analog input channel specification register (ADS). The ADCS bit of the ADM0 register is automatically set to 1 according to the hardware trigger input.
- <3> When A/D conversion ends, the conversion result is stored in the A/D conversion result register (ADCR, ADCRH), and the A/D conversion end interrupt request signal (INTAD) is generated.
- <4> After A/D conversion ends, the ADCS bit is automatically cleared to 0, and the A/D converter enters the stop status.
- <5> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is discarded.
- <6> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the analog input respecified by the ADS register. The partially converted data is discarded.
- <7> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts. The partially converted data is initialized.
- <8> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, the system enters the hardware trigger standby status, and the A/D converter enters the stop status. When ADCE = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

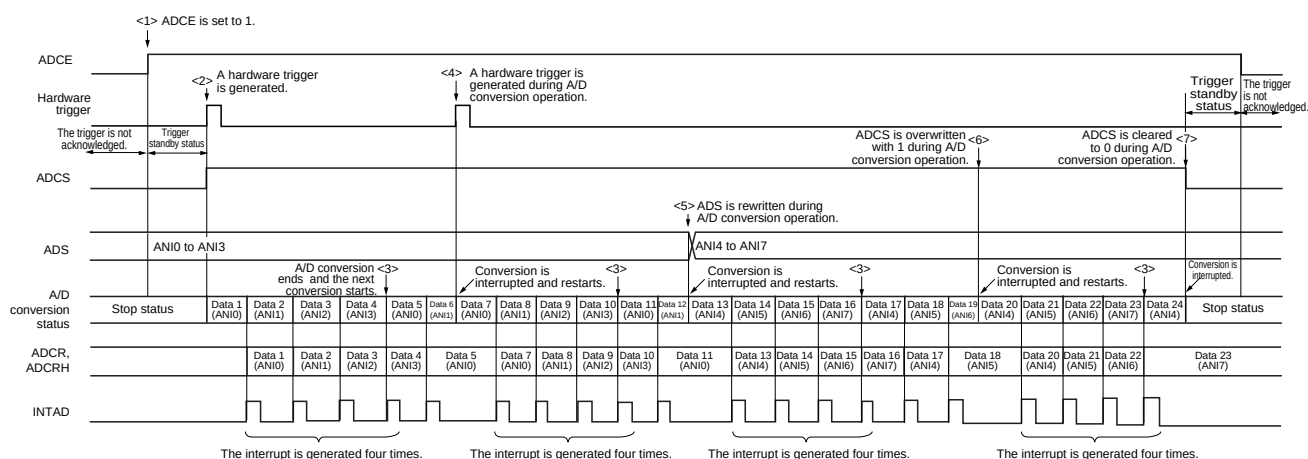
Figure 11-26. Example of Hardware Trigger Wait Mode (Select Mode, One-Shot Conversion Mode)
Operation Timing



11.6.11 Hardware trigger wait mode (scan mode, sequential conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> If a hardware trigger is input while in the hardware trigger standby status, A/D conversion is performed on the four analog input channels specified by scan 0 to scan 3, which are specified by the analog input channel specification register (ADS). The ADCS bit of the ADM0 register is automatically set to 1 according to the hardware trigger input. A/D conversion is performed on the analog input channels in order, starting with that specified by scan 0.
- <3> A/D conversion is sequentially performed on the four analog input channels, the conversion results are stored in the A/D conversion result register (ADCR, ADCRH) each time conversion ends, and the A/D conversion end interrupt request signal (INTAD) is generated. After A/D conversion of the four channels ends, the A/D conversion of the channel following the specified channel automatically starts.
- <4> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <5> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the first channel respecified by the ADS register. The partially converted data is discarded.
- <6> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <7> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, the system enters the hardware trigger standby status, and the A/D converter enters the stop status. When ADCE = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

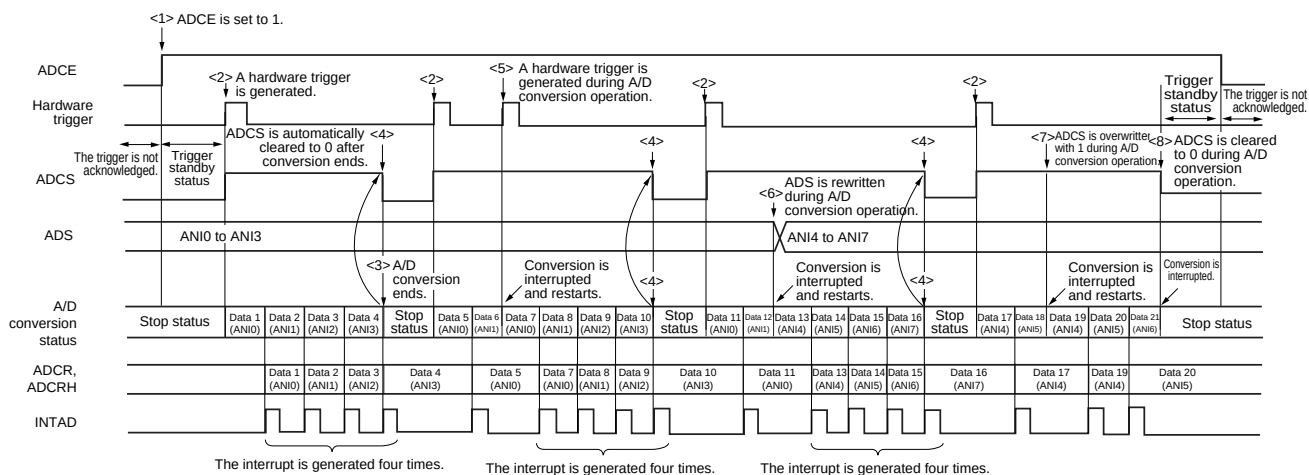
Figure 11-27. Example of Hardware Trigger Wait Mode (Scan Mode, Sequential Conversion Mode)
Operation Timing



11.6.12 Hardware trigger wait mode (scan mode, one-shot conversion mode)

- <1> In the stop status, the ADCE bit of A/D converter mode register 0 (ADM0) is set to 1, and the system enters the A/D conversion standby status.
- <2> If a hardware trigger is input while in the hardware trigger standby status, A/D conversion is performed on the four analog input channels specified by scan 0 to scan 3, which are specified by the analog input channel specification register (ADS). The ADCS bit of the ADM0 register is automatically set to 1 according to the hardware trigger input. A/D conversion is performed on the analog input channels in order, starting with that specified by scan 0.
- <3> A/D conversion is sequentially performed on the four analog input channels, the conversion results are stored in the A/D conversion result register (ADCR, ADCRH) each time conversion ends, and the A/D conversion end interrupt request signal (INTAD) is generated.
- <4> After A/D conversion ends, the ADCS bit is automatically cleared to 0, and the A/D converter enters the stop status.
- <5> If a hardware trigger is input during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <6> When the value of the ADS register is rewritten or overwritten during conversion operation, the current A/D conversion is interrupted, and A/D conversion is performed on the first channel respecified by the ADS register. The partially converted data is discarded.
- <7> When ADCS is overwritten with 1 during conversion operation, the current A/D conversion is interrupted, and conversion restarts at the first channel. The partially converted data is discarded.
- <8> When ADCS is cleared to 0 during conversion operation, the current A/D conversion is interrupted, the system enters the hardware trigger standby status, and the A/D converter enters the stop status. When ADCE = 0, inputting a hardware trigger is ignored and A/D conversion does not start.

Figure 11-28. Example of Hardware Trigger Wait Mode (Scan Mode, One-Shot Conversion Mode)
Operation Timing

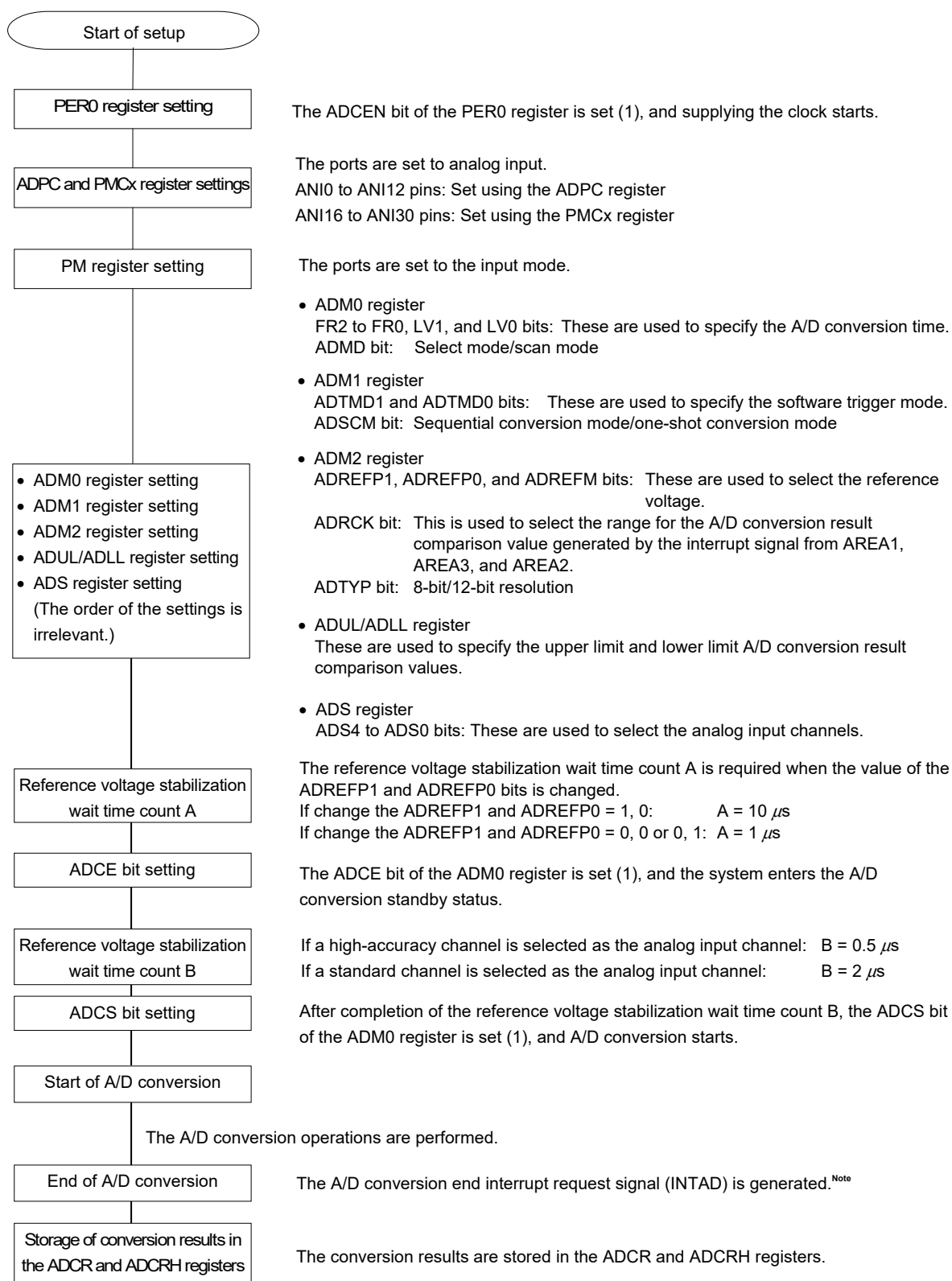


11.7 A/D Converter Setup Flowchart

The A/D converter setup flowchart in each operation mode is described below.

11.7.1 Setting up software trigger mode

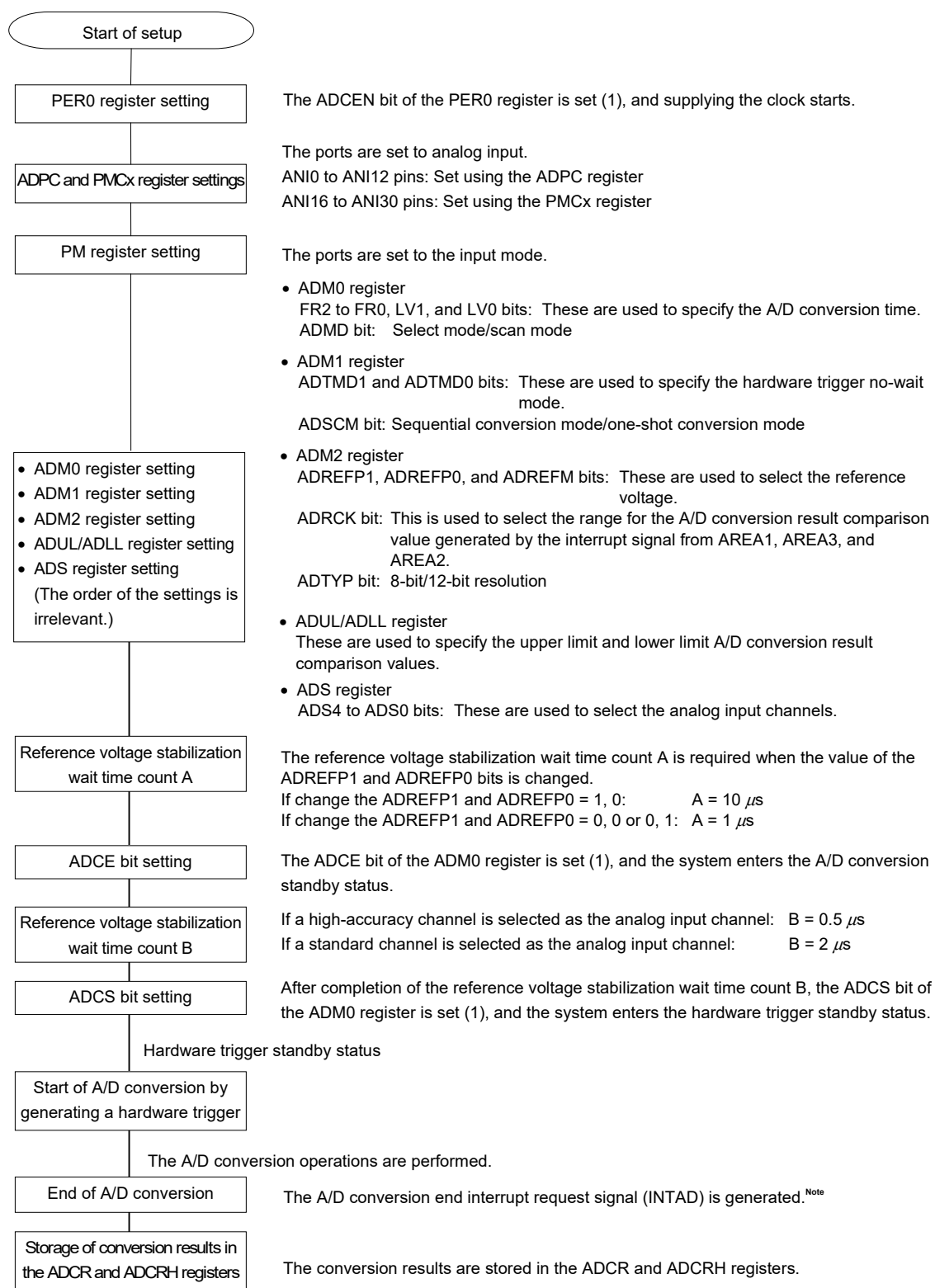
Figure 11-29. Setting up Software Trigger Mode



Note Depending on the settings of the ADRCK bit and ADUL/ADLL register, there is a possibility of no A/D conversion end interrupt request signal (INTAD) being generated. In this case, the results are not stored in the ADCR, ADCRH registers.

11.7.2 Setting up hardware trigger no-wait mode

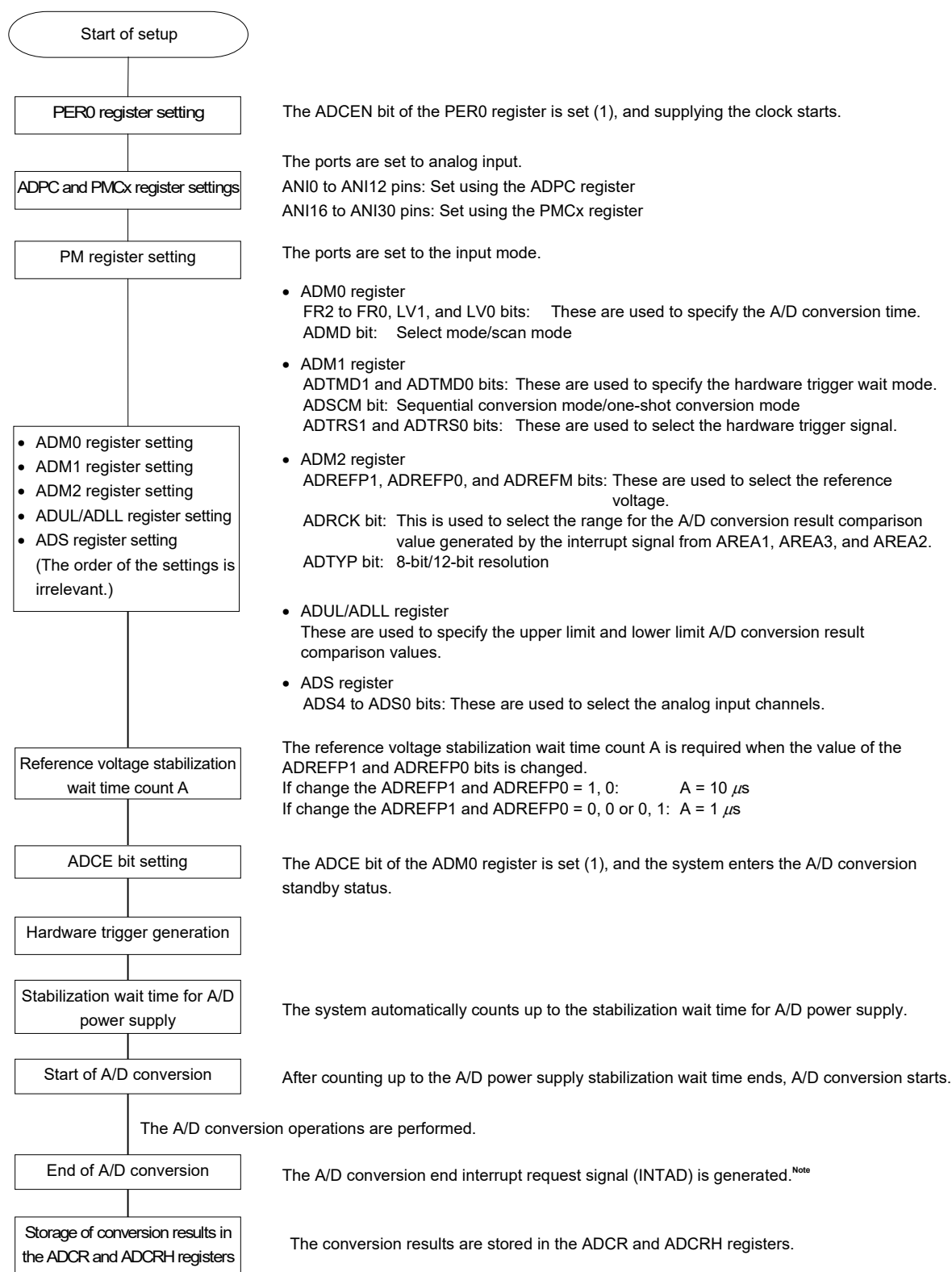
Figure 11-30. Setting up Hardware Trigger No-Wait Mode



Note Depending on the settings of the ADRCK bit and ADUL/ADLL register, there is a possibility of no A/D conversion end interrupt request signal (INTAD) being generated. In this case, the results are not stored in the ADCR, ADCRH registers.

11.7.3 Setting up hardware trigger wait mode

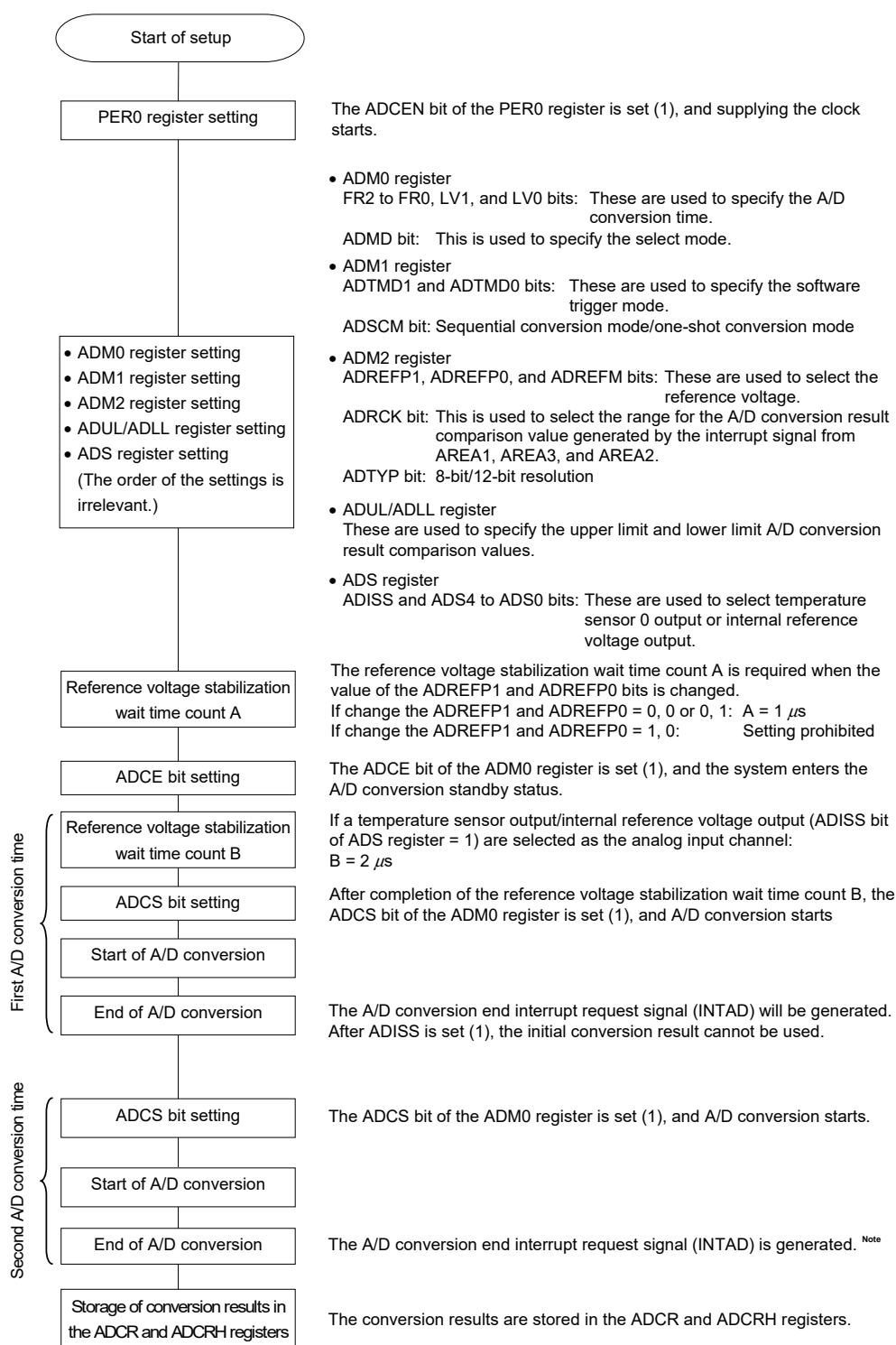
Figure 11-31. Setting up Hardware Trigger Wait Mode



Note Depending on the settings of the ADRCK bit and ADUL/ADLL register, there is a possibility of no A/D conversion end interrupt request signal (INTAD) being generated. In this case, the results are not stored in the ADCR, ADCRH registers.

11.7.4 Setup when temperature sensor output voltage/internal reference voltage is selected (example for software trigger mode and one-shot conversion mode)

Figure 11-32. Setup When Temperature Sensor Output Voltage/Internal Reference Voltage Is Selected

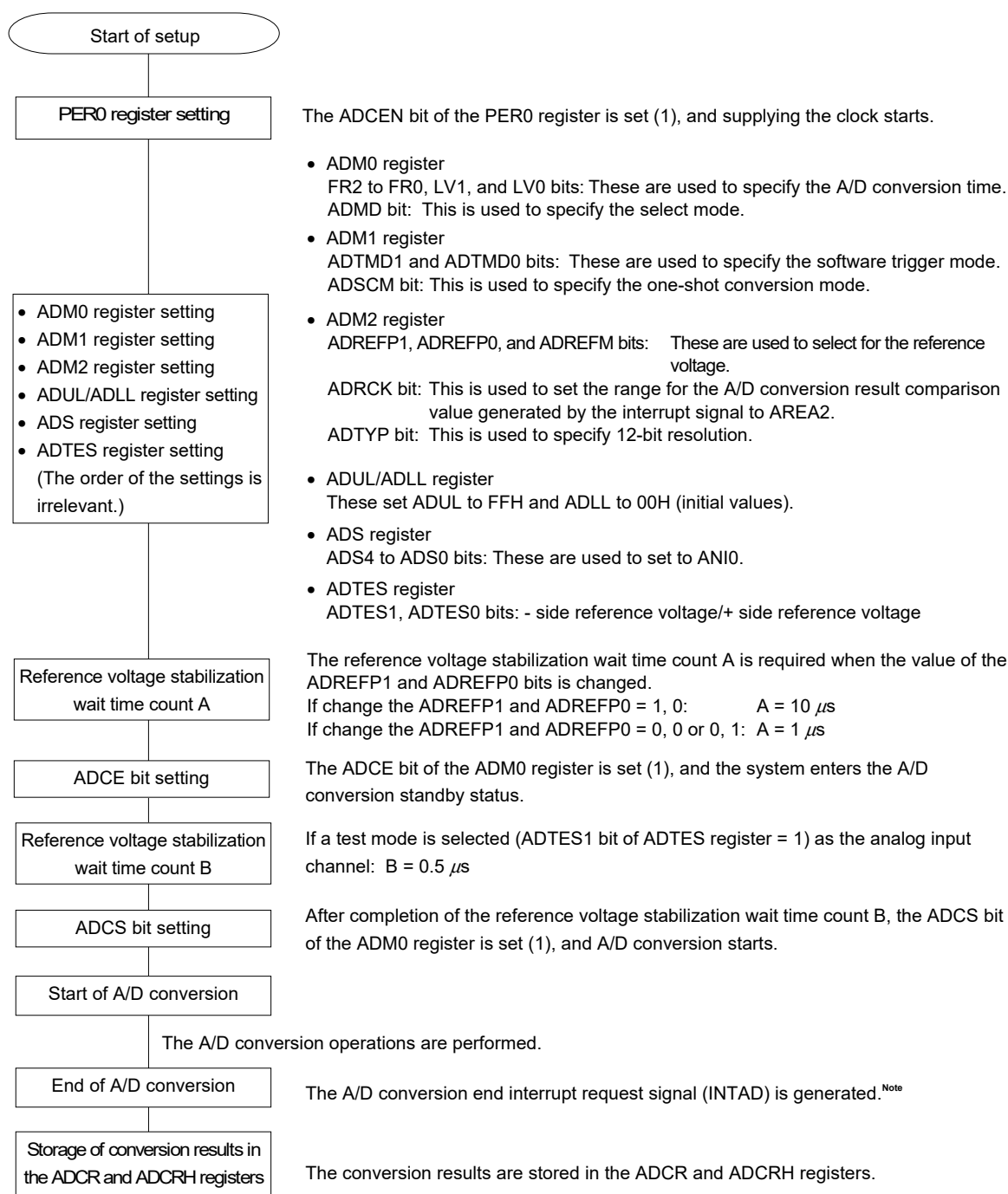


Note Depending on the settings of the ADRCK bit and ADUL/ADLL register, there is a possibility of no A/D conversion end interrupt request signal (INTAD) being generated. In this case, the results are not stored in the ADCR, ADCRH registers.

Caution This setting can be used only in HS (high-speed main) mode. For detail, see Figure 24-3 Format of User Option Byte (000C2H/010C2H).

11.7.5 Setting up test mode

Figure 11-33. Setting up Test Mode



Note Depending on the settings of the ADRCK bit and ADUL/ADLL register, there is a possibility of no A/D conversion end interrupt request signal (INTAD) being generated. In this case, the results are not stored in the ADCR, ADCRH registers.

Caution For the procedure for testing the A/D converter, see 22.3.8 A/D test function.

11.8 SNOOZE Mode Function

In the SNOOZE mode, A/D conversion is triggered by inputting a hardware trigger in the STOP mode. Normally, A/D conversion is stopped while in the STOP mode, but, by using the SNOOZE mode function, A/D conversion can be performed without operating the CPU. This is effective for reducing the operating current.

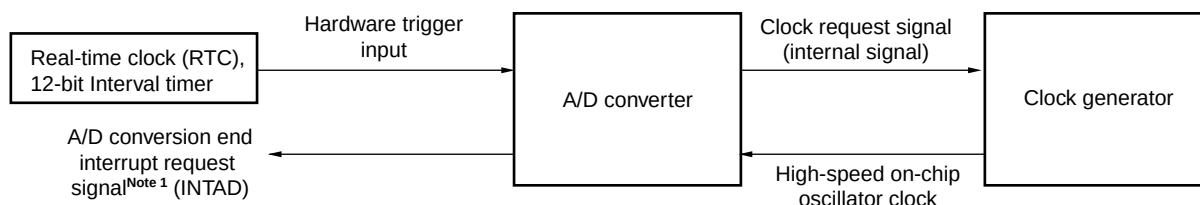
If the A/D conversion result range is specified using the ADUL and ADLL registers, A/D conversion results can be judged at a certain interval of time in SNOOZE mode. Using this function enables power supply voltage monitoring and input key judgment based on A/D inputs.

In the SNOOZE mode, only the following two conversion modes can be used:

- Hardware trigger wait mode (select mode, one-shot conversion mode)
- Hardware trigger wait mode (scan mode, one-shot conversion mode)

Caution The SNOOZE mode can only be specified when the high-speed on-chip oscillator clock is selected for f_{CLK} .

Figure 11-34. Block Diagram When Using SNOOZE Mode Function



When using the SNOOZE mode function, the initial setting of each register is specified before switching to the STOP mode. (For details about these settings, see **11.7.3 Setting up hardware trigger wait mode**^{Note 2}.) Just before move to STOP mode, bit 2 (AWC) of A/D converter mode register 2 (ADM2) is set to 1. After the initial settings are specified, bit 0 (ADCE) of A/D converter mode register 0 (ADM0) is set to 1.

If a hardware trigger is input after switching to the STOP mode, the high-speed on-chip oscillator clock is supplied to the A/D converter. After supplying this clock, the system automatically counts up to the A/D power supply stabilization wait time, and then A/D conversion starts.

The SNOOZE mode operation after A/D conversion ends differs depending on whether an interrupt signal is generated^{Note 1}.

- Notes**
1. Depending on the setting of the A/D conversion result comparison function (ADRCK bit, ADUL/ADLL register), there is a possibility of no interrupt signal being generated.
 2. Be sure to set the ADM1 register to E2H or E3H.

Remark The hardware trigger is INTRTC or INTIT.
Specify the hardware trigger by using the A/D Converter Mode Register 1 (ADM1).

(1) If an interrupt is generated after A/D conversion ends

If the A/D conversion result value is inside the range of values specified by the A/D conversion result comparison function (which is set up by using the ADRCK bit and ADUL/ADLL register), the A/D conversion end interrupt request signal (INTAD) is generated.

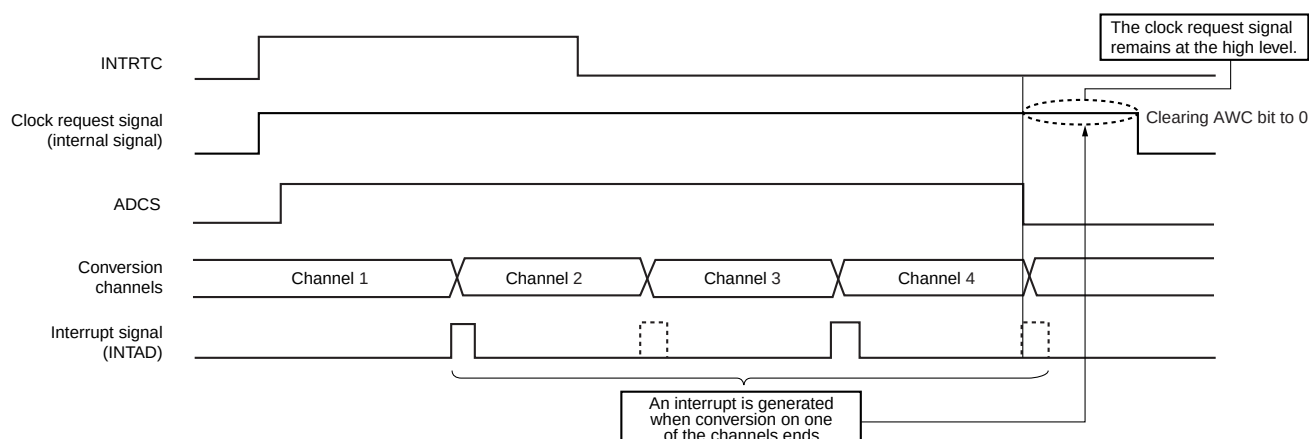
- While in the select mode

When A/D conversion ends and an A/D conversion end interrupt request signal (INTAD) is generated, the A/D converter returns to normal operation mode from SNOOZE mode. At this time, be sure to clear bit 2 (AWC = 0: SNOOZE mode release) of the A/D converter mode register 2 (ADM2). If the AWC bit is left set to 1, A/D conversion will not start normally in the subsequent SNOOZE or normal operation mode.

- While in the scan mode

If even one A/D conversion end interrupt request signal (INTAD) is generated during A/D conversion of the four channels, the clock request signal remains at the high level, and the A/D converter switches from the SNOOZE mode to the normal operation mode. At this time, be sure to clear bit 2 (AWC = 0: SNOOZE mode release) of A/D converter mode register 2 (ADM2) to 0. If the AWC bit is left set to 1, A/D conversion will not start normally in the subsequent SNOOZE or normal operation mode.

Figure 11-35. Operation Example When Interrupt Is Generated After A/D Conversion Ends (While in Scan Mode)



(2) If no interrupt is generated after A/D conversion ends

If the A/D conversion result value is outside the range of values specified by the A/D conversion result comparison function (which is set up by using the ADRCK bit and ADUL/ADLL register), the A/D conversion end interrupt request signal (INTAD) is not generated.

- While in the select mode

If the A/D conversion end interrupt request signal (INTAD) is not generated after A/D conversion ends, the clock request signal (an internal signal) is automatically set to the low level, and supplying the high-speed on-chip oscillator clock stops. If a hardware trigger is input later, A/D conversion work is again performed in the SNOOZE mode.

- While in the scan mode

If the A/D conversion end interrupt request signal (INTAD) is not generated even once during A/D conversion of the four channels, the clock request signal (an internal signal) is automatically set to the low level after A/D conversion of the four channels ends, and supplying the high-speed on-chip oscillator clock stops. If a hardware trigger is input later, A/D conversion work is again performed in the SNOOZE mode.

Figure 11-36. Operation Example When No Interrupt Is Generated After A/D Conversion Ends (While in Scan Mode)

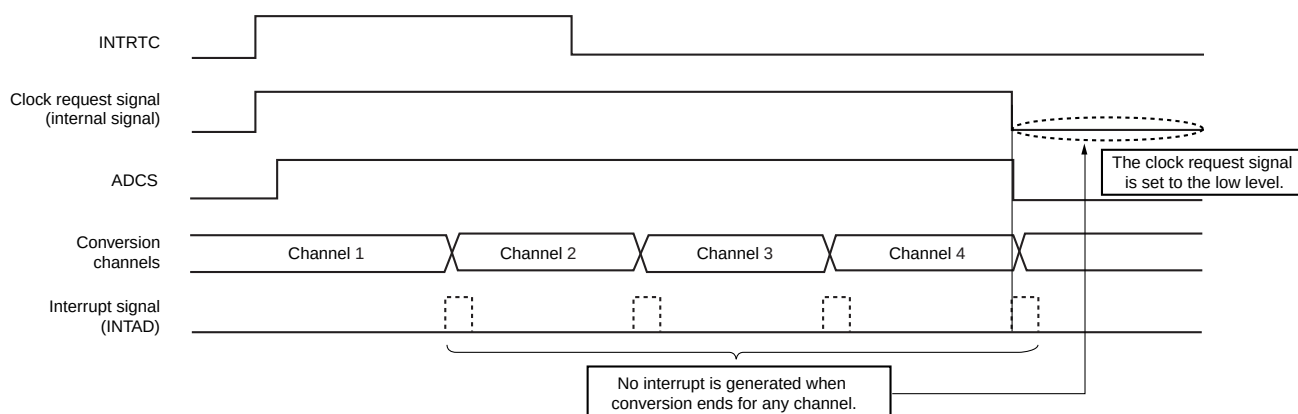
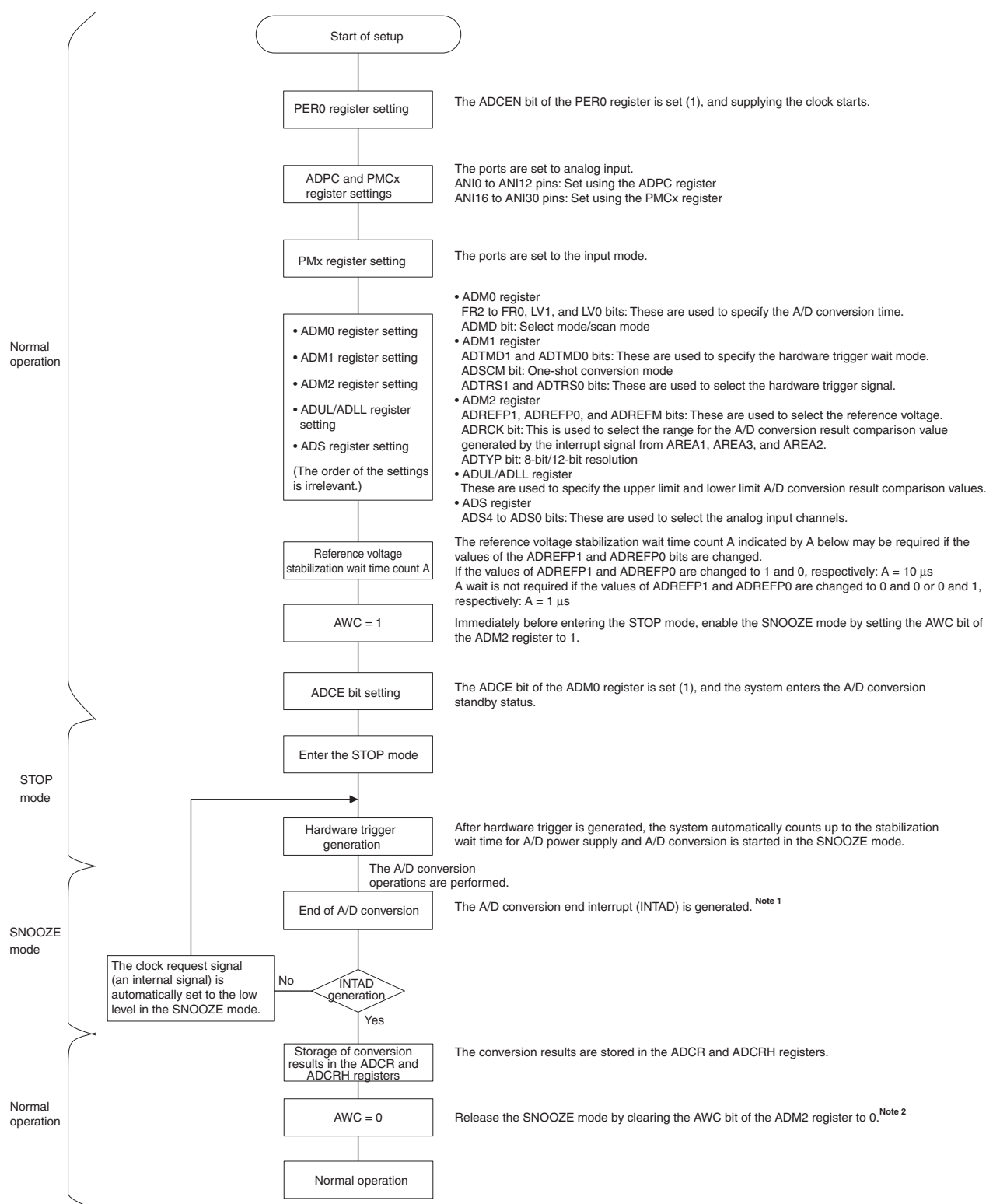


Figure 11-37. Flowchart for Setting up SNOOZE Mode



- Notes**
1. If the A/D conversion end interrupt request signal (INTAD) is not generated by setting ADRCK bit and ADUL/ADLL register, the result is not stored in the ADCR and ADCRH registers. The system enters the STOP mode again. If a hardware trigger is input later, A/D conversion operation is again performed in the SNOOZE mode.
 2. If the AWC bit is left set to 1, A/D conversion will not start normally in spite of the subsequent SNOOZE or normal operation mode. Be sure to clear the AWC bit to 0.

11.9 How to Read A/D Converter Characteristics Table

Here, special terms unique to the A/D converter are explained.

(1) Resolution

This is the minimum analog input voltage that can be identified. That is, the percentage of the analog input voltage per bit of digital output is called 1LSB (Least Significant Bit). The percentage of 1LSB with respect to the full scale is expressed by %FSR (Full Scale Range).

1LSB is as follows when the resolution is 12 bits.

$$\begin{aligned} 1\text{LSB} &= 1/2^{12} = 1/4096 \\ &\approx 0.024\%\text{FSR} \end{aligned}$$

Accuracy has no relation to resolution, but is determined by overall error.

(2) Overall error

This shows the maximum error value between the actual measured value and the theoretical value.

Zero-scale error, full-scale error, integral linearity error, and differential linearity errors that are combinations of these express the overall error.

Note that the quantization error is not included in the overall error in the characteristics table.

(3) Quantization error

When analog values are converted to digital values, a $\pm 1/2\text{LSB}$ error naturally occurs. In an A/D converter, an analog input voltage in a range of $\pm 1/2\text{LSB}$ is converted to the same digital code, so a quantization error cannot be avoided.

Note that the quantization error is not included in the overall error, zero-scale error, full-scale error, integral linearity error, and differential linearity error in the characteristics table.

Figure 11-38. Overall Error

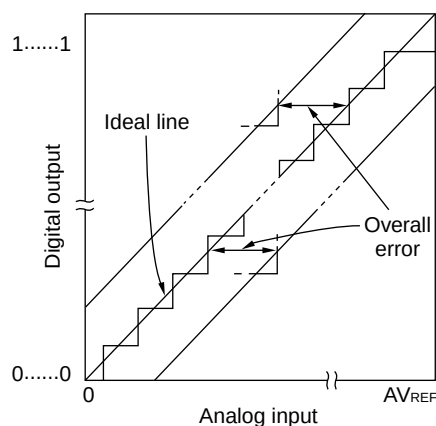
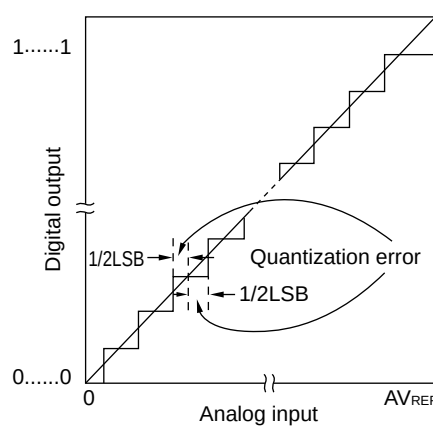


Figure 11-39. Quantization Error



(4) Zero-scale error

This shows the difference between the actual measurement value of the analog input voltage and the theoretical value ($1/2\text{LSB}$) when the digital output changes from 0.....000 to 0.....001.

If the actual measurement value is greater than the theoretical value, it shows the difference between the actual measurement value of the analog input voltage and the theoretical value ($3/2\text{LSB}$) when the digital output changes from 0.....001 to 0.....010.

(5) Full-scale error

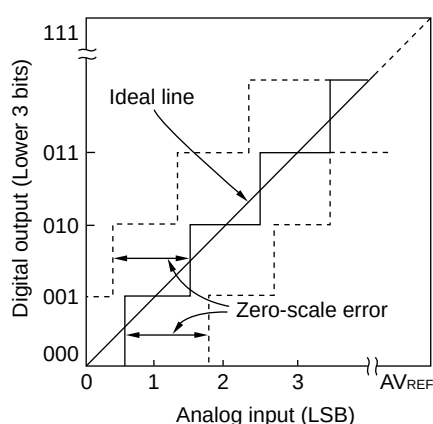
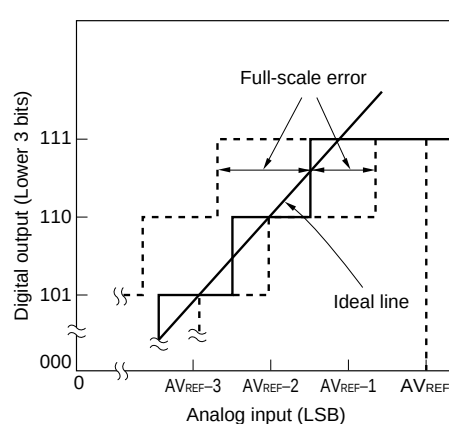
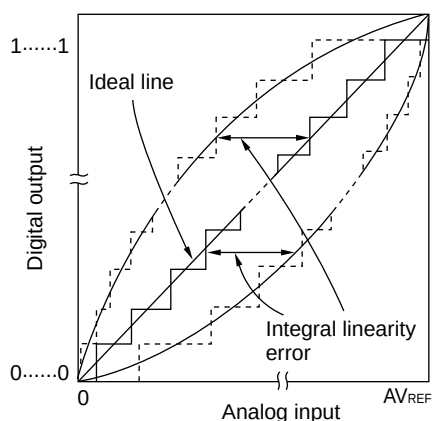
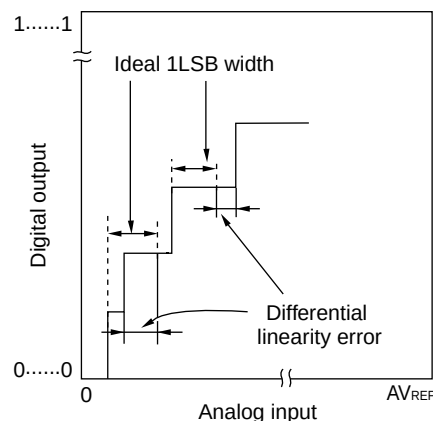
This shows the difference between the actual measurement value of the analog input voltage and the theoretical value (Full-scale – 3/2LSB) when the digital output changes from 1.....110 to 1.....111.

(6) Integral linearity error

This shows the degree to which the conversion characteristics deviate from the ideal linear relationship. It expresses the maximum value of the difference between the actual measurement value and the ideal straight line when the zero-scale error and full-scale error are 0.

(7) Differential linearity error

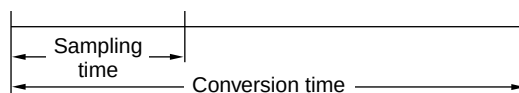
While the ideal width of code output is 1LSB, this indicates the difference between the actual measurement value and the ideal value.

Figure 11-40. Zero-Scale Error**Figure 11-41. Full-Scale Error****Figure 11-42. Integral Linearity Error****Figure 11-43. Differential Linearity Error****(8) Conversion time**

This expresses the time from the start of sampling to when the digital output is obtained. The sampling time is included in the conversion time in the characteristics table.

(9) Sampling time

This is the time the analog switch is turned on for the analog voltage to be sampled by the sample & hold circuit.



11.10 Cautions for A/D Converter

(1) Operating current in STOP mode

Shift to STOP mode after stopping the A/D converter (by setting bit 7 (ADCS) of A/D converter mode register 0 (ADM0) to 0). The operating current can be reduced by setting bit 0 (ADCE) of the ADM0 register to 0 at the same time.

To restart from the standby status, clear bit 0 (ADIF) of interrupt request flag register 1H (IF1H) to 0 and start operation.

(2) Input range of ANI0 to ANI12 and ANI16 to ANI30 pins

Observe the rated range of the ANI0 to ANI12 and ANI16 to ANI30 pins input voltage. If a voltage exceeding AV_{DD} and AV_{REFP} or a voltage lower than AV_{SS} and AV_{REFM} (even in the range of absolute maximum ratings) is input to an analog input channel, the converted value of that channel becomes undefined. In addition, the converted values of the other channels may also be affected.

When internal reference voltage (1.45 V) is selected reference voltage for the + side of the A/D converter, do not input internal reference voltage (1.45 V) or higher voltage to a pin selected by the ADS register. However, it is no problem that a pin not selected by the ADS register is input voltage greater than the internal reference voltage (1.45 V).

Caution Internal reference voltage (1.45 V) can be used only in HS (high-speed main) mode. For detail, see Figure 24-3 Format of User Option Byte (000C2H/010C2H).

(3) Conflicting operations

<1> Conflict between the A/D conversion result register (ADCR, ADCRH) write and the ADCR or ADCRH register read by instruction upon the end of conversion

The ADCR or ADCRH register read has priority. After the read operation, the new conversion result is written to the ADCR or ADCRH registers.

<2> Conflict between the ADCR or ADCRH register write and the A/D converter mode register 0 (ADM0) write, the analog input channel specification register (ADS), or A/D port configuration register (ADPC) write upon the end of conversion

The ADM0, ADS, or ADPC registers write has priority. The ADCR or ADCRH register write is not performed, nor is the conversion end interrupt request signal (INTAD) generated.

(4) Noise countermeasures

To maintain the 12-bit resolution, attention must be paid to noise input to the AV_{REFP} , AV_{DD} , ANI0 to ANI12, and ANI16 to ANI30 pins.

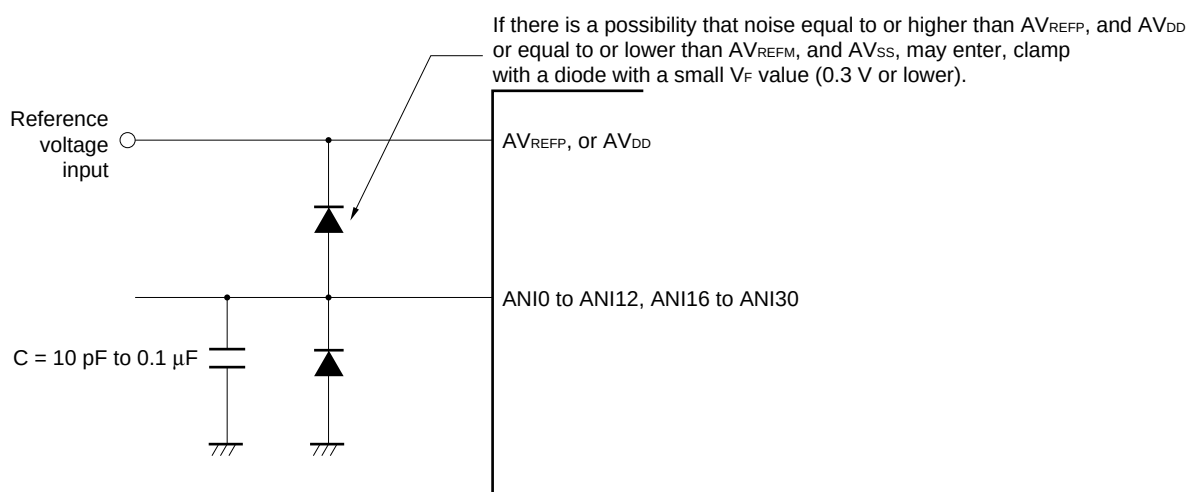
<1> Connect a capacitor with a low equivalent resistance and a good frequency response (capacitance of about 0.01 μ F) via the shortest possible run of relatively thick wiring to the power supply.

<2> The higher the output impedance of the analog input source, the greater the influence. To reduce the noise, connecting external capacitor as shown in Figure 11-44 is recommended.

<3> Do not switch these pins with other pins during conversion.

<4> The accuracy is improved if the HALT mode is set immediately after the start of conversion.

<5> Separate digital and analog signals so that they do not cross or approach each other.

Figure 11-44. Analog Input Pin Connection**(5) Analog input (ANIn) pins**

- <1> ANI0 to ANI12 pins (high-accuracy channel) are also used as P20 to P27, and P150 to P154 pins. When A/D conversion is performed with any of the high-accuracy channel (ANI0 to ANI12) pins selected, do not change the output value P20 to P27, and P150 to P154 while conversion is in progress; otherwise the conversion accuracy may be degraded.
- <2> If a pin adjacent to the pin whose value is being A/D converted is used as a digital I/O port pin, the A/D conversion value might differ from the expected value due to coupling noise. To prevent coupling noise, make sure that pulses whose voltage suddenly change, such as digital pulses, are not input or output to a pin adjacent to the pin whose value is being A/D converted.

(6) Input impedance of analog input (ANIn) pins

This A/D converter charges a sampling capacitor for sampling during sampling time.

Therefore, only a leakage current flows when sampling is not in progress, and a current that charges the capacitor flows during sampling. Consequently, the input impedance fluctuates depending on whether sampling is in progress, and on the other states.

However, in order to perform sampling accurately, the output impedance of the analog input source should be 1 k Ω or lower. If it is not possible to keep the output impedance below this level, it is recommended to either extend the sampling time or connect a capacitor of about 0.1 μF to the ANI0 to ANI12 and ANI16 to ANI30 pins. (See **Figure 11-44** for details.)

Also, if the ADCS bit is set to 0 or a reconversion is started during A/D conversion, the sampling capacitor will be insufficiently charged. This means that charging will start with an undefined conversion voltage from the next conversion in the case of setting the ADCS bit to 0, or from the current conversion in the case of starting a reconversion.

To ensure that the capacitor is fully charged, therefore, either reduce the output impedance of the analog input source or specify a sufficiently long sampling time, irrespective of the analog signal voltage variation.

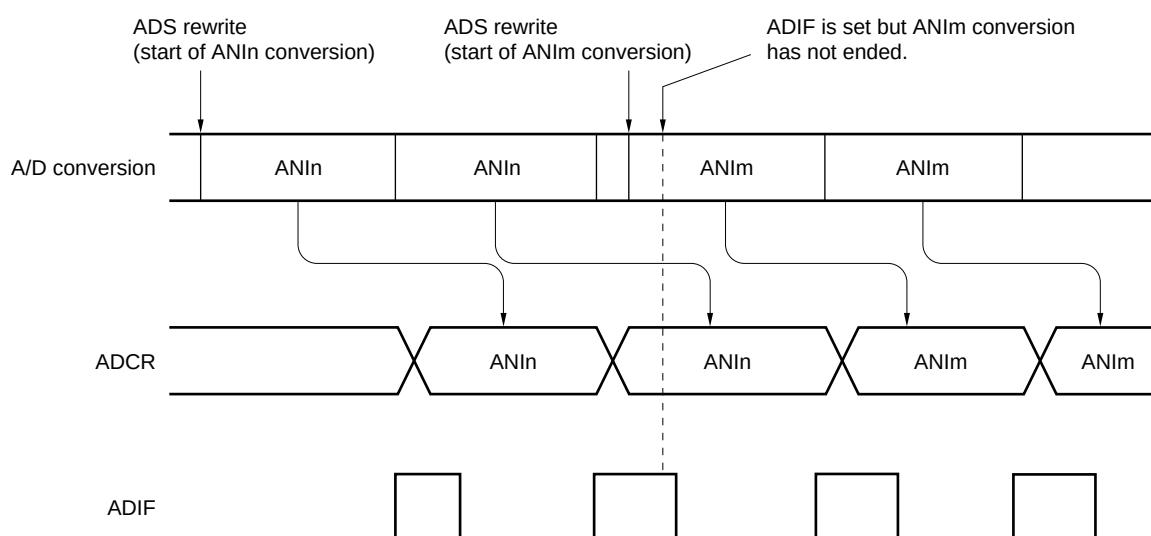
(7) Interrupt request flag (ADIF)

The interrupt request flag (ADIF) is not cleared even if the analog input channel specification register (ADS) is changed.

Therefore, if an analog input pin is changed during A/D conversion, the A/D conversion result and ADIF flag for the pre-change analog input may be set just before the ADS register rewrite. Caution is therefore required since, at this time, when ADIF flag is read immediately after the ADS register rewrite, ADIF flag is set despite the fact A/D conversion for the post-change analog input has not ended.

When A/D conversion is stopped and then resumed, clear ADIF flag before the A/D conversion operation is resumed.

Figure 11-45. Timing of A/D Conversion End Interrupt Request Generation

**(8) Conversion results just after A/D conversion start**

While in the software trigger mode or hardware trigger no-wait mode, the first A/D conversion value immediately after A/D conversion starts may not fall within the rating range if the ADCE bit is set to 1 within the stabilization wait time after the ADCE bit was set to 1. Take measures such as polling the A/D conversion end interrupt request (INTAD) and removing the first conversion result.

[Stabilization wait status]

If a high-accuracy channel is selected as the analog input channel: 0.5 μ s

If a test mode setting (ADTES1 bit of ADTES register = 1) is selected: 0.5 μ s

If a standard channel is selected as the analog input channel: 2 μ s

If a temperature sensor output/internal reference voltage output are selected as the analog input channel:

(ADISS bit of ADS register = 1): 2 μ s

(9) A/D conversion result register (ADCR, ADCRH) read operation

When a write operation is performed to A/D converter mode register 0 (ADM0), analog input channel specification register (ADS), A/D port configuration register (ADPC), and port mode control register (PMCx), the contents of the ADCR and ADCRH registers may become undefined. Read the conversion result following conversion completion before writing to the ADM0, ADS, ADPC, or PMCx register. Using a timing other than the above may cause an incorrect conversion result to be read.

(10) Internal equivalent circuit

The equivalent circuit of the analog input block is shown below.

Figure 11-46. Internal Equivalent Circuit of ANIn Pin

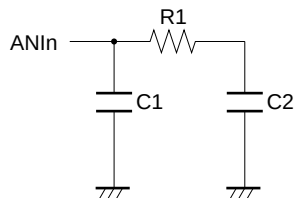


Table 11-4. Resistance and Capacitance Values of Equivalent Circuit (Reference Values)

AV_{DD}	ANIn pin	$R1[k\Omega]$	$C1[pF]$	$C2[pF]$
$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	ANI0 to ANI12	7.4	8	6.3
	ANI16 to ANI30	12.3	8	7.4
$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	ANI0 to ANI12	11	8	6.3
	ANI16 to ANI30	41	8	7.4
$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	ANI0 to ANI12	510	8	6.3
	ANI16 to ANI30	650	8	7.4

Remark The resistance and capacitance values shown in Table 11-4 are not guaranteed values.

(11) Starting the A/D converter

Start the A/D converter after the AV_{REFP} and AV_{DD} voltages stabilize.

CHAPTER 12 SERIAL ARRAY UNIT

A single serial array unit has up to four serial channels. Each channel can achieve Simplified SPI (CSI^{Note}), UART, and simplified I²C communication.

Function assignment of each channel supported by the RL78/G1A is as shown below.

Note Although the CSI function is generally called SPI, it is also called CSI in this product, so it is referred to as such in this manual.

- 25-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11

- 32-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	–		–

- 48-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

- 64-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	CSI10	UART1	IIC10
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

When “UART0” is used for channels 0 and 1 of the unit 0, CSI00 and CSI01 cannot be used, but CSI10, UART1, or IIC10 can be used.

Caution Most of the following descriptions in this chapter use the units and channels of the 64-pin products as an example.

12.1 Functions of Serial Array Unit

Each serial interface supported by the RL78/G1A has the following features.

12.1.1 Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21)

Data is transmitted or received in synchronization with the serial clock (SCK) output from the master channel. Simplified SPI communication is clocked communication performed by using three communication lines: one for the serial clock (SCK), one for transmitting serial data (SO), one for receiving serial data (SI).

For details about the settings, see **12.5 Operation of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) Communication.**

[Data transmission/reception]

- Data length of 7 or 8 bits
- Phase control of transmit/receive data
- MSB/LSB first selectable

[Clock control]

- Master/slave selection
- Phase control of I/O clock
- Setting of transfer period by prescaler and internal counter of each channel
- Maximum transfer rate^{Note}

During master communication: Max. $f_{CLK}/2$ (CSI00 only)

Max. $f_{CLK}/4$

During slave communication: Max. $f_{MCK}/6$

[Interrupt function]

- Transfer end interrupt/buffer empty interrupt

[Error detection flag]

- Overrun error

In addition, CSI00 of following channels supports the SNOOZE mode. When SCK input is detected while in the STOP mode, the SNOOZE mode makes data reception that does not require the CPU possible. Only CSI00 can be specified for asynchronous reception.

Note Use the clocks within a range satisfying the SCK cycle time (t_{KCY}) characteristics. For details, see **CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)**, **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$)**.

12.1.2 UART (UART0 to UART2)

This is a start-stop synchronization function using two lines: serial data transmission (TxD) and serial data reception (RxD) lines. By using these two communication lines, each data frame, which consist of a start bit, data, parity bit, and stop bit, is transferred asynchronously (using the internal baud rate) between the microcontroller and the other communication party. Full-duplex UART communication can be performed by using a channel dedicated to transmission (even-numbered channel) and a channel dedicated to reception (odd-numbered channel). The LIN-bus can be implemented by using timer array unit with an external interrupt (INTP0).

For details about the settings, see **12.6 Operation of UART (UART0 to UART2) Communication**.

[Data transmission/reception]

- Data length of 7, 8, or 9 bits^{Note}
- Select the MSB/LSB first
- Level setting of transmit/receive data and select of reverse
- Parity bit appending and parity check functions
- Stop bit appending

[Interrupt function]

- Transfer end interrupt/buffer empty interrupt
- Error interrupt in case of framing error, parity error, or overrun error

[Error detection flag]

- Framing error, parity error, or overrun error

In addition, UARTs of following channels supports the SNOOZE mode. When RxD input is detected while in the STOP mode, the SNOOZE mode makes data reception that does not require the CPU possible. Only UART0 can be specified for asynchronous reception.

The LIN-bus is accepted in UART2 (0 and 1 channels of unit 1) (32-pin to 64-pin products only).

[LIN-bus functions]

- Wakeup signal detection
- Break field (BF) detection
- Sync field measurement, baud rate calculation

} Using the external interrupt (INTP0) and timer array unit

Note Only UART0 can be specified for the 9-bit data length.

12.1.3 Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21)

This is a clocked communication function to communicate with two or more devices by using two lines: serial clock (SCL) and serial data (SDA). This simplified I²C is designed for single communication with a device such as EEPROM, flash memory, or A/D converter, and therefore, it functions only as a master.

Make sure by using software, as well as operating the control registers, that the AC specifications of the start and stop conditions are observed.

For details about the settings, see **12.8 Operation of Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21)**

[Data transmission/reception]

- Master transmission, master reception (only master function with a single master)
- ACK output function^{Note} and ACK detection function
- Data length of 8 bits (When an address is transmitted, the address is specified by the higher 7 bits, and the least significant bit is used for R/W control.)
- Manual generation of start condition and stop condition

[Interrupt function]

- Transfer end interrupt

[Error detection flag]

- ACK error, or overrun error

* [Functions not supported by simplified I²C]

- Slave transmission, slave reception
- Arbitration loss detection function
- Clock stretch detection functions

Note When receiving the last data, ACK will not be output if 0 is written to the SOEmn bit (serial output enable register m (SOEm)) and serial communication data output is stopped. See the processing flow in **12.8.3 (2)** for details.

Remarks 1. To use an I²C bus of full function, see **CHAPTER 13 SERIAL INTERFACE IICA**.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.2 Configuration of Serial Array Unit

The serial array unit includes the following hardware.

Table 12-1. Configuration of Serial Array Unit

Item	Configuration
Shift register	8 bits or 9 bits ^{Note 1}
Buffer register	Lower 8 bits or 9 bits of serial data register mn (SDRmn) ^{Notes 1, 2}
Serial clock I/O	SCK00, SCK01, SCK10, SCK11, SCK20, SCK21 pins (for simplified SPI), SCL00, SCL01, SCL10, SCL11, SCL20, SCL21 pins (for simplified I ² C)
Serial data input	SI00, SI01, SI10, SI11, SI20, SI21 pins (for simplified SPI), RxD0, RxD1 pins (for UART), RxD2 pin (for UART supporting LIN-bus)
Serial data output	SO00, SO01, SO10, SO11, SO20, SO21 pins (for simplified SPI), TxD0, TxD1 pins (for UART), TxD2 pin (for UART supporting LIN-bus)
Serial data I/O	SDA00, SDA01, SDA10, SDA11, SDA20, SDA21 pins (for simplified I ² C)
Control registers	<Registers of unit setting block> - Peripheral enable register 0 (PER0) - Serial clock select register m (SPSm) - Serial channel enable status register m (SEm) - Serial channel start register m (SSm) - Serial channel stop register m (STm) - Serial output enable register m (SOEm) - Serial output register m (SOM) - Serial output level register m (SOLm) - Serial standby control register m (SSCm) - Input switch control register (ISC) - Noise filter enable register 0 (NFEN0) <Registers of each channel> - Serial data register mn (SDRmn) - Serial mode register mn (SMRmn) - Serial communication operation setting register mn (SCRmn) - Serial status register mn (SSRmn) - Serial flag clear trigger register mn (SIRmn) - Port input mode registers 0, 1 (PIM0, PIM1) - Port output mode registers 0, 1, 5, 7 (POM0, POM1, POM5, POM7) - Port mode control registers 0, 1, 3, 5, 7 (PMC0, PMC1, PMC3, PMC5, PMC7) - Port mode registers 0, 1, 3, 5, 7 (PM0, PM1, PM3, PM5, PM7) - Port registers 0, 1, 3, 5, 7 (P0, P1, P3, P5, P7)

Notes 1. The number of bits used as the shift register and buffer register differs depending on the unit and channel.

- mn = 00, 01: lower 9 bits
- Other than above: lower 8 bits

2. The lower 8 bits of serial data register mn (SDRmn) can be read or written as the following SFR, depending on the communication mode.

- CSIp communication ... SIOp (CSIp data register)
- UARTq reception ... RXDq (UARTq receive data register)
- UARTq transmission ... TXDq (UARTq transmit data register)
- IICr communication ... SIOr (IICr data register)

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), q: UART number (q = 0 to 2), r: IIC number (r = 00, 01, 10, 11, 20, 21)

Figure 12-1 shows the block diagram of the serial array unit 0.

Figure 12-1. Block Diagram of Serial Array Unit 0

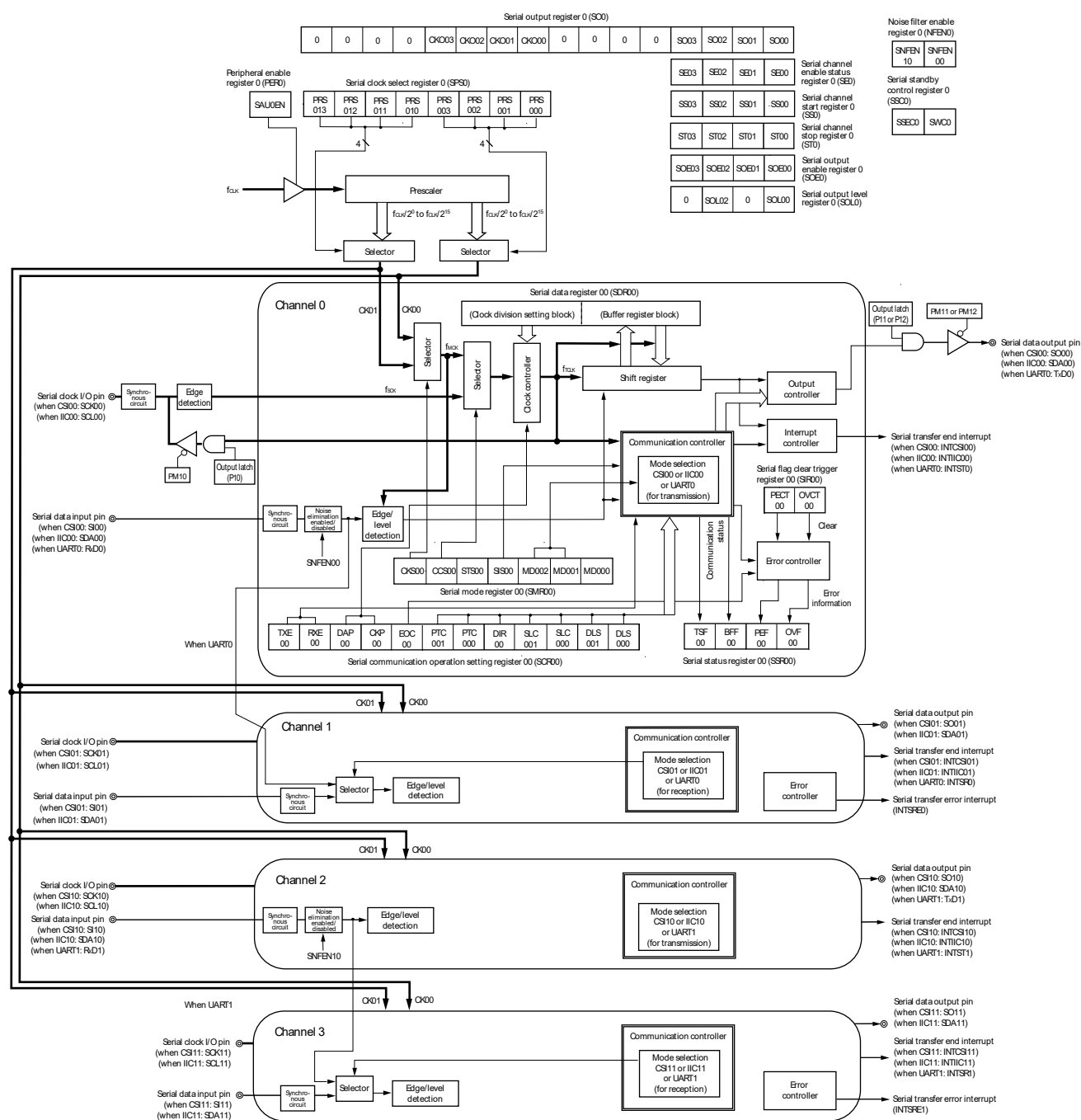
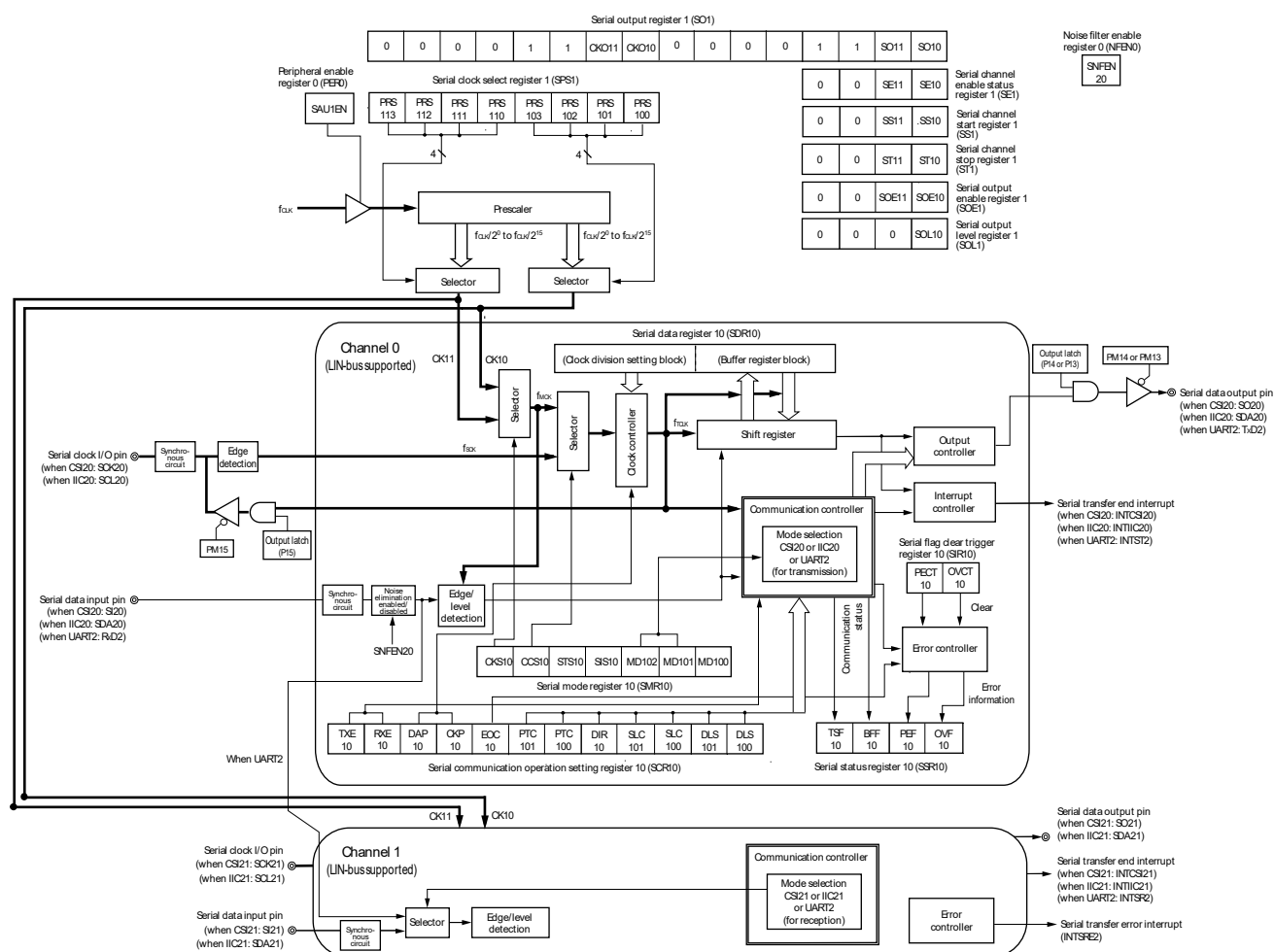


Figure 12-2 shows the block diagram of the serial array unit 1.

Figure 12-2. Block Diagram of Serial Array Unit 1



12.2.1 Shift register

This is a 9-bit register that converts parallel data into serial data or vice versa.

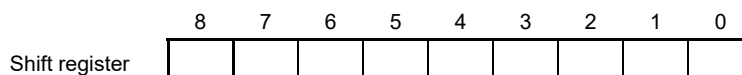
In case of the UART communication of nine bits of data, nine bits (bits 0 to 8) are used^{Note 1}.

The shift register cannot be directly manipulated by program.

During reception, it converts data input to the serial pin into parallel data, and stores to the lower 8/9 bits of the SDRmn register.

When data is transmitted, the value transferred from the lower 8/9 bits of the SDRmn register to this register is output as serial data from the serial output pin.

For details, see **12.2.2 Lower 8/9 bits of the serial data register mn (SDRmn)**.



12.2.2 Lower 8/9 bits of the serial data register mn (SDRmn)

The SDRmn register is the transmit/receive data register (16 bits) of channel n.

Bits 8 to 0 of SDR00, SDR01 (lower 9 bits) or bits 7 to 0 of SDR02, SDR03, SDR10^{Note 1}, and SDR11^{Note 1} (lower 8 bits) function as a transmit/receive buffer register, and bits 15 to 9 (higher 7 bits) are used as a register that sets the division ratio of the operation clock (f_{MCK}).

Remark For the function of the higher 7 bits of the SDRmn register, see **12.3.5 Higher 7 bits of the serial data register mn (SDRmn)**.

When data is received, parallel data converted by the shift register is stored in the lower 8/9 bits. When data is to be transmitted, set transmit to be transferred to the shift register to the lower 8/9 bits.

The data stored in the lower 8/9 bits of this register is as follows, depending on the setting of bits 0 and 1 (DLSmn0, DLSmn1) of serial communication operation setting register mn (SCRmn), regardless of the output sequence of the data.

- 7-bit data length (stored in bits 0 to 6 of SDRmn register)
- 8-bit data length (stored in bits 0 to 7 of SDRmn register)
- 9-bit data length (stored in bits 0 to 8 of SDRmn register)^{Note 1}

The lower 8/9 bits of the SDRmn register can be read or written^{Note 2} in 8-bit units as the following SFR, depending on the communication mode.

- CSIp communication ... SIOP (CSIp data register)
- UARTq reception ... RXDq (UARTq receive data register)
- UARTq transmission ... TXDq (UARTq transmit data register)
- IICr communication ... SIOr (IICr data register)

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

Reset signal generation clears the SDRmn register to 0000H.

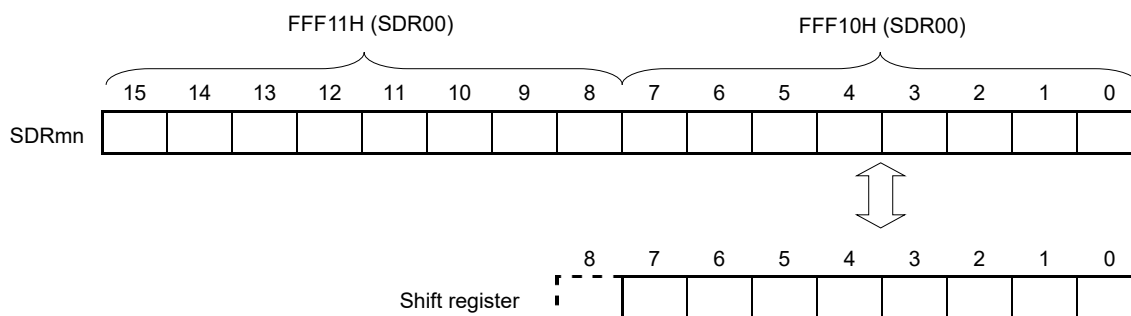
- Notes**
1. Only following UART0 can be specified for the 9-bit data length.
 2. When operation is stopped (SEmn = 0), do not rewrite SDRmn[7:0] by an 8-bit memory manipulation instruction (SDRmn[15:9] are all cleared to 0).

Remarks 1. After data is received, "0" is stored in bits 0 to 8 in bit portions that exceed the data length.

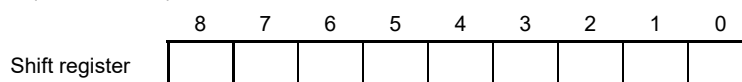
2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), q: UART number (q = 0 to 2), r: IIC number (r = 00, 01, 10, 11, 20, 21)

Figure 12-3. Format of Serial Data Register mn (SDRmn) (mn = 00, 01, 02, 03, 10, 11)

Address: FFF10H, FFF11H (SDR00), FFF12H, FFF13H (SDR01) After reset: 0000H R/W
 FFF44H, FFF45H (SDR02), FFF46H, FFF47H (SDR03),
 FFF48H, FFF49H (SDR10)^{Note}, FFF4AH, FFF4BH (SDR11)^{Note}



- For 9-bit data communication with UART0 (mn = 00, 01)



Note 32, 48, 64-pin products only

Caution For 9-bit data communication, be sure to clear bit 8 of the SDRmn register to “0”.

12.3 Registers Controlling Serial Array Unit

Serial array unit is controlled by the following registers.

- Peripheral enable register 0 (PER0)
- Serial clock select register m (SPSm)
- Serial mode register mn (SMRmn)
- Serial communication operation setting register mn (SCRmn)
- Serial data register mn (SDRmn)
- Serial flag clear trigger register mn (SIRmn)
- Serial status register mn (SSRmn)
- Serial channel start register m (SSm)
- Serial channel stop register m (STm)
- Serial channel enable status register m (SEm)
- Serial output enable register m (SOEm)
- Serial output level register m (SOLm)
- Serial output register m (SOM)
- Serial standby control register 0 (SSC0)
- Input switch control register (ISC)
- Noise filter enable register 0 (NFEN0)
- Port input mode registers 0, 1 (PIM0, PIM1)
- Port output mode registers 0, 1, 5, 7 (POM0, POM1, POM5, POM7)
- Port mode control registers 0, 1, 3, 5, 7 (PMC0, PMC1, PMC3, PMC5, PMC7)
- Port mode registers 0, 1, 3, 5, 7 (PM0, PM1, PM3, PM5, PM7)
- Port registers 0, 1, 3, 5, 7 (P0, P1, P3, P5, P7)

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.3.1 Peripheral enable register 0 (PER0)

PER0 is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

When serial array unit 0 is used, be sure to set bit 2 (SAU0EN) of this register to 1.

When serial array unit 1 is used, be sure to set bit 3 (SAU1EN) of this register to 1.

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears the PER0 register to 00H.

Figure 12-4. Format of Peripheral Enable Register 0 (PER0)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN ^{Note}	SAU0EN	0	TAU0EN

SAUmEN	Control of serial array unit m input clock supply
0	Stops supply of input clock. - SFR used by serial array unit m cannot be written. - Serial array unit m is in the reset status.
1	Enables input clock supply. SFR used by serial array unit m can be read/written.

Note 32, 48, and 64-pin products only.

Cautions 1. When setting serial array unit m, be sure to first set the following registers with the SAUmEN bit set to 1. If SAUmEN = 0, control registers of serial array unit m become default values and writing to them is ignored (except for the input switch control register (ISC), noise filter enable register 0 (NFEN0), port input mode registers 0, 1 (PIM0, PIM1), port output mode registers 0, 1, 5, 7 (POM0, POM1, POM5, POM7), Port mode control registers 0, 1, 3, 5, 7 (PMC0, PMC1, PMC3, PMC5, PMC7), port mode registers 0, 1, 3, 5, 7 (PM0, PM1, PM3, PM5, PM7), and port registers 0, 1, 3, 5, 7 (P0, P1, P3, P5, P7)).

- Serial clock select register m (SPSm)
- Serial mode register mn (SMRmn)
- Serial communication operation setting register mn (SCRmn)
- Serial data register mn (SDRmn)
- Serial flag clear trigger register mn (SIRmn)
- Serial status register mn (SSRmn)
- Serial channel start register m (SSm)
- Serial channel stop register m (STm)
- Serial channel enable status register m (SEm)
- Serial output enable register m (SOEm)
- Serial output level register m (SOLm)
- Serial output register m (SOM)
- Serial standby control register m (SSCm)

2. Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

Remark m: Unit number (m = 0, 1)

12.3.2 Serial clock select register m (SPSm)

The SPSm register is a 16-bit register that is used to select two types of operation clocks (CKm0, CKm1) that are commonly supplied to each channel. CKm1 is selected by bits 7 to 4 of the SPSm register, and CKm0 is selected by bits 3 to 0.

Rewriting the SPSm register is prohibited when the register is in operation (when SEMn = 1).

The SPSm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the SPSm register can be set with an 8-bit memory manipulation instruction with SPSmL.

Reset signal generation clears the SPSm register to 0000H.

Figure 12-5. Format of Serial Clock Select Register m (SPSm)

Address: F0126H, F0127H (SPS0), F0166H, F0167H (SPS1)^{Note 1} After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SPSm	0	0	0	0	0	0	0	0	PRS m13	PRS m12	PRS m11	PRS m10	PRS m03	PRS m02	PRS m01	PRS m00

PRS mk3	PRS mk2	PRS mk1	PRS mk0		Section of operation clock (CKmk) ^{Note 2}				
					f _{CLK} = 2 MHz	f _{CLK} = 5 MHz	f _{CLK} = 10 MHz	f _{CLK} = 20 MHz	f _{CLK} = 32 MHz
0	0	0	0	f _{CLK}	2 MHz	5 MHz	10 MHz	20 MHz	32 MHz
0	0	0	1	f _{CLK} /2	1 MHz	2.5 MHz	5 MHz	10 MHz	16 MHz
0	0	1	0	f _{CLK} /2 ²	500 kHz	1.25 MHz	2.5 MHz	5 MHz	8 MHz
0	0	1	1	f _{CLK} /2 ³	250 kHz	625 kHz	1.25 MHz	2.5 MHz	4 MHz
0	1	0	0	f _{CLK} /2 ⁴	125 kHz	313 kHz	625 kHz	1.25 MHz	2 MHz
0	1	0	1	f _{CLK} /2 ⁵	62.5 kHz	156 kHz	313 kHz	625 kHz	1 MHz
0	1	1	0	f _{CLK} /2 ⁶	31.3 kHz	78.1 kHz	156 kHz	313 kHz	500 kHz
0	1	1	1	f _{CLK} /2 ⁷	15.6 kHz	39.1 kHz	78.1 kHz	156 kHz	250 kHz
1	0	0	0	f _{CLK} /2 ⁸	7.81 kHz	19.5 kHz	39.1 kHz	78.1 kHz	125 kHz
1	0	0	1	f _{CLK} /2 ⁹	3.91 kHz	9.77 kHz	19.5 kHz	39.1 kHz	62.5 kHz
1	0	1	0	f _{CLK} /2 ¹⁰	1.95 kHz	4.88 kHz	9.77 kHz	19.5 kHz	31.3 kHz
1	0	1	1	f _{CLK} /2 ¹¹	977 Hz	2.44 kHz	4.88 kHz	9.77 kHz	15.6 kHz
1	1	0	0	f _{CLK} /2 ¹²	488 Hz	1.22 kHz	2.44 kHz	4.88 kHz	7.81 kHz
1	1	0	1	f _{CLK} /2 ¹³	244 Hz	610 Hz	1.22 kHz	2.44 kHz	3.91 kHz
1	1	1	0	f _{CLK} /2 ¹⁴	122 Hz	305 Hz	610 Hz	1.22 kHz	1.95 kHz
1	1	1	1	f _{CLK} /2 ¹⁵	61 Hz	153 kHz	305 Hz	610 Hz	977 Hz

Notes 1. 32, 48, and 64-pin products

- When changing the clock selected for f_{CLK} (by changing the system clock control register (CKC) value), do so after having stopped (serial channel stop register m (STm) = 000FH) the operation of the serial array unit (SAU).

Caution Be sure to clear bits 15 to 8 to “0”.

Remarks 1. f_{CLK}: CPU/peripheral hardware clock frequency

2. m: Unit number (m = 0, 1)

3. k = 0, 1

12.3.3 Serial mode register mn (SMRmn)

The SMRmn register is a register that sets an operation mode of channel n. It is also used to select an operation clock (f_{MCK}), specify whether the serial clock (f_{SCK}) may be input or not, set a start trigger, an operation mode (Simplified SPI, UART, or simplified I²C), and an interrupt source. This register is also used to invert the level of the receive data only in the UART mode.

Rewriting the SMRmn register is prohibited when the register is in operation (when $SE_{mn} = 1$). However, the MDmn0 bit can be rewritten during operation.

The SMRmn register can be set by a 16-bit memory manipulation instruction.

Reset signal generation sets the SMRmn register to 0020H.

Figure 12-6. Format of Serial Mode Register mn (SMRmn) (1/2)

Address: F0110H, F0111H (SMR00) to F0116H, F0117H (SMR03), After reset: 0020H R/W
F0150H, F0151H (SMR10), F0152H, F0153H (SMR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SMRmn	CKS mn	CCS mn	0	0	0	0	0	STS mn Note 2	0	SIS mn0 Note 2	1	0	0	MD mn2	MD mn1	MD mn0

CKS mn	Selection of operation clock (f_{MCK}) of channel n
0	Operation clock CKm0 set by the SPSm register
1	Operation clock CKm1 set by the SPSm register
Operation clock (f_{MCK}) is used by the edge detector. In addition, depending on the setting of the CCSmn bit and the higher 7 bits of the SDRmn register, a transfer clock (f_{TCLK}) is generated.	

CCS mn	Selection of transfer clock (f_{TCLK}) of channel n
0	Divided operation clock f_{MCK} specified by the CKSmn bit
1	Clock input f_{SCK} from the SCKp pin (slave transfer in simplified SPI (CSI) mode)
Transfer clock f_{TCLK} is used for the shift register, communication controller, output controller, interrupt controller, and error controller. When CCSmn = 0, the division ratio of operation clock (f_{MCK}) is set by the higher 7 bits of the SDRmn register.	

STS mn Note 2	Selection of start trigger source
0	Only software trigger is valid (selected for simplified SPI (CSI), UART transmission, and simplified I ² C).
1	Valid edge of the Rx/Dq pin (selected for UART reception)
Transfer is started when the above source is satisfied after 1 is set to the SSm register.	

- Notes**
1. SMR00 to SMR03: All products
SMR10, SMR11: 32, 48, and 64-pin products
 2. The SMR01, SMR03, and SMR11 registers only.

Caution Be sure to clear bits 13 to 9, 7, 4, and 3 (or bits 13 to 6, 4, and 3 for the SMR00, SMR02, or SMR10 register) to “0”. Be sure to set bit 5 to “1”.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
q: UART number (q = 0 to 2), r: IIC number (r = 00, 01, 10, 11, 20, 21)

Figure 12-6. Format of Serial Mode Register mn (SMRmn) (2/2)

Address: F0110H, F0111H (SMR00) to F0116H, F0117H (SMR03), After reset: 0020H R/W
 F0150H, F0151H (SMR10), F0152H, F0153H (SMR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SMRmn	CKS mn	CCS mn	0	0	0	0	0	STS mn Note 2	0	SIS mn0 Note 2	1	0	0	MD mn2	MD mn1	MD mn0

SIS mn0 Note 2	Controls inversion of level of receive data of channel n in UART mode
0	Falling edge is detected as the start bit. The input communication data is captured as is.
1	Rising edge is detected as the start bit. The input communication data is inverted and captured.

MD mn2	MD mn1	Setting of operation mode of channel n
0	0	Simplified SPI (CSI) mode
0	1	UART mode
1	0	Simplified I ² C mode
1	1	Setting prohibited

MD mn0	Selection of interrupt source of channel n
0	Transfer end interrupt
1	Buffer empty interrupt (Occurs when data is transferred from the SDRmn register to the shift register.)
For successive transmission, the next transmit data is written by setting the MDmn0 bit to 1 when SDRmn data has run out.	

- Notes** 1. SMR00 to SMR03: All products
 SMR10, SMR11: 32, 48, and 64-pin products
 2. The SMR01, SMR03, and SMR11 registers only.

Caution Be sure to clear bits 13 to 9, 7, 4, and 3 (or bits 13 to 6, 4, and 3 for the SMR00, SMR02, or SMR10 register) to “0”. Be sure to set bit 5 to “1”.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
 q: UART number (q = 0 to 2), r: IIC number (r = 00, 01, 10, 11, 20, 21)

12.3.4 Serial communication operation setting register mn (SCRmn)

The SCRmn register is a communication operation setting register of channel n. It is used to set a data transmission/reception mode, phase of data and clock, whether an error signal is to be masked or not, parity bit, start bit, stop bit, and data length.

Rewriting the SCRmn register is prohibited when the register is in operation (when SEMn = 1).

The SCRmn register can be set by a 16-bit memory manipulation instruction.

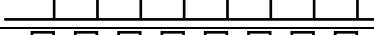
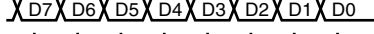
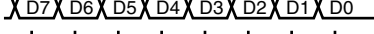
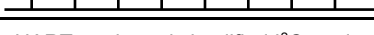
Reset signal generation sets the SCRmn register to 0087H.

Figure 12-7. Format of Serial Communication Operation Setting Register mn (SCRmn) (1/2)

Address: F0118H, F0119H (SCR00) to F011EH, F011FH (SCR03), After reset: 0087H R/W
 F0158H, F0159H (SCR10), F015AH, F015BH (SCR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCRmn	TXE mn	RXE mn	DAP mn	CKP mn	0	EOC mn	PTC mn1	PTC mn0	DIR mn	0	SLCm n1 ^{Note 2}	SLC mn0	0	1	DLSm n1 ^{Note 3}	DLS mn0

TXE mn	RXE mn	Setting of operation mode of channel n
0	0	Disable communication.
0	1	Reception only
1	0	Transmission only
1	1	Transmission/reception

DAP mn	CKP mn	Selection of data and clock phase in simplified SPI (CSI) mode	Type
0	0	SCKp  SOp  Sp input timing 	1
0	1	SCKp  SOp  Sp input timing 	2
1	0	SCKp  SOp  Sp input timing 	3
1	1	SCKp  SOp  Sp input timing 	4
Be sure to set DAPmn, CKPmn = 0, 0 in the UART mode and simplified I ² C mode.			

EOC mn	Mask control of error interrupt signal (INTSREx (x = 0 to 2))
0	Disables generation of error interrupt INTSREx (INTSRx is generated).
1	Enables generation of error interrupt INTSREx (INTSRx is not generated if an error occurs).
Set EOCmn = 0 in the simplified SPI (CSI) mode, simplified I ² C mode, and during UART transmission ^{Note 4} .	

Notes 1. SCR00 to SCR03: All products

SCR10, SCR11: 32, 48, and 64-pin products

2. The SCR00, SCR02, and SCR10 registers only.

3. The SCR00 and SCR01 registers only. Others are fixed to 1.

4. When using CSImn not with EOCmn = 0, error interrupt INTSREn may be generated.

Caution Be sure to clear bits 3, 6, and 11 to “0” (Also clear bit 5 of the SCR01, SCR03, or SCR11 register to 0). Be sure to set bit 2 to “1”.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21)

Figure 12-7. Format of Serial Communication Operation Setting Register mn (SCRmn) (2/2)

Address: F0118H, F0119H (SCR00) to F011EH, F011FH (SCR03), After reset: 0087H R/W
 F0158H, F0159H (SCR10), F015AH, F015BH (SCR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCRmn	TXE mn	RXE mn	DAP mn	CKP mn	0	EOC mn	PTC mn1	PTC mn0	DIR mn	0	SLCm n1 ^{Note 2}	SLC mn0	0	1	DLSm n1 ^{Note 3}	DLS mn0

PTC mn1	PTC mn0	Setting of parity bit in UART mode	
		Transmission	Reception
0	0	Does not output the parity bit.	Receives without parity
0	1	Outputs 0 parity ^{Note 4} .	No parity judgment
1	0	Outputs even parity.	Judged as even parity.
1	1	Outputs odd parity.	Judges as odd parity.

Be sure to set PTCmn1, PTCmn0 = 0, 0 in the simplified SPI (CSI) mode and simplified I²C mode.

DIR mn	Selection of data transfer sequence in simplified SPI (CSI) and UART modes
0	Inputs/outputs data with MSB first.
1	Inputs/outputs data with LSB first.

Be sure to clear DIRmn = 0 in the simplified I²C mode.

SLCm n1 ^{Note 2}	SLC mn0	Setting of stop bit in UART mode
0	0	No stop bit
0	1	Stop bit length = 1 bit
1	0	Stop bit length = 2 bits (mn = 00, 02, 10 only)
1	1	Setting prohibited

When the transfer end interrupt is selected, the interrupt is generated when all stop bits have been completely transferred.
 Set 1 bit (SLCmn1, SLCmn0 = 0, 1) during UART reception and in the simplified I²C mode.
 Set no stop bit (SLCmn1, SLCmn0 = 0, 0) in the simplified SPI (CSI) mode.
 Set 1 bit (SLCmn1, SLCmn0 = 0, 1) or 2 bits (SLCmn1, SLCmn0 = 1, 0) during UART transmission.

DLSm n1 ^{Note 3}	DLS mn0	Setting of data length in simplified SPI (CSI) and UART modes
0	1	9-bit data length (stored in bits 0 to 8 of the SDRmn register) (settable in UART mode only)
1	0	7-bit data length (stored in bits 0 to 6 of the SDRmn register)
1	1	8-bit data length (stored in bits 0 to 7 of the SDRmn register)
Other than above		Setting prohibited

Be sure to set DLSmn1, DLSmn0 = 1, 1 in the simplified I²C mode.

- Notes**
1. SCR00 to SCR03: All products
 SCR10, SCR11: 32, 48, and 64-pin products
 2. The SCR00, SCR02, and SCR10 registers only.
 3. The SCR00 and SCR01 registers only. Others are fixed to 1.
 4. 0 is always added regardless of the data contents.

(Caution and remark are listed on the next page.)

Caution Be sure to clear bits 3, 6, and 11 to “0”. (Also clear bit 5 of the SCR01, SCR03, or SCR11 register to 0). Be sure to set bit 2 to “1”.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21)

12.3.5 Higher 7 bits of the serial data register mn (SDRmn)

The SDRmn register is the transmit/receive data register (16 bits) of channel n.

Bits 8 to 0 (lower 9 bits) of SDR00, SDR01, SDR10, SDR11 or bits 7 to 0 (lower 8 bits) of SDR02, SDR03, SDR10^{Note 1}, and SDR11^{Note 1} function as a transmit/receive buffer register, and bits 15 to 9 (higher 7 bits) are used as a register that sets the division ratio of the operation clock (f_{MCK}).

Remark For the function of the lower 8/9 bits of the SDRmn register, see **12.2.2 Lower 8/9 bits of the serial data register mn (SDRmn)**.

If the CCSmn bit of serial mode register mn (SMRmn) is cleared to 0, the clock set by dividing the operating clock by the bits 15 to 9 (higher 7 bits) of the SDRmn register is used as the transfer clock.

If the CCSmn bit of serial mode register mn (SMRmn) is set to 1, bits 15 to 9 of SDR01, SDR00 (higher 7 bits) are set to “0000000B”. f_{SCK} of input clock from the SCKp pin (slave transfer of simplified SPI (CSI) mode) is the transfer clock.

The higher 7 bits can be written or read only when the operation is stopped ($SEmn = 0$). During operation ($SEmn = 1$), a value is written only to the lower 8/9 bits of the SDRmn register. When the SDRmn register is read during operation, the higher 7 bits are always read as 0.

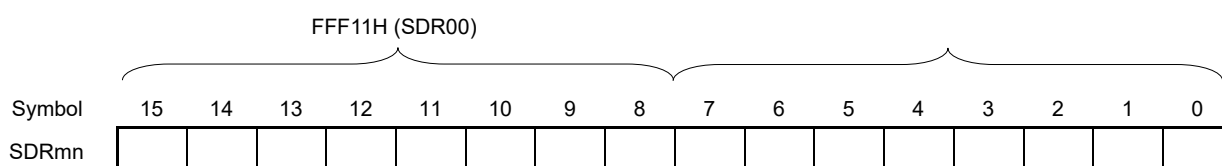
The SDRmn register can be read or written in 16-bit units.

Reset signal generation clears the SDRmn register to 0000H.

Figure 12-8. Format of Serial Data Register mn (SDRmn)

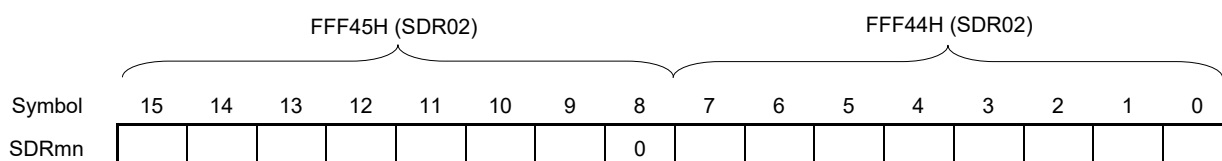
Address: FFF10H, FFF11H (SDR00), FFF12H, FFF13H (SDR01)

After reset: 0000H R/W



Address: FFF44H, FFF45H (SDR02), FFF46H, FFF47H (SDR03),

After reset: 0000H R/W

FFF48H, FFF49H (SDR10)^{Note}, FFF4AH, FFF4BH (SDR11)^{Note}

SDRmn[15:9]							Transfer clock setting by dividing the operating clock (f _{MCK})
0	0	0	0	0	0	0	f _{MCK} /2
0	0	0	0	0	0	1	f _{MCK} /4
0	0	0	0	0	1	0	f _{MCK} /6
0	0	0	0	0	1	1	f _{MCK} /8
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
1	1	1	1	1	1	0	f _{MCK} /254
1	1	1	1	1	1	1	f _{MCK} /256

Note 32, 48, and 64-pin products

- Cautions**
1. Be sure to clear bit 8 of the SDR02, SDR03, SDR10, and SDR11 to “0”.
 2. Setting SDRmn[15:9] = (0000000B, 0000001B) is prohibited when UART is used.
 3. Setting SDRmn[15:9] = 0000000B is prohibited when simplified I²C is used. Set SDRmn[15:9] to 0000001B or greater.
 4. When operation is stopped (SEmn = 0), do not rewrite SDRmn[7:0] by an 8-bit memory manipulation instruction (SDRmn[15:9] are all cleared to 0).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.3.6 Serial flag clear trigger register mn (SIRmn)

The SIRmn register is a trigger register that is used to clear each error flag of channel n.

When each bit (FECTmn, PECTmn, OVCTmn) of this register is set to 1, the corresponding bit (FEFmn, PEFmn, OVFMn) of serial status register mn (SSRmn) is cleared to 0. Because the SIRmn register is a trigger register, it is cleared immediately when the corresponding bit of the SSRmn register is cleared.

The SIRmn register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the SIRmn register can be set with an 8-bit memory manipulation instruction with SIRmnL.

Reset signal generation clears the SIRmn register to 0000H.

Figure 12-9. Format of Serial Flag Clear Trigger Register mn (SIRmn)

Address: F0108H, F0109H (SIR00) to F010EH, F010FH (SIR03), After reset: 0000H R/W
F0148H, F0149H (SIR10), F014AH, F014BH (SIR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SIRmn	0	0	0	0	0	0	0	0	0	0	0	0	0	FECT mn Note 2	PEC Tmn	OVC Tmn

FEC Tmn	Clear trigger of framing error of channel n
0	Not cleared
1	Clears the FEFmn bit of the SSRmn register to 0.

PEC Tmn	Clear trigger of parity error flag of channel n
0	Not cleared
1	Clears the PEFmn bit of the SSRmn register to 0.

OVC Tmn	Clear trigger of overrun error flag of channel n
0	Not cleared
1	Clears the OVFMn bit of the SSRmn register to 0.

- Notes**
1. SIR00 to SIR03: All products
SIR10, SIR11: 32, 48, and 64-pin products
 2. The SIR01, SIR03, and SIR11 registers only.

Caution Be sure to clear bits 15 to 3 (or bits 15 to 2 for the SIR00, SIR02, or SIR10 register) to “0”.

- Remarks**
1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)
 2. When the SIRmn register is read, 0000H is always read.

12.3.7 Serial status register mn (SSRmn)

The SSRmn register is a register that indicates the communication status and error occurrence status of channel n. The errors indicated by this register are a framing error, parity error, and overrun error.

The SSRmn register can be read by a 16-bit memory manipulation instruction.

The lower 8 bits of the SSRmn register can be set with an 8-bit memory manipulation instruction with SSRmnL.

Reset signal generation clears the SSRmn register to 0000H.

Figure 12-10. Format of Serial Status Register mn (SSRmn) (1/2)

Address: F0100H, F0101H (SSR00) to F0106H, F0107H (SSR03), After reset: 0000H R
F0140H, F0141H (SSR10), F0142H, F0143H (SSR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSRmn	0	0	0	0	0	0	0	0	0	TSF mn	BFF mn	0	0	FEFm n ^{Note 2}	PEF mn	OVF mn

TSF mn	Communication status indication flag of channel n
0	Communication is stopped or suspended.
1	Communication is in progress.
<Clear conditions> - The STmn bit of the STm register is set to 1 (communication is stopped) or the SSmn bit of the SSm register is set to 1 (communication is suspended). - Communication ends. <Set condition> - Communication starts.	

BFF mn	Buffer register status indication flag of channel n
0	Valid data is not stored in the SDRmn register.
1	Valid data is stored in the SDRmn register.
<Clear conditions> - Transferring transmit data from the SDRmn register to the shift register ends during transmission. - Reading receive data from the SDRmn register ends during reception. - The STmn bit of the STm register is set to 1 (communication is stopped) or the SSmn bit of the SSm register is set to 1 (communication is enabled). <Set conditions> - Transmit data is written to the SDRmn register while the TXEmn bit of the SCRmn register is set to 1 (transmission or transmission and reception mode in each communication mode). - Receive data is stored in the SDRmn register while the RXEmn bit of the SCRmn register is set to 1 (reception or transmission and reception mode in each communication mode). - A reception error occurs.	

- Notes**
1. SSR00 to SSR03: All products
SSR10, SSR11: 32, 48, and 64-pin products
 2. The SSR01, SSR03, and SSR11 registers only.

Caution When the simplified SPI (CSI) is handling reception in the SNOOZE mode (SWCm = 1), the BFFmn flag will not change.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

Figure 12-10. Format of Serial Status Register mn (SSRmn) (2/2)

Address: F0100H, F0101H (SSR00) to F0106H, F0107H (SSR03), After reset: 0000H R
 F0140H, F0141H (SSR10), F0142H, F0143H (SSR11)^{Note 1}

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSRmn	0	0	0	0	0	0	0	0	0	TSMn	BFFmn	0	0	FEFmn ^{Note 2}	PEFmn	OVFmn

FEFmn ^{Note 2}	Framing error detection flag of channel n
0	No error occurs.
1	An error occurs (during UART reception).
<Clear condition> 1 is written to the FECTmn bit of the SIRmn register. <Set condition> - A stop bit is not detected when UART reception ends.	

PEFmn	Parity/ACK error detection flag of channel n
0	No error occurs.
1	Parity error occurs (during UART reception) or ACK is not detected (during I ² C transmission).
<Clear condition> 1 is written to the PECTmn bit of the SIRmn register. <Set condition> - The parity of the transmit data and the parity bit do not match when UART reception ends (parity error). - No ACK signal is returned from the slave channel at the ACK reception timing during I²C transmission (ACK is not detected).	

OVFmn	Overrun error detection flag of channel n
0	No error occurs.
1	An error occurs
<Clear condition> 1 is written to the OVCTmn bit of the SIRmn register. <Set condition> - Even though receive data is stored in the SDRmn register, that data is not read and transmit data or the next receive data is written while the RXEmn bit of the SCRmn register is set to 1 (reception or transmission and reception mode in each communication mode). - Transmit data is not ready for slave transmission or transmission and reception in simplified SPI (CSI) mode.	

- Notes** 1. SSR00 to SSR03: All products
 SSR10, SSR11: 32, 48, and 64-pin products
 2. The SSR01, SSR03, and SSR11 registers only.

- Cautions** 1. If data is written to the SDRmn register when BFFmn = 1, the transmit/receive data stored in the register is discarded and an overrun error (OVEmn = 1) is detected.
 2. When the simplified SPI (CSI) is handling reception in the SNOOZE mode (SWCm = 1), the OVFmn flag will not change.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.3.8 Serial channel start register m (SSm)

The SSm register is a trigger register that is used to enable starting communication/count by each channel.

When 1 is written a bit of this register (SSmn), the corresponding bit (SEmn) of serial channel enable status register m (SEm) is set to 1 (Operation is enabled). Because the SSmn bit is a trigger bit, it is cleared immediately when SEMn = 1.

The SSm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the SSm register can be set with an 1-bit or 8-bit memory manipulation instruction with SSmL.

Reset signal generation clears the SSm register to 0000H.

Figure 12-11. Format of Serial Channel Start Register m (SSm)

Address: F0122H, F0123H (SS0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS0	0	0	0	0	0	0	0	0	0	0	0	0	SS03	SS02	SS01	SS00

Address: F0162H, F0163H (SS1)^{Note 1} After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SS11	SS10

SSmn	Operation start trigger of channel n
0	No trigger operation
1	Sets the SEMn bit to 1 and enters the communication wait status ^{Note 2} .

Notes 1. 32, 48, 64-pin products only

- If set the SSmn = 1 to during a communication operation, will wait status to stop the communication. At this time, holding status value of control register and shift register, SCKmn and SOMn pins, and FEFmn, PEFmn, OVFmn flags.

Cautions 1. Be sure to clear bits 15 to 4 of the SS0 register and bits 15 to 2 of the SS1 register to “0”.

- For the UART reception, set the RXEmn bit of SCRmn register to 1, and then be sure to set SSmn to 1 after 4 or more f_{MCK} clocks have elapsed.

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

- When the SSm register is read, 0000H is always read.

12.3.9 Serial channel stop register m (STm)

The STm register is a trigger register that is used to enable stopping communication/count by each channel.

When 1 is written a bit of this register (STmn), the corresponding bit (SEmn) of serial channel enable status register m (SEm) is cleared to 0 (operation is stopped). Because the STmn bit is a trigger bit, it is cleared immediately when SEmn = 0.

The STm register can set written by a 16-bit memory manipulation instruction.

The lower 8 bits of the STm register can be set with a 1-bit or 8-bit memory manipulation instruction with STmL.

Reset signal generation clears the STm register to 0000H.

Figure 12-12. Format of Serial Channel Stop Register m (STm)

Address: F0124H, F0125H (ST0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ST0	0	0	0	0	0	0	0	0	0	0	0	0	ST03	ST02	ST01	ST00

Address: F0164H, F0165H (ST1)^{Note 1} After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ST1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ST11	ST10

STmn	Operation stop trigger of channel n
0	No trigger operation
1	Clears the SEmn bit to 0 and stops the communication operation ^{Note 2} .

Notes 1. 32, 48, 64-pin products only

2. Holding status value of the control register and shift register, the SCKmn and SOMn pins, and FEFmn, PEFmn, OVFMn flags.

Caution Be sure to clear bits 15 to 4 of the ST0 register and bits 15 to 2 of the ST1 register to “0”.

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

2. When the STm register is read, 0000H is always read.

12.3.10 Serial channel enable status register m (SEm)

The SEm register indicates whether data transmission/reception operation of each channel is enabled or stopped.

When 1 is written a bit of serial channel start register m (SSm), the corresponding bit of this register is set to 1. When 1 is written a bit of serial channel stop register m (STm), the corresponding bit is cleared to 0.

Channel n that is enabled to operate cannot rewrite by software the value of the CKOm_n bit (serial clock output of channel n) of serial output register m (SOM) to be described below, and a value reflected by a communication operation is output from the serial clock pin.

Channel n that stops operation can set the value of the CKOm_n bit of the SOM register by software and output its value from the serial clock pin. In this way, any waveform, such as that of a start condition/stop condition, can be created by software.

The SEm register can be read by a 16-bit memory manipulation instruction.

The lower 8 bits of the SEm register can be set with a 1-bit or 8-bit memory manipulation instruction with SEmL.

Reset signal generation clears the SEm register to 0000H.

Figure 12-13. Format of Serial Channel Enable Status Register m (SEm)

Address: F0120H, F0121H (SE0) After reset: 0000H R

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SE0	0	0	0	0	0	0	0	0	0	0	0	0	SE03	SE02	SE01	SE00

Address: F0160H, F0161H (SE1)^{Note} After reset: 0000H R

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SE1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SE11	SE10

SEm _n	Indication of operation enable/stop status of channel n
0	Operation stops
1	Operation is enabled.

Note 32, 48, 64-pin products only

Caution Be sure to clear bits 15 to 4 of the SE0 register and bits 15 to 2 of the SE1 register to “0”.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.3.11 Serial output enable register m (SOEm)

The SOEm register is a register that is used to enable or stop output of the serial communication operation of each channel.

Channel n that enables serial output cannot rewrite by software the value of the SOMn bit of serial output register m (SOM) to be described below, and a value reflected by a communication operation is output from the serial data output pin.

For channel n, whose serial output is stopped, the SOMn bit value of the SOM register can be set by software, and that value can be output from the serial data output pin. In this way, any waveform of the start condition and stop condition can be created by software.

The SOEm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the SOEm register can be set with a 1-bit or 8-bit memory manipulation instruction with SOEmL.

Reset signal generation clears the SOEm register to 0000H.

Figure 12-14. Format of Serial Output Enable Register m (SOEm)

Address: F012AH, F012BH (SOE0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOE0	0	0	0	0	0	0	0	0	0	0	0	0	SOE 03	SOE 02	SOE 01	SOE 00

Address: F016AH, F016BH (SOE1)^{Note} After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOE1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SOE 11	SOE 10

SOE mn	Serial output enable/stop of channel n
0	Stops output by serial communication operation.
1	Enables output by serial communication operation.

Note 32, 48, 64-pin products only

Caution Be sure to clear bits 15 to 4 of the SOE0 register, and bits 15 to 2 of the SOE1 register to “0”.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.3.12 Serial output register m (SOM)

The SOM register is a buffer register for serial output of each channel.

The value of the SOMn bit of this register is output from the serial data output pin of channel n.

The value of the CKOMn bit of this register is output from the serial clock output pin of channel n.

The SOMn bit of this register can be rewritten by software only when serial output is disabled (SOEmn = 0). When serial output is enabled (SOEmn = 1), rewriting by software is ignored, and the value of the register can be changed only by a serial communication operation.

The CKOMn bit of this register can be rewritten by software only when the channel operation is stopped (SEmn = 0). While channel operation is enabled (SEmn = 1), rewriting by software is ignored, and the value of the CKOMn bit can be changed only by a serial communication operation.

To use the pin for serial interface as a port function pin, set the corresponding CKOMn and SOMn bits to "1".

The SOM register can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears the SO0 register to 0F0FH, and sets the SO1 register to 0303H.

Figure 12-15. Format of Serial Output Register m (SOM)

Address: F0128H, F0129H (SO0) After reset: 0F0FH R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SO0	0	0	0	0	CKO 03	CKO 02	CKO 01	CKO 00	0	0	0	0	SO 03	SO 02	SO 01	SO 00

Address: F0168H, F0169H (SO1)^{Note} After reset: 0303H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SO1	0	0	0	0	0	0	CKO 11	CKO 10	0	0	0	0	0	0	SO 11	SO 10

CKO mn	Serial clock output of channel n
0	Serial clock output value is "0".
1	Serial clock output value is "1".

SO mn	Serial data output of channel n
0	Serial data output value is "0".
1	Serial data output value is "1".

Note 32, 48, 64-pin products only

Caution Be sure to clear bits 15 to 12, 7 to 4 of the SO0 register, and bits 15 to 10, 7 to 2 of the SO1 register to "0".

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3)

12.3.13 Serial output level register m (SOLm)

The SOLm register is a register that is used to set inversion of the data output level of each channel.

This register can be set only in the UART mode. Be sure to set 0 for corresponding bit in the simplified SPI (CSI) mode and simplifies I²C mode.

Inverting channel n by using this register is reflected on pin output only when serial output is enabled (SOEmn = 1). When serial output is disabled (SOEmn = 0), the value of the SOMn bit is output as is.

Rewriting the SOLm register is prohibited when the register is in operation (when SEMn = 1).

The SOLm register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the SOLm register can be set with an 8-bit memory manipulation instruction with SOLmL.

Reset signal generation clears the SOLm register to 0000H.

Figure 12-16. Format of Serial Output Level Register m (SOLm)

Address: F0134H, F0135H (SOL0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOL0	0	0	0	0	0	0	0	0	0	0	0	0	0	SOL 02	0	SOL 00

Address: F0174H, F0175H (SOL1)^{Note} After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOL1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SOL 10

SOL mn	Selects inversion of the level of the transmit data of channel n in UART mode
0	Communication data is output as is.
1	Communication data is inverted and output.

Note 32, 48, 64-pin products only

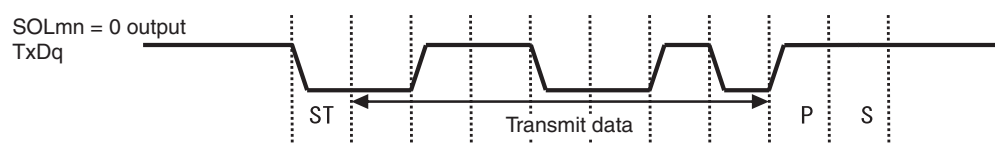
Caution Be sure to clear bits 15 to 3, and 1 of the SOL0 register and bits 15 to 1 of the SOL1 register to “0”.

(**Remark** is listed on the next page.)

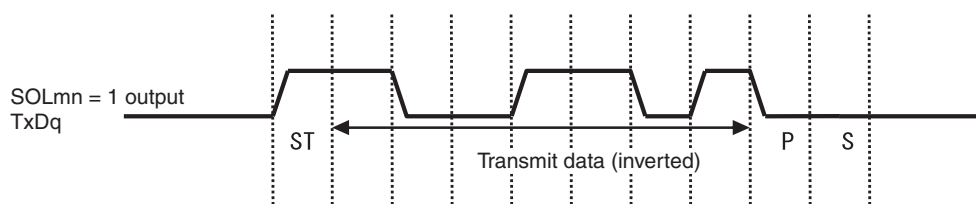
Figure 12-17 shows examples in which the level of transmit data is reversed during UART transmission.

Figure 12-17. Examples of Reverse Transmit Data

(a) Non-reverse Output (SOLmn = 0)



(b) Reverse Output (SOLmn = 1)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2)

12.3.14 Serial standby control register 0 (SSC0)

The SSC0 register is used to control the startup of reception (the SNOOZE mode) while in the STOP mode when receiving CSI00 or UART0 serial data.

The SSC0 register can be set by a 16-bit memory manipulation instruction.

The lower 8 bits of the SSC0 register can be set with an 8-bit memory manipulation instruction with SSC0L.

Reset signal generation clears the SSC0 register to 0000H.

Caution The maximum transfer rate in the SNOOZE mode is as follows.

- When using CSI00: Until 1 Mbps
- When using UART0: 4800 bps only

Figure 12-18. Format of Serial Standby Control Register 0 (SSC0)

Address: F0138H (SSC0) After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSC0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SSEC	SWC
															0	0

SSEC 0	Selection of whether to enable or stop the generation of communication error interrupts in the SNOOZE mode
0	Enable the generation of error interrupts (INTSRE0).
1	Stop the generation of error interrupts (INTSRE0).
• The SSEC0 bit can be set to 1 or 0 only when both the SWC0 and EOC0n bits are set to 1 during UART reception in the SNOOZE mode. In other cases, clear the SSEC0 bit to 0. • Setting SSEC0, SWC0 = 1, 0 is prohibited.	

SWC 0	Setting of the SNOOZE mode
0	Do not use the SNOOZE mode function.
1	Use the SNOOZE mode function.
• When there is a hardware trigger signal in the STOP mode, the STOP mode is exited, and simplified SPI (CSI) or UART reception is performed without operating the CPU (the SNOOZE mode). • The SNOOZE mode function can only be specified when the high-speed on-chip oscillator clock is selected for the CPU/peripheral hardware clock (f_{CLK}). If any other clock is selected, specifying this mode is prohibited. • Even when using SNOOZE mode, be sure to set the SWC0 bit to 0 in normal operation mode and change it to 1 just before shifting to STOP mode. Also, be sure to change the SWC0 bit to 0 after returning from STOP mode to normal operation mode.	

Figure 12-19. Interrupt Using the UART Reception with SNOOZE Mode

EOC0n Bit	SSEC0 Bit	Normal Reception	Reception Error
0	0	INTSR0 is generated.	INTSR0 is generated.
0	1	INTSR0 is generated.	INTSR0 is generated.
1	0	INTSR0 is generated.	INTSRE0 is generated.
1	1	INTSR0 is generated.	No interrupt is generated.

12.3.15 Input switch control register (ISC)

The ISC1 and ISC0 bits of the ISC register are used to realize a LIN-bus communication operation by UART2 in coordination with an external interrupt and the timer array unit.

When bit 0 is set to 1, the input signal of the serial data input (RxD2) pin is selected as an external interrupt (INTP0) that can be used to detect a wakeup signal.

When bit 1 is set to 1, the input signal of the serial data input (RxD2) pin is selected as a timer input, so that wake up signal can be detected, the low width of the break field, and the pulse width of the sync field can be measured by the timer.

The ISC register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears the ISC register to 00H.

Figure 12-20. Format of Input Switch Control Register (ISC)

Address: F0073H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ISC	0	0	0	0	0	0	ISC1	ISC0

ISC1	Switching channel 7 input of timer array unit
0	48- and 64-pin products: Uses the input signal of the TI07 pin as a timer input (normal operation). 25- and 32-pin products: Do not use a timer input signal for channel 7.
1	Input signal of the RxD2 pin is used as timer input (detects the wakeup signal and measures the low width of the break field and the pulse width of the sync field). Setting is prohibited in the 25-pin products.

ISC0	Switching external interrupt (INTP0) input
0	Uses the input signal of the INTP0 pin as an external interrupt (normal operation).
1	Uses the input signal of the RxD2 pin as an external interrupt (wakeup signal detection).

Caution Be sure to clear bits 7 to 2 to “0”.

12.3.16 Noise filter enable register 0 (NFEN0)

The NFEN0 register is used to set whether the noise filter can be used for the input signal from the serial data input pin to each channel.

Disable the noise filter of the pin used for simplified SPI (CSI) or simplified I²C communication, by clearing the corresponding bit of this register to 0.

Enable the noise filter of the pin used for UART communication, by setting the corresponding bit of this register to 1.

When the noise filter is enabled, after synchronization is performed with the operation clock (f_{MCK}) of the target channel, 2-clock match detection is performed. When the noise filter is OFF, only synchronization is performed with the operation clock (f_{MCK}) of the target channel.

The NFEN0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears the NFEN0 register to 00H.

Figure 12-21. Format of Noise Filter Enable Register 0 (NFEN0)

Address: F0070H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
NFEN0	0	0	0	SNFEN20	0	SNFEN10	0	SNFEN00

SNFEN20	Use of noise filter of RxD2 pin
0	Noise filter OFF
1	Noise filter ON
Set SNFEN20 to 1 to use the RxD2 pin. Clear SNFEN20 to 0 to use the other than RxD2 pin.	

SNFEN10	Use of noise filter of RxD1 pin
0	Noise filter OFF
1	Noise filter ON
Set the SNFEN10 bit to 1 to use the RxD1 pin. Clear the SNFEN10 bit to 0 to use the other than RxD1 pin.	

SNFEN00	Use of noise filter of RxD0 pin
0	Noise filter OFF
1	Noise filter ON
Set the SNFEN00 bit to 1 to use the RxD0 pin. Clear the SNFEN00 bit to 0 to use the other than RxD0 pin.	

Caution Be sure to clear bits 7 to 5, 3, and 1 to “0”.

12.3.17 Registers controlling port functions of serial input/output pins

Using the serial array unit requires setting of the registers that control the port functions multiplexed on the target channel (port mode register (PMxx), port register (Pxx), port input mode register (PIMxx), port output mode register (POMxx), port mode control register (PMCxx)).

For details, see **4.3.1 Port mode registers (PMxx)**, **4.3.2 Port registers (Pxx)**, **4.3.4 Port input mode registers (PIMxx)**, **4.3.5 Port output mode registers (POMxx)**, and **4.3.6 Port mode control registers (PMCxx)**.

Specifically, using a port pin with a multiplexed serial data or serial clock output function (e.g. P02/ANI17/SO10/TxD1) for serial data or serial clock output, requires setting the corresponding bits in the port mode control register (PMCxx) and port mode register (PMxx) to 0, and the corresponding bit in the port register (Pxx) to 1.

When using the port pin in N-ch open-drain output (V_{DD} tolerance^{Note 1}/EV_{DD} tolerance^{Note 2}) mode, set the corresponding bit in the port output mode register (POMxx) to 1. When connecting an external device operating on a different potential (1.8 V or 2.5 V), see **4.4.5 Handling different potential (1.8 V, 2.5 V) by using I/O buffers**.

Example: When P02/ANI17/SO10/TxD1 is to be used for serial data output

Set the PMC02 bit of port mode control register 0 to 0.

Set the PM02 bit of port mode register 0 to 0.

Set the P02 bit of port register 0 to 1.

Specifically, using a port pin with a multiplexed serial data or serial clock input function (e.g. P03/ANI16/SI10/RxD1/SDA10) for serial data or serial clock input, requires setting the corresponding bit in the port mode register (PMxx) to 1, and the corresponding bit in the port mode control register (PMCxx) to 0. In this case, the corresponding bit in the port register (Pxx) can be set to 0 or 1.

When the TTL input buffer is selected, set the corresponding bit in the port input mode register (PIMxx) to 1. When connecting an external device operating on a different potential (1.8 V or 2.5 V), see **4.4.5 Handling different potential (1.8 V, 2.5 V) by using I/O buffers**.

Example: When P03/ANI16/SI10/RxD1/SDA10 is to be used for serial data input

Set the PMC03 bit of port mode control register 0 to 0.

Set the PM03 bit of port mode register 0 to 1.

Set the P03 bit of port register 0 to 0 or 1.

Notes 1. 25 to 48-pin products

2. 64-pin product

12.4 Operation Stop Mode

Each serial interface of serial array unit has the operation stop mode.

In this mode, serial communication cannot be executed, thus reducing the power consumption.

In addition, the pin for serial interface can be used as port function pins in this mode.

12.4.1 Stopping the operation by units

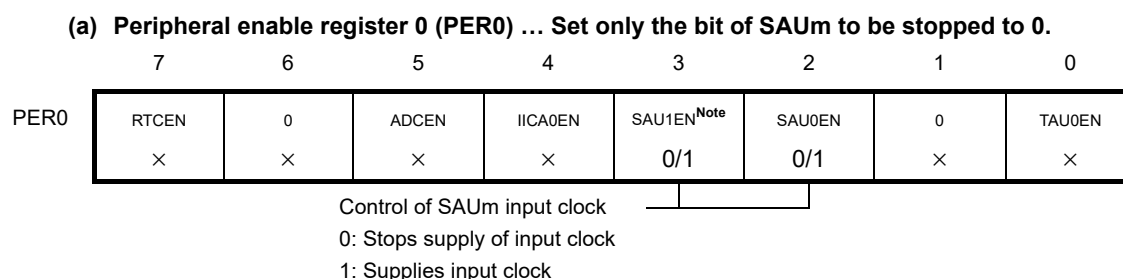
The stopping of the operation by units is set by using peripheral enable register 0 (PER0).

The PER0 register is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

To stop the operation of serial array unit 0, set bit 2 (SAU0EN) to 0.

To stop the operation of serial array unit 1, set bit 3 (SAU1EN) to 0.

Figure 12-22. Peripheral Enable Register 0 (PER0) Setting When Stopping the Operation by Units



Note 32, 48, and 64-pin products only.

Cautions 1. If SAUmEN = 0, writing to a control register of serial array unit m is ignored, and, even if the register is read, only the default value is read

Note that this does not apply to the following registers.

- Input switch control register (ISC)
- Noise filter enable register 0 (NFEN0)
- Port input mode registers 0, 1 (PIM0, PIM1)
- Port output mode registers 0, 1, 5, 7 (POM0, POM1, POM5, POM7)
- Port mode control registers 0, 1, 3, 5, 7 (PMC0, PMC1, PMC3, PMC5, PMC7)
- Port mode registers 0, 1, 3, 5, 7 (PM0, PM1, PM3, PM5, PM7)
- Port registers 0, 1, 3, 5, 7 (P0, P1, P3, P5, P7)

2. Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32, 48, 64-pin products: bits 1, 6

Remarks 1. ×: Bits not used with serial array units (depending on the settings of other peripheral functions)

0/1: Set to 0 or 1 depending on the usage of the user

2. m: Unit number (m = 0, 1)

12.4.2 Stopping the operation by channels

The stopping of the operation by channels is set using each of the following registers.

Figure 12-23. Each Register Setting When Stopping the Operation by Channels

- (a) **Serial channel stop register m (STm) ... This register is a trigger register that is used to enable stopping communication/count by each channel.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STm	0	0	0	0	0	0	0	0	0	0	0	0	STm3 ^{Note} 0/1	STm2 ^{Note} 0/1	STm1 0/1	STm0 0/1

1: Clears the SE_{mn} bit to 0 and stops the communication operation

* Because the ST_{mn} bit is a trigger bit, it is cleared immediately when SE_{mn} = 0.

- (b) **Serial Channel Enable Status Register m (SEm) ... This register indicates whether data transmission/reception operation of each channel is enabled or stopped.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SEm	0	0	0	0	0	0	0	0	0	0	0	0	SEm3 ^{Note} 0/1	SEm2 ^{Note} 0/1	SEm1 0/1	SEm0 0/1

0: Operation stops

* The SEm register is a read-only status register, whose operation is stopped by using the STm register. With a channel whose operation is stopped, the value of the CKO_{mn} bit of the SOm register can be set by software.

- (c) **Serial output enable register m (SOEm) ... This register is a register that is used to enable or stop output of the serial communication operation of each channel.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 ^{Note} 0/1	SOEm2 ^{Note} 0/1	SOEm1 0/1	SOEm0 0/1

0: Stops output by serial communication operation

* For channel n, whose serial output is stopped, the SO_{mn} bit value of the SOm register can be set by software.

- (d) **Serial output register m (SOm) ... This register is a buffer register for serial output of each channel.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOm	0	0	0	0	CKOm3 ^{Note} 0/1	CKOm2 ^{Note} 0/1	CKOm1 0/1	CKOm0 0/1	0	0	0	0	SOm3 ^{Note} 0/1	SOm2 ^{Note} 0/1	SOm1 0/1	SOm0 0/1

1: Serial clock output value is "1" 1: Serial data output value is "1"

* When using pins corresponding to each channel as port function pins, set the corresponding CKO_{mn}, SO_{mn} bits to "1".

Note Serial array unit 0 only.

- Remarks 1.** m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11
2.  : Setting disabled (fixed by hardware), 0/1: Set to 0 or 1 depending on the usage of the user

12.5 Operation of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) Communication

This is a clocked communication function that uses three lines: serial clock (SCK) and serial data (SI and SO) lines.

[Data transmission/reception]

- Data length of 7 or 8 bits
- Phase control of transmit/receive data
- MSB/LSB first selectable

[Clock control]

- Master/slave selection
- Phase control of I/O clock
- Setting of transfer period by prescaler and internal counter of each channel
- Maximum transfer rate^{Note}

During master communication: Max. $f_{CLK}/2$ (CSI00 only)

Max. $f_{CLK}/4$

During slave communication: Max. $f_{MCK}/6$

[Interrupt function]

- Transfer end interrupt/buffer empty interrupt

[Error detection flag]

- Overrun error

In addition, CSI00 of following channels supports the SNOOZE mode. When SCK input is detected while in the STOP mode, the SNOOZE mode makes data reception that does not require the CPU possible.

Note Use the clocks within a range satisfying the SCK cycle time (t_{KCY}) characteristics. For details, see **CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = -40 to +85°C)**, **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS T_A = -40 to +105°C)**.

The channels supporting simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) are channels 0 to 3 of SAU0 and channels 0 to 3 of SAU1.

- 25-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11

- 32-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	–		–

- 48-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

- 64-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	CSI10	UART1	IIC10
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) performs the following seven types of communication operations.

- Master transmission (See **12.5.1.**)
- Master reception (See **12.5.2.**)
- Master transmission/reception (See **12.5.3.**)
- Slave transmission (See **12.5.4.**)
- Slave reception (See **12.5.5.**)
- Slave transmission/reception (See **12.5.6.**)
- SNOOZE mode function (See **12.5.7.**)

12.5.1 Master transmission

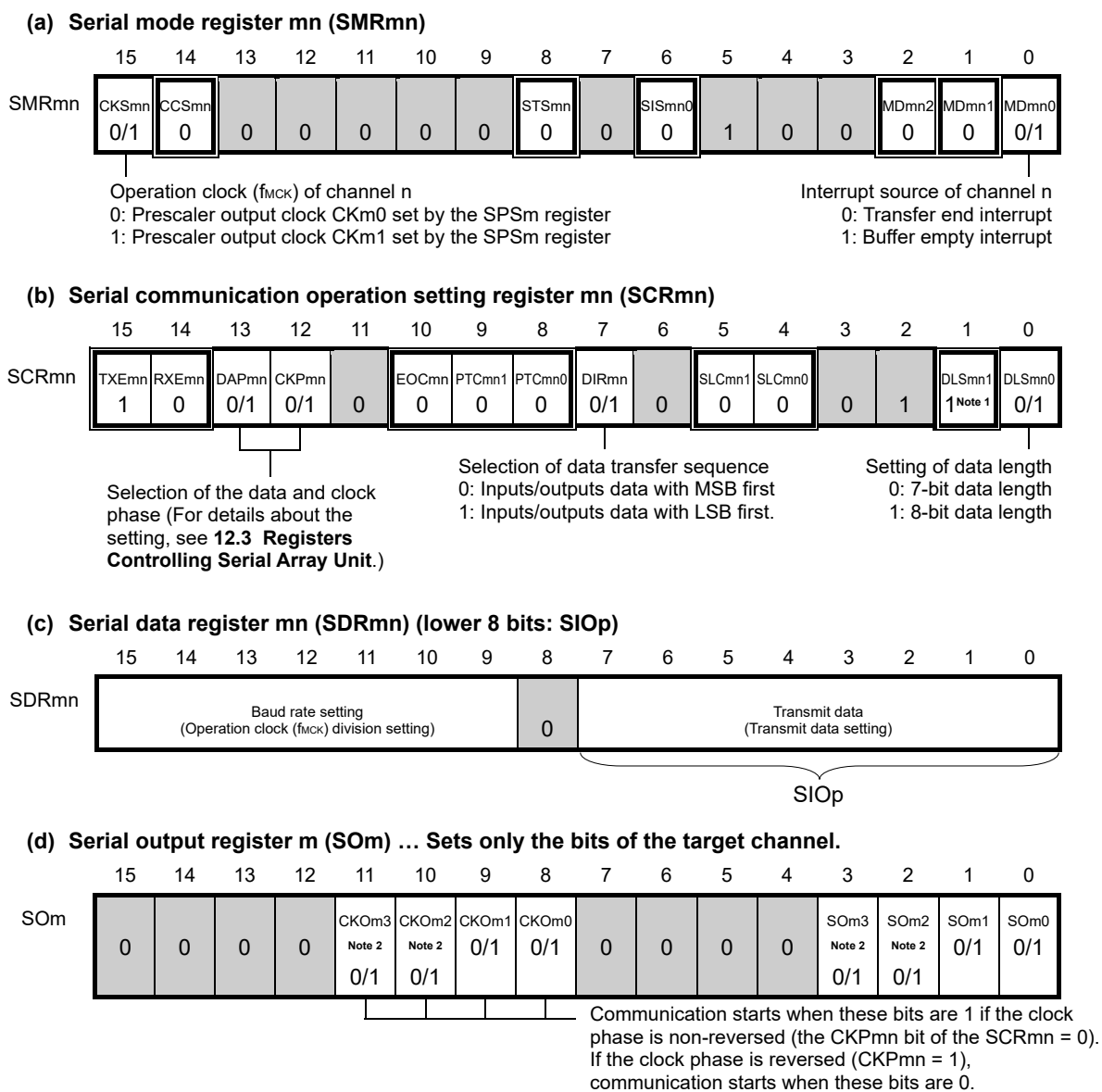
Master transmission is that the RL78 microcontroller outputs a transfer clock and transmits data to another device.

Simplified SPI	CSI00	CSI01	CSI10	CSI11	CSI20	CSI21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCK00, SO00	SCK01, SO01	SCK10, SO10	SCK11, SO11	SCK20, SO20	SCK21, SO21
Interrupt	INTCSI00	INTCSI01	INTCSI10	INTCSI11	INTCSI20	INTCSI21
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.					
Error detection flag	None					
Transfer data length	7 or 8 bits					
Transfer rate ^{Note}	Max. $f_{CLK}/2$ [MHz] (CSI00 only), $f_{CLK}/4$ [MHz] Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [Hz] ^{Note} f_{CLK} : System clock frequency					
Data phase	Selectable by the DAPmn bit of the SCRmn register - DAPmn = 0: Data output starts from the start of the operation of the serial clock. - DAPmn = 1: Data output starts half a clock before the start of the serial clock operation.					
Clock phase	Selectable by the CKPmn bit of the SCRmn register - CKPmn = 0: Non-reverse - CKPmn = 1: Reverse					
Data direction	MSB or LSB first					

Note Use this operation within a range that satisfies the conditions above and the peripheral functions characteristic in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)**, **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$)**).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(1) Register setting

Figure 12-24. Example of Contents of Registers for Master Transmission of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (1/2)

Notes 1. Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.

2. Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
 p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

- 2.** ☐ : Setting is fixed in the simplified SPI (CSI) master transmission mode,
☐ : Setting disabled (set to the initial value)
 0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-24. Example of Contents of Registers for Master Transmission of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (2/2)

(e) Serial output enable register m (SOEm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 0/1	SOEm2 Note 0/1	SOEm1 0/1	SOEm0 0/1

(f) Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

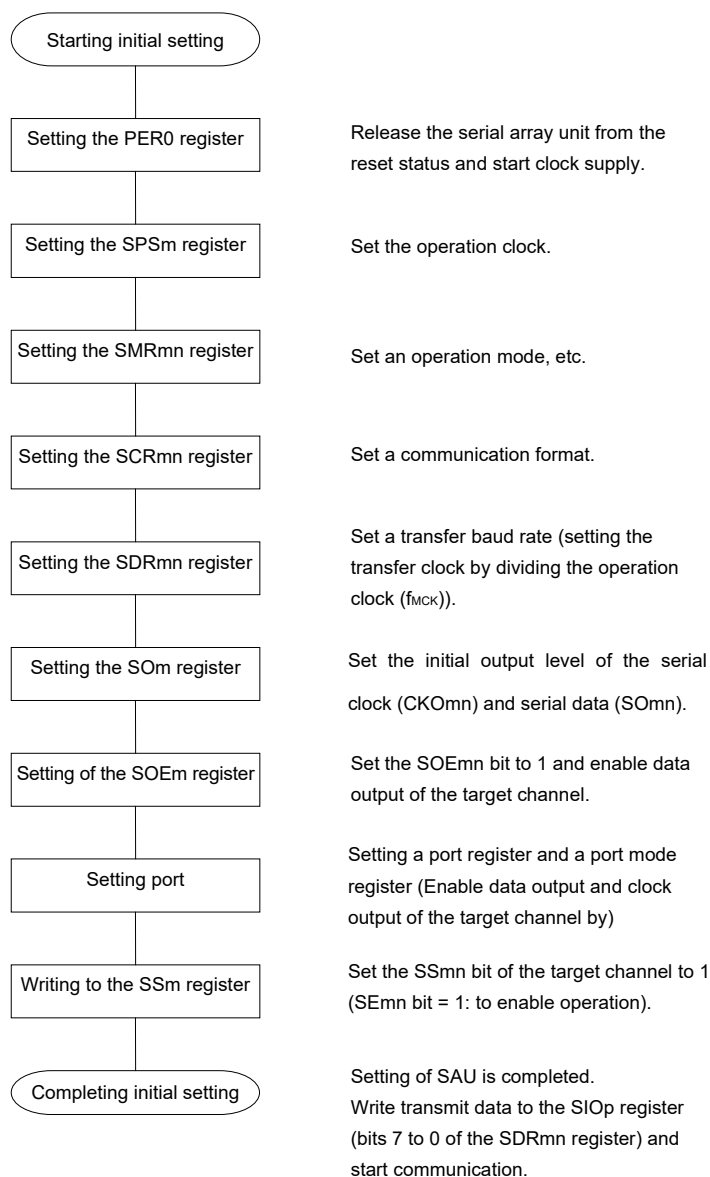
Note Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

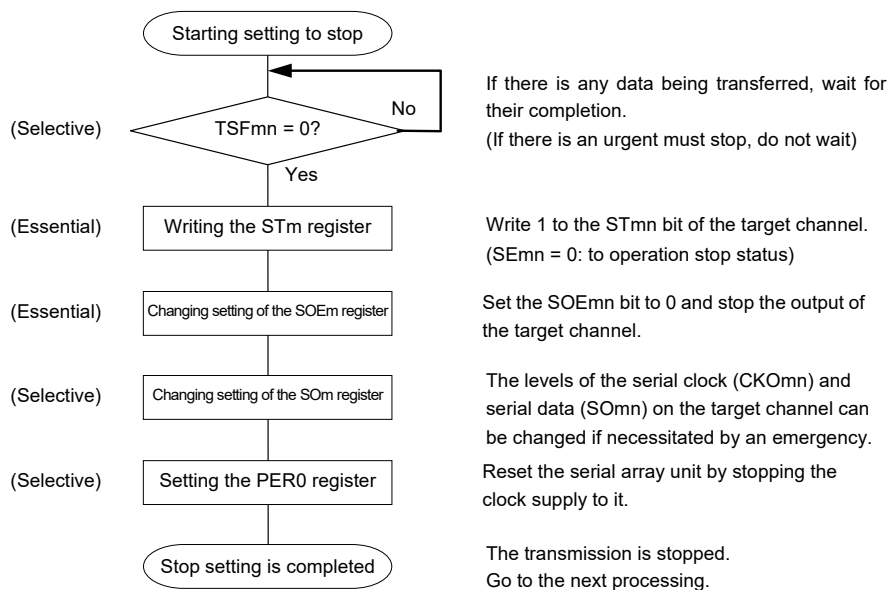
2. ☐: Setting is fixed in the simplified SPI (CSI) master transmission mode,
☒: Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

(2) Operation procedure

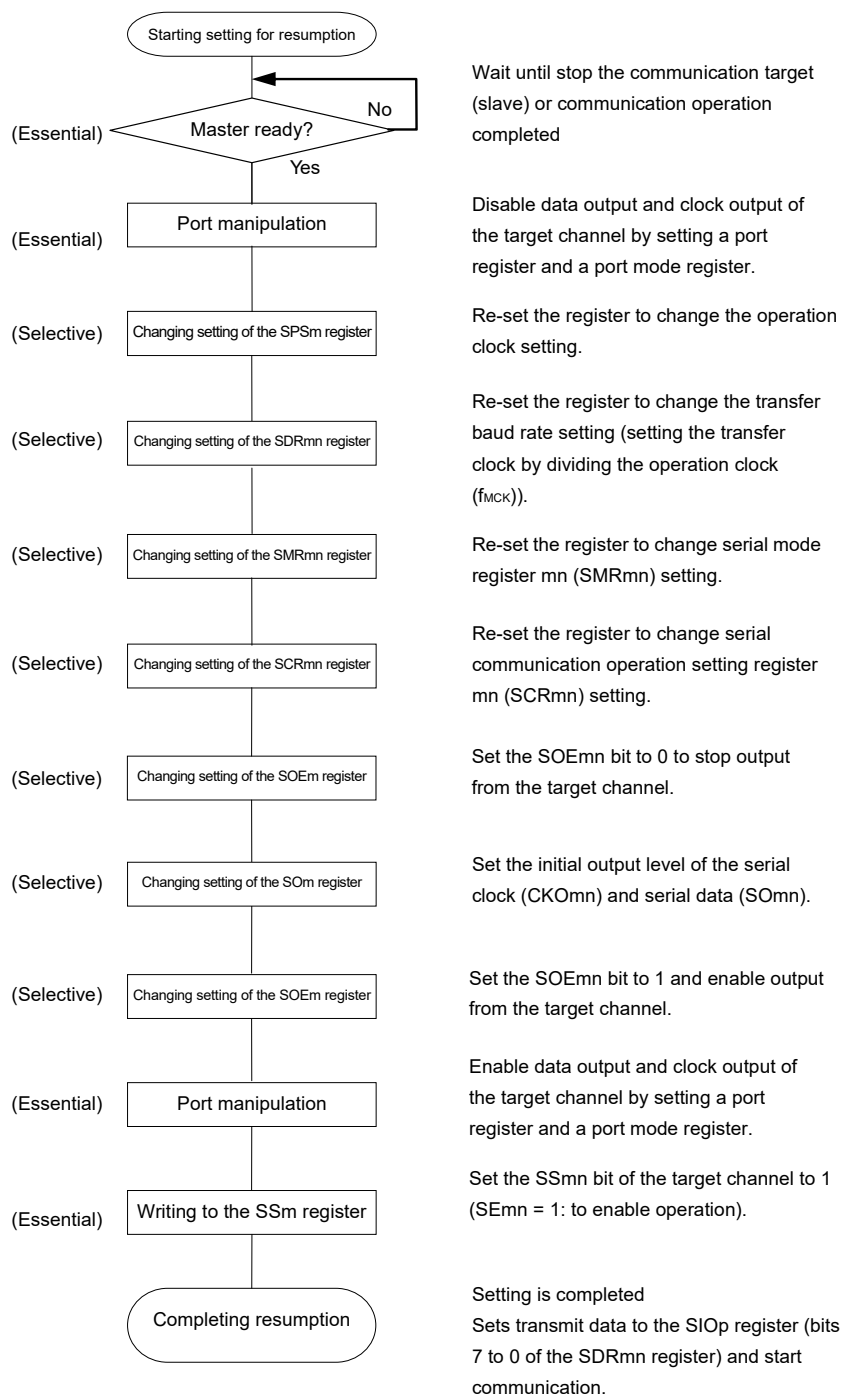
Figure 12-25. Initial Setting Procedure for Master Transmission



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-26. Procedure for Stopping Master Transmission

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

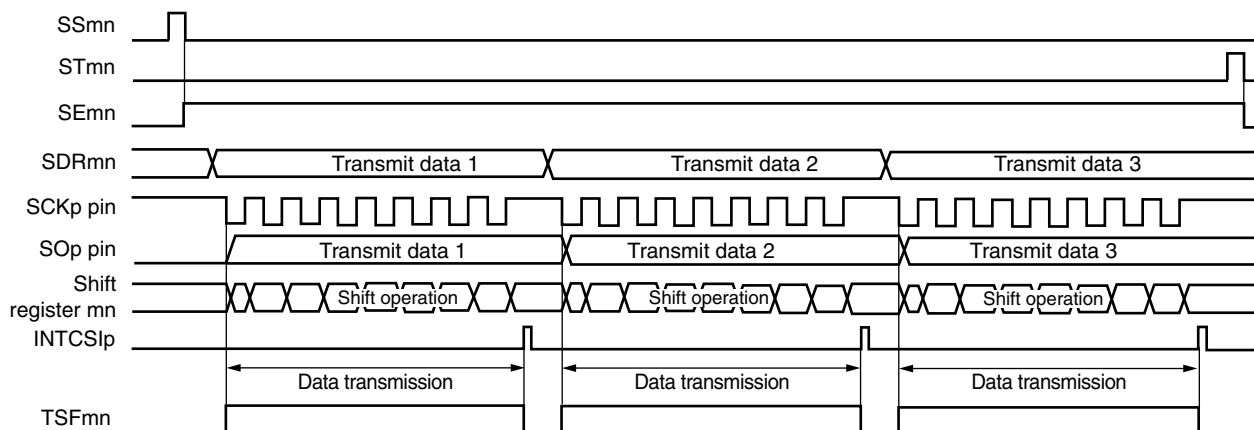
Figure 12-27. Procedure for Resuming Master Transmission

Remarks 1. If PER0 is rewritten while stopping the master transmission and the clock supply is stopped, wait until the transmission target (slave) stops or transmission finishes, and then perform initialization instead of restarting the transmission.

- 2.** m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

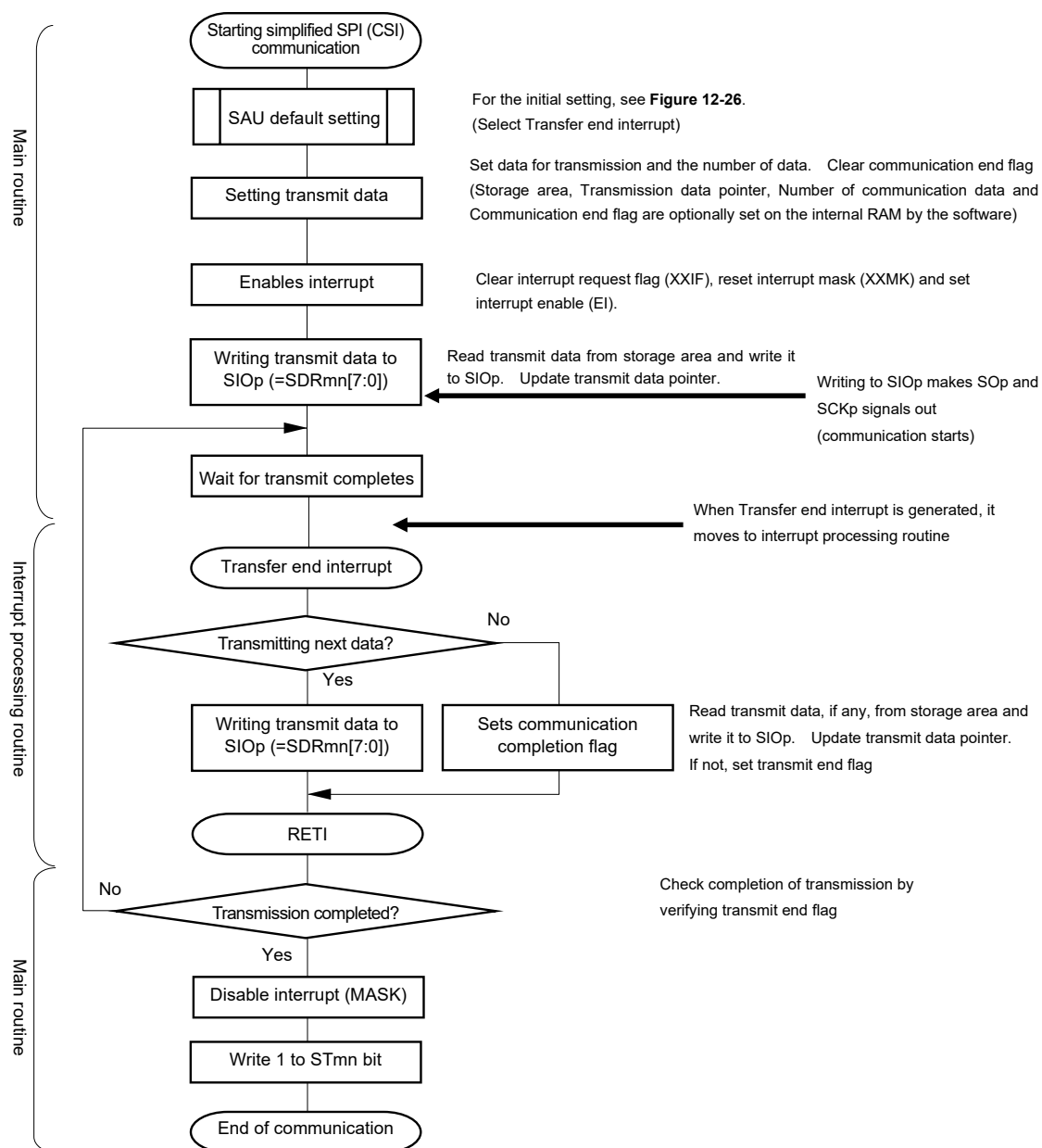
(3) Processing flow (in single-transmission mode)

Figure 12-28. Timing Chart of Master Transmission (in Single-Transmission Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
 mn = 00 to 03, 10, 11

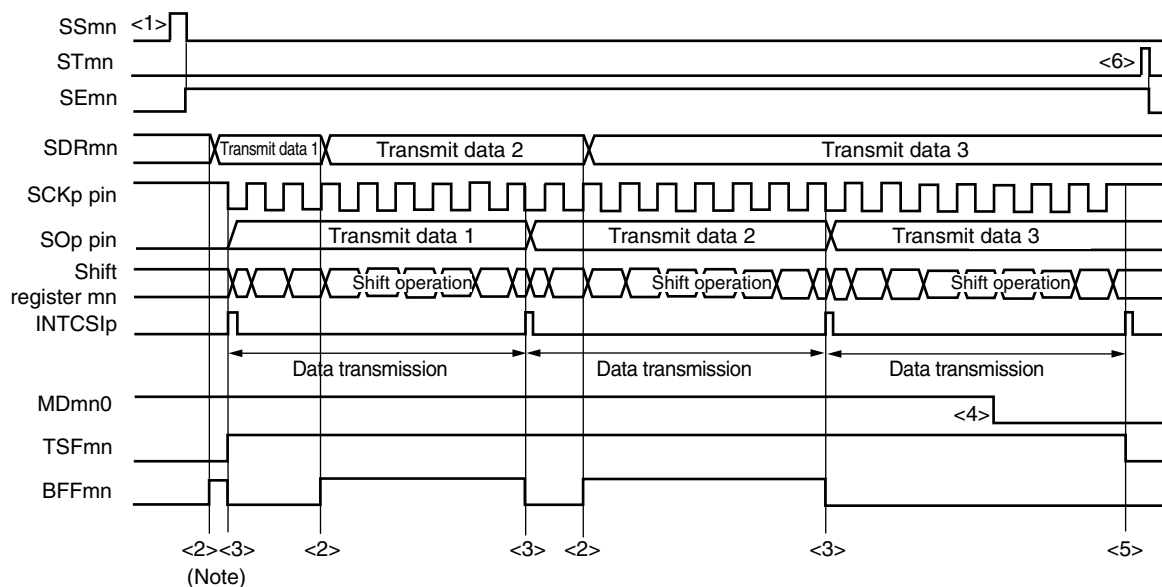
Figure 12-29. Flowchart of Master Transmission (in Single-Transmission Mode)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(4) Processing flow (in continuous transmission mode)

Figure 12-30. Timing Chart of Master Transmission (in Continuous Transmission Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)

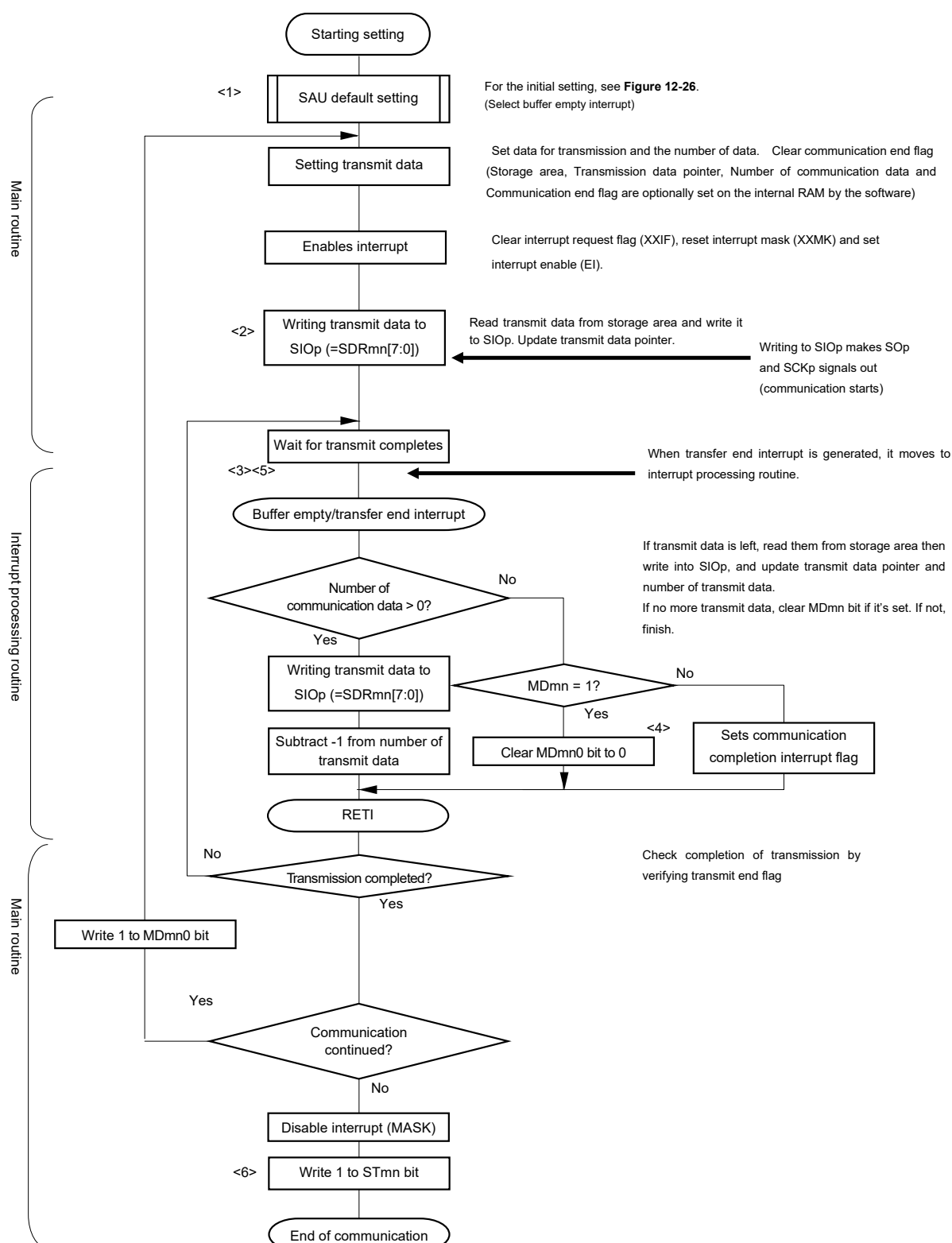


Note If transmit data is written to the SDRmn register while the BFFmn bit of serial status register mn (SSRmn) is 1 (valid data is stored in serial data register mn (SDRmn)), the transmit data is overwritten.

Caution The MDmn0 bit of serial mode register mn (SMRmn) can be rewritten even during operation. However, rewrite it before transfer of the last bit is started, so that it will be rewritten before the transfer end interrupt of the last transmit data.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-31. Flowchart of Master Transmission (in Continuous Transmission Mode)



Remarks 1. <1> to <6> in the figure correspond to <1> to <6> in **Figure 12-30 Timing Chart of Master Transmission (in Continuous Transmission Mode)**.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.5.2 Master reception

Master reception is that the RL78 microcontroller outputs a transfer clock and receives data from other device.

Simplified SPI	CSI00	CSI01	CSI10	CSI11	CSI20	CSI21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCK00, SI00	SCK01, SI01	SCK10, SI10	SCK11, SI11	SCK20, SI20	SCK21, SI21
Interrupt	INTCSI00	INTCSI01	INTCSI10	INTCSI11	INTCSI20	INTCSI21
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.					
Error detection flag	Overflow error detection flag (OVFmn) only					
Transfer data length	7 or 8 bits					
Transfer rate ^{Note}	Max. $f_{CLK}/2$ [MHz] (CSI00 only), $f_{CLK}/4$ [MHz] Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [Hz] ^{Note} f_{CLK} : System clock frequency					
Data phase	Selectable by the DAPmn bit of the SCRmn register - DAPmn = 0: Data input starts from the start of the operation of the serial clock. - DAPmn = 1: Data input starts half a clock before the start of the serial clock operation.					
Clock phase	Selectable by the CKPmn bit of the SCRmn register - CKPmn = 0: Non-reverse - CKPmn = 1: Reverse					
Data direction	MSB or LSB first					

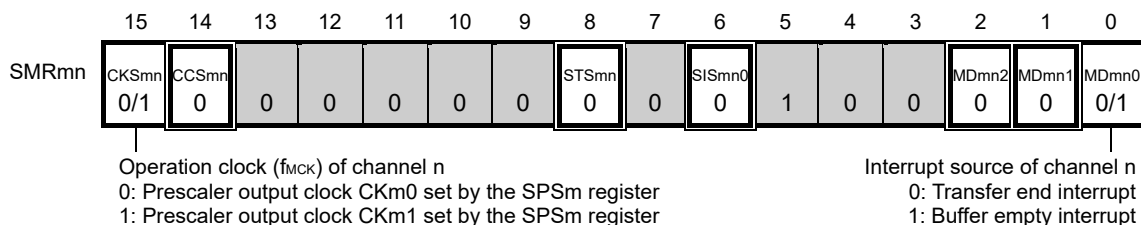
Note Use this operation within a range that satisfies the conditions above and the peripheral functions characteristic in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)**, **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$)**).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

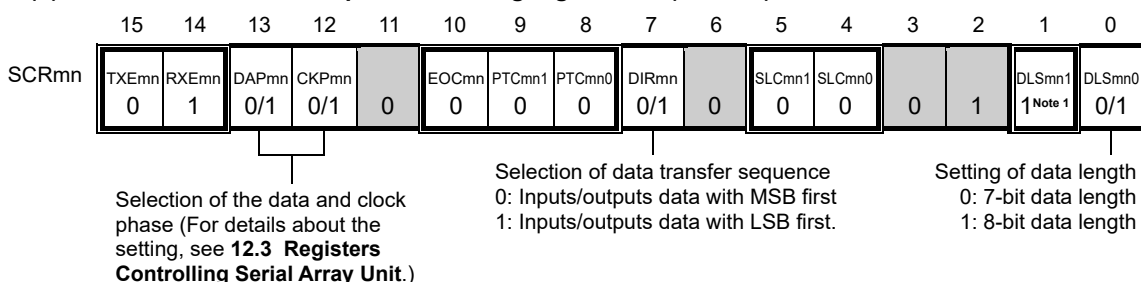
(1) Register setting

Figure 12-32. Example of Contents of Registers for Master Reception of Simplified SPI
(CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (1/2)

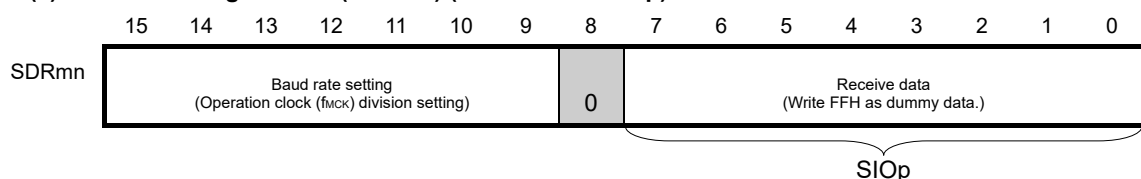
(a) Serial mode register mn (SMRmn)



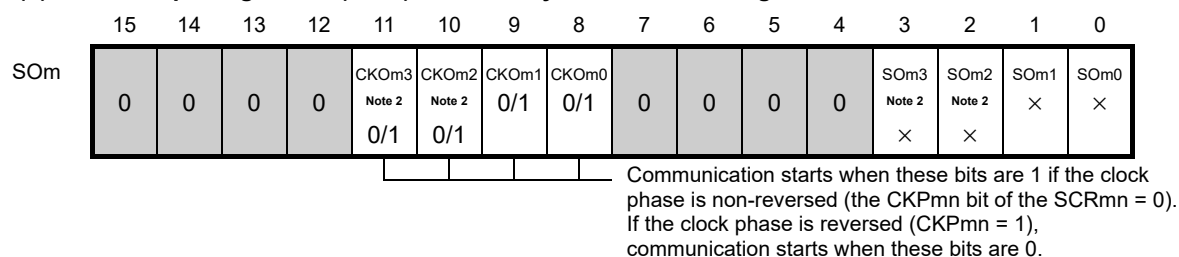
(b) Serial communication operation setting register mn (SCRmn)



(c) Serial data register mn (SDRmn) (lower 8 bits: SIOp)



(d) Serial output register m (SOM) ... Sets only the bits of the target channel.



Notes 1. Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.

2. Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

2. : Setting is fixed in the simplified SPI (CSI) master reception mode,

 : Setting disabled (set to the initial value)

×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)

0/1: Set to 0 or 1 depending on the usage of the user

**Figure 12-32. Example of Contents of Registers for Master Reception of Simplified SPI
(CSI00, CSI01, CSI10, CSI11, CSI20, CSI21, CSI30, CSI31) (2/2)**

(e) Serial output enable register m (SOEm) ...The register that not used in this mode.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note ×	SOEm2 Note ×	SOEm1 ×	SOEm0 ×

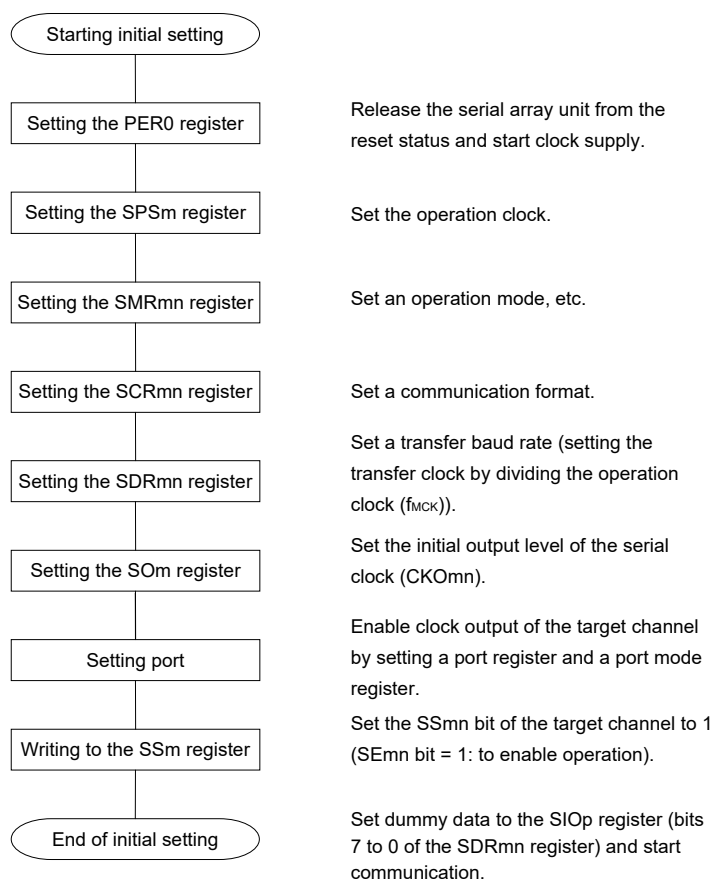
(f) Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

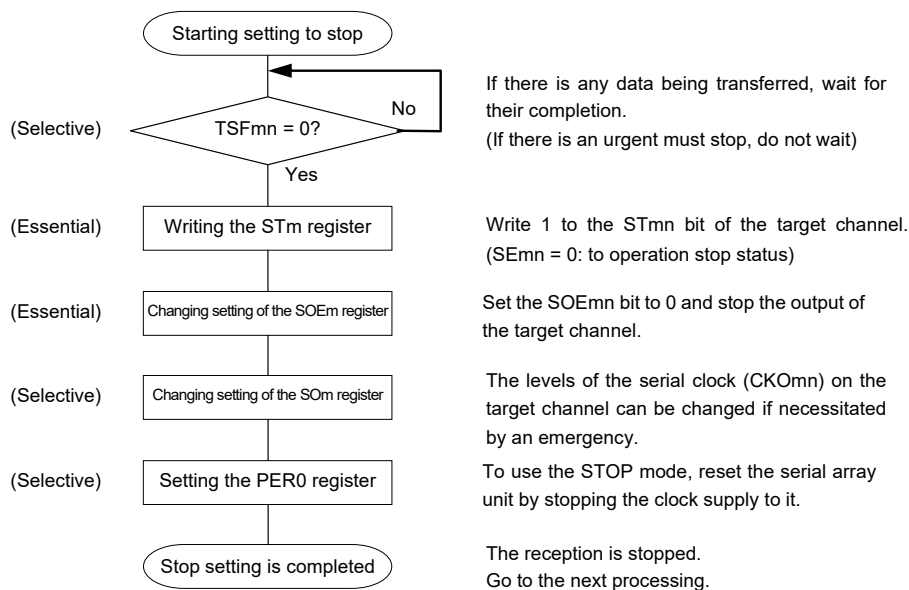
Note Unit 0 only

- Remarks** 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11
2. ☐: Setting is fixed in the simplified SPI (CSI) master reception mode,
☒: Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

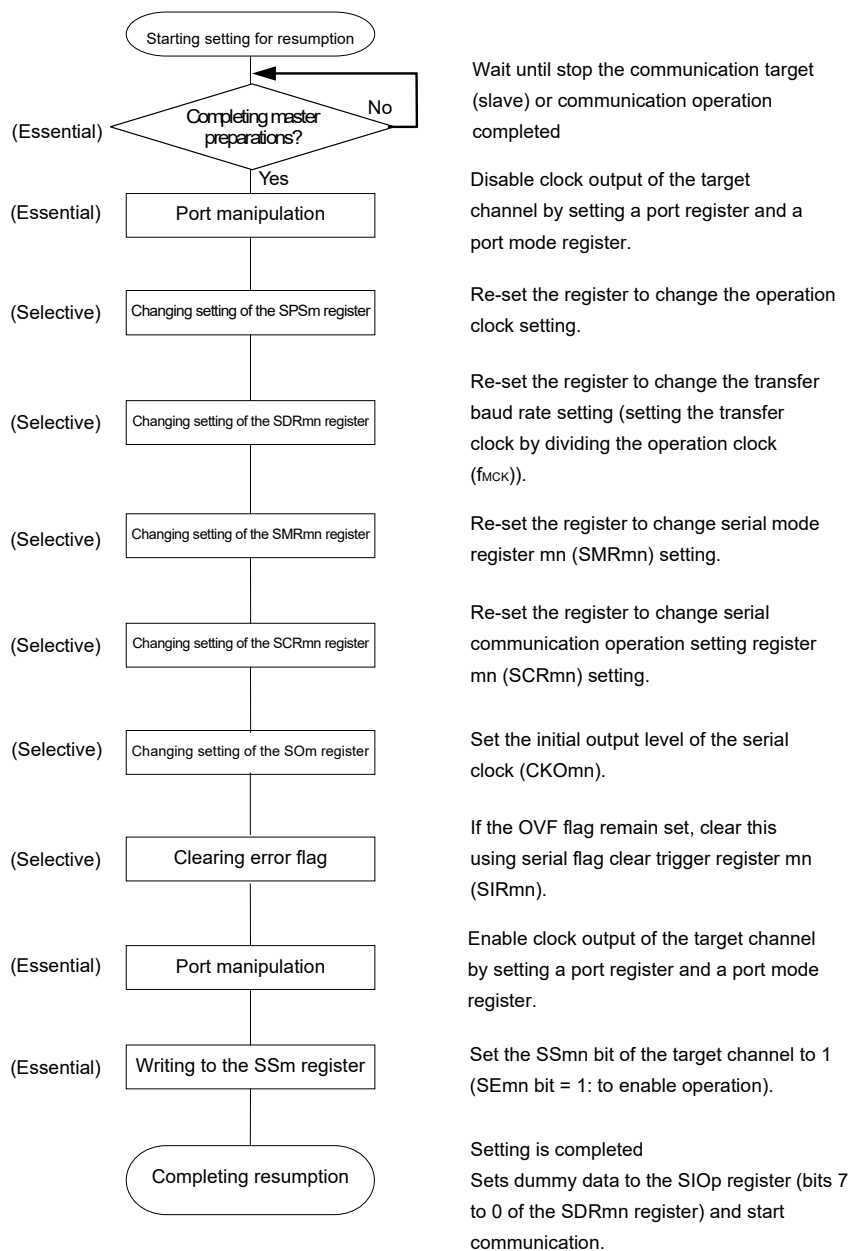
(2) Operation procedure

Figure 12-33. Initial Setting Procedure for Master Reception

Remark m: Unit number ($m = 0, 1$), n: Channel number ($n = 0$ to 3), p: CSI number ($p = 00, 01, 10, 11, 20, 21$), $mn = 00$ to 03, 10, 11

Figure 12-34. Procedure for Stopping Master Reception

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

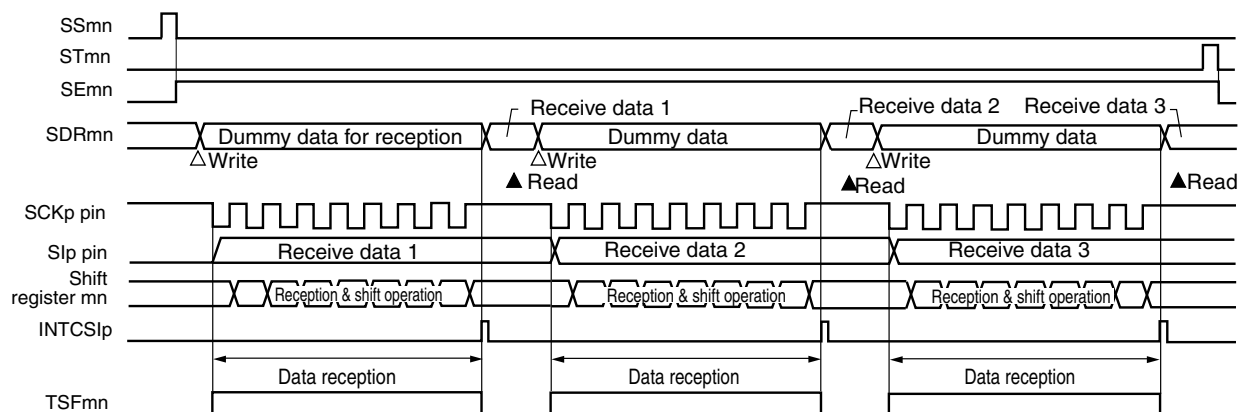
Figure 12-35. Procedure for Resuming Master Reception

Remarks 1. If PER0 is rewritten while stopping the master transmission and the clock supply is stopped, wait until the transmission target (slave) stops or transmission finishes, and then perform initialization instead of restarting the transmission.

- 2.** m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

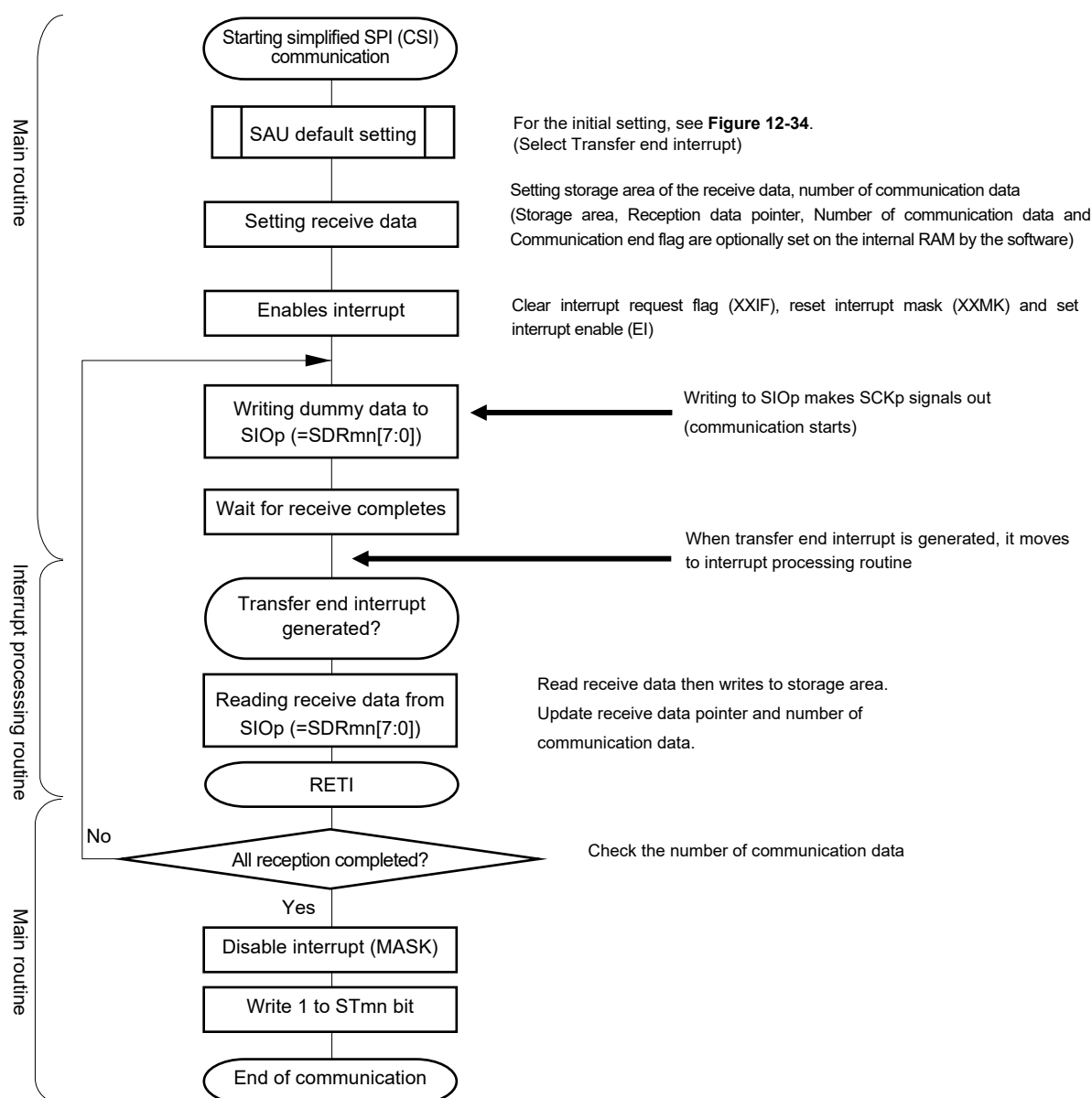
(3) Processing flow (in single-reception mode)

Figure 12-36. Timing Chart of Master Reception (in Single-Reception Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
 mn = 00 to 03, 10, 11

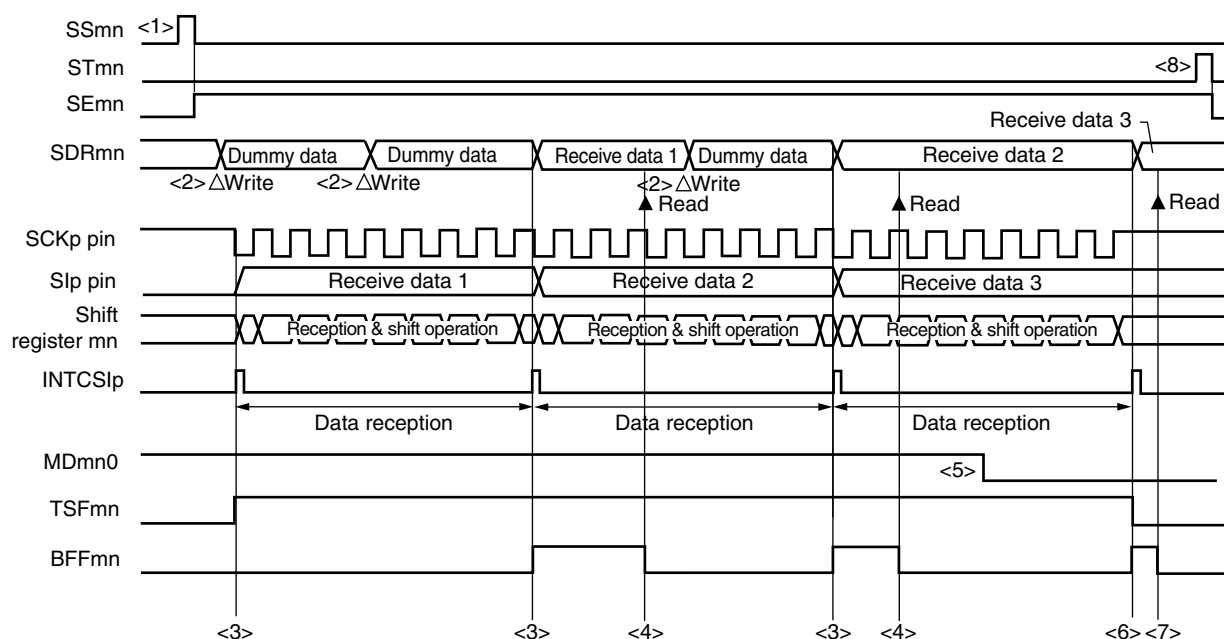
Figure 12-37. Flowchart of Master Reception (in Single-Reception Mode)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(4) Processing flow (in continuous reception mode)

Figure 12-38. Timing Chart of Master Reception (in Continuous Reception Mode) (Type 1: DAPmn = 0, CKPmn = 0)

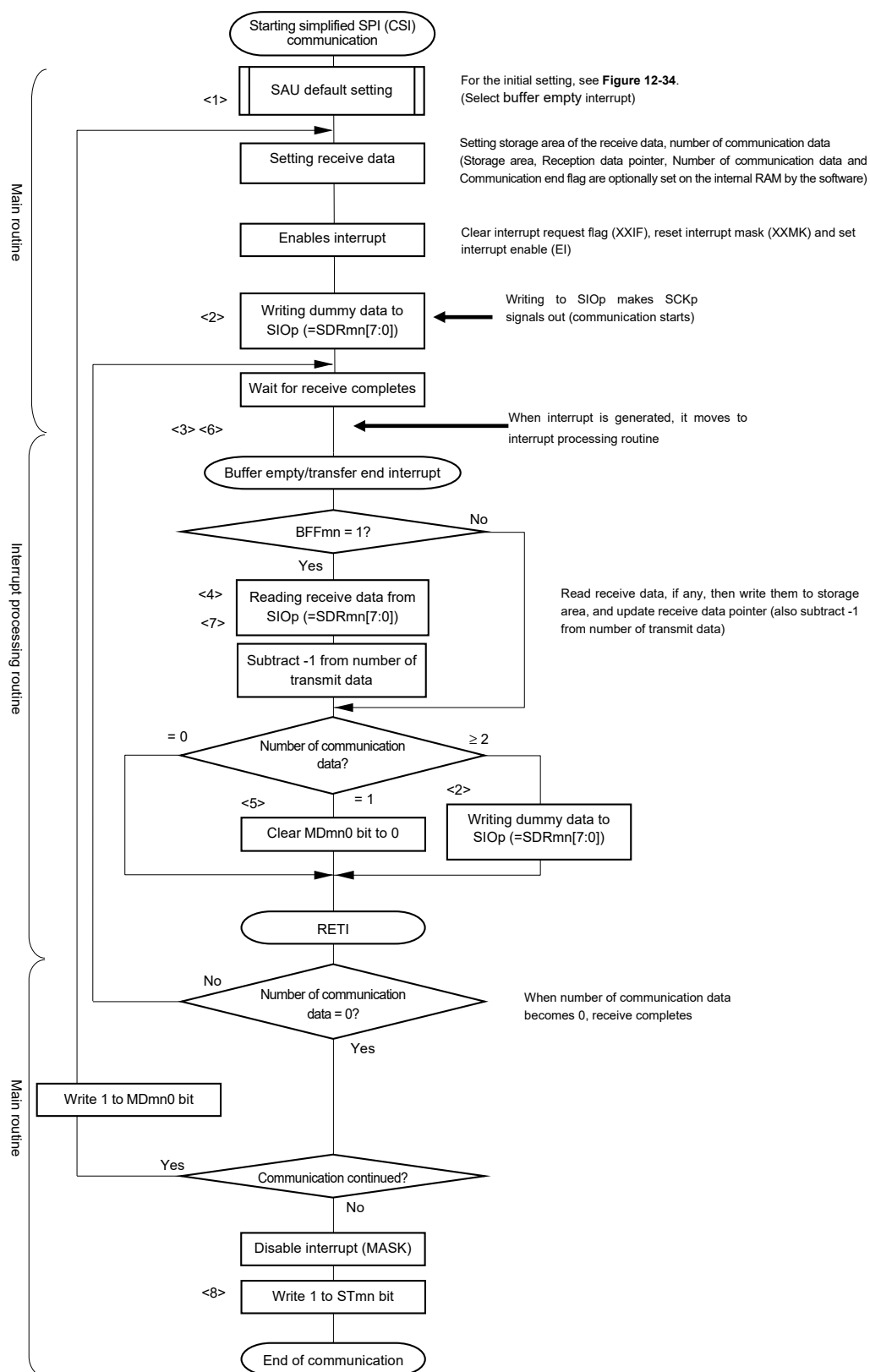


Caution The MDmn0 bit can be rewritten even during operation.
 However, rewrite it before receive of the last bit is started, so that it has been rewritten before the transfer end interrupt of the last receive data.

Remarks 1. <1> to <8> in the figure correspond to <1> to <8> in **Figure 12-39 Flowchart of Master Reception (in Continuous Reception Mode)**.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-39. Flowchart of Master Reception (in Continuous Reception Mode)



Remarks 1. <1> to <8> in the figure correspond to <1> to <8> in **Figure 12-38 Timing Chart of Master Reception (in Continuous Reception Mode)**.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.5.3 Master transmission/reception

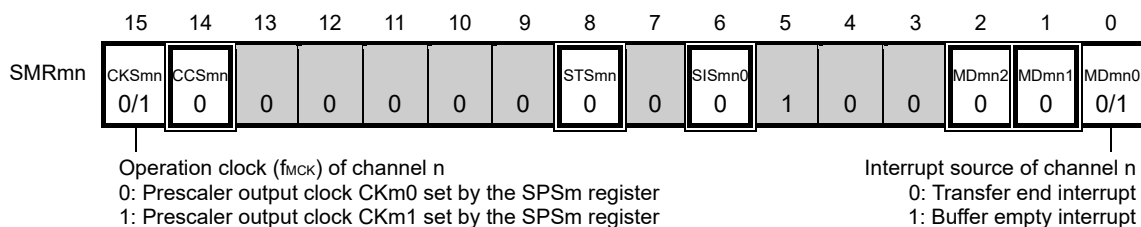
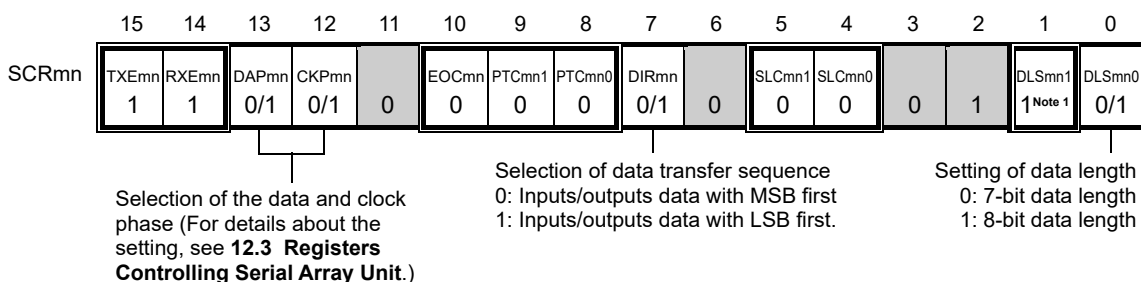
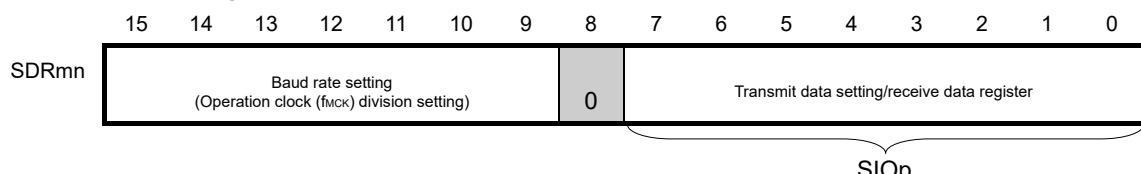
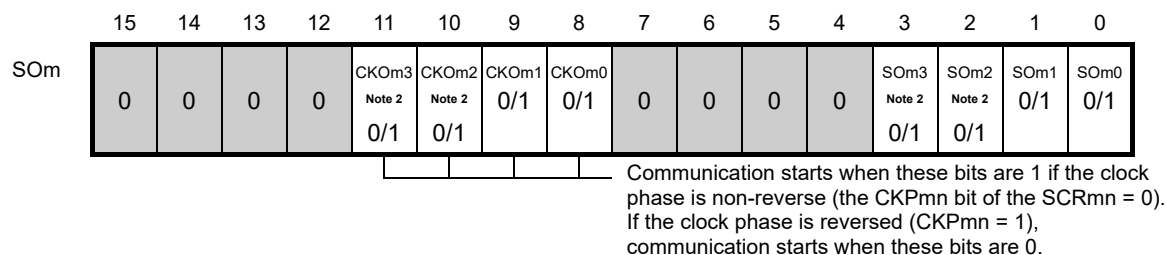
Master transmission/reception is that the RL78 microcontroller outputs a transfer clock and transmits/receives data to/from other device.

Simplified SPI	CSI00	CSI01	CSI10	CSI11	CSI20	CSI21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCK00, SI00, SO00	SCK01, SI01, SO01	SCK10, SI10, SO10	SCK11, SI11, SO11	SCK20, SI20, SO20	SCK21, SI21, SO21
Interrupt	INTCSI00	INTCSI01	INTCSI10	INTCSI11	INTCSI20	INTCSI21
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.					
Error detection flag	Overrun error detection flag (OVFmn) only					
Transfer data length	7 or 8 bits					
Transfer rate ^{Note}	Max. $f_{CLK}/2$ [MHz] (CSI00 only), $f_{CLK}/4$ [MHz] Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [Hz] ^{Note} f_{CLK} : System clock frequency					
Data phase	Selectable by the DAPmn bit of the SCRmn register - DAPmn = 0: Data I/O starts at the start of the operation of the serial clock. - DAPmn = 1: Data I/O starts half a clock before the start of the serial clock operation.					
Clock phase	Selectable by the CKPmn bit of the SCRmn register - CKPmn = 0: Non-reverse - CKPmn = 1: Reverse					
Data direction	MSB or LSB first					

Note Use this operation within a range that satisfies the conditions above and the peripheral functions characteristic in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)**, **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$)**).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(1) Register setting

Figure 12-40. Example of Contents of Registers for Master Transmission/Reception of Simplified SPI (CSi00, CSi01, CSi10, CSi11, CSi20, CSi21, CSi30, CSi31) (1/2)**(a) Serial mode register mn (SMRmn)****(b) Serial communication operation setting register mn (SCRmn)****(c) Serial data register mn (SDRmn) (lower 8 bits: SIOp)****(d) Serial output register m (SOM) ... Sets only the bits of the target channel.****Notes 1.** Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.**2.** Unit 0 only**Remarks 1.** m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11**2.** : Setting is fixed in the simplified SPI (CSI) master transmission/reception mode : Setting disabled (set to the initial value)

0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-40. Example of Contents of Registers for Master Transmission/Reception of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21, CSI30, CSI31) (2/2)

(e) Serial output enable register m (SOEm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 0/1	SOEm2 Note 0/1	SOEm1 0/1	SOEm0 0/1

(f) Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

Note Serial array unit 0 only.

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

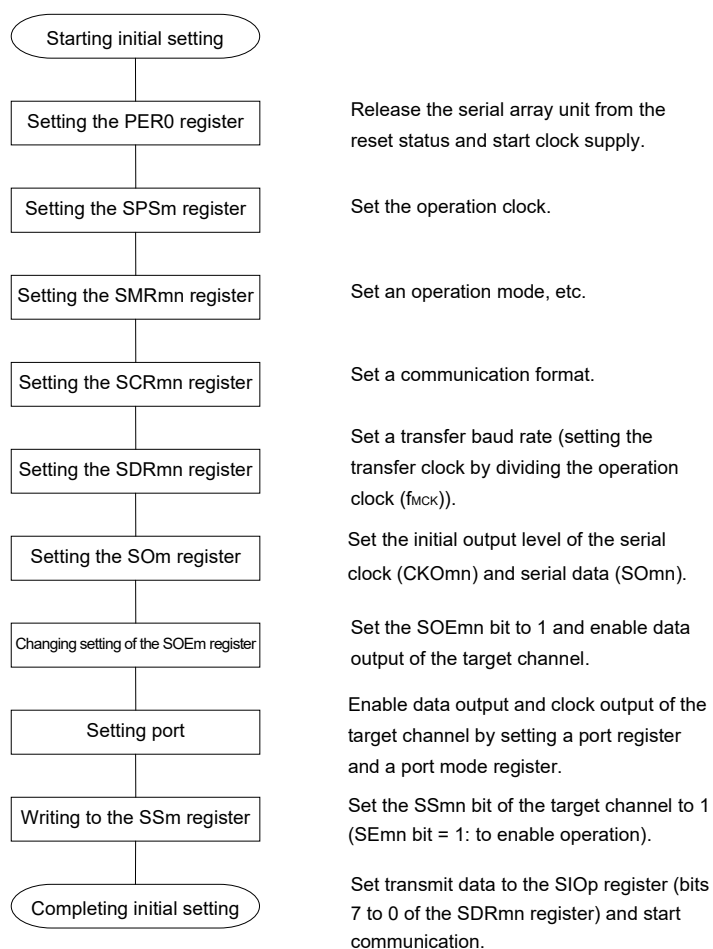
2. ☐ : Setting is fixed in the simplified SPI (CSI) master transmission/reception mode

☐ : Setting disabled (set to the initial value)

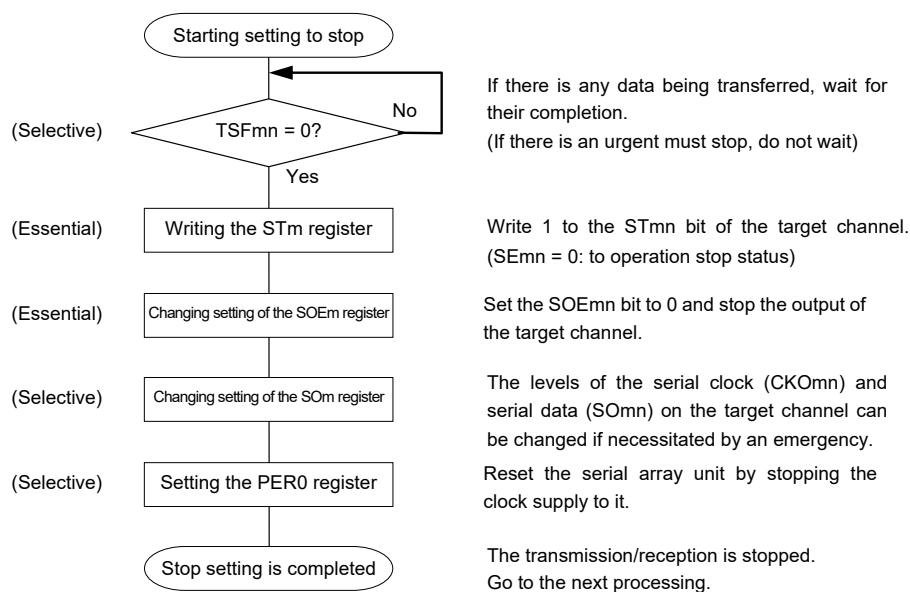
0/1: Set to 0 or 1 depending on the usage of the user

(2) Operation procedure

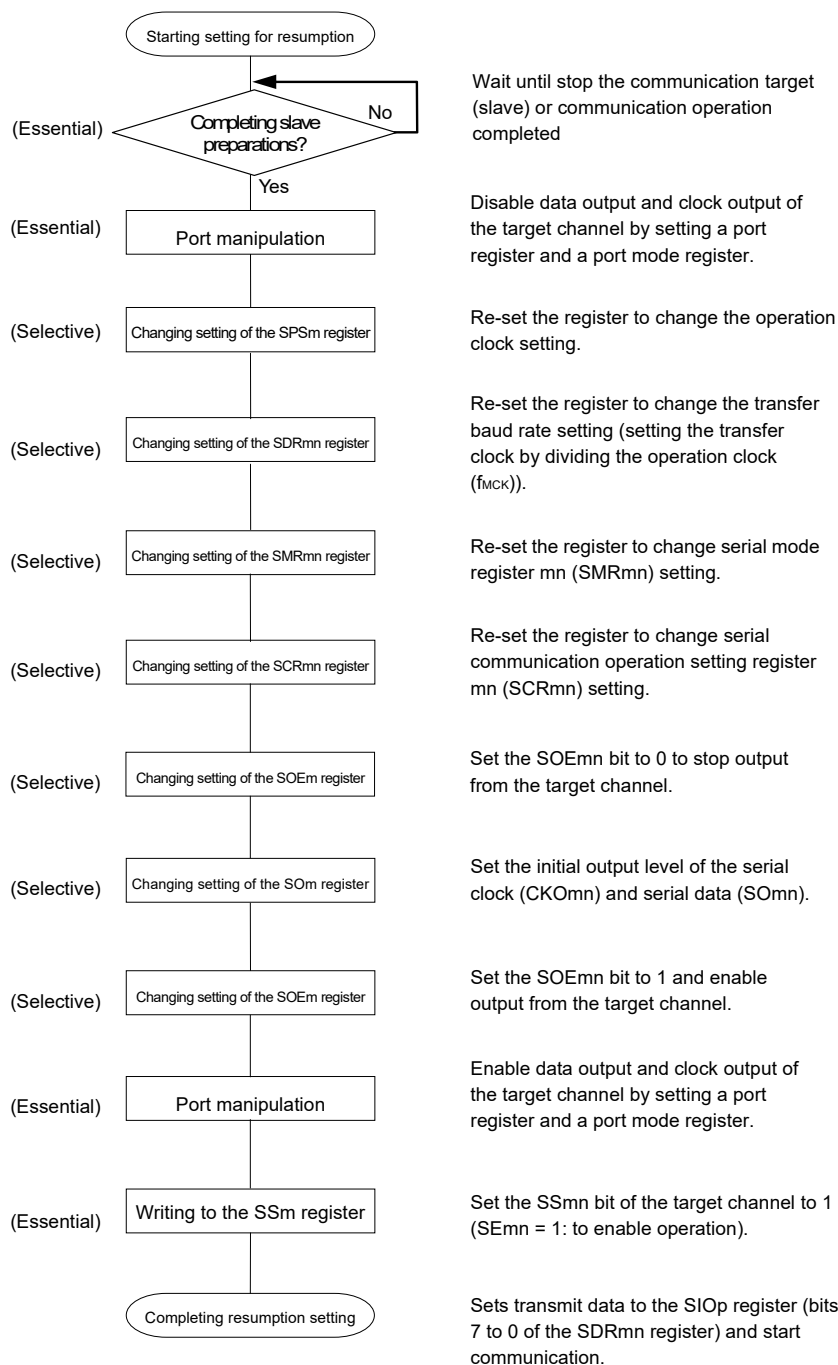
Figure 12-41. Initial Setting Procedure for Master Transmission/Reception



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-42. Procedure for Stopping Master Transmission/Reception

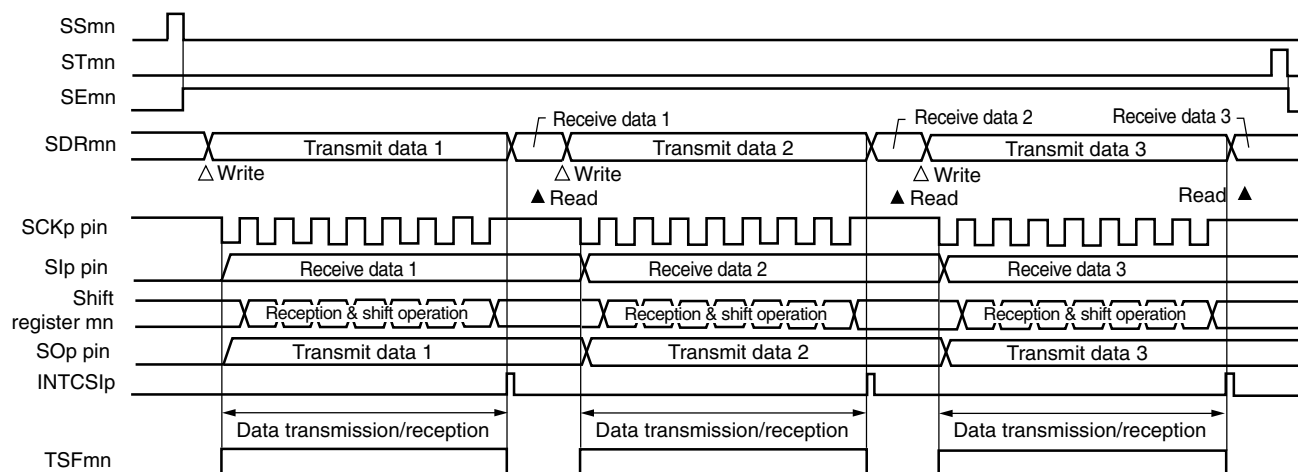
Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

Figure 12-43. Procedure for Resuming Master Transmission/Reception

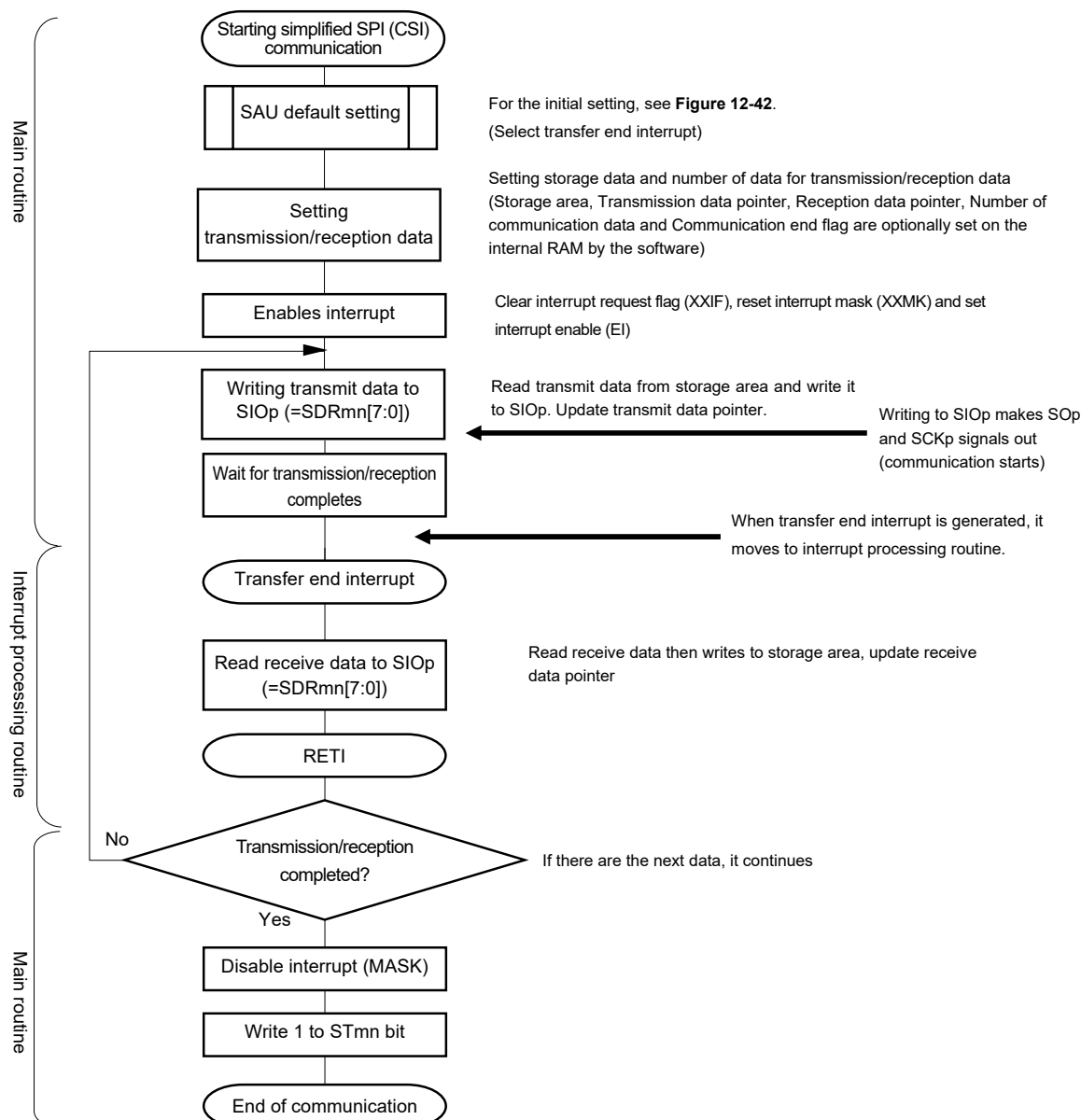
Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(3) Processing flow (in single-transmission/reception mode)

Figure 12-44. Timing Chart of Master Transmission/Reception (in Single-Transmission/Reception Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)



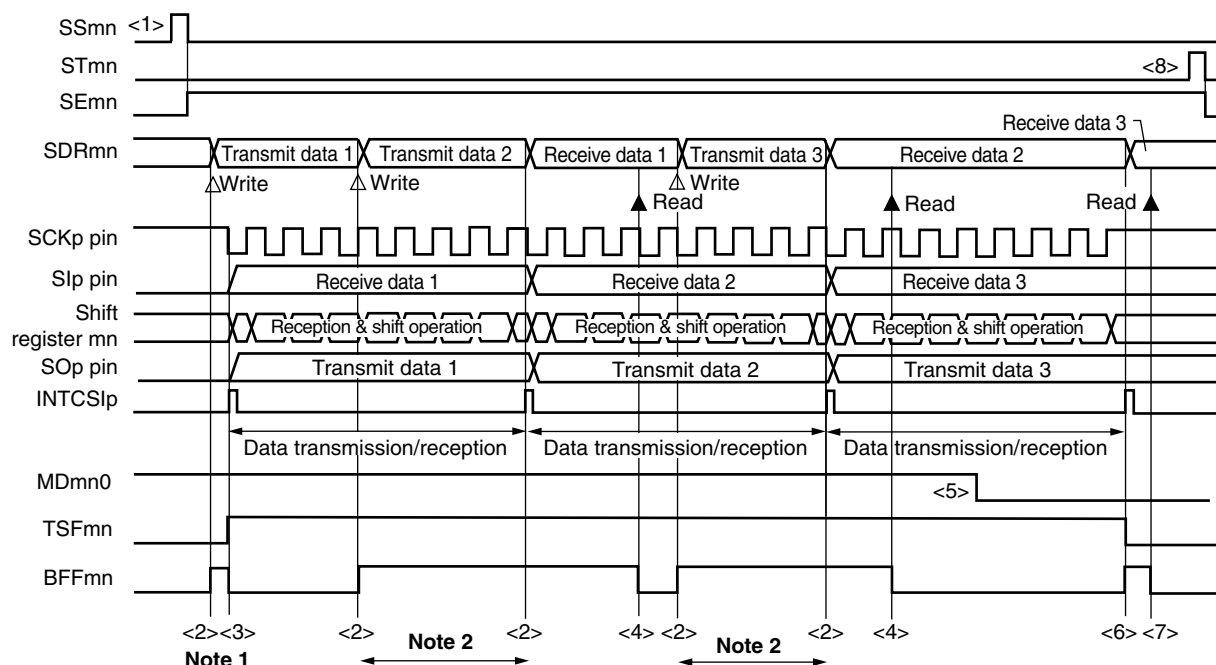
Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
 mn = 00 to 03, 10, 11

Figure 12-45. Flowchart of Master Transmission/Reception (in Single-Transmission/Reception Mode)

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(4) Processing flow (in continuous transmission/reception mode)

Figure 12-46. Timing Chart of Master Transmission/Reception (in Continuous Transmission/Reception Mode)
(Type 1: DAPmn = 0, CKPmn = 0)



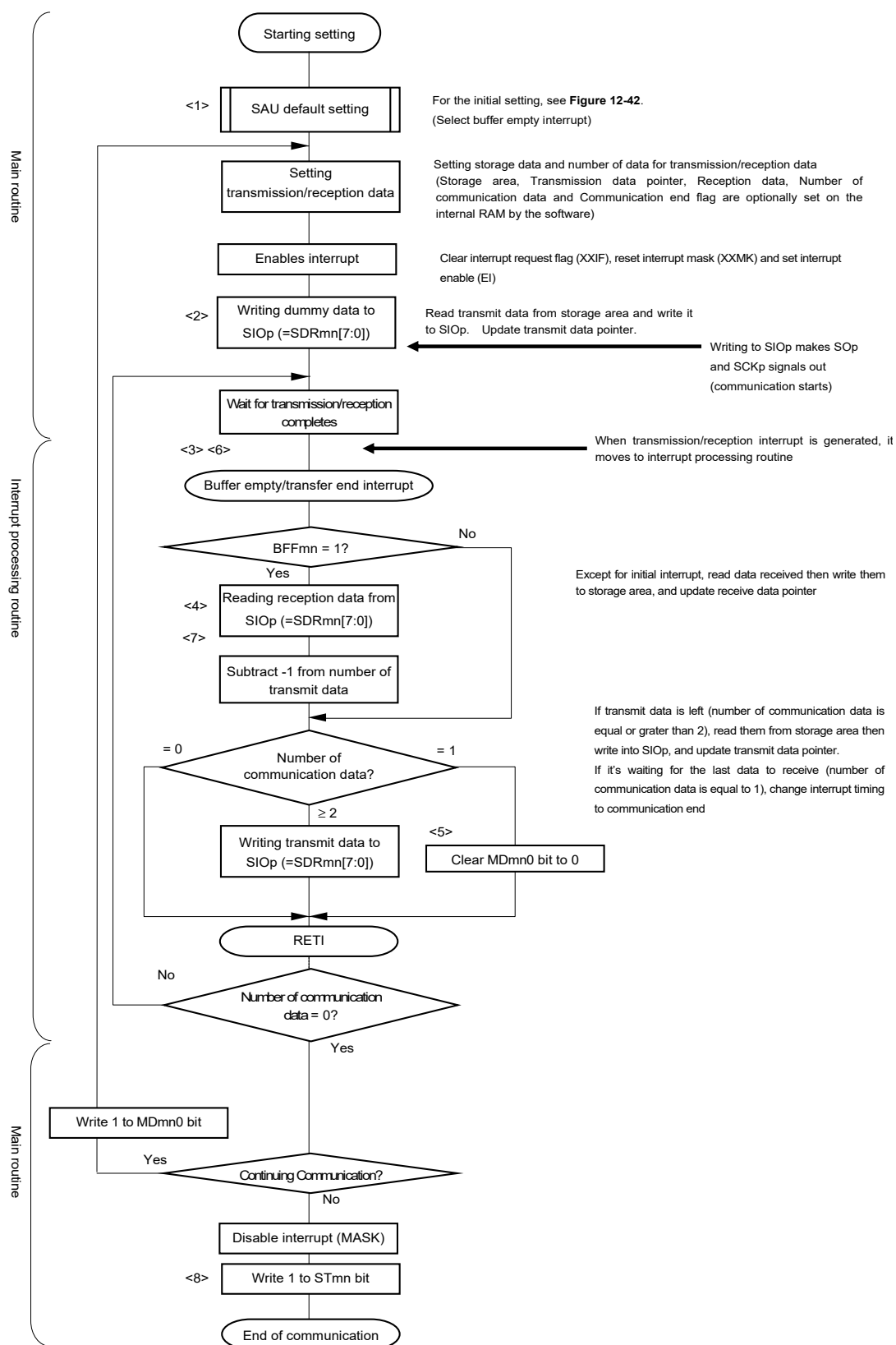
- Notes**
1. If transmit data is written to the SDRmn register while the BFFmn bit of serial status register mn (SSRmn) is 1 (valid data is stored in serial data register mn (SDRmn)), the transmit data is overwritten.
 2. The transmit data can be read by reading the SDRmn register during this period. At this time, the transfer operation is not affected.

Caution The MDmn0 bit of serial mode register mn (SMRmn) can be rewritten even during operation. However, rewrite it before transfer of the last bit is started, so that it has been rewritten before the transfer end interrupt of the last transmit data.

Remarks 1. <1> to <8> in the figure correspond to <1> to <8> in **Figure 12-47 Flowchart of Master Transmission/Reception (in Continuous Transmission/Reception Mode)**.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-47. Flowchart of Master Transmission/Reception (in Continuous Transmission/Reception Mode)



Remarks 1. <1> to <8> in the figure correspond to <1> to <8> in Figure 12-46 Timing Chart of Master Transmission/Reception (in Continuous Transmission/Reception Mode).

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.5.4 Slave transmission

Slave transmission is that the RL78 microcontroller transmits data to another device in the state of a transfer clock being input from another device.

Simplified SPI	CSI00	CSI01	CSI10	CSI11	CSI20	CSI21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCK00, SO00	SCK01, SO01	SCK10, SO10	SCK11, SO11	SCK20, SO20	SCK21, SO21
Interrupt	INTCSI00	INTCSI01	INTCSI10	INTCSI11	INTCSI20	INTCSI21
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.					
Error detection flag	Overrun error detection flag (OVFmn) only					
Transfer data length	7 or 8 bits					
Transfer rate	Max. $f_{MCK}/6$ [MHz] ^{Notes 1, 2.}					
Data phase	Selectable by the DAPmn bit of the SCRmn register • DAPmn = 0: Data output starts from the start of the operation of the serial clock. • DAPmn = 1: Data output starts half a clock before the start of the serial clock operation.					
Clock phase	Selectable by the CKPmn bit of the SCRmn register • CKPmn = 0: Forward • CKPmn = 1: Reverse					
Data direction	MSB or LSB first					

Notes 1. Because the external serial clock input to the SCK00, SCK01, SCK10, SCK11, SCK20, and SCK21 pins is sampled internally and used, the fastest transfer rate is $f_{MCK}/6$ [MHz].

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristic in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$), **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS)** ($T_A = -40$ to $+105^\circ\text{C}$)).

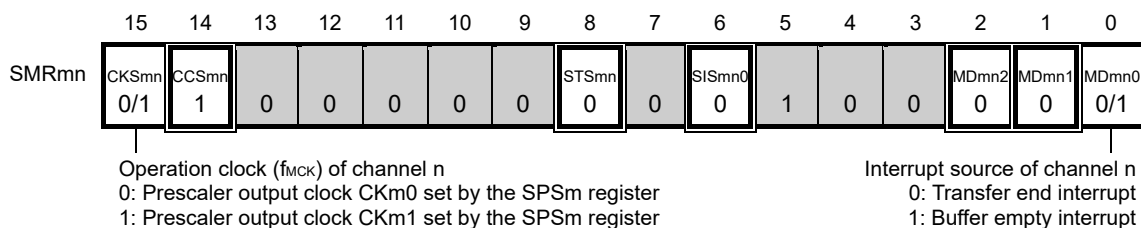
Remarks 1. f_{MCK} : Operation clock frequency of target channel

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

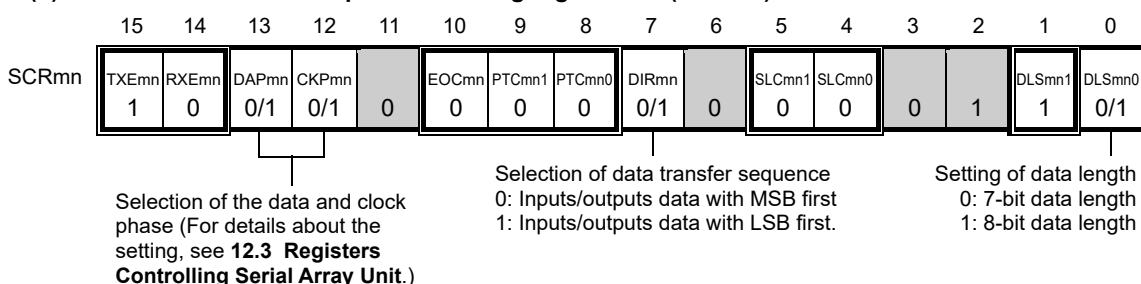
(1) Register setting

Figure 12-48. Example of Contents of Registers for Slave Transmission of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (1/2)

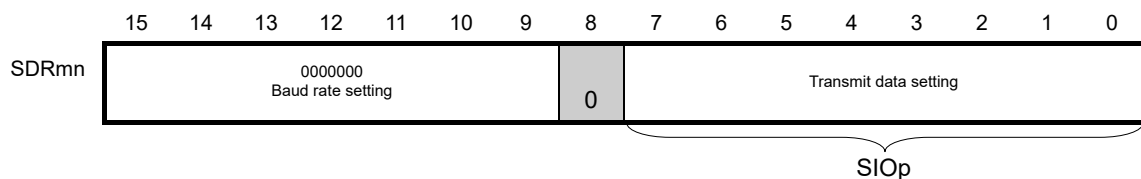
(a) Serial mode register mn (SMRmn)



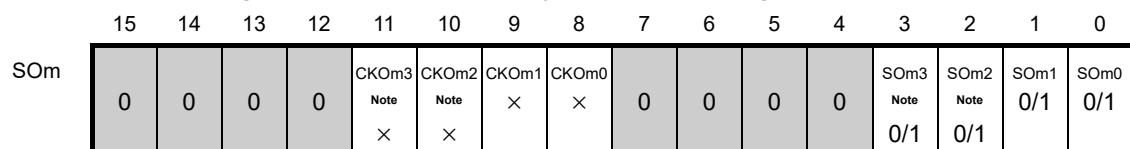
(b) Serial communication operation setting register mn (SCRmn)



(c) Serial data register mn (SDRmn) (lower 8 bits: SIOp)



(d) Serial output register m (SOM) ... Sets only the bits of the target channel.



Note Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

- 2.** : Setting is fixed in the simplified SPI (CSI) slave transmission mode,
 : Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-48. Example of Contents of Registers for Slave Transmission of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (2/2)

(e) Serial output enable register m (SOEm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 0/1	SOEm2 Note 0/1	SOEm1 0/1	SOEm0 0/1

(f) Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.

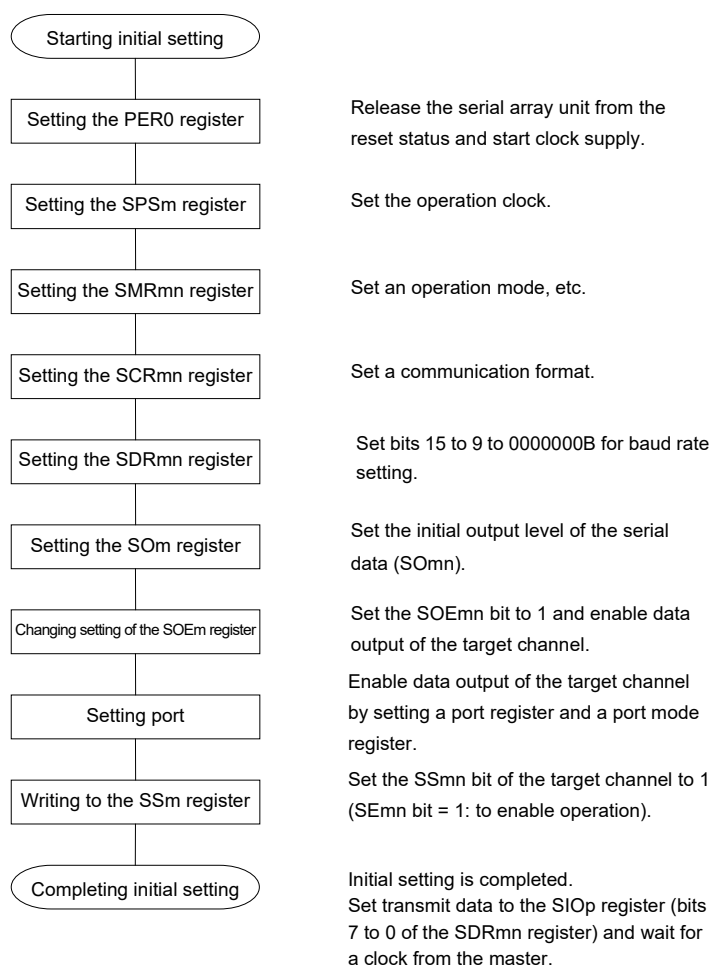
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

Note Unit 0 only

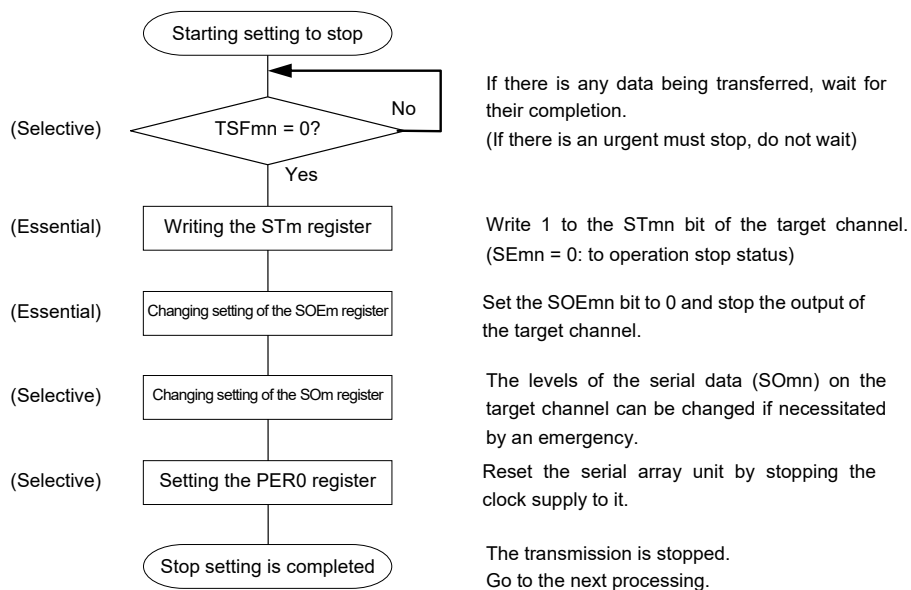
- Remarks**
1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11
 2. ☐: Setting is fixed in the simplified SPI (CSI) slave transmission mode,
☐: Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

(2) Operation procedure

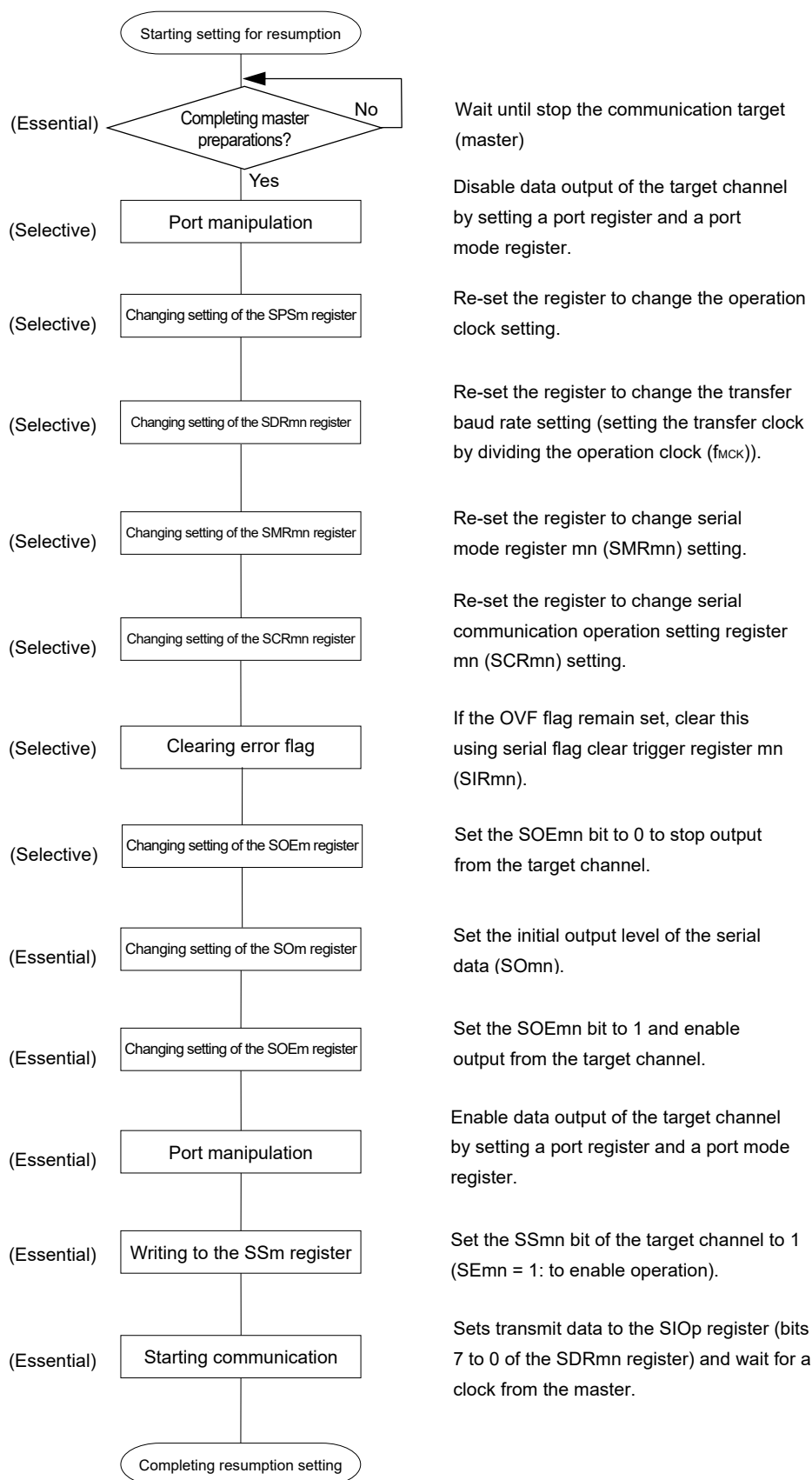
Figure 12-49. Initial Setting Procedure for Slave Transmission



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-50. Procedure for Stopping Slave Transmission

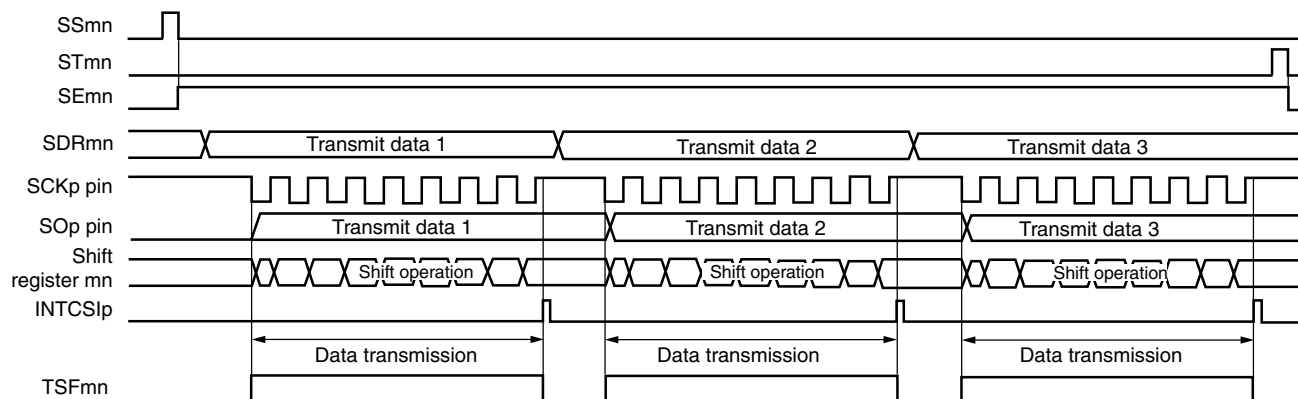
Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

Figure 12-51. Procedure for Resuming Slave Transmission

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

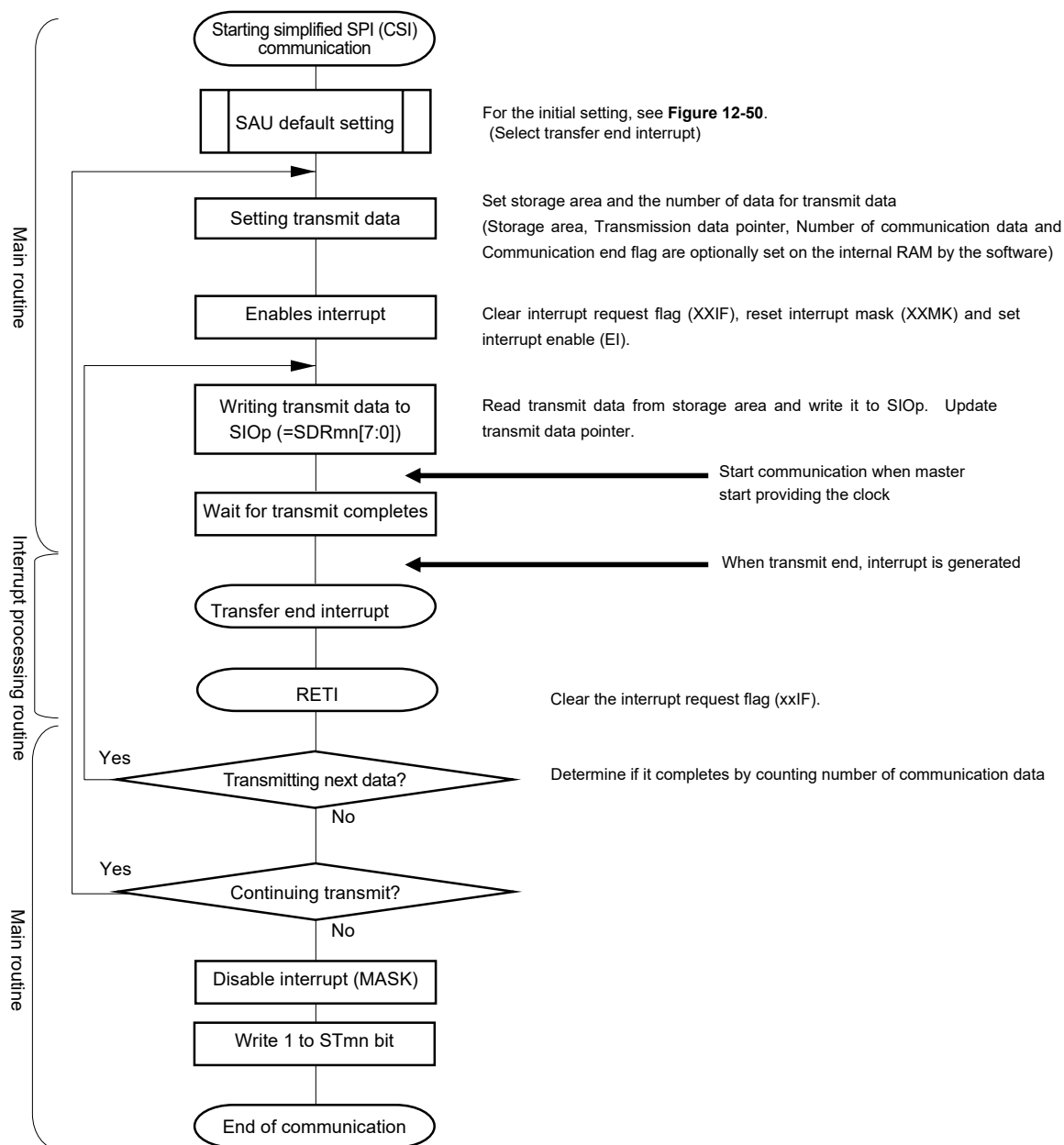
(3) Processing flow (in single-transmission mode)

Figure 12-52. Timing Chart of Slave Transmission (in Single-Transmission Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
 mn = 00 to 03, 10, 11

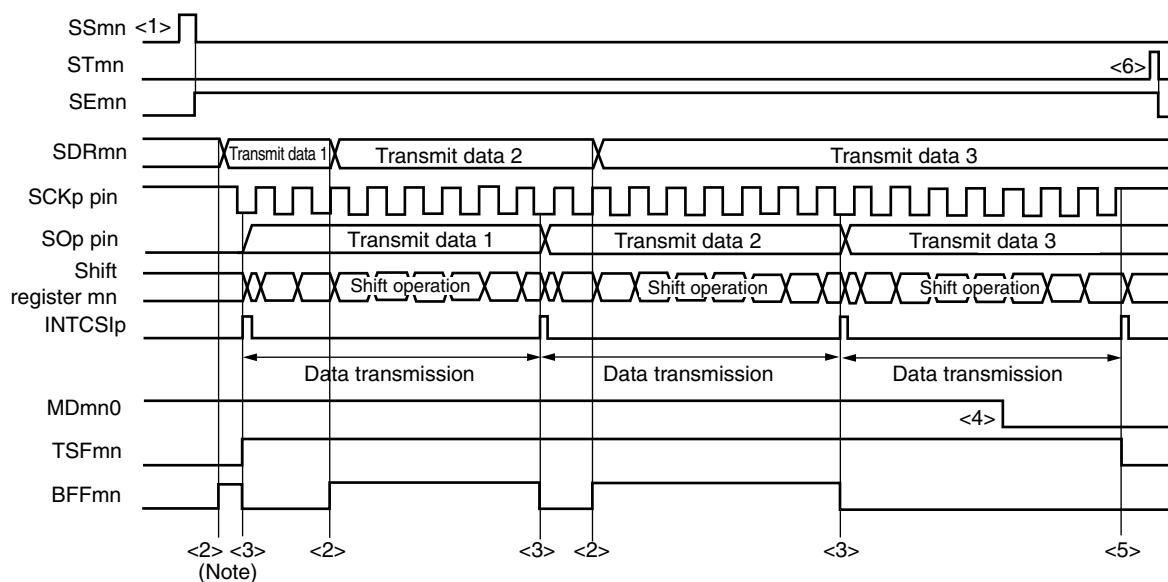
Figure 12-53. Flowchart of Slave Transmission (in Single-Transmission Mode)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(4) Processing flow (in continuous transmission mode)

Figure 12-54. Timing Chart of Slave Transmission (in Continuous Transmission Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)

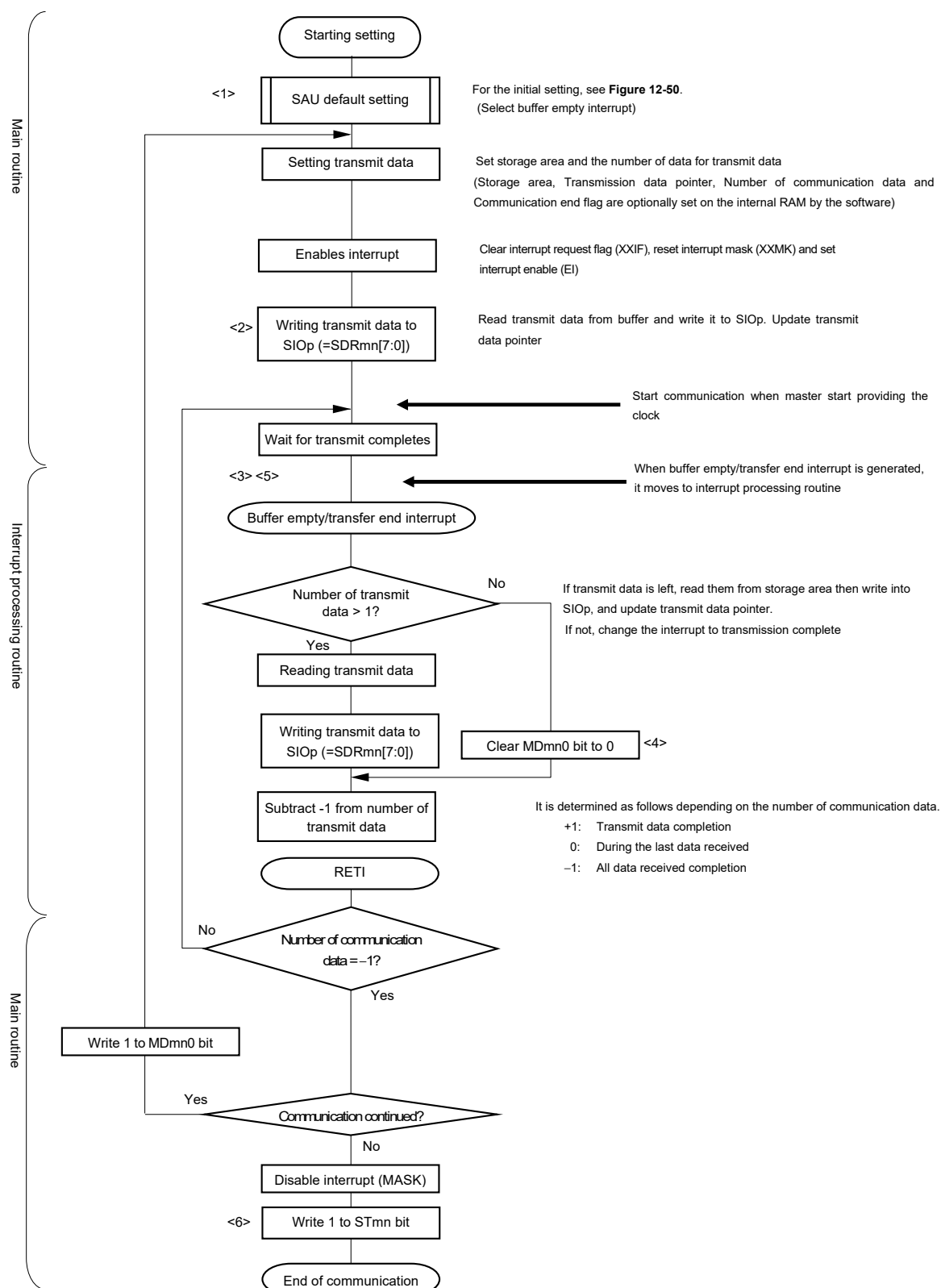


Note If transmit data is written to the SDRmn register while the BFFmn bit of serial status register mn (SSRmn) is 1 (valid data is stored in serial data register mn (SDRmn)), the transmit data is overwritten.

Caution The MDmn0 bit of serial mode register mn (SMRmn) can be rewritten even during operation. However, rewrite it before transfer of the last bit is started.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-55. Flowchart of Slave Transmission (in Continuous Transmission Mode)



Remarks 1. <1> to <6> in the figure correspond to <1> to <6> in **Figure 12-54 Timing Chart of Slave Transmission (in Continuous Transmission Mode).**

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.5.5 Slave reception

Slave reception is that the RL78 microcontroller receives data from another device in the state of a transfer clock being input from another device.

Simplified SPI	CSI00	CSI01	CSI10	CSI11	CSI20	CSI21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCK00, SI00	SCK01, SI01	SCK10, SI10	SCK11, SI11	SCK20, SI20	SCK21, SI21
Interrupt	INTCSI00	INTCSI01	INTCSI10	INTCSI11	INTCSI20	INTCSI21
	Transfer end interrupt only (Setting the buffer empty interrupt is prohibited.)					
Error detection flag	Overflow error detection flag (OVFmn) only					
Transfer data length	7 or 8 bits					
Transfer rate	Max. $f_{MCK}/6$ [MHz] ^{Notes 1, 2}					
Data phase	Selectable by the DAPmn bit of the SCRmn register • DAPmn = 0: Data input starts from the start of the operation of the serial clock. • DAPmn = 1: Data input starts half a clock before the start of the serial clock operation.					
Clock phase	Selectable by the CKPmn bit of the SCRmn register • CKPmn = 0: Non-reverse • CKPmn = 1: Reverse					
Data direction	MSB or LSB first					

Notes 1. Because the external serial clock input to the SCK00, SCK01, SCK10, SCK11, SCK20, and SCK21 pins is sampled internally and used, the fastest transfer rate is $f_{MCK}/6$ [MHz].

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristic in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = –40 to +85°C)**, **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS T_A = –40 to +105°C)**).

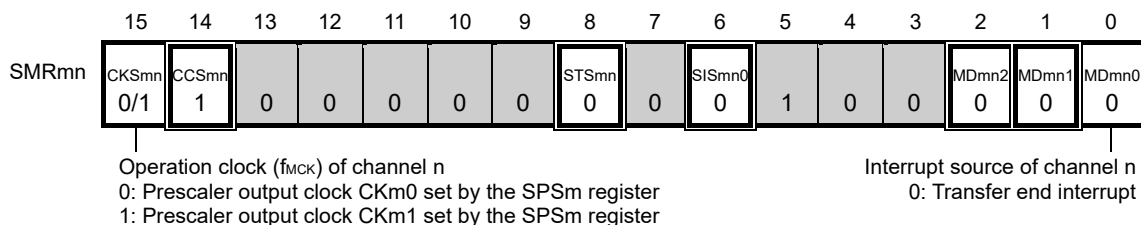
Remarks 1. f_{MCK} : Operation clock frequency of target channel

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

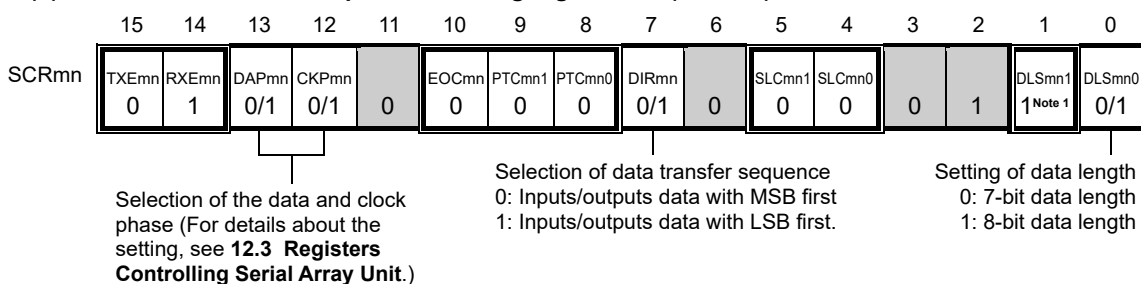
(1) Register setting

**Figure 12-56. Example of Contents of Registers for Slave Reception of Simplified SPI
(CSI00, CSI01, CSI10, CSI11, CSI20, CSI21)**

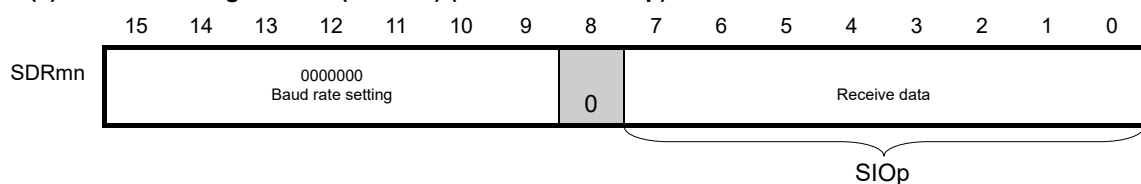
(a) Serial mode register mn (SMRmn)



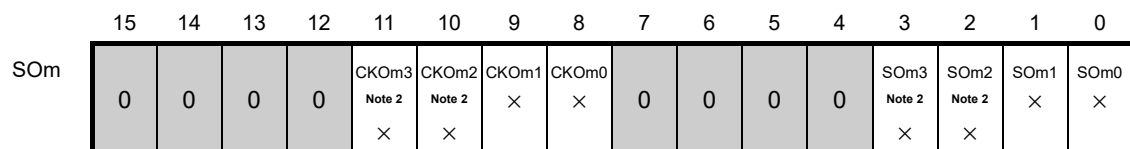
(b) Serial communication operation setting register mn (SCRmn)



(c) Serial data register mn (SDRmn) (lower 8 bits: SIOp)



(d) Serial output register m (SOM) ...The Register that not used in this mode.



Notes 1. Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.

2. Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),

p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

2. : Setting is fixed in the simplified SPI (CSI) slave reception mode,

 : Setting disabled (set to the initial value)

×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)

0/1: Set to 0 or 1 depending on the usage of the user

**Figure 12-56. Example of Contents of Registers for Slave Reception of Simplified SPI
(CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (2/2)**

(e) **Serial output enable register m (SOEm) ...The Register that not used in this mode.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note ×	SOEm2 Note ×	SOEm1 ×	SOEm0 ×

(f) **Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.**

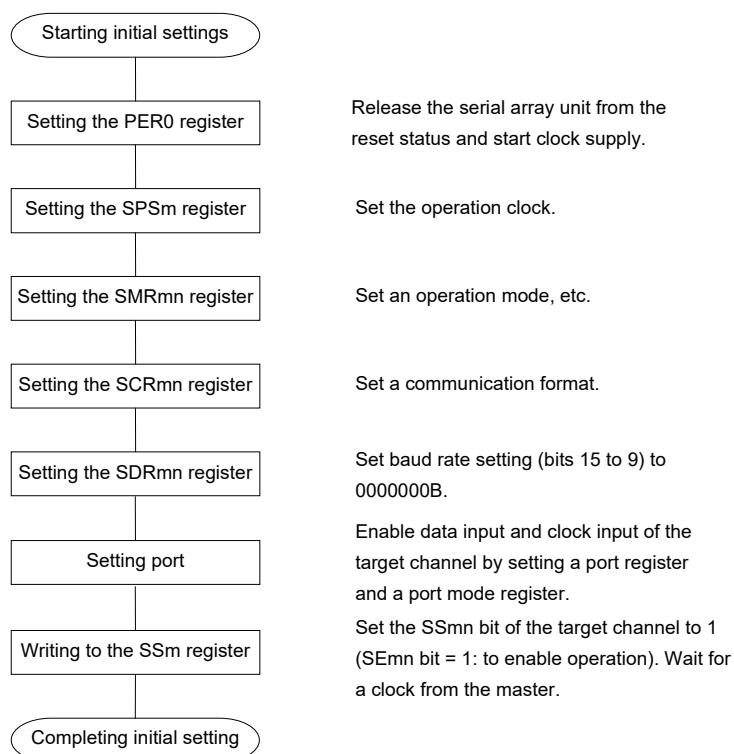
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

Note Unit 0 only

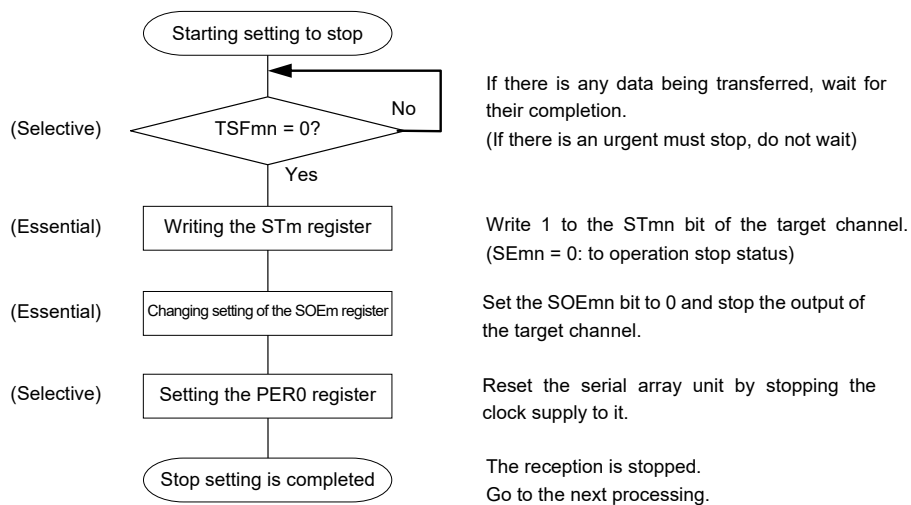
- Remarks** 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
mn = 00 to 03, 10, 11
2. ☐: Setting is fixed in the simplified SPI (CSI) slave reception mode,
☐: Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

(2) Operation procedure

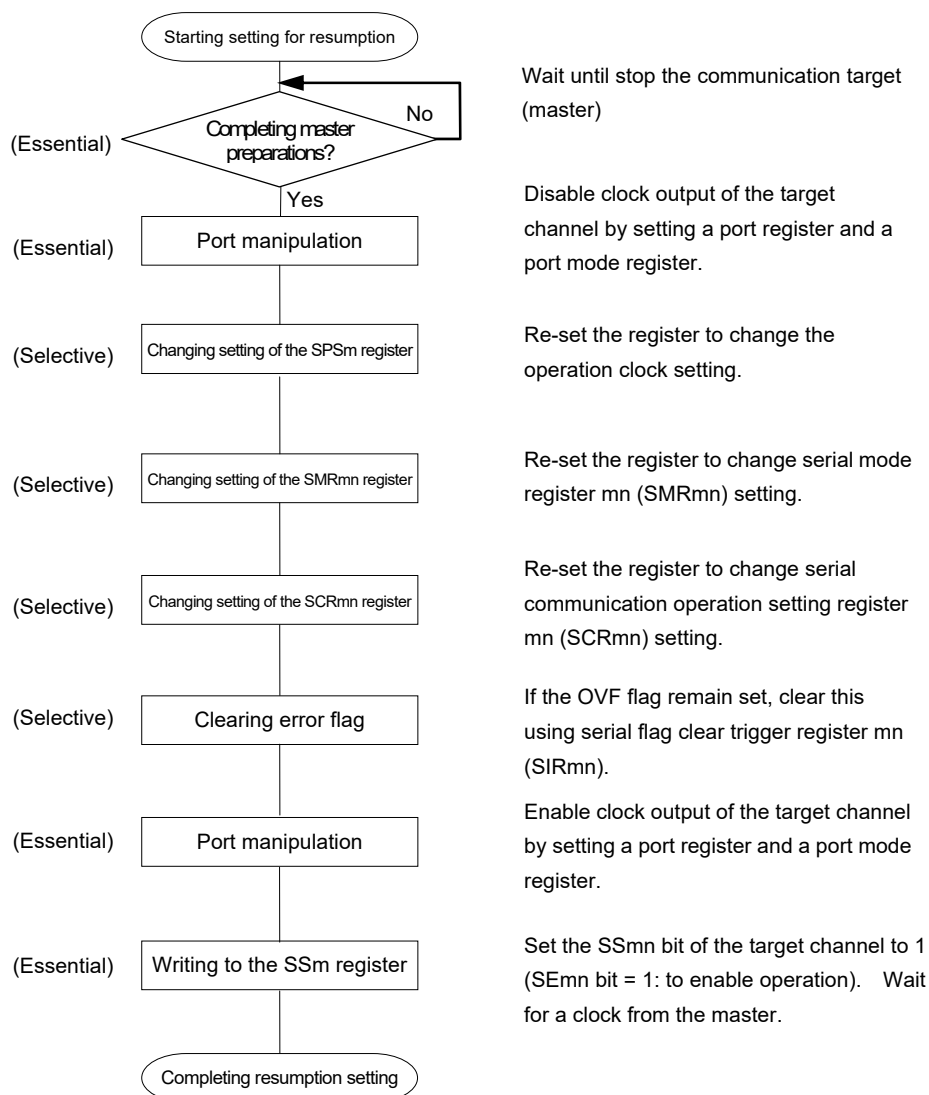
Figure 12-57. Initial Setting Procedure for Slave Reception



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

Figure 12-58. Procedure for Stopping Slave Reception

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

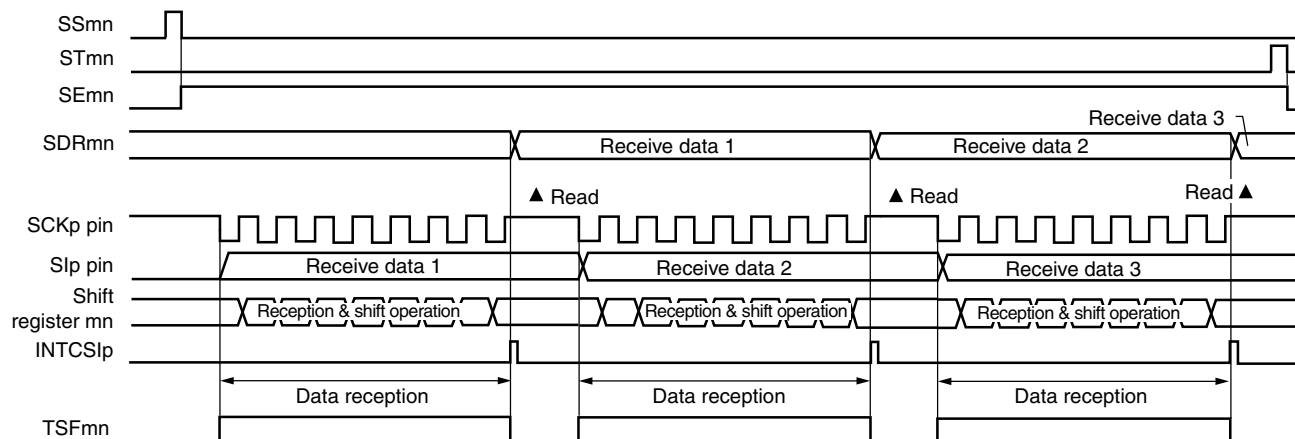
Figure 12-59. Procedure for Resuming Slave Reception

Remarks 1. If PER0 is rewritten while stopping the master transmission and the clock supply is stopped, wait until the transmission target (master) stops or transmission finishes, and then perform initialization instead of restarting the transmission.

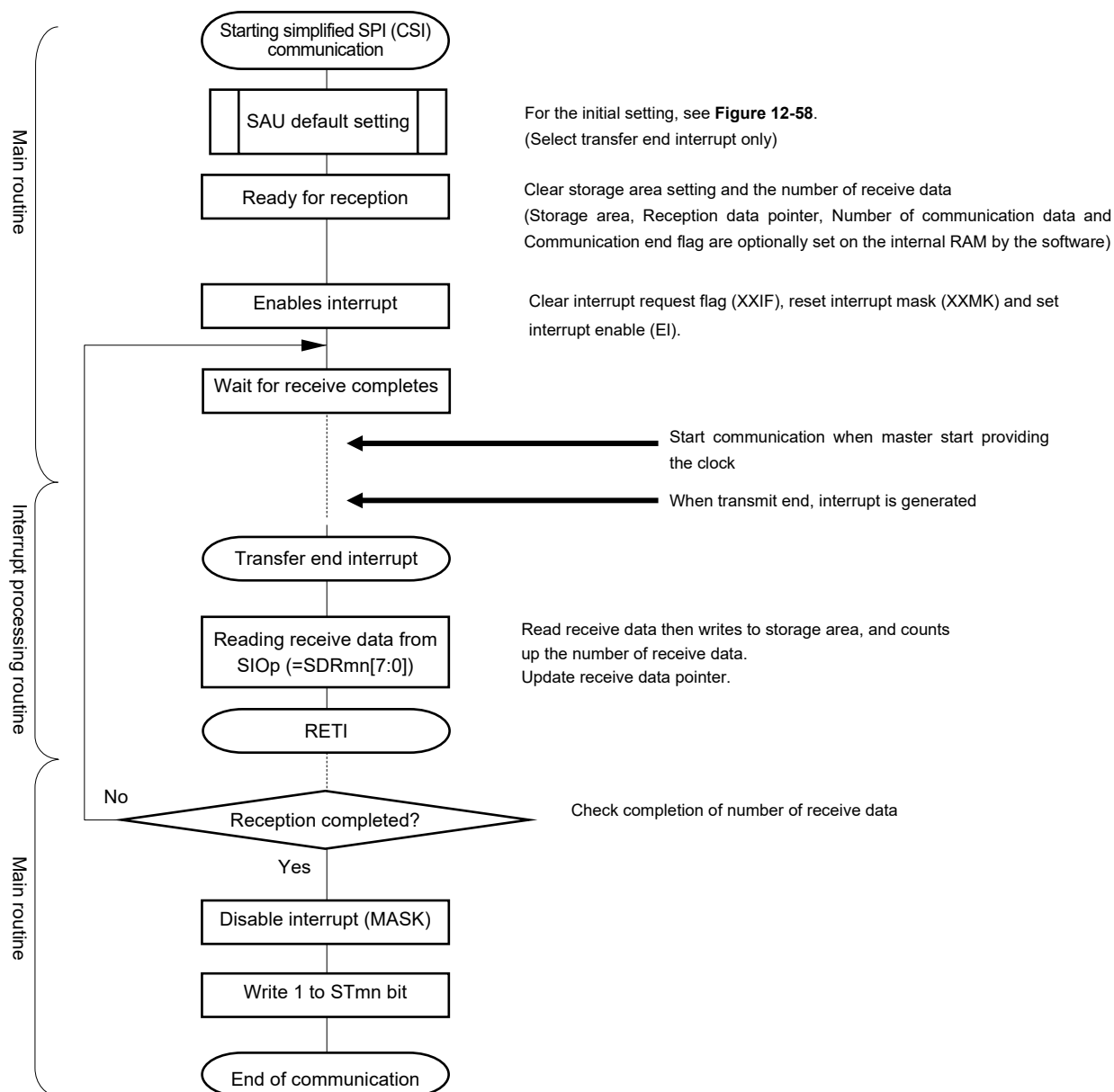
2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(3) Processing flow (in single-reception mode)

Figure 12-60. Timing Chart of Slave Reception (in Single-Reception Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21),
 mn = 00 to 03, 10, 11

Figure 12-61. Flowchart of Slave Reception (in Single-Reception Mode)

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.5.6 Slave transmission/reception

Slave transmission/reception is that the RL78 microcontroller transmits/receives data to/from another device in the state of a transfer clock being input from another device.

Simplified SPI	CSI00	CSI01	CSI10	CSI11	CSI20	CSI21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCK00, SI00, SO00	SCK01, SI01, SO01	SCK10, SI10, SO10	SCK11, SI11, SO11	SCK20, SI20, SO20	SCK21, SI21, SO21
Interrupt	INTCSI00	INTCSI01	INTCSI10	INTCSI11	INTCSI20	INTCSI21
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.					
Error detection flag	Overrun error detection flag (OVFmn) only					
Transfer data length	7 or 8 bits					
Transfer rate	Max. $f_{MCK}/6$ [MHz] ^{Notes 1, 2}					
Data phase	Selectable by the DAPmn bit of the SCRmn register - DAPmn = 0: Data I/O starts from the start of the operation of the serial clock. - DAPmn = 1: Data I/O starts half a clock before the start of the serial clock operation.					
Clock phase	Selectable by the CKPmn bit of the SCRmn register - CKPmn = 0: Non-reverse - CKPmn = 1: Reverse					
Data direction	MSB or LSB first					

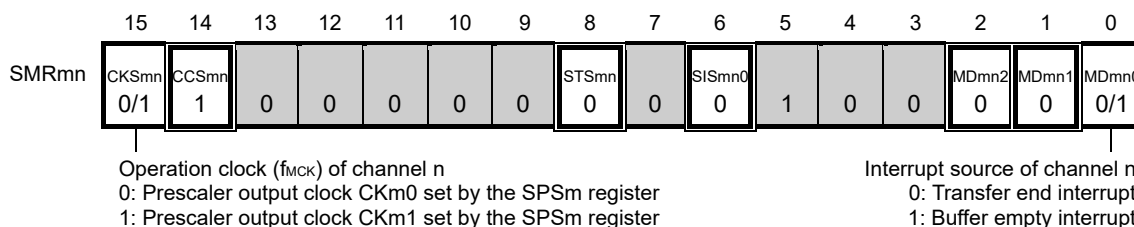
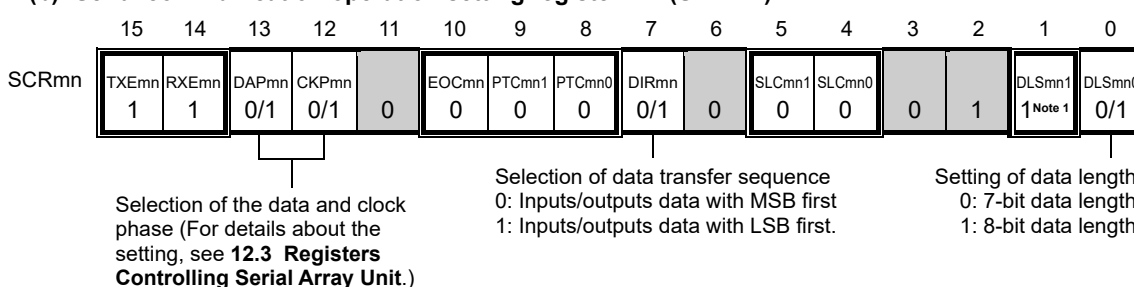
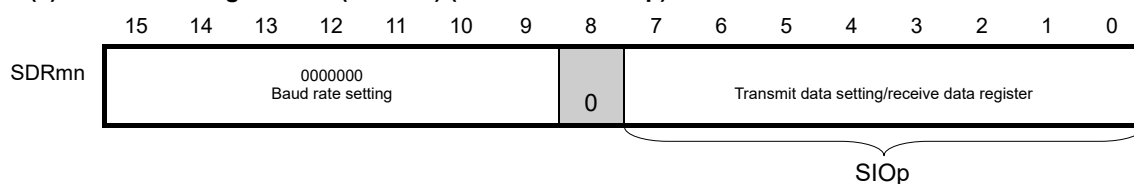
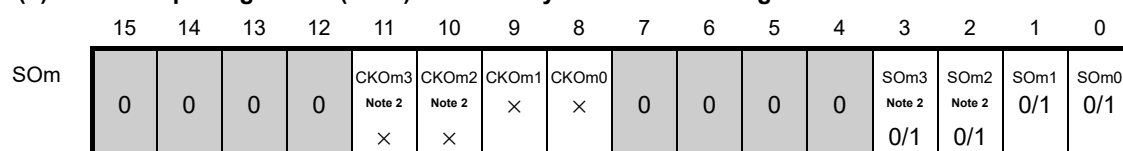
Notes 1. Because the external serial clock input to the SCK00, SCK01, SCK10, SCK11, SCK20, and SCK21 pins is sampled internally and used, the fastest transfer rate is $f_{MCK}/6$ [MHz].

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristic in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$), **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS** $T_A = -40$ to $+105^\circ\text{C}$)).

Remarks 1. f_{MCK} : Operation clock frequency of target channel

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(1) Register setting

Figure 12-62. Example of Contents of Registers for Slave Transmission/Reception of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) (1/2)**(a) Serial mode register mn (SMRmn)****(b) Serial communication operation setting register mn (SCRmn)****(c) Serial data register mn (SDRmn) (lower 8 bits: SIOp)****(d) Serial output register m (SOM) ... Sets only the bits of the target channel.****Notes 1.** Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.**2.** Unit 0 only**Caution** Be sure to set transmit data to the SIOp register before the clock from the master is started.**Remarks 1.** m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11**2.** : Setting is fixed in the simplified SPI (CSI) slave transmission/reception mode, : Setting disabled (set to the initial value)

×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)

0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-62. Example of Contents of Registers for Slave Transmission/Reception of Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21, CSI30, CSI31) (2/2)

(e) Serial output enable register m (SOEm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 0/1	SOEm2 Note 0/1	SOEm1 0/1	SOEm0 0/1

(f) Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.

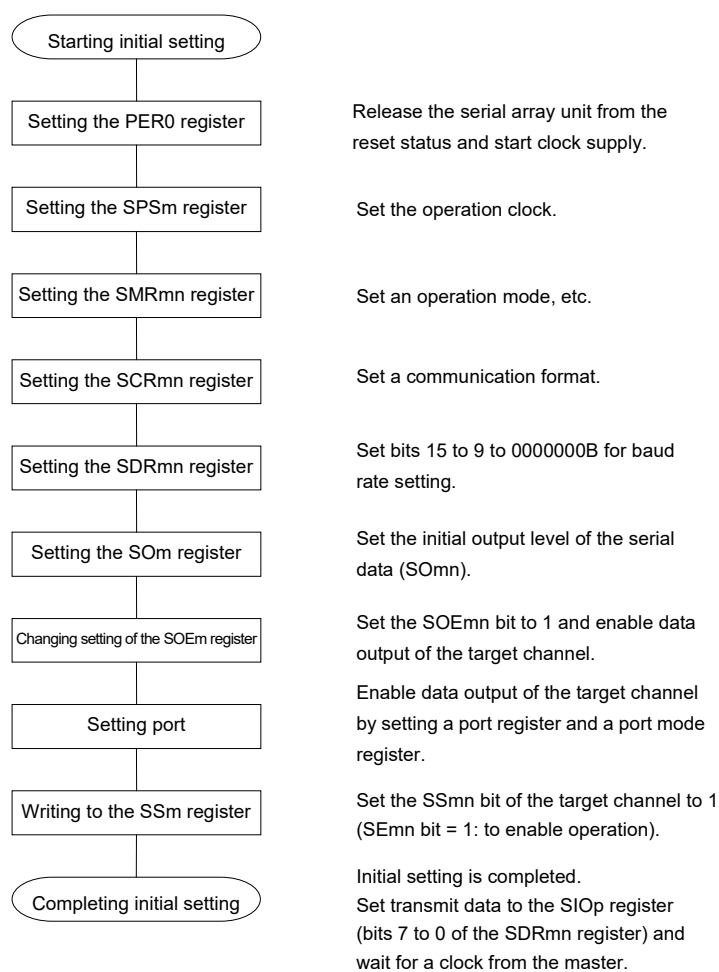
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

Note Unit 0 only

- Remarks**
- m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11
 - : Setting is fixed in the simplified SPI (CSI) slave transmission/reception mode,
 : Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

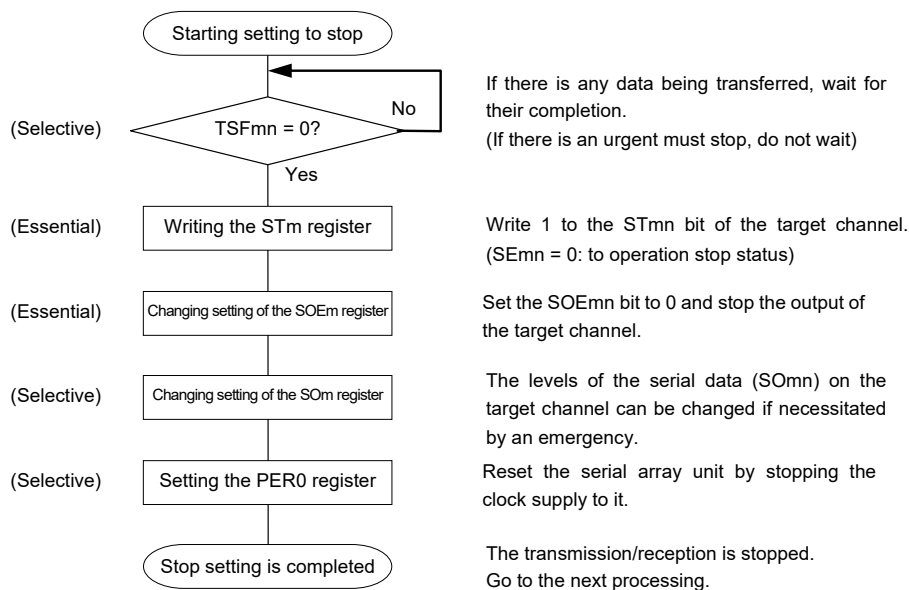
(2) Operation procedure

Figure 12-63. Initial Setting Procedure for Slave Transmission/Reception



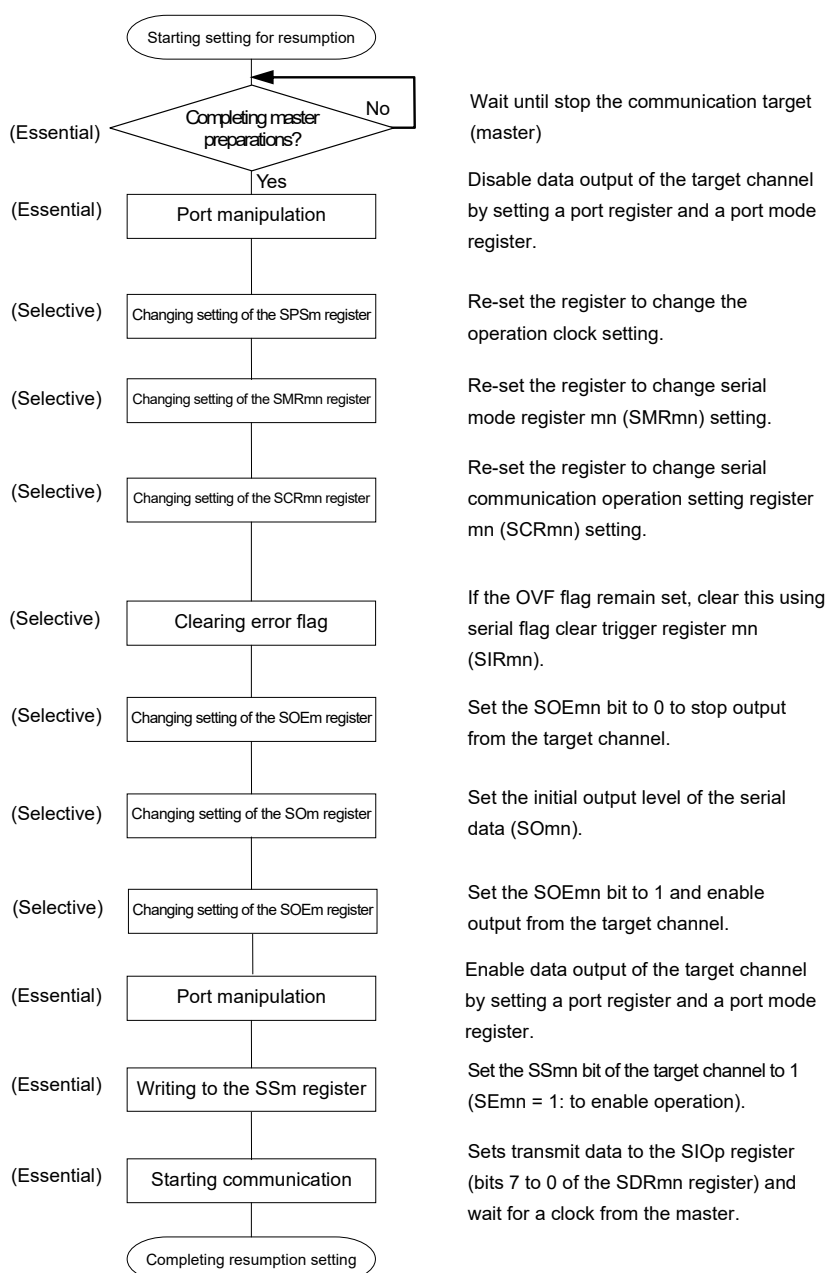
Caution Be sure to set transmit data to the SIOp register before the clock from the master is started.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-64. Procedure for Stopping Slave Transmission/Reception

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

Figure 12-65. Procedure for Resuming Slave Transmission/Reception

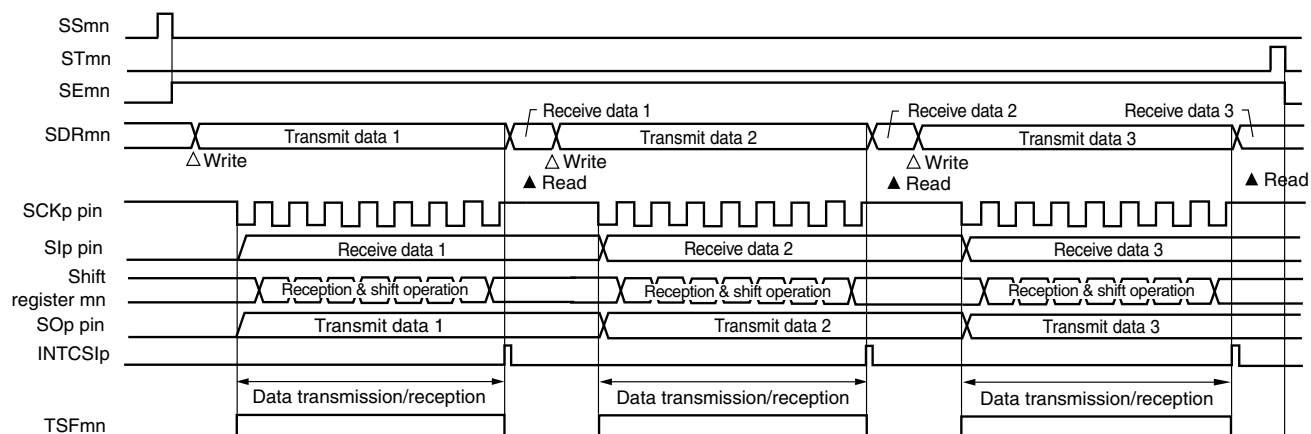


- Cautions**
1. Be sure to set transmit data to the SIOP register before the clock from the master is started.
 2. If PER0 is rewritten while stopping the master transmission and the clock supply is stopped, wait until the transmission target (master) stops or transmission finishes, and then perform initialization instead of restarting the transmission.

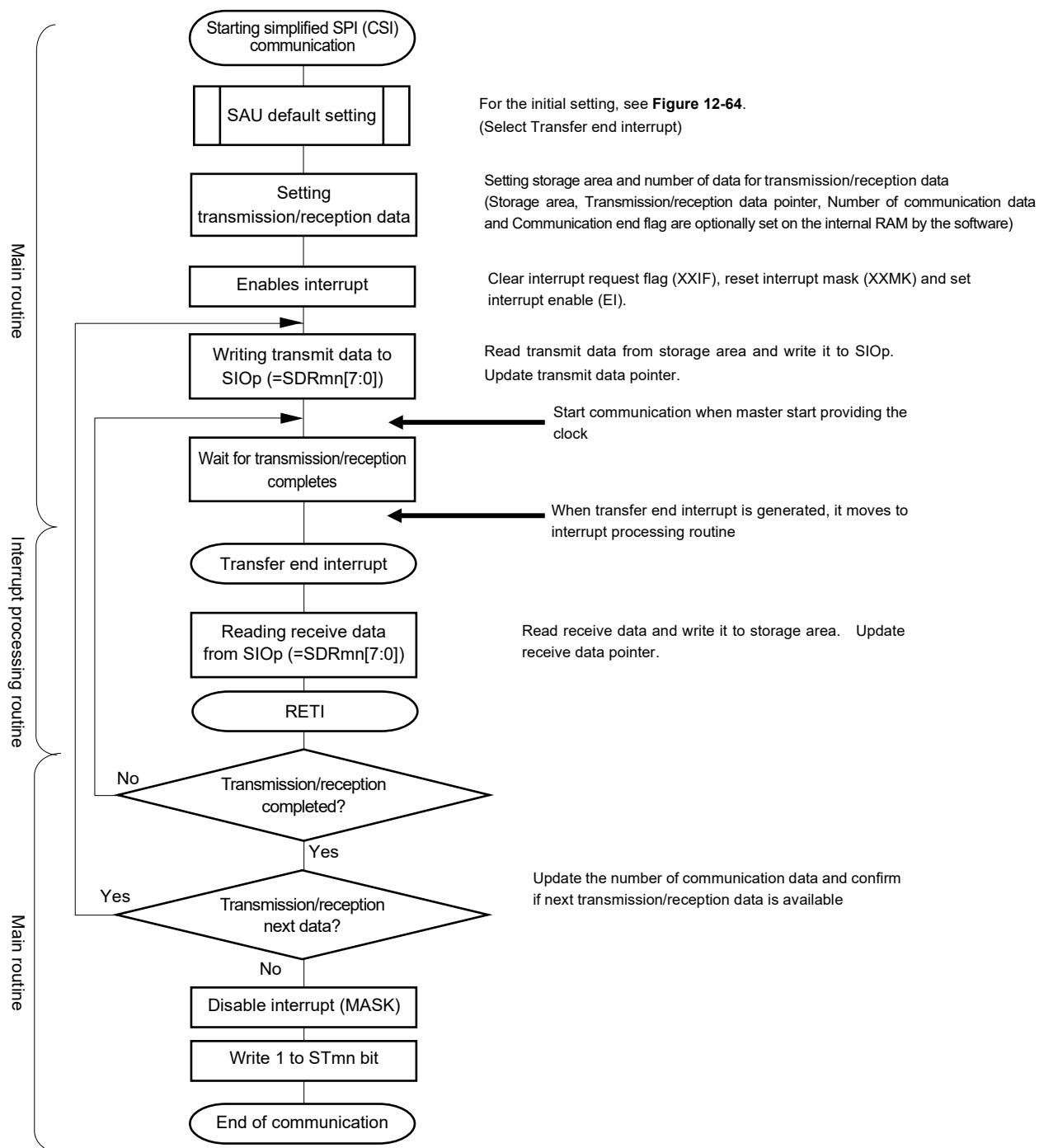
Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(3) Processing flow (in single-transmission/reception mode)

Figure 12-66. Timing Chart of Slave Transmission/Reception (in Single-Transmission/Reception Mode)
 (Type 1: DAPmn = 0, CKPmn = 0)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

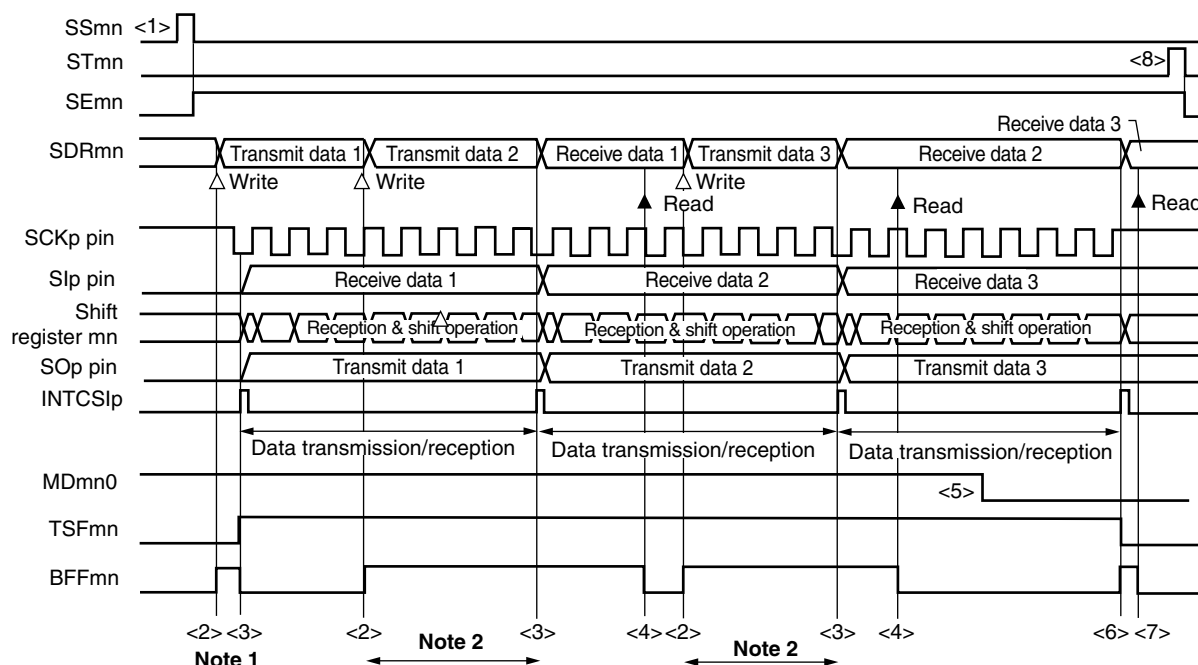
Figure 12-67. Flowchart of Slave Transmission/Reception (in Single-Transmission/Reception Mode)

Caution Be sure to set transmit data to the SIOp register before the clock from the master is started.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

(4) Processing flow (in continuous transmission/reception mode)

Figure 12-68. Timing Chart of Slave Transmission/Reception (in Continuous Transmission/Reception Mode)
(Type 1: DAPmn = 0, CKPmn = 0)



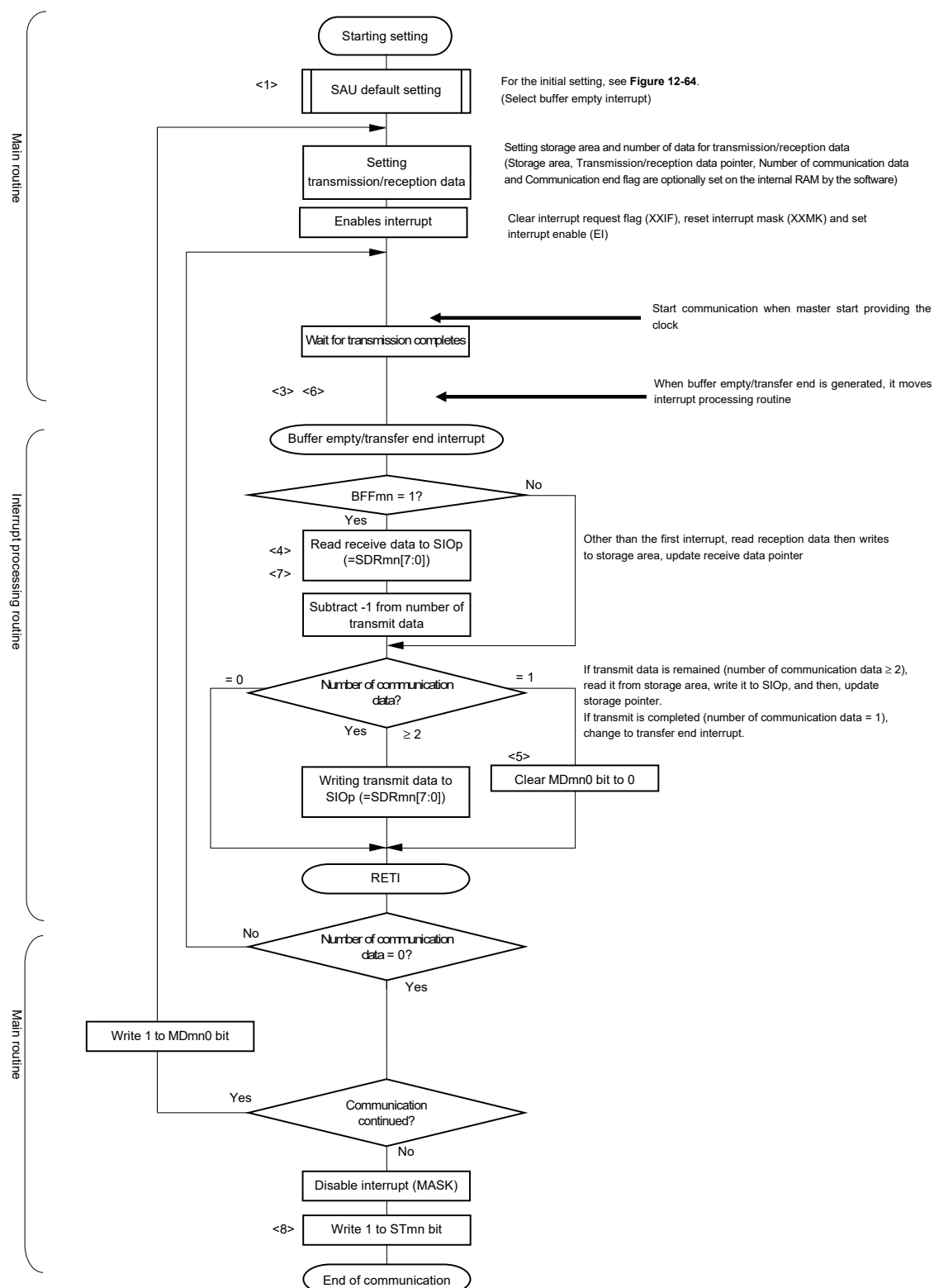
- Notes**
1. If transmit data is written to the SDRmn register while the BFFmn bit of serial status register mn (SSRmn) is 1 (valid data is stored in serial data register mn (SDRmn)), the transmit data is overwritten.
 2. The transmit data can be read by reading the SDRmn register during this period. At this time, the transfer operation is not affected.

Caution The MDmn0 bit of serial mode register mn (SMRmn) can be rewritten even during operation. However, rewrite it before transfer of the last bit is started, so that it has been rewritten before the transfer end interrupt of the last transmit data.

Remarks 1. <1> to <8> in the figure correspond to <1> to <8> in **Figure 12-69 Flowchart of Slave Transmission/Reception (in Continuous Transmission/Reception Mode)**.

- 2.** m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-69. Flowchart of Slave Transmission/Reception (in Continuous Transmission/Reception Mode)



Caution Be sure to set transmit data to the SIOp register before the clock from the master is started.

Remarks 1. <1> to <8> in the figure correspond to <1> to <8> in Figure 12-68 Timing Chart of Slave Transmission/Reception (in Continuous Transmission/Reception Mode).

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), p: CSI number (p = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.5.7 SNOOZE mode function

SNOOZE mode makes simplified SPI (CSI) operate reception by SCKp pin input detection while the STOP mode. Normally simplified SPI (CSI) stops communication in the STOP mode. But, using the SNOOZE mode makes reception simplified SPI (CSI) operate unless the CPU operation by detecting SCKp pin input. Only CSIs00 can be specified for asynchronous reception.

When using the simplified SPI (CSI) in SNOOZE mode, make the following setting before switching to the STOP mode (see **Figure 12-72 Flowchart of SNOOZE Mode Operation (Once Startup)** and **Figure 12-74 Flowchart of SNOOZE Mode Operation (Continuous Startup)**).

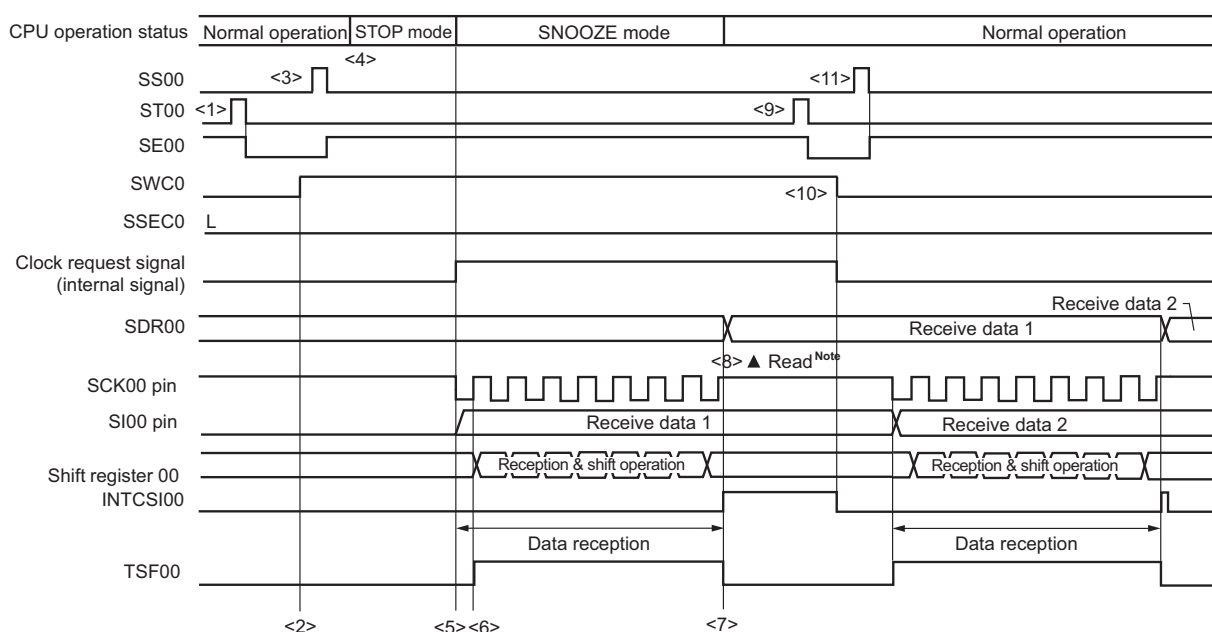
- When using the SNOOZE mode function, set the SWCm bit of serial standby control register m (SSCm) to 1 just before switching to the STOP mode. After the initial setting has been completed, set the SSm1 bit of serial channel start register m (SSm) to 1.
- The CPU shifts to the SNOOZE mode on detecting the valid edge of the SCKp signal following a transition to the STOP mode. A CSIp starts reception on detecting input of the serial clock on the SCKp pin.

Cautions 1. The SNOOZE mode can only be specified when the high-speed on-chip oscillator clock is selected for f_{CLK}.

2. The maximum transfer rate when using CSIp in the SNOOZE mode is 1 Mbps.

(1) SNOOZE mode operation (once startup)

Figure 12-70. Timing Chart of SNOOZE Mode Operation (Once Startup) (Type 1: DAPmn = 0, CKPmn = 0)



Note Only read received data while SWCm = 1 and before the next valid edge of the SCKp pin input is detected.

Cautions 1. Before switching to the SNOOZE mode or after reception operation in the SNOOZE mode finishes, set the STm0 bit to 1 (clear the SEm0 bit, and stop the operation).

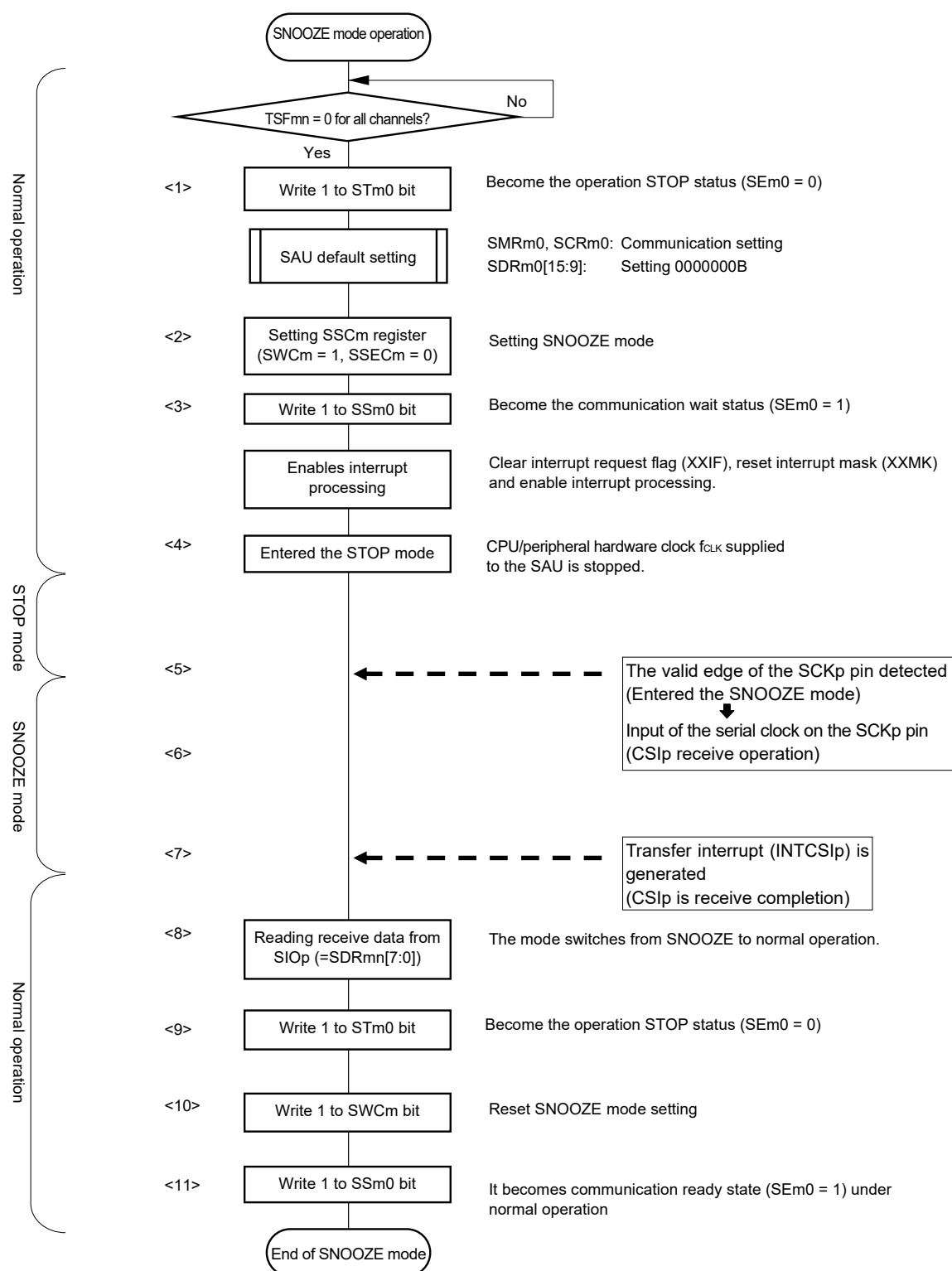
And after completion the receive operation, also clearing SWCm bit to 0 (SNOOZE mode release).

2. When SWCm = 1, BFFm1, OVFm1 flags are not operation.

Remarks 1. <1> to <11> in the figure correspond to <1> to <11> in **Figure 12-71 Flowchart of SNOOZE Mode Operation (Once Startup).**

2. m = 0; p = 00

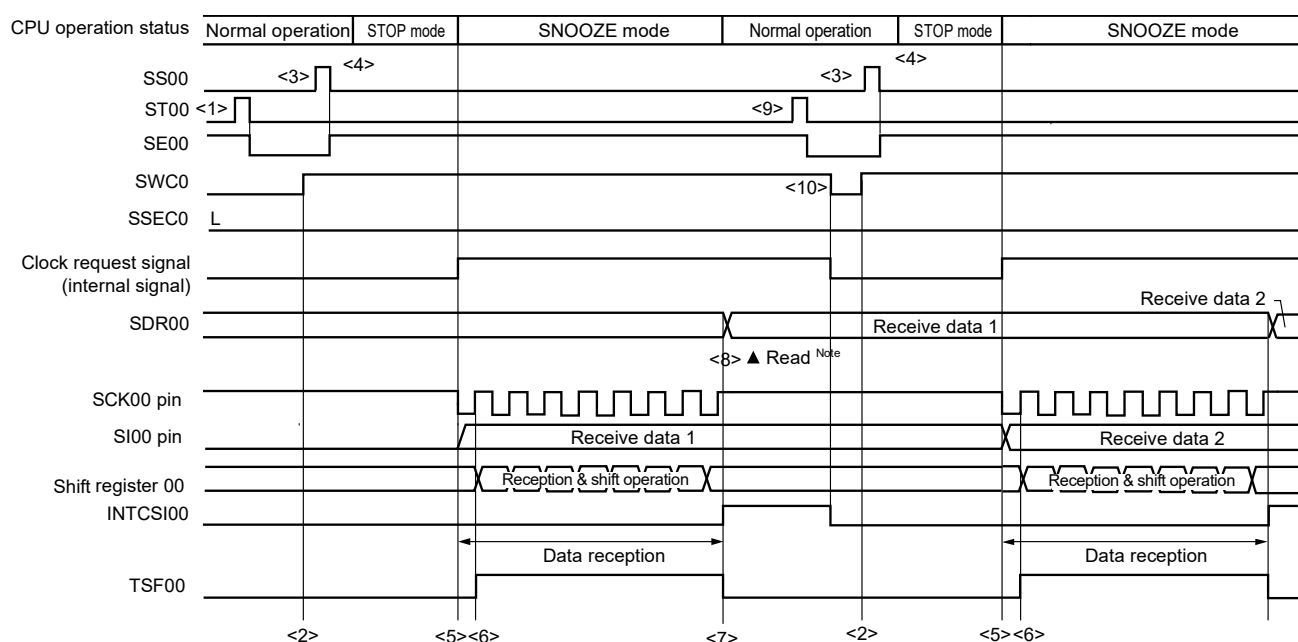
Figure 12-71. Flowchart of SNOOZE Mode Operation (Once Startup)



Remarks 1. <1> to <11> in the figure correspond to <1> to <11> in **Figure 12-70 Timing Chart of SNOOZE Mode Operation (Once Startup)**.

2. m = 0; p = 00

(2) SNOOZE mode operation (continuous startup)

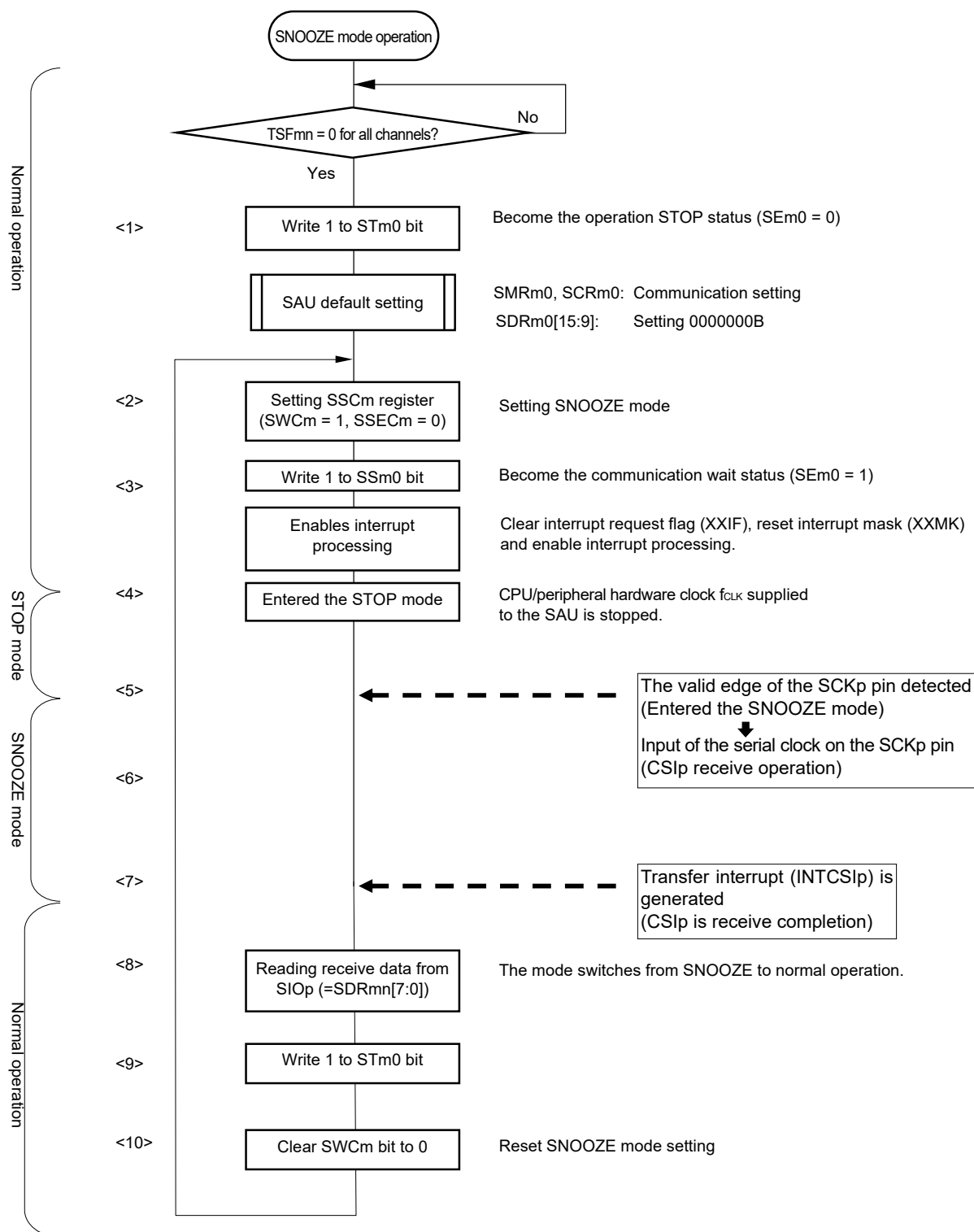
Figure 12-72. Timing Chart of SNOOZE Mode Operation (Continuous Startup) (Type 1: DAPmn = 0, CKPmn = 0)

Note Only read received data while SWCm = 1 and before the next valid edge of the SCKp pin input is detected.

- Cautions**
1. Before switching to the SNOOZE mode or after reception operation in the SNOOZE mode finishes, set the STm0 bit to 1 (clear the SEm0 bit, and stop the operation).
And after completion the receive operation, also clearing SWCm bit to 0 (SNOOZE release).
 2. When SWCm = 1, BFFm1, OVFM1 flags are not operation.

- Remarks**
1. <1> to <10> in the figure correspond to <1> to <10> in Figure 12-73 Flowchart of SNOOZE Mode Operation (Continuous Startup).
 2. m = 0; p = 00

Figure 12-73. Flowchart of SNOOZE Mode Operation (Continuous Startup)



Remarks 1. <1> to <10> in the figure correspond to <1> to <10> in **Figure 12-72 Timing Chart of SNOOZE Mode Operation (Continuous Startup)**.

2. m = 0; p = 00

12.5.8 Calculating transfer clock frequency

The transfer clock frequency for simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) communication can be calculated by the following expressions.

(1) Master

$$(\text{Transfer clock frequency}) = \{ \text{Operation clock (f}_{\text{MCK}}) \text{ frequency of target channel} \} \div (\text{SDRmn}[15:9] + 1) \div 2 \text{ [Hz]}$$

(2) Slave

$$(\text{Transfer clock frequency}) = \{ \text{Frequency of serial clock (SCK) supplied by master} \}^{\text{Note}} \text{ [Hz]}$$

Note The permissible maximum transfer clock frequency is $f_{\text{MCK}}/6$.

Remark The value of SDRmn[15:9] is the value of bits 15 to 9 of serial data register mn (SDRmn) (0000000B to 1111111B) and therefore is 0 to 127.

The operation clock (f_{MCK}) is determined by serial clock select register m (SPSm) and bit 15 (CKSmn) of serial mode register mn (SMRmn).

Table 12-2. Selection of Operation Clock for Simplified SPI

SMR _{mn} Register	SPS _m Register								Operation Clock (f _{CLK}) ^{Note}	
CKS _{mn}	PRS m13	PRS m12	PRS m11	PRS m10	PRS m03	PRS m02	PRS m01	PRS m00		f _{CLK} = 32 MHz
0	X	X	X	X	0	0	0	0	f _{CLK}	32 MHz
	X	X	X	X	0	0	0	1	f _{CLK} /2	16 MHz
	X	X	X	X	0	0	1	0	f _{CLK} /2 ²	8 MHz
	X	X	X	X	0	0	1	1	f _{CLK} /2 ³	4 MHz
	X	X	X	X	0	1	0	0	f _{CLK} /2 ⁴	2 MHz
	X	X	X	X	0	1	0	1	f _{CLK} /2 ⁵	1 MHz
	X	X	X	X	0	1	1	0	f _{CLK} /2 ⁶	500 kHz
	X	X	X	X	0	1	1	1	f _{CLK} /2 ⁷	250 kHz
	X	X	X	X	1	0	0	0	f _{CLK} /2 ⁸	125 kHz
	X	X	X	X	1	0	0	1	f _{CLK} /2 ⁹	62.5 kHz
	X	X	X	X	1	0	1	0	f _{CLK} /2 ¹⁰	31.25 kHz
	X	X	X	X	1	0	1	1	f _{CLK} /2 ¹¹	15.63 kHz
	X	X	X	X	1	1	0	0	f _{CLK} /2 ¹²	7.81 kHz
	X	X	X	X	1	1	0	1	f _{CLK} /2 ¹³	3.91 kHz
	X	X	X	X	1	1	1	0	f _{CLK} /2 ¹⁴	1.95 kHz
	X	X	X	X	1	1	1	1	f _{CLK} /2 ¹⁵	977 Hz
1	0	0	0	0	X	X	X	X	f _{CLK}	32 MHz
	0	0	0	1	X	X	X	X	f _{CLK} /2	16 MHz
	0	0	1	0	X	X	X	X	f _{CLK} /2 ²	8 MHz
	0	0	1	1	X	X	X	X	f _{CLK} /2 ³	4 MHz
	0	1	0	0	X	X	X	X	f _{CLK} /2 ⁴	2 MHz
	0	1	0	1	X	X	X	X	f _{CLK} /2 ⁵	1 MHz
	0	1	1	0	X	X	X	X	f _{CLK} /2 ⁶	500 kHz
	0	1	1	1	X	X	X	X	f _{CLK} /2 ⁷	250 kHz
	1	0	0	0	X	X	X	X	f _{CLK} /2 ⁸	125 kHz
	1	0	0	1	X	X	X	X	f _{CLK} /2 ⁹	62.5 kHz
	1	0	1	0	X	X	X	X	f _{CLK} /2 ¹⁰	31.25 kHz
	1	0	1	1	X	X	X	X	f _{CLK} /2 ¹¹	15.63 kHz
	1	1	0	0	X	X	X	X	f _{CLK} /2 ¹²	7.81 kHz
	1	1	0	1	X	X	X	X	f _{CLK} /2 ¹³	3.91 kHz
	1	1	1	0	X	X	X	X	f _{CLK} /2 ¹⁴	1.95 kHz
	1	1	1	1	X	X	X	X	f _{CLK} /2 ¹⁵	977 Hz
Other than above									Setting prohibited	

Note When changing the clock selected for f_{CLK} (by changing the system clock control register (CKC) value), do so after having stopped (serial channel stop register m (ST_m) = 000FH) the operation of the serial array unit (SAU).

Remarks 1. X: Don't care

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

12.5.9 Procedure for processing errors that occurred during Simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) communication

The procedure for processing errors that occurred during simplified SPI (CSI00, CSI01, CSI10, CSI11, CSI20, CSI21) communication is described in Figure 12-74.

Figure 12-74. Processing Procedure in Case of Overrun Error

Software Manipulation	Hardware Status	Remark
Reads serial data register mn (SDRmn).	→ The BFFmn bit of the SSRmn register is set to 0 and channel n is enabled to receive data.	This is to prevent an overrun error if the next reception is completed during error processing.
Reads serial status register mn (SSRmn).		Error type is identified and the read value is used to clear error flag.
Writes 1 to serial flag clear trigger register mn (SIRmn).	→ Error flag is cleared.	Error can be cleared only during reading, by writing the value read from the SSRmn register to the SIRmn register without modification.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

12.6 Operation of UART (UART0 to UART2) Communication

This is a start-stop synchronization function using two lines: serial data transmission (TxD) and serial data reception (RxD) lines. By using these two communication lines, each data frame, which consist of a start bit, data, parity bit, and stop bit, is transferred asynchronously (using the internal baud rate) between the microcontroller and the other communication party. Full-duplex UART communication can be performed by using a channel dedicated to transmission (even-numbered channel) and a channel dedicated to reception (odd-numbered channel). The LIN-bus can be implemented by using UART2, timer array unit 0 (channel 0) with an external interrupt (INTP0).

[Data transmission/reception]

- Data length of 7, 8, or 9 bits^{Note}
- Select the MSB/LSB first
- Level setting of transmit/receive data (selecting whether to reverse the level)
- Parity bit appending and parity check functions
- Stop bit appending, stop bit check function

[Interrupt function]

- Transfer end interrupt/buffer empty interrupt
- Error interrupt in case of framing error, parity error, or overrun error

[Error detection flag]

- Framing error, parity error, or overrun error

In addition, UART0 reception (channel 1 of unit 0) supports the SNOOZE mode. When RxD0 pin input is detected while in the STOP mode, the SNOOZE mode makes data reception that does not require the CPU possible. Only following UART0 can be specified for the reception baud rate adjustment function.

The LIN-bus is accepted in UART2 (channels 0 and 1 of unit 1) (32, 48, and 64-pin products only).

[LIN-bus functions]

- Wakeup signal detection
- Break field (BF) detection
- Sync field measurement, baud rate calculation

Using the external interrupt (INTP0) and timer array unit 0 (channel 7)

Note Only following UART0 can be specified for the 9-bit data length.

UART0 uses channels 0 and 1 of SAU0.

UART1 uses channels 2 and 3 of SAU0.

UART2 uses channels 0 and 1 of SAU1.

- 25-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11

- 32-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	–		–

- 48-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

- 64-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	CSI10	UART1	IIC10
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

Select any function for each channel. Only the selected function is possible. If UART0 is selected for channels 0 and 1 of unit 0, for example, these channels cannot be used for CSI00 and CSI01. At this time, however, channel 2, 3, or other channels of the same unit can be used for a function other than UART0, such as CSI10, UART1, and IIC10.

Caution When using a serial array unit for UART, both the transmitter side (even-numbered channel) and the receiver side (odd-numbered channel) can only be used for UART.

UART performs the following four types of communication operations.

- UART transmission (See 12.6.1.)
- UART reception (See 12.6.2.)
- LIN transmission (UART2 only) (See 12.7.1.)
- LIN reception (UART2 only) (See 12.7.2.)

12.6.1 UART transmission

UART transmission is an operation to transmit data from the RL78 microcontroller to another device asynchronously (start-stop synchronization).

Of two channels used for UART, the even channel is used for UART transmission.

UART	UART0	UART1	UART2
Target channel	Channel 0 of SAU0	Channel 2 of SAU0	Channel 0 of SAU1
Pins used	TxD0	TxD1	TxD2
Interrupt	INTST0	INTST1	INTST2
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.		
Error detection flag	None		
Transfer data length	7, 8, or 9 bits ^{Note 1}		
Transfer rate ^{Note 2}	Max. $f_{MCK}/6$ [bps] (SDRmn[15:9] = 2 or more), Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [bps]		
Data phase	Non-reverse output (default: high level) Reverse output (default: low level)		
Parity bit	The following selectable • No parity bit • Appending 0 parity • Appending even parity • Appending odd parity		
Stop bit	The following selectable • Appending 1 bit • Appending 2 bits		
Data direction	MSB or LSB first		

Notes 1. Only following UART0 can be specified for the 9-bit data length.

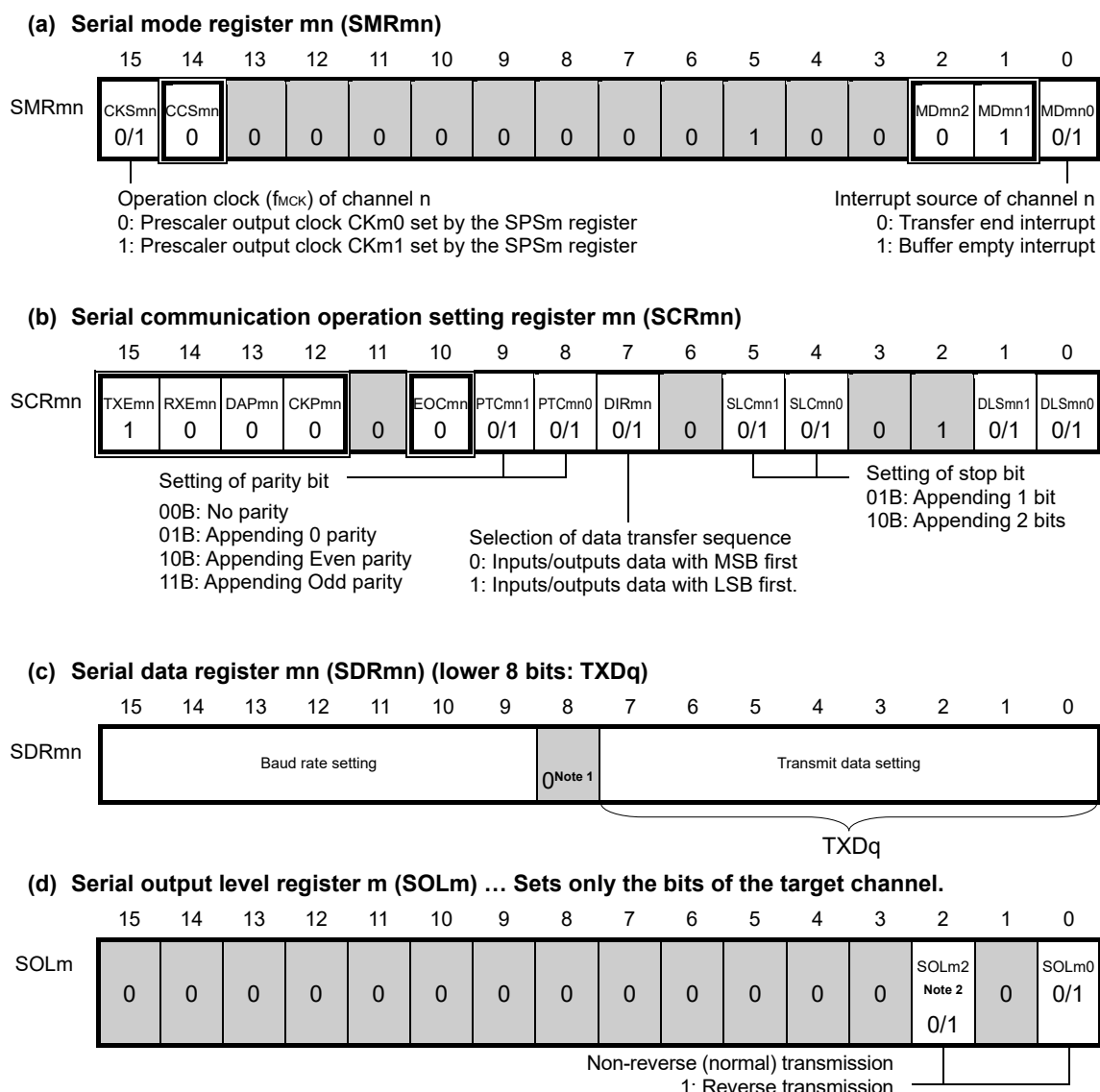
- 2.** Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$), **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS** $T_A = -40$ to $+105^\circ\text{C}$)).

Remarks 1. f_{MCK} : Operation clock frequency of target channel

f_{CLK} : System clock frequency

- 2.** m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 02, 10

(1) Register setting

Figure 12-75. Example of Contents of Registers for UART Transmission of UART (UART0 to UART2) (1/2)

Notes 1. SCR00 only. This bit is fixed to 1 for the other registers.

2. When UART0 performs 9-bit communication (by setting the DLS001 and DLS000 bits of the SCR00 register to 1), bits 0 to 8 of the SDR00 register are used as the transmission data specification area. Only following UART0 can be specified for the 9-bit data length.

3. Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2), mn = 00, 02, 10

2. : Setting is fixed in the UART transmission mode, : Setting disabled (set to the initial value)

×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)

0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-75. Example of Contents of Registers for UART Transmission of UART (UART0 to UART2) (2/2)

(e) Serial output register m (SOM) ... Sets only the bits of the target channel.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOM	0	0	0	0	CKOm3 Note 1	CKOm2 Note 1	CKOm1	CKOm0	0	0	0	0	Som3 Note 1	SOm2 Notes 1, 2	SOm1	SOm0 Note 2
					×	×	×	×					×	0/1	×	0/1

0: Serial data output value is "0"
1: Serial data output value is "1"

(f) Serial output enable register m (SOEm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 1	SOEm2 Note 1	SOEm1	SOEm0
													×	0/1	×	0/1

(g) Serial channel start register m (SSm) ... Sets only the bits of the target channel to 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 1	SSm2 Note 1	SSm1	SSm0
													×	0/1	×	0/1

Notes 1. Before transmission is started, be sure to set to 1 when the SOLmn bit of the target channel is set to 0, and set to 0 when the SOLmn bit of the target channel is set to 1. The value varies depending on the communication data during communication operation.

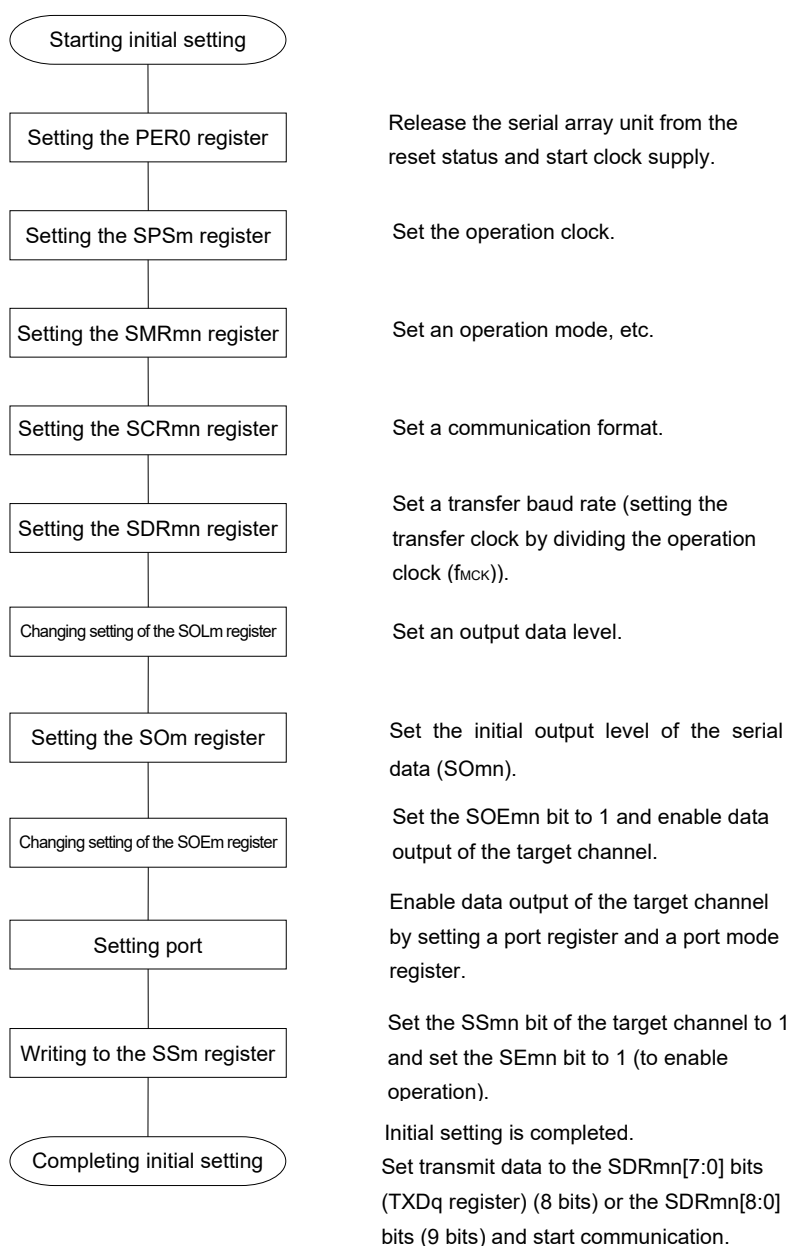
2. Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 02, 10

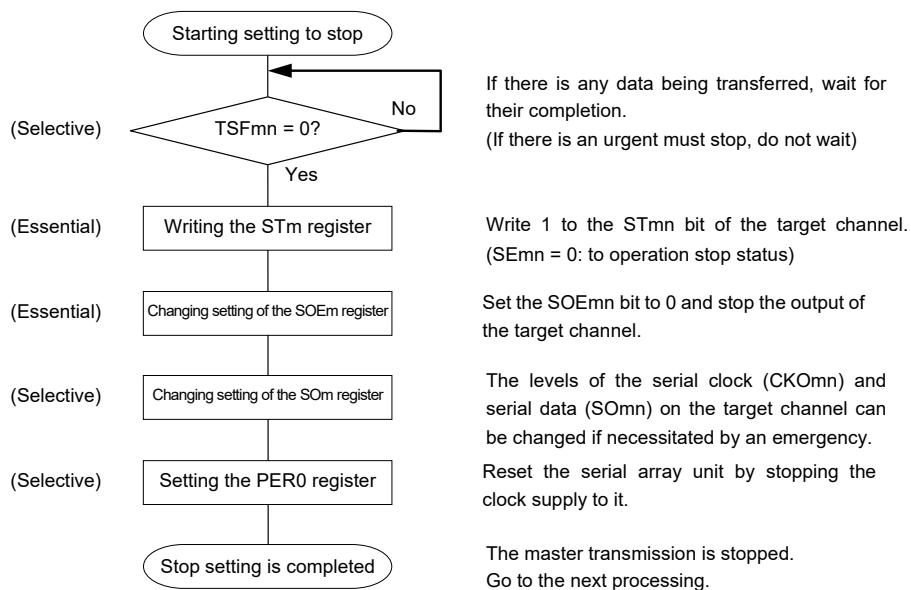
2. ☐: Setting is fixed in the UART transmission mode, ☒: Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

(2) Operation procedure

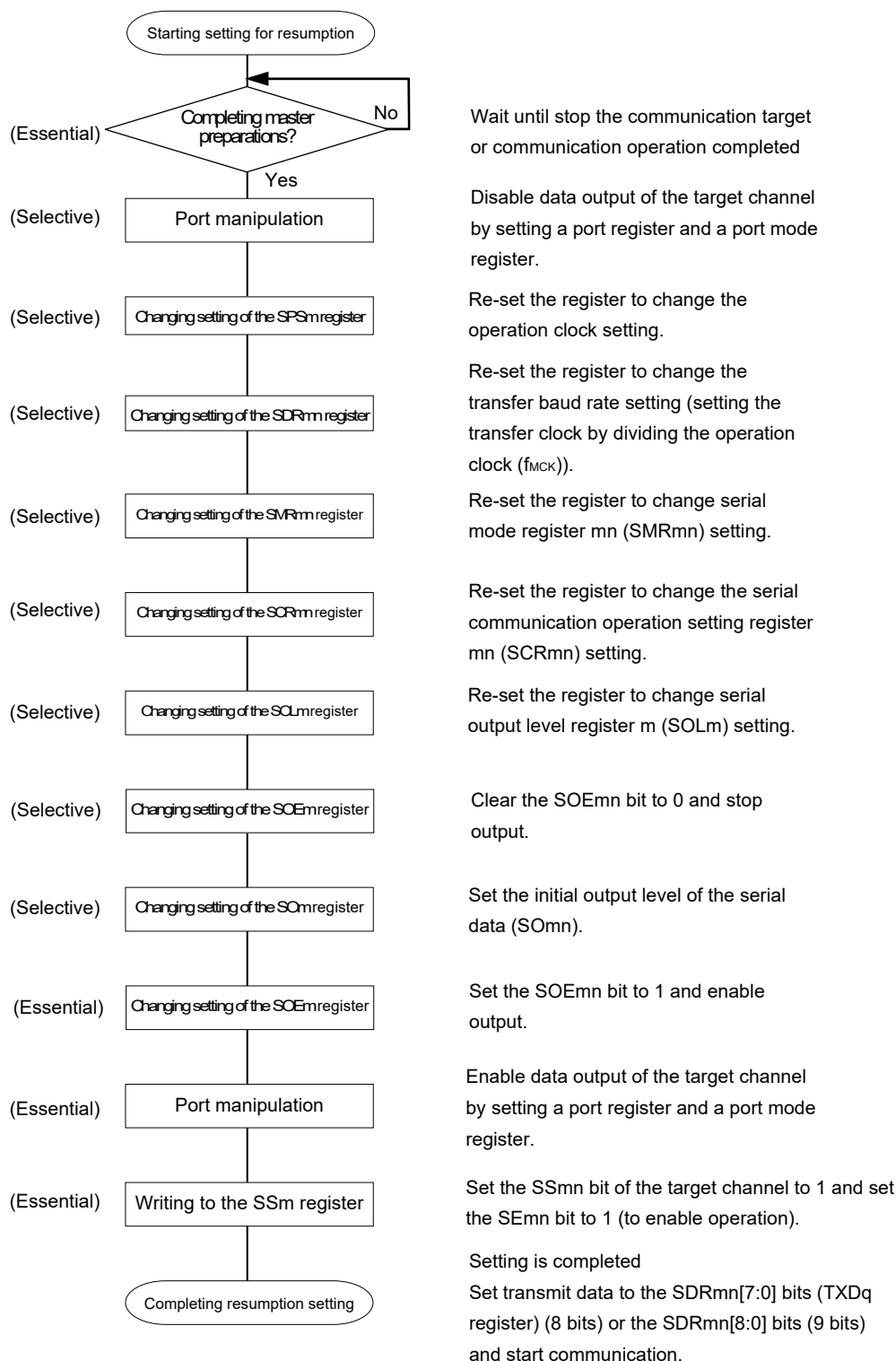
Figure 12-76. Initial Setting Procedure for UART Transmission



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2)
mn = 00, 02, 10

Figure 12-77. Procedure for Stopping UART Transmission

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 02, 10

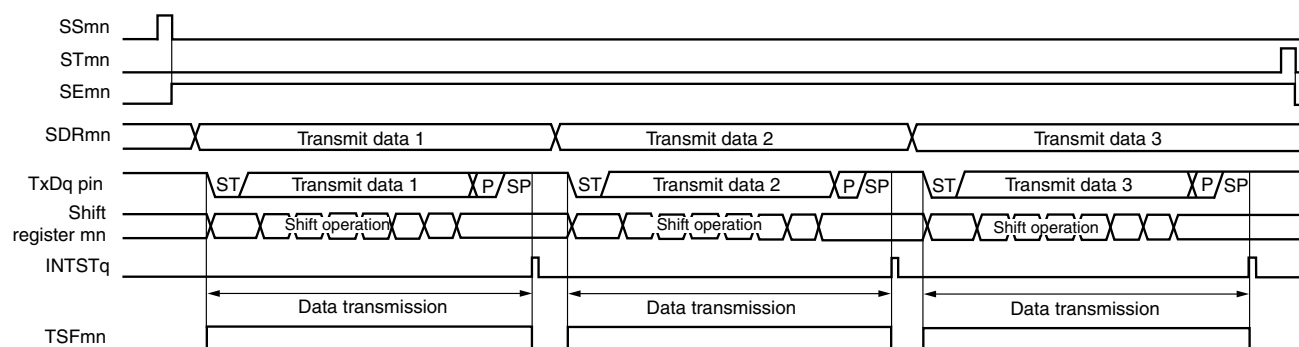
Figure 12-78. Procedure for Resuming UART Transmission

Remarks 1. If PER0 is rewritten while stopping the master transmission and the clock supply is stopped, wait until the transmission target stops or transmission finishes, and then perform initialization instead of restarting the transmission.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2), mn = 00, 02, 10

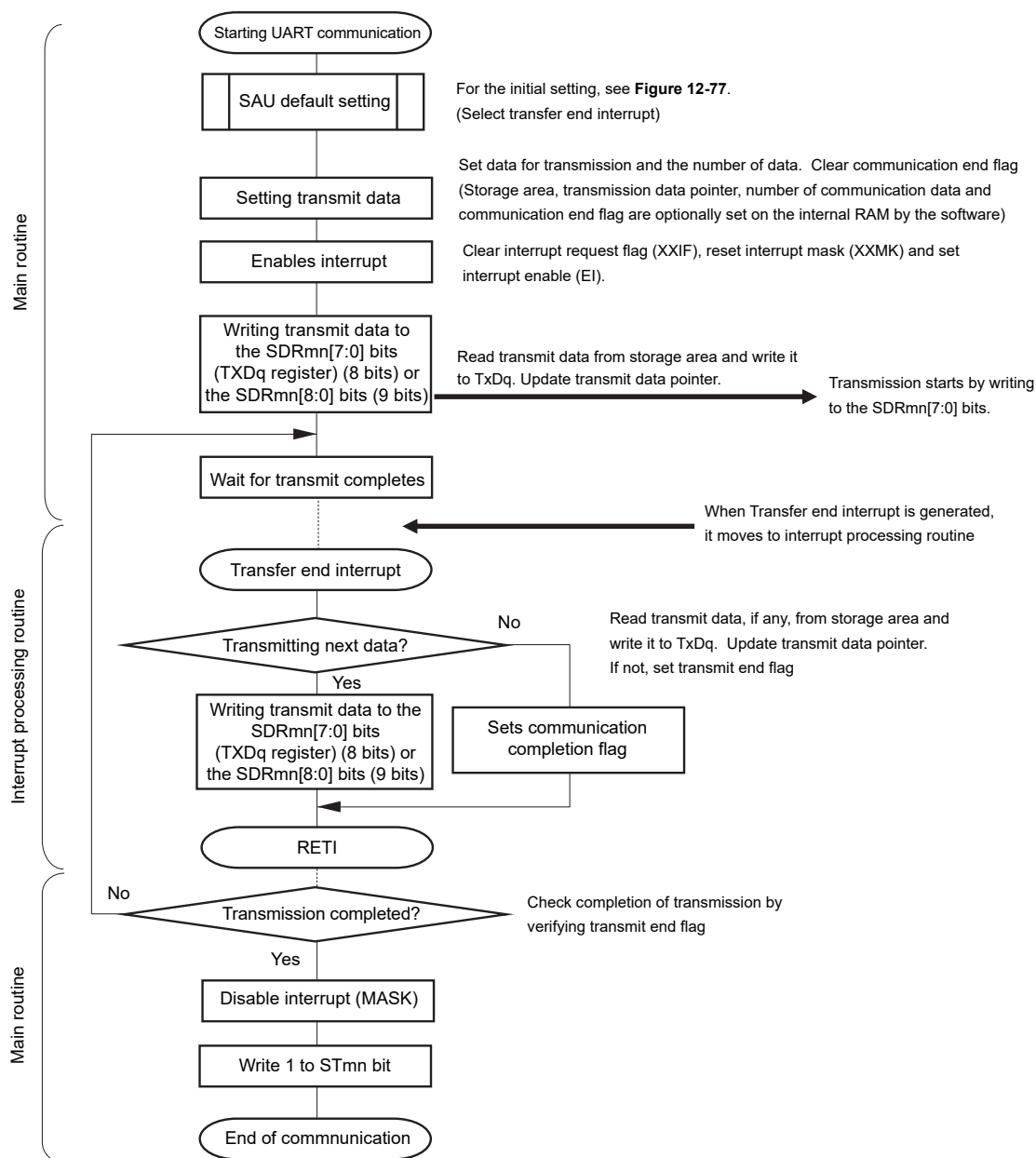
(3) Processing flow (in single-transmission mode)

Figure 12-79. Timing Chart of UART Transmission (in Single-Transmission Mode)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2)
mn = 00, 02, 10

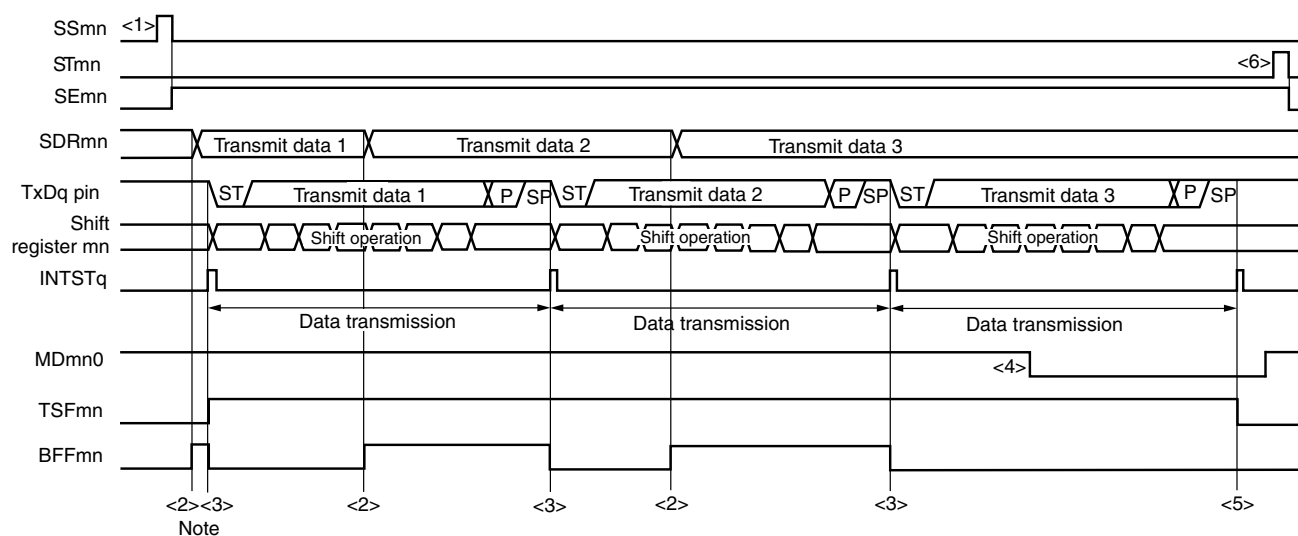
Figure 12-80. Flowchart of UART Transmission (in Single-Transmission Mode)



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2)
mn = 00, 02, 10

(4) Processing flow (in continuous transmission mode)

Figure 12-81. Timing Chart of UART Transmission (in Continuous Transmission Mode)

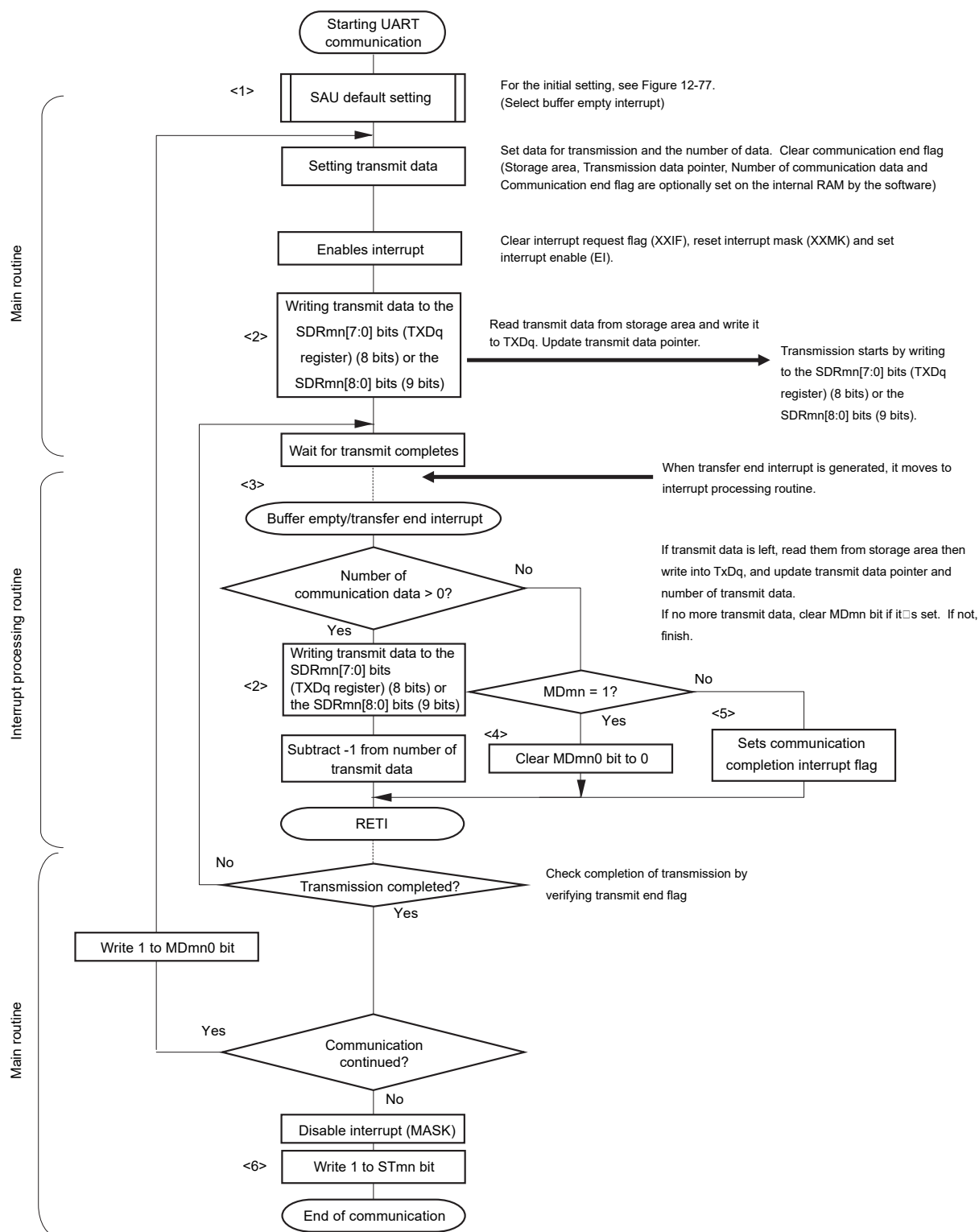


Note If transmit data is written to the SDRmn register while the BFFmn bit of serial status register mn (SSRmn) is 1 (valid data is stored in serial data register mn (SDRmn)), the transmit data is overwritten.

Caution The MDmn0 bit of serial mode register mn (SSRmn) can be rewritten even during operation. However, rewrite it before transfer of the last bit is started, so that it will be rewritten before the transfer end interrupt of the last transmit data.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2)
mn = 00, 02, 10

Figure 12-82. Flowchart of UART Transmission (in Continuous Transmission Mode)



Remarks 1. <1> to <6> in the figure correspond to <1> to <6> in **Figure 12-81 Timing Chart of UART Transmission (in Continuous Transmission Mode)**.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), q: UART number (q = 0 to 2)
mn = 00, 02, 10

12.6.2 UART reception

UART reception is an operation wherein the RL78 microcontroller asynchronously receives data from another device (start-stop synchronization).

For UART reception, the odd-number channel of the two channels used for UART is used. The SMR register of both the odd- and even-numbered channels must be set.

UART	UART0	UART1	UART2
Target channel	Channel 1 of SAU0	Channel 3 of SAU0	Channel 1 of SAU1
Pins used	RxD0	RxD1	RxD2
Interrupt	INTSR0	INTSR1	INTSR2
	Transfer end interrupt only (Setting the buffer empty interrupt is prohibited.)		
Error interrupt	INTSRE0	INTSRE1	INTSRE2
Error detection flag	- Framing error detection flag (FEFmn) - Parity error detection flag (PEFmn) - Overrun error detection flag (OVFmn)		
Transfer data length	7, 8 or 9 bits ^{Note 1}		
Transfer rate ^{Note 2}	Max. $f_{MCK}/6$ [bps] (SDRmn[15:9] = 2 or more), Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [bps]		
Data phase	Non-reverse output (default: high level) Reverse output (default: low level)		
Parity bit	The following selectable - No parity bit (no parity check) - No parity judgment (0 parity) - Appending even parity - Appending odd parity		
Stop bit	1 bit addition		
Data direction	MSB or LSB first		

Notes 1. Only following UART0 can be specified for the 8-bit data length.

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$), **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS** ($T_A = -40$ to $+105^\circ\text{C}$)).

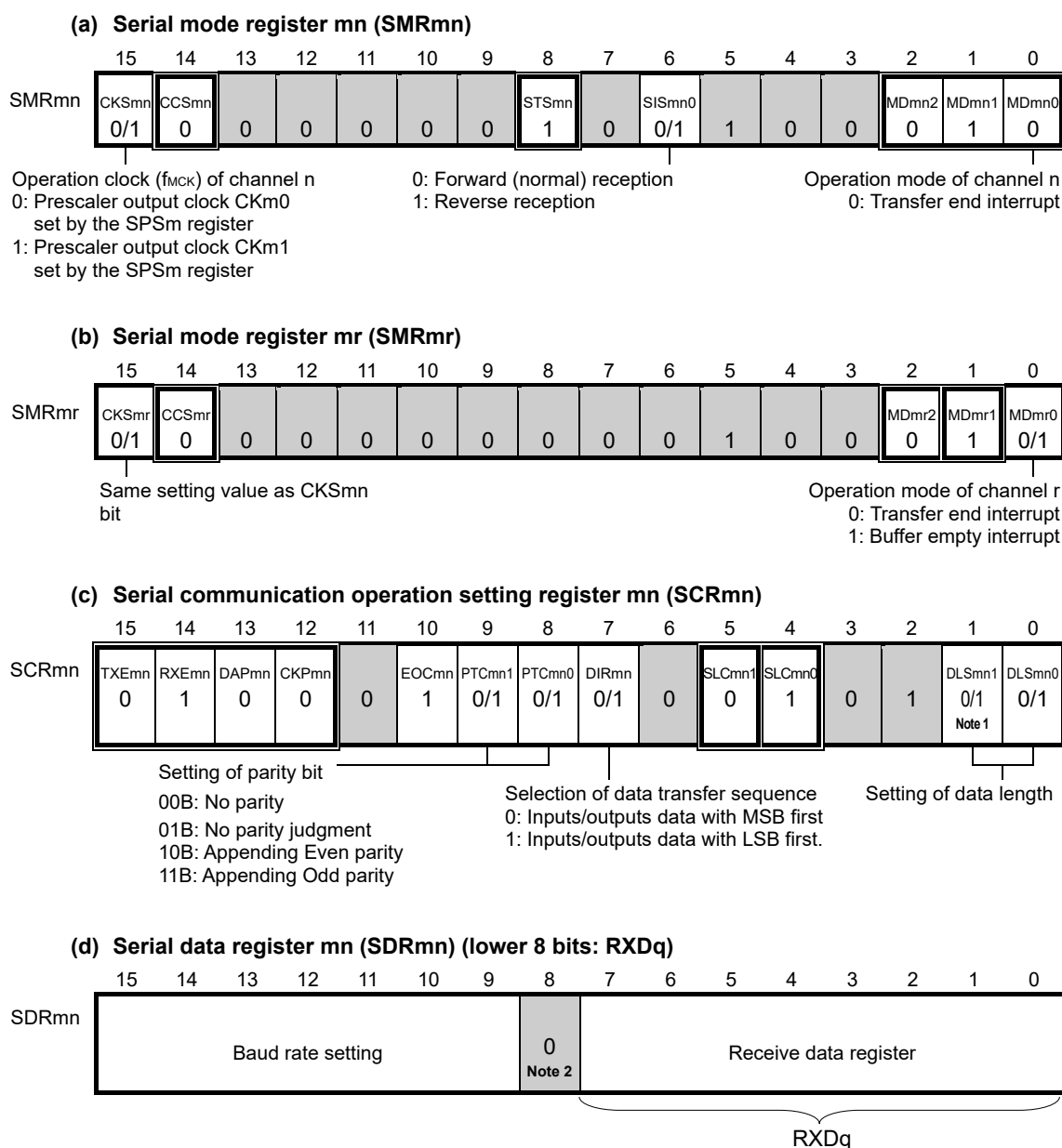
Remarks 1. f_{MCK} : Operation clock frequency of target channel

f_{CLK} : System clock frequency

2. m: Unit number (m = 0, 1), n: Channel number (n = 1, 3), mn = 01, 03, 11

(1) Register setting

Figure 12-83. Example of Contents of Registers for UART Reception of UART (UART0 to UART2) (1/2)



Notes 1. SCR01 only. This bit is fixed to 1 for the other registers.

2. When UART performs 9-bit communication, bits 0 to 8 of the SDRm1 register are used as the transmission data specification area. Only following UART0 can be specified for the 8-bit data length.

Caution For the UART reception, be sure to set the SMRmr register of channel r to UART transmission mode that is to be paired with channel n.

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 1, 3), mn = 01, 03, 11

r: Channel number (r = n - 1), q: UART number (q = 0 to 2)

2. : Setting is fixed in the UART reception mode, : Setting disabled (set to the initial value)

0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-83. Example of Contents of Registers for UART Reception of UART
(UART0 to UART2) (2/2)

(e) Serial output register m (SOM) ... The register that not used in this mode.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOM	0	0	0	0	CKOm3 Note ×	CKOm2 Note ×	CKOm1 ×	CKOm0 ×	0	0	0	0	SOM3 Note ×	SOM2 Note ×	SOM1 ×	SOM0 ×

(f) Serial output enable register m (SOEm) ...The register that not used in this mode.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note ×	SOEm2 Note ×	SOEm1 ×	SOEm0 ×

(g) Serial channel start register m (SSm) ... Sets only the bits of the target channel is 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note ×	SSm1 0/1	SSm0 ×

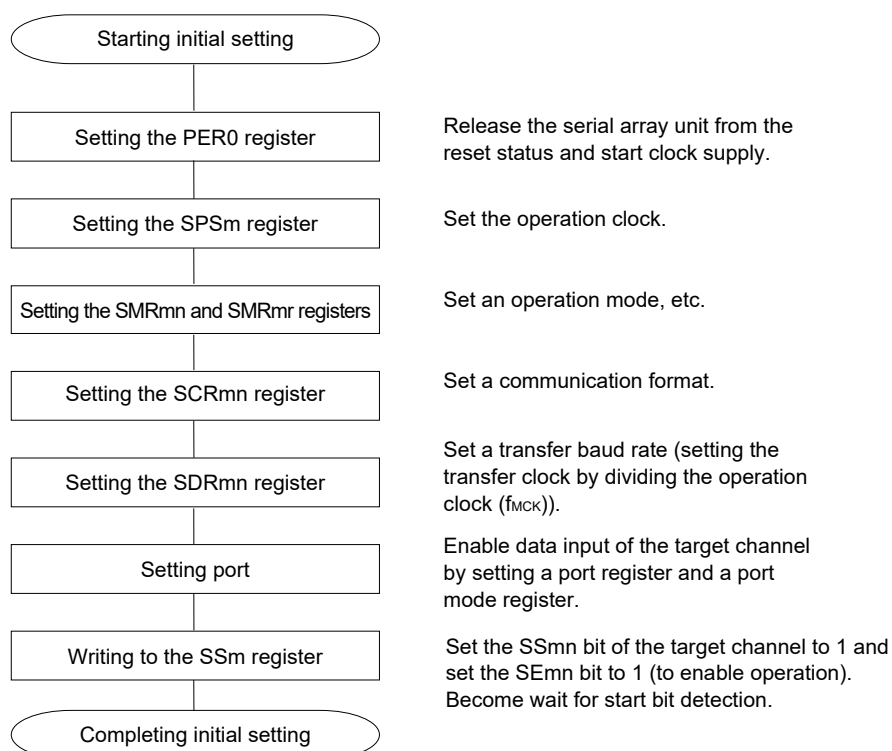
Note Unit 0 only

Remarks 1. m: Unit number (m = 0, 1)

2. ☐: Setting is fixed in the UART reception mode, ☐: Setting disabled (set to the initial value)
 ×: Bit that cannot be used in this mode (set to the initial value when not used in any mode)
 0/1: Set to 0 or 1 depending on the usage of the user

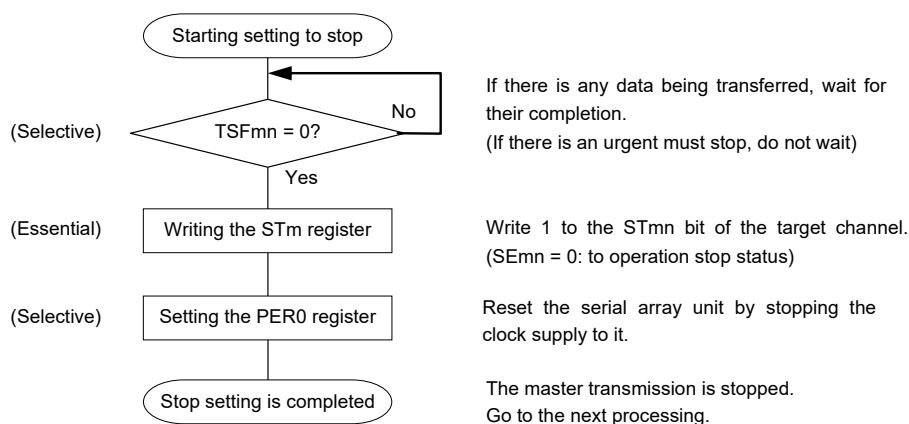
(2) Operation procedure

Figure 12-84. Initial Setting Procedure for UART Reception

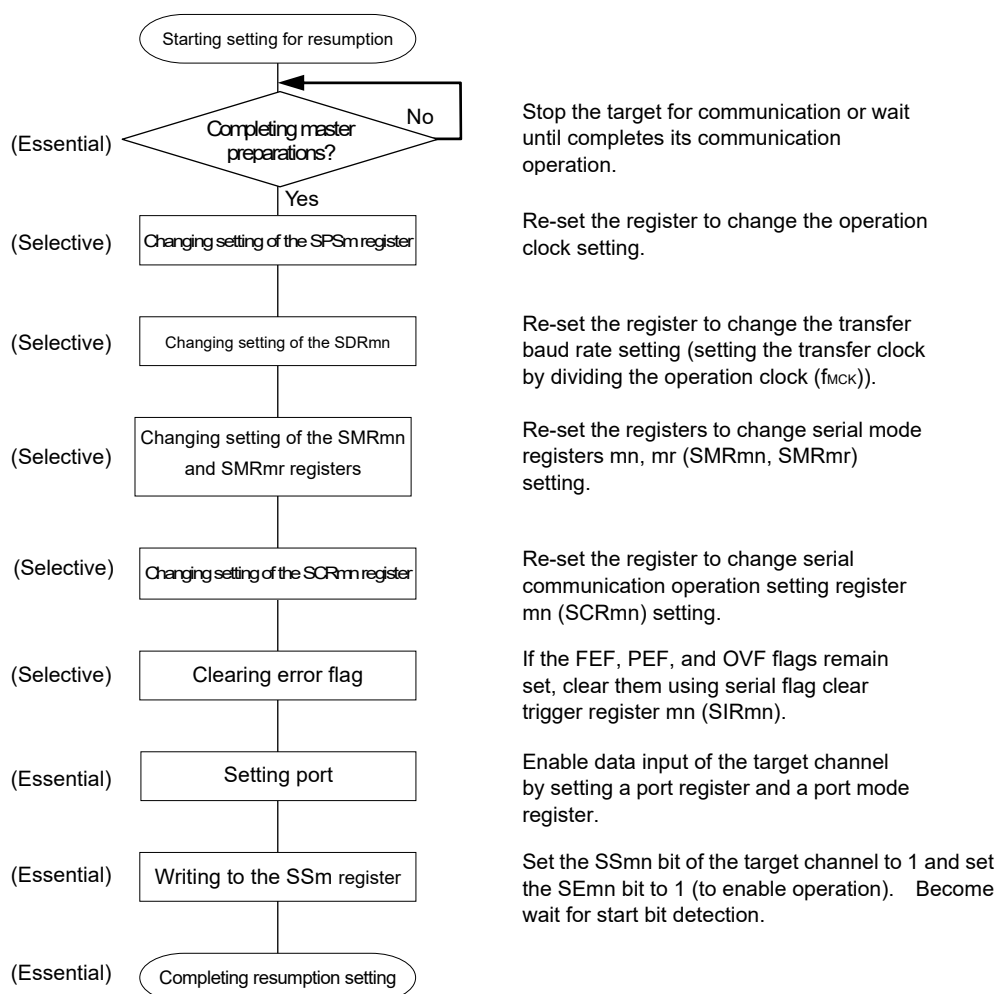


Caution Set the RXEmn bit of SCRmn register to 1, and then be sure to set SSmn to 1 after 4 or more f_{MCK} clocks have elapsed.

Figure 12-85. Procedure for Stopping UART Reception



Remark m: Unit number ($m = 0, 1$), n: Channel number ($n = 1, 3$), mn = 01, 03, 11
r: Channel number ($r = n - 1$)

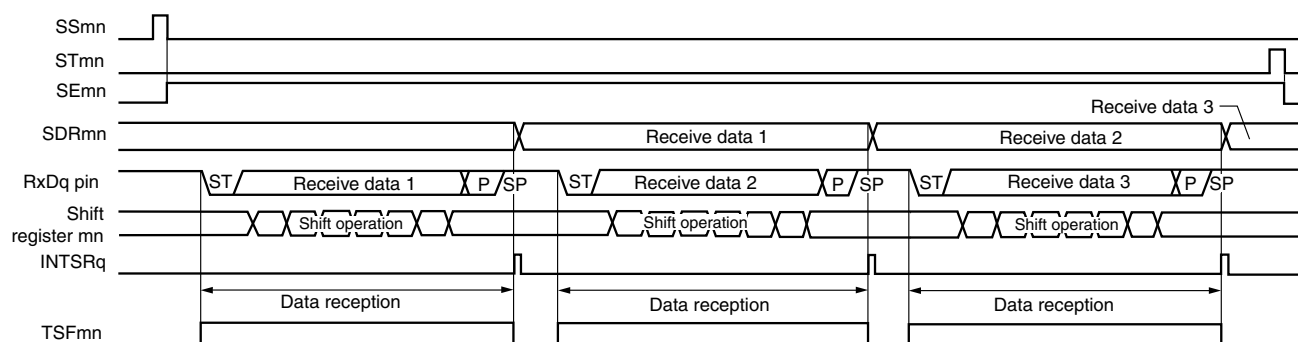
Figure 12-86. Procedure for Resuming UART Reception

Caution After is set RXEmn bit to 1 of SCRmn register, set the SSmn = 1 from an interval of at least four clocks of f_{MCK} .

- Remarks**
1. If PER0 is rewritten while stopping the master transmission and the clock supply is stopped, wait until the transmission target (slave) stops or transmission finishes, and then perform initialization instead of restarting the transmission.
 2. m: Unit number ($m = 0, 1$), n: Channel number ($n = 1, 3$), mn = 01, 03, 11
r: Channel number ($r = n - 1$)

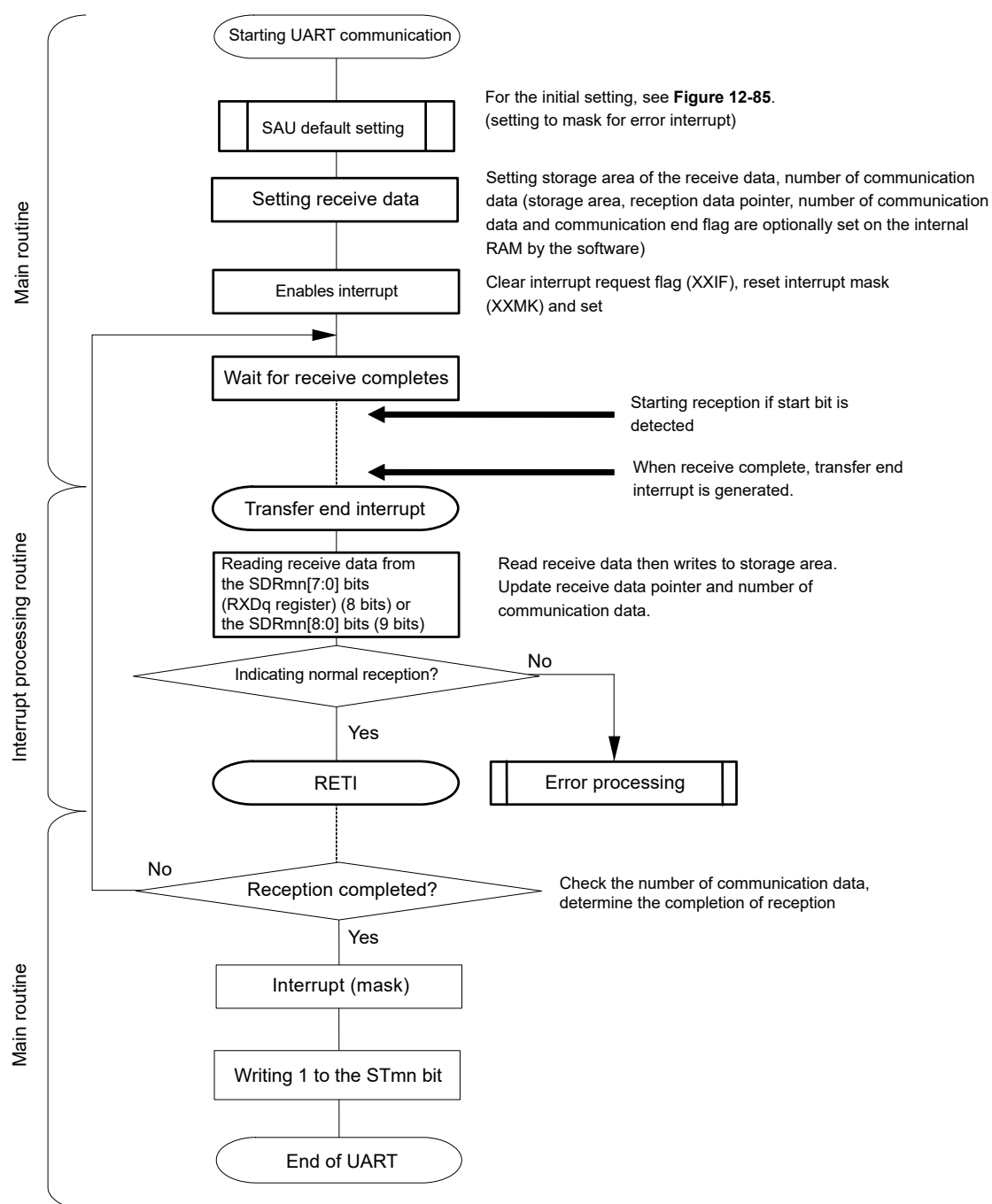
(3) Processing flow

Figure 12-87. Timing Chart of UART Reception



Remark m: Unit number (m = 0, 1), n: Channel number (n = 1, 3), mn = 01, 03, 11
 r: Channel number (r = n - 1), q: UART number (q = 0 to 2)

Figure 12-88. Flowchart of UART Reception



Remark m: Unit number (m = 0, 1), n: Channel number (n = 1, 3), mn = 01, 03, 11
 r: Channel number (r = n - 1), q: UART number (q = 0 to 2)

12.6.3 SNOOZE mode function

The SNOOZE mode makes the UART perform reception operations upon RxDq pin input detection while in the STOP mode. Normally the UART stops communication in the STOP mode. However, using the SNOOZE mode enables the UART to perform reception operations without CPU operation. Only UART0 channel can be set to the SNOOZE mode.

When using UARTq in the SNOOZE mode, perform the following steps before entering the STOP mode. (See **Figure 12-92 Flowchart of SNOOZE Mode Operation (EOCm1 = 0, SSECM = 0/1 or EOCm1 = 1, SSECM = 0)** and **Figure 12-94 Flowchart of SNOOZE Mode Operation (EOCm1 = 1, SSECM = 1).**)

- In the SNOOZE mode, the baud rate setting for UART reception needs to be changed to a value different from that in normal operation. Set the SPSm register and bits 15 to 9 of the SDRmn register with reference to Table 12-3.
- Set the EOCmn and SSECMn bits. This is for enabling or stopping generation of an error interrupt (INTSRE0) when a communication error occurs.
- Set the SWCm bit of serial standby control register m (SSCm) to 1 immediately before entering the STOP mode. After initial setup finishes, set the SSm1 bit of serial channel start register m (SSm) to 1, which sets the SEm1 bit to 1.
- A UARTq starts reception in SNOOZE mode on detecting input of the start bit on the RxDq pin following a transition of the CPU to the STOP mode.

- Cautions**
1. The SNOOZE mode can only be specified when the high-speed on-chip oscillator clock (f_{IH}) is selected for f_{CLK} .
 2. The maximum transfer rate when using UARTq in the SNOOZE mode is 4800 bps.
 3. When $SWCm = 1$, UARTq can be used only when the reception operation is started in the STOP mode. When used simultaneously with another SNOOZE mode function or interrupt, if the reception operation is started in a state other than the STOP mode, such as those given below, data may not be received correctly and a framing error or parity error may be generated.
 - When after the $SWCm$ bit has been set to 1, the reception operation is started before the STOP mode is entered
 - When the reception operation is started while another function is in the SNOOZE mode
 - When after returning from the STOP mode to normal operation due to an interrupt or other cause, the reception operation is started before the $SWCm$ bit is returned to 0
 4. If a parity error, framing error, or overrun error occurs while the $SSECM$ bit is set to 1, the $PEFmn$, $FEFmn$, or $OVFmn$ flag is not set and an error interrupt (INTSREq) is not generated. Therefore, when the setting of $SSECM = 1$ is made, clear the $PEFmn$, $FEFmn$, or $OVFmn$ flag before setting the $SWC0$ bit to 1 and read the value in bits 7 to 0 (RxDq register) of the SDRm1 register.
 5. The CPU shifts from the STOP mode to the SNOOZE mode on detecting the valid edge of the RxDq signal. Note, however, that transfer through the UART channel may not start and the CPU may remain in the SNOOZE mode if an input pulse on the RxDq pin is too short to be detected as a start bit.
In such cases, data may not be received correctly, and this may lead to a framing error or parity error in the next UART transfer.

Remark m = 0; q = 0

Table 12-3. UART Reception Baud Rate Setting in the SNOOZE Mode

High-speed On-chip Oscillator (f_{IH})	UART Reception Baud Rate Setting in the SNOOZE Mode			
	Baud Rate 4800 bps			
	Operation Clock (f_{MCK})	SDRmn [15:9]	Maximum Permissible Value	Minimum Permissible Value
32 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^5$	105	2.27%	-1.53%
24 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^5$	79	1.60%	-2.18%
16 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^4$	105	2.27%	-1.53%
12 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^4$	79	1.60%	-2.19%
8 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^3$	105	2.27%	-1.53%
6 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^3$	79	1.60%	-2.19%
4 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^2$	105	2.27%	-1.53%
3 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2^2$	79	1.60%	-2.19%
2 MHz $\pm$ 1.0% ^{Note}	$f_{CLK}/2$	105	2.27%	-1.54%
1 MHz $\pm$ 1.0% ^{Note}	f_{CLK}	105	2.27%	-1.57%

Note The allowable range is narrowed as described below when the accuracy of the high-speed on-chip oscillator clock frequency is $\pm 1.5\%$ or $\pm 2.0\%$.

- In the case of $f_{IH} \pm 1.5\%$, perform (Maximum permissible value - 0.5%) and (Minimum permissible value + 0.5%) to the values in the above table.
- In the case of $f_{IH} \pm 2.0\%$, perform (Maximum permissible value - 1.0%) and (Minimum permissible value + 1.0%) to the values in the above table.

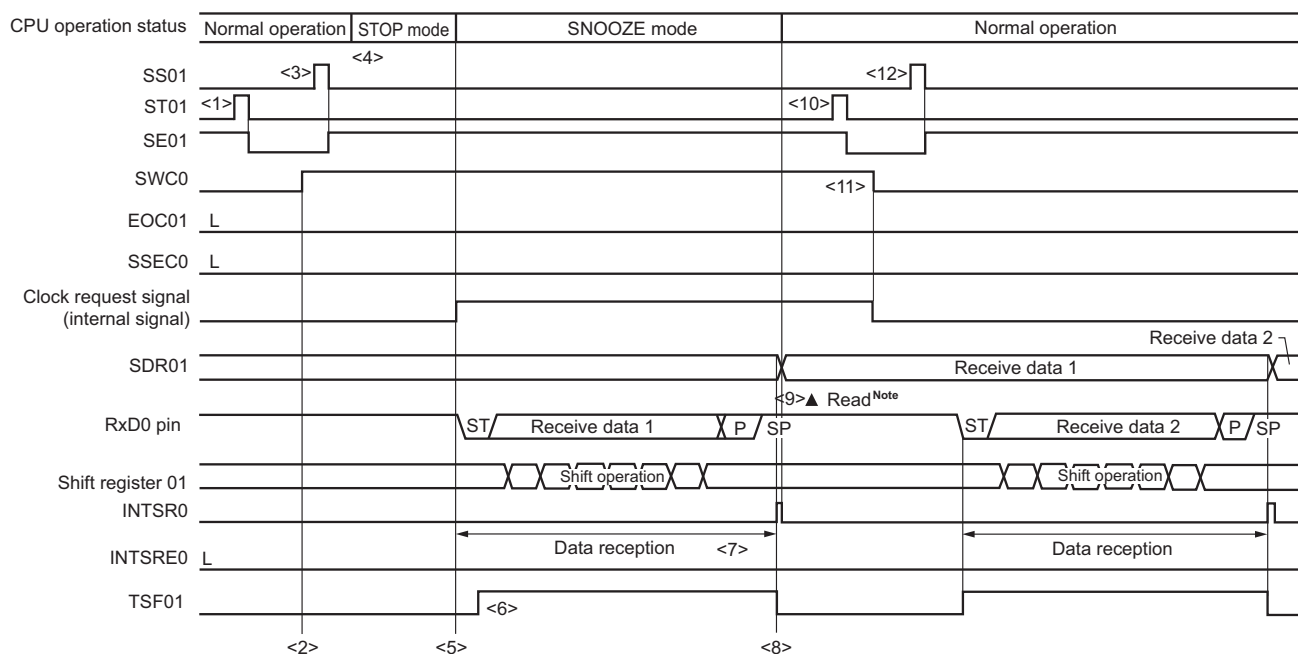
Remark The maximum and minimum allowable values indicate the allowable baud rate values for UART reception.

Specify the baud rate so that the baud rate on the transmission side is within this range.

(1) SNOOZE mode operation (EOCm1 = 0, SSECm = 0/1)

Because EOCm1 = 0, an error interrupt (INTSRE0) is not generated even if a communication error occurs independently of the setting of SSECmn bit. Transfer end interrupt (INTSR0) is generated.

Figure 12-89. Timing Chart of SNOOZE Mode Operation (OCm1 = 0, SSECm = 0/1)



Note Read the received data when SWCm is 1

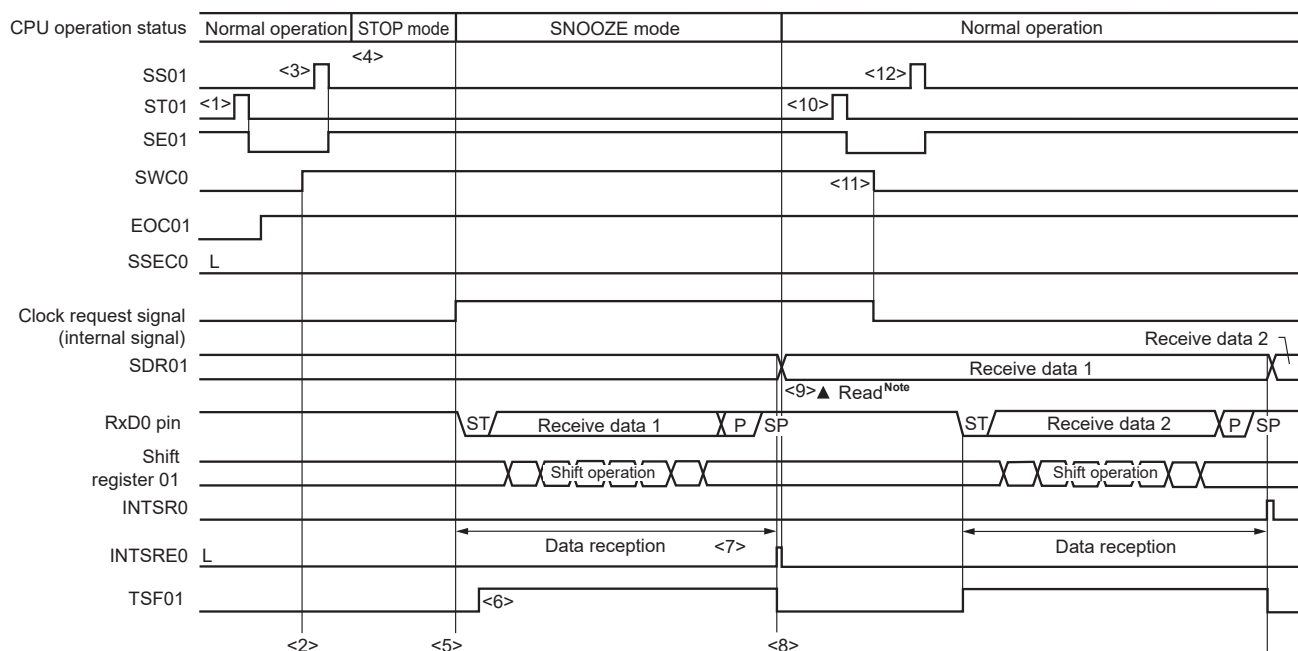
Caution Before switching to the SNOOZE mode or after reception operation in the SNOOZE mode finishes, set the STm1 bit to 1 (clear the SEm1 bit, and stop the operation). And after completion the receive operation, also clearing SWCm bit to 0 (SNOOZE mode release).

Remarks 1. <1> to <11> in the figure correspond to <1> to <11> in **Figure 12-91 Flowchart of SNOOZE Mode Operation (EOCm1 = 0, SSECm = 0/1 or EOCm1 = 1, SSECm = 0).**

2. m = 0; q = 0

(2) SNOOZE mode operation (EOCm1 = 1, SSECm = 0: error interrupt (INTSRE0) generation enable)

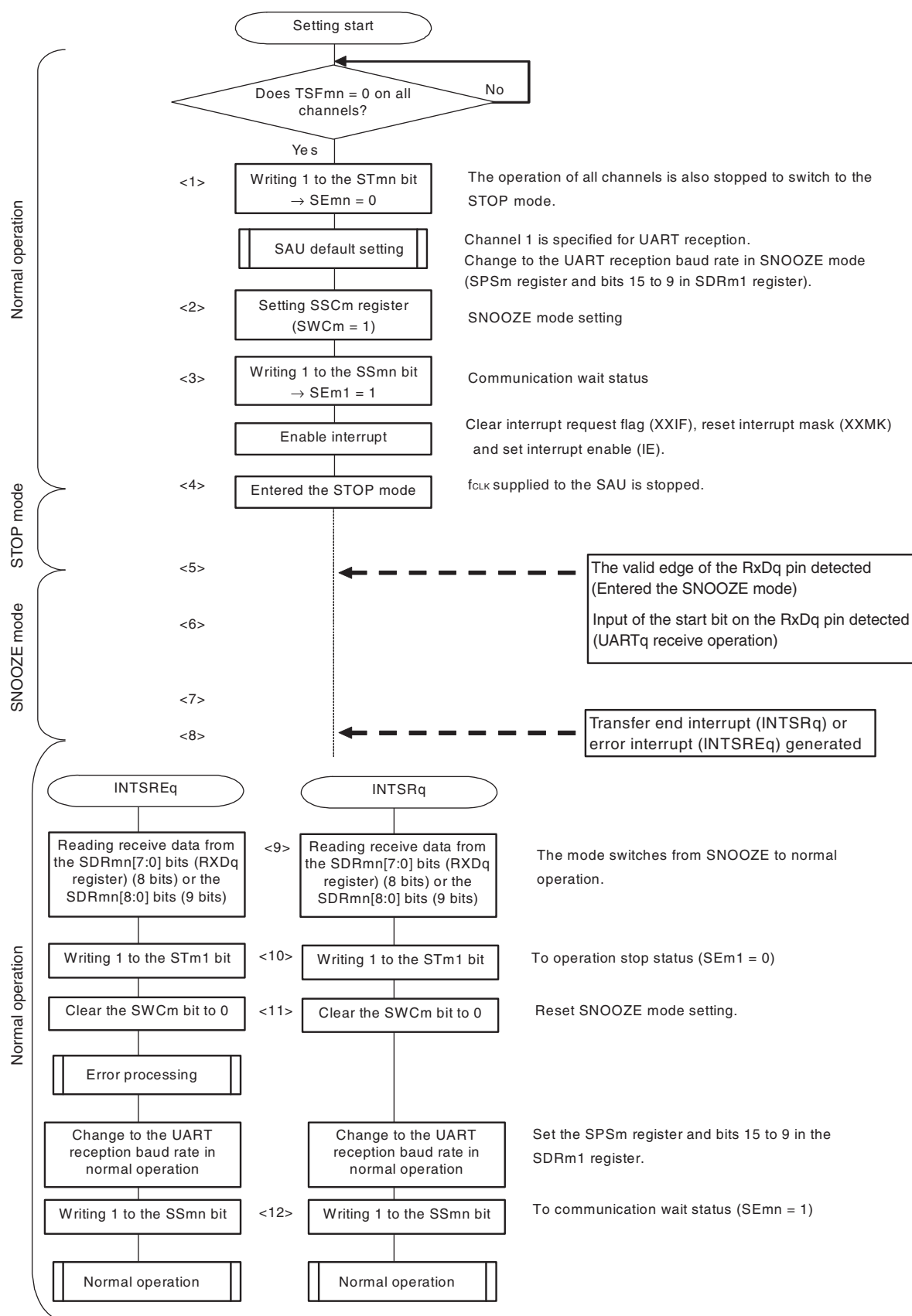
Because EOCm1 = 1, SSECm = 0, an error interrupt (INTSREq) is generated when a communication error occurs.

Figure 12-90. Timing Chart of SNOOZE Mode Operation (EOCm1 = 1, SSECm = 0)

Caution Before switching to the SNOOZE mode or after reception operation in the SNOOZE mode finishes, set the STm1 bit to 1 (clear the SEM1 bit, and stop the operation). And after completion the receive operation, also clearing SWCm bit to 0 (SNOOZE mode release).

Remarks 1. <1> to <11> in the figure correspond to <1> to <11> in Figure 12-91 Flowchart of SNOOZE Mode Operation (EOCm1 = 0, SSECm = 0/1 or EOCm1 = 1, SSECm = 0).

2. m = 0

Figure 12-91. Flowchart of SNOOZE Mode Operation (EOCm1 = 0, SSECM = 0/1 or EOCm1 = 1, SSECM = 0)

(Remarks are listed on the next page.)

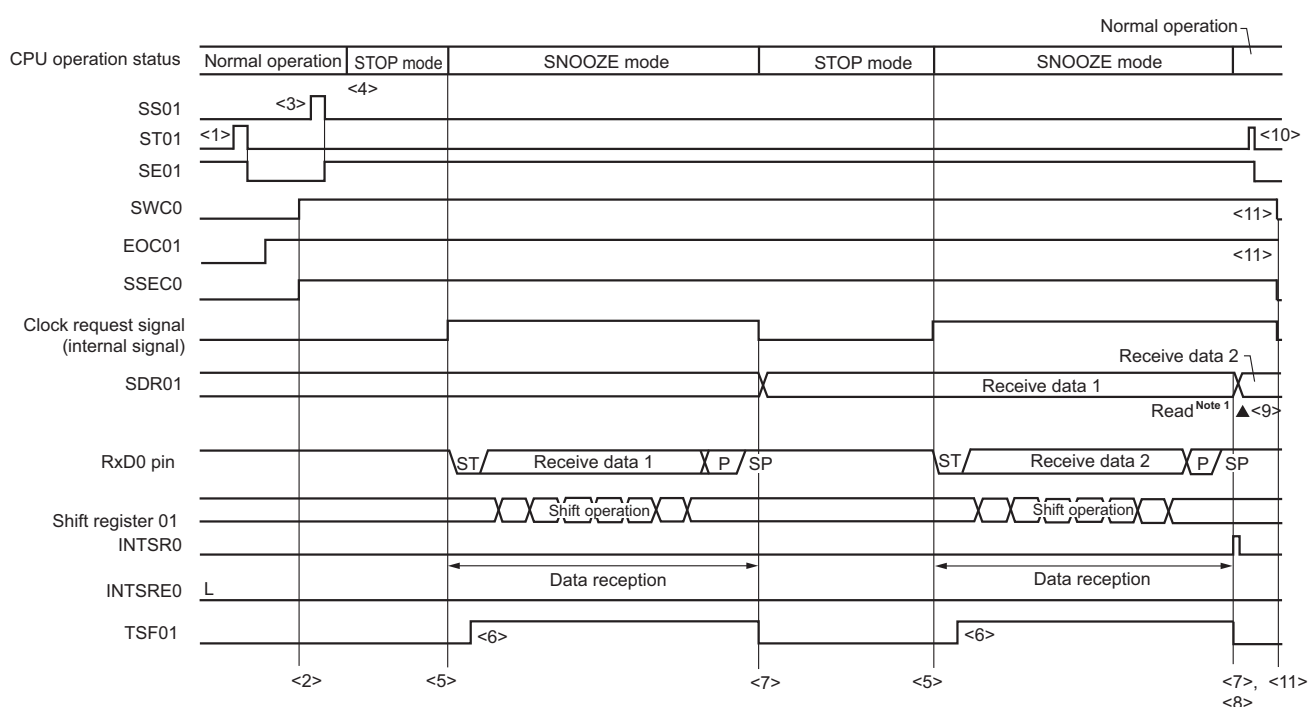
Remarks 1. <1> to <11> in the figure correspond to <1> to <11> in **Figure 12-89 Timing Chart of SNOOZE Mode Operation (EOCm1 = 0, SSECM = 0/1)** and **Figure 12-90 Timing Chart of SNOOZE Mode Operation (EOCm1 = 1, SSECM = 0)**.

2. m = 0; q = 0

(3) SNOOZE mode operation (EOCm1 = 1, SSECM = 1: error interrupt (INTSRE0) generation stop)

Because EOCm1 = 1, SSECM = 1, an error interrupt (INTSRE0) is not generated when a communication error occurs.

Figure 12-92. Timing Chart of SNOOZE Mode Operation (EOCm1 = 1, SSECM = 1)



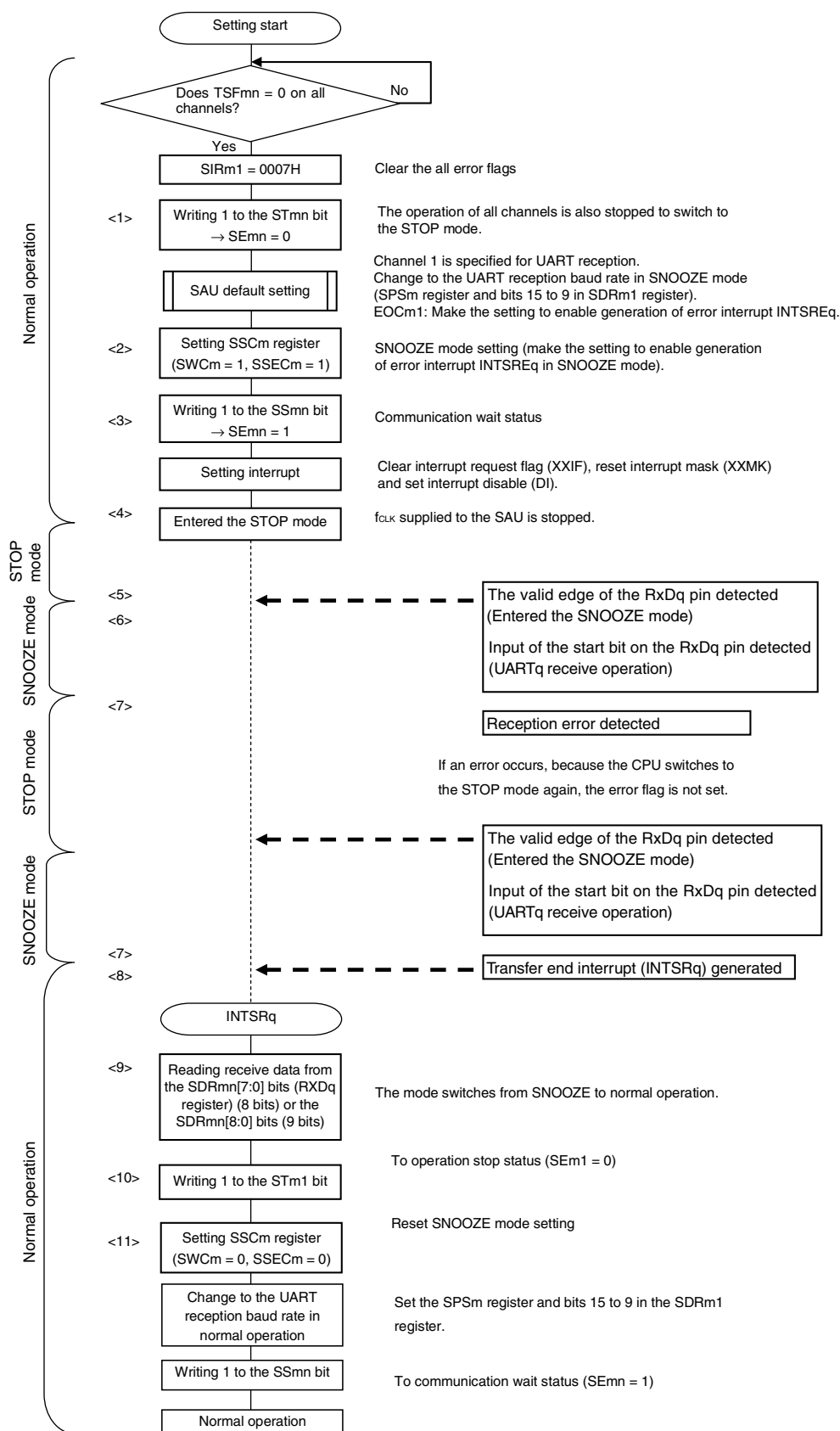
Note Read the received data when SWCm = 1.

- Cautions 1.** Before switching to the SNOOZE mode or after reception operation in the SNOOZE mode finishes, set the STm1 bit to 1 (clear the SEm1 bit, and stop the operation). And after completion the receive operation, also clearing SWCm bit to 0 (SNOOZE mode release).
- 2.** If the SSECM bit is 1, the PEFm1, FEFm1, and OVFM1 flags are not set when a parity error, framing error, or overrun error occurs and no error interrupt (INTSREq) is generated. Therefore, when the setting of SSECM = 1 is made, clear the PEFm1, FEFm1, or OVFM1 flag before setting the SWCm bit to 1 and read the value in SDRm1[7:0] (RxDq register) (8 bits) or SDRm1[8:0] (9 bits).

Remarks 1. <1> to <9> in the figure correspond to <1> to <9> in **Figure 12-93 Flowchart of SNOOZE Mode Operation (EOCm1 = 1, SSECM = 1)**.

2. m = 0; q = 0

Figure 12-93. Flowchart of SNOOZE Mode Operation (EOCm1 = 1, SSECm = 1)



(**Caution** and **Remarks** are listed on the next page.)

Caution If the SSECm bit is 1, the PEFm1, FEFm1, and OVFM1 flags are not set when a parity error, framing error, or overrun error occurs and no error interrupt (INTSREq) is generated. Therefore, when the setting of SSECm = 1 is made, clear the PEFm1, FEFm1, or OVFM1 flag before setting the SWCm bit to 1 and read the value in SDRm1[7:0] (RxDq register) (8 bits) or SDRm1[8:0] (9 bits).

Remarks 1. <1> to <9> in the figure correspond to <1> to <9> in **Figure 12-92 Timing Chart of SNOOZE Mode Operation (EOCm1 = 1, SSECm = 1)**.
2. m = 0; q = 0, n = 0 to 3

12.6.4 Calculating baud rate

(1) Baud rate calculation expression

The baud rate for UART (UART0 to UART2) communication can be calculated by the following expressions.

$$(\text{Baud rate}) = \{\text{Operation clock (f}_{\text{MCK}}) \text{ frequency of target channel}\} \div (\text{SDRmn}[15:9] + 1) \div 2 \text{ [bps]}$$

Caution Setting serial data register mn (SDRmn) SDRmn[15:9] = (0000000B, 0000001B) is prohibited.

Remarks 1. When UART is used, the value of SDRmn[15:9] is the value of bits 15 to 9 of the SDRmn register (0000010B to 1111111B) and therefore is 2 to 127.

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

The operation clock (f_{MCK}) is determined by serial clock select register m (SPSm) and bit 15 (CKSmn) of serial mode register mn (SMRmn).

Table 12-4. Selection of Operation Clock For UART

SMRmn Register	SPSm Register								Operation Clock (f_{CLK}) ^{Note}	
CKSmn	PRS m13	PRS m12	PRS m11	PRS m10	PRS m03	PRS m02	PRS m01	PRS m00		$f_{CLK} = 32 \text{ MHz}$
0	X	X	X	X	0	0	0	0	f_{CLK}	32 MHz
	X	X	X	X	0	0	0	1	$f_{CLK}/2$	16 MHz
	X	X	X	X	0	0	1	0	$f_{CLK}/2^2$	8 MHz
	X	X	X	X	0	0	1	1	$f_{CLK}/2^3$	4 MHz
	X	X	X	X	0	1	0	0	$f_{CLK}/2^4$	2 MHz
	X	X	X	X	0	1	0	1	$f_{CLK}/2^5$	1 MHz
	X	X	X	X	0	1	1	0	$f_{CLK}/2^6$	500 kHz
	X	X	X	X	0	1	1	1	$f_{CLK}/2^7$	250 kHz
	X	X	X	X	1	0	0	0	$f_{CLK}/2^8$	125 kHz
	X	X	X	X	1	0	0	1	$f_{CLK}/2^9$	62.5 kHz
	X	X	X	X	1	0	1	0	$f_{CLK}/2^{10}$	31.25 kHz
	X	X	X	X	1	0	1	1	$f_{CLK}/2^{11}$	15.63 kHz
	X	X	X	X	1	1	0	0	$f_{CLK}/2^{12}$	7.81 kHz
	X	X	X	X	1	1	0	1	$f_{CLK}/2^{13}$	3.91 kHz
	X	X	X	X	1	1	1	0	$f_{CLK}/2^{14}$	1.95 kHz
	X	X	X	X	1	1	1	1	$f_{CLK}/2^{15}$	977 Hz
1	0	0	0	0	X	X	X	X	f_{CLK}	32 MHz
	0	0	0	1	X	X	X	X	$f_{CLK}/2$	16 MHz
	0	0	1	0	X	X	X	X	$f_{CLK}/2^2$	8 MHz
	0	0	1	1	X	X	X	X	$f_{CLK}/2^3$	4 MHz
	0	1	0	0	X	X	X	X	$f_{CLK}/2^4$	2 MHz
	0	1	0	1	X	X	X	X	$f_{CLK}/2^5$	1 MHz
	0	1	1	0	X	X	X	X	$f_{CLK}/2^6$	500 kHz
	0	1	1	1	X	X	X	X	$f_{CLK}/2^7$	250 kHz
	1	0	0	0	X	X	X	X	$f_{CLK}/2^8$	125 kHz
	1	0	0	1	X	X	X	X	$f_{CLK}/2^9$	62.5 kHz
	1	0	1	0	X	X	X	X	$f_{CLK}/2^{10}$	31.25 kHz
	1	0	1	1	X	X	X	X	$f_{CLK}/2^{11}$	15.63 kHz
	1	1	0	0	X	X	X	X	$f_{CLK}/2^{12}$	7.81 kHz
	1	1	0	1	X	X	X	X	$f_{CLK}/2^{13}$	3.91 kHz
	1	1	1	0	X	X	X	X	$f_{CLK}/2^{14}$	1.95 kHz
	1	1	1	1	X	X	X	X	$f_{CLK}/2^{15}$	977 Hz
Other than above									Setting prohibited	

Note When changing the clock selected for f_{CLK} (by changing the system clock control register (CKC) value), do so after having stopped (serial channel stop register m (STm) = 000FH) the operation of the serial array unit (SAU).

Remarks 1. X: Don't care

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(2) Baud rate error during transmission

The baud rate error of UART (UART0 to UART2) communication during transmission can be calculated by the following expression. Make sure that the baud rate at the transmission side is within the permissible baud rate range at the reception side.

$$(\text{Baud rate error}) = (\text{Calculated baud rate value}) \div (\text{Target baud rate}) \times 100 - 100 [\%]$$

Here is an example of setting a UART baud rate at $f_{\text{CLK}} = 32 \text{ MHz}$.

UART Baud Rate (Target Baud Rate)	$f_{\text{CLK}} = 32 \text{ MHz}$			
	Operation Clock (f_{MCK})	SDRmn[15:9]	Calculated Baud Rate	Error from Target Baud Rate
300 bps	$f_{\text{CLK}}/2^9$	103	300.48 bps	+0.16 %
600 bps	$f_{\text{CLK}}/2^8$	103	600.96 bps	+0.16 %
1200 bps	$f_{\text{CLK}}/2^7$	103	1201.92 bps	+0.16 %
2400 bps	$f_{\text{CLK}}/2^6$	103	2403.85 bps	+0.16 %
4800 bps	$f_{\text{CLK}}/2^5$	103	4807.69 bps	+0.16 %
9600 bps	$f_{\text{CLK}}/2^4$	103	9615.38 bps	+0.16 %
19200 bps	$f_{\text{CLK}}/2^3$	103	19230.8 bps	+0.16 %
31250 bps	$f_{\text{CLK}}/2^3$	63	31250.0 bps	$\pm 0.0 \%$
38400 bps	$f_{\text{CLK}}/2^2$	103	38461.5 bps	+0.16 %
76800 bps	$f_{\text{CLK}}/2$	103	76923.1 bps	+0.16 %
153600 bps	f_{CLK}	103	153846 bps	+0.16 %
312500 bps	f_{CLK}	50	313725.5 bps	+0.39 %

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 02, 10

(3) Permissible baud rate range for reception

The permissible baud rate range for reception during UART (UART0 to UART2) communication can be calculated by the following expression. Make sure that the baud rate at the transmission side is within the permissible baud rate range at the reception side.

$$(\text{Maximum receivable baud rate}) = \frac{2 \times k \times \text{Nfr}}{2 \times k \times \text{Nfr} - k + 2} \times \text{Brate}$$

$$(\text{Minimum receivable baud rate}) = \frac{2 \times k \times (\text{Nfr} - 1)}{2 \times k \times \text{Nfr} - k - 2} \times \text{Brate}$$

Brate: Calculated baud rate value at the reception side (See **12.6.4 (1) Baud rate calculation expression.**)

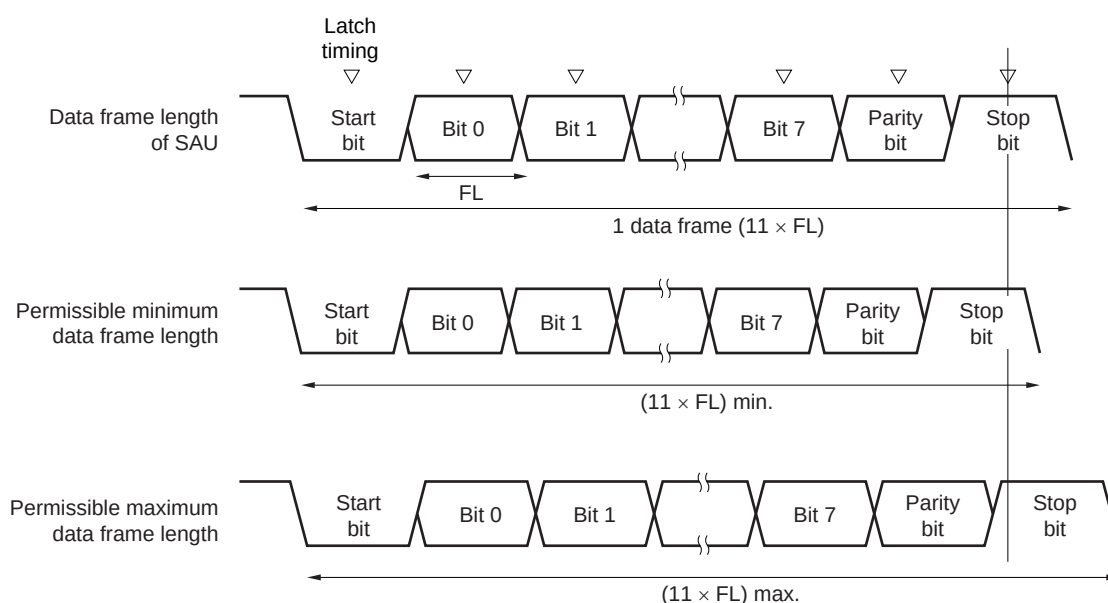
k: SDRmn[15:9] + 1

Nfr: 1 data frame length [bits]

= (Start bit) + (Data length) + (Parity bit) + (Stop bit)

Remark m: Unit number (m = 0, 1), n: Channel number (n = 1, 3), mn = 01, 03, 11

Figure 12-94. Permissible Baud Rate Range for Reception (1 Data Frame Length = 11 Bits)



As shown in Figure 12-94, the timing of latching receive data is determined by the division ratio set by bits 15 to 9 of serial data register mn (SDRmn) after the start bit is detected. If the last data (stop bit) is received before this latch timing, the data can be correctly received.

12.6.5 Procedure for processing errors that occurred during UART (UART0 to UART2) communication

The procedure for processing errors that occurred during UART (UART0 to UART2) communication is described in Figures 12-95 and 12-96.

Figure 12-95. Processing Procedure in Case of Parity Error or Overrun Error

Software Manipulation	Hardware Status	Remark
Reads serial data register mn (SDRmn). →	The BFFmn bit of the SSRmn register is set to 0 and channel n is enabled to receive data.	This is to prevent an overrun error if the next reception is completed during error processing.
Reads serial status register mn (SSRmn).		Error type is identified and the read value is used to clear error flag.
Writes 1 to serial flag clear trigger register mn (SIRmn). →	Error flag is cleared.	Error can be cleared only during reading, by writing the value read from the SSRmn register to the SIRmn register without modification.

Figure 12-96. Processing Procedure in Case of Framing Error

Software Manipulation	Hardware Status	Remark
Reads serial data register mn (SDRmn). →	The BFFmn bit of the SSRmn register is set to 0 and channel n is enabled to receive data.	This is to prevent an overrun error if the next reception is completed during error processing.
Reads serial status register mn (SSRmn).		Error type is identified and the read value is used to clear error flag.
Writes serial flag clear trigger register mn (SIRmn). →	Error flag is cleared.	Error can be cleared only during reading, by writing the value read from the SSRmn register to the SIRmn register without modification.
Sets the STmn bit of serial channel stop register m (STm) to 1. →	The SEMn bit of serial channel enable status register m (SEm) is set to 0 and channel n stops operating.	
Synchronization with other party of communication		Synchronization with the other party of communication is re-established and communication is resumed because it is considered that a framing error has occurred because the start bit has been shifted.
Sets the SSmn bit of serial channel start register m (SSm) to 1. →	The SEMn bit of serial channel enable status register m (SEm) is set to 1 and channel n is enabled to operate.	

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

12.7 LIN Communication Operation

12.7.1 LIN transmission

Of UART transmission, UART2 of the 32, 48, and 64-pin products support LIN communication.

For LIN transmission, channel 0 of unit 1 is used.

UART	UART0	UART1	UART2
Support of LIN communication	Not supported	Not supported	Supported
Target channel	–	–	Channel 0 of SAU1
Pins used	–	–	TxD2
Interrupt	–	–	INTST2
	Transfer end interrupt (in single-transfer mode) or buffer empty interrupt (in continuous transfer mode) can be selected.		
Error detection flag	None		
Transfer data length	8 bits		
Transfer rate ^{Note}	Max. $f_{MCK}/6$ [bps] (SDR10 [15:9] = 2 or more), Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [bps]		
Data phase	Non-reverse output (default: high level) Reverse output (default: low level)		
Parity bit	No parity bit		
Stop bit	Appending 1 bit		
Data direction	LSB first		

Note Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$), **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS** $T_A = -40$ to $+105^\circ\text{C}$)). In addition, LIN communication is usually 2.4/9.6/19.2 kbps is often used.

Remark f_{MCK} : Operation clock frequency of target channel
 f_{CLK} : System clock frequency

LIN stands for Local Interconnect Network and is a low-speed (1 to 20 kbps) serial communication protocol designed to reduce the cost of an automobile network.

Communication of LIN is single-master communication and up to 15 slaves can be connected to one master.

The slaves are used to control switches, actuators, and sensors, which are connected to the master via LIN.

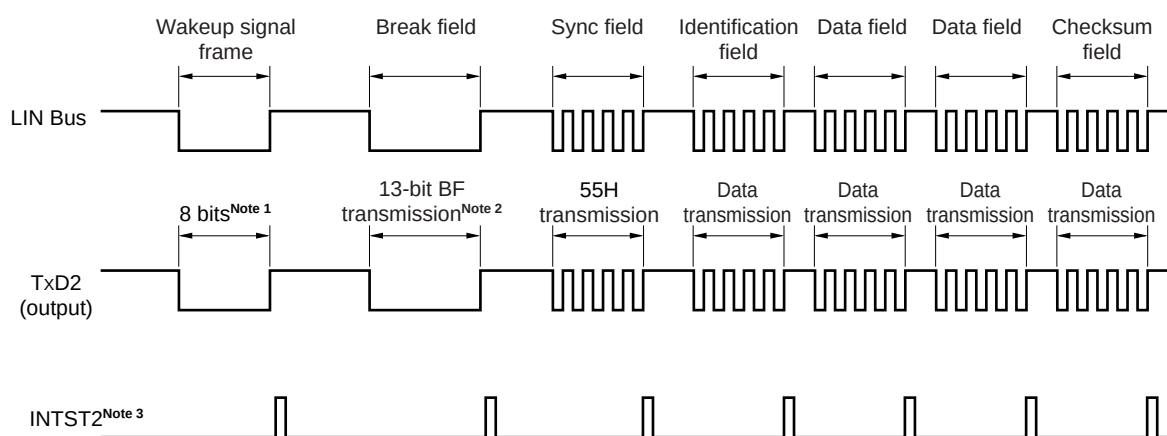
Usually, the master is connected to a network such as CAN (Controller Area Network).

A LIN bus is a single-wire bus to which nodes are connected via transceiver conforming to ISO9141.

According to the protocol of LIN, the master transmits a frame by attaching baud rate information to it. A slave receives this frame and corrects a baud rate error from the master. If the baud rate error of a slave is within $\pm 15\%$, communication can be established.

Figure 12-97 outlines a master transmission operation of LIN.

Figure 12-97. Master Transmission Operation of LIN



Notes 1. Set the baud rate in accordance with the wakeup signal regulations and transmit data of 80H.

2. A break field is defined to have a width of 13 bits and output a low level. Where the baud rate for main transfer is N [bps], therefore, the baud rate of the break field is calculated as follows.

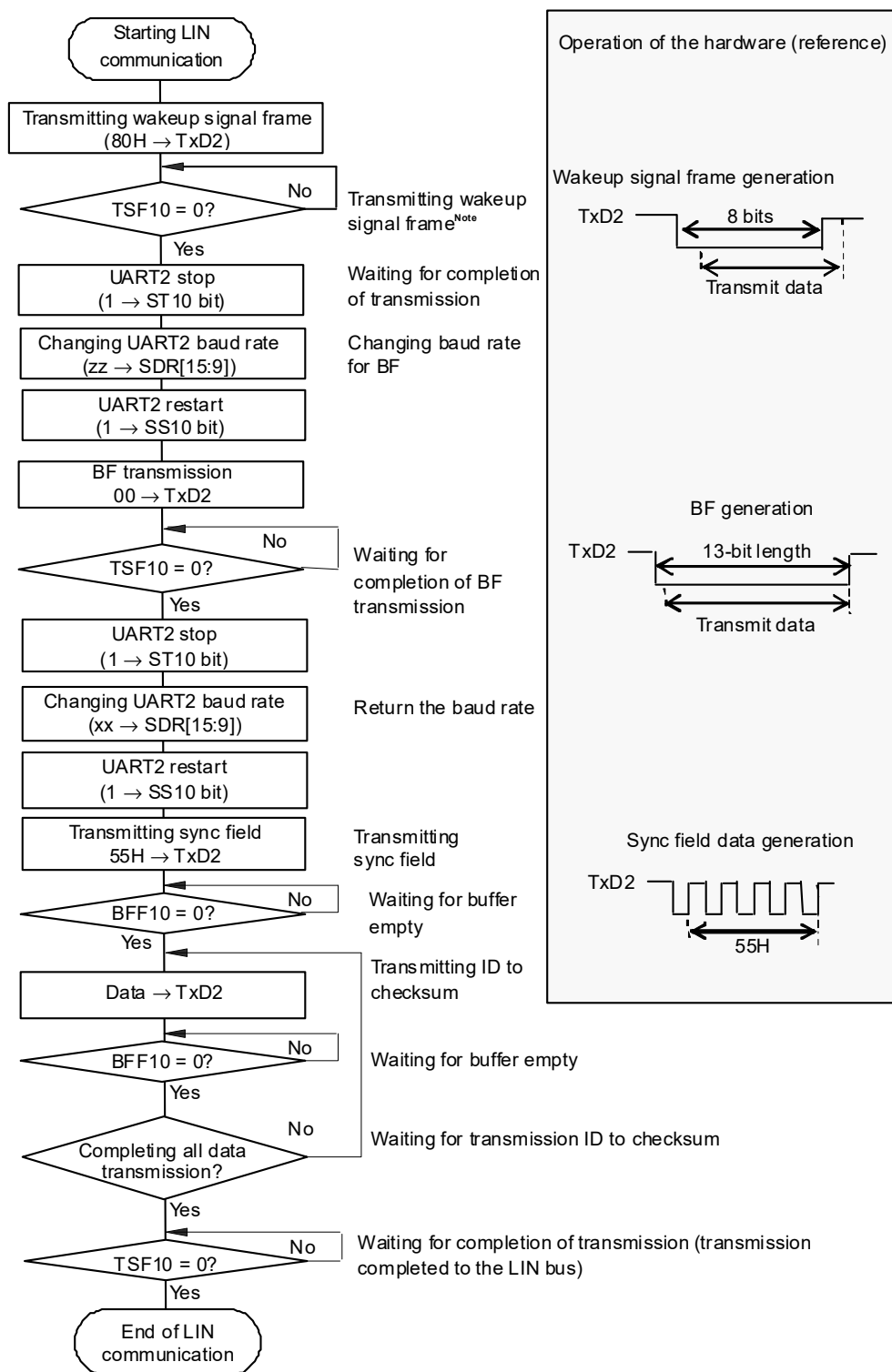
$$(\text{Baud rate of break field}) = 9/13 \times N$$

By transmitting data of 00H at this baud rate, a break field is generated.

3. INTST2 is output upon completion of transmission. INTST2 is also output at BF transmission.

Remark The interval between fields is controlled by software.

Figure 12-98. Flowchart for LIN Transmission



Note When LIN-bus start from sleep status only

Remark Default setting of the UART is complete, and the flow from the transmission enable status.

12.7.2 LIN reception

Of UART reception, UART2 of the 32, 48, and 64-pin products support LIN communication.

For LIN reception, channel 1 of unit 1 is used.

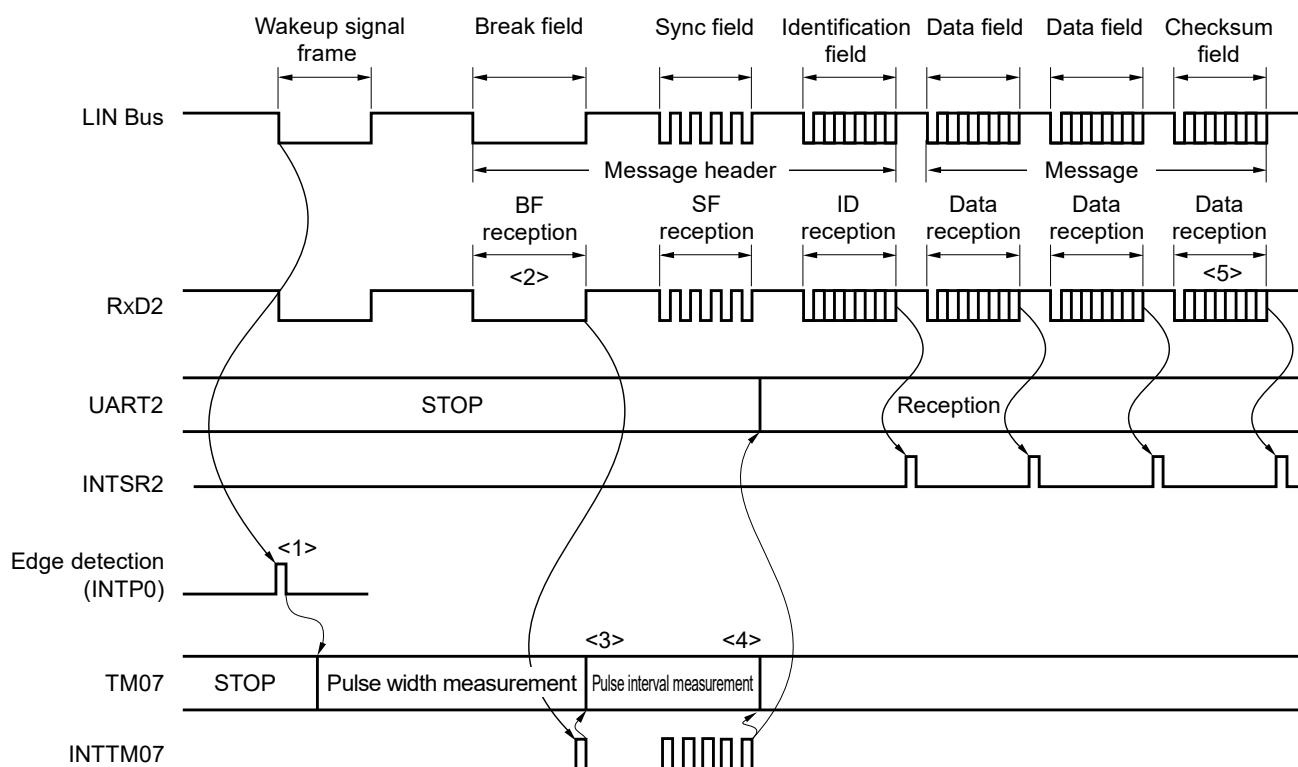
UART	UART0	UART1	UART2
Support of LIN communication	Not supported	Not supported	Supported
Target channel	–	–	Channel 1 of SAU1
Pins used	–	–	RxD2
Interrupt	–	–	INTSR2
	Transfer end interrupt only (Setting the buffer empty interrupt is prohibited.)		
Error interrupt	–	–	INTSRE2
Error detection flag	- Framing error detection flag (FEF11) - Overrun error detection flag (OVF11)		
Transfer data length	8 bits		
Transfer rate ^{Note}	Max. $f_{MCK}/6$ [bps] (SDR11 [15:9] = 2 or more), Min. $f_{CLK}/(2 \times 2^{15} \times 128)$ [bps]		
Data phase	Non-reverse output (default: high level) Reverse output (default: low level)		
Parity bit	No parity bit (The parity bit is not checked.)		
Stop bit	Check the first bit		
Data direction	LSB first		

Note Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$), **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS)** ($T_A = -40$ to $+105^\circ\text{C}$)).

Remark f_{MCK} : Operation clock frequency of target channel
 f_{CLK} : System clock frequency

Figure 12-99 outlines a reception operation of LIN.

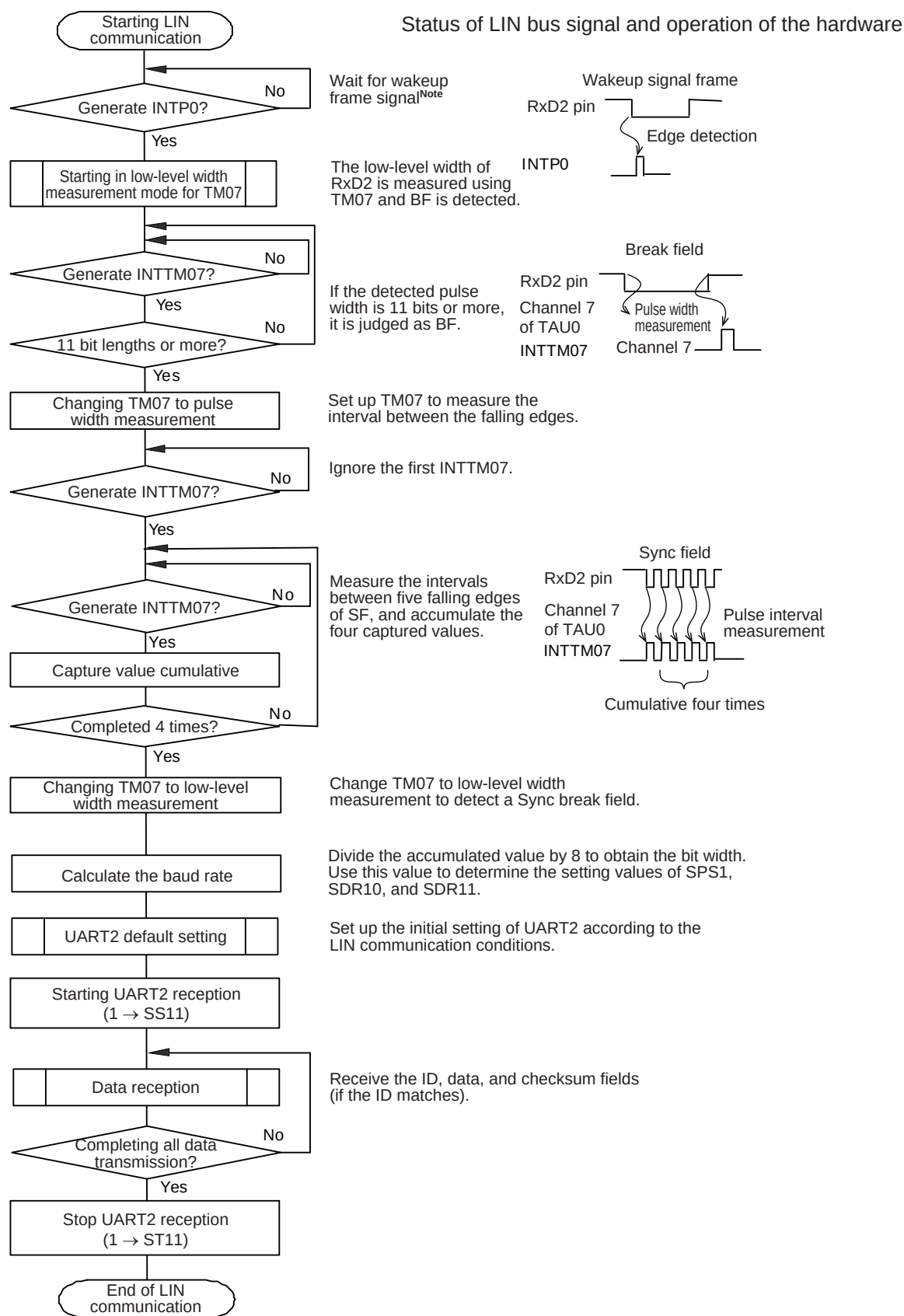
Figure 12-99. Reception Operation of LIN



Here is the flow of reception processing.

- <1> The wakeup signal is detected by detecting an interrupt edge (INTP0) on a pin. When the wakeup signal is detected, change TM07 to pulse width measurement upon detection of the wakeup signal to measure the low-level width of the BF signal. Then wait for BF signal reception.
- <2> TM07 starts measuring the low-level width upon detection of the falling edge of the BF signal, and then captures the data upon detection of the rising edge of the BF signal. The captured data is used to judge whether it is the BF signal.
- <3> When the BF signal has been received normally, change TM07 to pulse interval measurement and measure the interval between the falling edges of the RxD2 signal in the sync field four times (see **6.8.4 Operation as input pulse interval measurement**).
- <4> Calculate a baud rate error from the bit interval of sync field (SF). Stop UART2 once and adjust (re-set) the baud rate.
- <5> The checksum field should be distinguished by software. In addition, processing to initialize UART2 after the checksum field is received and to wait for reception of BF should also be performed by software.

Figure 12-100. Flowchart for LIN Reception



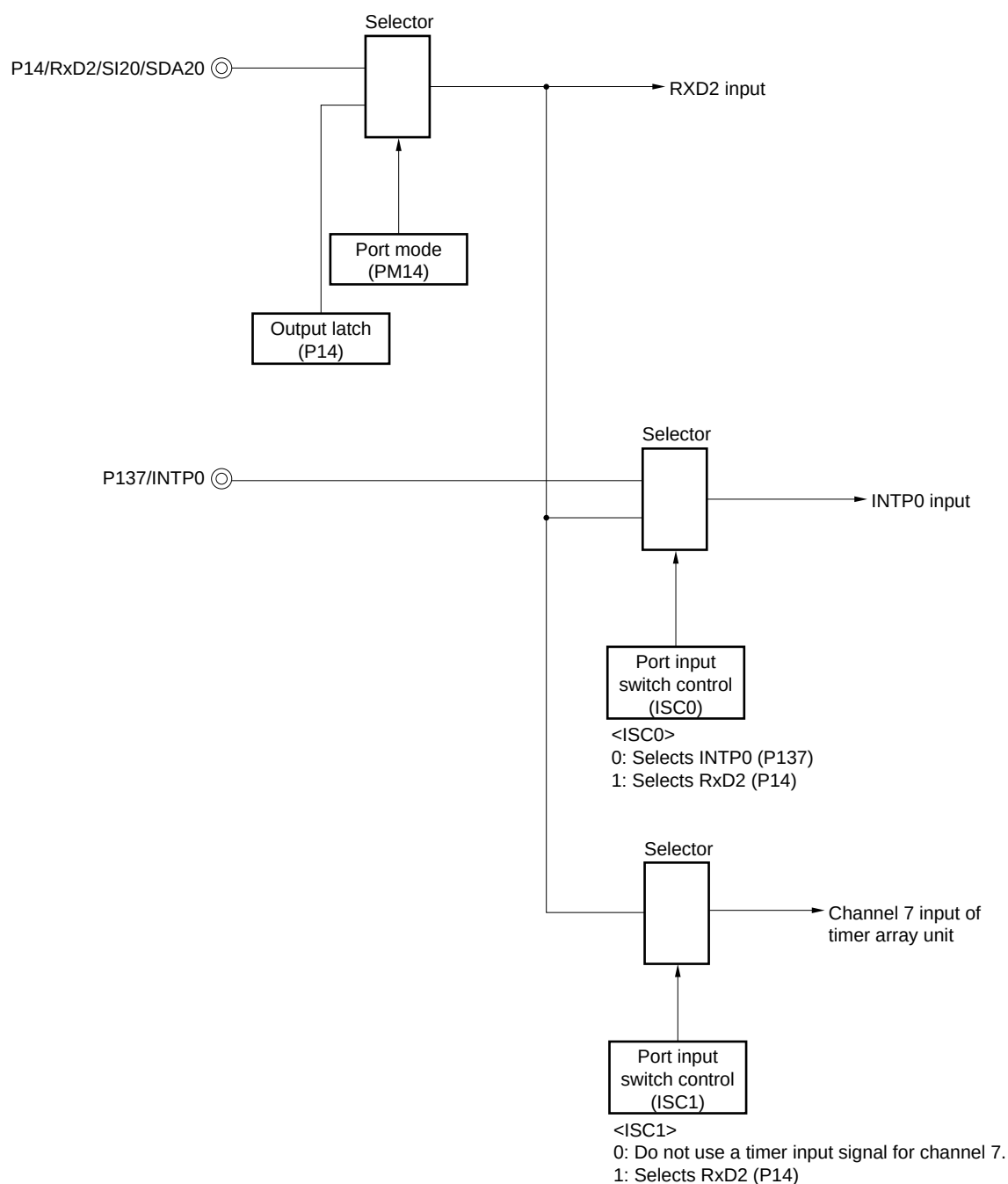
Note Required in the sleep status only.

Figure 12-101 and figure 12-102 show the configuration of a port that manipulates reception of LIN.

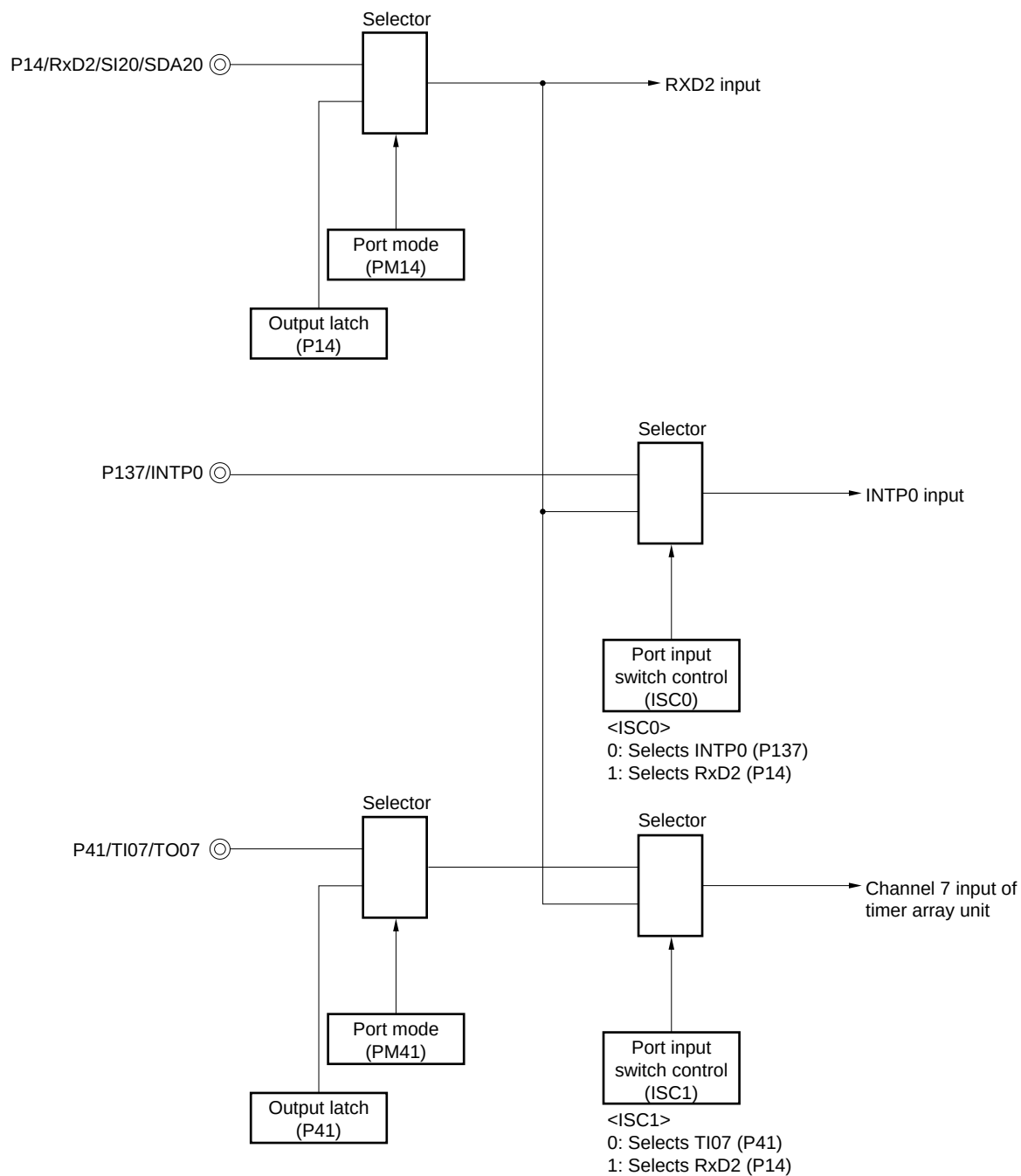
The wakeup signal transmitted from the master of LIN is received by detecting an edge of an external interrupt (INTP0). The length of the sync field transmitted from the master can be measured by using the external event capture operation of the timer array unit 0 to calculate a baud-rate error.

By controlling switch of port input (ISC0/ISC1), the input source of port input (RxD2) for reception can be input to the external interrupt pin (INTP0) and timer array unit

Figure 12-101. Port Configuration for Manipulating Reception of LIN (32-pin)



Remark ISC0, ISC1: Bits 0 and 1 of the input switch control register (ISC) (See **Figure 12-21**.)

Figure 12-102. Port Configuration for Manipulating Reception of LIN (48, 64-pin)

Remark ISC0, ISC1: Bits 0 and 1 of the input switch control register (ISC) (See **Figure 12-21**.)

The peripheral functions used for the LIN communication operation are as follows.

<Peripheral functions used>

- External interrupt (INTP0); Wakeup signal detection
Usage: To detect an edge of the wakeup signal and the start of communication
- Channel 7 of timer array unit; Baud rate error detection, break field detection.
Usage: To detect the length of the sync field (SF) and divide it by the number of bits in order to detect an error (The interval of the edge input to RxD2 is measured in the capture mode.)
Measured the low-level width, determine whether break field (BF).
- Channels 0 and 1 (UART2) of serial array unit 1 (SAU1)

12.8 Operation of Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) Communication

This is a clocked communication function to communicate with two or more devices by using two lines: serial clock (SCL) and serial data (SDA). This communication function is designed to execute single communication with devices such as EEPROM, flash memory, and A/D converter, and therefore, can be used only by the master.

Operate the control registers by software for setting the start and stop conditions while observing the specifications of the I²C bus line

[Data transmission/reception]

- Master transmission, master reception (only master function with a single master)
- ACK output function^{Note} and ACK detection function
- Data length of 8 bits
(When an address is transmitted, the address is specified by the higher 7 bits, and the least significant bit is used for R/W control.)
- Generation of start condition and stop condition for software

[Interrupt function]

- Transfer end interrupt

[Error detection flag]

- Overrun error
- ACK error

* [Functions not supported by simplified I²C]

- Slave transmission, slave reception
- Multi-master function (arbitration loss detection function)
- Clock stretch detection function

Note When receiving the last data, ACK will not be output if 0 is written to the SOEmn (SOEm register) bit and serial communication data output is stopped. See the processing flow in **12.8.3 (2)** for details.

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

The channel supporting simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) is channels 0 to 3 of SAU0 and channel 0 and 1 of SAU1.

- 25-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11

- 32-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	–		–
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	–		–

- 48-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	–	UART1	–
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

- 64-pin products

Unit	Channel	Used as Simplified SPI (CSI)	Used as UART	Used as Simplified I ² C
0	0	CSI00	UART0	IIC00
	1	CSI01		IIC01
	2	CSI10	UART1	IIC10
	3	CSI11		IIC11
1	0	CSI20	UART2 (supporting LIN-bus)	IIC20
	1	CSI21		IIC21

Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) performs the following four types of communication operations.

- Address field transmission (See **12.8.1.**)
- Data transmission (See **12.8.2.**)
- Data reception (See **12.8.3.**)
- Stop condition generation (See **12.8.4.**)

12.8.1 Address field transmission

Address field transmission is a transmission operation that first executes in I²C communication to identify the target for transfer (slave). After a start condition is generated, an address (7 bits) and a transfer direction (1 bit) are transmitted in one frame.

Simplified I ² C	IIC00	IIC01	IIC10	IIC11	IIC20	IIC21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCL00, SDA00 ^{Note 1}	SCL01, SDA01 ^{Note 1}	SCL10, SDA10 ^{Note 1}	SCL11, SDA11 ^{Note 1}	SCL20, SDA20 ^{Note 1}	SCL21, SDA21 ^{Note 1}
Interrupt	INTIIC00	INTIIC01	INTIIC10	INTIIC11	INTIIC20	INTIIC21
	Transfer end interrupt only (Setting the buffer empty interrupt is prohibited.)					
Error detection flag	ACK error detection flag (PEFmn)					
Transfer data length	8 bits (transmitted with specifying the higher 7 bits as address and the least significant bit as R/W control)					
Transfer rate ^{Note 2}	Max. $f_{MCK}/4$ [MHz] (SDRmn[15:9] = 1 or more) f_{MCK} : operation clock frequency of target channel However, the following condition must be satisfied in each mode of I ² C. • Max. 1 MHz (first mode plus) • Max. 400 kHz (first mode) • Max. 100 kHz (standard mode)					
Data level	Non-reversed output (default: high level)					
Parity bit	No parity bit					
Stop bit	Appending 1 bit (or ACK reception timing)					
Data direction	MSB first					

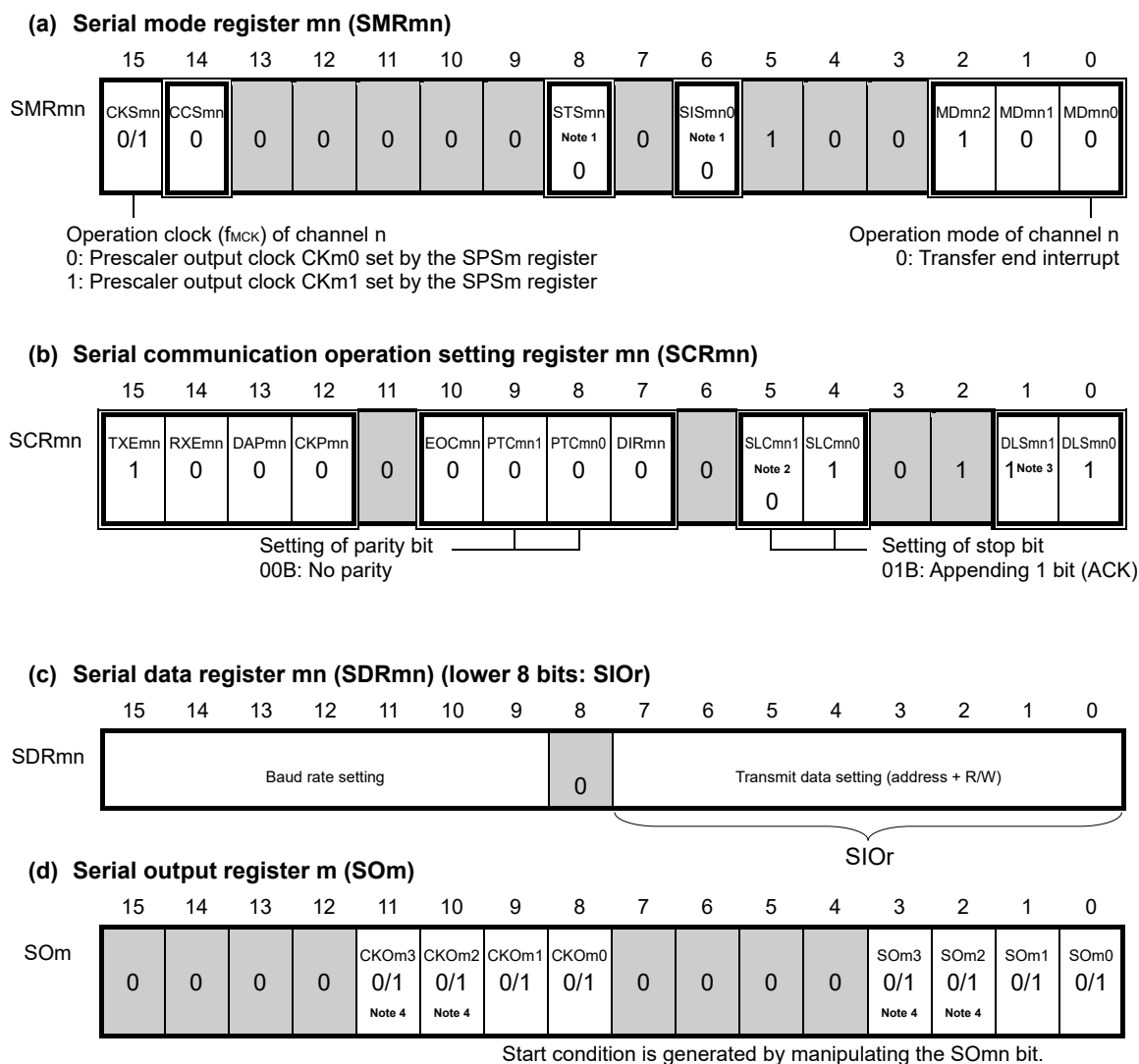
Notes 1. To perform communication via simplified I²C, set the N-ch open-drain output (V_{DD} tolerance (25- to 48-pin products/ EV_{DD} tolerance (64-pin products)) mode (POMxx = 1) for the port output mode registers (POMxx). See **4.3 Registers Controlling Port Function** and **4.5 Register Settings When Using Alternate Function** for details.

When IIC00, IIC10, IIC20 communicating with an external device with a different potential, set the N-ch open-drain output (V_{DD} tolerance (25 to 48-pin products/ EV_{DD} tolerance (64-pin products)) mode (POMxx = 1) also for the clock input/output pins (SCL00, SCL10, SCL20). See **4.4.5 Handling different potential (1.8 V, 2.5 V) by using I/O buffers** for details.

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS** ($T_A = -40$ to $+85^\circ\text{C}$) and **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS** $T_A = -40$ to $+105^\circ\text{C}$)).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(1) Register setting

Figure 12-103. Example of Contents of Registers for Address Field Transmission of Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) (1/2)

- Notes**
1. Only provided for the SMR01, SMR03, and SMR11 registers.
 2. Only provided for the SCR00, SCR02, and SCR10 registers.
 3. Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.
 4. Unit 0 only

- Remarks**
1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11
 2. : Setting is fixed in the IIC mode, : Setting disabled (set to the initial value)
 0/1: Set to 0 or 1 depending on the usage of the user

Figure 12-103. Example of Contents of Registers for Address Field Transmission of Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) (2/2)

(e) Serial output enable register m (SOEm)

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 0/1 ^{Note} e	SOEm2 0/1 ^{Note} e	SOEm1 0/1	SOEm0 0/1

SOEmn = 0 until the start condition is generated, and SOEmn = 1 after generation.

(f) Serial channel start register m (SSm) ... Sets only the bits of the target channel is 1.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 0/1 ^{Note}	SSm2 0/1 ^{Note}	SSm1 0/1	SSm0 0/1

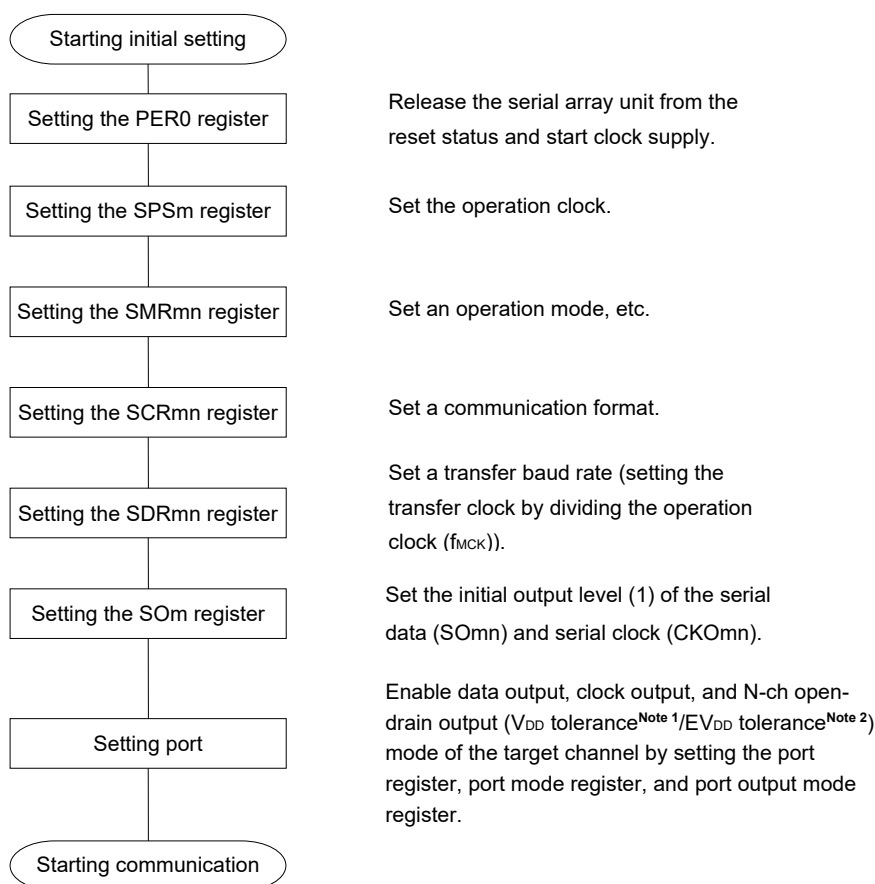
SSmn = 0 until the start condition is generated, and SSmn = 1 after generation.

Note Unit 0 only

Remarks 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

2. ☐: Setting is fixed in the IIC mode, ☐: Setting disabled (set to the initial value)
0/1: Set to 0 or 1 depending on the usage of the user

(2) Operation procedure

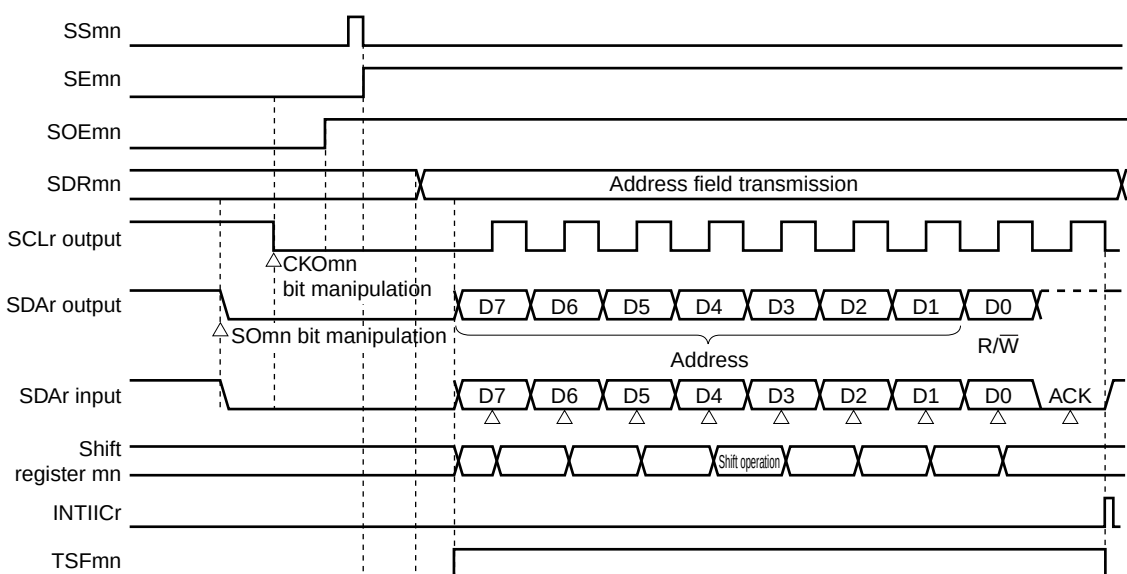
Figure 12-104. Initial Setting Procedure for Address Field Transmission**Notes** 1. 25 to 48-pin products

2. 64-pin products

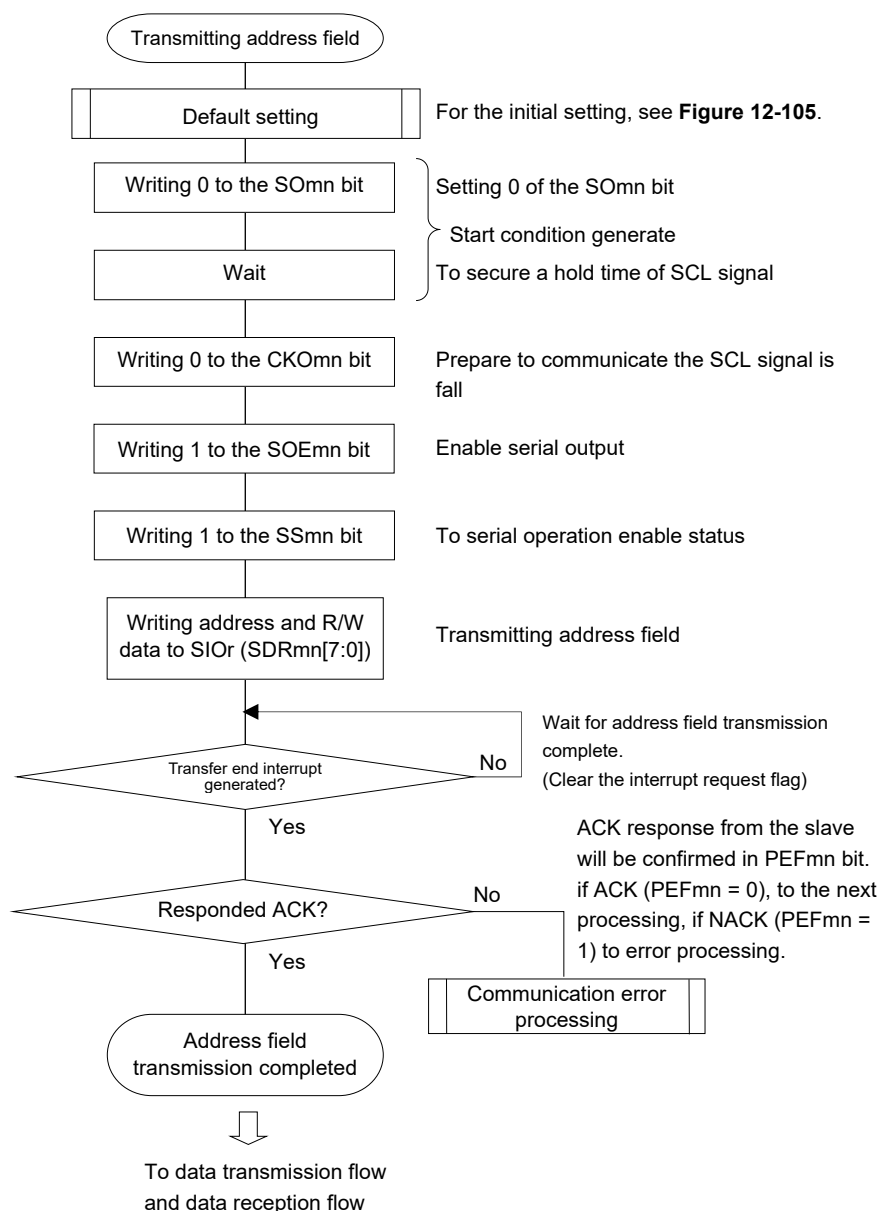
Remark m: Unit number ($m = 0, 1$), n: Channel number ($n = 0$ to 3), $mn = 00$ to 03, 10, 11

(3) Processing flow

Figure 12-105. Timing Chart of Address Field Transmission



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-106. Flowchart of Simplified I²C Address Field Transmission

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.8.2 Data transmission

Data transmission is an operation to transmit data to the target for transfer (slave) after transmission of an address field. After all data are transmitted to the slave, a stop condition is generated and the bus is released.

Simplified I ² C	IIC00	IIC01	IIC10	IIC11	IIC20	IIC21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCL00, SDA00 ^{Note 1}	SCL01, SDA01 ^{Note 1}	SCL10, SDA10 ^{Note 1}	SCL11, SDA11 ^{Note 1}	SCL20, SDA20 ^{Note 1}	SCL21, SDA21 ^{Note 1}
Interrupt	INTIIC00	INTIIC01	INTIIC10	INTIIC11	INTIIC20	INTIIC21
	Transfer end interrupt only (Setting the buffer empty interrupt is prohibited.)					
Error detection flag	ACK error detection flag (PEFmn)					
Transfer data length	8 bits					
Transfer rate ^{Note 2}	Max. $f_{MCK}/4$ [MHz] (SDRmn[15:9] = 1 or more) f_{MCK} : operation clock frequency of target channel However, the following condition must be satisfied in each mode of I ² C. • Max. 1 MHz (first mode plus) • Max. 400 kHz (first mode) • Max. 100 kHz (standard mode)					
Data level	Non-reversed output (default: high level)					
Parity bit	No parity bit					
Stop bit	Appending 1 bit (for ACK reception timing)					
Data direction	MSB first					

Notes 1. To perform communication via simplified I²C, set the N-ch open-drain output (V_{DD} tolerance (25- to 48-pin products/ EV_{DD} tolerance (64-pin products)) mode (POMxx = 1) for the port output mode registers (POMxx). See **4.3 Registers Controlling Port Function** and **4.5 Register Settings When Using Alternate Function** for details.

When IIC00, IIC10, IIC20 communicating with an external device with a different potential, set the N-ch open-drain output (V_{DD} tolerance (25 to 48-pin products/ EV_{DD} tolerance (64-pin products)) mode (POMxx = 1) also for the clock input/output pins (SCL00, SCL10, SCL20).

See **4.4.5 Handling different potential (1.8 V, 2.5 V) by using I/O buffers** for details.

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)** and **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$)**).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(1) Register setting

**Figure 12-107. Example of Contents of Registers for Data Transmission of Simplified I²C
(IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) (1/2)**

(a) **Serial mode register mn (SMRmn) ... Do not manipulate this register during data transmission/reception.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SMRmn	CKSmn 0/1	CCSmn 0	0	0	0	0	0	STSmn 0 Note 1	0	SISmn0 0 Note 1	1	0	0	MDmn2 1	MDmn1 0	MDmn0 0

(b) **Serial communication operation setting register mn (SCRmn) ... Do not manipulate the bits of this register, except the TXEmn and RXEmn bits, during data transmission/reception.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCRmn	TXEmn 1	RXEmn 0	DAPmn 0	CKPmn 0	0	EOCmn 0	PTCmn1 0	PTCmn0 0	DIRmn 0	0	SLCmn1 0 Note 2	SLCmn0 1	0	1	DLsmn1 1 Note 3	DLsmn0 1

(c) **Serial data register mn (SDRmn) (lower 8 bits: SIO_r) ... During data transmission/reception, valid only lower 8-bits (SIO_r)**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SDRmn	Baud rate setting ^{Note 4}							0	Transmit data setting							
SIO _r																

(d) **Serial output register m (SOM) ... Do not manipulate this register during data transmission/reception.**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOM	0	0	0	0	CKOm3 Note 5 0/1 Note 6	CKOm2 Note 5 0/1 Note 6	CKOm1 0/1 Note 6	CKOm0 0/1 Note 6	0	0	0	0	SOM3 Note 5 0/1 Note 6	SOM2 Note 5 0/1 Note 6	SOM1 0/1 Note 6	SOM0 0/1 Note 6

- Notes**
1. Only provided for the SMR01, SMR03, and SMR11 registers.
 2. Only provided for the SCR00, SCR02, and SCR10 registers.
 3. Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.
 4. Because the setting is completed by address field transmission, setting is not required.
 5. Unit 0 only.
 6. The value varies depending on the communication data during communication operation.

- Remarks**
1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11
 2. : Setting is fixed in the IIC mode, : Setting disabled (set to the initial value)
0/1: Set to 0 or 1 depending on the usage of the user

**Figure 12-107. Example of Contents of Registers for Data Transmission of Simplified I²C
(IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) (2/2)**

(e) Serial output enable register m (SOEm) ... Do not manipulate this register during data transmission/reception.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 1	SOEm2 Note 1	SOEm1 1	SOEm0 1

(f) Serial channel start register m (SSm) ... Do not manipulate this register during data transmission/reception.

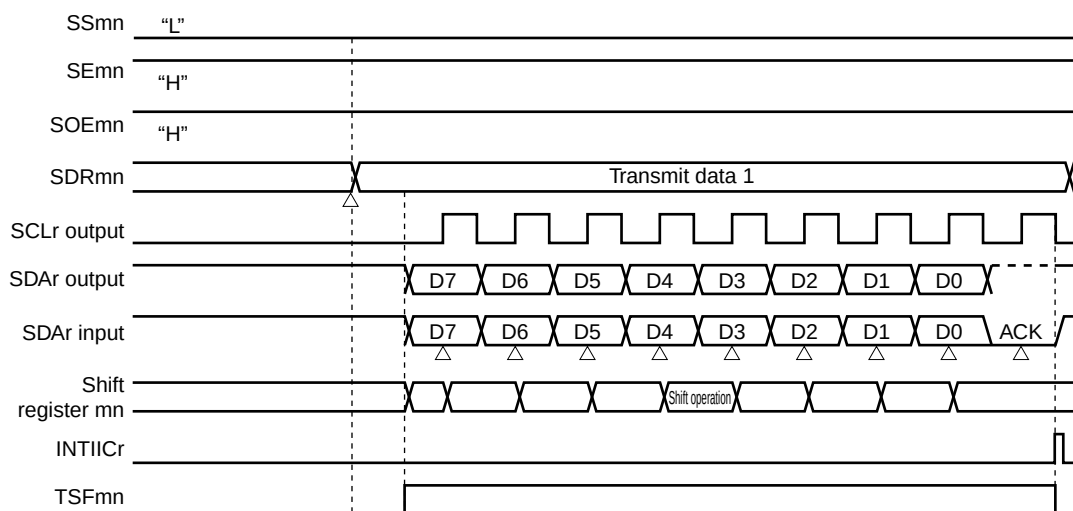
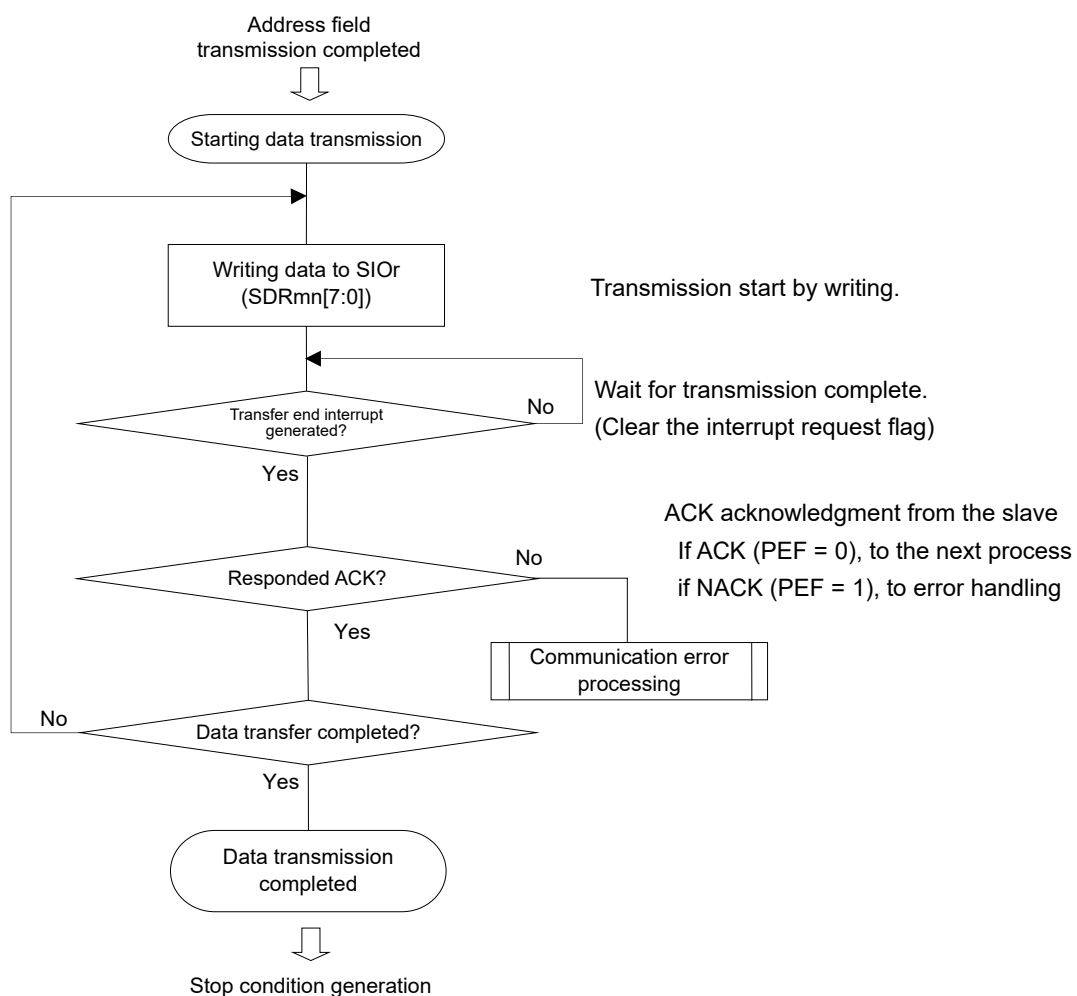
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

Note Unit 0 only.

- Remarks**
1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11
 2. ☐: Setting is fixed in the IIC mode, ☐: Setting disabled (set to the initial value)
0/1: Set to 0 or 1 depending on the usage of the user

(2) Processing flow

Figure 12-108. Timing Chart of Data Transmission

Figure 12-109. Flowchart of Simplified I²C Data Transmission

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.8.3 Data reception

Data reception is an operation to receive data to the target for transfer (slave) after transmission of an address field. After all data are received to the slave, a stop condition is generated and the bus is released.

Simplified I ² C	IIC00	IIC01	IIC10	IIC11	IIC20	IIC21
Target channel	Channel 0 of SAU0	Channel 1 of SAU0	Channel 2 of SAU0	Channel 3 of SAU0	Channel 0 of SAU1	Channel 1 of SAU1
Pins used	SCL00, SDA00 ^{Note 1}	SCL01, SDA01 ^{Note 1}	SCL10, SDA10 ^{Note 1}	SCL11, SDA11 ^{Note 1}	SCL20, SDA20 ^{Note 1}	SCL21, SDA21 ^{Note 1}
Interrupt	INTIIC00	INTIIC01	INTIIC10	INTIIC11	INTIIC20	INTIIC21
	Transfer end interrupt only (Setting the buffer empty interrupt is prohibited.)					
Error detection flag	Overrun error detection flag (OVFmn) only					
Transfer data length	8 bits					
Transfer rate ^{Note 2}	Max. $f_{MCK}/4$ [MHz] (SDRmn[15:9] = 1 or more) f_{MCK} : operation clock frequency of target channel However, the following condition must be satisfied in each mode of I ² C. • Max. 1 MHz (first mode plus) • Max. 400 kHz (first mode) • Max. 100 kHz (standard mode)					
Data level	Non-reversed output (default: high level)					
Parity bit	No parity bit					
Stop bit	Appending 1 bit (ACK transmission)					
Data direction	MSB first					

Notes 1. To perform communication via simplified I²C, set the N-ch open-drain output (V_{DD} tolerance (25 to 48-pin products/ EV_{DD} tolerance (64-pin products)) mode (POMxx = 1) for the port output mode registers (POMxx). See **4.3 Registers Controlling Port Function** and **4.5 Register Settings When Using Alternate Function** for details.

When IIC00, IIC10, IIC20 communicating with an external device with a different potential, set the N-ch open-drain output (V_{DD} tolerance (25 to 48-pin products/ EV_{DD} tolerance (64-pin products)) mode (POMxx = 1) also for the clock input/output pins (SCL00, SCL10, SCL20).

See **4.4.5 Handling different potential (1.8 V, 2.5 V) by using I/O buffers** for details.

2. Use this operation within a range that satisfies the conditions above and the peripheral functions characteristics in the electrical specifications (see **CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)** and **CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^\circ\text{C}$)**).

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

(1) Register setting

Figure 12-110. Example of Contents of Registers for Data Reception of Simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) (1/2)

(a) Serial mode register mn (SMRmn) ... Do not manipulate this register during data transmission/reception.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SMRmn	CKSmn 0/1	CCSmn 0	0	0	0	0	0	STSmn 0 Note 1	0	SISmn0 0 Note 1	1	0	0	MDmn2 1	MDmn1 0	MDmn0 0

(b) Serial communication operation setting register mn (SCRmn) ... Do not manipulate the bits of this register, except the TXEmn and RXEmn bits, during data transmission/reception.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCRmn	TXEmn 0	RXEmn 1	DAPmn 0	CKPmn 0	0	EOCmn 0	PTCmn1 0	PTCmn0 0	DIRmn 0	0	SLCmn1 0 Note 2	SLCmn0 1	0	1	DLSmn1 1 Note 3	DLSmn0 1

(c) Serial data register mn (SDRmn) (lower 8 bits: SIO_r)

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SDRmn	Baud rate setting ^{Note 4}							0	Dummy transmit data setting (FFH)							
SIO _r																

(d) Serial output register m (SOM) ... Do not manipulate this register during data transmission/reception.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOM	0	0	0	0	CKOm3 Note 5 0/1 Note 6	CKOm2 Note 5 0/1 Note 6	CKOm1 0/1 Note 6	CKOm0 0/1 Note 6	0	0	0	0	SOM3 Note 5 0/1 Note 6	SOM2 Note 5 0/1 Note 6	SOM1 0/1 Note 6	SOM0 0/1 Note 6

- Notes**
1. Only provided for the SMR01, SMR03, and SMR11 registers.
 2. Only provided for the SCR00, SCR02, and SCR10 registers.
 3. Only provided for the SCR00 and SCR01 registers. This bit is fixed to 1 for the other registers.
 4. Because the setting is completed by address field transmission, setting is not required.
 5. Unit 0 only.
 6. The value varies depending on the communication data during communication operation.

- Remarks**
1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11
 2. : Setting is fixed in the IIC mode, : Setting disabled (set to the initial value)
0/1: Set to 0 or 1 depending on the usage of the user

**Figure 12-110. Example of Contents of Registers for Data Reception of Simplified I²C
(IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) (2/2)**

(e) Serial output enable register m (SOEm) ... Do not manipulate this register during data transmission/reception.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SOEm	0	0	0	0	0	0	0	0	0	0	0	0	SOEm3 Note 0/1	SOEm2 Note 0/1	SOEm1 0/1	SOEm0 0/1

(f) Serial channel start register m (SSm) ... Do not manipulate this register during data transmission/reception.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SSm	0	0	0	0	0	0	0	0	0	0	0	0	SSm3 Note 0/1	SSm2 Note 0/1	SSm1 0/1	SSm0 0/1

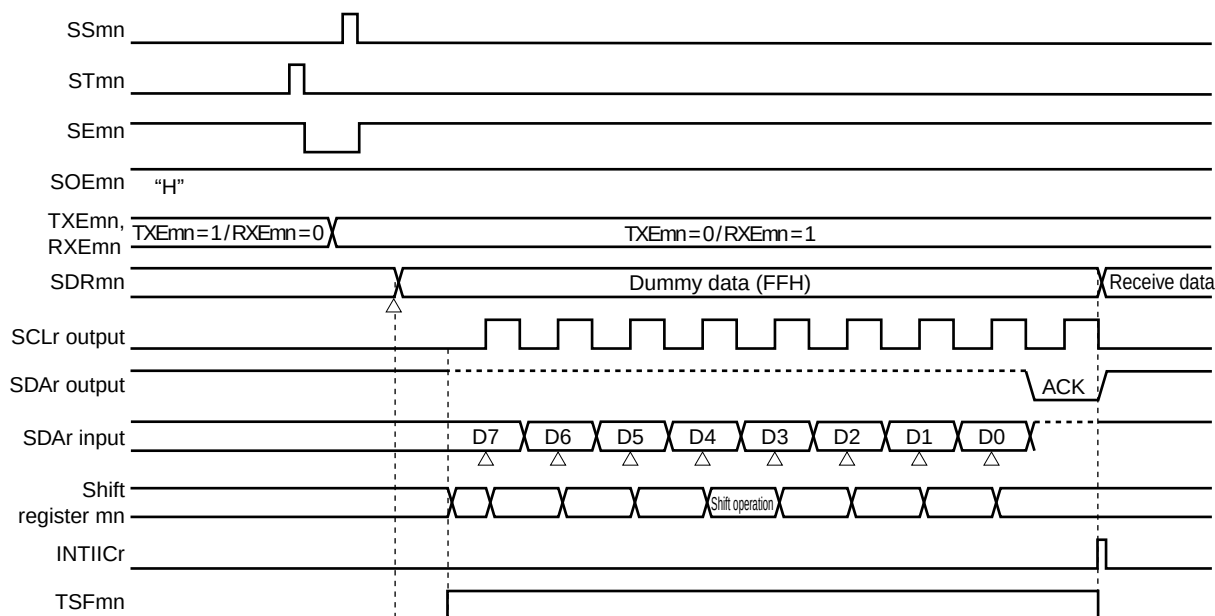
Note Unit 0 only

- Remarks** 1. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11
 2. ☐: Setting is fixed in the IIC mode, ☐: Setting disabled (set to the initial value)
 0/1: Set to 0 or 1 depending on the usage of the user

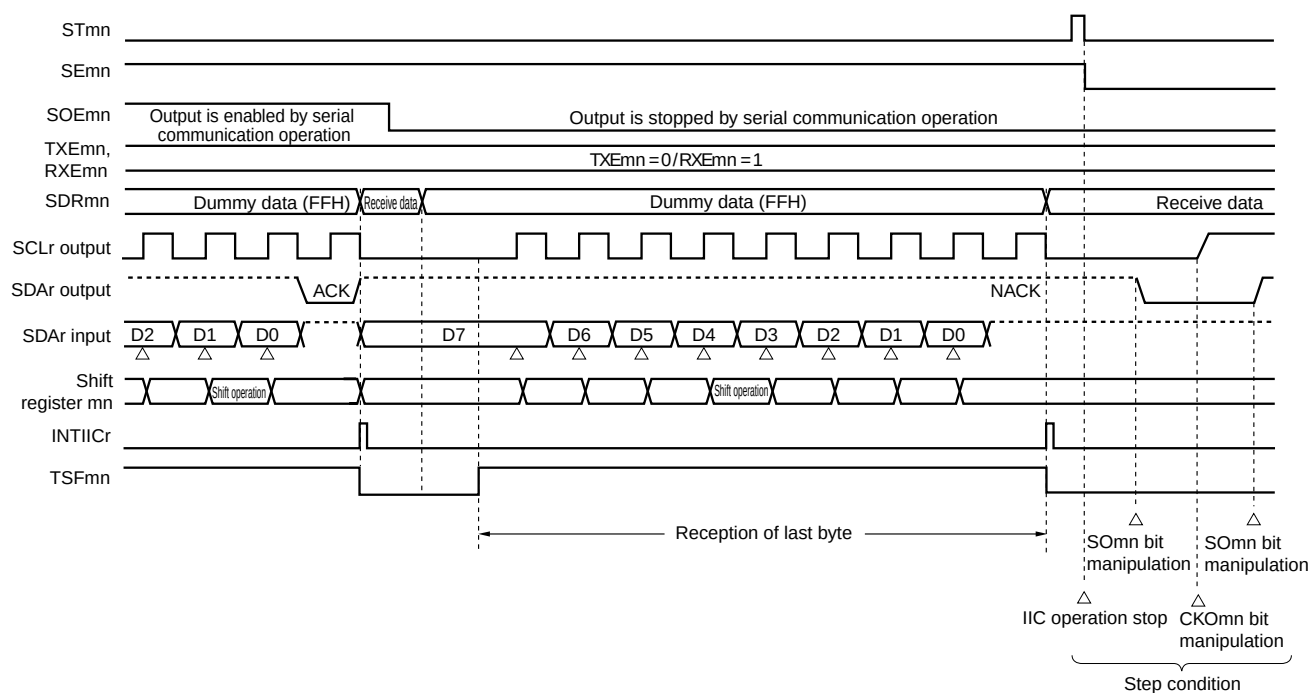
(2) Processing flow

Figure 12-111. Timing Chart of Data Reception

(a) When starting data reception

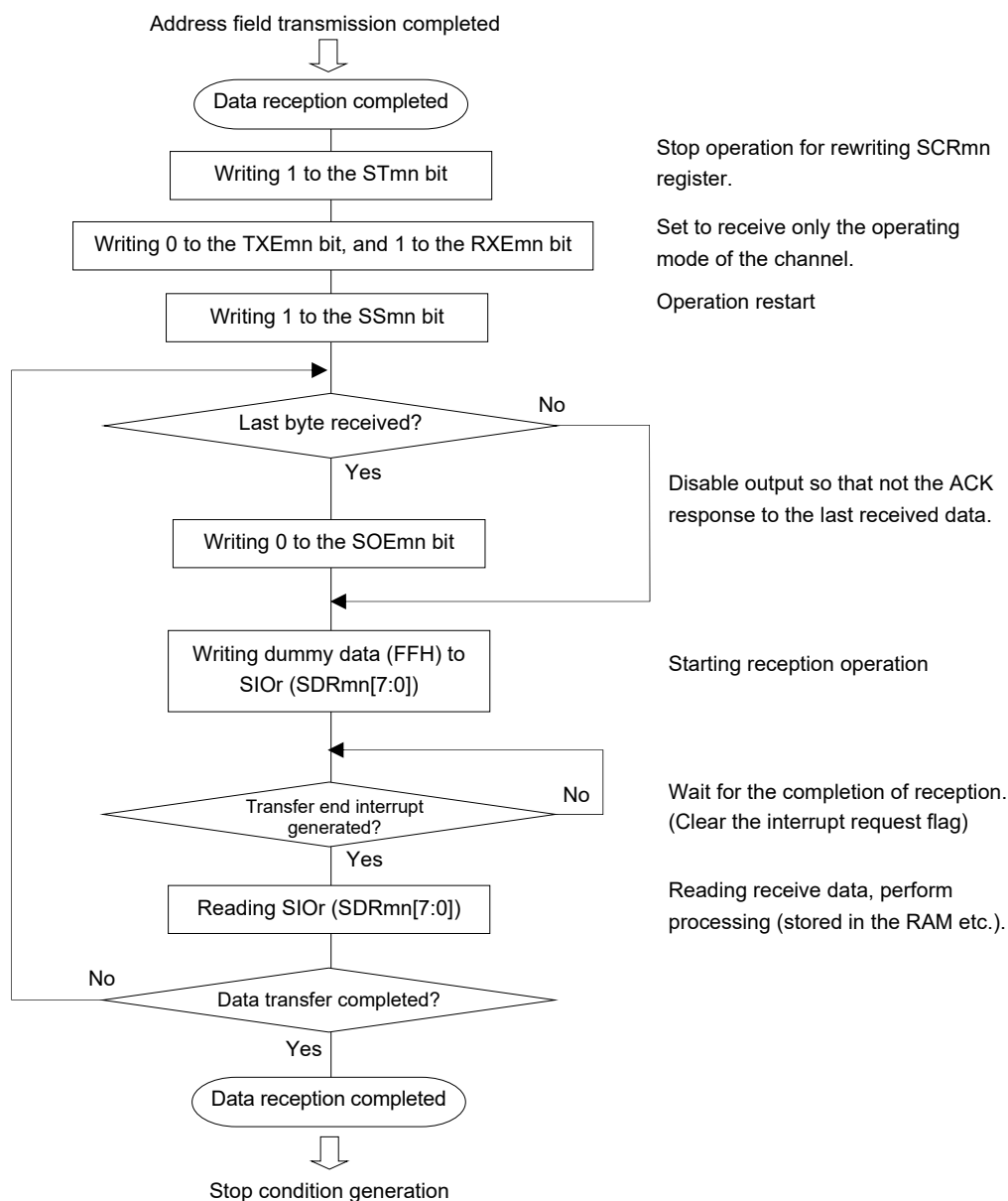


(b) When receiving last data



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

Figure 12-112. Flowchart of Data Reception



Caution ACK is not output when the last data is received (NACK). Communication is then completed by setting “1” to the STmn bit of serial channel stop register m (STm) to stop operation and generating a stop condition.

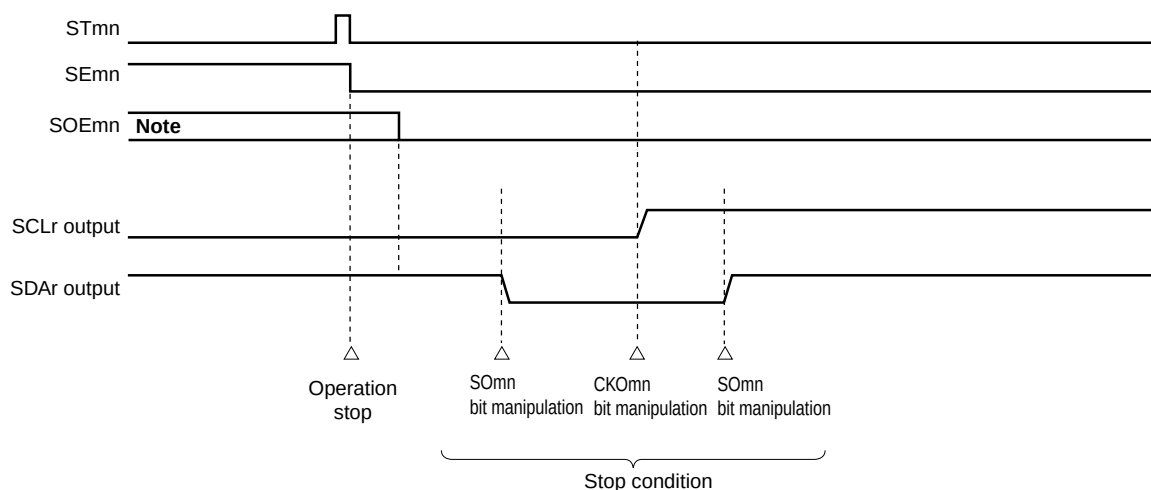
Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.8.4 Stop condition generation

After all data are transmitted to or received from the target slave, a stop condition is generated and the bus is released.

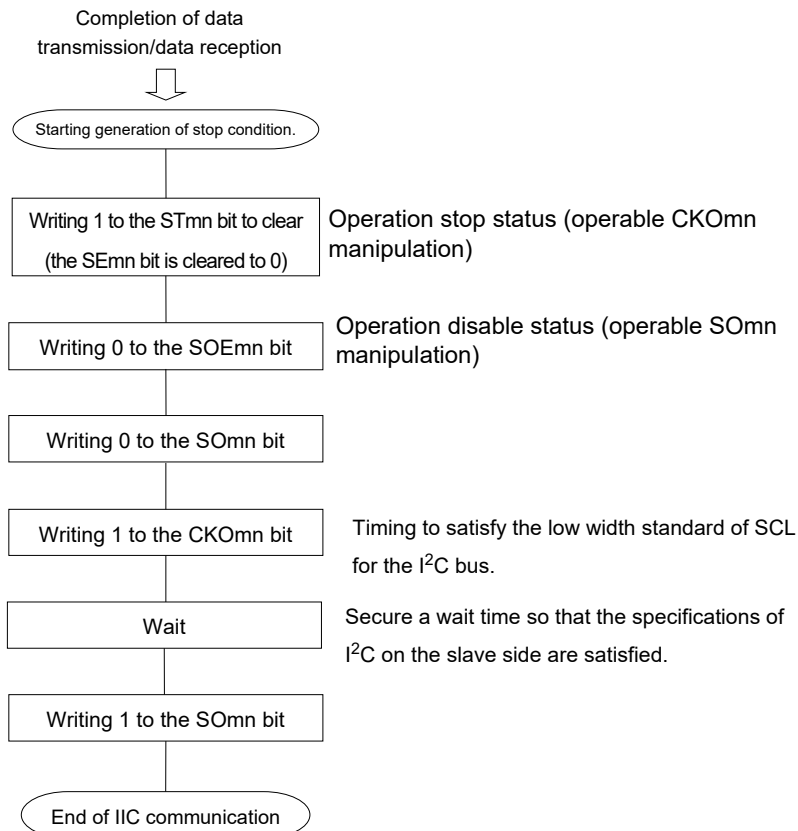
(1) Processing flow

Figure 12-113. Timing Chart of Stop Condition Generation



Note During a receive operation, the SOEmn bit of serial output enable register m (SOEm) is cleared to 0 before receiving the last data.

Figure 12-114. Flowchart of Stop Condition Generation



Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21), mn = 00 to 03, 10, 11

12.8.5 Calculating transfer rate

The transfer rate for simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) communication can be calculated by the following expressions.

$$(\text{Transfer rate}) = \{\text{Operation clock (f}_{\text{MCK}}) \text{ frequency of target channel}\} \div (\text{SDRmn}[15:9] + 1) \div 2$$

Caution SDRmn[15:9] must not be set to 00000000B. Be sure to set a value of 00000001B or greater for SDRmn[15:9]. The duty ratio of the SCL signal output by the simplified I²C is 50%. The I²C bus specifications define that the low-level width of the SCL signal is longer than the high-level width. If 400 kbps (fast mode) or 1 Mbps (fast mode plus) is specified, therefore, the low-level width of the SCL output signal becomes shorter than the value specified in the I²C bus specifications. Make sure that the SDRmn[15:9] value satisfies the I²C bus specifications.

- Remarks**
1. The value of SDRmn[15:9] is the value of bits 15 to 9 of the SDRmn register (0000001B to 1111111B) and therefore is 1 to 127.
 2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

The operation clock (f_{MCK}) is determined by serial clock select register m (SPSm) and bit 15 (CKSmn) of serial mode register mn (SMRmn).

Table 12-5. Selection of Operation Clock For Simplified I²C

SMRmn Register	SPSm Register								Operation Clock (f _{MCK}) ^{Note}	
CKSmn	PRS m13	PRS m12	PRS m11	PRS m10	PRS m03	PRS m02	PRS m01	PRS m00		f _{CLK} = 32 MHz
0	X	X	X	X	0	0	0	0	f _{CLK}	32 MHz
	X	X	X	X	0	0	0	1	f _{CLK} /2	16 MHz
	X	X	X	X	0	0	1	0	f _{CLK} /2 ²	8 MHz
	X	X	X	X	0	0	1	1	f _{CLK} /2 ³	4 MHz
	X	X	X	X	0	1	0	0	f _{CLK} /2 ⁴	2 MHz
	X	X	X	X	0	1	0	1	f _{CLK} /2 ⁵	1 MHz
	X	X	X	X	0	1	1	0	f _{CLK} /2 ⁶	500 kHz
	X	X	X	X	0	1	1	1	f _{CLK} /2 ⁷	250 kHz
	X	X	X	X	1	0	0	0	f _{CLK} /2 ⁸	125 kHz
	X	X	X	X	1	0	0	1	f _{CLK} /2 ⁹	62.5 kHz
	X	X	X	X	1	0	1	0	f _{CLK} /2 ¹⁰	31.25 kHz
	X	X	X	X	1	0	1	1	f _{CLK} /2 ¹¹	15.63 kHz
1	0	0	0	0	X	X	X	X	f _{CLK}	32 MHz
	0	0	0	1	X	X	X	X	f _{CLK} /2	16 MHz
	0	0	1	0	X	X	X	X	f _{CLK} /2 ²	8 MHz
	0	0	1	1	X	X	X	X	f _{CLK} /2 ³	4 MHz
	0	1	0	0	X	X	X	X	f _{CLK} /2 ⁴	2 MHz
	0	1	0	1	X	X	X	X	f _{CLK} /2 ⁵	1 MHz
	0	1	1	0	X	X	X	X	f _{CLK} /2 ⁶	500 kHz
	0	1	1	1	X	X	X	X	f _{CLK} /2 ⁷	250 kHz
	1	0	0	0	X	X	X	X	f _{CLK} /2 ⁸	125 kHz
	1	0	0	1	X	X	X	X	f _{CLK} /2 ⁹	62.5 kHz
	1	0	1	0	X	X	X	X	f _{CLK} /2 ¹⁰	31.25 kHz
	1	0	1	1	X	X	X	X	f _{CLK} /2 ¹¹	15.63 kHz
Other than above									Setting prohibited	

Note When changing the clock selected for f_{CLK} (by changing the system clock control register (CKC) value), do so after having stopped (serial channel stop register m (STm) = 000FH) the operation of the serial array unit (SAU).

Remarks 1. X: Don't care

2. m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11

Here is an example of setting an I²C transfer rate where f_{MCK} = f_{CLK} = 32 MHz.

I ² C Transfer Mode (Desired Transfer Rate)	f _{CLK} = 32 MHz			
	Operation Clock (f _{MCK})	SDRmn[15:9]	Calculated Transfer Rate	Error from Desired Transfer Rate
100 kHz	f _{CLK} /2	79	100 kHz	0.0%
400 kHz	f _{CLK}	41	380 kHz	5.0% ^{Note}
1 MHz	f _{CLK}	18	0.84 MHz	16.0% ^{Note}

Note The error cannot be set to about 0% because the duty ratio of the SCL signal is 50%.

12.8.6 Procedure for processing errors that occurred during simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) communication

The procedure for processing errors that occurred during simplified I²C (IIC00, IIC01, IIC10, IIC11, IIC20, IIC21) communication is described in Figure 12-115 and 12-116.

Figure 12-115. Processing Procedure in Case of Overrun Error

Software Manipulation	Hardware Status	Remark
Reads serial data register mn (SDRmn). →	The BFFmn bit of the SSRmn register is set to 0 and channel n is enabled to receive data.	This is to prevent an overrun error if the next reception is completed during error processing.
Reads serial status register mn (SSRmn).		Error type is identified and the read value is used to clear error flag.
Writes 1 to serial flag clear trigger register mn (SIRmn). →	Error flag is cleared.	Error can be cleared only during reading, by writing the value read from the SSRmn register to the SIRmn register without modification.

Figure 12-116. Processing Procedure in Case of ACK Error in Simplified I²C Mode

Software Manipulation	Hardware Status	Remark
Reads serial status register mn (SSRmn).		Error type is identified and the read value is used to clear error flag.
Writes serial flag clear trigger register mn (SIRmn). →	Error flag is cleared.	Error can be cleared only during reading, by writing the value read from the SSRmn register to the SIRmn register without modification.
Sets the STmn bit of serial channel stop register m (STm) to 1. →	The SEMn bit of serial channel enable status register m (SEm) is set to 0 and channel n stops operation.	Slave is not ready for reception because ACK is not returned. Therefore, a stop condition is created, the bus is released, and communication is started again from the start condition. Or, a restart condition is generated and transmission can be redone from address transmission.
Creates stop condition.		
Creates start condition.		
Sets the SSmn bit of serial channel start register m (SSm) to 1. →	The SEMn bit of serial channel enable status register m (SEm) is set to 1 and channel n is enabled to operate.	

Remark m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), r: IIC number (r = 00, 01, 10, 11, 20, 21)
mn = 00 to 03, 10, 11

CHAPTER 13 SERIAL INTERFACE IICA

13.1 Functions of Serial Interface IICA

Serial interface IICA has the following three modes.

(1) Operation stop mode

This mode is used when serial transfers are not performed. It can therefore be used to reduce power consumption.

(2) I²C bus mode (multimaster supported)

This mode is used for 8-bit data transfers with several devices via two lines: a serial clock (SCLA0) line and a serial data bus (SDAA0) line.

This mode complies with the I²C 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 these received status and data by hardware. This function can simplify the part of application program that controls the I²C bus.

Since the SCLA0 and SDAA0 pins are used for open drain outputs, serial interface IICA requires pull-up resistors for the serial clock line and the serial data bus line.

(3) Wakeup mode

The STOP mode can be released by generating an interrupt request signal (INTIICA0) when an extension code from the master device or a local address has been received while in STOP mode. This can be set by using the WUP0 bit of IICA control register 01 (IICCTL01).

Figure 13-1 shows a block diagram of serial interface IICA.

Figure 13-1. Block Diagram of Serial Interface IICA

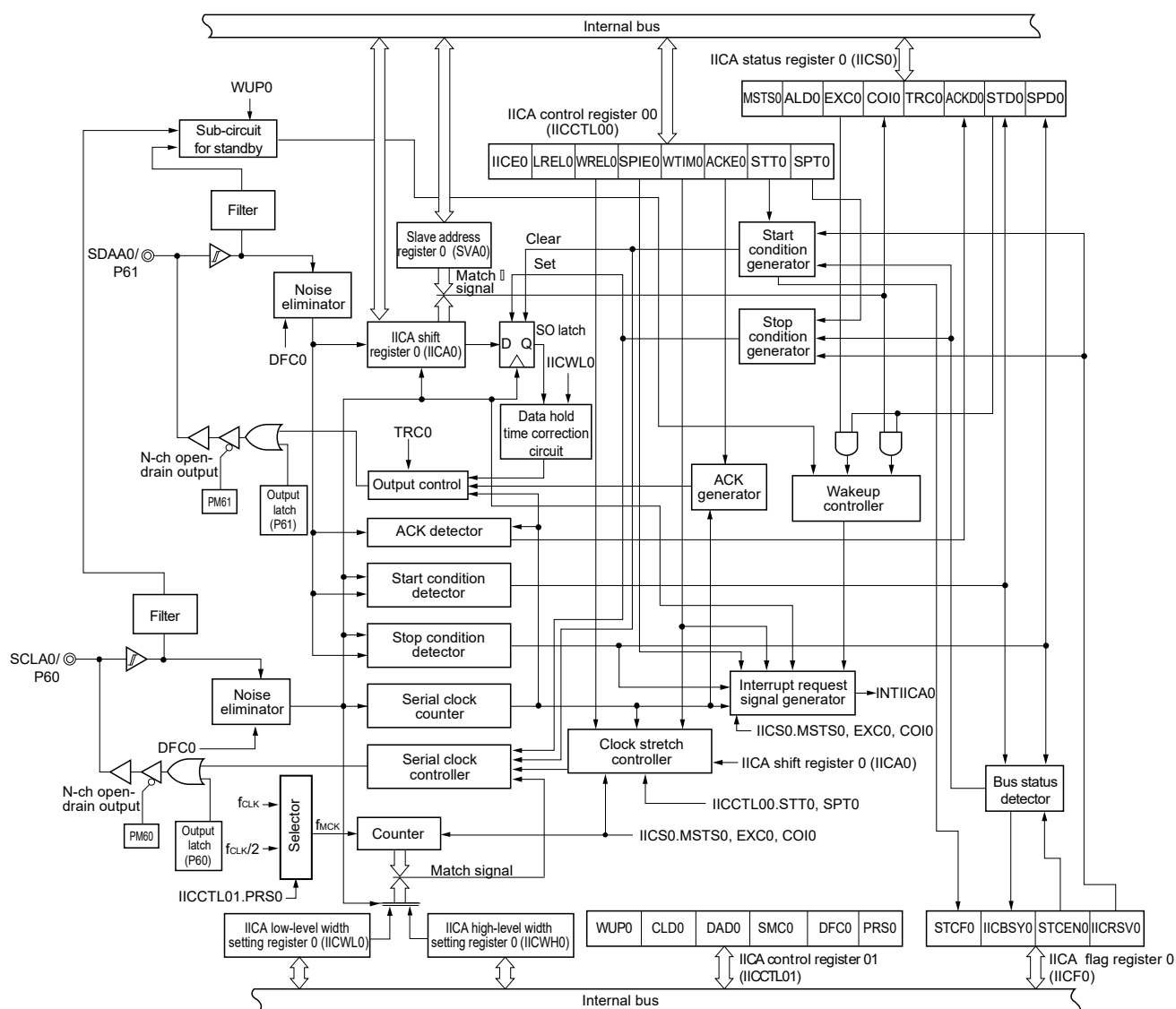
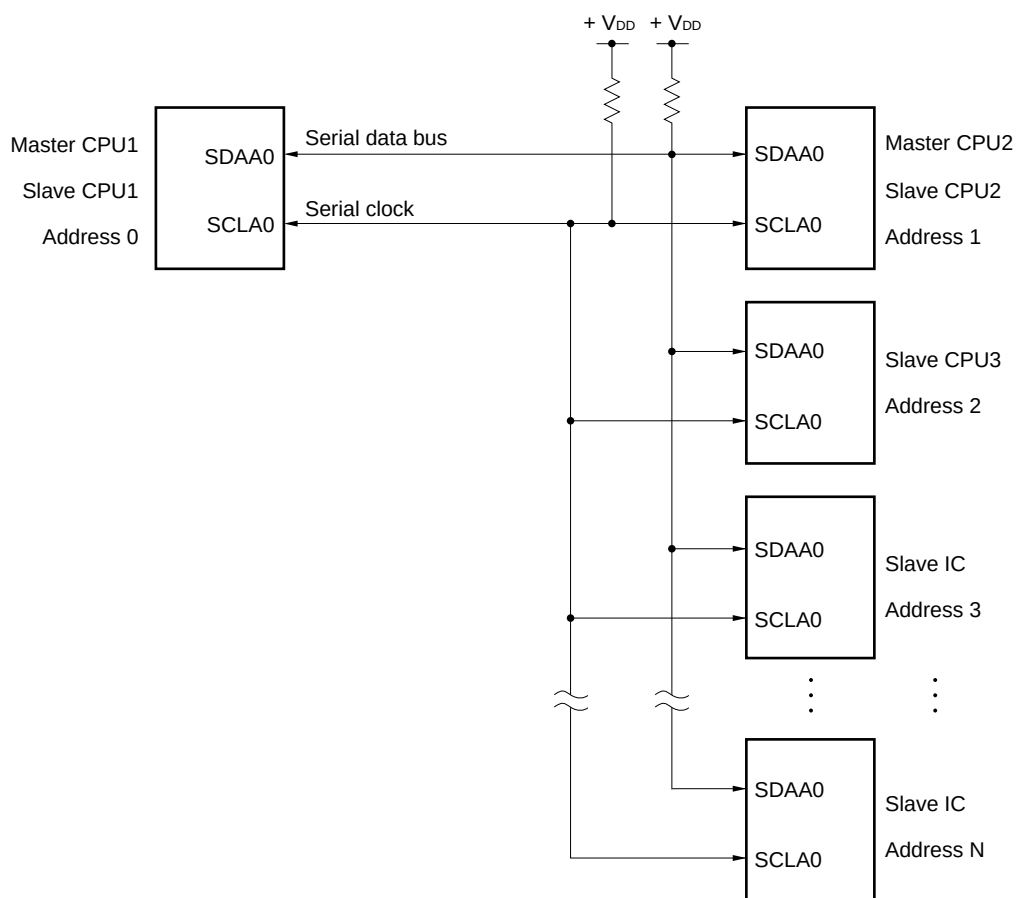


Figure 13-2 shows a serial bus configuration example.

Figure 13-2. Serial Bus Configuration Example Using I²C Bus



13.2 Configuration of Serial Interface IICA

Serial interface IICA includes the following hardware.

Table 13-1. Configuration of Serial Interface IICA

Item	Configuration
Registers	IICA shift register 0 (IICA0) Slave address register 0 (SVA0)
Control registers	Peripheral enable register 0 (PER0) IICA control register 00 (IICCTL00) IICA status register 0 (IICS0) IICA flag register 0 (IICF0) IICA control register 01 (IICCTL01) IICA low-level width setting register 0 (IICWL0) IICA high-level width setting register 0 (IICWH0) Port mode register 6 (PM6) Port register 6 (P6)

(1) IICA shift register 0 (IICA0)

The IICA0 register is used to convert 8-bit serial data to 8-bit parallel data and vice versa in synchronization with the serial clock. The IICA0 register can be used for both transmission and reception.

The actual transmit and receive operations can be controlled by writing and reading operations to the IICA0 register. Cancel the clock stretch state and start data transfer by writing data to the IICA0 register during the clock stretch period.

The IICA0 register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears IICA0 to 00H.

Figure 13-3. Format of IICA Shift Register 0 (IICA0)

Address: FFF50H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
IICA0								

Cautions 1. Do not write data to the IICA0 register during data transfer.

2. Write or read the IICA0 register only during the clock stretch period. Accessing the IICA0 register in a communication state other than during the clock stretch period is prohibited. When the device serves as the master, however, the IICA0 register can be written only once after the communication trigger bit (STT0) is set to 1.

3. When communication is reserved, write data to the IICA0 register after the interrupt triggered by a stop condition is detected.

(2) Slave address register 0 (SVA0)

This register stores seven bits of local addresses {A6, A5, A4, A3, A2, A1, A0} when in slave mode.

The SVA0 register can be set by an 8-bit memory manipulation instruction.

However, rewriting to this register is prohibited while STD0 = 1 (while the start condition is detected).

Reset signal generation clears the SVA0 register to 00H.

Figure 13-4. Format of Slave Address Register 0 (SVA0)

Address: F0234H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
SVA0	A6	A5	A4	A3	A2	A1	A0	0 ^{Note}

Note Bit 0 is fixed to 0.**(3) SO latch**

The SO latch is used to retain the SDAA0 pin's output level.

(4) Wakeup controller

This circuit generates an interrupt request (INTIICA0) when the address received by this register matches the address value set to the slave address register 0 (SVA0) or when an extension code is received.

(5) Serial clock counter

This counter counts the serial clocks that are output or input during transmit/receive operations and is used to verify that 8-bit data was transmitted or received.

(6) Interrupt request signal generator

This circuit controls the generation of interrupt request signals (INTIICA0).

An I²C interrupt request is generated by the following two triggers.

- Falling edge of eighth or ninth clock of the serial clock (set by the WTIM0 bit)
- Interrupt request generated when a stop condition is detected (set by the SPIE0 bit)

Remark WTIM0 bit: Bit 3 of IICA control register 00 (IICCTL00)

SPIE0 bit: Bit 4 of IICA control register 00 (IICCTL00)

(7) Serial clock controller

In master mode, this circuit generates the clock output via the SCLA0 pin from a sampling clock.

(8) Clock stretch controller

This circuit controls the timing of clock stretching.

(9) ACK generator, stop condition detector, start condition detector, and ACK detector

These circuits generate and detect each status.

(10) Data hold time correction circuit

This circuit generates the hold time for data corresponding to the falling edge of the serial clock.

(11) Start condition generator

This circuit generates a start condition when the STT0 bit is set to 1.

However, in the communication reservation disabled status (IICRSV bit = 1), when the bus is not released (IICBSY bit = 1), start condition requests are ignored and the STCF bit is set to 1.

(12) Stop condition generator

This circuit generates a stop condition when the SPT0 bit is set to 1.

(13) Bus status detector

This circuit detects whether or not the bus is released by detecting start conditions and stop conditions.

However, as the bus status cannot be detected immediately following operation, the initial status is set by the STCEN bit.

Remark	STT0 bit:	Bit 1 of IICA control register 00 (IICCTL00)
	SPT0 bit:	Bit 0 of IICA control register 00 (IICCTL00)
	IICRSV bit:	Bit 0 of IICA flag register 0 (IICF0)
	IICBSY bit:	Bit 6 of IICA flag register 0 (IICF0)
	STCF bit:	Bit 7 of IICA flag register 0 (IICF0)
	STCEN bit:	Bit 1 of IICA flag register 0 (IICF0)

13.3 Registers Controlling Serial Interface IICA

Serial interface IICA0 is controlled by the following registers.

- Peripheral enable register 0 (PER0)
- IICA control register 00 (IICCTL00)
- IICA flag register 0 (IICF0)
- IICA status register 0 (IICS0)
- IICA control register 01 (IICCTL01)
- IICA low-level width setting register 0 (IICWL0)
- IICA high-level width setting register 0 (IICWH0)
- Port mode register 6 (PM6)
- Port register 6 (P6)

13.3.1 Peripheral enable register 0 (PER0)

This register is used to enable or disable supplying the clock to the peripheral hardware. Clock supply to a hardware macro that is not used is stopped in order to reduce the power consumption and noise.

When serial interface IICA0 is used, be sure to set bit 4 (IICA0EN) of this register to 1.

The PER0 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 13-5. Format of Peripheral Enable Register 0 (PER0)

Address: F00F0H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PER0	RTCEN	0	ADCEN	IICA0EN	SAU1EN ^{Note}	SAU0EN	0	TAU0EN

IICA0EN	Control of serial interface IICA0 input clock supply
0	Stops input clock supply. • SFR used by serial interface IICA0 cannot be written. • Serial interface IICA0 is in the reset status.
1	Enables input clock supply. • SFR used by serial interface IICA0 can be read/written.

Note 32-, 48-, and 64-pin products only.

Cautions 1. When setting serial interface IICA0, be sure to set the following registers first while the IICA0EN bit is set to 1. If IICA0EN = 0, the control registers of serial interface IICA are set to their initial values, and writing to them is ignored (except for port mode register 6 (PM6) and port register 6 (P6)).

- IICA control register 00 (IICCTL00)
- IICA flag register 0 (IICF0)
- IICA status register 0 (IICS0)
- IICA control register 01 (IICCTL01)
- IICA low-level width setting register 0 (IICWL0)
- IICA high-level width setting register 0 (IICWH0)

2. Be sure to clear the following bits to 0.

25-pin products: bits 1, 3, 6

32-, 48-, 64-pin products: bits 1, 6

13.3.2 IICA control register 00 (IICCTL00)

This register is used to enable/stop I²C operations, set clock stretch timing, and set other I²C operations.

The IICCTL00 register can be set by a 1-bit or 8-bit memory manipulation instruction. However, set the SPIE0, WTIM0, and ACKE0 bits while IICE0 = 0 or during the clock stretch period. These bits can be set at the same time when the IICE0 bit is set from “0” to “1”.

Reset signal generation clears this register to 00H.

Figure 13-6. Format of IICA Control Register 00 (IICCTL00) (1/4)

Address: F0230H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IICCTL00	IICE0	LREL0	WREL0	SPIE0	WTIM0	ACKE0	STT0	SPT0

IICE0	I ² C operation enable
0	Stop operation. Reset the IICA status register 0 (IICS0) ^{Note 1} . Stop internal operation.
1	Enable operation.
Be sure to set this bit (1) while the SCLA0 and SDAA0 lines are at high level.	
Condition for clearing (IICE0 = 0)	
• Cleared by instruction • Reset	
Condition for setting (IICE0 = 1)	
• Set by instruction	
LREL0 ^{Notes 2, 3}	Exit from communications
0	Normal operation
1	This exits from the current communications and sets standby mode. This setting is automatically cleared to 0 after being executed. Its uses include cases in which a locally irrelevant extension code has been received. The SCLA0 and SDAA0 lines are set to high impedance. The following flags of IICA control register 00 (IICCTL00) and the IICA status register 0 (IICS0) are cleared to 0. • STT0 • SPT0 • MSTS0 • EXC0 • COI0 • TRC0 • ACKD0 • STD0
The standby mode following exit from communications remains in effect until the following communications entry conditions are met. • After a stop condition is detected, restart is in master mode. • An address match or extension code reception occurs after the start condition.	
Condition for clearing (LREL0 = 0)	
• Automatically cleared after execution • Reset	
Condition for setting (LREL0 = 1)	
• Set by instruction	
WREL0 ^{Notes 2, 3}	Clock stretch cancellation
0	Do not cancel clock stretch
1	Cancel clock stretch. This setting is automatically cleared after clock stretch is canceled.
When the WREL0 bit is set (clock stretch canceled) during the clock stretch period at the ninth clock pulse in the transmission status (TRC0 = 1), the SDAA0 line goes into the high impedance state (TRC0 = 0).	
Condition for clearing (WREL0 = 0)	
• Automatically cleared after execution • Reset	
Condition for setting (WREL0 = 1)	
• Set by instruction	

Notes 1. The IICA status register 0 (IICS0), the STCF and IICBSY bits of the IICA flag register 0 (IICF0), and the CLD0 and DAD0 bits of IICA control register 01 (IICCTL01) are reset.

2. The signal of this bit is invalid while IICE0 is 0.

3. When the LREL0 and WREL0 bits are read, 0 is always read.

Caution If the operation of I²C is enabled (IICE0 = 1) when the SCLA0 line is high level, the SDAA0 line is low level, and the digital filter is turned on (DFC0 bit of IICCTL01 register = 1), a start condition will be inadvertently detected immediately. In this case, set (1) the LREL0 bit by using a 1-bit memory manipulation instruction immediately after enabling operation of I²C (IICE0 = 1).

Figure 13-6. Format of IICA Control Register 00 (IICCTL00) (2/4)

SPIE0 ^{Note 1}	Enable/disable generation of interrupt request when stop condition is detected
0	Disable
1	Enable
If the WUP0 bit of IICA control register 01 (IICCTL01) is 1, no stop condition interrupt will be generated even if SPIE0 = 1.	
Condition for clearing (SPIE0 = 0)	Condition for setting (SPIE0 = 1)
• Cleared by instruction • Reset	• Set by instruction

WTIM0 ^{Note 1}	Control of clock stretch and interrupt request generation	
0	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 clock stretch is set. Slave mode: After input of eight clocks, the clock is set to low level and clock stretch is set for master device.	
1	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 clock stretch is set. Slave mode: After input of nine clocks, the clock is set to low level and clock stretch is set for master device.	
An interrupt is generated at the falling edge of the ninth clock during address transfer independently of the setting of this bit. The setting of this bit is valid when the address transfer is completed. When in master mode, a clock stretch is inserted at the falling edge of the ninth clock during address transfers. For a slave device that has received a local address, a clock stretch is inserted at the falling edge of the ninth clock after an acknowledge (ACK) is issued. However, when the slave device has received an extension code, a clock stretch is inserted at the falling edge of the eighth clock.		
Condition for clearing (WTIM0 = 0)		Condition for setting (WTIM0 = 1)
• Cleared by instruction • Reset		• Set by instruction

ACKE0 ^{Notes 1, 2}	Acknowledgment control	
0	Disable acknowledgment.	
1	Enable acknowledgment. During the ninth clock period, the SDAA0 line is set to low level.	
Condition for clearing (ACKE0 = 0)		Condition for setting (ACKE0 = 1)
• Cleared by instruction • Reset		• Set by instruction

- Notes**
1. The signal of this bit is invalid while IICE0 is 0. Set this bit during that period.
 2. The set value is invalid during address transfer and if the code is not an extension code.
When the device serves as a slave and the addresses match, an acknowledgment is generated regardless of the set value.

Figure 13-6. Format of IICA Control Register 00 (IICCTL00) (3/4)

STT0 ^{Notes} 1, 2	Start condition trigger
0	Do not generate a start condition.
1	When bus is released (in standby state, when IICBSY = 0): If this bit is set (1), a start condition is generated (startup as the master). When a third party is communicating: - When communication reservation function is enabled (IICRSV = 0) Functions as the start condition reservation flag. When set to 1, automatically generates a start condition after the bus is released. - When communication reservation function is disabled (IICRSV = 1) Even if this bit is set (1), the STT0 bit is cleared and the STT0 clear flag (STCF) is set (1). No start condition is generated. In the clock stretch state (when master device): Generates a restart condition after releasing the clock stretch.
Cautions concerning set timing - For master reception: Cannot be set to 1 during transfer. Can be set to 1 only in the clock stretch period when the ACKE0 bit has been cleared to 0 and slave has been notified of final reception. - For master transmission: A start condition cannot be generated normally during the acknowledge period. Set to 1 during the clock stretch period that follows output of the ninth clock. - Cannot be set to 1 at the same time as stop condition trigger (SPT0). - Once STT0 is set (1), setting it again (1) before the clear condition is met is not allowed.	
Condition for clearing (STT0 = 0)	Condition for setting (STT0 = 1)
- Cleared by setting the STT0 bit to 1 while communication reservation is prohibited. - Cleared by loss in arbitration - Cleared after start condition is generated by master device - Cleared by LREL0 = 1 (exit from communications) - When IICE0 = 0 (operation stop) - Reset	Set by instruction

Notes 1. The signal of this bit is invalid while IICE0 is 0.

2. The STT0 bit is always read as 0.

Remark IICRSV: Bit 0 of IIC flag register 0 (IICF0)

STCF: Bit 7 of IIC flag register 0 (IICF0)

Figure 13-6. Format of IICA Control Register 00 (IICCTL00) (4/4)

SPT0 ^{Note}	Stop condition trigger
0	Stop condition is not generated.
1	Stop condition is generated (termination of master device's transfer).
Cautions concerning set timing • For master reception: Cannot be set to 1 during transfer. Can be set to 1 only in the clock stretch period when the ACKE0 bit has been cleared to 0 and slave has been notified of final reception. • For master transmission: A stop condition cannot be generated normally during the acknowledge period. Therefore, set it during the clock stretch period that follows output of the ninth clock. • Cannot be set to 1 at the same time as start condition trigger (STT0). • The SPT0 bit can be set to 1 only when in master mode. • When the WTIM0 bit has been cleared to 0, if the SPT0 bit is set to 1 during the clock stretch 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 WTIM0 bit should be changed from 0 to 1 during the clock stretch period following the output of eight clocks, and the SPT0 bit should be set to 1 during the clock stretch period that follows the output of the ninth clock. • Once STT0 is set (1), setting it again (1) before the clear condition is met is not allowed.	
Condition for clearing (SPT0 = 0)	Condition for setting (SPT0 = 1)
• Cleared by loss in arbitration • Automatically cleared after stop condition is detected • Cleared by LREL0 = 1 (exit from communications) • When IICE0 = 0 (operation stop) • Reset	• Set by instruction

Note The SPT0 bit is always read as 0.

Caution When bit 3 (TRC0) of the IICA status register 0 (IICS0) is set to 1 (transmission status), bit 5 (WREL0) of IICA control register 00 (IICCTL00) is set to 1 during the ninth clock and clock stretch is canceled, after which the TRC0 bit is cleared (reception status) and the SDAA0 line is set to high impedance. Release the clock stretch performed while the TRC0 bit is 1 (transmission status) by writing to the IICA shift register 0.

Remark Bit 0 (SPT0) becomes 0 when it is read after data setting.

13.3.3 IICA status register 0 (IICS0)

This register indicates the status of I²C.

The IICS0 register is read by a 1-bit or 8-bit memory manipulation instruction only when STT0 = 1 and during the clock stretch period.

Reset signal generation clears this register to 00H.

Caution Reading the IICS0 register while the address match wakeup function is enabled (WUP0 = 1) in STOP mode is prohibited. When the WUP0 bit is changed from 1 to 0 (wakeup operation is stopped), regardless of the INTIICA0 interrupt request, the change in status is not reflected until the next start condition or stop condition is detected. To use the wakeup function, therefore, enable (SPIE0 = 1) the interrupt generated by detecting a stop condition and read the IICS0 register after the interrupt has been detected.

Remark STT0: bit 1 of IICA control register 00 (IICCTL00)
WUP0: bit 7 of IICA control register 01 (IICCTL01)

Figure 13-7. Format of IICA Status Register 0 (IICS0) (1/3)

Address: FFF51H After reset: 00H R

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IICS0	MSTS0	ALD0	EXC0	COI0	TRC0	ACKD0	STD0	SPD0

MSTS0	Master status check flag	
0	Slave device status or communication standby status	
1	Master device communication status	
Condition for clearing (MSTS0 = 0)		Condition for setting (MSTS0 = 1)
- When a stop condition is detected - When ALD0 = 1 (arbitration loss) - Cleared by LREL0 = 1 (exit from communications) - When the IICE0 bit changes from 1 to 0 (operation stop) - Reset		When a start condition is generated
ALD0	Detection of arbitration loss	
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 MSTS0 bit is cleared.	
Condition for clearing (ALD0 = 0)		Condition for setting (ALD0 = 1)
- Automatically cleared after the IICS0 register is read^{Note} - When the IICE0 bit changes from 1 to 0 (operation stop) - Reset		When the arbitration result is a "loss".

Note This register is also cleared when a 1-bit memory manipulation instruction is executed for bits other than the IICS0 register. Therefore, when using the ALD0 bit, read the data of this bit before the data of the other bits.

Remark LREL0: Bit 6 of IICA control register 00 (IICCTL00)
IICE0: Bit 7 of IICA control register 00 (IICCTL00)

Figure 13-7. Format of IICA Status Register 0 (IICS0) (2/3)

EXC0	Detection of extension code reception	
0	Extension code was not received.	
1	Extension code was received.	
Condition for clearing (EXC0 = 0)		Condition for setting (EXC0 = 1)
- When a start condition is detected - When a stop condition is detected - Cleared by LREL0 = 1 (exit from communications) - When the IICE0 bit changes from 1 to 0 (operation stop) - Reset		When the higher four bits of the received address data is either "0000" or "1111" (set at the rising edge of the eighth clock).

COI0	Detection of matching addresses	
0	Addresses do not match.	
1	Addresses match.	
Condition for clearing (COI0 = 0)		Condition for setting (COI0 = 1)
- When a start condition is detected - When a stop condition is detected - Cleared by LREL0 = 1 (exit from communications) - When the IICE0 bit changes from 1 to 0 (operation stop) - Reset		When the received address matches the local address (slave address register 0 (SVA0)) (set at the rising edge of the eighth clock).

TRC0	Detection of transmit/receive status	
0	Receive status (other than transmit status). The SDAA0 line is set for high impedance.	
1	Transmit status. The value in the SO0 latch is enabled for output to the SDAA0 line (valid starting at the falling edge of the first byte's ninth clock).	
Condition for clearing (TRC0 = 0)		Condition for setting (TRC0 = 1)
<Both master and slave> - When a stop condition is detected - Cleared by LREL0 = 1 (exit from communications) - When the IICE0 bit changes from 1 to 0 (operation stop) - Cleared by WREL0 = 1^{Note} (clock stretch cancel) - When the ALD0 bit changes from 0 to 1 (arbitration loss) - Reset - When not used for communication (MSTS0, EXC0, COI0 = 0) <Master> - When "1" is output to the first byte's LSB (transfer direction specification bit) <Slave> - When a start condition is detected - When "0" is input to the first byte's LSB (transfer direction specification bit)		<Master> - When a start condition is generated - When 0 (master transmission) is output to the LSB (transfer direction specification bit) of the first byte (during address transfer) <Slave> - When 1 (slave transmission) is input to the LSB (transfer direction specification bit) of the first byte from the master (during address transfer)

Note When bit 3 (TRC0) of the IICA status register 0 (IICS0) is set to 1 (transmission status), bit 5 (WREL0) of IICA control register 00 (IICCTL00) is set to 1 during the ninth clock and clock stretch is canceled, after which the TRC0 bit is cleared (reception status) and the SDAA0 line is set to high impedance. Release the clock stretch performed while the TRC0 bit is 1 (transmission status) by writing to the IICA shift register 0.

Remark LREL0: Bit 6 of IICA control register 00 (IICCTL00)
IICE0: Bit 7 of IICA control register 00 (IICCTL00)

Figure 13-7. Format of IICA Status Register 0 (IICS0) (3/3)

ACKD0	Detection of acknowledge (ACK)	
0	Acknowledge was not detected.	
1	Acknowledge was detected.	
Condition for clearing (ACKD0 = 0)		Condition for setting (ACKD0 = 1)
• When a stop condition is detected • At the rising edge of the next byte's first clock • Cleared by LREL0 = 1 (exit from communications) • When the IICE0 bit changes from 1 to 0 (operation stop) • Reset		• After the SDAA0 line is set to low level at the rising edge of SCLA0 line's ninth clock

STD0	Detection of start condition	
0	Start condition was not detected.	
1	Start condition was detected. This indicates that the address transfer period is in effect.	
Condition for clearing (STD0 = 0)		Condition for setting (STD0 = 1)
• When a stop condition is detected • At the rising edge of the next byte's first clock following address transfer • Cleared by LREL0 = 1 (exit from communications) • When the IICE0 bit changes from 1 to 0 (operation stop) • Reset		• When a start condition is detected

SPD0	Detection of stop condition	
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 (SPD0 = 0)		Condition for setting (SPD0 = 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 WUP0 bit changes from 1 to 0 • When the IICE0 bit changes from 1 to 0 (operation stop) • Reset		• When a stop condition is detected

Remark LREL0: Bit 6 of IICA control register 00 (IICCTL00)

IICE0: Bit 7 of IICA control register 00 (IICCTL00)

13.3.4 IICA flag register 0 (IICF0)

This register sets the operation mode of I²C and indicates the status of the I²C bus.

The IICF0 register can be set by a 1-bit or 8-bit memory manipulation instruction. However, the STT0 clear flag (STCF) and I²C bus status flag (IICBSY) bits are read-only.

The IICRSV bit can be used to enable/disable the communication reservation function.

The STCEN bit can be used to set the initial value of the IICBSY bit.

The IICRSV and STCEN bits can be written only when the operation of I²C is disabled (bit 7 (IICE0) of IICA control register 00 (IICCTL00) = 0). When operation is enabled, the IICF0 register can be read.

Reset signal generation clears this register to 00H.

Figure 13-8. Format of IICA Flag Register 0 (IICF0)

Address: FFF52H	After reset: 00H	R/W ^{Note}						
Symbol	<7>	<6>	5	4	3	2	<1>	<0>
IICF0	STCF0	IICBSY0	0	0	0	0	STCEN0	IICRSV0

STCF0	STT0 clear flag
0	Generate start condition
1	Start condition generation unsuccessful: clear the STT0 flag
Condition for clearing (STCF0 = 0)	
- Cleared by STT0 = 1 - When IICE0 = 0 (operation stop) - Reset	
Condition for setting (STCF0 = 1)	
Generating start condition unsuccessful and the STT0 bit cleared to 0 when communication reservation is disabled (IICRSV0 = 1).	

IICBSY0	I ² C bus status flag
0	Bus release status (communication initial status when STCEN0 = 1)
1	Bus communication status (communication initial status when STCEN0 = 0)
Condition for clearing (IICBSY0 = 0)	
- Detection of stop condition - When IICE0 = 0 (operation stop) - Reset	
Condition for setting (IICBSY0 = 1)	
- Detection of start condition - Setting of the IICE0 bit when STCEN0 = 0	

STCEN0	Initial start enable trigger
0	After operation is enabled (IICE0 = 1), enable generation of a start condition upon detection of a stop condition.
1	After operation is enabled (IICE0 = 1), enable generation of a start condition without detecting a stop condition.
Condition for clearing (STCEN0 = 0)	
- Cleared by instruction - Detection of start condition - Reset	
Condition for setting (STCEN0 = 1)	
Set by instruction	

IICRSV0	Communication reservation function disable bit
0	Enable communication reservation
1	Disable communication reservation
Condition for clearing (IICRSV0 = 0)	
- Cleared by instruction - Reset	
Condition for setting (IICRSV0 = 1)	
Set by instruction	

Note Bits 6 and 7 are read-only.

- Cautions**
1. Write to the STCEN bit only when the operation is stopped (IICE0 = 0).
 2. As the bus release status (IICBSY = 0) is recognized regardless of the actual bus status when STCEN = 1, when generating the first start condition (STT0 = 1), it is necessary to verify that no third party communications are in progress in order to prevent such communications from being destroyed.
 3. Write to IICRSV only when the operation is stopped (IICE0 = 0).

Remark STT0: Bit 1 of IICA control register 00 (IICCTL00)
IICE0: Bit 7 of IICA control register 00 (IICCTL00)

13.3.5 IICA control register 01 (IICCTL01)

This register is used to set the operation mode of I²C and detect the statuses of the SCLA0 and SDAA0 pins.

The IICCTL01 register can be set by a 1-bit or 8-bit memory manipulation instruction. However, the CLD0 and DAD0 bits are read-only.

Set the IICCTL01 register, except the WUP0 bit, while operation of I²C is disabled (bit 7 (IICE0) of IICA control register 00 (IICCTL00) is 0).

Reset signal generation clears this register to 00H.

Figure 13-9. Format of IICA Control Register 01 (IICCTL01) (1/2)

Address: F0231H After reset: 00H R/W^{Note 1}

Symbol	<7>	6	<5>	<4>	<3>	<2>	1	<0>
IICCTL01	WUP0	0	CLD0	DAD0	SMC0	DFC0	0	PRS0

WUP0	Control of address match wakeup
0	Stops operation of address match wakeup function in STOP mode.
1	Enables operation of address match wakeup function in STOP mode.
To shift to STOP mode when WUP0 = 1, execute the STOP instruction at least three clocks of f_{MCK} after setting (1) the WUP0 bit (see Figure 13-22 Flow When Setting WUP0 = 1). Clear (0) the WUP0 bit after the address has matched or an extension code has been received. The subsequent communication can be entered by the clearing (0) WUP0 bit. (The clock stretch must be released and transmit data must be written after the WUP0 bit has been cleared (0).) The interrupt timing when the address has matched or when an extension code has been received, while WUP0 = 1, is identical to the interrupt timing when WUP0 = 0. (A delay of the difference of sampling by the clock will occur.) Furthermore, when WUP0 = 1, a stop condition interrupt is not generated even if the SPIE0 bit is set to 1. When WUP0 = 0 is set by a source other than an interrupt from serial interface IICA, operation as the master device cannot be performed until the subsequent start condition or stop condition is detected. Do not output a start condition by setting (1) the STT0 bit, without waiting for the detection of the subsequent start condition or stop condition.	
Condition for clearing (WUP0 = 0)	
• Cleared by instruction (after address match or extension code reception)	
Condition for setting (WUP0 = 1)	
• Set by instruction (when the MST0, EXC0, and COI0 bits are "0", and the STD0 bit also "0" (communication not entered))^{Note 2}	

Notes 1. Bits 4 and 5 are read-only.

- 2.** The status of the IICA status register 0 (IICS0) must be checked and the WUP0 bit must be set during the period shown below.

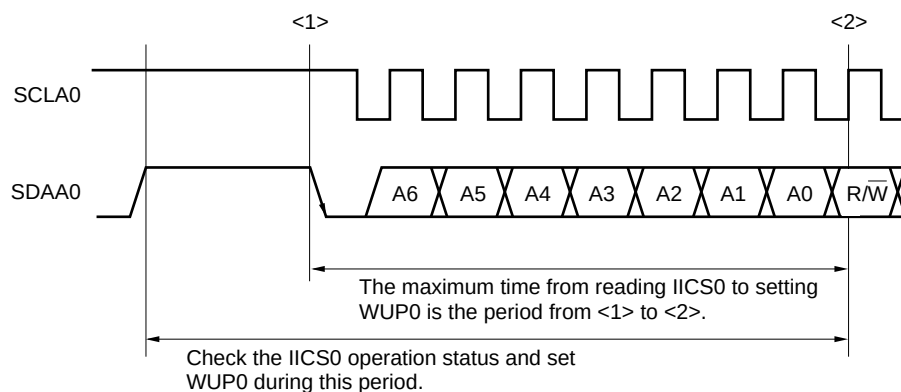


Figure 13-9. Format of IICA Control Register 01 (IICCTL01) (2/2)

CLD0	Detection of SCLA0 pin level (valid only when IICE0 = 1)	
0	The SCLA0 pin was detected at low level.	
1	The SCLA0 pin was detected at high level.	
Condition for clearing (CLD0 = 0)		Condition for setting (CLD0 = 1)
• When the SCLA0 pin is at low level • When IICE0 = 0 (operation stop) • Reset		• When the SCLA0 pin is at high level

DAD0	Detection of SDAA0 pin level (valid only when IICE0 = 1)	
0	The SDAA0 pin was detected at low level.	
1	The SDAA0 pin was detected at high level.	
Condition for clearing (DAD0 = 0)		Condition for setting (DAD0 = 1)
• When the SDAA0 pin is at low level • When IICE0 = 0 (operation stop) • Reset		• When the SDAA0 pin is at high level

SMC0	Operation mode switching	
0	Operates in standard mode (fastest transfer rate: 100 kbps).	
1	Operates in fast mode (fastest transfer rate: 400 kbps) or fast mode plus (fastest transfer rate: 1 Mbps).	

DFC0	Digital filter operation control	
0	Digital filter off.	
1	Digital filter on.	
Use the digital filter only in fast mode and fast mode plus. The digital filter is used for noise elimination. The transfer clock does not vary, regardless of the DFC0 bit being set (1) or cleared (0).		

PRS0	Control of IICA operation clock (fMCK)	
0	Selects fCLK (1 MHz ≤ fCLK ≤ 20 MHz).	
1	Selects fCLK/2 (20 MHz < fCLK).	

- Cautions**
- 1. The fastest operation frequency of the IICA operation clock (f_{MCK}) is 20 MHz (Max.).**
Set the bit 0 (PRS0) of the IICA control register 01 (IICCTL01) to 1, only when the f_{CLK} exceeds 20 MHz.
 - 2. Note** the minimum f_{CLK} operation frequency when setting the transfer clock.
 The **minimum** f_{CLK} operation frequency for serial interface IICA is determined according to the mode.
 Fast mode: $f_{CLK} = 3.5\text{ MHz (MIN.)}$
 Fast mode plus: $f_{CLK} = 10\text{ MHz (MIN.)}$
 Normal mode: $f_{CLK} = 1\text{ MHz (MIN.)}$

Remark IICE0: Bit 7 of IICA control register 00 (IICCTL00)

13.3.6 IICA low-level width setting register 0 (IICWL0)

This register is used to control the low-level width (t_{LOW}) of the SCLA0 pin signal that is output by serial interface IICA and the SDAA0 pin signal.

The IICWL0 register can be set by an 8-bit memory manipulation instruction.

Set the IICWL0 register while operation of I²C is disabled (bit 7 (IICE0) of IICA control register 00 (IICCTL00) is 0).

Reset signal generation sets this register to FFH.

For details about setting the IICWL0 register, see **13.4.2 Setting transfer clock by using IICWL0 and IICWH0 registers**.

The data hold time is one-quarter of the time set by the IICWL_n register.

Figure 13-10. Format of IICA Low-Level Width Setting Register 0 (IICWL0)

Address: F0232H	After reset: FFH	R/W						
Symbol	7	6	5	4	3	2	1	0
IICWL0								

13.3.7 IICA high-level width setting register 0 (IICWH0)

This register is used to control the high-level width of the SCLA0 pin signal that is output by serial interface IICA and the SDAA0 pin signal.

The IICWH0 register can be set by an 8-bit memory manipulation instruction.

Set the IICWH0 register while operation of I²C is disabled (bit 7 (IICE0) of IICA control register 00 (IICCTL00) is 0).

Reset signal generation sets this register to FFH.

Figure 13-11. Format of IICA High-Level Width Setting Register 0 (IICWH0)

Address: F0233H	After reset: FFH	R/W						
Symbol	7	6	5	4	3	2	1	0
IICWH0								

Remark For setting procedures of the transfer clock on master side and of the IICWL0 and IICWH0 registers on slave side, see **13.4.2 (1)** and **13.4.2 (2)**, respectively.

13.3.8 Port mode register 6 (PM6)

This register sets the input/output of port 6 in 1-bit units.

When using the P60/SCLA0 pin as clock I/O and the P61/SDAA0 pin as serial data I/O, clear PM60 and PM61, and the output latches of P60 and P61 to 0.

Set the IICE0 bit (bit 7 of IICA control register 00 (IICCTL00)) to 1 before setting the output mode because the P60/SCLA0 and P61/SDAA0 pins output a low level (fixed) when the IICE0 bit is 0.

The PM6 register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to FFH.

Figure 13-12. Format of Port Mode Register 6 (PM6) (in Case of 64-pin Products)

Address: FFF26H After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
PM6	1	1	1	1	PM63	PM62	PM61	PM60

PM6n	PM6n pin I/O mode selection (n = 0 to 3)
0	Output mode (output buffer on)
1	Input mode (output buffer off)

13.4 I²C Bus Mode Functions

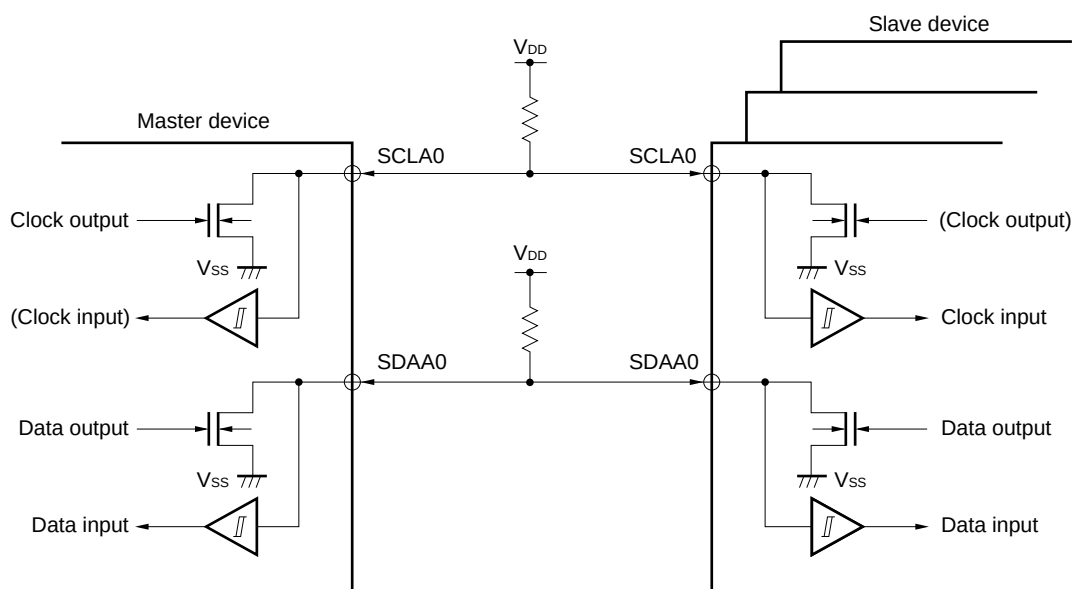
13.4.1 Pin configuration

The serial clock pin (SCLA0) and the serial data bus pin (SDAA0) are configured as follows.

- (1) SCLA0 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.
- (2) SDAA0 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 13-13. Pin Configuration Diagram



13.4.2 Setting transfer clock by using IICWL0 and IICWH0 registers

(1) Setting transfer clock on master side

$$\text{Transfer clock} = \frac{f_{\text{MCK}}}{\text{IICWL0} + \text{IICWH0} + f_{\text{MCK}}(t_{\text{R}} + t_{\text{F}})}$$

At this time, the optimal setting values of the IICWL0 and IICWH0 registers are as follows.

(The fractional parts of all setting values are rounded up.)

- When the fast mode

$$\begin{aligned}\text{IICWL0} &= \frac{0.52}{\text{Transfer clock}} \times f_{\text{MCK}} \\ \text{IICWH0} &= \left(\frac{0.48}{\text{Transfer clock}} - t_{\text{R}} - t_{\text{F}} \right) \times f_{\text{MCK}}\end{aligned}$$

- When the normal mode

$$\begin{aligned}\text{IICWL0} &= \frac{0.47}{\text{Transfer clock}} \times f_{\text{MCK}} \\ \text{IICWH0} &= \left(\frac{0.53}{\text{Transfer clock}} - t_{\text{R}} - t_{\text{F}} \right) \times f_{\text{MCK}}\end{aligned}$$

- When the fast mode plus

$$\begin{aligned}\text{IICWL0} &= \frac{0.50}{\text{Transfer clock}} \times f_{\text{MCK}} \\ \text{IICWH0} &= \left(\frac{0.50}{\text{Transfer clock}} - t_{\text{R}} - t_{\text{F}} \right) \times f_{\text{MCK}}\end{aligned}$$

(2) Setting IICWL0 and IICWH0 registers on slave side

(The fractional parts of all setting values are truncated.)

- When the fast mode

$$\begin{aligned}\text{IICWL0} &= 1.3 \mu\text{s} \times f_{\text{MCK}} \\ \text{IICWH0} &= (1.2 \mu\text{s} - t_{\text{R}} - t_{\text{F}}) \times f_{\text{MCK}}\end{aligned}$$

- When the normal mode

$$\begin{aligned}\text{IICWL0} &= 4.7 \mu\text{s} \times f_{\text{MCK}} \\ \text{IICWH0} &= (5.3 \mu\text{s} - t_{\text{R}} - t_{\text{F}}) \times f_{\text{MCK}}\end{aligned}$$

- When the fast mode plus

$$\begin{aligned}\text{IICWL0} &= 0.50 \mu\text{s} \times f_{\text{MCK}} \\ \text{IICWH0} &= (0.50 \mu\text{s} - t_{\text{R}} - t_{\text{F}}) \times f_{\text{MCK}}\end{aligned}$$

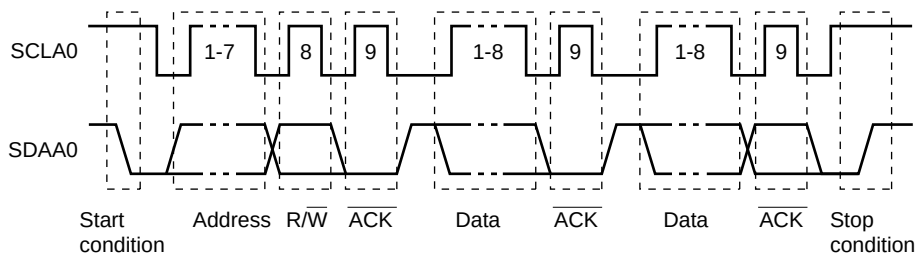
(**Caution** and **Remarks** are listed on the next page.)

- Cautions**
- 1. The fastest operation frequency of the IICA operation clock (f_{MCK}) is 20 MHz (Max.).**
Set the bit 0 (PRS0) of the IICA control register 01 (IICCTL01) to 1, only when the f_{CLK} exceeds 20 MHz.
 - 2. Note the minimum f_{CLK} operation frequency when setting the transfer clock.**
The minimum f_{CLK} operation frequency for serial interface IICA is determined according to the mode.
Fast mode: $f_{CLK} = 3.5 \text{ MHz (MIN.)}$
Fast mode plus: $f_{CLK} = 10 \text{ MHz (MIN.)}$
Normal mode: $f_{CLK} = 1 \text{ MHz (MIN.)}$
- Remarks**
- 1.** Calculate the rise time (t_R) and fall time (t_F) of the SDAA0 and SCLA0 signals separately, because they differ depending on the pull-up resistance and wire load.
 - 2.** IICWL0: IICA low-level width setting register 0
IICWH0: IICA high-level width setting register 0
 t_F : SDAA0 and SCLA0 signal falling times
 t_R : SDAA0 and SCLA0 signal rising times
 f_{MCK} : IICA operation clock frequency

13.5 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. Figure 13-14 shows the transfer timing for the "start condition", "address", "data", and "stop condition" output via the I²C bus's serial data bus.

Figure 13-14. I²C Bus Serial Data Transfer Timing



The master device generates the start condition, slave address, and stop condition.

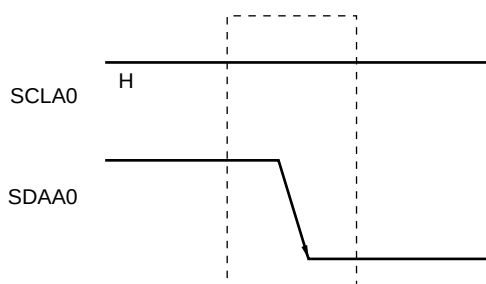
The acknowledge (ACK) can be generated by either the master or slave device (normally, it is output by the device that receives 8-bit data).

The serial clock (SCLA0) is continuously output by the master device. However, in the slave device, the SCLA0 pin low level period can be extended and a clock stretch can be inserted.

13.5.1 Start conditions

A start condition is met when the SCLA0 pin is at high level and the SDAA0 pin changes from high level to low level. The start conditions for the SCLA0 pin and SDAA0 pin are signals that the master device generates to the slave device when starting a serial transfer. When the device is used as a slave, start conditions can be detected.

Figure 13-15. Start Conditions



A start condition is output when bit 1 (STT0) of IICA control register 00 (IICCTL00) is set (1) after a stop condition has been detected (SPD0: Bit 0 of the IICA status register 0 (IICS0) = 1). When a start condition is detected, bit 1 (STD0) of the IICS0 register is set (1).

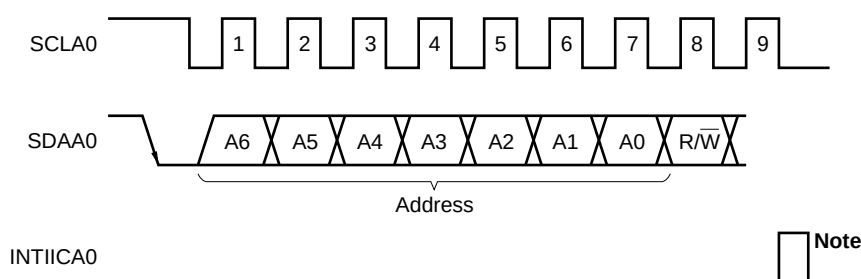
13.5.2 Addresses

The address is defined by the 7 bits of data that follow the start condition.

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 slave address register 0 (SVA0). If the address data matches the SVA0 register values, the slave device is selected and communicates with the master device until the master device generates a start condition or stop condition.

Figure 13-16. Address



Note INTIICA0 is not issued if data other than a local address or extension code is received during slave device operation.

Addresses are output when a total of 8 bits consisting of the slave address and the transfer direction described in **13.5.3 Transfer direction specification** are written to the IICA shift register 0 (IICA0). The received addresses are written to the IICA0 register.

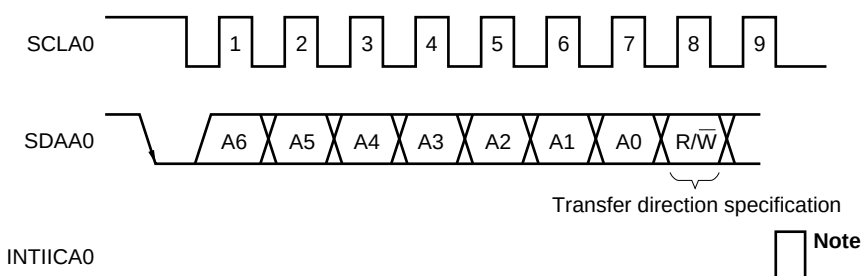
The slave address is assigned to the higher 7 bits of the IICA0 register.

13.5.3 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 13-17. Transfer Direction Specification



Note INTIICA0 is not issued if data other than a local address or extension code is received during slave device operation.

13.5.4 Acknowledge (ACK)

ACK is used to check the status of serial data at the transmission and reception sides.

The reception side returns ACK each time it has received 8-bit data.

The transmission side usually receives ACK after transmitting 8-bit data. When ACK is returned from the reception side, it is assumed that reception has been correctly performed and processing is continued. Whether ACK has been detected can be checked by using bit 2 (ACKD0) of the IICA status register 0 (IICS0).

When the master receives the last data item, it does not return ACK and instead generates a stop condition. If a slave does not return ACK after receiving data, the master outputs a stop condition or restart condition and stops transmission. If ACK is not returned, the possible causes are as follows.

- <1> Reception was not performed normally.
- <2> The final data item was received.
- <3> The reception side specified by the address does not exist.

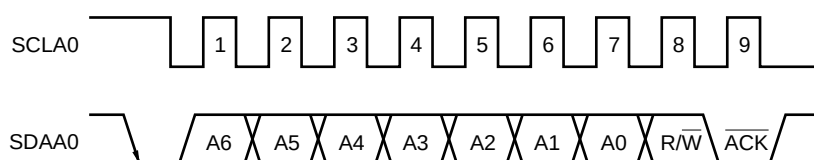
To generate ACK, the reception side makes the SDAA0 line low at the ninth clock (indicating normal reception).

Automatic generation of ACK is enabled by setting bit 2 (ACKE0) of IICA control register 00 (IICCTL00) to 1. Bit 3 (TRC0) of the IICS0 register is set by the data of the eighth bit that follows 7-bit address information. Usually, set the ACKE0 bit to 1 for reception (TRC0 = 0).

If a slave can receive no more data during reception (TRC0 = 0) or does not require the next data item, then the slave must inform the master, by clearing the ACKE0 bit to 0, that it will not receive any more data.

When the master does not require the next data item during reception (TRC0 = 0), it must clear the ACKE0 bit to 0 so that ACK is not generated. In this way, the master informs a slave at the transmission side that it does not require any more data (transmission will be stopped).

Figure 13-18. ACK



When the local address is received, ACK is automatically generated, regardless of the value of the ACKE0 bit. When an address other than that of the local address is received, ACK is not generated (NACK).

When an extension code is received, ACK is generated if the ACKE0 bit is set to 1 in advance.

How ACK is generated when data is received differs as follows depending on the setting of the clock stretch timing.

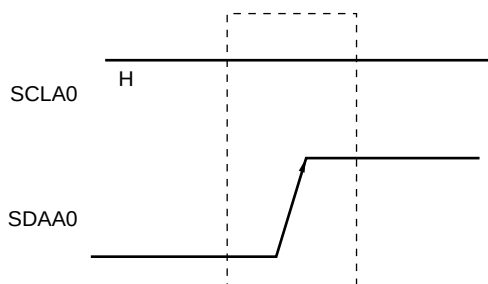
- When 8-clock clock stretch state is selected (bit 3 (WTIM0) of IICCTL00 register = 0):
By setting the ACKE0 bit to 1 before releasing the clock stretch state, ACK is generated at the falling edge of the eighth clock of the SCLA0 pin.
- When 9-clock clock stretch state is selected (bit 3 (WTIM0) of IICCTL00 register = 1):
ACK is generated by setting the ACKE0 bit to 1 in advance.

13.5.5 Stop condition

When the SCLA0 pin is at high level, changing the SDAA0 pin from low level to high level generates a stop condition.

A stop condition is a signal that the master device generates to the slave device when serial transfer has been completed. When the device is used as a slave, stop conditions can be detected.

Figure 13-19. Stop Condition



A stop condition is generated when bit 0 (SPT0) of IICA control register 00 (IICCTL00) is set to 1. When the stop condition is detected, bit 0 (SPD0) of the IICA status register 0 (IICS0) is set to 1 and INTIICA0 is generated when bit 4 (SPIE0) of the IICCTL00 register is set to 1.

13.5.6 Clock stretch

The clock stretch 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 clock stretch state).

Setting the SCLA0 pin to low level notifies the communication partner of the clock stretch state. When clock stretch state has been canceled for both the master and slave devices, the next data transfer can begin.

Figure 13-20. Clock stretch (1/2)

- (1) When master device has a nine-clock clock stretch and slave device has an eight-clock clock stretch (master transmits, slave receives, and ACKE0 = 1)**

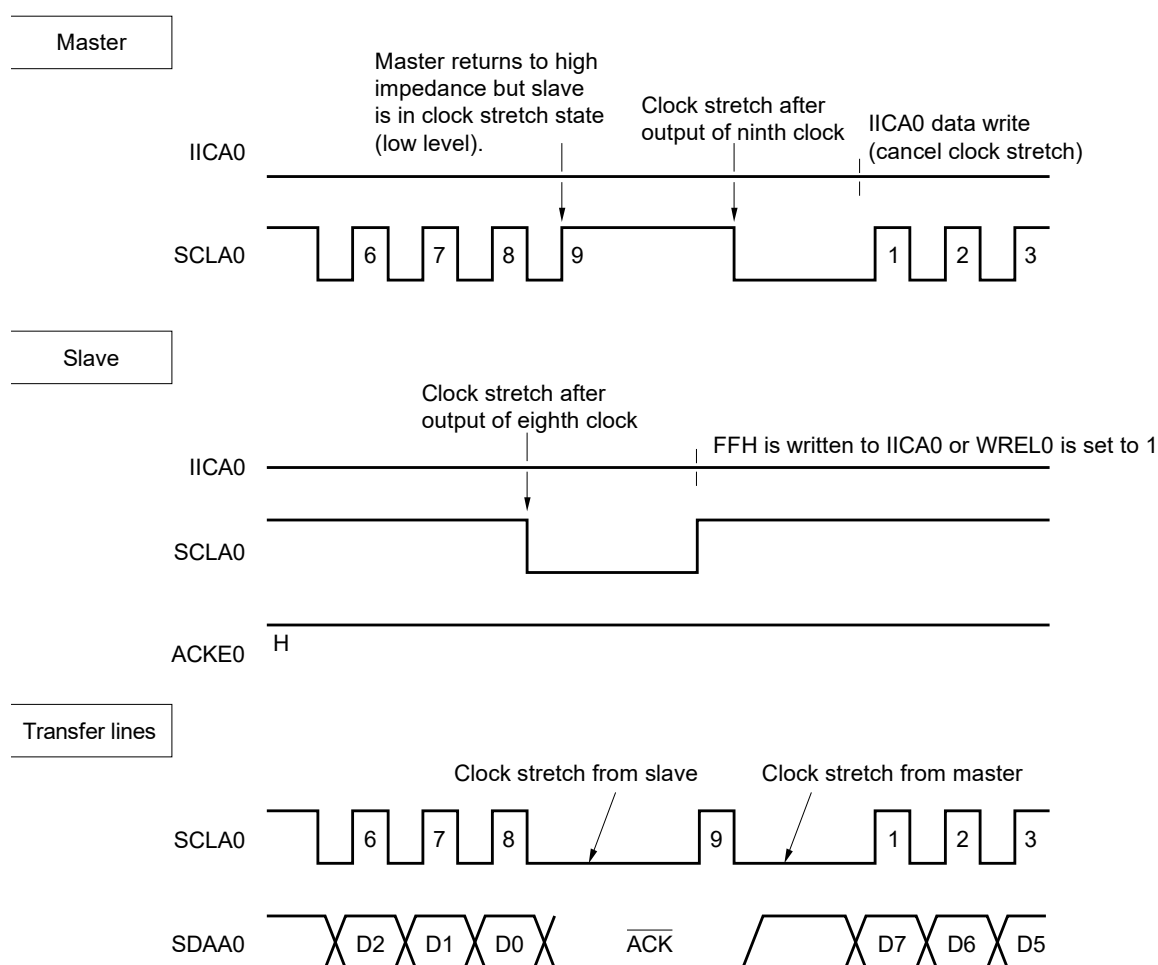
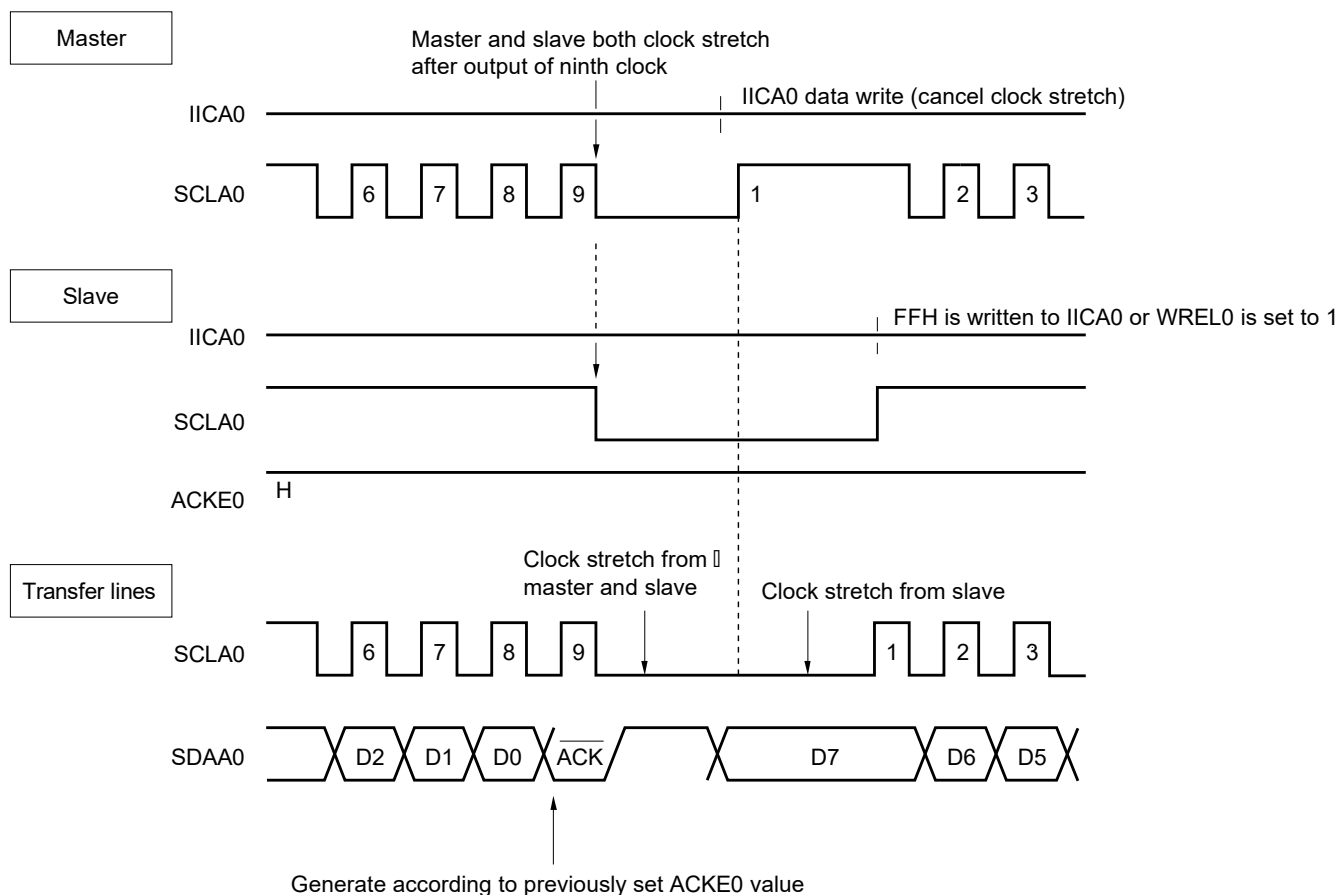


Figure 13-20. Clock stretch (2/2)

(2) When master and slave devices both have a nine-clock clock stretch
(master transmits, slave receives, and ACKE0 = 1)



Remark ACKE0: Bit 2 of IICA control register 00 (IICCTL00)
WREL0: Bit 5 of IICA control register 00 (IICCTL00)

A clock stretch may be automatically generated depending on the setting of bit 3 (WTIM0) of IICA control register 00 (IICCTL00).

Normally, the receiving side cancels the clock stretch state when bit 5 (WREL0) of the IICCTL00 register is set to 1 or when FFH is written to the IICA shift register 0 (IICA0), and the transmitting side cancels the clock stretch state when data is written to the IICA0 register.

The master device can also cancel the clock stretch state via either of the following methods.

- By setting bit 1 (STT0) of the IICCTL00 register to 1
- By setting bit 0 (SPT0) of the IICCTL00 register to 1

13.5.7 Canceling clock stretch

The I²C usually cancels a clock stretch state by the following processing.

- Writing data to the IICA shift register 0 (IICA0)
- Setting bit 5 (WREL0) of IICA control register 00 (IICCTL00) (canceling clock stretch)
- Setting bit 1 (STT0) of the IICCTL00 register (generating start condition)^{Note}
- Setting bit 0 (SPT0) of the IICCTL00 register (generating stop condition)^{Note}

Note Master only

When the above clock stretch canceling processing is executed, the I²C cancels the clock stretch state and communication is resumed.

To cancel a clock stretch state and transmit data (including addresses), write the data to the IICA0 register.

To receive data after canceling a clock stretch state, or to complete data transmission, set bit 5 (WREL0) of the IICCTL00 register to 1.

To generate a restart condition after canceling a clock stretch state, set bit 1 (STT0) of the IICCTL00 register to 1.

To generate a stop condition after canceling a clock stretch state, set bit 0 (SPT0) of the IICCTL00 register to 1.

Execute the canceling processing only once for one clock stretch state.

If, for example, data is written to the IICA0 register after canceling a clock stretch state by setting the WREL0 bit to 1, an incorrect value may be output to SDAA0 line because the timing for changing the SDAA0 line conflicts with the timing for writing the IICA0 register.

In addition to the above, communication is stopped if the IICE0 bit is cleared to 0 when communication has been aborted, so that the clock stretch state can be canceled.

If the I²C bus has deadlocked due to noise, processing is saved from communication by setting bit 6 (LREL0) of the IICCTL00 register, so that the clock stretch state can be canceled.

Caution If a processing to cancel a clock stretch state is executed when WUP0 = 1, the clock stretch state will not be canceled.

13.5.8 Interrupt request (INTIICA0) generation timing and clock stretch control

The setting of bit 3 (WTIM0) of IICA control register 00 (IICCTL00) determines the timing by which INTIICA0 is generated and the corresponding clock stretch control, as shown in Table 13-2.

Table 13-2. INTIICA0 Generation Timing and Clock Stretch Control

WTIM0	During Slave Device Operation			During Master Device Operation		
	Address	Data Reception	Data Transmission	Address	Data Reception	Data Transmission
0	gNotes 1, 2	gNote 2	gNote 2	9	8	8
1	gNotes 1, 2	gNote 2	gNote 2	9	9	9

Notes 1. The slave device's INTIICA0 signal and clock stretch period occurs at the falling edge of the ninth clock only when there is a match with the address set to the slave address register 0 (SVA0).

At this point, ACK is generated regardless of the value set to the IICCTL00 register's bit 2 (ACKE0). For a slave device that has received an extension code, INTIICA0 occurs at the falling edge of the eighth clock.

However, if the address does not match after restart, INTIICA0 is generated at the falling edge of the 9th clock, but clock stretch does not occur.

2. If the received address does not match the contents of the slave address register 0 (SVA0) and extension code is not received, neither INTIICA0 nor a clock stretch occurs.

Remark The numbers in the table indicate the number of the serial clock's clock signals. Interrupt requests and clock stretch control are both synchronized with the falling edge of these clock signals.

(1) During address transmission/reception

- Slave device operation: Interrupt and clock stretch timing are determined depending on the conditions described in Notes 1 and 2 above, regardless of the WTIM0 bit.
- Master device operation: Interrupt and clock stretch timing occur at the falling edge of the ninth clock regardless of the WTIM0 bit.

(2) During data reception

- Master/slave device operation: Interrupt and clock stretch timing are determined according to the WTIM0 bit.

(3) During data transmission

- Master/slave device operation: Interrupt and clock stretch timing are determined according to the WTIM0 bit.

(4) Clock stretch cancellation method

The four clock stretch cancellation methods are as follows.

- Writing data to the IICA shift register 0 (IICA0)
- Setting bit 5 (WREL0) of IICA control register 00 (IICCTL00) (canceling clock stretch)
- Setting bit 1 (STT0) of IICCTL00 register (generating start condition)^{Note}
- Setting bit 0 (SPT0) of IICCTL00 register (generating stop condition)^{Note}

Note Master only.

When an 8-clock clock stretch has been selected (WTIM0 = 0), the presence/absence of ACK generation must be determined prior to clock stretch cancellation.

(5) Stop condition detection

INTIICA0 is generated when a stop condition is detected (only when SPIE0 = 1).

13.5.9 Address match detection method

In I²C bus mode, the master device can select a particular slave device by transmitting the corresponding slave address.

Address match can be detected automatically by hardware. An interrupt request (INTIICA0) occurs when the address set to the slave address register 0 (SVA0) matches the slave address sent by the master device, or when an extension code has been received.

13.5.10 Error detection

In I²C bus mode, the status of the serial data bus (SDAA0) during data transmission is captured by the IICA shift register 0 (IICA0) of the transmitting device, so the IICA data prior to transmission can be compared with the transmitted IICA data to enable detection of transmission errors. A transmission error is judged as having occurred when the compared data values do not match.

13.5.11 Extension code

- (1) When the higher 4 bits of the receive address are either "0000" or "1111", the extension code reception flag (EXC0) is set to 1 for extension code reception and an interrupt request (INTIICA0) is issued at the falling edge of the eighth clock. The local address stored in the slave address register 0 (SVA0) is not affected.
- (2) The settings below are specified if 11110xx0 is transferred from the master by using a 10-bit address transfer when the SVA0 register is set to 11110xx0. Note that INTIICA0 occurs at the falling edge of the eighth clock.

- Higher four bits of data match: EXC0 = 1
- Seven bits of data match: COI0 = 1

Remark EXC0: Bit 5 of IICA status register 0 (IICS0)
COI0: Bit 4 of IICA status register 0 (IICS0)

- (3) Since the processing after the interrupt request occurs differs according to the data that follows the extension code, such processing is performed by software.

If the extension code is received while a slave device is operating, then the slave device is participating in communication even if its address does not match.

For example, after the extension code is received, if you do not wish to operate the target device as a slave device, set bit 6 (LREL0) of IICA control register 00 (IICCTL00) to 1 to set the standby mode for the next communication operation.

Table 13-3. Bit Definitions of Major Extension Codes

Slave Address	R/W Bit	Description
0 0 0 0 0 0 0	0	General call address
1 1 1 1 0 x x	0	10-bit slave address specification (during address authentication)
1 1 1 1 0 x x	1	10-bit slave address specification (after address match, when read command is issued)

Remark See the I²C bus specifications issued by NXP Semiconductors for details of extension codes other than those described above.

13.5.12 Arbitration

When several master devices simultaneously generate a start condition (when the STT0 bit is set to 1 before the STD0 bit is set to 1), communication among the master devices is performed as the number of clocks are adjusted until the data differs. This kind of operation is called arbitration.

When one of the master devices loses in arbitration, an arbitration loss flag (ALD0) in the IICA status register 0 (IICS0) is set (1) via the timing by which the arbitration loss occurred, and the SCLA0 and SDAA0 lines are both set to high impedance, which releases the bus.

The arbitration loss is detected based on the timing of the next interrupt request (the eighth or ninth clock, when a stop condition is detected, etc.) and the ALD0 = 1 setting that has been made by software.

For details of interrupt request timing, see **13.5.8 Interrupt request (INTIICA0) generation timing and clock stretch control**.

Remark STD0: Bit 1 of IICA status register 0 (IICS0)
STT0: Bit 1 of IICA control register 00 (IICCTL00)

Figure 13-21. Arbitration Timing Example

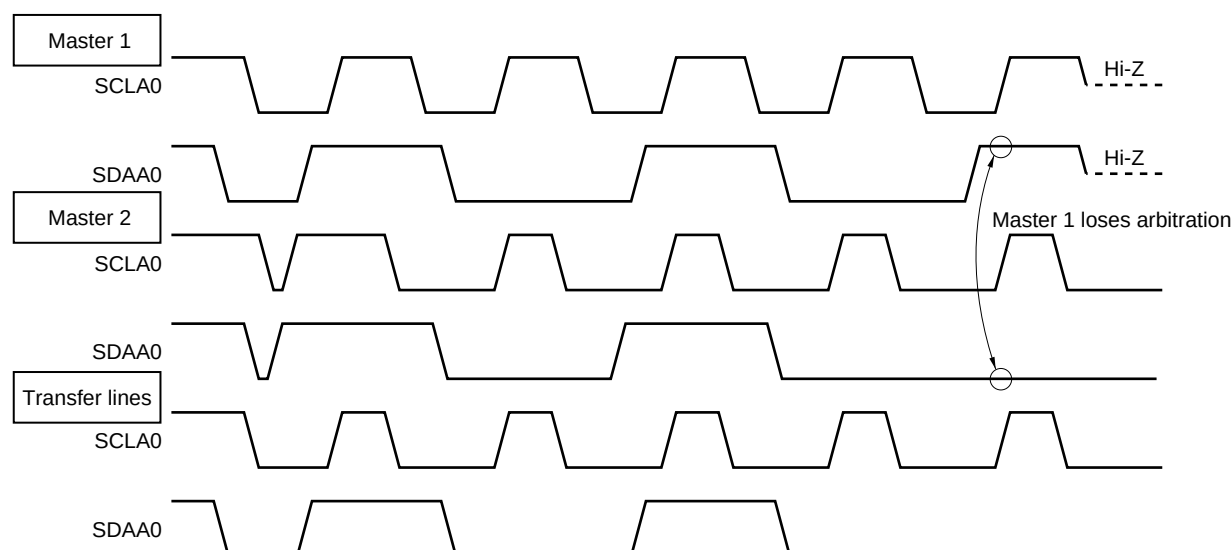


Table 13-4. Status During Arbitration and Interrupt Request Generation Timing

Status During Arbitration	Interrupt Request Generation Timing
During address transmission	At falling edge of eighth or ninth clock following byte transfer ^{Note 1}
Read/write data after address transmission	
During extension code transmission	
Read/write data after extension code transmission	
During data transmission	
During ACK transfer period after data transmission	
When restart condition is detected during data transfer	
When stop condition is detected during data transfer	When stop condition is generated (when SPIE0 = 1) ^{Note 2}
When data is at low level while attempting to generate a restart condition	At falling edge of eighth or ninth clock following byte transfer ^{Note 1}
When stop condition is detected while attempting to generate a restart condition	When stop condition is generated (when SPIE0 = 1) ^{Note 2}
When data is at low level while attempting to generate a stop condition	At falling edge of eighth or ninth clock following byte transfer ^{Note 1}
When SCLA0 is at low level while attempting to generate a restart condition	

- Notes**
1. When the WTIM0 bit (bit 3 of IICA control register 00 (IICCTL00)) = 1, an interrupt request occurs at the falling edge of the ninth clock. When WTIM0 = 0 and the extension code's slave address is received, an interrupt request occurs at the falling edge of the eighth clock.
 2. When there is a chance that arbitration will occur, set SPIE0 = 1 for master device operation.

Remark SPIE0: Bit 4 of IICA control register 00 (IICCTL00)

13.5.13 Wakeup function

The I²C bus slave function is a function that generates an interrupt request signal (INTIICA0) when a local address and extension code have been received.

This function makes processing more efficient by preventing unnecessary INTIICA0 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.

To use the wakeup function in the STOP mode, set the WUP0 bit to 1. Addresses can be received regardless of the operation clock. An interrupt request signal (INTIICA0) is also generated when a local address and extension code have been received. Operation returns to normal operation by using an instruction to clear (0) the WUP0 bit after this interrupt has been generated.

Figure 13-22 shows the flow for setting WUP0 = 1 and Figure 13-23 shows the flow for setting WUP0 = 0 upon an address match.

Figure 13-22. Flow When Setting WUP0 = 1

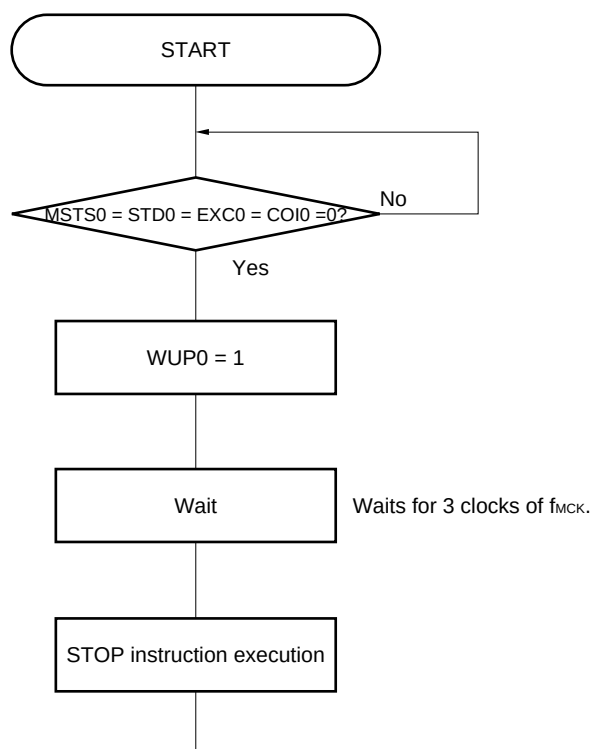
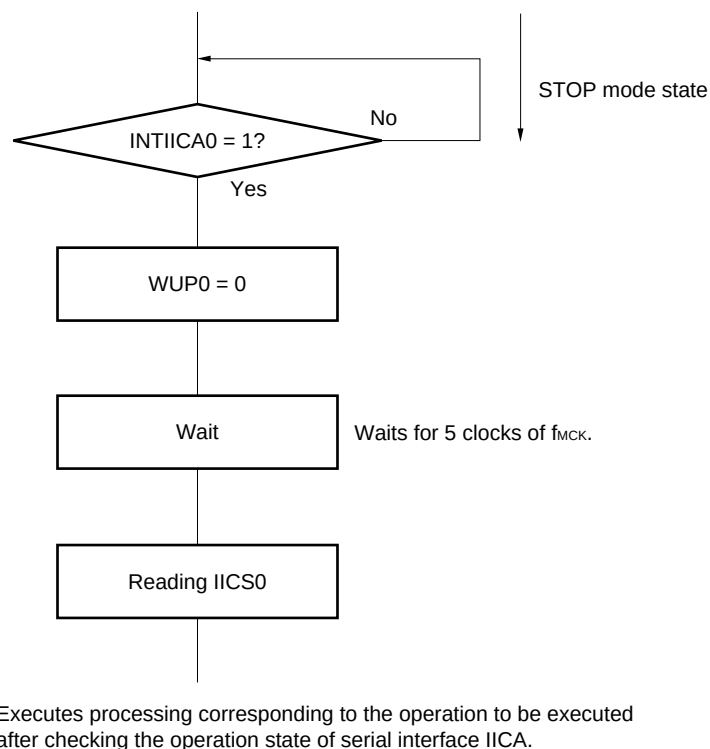
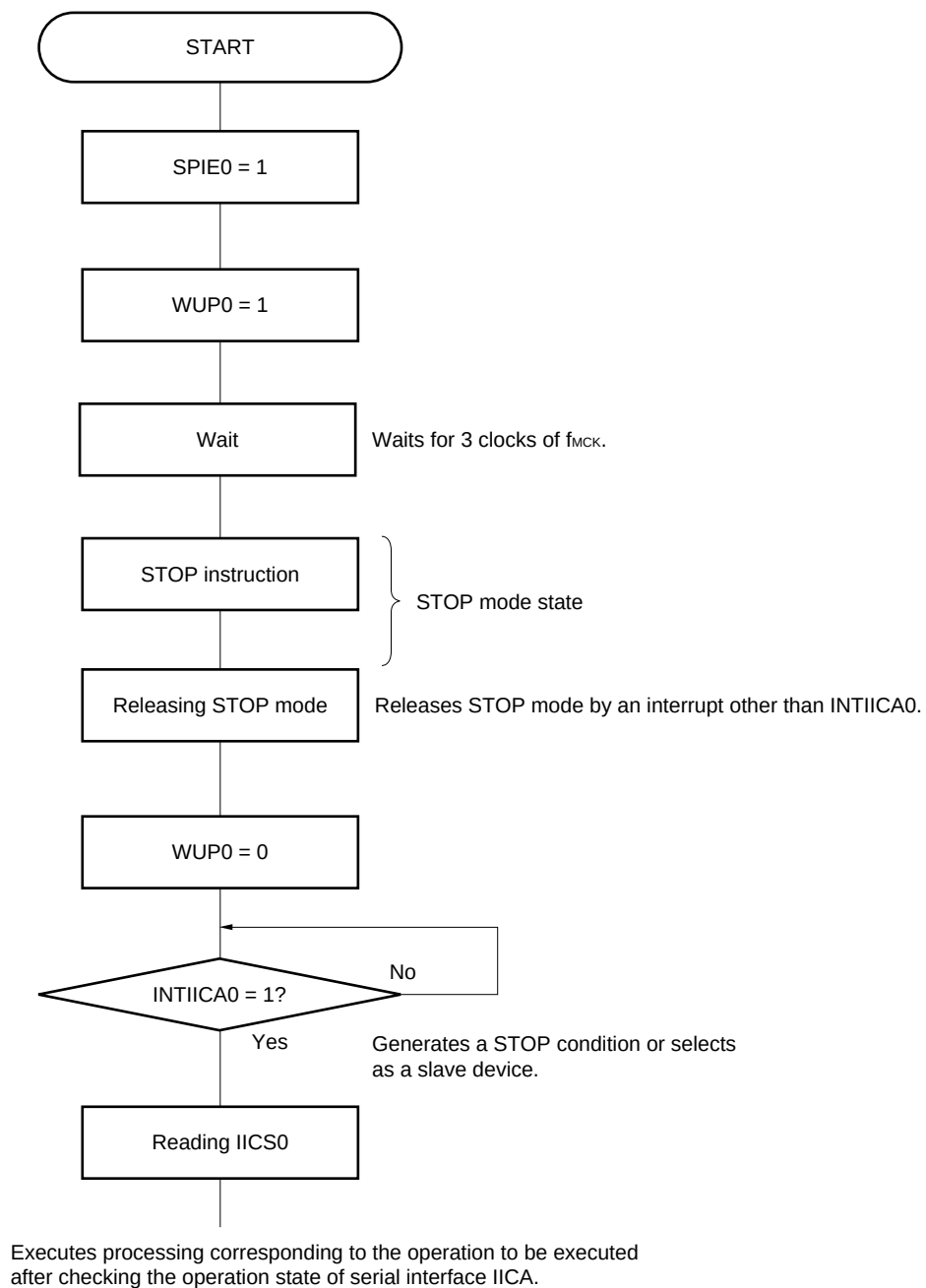


Figure 13-23. Flow When Setting WUP0 = 0 Upon Address Match (Including Extension Code Reception)

Use the following flows to perform the processing to release the STOP mode other than by an interrupt request (INTIICA0) generated from serial interface IICA.

- When operating next IIC communication as master: Flow shown in **Figure 13-24**.
- When operating next IIC communication as slave:
 - When restored by INTIICAn interrupt: Same as the flow in **Figure 13-23**.
 - When restored by other than INTIICAn interrupt: Wait for INTIICAn interrupt with WUPn left set to 1.

Figure 13-24. When Operating as Master Device After Releasing STOP Mode Other than by INTIICA0



13.5.14 Communication reservation

(1) When communication reservation function is enabled (bit 0 (IICRSV) of IICA flag register 0 (IICF0) = 0)

To start master device communications when not currently using a bus, a communication reservation can be made to enable transmission of a start condition when the bus is released. There are two modes under 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 (ACK is not returned and the bus was released by setting bit 6 (LREL0) of IICA control register 00 (IICCTL00) to 1 and saving communication).

If bit 1 (STT0) of the IICCTL00 register is set to 1 while the bus is not used (after a stop condition is detected), a start condition is automatically generated and wait state is set.

If an address is written to the IICA shift register 0 (IICA0) after bit 4 (SPIE0) of the IICCTL00 register was set to 1, and it was detected by generation of an interrupt request signal (INTIICA0) that the bus was released (detection of the stop condition), then the device automatically starts communication as the master. Data written to the IICA0 register before the stop condition is detected is invalid.

When the STT0 bit has been set to 1, the operation mode (as start condition or as communication reservation) is determined according to the bus status.

- If the bus has been released a start condition is generated
- If the bus has not been released (standby mode) communication reservation

Check whether the communication reservation operates or not by using the MSTS0 bit (bit 7 of the IICA status register 0 (IICS0)) after the STT0 bit is set to 1 and the wait time elapses.

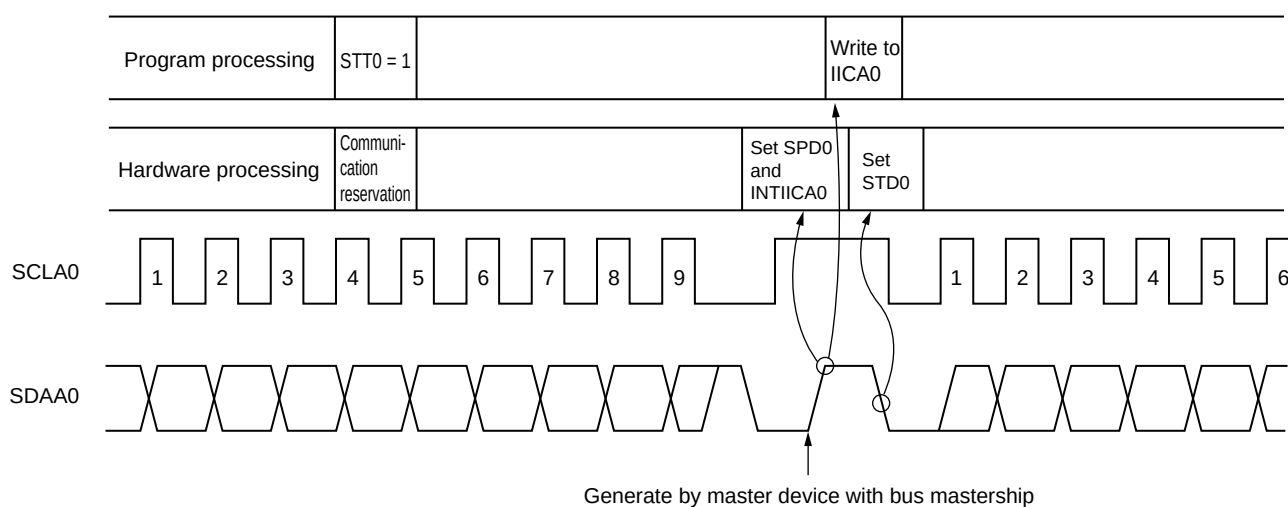
Use software to secure the wait time calculated by the following expression.

Wait time from setting STT0 = 1 to checking the MSTS0 flag:
 $(\text{IICWL0 setting value} + \text{IICWH0 setting value} + 4) / f_{\text{MCK}} + t_{\text{F}} \times 2$

Remark IICWL0: IICA low-level width setting register 0
 IICWH0: IICA high-level width setting register 0
 t_{F} : SDAA0 and SCLA0 signal falling times
 f_{MCK} : IICA operation clock frequency

Figure 13-25 shows the communication reservation timing.

Figure 13-25. Communication Reservation Timing



Remark IICA0: IICA shift register 0
 STT0: Bit 1 of IICA control register 00 (IICCTL00)
 STD0: Bit 1 of IICA status register 0 (IICS0)
 SPD0: Bit 0 of IICA status register 0 (IICS0)

Communication reservations are accepted via the timing shown in Figure 13-26. After bit 1 (STD0) of the IICA status register 0 (IICS0) is set to 1, a communication reservation can be made by setting bit 1 (STT0) of IICA control register 00 (IICCTL00) to 1 before a stop condition is detected.

Figure 13-26. Timing for Accepting Communication Reservations

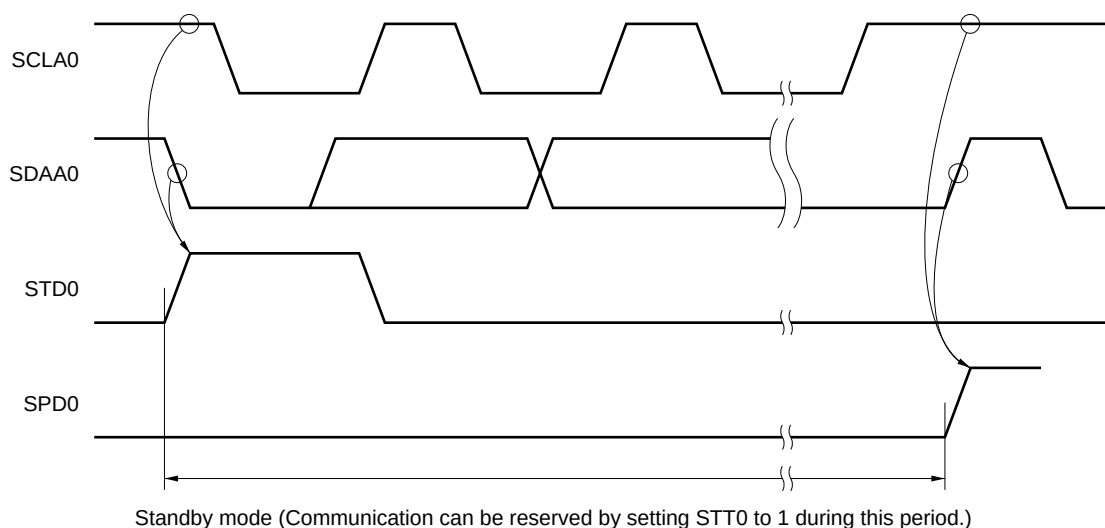
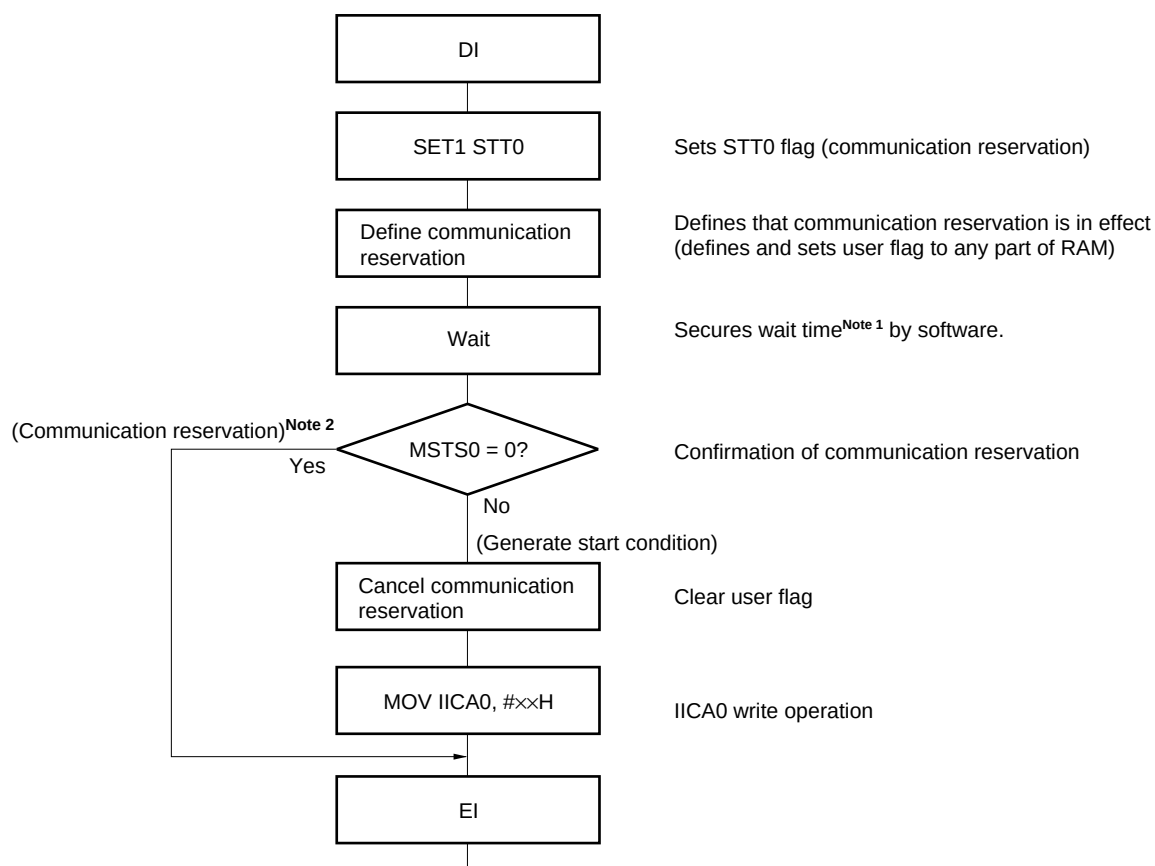


Figure 13-27 shows the communication reservation protocol.

Figure 13-27. Communication Reservation Protocol



Notes 1. The wait time is calculated as follows.

$$(\text{IICWL0 setting value} + \text{IICWH0 setting value} + 4) / f_{\text{MCK}} + t_{\text{F}} \times 2$$

2. The communication reservation operation executes a write to the IICA shift register 0 (IICA0) when a stop condition interrupt request occurs.

Remark STT0: Bit 1 of IICA control register 00 (IICCTL00)

MSTS0: Bit 7 of IICA status register 0 (IICS0)

IICA0: IICA shift register 0

IICWL0: IICA low-level width setting register 0

IICWH0: IICA high-level width setting register 0

t_{F} : SDAA0 and SCLA0 signal falling times

f_{MCK} : IICA operation clock frequency

(2) When communication reservation function is disabled (bit 0 (IICRSV) of IICA flag register 0 (IICF0) = 1)

When bit 1 (STT0) of IICA control register 00 (IICCTL00) is set to 1 when the bus is not used in a communication during bus communication, this request is rejected and a start condition is not generated. The following two statuses are included in the status where bus is not used.

- When arbitration results in neither master nor slave operation
- When an extension code is received and slave operation is disabled (ACK is not returned and the bus was released by setting bit 6 (LREL0) of the IICCTL00 register to 1 and saving communication)

To confirm whether the start condition was generated or request was rejected, check STCF (bit 7 of the IICF0 register). It takes up to 5 clocks of f_{MCK} until the STCF bit is set to 1 after setting STT0 = 1. Therefore, secure the time by software.

13.5.15 Cautions

(1) When STCEN = 0

Immediately after I²C operation is enabled (IICE0 = 1), the bus communication status (IICBSY = 1) is recognized regardless of the actual bus status. When changing from a mode in which no stop condition has been detected to a master device communication mode, first generate a stop condition to release the bus, then perform master device communication.

When using multiple masters, it is not possible to perform master device communication when the bus has not been released (when a stop condition has not been detected).

Use the following sequence for generating a stop condition.

<1> Set IICA control register 01 (IICCTL01).

<2> Set bit 7 (IICE0) of IICA control register 00 (IICCTL00) to 1.

<3> Set bit 0 (SPT0) of the IICCTL00 register to 1.

(2) When STCEN = 1

Immediately after I²C operation is enabled (IICE0 = 1), the bus released status (IICBSY = 0) is recognized regardless of the actual bus status. To generate the first start condition (STT0 = 1), it is necessary to confirm that the bus has been released, so as to not disturb other communications.

(3) If other I²C communications are already in progress

If I²C operation is enabled and the device participates in communication already in progress when the SDAA0 pin is low and the SCLA0 pin is high, the macro of I²C recognizes that the SDAA0 pin has gone low (detects a start condition). If the value on the bus at this time can be recognized as an extension code, ACK is returned, but this interferes with other I²C communications. To avoid this, start I²C in the following sequence.

<1> Clear bit 4 (SPIE0) of the IICCTL00 register to 0 to disable generation of an interrupt request signal (INTIICA0) when the stop condition is detected.

<2> Set bit 7 (IICE0) of the IICCTL00 register to 1 to enable the operation of I²C.

<3> Wait for detection of the start condition.

<4> Set bit 6 (LREL0) of the IICCTL00 register to 1 before ACK is returned (4 to 72 clocks of f_{MCK} after setting the IICE0 bit to 1), to forcibly disable detection.

(4) Setting the STT0 and SPT0 bits (bits 1 and 0 of the IICCTL00 register) again after they are set and before they are cleared to 0 is prohibited.

(5) When transmission is reserved, set the SPIE0 bit (bit 4 of the IICCTL0 register) to 1 so that an interrupt request is generated when the stop condition is detected. Transfer is started when communication data is written to the IICA shift register 0 (IICA0) after the interrupt request is generated. Unless the interrupt is generated when the stop condition is detected, the device stops in the wait state because the interrupt request is not generated when communication is started. However, it is not necessary to set the SPIE0 bit to 1 when the MSTS0 bit (bit 7 of the IICA status register 0 (IICS0)) is detected by software.

13.5.16 Communication operations

The following shows three operation procedures with the flowchart.

(1) Master operation in single master system

The flowchart when using the RL78/G1A 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 I²C bus multimaster system, whether the bus is released or used cannot be judged by the I²C 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 RL78/G1A 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 RL78/G1A 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

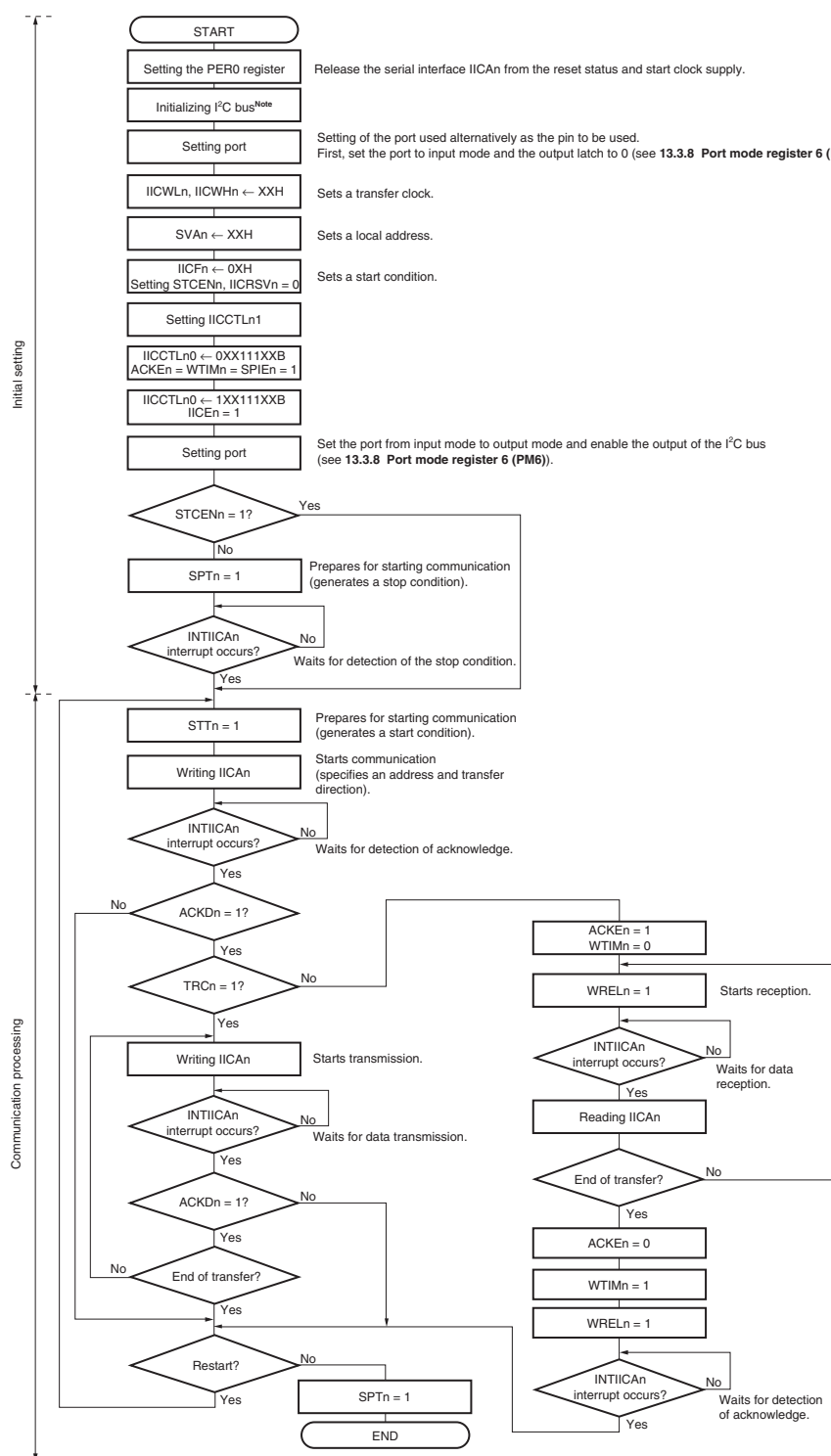
An example of when the RL78/G1A is used as the I²C bus slave is shown below.

When used as the slave, operation is started by an interrupt. Execute the initial settings at startup, then wait for the INTIICA0 interrupt occurrence (communication waiting). When an INTIICA0 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.

(1) Master operation in single-master system

Figure 13-28. Master Operation in Single-Master System



Note Release (SCLA0 and SDAA0 pins = high level) the I²C bus in conformance with the specifications of the product that is communicating. If EEPROM is outputting a low level to the SDAA0 pin, for example, set the SCLA0 pin in the output port mode, and output a clock pulse from the output port until the SDAA0 pin is constantly at high level.

Remarks 1. Conform to the specifications of the product that is communicating, with respect to the transmission and reception formats.

2. n = 0

(2) Master operation in multi-master system

Figure 13-29. Master Operation in Multi-Master System (1/4)

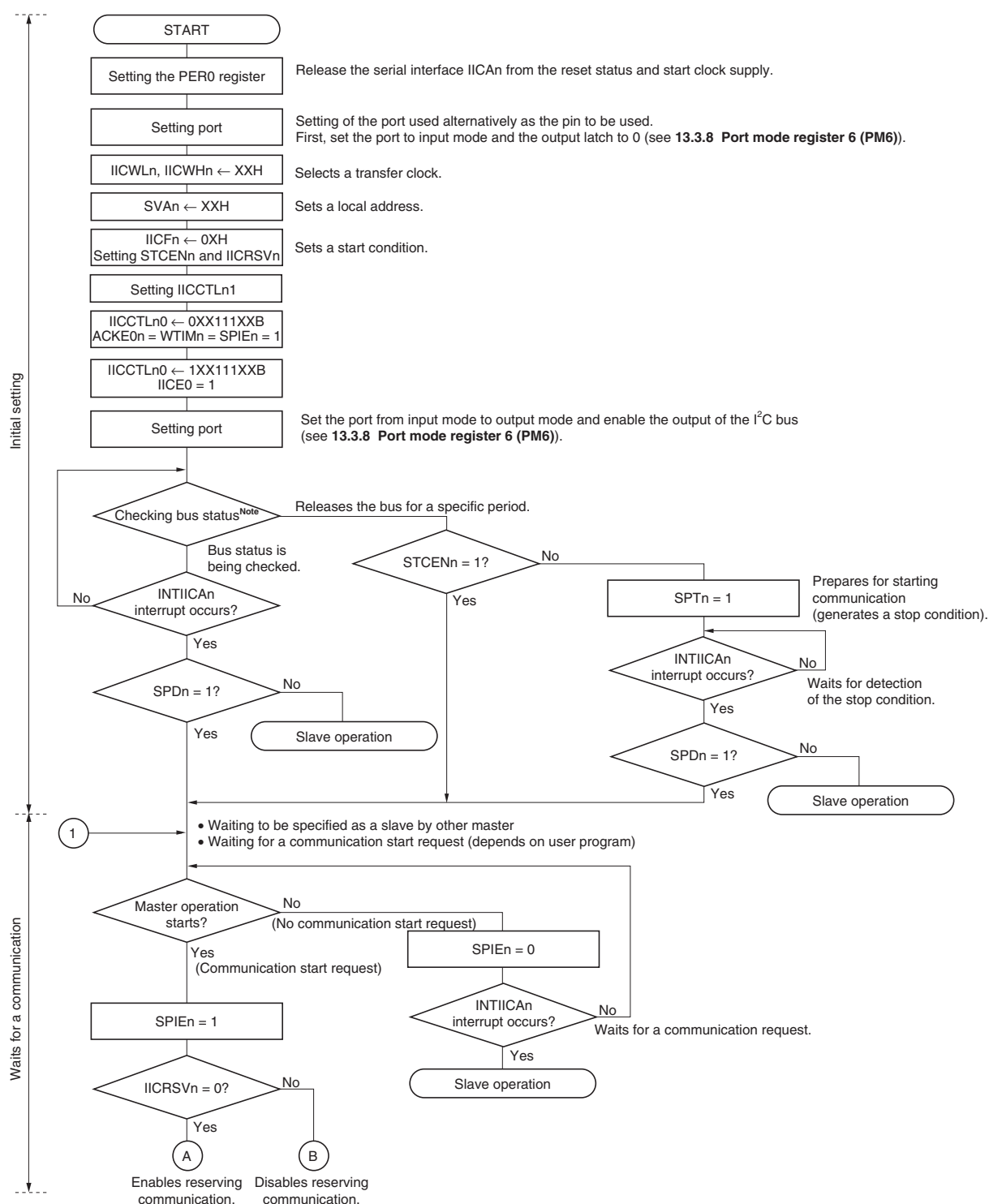
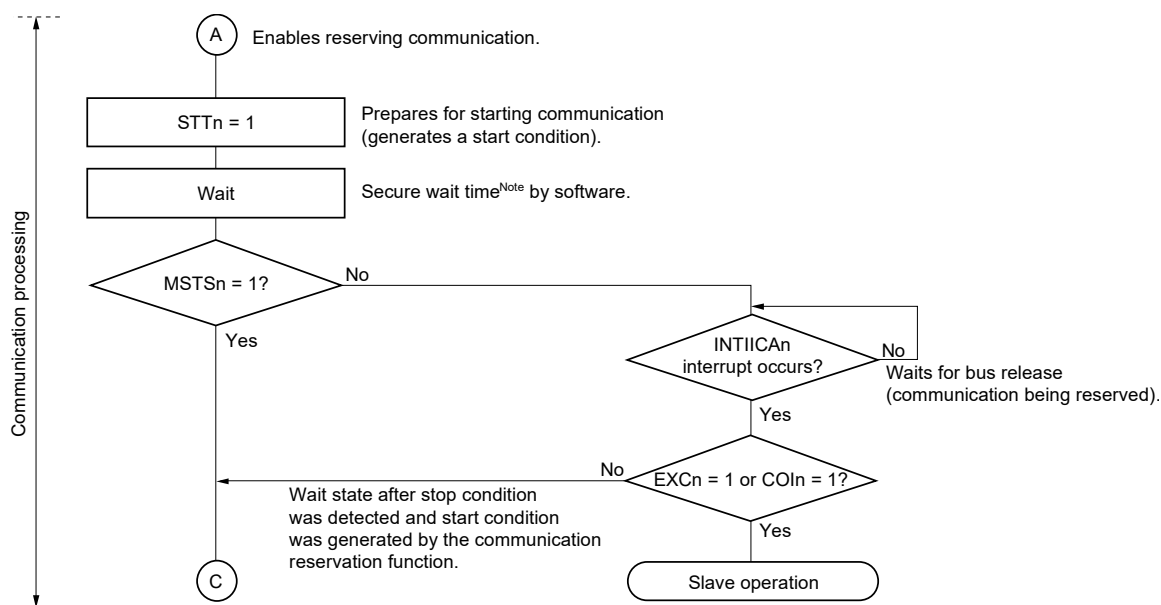


Figure 13-29. Master Operation in Multi-Master System (2/4)



Note The wait time is calculated as follows.

$$(IICWL_n \text{ setting value} + IICWH_n \text{ setting value} + 4) / f_{MCK} + t_F \times 2$$

Remark IICWL_n: IICA low-level width setting register 0
 IICWH_n: IICA high-level width setting register 0
 t_F: SDA_n and SCL_n signal falling times
 f_{MCK}: IICA operation clock frequency

Figure 13-29. Master Operation in Multi-Master System (3/4)

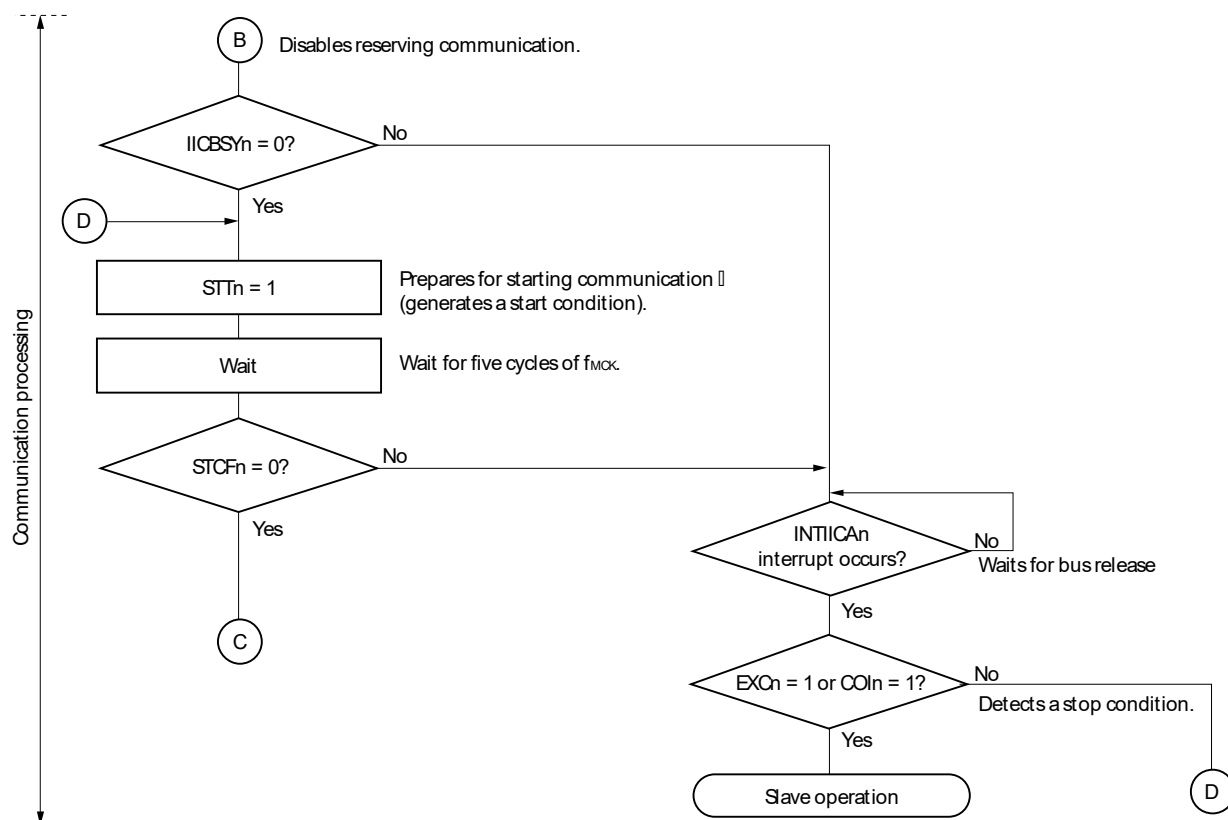
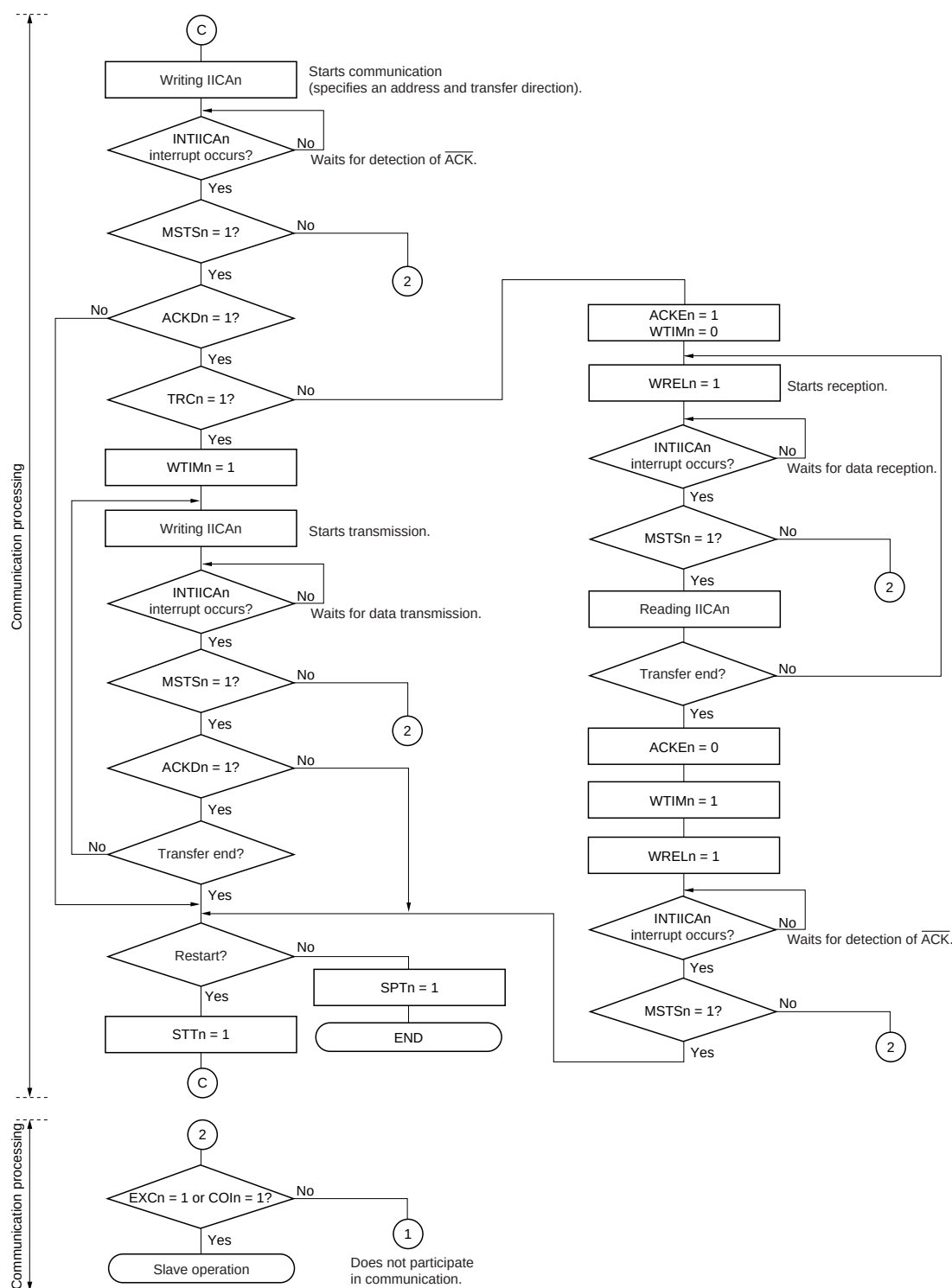


Figure 13-29. Master Operation in Multi-Master System (4/4)



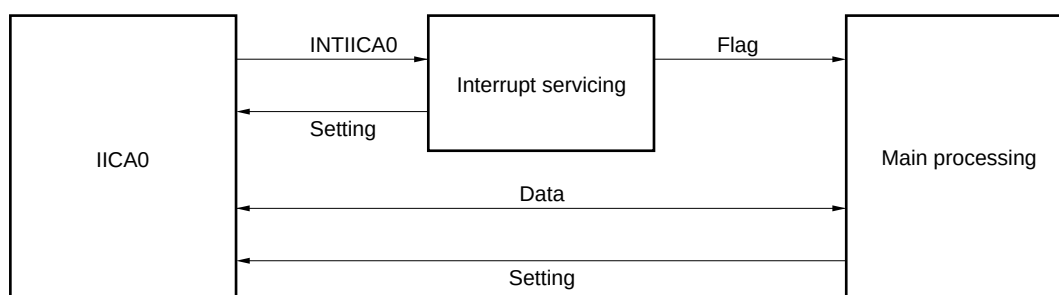
- Remarks**
1. Conform to the specifications of the product that is communicating, with respect to the transmission and reception formats.
 2. To use the device as a master in a multi-master system, read the MSTSn bit each time interrupt INTIICA0 has occurred to check the arbitration result.
 3. To use the device as a slave in a multi-master system, check the status by using the IICA status register 0 (IICS0) and IICA flag register 0 (IICF0) each time interrupt INTIICA0 has occurred, and determine the processing to be performed next.
 4. n = 0

(3) Slave operation

The processing procedure of the slave operation is as follows.

Basically, the slave operation is event-driven. Therefore, processing by the INTIICA0 interrupt (processing that must substantially change the operation status such as detection of a stop condition during communication) is necessary.

In the following explanation, it is assumed that the extension code is not supported for data communication. It is also assumed that the INTIICA0 interrupt servicing only performs status transition processing, and that actual data communication is performed by the main processing.



Therefore, data communication processing is performed by preparing the following three flags and passing them to the main processing instead of INTIICA0.

<1> Communication mode flag

This flag indicates the following two communication statuses.

- Clear mode: Status in which data communication is not performed
- Communication mode: Status in which data communication is performed (from valid address detection to stop condition detection, no detection of ACK from master, address mismatch)

<2> Ready flag

This flag indicates that data communication is enabled. Its function is the same as the INTIICA0 interrupt for ordinary data communication. This flag is set by interrupt servicing and cleared by the main processing. Clear this flag by interrupt servicing when communication is started. However, the ready flag is not set by interrupt servicing when the first data is transmitted. Therefore, the first data is transmitted without the flag being cleared (an address match is interpreted as a request for the next data).

<3> Communication direction flag

This flag indicates the direction of communication. Its value is the same as the TRC0 bit.

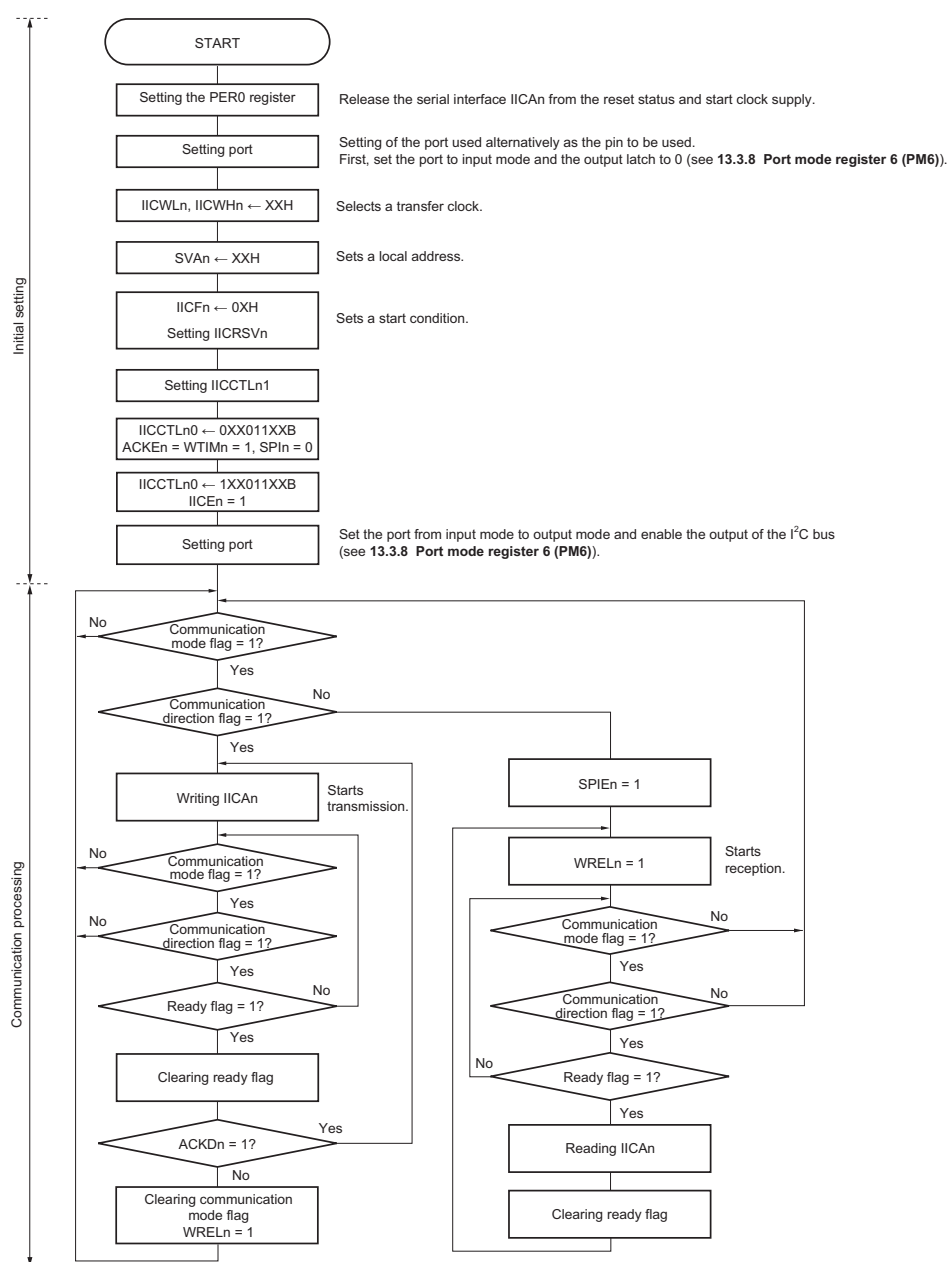
The main processing of the slave operation is explained next.

Start serial interface IICA and wait until communication is enabled. When communication is enabled, execute communication by using the communication mode flag and ready flag (processing of the stop condition and start condition is performed by an interrupt. Here, check the status by using the flags).

The transmission operation is repeated until the master no longer returns ACK. If ACK is not returned from the master, communication is completed.

For reception, the necessary amount of data is received. When communication is completed, ACK is not returned as the next data. After that, the master generates a stop condition or restart condition. Exit from the communication status occurs in this way.

Figure 13-30. Slave Operation Flowchart (1)



Remarks 1. Conform to the specifications of the product that is in communication, regarding the transmission and reception formats.

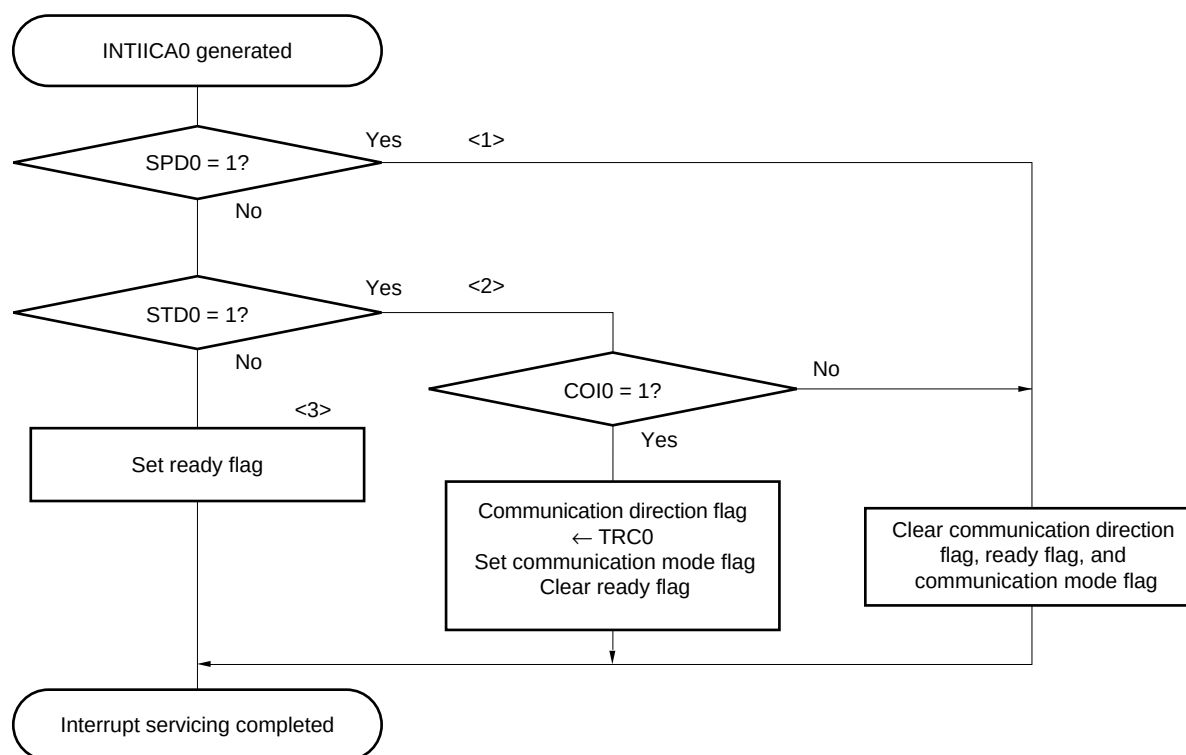
2. n = 0

An example of the processing procedure of the slave with the INTIICA0 interrupt is explained below (processing is performed assuming that no extension code is used). The INTIICA0 interrupt checks the status, and the following operations are performed.

- <1> Communication is stopped if the stop condition is issued.
- <2> If the start condition is issued, the address is checked and communication is completed if the address does not match. If the address matches, the communication mode is set, wait is cancelled, and processing returns from the interrupt (the ready flag is cleared).
- <3> For data transmit/receive, only the ready flag is set. Processing returns from the interrupt with the I²C bus remaining in the wait state.

Remark <1> to <3> above correspond to <1> to <3> in Figure 13-31 Slave Operation Flowchart (2).

Figure 13-31. Slave Operation Flowchart (2)



13.5.17 Timing of I²C interrupt request (INTIICA0) occurrence

The timing of transmitting or receiving data and generation of interrupt request signal INTIICA0, and the value of the IICA status register 0 (IICS0) when the INTIICA0 signal is generated are shown below.

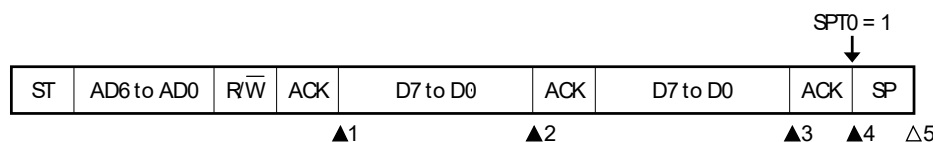
Remark

ST:	Start condition
AD6 to AD0:	Address
R/ $\overline{W}$:	Transfer direction specification
ACK:	Acknowledge
D7 to D0:	Data
SP:	Stop condition

(1) Master device operation

(a) Start ~ Address ~ Data ~ Data ~ Stop (transmission/reception)

(i) When WTIM0 = 0



▲1: IICS0 = 1000×110B

▲2: IICS0 = 1000×000B

▲3: IICS0 = 1000×000B (Sets the WTIM0 bit to 1)^{Note}

▲4: IICS0 = 1000××00B (Sets the SPT0 bit to 1)

Δ5: IICS0 = 00000001B

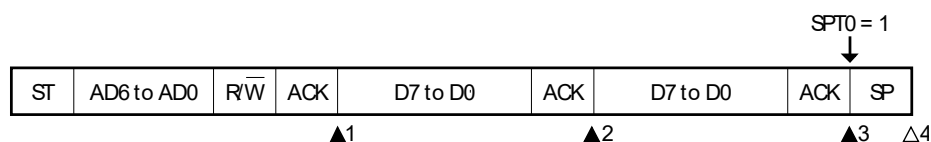
Note To generate a stop condition, set the WTIM0 bit to 1 and change the timing for generating the INTIICA0 interrupt request signal.

Remark ▲: Always generated

Δ: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1



▲1: IICS0 = 1000×110B

▲2: IICS0 = 1000×100B

▲3: IICS0 = 1000××00B (Sets the SPT0 bit to 1)

Δ4: IICS0 = 00000001B

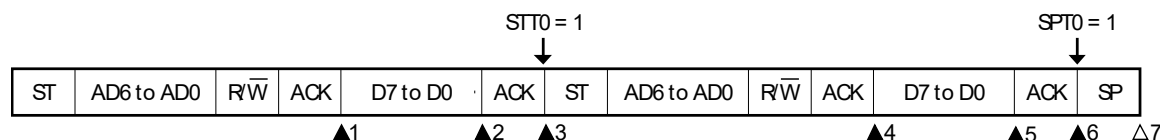
Remark ▲: Always generated

Δ: Generated only when SPIE0 = 1

×: Don't care

(b) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop (restart)

(i) When WTIM0 = 0



▲1: IICS0 = 1000×110B

▲2: IICS0 = 1000×000B (Sets the WTIM0 bit to 1)^{Note 1}▲3: IICS0 = 1000××00B (Clears the WTIM0 bit to 0^{Note 2}, sets the STT0 bit to 1)

▲4: IICS0 = 1000×110B

▲5: IICS0 = 1000×000B (Sets the WTIM0 bit to 1)^{Note 3}

▲6: IICS0 = 1000××00B (Sets the SPT0 bit to 1)

△7: IICS0 = 00000001B

Notes 1. To generate a start condition, set the WTIM0 bit to 1 and change the timing for generating the INTIICA0 interrupt request signal.

2. Clear the WTIM0 bit to 0 to restore the original setting.

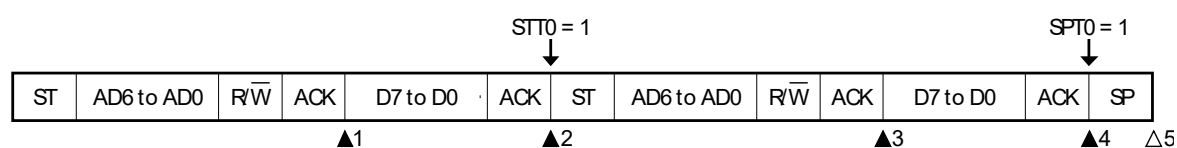
3. To generate a stop condition, set the WTIM0 bit to 1 and change the timing for generating the INTIICA0 interrupt request signal.

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1



▲1: IICS0 = 1000×110B

▲2: IICS0 = 1000××00B (Sets the STT0 bit to 1)

▲3: IICS0 = 1000×110B

▲4: IICS0 = 1000××00B (Sets the SPT0 bit to 1)

△5: IICS0 = 00000001B

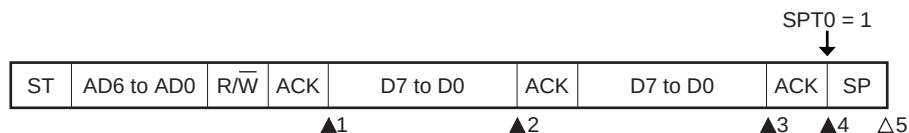
Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(c) Start ~ Code ~ Data ~ Data ~ Stop (extension code transmission)

(i) When WTIM0 = 0



▲1: IICS0 = 1010×110B

▲2: IICS0 = 1010×000B

▲3: IICS0 = 1010×000B (Sets the WTIM0 bit to 1)^{Note}

▲4: IICS0 = 1010××00B (Sets the SPT0 bit to 1)

Δ5: IICS0 = 00000001B

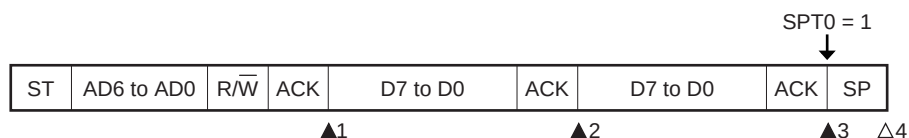
Note To generate a stop condition, set the WTIM0 bit to 1 and change the timing for generating the INTIICA0 interrupt request signal.

Remark ▲: Always generated

Δ: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1



▲1: IICS0 = 1010×110B

▲2: IICS0 = 1010×100B

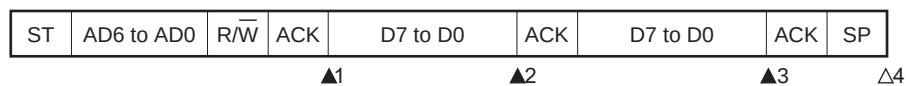
▲3: IICS0 = 1010××00B (Sets the SPT0 bit to 1)

Δ4: IICS0 = 00001001B

Remark ▲: Always generated

Δ: Generated only when SPIE0 = 1

×: Don't care

(2) Slave device operation (slave address data reception)**(a) Start ~ Address ~ Data ~ Data ~ Stop****(i) When WTIM0 = 0**

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001×000B

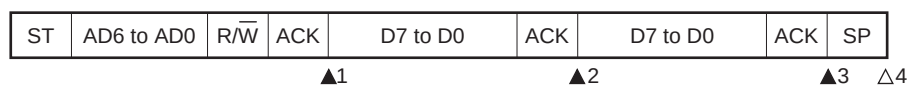
▲3: IICS0 = 0001×000B

△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001×100B

▲3: IICS0 = 0001××00B

△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(b) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop**(i) When WTIM0 = 0 (after restart, matches with SVA0)**

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001×000B

▲3: IICS0 = 0001×110B

▲4: IICS0 = 0001×000B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1 (after restart, matches with SVA0)

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001××00B

▲3: IICS0 = 0001×110B

▲4: IICS0 = 0001××00B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(c) Start ~ Address ~ Data ~ Start ~ Code ~ Data ~ Stop

(i) When $WTIM0 = 0$ (after restart, does not match address (= extension code))

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001×000B

▲3: IICS0 = 0010×010B

▲4: IICS0 = 0010×000B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When $WTIM0 = 1$ (after restart, does not match address (= extension code))

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001××00B

▲3: IICS0 = 0010×010B

▲4: IICS0 = 0010×110B

▲5: IICS0 = 0010××00B

△6: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(d) Start ~ Address ~ Data ~ Start ~ Address ~ Data ~ Stop**(i) When WTIM0 = 0 (after restart, does not match address (= not extension code))**

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001×000B

▲3: IICS_n = 00000×10B

△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1 (after restart, does not match address (= not extension code))

▲1: IICS0 = 0001×110B

▲2: IICS0 = 0001××00B

▲3: IICS_n = 00000×10B

△4: IICS0 = 00000001B

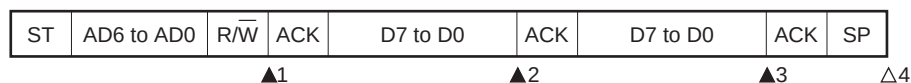
Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(3) Slave device operation (when receiving extension code)

The device is always participating in communication when it receives an extension code.

(a) Start ~ Code ~ Data ~ Data ~ Stop**(i) When WTIM0 = 0**

▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×000B

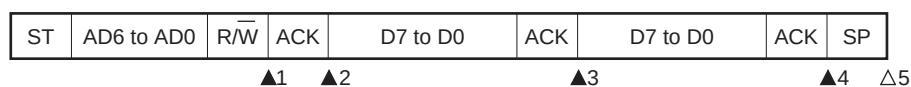
▲3: IICS0 = 0010×000B

△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1

▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×110B

▲3: IICS0 = 0010×100B

▲4: IICS0 = 0010××00B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(b) Start ~ Code ~ Data ~ Start ~ Address ~ Data ~ Stop

(i) When $WTIM0 = 0$ (after restart, matches SVA0)

▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×000B

▲3: IICS0 = 0001×110B

▲4: IICS0 = 0001×000B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When $WTIM0 = 1$ (after restart, matches SVA0)

▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×110B

▲3: IICS0 = 0010××00B

▲4: IICS0 = 0001×110B

▲5: IICS0 = 0001××00B

△6: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(c) Start ~ Code ~ Data ~ Start ~ Code ~ Data ~ Stop

(i) When WTIM0 = 0 (after restart, extension code reception)



▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×000B

▲3: IICS0 = 0010×010B

▲4: IICS0 = 0010×000B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1 (after restart, extension code reception)



▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×110B

▲3: IICS0 = 0010××00B

▲4: IICS0 = 0010×010B

▲5: IICS0 = 0010×110B

▲6: IICS0 = 0010××00B

△7: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(d) Start ~ Code ~ Data ~ Start ~ Address ~ Data ~ Stop

(i) When WTIM0 = 0 (after restart, does not match address (= not extension code))



▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×000B

▲3: IICS0 = 00000×10B

△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1 (after restart, does not match address (= not extension code))



▲1: IICS0 = 0010×010B

▲2: IICS0 = 0010×110B

▲3: IICS0 = 0010××00B

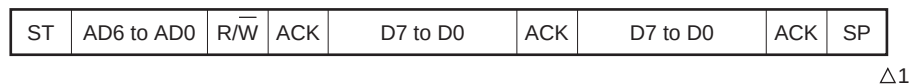
▲4: IICS0 = 00000×10B

△5: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

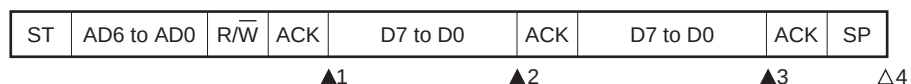
(4) Operation without communication**(a) Start ~ Code ~ Data ~ Data ~ Stop**

△1: IICS0 = 00000001B

Remark △: Generated only when SPIE0 = 1

(5) Arbitration loss operation (operation as slave after arbitration loss)

When the device is used as a master in a multi-master system, read the MSTSD bit each time interrupt request signal INTIICA0 has occurred to check the arbitration result.

(a) When arbitration loss occurs during transmission of slave address data**(i) When WTIM0 = 0**

▲1: IICS0 = 0101×110B

▲2: IICS0 = 0001×000B

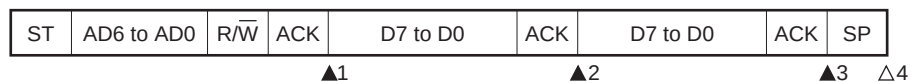
▲3: IICS0 = 0001×000B

△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When **WTIM0 = 1**

▲1: IICS0 = 0101×110B

▲2: IICS0 = 0001×100B

▲3: IICS0 = 0001××00B

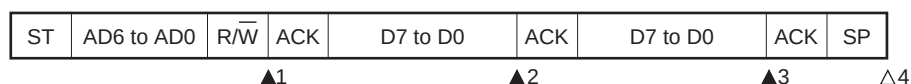
△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(b) When arbitration loss occurs during transmission of extension code

(i) When **WTIM0 = 0**

▲1: IICS0 = 0110×010B

▲2: IICS0 = 0010×000B

▲3: IICS0 = 0010×000B

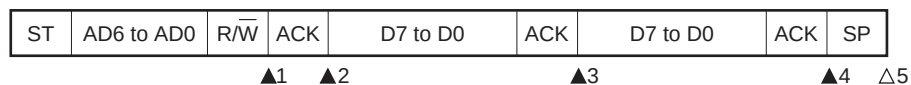
△4: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When WTIM0 = 1



▲1: IICS0 = 0110×010B

▲2: IICS0 = 0010×110B

▲3: IICS0 = 0010×100B

▲4: IICS0 = 0010××00B

Δ5: IICS0 = 00000001B

Remark ▲: Always generated

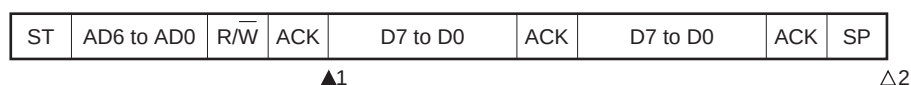
Δ: Generated only when SPIE0 = 1

×: Don't care

(6) Operation when arbitration loss occurs (no communication after arbitration loss)

When the device is used as a master in a multi-master system, read the MSTS0 bit each time interrupt request signal INTIICA0 has occurred to check the arbitration result.

(a) When arbitration loss occurs during transmission of slave address data (when WTIM0 = 1)

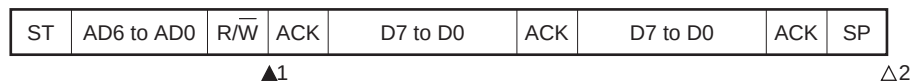


▲1: IICS0 = 01000110B

Δ2: IICS0 = 00000001B

Remark ▲: Always generated

Δ: Generated only when SPIE0 = 1

(b) When arbitration loss occurs during transmission of extension code

▲1: IICS0 = 0110×010B

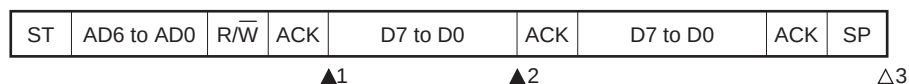
Sets LREL0 = 1 by software

△2: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(c) When arbitration loss occurs during transmission of data**(i) When WTIM0 = 0**

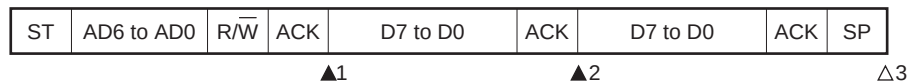
▲1: IICS0 = 10001110B

▲2: IICS0 = 01000000B

△3: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

(ii) When **WTIM0 = 1**

▲1: IICS0 = 10001110B

▲2: IICS0 = 01000100B

△3: IICS0 = 00000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

(d) When loss occurs due to restart condition during data transfer

(i) Not extension code (Example: unmatched with SVA0)



▲1: IICS0 = 1000×110B

▲2: IICS0 = 01000110B

△3: IICS0 = 00000001B

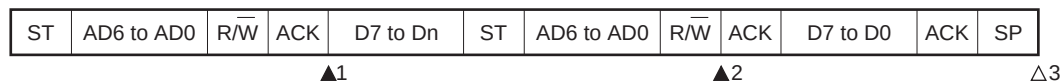
Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

n = 6 to 0

(ii) Extension code



▲1: IICS0 = 1000×110B

▲2: IICS0 = 01100010B

Sets LREL0 = 1 by software

△3: IICS0 = 00000001B

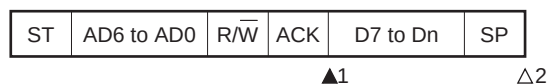
Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

n = 6 to 0

(e) When loss occurs due to stop condition during data transfer



▲1: IICS0 = 10000110B

△2: IICS0 = 01000001B

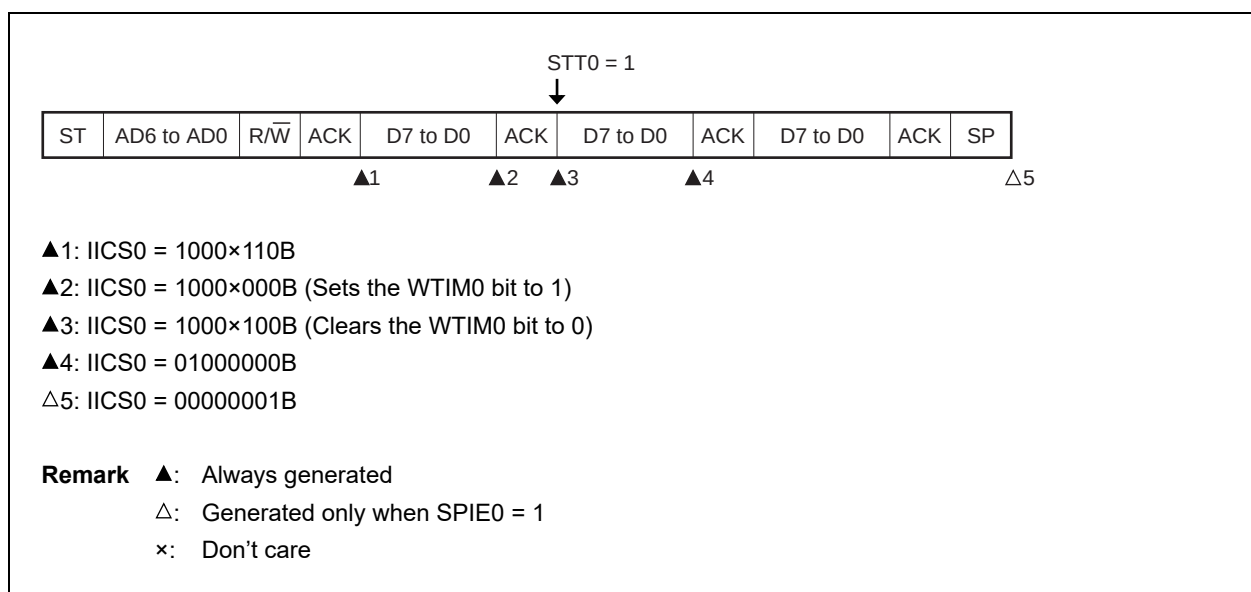
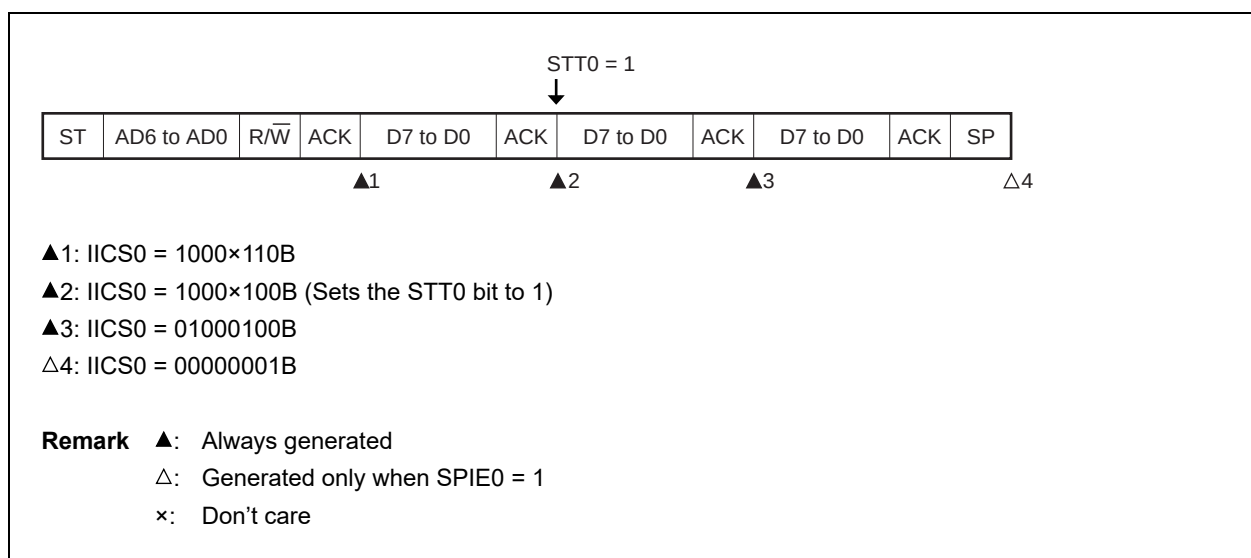
Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

n = 6 to 0

(f) When arbitration loss occurs due to low-level data when attempting to generate a restart condition

(i) When $WTIM0 = 0$ (ii) When $WTIM0 = 1$ 

(g) When arbitration loss occurs due to a stop condition when attempting to generate a restart condition

(i) When **WTIM0 = 0**



▲1: IICS0 = 1000×110B

▲2: IICS0 = 1000×000B (Sets the WTIM0 bit to 1)

▲3: IICS0 = 1000××00B (Sets the STT0 bit to 1)

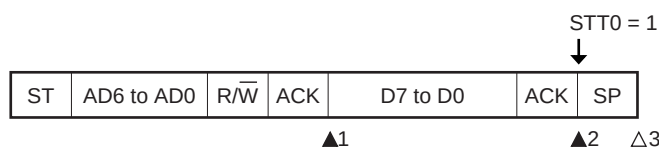
△4: IICS0 = 01000001B

Remark ▲: Always generated

△: Generated only when SPIE0 = 1

×: Don't care

(ii) When **WTIM0 = 1**



▲1: IICS0 = 1000×110B

▲2: IICS0 = 1000××00B (Sets the STT0 bit to 1)

△3: IICS0 = 01000001B

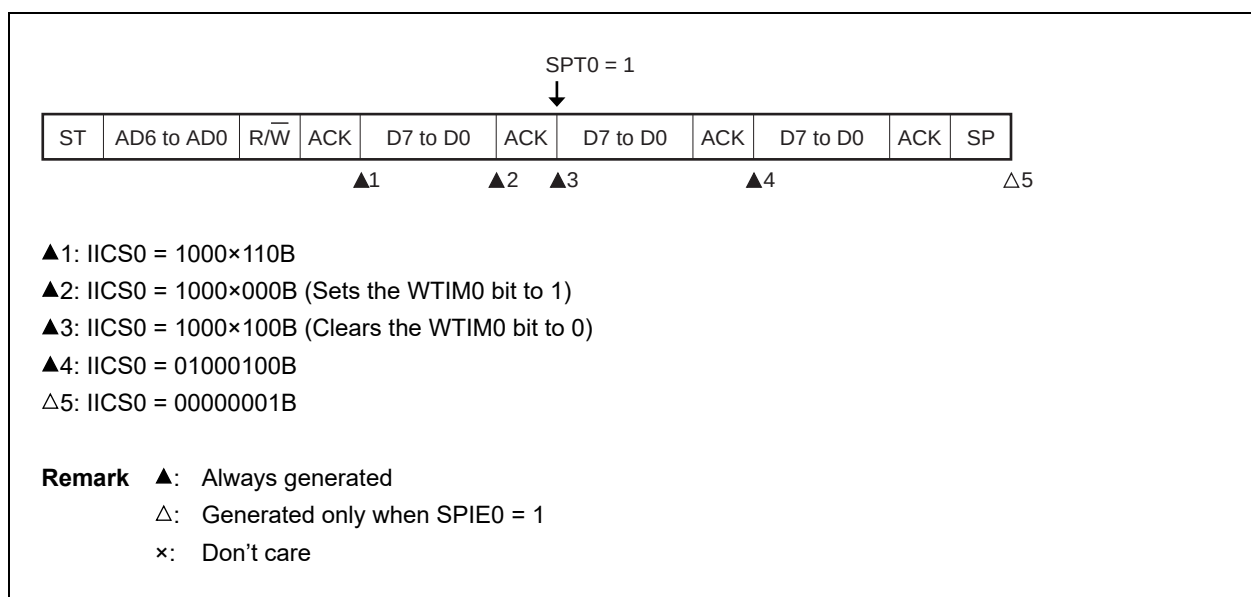
Remark ▲: Always generated

△: Generated only when SPIE0 = 1

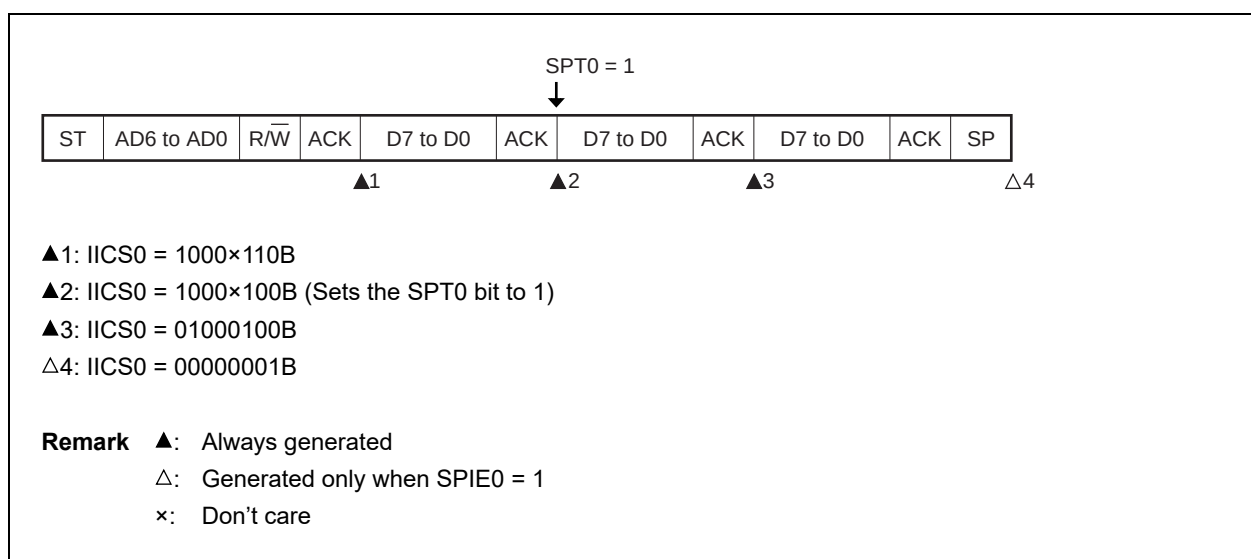
×: Don't care

(h) When arbitration loss occurs due to low-level data when attempting to generate a stop condition

(i) When $WTIM0 = 0$



(ii) When $WTIM0 = 1$



13.6 Timing Charts

When using the I²C 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 TRC0 bit (bit 3 of the IICA status register 0 (IICS0)), which specifies the data transfer direction, and then starts serial communication with the slave device.

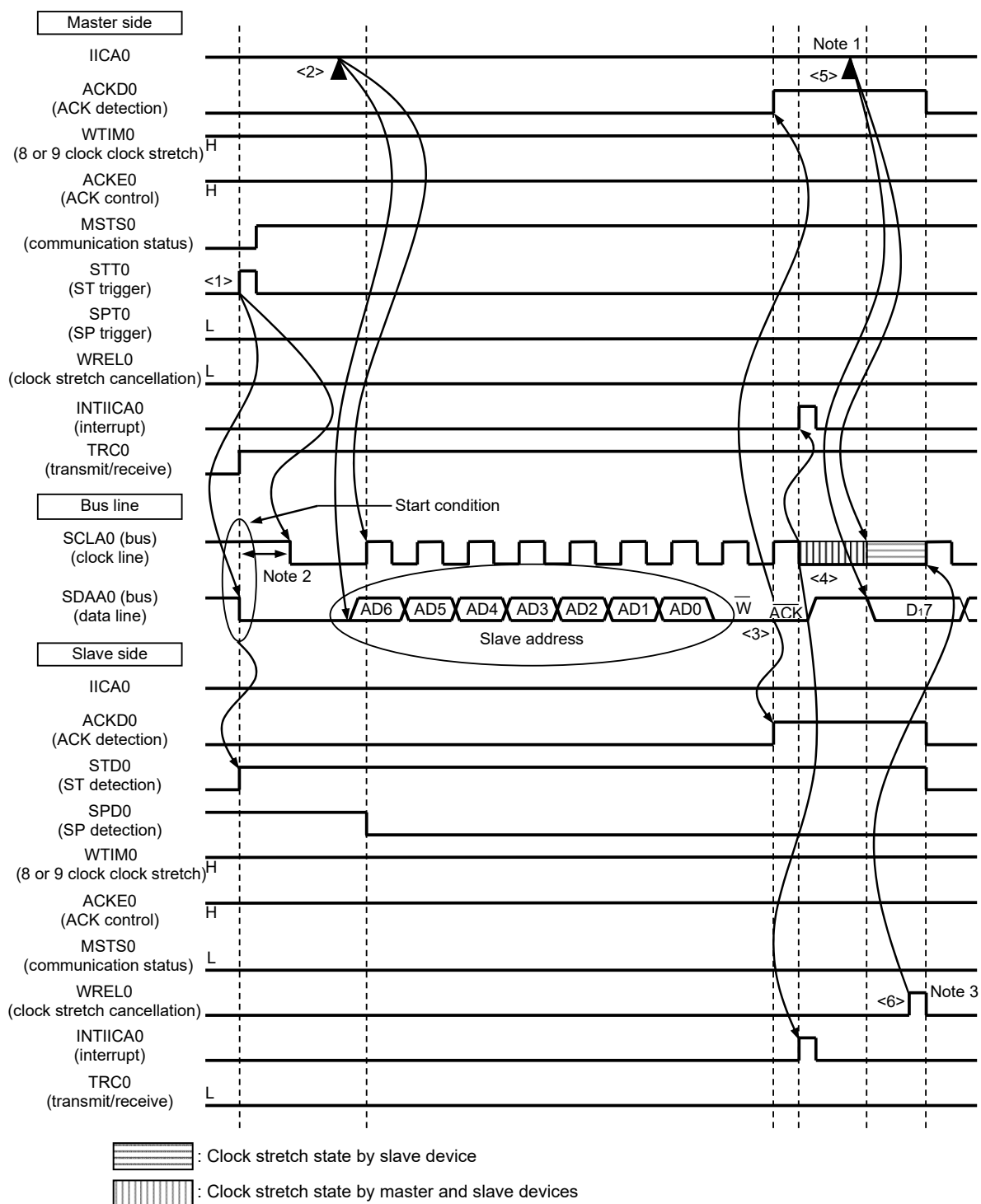
Figures 13-32 and 13-33 show timing charts of the data communication.

The IICA shift register 0 (IICA0)'s shift operation is synchronized with the falling edge of the serial clock (SCLA0). The transmit data is transferred to the SO latch and is output (MSB first) via the SDAA0 pin.

Data input via the SDAA0 pin is captured into IICA0 at the rising edge of SCLA0.

Figure 13-32. Example of Master to Slave Communication
(9-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (1/4)

(1) Start condition ~ address ~ data



The meanings of <1> to <6> in (1) Start condition ~ address ~ data in Figure 13-32 are explained below.

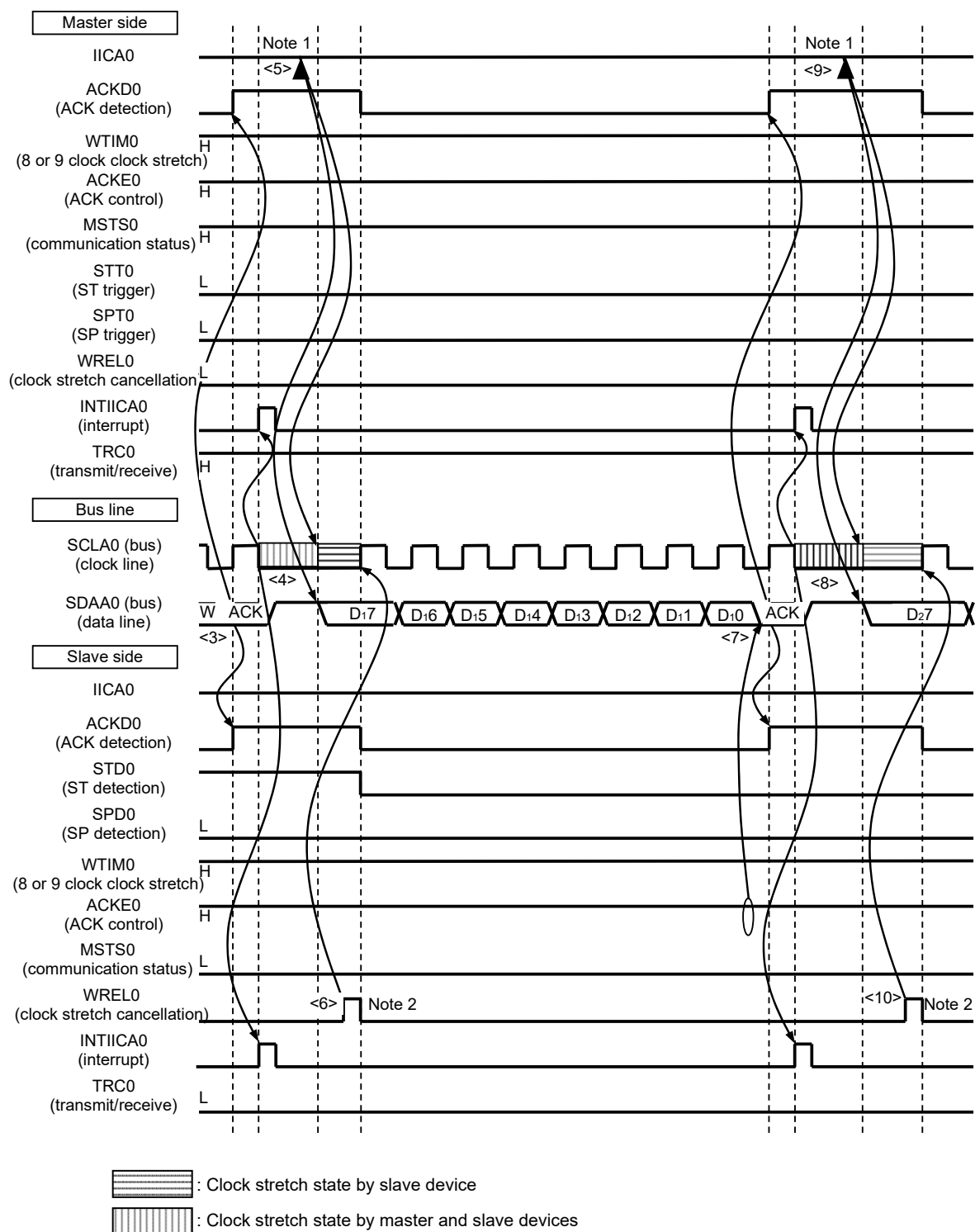
- <1> The start condition trigger is set by the master device (STT0 = 1) and a start condition (i.e. SCLA0 = 1 changes SDAA0 from 1 to 0) is generated once the bus data line goes low (SDAA0). When the start condition is subsequently detected, the master device enters the master device communication status (MSTS0 = 1). The master device is ready to communicate once the bus clock line goes low (SCLA0 = 0) after the hold time has elapsed.
- <2> The master device writes the address + W (transmission) to the IICA shift register 0 (IICA0) and transmits the slave address.
- <3> In the slave device if the address received matches the address (SVA0 value) of a slave device^{Note}, that slave device sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <4> The master device issues an interrupt (INTIICA0: end of address transmission) at the falling edge of the 9th clock. The slave device whose address matched the transmitted slave address sets a clock stretch status (SCLA0 = 0) and issues an interrupt (INTIICA0: address match)^{Note}.
- <5> The master device writes the data to transmit to the IICA0 register and releases the clock stretch status that it set by the master device.
- <6> If the slave device releases the clock stretch status (WREL0 = 1), the master device starts transferring data to the slave device.

Note If the transmitted address does not match the address of the slave device, the slave device does not return an ACK to the master device (NACK: SDAA0 = 1). The slave device also does not issue the INTIICA0 interrupt (address match) and does not set a clock stretch status. The master device, however, issues the INTIICA0 interrupt (end of address transmission) regardless of whether it receives an ACK or NACK.

Remark <1> to <15> in Figure 13-32 represent the entire procedure for communicating data using the I²C bus. Figure 13-32 (1) Start condition ~ address ~ data shows the processing from <1> to <6>, Figure 13-32 (2) Address ~ data ~ data shows the processing from <3> to <10>, and Figure 13-32 (3) Data ~ data ~ stop condition shows the processing from <7> to <15>.

Figure 13-32. Example of Master to Slave Communication
(9-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (2/4)

(2) Address ~ data ~ data



- Notes**
1. Write data to IICA0, not setting the WREL0 bit, in order to cancel a clock stretch state during transmission by a master device.
 2. For releasing clock stretch state during reception of a slave device, write "FFH" to IICA0 or set the WREL0 bit.

The meanings of <3> to <10> in (2) Address ~ data ~ data in Figure 13-32 are explained below.

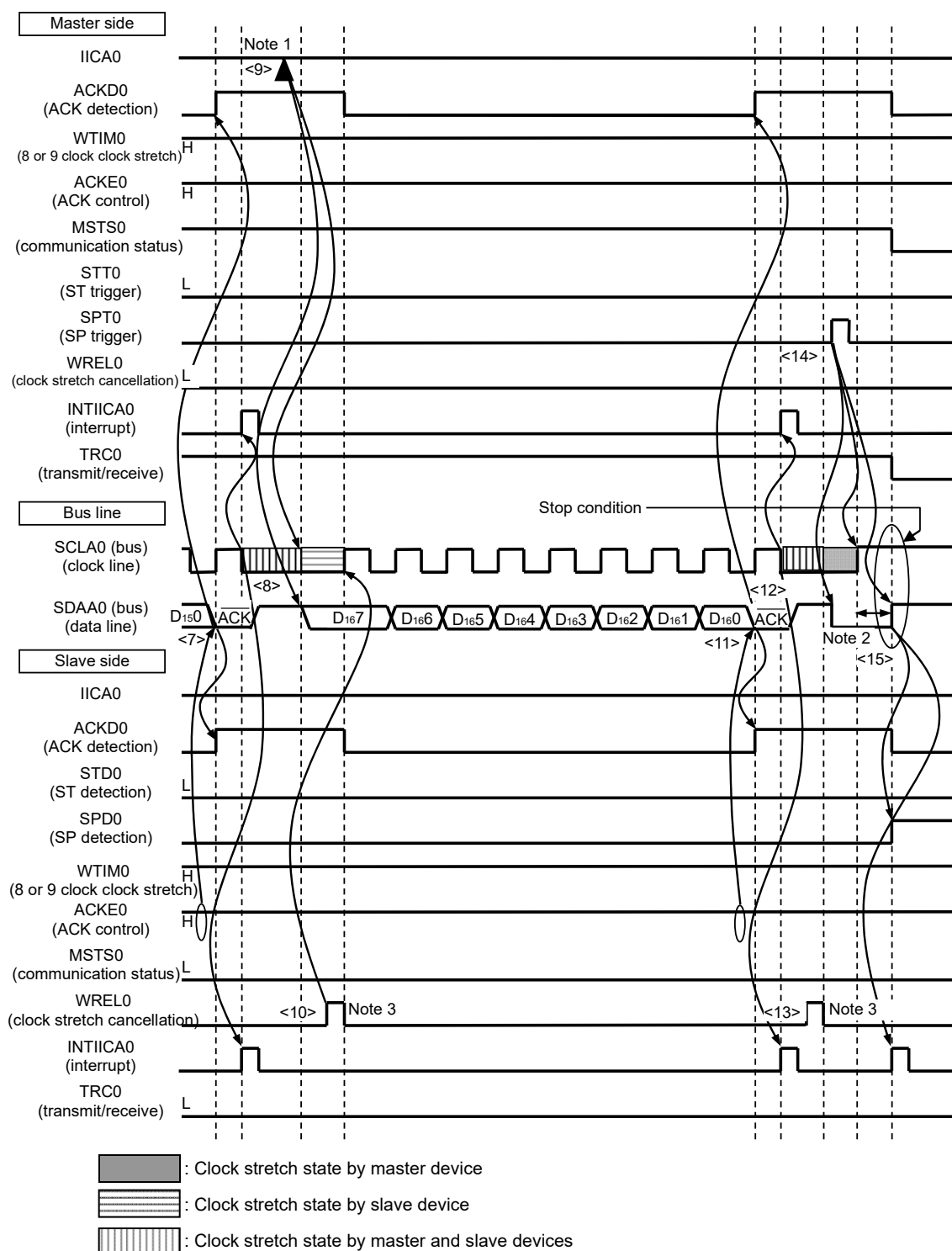
- <3> In the slave device if the address received matches the address (SVA0 value) of a slave device^{Note}, that slave device sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <4> The master device issues an interrupt (INTIICA0: end of address transmission) at the falling edge of the 9th clock. The slave device whose address matched the transmitted slave address sets a clock stretch status (SCLA0 = 0) and issues an interrupt (INTIICA0: address match)^{Note}.
- <5> The master device writes the data to transmit to the IICA shift register 0 (IICA0) and releases the clock stretch status that it set by the master device.
- <6> If the slave device releases the clock stretch status (WREL0 = 1), the master device starts transferring data to the slave device.
- <7> After data transfer is completed, because of ACKE0 = 1, the slave device sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <8> The master device and slave device set a clock stretch status (SCLA0 = 0) at the falling edge of the 9th clock, and both the master device and slave device issue an interrupt (INTIICA0: end of transfer).
- <9> The master device writes the data to transmit to the IICA0 register and releases the clock stretch status that it set by the master device.
- <10> The slave device reads the received data and releases the clock stretch status (WREL0 = 1). The master device then starts transferring data to the slave device.

Note If the transmitted address does not match the address of the slave device, the slave device does not return an ACK to the master device (NACK: SDAA0 = 1). The slave device also does not issue the INTIICA0 interrupt (address match) and does not set a clock stretch status. The master device, however, issues the INTIICA0 interrupt (end of address transmission) regardless of whether it receives an ACK or NACK.

Remark <1> to <15> in Figure 13-32 represent the entire procedure for communicating data using the I²C bus. Figure 13-32 (1) Start condition ~ address ~ data shows the processing from <1> to <6>, Figure 13-32 (2) Address ~ data ~ data shows the processing from <3> to <10>, and Figure 13-32 (3) Data ~ data ~ stop condition shows the processing from <7> to <15>.

Figure 13-32. Example of Master to Slave Communication
(9-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (3/4)

(3) Data ~ data ~ Stop condition



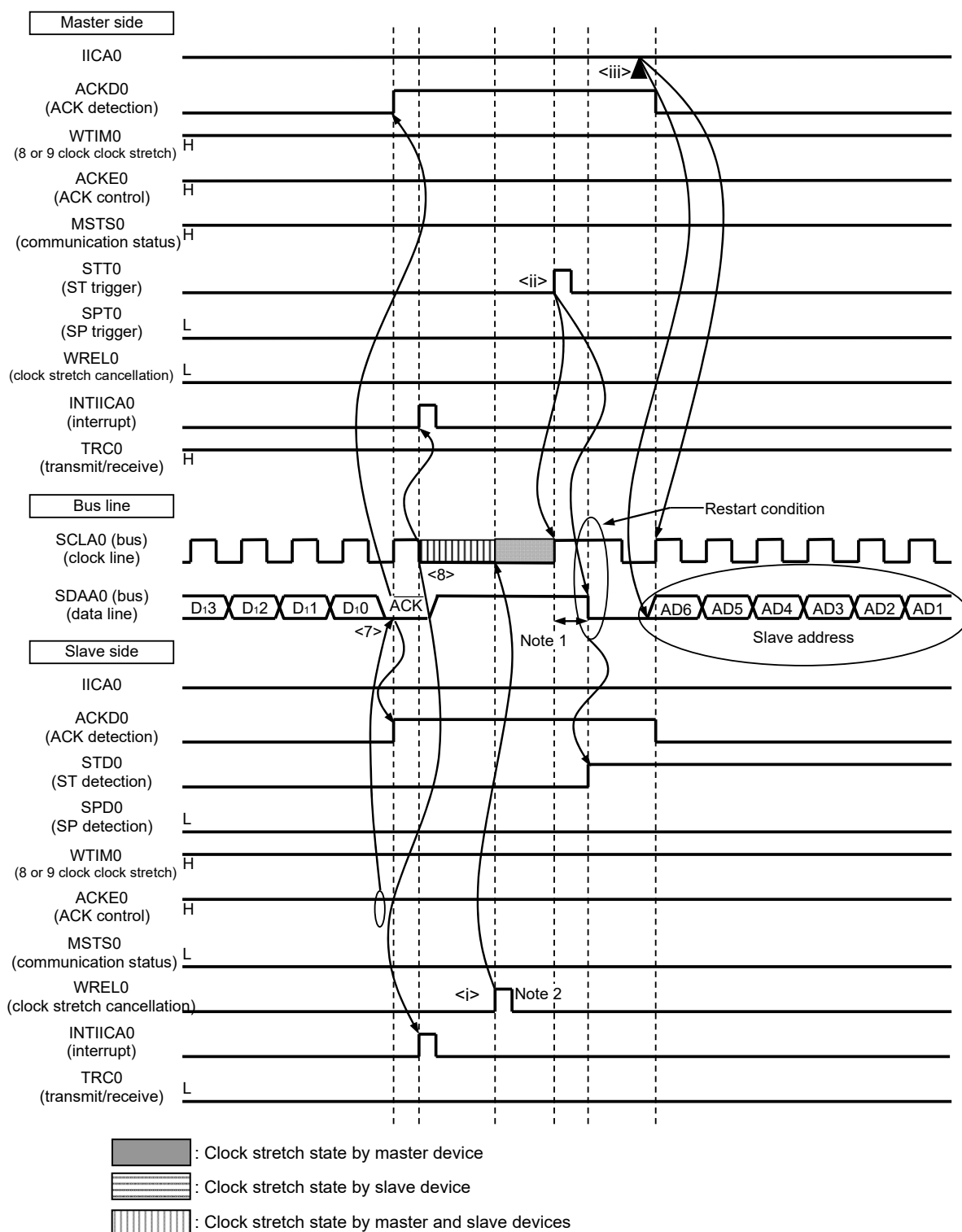
The meanings of <7> to <15> in (3) Data ~ data ~ stop condition in Figure 13-32 are explained below.

- <7> After data transfer is completed, because of ACKE0 = 1, the slave device sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <8> The master device and slave device set a clock stretch status (SCLA0 = 0) at the falling edge of the 9th clock, and both the master device and slave device issue an interrupt (INTIICA0: end of transfer).
- <9> The master device writes the data to transmit to the IICA shift register 0 (IICA0) and releases the clock stretch status that it set by the master device.
- <10> The slave device reads the received data and releases the clock stretch status (WREL0 = 1). The master device then starts transferring data to the slave device.
- <11> When data transfer is complete, the slave device (ACKE0 = 1) sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <12> The master device and slave device set a clock stretch status (SCLA0 = 0) at the falling edge of the 9th clock, and both the master device and slave device issue an interrupt (INTIICA0: end of transfer).
- <13> The slave device reads the received data and releases the clock stretch status (WREL0 = 1).
- <14> By the master device setting a stop condition trigger (SPT0 = 1), the bus data line is cleared (SDAA0 = 0) and the bus clock line is set (SCLA0 = 1). After the stop condition setup time has elapsed, by setting the bus data line (SDAA0 = 1), the stop condition is then generated (i.e. SCLA0 = 1 changes SDAA0 from 0 to 1).
- <15> When a stop condition is generated, the slave device detects the stop condition and issues an interrupt (INTIICA0: stop condition).

Remark <1> to <15> in Figure 13-32 represent the entire procedure for communicating data using the I²C bus. Figure 13-32 (1) Start condition ~ address ~ data shows the processing from <1> to <6>, Figure 13-32 (2) Address ~ data ~ data shows the processing from <3> to <10>, and Figure 13-32 (3) Data ~ data ~ stop condition shows the processing from <7> to <15>.

Figure 13-32. Example of Master to Slave Communication
(9-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (4/4)

(4) Data ~ restart condition ~ address



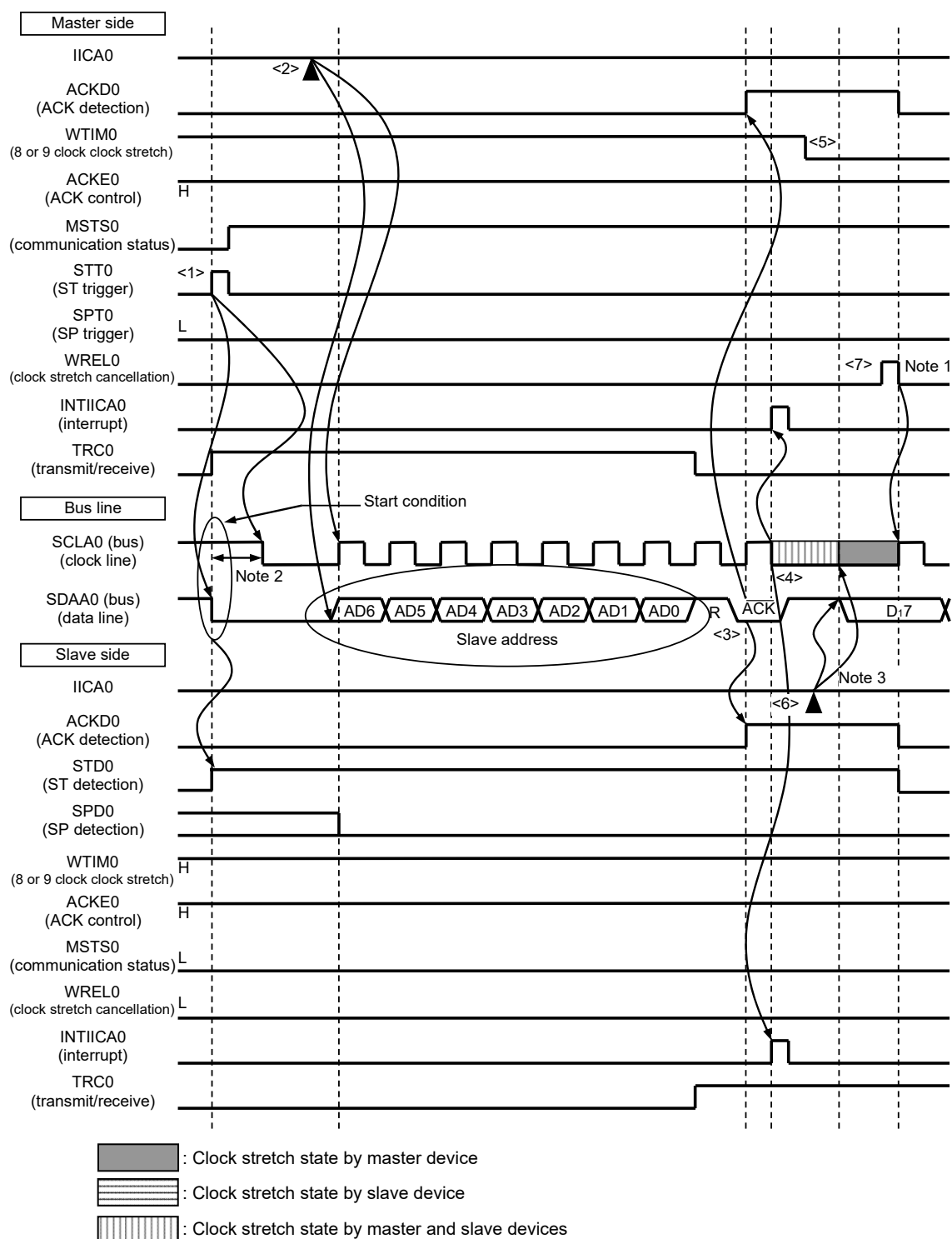
- Notes**
1. Make sure that the time between the rise of the SCLA0 pin signal and the generation of the start condition after a restart condition has been issued is at least 4.7 μ s when specifying standard mode and at least 0.6 μ s when specifying fast mode.
 2. For releasing clock stretch state during reception of a slave device, write "FFH" to IICA0 or set the WREL0 bit.

The following describes the operations in Figure 13-32 (4) Data ~ restart condition ~ address. After the operations in steps <7> and <8>, the operations in steps <i> to <iii> are performed. These steps return the processing to step <iii>, the data transmission step.

- <7> After data transfer is completed, because of $ACKEO = 1$, the slave device sends an ACK by hardware to the master device. The ACK is detected by the master device ($ACKD0 = 1$) at the rising edge of the 9th clock.
- <8> The master device and slave device set a clock stretch status ($SCLA0 = 0$) at the falling edge of the 9th clock, and both the master device and slave device issue an interrupt (INTIICA0: end of transfer).
- <i> The slave device reads the received data and releases the clock stretch status ($WREL0 = 1$).
- <ii> The start condition trigger is set again by the master device ($STT0 = 1$) and a start condition (i.e. $SCLA0 = 1$ changes $SDAA0$ from 1 to 0) is generated once the bus clock line goes high ($SCLA0 = 1$) and the bus data line goes low ($SDAA0 = 0$) after the restart condition setup time has elapsed. When the start condition is subsequently detected, the master device is ready to communicate once the bus clock line goes low ($SCLA0 = 0$) after the hold time has elapsed.
- <iii> The master device writing the address + R/W (transmission) to the IICA shift register (IICA0) enables the slave address to be transmitted.

Figure 13-33. Example of Slave to Master Communication
(8-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (1/3)

(1) Start condition ~ address ~ data



- Notes**
- For releasing clock stretch state during reception of a master device, write "FFH" to IICA0 or set the WREL0 bit.
 - Make sure that the time between the fall of the SDAA0 pin signal and the fall of the SCLA0 pin signal is at least 4.0 μ s when specifying standard mode and at least 0.6 μ s when specifying fast mode.
 - Write data to IICA0, not setting the WREL0 bit, in order to cancel a clock stretch state during transmission by a slave device.

The meanings of <1> to <7> in (1) Start condition ~ address ~ data in Figure 13-33 are explained below.

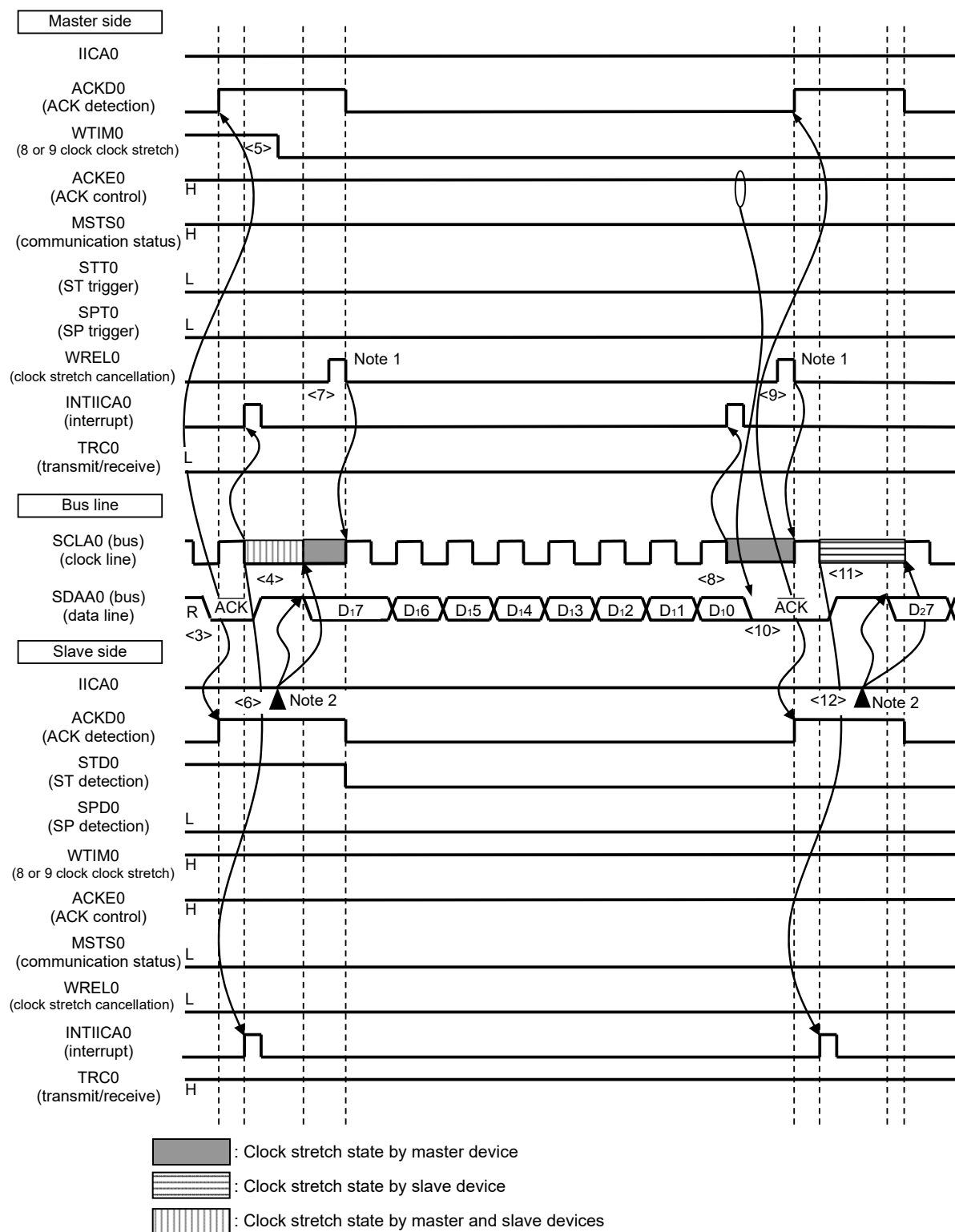
- <1> The start condition trigger is set by the master device (STT0 = 1) and a start condition (i.e. SCLA0 = 1 changes SDAA0 from 1 to 0) is generated once the bus data line goes low (SDAA0). When the start condition is subsequently detected, the master device enters the master device communication status (MSTS0 = 1). The master device is ready to communicate once the bus clock line goes low (SCLA0 = 0) after the hold time has elapsed.
- <2> The master device writes the address + R (reception) to the IICA shift register 0 (IICA0) and transmits the slave address.
- <3> In the slave device if the address received matches the address (SVA0 value) of a slave device^{Note}, that slave device sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <4> The master device issues an interrupt (INTIICA0: end of address transmission) at the falling edge of the 9th clock. The slave device whose address matched the transmitted slave address sets a clock stretch status (SCLA0 = 0) and issues an interrupt (INTIICA0: address match)^{Note}.
- <5> The timing at which the master device sets the clock stretch status changes to the 8th clock (WTIM0 = 0).
- <6> The slave device writes the data to transmit to the IICA0 register and releases the clock stretch status that it set by the slave device.
- <7> The master device releases the clock stretch status (WREL0 = 1) and starts transferring data from the slave device to the master device.

Note If the transmitted address does not match the address of the slave device, the slave device does not return an ACK to the master device (NACK: SDAA0 = 1). The slave device also does not issue the INTIICA0 interrupt (address match) and does not set a clock stretch status. The master device, however, issues the INTIICA0 interrupt (end of address transmission) regardless of whether it receives an ACK or NACK.

Remark <1> to <19> in Figure 13-33 represent the entire procedure for communicating data using the I²C bus. Figure 13-33 (1) Start condition ~ address ~ data shows the processing from <1> to <7>, Figure 13-33 (2) Address ~ data ~ data shows the processing from <3> to <12>, and Figure 13-33 (3) Data ~ data ~ stop condition shows the processing from <8> to <19>.

Figure 13-33. Example of Slave to Master Communication
(8-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (2/3)

(2) Address ~ data ~ data



Notes 1. For releasing clock stretch state during reception of a master device, write “FFH” to IICA0 or set the WRELO bit.

2. Write data to IICA0, not setting the WRELO bit, in order to cancel a clock stretch state during transmission by a slave device.

The meanings of <3> to <12> in (2) Address ~ data ~ data in Figure 13-33 are explained below.

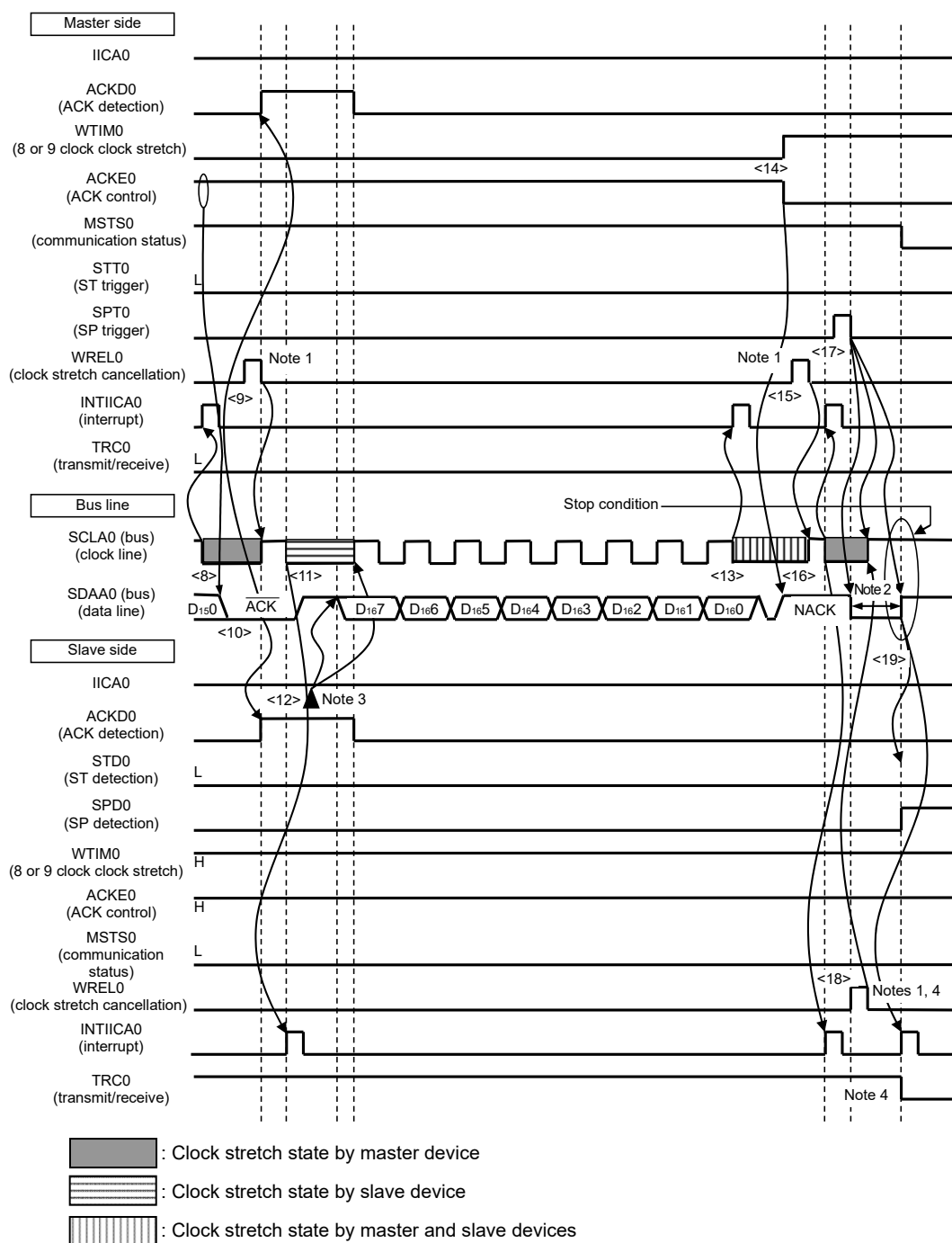
- <3> In the slave device if the address received matches the address (SVA0 value) of a slave device^{Note}, that slave device sends an ACK by hardware to the master device. The ACK is detected by the master device (ACKD0 = 1) at the rising edge of the 9th clock.
- <4> The master device issues an interrupt (INTIICA0: end of address transmission) at the falling edge of the 9th clock. The slave device whose address matched the transmitted slave address sets a clock stretch status (SCLA0 = 0) and issues an interrupt (INTIICA0: address match)^{Note}.
- <5> The master device changes the timing of the clock stretch status to the 8th clock (WTIM0 = 0).
- <6> The slave device writes the data to transmit to the IICA shift register 0 (IICA0) and releases the clock stretch status that it set by the slave device.
- <7> The master device releases the clock stretch status (WREL0 = 1) and starts transferring data from the slave device to the master device.
- <8> The master device sets a clock stretch status (SCLA0 = 0) at the falling edge of the 8th clock, and issues an interrupt (INTIICA0: end of transfer). Because of ACKE0 = 1 in the master device, the master device then sends an ACK by hardware to the slave device.
- <9> The master device reads the received data and releases the clock stretch status (WREL0 = 1).
- <10> The ACK is detected by the slave device (ACKD0 = 1) at the rising edge of the 9th clock.
- <11> The slave device set a clock stretch status (SCLA0 = 0) at the falling edge of the 9th clock, and the slave device issue an interrupt (INTIICA0: end of transfer).
- <12> By the slave device writing the data to transmit to the IICA0 register, the clock stretch status set by the slave device is released. The slave device then starts transferring data to the master device.

Note If the transmitted address does not match the address of the slave device, the slave device does not return an ACK to the master device (NACK: SDAA0 = 1). The slave device also does not issue the INTIICA0 interrupt (address match) and does not set a clock stretch status. The master device, however, issues the INTIICA0 interrupt (end of address transmission) regardless of whether it receives an ACK or NACK.

Remark <1> to <19> in Figure 13-33 represent the entire procedure for communicating data using the I²C bus. Figure 13-33 (1) Start condition ~ address ~ data shows the processing from <1> to <7>, Figure 13-33 (2) Address ~ data ~ data shows the processing from <3> to <12>, and Figure 13-33 (3) Data ~ data ~ stop condition shows the processing from <8> to <19>.

Figure 13-33. Example of Slave to Master Communication
(8-Clock and 9-Clock Clock Stretch Is Selected for Master, 9-Clock Clock Stretch Is Selected for Slave) (3/3)

(3) Data ~ data ~ stop condition



- Notes**
- To cancel a clock stretch state, write "FFH" to IICA0 or set the WREL0 bit.
 - Make sure that the time between the rise of the SCLA0 pin signal and the generation of the stop condition after a stop condition has been issued is at least 4.0 μ s when specifying standard mode and at least 0.6 μ s when specifying fast mode.
 - Write data to IICA0, not setting the WREL0 bit, in order to cancel a clock stretch state during transmission by a slave device.
 - If a clock stretch state during transmission by a slave device is canceled by setting the WREL0 bit, the TRC0 bit will be cleared.

The meanings of <8> to <19> in (3) Data ~ data ~ stop condition in Figure 13-33 are explained below.

- <8> The master device sets a clock stretch status (SCLA0 = 0) at the falling edge of the 8th clock, and issues an interrupt (INTIICA0: end of transfer). Because of ACKE0 = 0 in the master device, the master device then sends an ACK by hardware to the slave device.
- <9> The master device reads the received data and releases the clock stretch status (WREL0 = 1).
- <10> The ACK is detected by the slave device (ACKD0 = 1) at the rising edge of the 9th clock.
- <11> The slave device set a clock stretch status (SCLA0 = 0) at the falling edge of the 9th clock, and the slave device issue an interrupt (INTIICA0: end of transfer).
- <12> By the slave device writing the data to transmit to the IICA register, the clock stretch status set by the slave device is released. The slave device then starts transferring data to the master device.
- <13> The master device issues an interrupt (INTIICA0: end of transfer) at the falling edge of the 8th clock, and sets a clock stretch status (SCLA0 = 0). Because ACK control (ACKE0 = 1) is performed, the bus data line is at the low level (SDAA0 = 0) at this stage.
- <14> The master device sets NACK as the response (ACKE0 = 0) and changes the timing at which it sets the clock stretch status to the 9th clock (WTIM0 = 1).
- <15> If the master device releases the clock stretch status (WREL0 = 1), the slave device detects the NACK (ACK = 0) at the rising edge of the 9th clock.
- <16> The master device and slave device set a clock stretch status (SCLA0 = 0) at the falling edge of the 9th clock, and both the master device and slave device issue an interrupt (INTIICA0: end of transfer).
- <17> When the master device issues a stop condition (SPT0 = 1), the bus data line is cleared (SDAA0 = 0) and the master device releases the clock stretch status. The master device then waits until the bus clock line is set (SCLA0 = 1).
- <18> The slave device acknowledges the NACK, halts transmission, and releases the clock stretch status (WREL0 = 1) to end communication. Once the slave device releases the clock stretch status, the bus clock line is set (SCLA0 = 1).
- <19> Once the master device recognizes that the bus clock line is set (SCLA0 = 1) and after the stop condition setup time has elapsed, the master device sets the bus data line (SDAA0 = 1) and issues a stop condition (i.e. SCLA0 =1 changes SDAA0 from 0 to 1). The slave device detects the generated stop condition and slave device issue an interrupt (INTIICA0: stop condition).

Remark <1> to <19> in Figure 13-33 represent the entire procedure for communicating data using the I²C bus. Figure 13-33 (1) Start condition ~ address ~ data shows the processing from <1> to <7>, Figure 13-33 (2) Address ~ data ~ data shows the processing from <3> to <12>, and Figure 13-33 (3) Data ~ data ~ stop condition shows the processing from <8> to <19>.

CHAPTER 14 MULTIPLIER AND DIVIDER/MULTIPLY-ACCUMULATOR

14.1 Functions of Multiplier and Divider/Multiply-Accumulator

The multiplier and divider/multiply-accumulator has the following functions.

- $16 \text{ bits} \times 16 \text{ bits} = 32 \text{ bits}$ (Unsigned)
- $16 \text{ bits} \times 16 \text{ bits} = 32 \text{ bits}$ (Signed)
- $16 \text{ bits} \times 16 \text{ bits} + 32 \text{ bits} = 32 \text{ bits}$ (Unsigned)
- $16 \text{ bits} \times 16 \text{ bits} + 32 \text{ bits} = 32 \text{ bits}$ (Signed)
- $32 \text{ bits} \div 32 \text{ bits} = 32 \text{ bits}$, 32-bits remainder (Unsigned)

14.2 Configuration of Multiplier and Divider/Multiply-Accumulator

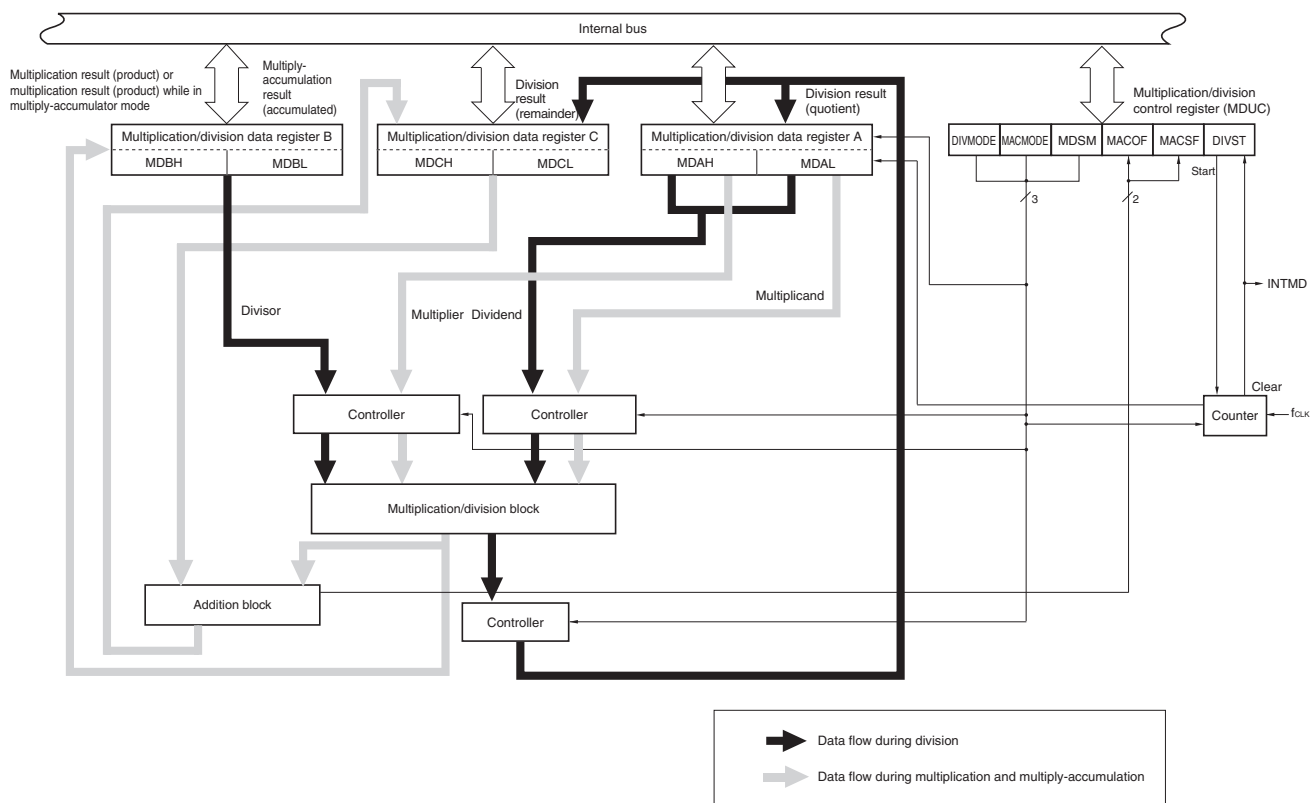
The multiplier and divider/multiply-accumulator consists of the following hardware.

Table 14-1. Configuration of Multiplier and Divider/Multiply-Accumulator

Item	Configuration
Registers	Multiplication/division data register A (L) (MDAL) Multiplication/division data register A (H) (MDAH) Multiplication/division data register B (L) (MDBL) Multiplication/division data register B (H) (MDBH) Multiplication/division data register C (L) (MDCL) Multiplication/division data register C (H) (MDCH)
Control register	Multiplication/division control register (MDUC)

Figure 14-1 shows a block diagram of the multiplier and divider/multiply-accumulator.

Figure 14-1. Block Diagram of Multiplier and Divider/Multiply-Accumulator



Remark f_{CLK}: CPU/peripheral hardware clock frequency

14.2.1 Multiplication/division data register A (MDAH, MDAL)

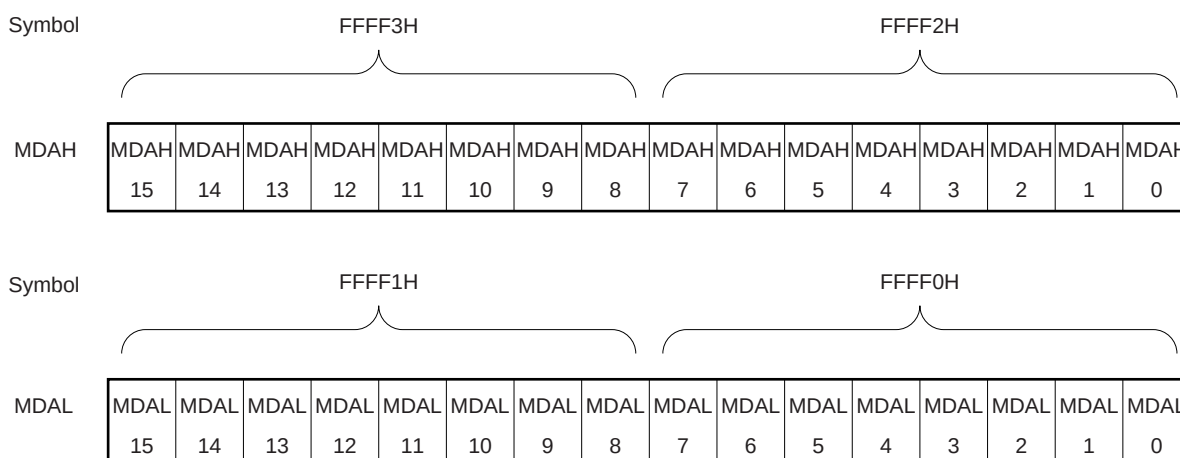
The MDAH and MDAL registers set the values that are used for a multiplication or division operation and store the operation result. They set the multiplier and multiplicand data in the multiplication mode or multiply-accumulator mode, and set the dividend data in the division mode. Furthermore, the operation result (quotient) is stored in the MDAH and MDAL registers in the division mode.

The MDAH and MDAL registers can be set by a 16-bit manipulation instruction.

Reset signal generation clears these registers to 0000H.

Figure 14-2. Format of Multiplication/Division Data Register A (MDAH, MDAL)

Address: FFFF0H, FFFF1H, FFFF2H, FFFF3H After reset: 0000H, 0000H R/W



- Cautions**
1. Do not rewrite the MDAH and MDAL registers values during division operation processing (when the multiplication/division control register (MDUC) value is 81H or C1H). The operation will be executed in this case, but the operation result will be an undefined value.
 2. The MDAH and MDAL registers values read during division operation processing (when the MDUC register value is 81H or C1H) will not be guaranteed.
 3. The data is in the two's complement format in either the multiplication mode (signed) or multiply-accumulator mode (signed).

The following table shows the functions of the MDAH and MDAL registers during operation execution.

Table 14-2. Functions of MDAH and MDAL Registers During Operation Execution

Operation Mode	Setting	Operation Result
Multiplication mode (unsigned) Multiply-accumulator mode (unsigned)	MDAH: Multiplier (unsigned) MDAL: Multiplicand (unsigned)	—
Multiplication mode (signed) Multiply-accumulator mode (signed)	MDAH: Multiplier (signed) MDAL: Multiplicand (signed)	—
Division mode (unsigned)	MDAH: Dividend (unsigned) (higher 16 bits) MDAL: Dividend (unsigned) (lower 16 bits)	MDAH: Division result (unsigned) Higher 16 bits MDAL: Division result (unsigned) Lower 16 bits

14.2.2 Multiplication/division data register B (MDBL, MDBH)

The MDBH and MDBL registers set the values that are used for multiplication or division operation and store the operation result. They store the operation result (product) in the multiplication mode and multiply-accumulator mode, and set the divisor data in the division mode.

The MDBH and MDBL registers can be set by a 16-bit manipulation instruction.

Reset signal generation clears these registers to 0000H.

Figure 14-3. Format of Multiplication/Division Data Register B (MDBH, MDBL)

Address: FFFF4H, FFFF5H, FFFF6H, FFFF7H After reset: 0000H, 0000H R/W



- Cautions**
1. Do not rewrite the MDBH and MDBL registers values during division operation processing (when the multiplication/division control register (MDUC) value is 81H or C1H) or multiply-accumulation operation processing. The operation result will be an undefined value.
 2. Do not set the MDBH and MDBL registers to 0000H in the division mode. If they are set, the operation result will be an undefined value.
 3. The data is in the two's complement format in either the multiplication mode (signed) or multiply-accumulator mode (signed).

The following table shows the functions of the MDBH and MDBL registers during operation execution.

Table 14-3. Functions of MDBH and MDBL Registers During Operation Execution

Operation Mode	Setting	Operation Result
Multiplication mode (unsigned) Multiply-accumulator mode (unsigned)	—	MDBH: Multiplication result (product) (unsigned) Higher 16 bits MDBL: Multiplication result (product) (unsigned) Lower 16 bits
Multiplication mode (signed) Multiply-accumulator mode (signed)	—	MDBH: Multiplication result (product) (signed) Higher 16 bits MDBL: Multiplication result (product) (signed) Lower 16 bits
Division mode (unsigned)	MDBH: Divisor (unsigned) (higher 16 bits) MDBL: Divisor (unsigned) (lower 16 bits)	—

14.2.3 Multiplication/division data register C (MDCL, MDCH)

The MDCH and MDCL registers are used to store the accumulated result while in the multiply-accumulator mode or the remainder of the operation result while in the division mode. These registers are not used while in the multiplication mode.

The MDCH and MDCL registers can be set by a 16-bit manipulation instruction.

Reset signal generation clears these registers to 0000H.

Figure 14-4. Format of Multiplication/Division Data Register C (MDCH, MDCL)

Address: F00E0H, F00E1H, F00E2H, F00E3H After reset: 0000H, 0000H R/W

Symbol

F00E3H

F00E2H

MDCH

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

Symbol

F00E1H

F00E0H

MDCL

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

- Cautions**
1. The MDCH and MDCL registers values read during division operation processing (when the multiplication/division control register (MDUC) value is 81H or C1H) will not be guaranteed.
 2. During multiply-accumulator processing, do not use software to rewrite the values of the MDCH and MDCL registers. If this is done, the operation result will be undefined.
 3. The data is in the two's complement format in the multiply-accumulator mode (signed).

Table 14-4. Functions of MDCH and MDCL Registers During Operation Execution

Operation Mode	Setting	Operation Result
Multiplication mode (unsigned or signed)	–	–
Multiply-accumulator mode (unsigned)	MDCH: Initial accumulated value (unsigned) (higher 16 bits) MDCL: Initial accumulated value (unsigned) (lower 16 bits)	MDCH: accumulated value (unsigned) (higher 16 bits) MDCL: accumulated value (unsigned) (lower 16 bits)
Multiply-accumulator mode (signed)	MDCH: Initial accumulated value (signed) (higher 16 bits) MDCL: Initial accumulated value (signed) (lower 16 bits)	MDCH: accumulated value (signed) (higher 16 bits) MDCL: accumulated value (signed) (lower 16 bits)
Division mode (unsigned)	–	MDCH: Remainder (unsigned) (higher 16 bits) MDCL: Remainder (unsigned) (lower 16 bits)

The register configuration differs between when multiplication is executed and when division is executed, as follows.

- Register configuration during multiplication

<Multiplier A>	<Multiplier B>	<Product>
MDAL (bits 15 to 0) × MDAH (bits 15 to 0)		[MDBH (bits 15 to 0), MDBL (bits 15 to 0)]

- Register configuration during multiply-accumulation

<Multiplier A>	<Multiplier B>	< accumulated value >	< accumulated result >
MDAL (bits 15 to 0) × MDAH (bits 15 to 0) + MDC (bits 31 to 0) = [MDCH (bits 15 to 0), MDCL (bits 15 to 0)]			
(The multiplication result is stored in the MDBH (bits 15 to 0) and MDBL (bits 15 to 0).)			

- Register configuration during division

$$\begin{array}{l} \text{<Dividend>} \qquad \qquad \qquad \text{<Divisor>} \\ \text{[MDAH (bits 15 to 0), MDAL (bits 15 to 0)]} \div \text{[MDBH (bits 15 to 0), MDBL (bits 15 to 0)]} = \\ \text{<Quotient>} \qquad \qquad \qquad \text{<Remainder>} \\ \text{[MDAH (bits 15 to 0), MDAL (bits 15 to 0)]} \dots \text{[MDCH (bits 15 to 0), MDCL (bits 15 to 0)]} \end{array}$$

14.3 Register Controlling Multiplier and Divider/Multiply-Accumulator

The multiplier and divider/multiply-accumulator is controlled by using the multiplication/division control register (MDUC).

14.3.1 Multiplication/division control register (MDUC)

The MDUC register is an 8-bit register that controls the operation of the multiplier and divider/multiply-accumulator.

The MDUC register can be set by a 1-bit or 8-bit memory manipulation instruction.

Note that the overflow flag (MACOF) and sign flag (MACSF) of the multiply-accumulation result (accumulated) are read-only flags.

Reset signal generation clears this register to 00H.

Figure 14-5. Format of Multiplication/Division Control Register (MDUC)

Address: F00E8H After reset: 00H R/W^{Note 1}

Symbol	<7>	<6>	5	4	<3>	<2>	<1>	<0>
MDUC	DIVMODE	MACMODE	0	0	MDSM	MACOF	MACSF	DIVST

DIVMODE	MACMODE	MDSM	Operation mode selection
0	0	0	Multiplication mode (unsigned) (default)
0	0	1	Multiplication mode (signed)
0	1	0	Multiply-accumulator mode (unsigned)
0	1	1	Multiply-accumulator mode (signed)
1	0	0	Division mode (unsigned), generation of a division completion interrupt (INTMD)
1	1	0	Division mode (unsigned), not generation of a division completion interrupt (INTMD)
Other than above			Setting prohibited

MACOF	Overflow flag of multiply-accumulation result (accumulated value)
0	No overflow
1	With over flow

<Set condition>

- For the multiply-accumulator mode (unsigned)
The bit is set when the accumulated value goes outside the range from 00000000h to FFFFFFFFh.
- For the multiply-accumulator mode (signed)
The bit is set when the result of adding a positive product to a positive accumulated value exceeds 7FFFFFFFh and is negative, or when the result of adding a negative product to a negative accumulated value exceeds 80000000h and is positive.

MACSF	Sign flag of multiply-accumulation result (accumulated value)
0	The accumulated value is positive.
1	The accumulated value is negative.
Multiply-accumulator mode (unsigned): The bit is always 0.	
Multiply-accumulator mode (signed): The bit indicates the sign bit of the accumulated value.	

DIVST ^{Note 2}	Division operation start/stop
0	Division operation processing complete
1	Starts division operation/division operation processing in progress

(Notes and Cautions are listed on the next page.)

Notes 1. Bits 1 and 2 are read-only bits.

2. The DIVST bit can only be set (1) in the division mode. In the division mode, division operation is started by setting (1) the DIVST bit. The DIVST bit is automatically cleared (0) when the operation ends. In the multiplication mode, operation is automatically started by setting the multiplier and multiplicand to multiplication/division data register A (MDAH, MDAL), respectively.

Cautions 1. Do not rewrite the DIVMODE, MDSM bits during operation processing (while the DIVST bit is 1). If it is rewritten, the operation result will be an undefined value.

2. The DIVST bit cannot be cleared (0) by using software during division operation processing (while the DIVST bit is 1).

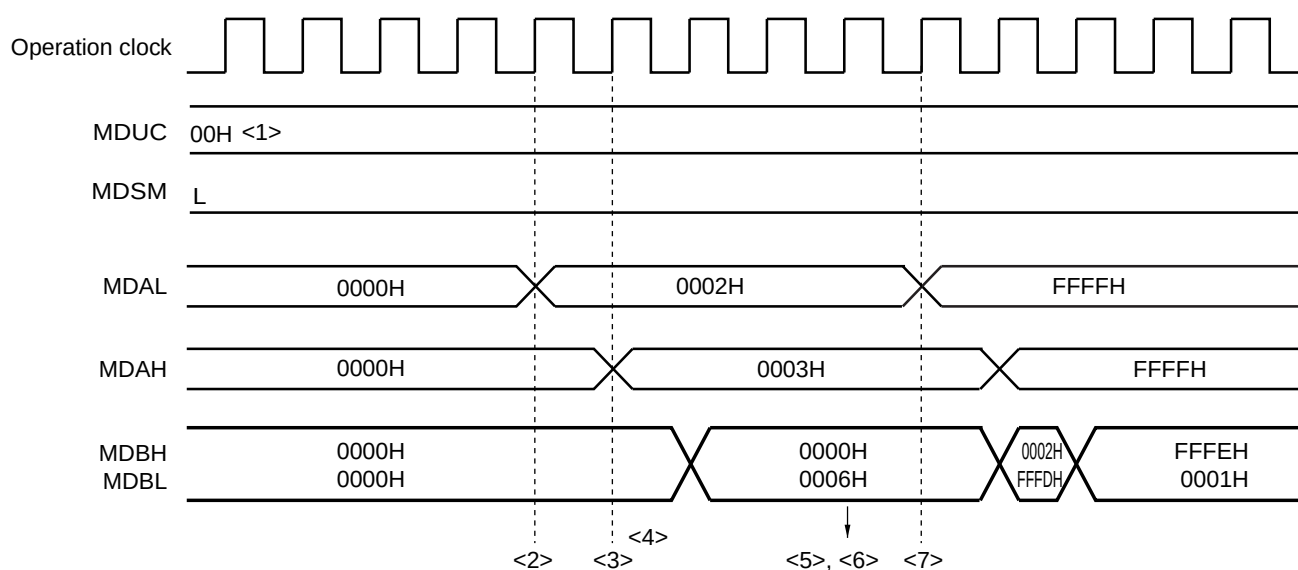
14.4 Operations of Multiplier and Divider/Multiply-Accumulator

14.4.1 Multiplication (unsigned) operation

- Initial setting
 - <1> Set the multiplication/division control register (MDUC) to 00H.
 - <2> Set the multiplicand to multiplication/division data register A (L) (MDAL).
 - <3> Set the multiplier to multiplication/division data register A (H) (MDAH).
(There is no preference in the order of executing steps <2> and <3>. Multiplication operation is automatically started when the multiplier and multiplicand are set to the MDAH and MDAL registers, respectively.)
- During operation processing
 - <4> Wait for at least one clock. The operation will end when one clock has been issued.
- Operation end
 - <5> Read the product (lower 16 bits) from multiplication/division data register B (L) (MDBL).
 - <6> Read the product (higher 16 bits) from multiplication/division data register B (H) (MDBH).
(There is no preference in the order of executing steps <5> and <6>.)
- Next operation
 - <7> Start with the initial settings of each step to change the operation mode. When the same operation mode is used sequentially, settings <1> and <2> can be omitted.

Remark Steps <1> to <7> correspond to <1> to <7> in Figure 14-6.

Figure 14-6. Timing Diagram of Multiplication (Unsigned) Operation ($2 \times 3 = 6$)



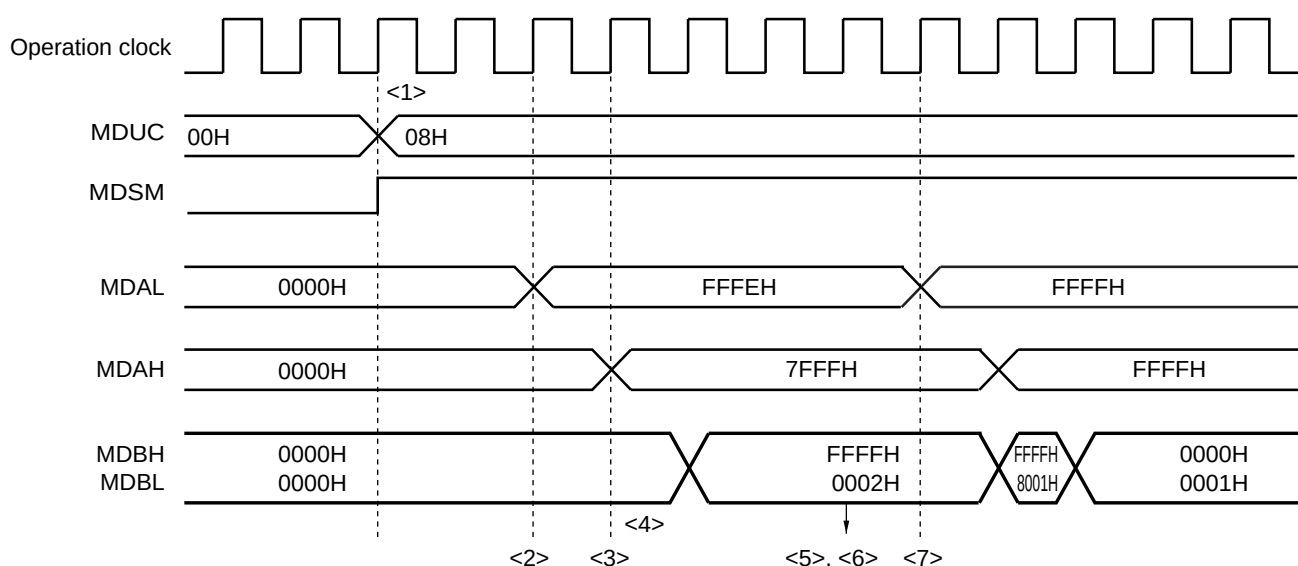
14.4.2 Multiplication (signed) operation

- Initial setting
 - <1> Set the multiplication/division control register (MDUC) to 08H.
 - <2> Set the multiplicand to multiplication/division data register A (L) (MDAL).
 - <3> Set the multiplier to multiplication/division data register A (H) (MDAH).
(There is no preference in the order of executing steps <2> and <3>. Multiplication operation is automatically started when the multiplier and multiplicand are set to the MDAH and MDAL registers, respectively.)
- During operation processing
 - <4> Wait for at least one clock. The operation will end when one clock has been issued.
- Operation end
 - <5> Read the product (lower 16 bits) from multiplication/division data register B (L) (MDBL).
 - <6> Read the product (higher 16 bits) from multiplication/division data register B (H) (MDBH).
(There is no preference in the order of executing steps <5> and <6>.)
- Next operation
 - <7> Start with the initial settings of each step to change the operation mode. When the same operation mode is used sequentially, settings <1> and <2> can be omitted.

Caution The data is in the two's complement format in multiplication mode (signed).

Remark Steps <1> to <7> correspond to <1> to <7> in Figure 14-7.

Figure 14-7. Timing Diagram of Multiplication (Signed) Operation ($-2 \times 32767 = -65534$)

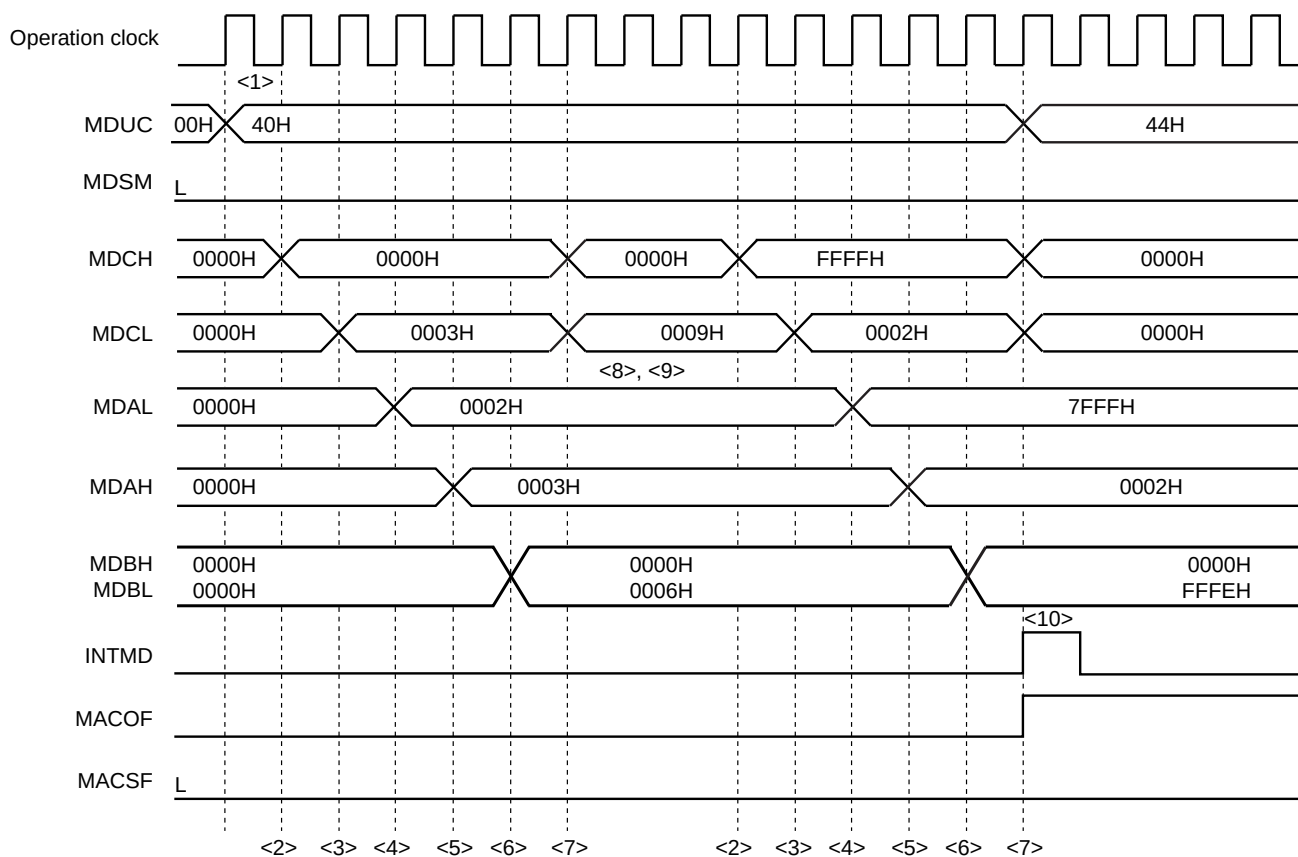


14.4.3 Multiply-accumulation (unsigned) operation

- Initial setting
 - <1> Set the multiplication/division control register (MDUC) to 40H.
 - <2> Set the initial accumulated value of higher 16 bits to multiplication/division data register C (L) (MDCL).
 - <3> Set the initial accumulated value of lower 16 bits to multiplication/division data register C (H) (MDCH).
 - <4> Set the multiplicand to multiplication/division data register A (L) (MDAL).
 - <5> Set the multiplier to multiplication/division data register A (H) (MDAH).
(There is no preference in the order of executing steps <2>, <3>, and <4>. Multiplication operation is automatically started when the multiplier is set to the MDAH register, respectively.)
- During operation processing
 - <6> The multiplication operation finishes in one clock cycle.
(The multiplication result is stored in multiplication/division data register B (L) (MDBL) and multiplication/division data register B (H) (MDBH).)
 - <7> After <6>, the multiply-accumulation operation finishes in one additional clock cycle. (There is a wait of at least two clock cycles after specifying the initial settings is finished (<5>).)
- Operation end
 - <8> Read the accumulated value (lower 16 bits) from the MDCL register.
 - <9> Read the accumulated value (higher 16 bits) from the MDCH register.
(There is no preference in the order of executing steps <8> and <9>.)
 - (<10> If the result of the multiply-accumulation operation causes an overflow, the MACOF bit is set to 1, INTMD signal is occurred.)
- Next operation
 - <11> Start with the initial settings of each step to change the operation mode. When the same operation mode is used sequentially, settings <1> to <4> can be omitted.

Remark Steps <1> to <10> correspond to <1> to <10> in Figure 14-8.

Figure 14-8. Timing Diagram of Multiply-Accumulation (Unsigned) Operation
 $(2 \times 3 + 3 = 9 \rightarrow 32767 \times 2 + 4294901762 = 0 \text{ (over flow generated)})$



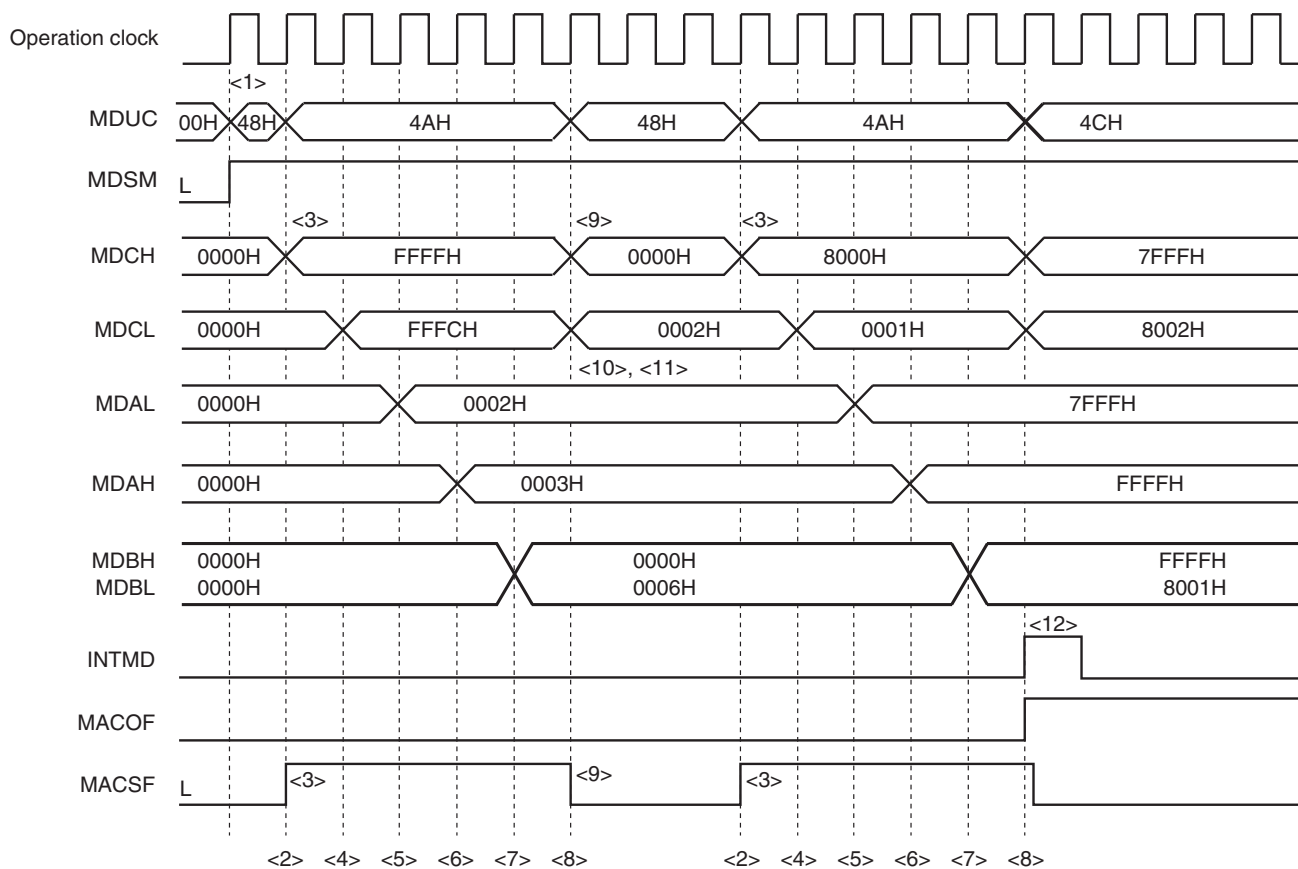
14.4.4 Multiply-accumulation (signed) operation

- Initial setting
 - <1> Set the multiplication/division control register (MDUC) to 48H.
 - <2> Set the initial accumulated value of higher 16 bits to multiplication/division data register C (H) (MDCH).
(<3> If the accumulated value in the MDCH register is negative, the MACSF bit is set to 1.)
 - <4> Set the initial accumulated value of lower 16 bits to multiplication/division data register C (L) (MDCL).
 - <5> Set the multiplicand to multiplication/division data register A (L) (MDAL).
 - <6> Set the multiplier to multiplication/division data register A (H) (MDAH).
(There is no preference in the order of executing steps <2>, <4>, and <5>. Multiplication operation is automatically started when the multiplier is set to the MDAH register of <6>, respectively.)
- During operation processing
 - <7> The multiplication operation finishes in one clock cycle.
(The multiplication result is stored in multiplication/division data register B (L) (MDBL) and multiplication/division data register B (H) (MDBH).)
 - <8> After <7>, the multiply-accumulation operation finishes in one additional clock cycle. (There is a wait of at least two clock cycles after specifying the initial settings is finished (<6>).)
- Operation end
 - <9> If the accumulated value stored in the MDCL and MDCH registers is positive, the MACSF bit is cleared to 0.
 - <10> Read the accumulated value (lower 16 bits) from the MDCL register.
 - <11> Read the accumulated value (higher 16 bits) from the MDCH register.
(There is no preference in the order of executing steps <10> and <11>.)
 - (<12> If the result of the multiply-accumulation operation causes an overflow, the MACOF bit is set to 1, INTMD signal is occurred.)
- Next operation
 - <13> Start with the initial settings of each step to change the operation mode. When the same operation mode is used sequentially, settings <1> to <5> can be omitted.

Caution The data is in the two's complement format in multiply-accumulation (signed) operation.

Remark Steps <1> to <12> correspond to <1> to <12> in Figure 14-9.

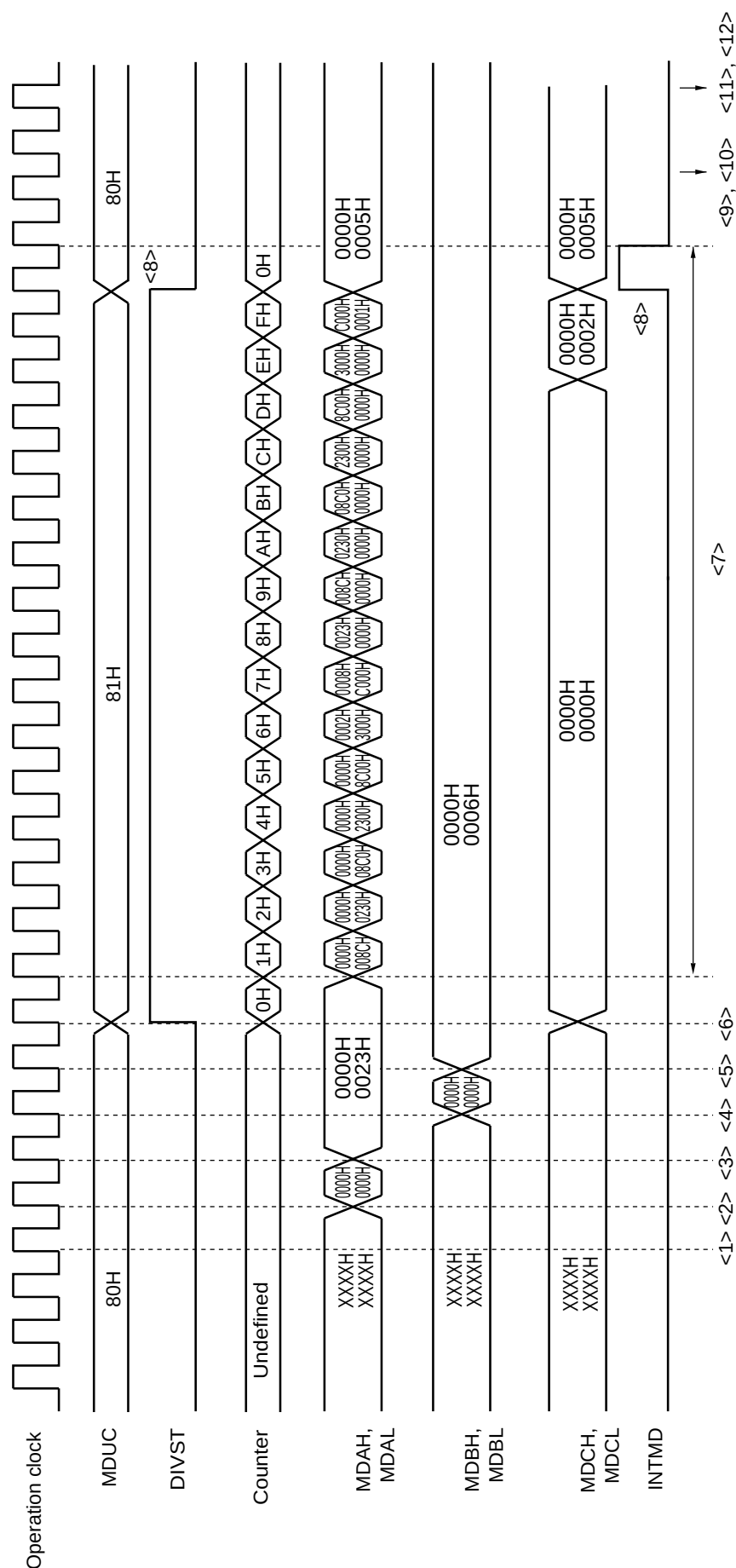
Figure 14-9. Timing Diagram of Multiply-Accumulation (signed) Operation
 $(2 \times 3 + (-4) = 2 \rightarrow 32767 \times (-1) + (-2147483647) = -2147450882 \text{ (overflow occurs.)})$



14.4.5 Division operation

- Initial setting
 - <1> Set the multiplication/division control register (MDUC) to 80H.
 - <2> Set the dividend (higher 16 bits) to multiplication/division data register A (H) (MDAH).
 - <3> Set the dividend (lower 16 bits) to multiplication/division data register A (L) (MDAL).
 - <4> Set the divisor (higher 16 bits) to multiplication/division data register B (H) (MDBH).
 - <5> Set the divisor (lower 16 bits) to multiplication/division data register B (L) (MDBL).
 - <6> Set bit 0 (DIVST) of the MDUC register to 1.
(There is no preference in the order of executing steps <2> to <5>.)
- During operation processing
 - <7> The operation will end when one of the following processing is completed.
 - A wait of at least 16 clocks (The operation will end when 16 clocks have been issued.)
 - A check whether the DIVST bit has been cleared
(The read values of the MDBL, MDBH, MDCL, and MDCH registers during operation processing are not guaranteed.)
- Operation end
 - <8> The DIVST bit is cleared and the operation ends. At this time, an interrupt request signal (INTMD) is generated if the operation was performed with MACMODE = 0.
 - <9> Read the quotient (lower 16 bits) from the MDAL register.
 - <10> Read the quotient (higher 16 bits) from the MDAH register.
 - <11> Read the remainder (lower 16 bits) from multiplication/division data register C (L) (MDCL).
 - <12> Read the remainder (higher 16 bits) from multiplication/division data register C (H) (MDCH).
(There is no preference in the order of executing steps <9> to <12>.)
- Next operation
 - <13> Start with the initial settings of each step to change the operation mode. When the same operation mode is used sequentially, settings <1> to <5> can be omitted.

Remark Steps <1> to <12> correspond to <1> to <12> in Figure 14-10.

Figure 14-10. Timing Diagram of Division Operation (Example: $35 \div 6 = 5$, Remainder 5)

CHAPTER 15 DMA CONTROLLER

The RL78/G1A has an internal DMA (Direct Memory Access) controller.

Data can be automatically transferred between the peripheral hardware supporting DMA, SFRs, and internal RAM without via CPU.

As a result, the normal internal operation of the CPU and data transfer can be executed in parallel with transfer between the SFR and internal RAM, and therefore, a large capacity of data can be processed. In addition, real-time control using communication, timer, and A/D can also be realized.

15.1 Functions of DMA Controller

- Number of DMA channels: 2 channels
- Transfer unit: 8 or 16 bits
- Maximum transfer unit: 1024 times
- Transfer type: 2-cycle transfer (One transfer is processed in 2 clocks and the CPU stops during that processing.)
- Transfer mode: Single-transfer mode
- Transfer request: Selectable from the following peripheral hardware interrupts
 - A/D converter
 - Serial interface
(CSI00, CSI01, CSI10, CSI11, CSI20, CSI21, UART0 to UART2)
 - Timer (channel 0, 1, 2, 3)
- Transfer target: Between SFR and internal RAM

Here are examples of functions using DMA.

- Successive transfer of serial interface
- Consecutive capturing of A/D conversion results
- Capturing port value at fixed interval

15.2 Configuration of DMA Controller

The DMA controller includes the following hardware.

Table 15-1. Configuration of DMA Controller

Item	Configuration
Address registers	• DMA SFR address registers 0, 1 (DSA0, DSA1) • DMA RAM address registers 0, 1 (DRA0, DRA1)
Count register	• DMA byte count registers 0, 1 (DBC0, DBC1)
Control registers	• DMA mode control registers 0, 1 (DMC0, DMC1) • DMA operation control register 0, 1 (DRC0, DRC1)

15.2.1 DMA SFR address register n (DSAn)

This is an 8-bit register that is used to set an SFR address that is the transfer source or destination of DMA channel n. Set the lower 8 bits of the SFR addresses FFF00H to FFFFH.

This register is not automatically incremented but fixed to a specific value.

In the 16-bit transfer mode, the least significant bit is ignored and is treated as an even address.

The DSAn register can be read or written in 8-bit units. However, it cannot be written during DMA transfer.

Reset signal generation clears this register to 00H.

Figure 15-1. Format of DMA SFR Address Register n (DSAn)

Address: FFFB0H (DSA0), FFFB1H (DSA1) After reset: 00H R/W

	7	6	5	4	3	2	1	0
DSAn								

Remark n: DMA channel number (n = 0, 1)

15.2.2 DMA RAM address register n (DRAn)

This is a 16-bit register that is used to set a RAM address that is the transfer source or destination of DMA channel n.

Addresses of the internal RAM area other than the general-purpose registers (see **Table 15-2**) can be set to this register.

Set the lower 16 bits of the RAM address.

This register is automatically incremented when DMA transfer has been started. It is incremented by +1 in the 8-bit transfer mode and by +2 in the 16-bit transfer mode. DMA transfer is started from the address set to this DRAn register. When the data of the last address has been transferred, the DRAn register stops with the value of the last address +1 in the 8-bit transfer mode, and the last address +2 in the 16-bit transfer mode.

In the 16-bit transfer mode, the least significant bit is ignored and is treated as an even address.

The DRAn register can be read or written in 8-bit or 16-bit units. However, it cannot be written during DMA transfer.

Reset generation clears this register to 0000H.

Figure 15-2. Format of DMA RAM Address Register n (DRAn)

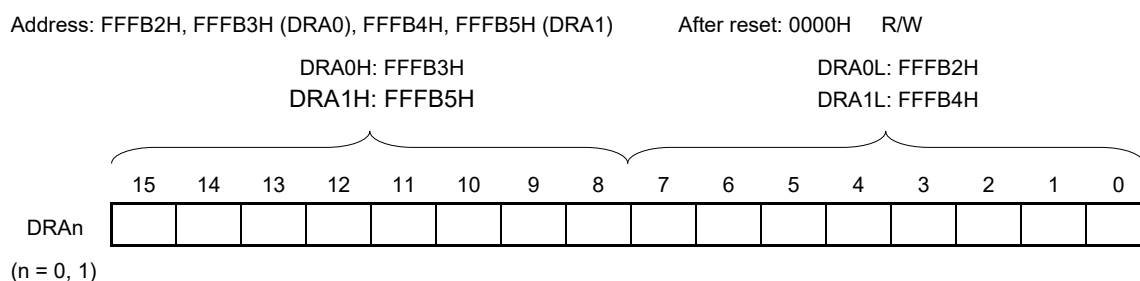


Table 15-2. Internal RAM Area other than the General-purpose Registers

Part Number	Internal RAM Area other than the General-purpose Registers
R5F10ExA (x = 8, B, G) R5F10ExC (x = 8, B, G, L)	FF700H to FFEDFH
R5F10ExD (x = 8, B, G, L)	FF300H to FFEDFH
R5F10ExE (x = 8, B, G, L)	FEF00H to FFEDFH

Remark n: DMA channel number (n = 0, 1)

15.2.3 DMA byte count register n (DBCn)

This is a 10-bit register that is used to set the number of times DMA channel n executes transfer. Be sure to set the number of times of transfer to this DBCn register before executing DMA transfer (up to 1024 times).

Each time DMA transfer has been executed, this register is automatically decremented. By reading this DBCn register during DMA transfer, the remaining number of times of transfer can be learned.

The DBCn register can be read or written in 8-bit or 16-bit units. However, it cannot be written during DMA transfer.

Reset signal generation clears this register to 0000H.

Figure 15-3. Format of DMA Byte Count Register n (DBCn)

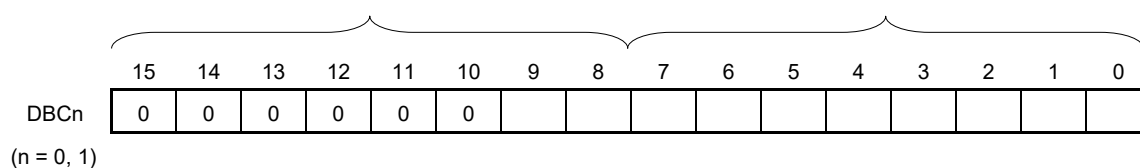
Address: FFFB6H, FFFB7H (DBC0), FFFB8H, FFFB9H (DBC1) After reset: 0000H R/W

DBC0H· FFFB7H

DBC1H: FFFB9H

DBC0L: FFFB6H

DBC1L: FFFB8H



DBCn[9:0]	Number of Times of Transfer (When DBCn is Written)	Remaining Number of Times of Transfer (When DBCn is Read)
000H	1024	Completion of transfer or waiting for 1024 times of DMA transfer
001H	1	Waiting for remaining one time of DMA transfer
002H	2	Waiting for remaining two times of DMA transfer
003H	3	Waiting for remaining three times of DMA transfer
• • •	• • •	• • •
3FEH	1022	Waiting for remaining 1022 times of DMA transfer
3FFH	1023	Waiting for remaining 1023 times of DMA transfer

Cautions 1. Be sure to clear bits 15 to 10 to “0”.

2. If the general-purpose register is specified or the internal RAM space is exceeded as a result of continuous transfer, the general-purpose register or SFR space are written or read, resulting in loss of data in these spaces. Be sure to set the number of times of transfer that is within the internal RAM space.

Remark n: DMA channel number (n = 0, 1)

15.3 Registers Controlling DMA Controller

DMA controller is controlled by the following registers.

- DMA mode control register n (DMCn)
- DMA operation control register n (DRCn)

Remark n: DMA channel number (n = 0, 1)

15.3.1 DMA mode control register n (DMCn)

The DMCn register is a register that is used to set a transfer mode of DMA channel n. It is used to select a transfer direction, data size, setting of pending, and start source. Bit 7 (STGn) is a software trigger that starts DMA.

Rewriting bits 6, 5, and 3 to 0 of the DMCn register is prohibited during operation (when DSTn = 1).

The DMCn register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 15-4. Format of DMA Mode Control Register n (DMCn) (1/2)

Address: FFFBAH (DMC0), FFFBBH (DMC1) After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	3	2	1	0
DMCn	STGn	DRSn	DSn	DWAITn	IFCn3	IFCn2	IFCn1	IFCn0

STGn ^{Note 1}	DMA transfer start software trigger
0	No trigger operation
1	DMA transfer is started when DMA operation is enabled (DENn = 1).
DMA transfer is performed once by writing 1 to the STGn bit when DMA operation is enabled (DENn = 1). When this bit is read, 0 is always read.	

DRSn	Selection of DMA transfer direction
0	SFR to internal RAM
1	Internal RAM to SFR

DSn	Specification of transfer data size for DMA transfer
0	8 bits
1	16 bits

DWAITn ^{Note 2}	Pending of DMA transfer
0	Executes DMA transfer upon DMA start request (not held pending).
1	Holds DMA start request pending if any.
DMA transfer that has been held pending can be started by clearing the value of the DWAITn bit to 0. It takes 2 clocks to actually hold DMA transfer pending when the value of the DWAITn bit is set to 1.	

- Notes**
1. The software trigger (STGn) can be used regardless of the IFCn0 to IFCn3 bits values.
 2. When DMA transfer is held pending while using two or more DMA channels, be sure to hold the DMA transfer pending for all channels (by setting the DWAIT0 and DWAIT1 bits to 1).

Remark n: DMA channel number (n = 0, 1)

Figure 15-4. Format of DMA Mode Control Register n (DMCn) (2/2)

Address: FFFBAH (DMC0), FFFBBH (DMC1) After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	3	2	1	0
DMCn	STGn	DRSn	DSn	DWAItn	IFCn3	IFCn2	IFCn1	IFCn0

(When n = 0 or 1)

IFCn 3	IFCn 2	IFCn 1	IFCn 0	Selection of DMA start source ^{Note}	
				Trigger signal	Trigger contents
0	0	0	0	–	Disables DMA transfer by interrupt. (Only software trigger is enabled.)
0	0	0	1	INTAD	A/D conversion end interrupt
0	0	1	0	INTTM00	End of timer channel 0 count or capture end interrupt
0	0	1	1	INTTM01	End of timer channel 1 count or capture end interrupt
0	1	0	0	INTTM02	End of timer channel 2 count or capture end interrupt
0	1	0	1	INTTM03	End of timer channel 3 count or capture end interrupt
0	1	1	0	INTST0/INTCSI00	UART0 transmission transfer end or buffer empty interrupt/CSI00 transfer end or buffer empty interrupt
0	1	1	1	INTSR0/INTCSI01	UART0 reception transfer end interrupt/CSI01 transfer end or buffer empty interrupt
1	0	0	0	INTST1/INTCSI10	UART1 transmission transfer end or buffer empty interrupt/CSI10 transfer end or buffer empty interrupt
1	0	0	1	INTSR1/INTCSI11	UART1 reception transfer end interrupt/CSI11 transfer end or buffer empty interrupt
1	0	1	0	INTST2/INTCSI20	UART2 transmission transfer end or buffer empty interrupt/CSI20 transfer end or buffer empty interrupt
1	0	1	1	INTSR2/INTCSI21	UART2 reception transfer end interrupt/CSI21 transfer end or buffer empty interrupt
Other than above				Setting prohibited	

Note The software trigger (STGn) can be used regardless of the IFCn0 to IFCn3 bits values.

Remark n: DMA channel number (n = 0, 1)

15.3.2 DMA operation control register n (DRCn)

The DRCn register is a register that is used to enable or disable transfer of DMA channel n.

Rewriting bit 7 (DENn) of this register is prohibited during operation (when DSTn = 1).

The DRCn register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 15-5. Format of DMA Operation Control Register n (DRCn)

Address: FFFBCH (DRC0), FFFBDH (DRC1) After reset: 00H R/W

Symbol	<7>	6	5	4	3	2	1	<0>
DRCn	DENn	0	0	0	0	0	0	DSTn

DENn	DMA operation enable flag
0	Disables operation of DMA channel n (stops operating clock of DMA).
1	Enables operation of DMA channel n.
DMAC waits for a DMA trigger when DSTn = 1 after DMA operation is enabled (DENn = 1).	

DSTn	DMA transfer mode flag
0	DMA transfer of DMA channel n is completed.
1	DMA transfer of DMA channel n is not completed (still under execution).
DMAC waits for a DMA trigger when DSTn = 1 after DMA operation is enabled (DENn = 1). When a software trigger (STGn) or the start source trigger set by the IFCn3 to IFCn0 bits is input, DMA transfer is started. When DMA transfer is completed after that, this bit is automatically cleared to 0. Write 0 to this bit to forcibly terminate DMA transfer under execution.	

Caution The DSTn flag is automatically cleared to 0 when a DMA transfer is completed.

Writing the DENn flag is enabled only when DSTn = 0. When a DMA transfer is terminated without waiting for generation of the interrupt (INTDMAn) of DMA n, therefore, set the DSTn bit to 0 and then the DENn bit to 0 (for details, see 15.5.5 Forced termination by software).

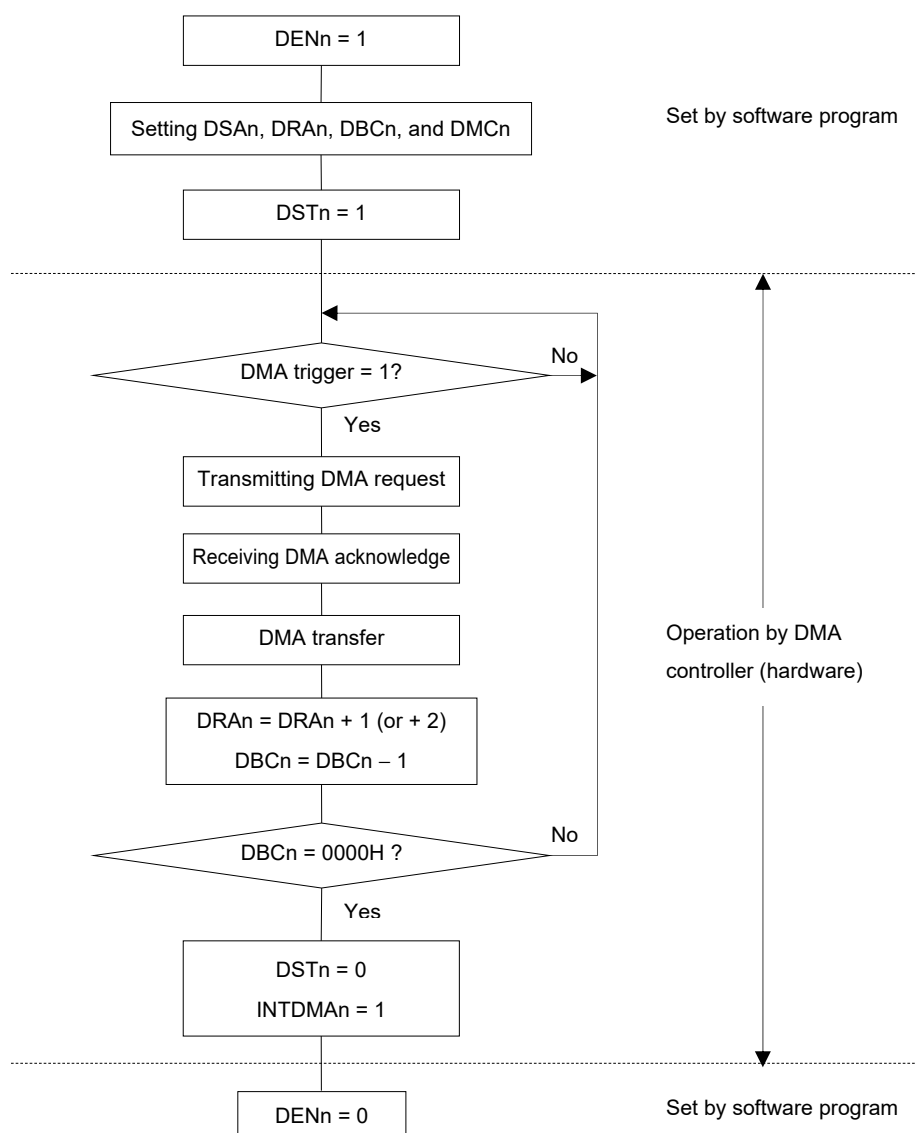
Remark n: DMA channel number (n = 0, 1)

15.4 Operation of DMA Controller

15.4.1 Operation procedure

- <1> The DMA controller is enabled to operate when DENn = 1. Before writing the other registers, be sure to set the DENn bit to 1. Use 80H to write with an 8-bit manipulation instruction.
- <2> Set an SFR address, a RAM address, the number of times of transfer, and a transfer mode of DMA transfer to DMA SFR address register n (DSAn), DMA RAM address register n (DRAn), DMA byte count register n (DBCn), and DMA mode control register n (DMCn).
- <3> The DMA controller waits for a DMA trigger when DSTn = 1. Use 81H to write with an 8-bit manipulation instruction.
- <4> When a software trigger (STGn) or a start source trigger specified by the IFCn3 to IFCn0 bits is input, a DMA transfer is started.
- <5> Transfer is completed when the number of times of transfer set by the DBCn register reaches 0, and transfer is automatically terminated by occurrence of an interrupt (INTDMA_n).
- <6> Stop the operation of the DMA controller by clearing the DENn bit to 0 when the DMA controller is not used.

Figure 15-6. Operation Procedure



Remark n: DMA channel number (n = 0, 1)

15.4.2 Transfer mode

The following four modes can be selected for DMA transfer by using bits 6 and 5 (DRSn and DS_n) of DMA mode control register n (DMCn).

DRS _n	DS _n	DMA Transfer Mode
0	0	Transfer from SFR of 1-byte data (fixed address) to RAM (address is incremented by +1)
0	1	Transfer from SFR of 2-byte data (fixed address) to RAM (address is incremented by +2)
1	0	Transfer from RAM of 1-byte data (address is incremented by +1) to SFR (fixed address)
1	1	Transfer from RAM of 2-byte data (address is incremented by +2) to SFR (fixed address)

By using these transfer modes, up to 1024 bytes of data can be consecutively transferred by using the serial interface, data resulting from A/D conversion can be consecutively transferred, and port data can be scanned at fixed time intervals by using a timer.

15.4.3 Termination of DMA transfer

When DBC_n = 00H and DMA transfer is completed, the DST_n bit is automatically cleared to 0. An interrupt request (INTDMA_n) is generated and transfer is terminated.

When the DST_n bit is cleared to 0 to forcibly terminate DMA transfer, DMA byte count register n (DBC_n) and DMA RAM address register n (DRAn) hold the value when transfer is terminated.

The interrupt request (INTDMA_n) is not generated if transfer is forcibly terminated.

Remark n: DMA channel number (n = 0, 1)

15.5 Example of Setting of DMA Controller

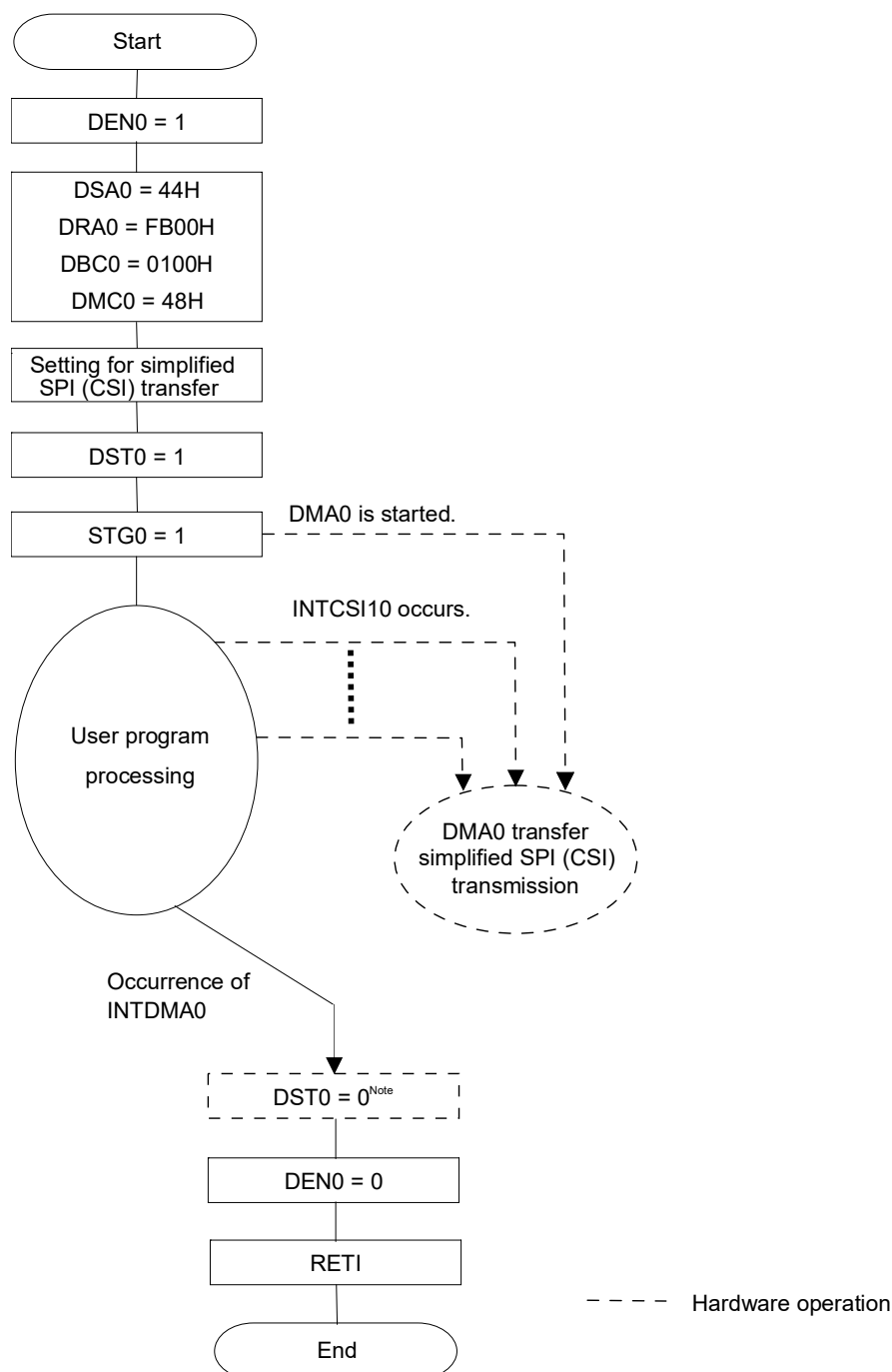
15.5.1 Simplified SPI (CSI) consecutive transmission

A flowchart showing an example of setting for simplified SPI (CSI) consecutive transmission is shown below.

- Consecutive transmission of CSI10 (256 bytes)
- DMA channel 0 is used for DMA transfer.
- DMA start source: INTCSI10 (software trigger (STG0) only for the first start source)
- Interrupt of CSI10 is specified by IFC03 to IFC00 = 1000B.
- Transfers FFB00H to FFBFFH (256 bytes) of RAM to FFF44H of the data register (SIO10) of simplified SPI (CSI).

Remark IFC03 to IFC00: Bits 3 to 0 of DMA mode control registers 0 (DMC0)

Figure 15-7. Example of Setting for Simplified SPI (CSI) Consecutive Transmission



Note The DST0 flag is automatically cleared to 0 when a DMA transfer is completed.

Writing the DEN0 flag is enabled only when DST0 = 0. To terminate a DMA transfer without waiting for occurrence of the interrupt of DMA0 (INTDMA0), set the DST0 bit to 0 and then the DEN0 bit to 0 (for details, see **15.5.5 Forced termination by software**).

The first trigger for consecutive transmission is not started by the interrupt of simplified SPI (CSI). In this example, it starts by a software trigger.

Simplified SPI (CSI) transmission of the second time and onward is automatically executed.

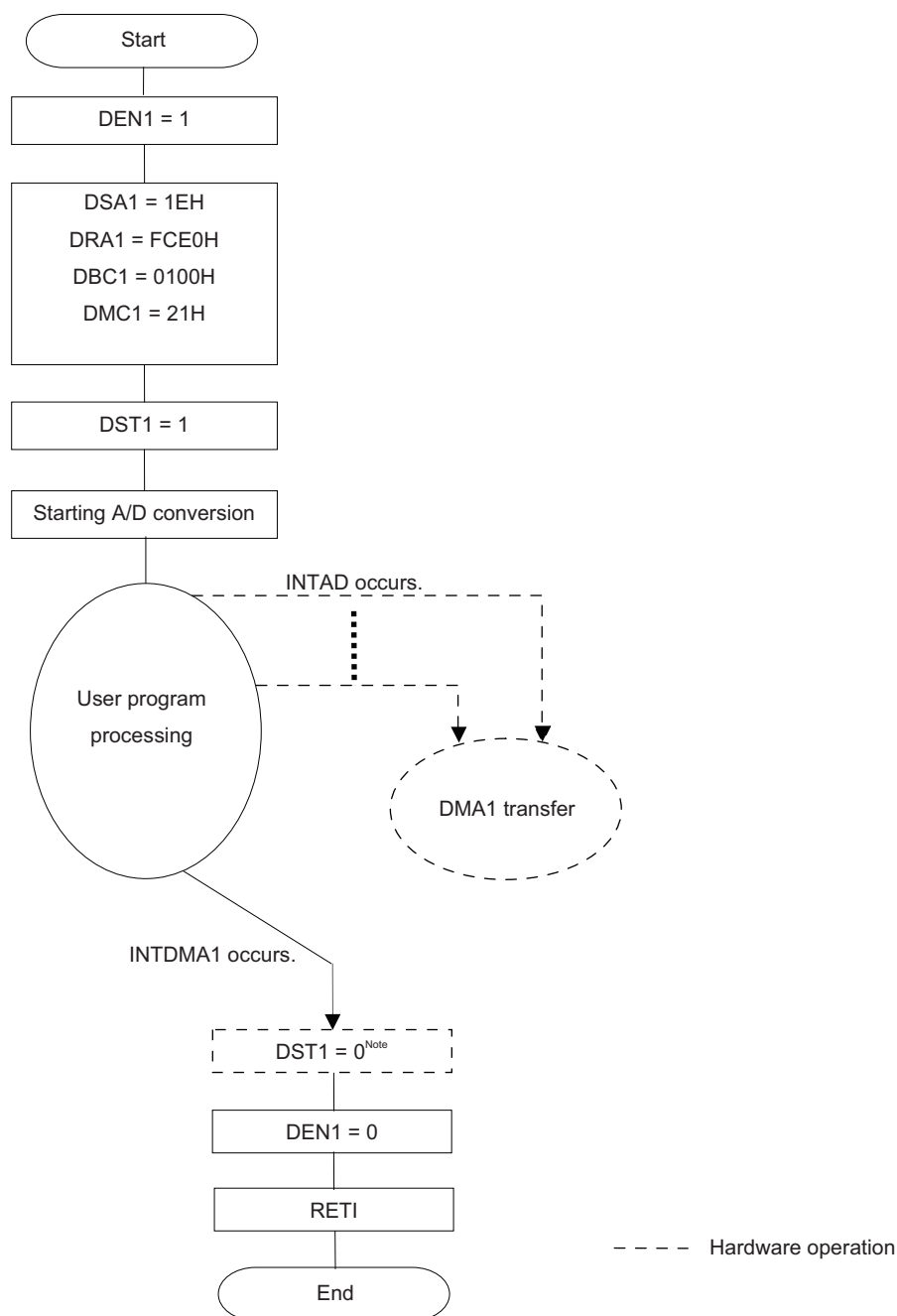
A DMA interrupt (INTDMA0) occurs when the last transmit data has been written to the data register.

15.5.2 Consecutive capturing of A/D conversion results

A flowchart of an example of setting for consecutively capturing A/D conversion results is shown below.

- Consecutive capturing of A/D conversion results.
- DMA channel 1 is used for DMA transfer.
- DMA start source: INTAD
- Interrupt of A/D is specified by IFC13 to IFC10 = 0001B.
- Transfers FFF1EH and FFF1FH (2 bytes) of the 12-bit A/D conversion result register (ADCR) to 512 bytes of FFCE0H to FFEDFH of RAM.

Remark IFC13 to IFC10: Bits 3 to 0 of DMA mode control registers 1 (DMC1)

Figure 15-8. Example of Setting of Consecutively Capturing A/D Conversion Results

Note The DST1 flag is automatically cleared to 0 when a DMA transfer is completed.

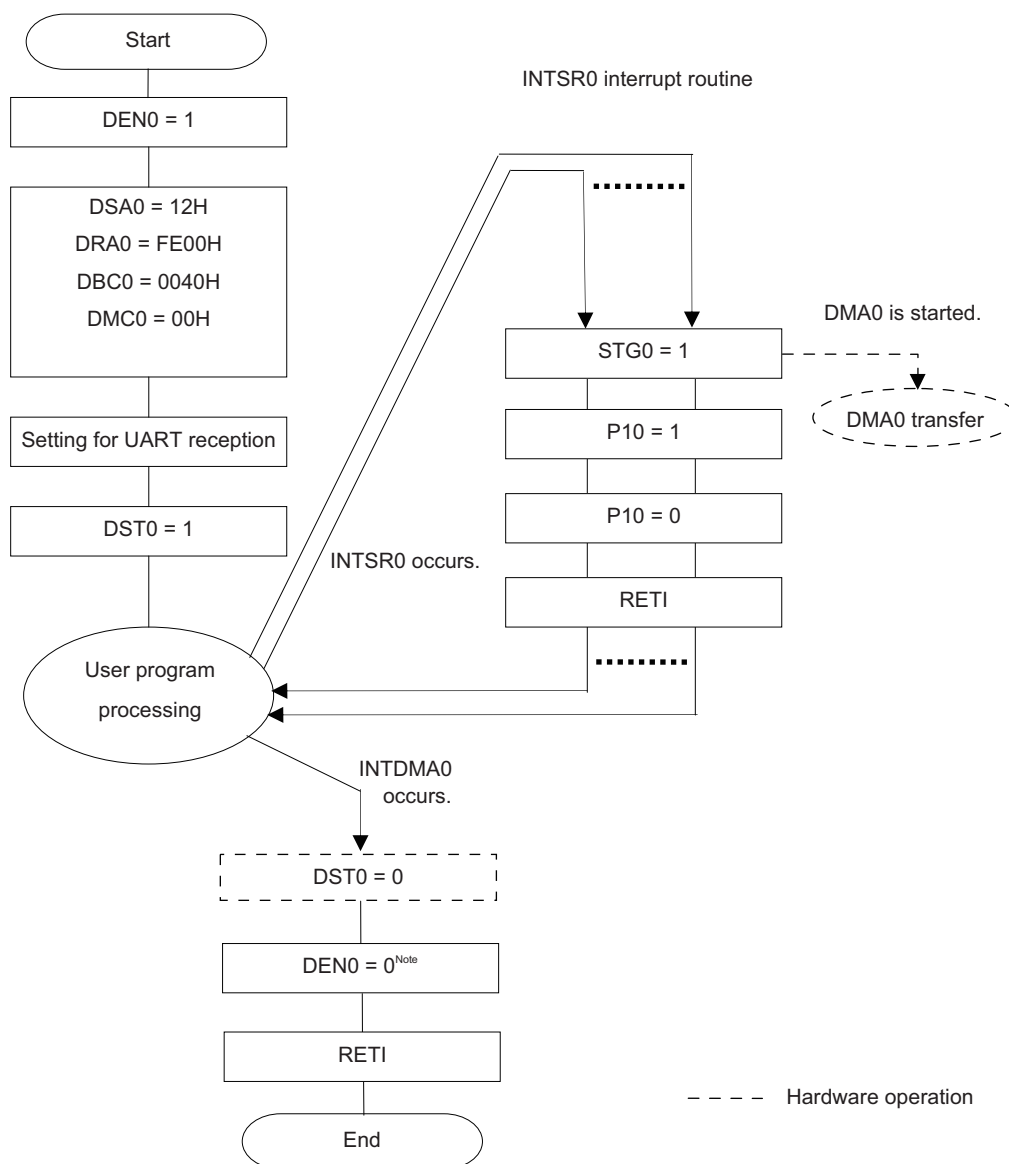
Writing the DEN1 flag is enabled only when DST1 = 0. To terminate a DMA transfer without waiting for occurrence of the interrupt of DMA1 (INTDMA1), set the DST1 bit to 0 and then the DEN1 bit to 0 (for details, see **15.5.5 Forced termination by software**).

15.5.3 UART consecutive reception + ACK transmission

A flowchart illustrating an example of setting for UART consecutive reception + ACK transmission is shown below.

- Consecutively receives data from UART0 and outputs ACK to P10 on completion of reception.
- DMA channel 0 is used for DMA transfer.
- DMA start source: Software trigger (DMA transfer on occurrence of an interrupt is disabled.)
- Transfers FFF12H of UART receive data register 0 (RXD0) to 64 bytes of FFE00H to FFE3FH of RAM.

Figure 15-9. Example of Setting for UART Consecutive Reception + ACK Transmission



Note The DST0 flag is automatically cleared to 0 when a DMA transfer is completed.

Writing the DEN0 flag is enabled only when DST0 = 0. To terminate a DMA transfer without waiting for occurrence of the interrupt of DMA0 (INTDMA0), set the DST0 bit to 0 and then the DEN0 bit to 0 (for details, see **15.5.5 Forced termination by software**).

Remark This is an example where a software trigger is used as a DMA start source.

If ACK is not transmitted and if only data is consecutively received from UART, the UART reception end interrupt (INTSR0) can be used to start DMA for data reception.

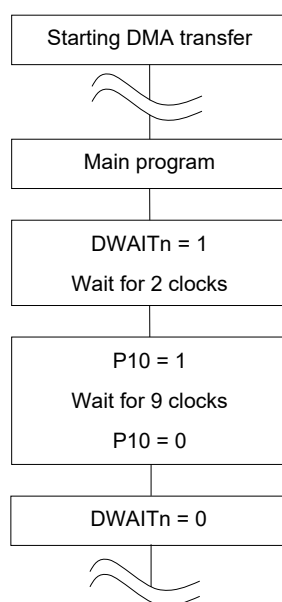
15.5.4 Holding DMA transfer pending by DWAITn bit

When DMA transfer is started, transfer is performed while an instruction is executed. At this time, the operation of the CPU is stopped and delayed for the duration of 2 clocks. If this poses a problem to the operation of the set system, a DMA transfer can be held pending by setting the DWAITn bit to 1. The DMA transfer for a transfer trigger that occurred while DMA transfer was held pending is executed after the pending status is canceled. However, because only one transfer trigger can be held pending for each channel, even if multiple transfer triggers occur for one channel during the pending status, only one DMA transfer is executed after the pending status is canceled.

To output a pulse with a width of 10 clocks of the operating frequency from the P10 pin, for example, the clock width increases to 12 if a DMA transfer is started midway. In this case, the DMA transfer can be held pending by setting the DWAITn bit to 1.

After setting the DWAITn bit to 1, it takes two clocks until a DMA transfer is held pending.

Figure 15-10. Example of Setting for Holding DMA Transfer Pending by DWAITn Bit



Caution When DMA transfer is held pending while using two or more DMA channels, be sure to held the DMA transfer pending for all channels (by setting DWAIT0 and DWAIT1 to 1). If the DMA transfer of one channel is executed while that of the other channel is held pending, DMA transfer might not be held pending for the latter channel.

Remarks

1. n: DMA channel number (n = 0, 1)
2. 1 clock: $1/f_{CLK}$ (f_{CLK} : CPU clock)

15.5.5 Forced termination by software

After the DSTn bit is set to 0 by software, it takes up to 2 clocks until a DMA transfer is actually stopped and the DSTn bit is set to 0. To forcibly terminate a DMA transfer by software without waiting for occurrence of the interrupt (INTDMA_n) of DMA_n, therefore, perform either of the following processes.

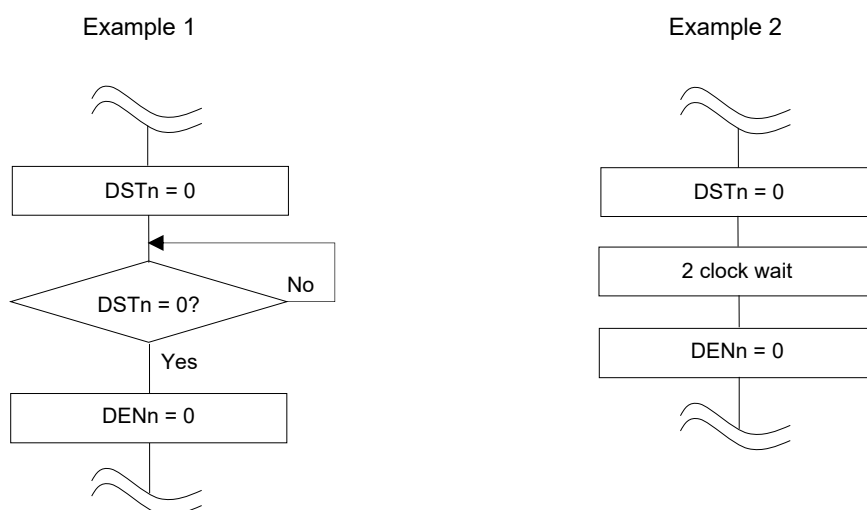
<When using one DMA channel>

- Set the DSTn bit to 0 (use DRCn = 80H to write with an 8-bit manipulation instruction) by software, confirm by polling that the DSTn bit has actually been cleared to 0, and then set the DENn bit to 0 (use DRCn = 00H to write with an 8-bit manipulation instruction).
- Set the DSTn bit to 0 (use DRCn = 80H to write with an 8-bit manipulation instruction) by software and then set the DENn bit to 0 (use DRCn = 00H to write with an 8-bit manipulation instruction) two or more clocks after.

<When using two or more DMA channels>

- To forcibly terminate DMA transfer by software when using two or more DMA channels (by setting DSTn to 0), clear the DSTn bit to 0 after the DMA transfer is held pending by setting the DWAITn bits of all using channels to 1. Next, clear the DWAITn bits of all using channels to 0 to cancel the pending status, and then clear the DENn bit to 0.

Figure 15-11. Forced Termination of DMA Transfer (1/2)

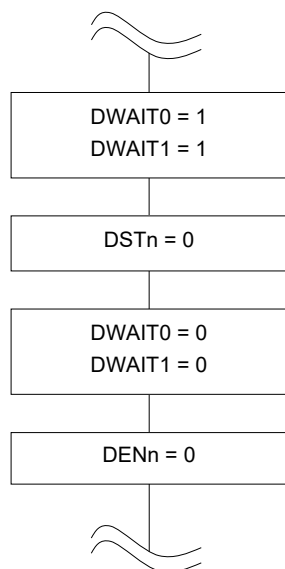


Remarks 1. n: DMA channel number (n = 0, 1)

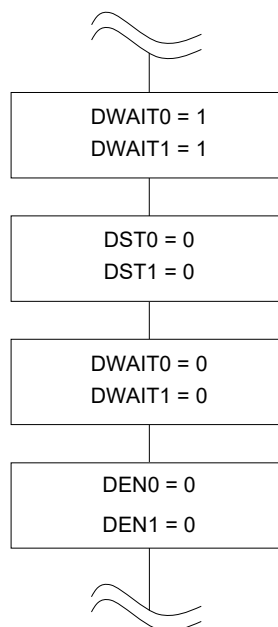
2. 1 clock: 1/f_{CLK} (f_{CLK}: CPU clock)

Figure 15-11. Forced Termination of DMA Transfer (2/2)**Example 3**

- Procedure for forcibly terminating the DMA transfer for one channel if both channels are used



- Procedure for forcibly terminating the DMA transfer for both channels if both channels are used



Caution In example 3, the system is not required to wait two clock cycles after the $DWAITn$ bit is set to 1. In addition, the system does not have to wait two clock cycles after clearing the $DSTn$ bit to 0, because more than two clock cycles elapse from when the $DSTn$ bit is cleared to 0 to when the $DENn$ bit is cleared to 0.

- Remarks**
1. n : DMA channel number ($n = 0, 1$)
 2. 1 clock: $1/f_{CLK}$ (f_{CLK} : CPU clock)

15.6 Cautions on Using DMA Controller

(1) Priority of DMA

During DMA transfer, a request from the other DMA channel is held pending even if generated. The pending DMA transfer is started after the ongoing DMA transfer is completed. If two or more DMA requests are generated at the same time, however, their priority are DMA channel 0 > DMA channel 1.

If a DMA request and an interrupt request are generated at the same time, the DMA transfer takes precedence, and then interrupt servicing is executed.

(2) DMA response time

The response time of DMA transfer is as follows.

Table 15-3. Response Time of DMA Transfer

	Minimum Time	Maximum Time
Response time	3 clocks	10 clocks ^{Note}

Note The maximum time necessary to execute an instruction from internal RAM is 16 clock cycles.

Cautions 1. The above response time does not include the two clock cycles required for a DMA transfer.

2. When executing a DMA pending instruction (see 15.6 (4)), the maximum response time is extended by the execution time of that instruction to be held pending.

3. Do not specify successive transfer triggers for a channel within a period equal to the maximum response time plus one clock cycle, because they might be ignored.

Remark 1 clock: $1/f_{CLK}$ (f_{CLK} : CPU clock)

(3) Operation in standby mode

The DMA controller operates as follows in the standby mode.

Table 15-4. DMA Operation in Standby Mode

Status	DMA Operation
HALT mode	Normal operation
STOP mode	Stops operation. If DMA transfer and STOP instruction execution contend, DMA transfer may be damaged. Therefore, stop DMA before executing the STOP instruction.

(4) DMA pending instruction

Even if a DMA request is generated, DMA transfer is held pending immediately after the following instructions.

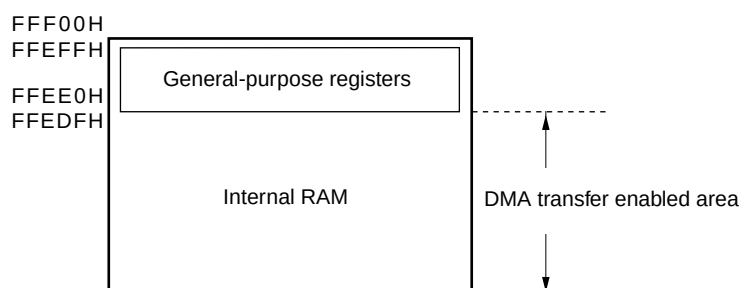
- CALL !addr16
- CALL \$!addr20
- CALL !!addr20
- CALL rp
- CALLT [addr5]
- BRK
- MOV PSW, #byte
- MOV PSW, A
- MOV1 PSW. bit, CY
- SET1 PSW. bit
- CLR1 PSW. bit
- POP PSW
- BTCLR PSW. bit, \$addr20
- EI
- DI
- Write instructions for registers IF0L, IF0H, IF1L, IF1H, IF2L, IF2H, MK0L, MK0H, MK1L, MK1H, MK2L, MK2H, PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, and PR12H each.
- Instruction for accessing the data flash memory

(5) Operation if address in general-purpose register area or other than those of internal RAM area is specified

The address indicated by DMA RAM address register n (DRAn) is incremented during DMA transfer. If the address is incremented to an address in the general-purpose register area or exceeds the area of the internal RAM, the following operation is performed.

- In mode of transfer from SFR to RAM
The data of that address is lost.
- In mode of transfer from RAM to SFR
Undefined data is transferred to SFR.

In either case, malfunctioning may occur or damage may be done to the system. Therefore, make sure that the address is within the internal RAM area other than the general-purpose register area.



(6) Operation if instructions for accessing the data flash area

If the data flash area is accessed after a next instruction execution from start of DMA transfer, a 3-clock wait will be inserted to the next instruction.

Instruction 1

DMA transfer

Instruction 2 ←The wait of three clock cycles occurs.

MOV A, ! DataFlash area

CHAPTER 16 INTERRUPT FUNCTIONS

The interrupt function switches the program execution to other processing. When the branch processing is finished, the program returns to the interrupted processing.

The number of interrupt sources differs, depending on the product.

		25-pin	32-pin	48-pin	64-pin
Maskable interrupts	External	5	6	10	13
	Internal	24	27	27	27

16.1 Interrupt Function Types

The following two types of interrupt functions are used.

(1) Maskable interrupts

These interrupts undergo mask control. Maskable interrupts can be divided into four priority groups by setting the priority specification flag registers (PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, PR12H).

Multiple interrupt servicing can be applied to low-priority interrupts when high-priority interrupts are generated. If two or more interrupt requests, each having the same priority, are simultaneously generated, then they are processed according to the default priority of vectored interrupt servicing. Default priority, see **Table 16-1**.

A standby release signal is generated and STOP, HALT, and SNOOZE modes are released.

External interrupt requests and internal interrupt requests are provided as maskable interrupts.

(2) Software interrupt

This is a vectored interrupt generated by executing the BRK instruction. It is acknowledged even when interrupts are disabled. The software interrupt does not undergo interrupt priority control.

16.2 Interrupt Sources and Configuration

Interrupt sources include maskable interrupts and software interrupts. In addition, they also have up to seven reset sources (see **Table 16-1**). The vector codes that store the program start address when branching due to the generation of a reset or various interrupt requests are two bytes each, so interrupts jump to a 64 K address of 00000H to 0FFFFH.

Table 16-1. Interrupt Source List (1/3)

Interrupt Type	Default Priority ^{Note 1}	Interrupt Source		Internal/ External	Vector Table Address	Basic Configuration Type ^{Note 2}	64-pin	48-pin	32-pin	25-pin
		Name	Trigger							
Maskable	0	INTWDTI	Watchdog timer interval ^{Note 3} (75% of overflow time+1/2f _{IL})	Internal	00004H	(A)	√	√	√	√
	1	INTLVI	Voltage detection ^{Note 4}		00006H		√	√	√	√
	2	INTP0	Pin input edge detection	External	00008H	(B)	√	√	√	√
	3	INTP1			0000AH		√	√	√	√
	4	INTP2			0000CH		√	√	√	√
	5	INTP3			0000EH		√	√	√	√
	6	INTP4			00010H		√	√	√	√
	7	INTP5			00012H		√	√	–	–
	8	INTST2/ INTCSI20/ INTIIC20	UART2 transmission transfer end or buffer empty interrupt/CSI20 transfer end or buffer empty interrupt/IIC20 transfer end	Internal	00014H	(A)	√	√	√	–
	9	INTSR2/ INTCSI21/ INTIIC21	UART2 reception transfer end/CSI21 transfer end or buffer empty interrupt/IIC21 transfer end		00016H		√	√	√ ^{Note 5}	–
	10	INTSRE2	UART2 reception communication error occurrence		00018H		√	√	√	–
	11	INTDMA0	End of DMA0 transfer		0001AH		√	√	√	√
	12	INTDMA1	End of DMA1 transfer		0001CH		√	√	√	√
	13	INTST0/ INTCSI00/ INTIIC00	UART0 transmission transfer end or buffer empty interrupt/CSI00 transfer end or buffer empty interrupt/IIC00 transfer end		0001EH		√	√	√	√
	14	INTSR0/ INTCSI01/ INTIIC01	UART0 reception transfer end/CSI01 transfer end or buffer empty interrupt/IIC01 transfer end		00020H		√	√	√ ^{Note 6}	√ ^{Note 6}
	15	INTSRE0	UART0 reception communication error occurrence	00022H	√	√	√	√		
		INTTM01H	End of timer channel 1 count or capture (at higher 8-bit timer operation)		√	√	√	√		

- Notes**
1. The default priority determines the sequence of interrupts if two or more maskable interrupts occur simultaneously. Zero indicates the highest priority and 39 indicates the lowest priority.
 2. Basic configuration types (A) to (D) correspond to (A) to (D) in Figure 16-1.
 3. When bit 7 (WDTINT) of the option byte (000C0H) is set to 1.
 4. When bit 7 (LVIMD) of the voltage detection level register (LVIS) is cleared to 0.
 5. INTSR2 only.
 6. INTSR0 only.

Table 16-1. Interrupt Source List (2/3)

Interrupt Type	Default Priority ^{Note 1}	Interrupt Source		Internal/External	Vector Table Address	Basic Configuration Type ^{Note 2}	64-pin	48-pin	32-pin	25-pin
		Name	Trigger							
Maskable	16	INTST1/ INTCSI10/ INTIIC10	UART1 transmission transfer end or buffer empty interrupt/CSI10 transfer end or buffer empty interrupt/IIC10 transfer end	Internal	00024H	(A)	√	√ ^{Note 3}	√ ^{Note 3}	√ ^{Note 3}
	17	INTSR1/ INTCSI11/ INTIIC11	UART1 reception transfer end/CSI11 transfer end or buffer empty interrupt/IIC11 transfer end		00026H		√	√	√	√
	18	INTSRE1	UART1 reception communication error occurrence		00028H		√	√	√	√
		INTTM03H	End of timer channel 3 count or capture (at higher 8-bit timer operation)				√	√	√	√
	19	INTIICA0	End of IICA0 communication		0002AH		√	√	√	√
	20	INTTM00	End of timer channel 0 count or capture		0002CH		√	√	√	√
	21	INTTM01	End of timer channel 1 count or capture (at 16-bit/lower 8-bit timer operation)		0002EH		√	√	√	√
	22	INTTM02	End of timer channel 2 count or capture		00030H		√	√	√	√
	23	INTTM03	End of timer channel 3 count or capture (at 16-bit/lower 8-bit timer operation)		00032H		√	√	√	√
	24	INTAD	End of A/D conversion		00034H		√	√	√	√
	25	INTRTC	Fixed-cycle signal of real-time clock/alarm match detection		00036H		√	√	√	√
	26	INTIT	Interval signal of 12-bit interval timer detection		00038H		√	√	√	√
	27	INTKR	Key return signal detection	External	0003AH	(C)	√	√	√	(√) ^{Note 4}
	28	INTTM04	End of timer channel 4 count or capture	Internal	00042H	(A)	√	√	√	√

- Notes**
1. The default priority determines the sequence of interrupts if two or more maskable interrupts occur simultaneously. Zero indicates the highest priority and 39 indicates the lowest priority.
 2. Basic configuration types (A) to (D) correspond to (A) to (D) in Figure 16-1.
 3. INTST1 only.
 4. When setting peripheral I/O redirection register (PIOR)

Table 16-1. Interrupt Source List (3/3)

Interrupt Type	Default Priority ^{Note 1}	Interrupt Source		Internal/ External	Vector Table Address	Basic Configuration Type ^{Note 2}	64-pin	48-pin	32-pin	25-pin
		Name	Trigger							
Maskable	29	INTTM05	End of timer channel 5 count or capture	Internal	00044H	(A)	√	√	√	√
	30	INTTM06	End of timer channel 6 count or capture		00046H		√	√	√	√
	31	INTTM07	End of timer channel 7 count or capture		00048H		√	√	√	√
	32	INTP6	Pin input edge detection	External	0004AH	(B)	√	√	–	–
	33	INTP7			0004CH		√	–	–	–
	34	INTP8			0004EH		√	√	–	–
	35	INTP9			00050H		√	√	–	–
	36	INTP10			00052H		√	–	–	–
	37	INTP11			00054H		√	–	–	–
	38	INTMD	End of division operation/ Overflow of multiply-accumulation result occurs	Internal	0005EH	(A)	√	√	√	√
	39	INTFL	Reserved ^{Note 3}		00062H		√	√	√	√
Software	–	BRK	Execution of BRK instruction	–	0007EH	(D)	√	√	√	√
Reset	–	RESET	RESET pin input	–	00000H	–	√	√	√	√
		POR	Power-on-reset				√	√	√	√
		LVD	Voltage detection ^{Note 3}				√	√	√	√
		WDT	Overflow of watchdog timer				√	√	√	√
		TRAP	Execution of illegal instruction ^{Note 4}				√	√	√	√
		IAW	Illegal-memory access				√	√	√	√
		RPE	RAM parity error				√	√	√	√

Notes 1. The default priority determines the sequence of interrupts if two or more maskable interrupts occur simultaneously. Zero indicates the highest priority and 39 indicates the lowest priority.

2. Basic configuration types (A) to (D) correspond to (A) to (D) in Figure 16-1.

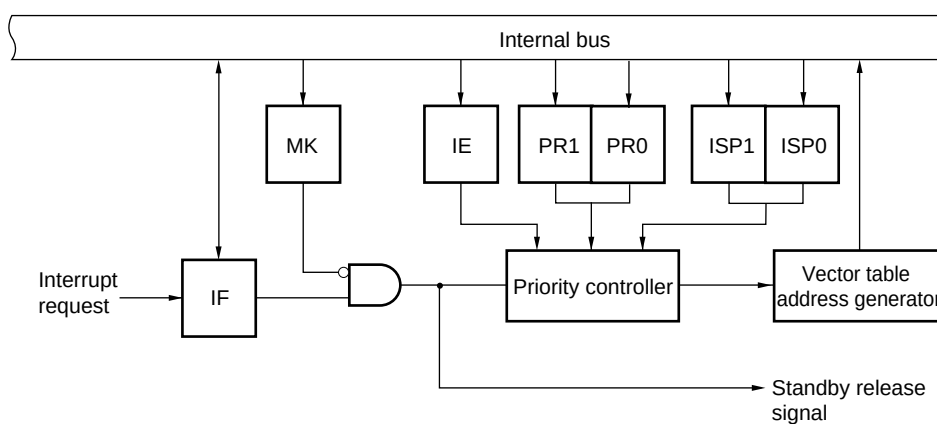
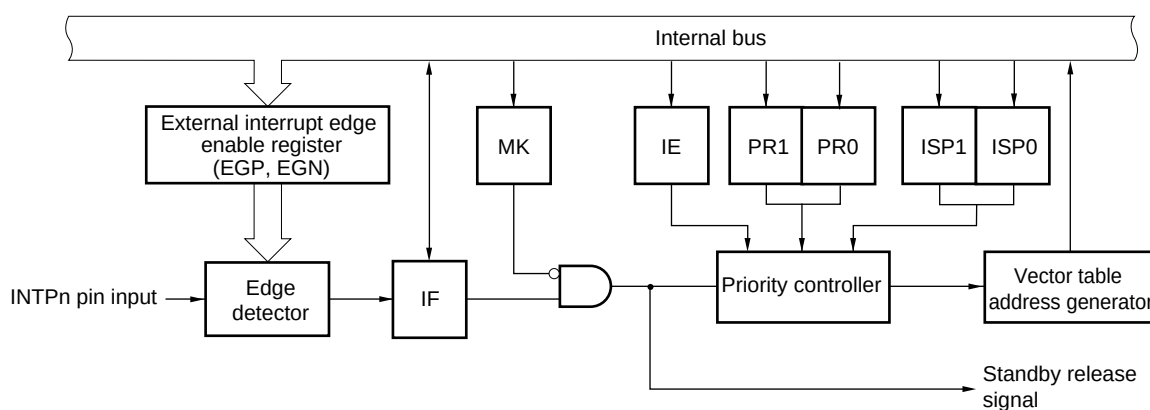
3. Be used at the flash self programming library or the data flash library.

4. When bit 7 (LVIMD) of the voltage detection level register (LVIS) is set to 1.

5. When the instruction code in FFH is executed.

Reset by the illegal instruction execution not issued by emulation with the in-circuit emulator or on-chip debug emulator.

Figure 16-1. Basic Configuration of Interrupt Function (1/2)

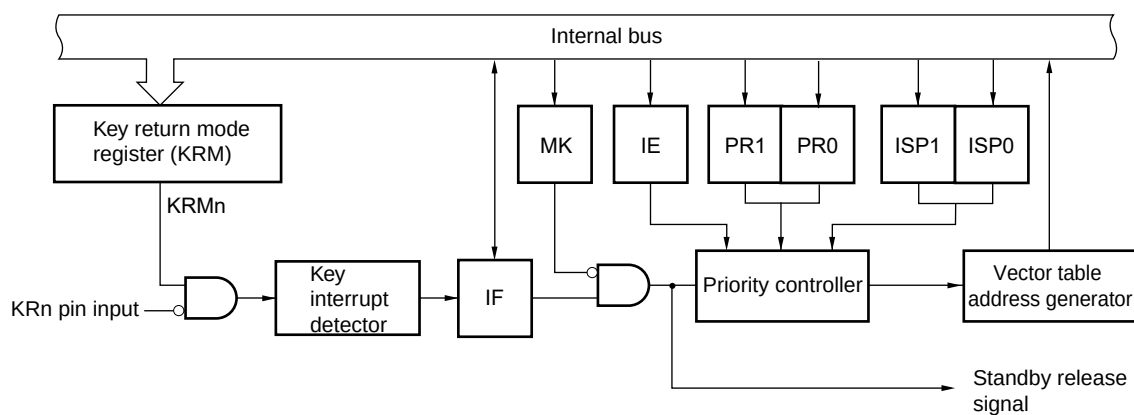
(A) Internal maskable interrupt**(B) External maskable interrupt (INTPn)**

IF: Interrupt request flag
 IE: Interrupt enable flag
 ISP0: In-service priority flag 0
 ISP1: In-service priority flag 1
 MK: Interrupt mask flag
 PR0: Priority specification flag 0
 PR1: Priority specification flag 1

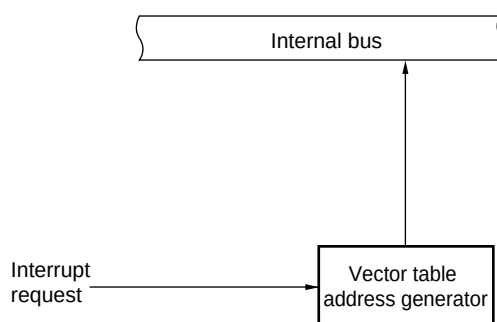
Remark 25, 32-pin: n = 0 to 4
 48-pin: n = 0 to 6, 8, 9
 64-pin: n = 0 to 11

Figure 16-1. Basic Configuration of Interrupt Function (2/2)

(C) External maskable interrupt (INTKR)



(D) Software interrupt



IF: Interrupt request flag
 IE: Interrupt enable flag
 ISP0: In-service priority flag 0
 ISP1: In-service priority flag 1
 MK: Interrupt mask flag
 PR0: Priority specification flag 0
 PR1: Priority specification flag 1

Remark 32-pin: n = 0
 48-pin: n = 0 to 5
 64-pin: n = 0 to 9

16.3 Registers Controlling Interrupt Functions

The following 6 types of registers are used to control the interrupt functions.

- Interrupt request flag registers (IF0L, IF0H, IF1L, IF1H, IF2L, IF2H)
- Interrupt mask flag registers (MK0L, MK0H, MK1L, MK1H, MK2L, MK2H)
- Priority specification flag registers (PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, PR12H)
- External interrupt rising edge enable registers (EGP0, EGP1)
- External interrupt falling edge enable registers (EGN0, EGN1)
- Program status word (PSW)

Table 16-2 shows a list of interrupt request flags, interrupt mask flags, and priority specification flags corresponding to interrupt request sources.

Table 16-2. Flags Corresponding to Interrupt Request Sources (1/4)

Interrupt Source	Interrupt Request Flag		Interrupt Mask Flag		Priority Specification Flag		64-pin	48-pin	32-pin	25-pin
		Register		Register		Register				
INTWDTI	WDTIIF	IF0L	WDTIMK	MK0L	WDTIPR0, WDTIPR1	PR00L, PR10L	√	√	√	√
INTLVI	LVIIIF		LVIMK		LVIPR0, LVIPR1		√	√	√	√
INTP0	PIF0		PMK0		PPR00, PPR10		√	√	√	√
INTP1	PIF1		PMK1		PPR01, PPR11		√	√	√	√
INTP2	PIF2		PMK2		PPR02, PPR12		√	√	√	√
INTP3	PIF3		PMK3		PPR03, PPR13		√	√	√	√
INTP4	PIF4		PMK4		PPR04, PPR14		√	√	√	√
INTP5	PIF5		PMK5		PPR05, PPR15		√	√	—	—

Table 16-2. Flags Corresponding to Interrupt Request Sources (2/4)

Interrupt Source	Interrupt Request Flag		Interrupt Mask Flag		Priority Specification Flag		64-pin	48-pin	32-pin	25-pin
		Register		Register		Register				
INTST2 ^{Note 1}	STIF2 ^{Note 1}	IF0H	STMK2 ^{Note 1}	MK0H	STPR02, STPR12 ^{Note 1}	PR00H, PR10H	√	√	√	–
INTCSI20 ^{Note 1}	CSIF20 ^{Note 1}		CSIMK20 ^{Note 1}		CSIPR020, CSIPR120 ^{Note 1}		√	√	√	–
INTIIC20 ^{Note 1}	IICIF20 ^{Note 1}		IICMK20 ^{Note 1}		IICPR020, IICPR120 ^{Note 1}		√	√	√	–
INTSR2 ^{Note 2}	SRIF2 ^{Note 2}		SRMK2 ^{Note 2}		SRPR02, SRPR12 ^{Note 2}		√	√	√	–
INTCSI21 ^{Note 2}	CSIF21 ^{Note 2}		CSIMK21 ^{Note 2}		CSIPR021, CSIPR121 ^{Note 2}		√	√	–	–
INTIIC21 ^{Note 2}	IICIF21 ^{Note 2}		IICMK21 ^{Note 2}		IICPR021, IICPR121 ^{Note 2}		√	√	–	–
INTSRE2	SREIF2		SREMK2		SREPR02, SREPR12		√	√	√	–
INTDMA0	DMAIF0		DMAMK0		DMAPR00, DMAPR10		√	√	√	√
INTDMA1	DMAIF1		DMAMK1		DMAPR01, DMAPR11		√	√	√	√
INTST0 ^{Note 3}	STIF0 ^{Note 3}		STMK0 ^{Note 3}		STPR00, STPR10 ^{Note 3}		√	√	√	√
INTCSI00 ^{Note 3}	CSIF00 ^{Note 3}	IF0H	CSIMK00 ^{Note 3}	MK0H	CSIPR000, CSIPR100 ^{Note 3}	PR00H, PR10H	√	√	√	√
INTIIC00 ^{Note 3}	IICIF00 ^{Note 3}		IICMK00 ^{Note 3}		IICPR000, IICPR100 ^{Note 3}		√	√	√	√
INTSR0 ^{Note 4}	SRIF0 ^{Note 4}		SRMK0 ^{Note 4}		SRPR00, SRPR10 ^{Note 4}		√	√	√	√
INTCSI01 ^{Note 4}	CSIF01 ^{Note 4}		CSIMK01 ^{Note 4}		CSIPR001, CSIPR101 ^{Note 4}		√	√	–	–
INTIIC01 ^{Note 4}	IICIF01 ^{Note 4}		IICMK01 ^{Note 4}		IICPR001, IICPR101 ^{Note 4}		√	√	–	–
INTSRE0 ^{Note 5}	SREIF0 ^{Note 5}		SREMK0 ^{Note 5}		SREPR00, SREPR10 ^{Note 5}		√	√	√	√
INTTM01H ^{Note 5}	TMIF01H ^{Note 5}		TMMK01H ^{Note 5}		TMPR001H, TMPR101H ^{Note 5}		√	√	√	√

- Notes**
1. If one of the interrupt sources INTST2, INTCSI20, and INTIIC20 is generated, bit 0 of the IF0H register is set to 1. Bit 0 of the MK0H, PR00H, and PR10H registers can be used for all three of these interrupt sources.
 2. If one of the interrupt sources INTSR2, INTCSI21, and INTIIC21 is generated, bit 1 of the IF0H register is set to 1. Bit 1 of the MK0H, PR00H, and PR10H registers can be used for all three of these interrupt sources.
 3. If one of the interrupt sources INTST0, INTCSI00, and INTIIC00 is generated, bit 5 of the IF0H register is set to 1. Bit 5 of the MK0H, PR00H, and PR10H registers can be used for all three of these interrupt sources.
 4. If one of the interrupt sources INTSR0, INTCSI01, and INTIIC01 is generated, bit 6 of the IF0H register is set to 1. Bit 6 of the MK0H, PR00H, and PR10H registers can be used for all three of these interrupt sources.
 5. Do not use the error interrupt of UART0 reception and the interrupt of channel 1 of TAU0 (while the higher 8 bits are operating at a timer) at the same time because they share flags for the interrupt request sources. If the error interrupt of UART0 reception is not used (EOC01 = 0), UART0 and channel 1 of TAU0 (while the higher 8 bits are operating at a timer) can be used at the same time. If the interrupt source INTSRE0 or INTTM01H is generated, bit 7 of the IF0H register is set to 1. Bit 7 of the MK0H, PR00H, and PR10H registers can be used for both these interrupt sources.

Table 16-2. Flags Corresponding to Interrupt Request Sources (3/4)

Interrupt Source	Interrupt Request Flag		Interrupt Mask Flag		Priority Specification Flag		64-pin	48-pin	32-pin	25-pin
		Register		Register		Register				
INTST1 ^{Note 1}	STIF1 ^{Note 1}	IF1L	STMK1 ^{Note 1}	MK1L	STPR01, STPR11 ^{Note 1}	PR01L, PR11L	√	√	√	√
INTCSI10 ^{Note 1}	CSIIF10 ^{Note 1}		CSIMK10 ^{Note 1}		CSIPR010, CSIPR110 ^{Note 1}		√	—	—	—
INTIIC10 ^{Note 1}	IICIF10 ^{Note 1}		IICMK10 ^{Note 1}		IICPR010, IICPR110 ^{Note 1}		√	—	—	—
INTSR1 ^{Note 2}	SRIF1 ^{Note 2}		SRMK1 ^{Note 2}		SRPR01, SRPR11 ^{Note 2}		√	√	√	√
INTCSI11 ^{Note 2}	CSIIF11 ^{Note 2}		CSIMK11 ^{Note 2}		CSIPR011, CSIPR111 ^{Note 2}		√	√	√	√
INTIIC11 ^{Note 2}	IICIF11 ^{Note 2}		IICMK11 ^{Note 2}		IICPR011, IICPR111 ^{Note 2}		√	√	√	√
INTSRE1 ^{Note 3}	SREIF1 ^{Note 3}		SREMK1 ^{Note 3}		SREPR01, SREPR11 ^{Note 3}		√	√	√	√
INTTM03H ^{Note 3}	TMIF03H ^{Note 3}		TMMK03H ^{Note 3}		TMPR003H, TMPR103H ^{Note 3}		√	√	√	√
INTIICA0	IICAIF0		IICAMK0		IICAPR00, IICAPR10		√	√	√	√
INTTM00	TMIF00		TMMK00		TMPR000, TMPR100		√	√	√	√
INTTM01	TMIF01		TMMK01		TMPR001, TMPR101		√	√	√	√
INTTM02	TMIF02		TMMK02		TMPR002, TMPR102		√	√	√	√
INTTM03	TMIF03		TMMK03		TMPR003, TMPR103		√	√	√	√
INTAD	ADIF	IF1H	ADMK	MK1H	ADPR0, ADPR1	PR01H, PR11H	√	√	√	√
INTRTC	RTCIF		RTCMK		RTCPR0, RTCPR1		√	√	√	√
INTIT	ITIF		ITMK		ITPR0, ITPR1		√	√	√	√
INTKR	KRIF		KRMK		KRPR0, KRPR1		√	√	√	(√)
INTTM04	TMIF04		TMMK04		TMPR004, TMPR104		√	√	√	√

- Notes**
1. If one of the interrupt sources INTST1, INTCSI10, and INTIIC10 is generated, bit 0 of the IF1L register is set to 1. Bit 0 of the MK1L, PR01L, and PR11L registers can be used for all three of these interrupt sources.
 2. If one of the interrupt sources INTSR1, INTCSI11, and INTIIC11 is generated, bit 1 of the IF1L register is set to 1. Bit 1 of the MK1L, PR01L, and PR11L registers can be used for all three of these interrupt sources.
 3. Do not use the error interrupt of UART1 reception and the interrupt of channel 3 of TAU0 (while the higher 8 bits are operating at a timer) at the same time because they share flags for the interrupt request sources. If the error interrupt of UART1 reception is not used (EOC03 = 0), UART1 and channel 3 of TAU0 (while the higher 8 bits are operating at a timer) can be used at the same time. If the interrupt source INTSRE1 or INTTM03H is generated, bit 2 of the IF1L register is set to 1. Bit 2 of the MK1L, PR01L, and PR11L registers can be used for both these interrupt sources.

Table 16-2. Flags Corresponding to Interrupt Request Sources (4/4)

Interrupt Source	Interrupt Request Flag		Interrupt Mask Flag		Priority Specification Flag		64-pin	48-pin	32-pin	25-pin
		Register		Register		Register				
INTTM05	TMIF05	IF2L	TMMK05	MK2L	TMPR005, TMPR105	PR02L, PR12L	√	√	√	√
INTTM06	TMIF06		TMMK06		TMPR006, TMPR106		√	√	√	√
INTTM07	TMIF07		TMMK07		TMPR007, TMPR107		√	√	√	√
INTP6	PIF6		PMK6		PPR06, PPR16		√	√	–	–
INTP7	PIF7		PMK7		PPR07, PPR17		√	–	–	–
INTP8	PIF8		PMK8		PPR08, PPR18		√	√	–	–
INTP9	PIF9		PMK9		PPR09, PPR19		√	√	–	–
INTP10	PIF10		PMK10		PPR010, PPR110		√	–	–	–
INTP11	PIF11	IF2H	PMK11	MK2H	PPR011, PPR111	PR02H, PR12H	√	–	–	–
INTMD	MDIF		MDMK		MDPR0, MDPR1		√	√	√	√
INTFL	FLIF		FLMK		FLPR0, FLPR1		√	√	√	√

16.3.1 Interrupt request flag registers (IF0L, IF0H, IF1L, IF1H, IF2L, IF2H)

The interrupt request flags are set to 1 when the corresponding interrupt request is generated or an instruction is executed. They are cleared to 0 when an instruction is executed upon acknowledgment of an interrupt request or upon reset signal generation.

When an interrupt is acknowledged, the interrupt request flag is automatically cleared and then the interrupt routine is entered.

The IF0L, IF0H, IF1L, IF1H, IF2L, and IF2H registers can be set by a 1-bit or 8-bit memory manipulation instruction. When the IF0L and IF0H registers, the IF1L and IF1H registers, and the IF2L and IF2H registers are combined to form 16-bit registers IF0, IF1, and IF2, they can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears these registers to 00H.

Remark If an instruction that writes data to this register is executed, the number of instruction execution clocks increases by 2 clocks.

Figure 16-2. Format of Interrupt Request Flag Registers (IF0L, IF0H, IF1L, IF1H, IF2L, IF2H) (1/2)

Address: FF0E0H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IF0L	PIF5	PIF4	PIF3	PIF2	PIF1	PIF0	LVIF	WDTIF

Address: FF0E1H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IF0H	SREIF0 TMIF01H	SRIF0 CSIF01 IICIF01	STIF0 CSIF00 IICIF00	DMAIF1	DMAIF0	SREIF2 TMIF11H	SRIF2 CSIF21 IICIF21	STIF2 CSIF20 IICIF20

Address: FF0E2H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IF1L	TMIF03	TMIF02	TMIF01	TMIF00	IICAF0	SREIF1 TMIF03H	SRIF1 CSIF11 IICIF11	STIF1 CSIF10 IICIF10

Address: FF0E3H After reset: 00H R/W

Symbol	<7>	6	5	4	<3>	<2>	<1>	<0>
IF1H	TMIF04	0	0	0	KRIF	ITIF	RTCIF	ADIF

Address: FF0D0H After reset: 00H R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
IF2L	PIF10	PIF9	PIF8	PIF7	PIF6	TMIF07	TMIF06	TMIF05

Figure 16-2. Format of Interrupt Request Flag Registers (IF0L, IF0H, IF1L, IF1H, IF2L, IF2H) (2/2)

Address: FFFD1H After reset: 00H R/W

Symbol	<7>	6	<5>	4	3	2	1	<0>
IF2H	FLIF	0	MDIF	0	0	0	0	PIF11

XXIFX	Interrupt request flag
0	No interrupt request signal is generated
1	Interrupt request is generated, interrupt request status

Cautions 1. The available registers and bits differ depending on the product. For details about the registers and bits available for each product, see Table 16-2. Be sure to clear bits that are not available to the initial value.

2. When manipulating a flag of the interrupt request flag register, use a 1-bit memory manipulation instruction (CLR1). When describing in C language, use a bit manipulation instruction such as “IF0L.0 = 0;” or “_asm(“clr1 IF0L, 0”);” because the compiled assembler must be a 1-bit memory manipulation instruction (CLR1).

If a program is described in C language using an 8-bit memory manipulation instruction such as “IF0L &= 0xfe;” and compiled, it becomes the assembler of three instructions.

```
mov a, IF0L
and a, #0FEH
mov IF0L, a
```

In this case, even if the request flag of the another bit of the same interrupt request flag register (IF0L) is set to 1 at the timing between “mov a, IF0L” and “mov IF0L, a”, the flag is cleared to 0 at “mov IF0L, a”. Therefore, care must be exercised when using an 8-bit memory manipulation instruction in C language.

16.3.2 Interrupt mask flag registers (MK0L, MK0H, MK1L, MK1H, MK2L, MK2H)

The interrupt mask flags are used to enable/disable the corresponding maskable interrupt.

The MK0L, MK0H, MK1L, MK1H, MK2L, and MK2H registers can be set by a 1-bit or 8-bit memory manipulation instruction. When the MK0L and MK0H registers, the MK1L and MK1H registers, and the MK2L and MK2H registers are combined to form 16-bit registers MK0, MK1, and MK2, they can be set by a 16-bit memory manipulation instruction.

Reset signal generation sets these registers to FFH.

Remark If an instruction that writes data to this register is executed, the number of instruction execution clocks increases by 2 clocks.

Figure 16-3. Format of Interrupt Mask Flag Registers (MK0L, MK0H, MK1L, MK1H, MK2L, MK2H)

Address: FFFE4H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
MK0L	PMK5	PMK4	PMK3	PMK2	PMK1	PMK0	LVIMK	WDTIMK

Address: FFFE5H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
MK0H	SREMK0 TMMK01H	SRMK0 CSIMK01 IICMK01	STMK0 CSIMK00 IICMK00	DMAMK1	DMAMK0	SREMK2 TMMK11H	SRMK2 CSIMK21 IICMK21	STMK2 CSIMK20 IICMK20

Address: FFFE6H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
MK1L	TMMK03	TMMK02	TMMK01	TMMK00	IICAMK0	SREMK1 TMMK03H	SRMK1 CSIMK11 IICMK11	STMK1 CSIMK10 IICMK10

Address: FFFE7H After reset: FFH R/W

Symbol	<7>	6	5	4	<3>	<2>	<1>	<0>
MK1H	TMMK04	1	1	1	KRMK	ITMK	RTCMK	ADMK

Address: FFFD4H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
MK2L	PMK10	PMK9	PMK8	PMK7	PMK6	TMMK07	TMMK06	TMMK05

Address: FFFD5H After reset: FFH R/W

Symbol	<7>	6	<5>	4	3	2	1	<0>
MK2H	FLMK	1	MDMK	1	1	1	1	PMK11

XXMKX	Interrupt servicing control						
0	Interrupt servicing enabled						
1	Interrupt servicing disabled						

Caution The available registers and bits differ depending on the product. For details about the registers and bits available for each product, see Table 16-2. Be sure to set bits that are not available to the initial value.

16.3.3 Priority specification flag registers (PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, PR12H)

The priority specification flag registers are used to set the corresponding maskable interrupt priority level.

A priority level is set by using the PR0xy and PR1xy registers in combination (xy = 0L, 0H, 1L, 1H, 2L, or 2H).

The PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, and the PR12H registers can be set by a 1-bit or 8-bit memory manipulation instruction. If the PR00L and PR00H registers, the PR01L and PR01H registers, the PR02L and PR02H registers, the PR10L and PR10H registers, the PR11L and PR11H registers, and the PR12L and PR12H registers are combined to form 16-bit registers PR00, PR01, PR02, PR10, PR11, and PR12, they can be set by a 16-bit memory manipulation instruction.

Reset signal generation sets these registers to FFH.

Remark If an instruction that writes data to this register is executed, the number of instruction execution clocks increases by 2 clocks.

Figure 16-4. Format of Priority Specification Flag Registers (PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, PR12H) (1/2)

Address: FFFE8H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR00L	PPR05	PPR04	PPR03	PPR02	PPR01	PPR00	LVIPR0	WDTIPR0

Address: FFFECH After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR10L	PPR15	PPR14	PPR13	PPR12	PPR11	PPR10	LVIPR1	WDTIPR1

Address: FFFE9H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR00H	SREPR00 TMPR001H	SRPR00 CSIPR001 IICPR001	STPR00 CSIPR000 IICPR000	DMAPR01	DMAPR00	SREPR02 TMPR011H	SRPR02 CSIPR021 IICPR021	STPR02 CSIPR020 IICPR020

Address: FFFEDH After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR10H	SREPR10 TMPR101H	SRPR10 CSIPR101 IICPR101	STPR10 CSIPR100 IICPR100	DMAPR11	DMAPR10	SREPR12 TMPR111H	SRPR12 CSIPR121 IICPR121	STPR12 CSIPR120 IICPR120

Address: FFFEAH After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR01L	TMPR003	TMPR002	TMPR001	TMPR000	IICAPR00	SREPR01 TMPR003H	SRPR01 CSIPR011 IICPR011	STPR01 CSIPR010 IICPR010

Address: FFFE6H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR11L	TMPR103	TMPR102	TMPR101	TMPR100	IICAPR10	SREPR11 TMPR103H	SRPR11 CSIPR111 IICPR111	STPR11 CSIPR110 IICPR110

Figure 16-4. Format of Priority Specification Flag Registers (PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, PR12H) (2/2)

Address: FFFEBH After reset: FFH R/W

Symbol	<7>	6	5	4	<3>	<2>	<1>	<0>
PR01H	TMPR004	1	1	1	KRPR0	ITPR0	RTCPR0	ADPR0

Address: FFFEFH After reset: FFH R/W

Symbol	<7>	6	5	4	<3>	<2>	<1>	<0>
PR11H	TMPR104	1	1	1	KRPR1	ITPR1	RTCPR1	ADPR1

Address: FFFD8H After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR02L	PPR010	PPR09	PPR08	PPR07	PPR06	TMPR007	TMPR006	TMPR005

Address: FFFDCH After reset: FFH R/W

Symbol	<7>	<6>	<5>	<4>	<3>	<2>	<1>	<0>
PR12L	PPR110	PPR19	PPR18	PPR17	PPR16	TMPR107	TMPR106	TMPR105

Address: FFFD9H After reset: FFH R/W

Symbol	<7>	6	<5>	4	3	2	1	<0>
PR02H	FLPR0	1	MDPR0	1	1	1	1	PPR011

Address: FFFDDH After reset: FFH R/W

Symbol	<7>	6	<5>	4	3	2	1	<0>
PR12H	FLPR1	1	MDPR1	1	1	1	1	PPR111

XXPR1X	XXPR0X	Priority level selection
0	0	Specify level 0 (high priority level)
0	1	Specify level 1
1	0	Specify level 2
1	1	Specify level 3 (low priority level)

Caution The available registers and bits differ depending on the product. For details about the registers and bits available for each product, see Table 16-2. Be sure to set bits that are not available to the initial value.

16.3.4 External interrupt rising edge enable registers (EGP0, EGP1), external interrupt falling edge enable registers (EGN0, EGN1)

The EGP0, EGP1, EGN0, and EGN1 registers can be set by a 1-bit or 8-bit memory manipulation instruction. Reset signal generation clears these registers to 00H.

Figure 16-5. Format of External Interrupt Rising Edge Enable Registers (EGP0, EGP1) and External Interrupt Falling Edge Enable Registers (EGN0, EGN1)

Address: FFF38H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
EGP0	EGP7	EGP6	EGP5	EGP4	EGP3	EGP2	EGP1	EGP0

Address: FFF39H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
EGN0	EGN7	EGN6	EGN5	EGN4	EGN3	EGN2	EGN1	EGN0

Address: FFF3AH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
EGP1	0	0	0	0	EGP11	EGP10	EGP9	EGP8

Address: FFF3BH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
EGN1	0	0	0	0	EGN11	EGN10	EGN9	EGN8

EGPn	EGNn	INTPn pin valid edge selection (n = 0 to 11)
0	0	Edge detection disabled
0	1	Falling edge
1	0	Rising edge
1	1	Both rising and falling edges

Table 16-3 shows the ports corresponding to the EGPn and EGNn bits.

Table 16-3. Interrupt Request Signal Corresponding to EGPn and EGNn bits

Detection Enable Bit		Edge Detection Port	Interrupt Request Signal	64-pin	48-pin	32-pin	25-pin
EGP0	EGN0	P137	INTP0	√	√	√	√
EGP1	EGN1	P50	INTP1	√	√	√	√
EGP2	EGN2	P51	INTP2	√	√	√	√
EGP3	EGN3	P30	INTP3	√	√	√	√
EGP4	EGN4	P31	INTP4	√	√	√	√
EGP5	EGN5	P16	INTP5	√	√	–	–
EGP6	EGN6	P140	INTP6	√	√	–	–
EGP7	EGN7	P141	INTP7	√	–	–	–
EGP8	EGN8	P74	INTP8	√	√	–	–
EGP9	EGN9	P75	INTP9	√	√	–	–
EGP10	EGN10	P76	INTP10	√	–	–	–
EGP11	EGN11	P77	INTP11	√	–	–	–

Caution When the input port pins used for the external interrupt functions are switched to the output mode, the INTPn interrupt might be generated upon detection of a valid edge.

When switching the input port pins to the output mode, set the port mode register (PMxx) to 0 after disabling the edge detection (by setting EGPn and EGNn to 0).

Remarks 1. For edge detection port, see **2.1 Port Function**.

2. n = 0 to 11

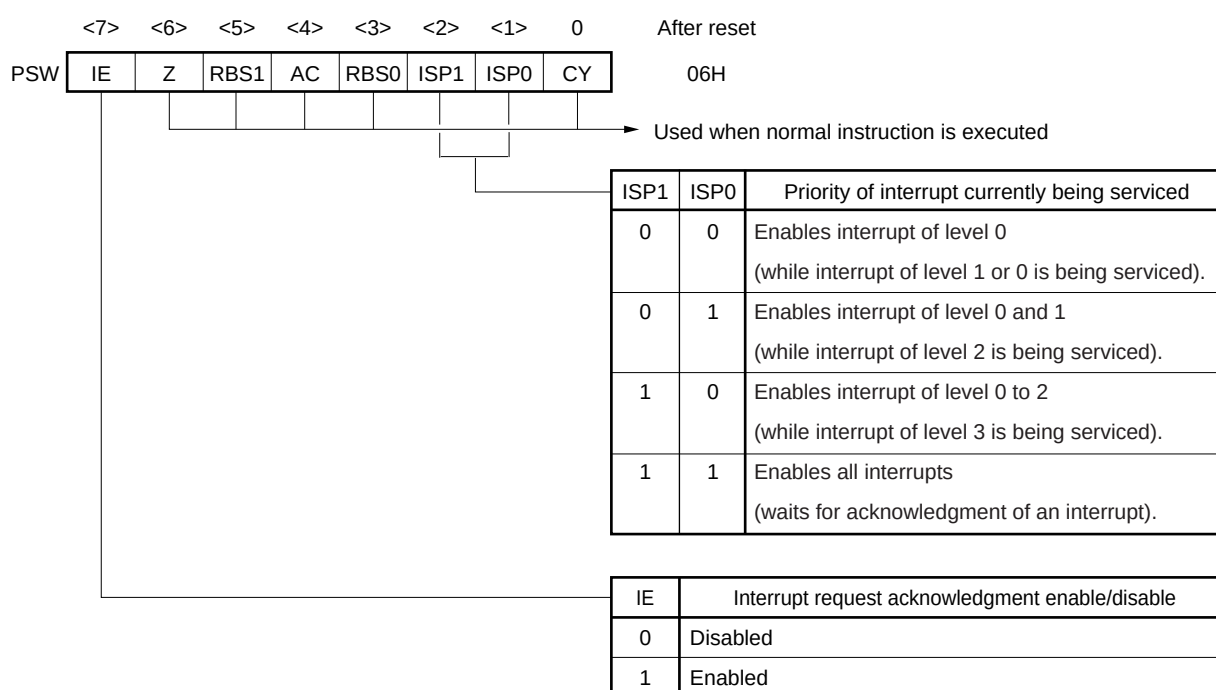
16.3.5 Program status word (PSW)

The program status word is a register used to hold the instruction execution result and the current status for an interrupt request. The IE flag that sets maskable interrupt enable/disable and the ISP0 and ISP1 flags that controls multiple interrupt servicing are mapped to the PSW.

Besides 8-bit read/write, this register can carry out operations using bit manipulation instructions and dedicated instructions (EI and DI). When a vectored interrupt request is acknowledged, if the BRK instruction is executed, the contents of the PSW are automatically saved into a stack and the IE flag is reset to 0. If a maskable interrupt request is acknowledged, the contents of the priority specification flag register of the acknowledged interrupt are not 00, its value minus 1 is transferred to the ISP0 and ISP1 flags. The PSW contents are also saved into the stack with the PUSH PSW instruction. They are restored from the stack with the RETI, RETB, and POP PSW instructions.

Reset signal generation sets PSW to 06H.

Figure 16-6. Configuration of Program Status Word



16.4 Interrupt Servicing Operations

16.4.1 Maskable interrupt request acknowledgment

A maskable interrupt request becomes acknowledgeable when the interrupt request flag is set to 1 and the mask (MK) flag corresponding to that interrupt request is cleared to 0. A vectored interrupt request is acknowledged if interrupts are in the interrupt enabled state (when the IE flag is set to 1). However, a low-priority interrupt request is not acknowledged during servicing of a higher priority interrupt request.

The times from generation of a maskable interrupt request until vectored interrupt servicing is performed are listed in Table 16-4 below.

For the interrupt request acknowledgment timing, see **Figures 16-8 and 16-9**.

Table 16-4. Time from Generation of Maskable Interrupt Until Servicing

	Minimum Time	Maximum Time ^{Note}
Servicing time	9 clocks	16 clocks

Note Maximum time does not apply when an instruction from the internal RAM area is executed.

Remark 1 clock: $1/f_{CLK}$ (f_{CLK} : CPU clock)

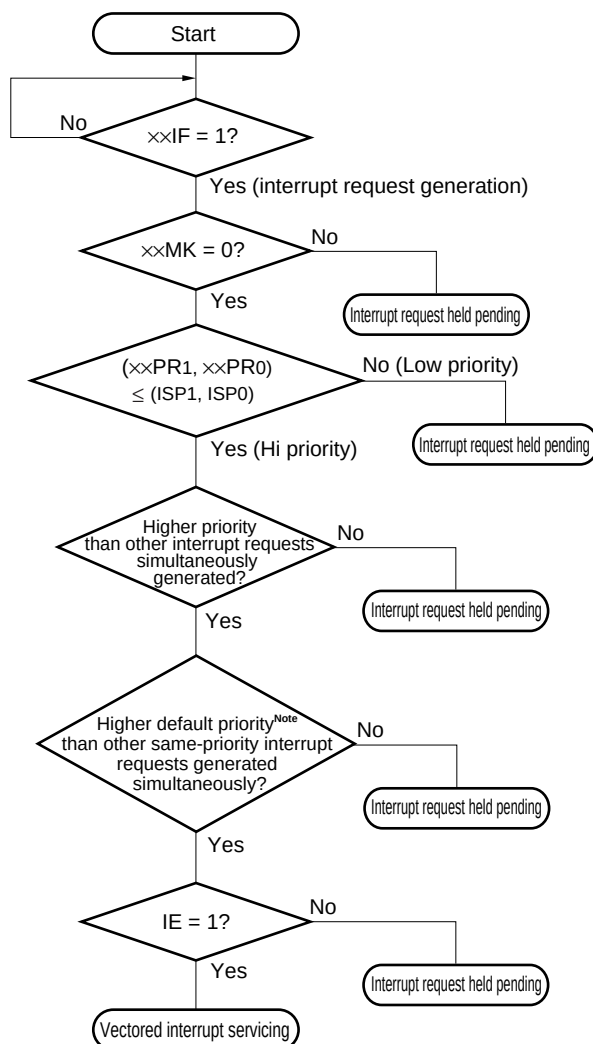
If two or more maskable interrupt requests are generated simultaneously, the request with a higher priority level specified in the priority specification flag is acknowledged first. If two or more interrupts requests have the same priority level, the request with the highest default priority is acknowledged first.

An interrupt request that is held pending is acknowledged when it becomes acknowledgeable.

Figure 16-7 shows the interrupt request acknowledgment algorithm.

If a maskable interrupt request is acknowledged, the contents are saved into the stacks in the order of PSW, then PC, the IE flag is reset (0), and the contents of the priority specification flag corresponding to the acknowledged interrupt are transferred to the ISP1 and ISP0 flags. The vector table data determined for each interrupt request is the loaded into the PC and branched.

Restoring from an interrupt is possible by using the RETI instruction.

Figure 16-7. Interrupt Request Acknowledgment Processing Algorithm

xxIF: Interrupt request flag

xxMK: Interrupt mask flag

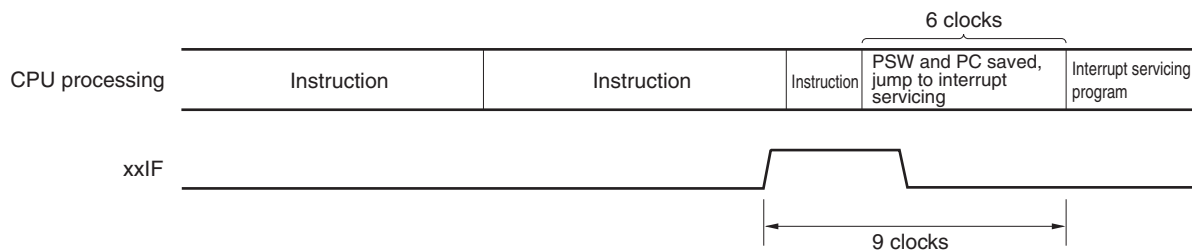
xxPR0: Priority specification flag 0

xxPR1: Priority specification flag 1

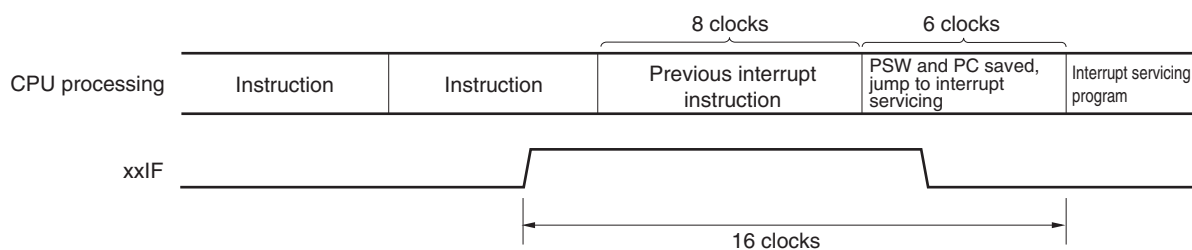
IE: Flag that controls acknowledgment of maskable interrupt request (1 = Enable, 0 = Disable)

ISP0, ISP1: Flag that indicates the priority level of the interrupt currently being serviced (see **Figure 16-6**)

Note For the default priority, see **Table 16-1 Interrupt Source List**.

Figure 16-8. Interrupt Request Acknowledgment Timing (Minimum Time)

Remark 1 clock: $1/f_{CLK}$ (f_{CLK} : CPU clock)

Figure 16-9. Interrupt Request Acknowledgment Timing (Maximum Time)

Remark 1 clock: $1/f_{CLK}$ (f_{CLK} : CPU clock)

16.4.2 Software interrupt request acknowledgment

A software interrupt request is acknowledged by BRK instruction execution. Software interrupts cannot be disabled.

If a software interrupt request is acknowledged, the contents are saved into the stacks in the order of the program status word (PSW), then program counter (PC), the IE flag is reset (0), and the contents of the vector table (0007EH, 0007FH) are loaded into the PC and branched.

Restoring from a software interrupt is possible by using the RETB instruction.

Caution Can not use the RETI instruction for restoring from the software interrupt.

16.4.3 Multiple interrupt servicing

Multiple interrupt servicing occurs when another interrupt request is acknowledged during execution of an interrupt.

Multiple interrupt servicing does not occur unless the interrupt request acknowledgment enabled state is selected (IE = 1). When an interrupt request is acknowledged, interrupt request acknowledgment becomes disabled (IE = 0). Therefore, to enable multiple interrupt servicing, it is necessary to set (1) the IE flag with the EI instruction during interrupt servicing to enable interrupt acknowledgment.

Moreover, even if interrupts are enabled, multiple interrupt servicing may not be enabled, this being subject to interrupt priority control. Two types of priority control are available: default priority control and programmable priority control. Programmable priority control is used for multiple interrupt servicing.

In the interrupt enabled state, if an interrupt request with a priority higher than that of the interrupt currently being serviced is generated, it is acknowledged for multiple interrupt servicing. If an interrupt with a priority equal to or lower than that of the interrupt currently being serviced is generated during interrupt servicing, it is not acknowledged for multiple interrupt servicing. Interrupt requests that are not enabled because interrupts are in the interrupt disabled state or because they have a lower priority are held pending. When servicing of the current interrupt ends, the pending interrupt request is acknowledged following execution of at least one main processing instruction execution.

Table 16-5 shows relationship between interrupt requests enabled for multiple interrupt servicing and Figure 16-10 shows multiple interrupt servicing examples.

Table 16-5. Relationship Between Interrupt Requests Enabled for Multiple Interrupt Servicing During Interrupt Servicing

Multiple Interrupt Request Interrupt Being Serviced		Maskable Interrupt Request								Software Interrupt Request
		Priority Level 0 (PR = 00)		Priority Level 1 (PR = 01)		Priority Level 2 (PR = 10)		Priority Level 3 (PR = 11)		
		IE = 1	IE = 0	IE = 1	IE = 0	IE = 1	IE = 0	IE = 1	IE = 0	
Maskable interrupt	ISP1 = 0 ISP0 = 0	○	×	×	×	×	×	×	×	○
	ISP1 = 0 ISP0 = 1	○	×	○	×	×	×	×	×	○
	ISP1 = 1 ISP0 = 0	○	×	○	×	○	×	×	×	○
	ISP1 = 1 ISP0 = 1	○	×	○	×	○	×	○	×	○
Software interrupt		○	×	○	×	○	×	○	×	○

Remarks 1. ○: Multiple interrupt servicing enabled

2. ×: Multiple interrupt servicing disabled

3. ISP0, ISP1, and IE are flags contained in the PSW.

ISP1 = 0, ISP0 = 0: An interrupt of level 1 or level 0 is being serviced.

ISP1 = 0, ISP0 = 1: An interrupt of level 2 is being serviced.

ISP1 = 1, ISP0 = 0: An interrupt of level 3 is being serviced.

ISP1 = 1, ISP0 = 1: Wait for An interrupt acknowledgment (all interrupts are enabled).

IE = 0: Interrupt request acknowledgment is disabled.

IE = 1: Interrupt request acknowledgment is enabled.

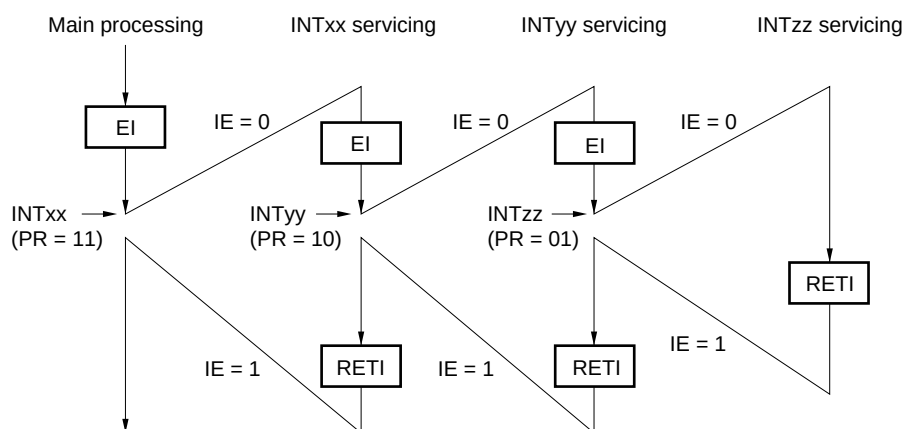
4. PR is a flag contained in the PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, and PR12H registers.

PR = 00: Specify level 0 with $\text{xxPR1x} = 0$, $\text{xxPR0x} = 0$ (higher priority level)

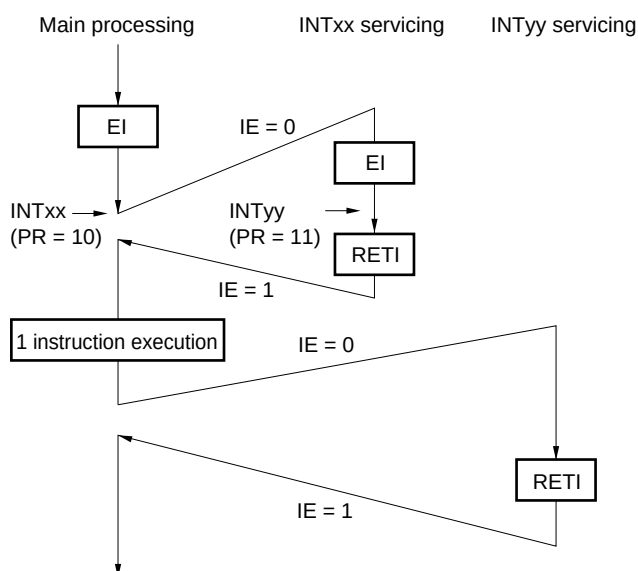
PR = 01: Specify level 1 with $\text{xxPR1x} = 0$, $\text{xxPR0x} = 1$

PR = 10: Specify level 2 with $\text{xxPR1x} = 1$, $\text{xxPR0x} = 0$

PR = 11: Specify level 3 with $\text{xxPR1x} = 1$, $\text{xxPR0x} = 1$ (lower priority level)

Figure 16-10. Examples of Multiple Interrupt Servicing (1/2)**Example 1. Multiple interrupt servicing occurs twice**

During servicing of interrupt INTxx, two interrupt requests, INTyy and INTzz, are acknowledged, and multiple interrupt servicing takes place. Before each interrupt request is acknowledged, the EI instruction must always be issued to enable interrupt request acknowledgment.

Example 2. Multiple interrupt servicing does not occur due to priority control

Interrupt request INTyy issued during servicing of interrupt INTxx is not acknowledged because its priority is lower than that of INTxx, and multiple interrupt servicing does not take place. The INTyy interrupt request is held pending, and is acknowledged following execution of one main processing instruction.

PR = 00: Specify level 0 with $\times\times PR1\times = 0$, $\times\times PR0\times = 0$ (higher priority level)

PR = 01: Specify level 1 with $\times\times PR1\times = 0$, $\times\times PR0\times = 1$

PR = 10: Specify level 2 with $\times\times PR1\times = 1$, $\times\times PR0\times = 0$

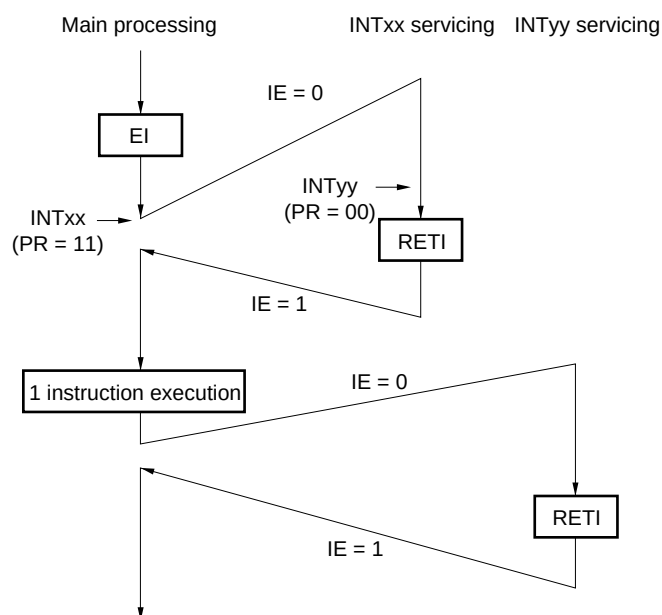
PR = 11: Specify level 3 with $\times\times PR1\times = 1$, $\times\times PR0\times = 1$ (lower priority level)

IE = 0: Interrupt request acknowledgment is disabled

IE = 1: Interrupt request acknowledgment is enabled.

Figure 16-10. Examples of Multiple Interrupt Servicing (2/2)

Example 3. Multiple interrupt servicing does not occur because interrupts are not enabled



Interrupts are not enabled during servicing of interrupt INTxx (EI instruction is not issued), therefore, interrupt request INTyy is not acknowledged and multiple interrupt servicing does not take place. The INTyy interrupt request is held pending, and is acknowledged following execution of one main processing instruction.

PR = 00: Specify level 0 with $\times\times\text{PR1}\times = 0$, $\times\times\text{PR0}\times = 0$ (higher priority level)

PR = 01: Specify level 1 with $\times\times\text{PR1}\times = 0$, $\times\times\text{PR0}\times = 1$

PR = 10: Specify level 2 with $\text{xxPR1x} = 1$, $\text{xxPR0x} = 0$

PR = 11: Specify level 3 with $\text{xxPR1x} = 1$, $\text{xxPR0x} = 1$ (lower priority level)

IE = 0: Interrupt request acknowledgment is disabled

IE = 1: Interrupt request acknowledgment is enabled.

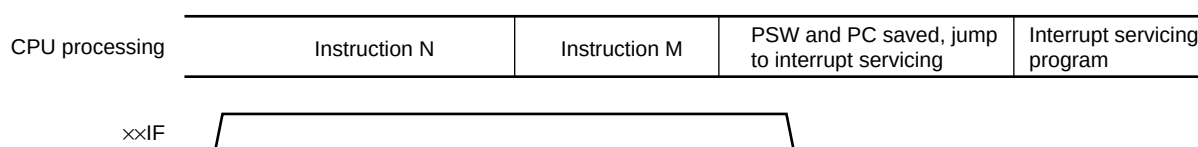
16.4.4 Interrupt request hold

There are instructions where, even if an interrupt request is issued while the instructions are being executed, interrupt request acknowledgment is held pending until the end of execution of the next instruction. These instructions (interrupt request hold instructions) are listed below.

- MOV PSW, #byte
- MOV PSW, A
- MOV1 PSW. bit, CY
- SET1 PSW. bit
- CLR1 PSW. bit
- RETB
- RETI
- POP PSW
- BTCLR PSW. bit, \$addr20
- EI
- DI
- SKC
- SKNC
- SKZ
- SKNZ
- SKH
- SKNH
- Write instructions for the IF0L, IF0H, IF1L, IF1H, IF2L, IF2H, MK0L, MK0H, MK1L, MK1H, MK2L, MK2H, PR00L, PR00H, PR01L, PR01H, PR02L, PR02H, PR10L, PR10H, PR11L, PR11H, PR12L, and PR12H registers

Figure 16-11 shows the timing at which interrupt requests are held pending.

Figure 16-11. Interrupt Request Hold



- Remarks**
1. Instruction N: Interrupt request hold instruction
 2. Instruction M: Instruction other than interrupt request hold instruction

CHAPTER 17 KEY INTERRUPT FUNCTION

The number of key interrupt input channels differs, depending on the product.

	25-pin	32-pin	48-pin	64-pin
Key interrupt input channels	0 (4) ch	1 (6) ch	6 ch	10 ch

- Remarks**
1. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR).
 2. Most of the following descriptions in this chapter use the 64-pin products

17.1 Functions of Key Interrupt

A key interrupt (INTKR) can be generated by inputting a rising/falling edge to the key interrupt input pins (KR0 to KR9). There are two ways to identify the channel(s) to which a valid edge has been input:

- Identify the channel(s) (KR0 to KR9) by using the port input level.
- Identify the channel(s) (KR0 to KR5) by using the key interrupt flag.

Table 17-1. Assignment of Key Interrupt Detection Pins

Key Interrupt Pins	Key Return Mode Registers (KRM0, KRM1)	Key Return Flag Register (KRF)
KR0	KRM00	KRF0
KR1	KRM01	KRF1
KR2	KRM02	KRF2
KR3	KRM03	KRF3
KR4	KRM04	KRF4
KR5	KRM05	KRF5
KR6	KRM06	—
KR7	KRM07	—
KR8	KRM08	—
KR9	KRM09	—

Remark

(KR0 to KR3):	25-pin products
KR0 (KR0 to KR5):	32-pin products
KR0 to KR5:	48-pin products
KR0 to KR9:	64-pin products

Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR)

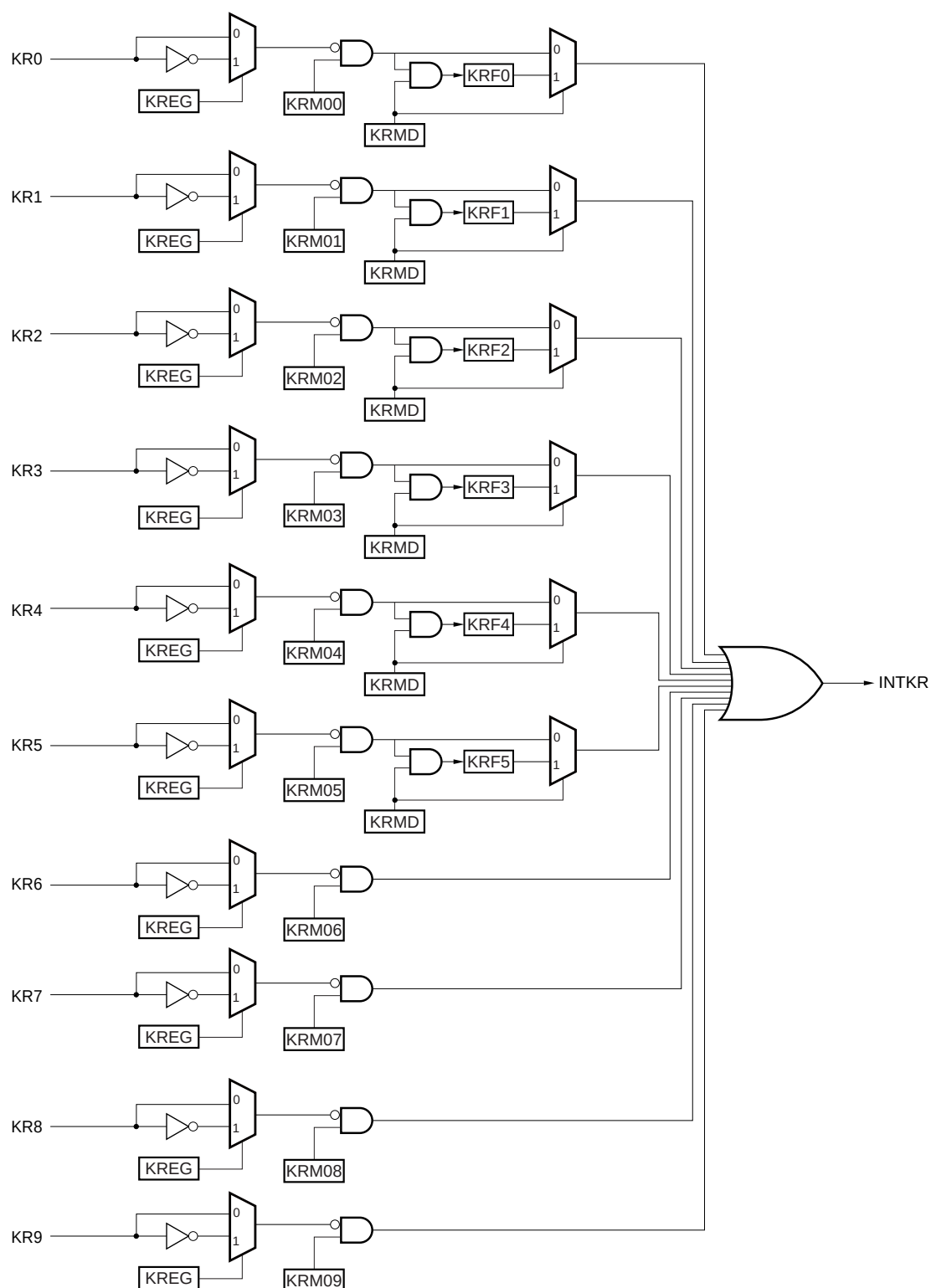
17.2 Configuration of Key Interrupt

The key interrupt includes the following hardware.

Table 17-2. Configuration of Key Interrupt

Item	Configuration
Control register	Key return control register (KRCTL) Key return mode registers 0, 1 (KRM0, KRM1) Key return flag register (KRF) Port mode registers 0 to 2, 7, 12, 15 (PM0 to PM2, PM7, PM12, PM15) Peripheral I/O redirection register (PIOR)

Figure 17-1. Block Diagram of Key Interrupt



Remark (KR0 to KR3): 25-pin products

KR0 (KR0 to KR5): 32-pin products

KR0 to KR5: 48-pin products

KR0 to KR9: 64-pin products

Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR)

17.3 Register Controlling Key Interrupt

The key interrupt function is controlled by the following five registers:

- Key return control register (KRCTL)
- Key return mode registers 0, 1 (KRM0, KRM1)
- Key return flag register (KRF)
- Port mode registers 0 to 2, 7, 12, and 15 (PM0 to PM2, PM7, PM12, PM15)
- Peripheral I/O redirection register (PIOR)

17.3.1 Key return control register (KRCTL)

This register controls the usage of the key interrupt flags (KRF0 to KRF5) and sets the detection edge.

The KRCTL register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 17-2. Format of Key Return Control Register (KRCTL)

Address: FFF34H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
KRCTL	KRMD	0	0	0	0	0	0	KREG

KRMD	Usage of t key interrupt flags (KRF0 to KRF5)
0	Does not use key interrupt flags
1	Uses key interrupt flags

KREG	Selection of detection edge (KR0 to KR9)
0	Falling edge
1	Rising edge

17.3.2 Key return mode registers 0, 1 (KRM0, KRM1)

These registers set the key interrupt mode.

The KRM0 and KRM1 registers can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation sets these registers to 00H.

Figure 17-3. Format of Key Return Mode Registers 0, 1 (KRM0, KRM1)

Address: FFF37H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
KRM0	KRM07	KRM06	KRM05	KRM04	KRM03	KRM02	KRM01	KRM00

Address: FFF36H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
KRM1	0	0	0	0	0	0	KRM09	KRM08

KRM0n	Key interrupt mode control
0	Does not detect key interrupt signal
1	Detects key interrupt signal

- Cautions**
1. The on-chip pull-up resistors can be applied by setting the corresponding key interrupt input pins (bits) in pull-up resistor registers 0, 1, 7, and 12 (PU0, PU1, PU7, PU12) to 1.
 2. An interrupt will be generated if the target bit of the KRM0, KRM1 registers are set while a low level (when KREG = 0)/high level (when KREG = 1) is being input to the key interrupt input pin.
To ignore this interrupt, set the KRM0, KRM1 registers after disabling interrupt servicing by using the interrupt mask flag. Afterward, clear the interrupt request flag and enable interrupt servicing after waiting for the key interrupt input high-level width/low-level width (see 29.4 AC Characteristics and 30.4 AC Characteristics).
 3. The pins not used in the key interrupt mode can be used as normal ports.

- Remarks**
1. n = 0 to 9
 2. (KR0 to KR3): 25-pin products
KR0 (KR0 to KR5): 32-pin products
KR0 to KR5: 48-pin products
KR0 to KR9: 64-pin products
Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR)

17.3.3 Key return flag register (KRF)

This register controls the key interrupt flags (KRF0 to KRF5).

The KRF register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 17-4. Format of Key return Flag Register (KRF)

Address: FFF35H After reset: 00H R/W^{Note}

Symbol	7	6	5	4	3	2	1	0
KRF	0	0	KRF5	KRF4	KRF3	KRF2	KRF1	KRF0

KRFn	Key interrupt flag
0	No key interrupt signal has been detected.
1	A key interrupt signal has been detected.

Note Writing to 1 is invalid. To clear KRFn, write “0” to the target bits and write “1” to other bits, with the 8-bit memory manipulation instruction.

Caution For KR6 to KR9, identify channels by sequentially verifying the input levels.

Remark n = 0 to 5

17.3.4 Port mode registers 0 to 2, 7, 12, 15 (PM0 to PM2, PM7, PM12, PM15)

When using P70/KR0 to P77/KR7, P05/KR8, P06/KR9, P00/(KR0) to P04/(KR4), P22/(KR5) to P26/(KR9), P10/(KR0) to P15/(KR5), P120/(KR0), P151/(KR6) to P154/(KR9) as a key input, set the bits corresponding to port mode registers 0 to 2, 7, 12, 15 (PM0 to PM2, PM7, PM12, PM15) to 1. At this time, the output latch of the bits corresponding to port registers 0 to 2, 7, 12, 15 (P0 to P2, P7, P12, P15) may be 0 or 1.

The PM0 to PM2, PM7, PM12, PM15 registers can be set by a 1-bit or 8-bit memory manipulation instruction. Reset signal generation sets these registers to FFH.

In addition, use of an on-chip pull-up resistor can be specified in 1-bit units by pull-up resistor option registers 0, 1, 7, 12 (PU0, PU1, PU7, PU12).

Remark Functions in parentheses can be assigned via settings in the peripheral I/O redirection register (PIOR)

Figure 17-5. Format of Port Mode Register 0 to 2, 7, 12, 15 (PM0 to PM2, PM7, PM12, PM15)

Address: FFF20H After reset: FFH R/W

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

Address: FFF21H After reset: FFH R/W

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

Address: FFF22H After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
PM2	PM27	PM26	PM25	PM24	PM23	PM22	PM21	PM20

Address: FFF27H After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
PM7	PM77	PM76	PM75	PM74	PM73	PM72	PM71	PM70

Address: FFF2CH After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
PM12	1	1	1	1	1	1	1	PM120

Address: FFF2FH After reset: FFH R/W

Symbol	7	6	5	4	3	2	1	0
PM15	1	1	1	PM154	PM153	PM152	PM151	PM150

PMmn	I/O mode selection for Pmn/KRk pin (m = 0 to 2, 7, 12, 15, n = 0 to 7, k = 0 to 9)
0	Output mode (output buffer on)
1	Input mode (output buffer off)

17.3.5 Peripheral I/O redirection register (PIOR)

This register is used to specify whether to enable or disable the peripheral I/O redirect function.

This function is used to switch ports to which alternate functions are assigned.

Use the PIOR register to assign a port to the function to redirect and enable the function.

In addition, can be changed the settings for redirection until its function enable operation. The PIOR register can be set by an 8-bit memory manipulation instruction.

Reset signal generation sets this register to 00H.

Figure 17-6. Format of Peripheral I/O Redirection Register (PIOR)

Address: F0077H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
PIOR	0	0	0	0	0	0	PIOR1	PIOR0

Function	64-pin				48-pin				32-pin				25-pin			
	Setting value of PIOR1, PIOR0				Setting value of PIOR1, PIOR0				Setting value of PIOR1, PIOR0				Setting value of PIOR1, PIOR0			
	0, 0	0, 1	1, 0	1, 1	0, 0	0, 1	1, 0	1, 1	0, 0	0, 1	1, 0	1, 1	0, 0	0, 1	1, 0	1, 1
KR0	P70	Setting prohibited	P00	P10	P70	Setting prohibited	P02	P10	P70	Setting prohibited	P120	P10	—	Setting prohibited	P02	Setting prohibited
KR1	P71		P01	P11	P71		P03	P11	—		P02	P11	—		P03	
KR2	P72		P02	P12	P72		P22	P12	—		P03	P12	—		P22	
KR3	P73		P03	P13	P73		P23	P13	—		P22	P13	—		P23	
KR4	P74		P04	P14	P74		P24	P14	—		P23	P14	—		—	
KR5	P75		P22	P15	P75		P25	P15	—		P24	P15	—		—	
KR6	P76		P23	P151	—		—	—	—		—	—	—		—	
KR7	P77		P24	P152	—		—	—	—		—	—	—		—	
KR8	P05		P25	P153	—		—	—	—		—	—	—		—	
KR9	P06		P26	P154	—		—	—	—		—	—	—		—	

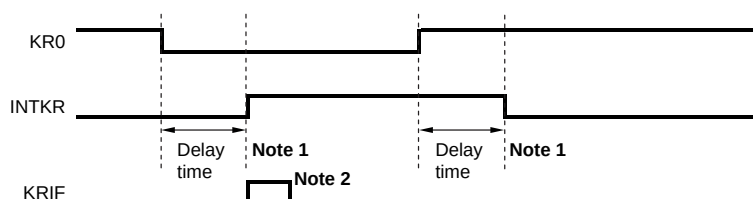
17.4 Key Interrupt Operation

17.4.1 When not using the key interrupt flag (KRMD = 0)

A key interrupt (INTKR) is generated when the valid edge specified by the setting of the KREG bit is input to a key interrupt pin (KR0 to KR9). The channel to which the valid edge was input can be identified by reading the port register and checking the port level after the key interrupt (INTKR) is generated.

The INTKR signal changes according to the input level of the key interrupt input pin (KR0 to KR9).

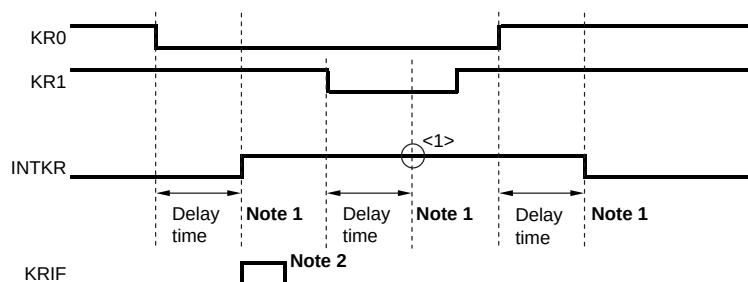
Figure 17-7. Operation of INTKR Signal When a Key Interrupt is Input to a Single Channel
(When KRMD = 0 and KREG = 0)



- Notes 1.** The maximum delay time is the maximum value of the high-level width and low-level width of the key interrupt input (see **29.4 AC Characteristics** and **30.4 AC Characteristics** for details).
- 2.** Acknowledgment of vectored interrupt request or bit cleared by software

The operation when a valid edge is input to multiple key interrupt input pins is shown in Figure 17-8 below. The INTKR signal is set while a low level is being input to one pin (when KREG is set to 0). Therefore, even if a falling edge is input to another pin in this period, a key interrupt (INTKR) will not be generated again (<1> in the figure).

Figure 17-8. Operation of INTKR Signal When Key Interrupts Are Input to Multiple Channels
(When KRMD = 0 and KREG = 0)



- Notes 1.** The maximum delay time is the maximum value of the high-level width and low-level width of the key interrupt input (see **29.4 AC Characteristics** and **30.4 AC Characteristics** for details).
- 2.** Acknowledgment of vectored interrupt request or bit cleared by software

17.4.2 When using the key interrupt flag (KRMD = 1)

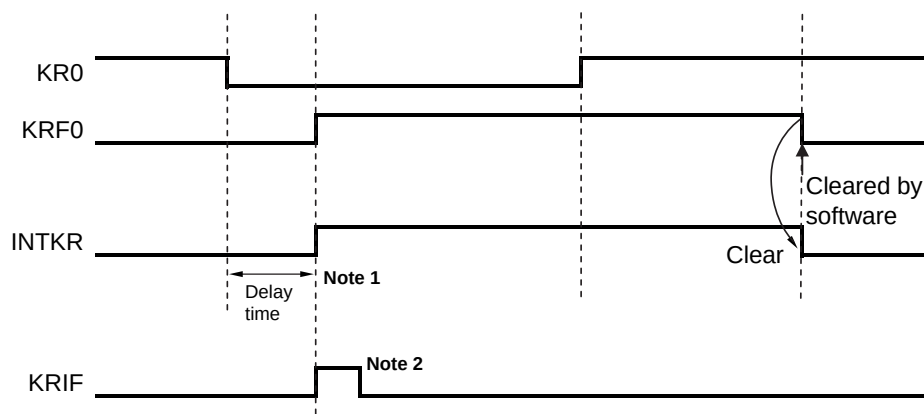
A key interrupt (INTKR) is generated when the valid edge specified by the setting of the KREG bit is input to a key interrupt pin (KR0 to KR5). The channels to which the valid edge was input can be identified by reading the key return flag register (KRF) after the key interrupt (INTKR) is generated.

If the KRMD bit is set to 1, the INTKR signal is cleared by clearing the corresponding bit in the KRF register.

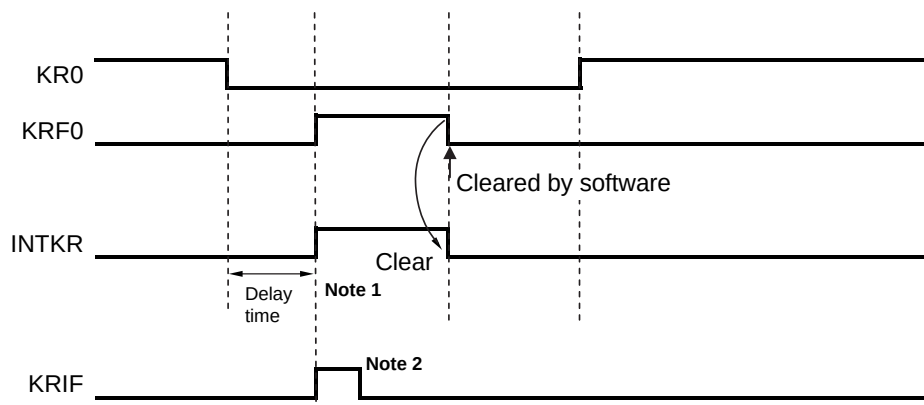
As shown in Figure 17-9, only one interrupt is generated each time a falling edge is input to one channel (when KREG = 0), regardless of whether the KRFn bit is cleared before or after a rising edge is input.

**Figure 17-9. Basic Operation of the INTKR Signal When the Key Interrupt Flag Is Used
(When KRMD = 1 and KREG = 0)**

(a) When KRF0 is cleared after a rising edge is input to the KR0 pin



(b) When KRF0 is cleared before a rising edge is input to the KR0 pin

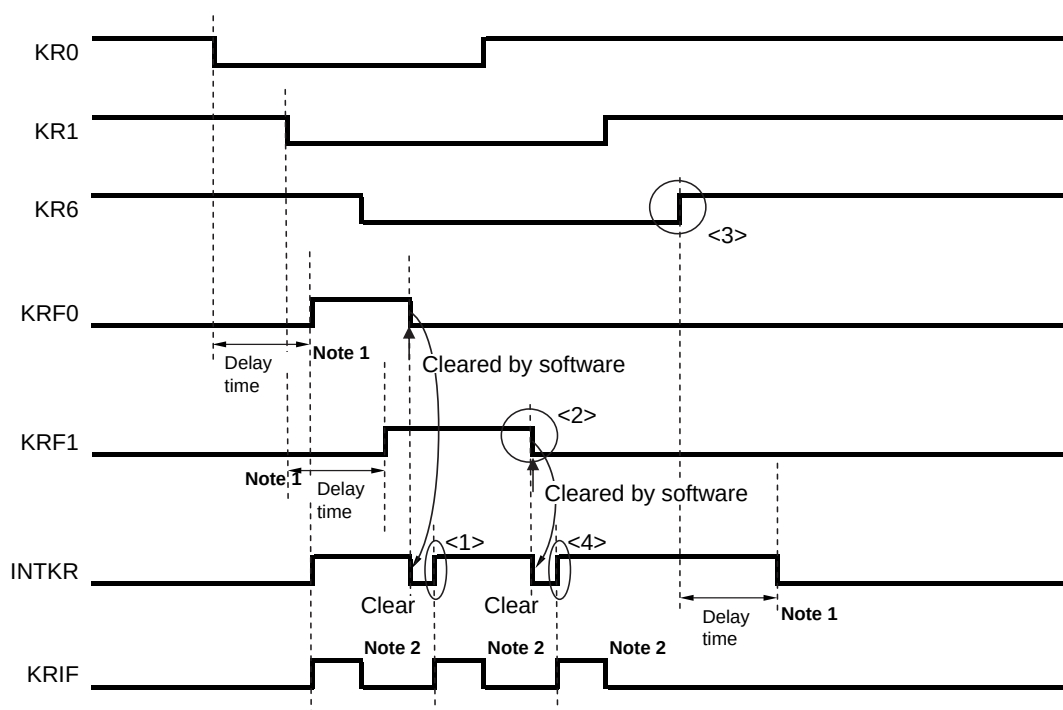


Notes 1. The maximum delay time is the maximum value of the high-level width and low-level width of the key interrupt input (see **29.4 AC Characteristics** and **30.4 AC Characteristics** for details).

2. Acknowledgment of vectored interrupt request or bit cleared by software

The operation when a valid edge is input to multiple key interrupt input pins is shown in Figure 17-10 below. A falling edge is also input to the KR1 and KR6 pins after a falling edge was input to the KR0 pin (when KREG = 0). The KRF1 bit is set when the KRF0 bit is cleared. A key interrupt (INTKR) is therefore generated one clock (f_{CLK}) after the KRF0 bit is cleared (<1> in the figure). Also, after a falling edge has been input to the KR6 pin, a low level continues to be input to this pin (<3> in the figure) until the KRF1 bit is cleared (<2> in the figure). A key interrupt (INTKR) is therefore generated one clock (f_{CLK}) after the KRF1 bit is cleared (<4> in the figure). It is thus possible to generate a key interrupt (INTKR) when a valid edge is input to multiple channels.

Figure 17-10. Operation of INTKR Signal When Key Interrupts Are Input to Multiple Channels
(When KRMD = 1 and KREG = 0)

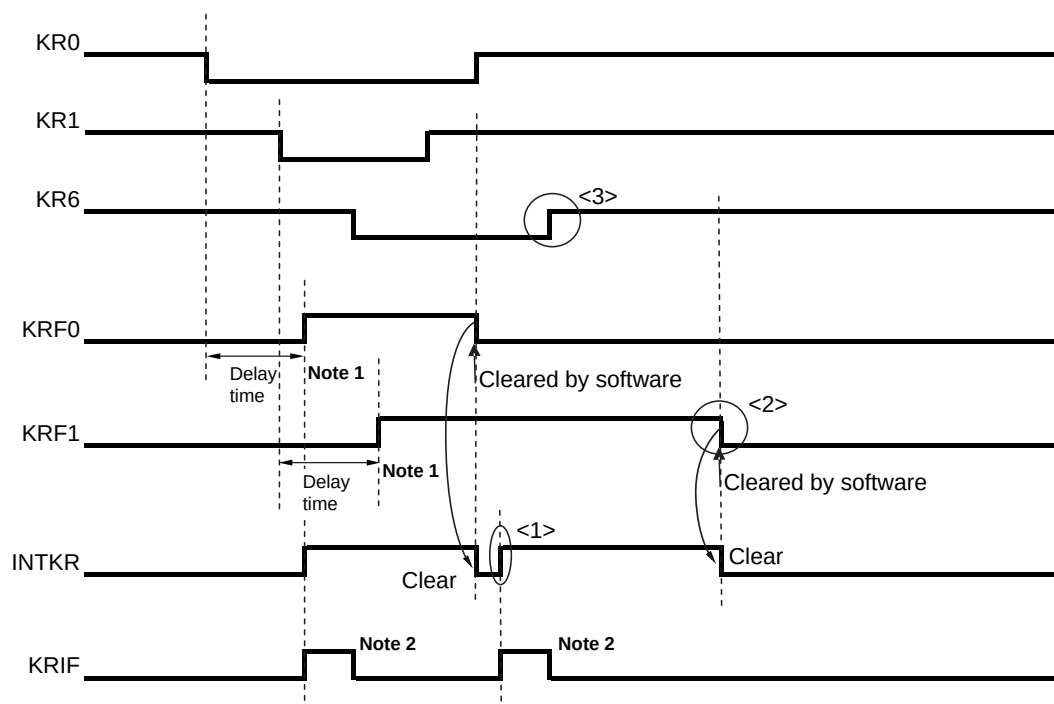


- Notes 1.** The maximum delay time is the maximum value of the high-level width and low-level width of the key interrupt input (see **29.4 AC Characteristics** and **30.4 AC Characteristics** for details).
- 2.** Acknowledgment of vectored interrupt request or bit cleared by software

Remark f_{CLK} : CPU/peripheral hardware clock frequency

The operation when a valid edge is input to the KR6 to KR9 pins without generating a key interrupt (INTKR) is shown in Figure 17-11 below. A falling edge is also input to the KR1 and KR6 pins after a falling edge was input to the KR0 pin (when KREG = 0). The KR1 pin becomes high level when the KRF0 bit is cleared, but because the KRF1 bit is set, a key interrupt (INTKR) is generated one clock (f_{CLK}) after the KRF0 bit is cleared (<1> in the figure). Also, because the KR6 pin was high level (<3> in the figure) before the KRF1 bit was cleared (<2> in the figure) a key interrupt (INTKR) is not generated for the KR6 pin.

**Figure 17-11. Operation When an INTKR Signal Is Not Generated upon Input of a Valid Edge to KR6 to KR9
(When KRMD = 1 and KREG = 0)**



- Notes 1.** The maximum delay time is the maximum value of the high-level width and low-level width of the key interrupt input (see **29.4 AC Characteristics** and **30.4 AC Characteristics** for details).
- 2.** Acknowledgment of vectored interrupt request or bit cleared by software

Remark f_{CLK} : CPU/peripheral hardware clock frequency

CHAPTER 18 STANDBY FUNCTION

18.1 Standby Function

The standby function reduces the operating current of the system, and the following three modes are available.

(1) HALT mode

HALT instruction execution sets the HALT mode. In the HALT mode, the CPU operation clock is stopped. If the high-speed system clock oscillator, high-speed on-chip oscillator, or subsystem clock oscillator is operating before the HALT mode is set, oscillation of each clock continues. In this mode, the operating current is not decreased as much as in the STOP mode, but the HALT mode is effective for restarting operation immediately upon interrupt request generation and carrying out intermittent operations frequently.

(2) STOP mode

STOP instruction execution sets the STOP mode. In the STOP mode, the high-speed system clock oscillator and high-speed on-chip oscillator stop, stopping the whole system, thereby considerably reducing the CPU operating current.

Because this mode can be cleared by an interrupt request, it enables intermittent operations to be carried out. However, because a wait time is required to secure the oscillation stabilization time after the STOP mode is released when the X1 clock is selected, select the HALT mode if it is necessary to start processing immediately upon interrupt request generation.

(3) SNOOZE mode

In the case of CSIp or UARTq data reception and an A/D conversion request by the timer trigger signal (the interrupt request signal (INTRTC/INTIT)), the STOP mode is exited, the CSIp or UARTq data is received without operating the CPU, and A/D conversion is performed. This can only be specified when the high-speed on-chip oscillator is selected for the CPU/peripheral hardware clock (f_{CLK}).

In either of these two modes, all the contents of registers, flags and data memory just before the standby mode is set are held. The I/O port output latches and output buffer statuses are also held.

- Cautions**
1. The STOP mode can be used only when the CPU is operating on the main system clock. Do not set to the STOP mode while the CPU operates with the subsystem clock. The HALT mode can be used when the CPU is operating on either the main system clock or the subsystem clock.
 2. When shifting to the STOP mode, be sure to stop the peripheral hardware operation operating with main system clock before executing STOP instruction (except SNOOZE mode setting unit).
 3. When using CSIp, UARTq, or the A/D converter in the SNOOZE mode, set up serial standby control register m (SSCm) and A/D converter mode register 2 (ADM2) before switching to the STOP mode. For details, see 12.3 Registers Controlling Serial Array Unit and 11.3 Registers Used in A/D Converter.
 4. The following sequence is recommended for power consumption reduction of the A/D converter when the standby function is used: First clear bit 7 (ADCS) and bit 0 (ADCE) of A/D converter mode register 0 (ADM0) to 0 to stop the A/D conversion operation, and then execute the STOP instruction.
 5. It can be selected by the option byte whether the low-speed on-chip oscillator continues oscillating or stops in the HALT or STOP mode. For details, see CHAPTER 24 OPTION BYTE.

Remark p = 00; q = 0; m = 0

18.2 Registers Controlling Standby Function

The registers which control the standby function are described below.

- Subsystem clock supply mode control register (OSMC)
- Oscillation stabilization time counter status register (OSTC)
- Oscillation stabilization time select register (OSTS)

Remark For details of registers described above, see **CHAPTER 5 CLOCK GENERATOR**. For registers which control the SNOOZE mode, **CHAPTER 11 A/D CONVERTER** and **CHAPTER 12 SERIAL ARRAY UNIT**.

18.3 Standby Function Operation

18.3.1 HALT mode

(1) HALT mode

The HALT mode is set by executing the HALT instruction. HALT mode can be set regardless of whether the CPU clock before the setting was the high-speed system clock, high-speed on-chip oscillator clock, or subsystem clock. The operating statuses in the HALT mode are shown below.

Caution Because the interrupt request signal is used to clear the HALT mode, if the interrupt mask flag is 0 (the interrupt processing is enabled) and the interrupt request flag is 1 (the interrupt request signal is generated), the HALT mode is not entered even if the HALT instruction is executed in such a situation.

Table 18-1. Operating Statuses in HALT Mode (1/2)

HALT Mode Setting		When HALT Instruction Is Executed While CPU Is Operating on Main System Clock		
		When CPU Is Operating on High-speed On-chip Oscillator Clock (f _{IH})	When CPU Is Operating on X1 Clock (f _x)	When CPU Is Operating on External Main System Clock (f _{EX})
Item				
System clock		Clock supply to the CPU is stopped		
Main system clock	f _{IH}	Operation continues (cannot be stopped)	Operation disabled	
	f _x	Operation disabled	Operation continues (cannot be stopped)	Cannot operate
	f _{EX}		Cannot operate	Operation continues (cannot be stopped)
Subsystem clock	f _{XT}	Status before HALT mode was set is retained		
	f _{EXS}			
f _{IL}		Set by bits 0 (WDSTBYON) and 4 (WDTON) of option byte (000C0H), and WUTMMCK0 bit of subsystem clock supply mode control register (OSMC) • WUTMMCK0 = 1: Oscillates • WUTMMCK0 = 0 and WDTON = 0: Stops • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 1: Oscillates • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 0: Stops		
CPU		Operation stopped		
Code flash memory				
Data flash memory				
RAM		Operation stopped (operable when DMA is executed)		
Port (latch)		Status before HALT mode was set is retained		
Timer array unit		Operable		
Real-time clock (RTC)				
12-bit interval timer				
Watchdog timer		See CHAPTER 10 WATCHDOG TIMER		
Clock output/buzzer output		Operable		
A/D converter				
Serial array unit (SAU)				
Serial interface (IICA)				
Multiplier and divider/multiply-accumulator				
DMA controller				
Power-on-reset function				
Voltage detection function				
External interrupt				
Key interrupt function				
CRC operation function	High-speed CRC	Operation stopped		
	General-purpose CRC			
RAM parity error detection function		Operation stopped		
RAM guard function				
SFR guard function				
Illegal-memory access detection function				

Remark Operation stopped: Operation is automatically stopped before switching to the HALT mode.

Operation disabled: Operation is stopped before switching to the HALT mode.

f_{IH} : High-speed on-chip oscillator clock f_{EX} : External main system clock

f_{IL} : Low-speed on-chip oscillator clock f_{XT} : XT1 clock

f_x : X1 clock f_{EXS} : External subsystem clock

Table 18-1. Operating Statuses in HALT Mode (2/2)

HALT Mode Setting Item		When HALT Instruction Is Executed While CPU Is Operating on Subsystem Clock		
		When CPU Is Operating on XT1 Clock (f _{XT})	When CPU Is Operating on External Subsystem Clock (f _{EXS})	
System clock		Clock supply to the CPU is stopped		
Main system clock	f _{IH}	Operation disabled		
	f _X			
	f _{EX}			
	Subsystem clock	f _{XT}	Operation continues (cannot be stopped)	Cannot operate
		f _{EXS}	Cannot operate	Operation continues (cannot be stopped)
f _{IL}		Set by bits 0 (WDSTBYON) and 4 (WDTON) of option byte (000C0H), and WUTMMCK0 bit of subsystem clock supply mode control register (OSMC) • WUTMMCK0 = 1: Oscillates • WUTMMCK0 = 0 and WDTON = 0: Stops • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 1: Oscillates • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 0: Stops		
CPU		Operation stopped		
Code flash memory				
Data flash memory				
RAM		Operation stopped (operable when DMA is executed)		
Port (latch)		Status before HALT mode was set is retained		
Timer array unit		Operates when the RTCLPC bit is 0 (operation is disabled when the RTCLPC bit is not 0).		
Real-time clock (RTC)		Operable		
12-bit interval timer				
Watchdog timer		See CHAPTER 10 WATCHDOG TIMER		
Clock output/buzzer output		Operates when the RTCLPC bit is 0 (operation is disabled when the RTCLPC bit is not 0)		
A/D converter		Operation disabled		
Serial array unit (SAU)		Operates when the RTCLPC bit is 0 (operation is disabled when the RTCLPC bit is not 0).		
Serial interface (IICA)		Operation disabled		
Multiplier and divider/multiply-accumulator		Operates when the RTCLPC bit is 0 (operation is disabled when the RTCLPC bit is not 0).		
DMA controller				
Power-on-reset function		Operable		
Voltage detection function				
External interrupt				
Key interrupt function				
CRC operation function	High-speed CRC	Operation disabled		
	General-purpose CRC	Operation stopped		
RAM parity error detection function		Operation stopped		
RAM guard function				
SFR guard function				
Illegal-memory access detection function				

Remark Operation stopped: Operation is automatically stopped before switching to the HALT mode.

Operation disabled: Operation is stopped before switching to the HALT mode.

f_{IH} : High-speed on-chip oscillator clock f_{EX} : External main system clock

f_{IL} : Low-speed on-chip oscillator clock f_{XT} : XT1 clock

f_X : X1 clock f_{EXS} : External subsystem clock

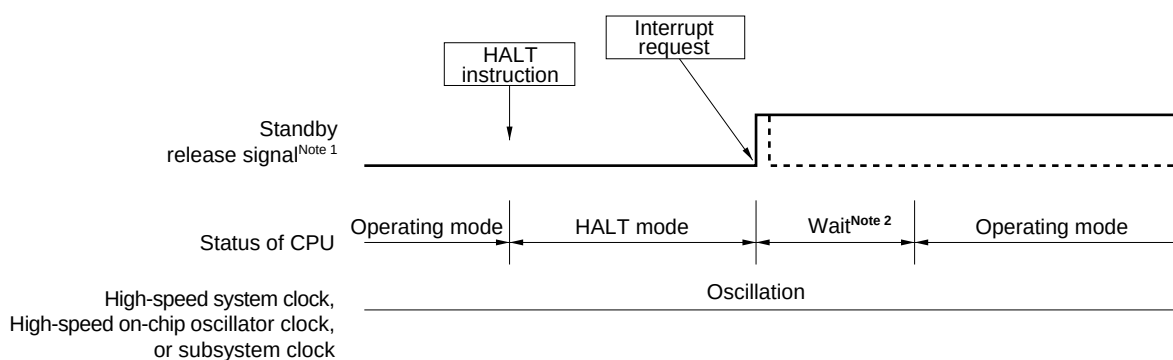
(2) HALT mode release

The HALT mode can be released by the following two sources.

(a) Release by unmasked interrupt request

When an unmasked interrupt request is generated, the HALT mode is released. If interrupt acknowledgment is enabled, vectored interrupt servicing is carried out. If interrupt acknowledgment is disabled, the next address instruction is executed.

Figure 18-1. HALT Mode Release by Interrupt Request Generation



Notes 1. For details of the standby release signal, see **Figure 16-1**.

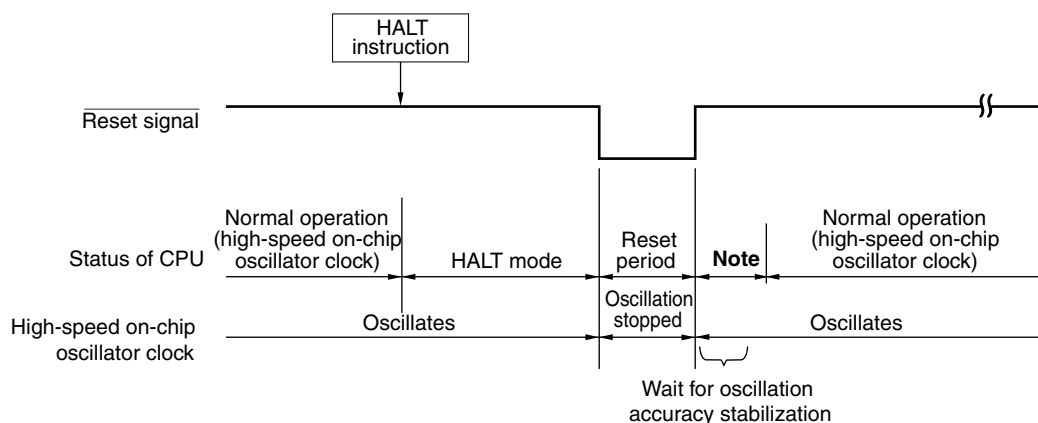
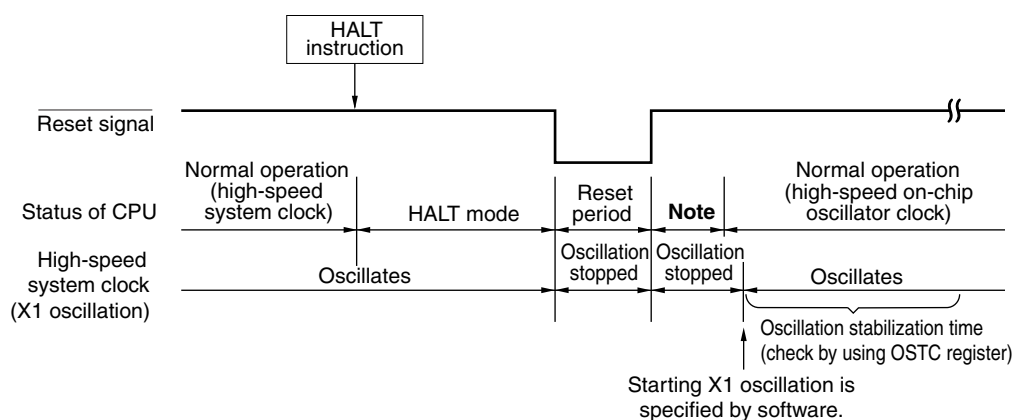
2. Wait time for HALT mode release

- When vectored interrupt servicing is carried out
 - Main system clock: 15 to 16 clock
 - Subsystem clock (RTCLPC = 0): 10 to 11 clock
 - Subsystem clock (RTCLPC = 1): 11 to 12 clock
- When vectored interrupt servicing is not carried out
 - Main system clock: 9 to 10 clock
 - Subsystem clock (RTCLPC = 0): 4 to 5 clock
 - Subsystem clock (RTCLPC = 1): 5 to 6 clock

Remark The broken lines indicate the case when the interrupt request which has released the standby mode is acknowledged.

(b) Release by reset signal generation

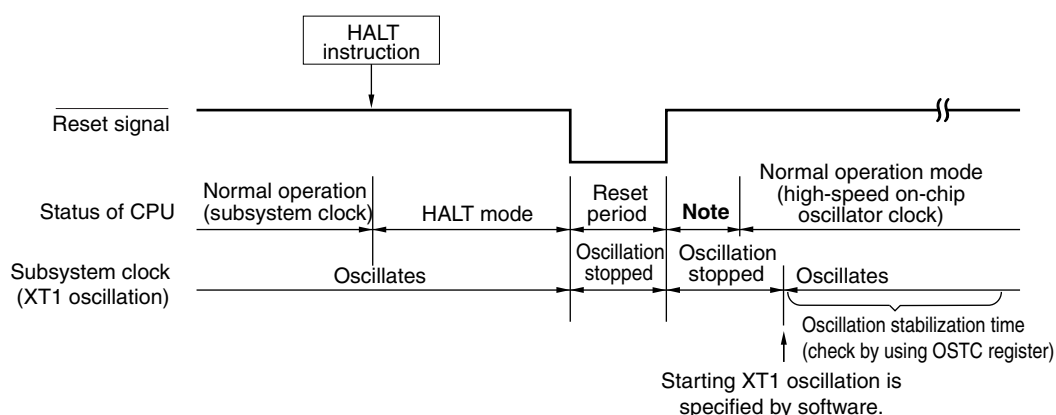
When the reset signal is generated, HALT mode is released, and then, as in the case with a normal reset operation, the program is executed after branching to the reset vector address.

Figure 18-2. HALT Mode Release by Reset (1/2)**(1) When high-speed on-chip oscillator clock is used as CPU clock****(2) When high-speed system clock is used as CPU clock**

Note For the reset processing time, see **CHAPTER 19 RESET FUNCTION**. For the reset processing time of the power-on-reset circuit (POR) and voltage detector (LVD), see **CHAPTER 20 POWER-ON-RESET CIRCUIT**.

Figure 18-2. HALT Mode Release by Reset (2/2)

(3) When subsystem clock is used as CPU clock



Note For the reset processing time, see **CHAPTER 19 RESET FUNCTION**. For the reset processing time of the power-on-reset circuit (POR) and voltage detector (LVD), see **CHAPTER 20 POWER-ON-RESET CIRCUIT**.

18.3.2 STOP mode

(1) STOP mode setting and operating statuses

The STOP mode is set by executing the STOP instruction, and it can be set only when the CPU clock before the setting was the high-speed on-chip oscillator clock, X1 clock, or external main system clock.

Caution Because the interrupt request signal is used to clear the STOP mode, if the interrupt mask flag is 0 (the interrupt processing is enabled) and the interrupt request flag is 1 (the interrupt request signal is generated), the STOP mode is immediately cleared if set when the STOP instruction is executed in such a situation. Accordingly, once the STOP instruction is executed, the system returns to its normal operating mode after the elapse of release time from the STOP mode.

Remark $p = 00$; $q = 0$; $m = 0$

The operating statuses in the STOP mode are shown below.

Table 18-2. Operating Statuses in STOP Mode

STOP Mode Setting Item		When STOP Instruction Is Executed While CPU Is Operating on Main System Clock		
		When CPU Is Operating on High-speed on-chip oscillator clock (f _{IH})	When CPU Is Operating on X1 Clock (f _x)	When CPU Is Operating on External Main System Clock (f _{EX})
System clock		Clock supply to the CPU is stopped		
Main system clock	f _{IH}	Stopped		
	f _x			
	f _{EX}			
Subsystem clock	f _{XT}	Status before STOP mode was set is retained		
	f _{EXS}			
f _{IL}		Set by bits 0 (WDSTBYON) and 4 (WDTON) of option byte (000C0H), and WUTMMCK0 bit of subsystem clock supply mode control register (OSMC) • WUTMMCK0 = 1: Oscillates • WUTMMCK0 = 0 and WDTON = 0: Stops • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 1: Oscillates • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 0: Stops		
CPU		Operation stopped		
Code flash memory				
Data flash memory		Operation stopped		
RAM		Operation stopped		
Port (latch)		Status before STOP mode was set is retained		
Timer array unit		Operation disabled		
Real-time clock (RTC)		Operable		
12-bit interval timer				
Watchdog timer		See CHAPTER 10 WATCHDOG TIMER		
Clock output/buzzer output		Operates when the subsystem clock is selected as the clock source for counting and the RTCLPC bit is 0 (operation is disabled when a clock other than the subsystem clock is selected and the RTCLPC bit is not 0).		
A/D converter		Wakeup operation is enabled (switching to the SNOOZE mode)		
Serial array unit (SAU)		Wakeup operation is enabled only for CSIp and UARTq (switching to the SNOOZE mode) Operation is disabled for anything other than CSIp and UARTq		
Serial interface (IICA)		Wakeup by address match operable		
Multiplier and divider/multiply-accumulator		Operation disabled		
DMA controller				
Power-on-reset function		Operable		
Voltage detection function				
External interrupt				
Key interrupt function				
CRC operation function	High-speed CRC	Operation stopped		
	General-purpose CRC			
RAM parity error detection function				
RAM guard function				
SFR guard function				
Illegal-memory access detection function				

Remarks 1. Operation stopped: Operation is automatically stopped before switching to the STOP mode.

Operation disabled: Operation is stopped before switching to the STOP mode.

f_{IH} : High-speed on-chip oscillator clock f_{IL} : Low-speed on-chip oscillator clock

f_x : X1 clock

f_{EX} : External main system clock

f_{XT} : XT1 clock

f_{EXS} : External subsystem clock

2. $p = 00$; $q = 0$

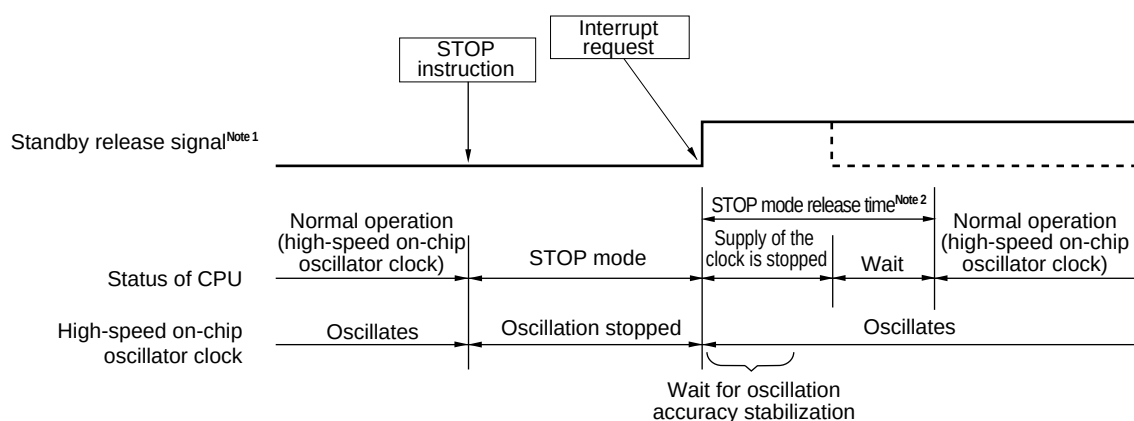
(2) STOP mode release

The STOP mode can be released by the following two sources.

(a) Release by unmasked interrupt request

When an unmasked interrupt request is generated, the STOP mode is released. After the oscillation stabilization time has elapsed, if interrupt acknowledgment is enabled, vectored interrupt servicing is carried out. If interrupt acknowledgment is disabled, the next address instruction is executed.

Figure 18-3. STOP Mode Release by Interrupt Request Generation (1/2)

(1) When high-speed on-chip oscillator clock is used as CPU clock

Notes 1. For details of the standby release signal, see **Figure 16-1**.

2. STOP mode release time

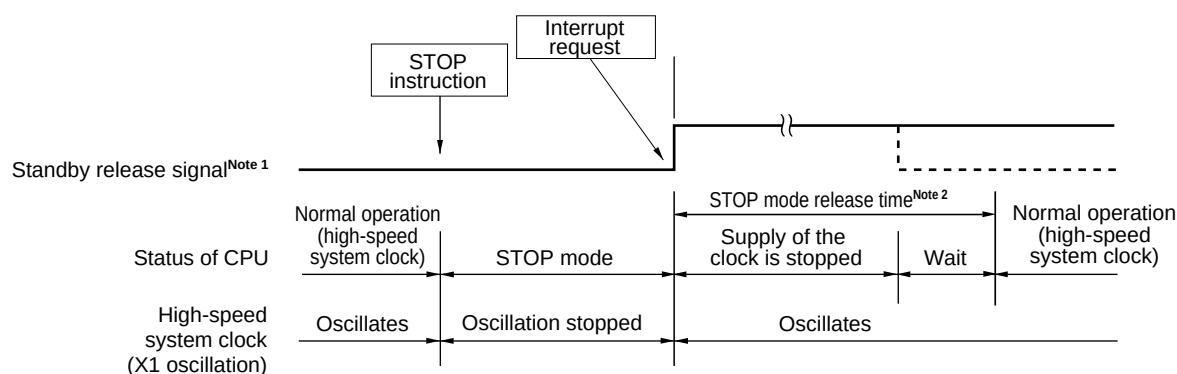
Supply of the clock is stopped: 18 μ s to 65 μ s

Wait

- When vectored interrupt servicing is carried out: 7 clocks
- When vectored interrupt servicing is not carried out: 1 clock

Remarks 1. The clock supply stop time varies depending on the temperature conditions and STOP mode period.

2. The broken lines indicate the case when the interrupt request that has released the standby mode is acknowledged.

Figure 18-3. STOP Mode Release by Interrupt Request Generation (2/2)**(2) When high-speed system clock (X1 oscillation) is used as CPU clock**

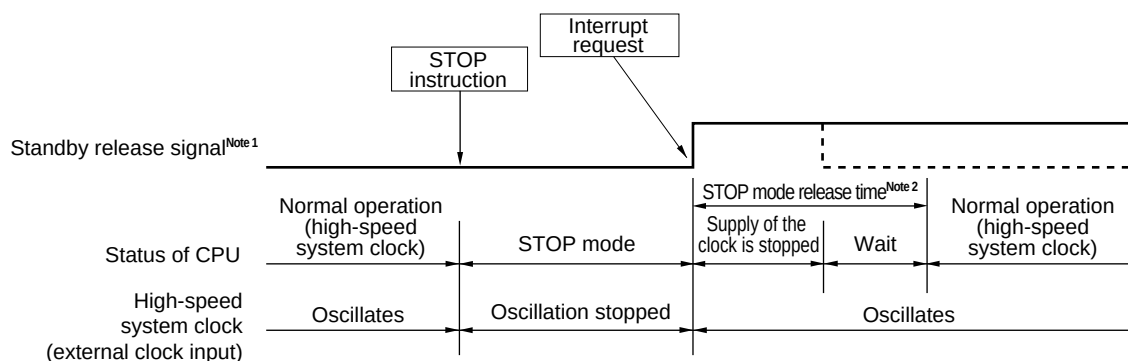
Notes 1. For details of the standby release signal, see **Figure 16-1**.

2. STOP mode release time

Supply of the clock is stopped: 18 μ s to "whichever is longer 65 μ s and the oscillation stabilization time (set by OSTS)"

Wait

- When vectored interrupt servicing is carried out: 10 to 11 clocks
- When vectored interrupt servicing is not carried out: 4 to 5 clocks

(3) When high-speed system clock (external clock input) is used as CPU clock

Notes 1. For details of the standby release signal, see **Figure 16-1**.

2. STOP mode release time

Supply of the clock is stopped: 18 to 65 μ s

Wait

- When vectored interrupt servicing is carried out: 7 clocks
- When vectored interrupt servicing is not carried out: 1 clock

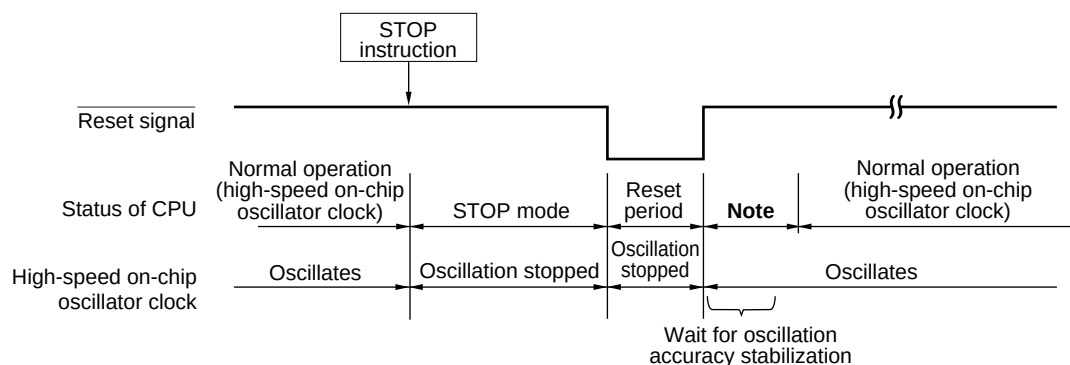
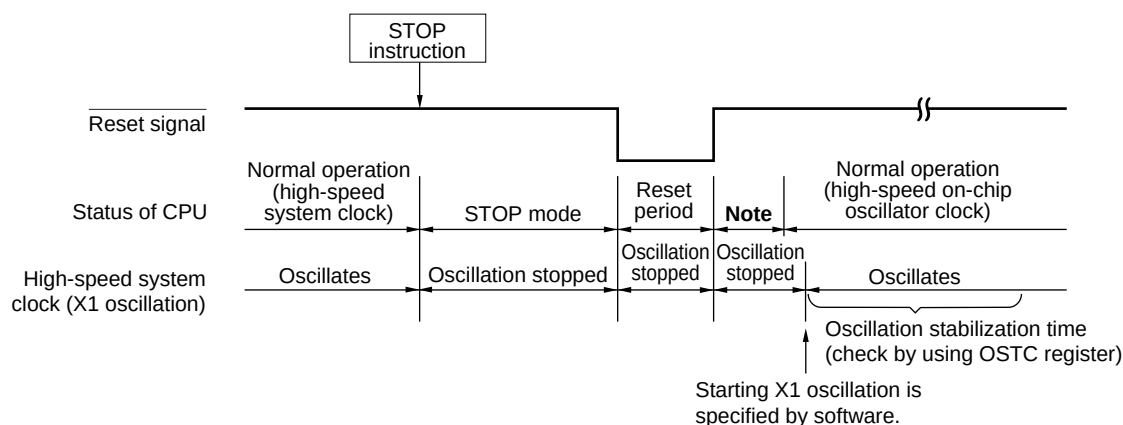
Caution To reduce the oscillation stabilization time after release from the STOP mode while CPU operates based on the high-speed system clock (X1 oscillation), switch the clock to the high-speed on-chip oscillator clock temporarily before executing the STOP instruction.

Remarks 1. The period during which clock supply stops depends on the temperature conditions and the STOP mode period.

2. The broken lines indicate the case when the interrupt request that has released the standby mode is acknowledged.

(b) Release by reset signal generation

When the reset signal is generated, STOP mode is released, and then, as in the case with a normal reset operation, the program is executed after branching to the reset vector address.

Figure 18-4. STOP Mode Release by Reset**(1) When high-speed on-chip oscillator clock is used as CPU clock****(2) When high-speed system clock is used as CPU clock**

Note For the reset processing time, see **CHAPTER 19 RESET FUNCTION**. For the reset processing time of the power-on-reset circuit (POR) and voltage detector (LVD), see **CHAPTER 20 POWER-ON-RESET CIRCUIT**.

18.3.3 SNOOZE mode

(1) SNOOZE mode setting and operating statuses

The SNOOZE mode can only be specified for CSIp, UARTq, or the A/D converter. Note that this mode can only be specified if the CPU clock is the high-speed on-chip oscillator clock.

When using CSIp or UARTq in the SNOOZE mode, set the SWCm bit of the serial standby control register m (SSCm) to 1 immediately before switching to the STOP mode. For details, see **12.3 Registers Controlling Serial Array Unit**.

When using the A/D converter in the SNOOZE mode, set the AWC bit of the A/D converter mode register 2 (ADM2) to 1 immediately before switching to the STOP mode. For details, see **11.3 Registers Used in A/D Converter**.

Remark p = 00; q = 0; m = 0

The following time is required for mode transition.

Transition time from STOP mode to SNOOZE mode: 18 to 65 μ s

Remark The time required to transition from STOP mode to SNOOZE mode depends on the temperature conditions and the STOP mode period.

Transition time from SNOOZE mode to normal operation:

- When vectored interrupt servicing is carried out:
 - HS (High-speed main) mode: 4.99 to 9.44 μ s + 7 clocks
 - LS (Low-speed main) mode: 1.10 to 5.08 μ s + 7 clocks
 - LV (Low-voltage main) mode: 16.58 to 25.40 μ s + 7 clocks
- When vectored interrupt servicing is not carried out:
 - HS (High-speed main) mode: 4.99 to 9.44 μ s + 1 clock
 - LS (Low-speed main) mode: 1.10 to 5.08 μ s + 1 clock
 - LV (Low-voltage main) mode: 16.58 to 25.40 μ s + 1 clock

The operating statuses in the SNOOZE mode are shown below.

Table 18-3. Operating Statuses in SNOOZE Mode

STOP Mode Setting		When Inputting CSIp/UARTq Data Reception Signal or A/D Converter Timer Trigger Signal While in STOP Mode	
		When CPU Is Operating on High-speed on-chip oscillator clock (f _{IH})	
Item			
System clock		Clock supply to the CPU is stopped	
Main system clock	f _{IH}	Operation started	
	f _X	Stopped	
	f _{EX}		
Subsystem clock	f _{XT}	Use of the status while in the STOP mode continues	
	f _{EXS}		
f _{IL}		Set by bits 0 (WDSTBYON) and 4 (WDTON) of option byte (000C0H), and WUTMMCK0 bit of subsystem clock supply mode control register (OSMC) • WUTMMCK0 = 1: Oscillates • WUTMMCK0 = 0 and WDTON = 0: Stops • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 1: Oscillates • WUTMMCK0 = 0, WDTON = 1, and WDSTBYON = 0: Stops	
CPU		Operation stopped	
Code flash memory			
Data flash memory			
RAM		Operation stopped (operable when DMA is executed)	
Port (latch)		Use of the status while in the STOP mode continues	
Timer array unit		Operation disabled	
Real-time clock (RTC)		Operable	
12-bit interval timer			
Watchdog timer		See CHAPTER 10 WATCHDOG TIMER	
Clock output/buzzer output		Operates when the subsystem clock is selected as the clock source for counting and the RTCLPC bit is 0 (operation is disabled when a clock other than the subsystem clock is selected and the RTCLPC bit is not 0).	
A/D converter		Operable	
Serial array unit (SAU)		Operable only CSIp and UARTq only. Operation disabled other than CSIp and UARTq.	
Serial interface (IICA)		Operation disabled	
Multiplier and divider/multiply-accumulator			
DMA controller			
Power-on-reset function		Operable	
Voltage detection function			
External interrupt			
Key interrupt function			
CRC operation function	High-speed CRC	Operation disabled	
	General-purpose CRC		
RAM parity error detection function			
RAM guard function			
SFR guard function			
Illegal-memory access detection function			

Remarks 1. Operation stopped: Operation is automatically stopped before switching to the SNOOZE mode.

Operation disabled: Operation is stopped before switching to the SNOOZE mode.

f_{IH} : High-speed on-chip oscillator clock f_{IL} : Low-speed on-chip oscillator clock

f_X : X1 clock

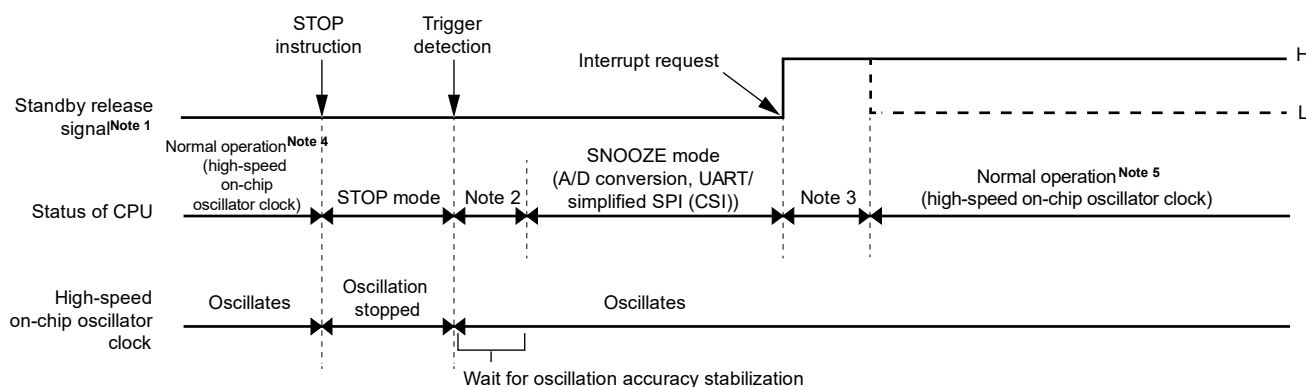
f_{EX} : External main system clock

f_{XT} : XT1 clock

f_{EXS} : External subsystem clock

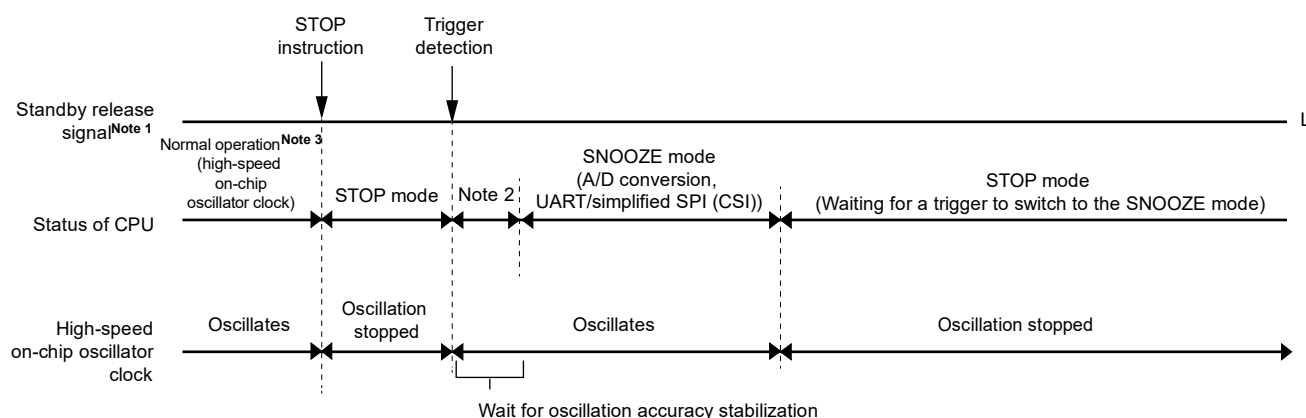
2. $p = 00$; $q = 0$

(2) Timing diagram when the interrupt request signal is generated in the SNOOZE mode

Figure 18-5. When the Interrupt Request Signal is Generated in the SNOOZE Mode

- Notes**
1. For details of the standby release signal, see **Figure 16-1**.
 2. Transition time from STOP mode to SNOOZE mode
 3. Transition time from SNOOZE mode to normal operation
 4. Enable the SNOOZE mode (AWC = 1 or SWCm = 1) immediately before switching to the STOP mode.
 5. Be sure to release the SNOOZE mode (AWC = 0 or SWCm = 0) immediately after return to the normal operation.

(3) Timing diagram when the interrupt request signal is not generated in the SNOOZE mode

Figure 18-6. When the Interrupt Request Signal is not Generated in the SNOOZE Mode

- Notes**
1. For details of the standby release signal, see **Figure 16-1**.
 2. Transition time from STOP mode to SNOOZE mode
 3. Enable the SNOOZE mode (AWC = 1 or SWCm = 1) immediately before switching to the STOP mode.

Remark For details of the SNOOZE mode function, see **CHAPTER 11 A/D CONVERTER** and **CHAPTER 12 SERIAL ARRAY UNIT**.

CHAPTER 19 RESET FUNCTION

The following seven operations are available to generate a reset signal.

- (1) External reset input via $\overline{\text{RESET}}$ pin
- (2) Internal reset by watchdog timer program loop detection
- (3) Internal reset by comparison of supply voltage and detection voltage of power-on-reset (POR) circuit
- (4) Internal reset by comparison of supply voltage of the voltage detector (LVD) and detection voltage
- (5) Internal reset by execution of illegal instruction^{Note}
- (6) Internal reset by RAM parity error
- (7) Internal reset by illegal-memory access

External and internal resets start program execution from the address stored at 00000H and 00001H when the reset signal is generated.

A reset is effected when a low level is input to the $\overline{\text{RESET}}$ pin, the watchdog timer overflows, or by POR and LVD circuit voltage detection, execution of illegal instruction^{Note}, RAM parity error or illegal-memory access, and each item of hardware is set to the status shown in Table 19-1.

Note The illegal instruction is generated when instruction code FFH is executed.

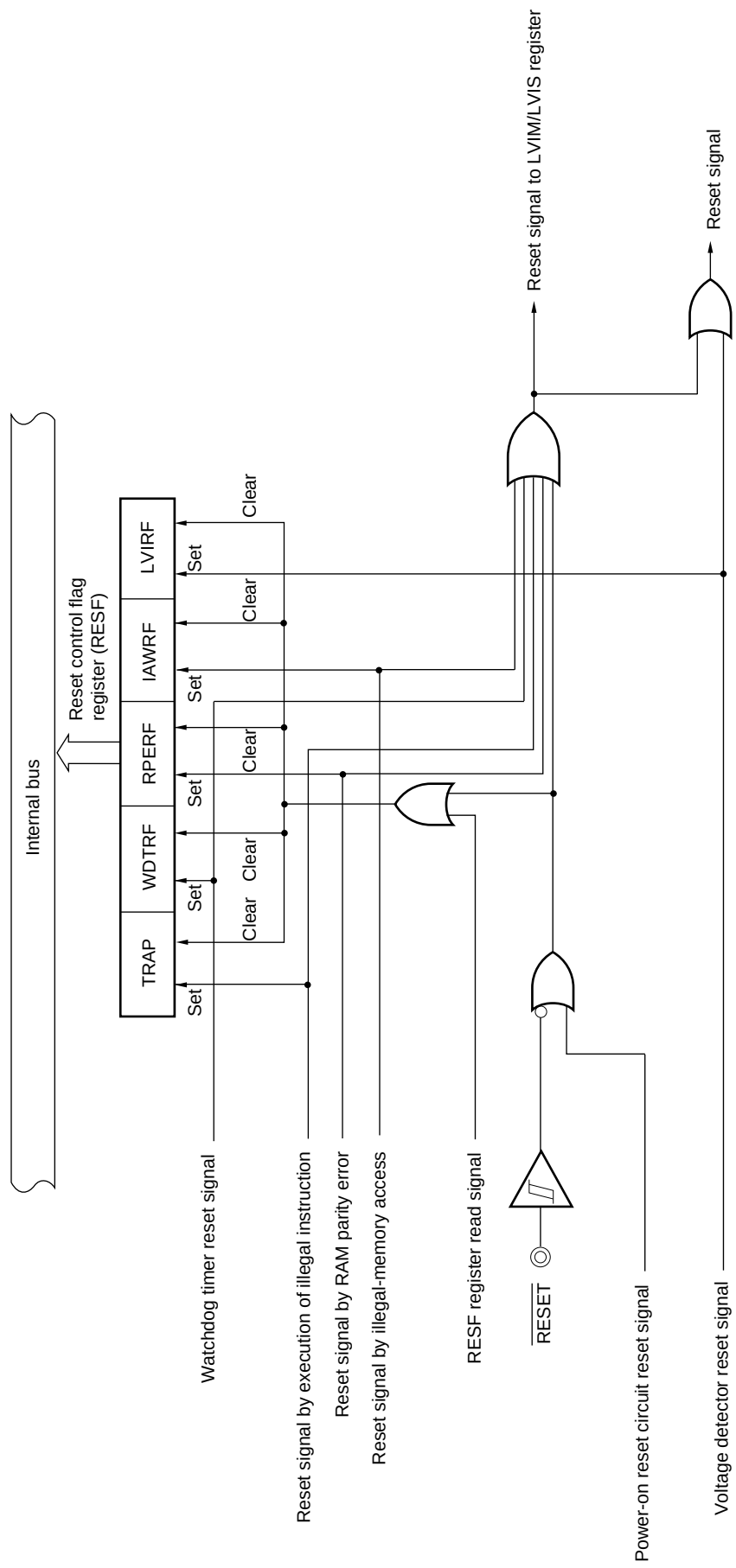
Reset by the illegal instruction execution not issued by emulation with the in-circuit emulator or on-chip debug emulator.

Cautions 1. For an external reset, input a low level for 10 μs or more to the $\overline{\text{RESET}}$ pin.

To perform an external reset upon power application, input a low level to the $\overline{\text{RESET}}$ pin, turn power on, continue to input a low level to the pin for 10 μs or more within the operating voltage range shown in 29.4 or 30.4 AC Characteristics, and then input a high level to the pin.

2. During reset input, the X1 clock, XT1 clock, high-speed on-chip oscillator clock, and low-speed on-chip oscillator clock stop oscillating. External main system clock input and external subsystem clock input become invalid.
3. The port pins become the following state because each SFR and 2nd SFR are initialized after reset.
 - P40: High-impedance during the external reset period or reset period by the POR. High level during other types of reset or after receiving a reset signal (connected to the internal pull-up resistor).
 - P130: Low level during the reset period or after receiving a reset signal.
 - Ports other than P40 and P130: High-impedance during the reset period or after receiving a reset signal.

Figure 19-1. Block Diagram of Reset Function



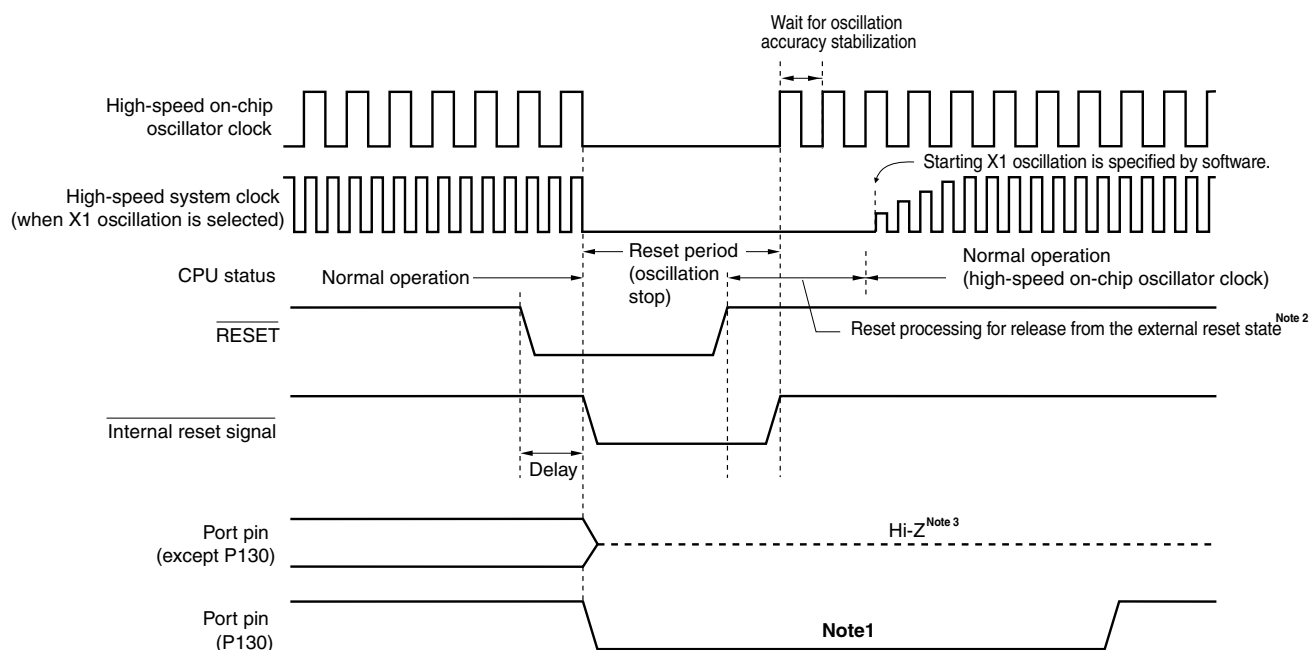
Caution An LVD circuit internal reset does not reset the LVD circuit.

- Remarks**
- 1. LVIM: Voltage detection register
 - 2. LVIS: Voltage detection level register

19.1 Timing of Reset Operation

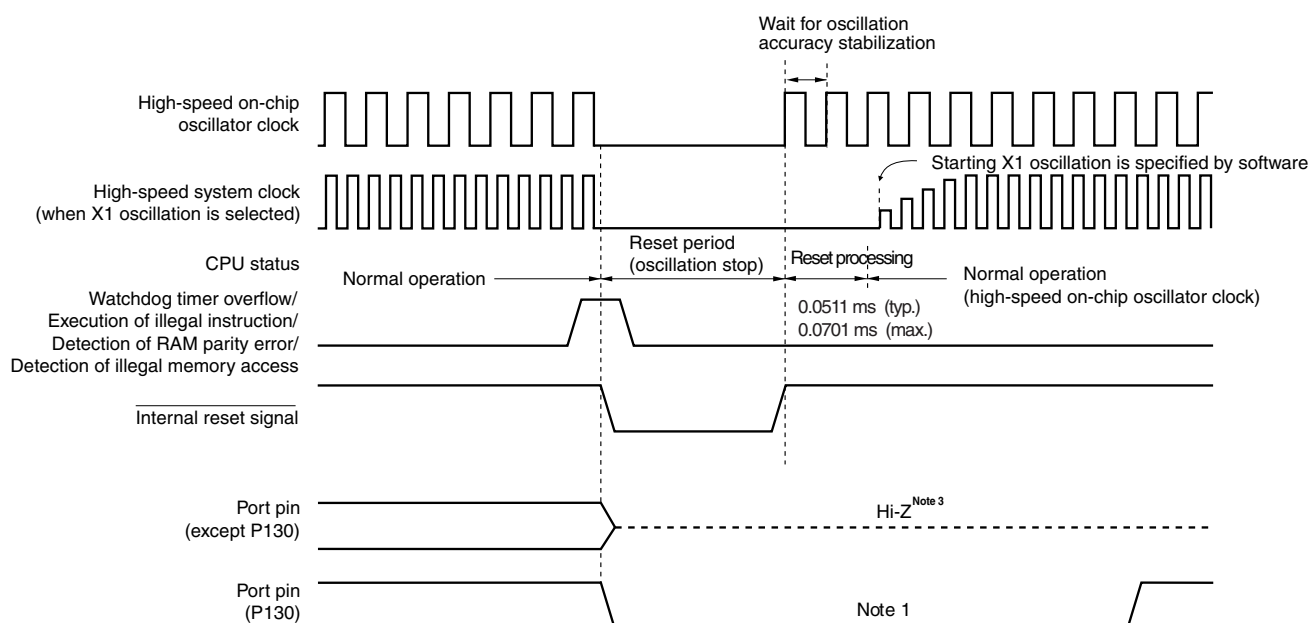
This LSI is reset by input of the low level on the $\overline{\text{RESET}}$ pin and released from the reset state by input of the high level on the $\overline{\text{RESET}}$ pin. After reset processing, execution of the program with the high-speed on-chip oscillator clock as the operating clock starts.

Figure 19-2. Timing of Reset by $\overline{\text{RESET}}$ Input



Release from the reset state is automatic in the case of a reset due to a watchdog timer overflow, execution of an illegal instruction, detection of a RAM parity error, or detection of illegal memory access. After reset processing, execution of the program with the high-speed on-chip oscillator clock as the operating clock starts.

Figure 19-3. Timing of Reset Due to Watchdog Timer Overflow, Execution of Illegal Instruction, Detection of RAM Parity Error, or Detection of Illegal Memory Access



(Notes and Caution are listed on the next page.)

- Notes**
1. When P130 is set to high-level output before reset is effected, the output signal of P130 can be dummy-output as a reset signal to an external device, because P130 outputs a low level when reset is effected. To release a reset signal to an external device, set P130 to high-level output by software.
 2. Reset times (times for release from the external reset state)
After the first release of the POR: 0.672 ms (typ.), 0.832 ms (max.) when the LVD is in use.
0.399 ms (typ.), 0.519 ms (max.) when the LVD is off.
After the second release of the POR: 0.531 ms (typ.), 0.675 ms (max.) when the LVD is in use.
0.259 ms (typ.), 0.362 ms (max.) when the LVD is off.

After power is supplied, a voltage stabilization waiting time of about 0.99 ms (typ.) and up to 2.30 ms (max.) is required before reset processing starts after release of the external reset.
 3. The state of P40 is as follows.
 - High-impedance during the external reset period or reset period by the POR.
 - High level during other types of reset or after receiving a reset signal (connected to the internal pull-up resistor).

Caution The watchdog timer is also reset without exception.

Reset by POR and LVD circuit supply voltage detection is automatically released when $V_{DD} \geq V_{POR}$ or $V_{DD} \geq V_{LVD}$ after the reset. After reset processing, execution of the program with the high-speed on-chip oscillator clock as the operating clock starts. For details, see **CHAPTER 20 POWER-ON-RESET CIRCUIT** or **CHAPTER 21 VOLTAGE DETECTOR**.

Remark V_{POR} : POR power supply rise detection voltage
 V_{LVD} : LVD detection voltage

19.2 States of Operation During Reset Periods

Table 19-1 shows the states of operation during reset periods. Table 19-2 shows the states of the hardware after receiving a reset signal.

Table 19-1. States of Operation During Reset Period

Item			During Reset Period	
System clock			Clock supply to the CPU is stopped.	
	Main system clock	f _{IH}	Operation stopped	
		f _X	Operation stopped (the X1 and X2 pins are input port mode)	
		f _{EX}	Clock input invalid (the pin is input port mode)	
	Subsystem clock	f _{XT}	Operation stopped (the XT1 and XT2 pins are input port mode)	
		f _{EXS}	Clock input invalid (the pin is input port mode)	
f _{IL}		Operation stopped		
CPU			Operation stopped	
Code flash memory			Operation stopped	
Data flash memory			Operation stopped	
RAM			Operation stopped	
Port (latch)			High impedance ^{Note}	
Timer array unit			Operation stopped	
Real-time clock (RTC)				
12-bit interval timer				
Watchdog timer				
Clock output/buzzer output				
A/D converter				
Serial array unit (SAU)				
Serial interface (IICA)				
Multiplier & divider, multiply-accumulator				
DMA controller				
Power-on-reset function			Detection operation possible	
Voltage detection function			Operation is possible in the case of an LVD reset and stopped in the case of other types of reset.	
External interrupt			Operation stopped	
Key interrupt function				
CRC operation function	High-speed CRC			
	General-purpose CRC			
RAM parity error detection function				
RAM guard function				
SFR guard function				
Illegal-memory access detection function				

Note P40 and P130 become the following state.

- P40: High-impedance during the external reset period or reset period by the POR. High level during other types of reset (connected to the internal pull-up resistor).
- P130: Low level during the reset period

(Remark is listed on the next page.)

Remark f_{IH}: High-speed on-chip oscillator clock
 f_X: X1 oscillation clock
 f_{EX}: External main system clock
 f_{XT}: XT1 oscillation clock
 f_{EXS}: External subsystem clock
 f_{IL}: Low-speed on-chip oscillator clock

Table 19-2. State of Hardware After Receiving a Reset Signal

Hardware		After Reset Acknowledgment ^{Note}
Program counter (PC)		The contents of the reset vector table (00000H, 00001H) are set.
Stack pointer (SP)		Undefined
Program status word (PSW)		06H
RAM	Data memory	Undefined
	General-purpose registers	Undefined

Note During reset signal generation or oscillation stabilization time wait, only the PC contents among the hardware statuses become undefined. All other hardware statuses remain unchanged after reset.

Remark For the state of the special function register (SFR) after receiving a reset signal, see **3.1.4 Special function register (SFR) area** and **3.1.5 Extended special function register (2nd SFR: 2nd Special Function Register) area**.

19.3 Register for Confirming Reset Source

19.3.1 Reset control flag register (RESF)

Many internal reset generation sources exist in the RL78 microcontroller. The reset control flag register (RESF) is used to store which source has generated the reset request.

The RESF register can be read by an 8-bit memory manipulation instruction.

$\overline{\text{RESET}}$ input, reset by power-on-reset (POR) circuit, and reading the RESF register clear TRAP, WDTRF, RPERF, IAWRF, and LVIRF flags.

Figure 19-4. Format of Reset Control Flag Register (RESF)

Address: FFFA8H After reset: Undefined ^{Note 1} R

Symbol	7	6	5	4	3	2	1	0
RESF	TRAP	0	0	WDTRF	0	RPERF	IAWRF	LVIRF

TRAP	Internal reset request by execution of illegal instruction ^{Note 2}
0	Internal reset request is not generated, or the RESF register is cleared.
1	Internal reset request is generated.

WDTRF	Internal reset request by watchdog timer (WDT)
0	Internal reset request is not generated, or the RESF register is cleared.
1	Internal reset request is generated.

RPERF	Internal reset request t by RAM parity
0	Internal reset request is not generated, or the RESF register is cleared.
1	Internal reset request is generated.

IAWRF	Internal reset request t by illegal-memory access
0	Internal reset request is not generated, or the RESF register is cleared.
1	Internal reset request is generated.

LVIRF	Internal reset request by voltage detector (LVD)
0	Internal reset request is not generated, or the RESF register is cleared.
1	Internal reset request is generated.

Notes 1. The value after reset varies depending on the reset source. See **Table 19-3**.

2. The illegal instruction is generated when instruction code FFH is executed.

Reset by the illegal instruction execution not issued by emulation with the in-circuit emulator or on-chip debug emulator.

Cautions 1. Do not read data by a 1-bit memory manipulation instruction.

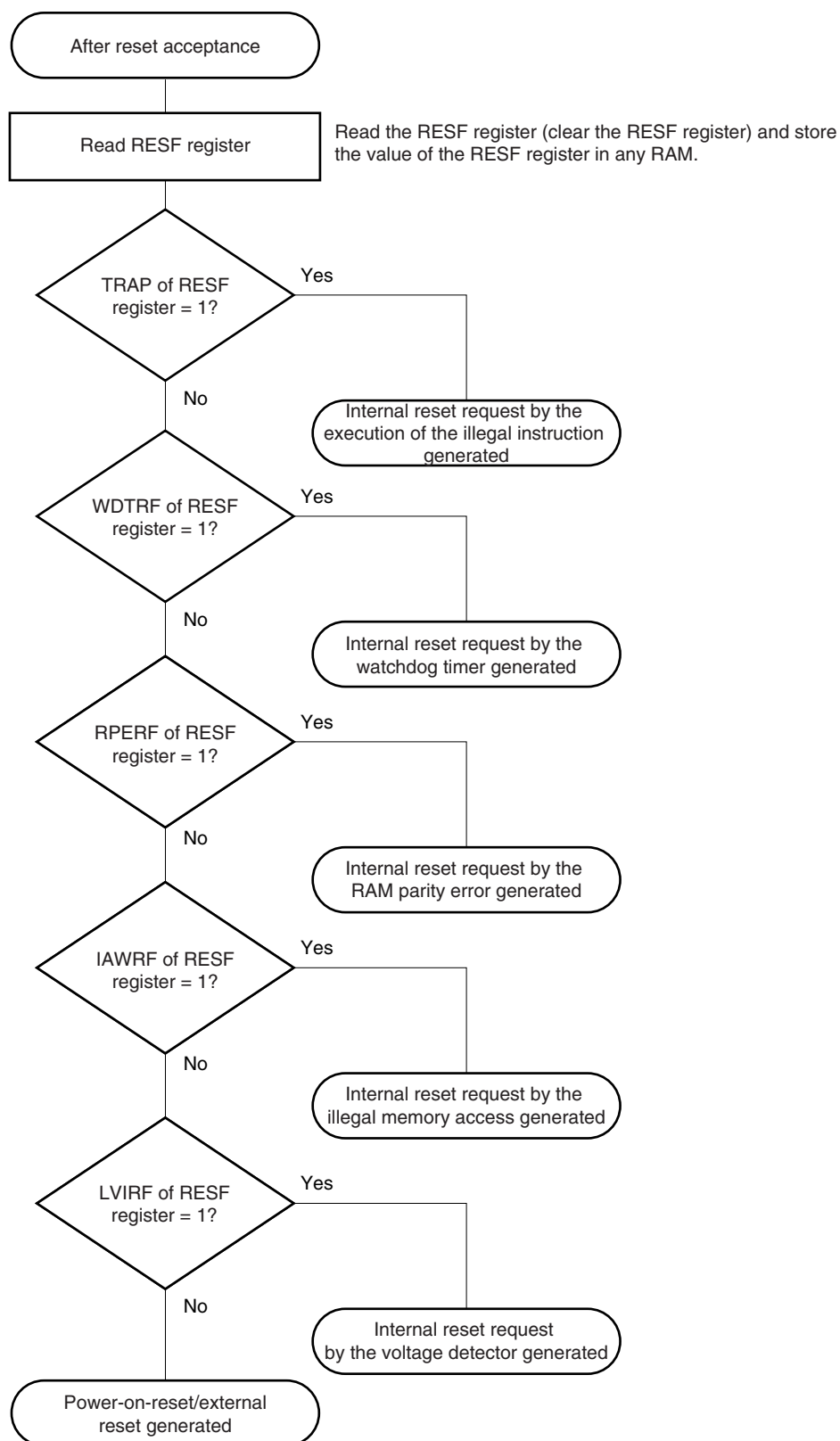
2. When enabling RAM parity error resets (RPERDIS = 0), be sure to initialize the used RAM area at data access or the used RAM area + 10 bytes at execution of instruction from the RAM area. Reset generation enables RAM parity error resets (RPERDIS = 0). For details, see 22.3.3 RAM parity error detection function.

The status of the RESF register when a reset request is generated is shown in Table 19-3.

Table 19-3. RESF Register Status When Reset Request Is Generated

Reset Source Flag	$\overline{\text{RESET}}$ Input	Reset by POR	Reset by Execution of Illegal Instruction	Reset by WDT	Reset by RAM Parity Error	Reset by Illegal- memory Access	Reset by LVD
TRAP bit	Cleared (0)		Set (1)	Held			
WDTRF bit			Held	Set (1)	Held		
RPERF bit			Held		Set (1)	Held	
IAWRF bit			Held			Set (1)	Held
LVIRF bit			Held				Set (1)

The RESF register is automatically cleared when it is read by an 8-bit memory manipulation instruction. Figure 19-5 shows the procedure for checking a reset source.

Figure 19-5. Example of Procedure for Checking Reset Source

The flow described above is an example of the procedure for checking.

CHAPTER 20 POWER-ON-RESET CIRCUIT

20.1 Functions of Power-on-reset Circuit

The power-on-reset circuit (POR) has the following functions.

- Generates internal reset signal at power on.

The reset signal is released when the supply voltage (V_{DD}) exceeds the detection voltage (V_{POR}). Note that the reset state must be retained until the operating voltage^{Note} becomes in the range defined in **29.4** or **30.4 AC Characteristics**. This is done by utilizing the voltage detection circuit or controlling the externally input reset signal.

- Compares supply voltage (V_{DD}) and detection voltage (V_{PDR}), generates internal reset signal when $V_{DD} < V_{PDR}$. Note that, after the power supply is turned off, this LSI should be placed in the STOP mode, or in the reset state by utilizing the voltage detection circuit or externally input reset signal, before the operation voltage^{Note} falls below the range defined in **29.4** or **30.4 AC Characteristics**. When restarting the operation, make sure that the operation voltage^{Note} has returned within the range of operation.

Note The operating voltage range varies depending on the setting specified by the user option byte 000C2H/010C2H.

Caution If an internal reset signal is generated in the power-on-reset circuit, the reset control flag register (RESF) is cleared.

Remarks 1. The RL78 microcontroller incorporates multiple hardware functions that generate an internal reset signal. A flag that indicates the reset source is located in the reset control flag register (RESF) for when an internal reset signal is generated by the watchdog timer (WDT), voltage-detector (LVD), illegal instruction execution, RAM parity error, or illegal-memory access. The RESF register is not cleared to 00H and the flag is set to 1 when an internal reset signal is generated by the watchdog timer (WDT), voltage-detector (LVD), illegal instruction execution, RAM parity error, or illegal-memory access.

For details of the RESF register, see **CHAPTER 19 RESET FUNCTION**.

2. V_{POR} : POR power supply rise detection voltage

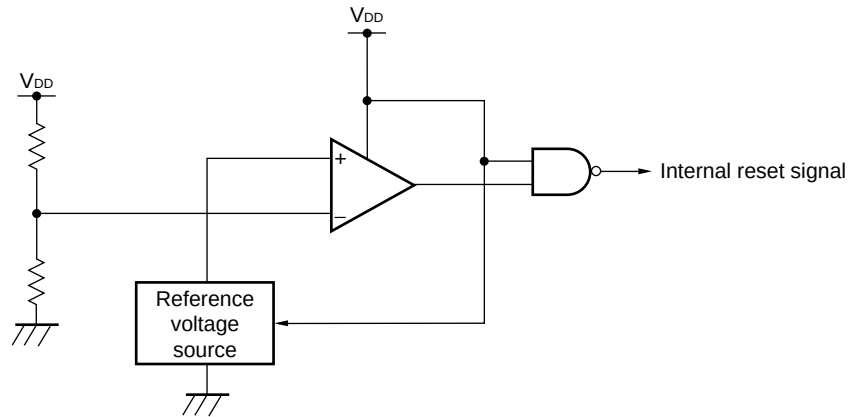
V_{PDR} : POR power supply fall detection voltage

For details, see **29.6.3** or **30.6.3 POR circuit characteristics**.

20.2 Configuration of Power-on-reset Circuit

The block diagram of the power-on-reset circuit is shown in Figure 20-1.

Figure 20-1. Block Diagram of Power-on-reset Circuit

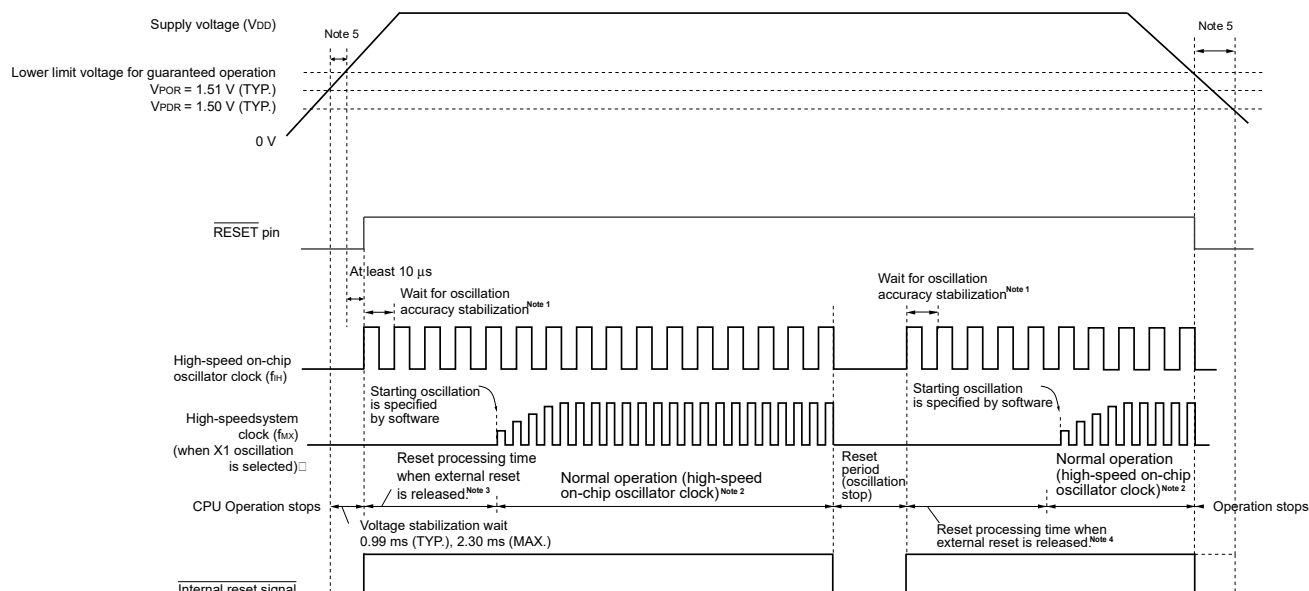


20.3 Operation of Power-on-reset Circuit

The timing of generation of the internal reset signal by the power-on-reset circuit and voltage detector is shown below.

Figure 20-2. Timing of Generation of Internal Reset Signal by Power-on-reset Circuit and Voltage Detector (1/3)

(1) When the externally input reset signal on the $\overline{\text{RESET}}$ pin is used



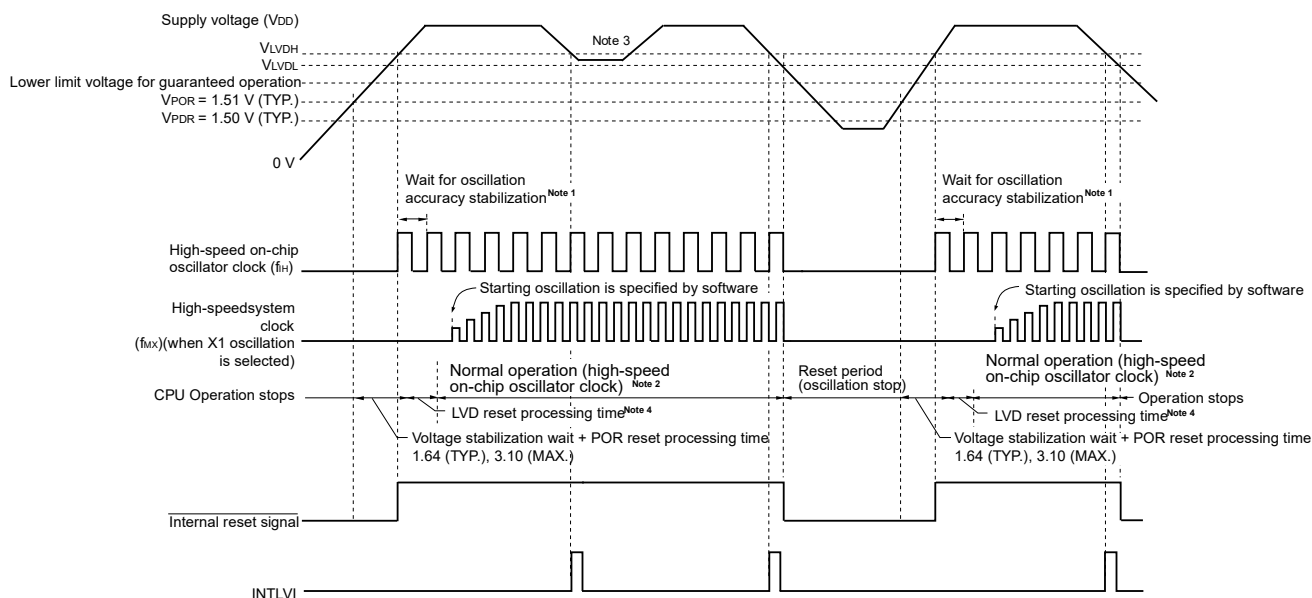
- Notes**
1. The internal reset processing time includes the oscillation accuracy stabilization time of the high-speed on-chip oscillator clock.
 2. The high-speed on-chip oscillator clock and a high-speed system clock or subsystem clock can be selected as the CPU clock. To use the X1 clock, use the oscillation stabilization time counter status register (OSTC) to confirm the lapse of the oscillation stabilization time. To use the XT1 clock, use the timer function for confirmation of the lapse of the stabilization time.
 3. The time until normal operation starts includes the following reset processing time when the external reset is released (release from the first external reset following release from the POR state) after the $\overline{\text{RESET}}$ signal is driven high (1) as well as the voltage stabilization wait time after V_{POR} (1.51 V, typ.) is reached. Reset processing time when the external reset is released is shown below.
Release from the first external reset following release from the POR state:
0.672 ms (typ.), 0.832 ms (max.) (when the LVD is in use)
0.399 ms (typ.), 0.519 ms (max.) (when the LVD is off)
 4. Reset times in cases of release from an external reset other than the above are listed below.
Release from the reset state for external resets other than the above case:
0.531 ms (typ.), 0.675 ms (max.) (when the LVD is in use)
0.259 ms (typ.), 0.362 ms (max.) (when the LVD is off)
 5. After power is supplied, the reset state must be retained until the operating voltage becomes in the range defined in **29.4** or **30.4 AC Characteristics**. This is done by controlling the externally input reset signal. After power supply is turned off, this LSI should be placed in the STOP mode, or in the reset state by utilizing the voltage detection circuit or externally input reset signal, before the voltage falls below the operating range. When restarting the operation, make sure that the operation voltage has returned within the range of operation.

Remark V_{POR} : POR power supply rise detection voltage
 V_{PDR} : POR power supply fall detection voltage

Caution For power-on reset, be sure to use the externally input reset signal on the $\overline{\text{RESET}}$ pin when the LVD is off. For details, see CHAPTER 21 VOLTAGE DETECTOR.

Figure 20-2. Timing of Generation of Internal Reset Signal by Power-on-reset Circuit and Voltage Detector (2/3)

(2) LVD interrupt & reset mode (option byte 000C1: LVIMDS1, LVIMDS0 = 1, 0)

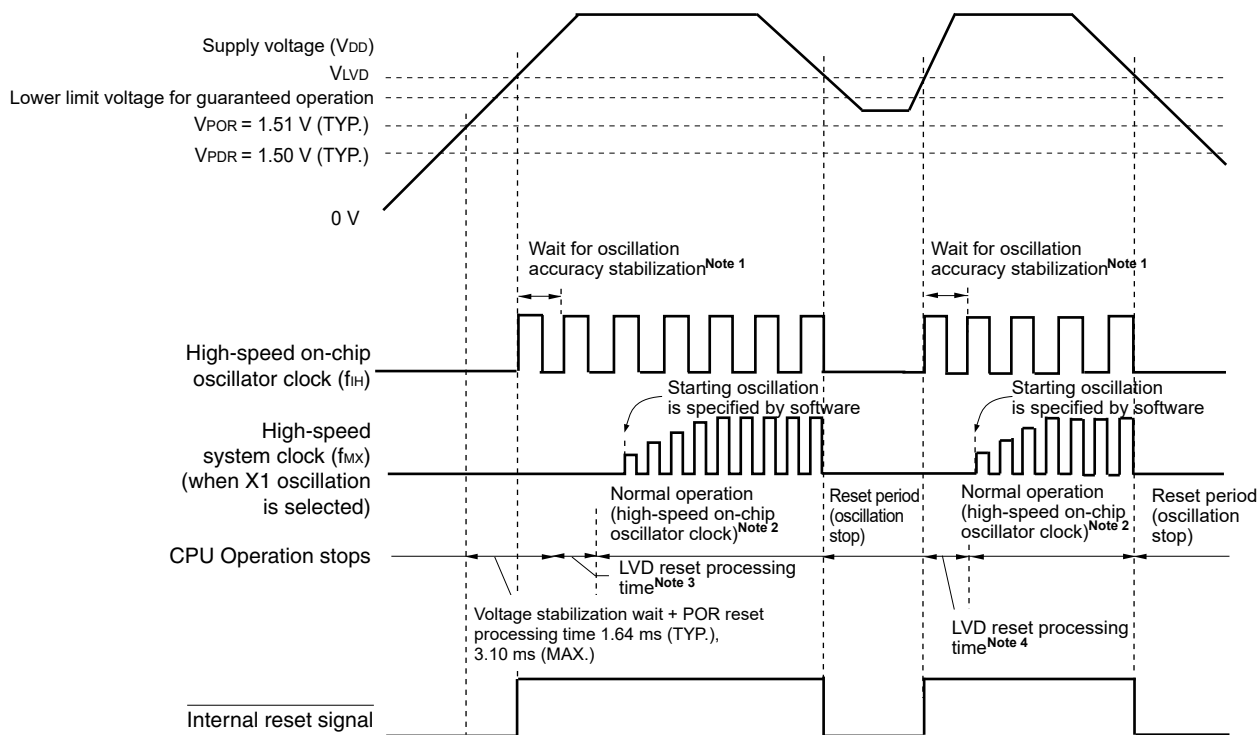


- Notes**
1. The internal reset processing time includes the oscillation accuracy stabilization time of the high-speed on-chip oscillator clock.
 2. The high-speed on-chip oscillator clock and a high-speed system clock or subsystem clock can be selected as the CPU clock. To use the X1 clock, use the oscillation stabilization time counter status register (OSTC) to confirm the lapse of the oscillation stabilization time. To use the XT1 clock, use the timer function for confirmation of the lapse of the stabilization time.
 3. After the interrupt request signal (INTLVI) is generated, the LVILV and LVIMD bits of the voltage detection level register (LVIS) are automatically set to 1. After INTLVI is generated, appropriate settings should be made according to **Figure 21-8 Processing Procedure After an Interrupt Is Generated** and **Figure 21-9 Setting Procedure for Initial Setting of Interrupt and Reset Mode**, taking into consideration that the supply voltage might return to the high voltage detection level (VLVDH) or higher without falling below the low voltage detection level (VLVDL).
 4. The time until normal operation starts includes the following LVD reset processing time after the LVD detection level (VLVDH) is reached as well as the voltage stabilization wait + POR reset processing time after the VPOR (1.51 V, typ.) is reached.
LVD reset processing time: 0 ms to 0.0701 ms (max.)

Remark VLVDH, VLVDL: LVD detection voltage
 VPOR: POR power supply rise detection voltage
 VPDR: POR power supply fall detection voltage

Figure 20-2. Timing of Generation of Internal Reset Signal by Power-on-reset Circuit and Voltage Detector (3/3)

(3) LVD reset mode (option byte 000C1H: LVIMDS1 = 1, LVIMDS0 = 1)



- Notes**
1. The internal reset processing time includes the oscillation accuracy stabilization time of the high-speed on-chip oscillator clock.
 2. The high-speed on-chip oscillator clock and a high-speed system clock or subsystem clock can be selected as the CPU clock. To use the X1 clock, use the oscillation stabilization time counter status register (OSTC) to confirm the lapse of the oscillation stabilization time. To use the XT1 clock, use the timer function for confirmation of the lapse of the stabilization time.
 3. The time until normal operation starts includes the following LVD reset processing time after the LVD detection level (V_{LVD}) is reached as well as the voltage stabilization wait + POR reset processing time after the V_{POR} (1.51 V, typ.) is reached.
LVD reset processing time: 0 ms to 0.0701 ms (max.)
 4. When the power supply voltage is below the lower limit for operation and the power supply voltage is then restored after an internal reset is generated only by the voltage detector (LVD), the following LVD reset processing time is required after the LVD detection level (V_{LVD}) is reached.
LVD reset processing time: 0.0511 ms (typ.), 0.0701 ms (max.)

Remarks 1. V_{LVDH} , V_{LVDL} : LVD detection voltage

V_{POR} : POR power supply rise detection voltage

V_{PDR} : POR power supply fall detection voltage

2. When the LVD interrupt mode is selected (option byte 000C1H: LVIMD1 = 0, LVIMD0 = 1), the time until normal operation starts after power is turned on is the same as the time specified in Note 3 of Figure 20-2 (3).

CHAPTER 21 VOLTAGE DETECTOR

21.1 Functions of Voltage Detector

The operation mode and detection voltages (V_{LVDH} , V_{LVDL} , V_{LVD}) for the voltage detector is set by using the option byte (000C1H).

The voltage detector (LVD) has the following functions.

- The LVD circuit compares the supply voltage (V_{DD}) with the detection voltage (V_{LVDH} , V_{LVDL} , V_{LVD}), and generates an internal reset or interrupt request signal.
- The detection level for the power supply detection voltage (V_{LVDH} , V_{LVDL} , V_{LVD}) can be selected by using the option byte as one of 12 levels (for details, see **CHAPTER 24 OPTION BYTE**).
- Operable in STOP mode.
- After power is supplied, the reset state must be retained until the operating voltage becomes in the range defined in **29.4** or **30.4 AC Characteristics**. This is done by utilizing the voltage detector or controlling the externally input reset signal. After the power supply is turned off, this LSI should be placed in the STOP mode, or placed in the reset state by utilizing the voltage detector or controlling the externally input reset signal before the voltage falls below the operating range. The range of operating voltage varies with the setting of the user option byte (000C2H or 010C2H).

(a) Interrupt & reset mode (option byte LVIMDS1, LVIMDS0 = 1, 0)

The two detection voltages (V_{LVDH} , V_{LVDL}) are selected by the option byte 000C1H. The high-voltage detection level (V_{LVDH}) is used for releasing resets and generating interrupts. The low-voltage detection level (V_{LVDL}) is used for generating resets.

(b) Reset mode (option byte LVIMDS1, LVIMDS0 = 1, 1)

The detection voltage (V_{LVD}) selected by the option byte 000C1H is used for generating/releasing resets.

(c) Interrupt mode (option byte LVIMDS1, LVIMDS0 = 0, 1)

The detection voltage (V_{LVD}) selected by the option byte 000C1H is used for releasing resets/generating interrupts.

The reset and internal interrupt signals are generated in each mode as follows.

Interrupt & Reset Mode (LVIMDS1, LVIMDS0 = 1, 0)	Reset Mode (LVIMDS1, LVIMDS0 = 1, 1)	Interrupt Mode (LVIMDS1, LVIMDS0 = 0, 1)
Generates an interrupt request signal by detecting $V_{DD} < V_{LVDH}$ when the operating voltage falls, and an internal reset by detecting $V_{DD} < V_{LVDL}$. Releases an internal reset by detecting $V_{DD} \geq V_{LVDH}$.	Releases an internal reset by detecting $V_{DD} \geq V_{LVD}$. Generates an interrupt request signal by detecting $V_{DD} < V_{LVD}$.	Retains the state of an internal reset by the LVD immediately after a reset until $V_{DD} \geq V_{LVD}$. Releases the LVD internal reset by detecting $V_{DD} \geq V_{LVD}$. Generates an interrupt request signal (INTLVI) by detecting $V_{DD} < V_{LVD}$ or $V_{DD} \geq V_{LVD}$ after the LVD internal reset is released.

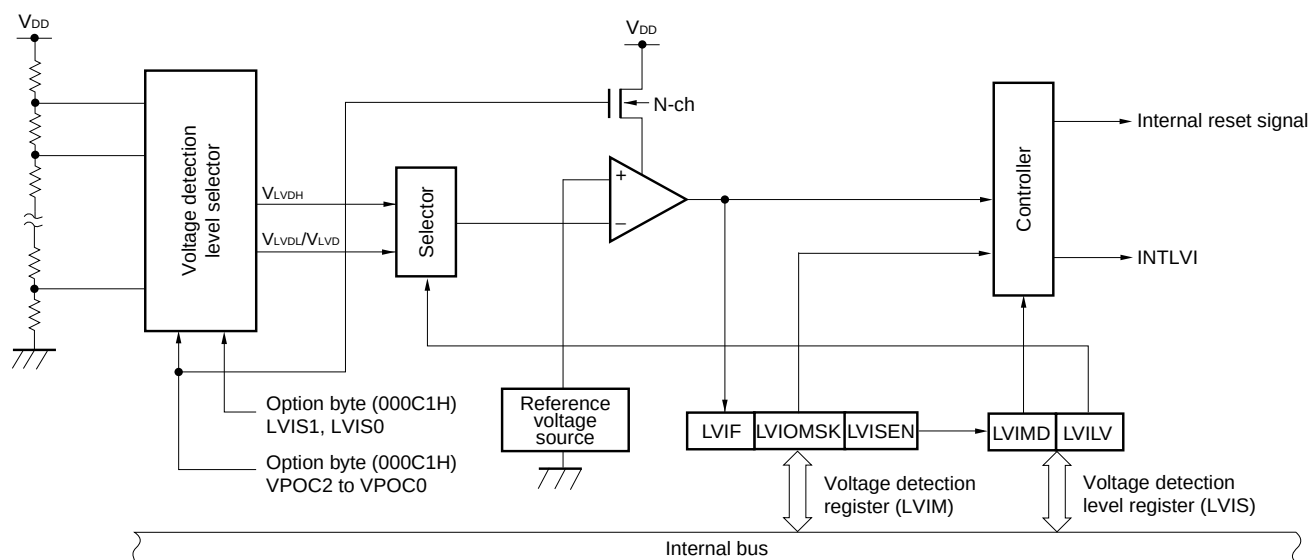
While the voltage detector is operating, whether the supply voltage is more than or less than the detection level can be checked by reading the voltage detection flag (LVIF: bit 0 of the voltage detection register (LVIM)).

Bit 0 (LVIRF) of the reset control flag register (RESF) is set to 1 if reset occurs. For details of the RESF register, see **CHAPTER 19 RESET FUNCTION**.

21.2 Configuration of Voltage Detector

The block diagram of the voltage detector is shown in Figure 21-1.

Figure 21-1. Block Diagram of Voltage Detector



21.3 Registers Controlling Voltage Detector

The voltage detector is controlled by the following registers.

- Voltage detection register (LVIM)
- Voltage detection level register (LVIS)

21.3.1 Voltage detection register (LVIM)

This register is used to specify whether to enable or disable rewriting the voltage detection level register (LVIS), as well as to check the LVD output mask status.

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

Reset signal generation clears this register to 00H.

Figure 21-2. Format of Voltage Detection Register (LVIM)

Address: FFFA9H After reset: 00H^{Note 1} R/W^{Note 2}

Symbol	<7>	6	5	4	3	2	<1>	<0>
LVIM	LVISEN ^{Note 3}	0	0	0	0	0	LVIOMSK	LVIF

LVISEN ^{Note 3}	Specification of whether to enable or disable rewriting the voltage detection level register (LVIS)
0	Disabling of rewriting the LVIS register (LVIOMSK = 0 (Mask of LVD output is invalid))
1	Enabling of rewriting the LVIS register (LVIOMSK = 1 (Mask of LVD output is valid))

LVIOMSK	Mask status flag of LVD output
0	Mask of LVD output is invalid
1	Mask of LVD output is valid ^{Note 4}

LVIF	Voltage detection flag
0	Supply voltage (V_{DD}) $\geq$ detection voltage (V_{LVD}), or when LVD is off
1	Supply voltage (V_{DD}) $<$ detection voltage (V_{LVD})

- Notes**
- The reset value changes depending on the reset source.
If the LVIS register is reset by LVD, it is not reset but holds the current value. In other reset, LVISEN is cleared to 0.
 - Bits 0 and 1 are read-only.
 - LVISEN can only be set in the interrupt & reset mode (option byte LVIMDS1, LVIMDS0 = 1, 0). Do not change the initial value in other modes.
 - LVIOMSK bit is only automatically set to "1" when the interrupt & reset mode is selected (option byte LVIMDS1, LVIMDS0 = 1, 0) and reset or interrupt by LVD is masked.
 - Period during LVISEN = 1
 - Waiting period from the time when LVD interrupt is generated until LVD detection voltage becomes stable
 - Waiting period from the time when the value of LVILV bit changes until LVD detection voltage becomes stable

21.3.2 Voltage detection level register (LVIS)

This register selects the voltage detection level.

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

Reset signal generation input sets this register to 00H/01H/81H^{Note 1}.

Figure 21-3. Format of Voltage Detection Level Select Register (LVIS)

Address: FFFAAH After reset: 00H/01H/81H^{Note 1} R/W

Symbol	<7>	6	5	4	3	2	1	<0>
LVIS	LVIMD	0	0	0	0	0	0	LVILV

LVIMD ^{Note 2}	Operation mode of voltage detection
0	Interrupt mode
1	Reset mode

LVILV ^{Note 2}	LVD detection level
0	High-voltage detection level (V_{LVDH})
1	Low-voltage detection level (V_{LVDL} or V_{LVDL})

- Notes**
- The reset value changes depending on the reset source and the setting of the option byte.
This register is not cleared (00H) by LVD reset.
The generation of reset signal other than an LVD reset sets as follows.
 - When option byte LVIMDS1, LVIMDS0 = 1, 0: 00H
 - When option byte LVIMDS1, LVIMDS0 = 1, 1: 81H
 - When option byte LVIMDS1, LVIMDS0 = 0, 1: 01H
 - Writing "0" can only be allowed in the interrupt & reset mode (option byte LVIMDS1, LVIMDS0 = 1, 0). Do not set LVIMD and LVILV in other cases. The value is switched automatically when reset or interrupt is generated in the interrupt & reset mode.

- Cautions**
- Rewrite the value of the LVIS register according to Figures 21-8 and 21-9.
 - Specify the LVD operation mode and detection voltage (V_{LVDH} , V_{LVDL} , V_{LVD}) of each mode by using the option byte 000C1H. Figure 21-4 shows the format of the user option byte (000C1H/010C1H). For details about the option byte, see CHAPTER 24 OPTION BYTE.

Figure 21-4. Format of User Option Byte (000C1H/010C1H) (1/2)

Address: 000C1H/010C1H^{Note}

7	6	5	4	3	2	1	0
VPOC2	VPOC1	VPOC0	1	LVIS1	LVIS0	LVIMDS1	LVIMDS0

• LVD setting (interrupt & reset mode)

Detection voltage			Option byte setting value						
VLVDH		VLVDL	VPOC2	VPOC1	VPOC0	LVIS1	LVIS0	Mode setting	
Rising edge	Falling edge	Falling edge						LVIMDS1	LVIMDS0
1.77 V	1.73 V	1.63 V	0	0	0	1	0	1	0
1.88 V	1.84 V					0	1		
2.92 V	2.86 V					0	0		
1.98 V	1.94 V	1.84 V		0	1	1	0		
2.09 V	2.04 V					0	1		
3.13 V	3.06 V					0	0		
2.61 V	2.55 V	2.45 V		1	0	1	0		
2.71 V	2.65 V					0	1		
2.92 V	2.86 V	2.75 V		1	1	1	0		
3.02 V	2.96 V					0	1		
—			Value other than above is setting prohibited.						

• LVD setting (reset mode)

LVD setting (reset mode)		Option byte setting value						
Detection voltage		VPOC2	VPOC1	VPOC0	LVIS1	LVIS0	Mode setting	
V _{LVD}							LVIMDS1	LVIMDS0
Rising edge	Falling edge							
1.67 V	1.63 V	0	0	0	1	1	1	1
1.77 V	1.73 V		0	0	1	0		
1.88 V	1.84 V		0	1	1	1		
1.98 V	1.94 V		0	1	1	0		
2.09 V	2.04 V		0	1	0	1		
2.50 V	2.45 V		1	0	1	1		
2.61 V	2.55 V		1	0	1	0		
2.71 V	2.65 V		1	0	0	1		
2.81 V	2.75 V		1	1	1	1		
2.92 V	2.86 V		1	1	1	0		
3.02 V	2.96 V		1	1	0	1		
3.13 V	3.06 V		0	1	0	0		
—		Value other than above is setting prohibited.						

Note Set the same value as 000C1H to 010C1H when the boot swap operation is used because 000C1H is replaced by 010C1H.

Remarks 1. For details on the LVD circuit, see **CHAPTER 21 VOLTAGE DETECTOR**.

2. The detection voltage is a TYP. value. For details, see **29.6.4** or **30.6.4 LVD circuit characteristics**.

(Cautions are listed on the next page.)

Figure 21-4. Format of User Option Byte (000C1H/010C1H) (2/2)

Address: 000C1H/010C1H^{Note}

7	6	5	4	3	2	1	0
VPOC2	VPOC1	VPOC0	1	LVIS1	LVIS0	LVIMDS1	LVIMDS0

• LVD setting (interrupt mode)

LVD setting (interrupt mode)

Detection voltage		Option byte setting value						
V _{LVD}		VPOC2	VPOC1	VPOC0	LVIS1	LVIS0	Mode setting	
Rising edge	Falling edge						LVIMDS1	LVIMDS0
1.67 V	1.63 V	0	0	0	1	1	0	1
1.77 V	1.73 V		0	0	1	0		
1.88 V	1.84 V		0	1	1	1		
1.98 V	1.94 V		0	1	1	0		
2.09 V	2.04 V		0	1	0	1		
2.50 V	2.45 V		1	0	1	1		
2.61 V	2.55 V		1	0	1	0		
2.71 V	2.65 V		1	0	0	1		
2.81 V	2.75 V		1	1	1	1		
2.92 V	2.86 V		1	1	1	0		
3.02 V	2.96 V		1	1	0	1		
3.13 V	3.06 V		0	1	0	0		
—		Value other than above is setting prohibited.						

• LVD off (use of external reset input via $\overline{\text{RESET}}$ pin)

Detection voltage		Option byte setting value						
V _{LVD}		VPOC2	VPOC1	VPOC0	LVIS1	LVIS0	Mode setting	
Rising edge	Falling edge						LVIMDS1	LVIMDS0
–	–	1	×	×	×	×	×	1
–	–	Value other than above is setting prohibited.						

Note Set the same value as 000C1H to 010C1H when the boot swap operation is used because 000C1H is replaced by 010C1H.

Cautions 1. Set bit 4 to 1.

2. After power is supplied, the reset state must be retained until the operating voltage becomes in the range defined in 29.4 or 30.4 AC Characteristics. This is done by utilizing the voltage detector or controlling the externally input reset signal. After the power supply is turned off, this LSI should be placed in the STOP mode, or placed in the reset state by utilizing the voltage detector or controlling the externally input reset signal, before the voltage falls below the operating range.

The range of operating voltage varies with the setting of the user option byte (000C2H or 010C2H).

Remarks 1. ×: don't care

2. For details on the LVD circuit, see **CHAPTER 21 VOLTAGE DETECTOR**.
 3. The detection voltage is a TYP. value. For details, see 29.6.4 or 30.6.4 LVD circuit characteristics.

21.4 Operation of Voltage Detector

21.4.1 When used as reset mode

Specify the operation mode (the reset mode (LVIMDS1, LVIMDS0 = 1, 1)) and the detection voltage (V_{LVD}) by using the option byte 000C1H.

The operation is started in the following initial setting state when the reset mode is set.

- Bit 7 (LVISEN) of the voltage detection register (LVIM) is set to 0 (disable rewriting of voltage detection level register (LVIS))
- The initial value of the voltage detection level select register (LVIS) is set to 81H.
Bit 7 (LVIMD) is 1 (reset mode).
Bit 0 (LVILV) is 1 (voltage detection level: V_{LVD}).

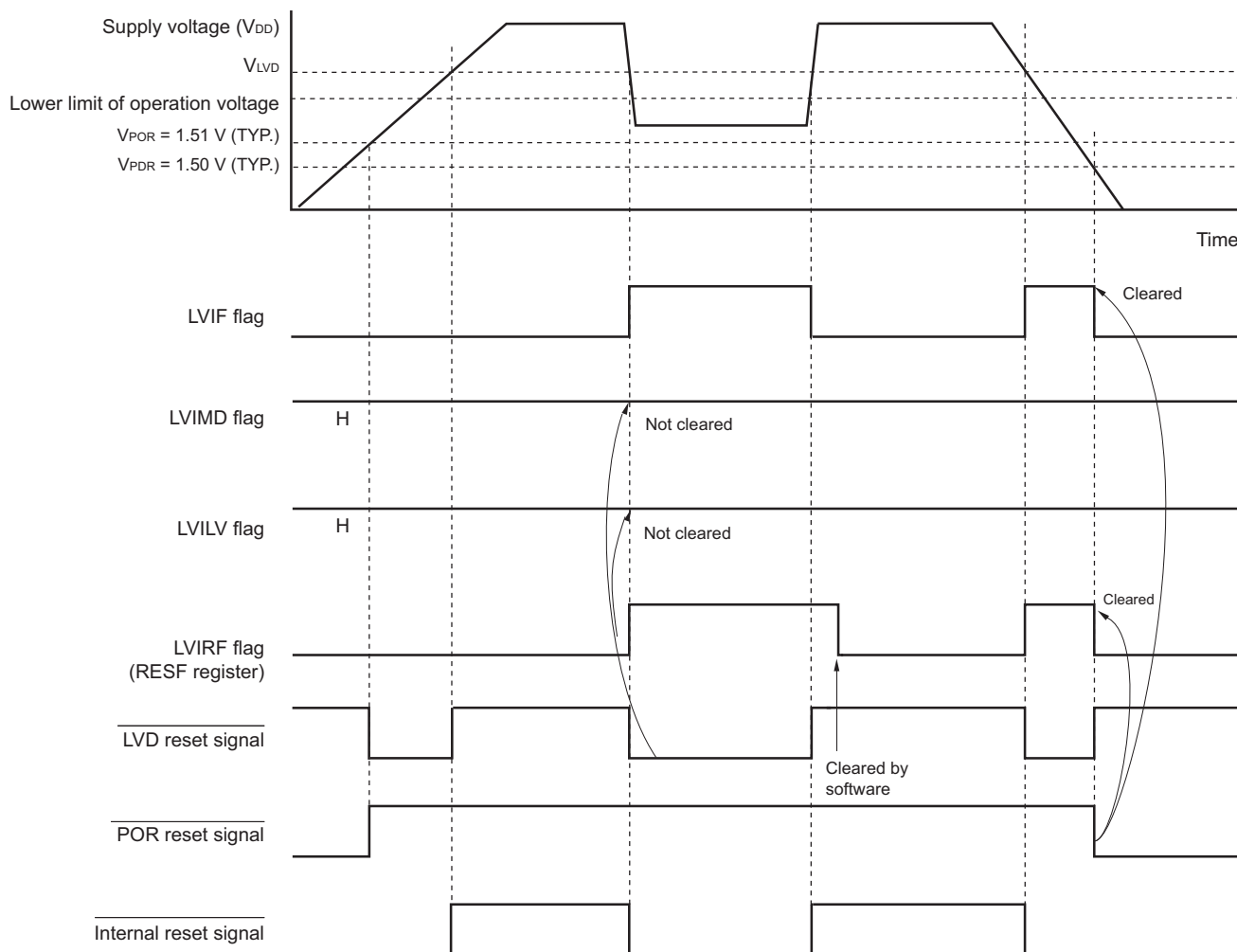
- Operation in LVD reset mode

In the reset mode (option byte LVIMDS1, LVIMDS0 = 1, 1), the state of an internal reset by LVD is retained until the supply voltage (V_{DD}) exceeds the voltage detection level (V_{LVD}) after power is supplied. The internal reset is released when the supply voltage (V_{DD}) exceeds the voltage detection level (V_{LVD}).

At the fall of the operating voltage, an internal reset by LVD is generated when the supply voltage (V_{DD}) falls below the voltage detection level (V_{LVD}).

Figure 21-5 shows the timing of the internal reset signal generated in the LVD reset mode.

Figure 21-5. Timing of Voltage Detector Internal Reset Signal Generation
 (Option Byte LVIMDS1, LVIMDS0 = 1, 1)



Remark V_{POR} : POR power supply rise detection voltage
 V_{PDR} : POR power supply fall detection voltage

21.4.2 When used as interrupt mode

Specify the operation mode (the interrupt mode (LVIMDS1, LVIMDS0 = 0, 1)) and the detection voltage (V_{LVD}) by using the option byte 000C1H.

The operation is started in the following initial setting state when the interrupt mode is set.

- Bit 7 (LVISEN) of the voltage detection register (LVIM) is set to 0 (disable rewriting of voltage detection level register (LVIS))
- The initial value of the voltage detection level select register (LVIS) is set to 01H.
 - Bit 7 (LVIMD) is 0 (interrupt mode).
 - Bit 0 (LVILV) is 1 (low-voltage detection level: V_{LVD}).

- Operation in LVD interrupt mode

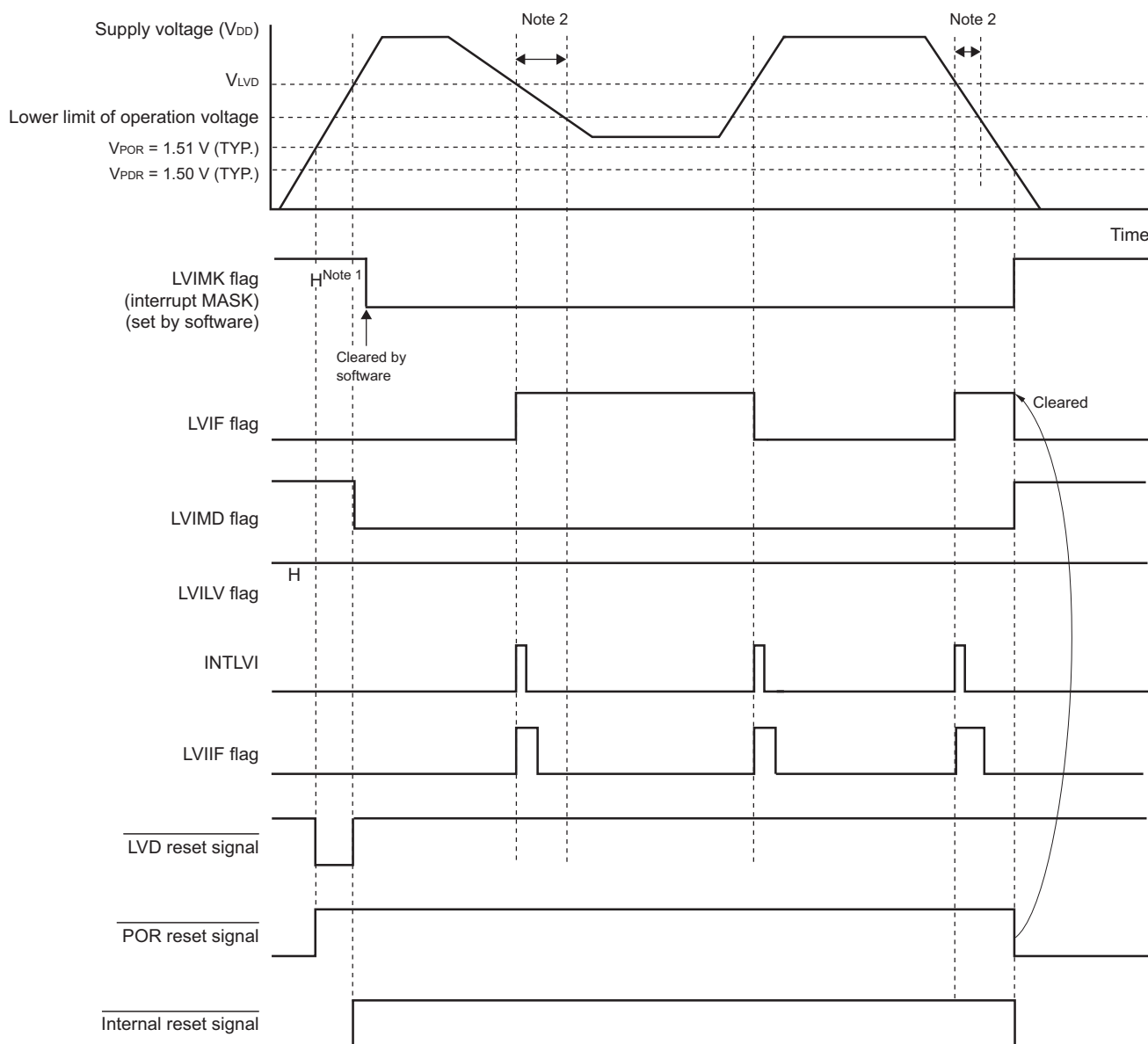
In the interrupt mode (option byte LVIMDS1, LVIMDS0 = 0, 1), the state of an internal reset by LVD is retained immediately after a reset until the supply voltage (V_{DD}) exceeds the voltage detection level (V_{LVD}). The internal reset is released when the supply voltage (V_{DD}) exceeds the voltage detection level (V_{LVD}).

After the LVD internal reset is released, an interrupt request signal (INTLVI) by the LVD is generated when the supply voltage (V_{DD}) exceeds the voltage detection level (V_{LVD}).

When the voltage falls, this LSI should be placed in the STOP mode, or placed in the reset state by controlling the externally input reset signal, before the voltage falls below the operating voltage range defined in **29.4** or **30.4 AC Characteristics**. When restarting the operation, make sure that the operation voltage has returned within the range of operation.

Figure 21-6 shows the timing of the interrupt request signal generated in the LVD interrupt mode.

Figure 21-6. Timing of Voltage Detector Internal Interrupt Signal Generation
(Option Byte LVIMDS1, LVIMDS0 = 0, 1)



- Notes**
- The LVIMK flag is set to "1" by reset signal generation.
 - When the voltage falls, this LSI should be placed in the STOP mode, or placed in the reset state by controlling the externally input reset signal, before the voltage falls below the operating voltage range defined in **29.4** or **30.4 AC characteristics**. When restarting the operation, make sure that the operation voltage has returned within the range of operation.

Remark V_{POR} : POR power supply rise detection voltage
 V_{PDR} : POR power supply fall detection voltage

21.4.3 When used as interrupt & reset mode

Specify the operation mode (the interrupt & reset (LVIMDS1, LVIMDS0 = 1, 0)) and the detection voltage (V_{LVDH} , V_{LVDL}) by using the option byte 000C1H.

The operation is started in the following initial setting state when the interrupt & reset mode is set.

- Bit 7 (LVISEN) of the voltage detection register (LVIM) is set to 0 (disable rewriting of voltage detection level register (LVIS))
- The initial value of the voltage detection level select register (LVIS) is set to 00H.
 - Bit 7 (LVIMD) is 0 (interrupt mode).
 - Bit 0 (LVILV) is 0 (high-voltage detection level: V_{LVDH}).

- Operation in LVD interrupt & reset mode

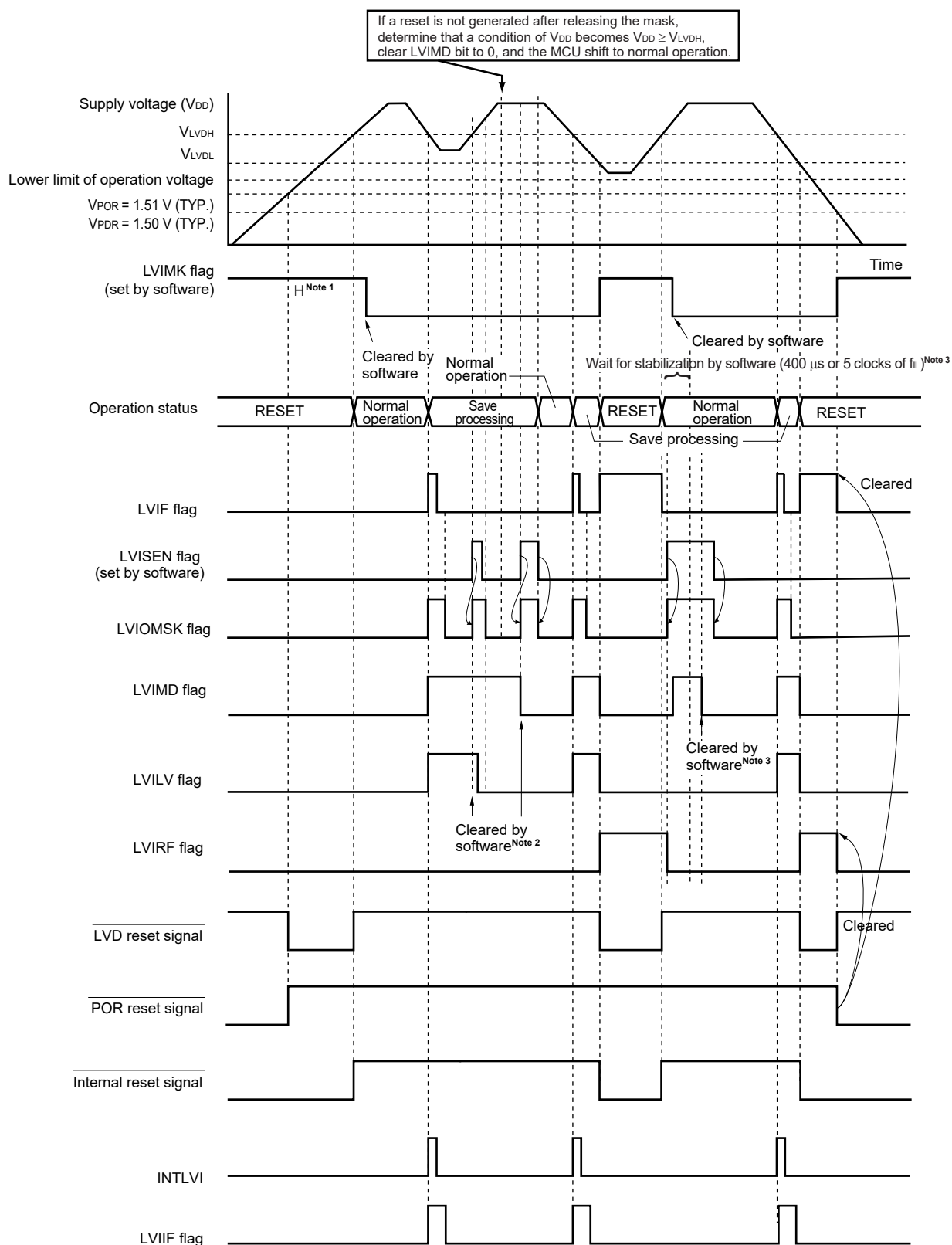
In the interrupt & reset mode (option byte LVIMDS1, LVIMDS0 = 1, 0), the state of an internal reset by LVD is retained until the supply voltage (V_{DD}) exceeds the high-voltage detection level (V_{LVDH}) after power is supplied. The internal reset is released when the supply voltage (V_{DD}) exceeds the high-voltage detection level (V_{LVDH}).

At the fall of the operating voltage, an interrupt request signal (INTLVI) by LVD is generated and arbitrary save processing is performed when the supply voltage (V_{DD}) falls below the high-voltage detection level (V_{LVDH}). After that, an internal reset by LVD is generated when the supply voltage (V_{DD}) falls below the low-voltage detection level (V_{LVDL}). However, after INTLVI is generated, an interrupt request signal is not generated even if the supply voltage becomes equal to or higher than the high-voltage detection voltage (V_{LVDH}) without falling below the low-voltage detection voltage (V_{LVDL}).

To use the LVD reset & interrupt mode, perform the processing according to **Figure 21-8 Processing Procedure After an Interrupt Is Generated** and **Figure 21-9 Setting Procedure for Initial Setting of Interrupt and Reset Mode**.

Figure 21-7 shows the timing of the internal reset signal and interrupt signal generated in the LVD interrupt & reset mode.

Figure 21-7. Timing of Voltage Detector Reset Signal and Interrupt Signal Generation
(Option Byte LVIMDS1, LVIMDS0 = 1, 0) (1/2)

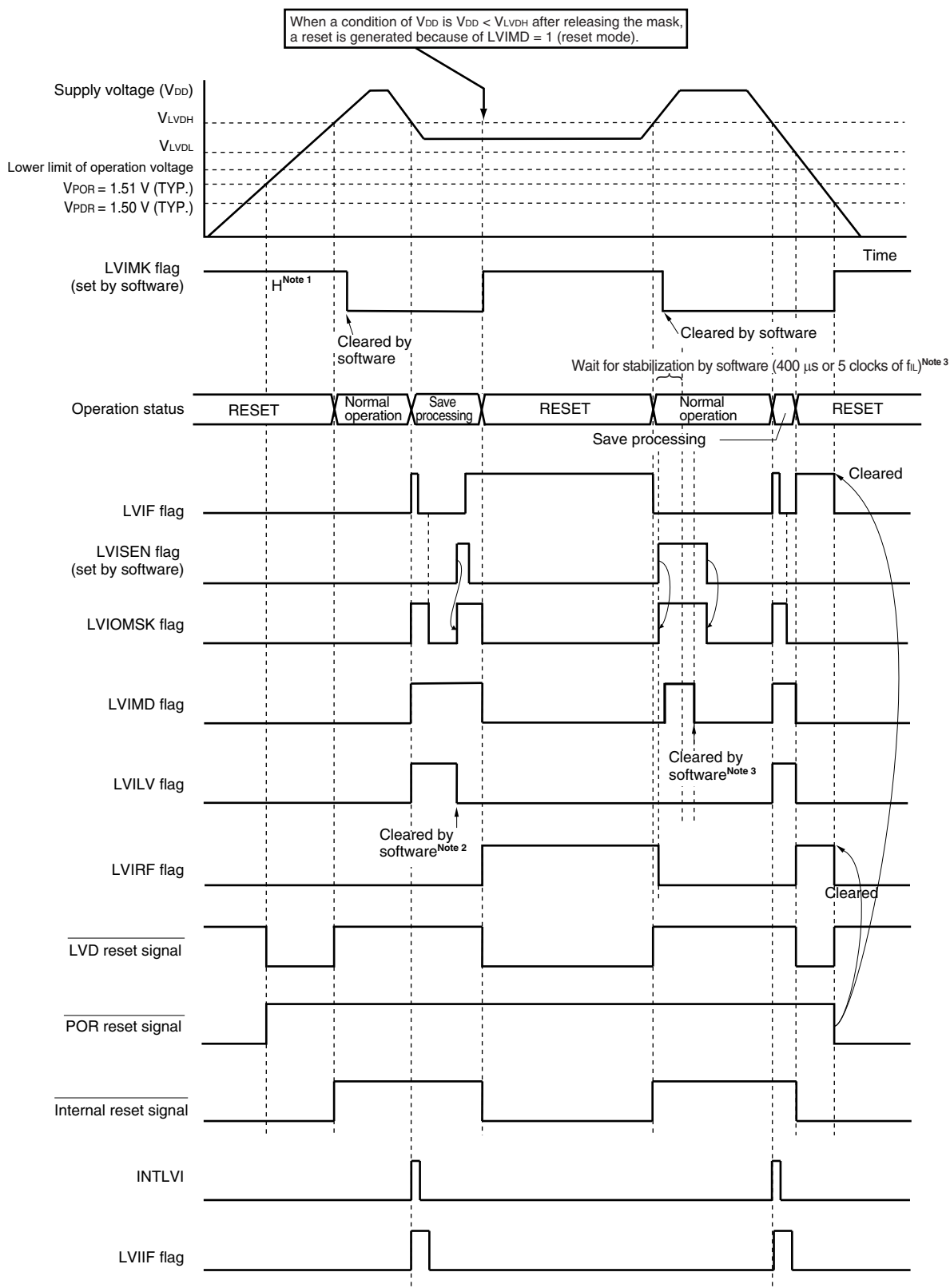


(Notes and Remark are listed on the next page.)

- Notes**
1. The LVIMK flag is set to "1" by reset signal generation.
 2. After an interrupt is generated, perform the processing according to **Figure 21-8 Processing Procedure After an Interrupt Is Generated**.
 3. After a reset is released, perform the processing according to **Figure 21-9 Setting Procedure for Initial Setting of Interrupt and Reset Mode**.

Remark V_{POR} : POR power supply rise detection voltage
 V_{PDR} : POR power supply fall detection voltage

Figure 21-7. Timing of Voltage Detector Reset Signal and Interrupt Signal Generation
(Option Byte LVIMDS1, LVIMDS0 = 1, 0) (2/2)

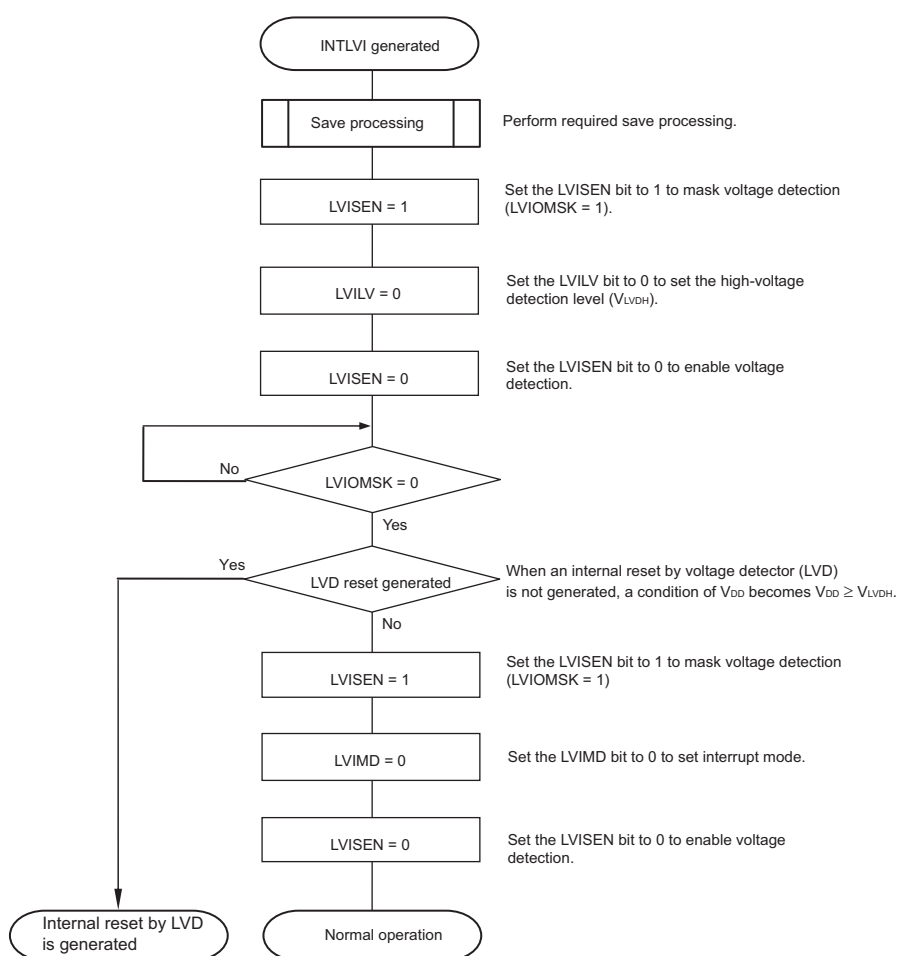


(**Notes** and **Remark** are listed on the next page.)

- Notes**
1. The LVIMK flag is set to "1" by reset signal generation.
 2. After an interrupt is generated, perform the processing according to **Figure 21-8 Processing Procedure After an Interrupt Is Generated**.
 3. After a reset is released, perform the processing according to **Figure 21-9 Setting Procedure for Initial Setting of Interrupt and Reset Mode**.

Remark V_{POR} : POR power supply rise detection voltage
 V_{PDR} : POR power supply fall detection voltage

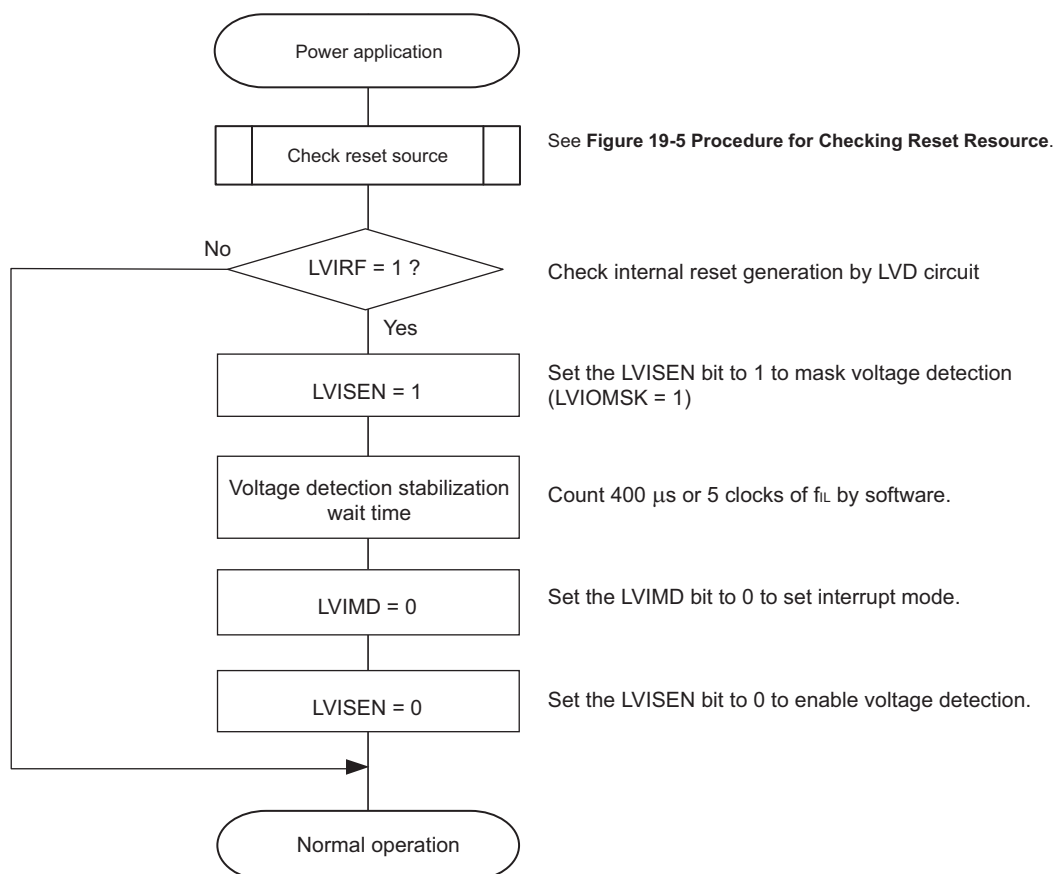
Figure 21-8. Processing Procedure After an Interrupt Is Generated



When setting an interrupt and reset mode (LVIMDS1, LVIMDS0 = 1, 0), voltage detection stabilization wait time for 400 μ s or 5 clocks of f_{IL} is necessary after LVD reset is released (LVIRF = 1). After waiting until voltage detection stabilizes, (0) clear the LVIMD bit for initialization. While voltage detection stabilization wait time is being counted and when the LVIMD bit is rewritten, set LVISEN to 1 to mask a reset or interrupt generation by LVD.

Figure 21-9 shows the procedure for initial setting of interrupt and reset mode.

Figure 21-9. Setting Procedure for Initial Setting of Interrupt and Reset Mode



Remark f_{IL} : Low-speed on-chip oscillator clock frequency

21.5 Cautions for Voltage Detector

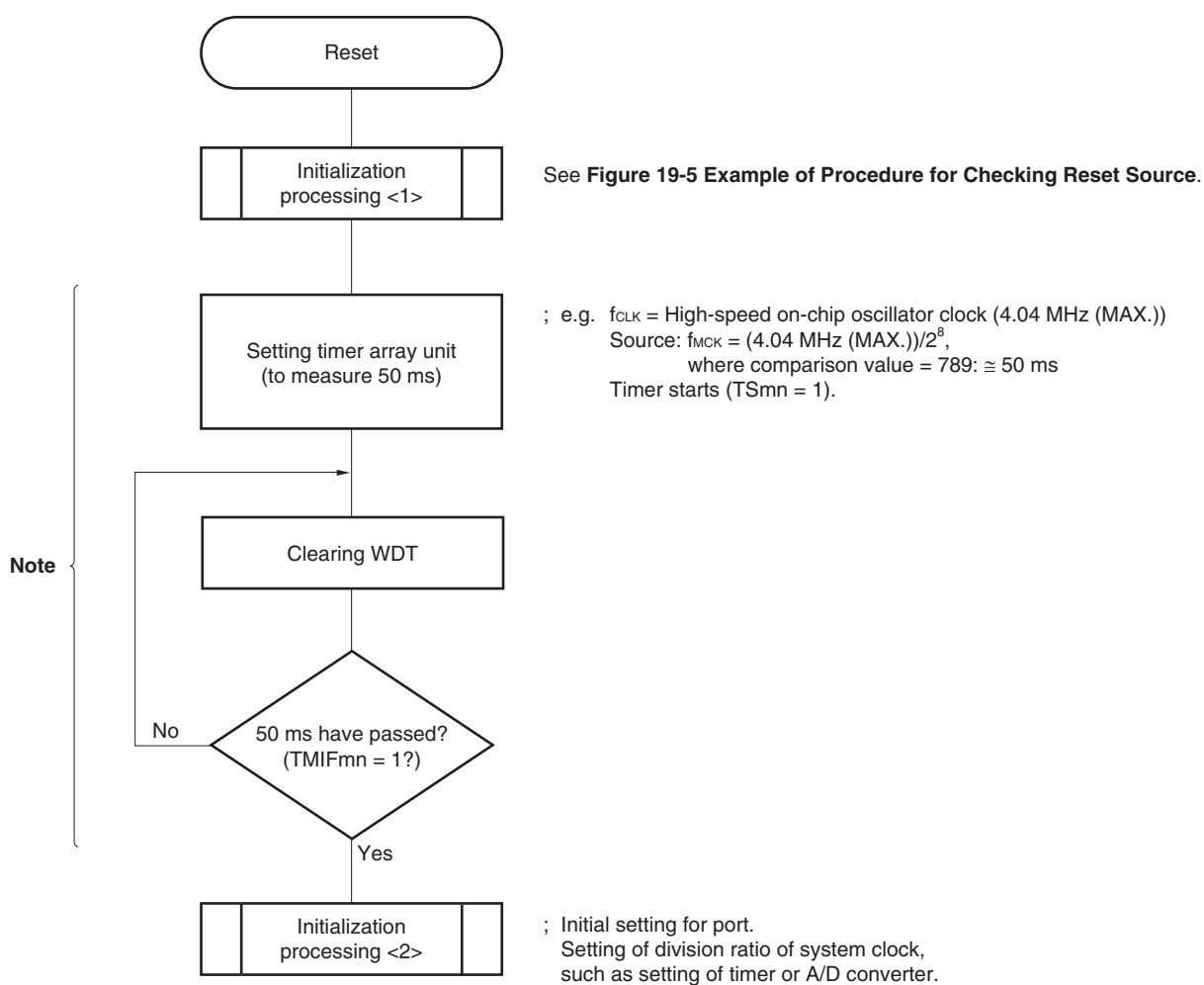
(1) Voltage fluctuation when power is supplied

In a system where the supply voltage (V_{DD}) fluctuates for a certain period in the vicinity of the LVD detection voltage, the system may be repeatedly reset and released from the reset status. In this case, the time from release of reset to the start of the operation of the microcontroller can be arbitrarily set by taking the following action.

<Action>

After releasing the reset signal, wait for the supply voltage fluctuation period of each system by means of a software counter that uses a timer, and then initialize the ports.

Figure 21-10. Example of Software Processing If Supply Voltage Fluctuation Is 50 ms or Less in Vicinity of LVD Detection Voltage



Note If reset is generated again during this period, initialization processing <2> is not started.

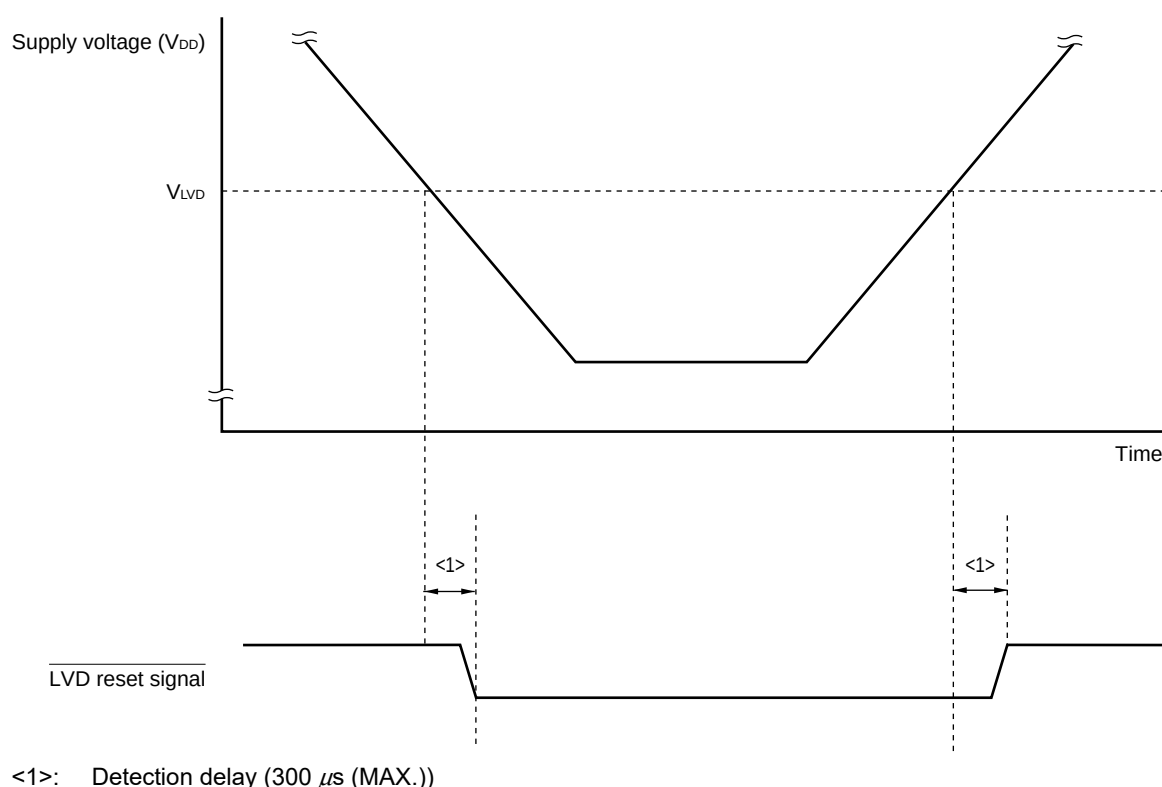
Remark $m = 0$
 $n = 0 \text{ to } 7$

(2) Delay from the time LVD reset source is generated until the time LVD reset has been generated or released

There is some delay from the time supply voltage (V_{DD}) < LVD detection voltage (V_{LVD}) until the time LVD reset has been generated.

In the same way, there is also some delay from the time LVD detection voltage (V_{LVD}) $\leq$ supply voltage (V_{DD}) until the time LVD reset has been released (see **Figure 21-11**).

Figure 21-11. Delay from the Time LVD Reset Source Is Generated Until the Time LVD Reset has Been Generated or Released

**(3) Power on when LVD is off**

Use the external reset input via the $\overline{\text{RESET}}$ pin when the LVD is off.

For an external reset, input a low level for 10 μs or more to the $\overline{\text{RESET}}$ pin. To perform an external reset upon power application, input a low level to the $\overline{\text{RESET}}$ pin, turn power on, continue to input a low level to the pin for 10 μs or more within the operating voltage range shown in **29.4** or **30.4 AC Characteristics**, and then input a high level to the pin.

(4) Operating voltage fall when LVD is off or LVD interrupt mode is selected

When the operating voltage falls with the LVD is off or with the LVD interrupt mode is selected, this LSI should be placed in the STOP mode, or placed in the reset state by controlling the externally input reset signal, before the voltage falls below the operating voltage range defined in **29.4** or **30.4 AC characteristics**. When restarting the operation, make sure that the operation voltage has returned within the range of operation.

CHAPTER 22 SAFETY FUNCTIONS

22.1 Overview of Safety Functions

<R>

The following safety functions are provided in the RL78/G1A to comply with the IEC60730 safety standards.

These functions enable the microcontroller to self-diagnose abnormalities and stop operating if an abnormality is detected.

(1) Flash memory CRC operation function (high-speed CRC, general-purpose CRC)

This detects data errors in the flash memory by performing CRC operations.

Two CRC functions are provided in the RL78/G1A that can be used according to the application or purpose of use.

- High-speed CRC: The CPU can be stopped and a high-speed check executed on its entire code flash memory area during the initialization routine.
- General CRC: This can be used for checking various data in addition to the code flash memory area while the CPU is running.

(2) RAM parity error detection function

This detects parity errors when reading RAM data.

(3) RAM guard function

This prevents RAM data from being rewritten when the CPU freezes.

(4) SFR guard function

This prevents SFRs from being rewritten when the CPU freezes.

(5) Invalid memory access detection function

This detects illegal accesses to invalid memory areas (such as areas where no memory is allocated and areas to which access is restricted).

(6) Frequency detection function

This function allows a self-check of the CPU/peripheral hardware clock frequencies using the timer array unit.

(7) A/D test function

This is used to perform a self-check of the A/D converter by performing A/D conversion of the A/D converter's positive and negative reference voltages, analog input channel (ANI), temperature sensor output voltage, and internal reference voltage.

Remark For usage examples of the safety functions complying with the IEC60730 safety standards, refer to the RL78 MCU series IEC60730/60335 application notes (R01AN1062, R01AN1296).

22.2 Registers Used by Safety Functions

The safety functions use the following registers for each function.

Register	Each Function of Safety Function
- Flash memory CRC control register (CRC0CTL) - Flash memory CRC operation result register (PGCRCL)	Flash memory CRC operation function (high-speed CRC)
- CRC input register (CRCIN) - CRC data register (CRCD)	CRC operation function (general-purpose CRC)
RAM parity error control register (RPECTL)	RAM parity error detection function
Invalid memory access detection control register (IAWCTL)	RAM guard function
	SFR guard function
	Invalid memory access detection function
Timer input select register 0 (TIS0)	Frequency detection function
A/D test register (ADTES)	A/D test function

The content of each register is described in **22.3 Operation of Safety Functions**.

22.3 Operation of Safety Functions

22.3.1 Flash memory CRC operation function (high-speed CRC)

The IEC60730 standard mandates the checking of data in the flash memory, and recommends using CRC to do it. The high-speed CRC provided in the RL78/G1A can be used to check the entire code flash memory area during the initialization routine. The high-speed CRC can be executed only when the program is allocated on the RAM and in the HALT mode of the main system clock.

The high-speed CRC performs an operation by reading 32-bit data per clock from the flash memory while stopping the CPU. This function therefore can finish a check in a shorter time (for example, 512 μ s@32 MHz with 64 KB flash memory).

The CRC generator polynomial used complies with “ $X^{16} + X^{12} + X^5 + 1$ ” of CRC-16-CCITT.

The high-speed CRC operates in MSB first order from bit 31 to bit 0.

Caution The CRC operation result might differ during on-chip debugging because the monitor program is allocated.

Remark The operation result is different between the high-speed CRC and the general CRC, because the general CRC operates in LSB first order.

22.3.1.1 Flash memory CRC control register (CRC0CTL)

This register is used to control the operation of the high-speed CRC ALU, as well as to specify the operation range.

The CRC0CTL register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-1. Format of Flash Memory CRC Control Register (CRC0CTL)

Address: F02F0H After reset: 00H R/W

Symbol	<7>	6	5	4	3	2	1	0
CRC0CTL	CRC0EN	0	FEA5	FEA4	FEA3	FEA2	FEA1	FEA0

CRC0EN	Control of CRC ALU operation
0	Stop the operation.
1	Start the operation according to HALT instruction execution.

FEA5	FEA4	FEA3	FEA2	FEA1	FEA0	High-speed CRC operation range
0	0	0	0	0	0	00000H to 03FFBH (16 Kbytes - 4 bytes)
0	0	0	0	0	1	00000H to 07FFBH (32 Kbytes - 4 bytes)
0	0	0	0	1	0	00000H to 0BFFBH (48 Kbytes - 4 bytes)
0	0	0	0	1	1	00000H to 0FFFBH (64 Kbytes - 4 bytes)
Other than above						Setting prohibited

Remark Input the expected CRC operation result value to be used for comparison in the lowest 4 bytes of the flash memory. Note that the operation range will thereby be reduced by 4 bytes.

22.3.1.2 Flash memory CRC operation result register (PGCRCL)

This register is used to store the high-speed CRC operation results.

The PGCRCL register can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears this register to 0000H.

Figure 22-2. Format of Flash Memory CRC Operation Result Register (PGCRCL)

Address: F02F2H After reset: 0000H R/W

Symbol	15	14	13	12	11	10	9	8
PGCRCL	PGCRC15	PGCRC14	PGCRC13	PGCRC12	PGCRC11	PGCRC10	PGCRC9	PGCRC8
	7	6	5	4	3	2	1	0
	PGCRC7	PGCRC6	PGCRC5	PGCRC4	PGCRC3	PGCRC2	PGCRC1	PGCRC0

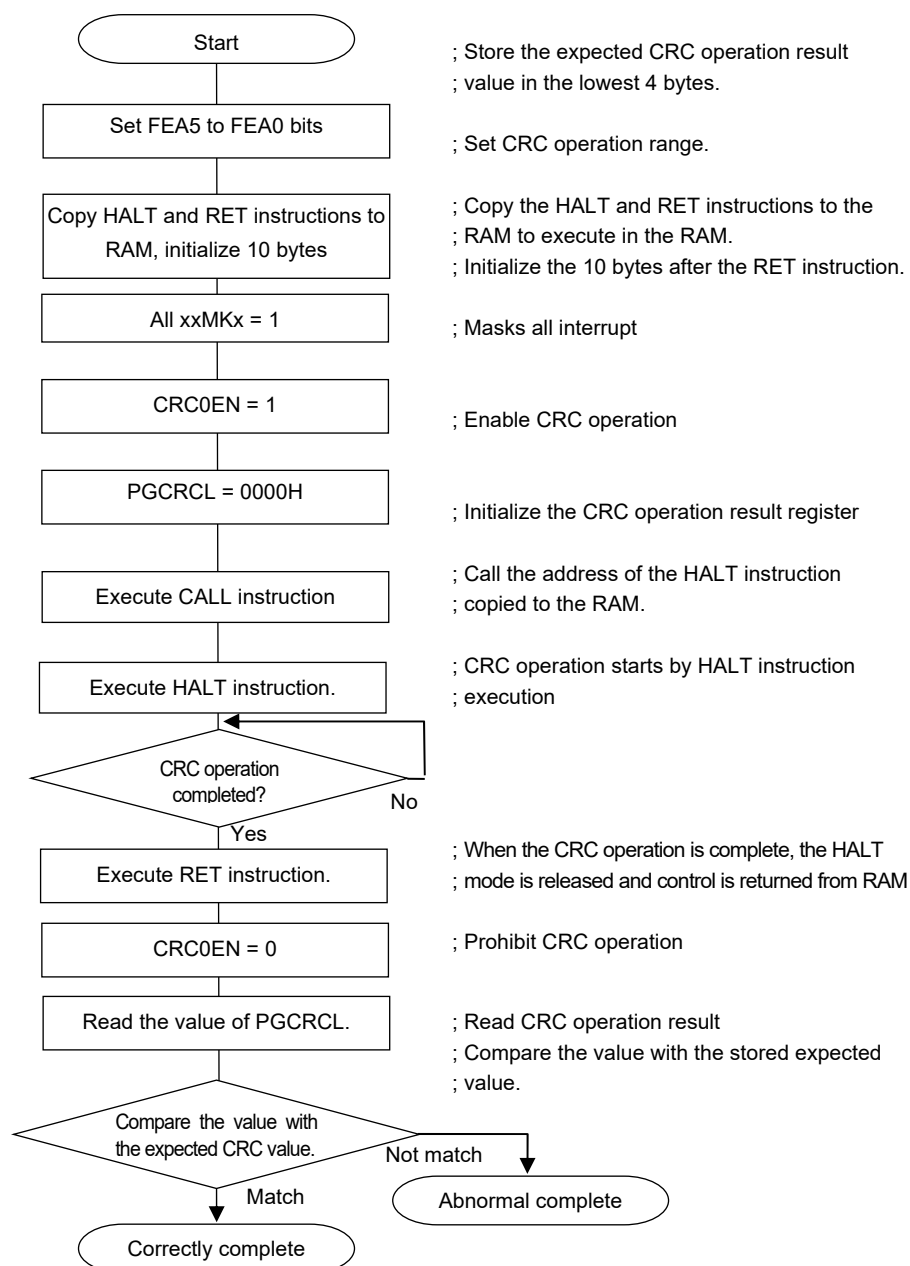
PGCRC15 to 0	High-speed CRC operation results
0000H to FFFFH	Store the high-speed CRC operation results.

Caution The PGCRCL register can only be written if CRC0EN (bit 7 of the CRC0CTL register) = 1.

Figure 22-3 shows the flowchart of flash memory CRC operation function (high-speed CRC).

<Operation flow>

Figure 22-3. Flowchart of Flash Memory CRC Operation Function (High-speed CRC)



- Cautions**
1. The CRC operation is executed only on the code flash.
 2. Store the expected CRC operation value in the area below the operation range in the code flash.
 3. The CRC operation is enabled by executing the HALT instruction in the RAM area.
Be sure to execute the HALT instruction in RAM area.

The expected CRC value can be calculated by using the Integrated Development Environment CubeSuite+. See the Integrated Development Environment CubeSuite+ user's manual for details.

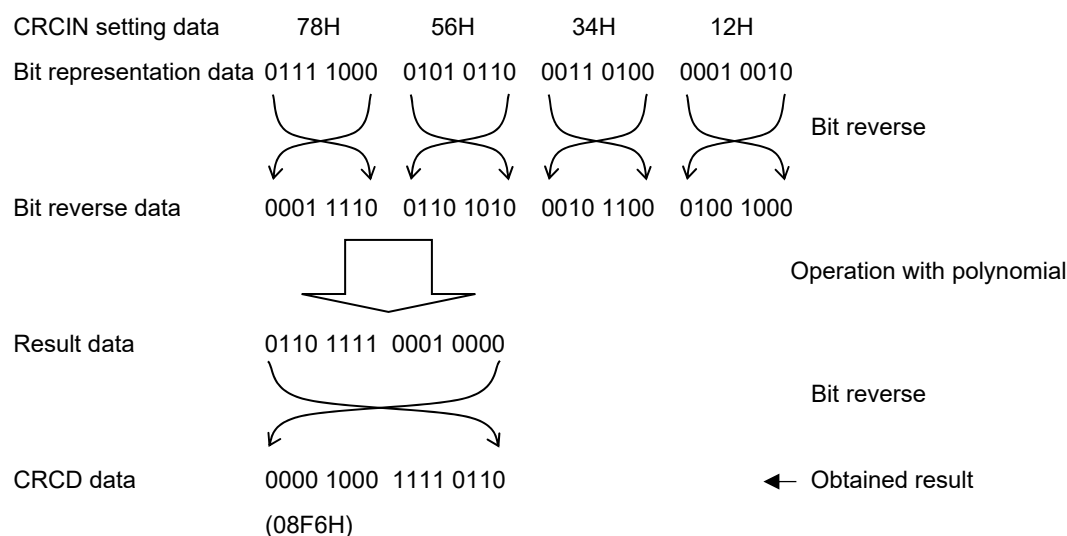
22.3.2 CRC operation function (general-purpose CRC)

<R>

In the RL78/G1A, a general CRC operation can be executed as a peripheral function while the CPU is operating. The general CRC can be used for checking various data in addition to the code flash memory area. The data to be checked can be specified by using software (a user-created program). CRC calculation function in the HALT mode can be used only during the DMA transmission.

The general CRC operation can be executed in the main system clock operation mode as well as the subsystem clock operation mode.

The CRC generator polynomial used is " $X^{16} + X^{12} + X^5 + 1$ " of CRC-16-CCITT. The data to be input is inverted in bit order and then calculated to allow for LSB-first communication. For example, if the data 12345678H is sent from the LSB, values are written to the CRCIN register in the order of 78H, 56H, 34H, and 12H, enabling a value of 08F6H to be obtained from the CRCD register. This is the result obtained by executing a CRC operation on the bit rows shown below, which consist of the data 12345678H inverted in bit order.



Caution Because the debugger rewrites the software break setting line to a break instruction during program execution, the CRC operation result differs if a software break is set in the CRC operation target area.

22.3.2.1 CRC input register (CRCIN)

CRCIN register is an 8-bit register that is used to set the CRC operation data of general-purpose CRC.

The possible setting range is 00H to FFH.

The CRCIN register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-4. Format of CRC Input Register (CRCIN)

Address: FFFACH After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
CRCIN								
Bits 7 to 0				Function				
00H to FFH				Data input.				

22.3.2.2 CRC data register (CRCD)

This register is used to store the CRC operation result of the general-purpose CRC.

The setting range is 0000H to FFFFH.

After 1 clock of CPU/peripheral hardware clock (f_{CLK}) has elapsed from the time CRCIN register is written, the CRC operation result is stored to the CRCD register.

The CRCD register can be set by a 16-bit memory manipulation instruction.

Reset signal generation clears this register to 0000H.

Figure 22-5. Format of CRC Data Register (CRCD)

Address: F02FAH After reset: 0000H R/W

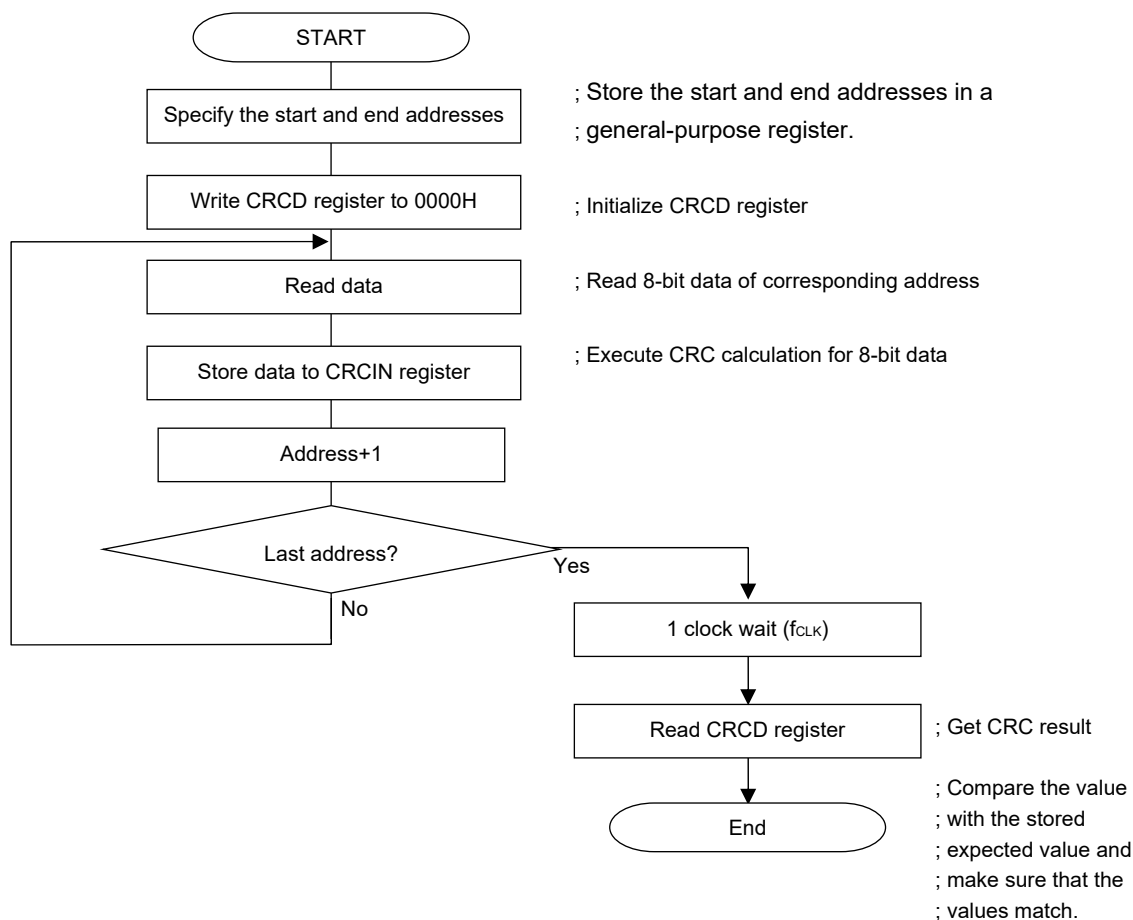
Symbol	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRCD																

Cautions 1. Read the value written to CRCD register before writing to CRCIN register.

2. If conflict between writing and storing operation result to CRCD register occurs, the writing is ignored.

<Operation flow>

Figure 22-6. CRC Operation Function (General-Purpose CRC)



22.3.3 RAM parity error detection function

The IEC60730 standard mandates the checking of RAM data. A single-bit parity bit is therefore added to all 8-bit data in the RL78/G1A's RAM. By using this RAM parity error detection function, the parity bit is appended when data is written, and the parity is checked when the data is read. This function can also be used to trigger a reset when a parity error occurs.

22.3.3.1 RAM parity error control register (RPECTL)

This register is used to control parity error generation check bit and reset generation due to parity errors.

The RPECTL register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-7. Format of RAM Parity Error Control Register (RPECTL)

Address: F00F5H After reset: 00H R/W

Symbol	<7>	6	5	4	3	2	1	<0>
RPECTL	RPERDIS	0	0	0	0	0	0	RPEF

RPERDIS	Parity error reset mask flag
0	Enable parity error resets.
1	Disable parity error resets.

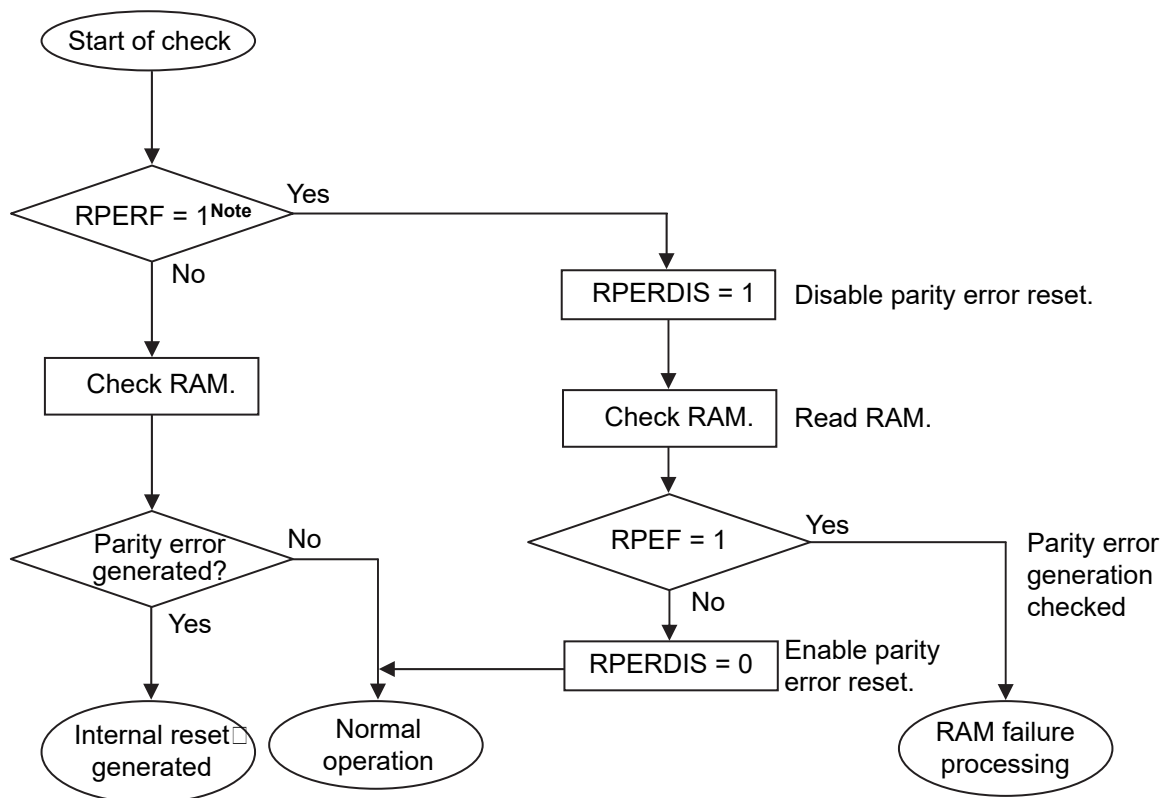
RPEF	Parity error status flag
0	No parity error has occurred.
1	A parity error has occurred.

Caution The parity bit is appended when data is written, and the parity is checked when the data is read. Therefore, while RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize RAM areas where data access is to proceed before reading data.

The RL78's CPU executes look-ahead due to the pipeline operation, the CPU might read an uninitialized RAM area that is allocated beyond the RAM used, which causes a RAM parity error. Therefore, while RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize the RAM area + 10 bytes when instructions are fetched from RAM areas. When using the self-programming function while RAM parity error resets are enabled (RPERDIS = 0), be sure to initialize the RAM area to overwrite + 10 bytes before overwriting.

- Remarks**
1. The parity error reset is enabled by default (RPERDIS = 0).
 2. Even if the parity error reset is disabled (RPERDIS = 1), the RPEF flag will be set (1) if a parity error occurs. If parity error resets are enabled (RPERDIS = 0) with RPEF set to 1, a parity error reset is generated when the RPERDIS bit is cleared to 0.
 3. The RPEF flag in the RPECTL register is set (1) when the RAM parity error occurs and cleared (0) by writing 0 to it or by any reset source. When RPEF = 1, the value is retained even if RAM for which no parity error has occurred is read.
 4. The general registers are not included for RAM parity error detection.

Figure 22-8. Flowchart of RAM Parity Check



Note To check internal reset status using a RAM parity error, see **CHAPTER 19 RESET FUNCTION**.

22.3.4 RAM guard function

<R> This RAM guard function is used to protect data in the specified memory space.

If the RAM guard function is specified, writing to the specified RAM space is disabled, but reading from the space can be carried out as usual.

22.3.4.1 Invalid memory access detection control register (IAWCTL)

This register is used to control the detection of invalid memory access and RAM/SFR guard function.

GRAM1 and GRAM0 bits are used in RAM guard function.

The IAWCTL register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-9. Format of Invalid Memory Access Detection Control Register (IAWCTL)

Address: F0078H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
IAWCTL	IAWEN	0	GRAM1	GRAM0	0	GPORT	GINT	GCSC

GRAM1	GRAM0	RAM guard space ^{Note}
0	0	Disabled. RAM can be written to.
0	1	The 128 bytes of space starting at the start address in the RAM
1	0	The 256 bytes of space starting at the start address in the RAM
1	1	The 512 bytes of space starting at the start address in the RAM

Note The RAM start address differs depending on the size of the RAM provided with the product.

22.3.5 SFR guard function

<R>

This SFR guard function is used to protect data in the control registers used by the port function, interrupt function, clock control function, voltage detection function, and RAM parity error function.

If the SFR guard function is specified, writing to the specified SFRs is disabled, but reading from the SFRs can be carried out as usual.

22.3.5.1 Invalid memory access detection control register (IAWCTL)

This register is used to control the detection of invalid memory access and RAM/SFR guard function.

GPORT, GINT and GCSC bits are used in SFR guard function.

The IAWCTL register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-10. Format of Invalid Memory Access Detection Control Register (IAWCTL)

Address: F0078H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
IAWCTL	IAWEN	0	GRAM1	GRAM0	0	GPORT	GINT	GCSC

GPORT	Control registers of port function guard
0	Disabled. Control registers of port function can be read or written to.
1	Enabled. Writing to control registers of port function is disabled. Reading is enabled. [Guarded SFR] PMxx, PUxx, PIMxx, POMxx, PMCxx, ADPC, PIOR ^{Note}

GINT	Registers of interrupt function guard
0	Disabled. Registers of interrupt function can be read or written to.
1	Enabled. Writing to registers of interrupt function is disabled. Reading is enabled. [Guarded SFR] IFxx, MKxx, PRxx, EGPx, EGNx

GCSC	Control registers of clock control function, voltage detector and RAM parity error detection function guard
0	Disabled. Control registers of clock control function, voltage detector and RAM parity error detection function can be read or written to.
1	Enabled. Writing to control registers of clock control function, voltage detector and RAM parity error detection function is disabled. Reading is enabled. [Guarded SFR] CMC, CSC, OSTs, CKC, PERx, OSMC, LVIM, LVIS, RPECTL

Note Pxx (Port register) is not guarded.

22.3.6 Invalid memory access detection function

The IEC60730 standard mandates checking that the CPU and interrupts are operating correctly.

The illegal memory access detection function triggers a reset if a memory space specified as access-prohibited is accessed.

The illegal memory access detection function applies to the areas indicated by NG in Figure 22-11.

Figure 22-11. Invalid Access Detection Area

		Accessibility		
		Read	Write	Instruction fetch (execution)
FFFFFH	Special function register (SFR) 256 bytes	OK	OK	NG
FFF00H FFEFFH	General-purpose register 32 bytes			OK
FFEE0H FFEDFH	RAM ^{Note}			
zzzzzH				
⋮	Mirror	OK	NG	NG
	Data flash memory			
F1000H F0FFFH	Reserved		OK	OK
F0800H F07FFH	Special function register (2nd SFR) 2 Kbytes			NG
F0000H EFFFFH	⋮	NG	NG	OK
EF000H EEFFFH				
⋮	Reserved	NG	NG	NG
yyyyyH	⋮			
xxxxxH				
⋮	Code flash memory ^{Note}			
00000H				

Note The following table lists the code flash memory, RAM, and lowest detection address for each product:

(The explanation is described on the next page.)

Products	Code Flash Memory (00000H to xxxxxH)	RAM (zzzzzH to FFEFFH)	Detected Lowest Address for Read/Instruction Fetch (Execution) (yyyyyH)
R5F10ExA (x = 8, B, G)	16384 × 8 bit (00000H to 03FFFFH)	2048 × 8 bit (FF700H to FFEFFH)	10000H
R5F10ExC (x = 8, B, G, ,L)	32768 × 8 bit (00000H to 07FFFFH)	2048 × 8 bit (FF700H to FFEFFH)	10000H
R5F10ExD (x = 8, B, G, L)	49152 × 8 bit (00000H to 0BFFFFH)	3072 × 8 bit (FF300H to FFEFFH)	10000H
R5F10ExE (x = 8, B, G, L)	65536 × 8 bit (00000H to 0FFFFH)	4096 × 8 bit (FEF00H to FFEFFH)	10000H

22.3.6.1 Invalid memory access detection control register (IAWCTL)

This register is used to control the detection of invalid memory access and RAM/SFR guard function.

IAWEN bit is used in invalid memory access detection function.

The IAWCTL register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-12. Format of Invalid Memory Access Detection Control Register (IAWCTL)

Address: F0078H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
IAWCTL	IAWEN	0	GRAM1	GRAM0	0	GPORT	GINT	GCSC

IAWEN ^{Note}	Control of invalid memory access detection
0	Disable the detection of invalid memory access.
1	Enable the detection of invalid memory access.

Note Only writing 1 to the IAWEN bit is enabled, not writing 0 to it after setting it to 1.

Remark By specifying WDTON = 1 (watchdog timer operation enable) for the option byte (000C0H), the invalid memory access function is enabled even IAWEN = 0.

22.3.7 Frequency detection function

The IEC60730 standard mandates checking that the oscillation frequency is correct.

By using the CPU/peripheral hardware clock frequency (f_{CLK}) and measuring the pulse width of the input signal to channel 5 of the timer array unit 0 (TAU0), whether the proportional relationship between the two clock frequencies is correct can be determined. Note that, however, if one or both clock operations are completely stopped, the proportional relationship between the clocks cannot be determined.

<Clocks to be compared>

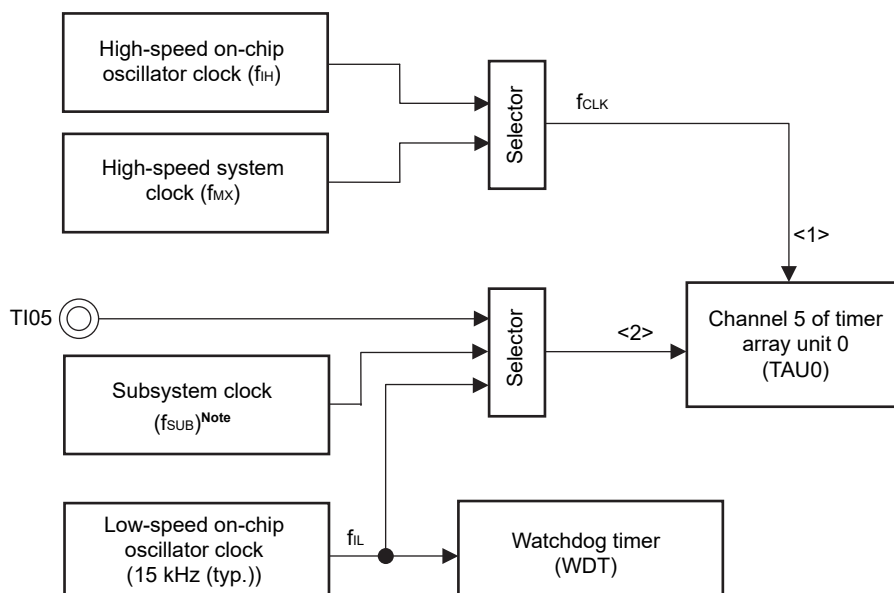
<1> CPU/peripheral hardware clock frequency (f_{CLK}):

- High-speed on-chip oscillator clock (f_{IH})
- High-speed system clock (f_{MX})

<2> Input to channel 5 of the timer array unit

- Timer input to channel 5 (TI05)
- Low-speed on-chip oscillator clock (f_{IL} : 15 kHz (typ.))
- Subsystem clock (f_{SUB})^{Note}

Figure 22-13. Configuration of Frequency Detection Function



If input pulse interval measurement results in an abnormal value, it can be concluded that the clock frequency is abnormal.

For how to execute input pulse interval measurement, see **6.8.4 Operation as input pulse interval measurement**.

Note Can only be selected in the products incorporating the subsystem clock.

22.3.7.1 Timer input select register 0 (TIS0)

The TIS0 register is used to select the timer input of channel 5 of the timer array unit 0 (TAU0).

The TIS0 register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-14. Format of Timer Input Select Register 0 (TIS0)

Address: F0074H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
TIS0	0	0	0	0	0	TIS02	TIS01	TIS00

TIS02	TIS01	TIS00	Selection of timer input used with channel 5
0	0	0	Input signal of timer input pin (TI05)
0	0	1	
0	1	0	
0	1	1	
1	0	0	Low-speed on-chip oscillator clock (f_{IL})
1	0	1	Subsystem clock (f_{SUB})
Other than above			Setting prohibited

22.3.8 A/D test function

The IEC60730 standard mandates testing the A/D converter. The A/D test function checks whether or not the A/D converter is operating normally by executing A/D conversions of the A/D converter's positive and negative reference voltages, analog input channel (ANI), temperature sensor output voltage, and the internal reference voltage. For details of the check method, see the safety function (A/D test) application note (R01AN0955).

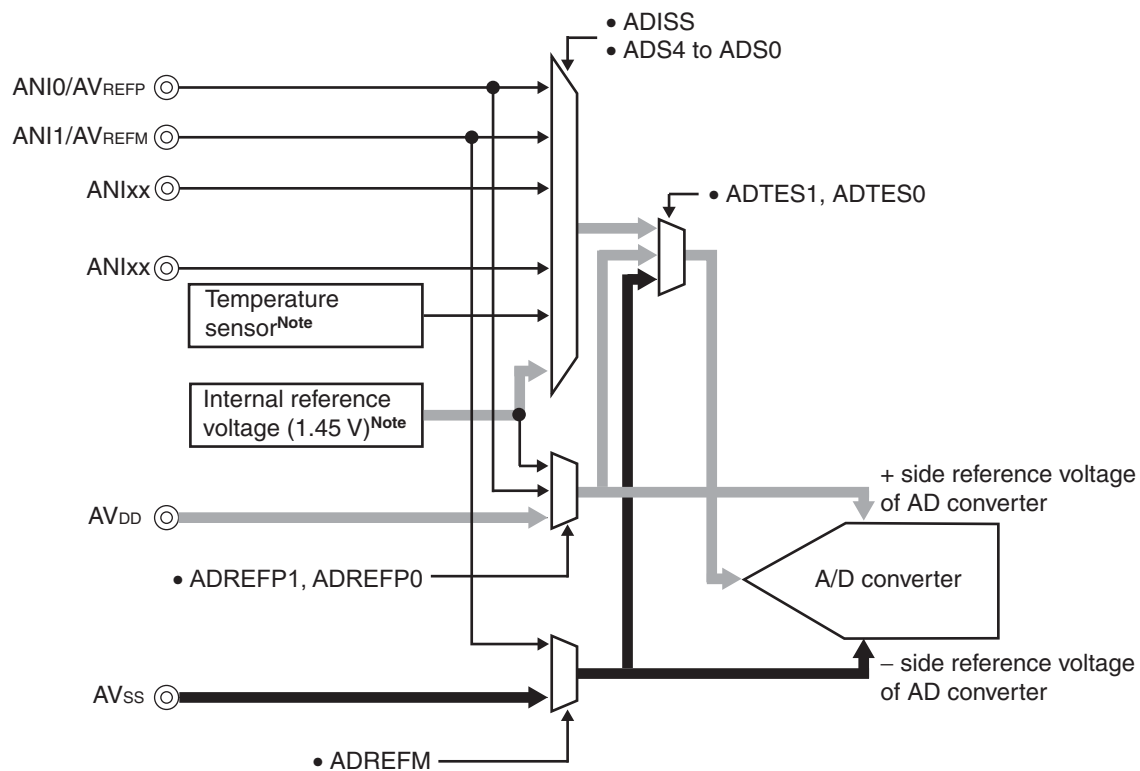
The analog multiplexer can be checked using the following procedure.

- <1> Select the ANIx pin for A/D conversion using the ADTES register (ADTES1 = 0, ADTES0 = 0).
- <2> Perform A/D conversion for the ANIx pin (conversion result 1-1).
- <3> Select the A/D converter's negative reference voltage for A/D conversion using the ADTES register (ADTES1 = 1, ADTES0 = 0)
- <4> Perform A/D conversion of the negative reference voltage of the A/D converter (conversion result 2-1).
- <5> Select the ANIx pin for A/D conversion using the ADTES register (ADTES1 = 0, ADTES0 = 0).
- <6> Perform A/D conversion for the ANIx pin (conversion result 1-2).
- <7> Select the A/D converter's positive reference voltage for A/D conversion using the ADTES register (ADTES1 = 1, ADTES0 = 1)
- <8> Perform A/D conversion of the positive reference voltage of the A/D converter (conversion result 2-2).
- <9> Select the ANIx pin for A/D conversion using the ADTES register (ADTES1 = 0, ADTES0 = 0).
- <10> Perform A/D conversion for the ANIx pin (conversion result 1-3).
- <11> Check that the conversion results 1-1, 1-2, and 1-3 are equal.
- <12> Check that the A/D conversion result 2-1 is all zero and conversion result 2-2 is all one.

Using the procedure above can confirm that the analog multiplexer is selected and all wiring is connected.

- Remarks**
1. If the analog input voltage is variable during A/D conversion in steps <1> to <10> above, use another method to check the analog multiplexer.
 2. The conversion results might contain an error. Consider an appropriate level of error when comparing the conversion results.

Figure 22-15. Configuration of A/D Test Function



Note This setting can be used only in HS (high-speed main) mode.

22.3.8.1 A/D test register (ADTES)

This register is used to select the A/D converter's positive reference voltage, A/D converter's negative reference voltage, analog input channel (ANLxx), temperature sensor output voltage, or internal reference voltage (1.45 V) as the target of A/D conversion.

When using the A/D test function, specify the following settings:

- Select negative reference voltage as the target of A/D conversion for zero-scale measurement.
- Select positive reference voltage as the target of A/D conversion for full-scale measurement.

The ADTES register can be set by an 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-16. Format of A/D Test Register (ADTES)

Address: F0013H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADTES	0	0	0	0	0	0	ADTES1	ADTES0

ADTES1	ADTES0	A/D conversion target
0	0	ANLxx/temperature sensor output voltage ^{Note} /internal reference voltage (1.45 V) ^{Note} (This is specified using the analog input channel specification register (ADS).)
1	0	Negative reference voltage (selected with the ADREFM bit in ADM2)
1	1	Positive reference voltage (selected with the ADREFP1 or ADREFP0 bit in ADM2)
Other than above		Setting prohibited

Note Temperature sensor output voltage and internal reference voltage (1.45 V) can be used only in HS (high-speed main) mode.

22.3.8.2 Analog input channel specification register (ADS)

This register specifies the input channel of the analog voltage to be A/D converted.

Set A/D test register (ADTES) to 00H when measuring the ANLxx/temperature sensor output voltage/internal reference voltage (1.45 V).

The ADS register can be set by a 1-bit or 8-bit memory manipulation instruction.

Reset signal generation clears this register to 00H.

Figure 22-17. Format of Analog Input Channel Specification Register (ADS) (1/2)

Address: FFF31H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	0
ADS	ADISS	0	0	ADS4	ADS3	ADS2	ADS1	ADS0

○ Select mode (ADMD = 0)

ADISS	ADS4	ADS3	ADS2	ADS1	ADS0	Analog input channel	Input source
0	0	0	0	0	0	ANI0	P20/ANI0/AV _{REFP} pin
0	0	0	0	0	1	ANI1	P21/ANI1/AV _{REFM} pin
0	0	0	0	1	0	ANI2	P22/ANI2 pin
0	0	0	0	1	1	ANI3	P23/ANI3 pin
0	0	0	1	0	0	ANI4	P24/ANI4 pin
0	0	0	1	0	1	ANI5	P25/ANI5 pin
0	0	0	1	1	0	ANI6	P26/ANI6 pin
0	0	0	1	1	1	ANI7	P27/ANI7 pin
0	0	1	0	0	0	ANI8	P150/ANI8 pin
0	0	1	0	0	1	ANI9	P151/ANI9 pin
0	0	1	0	1	0	ANI10	P152/ANI10 pin
0	0	1	0	1	1	ANI11	P153/ANI11 pin
0	0	1	1	0	0	ANI12	P154/ANI12 pin
0	0	1	1	0	1	Setting prohibited	
0	0	1	1	1	0	Setting prohibited	
0	0	1	1	1	1	Setting prohibited	
0	1	0	0	0	0	ANI16	P03/ANI16 pin
0	1	0	0	0	1	ANI17	P02/ANI17 pin
0	1	0	0	1	0	ANI18	P10/ANI18 pin
0	1	0	0	1	1	ANI19	P120/ANI19 pin
0	1	0	1	0	0	ANI20	P11/ANI20 pin
0	1	0	1	0	1	ANI21	P12/ANI21 pin
0	1	0	1	1	0	ANI22	P13/ANI22 pin
0	1	0	1	1	1	ANI23	P14/ANI23 pin
0	1	1	0	0	0	ANI24	P15/ANI24 pin
0	1	1	0	0	1	ANI25	P51/ANI25 pin
0	1	1	0	1	0	ANI26	P50/ANI26 pin
0	1	1	0	1	1	ANI27	P30/ANI27 pin
0	1	1	1	0	0	ANI28	P70/ANI28 pin
0	1	1	1	0	1	ANI29	P31/ANI29 pin
0	1	1	1	1	0	ANI30	P41/ANI30 pin
0	1	1	1	1	1	Setting prohibited	
1	0	0	0	0	0	–	Temperature sensor output voltage ^{Note}
1	0	0	0	0	1	–	Internal reference voltage output (1.45 V) ^{Note}
Other than above						Setting prohibited	

Note This setting can be used only in HS (high-speed main) mode. For details, see **Figure 24-3**.

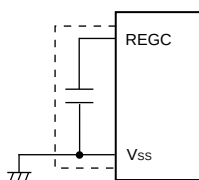
(Cautions 1 to 9 are listed on the next page.)

- Cautions**
1. Be sure to clear bits 5 and 6 to 0.
 2. Select input mode for the ports which are set to analog input with the ADPC and PMC registers, using the port mode registers 0 to 5, 7, 12, and 15 (PM0 to PM5, PM7, PM12, and PM15).
 3. Do not use the ADS register to set the pins which should be set as digital I/O with the A/D port configuration register (ADPC).
 4. Do not use the ADS register to set the pins which should be set as digital I/O with the port mode control registers 0, 1, 3 to 5, 7, and 12 (PMC0, PMC1, PMC3 to PMC5, PMC7, and PMC12).
 5. Only rewrite the value of the ADISS bit while conversion operation is stopped (ADCS = 0, ADCE = 0).
 6. If using AV_{REFP} as the positive reference voltage source of the A/D converter, do not select ANI0 as an A/D conversion channel.
 7. If using AV_{REFM} as the negative reference voltage source of the A/D converter, do not select ANI1 as an A/D conversion channel.
 8. When ADISS is 1, the internal reference voltage (1.45 V) cannot be used for the positive reference voltage. In addition, the first conversion result obtained after setting ADISS to 1 is not available. For detailed setting flow, see 11.7.4 Setup when temperature sensor output voltage/internal reference voltage is selected (example for software trigger mode and one-shot conversion mode).
 9. If a transition is made to STOP mode or a transition is made to HALT mode during CPU operation with subsystem clock, do not set ADISS to 1. When ADISS is 1, the A/D converter reference voltage current (I_{ADREF}) shown in 29.3.2 Supply current characteristics is added.

CHAPTER 23 REGULATOR

23.1 Regulator Overview

The RL78/G1A contains a circuit for operating the device with a constant voltage. At this time, in order to stabilize the regulator output voltage, connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μ F). Also, use a capacitor with good characteristics, since it is used to stabilize internal voltage.



Caution Keep the wiring length as short as possible for the broken-line part in the above figure.

The regulator output voltage, see Table 23-1.

Table 23-1. Regulator Output Voltage Conditions

Mode	Output Voltage	Condition
LV (Low voltage main) mode	1.8 V	—
LS (Low-speed main) mode		
HS (High-speed main) mode	1.8 V	In STOP mode
		When both the high-speed system clock (f_{MX}) and the high-speed on-chip oscillator clock (f_{IH}) are stopped during CPU operation with the subsystem clock (f_{SUB})
		When both the high-speed system clock (f_{MX}) and the high-speed on-chip oscillator clock (f_{IH}) are stopped during the HALT mode when the CPU operation with the subsystem clock (f_{SUB}) has been set
	2.1 V	Other than above (include during OCD mode) ^{Note}

Note When it shifts to the subsystem clock operation or STOP mode during the on-chip debugging, the regulator output voltage is kept at 2.1 V (not decline to 1.8 V).

CHAPTER 24 OPTION BYTE

24.1 Functions of Option Bytes

Addresses 000C0H to 000C3H of the flash memory of the RL78/G1A form an option byte area.

Option bytes consist of user option byte (000C0H to 000C2H) and on-chip debug option byte (000C3H).

Upon power application or resetting and starting, an option byte is automatically referenced and a specified function is set.

For the bits to which no function is allocated, do not change their initial values.

To use the boot swap operation during self programming, 000C0H to 000C3H are replaced by 010C0H to 010C3H. Therefore, set the same values as 000C0H to 000C3H to 010C0H to 010C3H.

Remark The option bytes should always be set regardless of whether each function is used.

24.1.1 User option byte (000C0H to 000C2H/010C0H to 010C2H)

(1) 000C0H/010C0H

- Setting of watchdog timer operation
 - Enabling or disabling of counter operation
 - Enabling or disabling of counter operation in the HALT or STOP mode
- Setting of overflow time of watchdog timer
- Setting of window open period of watchdog timer
- Setting of interval interrupt of watchdog timer
 - Whether or not to use the interval interrupt is selectable.

Caution Set the same value as 000C0H to 010C0H when the boot swap operation is used because 000C0H is replaced by 010C0H.

(2) 000C1H/010C1H

- Setting of LVD operation mode
 - Interrupt & reset mode.
 - Reset mode.
 - Interrupt mode.
 - LVD off (by controlling the externally input reset signal on the $\overline{\text{RESET}}$ pin)
- Setting of LVD detection level (V_{LVDH} , V_{LVDL} , V_{LVD})

- Cautions**
1. After power is supplied, the reset state must be retained until the operating voltage becomes in the range defined in 29.4 or 30.4 AC Characteristics. This is done by utilizing the voltage detection circuit or controlling the externally input reset signal. After the power supply is turned off, this LSI should be placed in the STOP mode, or placed in the reset state by utilizing the voltage detection circuit or controlling the externally input reset signal, before the voltage falls below the operating range. The range of operating voltage varies with the setting of the user option byte (000C2H or 010C2H).
 2. Set the same value as 000C1H to 010C1H when the boot swap operation is used because 000C1H is replaced by 010C1H.

(3) 000C2H/010C2H

- Setting of flash operation mode

Make the setting depending on the main system clock frequency (f_{MAIN}) and power supply voltage (V_{DD}) to be used.

- LV (low voltage main) mode
- LS (low speed main) mode
- HS (high speed main) mode

- Setting of the frequency of the high-speed on-chip oscillator

- Select from 32 MHz/24 MHz/16 MHz/12 MHz/8 MHz/6 MHz/4 MHz/3 MHz/2 MHz/1 MHz (TYP.).

Caution Set the same value as 000C2H to 010C2H when the boot swap operation is used because 000C2H is replaced by 010C2H.

24.1.2 On-chip debug option byte (000C3H/ 010C3H)

- Control of on-chip debug operation

- On-chip debug operation is disabled or enabled.

- Handling of data of flash memory in case of failure in on-chip debug security ID authentication

- Data of flash memory is erased or not erased in case of failure in on-chip debug security ID authentication.

Caution Set the same value as 000C3H to 010C3H when the boot swap operation is used because 000C3H is replaced by 010C3H.

24.2 Format of User Option Byte

The format of user option byte is shown below.

Figure 24-1. Format of User Option Byte (000C0H/010C0H)

Address: 000C0H/010C0H^{Note 1}

7	6	5	4	3	2	1	0
WDTINIT	WINDOW1	WINDOW0	WDTON	WDCS2	WDCS1	WDCS0	WDSTBYON
WDTINIT	Use of interval interrupt of watchdog timer						
0	Interval interrupt is not used.						
1	Interval interrupt is generated when $75\% + 1/2f_{IL}$ of the overflow time is reached.						
WINDOW1	WINDOW0	Watchdog timer window open period ^{Note 2}					
0	0	Setting prohibited					
0	1	50%					
1	0	75%					
1	1	100%					
WDTON	Operation control of watchdog timer counter						
0	Counter operation disabled (counting stopped after reset)						
1	Counter operation enabled (counting started after reset)						
WDCS2	WDCS1	WDCS0	Watchdog timer overflow time ($f_{IL} = 17.25 \text{ kHz (MAX.)}$)				
0	0	0	$2^6/f_{IL}$ (3.71 ms)				
0	0	1	$2^7/f_{IL}$ (7.42 ms)				
0	1	0	$2^8/f_{IL}$ (14.84 ms)				
0	1	1	$2^9/f_{IL}$ (29.68 ms)				
1	0	0	$2^{11}/f_{IL}$ (118.72 ms)				
1	0	1	$2^{13}/f_{IL}$ (474.89 ms)				
1	1	0	$2^{14}/f_{IL}$ (949.79 ms)				
1	1	1	$2^{16}/f_{IL}$ (3799.18 ms)				
WDSTBYON	Operation control of watchdog timer counter (HALT/STOP mode)						
0	Counter operation stopped in HALT/STOP mode ^{Note 2}						
1	Counter operation enabled in HALT/STOP mode						

- Notes**
1. Set the same value as 000C0H to 010C0H when the boot swap operation is used because 000C0H is replaced by 010C0H.
 2. The window open period is 100% when WDSTBYON = 0, regardless the value of the WINDOW1 and WINDOW0 bits.

Remark f_{IL} : Low-speed on-chip oscillator clock frequency

Figure 24-2. Format of User Option Byte (000C1H/010C1H) (1/2)Address: 000C1H/010C1H^{Note}

7	6	5	4	3	2	1	0
VPOC2	VPOC1	VPOC0	1	LVIS1	LVIS0	LVIMDS1	LVIMDS0

• LVD setting (interrupt & reset mode)

Detection voltage			Option byte setting value						
VLVDH		VLVDL	VPOC2	VPOC1	VPOC0	LVIS1	LVIS0	Mode setting	
Rising edge	Falling edge	Falling edge						LVIMDS1	LVIMDS0
1.77 V	1.73 V	1.63 V	0	0	0	1	0	1	0
1.88 V	1.84 V					0	1		
2.92 V	2.86 V					0	0		
1.98 V	1.94 V	1.84 V		0	1	1	0		
2.09 V	2.04 V					0	1		
3.13 V	3.06 V					0	0		
2.61 V	2.55 V	2.45 V		1	0	1	0		
2.71 V	2.65 V					0	1		
2.92 V	2.86 V	2.75 V		1	1	1	0		
3.02 V	2.96 V					0	1		
—			Setting of values other than above is prohibited.						

• LVD setting (reset mode)

Detection voltage		Option byte setting value						
V _{LVD}		VPOC2	VPOC1	VPOC0	LVIS1	LVIS0	Mode setting	
Rising edge	Falling edge						LVIMDS1	LVIMDS0
1.67 V	1.63 V	0	0	0	1	1	1	1
1.77 V	1.73 V		0	0	1	0		
1.88 V	1.84 V		0	1	1	1		
1.98 V	1.94 V		0	1	1	0		
2.09 V	2.04 V		0	1	0	1		
2.50 V	2.45 V		1	0	1	1		
2.61 V	2.55 V		1	0	1	0		
2.71 V	2.65 V		1	0	0	1		
2.81 V	2.75 V		1	1	1	1		
2.92 V	2.86 V		1	1	1	0		
3.02 V	2.96 V		1	1	0	1		
3.13 V	3.06 V		0	1	0	0		
—		Setting of values other than above is prohibited.						

Note Set the same value as 000C1H to 010C1H when the boot swap operation is used because 000C1H is replaced by 010C1H.

Remarks 1. For details on the LVD circuit, see **CHAPTER 21 VOLTAGE DETECTOR**.

2. The detection voltage is a typical value. For details, see **29.6.4** or **30.6.4 LVD circuit characteristics**.

(**Cautions** are listed on the next page.)

Figure 24-3. Format of Option Byte (000C2H/010C2H)Address: 000C2H/010C2H^{Note}

7	6	5	4	3	2	1	0
CMODE1	CMODE0	1	0	FRQSEL3	FRQSEL2	FRQSEL1	FRQSEL0

CMODE1	CMODE0	Setting of flash operation mode		
			Operating Frequency Range (f _{MAIN})	Operating Voltage Range (V _{DD})
0	0	LV (low voltage main) mode	1 to 4 MHz	1.6 to 3.6 V
1	0	LS (low speed main) mode	1 to 8 MHz	1.8 to 3.6 V
1	1	HS (high speed main) mode	1 to 16 MHz	2.4 to 3.6 V
			1 to 32 MHz	2.7 to 3.6 V
Other than above		Setting prohibited		

FRQSEL3	FRQSEL2	FRQSEL1	FRQSEL0	Frequency of the high-speed on-chip oscillator
1	0	0	0	32 MHz
0	0	0	0	24 MHz
1	0	0	1	16 MHz
0	0	0	1	12 MHz
1	0	1	0	8 MHz
0	0	1	0	6 MHz
1	0	1	1	4 MHz
0	0	1	1	3 MHz
1	1	0	0	2 MHz
1	1	0	1	1 MHz
Other than above				Setting prohibited

Note Set the same value as 000C2H to 010C2H when the boot swap operation is used because 000C2H is replaced by 010C2H.

- Cautions**
1. Be sure to set bits 4 and 5 to “10B”.
 2. The ranges of operation frequency and operation voltage vary depending on the flash operation mode. For details, see 29.4 or 30.4 AC Characteristics.

24.3 Format of On-chip Debug Option Byte

The format of on-chip debug option byte is shown below.

Figure 24-4. Format of On-chip Debug Option Byte (000C3H/010C3H)

Address: 000C3H/010C3H^{Note}

7	6	5	4	3	2	1	0
OCDENSET	0	0	0	0	1	0	OCDERSD

OCDENSET	OCDERSD	Control of on-chip debug operation
0	0	Disables on-chip debug operation.
0	1	Setting prohibited
1	0	Enables on-chip debugging. Erases data of flash memory in case of failures in authenticating on-chip debug security ID.
1	1	Enables on-chip debugging. Does not erase data of flash memory in case of failures in authenticating on-chip debug security ID.

Note Set the same value as 000C3H to 010C3H when the boot swap operation is used because 000C3H is replaced by 010C3H.

Caution Bits 7 and 0 (OCDENSET and OCDERSD) can only be specified a value.

Be sure to set 000010B to bits 6 to 1.

Remark The value on bits 3 to 1 will be written over when the on-chip debug function is in use and thus it will become unstable after the setting.

However, be sure to set the default values (0, 1, and 0) to bits 3 to 1 at setting.

24.4 Setting of Option Byte

The user option byte and on-chip debug option byte can be set using the link option, in addition to describing to the source. When doing so, the contents set by using the link option take precedence, even if descriptions exist in the source, as mentioned below.

A software description example of the option byte setting is shown below.

OPT	CSEG	OPT_BYTE	
	DB	36H	; Does not use interval interrupt of watchdog timer, ; Enables watchdog timer operation, ; Window open period of watchdog timer is 50%, ; Overflow time of watchdog timer is $2^9/f_{IL}$, ; Stops watchdog timer operation during HALT/STOP mode
	DB	1AH	; Select 1.63 V for V_{LVDL} ; Select rising edge 1.77 V, falling edge 1.73 V for V_{LVDH} ; Select the interrupt & reset mode as the LVD operation mode
	DB	2DH	; Select the LV (low voltage main) mode as the flash operation mode and 1 MHz as the frequency of the high-speed on-chip oscillator
	DB	85H	; Enables on-chip debug operation, does not erase flash memory data when security ID authorization fails

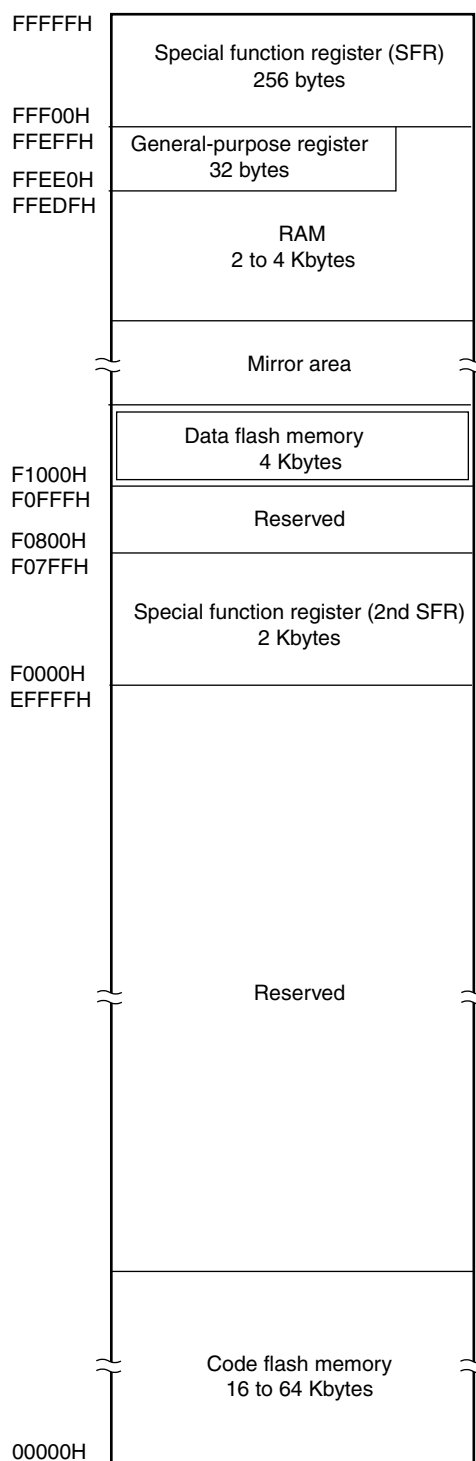
When the boot swap function is used during self programming, 000C0H to 000C3H is switched to 010C0H to 010C3H. Describe to 010C0H to 010C3H, therefore, the same values as 000C0H to 000C3H as follows.

OPT2	CSEG	AT	010C0H	
	DB		36H	; Does not use interval interrupt of watchdog timer, ; Enables watchdog timer operation, ; Window open period of watchdog timer is 50%, ; Overflow time of watchdog timer is $2^{10}/f_{IL}$, ; Stops watchdog timer operation during HALT/STOP mode
	DB		1AH	; Select 1.63 V for V_{LVDL} ; Select rising edge 1.77 V, falling edge 1.73 V for V_{LVDH} ; Select the interrupt & reset mode as the LVD operation mode
	DB		2DH	; Select the LV (low main voltage) mode as the flash operation mode and 1 MHz as the frequency of the high-speed on-chip oscillator
	DB		85H	; Enables on-chip debug operation, does not erase flash memory data when security ID authorization fails

Caution To specify the option byte by using assembly language, use **OPT_BYTE** as the relocation attribute name of the **CSEG** pseudo instruction. To specify the option byte to 010C0H to 010C3H in order to use the boot swap function, use the relocation attribute **AT** to specify an absolute address.

CHAPTER 25 FLASH MEMORY

The RL78 microcontroller incorporates the flash memory to which a program can be written, erased, and overwritten while mounted on the board. The flash memory includes the “code flash memory”, in which programs can be executed, and the “data flash memory”, an area for storing data.



The following methods for programming the flash memory are available.

The code flash memory can be rewritten to through serial programming using a flash memory programmer or an external device (UART communication), or through self-programming.

- Serial programming using flash memory programmer (see **25.4**)

Data can be written to the flash memory on-board or off-board by using a dedicated flash memory programmer.

- Serial programming using external device (UART communication) (see **25.2**)

Data can be written to the flash memory on-board through UART communication with an external device (microcontroller or ASIC).

- Self-programming (see **25.6**)

The user application can execute self-programming of the code flash memory by using the flash self-programming library.

The data flash memory can be rewritten to by using the data flash library during user program execution (background operation). For access and writing to the data flash memory, see **25.8 Data Flash**.

25.1 Serial Programming Using Flash Memory Programmer

The following dedicated flash memory programmer can be used to write data to the internal flash memory of the RL78 microcontroller.

- PG-FP5, FL-PR5
- E1 on-chip debugging emulator

Data can be written to the flash memory on-board or off-board, by using a dedicated flash memory programmer.

(1) On-board programming

The contents of the flash memory can be rewritten after the RL78 microcontroller has been mounted on the target system. The connectors that connect the dedicated flash memory programmer must be mounted on the target system.

(2) Off-board programming

Data can be written to the flash memory with a dedicated program adapter (FA series) before the RL78 microcontroller is mounted on the target system.

Remark FL-PR5 and FA series are products of Naito Densei Machida Mfg. Co., Ltd.

Table 25-1. Wiring between RL78/G1A and Dedicated Flash Memory Programmer

Pin Configuration of Dedicated Flash Memory Programmer				Pin Name	Pin No.				
Signal Name		I/O	Pin Function		25-pin	32-pin	48-pin	64-pin	
PG-FP5, FL-PR5	E1 on-chip debugging emulator				FLGA (3x3)	WQFN (5x5)	LQFP (7x7), WQFN (7x7)	LQFP (10x10)	FBGA (4x4)
–	TOOL0	I/O	Transmit/ receive signal	TOOL0/ P40	A5	1	39	5	D6
SI/RxD	–	I/O	Transmit/ receive signal						
–	RESET	Output	Reset signal	RESET	B5	2	40	6	E7
/RESET	–	Output							
V _{DD}		I/O	V _{DD} voltage generation/ power monitoring	V _{DD}	B3	8	48	15	B7
GND		–	Ground	V _{SS}	B2	7	47	13	C7
				EV _{SS}	–	–	–	14	B8
				REGC ^{Note}	A2	6	46	12	D7
FLMD1	EMV _{DD}	–	Driving power for TOOL0 pin	V _{DD}	B3	8	48	–	–
				EV _{DD}	–	–	–	16	A8

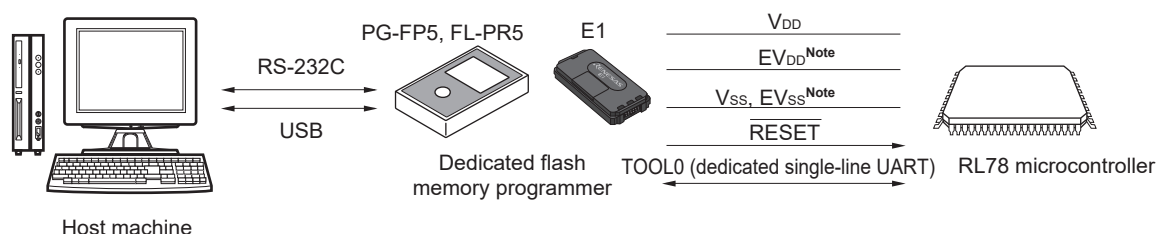
Note Connect REGC pin to ground via a capacitor (0.47 to 1 μ F).

Remark Pins that are not indicated in the above table can be left open when using the flash memory programmer for flash programming.

25.1.1 Programming environment

The environment required for writing a program to the flash memory of the RL78 microcontroller is illustrated below.

Figure 25-1. Environment for Writing Program to Flash Memory



Note 64-pin product only.

A host machine that controls the dedicated flash memory programmer is necessary.

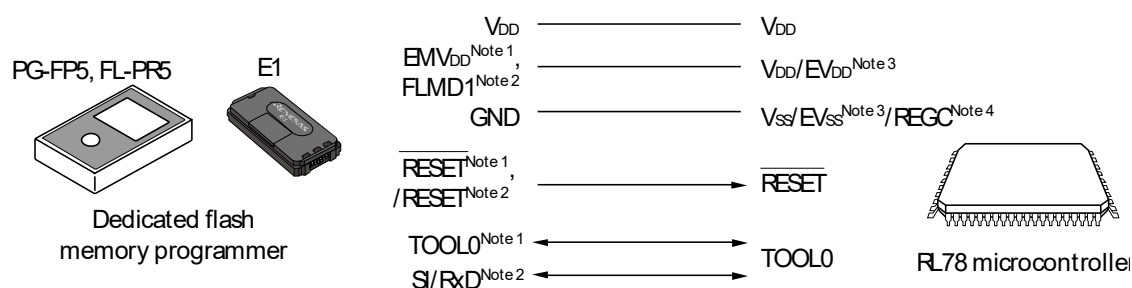
To interface between the dedicated flash memory programmer and the RL78 microcontroller, the TOOL0 pin is used for manipulation such as writing and erasing via a dedicated single-line UART.

25.1.2 Communication mode

Communication between the dedicated flash memory programmer and the RL78 microcontroller is established by serial communication using the TOOL0 pin via a dedicated single-line UART of the RL78 microcontroller.

Transfer rate: 1 M, 500 k, 250 k, 115.2 kbps

Figure 25-2. Communication with Dedicated Flash Memory Programmer



- Notes**
1. When using E1 on-chip debugging emulator.
 2. When using PG-FP5 or FL-PR5.
 3. 64-pin product only.
 4. Connect REGC pin to ground via a capacitor (0.47 to 1 μ F).

The dedicated flash memory programmer generates the following signals for the RL78 microcontroller. See each manual of PG-FP5, FL-PR5, or E1 on-chip debugging emulator for details.

Table 25-2. Pin Connection

Dedicated Flash Memory Programmer			RL78 Microcontroller
Signal Name		I/O	Pin Name ^{Note 2}
PG-FP5, FL-PR5	E1 On-chip Debugging Emulator		
V _{DD}		I/O	V _{DD} voltage generation/power monitoring
GND		–	Ground
FLMD1	EMV _{DD}	–	Driving power for TOOL0 pin
/RESET	–	Output	Reset signal
–	RESET	Output	
–	TOOL0	I/O	Transmit/receive signal
SI/RxD	–	I/O	
			TOOL0

- Notes**
1. Connect REGC pin to ground via a capacitor (0.47 to 1 μ F).
 2. Pins to be connected differ with the product. For details, see **Table 25-1**.

25.2 Serial Programming Using External Device (that Incorporates UART)

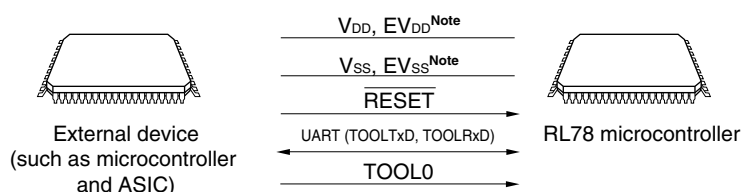
On-board data writing to the internal flash memory is possible by using the RL78 microcontroller and an external device (a microcontroller or ASIC) connected to a UART.

On the development of flash memory programmer by user, refer to the **RL78 Microcontrollers (RL78 Protocol A) Programmer Edition Application Note (R01AN0815)**.

25.2.1 Programming environment

The environment required for writing a program to the flash memory of the RL78 microcontroller is illustrated below.

Figure 25-3. Environment for Writing Program to Flash Memory



Note 64-pin product only.

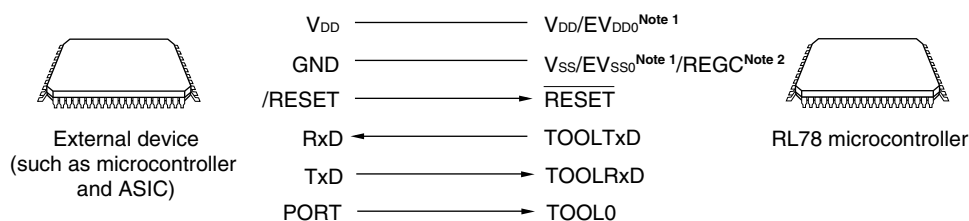
Processing to write data to or erase data from the RL78 microcontroller by using an external device is performed on-board. Off-board writing is not possible.

25.2.2 Communication mode

Communication between the external device and the RL78 microcontroller is established by serial communication using the TOOLTxD and TOOLRxD pins via the dedicated UART of the RL78 microcontroller.

Transfer rate: 1 M, 500 k, 250 k, 115.2kbps

Figure 25-4. Communication with External Device



Notes 1. 64-pin product only.

2. Connect REGC pin to ground via a capacitor (0.47 to 1 μ F).

The external device generates the following signals for the RL78 microcontroller.

Table 25-3. Pin Connection

External Device			RL78 Microcontroller
Signal Name	I/O	Pin Function	Pin Name
VDD	I/O	VDD voltage generation/power monitoring	VDD, EVDD0
GND	—	Ground	VSS, EVSS0, REGC ^{Note}
RESETOUT	Output	Reset signal output	RESET
RxD	Input	Receive signal	TOOLTxD
TxD	Output	Transmit signal	TOOLRxD
PORT	Output	Mode signal	TOOL0

Note Connect REGC pin to ground via a capacitor (0.47 to 1 μ F).

25.3 Connection of Pins on Board

To write the flash memory on-board by using the flash memory programmer, connectors that connect the dedicated flash memory programmer must be provided on the target system. First provide a function that selects the normal operation mode or flash memory programming mode on the board.

When the flash memory programming mode is set, all the pins not used for programming the flash memory are in the same status as immediately after reset. Therefore, if the external device does not recognize the state immediately after reset, the pins must be handled as described below.

Remark For the flash memory programming mode, see **25.4.2 Flash memory programming mode**.

25.3.1 P40/TOOL0 pin

In the flash memory programming mode, connect this pin to the dedicated flash memory programmer via an external 1 k Ω pull-up resistor.

When this pin is used as the port pin, use that by the following method.

When used as an input pin: Input of low-level is prohibited for t_{HD} period after external pin reset release. However, when this pin is used via pull-down resistors, use the 500 k Ω or more resistors.

When used as an output pin: When this pin is used via pull-down resistors, use the 500 k Ω or more resistors.

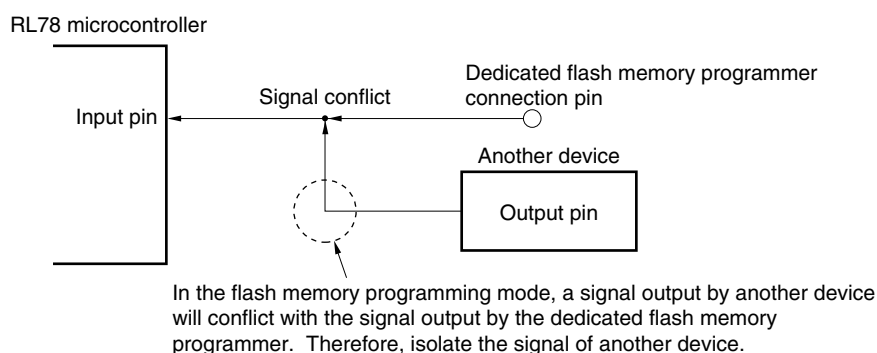
- Remarks**
1. t_{HD} : How long to keep the TOOL0 pin at the low level from when the external and internal resets end for setting of the flash memory programming mode (see **29.10** or **30.10 Timing Specs for Switching Flash Memory Programming Modes**)
 2. The SAU and IICA pins are not used for communication between the RL78 microcontroller and dedicated flash memory programmer, because single-line UART (TOOL0 pin) is used.

25.3.2 $\overline{\text{RESET}}$ pin

Signal conflict will occur if the reset signal of the dedicated flash memory programmer and external device are connected to the $\overline{\text{RESET}}$ pin that is connected to the reset signal generator on the board. To prevent this conflict, isolate the connection with the reset signal generator.

The flash memory will not be correctly programmed if the reset signal is input from the user system while the flash memory programming mode is set. Do not input any signal other than the reset signal of the dedicated flash memory programmer and external device.

Figure 25-5. Signal Conflict ($\overline{\text{RESET}}$ Pin)



25.3.3 Port pins

When the flash memory programming mode is set, all the pins not used for flash memory programming enter the same status as that immediately after reset. If external devices connected to the ports do not recognize the port status immediately after reset, the port pin must be connected to either V_{DD} or EV_{DD0} , or V_{SS} or EV_{SS0} , via a resistor.

25.3.4 REGC pin

Connect the REGC pin to GND via a capacitor having excellent characteristics (0.47 to 1 μ F) in the same manner as during normal operation. Also, use a capacitor with good characteristics, since it is used to stabilize internal voltage.

25.3.5 X1 and X2 pins

Connect X1 and X2 in the same status as in the normal operation mode.

Remark In the flash memory programming mode, the high-speed on-chip oscillator clock (f_{IH}) is used.

25.3.6 Power supply

To use the supply voltage output of the flash memory programmer, connect the V_{DD} pin to V_{DD} of the flash memory programmer, and the V_{SS} pin to GND of the flash memory programmer.

To use the on-board supply voltage, connect in compliance with the normal operation mode.

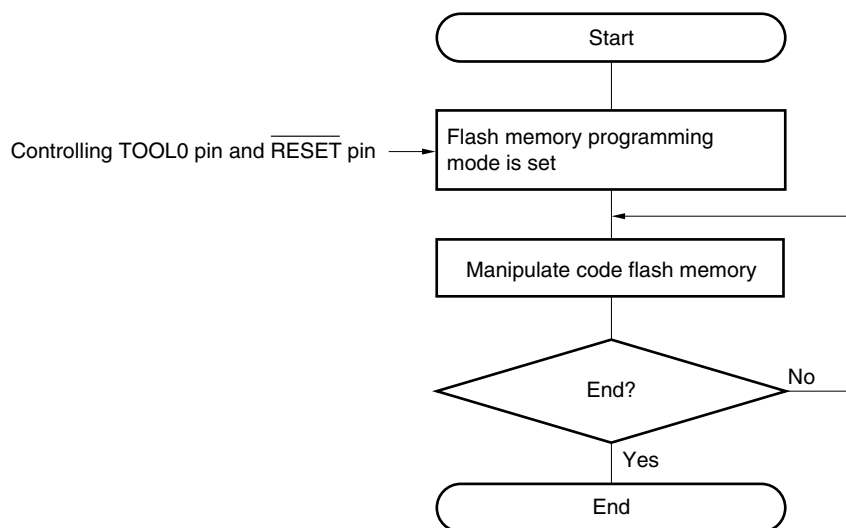
However, when writing to the flash memory by using the flash memory programmer and using the on-board supply voltage, be sure to connect the V_{DD} and V_{SS} pins to V_{DD} and GND of the flash memory programmer to use the power monitor function with the flash memory programmer.

25.4 Serial Programming Method

25.4.1 Serial programming procedure

The following figure illustrates a flow for rewriting the code flash memory through serial programming.

Figure 25-6. Code Flash Memory Manipulation Procedure



25.4.2 Flash memory programming mode

To rewrite the contents of the code flash memory through serial programming, specify the flash memory programming mode. To enter the mode, set as follows.

<Serial programming using the dedicated flash memory programmer>

Connect the RL78 microcontroller to a dedicated flash memory programmer. Communication from the dedicated flash memory programmer is performed to automatically switch to the flash memory programming mode.

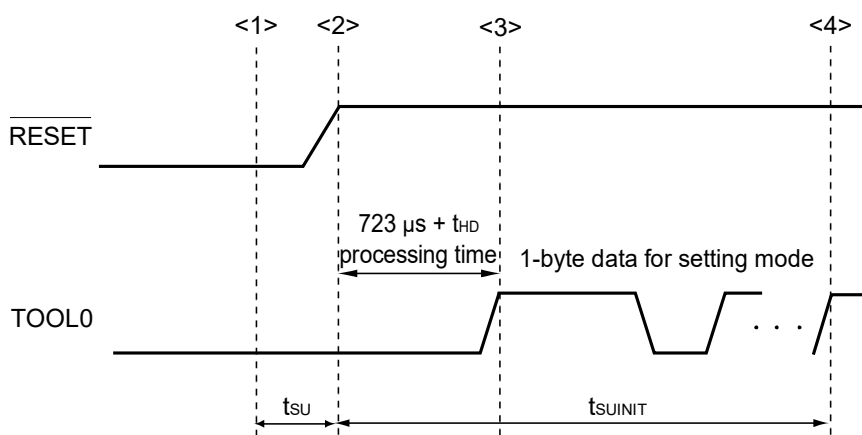
<Serial programming using an external device (UART communication)>

Set the TOOL0 pin to the low level, and then cancel the reset (see **Table 25-4**). After that, enter flash memory programming mode according to the procedures <1> to <4> shown in **Figure 25-7**. For details, refer to the **RL78 Microcontrollers (RL78 Protocol A) Programmer Edition Application Note (R01AN0815)**.

Table 25-4. Relationship Between TOOL0 Pin and Operation Mode After Reset Release

TOOL0	Operation Mode
V_{DD0}	Normal operation mode
0 V	Flash memory programming mode

Figure 25-7. Setting of Flash Memory Programming Mode



<1> The low level is input to the TOOL0 pin.

<2> The external reset ends (POR and LVD reset must end before the external reset ends.).

<3> The TOOL0 pin is set to the high level.

<4> Baud rate setting by UART reception is completed.

Remark t_{SUINIT} : The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.

t_{SU} : How long from when the TOOL0 pin is placed at the low level until an external reset ends

t_{HD} : How long to keep the TOOL0 pin at the low level from when the external and internal resets end (the flash firmware processing time is excluded)

For details, see **29.10** or **30.10 Timing Specs for Switching Flash Memory Programming Modes**.

There are two flash memory programming modes: wide voltage mode and full speed mode. The supply voltage value applied to the microcontroller during write operations and the setting information of the user option byte for setting of the flash memory programming mode determine which mode is selected.

When a dedicated flash memory programmer is used for serial programming, setting the voltage on GUI selects the mode automatically.

Table 25-5. Programming Modes and Voltages at Which Data Can Be Written, Erased, or Verified

Power Supply Voltage (V _{DD})	User Option Byte Setting for Switching to Flash Memory Programming Mode		Flash Programming Mode
	Flash Operation Mode	Operating Frequency	
$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	Blank state		Full speed mode
	HS (high speed main) mode	1 MHz to 32 MHz	Full speed mode
	LS (low speed main) mode	1 MHz to 8 MHz	Wide voltage mode
	LV (low voltage main) mode	1 MHz to 4 MHz	Wide voltage mode
$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$	Blank state		Full speed mode
	HS (high speed main) mode	1 MHz to 16 MHz	Full speed mode
	LS (low speed main) mode	1 MHz to 8 MHz	Wide voltage mode
	LV (low voltage main) mode	1 MHz to 4 MHz	Wide voltage mode
$1.8\text{ V} \leq V_{DD} < 2.4\text{ V}$	Blank state		Wide voltage mode
	LS (low speed main) mode	1 MHz to 8 MHz	Wide voltage mode
	LV (low voltage main) mode	1 MHz to 4 MHz	Wide voltage mode

- Remarks**
1. Using both the wide voltage mode and full speed mode imposes no restrictions on writing, erasing, or verification.
 2. For details about communication commands, see **25.4.4 Communication commands**.

25.4.3 Selecting communication mode

Communication modes of the RL78 microcontroller are as follows.

Table 25-6. Communication Modes

Communication Mode	Standard Setting ^{Note 1}				Pins Used
	Port	Speed ^{Note 2}	Frequency	Multiply Rate	
1-line UART (when flash memory programmer is used, or when external device is used)	UART	115200 bps, 250000 bps, 500000 bps, 1 Mbps	—	—	TOOL0
Dedicated UART (when external device is used)	UART	115200 bps, 250000 bps, 500000 bps, 1 Mbps	—	—	TOOLTxD, TOOLRxD

Notes 1. Selection items for Standard settings on GUI of the flash memory programmer.

2. Because factors other than the baud rate error, such as the signal waveform slew, also affect UART communication, thoroughly evaluate the slew as well as the baud rate error.

25.4.4 Communication commands

The RL78 microcontroller executes serial programming through the commands listed in **Table 25-7**.

The signals sent from the dedicated flash memory programmer or external device to the RL78 microcontroller are called commands, and programming functions corresponding to the commands are executed. For details, refer to the **RL78 Microcontrollers (RL78 Protocol A) Programmer Edition Application Note (R01AN0815)**.

Table 25-7. Flash Memory Control Commands

Classification	Command Name	Function
Verify	Verify	Compares the contents of a specified area of the flash memory with data transmitted from the programmer.
Erase	Block Erase	Erases a specified area in the flash memory.
Blank check	Block Blank Check	Checks if a specified block in the flash memory has been correctly erased.
Write	Programming	Writes data to a specified area in the flash memory.
Getting information	Silicon Signature	Gets the RL78 microcontroller information (such as the part number, flash memory configuration, and programming firmware version).
	Checksum	Gets the checksum data for a specified area.
Security	Security Set	Sets security information.
	Security Get	Gets security information.
	Security Release	Release setting of prohibition of writing.
Others	Reset	Used to detect synchronization status of communication.
	Baud Rate Set	Sets baud rate when UART communication mode is selected.

Note Confirm that no data has been written to the write area. Because data cannot be erased after block erase is prohibited, do not write data if the data has not been erased.

Product information (such as product name and firmware version) can be obtained by executing the “Silicon Signature” command.

Table 25-8 is a list of signature data and **Table 25-9** shows an example of signature data.

Table 25-8. Signature Data List

Field Name	Description	Number of Transmit Data
Device code	The serial number assigned to the device	3 bytes
Device name	Device name (ASCII code)	10 bytes
Code flash memory area last address	Last address of code flash memory area (Sent from lower address. Example: 00000H to 0FFFFH (64 KB) → FFH, 1FH, 00H)	3 bytes
Data flash memory area last address	Last address of data flash memory area (Sent from lower address. Example: F1000H to F1FFFH (4 KB) → FFH, 1FH, 0FH)	3 bytes
Firmware version	Version information of firmware for programming (Sent from upper address. Example: From Ver. 1.23 → 01H, 02H, 03H)	3 bytes

Table 25-9. Example of Signature Data

Field Name	Description	Number of Transmit Data	Data (Hexadecimal)
Device code	RL78 protocol A	3 bytes	10 00 06
Device name	R5F10ELE	10 bytes	52 = “R” 35 = “5” 46 = “F” 31 = “1” 30 = “0” 45 = “E” 4C = “L” 45 = “E” 20 = “ ” 20 = “ ”
Code flash memory area last address	Code flash memory area 00000H to 0FFFFH (64 KB)	3 bytes	FF FF 00
Data flash memory area last address	Data flash memory area F1000H to F1FFFH (4 KB)	3 bytes	FF 1F 0F
Firmware version	Ver.1.23	3 bytes	01 02 03

25.5 Processing Time for Each Command When PG-FP5 Is in Use (Reference Value)

The following shows the processing time for each command (reference value) when PG-FP5 is used as a dedicated flash memory programmer.

Table 25-10. Processing Time for Each Command When PG-FP5 Is in Use (Reference Value)

PG-FP5 Command	Code Flash			
	16 KB	32 KB	48 KB	64 KB
Erasing	1 s	1 s	1 s	1.5 s
Writing	1.5 s	1.5 s	2 s	2.5 s
Verification	1.5 s	1.5 s	2 s	2 s
Writing after erasing	1.5 s	2 s	2.5 s	3 s

Remark The command processing times (reference values) shown in the table are typical values under the following conditions.

Port: TOOL0 (single-line UART)

Speed: 1,000,000 bps

Mode: Full speed mode (flash operation mode: HS (high speed main) mode)

25.6 Self-Programming

The RL78 microcontroller supports a self-programming function that can be used to rewrite the code flash memory via a user program. Because this function allows a user application to rewrite the code flash memory by using the flash self-programming library, it can be used to upgrade the program in the field.

- Cautions**
1. The self-programming function cannot be used when the CPU operates with the subsystem clock.
 2. To prohibit an interrupt during self-programming, in the same way as in the normal operation mode, execute the flash self-programming library in the state where the IE flag is cleared (0) by the DI instruction. To enable an interrupt, clear (0) the interrupt mask flag to accept in the state where the IE flag is set (1) by the EI instruction, and then execute the flash self-programming library.
 3. The high-speed on-chip oscillator should be kept operating during self-programming. If it is kept stopping, the high-speed on-chip oscillator clock should be operated (HIOSSTOP = 0). The flash self-programming library should be executed after 30 μ s have elapsed.

- Remarks**
1. For details of the self-programming function, refer to the **RL78 Microcontroller Flash Self Programming Library Type01 User's Manual (R01US0050)**.
 2. For details of the time required to execute self-programming, see the notes on use that accompany the flash self-programming library tool.

The self-programming function has two flash memory programming modes; wide voltage mode and full speed mode.

Specify the mode that corresponds to the flash operation mode specified in bits CMODE1 and CMODE0 in option byte 000C2H.

Specify the full speed mode when the HS (high speed main) mode is specified. Specify the wide voltage mode when the LS (low speed main) mode or LV (low voltage main) mode is specified.

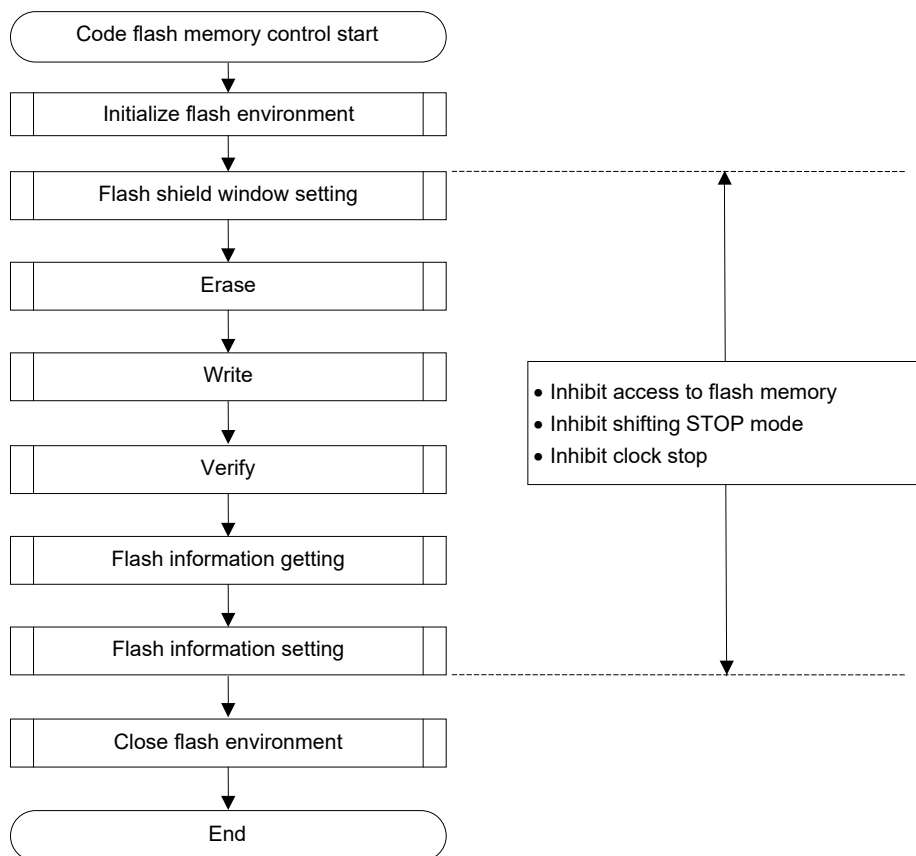
If the argument fsl_flash_voltage_u08 is 00H when the FSL_Init function of the flash self-programming library provided by Renesas Electronics is executed, full speed mode is specified. If the argument is other than 00H, the wide voltage mode is specified.

- Remark** Using both the wide voltage mode and full speed mode imposes no restrictions on writing, erasing, or verification.

25.6.1 Self-programming procedure

The following figure illustrates a flow for rewriting the code flash memory by using a flash self-programming library.

Figure 25-8. Flow of Self-Programming (Rewriting Flash Memory)



25.6.2 Boot swap function

If rewriting the boot area failed by temporary power failure or other reasons, restarting a program by resetting or overwriting is disabled due to data destruction in the boot area.

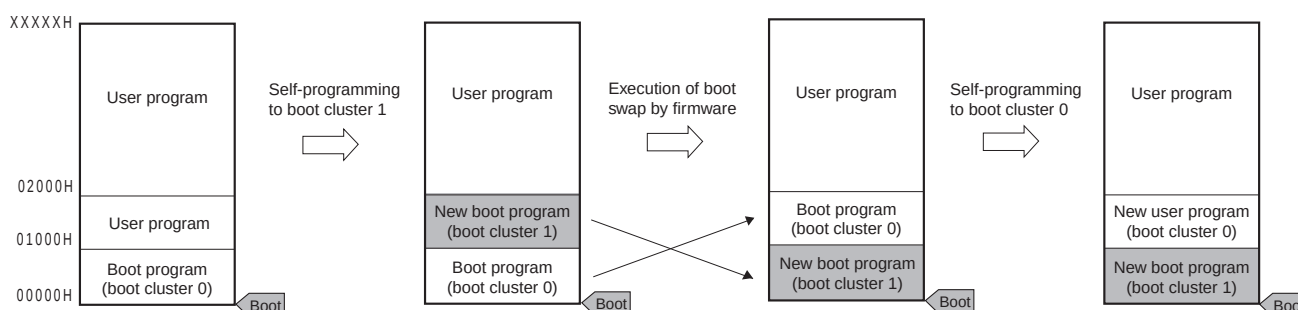
The boot swap function is used to avoid this problem.

Before erasing boot cluster 0^{Note}, which is a boot area, by self-programming, write a new boot program to boot cluster 1 in advance. When the program has been correctly written to boot cluster 1, swap this boot cluster 1 and boot cluster 0 by using the set information function of the firmware of the RL78 microcontroller, so that boot cluster 1 is used as a boot area. After that, erase or write the original area, boot cluster 0.

As a result, even if a power failure occurs while the area is being rewritten, the program is executed correctly because it is booted from boot cluster 1 to be swapped when the program is reset and started next.

Note A boot cluster is a 4 KB area and boot clusters 0 and 1 are swapped by the boot swap function.

Figure 25-9. Boot Swap Function

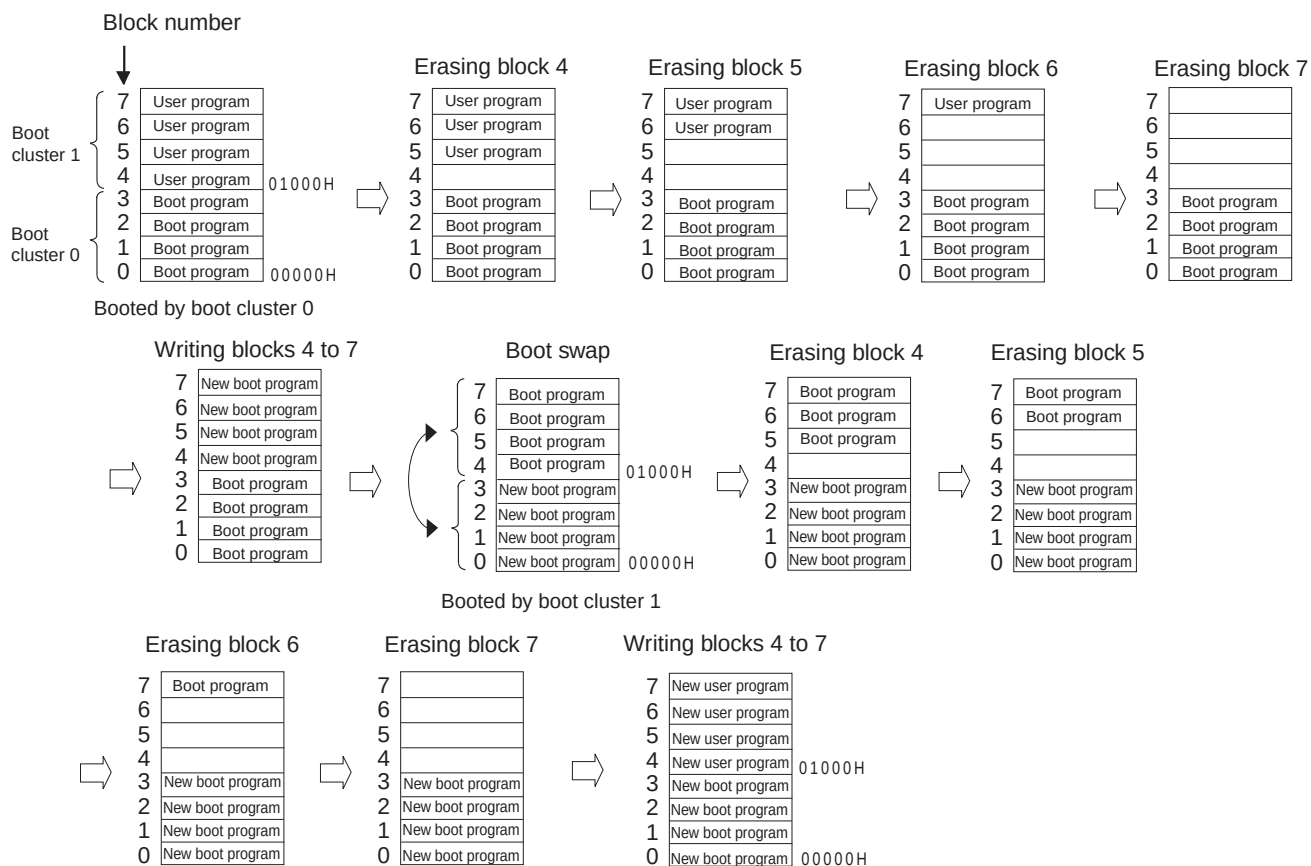


In an example of above figure, it is as follows.

Boot cluster 0: Boot area before boot swap

Boot cluster 1: Boot area after boot swap

Figure 25-10. Example of Executing Boot Swapping



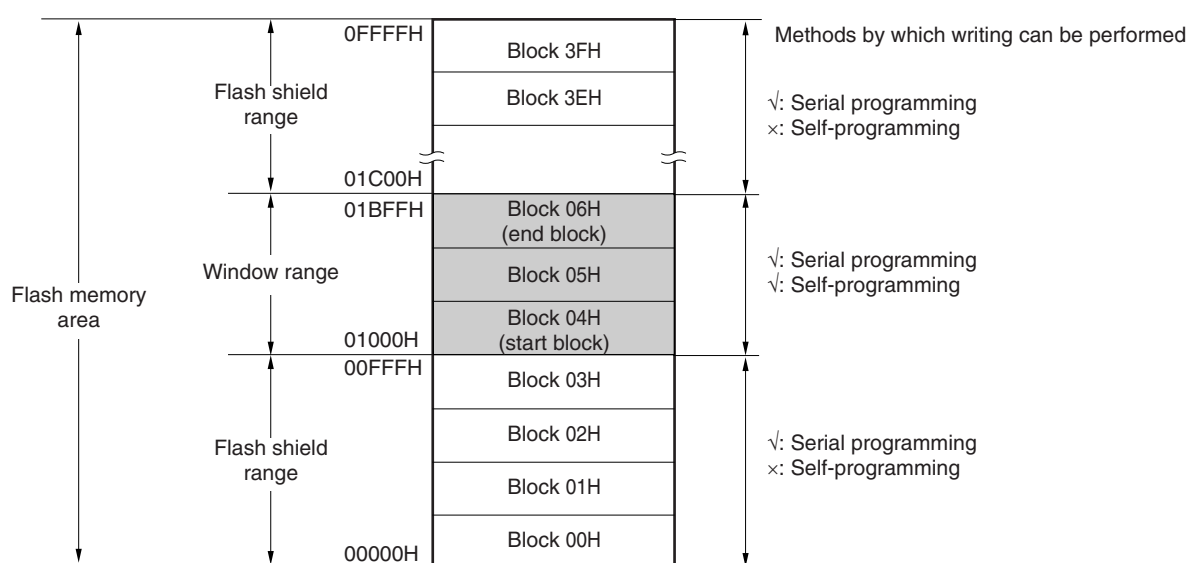
25.6.3 Flash shield window function

The flash shield window function is provided as one of the security functions for self-programming. It disables writing to and erasing areas outside the range specified as a window only during self-programming.

The window range can be set by specifying the start and end blocks. The window range can be set or changed during both serial programming and self-programming.

Writing to and erasing areas outside the window range are disabled during self-programming. During serial programming, however, areas outside the range specified as a window can be written and erased.

Figure 25-11. Flash Shield Window Setting Example
(Target Devices: R5F10ELE, Start Block: 04H, End Block: 06H)



- Cautions**
1. If the rewrite-prohibited area of the boot cluster 0 overlaps with the flash shield window range, prohibition to rewrite the boot cluster 0 takes priority.
 2. The flash shield window can only be used for the code flash memory (and is not supported for the data flash memory).

Table 25-11. Relationship Between Flash Shield Window Function Setting/Change Methods and Commands

Programming Conditions	Window Range Setting/Change Methods	Execution Commands	
		Block Erase	Write
Self-programming	Specify the starting and ending blocks by the flash self-programming library.	Block erasing is enabled only within the window range.	Writing is enabled only within the range of window range.
Serial programming	Specify the starting and ending blocks on GUI of dedicated flash memory programmer, etc.	Block erasing is enabled also outside the window range.	Writing is enabled also outside the window range.

Remark See 25.7 Security Settings to prohibit writing/erasing during serial programming.

25.7 Security Settings

The RL78 microcontroller supports a security function that prohibits rewriting the user program written to the internal flash memory, so that the program cannot be changed by an unauthorized person.

The operations shown below can be performed using the Security Set command.

- Disabling block erase

Execution of the block erase command for a specific block in the flash memory is prohibited during serial programming. However, blocks can be erased by means of self-programming.

- Disabling write

Execution of the write command for entire blocks in the code flash memory is prohibited during serial programming. However, blocks can be written by means of self-programming.

After the setting of prohibition of writing is specified, releasing the setting by the Security Release command is enabled by a reset.

- Disabling rewriting boot cluster 0

Execution of the block erase command and write command on boot cluster 0 (00000H to 00FFFH) in the code flash memory is prohibited by this setting.

The block erase, write commands and rewriting boot cluster 0 are enabled by the default setting when the flash memory is shipped. Security can be set by serial programming and self-programming. Each security setting can be used in combination.

Table 25-12 shows the relationship between the erase and write commands when the RL78 microcontroller security function is enabled.

Caution The security function of the dedicated flash programmer does not support self-programming.

Remark To prohibit writing and erasing during self-programming, use the flash shield window function (see **25.6.3** for details).

Table 25-12. Relationship Between Enabling Security Function and Command

(1) During serial programming

Valid Security	Executed Command	
	Block Erase	Write
Prohibition of block erase	Blocks cannot be erased.	Can be performed. ^{Note}
Prohibition of writing	Blocks can be erased.	Cannot be performed.
Prohibition of rewriting boot cluster 0	Boot cluster 0 cannot be erased.	Boot cluster 0 cannot be written.

Note Confirm that no data has been written to the write area. Because data cannot be erased after block erase is prohibited, do not write data if the data has not been erased.

(2) During self-programming

Valid Security	Executed Command	
	Block Erase	Write
Prohibition of block erase	Blocks can be erased.	Can be performed.
Prohibition of writing		
Prohibition of rewriting boot cluster 0	Boot cluster 0 cannot be erased.	Boot cluster 0 cannot be written.

Remark To prohibit writing and erasing during self-programming, use the flash shield window function (see 25.6.3 for detail).

Table 25-13. Setting Security in Each Programming Mode

(1) During serial programming

Security	Security Setting	How to Disable Security Setting
Prohibition of block erase	Set via GUI of dedicated flash memory programmer, etc.	Cannot be disabled after set.
Prohibition of writing		Set via GUI of dedicated flash memory programmer, etc.
Prohibition of rewriting boot cluster 0		Cannot be disabled after set.

Caution Releasing the setting of prohibition of writing is enabled only when the security is not set as the block erase prohibition and the boot cluster 0 rewrite prohibition with code flash memory area and data flash memory area being blanks.

(2) During self-programming

Security	Security Setting	How to Disable Security Setting
Prohibition of block erase	Set by using flash self-programming library.	Cannot be disabled after set.
Prohibition of writing		Cannot be disabled during self-programming (set via GUI of dedicated flash memory programmer, etc. during serial programming).
Prohibition of rewriting boot cluster 0		Cannot be disabled after set.

25.8 Data Flash

25.8.1 Data flash overview

An overview of the data flash memory is provided below.

- The user program can rewrite the data flash memory by using the data flash library. For details, refer to the **RL78 Family Data Flash Library User's Manual**.
- The data flash memory can also be rewritten through serial programming using the dedicated flash memory programmer or an external device.
- The data flash can be erased in 1-block (1 KB) units.
- The data flash can be accessed only in 8-bit units.
- The data flash can be directly read by CPU instructions.
- Instructions can be executed from the code flash memory while rewriting the data flash memory (that is, background operation (BGO) is supported).
- Because the data flash memory is an area exclusively used for data, it cannot be used to execute instructions.
- Accessing the data flash memory is not possible while rewriting the code flash memory (during self-programming).
- Manipulating the DFLCTL register is not possible while rewriting the data flash memory.
- Transition to the STOP mode is not possible while rewriting the data flash memory.

Cautions

1. The data flash memory is stopped after a reset is canceled. The data flash control register (DFLCTL) must be set up in order to use the data flash memory.
2. The high-speed on-chip oscillator should be kept operating during data flash rewrite. If it is kept stopping, the high-speed on-chip oscillator clock should be operated (HIOSTOP = 0). The data flash library should be executed after 30 μ s have elapsed.

Remark For rewriting the code flash memory via a user program, see **25.6 Self-Programming**.

25.8.2 Register controlling data flash memory

25.8.2.1 Data flash control register (DFLCTL)

This register is used to enable or disable accessing to the data flash.

The DFLCTL register is set by a 1-bit or 8-bit memory manipulation instruction.

Reset input sets this register to 00H.

Figure 25-12. Format of Data Flash Control Register (DFLCTL)

Address: F0090H After reset: 00H R/W

Symbol	7	6	5	4	3	2	1	<0>
DFLCTL	0	0	0	0	0	0	0	DFLEN

DFLEN	Data flash access control
0	Disables data flash access
1	Enables data flash access

Caution Manipulating the DFLCTL register is not possible while rewriting the data flash memory.

25.8.3 Procedure for accessing data flash memory

The data flash memory is stopped after a reset ends. To access the data flash, make initial settings according to the following procedure.

- <1> Set bit 0 (DFLEN) of the data flash control register (DFLCTL) to 1.
- <2> Wait for the setup to finish for software timer, etc.
The time setup takes differs for each flash operation mode for the main clock.
<Setup time for each flash operation mode>
- HS (High speed main): 5 μ s
 - LS (Low speed main): 720 ns
 - LV (Low voltage main): 10 μ s
- <3> After the wait, the data flash memory can be accessed.

Cautions 1. Accessing the data flash memory is not possible during the setup time.

2. Transition to the STOP mode is not possible during the setup time. To enter the STOP mode during the setup time, clear DFLEN to 0 and then execute the STOP instruction.
3. The high-speed on-chip oscillator should be kept operating during data flash rewrite. If it is kept stopping, operate the high-speed on-chip oscillator clock (HIOSTOP = 0) and execute the data flash library after 30 μ s have elapsed.
4. Once the data flash memory is read while the subsystem clock is selected as the CPU/peripheral hardware clock (CLS = 1), follow the procedure listed as steps (1) to (3) below, in that order, to read the data flash area after switching the CPU/peripheral hardware clock from the subsystem clock to the main system clock.
- (1) Make sure the main system clock is selected as the CPU/peripheral hardware clock (CLS = 0).
- (2) Read data from any location in the data flash area. The value read at this point is undefined.
- (3) Wait for the time listed below according to the operating mode, then read data from the desired parts of the data flash area.
- HS (high-speed main) mode: 5 μ s
LS (low-speed main) mode: 1 μ s
LV (low-voltage main) mode: 10 μ s

After initialized, the data flash memory can be read by using a CPU instruction or can be read/written by using a data flash library.

If the DMA controller operates when the data flash memory is accessed, however, follow one of these procedures:

(A) Suspending/forcibly terminating DMA transfer

Before reading the data flash memory, suspend DMA transfer of all the channels used.

After setting the DWAITn bit to 1, however, wait at least for the duration of three clocks (f_{CLK}) before reading the data flash memory. After reading the data flash memory, lift the suspension of transfer by clearing the DWAITn bit to 0.

Or, forcibly terminate DMA transfer in accordance with the procedure in 15.5.5 Forced termination by software before reading the data flash memory. Resume DMA transfer after the data flash memory has been read.

(B) Access the data flash memory by using the newest data flash library.

(C) Insertion of NOP

Insert an NOP instruction immediately before the instruction that reads the data flash memory.

<Example>

```
MOVW    HL, laddr16    ; Reads RAM.
NOP      ; Insert NOP instruction before reading data flash memory.
MOV      A, [DE]        ; Read data flash memory.
```

If a high-level language such as C is used, however, the compiler may generate two instructions for one code. In this case, the NOP instruction is not inserted immediately before the data flash memory read instruction. Therefore, read the data flash memory by (A) or (B) above.

- Remarks**
1. n: DMA channel number (n = 0, 1)
 2. f_{CLK}: CPU/peripheral hardware clock frequency

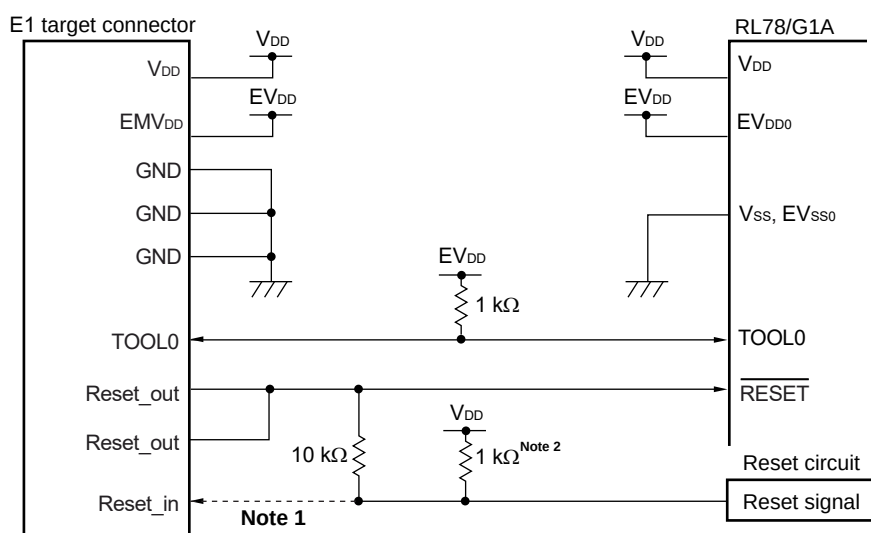
CHAPTER 26 ON-CHIP DEBUG FUNCTION

26.1 Connecting E1 On-Chip Debugging Emulator

The RL78 microcontroller uses the V_{DD} , $\overline{\text{RESET}}$, TOOL0, and V_{SS} pins to communicate with the host machine via an E1 on-chip debugging emulator. Serial communication is performed by using a single-line UART that uses the TOOL0 pin.

Caution The RL78 microcontroller has an on-chip debug function, which is provided for development and evaluation. Do not use the on-chip debug function in products designated for mass production, because the guaranteed number of rewritable times of the flash memory may be exceeded when this function is used, and product reliability therefore cannot be guaranteed. Renesas Electronics is not liable for problems occurring when the on-chip debug function is used.

Figure 26-1. Connection Example of E1 On-chip Debugging Emulator



Notes 1. Connecting the dotted line is not necessary during serial flash programming.

2. If the reset circuit on the target system does not have a buffer and generates a reset signal only with resistors and capacitors, this pull-up resistor is not necessary.

Caution This circuit diagram is assumed that the reset signal outputs from an N-ch O.D. buffer (output resistor: 100 Ω or less)

Remark With products not provided with an EV_{DD0} or EV_{SS0} pin, replace EV_{DD0} with V_{DD} , or replace EV_{SS0} with V_{SS} .

26.2 On-Chip Debug Security ID

The RL78 microcontroller has an on-chip debug operation control bit in the flash memory at 000C3H (see **CHAPTER 24 OPTION BYTE**) and an on-chip debug security ID setting area at 000C4H to 000CDH, to prevent third parties from reading memory content.

When the boot swap function is used, also set a value that is the same as that of 010C3H and 010C4H to 010CDH in advance, because 000C3H, 000C4H to 000CDH and 010C3H, and 010C4H to 010CDH are switched.

Table 26-1. On-Chip Debug Security ID

Address	On-Chip Debug Security ID
000C4H to 000CDH	Any ID code of 10 bytes (except All FFH)
010C4H to 010CDH	

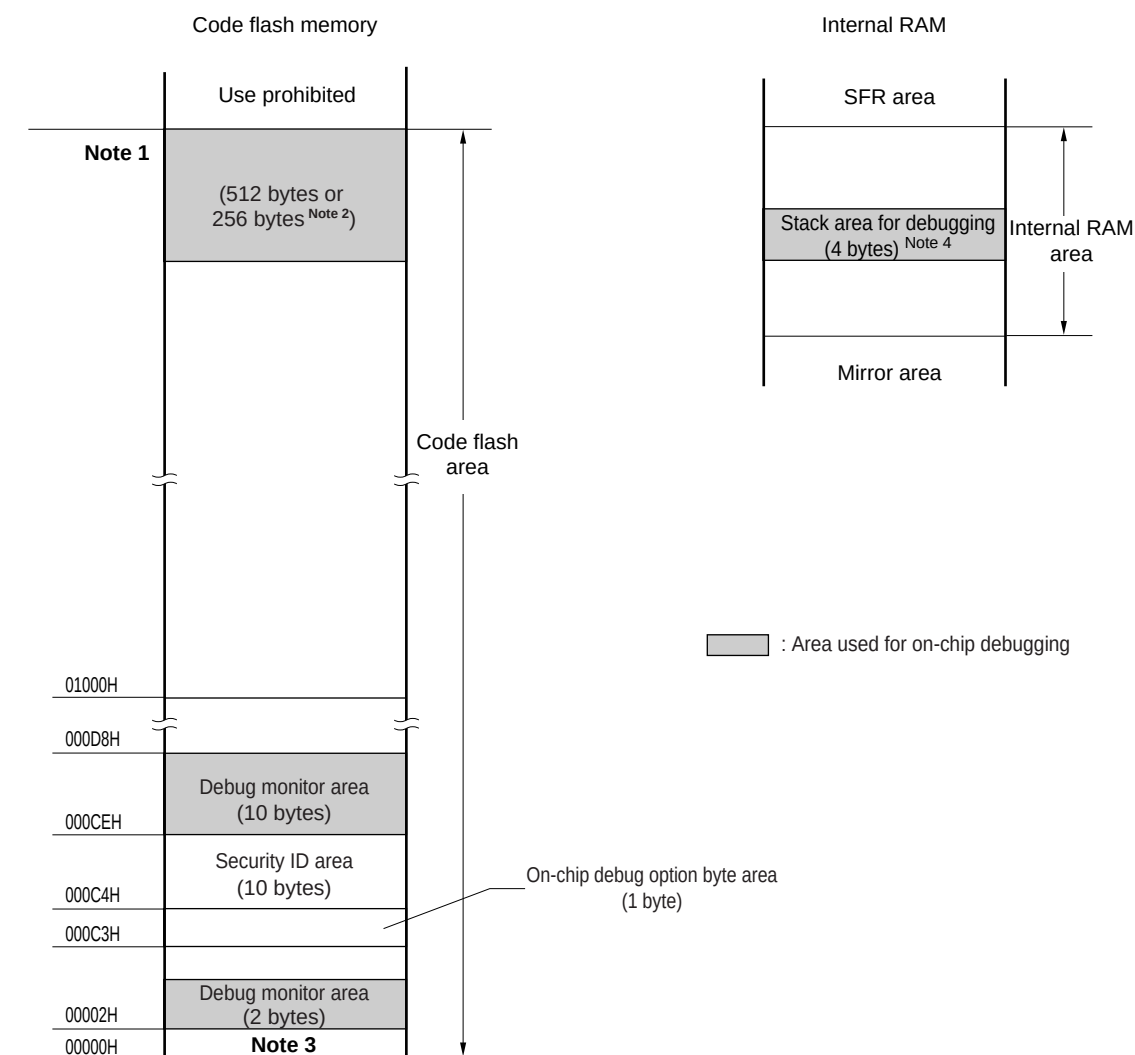
26.3 Securing of User Resources

To perform communication between the RL78 microcontroller and E1 on-chip debugging emulator, as well as each debug function, the securing of memory space must be done beforehand.

If Renesas Electronics assembler or compiler is used, the items can be set by using link options.

(1) Securement of memory space

The shaded portions in Figure 26-2 are the areas reserved for placing the debug monitor program, so user programs or data cannot be allocated in these spaces. When using the on-chip debug function, these spaces must be secured so as not to be used by the user program. Moreover, this area must not be rewritten by the user program.

Figure 26-2. Memory Spaces Where Debug Monitor Programs Are Allocated

Notes 1. Address differs depending on products as follows.

Products (code flash memory capacity)	Address of Note 1
R5F10ExA (x = 8, B, G)	03FFFFH
R5F10ExC (x = 8, B, G, L)	07FFFFH
R5F10ExD (x = 8, B, G, L)	0BFFFFH
R5F10ExE (x = 8, B, G, L)	0FFFFFH

- When real-time RAM monitor (RRM) function and dynamic memory modification (DMM) function are not used, it is 256 bytes.
- In debugging, reset vector is rewritten to address allocated to a monitor program.
- Since this area is allocated immediately before the stack area, the address of this area varies depending on the stack increase and decrease. That is, 4 extra bytes are consumed for the stack area used. When using self-programming, 12 extra bytes are consumed for the stack area used.

CHAPTER 27 BCD CORRECTION CIRCUIT

27.1 BCD Correction Circuit Function

The result of addition/subtraction of the BCD (binary-coded decimal) code and BCD code can be obtained as BCD code with this circuit.

The decimal correction operation result is obtained by performing addition/subtraction having the A register as the operand and then adding/ subtracting the BCD correction result register (BCDADJ).

27.2 Registers Used by BCD Correction Circuit

The BCD correction circuit uses the following registers.

- BCD correction result register (BCDADJ)

27.2.1 BCD correction result register (BCDADJ)

The BCDADJ register stores correction values for obtaining the add/subtract result as BCD code through add/subtract instructions using the A register as the operand.

The value read from the BCDADJ register varies depending on the value of the A register when it is read and those of the CY and AC flags.

The BCDADJ register is read by an 8-bit memory manipulation instruction.

Reset input sets this register to undefined.

Figure 27-1. Format of BCD Correction Result Register (BCDADJ)

Address: F00FEH After reset: undefined R

Symbol	7	6	5	4	3	2	1	0
BCDADJ								

27.3 BCD Correction Circuit Operation

The basic operation of the BCD correction circuit is as follows.

(1) Addition: Calculating the result of adding a BCD code value and another BCD code value by using a BCD code value

- <1> The BCD code value to which addition is performed is stored in the A register.
- <2> By adding the value of the A register and the second operand (value of one more BCD code to be added) as are in binary, the binary operation result is stored in the A register and the correction value is stored in the BCD correction result register (BCDADJ).
- <3> Decimal correction is performed by adding in binary the value of the A register (addition result in binary) and the BCDADJ register (correction value), and the correction result is stored in the A register and CY flag.

Caution The value read from the BCDADJ register varies depending on the value of the A register when it is read and those of the CY and AC flags. Therefore, execute the instruction <3> after the instruction <2> instead of executing any other instructions. To perform BCD correction in the interrupt enabled state, saving and restoring the A register is required within the interrupt function. PSW (CY flag and AC flag) is restored by the RETI instruction.

An example is shown below.

Examples 1: $99 + 89 = 188$

Instruction	A Register	CY Flag	AC Flag	BCDADJ Register
MOV A, #99H ; <1>	99H	–	–	–
ADD A, #89H ; <2>	22H	1	1	66H
ADD A, !BCDADJ ; <3>	88H	1	0	–

Examples 2: $85 + 15 = 100$

Instruction	A Register	CY Flag	AC Flag	BCDADJ Register
MOV A, #85H ; <1>	85H	–	–	–
ADD A, #15H ; <2>	9AH	0	0	66H
ADD A, !BCDADJ ; <3>	00H	1	1	–

Examples 3: $80 + 80 = 160$

Instruction	A Register	CY Flag	AC Flag	BCDADJ Register
MOV A, #80H ; <1>	80H	–	–	–
ADD A, #80H ; <2>	00H	1	0	60H
ADD A, !BCDADJ ; <3>	60H	1	0	–

(2) Subtraction: Calculating the result of subtracting a BCD code value from another BCD code value by using a BCD code value

- <1> The BCD code value from which subtraction is performed is stored in the A register.
- <2> By subtracting the value of the second operand (value of BCD code to be subtracted) from the A register as is in binary, the calculation result in binary is stored in the A register, and the correction value is stored in the BCD correction result register (BCDADJ).
- <3> Decimal correction is performed by subtracting the value of the BCDADJ register (correction value) from the A register (subtraction result in binary) in binary, and the correction result is stored in the A register and CY flag.

Caution The value read from the BCDADJ register varies depending on the value of the A register when it is read and those of the CY and AC flags. Therefore, execute the instruction <3> after the instruction <2> instead of executing any other instructions. To perform BCD correction in the interrupt enabled state, saving and restoring the A register is required within the interrupt function. PSW (CY flag and AC flag) is restored by the RETI instruction.

An example is shown below.

Example: $91 - 52 = 39$

Instruction	A Register	CY Flag	AC Flag	BCDADJ Register
MOV A, #91H ; <1>	91H	–	–	–
SUB A, #52H ; <2>	3FH	0	1	06H
SUB A, !BCDADJ ; <3>	39H	0	0	–

CHAPTER 28 INSTRUCTION SET

This chapter lists the instructions in the RL78 microcontroller instruction set. For details of each operation and operation code, refer to the separate document **RL78 Microcontrollers User's Manual: Software (R01US0015)**.

28.1 Conventions Used in Operation List

28.1.1 Operand identifiers and specification methods

Operands are described in the "Operand" column of each instruction in accordance with the description method of the instruction operand identifier (refer to the assembler specifications for details). When there are two or more description methods, select one of them. Alphabetic letters in capitals and the symbols, #, !, !!, \$, \$!, [], and ES: are keywords and are described as they are. Each symbol has the following meaning.

- #: Immediate data specification
- !: 16-bit absolute address specification
- !!: 20-bit absolute address specification
- \$: 8-bit relative address specification
- \$!: 16-bit relative address specification
- []: Indirect address specification
- ES:: Extension address specification

In the case of immediate data, describe an appropriate numeric value or a label. When using a label, be sure to describe the #, !, !!, \$, \$!, [], and ES: symbols.

For operand register identifiers, r and rp, either function names (X, A, C, etc.) or absolute names (names in parentheses in the table below, R0, R1, R2, etc.) can be used for description.

Table 28-1. Operand Identifiers and Specification Methods

Identifier	Description Method
r	X (R0), A (R1), C (R2), B (R3), E (R4), D (R5), L (R6), H (R7)
rp	AX (RP0), BC (RP1), DE (RP2), HL (RP3)
sfr	Special-function register symbol (SFR symbol) FFF00H to FFFFFH
sfrp	Special-function register symbols (16-bit manipulatable SFR symbol. Even addresses only ^{Note}) FFF00H to FFFFFH
saddr	FFE20H to FFF1FH Immediate data or labels
saddrp	FFE20H to FF1FH Immediate data or labels (even addresses only ^{Note})
addr20	00000H to FFFFFH Immediate data or labels
addr16	0000H to FFFFH Immediate data or labels (only even addresses for 16-bit data transfer instructions ^{Note})
addr5	0080H to 00BFH Immediate data or labels (even addresses only ^{Note})
word	16-bit immediate data or label
byte	8-bit immediate data or label
bit	3-bit immediate data or label
RBn	RB0 to RB3

Note Bit 0 = 0 when an odd address is specified.

Remark The special function registers can be described to operand sfr as symbols. See **Table 3-5 SFR List** for the symbols of the special function registers. The extended special function registers can be described to operand !addr16 as symbols. See **Table 3-6 Extended SFR (2nd SFR) List** for the symbols of the extended special function registers.

28.1.2 Description of operation column

The operation when the instruction is executed is shown in the “Operation” column using the following symbols.

Table 28-2. Symbols in “Operation” Column

Symbol	Function
A	A register; 8-bit accumulator
X	X register
B	B register
C	C register
D	D register
E	E register
H	H register
L	L register
ES	ES register
CS	CS register
AX	AX register pair; 16-bit accumulator
BC	BC register pair
DE	DE register pair
HL	HL register pair
PC	Program counter
SP	Stack pointer
PSW	Program status word
CY	Carry flag
AC	Auxiliary carry flag
Z	Zero flag
RBS	Register bank select flag
IE	Interrupt request enable flag
()	Memory contents indicated by address or register contents in parentheses
X _H , X _L	16-bit registers: X _H = higher 8 bits, X _L = lower 8 bits
X _S , X _H , X _L	20-bit registers: X _S = (bits 19 to 16), X _H = (bits 15 to 8), X _L = (bits 7 to 0)
^	Logical product (AND)
∨	Logical sum (OR)
⊕	Exclusive logical sum (exclusive OR)
—	Inverted data
addr5	16-bit immediate data (even addresses only in 0080H to 00BFH)
addr16	16-bit immediate data
addr20	20-bit immediate data
jdisp8	Signed 8-bit data (displacement value)
jdisp16	Signed 16-bit data (displacement value)

28.1.3 Description of flag operation column

The change of the flag value when the instruction is executed is shown in the “Flag” column using the following symbols.

Table 28-3. Symbols in “Flag” Column

Symbol	Change of Flag Value
(Blank)	Unchanged
0	Cleared to 0
1	Set to 1
×	Set/cleared according to the result
R	Previously saved value is restored

28.1.4 PREFIX instruction

Instructions with “ES:” have a PREFIX operation code as a prefix to extend the accessible data area to the 1 MB space (00000H to FFFFFH), by adding the ES register value to the 64 KB space from F0000H to FFFFFH. When a PREFIX operation code is attached as a prefix to the target instruction, only one instruction immediately after the PREFIX operation code is executed as the addresses with the ES register value added.

A interrupt and DMA transfer are not acknowledged between a PREFIX instruction code and the instruction immediately after.

Table 28-4. Use Example of PREFIX Operation Code

Instruction	Opcode				
	1	2	3	4	5
MOV !addr16, #byte	CFH	!addr16		#byte	–
MOV ES:!addr16, #byte	11H	CFH	!addr16		#byte
MOV A, [HL]	8BH	–	–	–	–
MOV A, ES:[HL]	11H	8BH	–	–	–

Caution Set the ES register value with MOV ES, A, etc., before executing the PREFIX instruction.

28.2 Operation List

Table 28-5. Operation List (1/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit data transfer	MOV	r, #byte	2	1	–	$r \leftarrow \text{byte}$			
		PSW, #byte	3	3	–	$\text{PSW} \leftarrow \text{byte}$	x	x	x
		CS, #byte	3	1	–	$\text{CS} \leftarrow \text{byte}$			
		ES, #byte	2	1	–	$\text{ES} \leftarrow \text{byte}$			
		!addr16, #byte	4	1	–	$(\text{addr16}) \leftarrow \text{byte}$			
		ES:!addr16, #byte	5	2	–	$(\text{ES}, \text{addr16}) \leftarrow \text{byte}$			
		saddr, #byte	3	1	–	$(\text{saddr}) \leftarrow \text{byte}$			
		sfr, #byte	3	1	–	$\text{sfr} \leftarrow \text{byte}$			
		[DE+byte], #byte	3	1	–	$(\text{DE}+\text{byte}) \leftarrow \text{byte}$			
		ES:[DE+byte], #byte	4	2	–	$((\text{ES}, \text{DE})+\text{byte}) \leftarrow \text{byte}$			
		[HL+byte], #byte	3	1	–	$(\text{HL}+\text{byte}) \leftarrow \text{byte}$			
		ES:[HL+byte], #byte	4	2	–	$((\text{ES}, \text{HL})+\text{byte}) \leftarrow \text{byte}$			
		[SP+byte], #byte	3	1	–	$(\text{SP}+\text{byte}) \leftarrow \text{byte}$			
		word[B], #byte	4	1	–	$(\text{B}+\text{word}) \leftarrow \text{byte}$			
		ES:word[B], #byte	5	2	–	$((\text{ES}, \text{B})+\text{word}) \leftarrow \text{byte}$			
		word[C], #byte	4	1	–	$(\text{C}+\text{word}) \leftarrow \text{byte}$			
		ES:word[C], #byte	5	2	–	$((\text{ES}, \text{C})+\text{word}) \leftarrow \text{byte}$			
		word[BC], #byte	4	1	–	$(\text{BC}+\text{word}) \leftarrow \text{byte}$			
		ES:word[BC], #byte	5	2	–	$((\text{ES}, \text{BC})+\text{word}) \leftarrow \text{byte}$			
		A, r Note 3	1	1	–	$\text{A} \leftarrow r$			
		r, A Note 3	1	1	–	$r \leftarrow \text{A}$			
		A, PSW	2	1	–	$\text{A} \leftarrow \text{PSW}$			
		PSW, A	2	3	–	$\text{PSW} \leftarrow \text{A}$	x	x	x
		A, CS	2	1	–	$\text{A} \leftarrow \text{CS}$			
		CS, A	2	1	–	$\text{CS} \leftarrow \text{A}$			
		A, ES	2	1	–	$\text{A} \leftarrow \text{ES}$			
		ES, A	2	1	–	$\text{ES} \leftarrow \text{A}$			
		A, !addr16	3	1	4	$\text{A} \leftarrow (\text{addr16})$			
		A, ES:!addr16	4	2	5	$\text{A} \leftarrow (\text{ES}, \text{addr16})$			
		!addr16, A	3	1	–	$(\text{addr16}) \leftarrow \text{A}$			
		ES:!addr16, A	4	2	–	$(\text{ES}, \text{addr16}) \leftarrow \text{A}$			
		A, saddr	2	1	–	$\text{A} \leftarrow (\text{saddr})$			
		saddr, A	2	1	–	$(\text{saddr}) \leftarrow \text{A}$			

- Notes**
1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.
 2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.
 3. Except $r = \text{A}$

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (2/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit data transfer	MOV	A, sfr	2	1	–	$A \leftarrow \text{sfr}$			
		sfr, A	2	1	–	$\text{sfr} \leftarrow A$			
		A, [DE]	1	1	4	$A \leftarrow (\text{DE})$			
		[DE], A	1	1	–	$(\text{DE}) \leftarrow A$			
		A, ES:[DE]	2	2	5	$A \leftarrow (\text{ES}, \text{DE})$			
		ES:[DE], A	2	2	–	$(\text{ES}, \text{DE}) \leftarrow A$			
		A, [HL]	1	1	4	$A \leftarrow (\text{HL})$			
		[HL], A	1	1	–	$(\text{HL}) \leftarrow A$			
		A, ES:[HL]	2	2	5	$A \leftarrow (\text{ES}, \text{HL})$			
		ES:[HL], A	2	2	–	$(\text{ES}, \text{HL}) \leftarrow A$			
		A, [DE+byte]	2	1	4	$A \leftarrow (\text{DE} + \text{byte})$			
		[DE+byte], A	2	1	–	$(\text{DE} + \text{byte}) \leftarrow A$			
		A, ES:[DE+byte]	3	2	5	$A \leftarrow ((\text{ES}, \text{DE}) + \text{byte})$			
		ES:[DE+byte], A	3	2	–	$((\text{ES}, \text{DE}) + \text{byte}) \leftarrow A$			
		A, [HL+byte]	2	1	4	$A \leftarrow (\text{HL} + \text{byte})$			
		[HL+byte], A	2	1	–	$(\text{HL} + \text{byte}) \leftarrow A$			
		A, ES:[HL+byte]	3	2	5	$A \leftarrow ((\text{ES}, \text{HL}) + \text{byte})$			
		ES:[HL+byte], A	3	2	–	$((\text{ES}, \text{HL}) + \text{byte}) \leftarrow A$			
		A, [SP+byte]	2	1	–	$A \leftarrow (\text{SP} + \text{byte})$			
		[SP+byte], A	2	1	–	$(\text{SP} + \text{byte}) \leftarrow A$			
		A, word[B]	3	1	4	$A \leftarrow (\text{B} + \text{word})$			
		word[B], A	3	1	–	$(\text{B} + \text{word}) \leftarrow A$			
		A, ES:word[B]	4	2	5	$A \leftarrow ((\text{ES}, \text{B}) + \text{word})$			
		ES:word[B], A	4	2	–	$((\text{ES}, \text{B}) + \text{word}) \leftarrow A$			
		A, word[C]	3	1	4	$A \leftarrow (\text{C} + \text{word})$			
		word[C], A	3	1	–	$(\text{C} + \text{word}) \leftarrow A$			
		A, ES:word[C]	4	2	5	$A \leftarrow ((\text{ES}, \text{C}) + \text{word})$			
		ES:word[C], A	4	2	–	$((\text{ES}, \text{C}) + \text{word}) \leftarrow A$			
		A, word[BC]	3	1	4	$A \leftarrow (\text{BC} + \text{word})$			
		word[BC], A	3	1	–	$(\text{BC} + \text{word}) \leftarrow A$			
		A, ES:word[BC]	4	2	5	$A \leftarrow ((\text{ES}, \text{BC}) + \text{word})$			
		ES:word[BC], A	4	2	–	$((\text{ES}, \text{BC}) + \text{word}) \leftarrow A$			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (3/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit data transfer	MOV	A, [HL+B]	2	1	4	$A \leftarrow (HL + B)$			
		[HL+B], A	2	1	–	$(HL + B) \leftarrow A$			
		A, ES:[HL+B]	3	2	5	$A \leftarrow ((ES, HL) + B)$			
		ES:[HL+B], A	3	2	–	$((ES, HL) + B) \leftarrow A$			
		A, [HL+C]	2	1	4	$A \leftarrow (HL + C)$			
		[HL+C], A	2	1	–	$(HL + C) \leftarrow A$			
		A, ES:[HL+C]	3	2	5	$A \leftarrow ((ES, HL) + C)$			
		ES:[HL+C], A	3	2	–	$((ES, HL) + C) \leftarrow A$			
		X, laddr16	3	1	4	$X \leftarrow (addr16)$			
		X, ES:laddr16	4	2	5	$X \leftarrow (ES, addr16)$			
		X, saddr	2	1	–	$X \leftarrow (saddr)$			
		B, laddr16	3	1	4	$B \leftarrow (addr16)$			
		B, ES:laddr16	4	2	5	$B \leftarrow (ES, addr16)$			
		B, saddr	2	1	–	$B \leftarrow (saddr)$			
		C, laddr16	3	1	4	$C \leftarrow (addr16)$			
		C, ES:laddr16	4	2	5	$C \leftarrow (ES, addr16)$			
		C, saddr	2	1	–	$C \leftarrow (saddr)$			
		ES, saddr	3	1	–	$ES \leftarrow (saddr)$			
	XCH	A, r ^{Note 3}	1 (r = X) 2 (other than r = X)	1	–	$A \longleftrightarrow r$			
		A, laddr16	4	2	–	$A \longleftrightarrow (addr16)$			
		A, ES:laddr16	5	3	–	$A \longleftrightarrow (ES, addr16)$			
		A, saddr	3	2	–	$A \longleftrightarrow (saddr)$			
		A, sfr	3	2	–	$A \longleftrightarrow sfr$			
		A, [DE]	2	2	–	$A \longleftrightarrow (DE)$			
		A, ES:[DE]	3	3	–	$A \longleftrightarrow (ES, DE)$			
		A, [HL]	2	2	–	$A \longleftrightarrow (HL)$			
		A, ES:[HL]	3	3	–	$A \longleftrightarrow (ES, HL)$			
		A, [DE+byte]	3	2	–	$A \longleftrightarrow (DE + \text{byte})$			
		A, ES:[DE+byte]	4	3	–	$A \longleftrightarrow ((ES, DE) + \text{byte})$			
		A, [HL+byte]	3	2	–	$A \longleftrightarrow (HL + \text{byte})$			
		A, ES:[HL+byte]	4	3	–	$A \longleftrightarrow ((ES, HL) + \text{byte})$			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except $r = A$

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (4/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit data transfer	XCH	A, [HL+B]	2	2	–	$A \leftrightarrow (HL+B)$			
		A, ES:[HL+B]	3	3	–	$A \leftrightarrow ((ES, HL)+B)$			
		A, [HL+C]	2	2	–	$A \leftrightarrow (HL+C)$			
		A, ES:[HL+C]	3	3	–	$A \leftrightarrow ((ES, HL)+C)$			
	ONEB	A	1	1	–	$A \leftarrow 01H$			
		X	1	1	–	$X \leftarrow 01H$			
		B	1	1	–	$B \leftarrow 01H$			
		C	1	1	–	$C \leftarrow 01H$			
		!addr16	3	1	–	$(addr16) \leftarrow 01H$			
		ES:!addr16	4	2	–	$(ES, addr16) \leftarrow 01H$			
		saddr	2	1	–	$(saddr) \leftarrow 01H$			
	CLRB	A	1	1	–	$A \leftarrow 00H$			
		X	1	1	–	$X \leftarrow 00H$			
		B	1	1	–	$B \leftarrow 00H$			
		C	1	1	–	$C \leftarrow 00H$			
		!addr16	3	1	–	$(addr16) \leftarrow 00H$			
		ES:!addr16	4	2	–	$(ES, addr16) \leftarrow 00H$			
		saddr	2	1	–	$(saddr) \leftarrow 00H$			
	MOVS	[HL+byte], X	3	1	–	$(HL+byte) \leftarrow X$	×		×
		ES:[HL+byte], X	4	2	–	$(ES, HL+byte) \leftarrow X$	×		×
16-bit data transfer	MOVW	rp, #word	3	1	–	$rp \leftarrow word$			
		saddrp, #word	4	1	–	$(saddrp) \leftarrow word$			
		sfrp, #word	4	1	–	$sfrp \leftarrow word$			
		AX, rp ^{Note 3}	1	1	–	$AX \leftarrow rp$			
		rp, AX ^{Note 3}	1	1	–	$rp \leftarrow AX$			
		AX, !addr16	3	1	4	$AX \leftarrow (addr16)$			
		!addr16, AX	3	1	–	$(addr16) \leftarrow AX$			
		AX, ES:!addr16	4	2	5	$AX \leftarrow (ES, addr16)$			
		ES:!addr16, AX	4	2	–	$(ES, addr16) \leftarrow AX$			
		AX, saddrp	2	1	–	$AX \leftarrow (saddrp)$			
		saddrp, AX	2	1	–	$(saddrp) \leftarrow AX$			
		AX, sfrp	2	1	–	$AX \leftarrow sfrp$			
		sfrp, AX	2	1	–	$sfrp \leftarrow AX$			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except rp = AX

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (5/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
16-bit data transfer	MOVW	AX, [DE]	1	1	4	$AX \leftarrow (DE)$			
		[DE], AX	1	1	–	$(DE) \leftarrow AX$			
		AX, ES:[DE]	2	2	5	$AX \leftarrow (ES, DE)$			
		ES:[DE], AX	2	2	–	$(ES, DE) \leftarrow AX$			
		AX, [HL]	1	1	4	$AX \leftarrow (HL)$			
		[HL], AX	1	1	–	$(HL) \leftarrow AX$			
		AX, ES:[HL]	2	2	5	$AX \leftarrow (ES, HL)$			
		ES:[HL], AX	2	2	–	$(ES, HL) \leftarrow AX$			
		AX, [DE+byte]	2	1	4	$AX \leftarrow (DE+byte)$			
		[DE+byte], AX	2	1	–	$(DE+byte) \leftarrow AX$			
		AX, ES:[DE+byte]	3	2	5	$AX \leftarrow ((ES, DE) + byte)$			
		ES:[DE+byte], AX	3	2	–	$((ES, DE) + byte) \leftarrow AX$			
		AX, [HL+byte]	2	1	4	$AX \leftarrow (HL + byte)$			
		[HL+byte], AX	2	1	–	$(HL + byte) \leftarrow AX$			
		AX, ES:[HL+byte]	3	2	5	$AX \leftarrow ((ES, HL) + byte)$			
		ES:[HL+byte], AX	3	2	–	$((ES, HL) + byte) \leftarrow AX$			
		AX, [SP+byte]	2	1	–	$AX \leftarrow (SP + byte)$			
		[SP+byte], AX	2	1	–	$(SP + byte) \leftarrow AX$			
		AX, word[B]	3	1	4	$AX \leftarrow (B + word)$			
		word[B], AX	3	1	–	$(B + word) \leftarrow AX$			
		AX, ES:word[B]	4	2	5	$AX \leftarrow ((ES, B) + word)$			
		ES:word[B], AX	4	2	–	$((ES, B) + word) \leftarrow AX$			
		AX, word[C]	3	1	4	$AX \leftarrow (C + word)$			
		word[C], AX	3	1	–	$(C + word) \leftarrow AX$			
		AX, ES:word[C]	4	2	5	$AX \leftarrow ((ES, C) + word)$			
		ES:word[C], AX	4	2	–	$((ES, C) + word) \leftarrow AX$			
		AX, word[BC]	3	1	4	$AX \leftarrow (BC + word)$			
		word[BC], AX	3	1	–	$(BC + word) \leftarrow AX$			
		AX, ES:word[BC]	4	2	5	$AX \leftarrow ((ES, BC) + word)$			
		ES:word[BC], AX	4	2	–	$((ES, BC) + word) \leftarrow AX$			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (6/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
16-bit data transfer	MOVW	BC, !addr16	3	1	4	$BC \leftarrow (addr16)$			
		BC, ES:!addr16	4	2	5	$BC \leftarrow (ES, addr16)$			
		DE, !addr16	3	1	4	$DE \leftarrow (addr16)$			
		DE, ES:!addr16	4	2	5	$DE \leftarrow (ES, addr16)$			
		HL, !addr16	3	1	4	$HL \leftarrow (addr16)$			
		HL, ES:!addr16	4	2	5	$HL \leftarrow (ES, addr16)$			
		BC, saddrp	2	1	–	$BC \leftarrow (saddrp)$			
		DE, saddrp	2	1	–	$DE \leftarrow (saddrp)$			
		HL, saddrp	2	1	–	$HL \leftarrow (saddrp)$			
	XCHW	AX, rp ^{Note 3}	1	1	–	$AX \leftrightarrow rp$			
	ONEW	AX	1	1	–	$AX \leftarrow 0001H$			
		BC	1	1	–	$BC \leftarrow 0001H$			
	CLRW	AX	1	1	–	$AX \leftarrow 0000H$			
		BC	1	1	–	$BC \leftarrow 0000H$			
8-bit operation	ADD	A, #byte	2	1	–	$A, CY \leftarrow A + \text{byte}$	x	x	x
		saddr, #byte	3	2	–	$(saddr), CY \leftarrow (saddr) + \text{byte}$	x	x	x
		A, r ^{Note 4}	2	1	–	$A, CY \leftarrow A + r$	x	x	x
		r, A	2	1	–	$r, CY \leftarrow r + A$	x	x	x
		A, !addr16	3	1	4	$A, CY \leftarrow A + (addr16)$	x	x	x
		A, ES:!addr16	4	2	5	$A, CY \leftarrow A + (ES, addr16)$	x	x	x
		A, saddr	2	1	–	$A, CY \leftarrow A + (saddr)$	x	x	x
		A, [HL]	1	1	4	$A, CY \leftarrow A + (HL)$	x	x	x
		A, ES:[HL]	2	2	5	$A, CY \leftarrow A + (ES, HL)$	x	x	x
		A, [HL+byte]	2	1	4	$A, CY \leftarrow A + (HL + \text{byte})$	x	x	x
		A, ES:[HL+byte]	3	2	5	$A, CY \leftarrow A + ((ES, HL) + \text{byte})$	x	x	x
		A, [HL+B]	2	1	4	$A, CY \leftarrow A + (HL + B)$	x	x	x
		A, ES:[HL+B]	3	2	5	$A, CY \leftarrow A + ((ES, HL) + B)$	x	x	x
		A, [HL+C]	2	1	4	$A, CY \leftarrow A + (HL + C)$	x	x	x
		A, ES:[HL+C]	3	2	5	$A, CY \leftarrow A + ((ES, HL) + C)$	x	x	x

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except $rp = AX$

4. Except $r = A$

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (7/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit operation	ADDC	A, #byte	2	1	–	$A, CY \leftarrow A + \text{byte} + CY$	x	x	x
		saddr, #byte	3	2	–	$(saddr), CY \leftarrow (saddr) + \text{byte} + CY$	x	x	x
		A, r ^{Note 3}	2	1	–	$A, CY \leftarrow A + r + CY$	x	x	x
		r, A	2	1	–	$r, CY \leftarrow r + A + CY$	x	x	x
		A, laddr16	3	1	4	$A, CY \leftarrow A + (\text{laddr16}) + CY$	x	x	x
		A, ES:laddr16	4	2	5	$A, CY \leftarrow A + (ES, \text{laddr16}) + CY$	x	x	x
		A, saddr	2	1	–	$A, CY \leftarrow A + (saddr) + CY$	x	x	x
		A, [HL]	1	1	4	$A, CY \leftarrow A + (HL) + CY$	x	x	x
		A, ES:[HL]	2	2	5	$A, CY \leftarrow A + (ES, HL) + CY$	x	x	x
		A, [HL+byte]	2	1	4	$A, CY \leftarrow A + (HL + \text{byte}) + CY$	x	x	x
		A, ES:[HL+byte]	3	2	5	$A, CY \leftarrow A + ((ES, HL) + \text{byte}) + CY$	x	x	x
		A, [HL+B]	2	1	4	$A, CY \leftarrow A + (HL + B) + CY$	x	x	x
		A, ES:[HL+B]	3	2	5	$A, CY \leftarrow A + ((ES, HL) + B) + CY$	x	x	x
		A, [HL+C]	2	1	4	$A, CY \leftarrow A + (HL + C) + CY$	x	x	x
		A, ES:[HL+C]	3	2	5	$A, CY \leftarrow A + ((ES, HL) + C) + CY$	x	x	x
	SUB	A, #byte	2	1	–	$A, CY \leftarrow A - \text{byte}$	x	x	x
		saddr, #byte	3	2	–	$(saddr), CY \leftarrow (saddr) - \text{byte}$	x	x	x
		A, r ^{Note 3}	2	1	–	$A, CY \leftarrow A - r$	x	x	x
		r, A	2	1	–	$r, CY \leftarrow r - A$	x	x	x
		A, laddr16	3	1	4	$A, CY \leftarrow A - (\text{laddr16})$	x	x	x
		A, ES:laddr16	4	2	5	$A, CY \leftarrow A - (ES, \text{laddr16})$	x	x	x
		A, saddr	2	1	–	$A, CY \leftarrow A - (saddr)$	x	x	x
		A, [HL]	1	1	4	$A, CY \leftarrow A - (HL)$	x	x	x
		A, ES:[HL]	2	2	5	$A, CY \leftarrow A - (ES, HL)$	x	x	x
		A, [HL+byte]	2	1	4	$A, CY \leftarrow A - (HL + \text{byte})$	x	x	x
		A, ES:[HL+byte]	3	2	5	$A, CY \leftarrow A - ((ES, HL) + \text{byte})$	x	x	x
		A, [HL+B]	2	1	4	$A, CY \leftarrow A - (HL + B)$	x	x	x
		A, ES:[HL+B]	3	2	5	$A, CY \leftarrow A - ((ES, HL) + B)$	x	x	x
		A, [HL+C]	2	1	4	$A, CY \leftarrow A - (HL + C)$	x	x	x
		A, ES:[HL+C]	3	2	5	$A, CY \leftarrow A - ((ES, HL) + C)$	x	x	x

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except $r = A$

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (8/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit operation	SUBC	A, #byte	2	1	–	$A, CY \leftarrow A - \text{byte} - CY$	x	x	x
		saddr, #byte	3	2	–	$(saddr), CY \leftarrow (saddr) - \text{byte} - CY$	x	x	x
		A, r ^{Note 3}	2	1	–	$A, CY \leftarrow A - r - CY$	x	x	x
		r, A	2	1	–	$r, CY \leftarrow r - A - CY$	x	x	x
		A, !addr16	3	1	4	$A, CY \leftarrow A - (\text{addr16}) - CY$	x	x	x
		A, ES:!addr16	4	2	5	$A, CY \leftarrow A - (ES, \text{addr16}) - CY$	x	x	x
		A, saddr	2	1	–	$A, CY \leftarrow A - (saddr) - CY$	x	x	x
		A, [HL]	1	1	4	$A, CY \leftarrow A - (HL) - CY$	x	x	x
		A, ES:[HL]	2	2	5	$A, CY \leftarrow A - (ES, HL) - CY$	x	x	x
		A, [HL+byte]	2	1	4	$A, CY \leftarrow A - (HL+\text{byte}) - CY$	x	x	x
		A, ES:[HL+byte]	3	2	5	$A, CY \leftarrow A - ((ES, HL)+\text{byte}) - CY$	x	x	x
		A, [HL+B]	2	1	4	$A, CY \leftarrow A - (HL+B) - CY$	x	x	x
		A, ES:[HL+B]	3	2	5	$A, CY \leftarrow A - ((ES, HL)+B) - CY$	x	x	x
		A, [HL+C]	2	1	4	$A, CY \leftarrow A - (HL+C) - CY$	x	x	x
		A, ES:[HL+C]	3	2	5	$A, CY \leftarrow A - ((ES:HL)+C) - CY$	x	x	x
	AND	A, #byte	2	1	–	$A \leftarrow A \wedge \text{byte}$	x		
		saddr, #byte	3	2	–	$(saddr) \leftarrow (saddr) \wedge \text{byte}$	x		
		A, r ^{Note 3}	2	1	–	$A \leftarrow A \wedge r$	x		
		r, A	2	1	–	$r \leftarrow r \wedge A$	x		
		A, !addr16	3	1	4	$A \leftarrow A \wedge (\text{addr16})$	x		
		A, ES:!addr16	4	2	5	$A \leftarrow A \wedge (ES:\text{addr16})$	x		
		A, saddr	2	1	–	$A \leftarrow A \wedge (saddr)$	x		
		A, [HL]	1	1	4	$A \leftarrow A \wedge (HL)$	x		
		A, ES:[HL]	2	2	5	$A \leftarrow A \wedge (ES:HL)$	x		
		A, [HL+byte]	2	1	4	$A \leftarrow A \wedge (HL+\text{byte})$	x		
		A, ES:[HL+byte]	3	2	5	$A \leftarrow A \wedge ((ES:HL)+\text{byte})$	x		
		A, [HL+B]	2	1	4	$A \leftarrow A \wedge (HL+B)$	x		
		A, ES:[HL+B]	3	2	5	$A \leftarrow A \wedge ((ES:HL)+B)$	x		
		A, [HL+C]	2	1	4	$A \leftarrow A \wedge (HL+C)$	x		
		A, ES:[HL+C]	3	2	5	$A \leftarrow A \wedge ((ES:HL)+C)$	x		

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except $r = A$

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (9/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit operation	OR	A, #byte	2	1	–	$A \leftarrow A \vee \text{byte}$	x		
		saddr, #byte	3	2	–	$(\text{saddr}) \leftarrow (\text{saddr}) \vee \text{byte}$	x		
		A, r ^{Note 3}	2	1	–	$A \leftarrow A \vee r$	x		
		r, A	2	1	–	$r \leftarrow r \vee A$	x		
		A, !addr16	3	1	4	$A \leftarrow A \vee (\text{addr16})$	x		
		A, ES:!addr16	4	2	5	$A \leftarrow A \vee (\text{ES:addr16})$	x		
		A, saddr	2	1	–	$A \leftarrow A \vee (\text{saddr})$	x		
		A, [HL]	1	1	4	$A \leftarrow A \vee (\text{H})$	x		
		A, ES:[HL]	2	2	5	$A \leftarrow A \vee (\text{ES:HL})$	x		
		A, [HL+byte]	2	1	4	$A \leftarrow A \vee (\text{HL}+\text{byte})$	x		
		A, ES:[HL+byte]	3	2	5	$A \leftarrow A \vee ((\text{ES:HL})+\text{byte})$	x		
		A, [HL+B]	2	1	4	$A \leftarrow A \vee (\text{HL}+\text{B})$	x		
		A, ES:[HL+B]	3	2	5	$A \leftarrow A \vee ((\text{ES:HL})+\text{B})$	x		
		A, [HL+C]	2	1	4	$A \leftarrow A \vee (\text{HL}+\text{C})$	x		
		A, ES:[HL+C]	3	2	5	$A \leftarrow A \vee ((\text{ES:HL})+\text{C})$	x		
	XOR	A, #byte	2	1	–	$A \leftarrow A \oplus \text{byte}$	x		
		saddr, #byte	3	2	–	$(\text{saddr}) \leftarrow (\text{saddr}) \oplus \text{byte}$	x		
		A, r ^{Note 3}	2	1	–	$A \leftarrow A \oplus r$	x		
		r, A	2	1	–	$r \leftarrow r \oplus A$	x		
		A, !addr16	3	1	4	$A \leftarrow A \oplus (\text{addr16})$	x		
		A, ES:!addr16	4	2	5	$A \leftarrow A \oplus (\text{ES:addr16})$	x		
		A, saddr	2	1	–	$A \leftarrow A \oplus (\text{saddr})$	x		
		A, [HL]	1	1	4	$A \leftarrow A \oplus (\text{HL})$	x		
		A, ES:[HL]	2	2	5	$A \leftarrow A \oplus (\text{ES:HL})$	x		
		A, [HL+byte]	2	1	4	$A \leftarrow A \oplus (\text{HL}+\text{byte})$	x		
		A, ES:[HL+byte]	3	2	5	$A \leftarrow A \oplus ((\text{ES:HL})+\text{byte})$	x		
		A, [HL+B]	2	1	4	$A \leftarrow A \oplus (\text{HL}+\text{B})$	x		
		A, ES:[HL+B]	3	2	5	$A \leftarrow A \oplus ((\text{ES:HL})+\text{B})$	x		
		A, [HL+C]	2	1	4	$A \leftarrow A \oplus (\text{HL}+\text{C})$	x		
		A, ES:[HL+C]	3	2	5	$A \leftarrow A \oplus ((\text{ES:HL})+\text{C})$	x		

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except $r = A$

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (10/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
8-bit operation	CMP	A, #byte	2	1	–	A – byte	x	x	x
		!addr16, #byte	4	1	4	(addr16) – byte	x	x	x
		ES:!addr16, #byte	5	2	5	(ES:addr16) – byte	x	x	x
		saddr, #byte	3	1	–	(saddr) – byte	x	x	x
		A, r ^{Note3}	2	1	–	A – r	x	x	x
		r, A	2	1	–	r – A	x	x	x
		A, !addr16	3	1	4	A – (addr16)	x	x	x
		A, ES:!addr16	4	2	5	A – (ES:addr16)	x	x	x
		A, saddr	2	1	–	A – (saddr)	x	x	x
		A, [HL]	1	1	4	A – (HL)	x	x	x
		A, ES:[HL]	2	2	5	A – (ES:HL)	x	x	x
		A, [HL+byte]	2	1	4	A – (HL+byte)	x	x	x
		A, ES:[HL+byte]	3	2	5	A – ((ES:HL)+byte)	x	x	x
		A, [HL+B]	2	1	4	A – (HL+B)	x	x	x
		A, ES:[HL+B]	3	2	5	A – ((ES:HL)+B)	x	x	x
		A, [HL+C]	2	1	4	A – (HL+C)	x	x	x
		A, ES:[HL+C]	3	2	5	A – ((ES:HL)+C)	x	x	x
	CMP0	A	1	1	–	A – 00H	x	0	0
		X	1	1	–	X – 00H	x	0	0
		B	1	1	–	B – 00H	x	0	0
		C	1	1	–	C – 00H	x	0	0
		!addr16	3	1	4	(addr16) – 00H	x	0	0
		ES:!addr16	4	2	5	(ES:addr16) – 00H	x	0	0
		saddr	2	1	–	(saddr) – 00H	x	0	0
	CMPS	X, [HL+byte]	3	1	4	X – (HL+byte)	x	x	x
		X, ES:[HL+byte]	4	2	5	X – ((ES:HL)+byte)	x	x	x

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. Except r = A

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (11/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
16-bit operation	ADDW	AX, #word	3	1	–	AX, CY ← AX+word	x	x	x
		AX, AX	1	1	–	AX, CY ← AX+AX	x	x	x
		AX, BC	1	1	–	AX, CY ← AX+BC	x	x	x
		AX, DE	1	1	–	AX, CY ← AX+DE	x	x	x
		AX, HL	1	1	–	AX, CY ← AX+HL	x	x	x
		AX, !addr16	3	1	4	AX, CY ← AX+(addr16)	x	x	x
		AX, ES:!addr16	4	2	5	AX, CY ← AX+(ES:addr16)	x	x	x
		AX, saddrp	2	1	–	AX, CY ← AX+(saddrp)	x	x	x
		AX, [HL+byte]	3	1	4	AX, CY ← AX+(HL+byte)	x	x	x
		AX, ES: [HL+byte]	4	2	5	AX, CY ← AX+((ES:HL)+byte)	x	x	x
	SUBW	AX, #word	3	1	–	AX, CY ← AX – word	x	x	x
		AX, BC	1	1	–	AX, CY ← AX – BC	x	x	x
		AX, DE	1	1	–	AX, CY ← AX – DE	x	x	x
		AX, HL	1	1	–	AX, CY ← AX – HL	x	x	x
		AX, !addr16	3	1	4	AX, CY ← AX – (addr16)	x	x	x
		AX, ES:!addr16	4	2	5	AX, CY ← AX – (ES:addr16)	x	x	x
		AX, saddrp	2	1	–	AX, CY ← AX – (saddrp)	x	x	x
		AX, [HL+byte]	3	1	4	AX, CY ← AX – (HL+byte)	x	x	x
		AX, ES: [HL+byte]	4	2	5	AX, CY ← AX – ((ES:HL)+byte)	x	x	x
	CMPW	AX, #word	3	1	–	AX – word	x	x	x
		AX, BC	1	1	–	AX – BC	x	x	x
		AX, DE	1	1	–	AX – DE	x	x	x
		AX, HL	1	1	–	AX – HL	x	x	x
		AX, !addr16	3	1	4	AX – (addr16)	x	x	x
		AX, ES:!addr16	4	2	5	AX – (ES:addr16)	x	x	x
		AX, saddrp	2	1	–	AX – (saddrp)	x	x	x
		AX, [HL+byte]	3	1	4	AX – (HL+byte)	x	x	x
		AX, ES: [HL+byte]	4	2	5	AX – ((ES:HL)+byte)	x	x	x
Multiply	MULU	X	1	1	–	AX ← A×X			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (12/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
Increment/decrement	INC	r	1	1	—	$r \leftarrow r+1$	x	x	
		!addr16	3	2	—	$(addr16) \leftarrow (addr16)+1$	x	x	
		ES:!addr16	4	3	—	$(ES, addr16) \leftarrow (ES, addr16)+1$	x	x	
		saddr	2	2	—	$(saddr) \leftarrow (saddr)+1$	x	x	
		[HL+byte]	3	2	—	$(HL+byte) \leftarrow (HL+byte)+1$	x	x	
		ES: [HL+byte]	4	3	—	$((ES:HL)+byte) \leftarrow ((ES:HL)+byte)+1$	x	x	
	DEC	r	1	1	—	$r \leftarrow r-1$	x	x	
		!addr16	3	2	—	$(addr16) \leftarrow (addr16)-1$	x	x	
		ES:!addr16	4	3	—	$(ES, addr16) \leftarrow (ES, addr16)-1$	x	x	
		saddr	2	2	—	$(saddr) \leftarrow (saddr)-1$	x	x	
		[HL+byte]	3	2	—	$(HL+byte) \leftarrow (HL+byte)-1$	x	x	
		ES: [HL+byte]	4	3	—	$((ES:HL)+byte) \leftarrow ((ES:HL)+byte)-1$	x	x	
	INCW	rp	1	1	—	$rp \leftarrow rp+1$			
		!addr16	3	2	—	$(addr16) \leftarrow (addr16)+1$			
		ES:!addr16	4	3	—	$(ES, addr16) \leftarrow (ES, addr16)+1$			
		saddrp	2	2	—	$(saddrp) \leftarrow (saddrp)+1$			
		[HL+byte]	3	2	—	$(HL+byte) \leftarrow (HL+byte)+1$			
		ES: [HL+byte]	4	3	—	$((ES:HL)+byte) \leftarrow ((ES:HL)+byte)+1$			
	DECW	rp	1	1	—	$rp \leftarrow rp-1$			
		!addr16	3	2	—	$(addr16) \leftarrow (addr16)-1$			
		ES:!addr16	4	3	—	$(ES, addr16) \leftarrow (ES, addr16)-1$			
		saddrp	2	2	—	$(saddrp) \leftarrow (saddrp)-1$			
		[HL+byte]	3	2	—	$(HL+byte) \leftarrow (HL+byte)-1$			
		ES: [HL+byte]	4	3	—	$((ES:HL)+byte) \leftarrow ((ES:HL)+byte)-1$			
Shift	SHR	A, cnt	2	1	—	$(CY \leftarrow A_0, A_{m-1} \leftarrow A_m, A_7 \leftarrow 0) \times cnt$			x
	SHRW	AX, cnt	2	1	—	$(CY \leftarrow AX_0, AX_{m-1} \leftarrow AX_m, AX_{15} \leftarrow 0) \times cnt$			x
	SHL	A, cnt	2	1	—	$(CY \leftarrow A_7, A_m \leftarrow A_{m-1}, A_0 \leftarrow 0) \times cnt$			x
		B, cnt	2	1	—	$(CY \leftarrow B_7, B_m \leftarrow B_{m-1}, B_0 \leftarrow 0) \times cnt$			x
		C, cnt	2	1	—	$(CY \leftarrow C_7, C_m \leftarrow C_{m-1}, C_0 \leftarrow 0) \times cnt$			x
	SHLW	AX, cnt	2	1	—	$(CY \leftarrow AX_{15}, AX_m \leftarrow AX_{m-1}, AX_0 \leftarrow 0) \times cnt$			x
		BC, cnt	2	1	—	$(CY \leftarrow BC_{15}, BC_m \leftarrow BC_{m-1}, BC_0 \leftarrow 0) \times cnt$			x
	SAR	A, cnt	2	1	—	$(CY \leftarrow A_0, A_{m-1} \leftarrow A_m, A_7 \leftarrow A_7) \times cnt$			x
	SARW	AX, cnt	2	1	—	$(CY \leftarrow AX_0, AX_{m-1} \leftarrow AX_m, AX_{15} \leftarrow AX_{15}) \times cnt$			x

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remarks 1. Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

2. cnt indicates the bit shift count.

Table 28-5. Operation List (13/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
Rotate	ROR	A, 1	2	1	–	$(CY, A_7 \leftarrow A_0, A_{m-1} \leftarrow A_m) \times 1$			×
	ROL	A, 1	2	1	–	$(CY, A_0 \leftarrow A_7, A_{m+1} \leftarrow A_m) \times 1$			×
	RORC	A, 1	2	1	–	$(CY \leftarrow A_0, A_7 \leftarrow CY, A_{m-1} \leftarrow A_m) \times 1$			×
	ROLC	A, 1	2	1	–	$(CY \leftarrow A_7, A_0 \leftarrow CY, A_{m+1} \leftarrow A_m) \times 1$			×
	ROLWC	AX, 1	2	1	–	$(CY \leftarrow AX_{15}, AX_0 \leftarrow CY, AX_{m+1} \leftarrow AX_m) \times 1$			×
		BC, 1	2	1	–	$(CY \leftarrow BC_{15}, BC_0 \leftarrow CY, BC_{m+1} \leftarrow BC_m) \times 1$			×
Bit manipulate	MOV1	CY, A.bit	2	1	–	$CY \leftarrow A.bit$			×
		A.bit, CY	2	1	–	$A.bit \leftarrow CY$			
		CY, PSW.bit	3	1	–	$CY \leftarrow PSW.bit$			×
		PSW.bit, CY	3	4	–	$PSW.bit \leftarrow CY$	×	×	
		CY, saddr.bit	3	1	–	$CY \leftarrow (saddr).bit$			×
		saddr.bit, CY	3	2	–	$(saddr).bit \leftarrow CY$			
		CY, sfr.bit	3	1	–	$CY \leftarrow sfr.bit$			×
		sfr.bit, CY	3	2	–	$sfr.bit \leftarrow CY$			
		CY, [HL].bit	2	1	4	$CY \leftarrow (HL).bit$			×
		[HL].bit, CY	2	2	–	$(HL).bit \leftarrow CY$			
		CY, ES:[HL].bit	3	2	5	$CY \leftarrow (ES, HL).bit$			×
		ES:[HL].bit, CY	3	3	–	$(ES, HL).bit \leftarrow CY$			
	AND1	CY, A.bit	2	1	–	$CY \leftarrow CY \wedge A.bit$			×
		CY, PSW.bit	3	1	–	$CY \leftarrow CY \wedge PSW.bit$			×
		CY, saddr.bit	3	1	–	$CY \leftarrow CY \wedge (saddr).bit$			×
		CY, sfr.bit	3	1	–	$CY \leftarrow CY \wedge sfr.bit$			×
		CY, [HL].bit	2	1	4	$CY \leftarrow CY \wedge (HL).bit$			×
		CY, ES:[HL].bit	3	2	5	$CY \leftarrow CY \wedge (ES, HL).bit$			×
	OR1	CY, A.bit	2	1	–	$CY \leftarrow CY \vee A.bit$			×
		CY, PSW.bit	3	1	–	$CY \leftarrow CY \vee PSW.bit$			×
		CY, saddr.bit	3	1	–	$CY \leftarrow CY \vee (saddr).bit$			×
		CY, sfr.bit	3	1	–	$CY \leftarrow CY \vee sfr.bit$			×
		CY, [HL].bit	2	1	4	$CY \leftarrow CY \vee (HL).bit$			×
		CY, ES:[HL].bit	3	2	5	$CY \leftarrow CY \vee (ES, HL).bit$			×

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (14/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
Bit manipulate	XOR1	CY, A.bit	2	1	–	$CY \leftarrow CY \nabla A.bit$			x
		CY, PSW.bit	3	1	–	$CY \leftarrow CY \nabla PSW.bit$			x
		CY, saddr.bit	3	1	–	$CY \leftarrow CY \nabla (saddr).bit$			x
		CY, sfr.bit	3	1	–	$CY \leftarrow CY \nabla sfr.bit$			x
		CY, [HL].bit	2	1	4	$CY \leftarrow CY \nabla (HL).bit$			x
		CY, ES:[HL].bit	3	2	5	$CY \leftarrow CY \nabla (ES, HL).bit$			x
	SET1	A.bit	2	1	–	$A.bit \leftarrow 1$			
		PSW.bit	3	4	–	$PSW.bit \leftarrow 1$	x	x	x
		!addr16.bit	4	2	–	$(addr16).bit \leftarrow 1$			
		ES:!addr16.bit	5	3	–	$(ES, addr16).bit \leftarrow 1$			
		saddr.bit	3	2	–	$(saddr).bit \leftarrow 1$			
		sfr.bit	3	2	–	$sfr.bit \leftarrow 1$			
		[HL].bit	2	2	–	$(HL).bit \leftarrow 1$			
		ES:[HL].bit	3	3	–	$(ES, HL).bit \leftarrow 1$			
	CLR1	A.bit	2	1	–	$A.bit \leftarrow 0$			
		PSW.bit	3	4	–	$PSW.bit \leftarrow 0$	x	x	x
		!addr16.bit	4	2	–	$(addr16).bit \leftarrow 0$			
		ES:!addr16.bit	5	3	–	$(ES, addr16).bit \leftarrow 0$			
		saddr.bit	3	2	–	$(saddr).bit \leftarrow 0$			
		sfr.bit	3	2	–	$sfr.bit \leftarrow 0$			
		[HL].bit	2	2	–	$(HL).bit \leftarrow 0$			
		ES:[HL].bit	3	3	–	$(ES, HL).bit \leftarrow 0$			
	SET1	CY	2	1	–	$CY \leftarrow 1$			1
	CLR1	CY	2	1	–	$CY \leftarrow 0$			0
	NOT1	CY	2	1	–	$CY \leftarrow \overline{CY}$			x

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (15/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
Call/ return	CALL	rp	2	3	–	(SP – 2) ← (PC+2) _S , (SP – 3) ← (PC+2) _H , (SP – 4) ← (PC+2) _L , PC ← CS, rp, SP ← SP – 4			
		\$!addr20	3	3	–	(SP – 2) ← (PC+3) _S , (SP – 3) ← (PC+3) _H , (SP – 4) ← (PC+3) _L , PC ← PC+3+jdisp16, SP ← SP – 4			
		!addr16	3	3	–	(SP – 2) ← (PC+3) _S , (SP – 3) ← (PC+3) _H , (SP – 4) ← (PC+3) _L , PC ← 0000, addr16, SP ← SP – 4			
		!!addr20	4	3	–	(SP – 2) ← (PC+4) _S , (SP – 3) ← (PC+4) _H , (SP – 4) ← (PC+4) _L , PC ← addr20, SP ← SP – 4			
	CALLT	[addr5]	2	5	–	(SP – 2) ← (PC+2) _S , (SP – 3) ← (PC+2) _H , (SP – 4) ← (PC+2) _L , PC _S ← 0000, PC _H ← (0000, addr5+1), PC _L ← (0000, addr5), SP ← SP – 4			
	BRK	–	2	5	–	(SP – 1) ← PSW, (SP – 2) ← (PC+2) _S , (SP – 3) ← (PC+2) _H , (SP – 4) ← (PC+2) _L , PC _S ← 0000, PC _H ← (0007FH), PC _L ← (0007EH), SP ← SP – 4, IE ← 0			
	RET	–	1	6	–	PC _L ← (SP), PC _H ← (SP+1), PC _S ← (SP+2), SP ← SP+4			
	RETI	–	2	6	–	PC _L ← (SP), PC _H ← (SP+1), PC _S ← (SP+2), PSW ← (SP+3), SP ← SP+4	R	R	R
	RETB	–	2	6	–	PC _L ← (SP), PC _H ← (SP+1), PC _S ← (SP+2), PSW ← (SP+3), SP ← SP+4	R	R	R

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (16/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
Stack manipulate	PUSH	PSW	2	1	–	$(SP - 1) \leftarrow PSW, (SP - 2) \leftarrow 00H,$ $SP \leftarrow SP - 2$			
		rp	1	1	–	$(SP - 1) \leftarrow rpH, (SP - 2) \leftarrow rpL,$ $SP \leftarrow SP - 2$			
	POP	PSW	2	3	–	$PSW \leftarrow (SP+1), SP \leftarrow SP + 2$	R	R	R
		rp	1	1	–	$rpL \leftarrow (SP), rpH \leftarrow (SP+1), SP \leftarrow SP + 2$			
	MOVW	SP, #word	4	1	–	$SP \leftarrow word$			
		SP, AX	2	1	–	$SP \leftarrow AX$			
		AX, SP	2	1	–	$AX \leftarrow SP$			
		HL, SP	3	1	–	$HL \leftarrow SP$			
		BC, SP	3	1	–	$BC \leftarrow SP$			
		DE, SP	3	1	–	$DE \leftarrow SP$			
	ADDW	SP, #byte	2	1	–	$SP \leftarrow SP + byte$			
	SUBW	SP, #byte	2	1	–	$SP \leftarrow SP - byte$			
Unconditional branch	BR	AX	2	3	–	$PC \leftarrow CS, AX$			
		\$addr20	2	3	–	$PC \leftarrow PC + 2 + jdisp8$			
		!\$addr20	3	3	–	$PC \leftarrow PC + 3 + jdisp16$			
		!addr16	3	3	–	$PC \leftarrow 0000, addr16$			
		!!addr20	4	3	–	$PC \leftarrow addr20$			
Conditional branch	BC	\$addr20	2	2/4 ^{Note3}	–	$PC \leftarrow PC + 2 + jdisp8$ if CY = 1			
	BNC	\$addr20	2	2/4 ^{Note3}	–	$PC \leftarrow PC + 2 + jdisp8$ if CY = 0			
	BZ	\$addr20	2	2/4 ^{Note3}	–	$PC \leftarrow PC + 2 + jdisp8$ if Z = 1			
	BNZ	\$addr20	2	2/4 ^{Note3}	–	$PC \leftarrow PC + 2 + jdisp8$ if Z = 0			
	BH	\$addr20	3	2/4 ^{Note3}	–	$PC \leftarrow PC + 3 + jdisp8$ if (Z∨CY)=0			
	BNH	\$addr20	3	2/4 ^{Note3}	–	$PC \leftarrow PC + 3 + jdisp8$ if (Z∨CY)=1			
	BT	saddr.bit, \$addr20	4	3/5 ^{Note3}	–	$PC \leftarrow PC + 4 + jdisp8$ if (saddr).bit = 1			
		sfr.bit, \$addr20	4	3/5 ^{Note3}	–	$PC \leftarrow PC + 4 + jdisp8$ if sfr.bit = 1			
		A.bit, \$addr20	3	3/5 ^{Note3}	–	$PC \leftarrow PC + 3 + jdisp8$ if A.bit = 1			
		PSW.bit, \$addr20	4	3/5 ^{Note3}	–	$PC \leftarrow PC + 4 + jdisp8$ if PSW.bit = 1			
		[HL].bit, \$addr20	3	3/5 ^{Note3}	6/7	$PC \leftarrow PC + 3 + jdisp8$ if (HL).bit = 1			
		ES:[HL].bit, \$addr20	4	4/6 ^{Note3}	7/8	$PC \leftarrow PC + 4 + jdisp8$ if (ES, HL).bit = 1			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. This indicates the number of clocks “when condition is not met/when condition is met”.

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

Table 28-5. Operation List (17/17)

Instruction Group	Mnemonic	Operands	Bytes	Clocks		Clocks	Flag		
				Note 1	Note 2		Z	AC	CY
Conditional branch	BF	saddr.bit, \$addr20	4	3/5 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if (saddr).bit = 0			
		sfr.bit, \$addr20	4	3/5 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if sfr.bit = 0			
		A.bit, \$addr20	3	3/5 ^{Note 3}	–	PC ← PC + 3 + jdisp8 if A.bit = 0			
		PSW.bit, \$addr20	4	3/5 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if PSW.bit = 0			
		[HL].bit, \$addr20	3	3/5 ^{Note 3}	6/7	PC ← PC + 3 + jdisp8 if (HL).bit = 0			
		ES:[HL].bit, \$addr20	4	4/6 ^{Note 3}	7/8	PC ← PC + 4 + jdisp8 if (ES, HL).bit = 0			
	BTCLR	saddr.bit, \$addr20	4	3/5 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if (saddr).bit = 1 then reset (saddr).bit			
		sfr.bit, \$addr20	4	3/5 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if sfr.bit = 1 then reset sfr.bit			
		A.bit, \$addr20	3	3/5 ^{Note 3}	–	PC ← PC + 3 + jdisp8 if A.bit = 1 then reset A.bit			
		PSW.bit, \$addr20	4	3/5 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if PSW.bit = 1 then reset PSW.bit	x	x	x
		[HL].bit, \$addr20	3	3/5 ^{Note 3}	–	PC ← PC + 3 + jdisp8 if (HL).bit = 1 then reset (HL).bit			
		ES:[HL].bit, \$addr20	4	4/6 ^{Note 3}	–	PC ← PC + 4 + jdisp8 if (ES, HL).bit = 1 then reset (ES, HL).bit			
Conditional skip	SKC	–	2	1	–	Next instruction skip if CY = 1			
	SKNC	–	2	1	–	Next instruction skip if CY = 0			
	SKZ	–	2	1	–	Next instruction skip if Z = 1			
	SKNZ	–	2	1	–	Next instruction skip if Z = 0			
	SKH	–	2	1	–	Next instruction skip if (Z∨CY)=0			
	SKNH	–	2	1	–	Next instruction skip if (Z∨CY)=1			
CPU control	SEL ^{Note 4}	RBn	2	1	–	RBS[1:0] ← n			
	NOP	–	1	1	–	No Operation			
	EI	–	3	4	–	IE ← 1 (Enable Interrupt)			
	DI	–	3	4	–	IE ← 0 (Disable Interrupt)			
	HALT	–	2	3	–	Set HALT Mode			
	STOP	–	2	3	–	Set STOP Mode			

Notes 1. Number of CPU clocks (f_{CLK}) when the internal RAM area, SFR area, or extended SFR area is accessed, or when no data is accessed.

2. Number of CPU clocks (f_{CLK}) when the code flash memory is accessed, or when the data flash memory is accessed by an 8-bit instruction.

3. This indicates the number of clocks “when condition is not met/when condition is met”.

4. n indicates the number of register banks (n = 0 to 3).

Remark Number of clock is when program exists in the internal ROM (flash memory) area. If fetching the instruction from the internal RAM area, the number becomes double number plus 3 clocks at a maximum.

CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^\circ\text{C}$)

This chapter describes the following electrical specifications.

Target products A: Consumer applications $T_A = -40$ to $+85^\circ\text{C}$

R5F10E8AALA, R5F10E8CALA, R5F10E8DALA, R5F10E8EALA
R5F10EBAANA, R5F10EBCANA, R5F10EBDANA, R5F10EBEANA
R5F10EGAAFB, R5F10EGCAFB, R5F10EGDAFB, R5F10EGEAFB
R5F10EGAANA, R5F10EGCANA, R5F10EGDANA, R5F10EGEANA
R5F10ELCAFB, R5F10ELDAFB, R5F10ELEAFB
R5F10ELCABG, R5F10ELDABG, R5F10ELEABG

G: Industrial applications When $T_A = -40$ to $+105^\circ\text{C}$ products is used in the range of $T_A = -40$ to $+85^\circ\text{C}$

R5F10EBAGNA, R5F10EBCGNA, R5F10EBDGNA, R5F10EBEGNA
R5F10EGAGFB, R5F10EGCGFB, R5F10EGDGFB, R5F10EGEGFB
R5F10EGAGNA, R5F10EGCGNA, R5F10EGDGNA, R5F10EGEGNA
R5F10ELCGFB, R5F10ELDGFB, R5F10ELEGFB

- Cautions**
1. The RL78 microcontrollers have an on-chip debug function, which is provided for development and evaluation. Do not use the on-chip debug function in products designated for mass production, because the guaranteed number of rewritable times of the flash memory may be exceeded when this function is used, and product reliability therefore cannot be guaranteed. Renesas Electronics is not liable for problems occurring when the on-chip debug function is used.
 2. With products not provided with an EV_{DD0} or EV_{SS0} pin, replace EV_{DD0} with V_{DD} , or replace EV_{SS0} with V_{SS} .
 3. The pins mounted depend on the product. See 2.1 Port Function to 2.2.1 With functions for each product.

29.1 Absolute Maximum Ratings

Absolute Maximum Ratings ($T_A = 25^\circ\text{C}$) (1/2)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V_{DD}		-0.5 to $+6.5$	V
	EV_{DD0}		-0.5 to $+6.5$	V
	AV_{DD}		-0.5 to $+4.6$	V
	AV_{REFP}		-0.3 to $AV_{DD} + 0.3$ ^{Note 3}	V
	EV_{SS0}		-0.5 to $+0.3$	V
	AV_{SS}		-0.5 to $+0.3$	V
	AV_{REFM}		-0.3 to $AV_{DD} + 0.3$ ^{Note 3} and $AV_{REFM} \leq AV_{REFP}$	V
REGC pin input voltage	V_{IREGC}	REGC	-0.3 to $+2.8$ and -0.3 to $V_{DD} + 0.3$ ^{Note 1}	V
Input voltage	V_{I1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	-0.3 to $EV_{DD0} + 0.3$ and -0.3 to $V_{DD} + 0.3$ ^{Note 2}	V
	V_{I2}	P60 to P63 (N-ch open-drain)	-0.3 to $+6.5$	V
	V_{I3}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$	-0.3 to $V_{DD} + 0.3$ ^{Note 2}	V
	V_{I4}	P20 to P27, P150 to P154	-0.3 to $AV_{DD} + 0.3$ ^{Note 2}	V
Output voltage	V_{O1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P63, P70 to P77, P120, P130, P140, P141	-0.3 to $EV_{DD0} + 0.3$ ^{Note 2}	V
	V_{O2}	P20 to P27, P150 to P154	-0.3 to $AV_{DD} + 0.3$ ^{Note 2}	V
Analog input voltage	V_{AI1}	ANI16 to ANI30	-0.3 to $EV_{DD0} + 0.3$ and -0.3 to $AV_{REF(+)} + 0.3$ ^{Notes 2, 4}	V
	V_{AI2}	ANI0 to ANI12	-0.3 to $AV_{DD} + 0.3$ and -0.3 to $AV_{REF(+)} + 0.3$ ^{Notes 2, 4}	V

Notes 1. Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF). This value regulates the absolute maximum rating of the REGC pin. Do not use this pin with voltage applied to it.

2. Must be 6.5 V or lower.

3. Must be 4.6 V or lower.

4. Do not exceed $AV_{REF(+)} + 0.3$ V in case of A/D conversion target pin.

Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

Remarks 1. Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

2. $AV_{REF(+)}$: + side reference voltage of the A/D converter.

3. V_{SS} : Reference voltage

Absolute Maximum Ratings ($T_A = 25^{\circ}\text{C}$) (2/2)

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	I _{OH1}	Per pin	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	−40	mA
		Total of all pins −170 mA	P00 to P04, P40 to P43, P120, P130, P140, P141	−70	mA
			P05, P06, P10 to P16, P30, P31, P50, P51, P70 to P77,	−100	mA
	I _{OH2}	Per pin	P20 to P27, P150 to P154	−0.1	mA
		Total of all pins		−1.3	mA
Output current, low	I _{OL1}	Per pin	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P63, P70 to P77, P120, P130, P140, P141	40	mA
		Total of all pins 170 mA	P00 to P04, P40 to P43, P120, P130, P140, P141	70	mA
			P05, P06, P10 to P16, P30, P31, P50, P51, P60 to P63, P70 to P77	100	mA
	I _{OL2}	Per pin	P20 to P27, P150 to P154	0.4	mA
		Total of all pins		6.4	mA
Operating ambient temperature	T _A	In normal operation mode		−40 to +85	°C
		In flash memory programming mode			
Storage temperature	T _{stg}			−65 to +150	°C

Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

29.2 Oscillator Characteristics

29.2.1 X1, XT1 oscillator characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (f_x) ^{Note}	Ceramic resonator/crystal resonator	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	1.0		20.0	MHz
		$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$	1.0		16.0	MHz
		$1.8\text{ V} \leq V_{DD} < 2.4\text{ V}$	1.0		8.0	MHz
		$1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$	1.0		4.0	MHz
XT1 clock oscillation frequency (f_x) ^{Note}	Crystal resonator		32	32.768	35	kHz

Note Indicates only permissible oscillator frequency ranges. See AC Characteristics for instruction execution time. Request evaluation by the manufacturer of the oscillator circuit mounted on a board to check the oscillator characteristics.

Caution Since the CPU is started by the high-speed on-chip oscillator clock after a reset release, check the X1 clock oscillation stabilization time using the oscillation stabilization time counter status register (OSTC) by the user. Determine the oscillation stabilization time of the OSTC register and the oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.

Remark When using the X1 oscillator and XT1 oscillator, see 5.4 System Clock Oscillator.

29.2.2 On-chip oscillator characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Oscillators	Parameters	Conditions		MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator clock frequency ^{Notes 1, 2}	f_{IH}			1		32	MHz
High-speed on-chip oscillator clock frequency accuracy		-20 to $+85^\circ\text{C}$	$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	-1.0		$+1.0$	%
			$1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$	-5.0		$+5.0$	%
		-40 to -20°C	$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	-1.5		$+1.5$	%
			$1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$	-5.5		$+5.5$	%
Low-speed on-chip oscillator clock frequency	f_{IL}				15		kHz
Low-speed on-chip oscillator clock frequency accuracy				-15		$+15$	%

Notes 1. High-speed on-chip oscillator frequency is selected by bits 0 to 3 of option byte (000C2H/010C2H) and bits 0 to 2 of HOCODIV register.

2. This indicates the oscillator characteristics only. See AC Characteristics for instruction execution time.

29.3 DC Characteristics

29.3.1 Pin characteristics

(T_A = –40 to +85°C, 1.6 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, 1.6 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V)

(1/5)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output current, high ^{Note 1}	IOH1	Per pin for P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	$1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$			−10.0 ^{Note 2}	mA
		Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty ≤ 70% ^{Note 3})	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$			−10.0	mA
			$1.8\text{ V} \leq \text{EV}_{\text{DD}0} < 2.7\text{ V}$			−5.0	mA
			$1.6\text{ V} \leq \text{EV}_{\text{DD}0} < 1.8\text{ V}$			−2.5	mA
		Total of P05, P06, P10 to P16, P30, P31, P50, P51, P70 to P77, (When duty ≤ 70% ^{Note 3})	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$			−19.0	mA
			$1.8\text{ V} \leq \text{EV}_{\text{DD}0} < 2.7\text{ V}$			−10.0	mA
			$1.6\text{ V} \leq \text{EV}_{\text{DD}0} < 1.8\text{ V}$			−5.0	mA
		Total of all pins (When duty ≤ 70% ^{Note 3})	$1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$			−29.0	mA
	IOH2	Per pin for P20 to P27, P150 to P154	$1.6\text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			−0.1 ^{Note 2}	mA
		Total of all pins (When duty ≤ 70% ^{Note 3})	$1.6\text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			−1.3	mA

Notes 1. Value of current at which the device operation is guaranteed even if the current flows from the EV_{DD0}, V_{DD} pins to an output pin.

2. However, do not exceed the total current value.

3. Specification under conditions where the duty factor ≤ 70%.

The output current value that has changed to the duty factor > 70% the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = (I_{OH} × 0.7)/(n × 0.01)

<Example> Where n = 80% and I_{OH} = –10.0 mA

$$\text{Total output current of pins} = (-10.0 \times 0.7)/(80 \times 0.01) \cong -8.7 \text{ mA}$$

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

Caution P00, P02 to P04, P10 to P15, P43, P50, P71, and P74 do not output high level in N-ch open-drain mode.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

$(T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $1.6\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)

(2/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output current, low ^{Note 1}	I _{OL1}	Per pin for P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141			20.0 ^{Note 2}	mA
		Per pin for P60 to P63			15.0 ^{Note 2}	mA
		Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty $\leq 70\%$ ^{Note 3})	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$		15.0	mA
			$1.8\text{ V} \leq EV_{DD0} < 2.7\text{ V}$		9.0	mA
			$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$		4.5	mA
		Total of P05, P06, P10 to P16, P30, P31, P50, P51, P60 to P63, P70 to P77 (When duty $\leq 70\%$ ^{Note 3})	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$		35.0	mA
			$1.8\text{ V} \leq EV_{DD0} < 2.7\text{ V}$		20.0	mA
			$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$		10.0	mA
		Total of all pins (When duty $\leq 70\%$ ^{Note 3})			50.0	mA
	I _{OL2}	Per pin for P20 to P27, P150 to P154			0.4 ^{Note 2}	mA
		Total of all pins (When duty $\leq 70\%$ ^{Note 3})	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$		5.2	mA

- Notes**
1. Value of current at which the device operation is guaranteed even if the current flows from an output pin to the EV_{SS0} and V_{SS} pin.
 2. However, do not exceed the total current value.
 3. Specification under conditions where the duty factor $\leq 70\%$.

The output current value that has changed to the duty factor $> 70\%$ the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = $(I_{OL} \times 0.7)/(n \times 0.01)$

<Example> Where $n = 80\%$ and $I_{OL} = 10.0\text{ mA}$

$$\text{Total output current of pins} = (10.0 \times 0.7)/(80 \times 0.01) \cong 8.7\text{ mA}$$

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

(T_A = -40 to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $1.6\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)

(3/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage, high	V _{IH1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	Normal input buffer	0.8EV _{DD0}	EV _{DD0}	V
	V _{IH2}	P01, P03, P04, P10, P11, P13 to P16, P43	TTL input buffer $3.3\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$	2.0	EV _{DD0}	V
			TTL input buffer $1.6\text{ V} \leq EV_{DD0} < 3.3\text{ V}$	1.5	EV _{DD0}	V
	V _{IH3}	P20 to P27, P150 to P154	0.7AV _{DD}		AV _{DD}	V
	V _{IH4}	P60 to P63	0.7EV _{DD0}		6.0	V
	V _{IH5}	P121 to P124, P137, EXCLK, EXCLKS, RESET	0.8V _{DD}		V _{DD}	V
Input voltage, low	V _{IL1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	Normal input buffer	0	0.2EV _{DD0}	V
	V _{IL2}	P01, P03, P04, P10, P11, P13 to P16, P43	TTL input buffer $3.3\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$	0	0.5	V
			TTL input buffer $1.6\text{ V} \leq EV_{DD0} < 3.3\text{ V}$	0	0.32	V
	V _{IL3}	P20 to P27, P150 to P154	0		0.3AV _{DD}	V
	V _{IL4}	P60 to P63	0		0.3EV _{DD0}	V
	V _{IL5}	P121 to P124, P137, EXCLK, EXCLKS, RESET	0		0.2V _{DD}	V

Caution The maximum value of V_{IH} of pins P00, P02 to P04, P10 to P15, P43, P50, P71, and P74 is EV_{DD0}, even in the N-ch open-drain mode.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $1.6\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)**(4/5)**

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output voltage, high	V _{OH1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OH1} = -2.0\text{ mA}$	$EV_{DD0} - 0.6$		V
			$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OH1} = -1.5\text{ mA}$	$EV_{DD0} - 0.5$		V
			$1.6\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OH1} = -1.0\text{ mA}$	$EV_{DD0} - 0.5$		V
	V _{OH2}	P20 to P27, P150 to P154	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$, $I_{OH2} = -100\text{ }\mu\text{A}$	$AV_{DD} - 0.5$		V
Output voltage, low	V _{OL1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL1} = 3.0\text{ mA}$		0.6	V
			$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL1} = 1.5\text{ mA}$		0.4	V
			$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL1} = 0.6\text{ mA}$		0.4	V
			$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$, $I_{OL1} = 0.3\text{ mA}$		0.4	V
	V _{OL2}	P20 to P27, P150 to P154	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$, $I_{OL2} = 400\text{ }\mu\text{A}$		0.4	V
	V _{OL3}	P60 to P63	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL3} = 3.0\text{ mA}$		0.4	V
			$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL3} = 2.0\text{ mA}$		0.4	V
			$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$, $I_{OL3} = 1.0\text{ mA}$		0.4	V

Caution P00, P02 to P04, P10 to P15, P43, P50, P71, and P74 do not output high level in N-ch open-drain mode.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

(TA = -40 to +85°C, 1.6 V ≤ AVDD ≤ VDD ≤ 3.6 V, 1.6 V ≤ EVDD0 ≤ VDD ≤ 3.6 V, VSS = EVSS0 = 0 V)

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit	
Input leakage current, high	I _{LIH1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P63, P70 to P77, P120, P140, P141	V _I = EV _{DD0}			1	μA	
	I _{LIH2}	P137, RESET	V _I = V _{DD}			1	μA	
	I _{LIH3}	P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS)	V _I = V _{DD}	In input port or external clock input		1	μA	
				In resonator connection		10	μA	
	I _{LIH4}	P20 to P27, P150 to P154	V _I = AV _{DD}			1	μA	
Input leakage current, low	I _{LIL1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P67, P70 to P77, P120, P140, P141	V _I = EV _{SS0}			−1	μA	
	I _{LIL2}	P137, RESET	V _I = V _{SS}			−1	μA	
	I _{LIL3}	P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS)	V _I = V _{SS}	In input port or external clock input		−1	μA	
				In resonator connection		−10	μA	
	I _{LIL4}	P20 to P27, P150 to P154	V _I = AV _{SS}			−1	μA	
On-chip pull-up resistance	R _U	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	V _I = EV _{SS0} , In input port		10	20	100	kΩ

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

29.3.2 Supply current characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = V_{SS0} = 0\text{ V}$)

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Parameter	Symbol	Conditions					MIN.	TYP.	MAX.	Unit
Supply current ^{Note 1}	I_{DD1}	Operating mode	HS (high-speed main) mode ^{Note 5}	$f_{IH} = 32\text{ MHz}$ ^{Note 3}	Basic operation	$V_{DD} = 3.0\text{ V}$		2.1		mA
					Normal operation	$V_{DD} = 3.0\text{ V}$		4.6	7.0	mA
				$f_{IH} = 24\text{ MHz}$ ^{Note 3}	Normal operation	$V_{DD} = 3.0\text{ V}$		3.7	5.5	mA
					Normal operation	$V_{DD} = 3.0\text{ V}$		2.7	4.0	mA
			LS (low-speed main) mode ^{Note 5}	$f_{IH} = 8\text{ MHz}$ ^{Note 3}	Normal operation	$V_{DD} = 3.0\text{ V}$		1.2	1.8	mA
						$V_{DD} = 2.0\text{ V}$		1.2	1.8	
			LV (Low-voltage main) mode ^{Note 5}	$f_{IH} = 4\text{ MHz}$ ^{Note 3}	Normal operation	$V_{DD} = 3.0\text{ V}$		1.2	1.7	mA
						$V_{DD} = 2.0\text{ V}$		1.2	1.7	
			HS (high-speed main) mode ^{Note 5}	$f_{MX} = 20\text{ MHz}$ ^{Note 2} , $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input		3.0	4.6	mA
						Resonator connection		3.2	4.8	
				$f_{MX} = 10\text{ MHz}$ ^{Note 2} , $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input		1.9	2.7	mA
						Resonator connection		1.9	2.7	
			LS (low-speed main) mode ^{Note 5}	$f_{MX} = 8\text{ MHz}$ ^{Note 2} , $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input		1.1	1.7	mA
						Resonator connection		1.1	1.7	
				$f_{MX} = 8\text{ MHz}$ ^{Note 2} , $V_{DD} = 2.0\text{ V}$	Normal operation	Square wave input		1.1	1.7	mA
						Resonator connection		1.1	1.7	
			Subsystem clock mode	$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = -40^\circ\text{C}$	Normal operation	Square wave input		4.1	4.9	μA
						Resonator connection		4.2	5.0	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +25^\circ\text{C}$	Normal operation	Square wave input		4.2	4.9	μA
						Resonator connection		4.3	5.0	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +50^\circ\text{C}$	Normal operation	Square wave input		4.3	5.5	μA
						Resonator connection		4.4	5.6	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +70^\circ\text{C}$	Normal operation	Square wave input		4.5	6.3	μA
						Resonator connection		4.6	6.4	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +85^\circ\text{C}$	Normal operation	Square wave input		4.8	7.7	μA
						Resonator connection		4.9	7.8	

(Notes and Remarks are listed on the next page.)

Notes 1. Total current flowing into V_{DD} and EV_{DD0} , including the input leakage current flowing when the level of the input pin is fixed to V_{DD} , EV_{DD0} or V_{SS} , EV_{SS0} . The following points apply in the HS (high-speed main), LS (low-speed main), and LV (low-voltage main) modes.

- The currents in the “TYP.” column do not include the operating currents of the peripheral modules.
- The currents in the “MAX.” column include the operating currents of the peripheral modules, except for those flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors, and those flowing while the data flash memory is being rewritten.

In the subsystem clock operation, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules. However, in HALT mode, including the current flowing into the RTC.

2. When high-speed on-chip oscillator and subsystem clock are stopped.
3. When high-speed system clock and subsystem clock are stopped.
4. When high-speed on-chip oscillator and high-speed system clock are stopped. When setting ultra-low power consumption oscillation ($AMP_{HS1} = 1$).
5. Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

HS (high-speed main) mode:	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$
	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
LS (low-speed main) mode:	$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
LV (Low-voltage main) mode:	$1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$

Remarks 1. f_{MX} : High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

2. f_{IH} : High-speed on-chip oscillator clock frequency
3. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
4. Except subsystem clock operation, temperature condition of the TYP. value is $T_A = 25^{\circ}\text{C}$

$(T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

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Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit	
Supply current ^{Note 1}	I _{DD2} ^{Note 2}	HALT mode	HS (high-speed main) mode ^{Note 7}	f _{IH} = 32 MHz ^{Note 4}	V _{DD} = 3.0 V		0.54	1.63	mA	
				f _{IH} = 24 MHz ^{Note 4}	V _{DD} = 3.0 V		0.44	1.28	mA	
				f _{IH} = 16 MHz ^{Note 4}	V _{DD} = 3.0 V		0.40	1.00	mA	
			LS (low-speed main) mode ^{Note 7}	f _{IH} = 8 MHz ^{Note 4}	V _{DD} = 3.0 V		270	530	μA	
					V _{DD} = 2.0 V		270	530		
			LV (Low-voltage main) mode ^{Note 7}	f _{IH} = 4 MHz ^{Note 4}	V _{DD} = 3.0 V		435	640	μA	
					V _{DD} = 2.0 V		435	640		
			HS (high-speed main) mode ^{Note 7}	f _{MX} = 20 MHz ^{Note 3} , V _{DD} = 3.0 V	Square wave input		0.28	1.00	mA	
					Resonator connection		0.45	1.17	mA	
					Square wave input		0.19	0.60		mA
					Resonator connection		0.26	0.67		
			LS (low-speed main) mode ^{Note 7}	f _{MX} = 8 MHz ^{Note 3} , V _{DD} = 3.0 V	Square wave input		95	330	μA	
					Resonator connection		145	380		
					f _{MX} = 8 MHz ^{Note 3} , V _{DD} = 2.0 V	Square wave input		95	330	μA
						Resonator connection		145	380	
			Subsystem clock mode	f _{SUB} = 32.768 kHz ^{Note 5} T _A = −40°C	Square wave input		0.25	0.57	μA	
					Resonator connection		0.44	0.76		
				f _{SUB} = 32.768 kHz ^{Note 5} T _A = +25°C	Square wave input		0.30	0.57	μA	
					Resonator connection		0.49	0.76		
				f _{SUB} = 32.768 kHz ^{Note 5} T _A = +50°C	Square wave input		0.38	1.17	μA	
					Resonator connection		0.57	1.36		
				f _{SUB} = 32.768 kHz ^{Note 5} T _A = +70°C	Square wave input		0.52	1.97	μA	
					Resonator connection		0.71	2.16		
				f _{SUB} = 32.768 kHz ^{Note 5} T _A = +85°C	Square wave input		0.97	3.37	μA	
					Resonator connection		1.16	3.56		
	I _{DD3} ^{Note 6}	STOP mode ^{Note 8}	T _A = −40°C					0.16	0.50	μA
			T _A = +25°C					0.23	0.50	
			T _A = +50°C					0.34	1.10	
			T _A = +70°C					0.46	1.90	
			T _A = +85°C					0.75	3.30	

(Notes and Remarks are listed on the next page.)

Notes 1. Total current flowing into V_{DD} and EV_{DD0} , including the input leakage current flowing when the level of the input pin is fixed to V_{DD} , EV_{DD0} or V_{SS} , EV_{SS0} . The following points apply in the HS (high-speed main), LS (low-speed main), and LV (low-voltage main) modes.

- The currents in the “TYP.” column do not include the operating currents of the peripheral modules.
- The currents in the “MAX.” column include the operating currents of the peripheral modules, except for those flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors, and those flowing while the data flash memory is being rewritten.

In the subsystem clock operation, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules. However, in HALT mode, including the current flowing into the RTC.

In the STOP mode, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules.

2. During HALT instruction execution by flash memory.
3. When high-speed on-chip oscillator and subsystem clock are stopped.
4. When high-speed system clock and subsystem clock are stopped.
5. When high-speed on-chip oscillator and high-speed system clock are stopped. When $RTCLPC = 1$ and setting ultra-low current consumption ($AMPHS1 = 1$).
6. When subsystem clock is stopped.
7. Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
 - HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
 - LS (low-speed main) mode: $1.8\text{ V} \leq V_{DD} < 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
 - LV (low-voltage main) mode: $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$
8. Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.

Remarks 1. f_{MX} : High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

2. f_{IH} : High-speed on-chip oscillator clock frequency
3. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
4. Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is $T_A = 25^{\circ}\text{C}$

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 3.6 V, VSS = EVSS0 = 0 V)

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Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	I_{FIL} ^{Note 1}				0.20		μA
RTC operating current	I_{RTC} ^{Notes 1, 2, 3}				0.02		μA
12-bit interval timer operating current	I_{IT} ^{Notes 1, 2, 4}				0.02		μA
Watchdog timer operating current	I_{WDT} ^{Notes 1, 2, 5}	$f_{IL} = 15 \text{ kHz}$			0.22		μA
A/D converter operating current	I_{ADC} ^{Notes 6, 7}	$AV_{DD} = 3.0 \text{ V}$, When conversion at maximum speed			420	720	μA
$AV_{REF(+)}$ current	I_{AVREF} ^{Note 8}	$AV_{DD} = 3.0 \text{ V}$, $ADREFP1 = 0$, $ADREFP0 = 0$ ^{Note 7}			14.0	25.0	μA
		$AV_{REFP} = 3.0 \text{ V}$, $ADREFP1 = 0$, $ADREFP0 = 1$ ^{Note 10}			14.0	25.0	μA
		$ADREFP1 = 1$, $ADREFP0 = 0$ ^{Note 1}			14.0	25.0	μA
A/D converter reference voltage current	I_{ADREF} ^{Notes 1, 9}	$V_{DD} = 3.0 \text{ V}$			75.0		μA
Temperature sensor operating current	I_{TMP} ^{Note 1}	$V_{DD} = 3.0 \text{ V}$			75.0		μA
LVD operating current	I_{LVD} ^{Notes 1, 11}				0.08		μA
BGO operating current	I_{BGO} ^{Notes 1, 12}				2.5	12.2	mA
Self-programming operating current	I_{FSP} ^{Notes 1, 13}				2.5	12.2	mA
SNOOZE operating current	I_{SNOZ}	A/D converter operation ($AV_{DD} = 3.0 \text{ V}$)	The mode is performed ^{Notes 1, 14}		0.50	0.60	mA
			During A/D conversion ^{Note 1}		0.60	0.75	mA
			During A/D conversion ^{Note 7}		420	720	μA
		Simplified SPI (CSI)/UART operation ^{Note 1}			0.70	0.84	mA

(Notes and Remarks are listed on the next page.)

Notes 1. Current flowing to V_{DD} .

2. When high-speed on-chip oscillator and high-speed system clock are stopped.
3. Current flowing only to the real-time clock (RTC) (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2} , and I_{RTC} , when the real-time clock operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of the real-time clock.
4. Current flowing only to the 12-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2} , and I_{IT} , when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added.
5. Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The supply current of the RL78 microcontrollers is the sum of I_{DD1} , I_{DD2} , or I_{DD3} and I_{WDT} when the watchdog timer is in operation.
6. Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2} and I_{ADC} , I_{AVREF} , I_{ADREF} when the A/D converter operates in an operation mode or the HALT mode.
7. Current flowing to the AV_{DD} .
8. Current flowing from the reference voltage source of A/D converter.
9. Operation current flowing to the internal reference voltage.
10. Current flowing to the AV_{REFP} .
11. Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of I_{DD1} , I_{DD2} or I_{DD3} and I_{LVD} when the LVD circuit is in operation.
12. Current flowing only during data flash rewrite.
13. Current flowing only during self programming.
14. For shift time to the SNOOZE mode, see **18.3.3 SNOOZE mode**.

Remarks 1. f_{IL} : Low-speed on-chip oscillator clock frequency

2. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
3. f_{CLK} : CPU/peripheral hardware clock frequency
4. Temperature condition of the TYP. value is $T_A = 25^\circ\text{C}$

29.4 AC Characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $1.6\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Instruction cycle (minimum instruction execution time)	T_{CY}	Main system clock (f_{MAIN}) operation	HS (high-speed main) mode	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	0.03125		1	μs
				$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$	0.0625		1	μs
			LS (low-speed main) mode	$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	0.125		1	μs
			LV (low-voltage main) mode	$1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	0.25		1	μs
		Subsystem clock (f_{SUB}) operation		$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	28.5	30.5	31.3	μs
		In the self programming mode	HS (high-speed main) mode	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	0.03125		1	μs
				$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$	0.0625		1	μs
			LS (low-speed main) mode	$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	0.125		1	μs
			LV (low-voltage main) mode	$1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	0.25		1	μs
External system clock frequency	f_{EX}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$			1.0		20.0	MHz
		$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$			1.0		16.0	MHz
		$1.8\text{ V} \leq V_{DD} < 2.4\text{ V}$			1.0		8.0	MHz
		$1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$			1.0		4.0	MHz
	f_{EXS}				32		35	kHz
External system clock input high-level width, low-level width	t_{EXH}, t_{EXL}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$			24			ns
		$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$			30			ns
		$1.8\text{ V} \leq V_{DD} < 2.4\text{ V}$			60			ns
		$1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$			120			ns
	t_{EXHS}, t_{EXLS}				13.7			μs
TI00, TI01, TI03 to TI07 input high-level width, low-level width	t_{TIH}, t_{TIL}				$1/f_{MCK} + 10$			ns ^{Note}
TO00, TO01, TO03 to TO07 output frequency	f_{TO}	HS (high-speed main) mode		$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$			8	MHz
				$1.8\text{ V} \leq EV_{DD0} < 2.7\text{ V}$			4	MHz
				$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$			2	MHz
		LS (low-speed main) mode		$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$			4	MHz
				$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$			2	MHz
		LV (low-voltage main) mode		$1.6\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$			2	MHz
PCLBUZ0, PCLBUZ1 output frequency	f_{PCL}	HS (high-speed main) mode		$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$			8	MHz
				$1.8\text{ V} \leq EV_{DD0} < 2.7\text{ V}$			4	MHz
				$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$			2	MHz
		LS (low-speed main) mode		$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$			4	MHz
				$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$			2	MHz
		LV (low-voltage main) mode		$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$			4	MHz
Interrupt input high-level width, low-level width	t_{INTH}, t_{INTL}	INTP0		$1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	1			μs
		INTP1 to INTP11		$1.6\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$	1			μs
Key interrupt input high-level width, low-level width	t_{KR}	KR0 to KR9		$1.8\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $1.8\text{ V} \leq AV_{DD0} \leq 3.6\text{ V}$	250			ns
				$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$, $1.6\text{ V} \leq AV_{DD0} < 1.8\text{ V}$	1			μs
RESET low-level width	t_{RSL}				10			μs

(Note and Remark are listed on the next page.)

Note The following conditions are required for low-voltage interface when $EV_{DD0} < V_{DD}$.

$1.8\text{ V} \leq EV_{DD0} < 2.7\text{ V}$: MIN. 125 ns

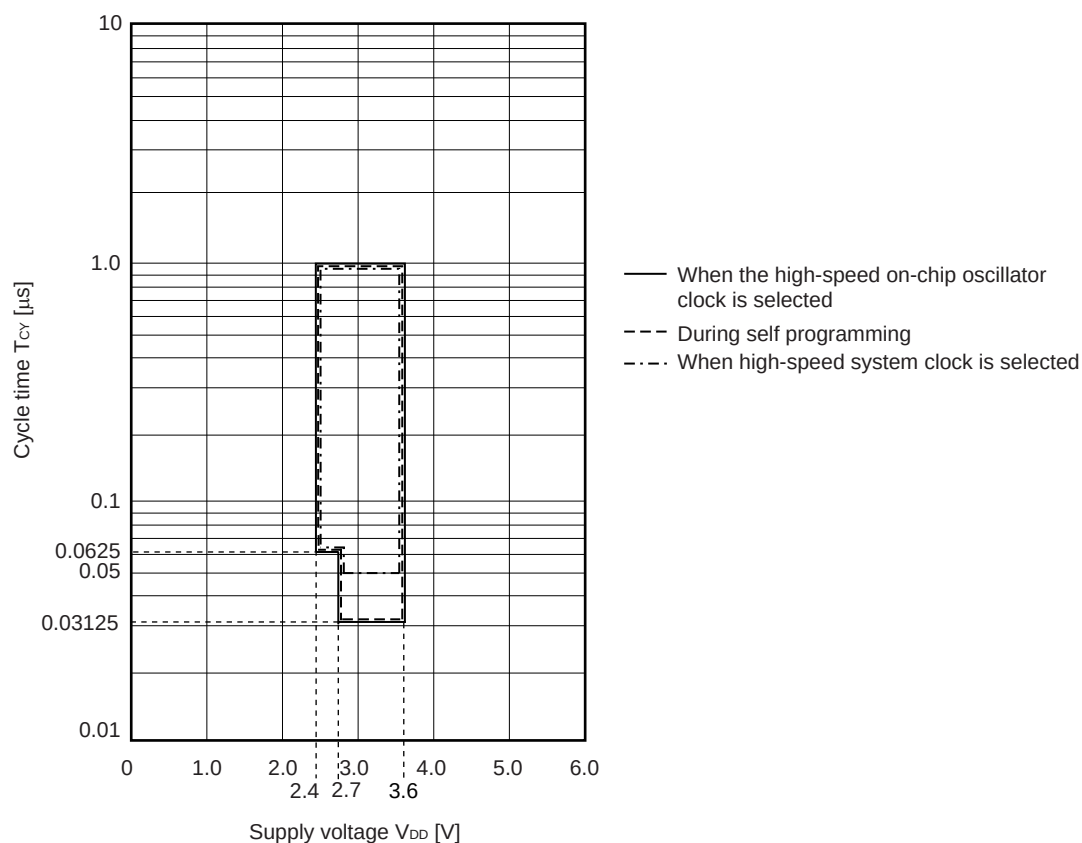
$1.6\text{ V} \leq EV_{DD0} < 1.8\text{ V}$: MIN. 250 ns

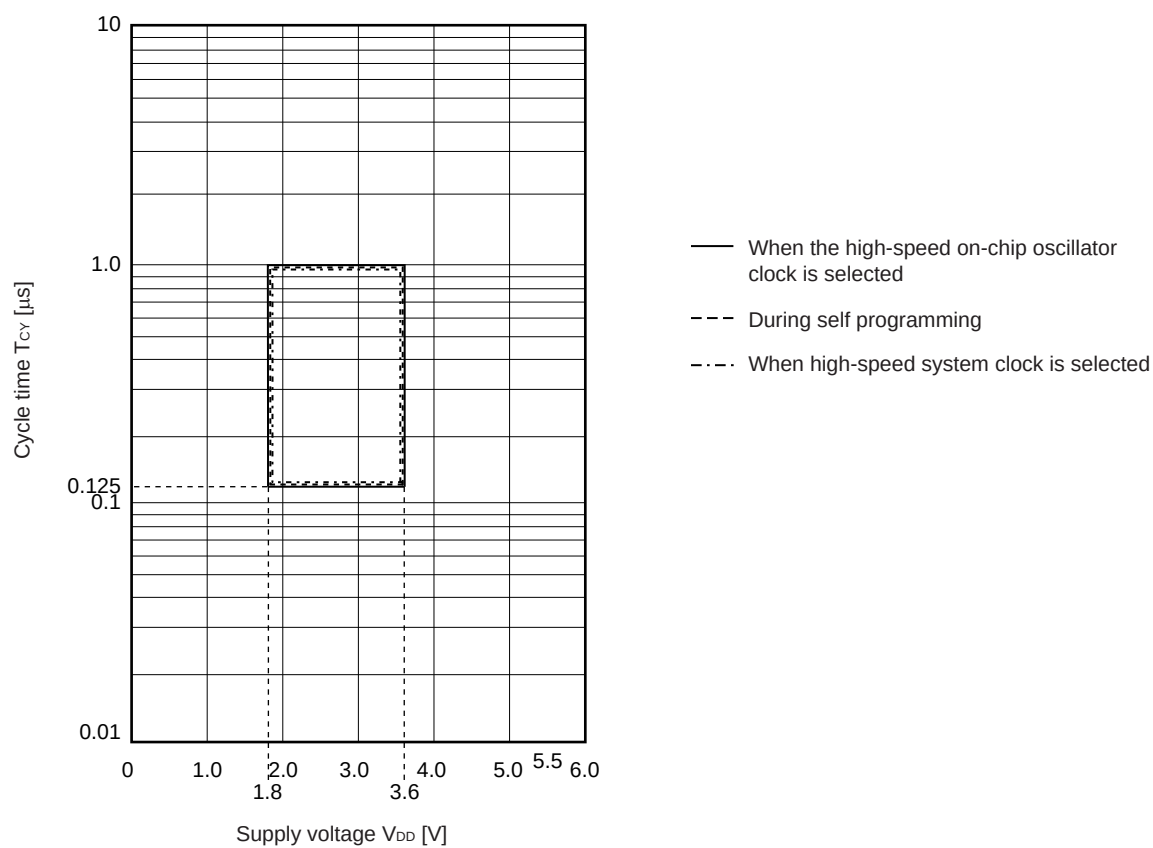
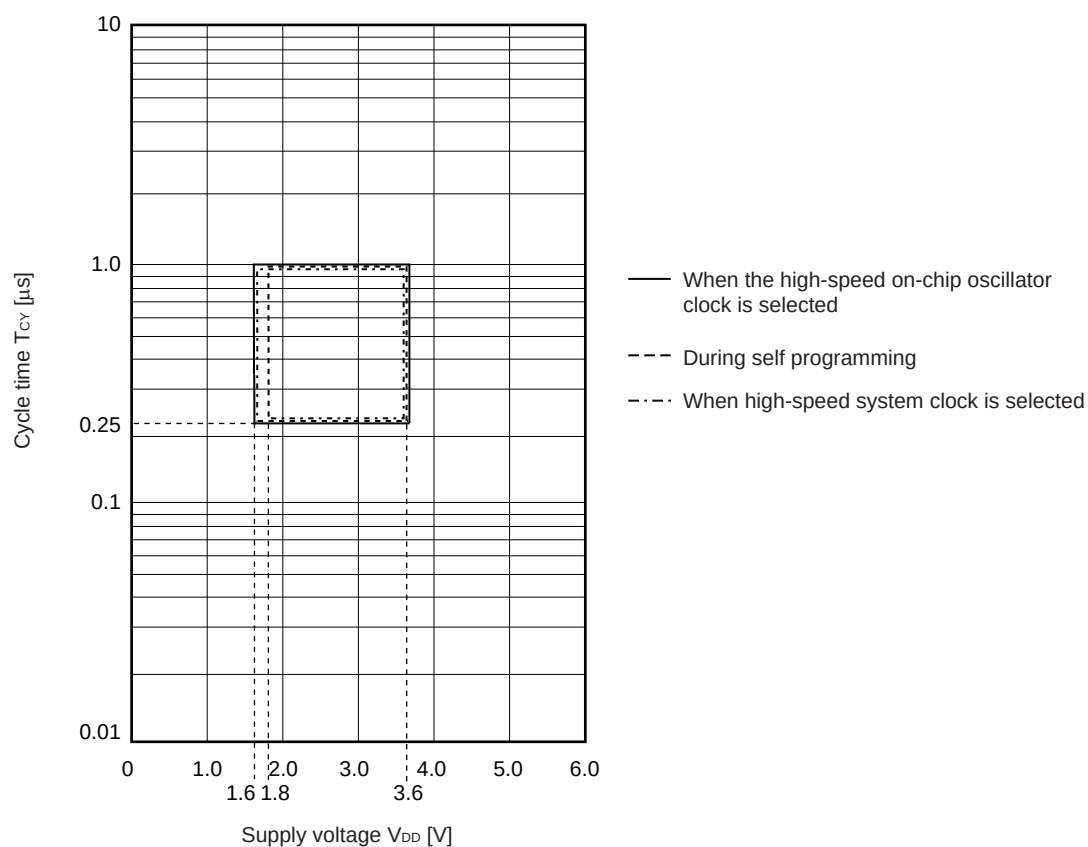
Remark f_{MCK} : Timer array unit operation clock frequency

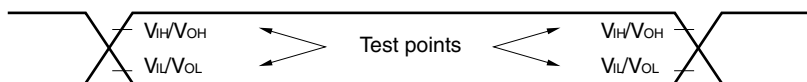
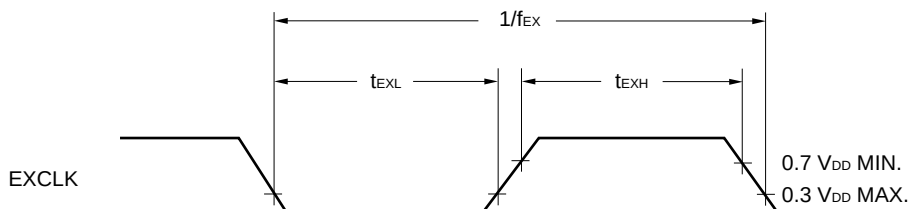
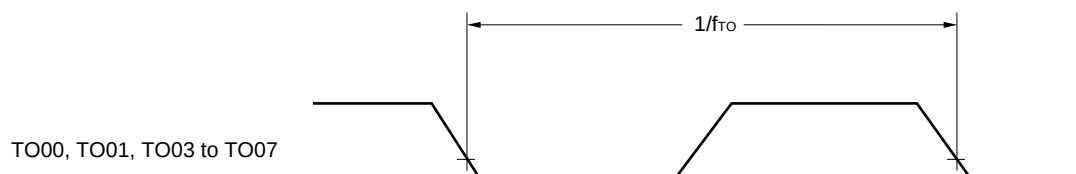
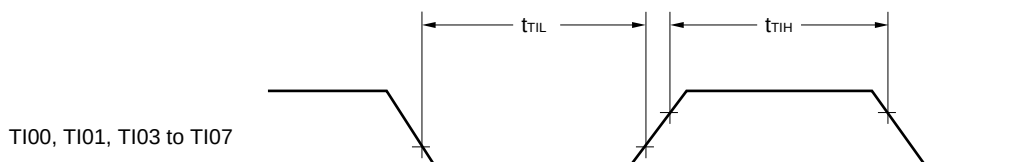
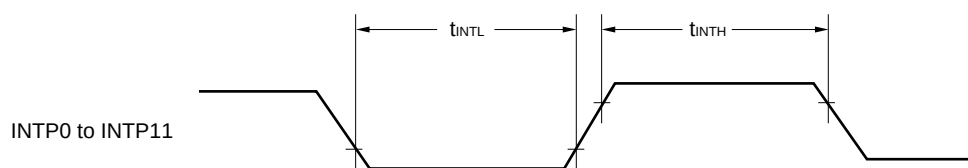
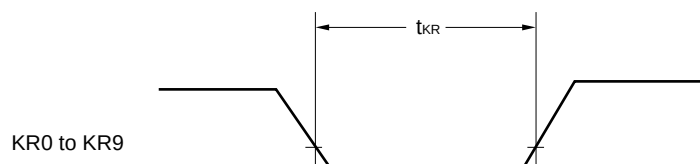
(Operation clock to be set by the CKS0n bit of timer clock select register 0 (TPS0) and timer mode register 0n (TMR0n). n: Channel number (n = 0 to 7))

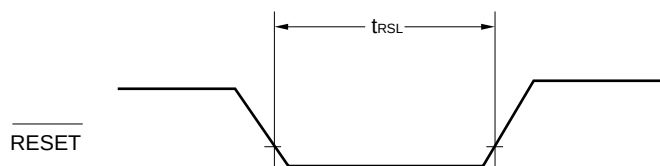
Minimum Instruction Execution Time during Main System Clock Operation

T_{CY} vs V_{DD} (HS (high-speed main) mode)



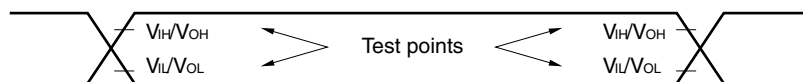
T_{CY} vs V_{DD} (LS (low-speed main) mode) T_{CY} vs V_{DD} (LV (low-voltage main) mode)

AC Timing Test Points**External System Clock Timing****TI/TO Timing****Interrupt Request Input Timing****Key Interrupt Input Timing**

$\overline{\text{RESET}}$ Input Timing

29.5 Peripheral Functions Characteristics

AC Timing Test Points



29.5.1 Serial array unit

(1) During communication at same potential (UART mode)

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS}0} = 0\text{ V}$)

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate ^{Note 4}		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$	bps
		Theoretical value of the maximum transfer rate $f_{\text{MCK}} = f_{\text{CLK}}$ ^{Note 6}		$5.3^{\text{Note 5}}$		1.3		0.6	Mbps
		$1.8\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$	bps
		Theoretical value of the maximum transfer rate $f_{\text{MCK}} = f_{\text{CLK}}$ ^{Note 6}		$5.3^{\text{Note 5}}$		1.3		0.6	Mbps
		$1.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$	bps
		Theoretical value of the maximum transfer rate $f_{\text{MCK}} = f_{\text{CLK}}$ ^{Note 6}		$5.3^{\text{Note 5}}$		$1.3^{\text{Note 5}}$		0.6	Mbps
		$1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		—		$f_{\text{MCK}}/6$		$f_{\text{MCK}}/6$	bps
		Theoretical value of the maximum transfer rate $f_{\text{MCK}} = f_{\text{CLK}}$ ^{Note 6}		—		$1.3^{\text{Note 5}}$		0.6	Mbps

Notes 1. HS is condition of HS (high-speed main) mode.

2. LS is condition of LS (low-speed main) mode.

3. LV is condition of LV (low-voltage main) mode.

4. Transfer rate in the SNOOZE mode is 4800 bps.

5. The following conditions are required for low-voltage interface when $\text{EV}_{\text{DD}0} < \text{V}_{\text{DD}}$.

$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 2.7\text{ V}$: MAX. 2.6 Mbps

$1.8\text{ V} \leq \text{EV}_{\text{DD}0} < 2.4\text{ V}$: MAX. 1.3 Mbps

$1.6\text{ V} \leq \text{EV}_{\text{DD}0} < 1.8\text{ V}$: MAX. 0.6 Mbps

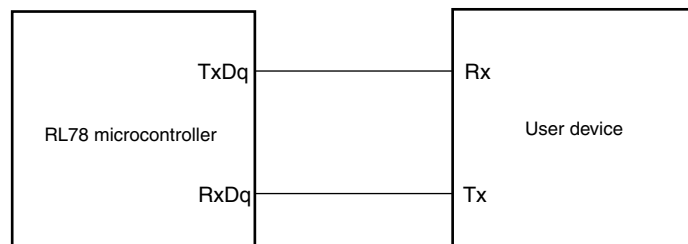
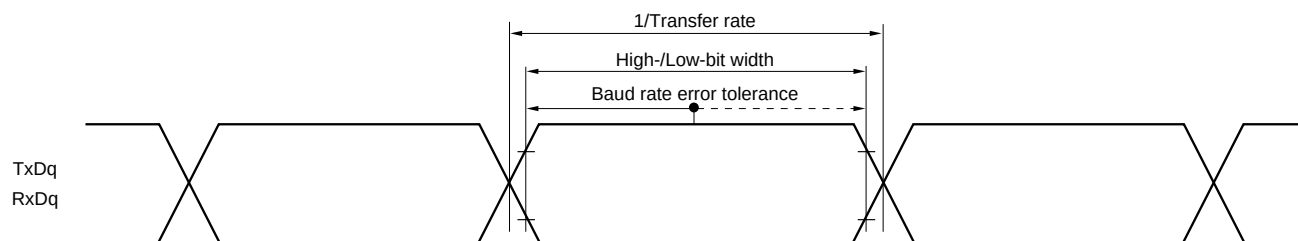
6. f_{CLK} in each operating mode is as below.

HS (high-speed main) mode: $f_{\text{CLK}} = 32\text{ MHz}$

LS (low-speed main) mode: $f_{\text{CLK}} = 8\text{ MHz}$

LV (low-voltage main) mode: $f_{\text{CLK}} = 4\text{ MHz}$

Caution Select the normal input buffer for the RxDq pin and the normal output mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).

UART mode connection diagram (during communication at same potential)**UART mode bit width (during communication at same potential) (reference)**

- Remarks**
1. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1)
 2. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

(2) During communication at same potential (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)

($T_A = -40$ to $+85^\circ\text{C}$, $2.7\text{ V} \leq V_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = V_{SS0} = 0\text{ V}$)

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $t_{KCY1} \geq 2/f_{CLK}$	83.3		250		500		ns
SCKp high-/low-level width	t_{KH1} , t_{KL1}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	$t_{KCY1}/2$ -10		$t_{KCY1}/2$ -50		$t_{KCY1}/2$ -50		ns
Slp setup time (to SCKp $\uparrow$) ^{Note 4}	t_{SIK1}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	33		110		110		ns
Slp hold time (from SCKp $\uparrow$) ^{Note 4}	t_{KSI1}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	10		10		10		ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 5}	t_{KSO1}	$C = 20\text{ pF}$ ^{Note 6}		10		10		10	ns

Notes 1. HS is condition of HS (high-speed main) mode.

2. LS is condition of LS (low-speed main) mode.

3. LV is condition of LV (low-voltage main) mode.

4. When $DAPmn = 0$ and $CKPmn = 0$, or $DAPmn = 1$ and $CKPmn = 1$. The Slp setup time or Slp hold time becomes "from SCKp $\downarrow$ " when $DAPmn = 0$ and $CKPmn = 1$, or $DAPmn = 1$ and $CKPmn = 0$.

5. When $DAPmn = 0$ and $CKPmn = 0$, or $DAPmn = 1$ and $CKPmn = 1$. The delay time to SOp output becomes "from SCKp $\uparrow$ " when $DAPmn = 0$ and $CKPmn = 1$, or $DAPmn = 1$ and $CKPmn = 0$.

6. C is the load capacitance of the SCKp and SOp output lines.

Caution Select the normal input buffer for the Slp pin and the normal output mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

Remarks 1. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0),
g: PIM and POM numbers (g = 1)

2. f_{MCK} : Serial array unit operation clock frequency

(Operation clock to be set by the CKS mn bit of serial mode register mn (SMR mn). m: Unit number,

n: Channel number (mn = 00))

(3) During communication at same potential (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output)**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS}0} = 0\text{ V}$)**

Parameter	Symbol	Conditions		HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	$t_{\text{KCY}2}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$	$t_{\text{KCY}1} \geq 4/f_{\text{CLK}}$	125		500		1000		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$	$t_{\text{KCY}1} \geq 4/f_{\text{CLK}}$	250		500		1000		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$	$t_{\text{KCY}1} \geq 4/f_{\text{CLK}}$	500		500		1000		ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$	$t_{\text{KCY}1} \geq 4/f_{\text{CLK}}$	1000		1000		1000		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$	$t_{\text{KCY}1} \geq 4/f_{\text{CLK}}$	—		1000		1000		ns
SCKp high-/low-level width	$t_{\text{KH}2}$, $t_{\text{KL}2}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$t_{\text{KCY}2}/2$ -18		$t_{\text{KCY}2}/2$ -50		$t_{\text{KCY}2}/2$ -50		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$t_{\text{KCY}2}/2$ -38		$t_{\text{KCY}2}/2$ -50		$t_{\text{KCY}2}/2$ -50		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$t_{\text{KCY}2}/2$ -50		$t_{\text{KCY}2}/2$ -50		$t_{\text{KCY}2}/2$ -50		ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		$t_{\text{KCY}2}/2$ -100		$t_{\text{KCY}2}/2$ -100		$t_{\text{KCY}2}/2$ -100		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		—		$t_{\text{KCY}2}/2$ -100		$t_{\text{KCY}2}/2$ -100		ns
Slp setup time (to SCKp $\uparrow$) ^{Note 4}	$t_{\text{SIK}2}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		44		110		110		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		75		110		110		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		110		110		110		ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		220		220		220		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$		—		220		220		ns
Slp hold time (from SCKp $\uparrow$) ^{Note 4}	$t_{\text{SIK}2}$	$1.7\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$		19		19		19		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$		—		19		19		ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 5}	$t_{\text{SO}2}$	$1.7\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$	$C = 30\text{ pF}$ ^{Note 6}		25		25		25	ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$	$C = 30\text{ pF}$ ^{Note 6}		—		25		25	ns

Notes 1. HS is condition of HS (high-speed main) mode.**2.** LS is condition of LS (low-speed main) mode.**3.** LV is condition of LV (low-voltage main) mode.**4.** When $\text{DAP}_{\text{mn}} = 0$ and $\text{CKP}_{\text{mn}} = 0$, or $\text{DAP}_{\text{mn}} = 1$ and $\text{CKP}_{\text{mn}} = 1$. The Slp setup time or Slp hold time becomes “from SCKp $\downarrow$ ” when $\text{DAP}_{\text{mn}} = 0$ and $\text{CKP}_{\text{mn}} = 1$, or $\text{DAP}_{\text{mn}} = 1$ and $\text{CKP}_{\text{mn}} = 0$.**5.** When $\text{DAP}_{\text{mn}} = 0$ and $\text{CKP}_{\text{mn}} = 0$, or $\text{DAP}_{\text{mn}} = 1$ and $\text{CKP}_{\text{mn}} = 1$. The delay time to SOp output becomes “from SCKp $\uparrow$ ” when $\text{DAP}_{\text{mn}} = 0$ and $\text{CKP}_{\text{mn}} = 1$, or $\text{DAP}_{\text{mn}} = 1$ and $\text{CKP}_{\text{mn}} = 0$.**6.** C is the load capacitance of the SCKp and SOp output lines.**Caution** Select the normal input buffer for the Slp pin and the normal output mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**Remark** p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 1)

(4) During communication at same potential (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)

 $(T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq E_{VDD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = E_{VSS0} = 0\text{ V}$)

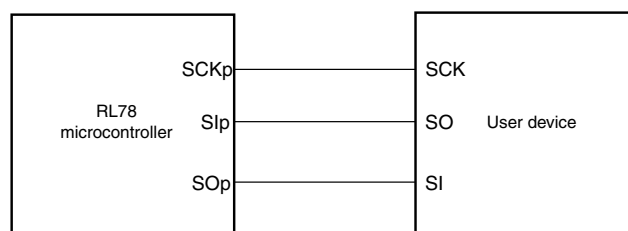
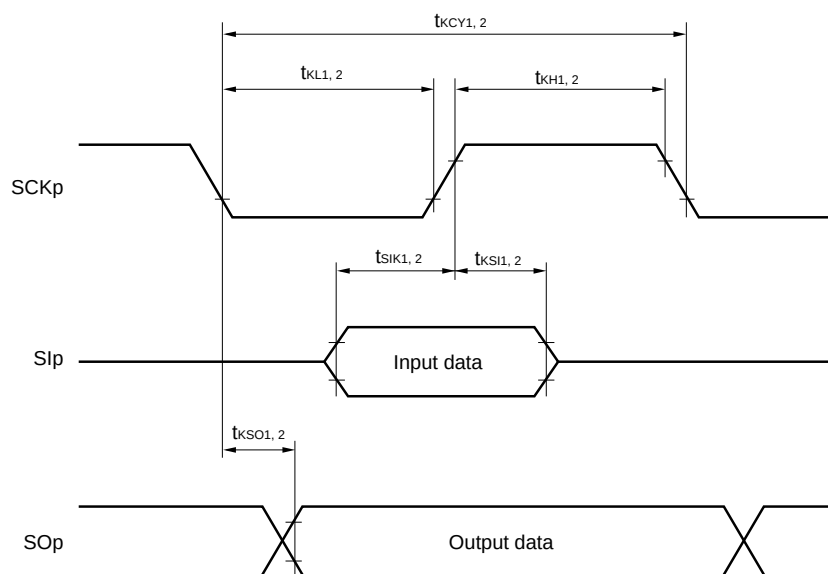
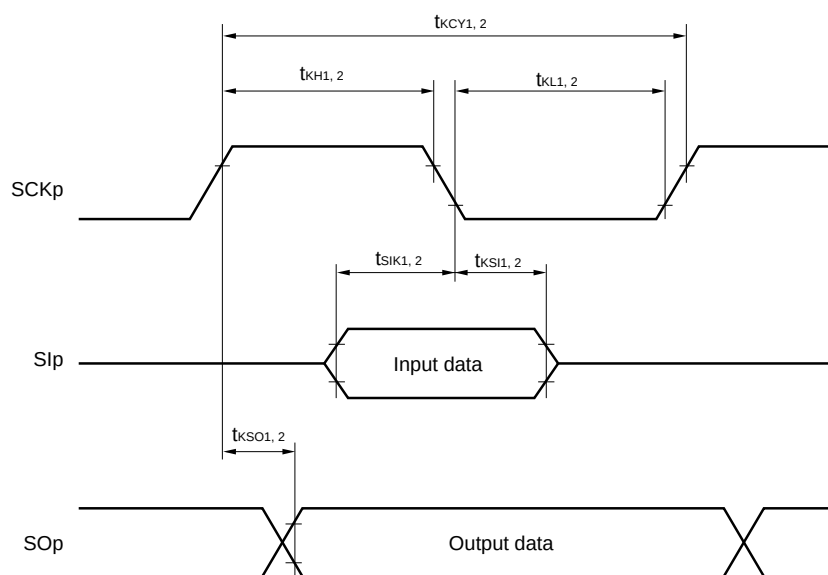
Parameter	Symbol	Conditions		HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time ^{Note 4}	t _{KCY2}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	16 MHz < f _{MCK}	8/f _{MCK}		—		—		ns
			f _{MCK} ≤ 16 MHz	6/f _{MCK}		6/f _{MCK}		6/f _{MCK}		ns
		2.4 V ≤ EV _{DD0} ≤ 3.6 V		6/f _{MCK} and 500ns		6/f _{MCK} and 500ns		6/f _{MCK} and 500ns		ns
		1.8 V ≤ EV _{DD0} ≤ 3.6 V		6/f _{MCK} and 750ns		6/f _{MCK} and 750ns		6/f _{MCK} and 750ns		ns
		1.7 V ≤ EV _{DD0} ≤ 3.6 V		6/f _{MCK} and 1500ns		6/f _{MCK} and 1500ns		6/f _{MCK} and 1500ns		ns
		1.6 V ≤ EV _{DD0} ≤ 3.6 V		—		6/f _{MCK} and 1500ns		6/f _{MCK} and 1500ns		ns
SCKp high-/low-level width	t _{KH2} , t _{KL2}	2.7 V ≤ EV _{DD} ≤ 3.6 V		t _{KCY2} /2 –8		t _{KCY2} /2 –8		t _{KCY2} /2 –8		ns
		1.8 V ≤ EV _{DD0} ≤ 3.6 V		t _{KCY2} /2 –18		t _{KCY2} /2 –18		t _{KCY2} /2 –18		ns
		1.7 V ≤ EV _{DD0} ≤ 3.6 V		t _{KCY2} /2 –66		t _{KCY2} /2 –66		t _{KCY2} /2 –66		ns
		1.6 V ≤ EV _{DD0} ≤ 3.6 V		—		t _{KCY2} /2 –66		t _{KCY2} /2 –66		ns
Slp setup time (to SCKp↑) ^{Note 5}	t _{SIK2}	2.7 V ≤ EV _{DD0} ≤ 3.6 V		1/f _{MCK} +20		1/f _{MCK} +30		1/f _{MCK} +30		ns
		1.8 V ≤ EV _{DD0} ≤ 3.6 V		1/f _{MCK} +30		1/f _{MCK} +30		1/f _{MCK} +30		ns
		1.7 V ≤ EV _{DD0} ≤ 3.6 V		1/f _{MCK} +40		1/f _{MCK} +40		1/f _{MCK} +40		ns
		1.6 V ≤ EV _{DD0} ≤ 3.6 V		—		1/f _{MCK} +40		1/f _{MCK} +40		ns
Slp hold time (from SCKp↑) ^{Note 5}	t _{SI2}	1.8 V ≤ EV _{DD0} ≤ 3.6 V		1/f _{MCK} +31		1/f _{MCK} +31		1/f _{MCK} +31		ns
		1.7 V ≤ EV _{DD0} ≤ 3.6 V		1/f _{MCK} + 250		1/f _{MCK} + 250		1/f _{MCK} + 250		ns
		1.6 V ≤ EV _{DD0} ≤ 3.6 V		—		1/f _{MCK} + 250		1/f _{MCK} + 250		ns
Delay time from SCKp↓ to SOp output ^{Note 6}	t _{KSO2}	C = 30 pF ^{Note 7}	2.7 V ≤ EV _{DD0} ≤ 3.6 V		2/f _{MCK} +44		2/f _{MCK} +110		2/f _{MCK} +110	ns
			2.4 V ≤ EV _{DD0} ≤ 3.6 V		2/f _{MCK} +75		2/f _{MCK} +110		2/f _{MCK} +110	ns
			1.8 V ≤ EV _{DD0} ≤ 3.6 V		2/f _{MCK} +110		2/f _{MCK} +110		2/f _{MCK} +110	ns
			1.7 V ≤ EV _{DD0} ≤ 3.6 V		2/f _{MCK} +220		2/f _{MCK} +220		2/f _{MCK} +220	ns
			1.6 V ≤ EV _{DD0} ≤ 3.6 V		—		2/f _{MCK} +220		2/f _{MCK} +220	ns

(Note, Caution and Remark are listed on the next page.)

- Notes**
1. HS is condition of HS (high-speed main) mode.
 2. LS is condition of LS (low-speed main) mode.
 3. LV is condition of LV (low-voltage main) mode.
 4. Transfer rate in the SNOOZE mode: MAX. 1 Mbps
 5. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The SIp setup time or SIp hold time becomes “from $\text{SCKp}\downarrow$ ” when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.
 6. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The delay time to SOp output becomes “from $\text{SCKp}\uparrow$ ” when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.
 7. C is the load capacitance of the SOp output lines.

Caution Select the normal input buffer for the SIp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

- Remarks**
1. p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM number (g = 0, 1)
 2. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

Simplified SPI (CSI) mode connection diagram (during communication at same potential)**Simplified SPI (CSI) mode serial transfer timing (during communication at same potential)
(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)****Simplified SPI (CSI) mode serial transfer timing (during communication at same potential)
(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)**

- Remarks**
1. p: CSI number (p = 00, 01, 10, 11, 20, 21)
 2. m: Unit number, n: Channel number (mn = 00 to 03, 10, 11)

(5) During communication at same potential (simplified I²C mode) (1/2)**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f _{SCL}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		1000 ^{Note 4}		400 ^{Note 4}		400 ^{Note 4}	kHz
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$		400 ^{Note 4}		400 ^{Note 4}		400 ^{Note 4}	kHz
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$		300 ^{Note 4}		300 ^{Note 4}		300 ^{Note 4}	kHz
		$1.7\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$		250 ^{Note 4}		250 ^{Note 4}		250 ^{Note 4}	kHz
		$1.6\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$		—		250 ^{Note 4}		250 ^{Note 4}	kHz
Hold time when SCLr = "L"	t _{LOW}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	475		1150		1150		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	1150		1150		1150		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	1550		1550		1550		ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	1850		1850		1850		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	—		1850		1850		ns
Hold time when SCLr = "H"	t _{HIGH}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	475		1150		1150		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	1150		1150		1150		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	1550		1550		1550		ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	1850		1850		1850		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	—		1850		1850		ns
Data setup time (reception)	t _{SU:DAT}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$1/f_{\text{MCK}} + 85$ ^{Note 5}		$1/f_{\text{MCK}} + 145$ ^{Note 5}		$1/f_{\text{MCK}} + 145$ ^{Note 5}		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	$1/f_{\text{MCK}} + 145$ ^{Note 5}		$1/f_{\text{MCK}} + 145$ ^{Note 5}		$1/f_{\text{MCK}} + 145$ ^{Note 5}		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	$1/f_{\text{MCK}} + 230$ ^{Note 5}		$1/f_{\text{MCK}} + 230$ ^{Note 5}		$1/f_{\text{MCK}} + 230$ ^{Note 5}		ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	$1/f_{\text{MCK}} + 290$ ^{Note 5}		$1/f_{\text{MCK}} + 290$ ^{Note 5}		$1/f_{\text{MCK}} + 290$ ^{Note 5}		ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	—		$1/f_{\text{MCK}} + 290$ ^{Note 5}		$1/f_{\text{MCK}} + 290$ ^{Note 5}		ns

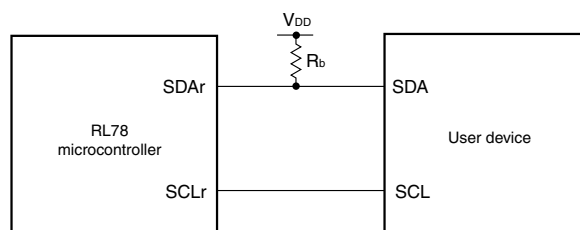
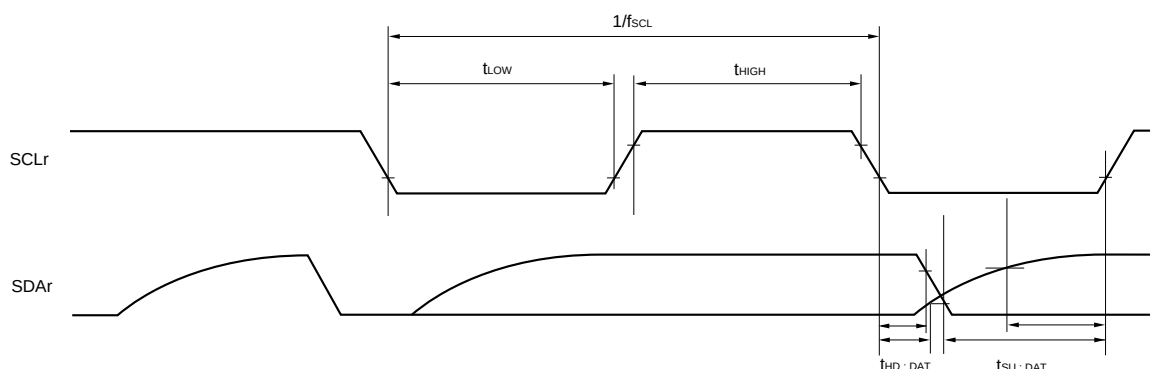
(Notes, Caution and Remarks are listed on the next page.)

(5) During communication at same potential (simplified I²C mode) (2/2)**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Data hold time (transmission)	$t_{\text{HD:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	0	305	0	305	0	305	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	0	355	0	355	0	355	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	0	405	0	405	0	405	ns
		$1.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	0	405	0	405	0	405	ns
		$1.6\text{ V} \leq \text{EV}_{\text{DD0}} < 1.8\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5\text{ k}\Omega$	—	—	0	405	0	405	ns

- Notes**
1. HS is condition of HS (high-speed main) mode.
 2. LS is condition of LS (low-speed main) mode.
 3. LV is condition of LV (low-voltage main) mode.
 4. The value must also be $f_{\text{CLK}}/4$ or lower.
 5. Set the f_{MCK} value to keep the hold time of $\text{SCLr} = \text{"L"}$ and $\text{SCLr} = \text{"H"}$.

Caution Select the normal input buffer and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SDAr pin and the normal output mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register h (POMh).

Simplified I²C mode mode connection diagram (during communication at same potential)**Simplified I²C mode serial transfer timing (during communication at same potential)**

- Remarks**
1. $R_b[\Omega]$: Communication line (SDAr) pull-up resistance, $C_b[\text{F}]$: Communication line (SDAr , SCLr) load capacitance
 2. r: IIC number (r = 00, 01, 10, 11, 20, 21), g: PIM number (g = 0, 1), h: POM number (h = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number, mn = 00 to 03, 10, 11)

(6) Communication at different potential (1.8 V, 2.5 V) (UART mode) (dedicated baud rate generator output) (1/2)
(T_A = –40 to +85°C, 1.8 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V)

Parameter	Symbol	Conditions			HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
					MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate ^{Note 4}		Reception	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V			f _{MCK} /6		f _{MCK} /6		f _{MCK} /6	bps
				Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} ^{Note 7}		5.3		1.3		0.6	Mbps
			1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 5}			f _{MCK} /6		f _{MCK} /6		f _{MCK} /6	bps
				Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} ^{Note 7}		5.3 ^{Note 6}		1.3		0.6	Mbps

Notes 1. HS is condition of HS (high-speed main) mode.

2. LS is condition of LS (low-speed main) mode.

3. LV is condition of LV (low-voltage main) mode.

4. Transfer rate in the SNOOZE mode is 4800 bps.

5. Use it with EV_{DD0} ≥ V_b.

6. The following conditions are required for low-voltage interface when EV_{DD0} < V_{DD}.

2.4 V ≤ EV_{DD0} < 2.7 V : MAX. 2.6 Mbps

1.8 V ≤ EV_{DD0} < 2.4 V : MAX. 1.3 Mbps

7. f_{CLK} in each operating mode is as below.

HS (high-speed main) mode: f_{CLK} = 32 MHz

LS (low-speed main) mode: f_{CLK} = 8 MHz

LV (low-voltage main) mode: f_{CLK} = 4 MHz

Caution Select the TTL input buffer for the Rx_{Dq} pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/EV_{DD} tolerance (When 64-pin products)) mode for the Tx_{Dq} pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

Remarks 1. V_b[V]: Communication line voltage

2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1)

3. f_{MCK}: Serial array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

(6) Communication at different potential (1.8 V, 2.5 V) (UART mode) (dedicated baud rate generator output) (2/2)
(T_A = –40 to +85°C, 1.8 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V)

Parameter	Symbol	Conditions			HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
					MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate		Transmission	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V			Note 4		Note 4		Note 4	bps
				Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 2.7 kΩ, V _b = 2.3 V		1.2 Note 5		1.2 Note 5		1.2 Note 5	Mbps
			1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6}			Note 7		Note 7		Note 7	bps
				Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 5.5 kΩ, V _b = 1.6 V		0.43 Note 8		0.43 Note 8		0.43 Note 8	Mbps

- Notes**
1. HS is condition of HS (high-speed main) mode.
 2. LS is condition of LS (low-speed main) mode.
 3. LV is condition of LV (low-voltage main) mode.
 4. The smaller maximum transfer rate derived by using f_{MCK}/6 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 2.7 V ≤ EV_{DD0} ≤ 3.6 V and 2.3 V ≤ V_b ≤ 2.7 V

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

5. This value as an example is calculated when the conditions described in the “Conditions” column are met. See **Note 4** above to calculate the maximum transfer rate under conditions of the customer.
6. Use it with EV_{DD0} ≥ V_b.
7. The smaller maximum transfer rate derived by using f_{MCK}/6 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 1.8 V ≤ EV_{DD0} < 3.3 V and 1.6 V ≤ V_b ≤ 2.0 V

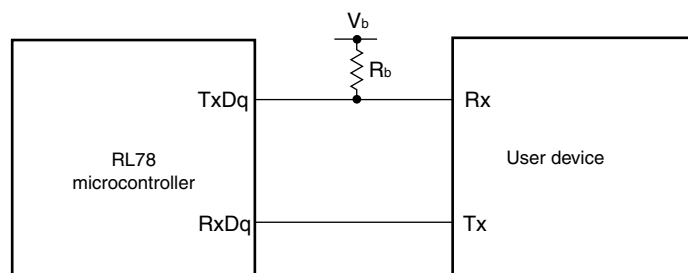
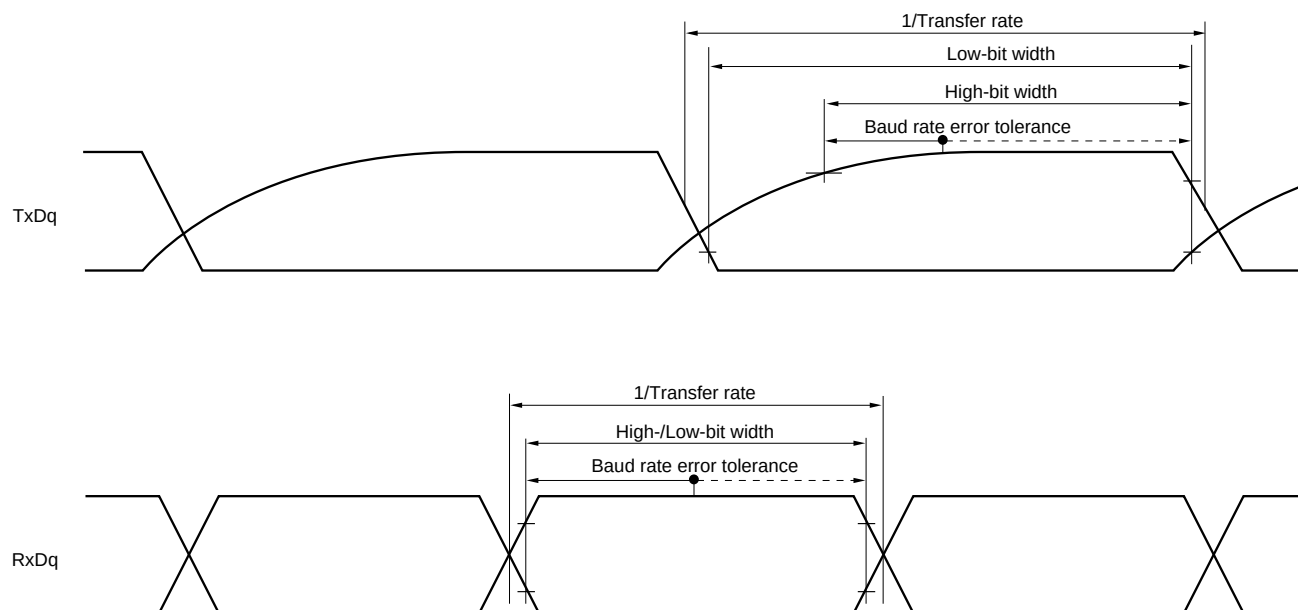
$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

8. This value as an example is calculated when the conditions described in the “Conditions” column are met. See **Note 7** above to calculate the maximum transfer rate under conditions of the customer.

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/EV_{DD} tolerance (When 64-pin products)) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

UART mode connection diagram (during communication at different potential)**UART mode bit width (during communication at different potential) (reference)**

- Remarks**
1. $R_b[\Omega]$: Communication line (TxDq) pull-up resistance,
 $C_b[\text{F}]$: Communication line (TxDq) load capacitance, $V_b[\text{V}]$: Communication line voltage
 2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
 m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

(7) Communication at different potential (2.5 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)

($T_A = -40$ to $+85^\circ\text{C}$, $2.7\text{ V} \leq V_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ $t_{KCY1} \geq 2/f_{CLK}$	300		1150		1150		ns
SCKp high-level width	t_{KH1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$t_{KCY1}/2 - 120$		$t_{KCY1}/2 - 120$		$t_{KCY1}/2 - 120$		ns
SCKp low-level width	t_{KL1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$t_{KCY1}/2 - 10$		$t_{KCY1}/2 - 50$		$t_{KCY1}/2 - 50$		ns
Slp setup time (to SCKp $\uparrow$) ^{Note 4}	t_{SIK1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	121		479		479		ns
Slp hold time (from SCKp $\uparrow$) ^{Note 4}	t_{KSH1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	10		10		10		ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 4}	t_{KSO1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		130		130		130	ns
Slp setup time (to SCKp $\downarrow$) ^{Note 5}	t_{SIK1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	33		110		110		ns
Slp hold time (from SCKp $\downarrow$) ^{Note 5}	t_{KSH1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	10		10		10		ns
Delay time from SCKp $\uparrow$ to SOp output ^{Note 5}	t_{KSO1}	$2.7\text{ V} \leq V_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		10		10		10	ns

- Notes**
1. HS is condition of HS (high-speed main) mode.
 2. LS is condition of LS (low-speed main) mode.
 3. LV is condition of LV (low-voltage main) mode.
 4. When $DAPmn = 0$ and $CKPmn = 0$, or $DAPmn = 1$ and $CKPmn = 1$.
 5. When $DAPmn = 0$ and $CKPmn = 1$, or $DAPmn = 1$ and $CKPmn = 0$.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

- Remarks**
1. $R_b[\Omega]$: Communication line (SCKp, SOp) pull-up resistance, $C_b[\text{F}]$: Communication line (SCKp, SOp) load capacitance, $V_b[\text{V}]$: Communication line voltage
 2. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0),
g: PIM and POM number (g = 1)

(8) Communication at different potential (1.8V, 2.5 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output) (1/2)**($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions		HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$t_{\text{KCY1}} \geq 4/f_{\text{CLK}}$	500		1150		1150		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 4} , $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	$t_{\text{KCY1}} \geq 4/f_{\text{CLK}}$	1150		1150		1150		ns
SCKp high-level width	t_{KH1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$		$t_{\text{KCY1}}/2 - 170$		$t_{\text{KCY1}}/2 - 170$		$t_{\text{KCY1}}/2 - 170$		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 4} , $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$		$t_{\text{KCY1}}/2 - 458$		$t_{\text{KCY1}}/2 - 458$		$t_{\text{KCY1}}/2 - 458$		ns
SCKp low-level width	t_{KL1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$		$t_{\text{KCY1}}/2 - 18$		$t_{\text{KCY1}}/2 - 50$		$t_{\text{KCY1}}/2 - 50$		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 4} , $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$		$t_{\text{KCY1}}/2 - 50$		$t_{\text{KCY1}}/2 - 50$		$t_{\text{KCY1}}/2 - 50$		ns

Notes 1. HS is condition of HS (high-speed main) mode.

2. LS is condition of LS (low-speed main) mode.

3. LV is condition of LV (low-voltage main) mode.

4. Use it with $\text{EV}_{\text{DD0}} \geq \text{V}_b$.

Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

Remarks 1. $\text{R}_b[\Omega]$: Communication line (SCKp, SOp) pull-up resistance, $\text{C}_b[\text{F}]$: Communication line (SCKp, SOp) load capacitance, $\text{V}_b[\text{V}]$: Communication line voltage

2. p: CSI number (p = 00, 10, 20), m: Unit number, n: Channel number (mn = 00, 02, 10),
g: PIM and POM number (g = 0, 1)

3. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

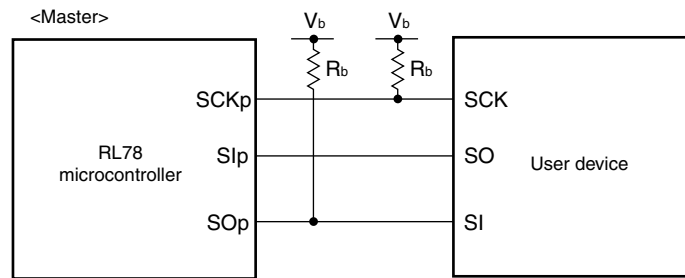
(8) Communication at different potential (1.8 V, 2.5 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output) (2/2)(T_A = -40 to +85°C, 1.8 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V)

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Slp setup time (to SCKp↑) ^{Note 4}	t _{SIK1}	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	177		479		479		ns
		1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6} , C _b = 30 pF, R _b = 5.5 kΩ	479		479		479		ns
Slp hold time (from SCKp↑) ^{Note 4}	t _{SIH1}	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	19		19		19		ns
		1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6} , C _b = 30 pF, R _b = 5.5 kΩ	19		19		19		ns
Delay time from SCKp↓ to SOp output ^{Note 4}	t _{KSO1}	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ		195		195		195	ns
		1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6} , C _b = 30 pF, R _b = 5.5 kΩ		483		483		483	ns
Slp setup time (to SCKp↓) ^{Note 5}	t _{SIK1}	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	44		110		110		ns
		1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6} , C _b = 30 pF, R _b = 5.5 kΩ	110		110		110		ns
Slp hold time (from SCKp↓) ^{Note 5}	t _{SIH1}	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	19		19		19		ns
		1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6} , C _b = 30 pF, R _b = 5.5 kΩ	19		19		19		ns
Delay time from SCKp↑ to SOp output ^{Note 5}	t _{KSO1}	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ		25		25		25	ns
		1.8 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 6} , C _b = 30 pF, R _b = 5.5 kΩ		25		25		25	ns

Notes 1. HS is condition of HS (high-speed main) mode.**2.** LS is condition of LS (low-speed main) mode.**3.** LV is condition of LV (low-voltage main) mode.**4.** When DAP_{mn} = 0 and CKP_{mn} = 0, or DAP_{mn} = 1 and CKP_{mn} = 1.**5.** When DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.**6.** Use it with EV_{DD0} ≥ V_b.

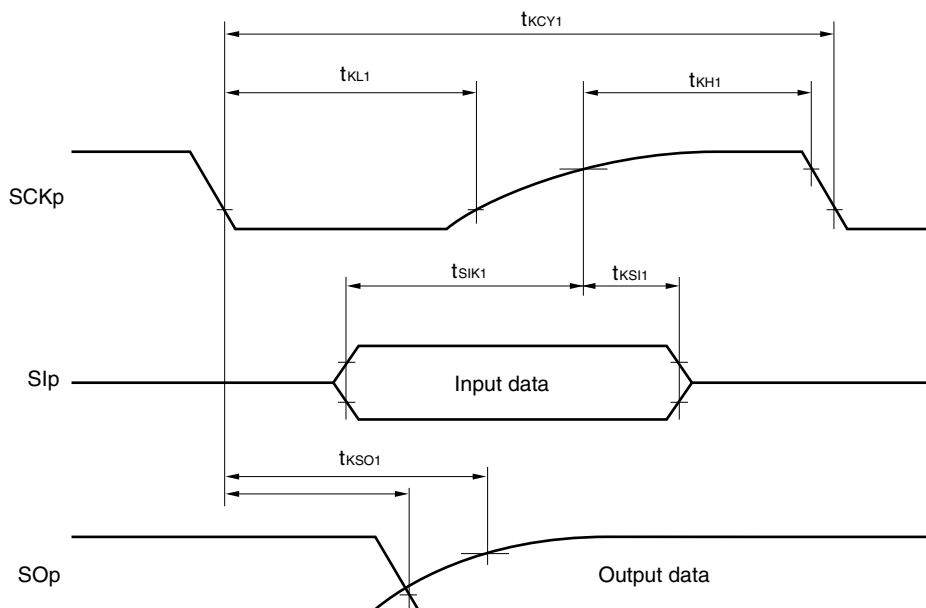
Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/EV_{DD} tolerance (When 64-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

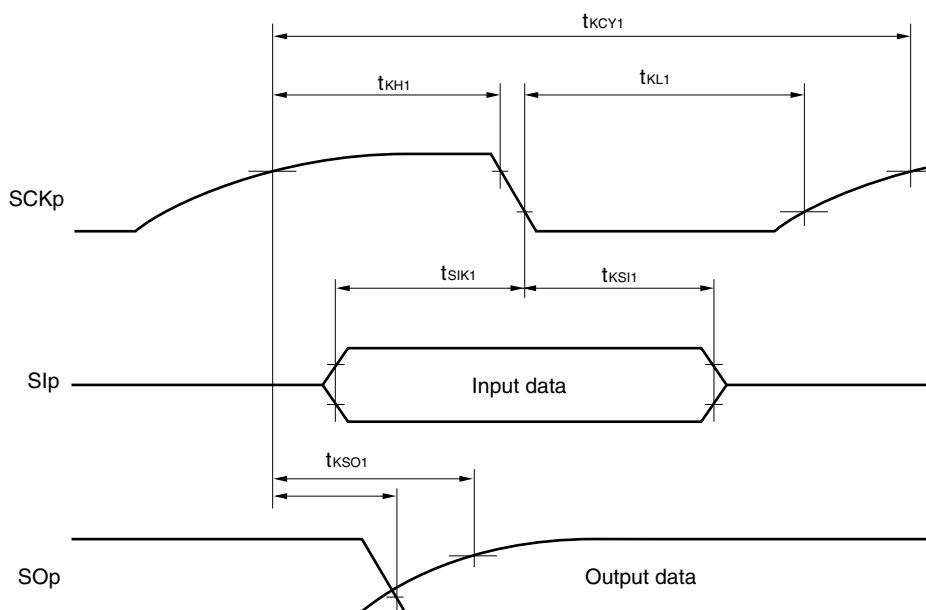
Simplified SPI (CSI) mode connection diagram (during communication at different potential)

- Remarks**
1. $R_b[\Omega]$: Communication line (SCKp, SOp) pull-up resistance, $C_b[\text{F}]$: Communication line (SCKp, SOp) load capacitance, $V_b[\text{V}]$: Communication line voltage
 2. p: CSI number ($p = 00, 10, 20$), m: Unit number, n: Channel number ($mn = 00, 02, 10$), g: PIM and POM number ($g = 0, 1$)
 3. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

Simplified SPI (CSI) mode serial transfer timing (master mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)



Simplified SPI (CSI) mode serial transfer timing (master mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)



- Remarks**
1. p: CSI number (p = 00, 10, 20), m: Unit number, n: Channel number (m = 00, 02, 10), g: PIM and POM number (g = 0, 1)
 2. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

(9) Communication at different potential (1.8 V, 2.5 V) (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)**($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time ^{Note 4}	t_{KCY2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$	$24\text{ MHz} < f_{\text{MCK}}$	$20/f_{\text{MCK}}$	—	—	—	—	ns
			$20\text{ MHz} < f_{\text{MCK}} \leq 24\text{ MHz}$	$16/f_{\text{MCK}}$	—	—	—	—	ns
			$16\text{ MHz} < f_{\text{MCK}} \leq 20\text{ MHz}$	$14/f_{\text{MCK}}$	—	—	—	—	ns
			$8\text{ MHz} < f_{\text{MCK}} \leq 16\text{ MHz}$	$12/f_{\text{MCK}}$	—	—	—	—	ns
			$4\text{ MHz} < f_{\text{MCK}} \leq 8\text{ MHz}$	$8/f_{\text{MCK}}$	$16/f_{\text{MCK}}$	—	—	—	ns
			$f_{\text{MCK}} \leq 4\text{ MHz}$	$6/f_{\text{MCK}}$	$10/f_{\text{MCK}}$	—	$10/f_{\text{MCK}}$	—	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 5}	$24\text{ MHz} < f_{\text{MCK}}$	$48/f_{\text{MCK}}$	—	—	—	—	ns
			$20\text{ MHz} < f_{\text{MCK}} \leq 24\text{ MHz}$	$36/f_{\text{MCK}}$	—	—	—	—	ns
			$16\text{ MHz} < f_{\text{MCK}} \leq 20\text{ MHz}$	$32/f_{\text{MCK}}$	—	—	—	—	ns
			$8\text{ MHz} < f_{\text{MCK}} \leq 16\text{ MHz}$	$26/f_{\text{MCK}}$	—	—	—	—	ns
			$4\text{ MHz} < f_{\text{MCK}} \leq 8\text{ MHz}$	$16/f_{\text{MCK}}$	$16/f_{\text{MCK}}$	—	—	—	ns
			$f_{\text{MCK}} \leq 4\text{ MHz}$	$10/f_{\text{MCK}}$	$10/f_{\text{MCK}}$	—	$10/f_{\text{MCK}}$	—	ns
SCKp high-/low-level width	t_{KH2} , t_{KL2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$	$t_{\text{KCY2}}/2$ – 18	—	$t_{\text{KCY2}}/2$ – 50	—	$t_{\text{KCY2}}/2$ – 50	—	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 5}	$t_{\text{KCY2}}/2$ – 50	—	$t_{\text{KCY2}}/2$ – 50	—	$t_{\text{KCY2}}/2$ – 50	—	ns
Slp setup time (to SCKp $\uparrow$) ^{Note 6}	t_{SIK2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$	$1/f_{\text{MCK}}$ + 20	—	$1/f_{\text{MCK}}$ + 30	—	$1/f_{\text{MCK}}$ + 30	—	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 5}	$1/f_{\text{MCK}}$ + 30	—	$1/f_{\text{MCK}}$ + 30	—	$1/f_{\text{MCK}}$ + 30	—	ns
Slp hold time (from SCKp $\uparrow$) ^{Note 6}	t_{SIH2}		$1/f_{\text{MCK}}$ + 31	—	$1/f_{\text{MCK}}$ + 31	—	$1/f_{\text{MCK}}$ + 31	—	ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 7}	t_{KSO2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	—	$2/f_{\text{MCK}}$ + 214	—	$2/f_{\text{MCK}}$ + 573	—	$2/f_{\text{MCK}}$ + 573	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 5} , $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	—	$2/f_{\text{MCK}}$ + 573	—	$2/f_{\text{MCK}}$ + 573	—	$2/f_{\text{MCK}}$ + 573	ns

Notes 1. HS is condition of HS (high-speed main) mode.

2. LS is condition of LS (low-speed main) mode.

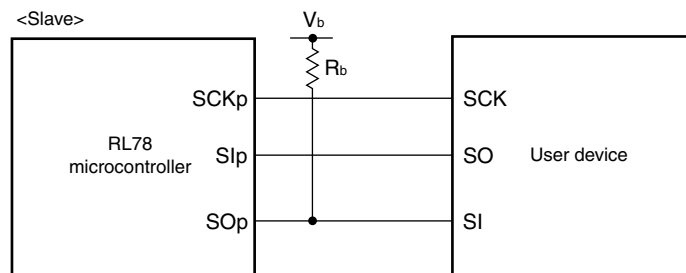
3. LV is condition of LV (low-voltage main) mode.

4. Transfer rate in the SNOOZE mode : MAX. 1 Mbps

5. Use it with $\text{EV}_{\text{DD0}} \geq \text{V}_b$.6. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The Slp setup time or Slp hold time becomes “from SCKp $\downarrow$ ” when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.7. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The delay time to SOp output becomes “from SCKp $\uparrow$ ” when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.

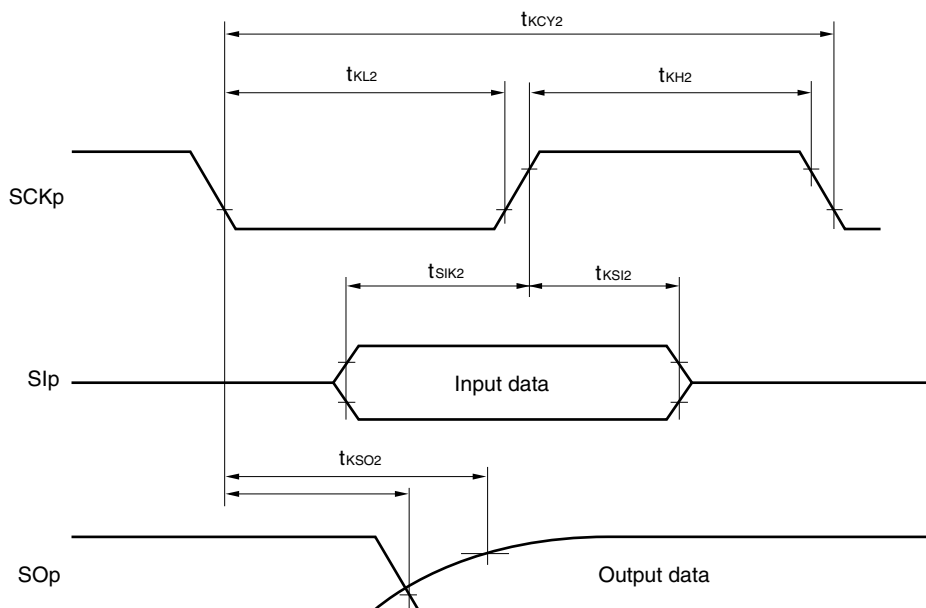
Caution Select the TTL input buffer for the Slp pin and SCKp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

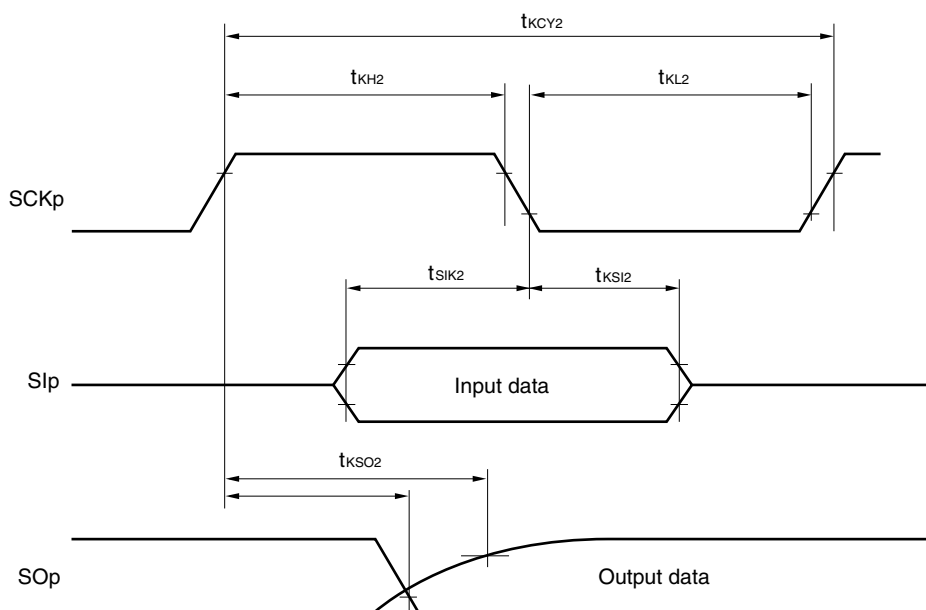
Simplified SPI (CSI) mode connection diagram (during communication at different potential)

- Remarks**
1. $R_b[\Omega]$: Communication line (SO_p) pull-up resistance, $C_b[\text{F}]$: Communication line (SO_p) load capacitance, $V_b[\text{V}]$: Communication line voltage
 2. p: CSI number ($p = 00, 10, 20$), m: Unit number ($m = 0, 1$), n: Channel number ($n = 00, 02, 10$), g: PIM and POM number ($g = 0, 1$)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number ($mn = 00, 02, 10$))
 4. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

Simplified SPI (CSI) mode serial transfer timing (slave mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)



Simplified SPI (CSI) mode serial transfer timing (slave mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)



- Remarks**
1. p: CSI number (p = 00, 10, 20), m: Unit number, n: Channel number (mn = 00, 02, 10), g: PIM and POM number (g = 0, 1)
 2. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

(10) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode) (1/2)**($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f_{SCL}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$		1000 ^{Note 4}		300 ^{Note 4}		300 ^{Note 4}	kHz
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$		400 ^{Note 4}		300 ^{Note 4}		300 ^{Note 4}	kHz
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}^{\text{Note 5}}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$		300 ^{Note 4}		300 ^{Note 4}		300 ^{Note 4}	kHz
Hold time when SCLr = "L"	t_{LOW}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	475		1550		1550		ns
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	1150		1550		1550		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}^{\text{Note 5}}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	1550		1550		1550		ns
Hold time when SCLr = "H"	t_{HIGH}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	200		610		610		ns
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	600		610		610		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}^{\text{Note 5}}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	610		610		610		ns

(Notes, Caution and Remarks are listed on the next page.)

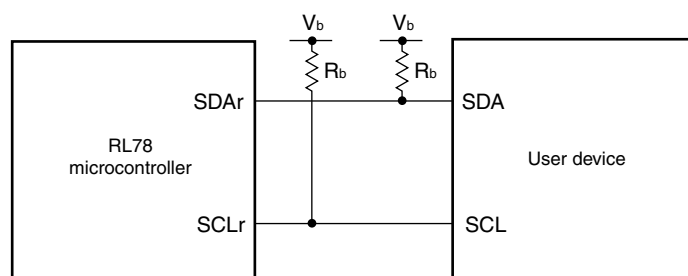
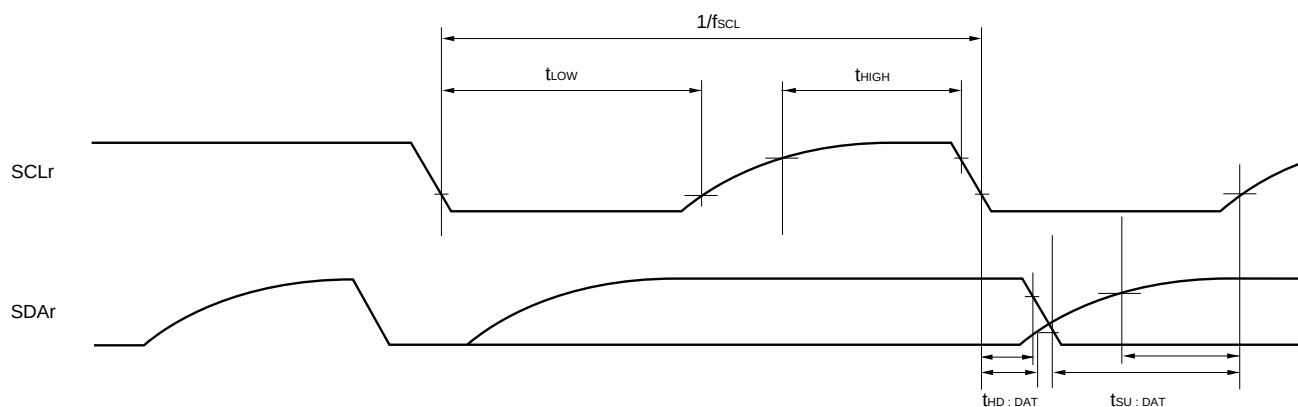
(10) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode) (2/2)**($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS ^{Note 1}		LS ^{Note 2}		LV ^{Note 3}		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Data setup time (reception)	$t_{\text{SU:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$1/f_{\text{MCK}} + 135$ ^{Note 6}		$1/f_{\text{MCK}} + 190$ ^{Note 6}		$1/f_{\text{MCK}} + 190$ ^{Note 6}		ns
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$1/f_{\text{MCK}} + 190$ ^{Note 6}		$1/f_{\text{MCK}} + 190$ ^{Note 6}		$1/f_{\text{MCK}} + 190$ ^{Note 6}		ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 5} , $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	$1/f_{\text{MCK}} + 190$ ^{Note 6}		$1/f_{\text{MCK}} + 190$ ^{Note 6}		$1/f_{\text{MCK}} + 190$ ^{Note 6}		ns
Data hold time (transmission)	$t_{\text{HD:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	0	305	0	305	0	305	ns
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	0	355	0	355	0	355	ns
		$1.8\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$ ^{Note 5} , $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	0	405	0	405	0	405	ns

Notes 1. HS is condition of HS (high-speed main) mode.**2.** LS is condition of LS (low-speed main) mode.**3.** LV is condition of LV (low-voltage main) mode.**4.** The value must also be $f_{\text{CLK}}/4$ or lower.**5.** Use it with $\text{EV}_{\text{DD0}} \geq \text{V}_b$.**6.** Set the f_{MCK} value to keep the hold time of $\text{SCLr} = \text{"L"}$ and $\text{SCLr} = \text{"H"}$.

Caution Select the TTL input buffer and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

Simplified I²C mode connection diagram (during communication at different potential)**Simplified I²C mode serial transfer timing (during communication at different potential)**

- Remarks**
1. $R_b[\Omega]$: Communication line (SDAr, SCLr) pull-up resistance, $C_b[F]$: Communication line (SDAr, SCLr) load capacitance, $V_b[V]$: Communication line voltage
 2. r: IIC number ($r = 00, 10, 20$), g: PIM, POM number ($g = 0, 1$)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number ($mn = 00, 02, 10$))
 4. IIC01, IIC11, and IIC21 cannot communicate at different potential. Use IIC00, IIC10, or IIC20 for communication at different potential.

29.5.2 Serial interface IICA

(1) I²C standard mode(T_A = -40 to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

Parameter	Symbol	Conditions	Standard Mode ^{Note 1}						Unit
			HS ^{Note 2}		LS ^{Note 3}		LV ^{Note 4}		
			MIN.	MAX.	MIN.	MIN.	MAX.	MIN.	
SCLA0 clock frequency	f _{SCL}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0	100	0	100	0	100	kHz
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0	100	0	100	0	100	
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	0	100	0	100	0	100	
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		0	100	0	100	
Setup time of restart condition	t _{SU:STA}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		4.7		4.7		
Hold time ^{Note 5}	t _{HD:STA}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		4.0		4.0		
Hold time when SCLA0 = “L”	t _{LOW}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		4.7		4.7		
Hold time when SCLA0 = “H”	t _{HIGH}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		4.0		4.0		
Data setup time (reception)	t _{SU:DAT}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	250		250		250		ns
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	250		250		250		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	250		250		250		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		250		250		
Data hold time (transmission) ^{Note 6}	t _{HD:DAT}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0	3.45	0	3.45	0	3.45	μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0	3.45	0	3.45	0	3.45	
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	0	3.45	0	3.45	0	3.45	
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–	–	0	3.45	0	3.45	
Setup time of stop condition	t _{SU:STO}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	4.0		4.0		4.0		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		4.0		4.0		
Bus-free time	t _{BUF}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		
		1.7 V ≤ EV _{DD0} ≤ 3.6 V	4.7		4.7		4.7		
		1.6 V ≤ EV _{DD0} ≤ 3.6 V	–		4.7		4.7		

(Note and Remark are listed on the next page.)

(2) I²C fast mode, fast mode plus(T_A = -40 to $+85^\circ\text{C}$, $1.6\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

Parameter	Symbol	Conditions	Fast Mode ^{Note 7}						Fast Mode Plus ^{Note 8}		Unit
			HS ^{Note 2}		LS ^{Note 3}		LV ^{Note 4}		HS ^{Note 2}		
			MIN.	MAX.	MIN.	MIN.	MAX.	MIN.	MAX.	MIN.	
SCLA0 clock frequency	f _{SCL}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0	400	0	400	0	400	0	1000	kHz
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0	400	0	400	0	400	–		
Setup time of restart condition	t _{SU:STA}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		0.26		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		–		
Hold time ^{Note 5}	t _{HD:STA}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		0.26		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		–		
Hold time when SCLA0 = “L”	t _{LOW}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	1.3		1.3		1.3		0.5		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	1.3		1.3		1.3		–		
Hold time when SCLA0 = “H”	t _{HIGH}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		0.26		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		–		
Data setup time (reception)	t _{SU:DAT}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	100		100		100		50		ns
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	100		100		100		–		
Data hold time (transmission) ^{Note 6}	t _{HD:DAT}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0	0.9	0	0.9	0	0.9	0	450	μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0	0.9	0	0.9	0	0.9	–		
Setup time of stop condition	t _{SU:STO}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		0.26		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	0.6		0.6		0.6		–		
Bus-free time	t _{BUF}	2.7 V ≤ EV _{DD0} ≤ 3.6 V	1.3		1.3		1.3		0.5		μs
		1.8 V ≤ EV _{DD0} ≤ 3.6 V	1.3		1.3		1.3		–		

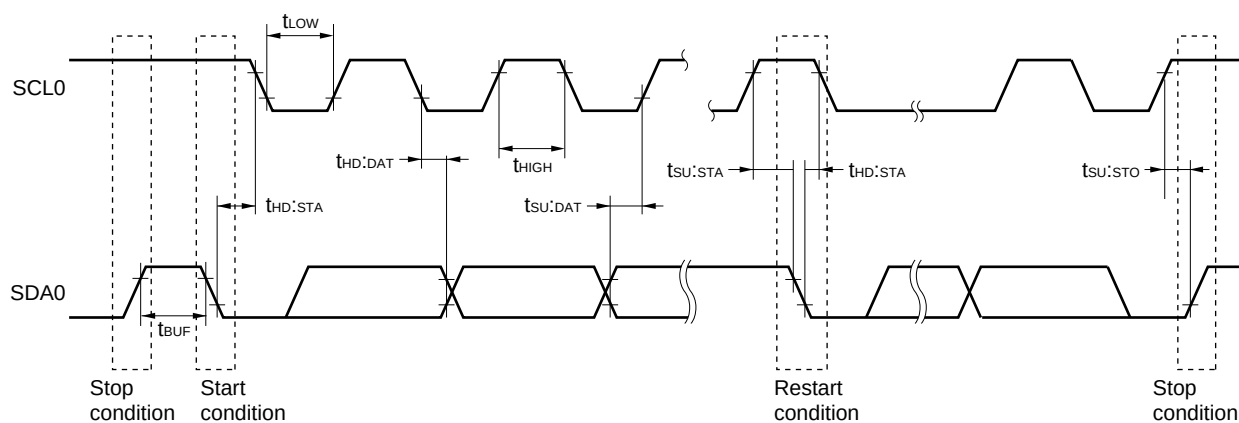
- Notes**
1. In normal mode, use it with $f_{\text{CLK}} \geq 1\text{ MHz}$, $1.6\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$.
 2. HS is condition of HS (high-speed main) mode.
 3. LS is condition of LS (low-speed main) mode.
 4. LV is condition of LV (low-voltage main) mode.
 5. The first clock pulse is generated after this period when the start/restart condition is detected.
 6. The maximum value (MAX.) of t_{HD:DAT} is during normal transfer and a clock stretch state is inserted in the ACK (acknowledge) timing.
 7. In fast mode, use it with $f_{\text{CLK}} \geq 3.5\text{ MHz}$, $1.8\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$.
 8. In fast mode plus, use it with $f_{\text{CLK}} \geq 10\text{ MHz}$, $2.7\text{ V} \leq \text{EV}_{\text{DD}} \leq 3.6\text{ V}$.

Remark The maximum value of C_b (communication line capacitance) and the value of R_b (communication line pull-up resistor) at that time in each mode are as follows.

Standard mode: C_b = 400 pF, R_b = 2.7 kΩ

Fast mode: C_b = 320 pF, R_b = 1.1 kΩ

Fast mode plus: C_b = 120 pF, R_b = 1.1 kΩ

IICA serial transfer timing

29.6 Analog Characteristics

29.6.1 A/D converter characteristics

Division of A/D Converter Characteristics

Reference voltage Input channel	Reference voltage (+) = AV_{REFP} Reference voltage (–) = AV_{REFM}	Reference voltage (+) = AV_{DD} Reference voltage (–) = AV_{SS}	Reference voltage (+) = Internal reference voltage Reference voltage (–) = AV_{SS}
High-accuracy channel; ANI0 to ANI12 (input buffer power supply: AV_{DD})	See 29.6.1 (1) See 29.6.1 (2)	See 29.6.1 (3)	See 29.6.1 (6)
Standard channel; ANI16 to ANI30 (input buffer power supply: V_{DD} or EV_{DD0})	See 29.6.1 (4)	See 29.6.1 (5)	
Temperature sensor, internal reference voltage output	See 29.6.1 (4)	See 29.6.1 (5)	–

(1) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (–) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), target for conversion: ANI2 to ANI12

($T_A = -40$ to $+85^\circ\text{C}$, $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (–) = $AV_{REFM} = 0\text{ V}$, HALT mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}				12	bit
Overall error ^{Notes 1, 2, 3}	A_{INL}	12-bit resolution		± 1.7	± 3.3	LSB
Conversion time	t_{CONV}	$ADTYP = 0$, 12-bit resolution	3.375			μs
Zero-scale error ^{Notes 1, 2, 3}	E_{ZS}	12-bit resolution		± 1.3	± 3.2	LSB
Full-scale error ^{Notes 1, 2, 3}	E_{FS}	12-bit resolution		± 0.7	± 2.9	LSB
Integral linearity error ^{Notes 1, 2, 3}	I_{LE}	12-bit resolution		± 1.0	± 1.4	LSB
Differential linearity error ^{Notes 1, 2, 3}	D_{LE}	12-bit resolution		± 0.9	± 1.2	LSB
Analog input voltage	V_{AIN}		0		AV_{REFP}	V

Notes 1. TYP. Value is the average value at $AV_{DD} = AV_{REFP} = 3\text{ V}$ and $T_A = 25^\circ\text{C}$. MAX. value is the average value $\pm 3\sigma$ at normalized distribution.

2. These values are the results of characteristic evaluation and are not checked for shipment.

3. Excludes quantization error ($\pm 1/2$ LSB).

Cautions 1. Route the wiring so that noise will not be superimposed on each power line and ground line, and insert a capacitor to suppress noise.

In addition, separate the reference voltage line of AV_{REFP} from the other power lines to keep it free from the influences of noise.

2. During A/D conversion, keep a pulse, such as a digital signal, that abruptly changes its level from being input to or output from the pins adjacent to the converter pins and P20 to P27 and P150 to P154.

(2) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (–) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), target for conversion: $ANI2$ to $ANI12$

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (–) = $AV_{REFM} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	Res		$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
			$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		10 ^{Note 1}	
			$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8 ^{Note 2}			
Overall error ^{Note 3}	AINL	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±6.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	3.375			μs
		ADTYP = 0, 10-bit resolution ^{Note 1}	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	6.75			
		ADTYP = 0, 8-bit resolution ^{Note 2}	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	13.5			
		ADTYP = 1, 8-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	2.5625			
			$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	5.125			
			$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	10.25			
Zero-scale error ^{Note 3}	EzS	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±4.5	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±4.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
Full-scale error ^{Note 3}	EFs	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±4.5	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±4.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
Integral linearity error ^{Note 3}	ILE	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.0	
Differential linearity error ^{Note 3}	DLE	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.0	
Analog input voltage	VAIN			0		AVREFP	V

Notes 1. Cannot be used for lower 2 bit of ADCR register

2. Cannot be used for lower 4 bit of ADCR register

3. Excludes quantization error ($\pm 1/2$ LSB).

(3) When reference voltage (+) = AV_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = AV_{SS} (ADREFM = 0), target for conversion: ANI0 to ANI12

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{DD} , Reference voltage (–) = $AV_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	R _{ES}		2.4 V ≤ AV _{DD} ≤ 3.6 V	8		12	bit
			1.8 V ≤ AV _{DD} ≤ 3.6 V	8		10 ^{Note 1}	
			1.6 V ≤ AV _{DD} ≤ 3.6 V	8 ^{Note 2}			
Overall error ^{Note 3}	A _{INL}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±7.5	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.5	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±3.0	
Conversion time	t _{CONV}	ADTYP = 0, 12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V	3.375			μs
		ADTYP = 0, 10-bit resolution ^{Note 1}	1.8 V ≤ AV _{DD} ≤ 3.6 V	6.75			
		ADTYP = 0, 8-bit resolution ^{Note 2}	1.6 V ≤ AV _{DD} ≤ 3.6 V	13.5			
		ADTYP = 1, 8-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V	2.5625			
			1.8 V ≤ AV _{DD} ≤ 3.6 V	5.125			
			1.6 V ≤ AV _{DD} ≤ 3.6 V	10.25			
Zero-scale error ^{Note 3}	E _{ZS}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±6.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±2.5	
Full-scale error ^{Note 3}	E _{FS}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±6.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±2.5	
Integral linearity error ^{Note 3}	I _{LE}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±3.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±2.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±1.5	
Differential linearity error ^{Note 3}	D _{LE}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±2.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±2.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±1.5	
Analog input voltage	V _{AIN}			0		AV _{DD}	V

- Notes**
1. Cannot be used for lower 2 bit of ADCR register
 2. Cannot be used for lower 4 bit of ADCR register
 3. Excludes quantization error ($\pm 1/2$ LSB).

(4) When reference voltage (+) = AV_{REFP}/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AV_{REFM}/ANI1 (ADREFM = 1), target for conversion: ANI16 to ANI30, internal reference voltage, temperature sensor output voltage

(T_A = -40 to +85°C, 1.6 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, 1.6 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V, AV_{SS} = 0 V, Reference voltage (+) = AV_{REFP}, Reference voltage (-) = AV_{REFM} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
			$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		10 ^{Note 1}	
			$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8 ^{Note 2}			
Overall error ^{Note 3}	AINL	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±7.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±3.0	
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	4.125			μs
		ADTYP = 0, 10-bit resolution ^{Note 1}	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	9.5			
		ADTYP = 0, 8-bit resolution ^{Note 2}	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	57.5			
		ADTYP = 1, 8-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	3.3125			
			$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	7.875			
			$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	54.25			
Zero-scale error ^{Note 3}	E _{ZS}	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
Full-scale error ^{Note 3}	E _{FS}	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
Integral linearity error ^{Note 3}	ILE	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±3.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
Differential linearity error ^{Note 3}	DLE	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
Analog input voltage	V _{AIN}			0		AV _{REFP} and EV _{DD0}	V
		Interanal reference voltage (2.4 V ≤ V _{DD} ≤ 3.6 V, HS (high-speed main) mode)		V _{BGR} ^{Note 4}			V
		Temperature sensor output voltage (2.4 V ≤ V _{DD} ≤ 3.6 V, HS (high-speed main) mode)		V _{TMPS25} ^{Note 4}			V

- Notes 1.** Cannot be used for lower 2 bit of ADCR register
2. Cannot be used for lower 4 bit of ADCR register
3. Excludes quantization error (±1/2 LSB).
4. See 29.6.2 Temperature sensor, internal reference voltage output characteristics.

(5) When reference voltage (+) = AV_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = AV_{SS} (ADREFM = 0), target for conversion: ANI16 to ANI30, internal reference voltage, temperature sensor output voltage

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq EV_{DD0} \leq V_{DD0} \leq 3.6\text{ V}$, $1.6\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{DD} , Reference voltage (–) = $AV_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
			$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8		10 ^{Note 1}	
			$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8 ^{Note 2}			
Overall error ^{Note 3}	AINL	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±8.5	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±6.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±3.5	
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	4.125			μs
		ADTYP = 0, 10-bit resolution ^{Note 1}	$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	9.5			
		ADTYP = 0, 8-bit resolution ^{Note 2}	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	57.5			
		ADTYP = 1, 8-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	3.3125			μs
			$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	7.875			
			$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	54.25			
Zero-scale error ^{Note 3}	E _{ZS}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±8.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±5.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±3.0	
Full-scale error ^{Note 3}	E _{FS}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±8.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±5.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±3.0	
Integral linearity error ^{Note 3}	ILE	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±3.5	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
Differential linearity error ^{Note 3}	DLE	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
Analog input voltage	V _{AIN}			0		AV _{DD} and EV _{DD0}	V
		Internal reference voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		V _{BGR} ^{Note 4}			V
		Temperature sensor output voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		V _{TMPS25} ^{Note 4}			V

- Notes**
1. Cannot be used for lower 2 bit of ADCR register
 2. Cannot be used for lower 4 bit of ADCR register
 3. Excludes quantization error ($\pm 1/2$ LSB).
 4. See 29.6.2 Temperature sensor, internal reference voltage output characteristics.

(6) When reference voltage (+) = Internal reference voltage (1.45 V) (ADREFP1 = 1, ADREFP0 = 0), reference voltage (–) = AV_{SS} (ADREFM = 0), target ANI pin: ANI0 to ANI12, ANI16 to ANI30

($T_A = -40$ to $+85^\circ\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $1.6\text{ V} \leq EV_{DD} \leq V_{DD}$, $1.6\text{ V} \leq AV_{DD} \leq V_{DD}$, $V_{SS} = EV_{SS0} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = Internal reference voltage, Reference voltage (–) = $AV_{SS} = 0\text{ V}$, HS (high-speed main) mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}		8			bit
Conversion time	t_{CONV}	8-bit resolution	16			μs
Zero-scale error ^{Note}	E_{ZS}	8-bit resolution			± 4.0	LSB
Integral linearity error ^{Note}	I_{LE}	8-bit resolution			± 2.0	LSB
Differential linearity error ^{Note}	D_{LE}	8-bit resolution			± 2.5	LSB
Reference voltage (+)	$AV_{REF(+)}$	= Internal reference voltage (V_{BGR})	1.38	1.45	1.5	V
Analog input voltage	V_{AIN}		0		V_{BGR}	V

Note Excludes quantization error ($\pm 1/2$ LSB).

29.6.2 Temperature sensor, internal reference voltage output characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, HS (high-speed main) mode)

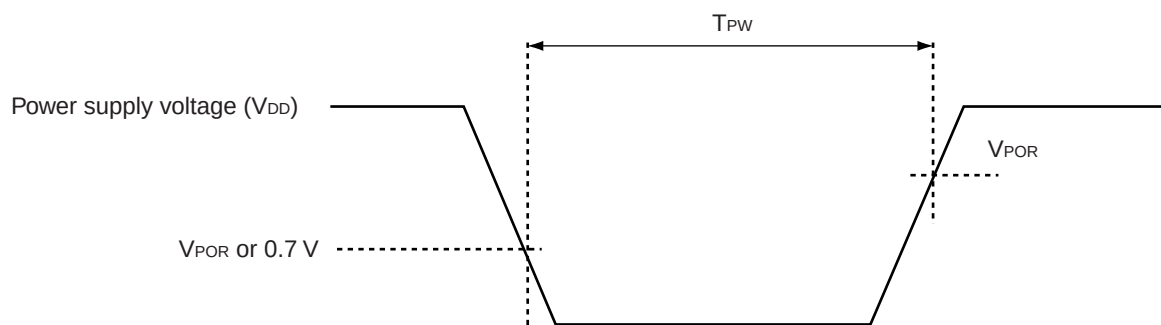
Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Temperature sensor output voltage	V_{TMPS25}	Setting ADS register = 80H, $T_A = +25^\circ\text{C}$		1.05		V
Internal reference voltage	V_{BGR}	Setting ADS register = 81H	1.38	1.45	1.5	V
Temperature coefficient	F_{VTMPS}	Temperature sensor output voltage that depends on the temperature		-3.6		$\text{mV}/^\circ\text{C}$
Operation stabilization wait time	t_{AMP}		10			μs

29.6.3 POR circuit characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V_{POR}	Power supply rise time	1.47	1.51	1.55	V
	V_{PDR}	Power supply fall time	1.46	1.50	1.54	V
Minimum pulse width ^{Note}	T_{PW}		300			μs

Note This is the time required for the POR circuit to execute a reset when V_{DD} falls below V_{PDR} . When the microcontroller enters STOP mode or if the main system clock (f_{MAIN}) has been stopped by setting bit 0 (HI0STOP) and bit 7 (MSTOP) of the clock operation status control register (CSC), this is the time required for the POR circuit to execute a reset before V_{DD} rises to V_{POR} after having fallen below 0.7 V.



29.6.4 LVD circuit characteristics

LVD Detection Voltage of Reset Mode and Interrupt Mode

($T_A = -40$ to $+85^\circ\text{C}$, $V_{PDR} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	Supply voltage level	V _{LVD2}	Power supply rise time	3.07	3.13	3.19	V
			Power supply fall time	3.00	3.06	3.12	V
		V _{LVD3}	Power supply rise time	2.96	3.02	3.08	V
			Power supply fall time	2.90	2.96	3.02	V
		V _{LVD4}	Power supply rise time	2.86	2.92	2.97	V
			Power supply fall time	2.80	2.86	2.91	V
		V _{LVD5}	Power supply rise time	2.76	2.81	2.87	V
			Power supply fall time	2.70	2.75	2.81	V
		V _{LVD6}	Power supply rise time	2.66	2.71	2.76	V
			Power supply fall time	2.60	2.65	2.70	V
		V _{LVD7}	Power supply rise time	2.56	2.61	2.66	V
			Power supply fall time	2.50	2.55	2.60	V
		V _{LVD8}	Power supply rise time	2.45	2.50	2.55	V
			Power supply fall time	2.40	2.45	2.50	V
		V _{LVD9}	Power supply rise time	2.05	2.09	2.13	V
			Power supply fall time	2.00	2.04	2.08	V
		V _{LVD10}	Power supply rise time	1.94	1.98	2.02	V
			Power supply fall time	1.90	1.94	1.98	V
		V _{LVD11}	Power supply rise time	1.84	1.88	1.91	V
			Power supply fall time	1.80	1.84	1.87	V
		V _{LVD12}	Power supply rise time	1.74	1.77	1.81	V
			Power supply fall time	1.70	1.73	1.77	V
		V _{LVD13}	Power supply rise time	1.64	1.67	1.70	V
			Power supply fall time	1.60	1.63	1.66	V
Minimum pulse width		t _{LW}		300			μs
Detection delay time						300	μs

Caution Set the detection voltage (V_{LVD}) to be within the operating voltage range. The operating voltage range depends on the setting of the user option byte (000C2H/010C2H). The following shows the operating voltage range.

HS (high-speed main) mode: $V_{DD} = 2.7$ to $3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$

$V_{DD} = 2.4$ to $3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$

LS (low-speed main) mode: $V_{DD} = 1.8$ to $3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$

LV (low-voltage main) mode: $V_{DD} = 1.6$ to $3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$

LVD Detection Voltage of Interrupt & Reset Mode**($T_A = -40$ to $+85^\circ\text{C}$, $V_{PDR} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)**

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Interrupt & reset mode	V _{LVD13}	VPOC2, VPOC1, VPOC0 = 0, 0, 0, falling reset voltage		1.60	1.63	1.66	V
	V _{LVD12}	LVIS1, LVIS0 = 1, 0	Rising release reset voltage	1.74	1.77	1.81	V
			Falling interrupt voltage	1.70	1.73	1.77	V
	V _{LVD11}	LVIS1, LVIS0 = 0, 1	Rising release reset voltage	1.84	1.88	1.91	V
			Falling interrupt voltage	1.80	1.84	1.87	V
	V _{LVD4}	LVIS1, LVIS0 = 0, 0	Rising release reset voltage	2.86	2.92	2.97	V
			Falling interrupt voltage	2.80	2.86	2.91	V
	V _{LVD11}	VPOC2, VPOC1, VPOC0 = 0, 0, 1, falling reset voltage		1.80	1.84	1.87	V
	V _{LVD10}	LVIS1, LVIS0 = 1, 0	Rising release reset voltage	1.94	1.98	2.02	V
			Falling interrupt voltage	1.90	1.94	1.98	V
	V _{LVD9}	LVIS1, LVIS0 = 0, 1	Rising release reset voltage	2.05	2.09	2.13	V
			Falling interrupt voltage	2.00	2.04	2.08	V
	V _{LVD2}	LVIS1, LVIS0 = 0, 0	Rising release reset voltage	3.07	3.13	3.19	V
			Falling interrupt voltage	3.00	3.06	3.12	V
	V _{LVD8}	VPOC2, VPOC1, VPOC0 = 0, 1, 0, falling reset voltage		2.40	2.45	2.50	V
	V _{LVD7}	LVIS1, LVIS0 = 1, 0	Rising release reset voltage	2.56	2.61	2.66	V
			Falling interrupt voltage	2.50	2.55	2.60	V
	V _{LVD6}	LVIS1, LVIS0 = 0, 1	Rising release reset voltage	2.66	2.71	2.76	V
			Falling interrupt voltage	2.60	2.65	2.70	V
	V _{LVD5}	VPOC2, VPOC1, VPOC0 = 0, 1, 1, falling reset voltage		2.70	2.75	2.81	V
	V _{LVD4}	LVIS1, LVIS0 = 1, 0	Rising release reset voltage	2.86	2.92	2.97	V
			Falling interrupt voltage	2.80	2.86	2.91	V
	V _{LVD3}	LVIS1, LVIS0 = 0, 1	Rising release reset voltage	2.96	3.02	3.08	V
			Falling interrupt voltage	2.90	2.96	3.02	V

Caution Set the detection voltage (V_{LVD}) to be within the operating voltage range. The operating voltage range depends on the setting of the user option byte (000C2H/010C2H). The following shows the operating voltage range.

HS (high-speed main) mode: $V_{DD} = 2.7$ to $3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$

$V_{DD} = 2.4$ to $3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$

LS (low-speed main) mode: $V_{DD} = 1.8$ to $3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$

LV (low-voltage main) mode: $V_{DD} = 1.6$ to $3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$

29.6.5 Supply voltage rise slope characteristics**($T_A = -40$ to $+85^\circ\text{C}$, $V_{SS} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Supply voltage rise	SV_{DD}				54	V/ms

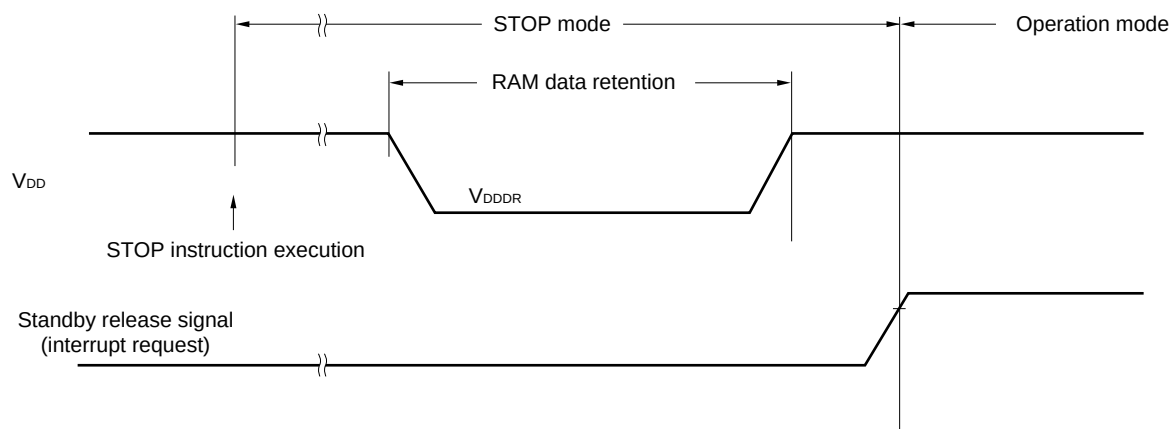
Caution Be sure to maintain the internal reset state until V_{DD} reaches the operating voltage range specified in 29.4 AC Characteristics, by using the LVD circuit or external reset pin.

29.7 RAM Data Retention Characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	V_{DDDR}		1.46 ^{Note}		3.6	V

Note This depends on the POR detection voltage. For a falling voltage, data in RAM are retained until the voltage reaches the level that triggers a POR reset but not once it reaches the level at which a POR reset is generated.



29.8 Flash Memory Programming Characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CPU/peripheral hardware clock frequency	f_{CLK}	$1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	1		32	MHz
Number of code flash rewrites ^{Notes 1, 2}	C_{erwr}	Retained for 20 years $T_A = 85^\circ\text{C}$ ^{Note 3}	1,000			Times
Number of data flash rewrites ^{Notes 1, 2}		Retained for 1 years $T_A = 25^\circ\text{C}$ ^{Note 3}		1,000,000		
		Retained for 5 years $T_A = 85^\circ\text{C}$ ^{Note 3}	100,000			
		Retained for 20 years $T_A = 85^\circ\text{C}$ ^{Note 3}	10,000			

Notes 1. 1 erase + 1 write after the erase is regarded as 1 rewrite.

The retaining years are until next rewrite after the rewrite.

2. When using flash memory programmer and Renesas Electronics self programming library

3. These are the characteristics of the flash memory and the results obtained from reliability testing by Renesas Electronics Corporation.

29.9 Dedicated Flash Memory Programmer Communication (UART)

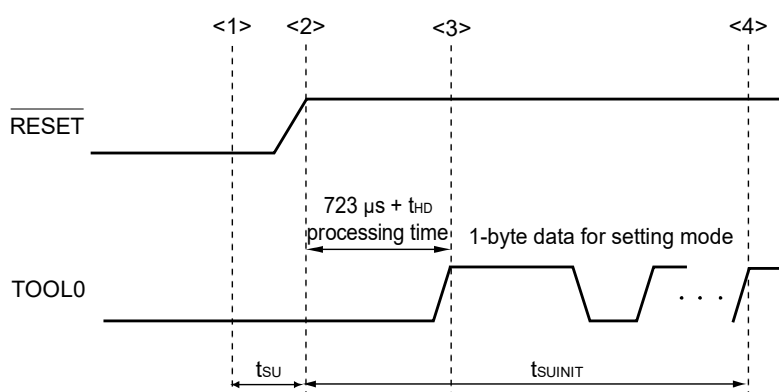
($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq V_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = V_{SS0} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Transfer rate		During flash memory programming	115.2 k		1 M	bps

29.10 Timing Specs for Switching Flash Memory Programming Modes

($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
How long from when an external reset ends until the initial communication settings are specified	t_{SUINIT}	POR and LVD reset must end before the external reset ends.			100	ms
How long from when the TOOL0 pin is placed at the low level until a external reset ends	t_{SU}	POR and LVD reset must end before the external reset ends.	10			μs
How long the TOOL0 pin must be kept at the low level after an external reset ends (except flash firmware processing time)	t_{HD}	POR and LVD reset must end before the external reset ends.	1			ms



<1> The low level is input to the TOOL0 pin.

<2> The pins reset ends (POR and LVD reset must end before the external reset ends.).

<3> The TOOL0 pin is set to the high level.

<4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

Remark t_{SUINIT} : The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.

t_{SU} : How long from when the TOOL0 pin is placed at the low level until a external reset ends

t_{HD} : How long to keep the TOOL0 pin at the low level from when the external resets end (except flash firmware processing time)

CHAPTER 30 ELECTRICAL SPECIFICATIONS

(G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^{\circ}\text{C}$)

This chapter describes the following electrical specifications.

Target products G: Industrial applications $T_A = -40$ to $+105^{\circ}\text{C}$

R5F10EBAGNA, R5F10EBCGNA, R5F10EBDGNA, R5F10EBEGNA
R5F10EGAGFB, R5F10EGCGFB, R5F10EGDGFB, R5F10EGEGFB
R5F10EGAGNA, R5F10EGCGNA, R5F10EGDGNA, R5F10EGEGNA
R5F10ELCGFB, R5F10ELDGFB, R5F10ELEGFB

- Cautions**
1. The RL78/G1A has an on-chip debug function, which is provided for development and evaluation. Do not use the on-chip debug function in products designated for mass production, because the guaranteed number of rewritable times of the flash memory may be exceeded when this function is used, and product reliability therefore cannot be guaranteed. Renesas Electronics is not liable for problems occurring when the on-chip debug function is used.
 2. With products not provided with an EV_{DD0} or EV_{SS0} pin, replace EV_{DD0} with V_{DD} , or replace EV_{SS0} with V_{SS} .
 3. The pins mounted depend on the product. See 2.1 Port Function to 2.2.1 With functions for each product.
 4. Please contact Renesas Electronics sales office for derating of operation under $T_A = +85^{\circ}\text{C}$ to $+105^{\circ}\text{C}$. Derating is the systematic reduction of load for the sake of improved reliability.

Remark When RL78/G1A is used in the range of $T_A = -40$ to $+85^{\circ}\text{C}$, see CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^{\circ}\text{C}$).

30.1 Absolute Maximum Ratings

Absolute Maximum Ratings ($T_A = 25^{\circ}\text{C}$) (1/2)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V_{DD}		-0.5 to $+6.5$	V
	EV_{DD0}		-0.5 to $+6.5$	V
	AV_{DD}		-0.5 to $+4.6$	V
	AV_{REFP}		-0.3 to $AV_{DD} + 0.3$ ^{Note 3}	V
	EV_{SS0}		-0.5 to $+0.3$	V
	AV_{SS}		-0.5 to $+0.3$	V
	AV_{REFM}		-0.3 to $AV_{DD} + 0.3$ ^{Note 3} and $AV_{REFM} \leq AV_{REFP}$	V
REGC pin input voltage	V_{IREGC}	REGC	-0.3 to $+2.8$ and -0.3 to $V_{DD} + 0.3$ ^{Note 1}	V
Input voltage	V_{I1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	-0.3 to $EV_{DD0} + 0.3$ and -0.3 to $V_{DD} + 0.3$ ^{Note 2}	V
	V_{I2}	P60 to P63 (N-ch open-drain)	-0.3 to $+6.5$	V
	V_{I3}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$	-0.3 to $V_{DD} + 0.3$ ^{Note 2}	V
	V_{I4}	P20 to P27, P150 to P154	-0.3 to $AV_{DD} + 0.3$ ^{Note 2}	V
Output voltage	V_{O1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P63, P70 to P77, P120, P130, P140, P141	-0.3 to $EV_{DD0} + 0.3$ ^{Note 2}	V
	V_{O2}	P20 to P27, P150 to P154	-0.3 to $AV_{DD} + 0.3$ ^{Note 2}	V
Analog input voltage	V_{AI1}	ANI16 to ANI30	-0.3 to $EV_{DD0} + 0.3$ and -0.3 to $AV_{REF(+)} + 0.3$ ^{Notes 2, 4}	V
	V_{AI2}	ANI0 to ANI12	-0.3 to $AV_{DD} + 0.3$ and -0.3 to $AV_{REF(+)} + 0.3$ ^{Notes 2, 4}	V

- Notes 1.** Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF). This value regulates the absolute maximum rating of the REGC pin. Do not use this pin with voltage applied to it.
- 2.** Must be 6.5 V or lower.
- 3.** Must be 4.6 V or lower.
- 4.** Do not exceed $AV_{REF(+)} + 0.3$ V in case of A/D conversion target pin.

Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

- Remarks 1.** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.
- 2.** $AV_{REF(+)}$: + side reference voltage of the A/D converter.
- 3.** V_{SS} : Reference voltage

Absolute Maximum Ratings ($T_A = 25^{\circ}\text{C}$) (2/2)

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	I _{OH1}	Per pin	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	−40	mA
		Total of all pins −170 mA	P00 to P04, P40 to P43, P120, P130, P140, P141	−70	mA
			P05, P06, P10 to P16, P30, P31, P50, P51, P70 to P77,	−100	mA
	I _{OH2}	Per pin	P20 to P27, P150 to P154	−0.1	mA
		Total of all pins		−1.3	mA
Output current, low	I _{OL1}	Per pin	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P63, P70 to P77, P120, P130, P140, P141	40	mA
		Total of all pins 170 mA	P00 to P04, P40 to P43, P120, P130, P140, P141	70	mA
			P05, P06, P10 to P16, P30, P31, P50, P51, P60 to P63, P70 to P77	100	mA
	I _{OL2}	Per pin	P20 to P27, P150 to P154	0.4	mA
		Total of all pins		6.4	mA
Operating ambient temperature	T _A	In normal operation mode		−40 to +105	°C
		In flash memory programming mode			
Storage temperature	T _{stg}			−65 to +150	°C

Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

30.2 Oscillator Characteristics

30.2.1 X1, XT1 oscillator characteristics

($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (f_x) ^{Note}	Ceramic resonator/crystal resonator	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	1.0		20.0	MHz
		$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$	1.0		16.0	
XT1 clock oscillation frequency (f_x) ^{Note}	Crystal resonator		32	32.768	35	kHz

Note Indicates only permissible oscillator frequency ranges. See AC Characteristics for instruction execution time. Request evaluation by the manufacturer of the oscillator circuit mounted on a board to check the oscillator characteristics.

Caution Since the CPU is started by the high-speed on-chip oscillator clock after a reset release, check the X1 clock oscillation stabilization time using the oscillation stabilization time counter status register (OSTC) by the user. Determine the oscillation stabilization time of the OSTC register and the oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.

Remark When using the X1 oscillator and XT1 oscillator, see 5.4 System Clock Oscillator.

30.2.2 On-chip oscillator characteristics

($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Oscillators	Parameters	Conditions		MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator oscillation frequency ^{Notes 1, 2}	f_{IH}			1		32	MHz
High-speed on-chip oscillator oscillation frequency accuracy		+85 to $+105^{\circ}\text{C}$	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	-2		+2	%
		-20 to $+85^{\circ}\text{C}$	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	-1		+1	%
		-40 to -20°C	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	-1.5		+1.5	%
Low-speed on-chip oscillator oscillation frequency	f_{IL}				15		kHz
Low-speed on-chip oscillator oscillation frequency accuracy				-15		+15	%

Notes 1. High-speed on-chip oscillator frequency is selected by bits 0 to 3 of option byte (000C2H/010C2H) and bits 0 to 2 of HOCODIV register.

2. This indicates the oscillator characteristics only. See AC Characteristics for instruction execution time.

30.3 DC Characteristics

30.3.1 Pin characteristics

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$) (1/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output current, high ^{Note 1}	I_{OH1}	Per pin for P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	$2.4\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$		$-3.0^{\text{Note 2}}$	mA
		Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty $\leq 70\%$ ^{Note 3})	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$		-10.0	mA
			$2.4\text{ V} \leq EV_{DD0} < 2.7\text{ V}$		-5.0	mA
		Total of P05, P06, P10 to P16, P30, P31, P50, P51, P70 to P77, (When duty $\leq 70\%$ ^{Note 3})	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$		-19.0	mA
			$2.4\text{ V} \leq EV_{DD0} < 2.7\text{ V}$		-10.0	mA
		Total of all pins (When duty $\leq 70\%$ ^{Note 3})	$2.4\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$		-29.0	mA
	I_{OH2}	Per pin for P20 to P27, P150 to P154	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$		$-0.1^{\text{Note 2}}$	mA
		Total of all pins (When duty $\leq 70\%$ ^{Note 3})	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$		-1.3	mA

- Notes**
- Value of current at which the device operation is guaranteed even if the current flows from the EV_{DD0} , V_{DD} pins to an output pin.
 - However, do not exceed the total current value.
 - Specification under conditions where the duty factor $\leq 70\%$.
The output current value that has changed to the duty factor $> 70\%$ the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to $n\%$).

- Total output current of pins = $(I_{OH} \times 0.7)/(n \times 0.01)$

<Example> Where $n = 80\%$ and $I_{OH} = -10.0\text{ mA}$

$$\text{Total output current of pins} = (-10.0 \times 0.7)/(80 \times 0.01) \cong -8.7\text{ mA}$$

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

Caution P00, P02 to P04, P10 to P15, P43, P50, P71, and P74 do not output high level in N-ch open-drain mode.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

(T_A = -40 to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{AV}_{\text{DD}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

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Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output current, low ^{Note 1}	I _{OL1}	Per pin for P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141			8.5 ^{Note 2}	mA
		Per pin for P60 to P63			15.0 ^{Note 2}	mA
		Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty $\leq 70\%$ ^{Note 3})	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		15.0	mA
			$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$		9.0	mA
		Total of P05, P06, P10 to P16, P30, P31, P50, P51, P60 to P63, P70 to P77 (When duty $\leq 70\%$ ^{Note 3})	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		35.0	mA
			$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$		20.0	mA
		Total of all pins (When duty $\leq 70\%$ ^{Note 3})			50.0	mA
	I _{OL2}	Per pin for P20 to P27, P150 to P154			0.4 ^{Note 2}	mA
		Total of all pins (When duty $\leq 70\%$ ^{Note 3})	$2.4\text{ V} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$		5.2	mA

Notes 1. Value of current at which the device operation is guaranteed even if the current flows from an output pin to the EV_{SS0} and V_{SS} pin.

2. However, do not exceed the total current value.

3. Specification under conditions where the duty factor $\leq 70\%$.

The output current value that has changed to the duty factor $> 70\%$ the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = $(I_{OL} \times 0.7)/(n \times 0.01)$

<Example> Where $n = 80\%$ and $I_{OL} = 10.0\text{ mA}$

$$\text{Total output current of pins} = (10.0 \times 0.7)/(80 \times 0.01) \cong 8.7\text{ mA}$$

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

(T_A = -40 to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{AV}_{\text{DD}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage, high	V _{IH1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	Normal input buffer	0.8EV _{DD0}		EV _{DD0}	V
	V _{IH2}	P01, P03, P04, P10, P11, P13 to P16, P43	TTL input buffer 3.3 V ≤ EV _{DD0} ≤ 3.6 V	2.0		EV _{DD0}	V
			TTL input buffer 2.4 V ≤ EV _{DD0} < 3.3 V	1.5		EV _{DD0}	V
	V _{IH3}	P20 to P27, P150 to P154		0.7AV _{DD}		AV _{DD}	V
	V _{IH4}	P60 to P63		0.7EV _{DD0}		6.0	V
	V _{IH5}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$		0.8V _{DD}		V _{DD}	V
Input voltage, low	V _{IL1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	Normal input buffer	0		0.2EV _{DD0}	V
	V _{IL2}	P01, P03, P04, P10, P11, P13 to P16, P43	TTL input buffer 3.3 V ≤ EV _{DD0} ≤ 3.6 V	0		0.5	V
			TTL input buffer 2.4 V ≤ EV _{DD0} < 3.3 V	0		0.32	V
	V _{IL3}	P20 to P27, P150 to P154		0		0.3AV _{DD}	V
	V _{IL4}	P60 to P63		0		0.3EV _{DD0}	V
	V _{IL5}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$		0		0.2V _{DD}	V

Caution The maximum value of V_{IH} of pins P00, P02 to P04, P10 to P15, P43, P50, P71, and P74 is EV_{DD0}, even in the N-ch open-drain mode.

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

(T_A = -40 to $+105^\circ\text{C}$, $2.4\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)

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Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output voltage, high	V _{OH1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OH1} = -2.0\text{ mA}$	$EV_{DD0} - 0.6$		V
			$2.4\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OH1} = -1.5\text{ mA}$	$EV_{DD0} - 0.5$		V
	V _{OH2}	P20 to P27, P150 to P154	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$, $I_{OH2} = -100\text{ }\mu\text{A}$	$AV_{DD} - 0.5$		V
Output voltage, low	V _{OL1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P130, P140, P141	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL1} = 3.0\text{ mA}$		0.6	V
			$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL1} = 1.5\text{ mA}$		0.4	V
			$2.4\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL1} = 0.6\text{ mA}$		0.4	V
	V _{OL2}	P20 to P27, P150 to P154	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$, $I_{OL2} = 400\text{ }\mu\text{A}$		0.4	V
	V _{OL3}	P60 to P63	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL3} = 3.0\text{ mA}$		0.4	V
			$2.4\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $I_{OL3} = 2.0\text{ mA}$		0.4	V

Caution P00, P02 to P04, P10 to P15, P43, P50, P71, and P74 do not output high level in N-ch open-drain mode.**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

(TA = -40 to $+105^\circ\text{C}$, $2.4\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input leakage current, high	I _{LH1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P63, P70 to P77, P120, P140, P141	V _I = EV _{DD0}				1 μA
	I _{LH2}	P137, RESET	V _I = V _{DD}				1 μA
	I _{LH3}	P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS)	V _I = V _{DD}	In input port or external clock input			1 μA
				In resonator connection			10 μA
	I _{LH4}	P20 to P27, P150 to P154	V _I = AV _{DD}				1 μA
Input leakage current, low	I _{LIL1}	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P60 to P67, P70 to P77, P120, P140, P141	V _I = EV _{SS0}				−1 μA
	I _{LIL2}	P137, RESET	V _I = V _{SS}				−1 μA
	I _{LIL3}	P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS)	V _I = V _{SS}	In input port or external clock input			−1 μA
				In resonator connection			−10 μA
	I _{LIL4}	P20 to P27, P150 to P154	V _I = AV _{SS}				−1 μA
On-chip pull-up resistance	R _U	P00 to P06, P10 to P16, P30, P31, P40 to P43, P50, P51, P70 to P77, P120, P140, P141	V _I = EV _{SS0} , In input port		10	20	100 kΩ

Remark Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

30.3.2 Supply current characteristics

 $(T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq V_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = V_{SS0} = 0\text{ V}$)

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Parameter	Symbol	Conditions					MIN.	TYP.	MAX.	Unit
Supply current	I_{DD1} ^{Note 1}	Operating mode	HS (high-speed main) mode ^{Note 5}	$f_{IH} = 32\text{ MHz}$ ^{Note 3}	Basic operation	$V_{DD} = 3.0\text{ V}$		2.1		mA
					Normal operation	$V_{DD} = 3.0\text{ V}$		4.6	7.5	mA
				$f_{IH} = 24\text{ MHz}$ ^{Note 3}	Normal operation	$V_{DD} = 3.0\text{ V}$		3.7	5.8	mA
				$f_{IH} = 16\text{ MHz}$ ^{Note 3}	Normal operation	$V_{DD} = 3.0\text{ V}$		2.7	4.2	mA
			HS (high-speed main) mode ^{Note 5}	$f_{MX} = 20\text{ MHz}$ ^{Note 2} , $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input		3.0	4.9	mA
						Resonator connection		3.2	5.0	
				$f_{MX} = 10\text{ MHz}$ ^{Note 2} , $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input		1.9	2.9	mA
						Resonator connection		1.9	2.9	
			Subsystem clock mode	$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = -40^\circ\text{C}$	Normal operation	Square wave input		4.1	4.9	μA
						Resonator connection		4.2	5.0	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +25^\circ\text{C}$	Normal operation	Square wave input		4.2	4.9	μA
						Resonator connection		4.3	5.0	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +50^\circ\text{C}$	Normal operation	Square wave input		4.3	5.5	μA
						Resonator connection		4.4	5.6	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +70^\circ\text{C}$	Normal operation	Square wave input		4.5	6.3	μA
						Resonator connection		4.6	6.4	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +85^\circ\text{C}$	Normal operation	Square wave input		4.8	7.7	μA
						Resonator connection		4.9	7.8	
				$f_{SUB} = 32.768\text{ kHz}$ ^{Note 4} $T_A = +105^\circ\text{C}$	Normal operation	Square wave input		6.9	19.7	μA
						Resonator connection		7.0	19.8	

(Notes and Remarks are listed on the next page.)

Notes 1. Total current flowing into V_{DD} and EV_{DD0} , including the input leakage current flowing when the level of the input pin is fixed to V_{DD} , EV_{DD0} or V_{SS} , EV_{SS0} . The following points apply in the HS (high-speed main) mode.

- The currents in the “TYP.” column do not include the operating currents of the peripheral modules.
- The currents in the “MAX.” column include the operating currents of the peripheral modules, except for those flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors, and those flowing while the data flash memory is being rewritten.

In the subsystem clock operation, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules. However, in HALT mode, including the current flowing into the RTC.

2. When high-speed on-chip oscillator and subsystem clock are stopped.
3. When high-speed system clock and subsystem clock are stopped.
4. When high-speed on-chip oscillator and high-speed system clock are stopped. When setting ultra-low power consumption oscillation (AMPHS1 = 1).
5. Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$

$92.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$

Remarks 1. f_{MX} : High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

2. f_{IH} : High-speed on-chip oscillator clock frequency

3. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)

4. Except subsystem clock operation, temperature condition of the TYP. value is $T_A = 25^{\circ}\text{C}$

$(T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq V_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = V_{SS0} = 0\text{ V}$)

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Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit	
Supply current ^{Note 1}	I _{DD2} ^{Note 2}	HALT mode	HS (high-speed main) mode ^{Note 7}	f _{IH} = 32 MHz ^{Note 4}	V _{DD} = 3.0 V		0.54	2.90	mA	
				f _{IH} = 24 MHz ^{Note 4}	V _{DD} = 3.0 V		0.44	2.30	mA	
				f _{IH} = 16 MHz ^{Note 4}	V _{DD} = 3.0 V		0.40	1.70	mA	
			HS (high-speed main) mode ^{Note 7}	f _{MX} = 20 MHz ^{Note 3} , V _{DD} = 3.0 V	Square wave input		0.28	1.90	mA	
					Resonator connection		0.45	2.00		
				f _{MX} = 10 MHz ^{Note 3} , V _{DD} = 3.0 V	Square wave input		0.19	1.02	mA	
					Resonator connection		0.26	1.10		
				Subsystem clock mode	f _{SUB} = 32.768 kHz ^{Note 5} T _A = −40°C	Square wave input		0.25	0.57	μA
						Resonator connection		0.44	0.76	
		f _{SUB} = 32.768 kHz ^{Note 5} T _A = +25°C	Square wave input			0.30	0.57	μA		
			Resonator connection			0.49	0.76			
		f _{SUB} = 32.768 kHz ^{Note 5} T _A = +50°C	Square wave input			0.38	1.17	μA		
			Resonator connection			0.57	1.36			
		f _{SUB} = 32.768 kHz ^{Note 5} T _A = +70°C	Square wave input			0.52	1.97	μA		
			Resonator connection			0.71	2.16			
		f _{SUB} = 32.768 kHz ^{Note 5} T _A = +85°C	Square wave input			0.97	3.37	μA		
			Resonator connection			1.16	3.56			
		f _{SUB} = 32.768 kHz ^{Note 5} T _A = +105°C	Square wave input		3.01	15.37	μA			
			Resonator connection		3.20	15.56				
	I _{DD3} ^{Note 6}	STOP mode ^{Note 8}	T _A = −40°C					0.16	0.50	μA
			T _A = +25°C					0.23	0.50	
			T _A = +50°C					0.34	1.10	
			T _A = +70°C					0.46	1.90	
			T _A = +85°C					0.75	3.30	
			T _A = +105°C					2.94	15.30	

(Notes and Remarks are listed on the next page.)

Notes 1. Total current flowing into V_{DD} and EV_{DD0} , including the input leakage current flowing when the level of the input pin is fixed to V_{DD} , EV_{DD0} or V_{SS} , EV_{SS0} . The following points apply in the HS (high-speed main) mode.

- The currents in the “TYP.” column do not include the operating currents of the peripheral modules.
- The currents in the “MAX.” column include the operating currents of the peripheral modules, except for those flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors, and those flowing while the data flash memory is being rewritten.

In the subsystem clock operation, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules. However, in HALT mode, including the current flowing into the RTC.

In the STOP mode, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules.

2. During HALT instruction execution by flash memory.
3. When high-speed on-chip oscillator and subsystem clock are stopped.
4. When high-speed system clock and subsystem clock are stopped.
5. When high-speed on-chip oscillator and high-speed system clock are stopped. When $RTCLPC = 1$ and setting ultra-low current consumption ($AMPHS1 = 1$).
6. When subsystem clock is stopped.
7. Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
 HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
8. Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.

Remarks 1. f_{MX} : High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

2. f_{IH} : High-speed on-chip oscillator clock frequency
3. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
4. Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is $T_A = 25^{\circ}\text{C}$

(T_A = -40 to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS}0} = 0\text{ V}$)

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Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	I_{FIL} ^{Note 1}				0.20		μA
RTC operating current	I_{RTC} ^{Notes 1, 2, 3}				0.02		μA
12-bit interval timer operating current	I_{IT} ^{Notes 1, 2, 4}				0.02		μA
Watchdog timer operating current	I_{WDT} ^{Notes 1, 2, 5}	$f_{\text{IL}} = 15\text{ kHz}$			0.22		μA
A/D converter operating current	I_{ADC} ^{Notes 6, 7}	$\text{AV}_{\text{DD}} = 3.0\text{ V}$, When conversion at maximum speed			420	720	μA
AV _{REF(+)} current	I_{AVREF} ^{Note 8}	$\text{AV}_{\text{DD}} = 3.0\text{ V}$, $\text{ADREFP1} = 0$, $\text{ADREFP0} = 0$ ^{Note 7}			14.0	25.0	μA
		$\text{AV}_{\text{REFP}} = 3.0\text{ V}$, $\text{ADREFP1} = 0$, $\text{ADREFP0} = 1$ ^{Note 10}			14.0	25.0	μA
		$\text{ADREFP1} = 1$, $\text{ADREFP0} = 0$ ^{Note 1}			14.0	25.0	μA
A/D converter reference voltage current	I_{ADREF} ^{Notes 1, 9}	$\text{V}_{\text{DD}} = 3.0\text{ V}$			75.0		μA
Temperature sensor operating current	I_{TMPS} ^{Note 1}	$\text{V}_{\text{DD}} = 3.0\text{ V}$			75.0		μA
LVD operating current	I_{LVD} ^{Notes 1, 11}				0.08		μA
BGO operating current	I_{BGO} ^{Notes 1, 12}				2.5	12.2	mA
Self-programming operating current	I_{FSP} ^{Notes 1, 13}				2.5	12.2	mA
SNOOZE operating current	I_{SNOZ}	A/D converter operation ($\text{AV}_{\text{DD}} = 3.0\text{ V}$)	The mode is performed ^{Notes 1, 14}		0.50	1.10	mA
			During A/D conversion ^{Note 1}		0.60	1.34	mA
			During A/D conversion ^{Note 7}		420	720	μA
		Simplified SPI (CSI)/UART operation ^{Note 1}			0.70	1.54	mA

(Notes and Remarks are listed on the next page.)

Notes 1. Current flowing to V_{DD} .

2. When high-speed on-chip oscillator and high-speed system clock are stopped.
3. Current flowing only to the real-time clock (RTC) (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2} , and I_{RTC} , when the real-time clock operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of the real-time clock.
4. Current flowing only to the 12-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2} , and I_{IT} , when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added.
5. Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The supply current of the RL78 microcontrollers is the sum of I_{DD1} , I_{DD2} , or I_{DD3} and I_{WDT} when the watchdog timer is in operation.
6. Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2} and I_{ADC} , I_{AVREF} , I_{ADREF} when the A/D converter operates in an operation mode or the HALT mode.
7. Current flowing to the AV_{DD} .
8. Current flowing from the reference voltage source of A/D converter.
9. Operation current flowing to the internal reference voltage.
10. Current flowing to the AV_{REFP} .
11. Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of I_{DD1} , I_{DD2} or I_{DD3} and I_{LVD} when the LVD circuit is in operation.
12. Current flowing only during data flash rewrite.
13. Current flowing only during self programming.
14. For shift time to the SNOOZE mode, see **18.3.3 SNOOZE mode**.

Remarks 1. f_{IL} : Low-speed on-chip oscillator clock frequency

2. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
3. f_{CLK} : CPU/peripheral hardware clock frequency
4. Temperature condition of the TYP. value is $T_A = 25^{\circ}\text{C}$

30.4 AC Characteristics

(T_A = -40 to $+105^\circ\text{C}$, AV_{DD} ≤ V_{DD} ≤ 3.6 V, 2.4 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V)

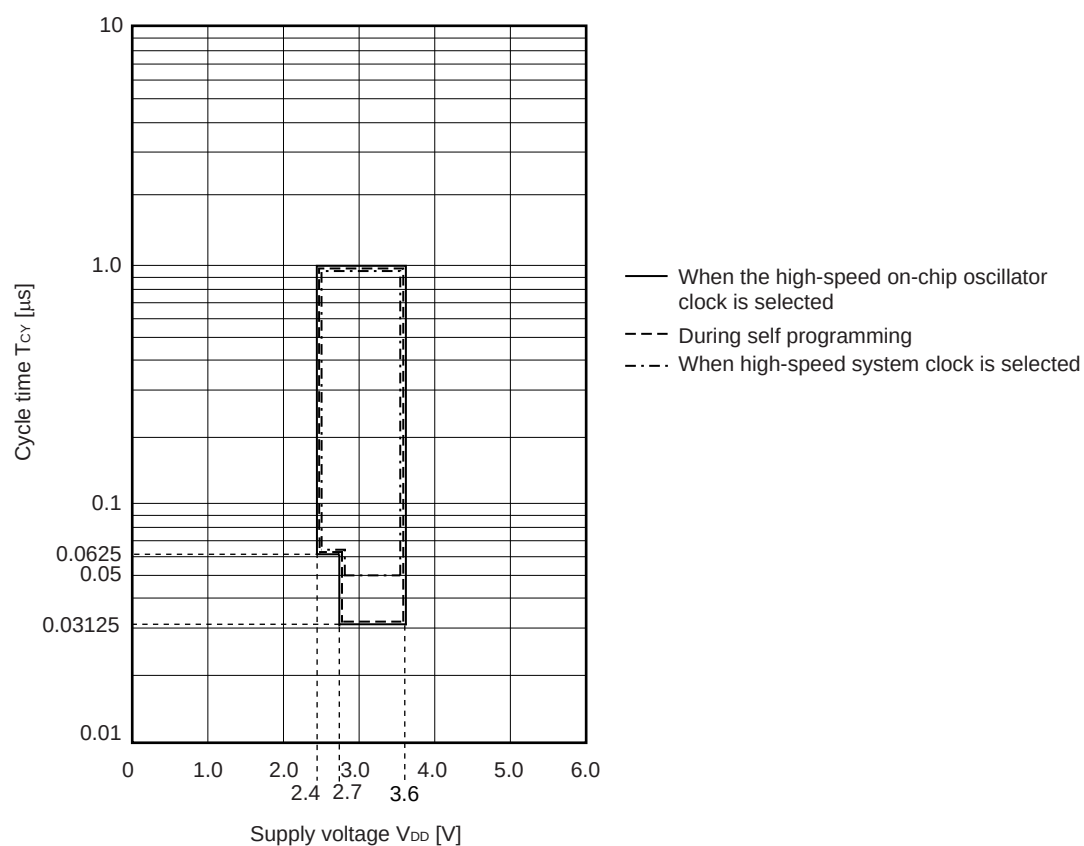
Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Instruction cycle (minimum instruction execution time)	T _{CY}	Main system clock (f _{MAIN}) operation	HS (high-speed main) mode	2.7 V ≤ V _{DD} ≤ 3.6 V	0.03125		1	μs
				2.4 V ≤ V _{DD} < 2.7 V	0.0625		1	μs
		Subsystem clock (f _{SUB}) operation		2.4 V ≤ V _{DD} ≤ 3.6 V	28.5	30.5	31.3	μs
		In the self programming mode	HS (high-speed main) mode	2.7 V ≤ V _{DD} ≤ 3.6 V	0.03125		1	μs
				2.4 V ≤ V _{DD} < 2.7 V	0.0625		1	μs
External system clock frequency	f _{EX}	2.7 V ≤ V _{DD} ≤ 3.6 V			1.0		20.0	MHz
		2.4 V ≤ V _{DD} < 2.7 V			1.0		16.0	MHz
	f _{EXS}				32		35	kHz
External system clock input high-level width, low-level width	t _{EXH} , t _{EXL}	2.7 V ≤ V _{DD} ≤ 3.6 V			24			ns
		2.4 V ≤ V _{DD} < 2.7 V			30			ns
	t _{EXHS} , t _{EXLS}				13.7			μs
TI00, TI01, TI03 to TI07 input high-level width, low-level width	t _{TIH} , t _{TIL}				1/f _{MCK} +10			ns ^{Note}
TO00, TO01, TO03 to TO07 output frequency	f _{TO}	HS (high-speed main) mode	2.7 V ≤ EV _{DD0} ≤ 3.6 V				8	MHz
			2.4 V ≤ EV _{DD0} < 2.7 V				4	MHz
PCLBUZ0, PCLBUZ1 output frequency	f _{PCL}	HS (high-speed main) mode	2.7 V ≤ EV _{DD0} ≤ 3.6 V				8	MHz
			2.4 V ≤ EV _{DD0} < 2.7 V				4	MHz
Interrupt input high-level width, low-level width	t _{INTH} , t _{INTL}	INTP0	2.4 V ≤ V _{DD} ≤ 3.6 V		1			μs
		INTP1 to INTP11	2.4 V ≤ EV _{DD0} ≤ 3.6 V		1			μs
Key interrupt input high-level width, low-level width	t _{KR}	KR0 to KR9	2.4 V ≤ EV _{DD0} ≤ 3.6 V, 2.4 V ≤ AV _{DD0} ≤ 3.6 V		250			ns
RESET low-level width	t _{RSL}				10			μs

Note The following conditions are required for low-voltage interface when EV_{DD0} < V_{DD}.2.4 V ≤ EV_{DD0} < 2.7 V : MIN. 125 ns**Remark** f_{MCK}: Timer array unit operation clock frequency

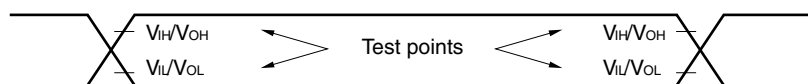
(Operation clock to be set by the CKS0n bit of timer clock select register 0 (TPS0) and timer mode register 0n (TMR0n). n: Channel number (n = 0 to 7))

Minimum Instruction Execution Time during Main System Clock Operation

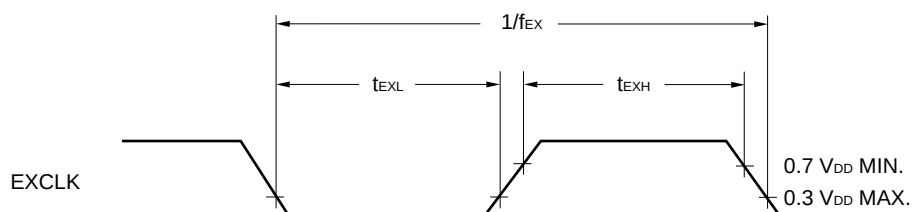
T_{CY} vs V_{DD} (HS (high-speed main) mode)



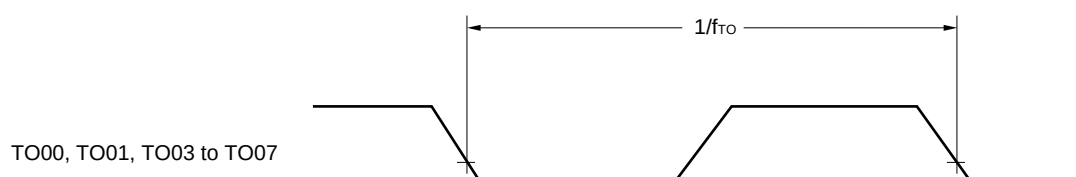
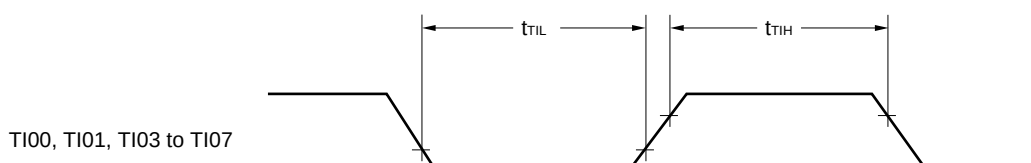
AC Timing Test Points



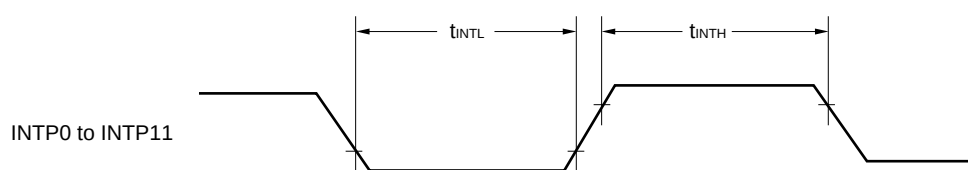
External System Clock Timing



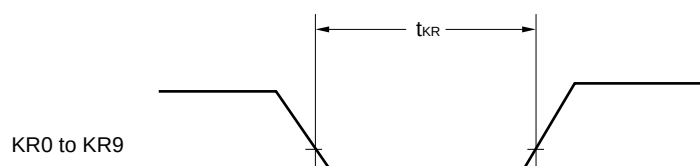
TI/TO Timing



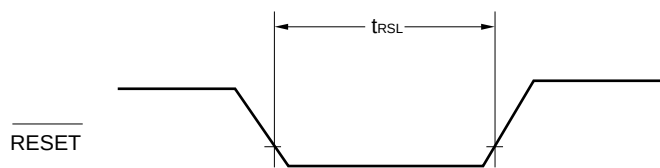
Interrupt Request Input Timing



Key Interrupt Input Timing

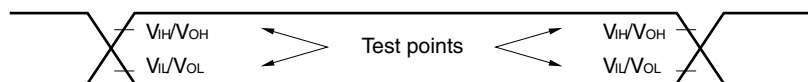


RESET Input Timing



30.5 Peripheral Functions Characteristics

AC Timing Test Points



30.5.1 Serial array unit

(1) During communication at same potential (UART mode) (dedicated baud rate generator output)

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS}0} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Transfer rate ^{Note 1}					$f_{\text{MCK}}/12$	bps
		Theoretical value of the maximum transfer rate $f_{\text{CLK}} = 32\text{ MHz}$, $f_{\text{MCK}} = f_{\text{CLK}}$			$2.6^{\text{Note 2}}$	Mbps

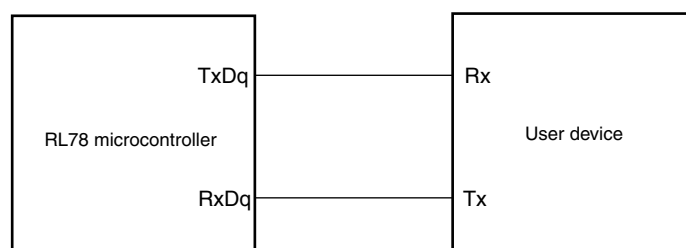
Notes 1. Transfer rate in the SNOOZE mode is 4800 bps.

2. The following conditions are required for low-voltage interface when $\text{EV}_{\text{DD}0} < \text{V}_{\text{DD}}$.

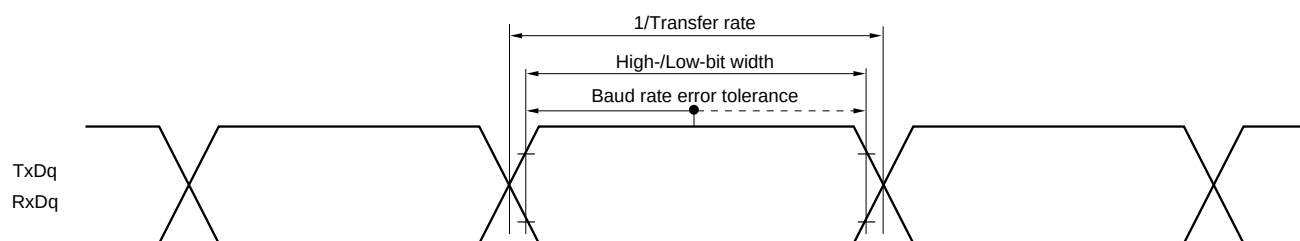
$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 2.7\text{ V}$: MAX. 1.3 Mbps

Caution Select the normal input buffer for the RxDq pin and the normal output mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).

UART mode connection diagram (during communication at same potential)



UART mode bit width (during communication at same potential) (reference)



Remarks 1. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1)

2. f_{MCK} : Serial array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

(2) During communication at same potential (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output)**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
SCKp cycle time	t_{KCY1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$ $t_{\text{KCY1}} \geq 4/f_{\text{CLK}}$	250			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$ $t_{\text{KCY1}} \geq 4/f_{\text{CLK}}$	500			ns
SCKp high-/low-level width	t_{KH1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$	$t_{\text{KCY1}}/2 - 36$			ns
	t_{KL1}	$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$	$t_{\text{KCY1}}/2 - 76$			ns
Slp setup time (to SCKp $\uparrow$) ^{Note 1}	t_{SIK1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$	66			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$	113			ns
Slp hold time (from SCKp $\uparrow$) ^{Note 1}	t_{KSI1}		38			ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 2}	t_{KSO1}	$C = 30\text{ p}$ ^{Note 3}			50	ns

Notes 1. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The Slp setup time or Slp hold time becomes “from SCKp $\downarrow$ ” when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.

2. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The delay time to SOp output becomes “from SCKp $\uparrow$ ” when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.

3. C is the load capacitance of the SCKp and SOp output lines.

Caution Select the normal input buffer for the Slp pin and the normal output mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

Remark p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 1)

(3) During communication at same potential (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
SCKp cycle time ^{Note 1}	t_{KCY2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$	$16\text{ MHz} < f_{\text{MCK}}$	$16/f_{\text{MCK}}$			ns
			$f_{\text{MCK}} \leq 16\text{ MHz}$	$12/f_{\text{MCK}}$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$12/f_{\text{MCK}}$ and 1000			ns
SCKp high-/low-level width	$t_{\text{KH2}},$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$t_{\text{KCY2}}/2-14$			ns
	t_{KL2}	$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$t_{\text{KCY2}}/2-16$			ns
Slp setup time (to SCKp $\uparrow$) ^{Note 2}	t_{SIK2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$1/f_{\text{MCK}} + 40$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$1/f_{\text{MCK}} + 60$			ns
Slp hold time (from SCKp $\uparrow$) ^{Note 2}	t_{KSI2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$1/f_{\text{MCK}}+62$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$		$1/f_{\text{MCK}}+62$			ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 3}	t_{KSO2}	$C = 30\text{ pF}$ ^{Note 4}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$			$2/f_{\text{MCK}}+66$	ns
			$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$			$2/f_{\text{MCK}}+113$	ns

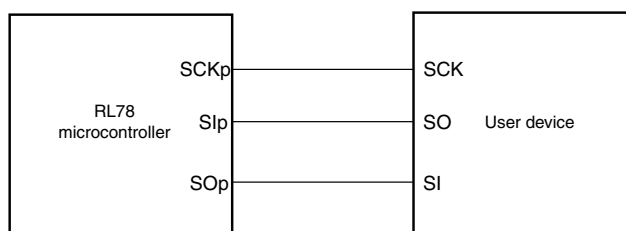
Notes 1. Transfer rate in the SNOOZE mode : MAX. 1 Mbps

2. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The Slp setup time or Slp hold time becomes "from SCKp $\downarrow$ " when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.
3. When $\text{DAPmn} = 0$ and $\text{CKPmn} = 0$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 1$. The delay time to SOp output becomes "from SCKp $\uparrow$ " when $\text{DAPmn} = 0$ and $\text{CKPmn} = 1$, or $\text{DAPmn} = 1$ and $\text{CKPmn} = 0$.
4. C is the load capacitance of the SOp output lines.

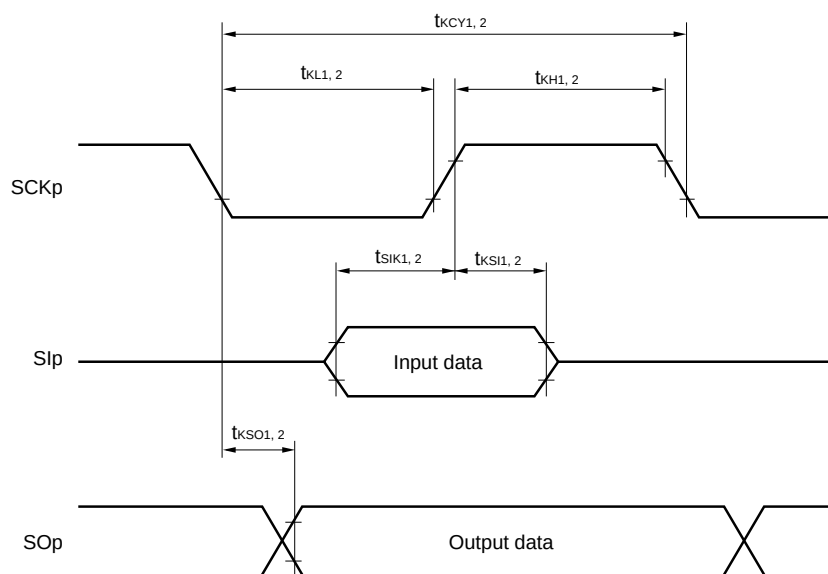
Caution Select the normal input buffer for the Slp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

- Remarks 1.** p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM number (g = 0, 1)
2. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

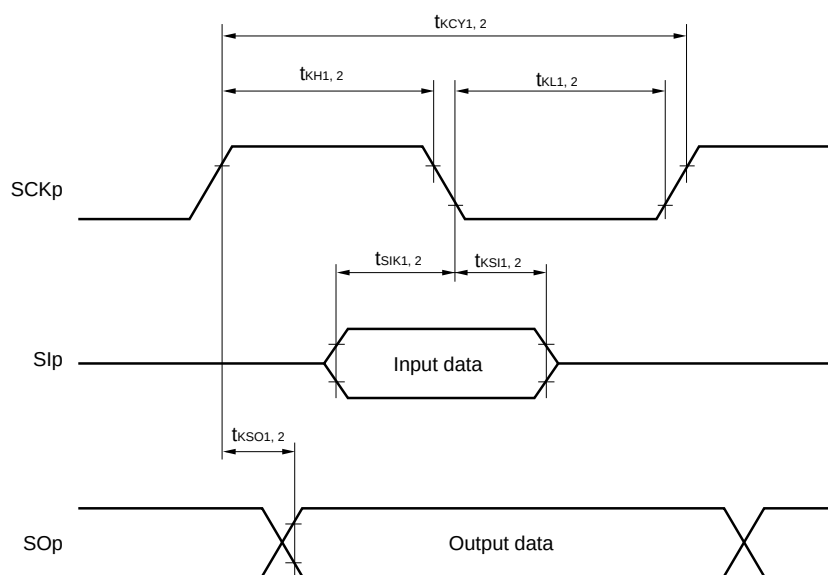
Simplified SPI (CSI) mode connection diagram (during communication at same potential)



Simplified SPI (CSI) mode serial transfer timing (during communication at same potential)
(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)



Simplified SPI (CSI) mode serial transfer timing (during communication at same potential)
(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)



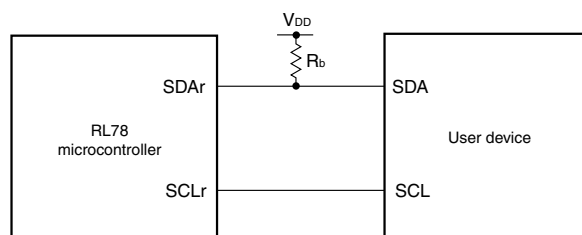
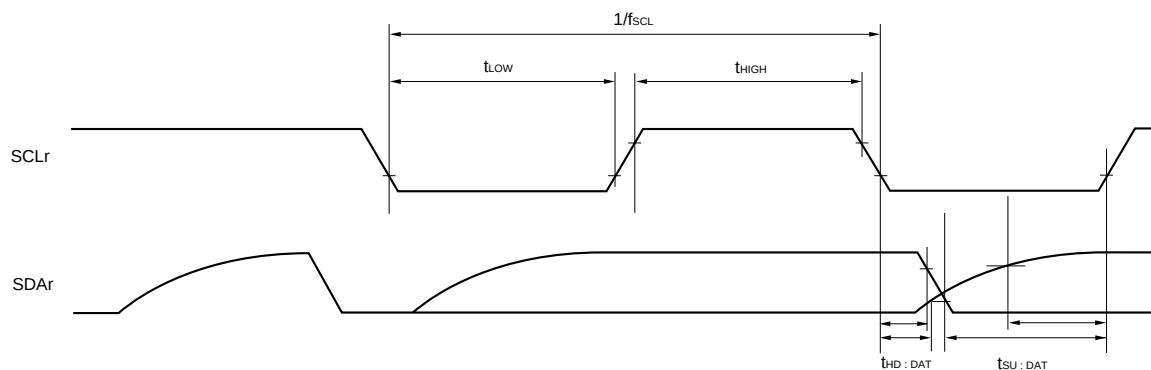
- Remarks**
1. p: CSI number (p = 00, 01, 10, 11, 20, 21)
 2. m: Unit number, n: Channel number (mn = 00 to 03, 10, 11)

(4) During communication at same potential (simplified I²C mode)**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	MAX.	Unit
SCLr clock frequency	f_{SCL}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		400 ^{Note 1}	kHz
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$		100 ^{Note 1}	kHz
Hold time when SCLr = "L"	t_{LOW}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1200		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	4600		ns
Hold time when SCLr = "H"	t_{HIGH}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1200		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	4600		ns
Data setup time (reception)	$t_{\text{SU:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$1/f_{\text{MCK}} + 220$ ^{Note 2}		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	$1/f_{\text{MCK}} + 580$ ^{Note 2}		ns
Data hold time (transmission)	$t_{\text{HD:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	0	770	ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	0	1420	ns

Notes 1. The value must also be $f_{\text{CLK}}/4$ or lower.**2.** Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

Caution Select the normal input buffer and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SDAr pin and the normal output mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register h (POMh).

Simplified I²C mode connection diagram (during communication at same potential)**Simplified I²C mode serial transfer timing (during communication at same potential)**

- Remarks**
1. $R_b[\Omega]$: Communication line (SDAr) pull-up resistance, $C_b[F]$: Communication line (SDAr, SCLr) load capacitance
 2. r: IIC number (r = 00, 01, 10, 11, 20, 21), g: PIM number (g = 0, 1), h: POM number (h = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number, mn = 00 to 03, 10, 11)

(5) Communication at different potential (1.8 V, 2.5 V) (UART mode) (dedicated baud rate generator output) (1/2)
($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Transfer rate ^{Note 1}		Reception	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$			$f_{\text{MCK}}/12$	bps
			Theoretical value of the maximum transfer rate $f_{\text{CLK}} = 32\text{ MHz}$, $f_{\text{MCK}} = f_{\text{CLK}}$			2.6	Mbps
			$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$			$f_{\text{MCK}}/12$	bps
			Theoretical value of the maximum transfer rate $f_{\text{CLK}} = 32\text{ MHz}$, $f_{\text{MCK}} = f_{\text{CLK}}$			2.6 ^{Note 2}	Mbps

Notes 1. Transfer rate in the SNOOZE mode is 4800 bps.

2. The following conditions are required for low-voltage interface when $\text{EV}_{\text{DD0}} < \text{V}_{\text{DD}}$.

$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 2.7\text{ V}$: MAX. 1.3 Mbps

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

Remarks 1. $\text{V}_b[\text{V}]$: Communication line voltage

2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1)

3. f_{MCK} : Serial array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number,

n: Channel number (mn = 00 to 03, 10, 11)

(5) Communication at different potential (1.8 V, 2.5 V) (UART mode) (dedicated baud rate generator output) (2/2)
(T_A = -40 to +105°C, 2.4 V ≤ EV_{DD0} ≤ V_{DD} ≤ 3.6 V, V_{SS} = EV_{SS0} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Transfer rate		Transmission	2.7 V ≤ EV _{DD0} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V			Note 1	bps
			Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 2.7 kΩ, V _b = 2.3 V			1.2 ^{Note 2}	Mbps
			2.4 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V			Note 3	bps
			Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 5.5 kΩ, V _b = 1.6 V			0.43 ^{Note 4}	Mbps

Notes 1. The smaller maximum transfer rate derived by using f_{MCK}/12 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 2.7 V ≤ EV_{DD0} ≤ 3.6 V and 2.3 V ≤ V_b ≤ 2.7 V

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\} \times 3} \quad [\text{bps}]$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \quad [\%]$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

2. This value as an example is calculated when the conditions described in the "Conditions" column are met. See **Note 1** above to calculate the maximum transfer rate under conditions of the customer.

3. The smaller maximum transfer rate derived by using f_{MCK}/12 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 2.4 V ≤ EV_{DD0} < 3.3 V and 1.6 V ≤ V_b ≤ 2.0 V

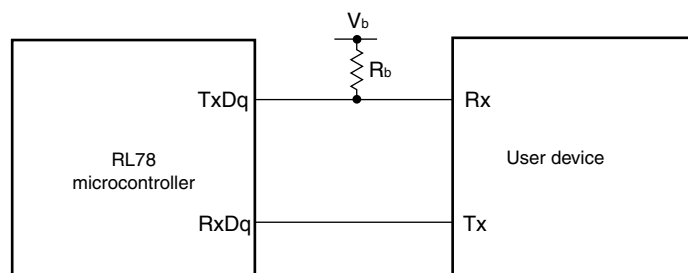
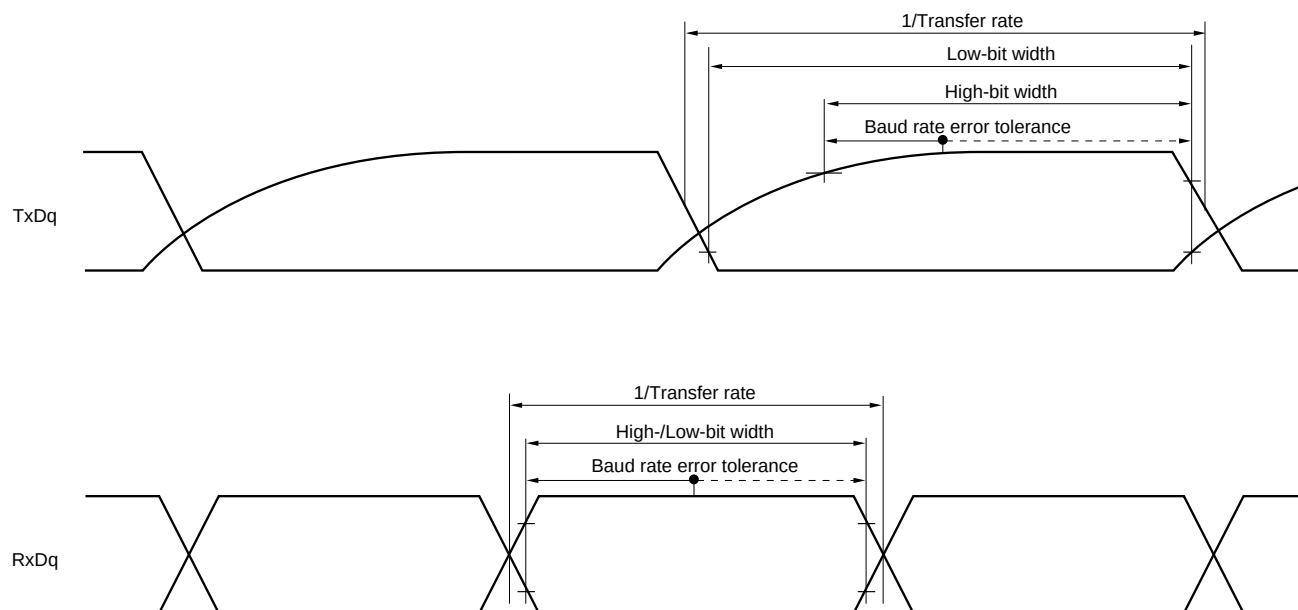
$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\} \times 3} \quad [\text{bps}]$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \quad [\%]$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

4. This value as an example is calculated when the conditions described in the "Conditions" column are met. See **Note 3** above to calculate the maximum transfer rate under conditions of the customer.

Caution Select the TTL input buffer for the Rx_{Dq} pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/EV_{DD} tolerance (When 64-pin products)) mode for the Tx_{Dq} pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

UART mode connection diagram (during communication at different potential)**UART mode bit width (during communication at different potential) (reference)**

- Remarks**
1. $R_b[\Omega]$: Communication line (TxDq) pull-up resistance,
 $C_b[\text{F}]$: Communication line (TxDq) load capacitance, $V_b[\text{V}]$: Communication line voltage
 2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
 m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

(6) Communication at different potential (1.8 V, 2.5 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output) (1/2)**($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
SCKp cycle time	t_{KCY1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$t_{\text{KCY1}} \geq 4/f_{\text{CLK}}$	1000		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	$t_{\text{KCY1}} \geq 4/f_{\text{CLK}}$	2300		ns
SCKp high-level width	t_{KH1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$t_{\text{KCY1}}/2 - 340$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	$t_{\text{KCY1}}/2 - 916$			ns
SCKp low-level width	t_{KL1}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$t_{\text{KCY1}}/2 - 36$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	$t_{\text{KCY1}}/2 - 100$			ns

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

Remarks

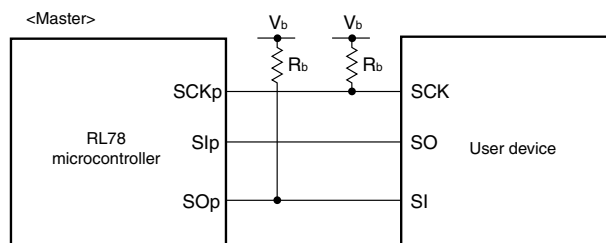
- $\text{R}_b[\Omega]$: Communication line (SCKp, SOp) pull-up resistance, $\text{C}_b[\text{F}]$: Communication line (SCKp, SOp) load capacitance, $\text{V}_b[\text{V}]$: Communication line voltage
- p: CSI number ($p = 00, 10, 20$), m: Unit number, n: Channel number ($mn = 00, 02, 10$), g: PIM and POM number ($g = 0, 1$)
- CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

(6) Communication at different potential (1.8 V, 2.5 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output) (2/2)**($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD}0} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS}0} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Slp setup time (to SCKp $\uparrow$) ^{Note 1}	$t_{\text{SIK}1}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	354			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	958			ns
Slp hold time (from SCKp $\uparrow$) ^{Note 1}	$t_{\text{KSI}1}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	38			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	38			ns
Delay time from SCKp $\downarrow$ to SO _p output ^{Note 1}	$t_{\text{KSO}1}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$			390	ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$			966	ns
Slp setup time (to SCKp $\downarrow$) ^{Note 2}	$t_{\text{SIK}1}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	88			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	220			ns
Slp hold time (from SCKp $\downarrow$) ^{Note 2}	$t_{\text{KSI}1}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	38			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	38			ns
Delay time from SCKp $\uparrow$ to SO _p output ^{Note 2}	$t_{\text{KSO}1}$	$2.7\text{ V} \leq \text{EV}_{\text{DD}0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$			50	ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD}0} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 30\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$			50	ns

Notes 1. When DAP_{mn} = 0 and CKP_{mn} = 0, or DAP_{mn} = 1 and CKP_{mn} = 1.**2.** When DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SO_p pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

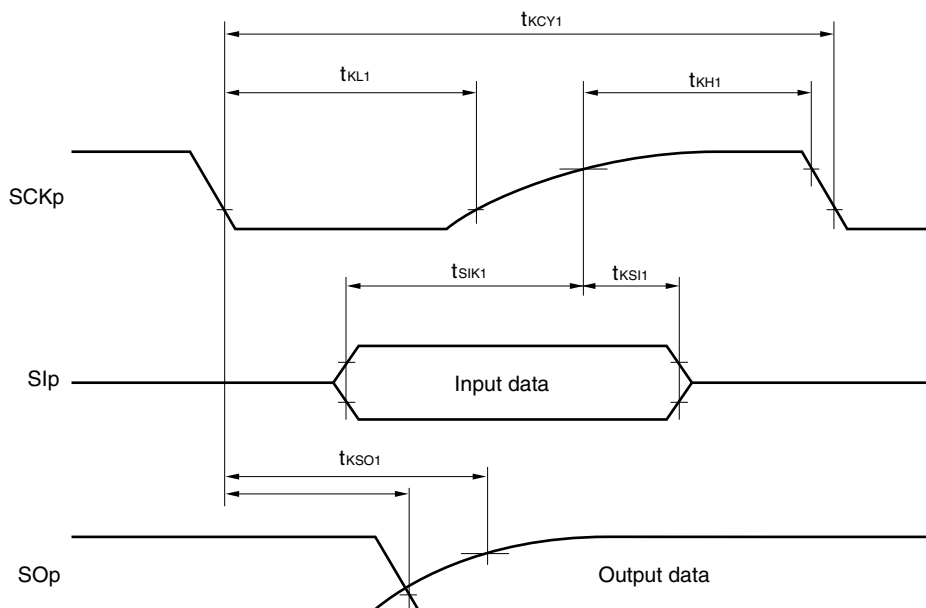
Simplified SPI (CSI) mode connection diagram (during communication at different potential)

Remarks 1. $\text{R}_b[\Omega]$: Communication line (SCKp, SO_p) pull-up resistance, $\text{C}_b[\text{F}]$: Communication line (SCKp, SO_p) load capacitance, $\text{V}_b[\text{V}]$: Communication line voltage

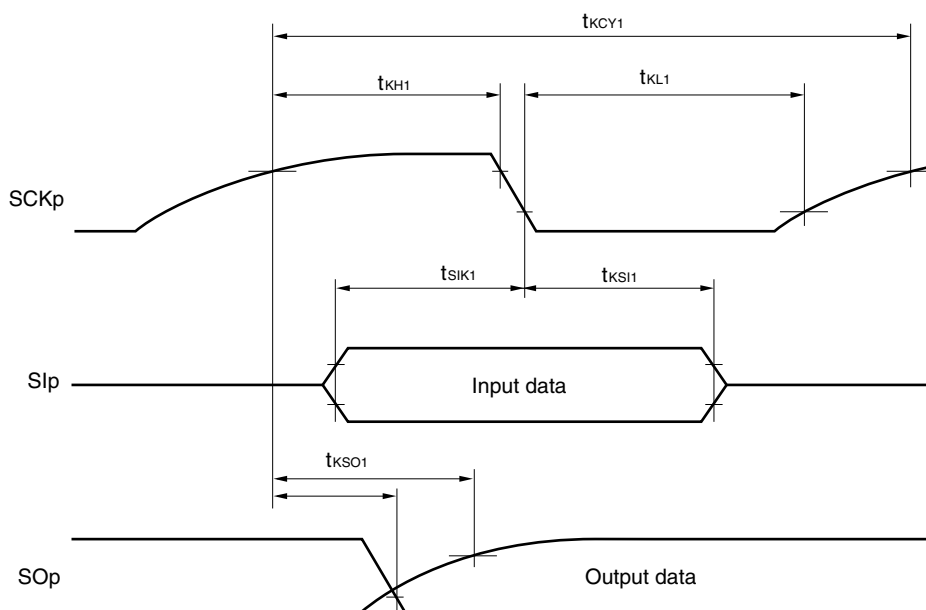
2. p: CSI number (p = 00, 10, 20), m: Unit number, n: Channel number (mn = 00, 02, 10),
g: PIM and POM number (g = 0, 1)

3. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

Simplified SPI (CSI) mode serial transfer timing (master mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)



Simplified SPI (CSI) mode serial transfer timing (master mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)



- Remarks**
1. p: CSI number (p = 00, 10, 20), m: Unit number, n: Channel number (m = 00, 02, 10), g: PIM and POM number (g = 0, 1)
 2. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

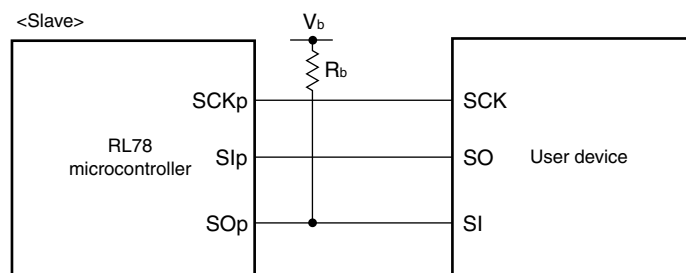
(7) Communication at different potential (1.8 V, 2.5 V) (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)**($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
SCKp cycle time ^{Note 1}	t_{KCY2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$	$24\text{ MHz} < f_{\text{MCK}}$	$40/f_{\text{MCK}}$		ns
			$20\text{ MHz} < f_{\text{MCK}} \leq 24\text{ MHz}$	$32/f_{\text{MCK}}$		ns
			$16\text{ MHz} < f_{\text{MCK}} \leq 20\text{ MHz}$	$28/f_{\text{MCK}}$		ns
			$8\text{ MHz} < f_{\text{MCK}} \leq 16\text{ MHz}$	$24/f_{\text{MCK}}$		ns
			$4\text{ MHz} < f_{\text{MCK}} \leq 8\text{ MHz}$	$16/f_{\text{MCK}}$		ns
			$f_{\text{MCK}} \leq 4\text{ MHz}$	$12/f_{\text{MCK}}$		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$	$24\text{ MHz} < f_{\text{MCK}}$	$96/f_{\text{MCK}}$		ns
			$20\text{ MHz} < f_{\text{MCK}} \leq 24\text{ MHz}$	$72/f_{\text{MCK}}$		ns
			$16\text{ MHz} < f_{\text{MCK}} \leq 20\text{ MHz}$	$64/f_{\text{MCK}}$		ns
			$8\text{ MHz} < f_{\text{MCK}} \leq 16\text{ MHz}$	$52/f_{\text{MCK}}$		ns
			$4\text{ MHz} < f_{\text{MCK}} \leq 8\text{ MHz}$	$32/f_{\text{MCK}}$		ns
			$f_{\text{MCK}} \leq 4\text{ MHz}$	$20/f_{\text{MCK}}$		ns
SCKp high-/low-level width	t_{KH2} , t_{KL2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$	$t_{\text{KCY2}}/2 - 36$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$	$t_{\text{KCY2}}/2 - 100$			ns
Slp setup time (to SCKp $\uparrow$) ^{Note 2}	t_{SIK2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$	$1/f_{\text{MCK}} + 40$			ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$	$1/f_{\text{MCK}} + 60$			
Slp hold time (from SCKp $\uparrow$) ^{Note 2}	t_{KSI2}		$1/f_{\text{MCK}} + 62$			ns
Delay time from SCKp $\downarrow$ to SOp output ^{Note 3}	t_{KSO2}	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$			$2/f_{\text{MCK}} + 428$	ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$			$2/f_{\text{MCK}} + 1146$	ns

Notes 1. Transfer rate in the SNOOZE mode : MAX. 1 Mbps**2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time or Slp hold time becomes "from SCKp $\downarrow$ " when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes "from SCKp $\uparrow$ " when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

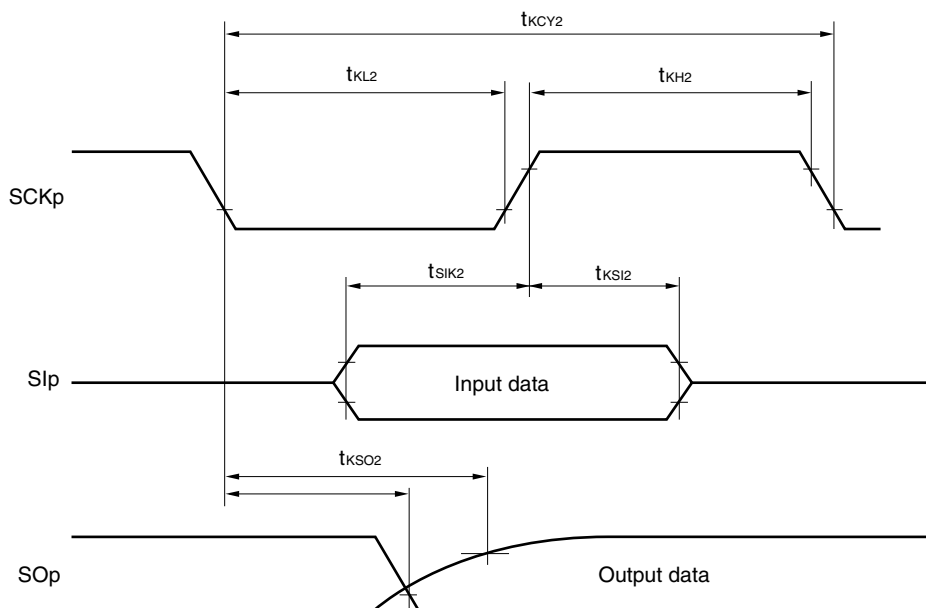
Caution Select the TTL input buffer for the Slp pin and SCKp pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

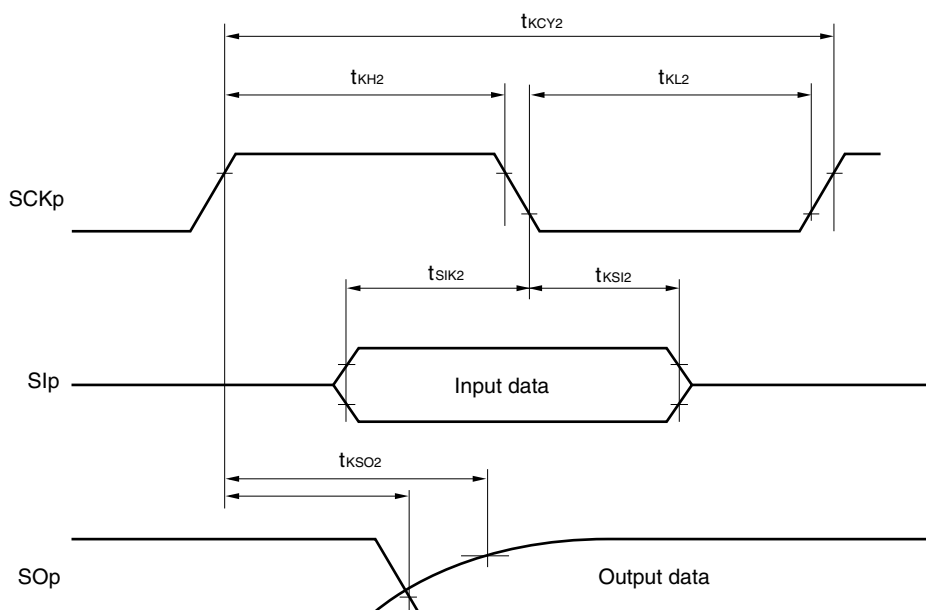
Simplified SPI (CSI) mode connection diagram (during communication at different potential)

- Remarks**
1. $R_b[\Omega]$: Communication line (SO_p) pull-up resistance, $C_b[\text{F}]$: Communication line (SO_p) load capacitance, $V_b[\text{V}]$: Communication line voltage
 2. p: CSI number ($p = 00, 10, 20$), m: Unit number ($m = 0, 1$), n: Channel number ($n = 00, 02, 10$), g: PIM and POM number ($g = 0, 1$)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number ($mn = 00, 02, 10$))
 4. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

Simplified SPI (CSI) mode serial transfer timing (slave mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)



Simplified SPI (CSI) mode serial transfer timing (slave mode) (during communication at different potential)
(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)



- Remarks**
1. p: CSI number (p = 00, 10, 20), m: Unit number, n: Channel number (mn = 00, 02, 10), g: PIM and POM number (g = 0, 1)
 2. CSI01, CSI11, and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

(8) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode) (1/2)**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	MAX.	Unit
SCLr clock frequency	f_{SCL}	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		400 ^{Note 1}	kHz
		$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		100 ^{Note 1}	kHz
		$2.4\text{ V} \leq EV_{DD0} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$		100 ^{Note 1}	kHz
Hold time when SCLr = "L"	t_{LOW}	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1200		ns
		$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	4600		ns
		$2.4\text{ V} \leq EV_{DD0} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	4650		ns
Hold time when SCLr = "H"	t_{HIGH}	$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	500		ns
		$2.7\text{ V} \leq EV_{DD0} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	2400		ns
		$2.4\text{ V} \leq EV_{DD0} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	1830		ns

(Notes, Caution and Remarks are listed on the next page.)

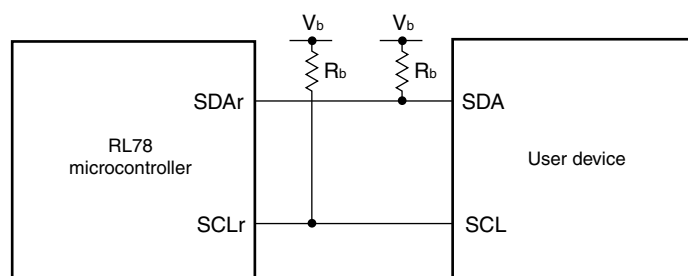
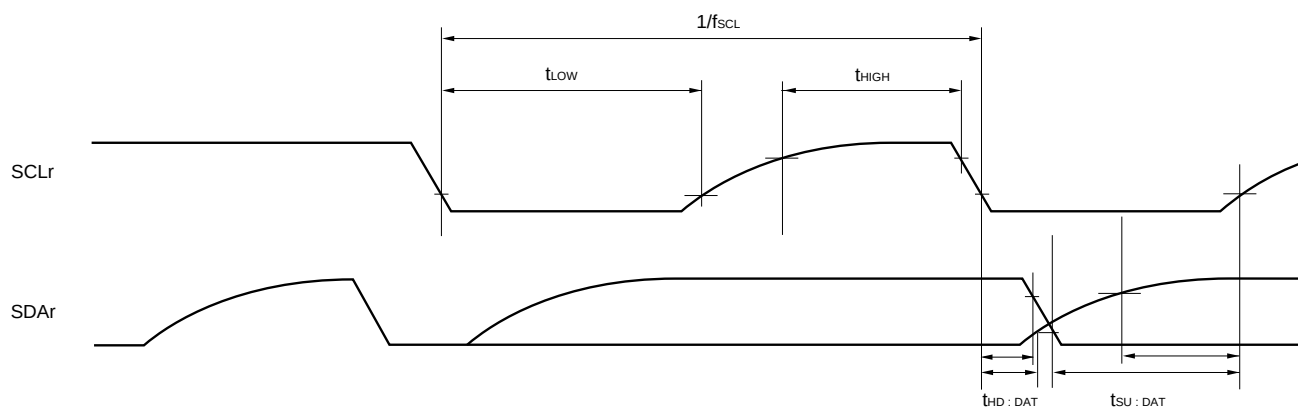
(8) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode) (2/2)**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	MAX.	Unit
Data setup time (reception)	$t_{\text{SU:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$1/f_{\text{MCK}} + 340$ ^{Note 2}		ns
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	$1/f_{\text{MCK}} + 760$ ^{Note 2}		ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	$1/f_{\text{MCK}} + 570$ ^{Note 2}		ns
Data hold time (transmission)	$t_{\text{HD:DAT}}$	$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 50\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	0	770	ns
		$2.7\text{ V} \leq \text{EV}_{\text{DD0}} \leq 3.6\text{ V}$, $2.3\text{ V} \leq \text{V}_b \leq 2.7\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 2.7\text{ k}\Omega$	0	1420	ns
		$2.4\text{ V} \leq \text{EV}_{\text{DD0}} < 3.3\text{ V}$, $1.6\text{ V} \leq \text{V}_b \leq 2.0\text{ V}$, $\text{C}_b = 100\text{ pF}$, $\text{R}_b = 5.5\text{ k}\Omega$	0	1215	ns

Notes 1. The value must also be $f_{\text{CLK}}/4$ or lower.2. Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

Caution Select the TTL input buffer and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance (When 25- to 48-pin products)/ EV_{DD} tolerance (When 64-pin products)) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

Simplified I²C mode connection diagram (during communication at different potential)**Simplified I²C mode serial transfer timing (during communication at different potential)**

- Remarks**
1. $R_b[\Omega]$: Communication line (SDAr, SCLr) pull-up resistance, $C_b[F]$: Communication line (SDAr, SCLr) load capacitance, $V_b[V]$: Communication line voltage
 2. r: IIC number (r = 00, 10, 20), g: PIM, POM number (g = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00, 02, 10))
 4. IIC01, IIC11, and IIC21 cannot communicate at different potential. Use IIC00, IIC10, or IIC20 for communication at different potential.

30.5.2 Serial interface IICA

(1) I²C standard mode, fast mode $(T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq E_{VDD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = E_{VSS0} = 0\text{ V}$)

Parameter	Symbol	Conditions	Standard Mode		Fast Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Fast mode: $f_{CLK} \geq 3.5\text{ MHz}$			0	400	kHz
		Normal mode: $f_{CLK} \geq 1\text{ MHz}$	0	100			kHz
Setup time of restart condition	$t_{SU:STA}$		4.7		0.6		μs
Hold time ^{Note 1}	$t_{HD:STA}$		4.0		0.6		μs
Hold time when SCLA0 = "L"	t_{LOW}		4.7		1.3		μs
Hold time when SCLA0 = "H"	t_{HIGH}		4.0		0.6		μs
Data setup time (reception)	$t_{SU:DAT}$		250		100		ns
Data hold time (transmission) ^{Note 2}	$t_{HD:DAT}$		0	3.45	0	0.9	μs
Setup time of stop condition	$t_{SU:STO}$		4.0		0.6		μs
Bus-free time	t_{BUF}		4.7		1.3		μs

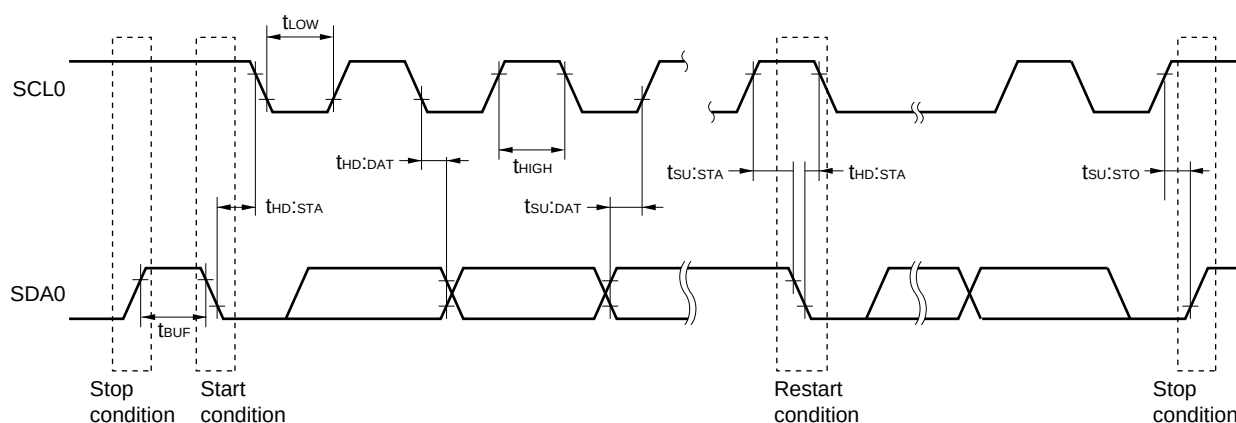
- Notes**
- The first clock pulse is generated after this period when the start/restart condition is detected.
 - The maximum value (MAX.) of $t_{HD:DAT}$ is during normal transfer and a clock stretch state is inserted in the ACK (acknowledge) timing.

Remark The maximum value of C_b (communication line capacitance) and the value of R_b (communication line pull-up resistor) at that time in each mode are as follows.

Standard mode: $C_b = 400\text{ pF}$, $R_b = 2.7\text{ k}\Omega$

Fast mode: $C_b = 320\text{ pF}$, $R_b = 1.1\text{ k}\Omega$

IICA serial transfer timing



30.6 Analog Characteristics

30.6.1 A/D converter characteristics

Division of A/D Converter Characteristics

Reference voltage Input channel	Reference voltage (+) = AV_{REFP} Reference voltage (–) = AV_{REFM}	Reference voltage (+) = AV_{DD} Reference voltage (–) = AV_{SS}	Reference voltage (+) = Internal reference voltage Reference voltage (–) = AV_{SS}
High-accuracy channel; ANI0 to ANI12 (input buffer power supply: AV_{DD})	See 30.6.1 (1)	See 30.6.1 (2)	See 30.6.1 (5)
Standard channel; ANI16 to ANI30 (input buffer power supply: V_{DD} or EV_{DD0})	See 30.6.1 (3)	See 30.6.1 (4)	
Temperature sensor, internal reference voltage output	See 30.6.1 (3)	See 30.6.1 (4)	–

(1) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (–) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), target for conversion: ANI2 to ANI12

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (–) = $AV_{REFM} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8.		12.	bit
Overall error ^{Note}	A_{INL}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 6.0	LSB
Conversion time	t_{CONV}	$ADTYP = 0$, 12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	3.375			μs
Zero-scale error ^{Note}	E_{ZS}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 4.5	LSB
Full-scale error ^{Note}	E_{FS}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 4.5	LSB
Integral linearity error ^{Note}	I_{LE}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.0	LSB
Differential linearity error ^{Note}	D_{LE}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 1.5	LSB
Analog input voltage	V_{AIN}		0		AV_{REFP}	V

Note Excludes quantization error ($\pm 1/2$ LSB).

(2) When reference voltage (+) = AV_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = AV_{SS} (ADREFM = 0), target for conversion: ANI0 to ANI12

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{DD} , Reference voltage (–) = $AV_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}		$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
Overall error ^{Note}	A_{INL}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 7.5	LSB
Conversion time	t_{CONV}	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	3.375			μs
Zero-scale error ^{Note}	E_{ZS}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 6.0	LSB
Full-scale error ^{Note}	E_{FS}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 6.0	LSB
Integral linearity error ^{Note}	I_{LE}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 3.0	LSB
Differential linearity error ^{Note}	D_{LE}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.0	LSB
Analog input voltage	V_{AIN}			0		AV_{DD}	V

Note Excludes quantization error ($\pm 1/2$ LSB).

(3) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (–) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), target for conversion: $ANI16$ to $ANI30$, internal reference voltage, temperature sensor output voltage

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (–) = $AV_{REFM} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
Overall error ^{Note 1}	$AINL$	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 7.0	LSB
Conversion time	t_{CONV}	$ADTYP = 0$, 12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	4.125			μs
Zero-scale error ^{Note 1}	E_{ZS}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 5.0	LSB
Full-scale error ^{Note 1}	E_{FS}	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 5.0	LSB
Integral linearity error ^{Note 1}	ILE	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 3.0	LSB
Differential linearity error ^{Note 1}	DLE	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.0	LSB
Analog input voltage	V_{AIN}		0.		AV_{REFP} and EV_{DD0}	V
		Internal reference voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)	V_{BGR} ^{Note 2}			V
		Temperature sensor output voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)	V_{TMPS25} ^{Note 2}			V

Notes 1. Excludes quantization error ($\pm 1/2$ LSB).

2. See 30.6.2 Temperature sensor, internal reference voltage output characteristics.

(4) When reference voltage (+) = AV_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = AV_{SS} (ADREFM = 0), target for conversion: ANI16 to ANI30, internal reference voltage, temperature sensor output voltage

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD0} \leq 3.6\text{ V}$, $2.4\text{ V} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{DD} , Reference voltage (–) = $AV_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}		$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
Overall error ^{Note 1}	A_{INL}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 8.5	LSB
Conversion time	t_{CONV}	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	4.125			μs
Zero-scale error ^{Note 1}	E_{ZS}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 8.0	LSB
Full-scale error ^{Note 1}	E_{FS}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 8.0	LSB
Integral linearity error ^{Note 1}	I_{LE}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 3.5	LSB
Differential linearity error ^{Note 1}	D_{LE}	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.5	LSB
Analog input voltage	V_{AIN}			0		AV_{DD} and EV_{DD0}	V
		Internal reference voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		V_{BGR} ^{Note 2}			V
		Temperature sensor output voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		V_{TMPS25} ^{Note 2}			V

Notes 1. Excludes quantization error ($\pm 1/2$ LSB).

2. See 30.6.2 Temperature sensor, internal reference voltage output characteristics.

(5) When reference voltage (+) = Internal reference voltage (1.45 V) (ADREFP1 = 1, ADREFP0 = 0), reference voltage (–) = AV_{SS} (ADREFM = 0), target for conversion: ANI0 to ANI12, ANI16 to ANI30

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq EV_{DD} \leq V_{DD}$, $2.4\text{ V} \leq AV_{DD} \leq V_{DD}$, $V_{SS} = EV_{SS0} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = Internal reference voltage, Reference voltage (–) = $AV_{SS} = 0\text{ V}$, HS (high-speed main) mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	R_{ES}		8			bit
Conversion time	t_{CONV}	8-bit resolution	16.0			μs
Zero-scale error ^{Note}	E_{ZS}	8-bit resolution			± 4.0	LSB
Integral linearity error ^{Note}	ILE	8-bit resolution			± 2.0	LSB
Differential linearity error ^{Note}	DLE	8-bit resolution			± 2.5	LSB
Reference voltage (+)	$AV_{REF(+)}$	= Internal reference voltage (V_{BGR})	1.38	1.45	1.50	V
Analog input voltage	V_{AIN}		0		V_{BGR}	V

Note Excludes quantization error ($\pm 1/2$ LSB).

30.6.2 Temperature sensor, internal reference voltage output characteristics

($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, HS (high-speed main) mode)

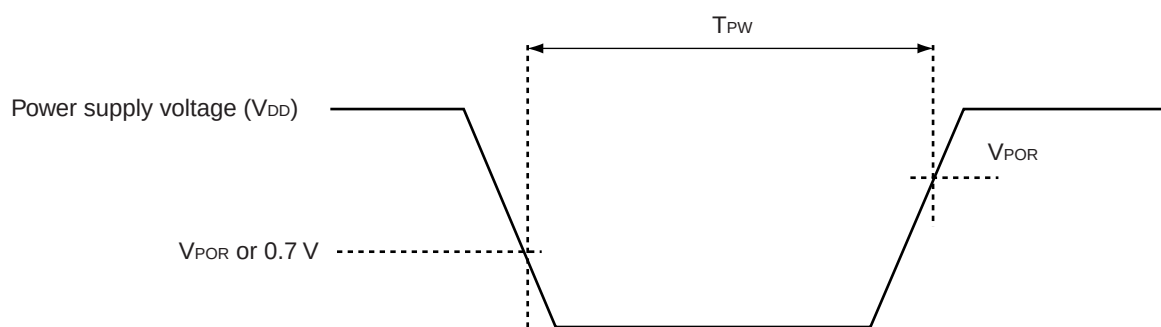
Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Temperature sensor output voltage	V_{TMPS25}	Setting ADS register = 80H, $T_A = +25^\circ\text{C}$		1.05		V
Internal reference voltage	V_{BGR}	Setting ADS register = 81H	1.38	1.45	1.5	V
Temperature coefficient	F_{VTMPS}	Temperature sensor output voltage that depends on the temperature		-3.6		$\text{mV}/^\circ\text{C}$
Operation stabilization wait time	t_{AMP}		10			μs

30.6.3 POR circuit characteristics

($T_A = -40$ to $+105^\circ\text{C}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V_{POR}	Power supply rise time	1.45	1.51	1.57	V
	V_{PDR}	Power supply fall time	1.44	1.50	1.56	V
Minimum pulse width ^{Note}	T_{PW}		300			μs

Note This is the time required for the POR circuit to execute a reset when V_{DD} falls below V_{PDR} . When the microcontroller enters STOP mode or if the main system clock (f_{MAIN}) has been stopped by setting bit 0 (HI0STOP) and bit 7 (MSTOP) of the clock operation status control register (CSC), this is the time required for the POR circuit to execute a reset before V_{DD} rises to V_{POR} after having fallen below 0.7 V.



30.6.4 LVD circuit characteristics

LVD Detection Voltage of Reset Mode and Interrupt Mode

(T_A = -40 to $+105^\circ\text{C}$, V_{PDR} ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	Supply voltage level	V _{LVD2}	Power supply rise time	3.01	3.13	3.25	V
			Power supply fall time	2.94	3.06	3.18	V
		V _{LVD3}	Power supply rise time	2.90	3.02	3.14	V
			Power supply fall time	2.85	2.96	3.07	V
		V _{LVD4}	Power supply rise time	2.81	2.92	3.03	V
			Power supply fall time	2.75	2.86	2.97	V
		V _{LVD5}	Power supply rise time	2.70	2.81	2.92	V
			Power supply fall time	2.64	2.75	2.86	V
		V _{LVD6}	Power supply rise time	2.61	2.71	2.81	V
			Power supply fall time	2.55	2.65	2.75	V
		V _{LVD7}	Power supply rise time	2.51	2.61	2.71	V
			Power supply fall time	2.45	2.55	2.65	V
Minimum pulse width		t _{LW}		300			μs
Detection delay time						300	μs

Remark V_{LVD} (n-1) > V_{LVDn}: n = 3 to 7

LVD Detection Voltage of Interrupt & Reset Mode

(T_A = -40 to $+105^\circ\text{C}$, V_{PDR} ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Interrupt & reset mode	V _{LVD5}	VPOC2, VPOC1, VPOC0 = 0, 1, 1, falling reset voltage		2.64	2.75	2.86	V
	V _{LVD4}	LVIS1, LVIS0 = 1, 0	Rising release reset voltage	2.81	2.92	3.03	V
			Falling interrupt voltage	2.75	2.86	2.97	V
	V _{LVD3}	LVIS1, LVIS0 = 0, 1	Rising release reset voltage	2.90	3.02	3.14	V
			Falling interrupt voltage	2.85	2.96	3.07	V

Caution Set the detection voltage (V_{LVD}) to be within the operating voltage range. The operating voltage range depends on the setting of the user option byte (000C2H/010C2H). The following shows the operating voltage range.

HS (high-speed main) mode: V_{DD} = 2.7 to 3.6 V@1 MHz to 32 MHzV_{DD} = 2.4 to 3.6 V@1 MHz to 16 MHz

30.6.5 Supply voltage rise slope characteristics

(T_A = -40 to $+105^\circ\text{C}$, V_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Supply voltage rise	SV _{DD}				54	V/ms

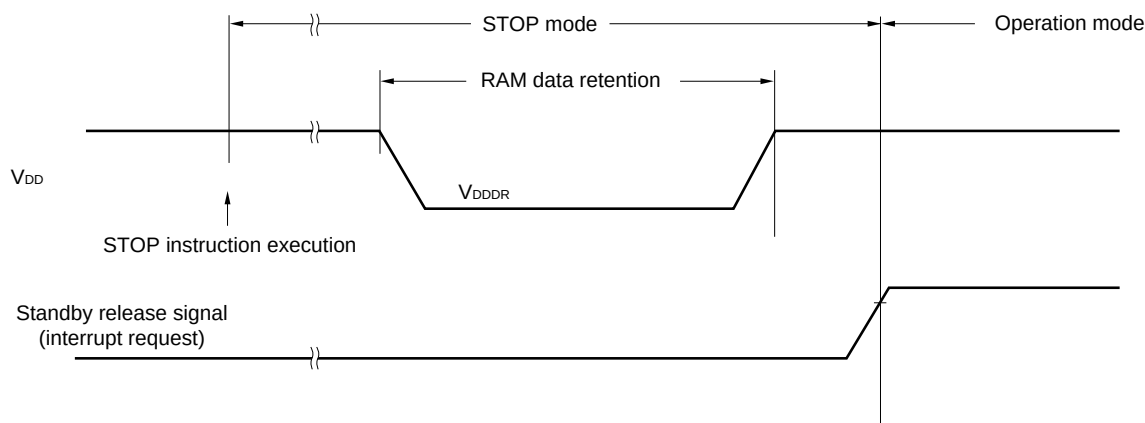
Caution Be sure to maintain the internal reset state until V_{DD} reaches the operating voltage range specified in 30.4 AC Characteristics, by using the LVD circuit or external reset pin.

30.7 RAM Data Retention Characteristics

($T_A = -40$ to $+105^{\circ}\text{C}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	V_{DDDR}		1.44 ^{Note}		3.6	V

Note This depends on the POR detection voltage. For a falling voltage, data in RAM are retained until the voltage reaches the level that triggers a POR reset but not once it reaches the level at which a POR reset is generated.



30.8 Flash Memory Programming Characteristics

($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CPU/peripheral hardware clock frequency	f _{CLK}	2.4 V ≤ V _{DD} ≤ 3.6 V	1		32	MHz
Number of code flash rewrites ^{Notes 1, 2, 3}	C _{erwr}	Retained for 20 years T _A = 85°C	1,000			Times
Number of data flash rewrites ^{Notes 1, 2, 3}		Retained for 1 years T _A = 25°C		1,000,000		
		Retained for 5 years T _A = 85°C	100,000			
		Retained for 20 years T _A = 85°C	10,000			

Notes 1. 1 erase + 1 write after the erase is regarded as 1 rewrite.

The retaining years are until next rewrite after the rewrite.

2. When using flash memory programmer and Renesas Electronics self programming library

3. These are the characteristics of the flash memory and the results obtained from reliability testing by Renesas Electronics Corporation.

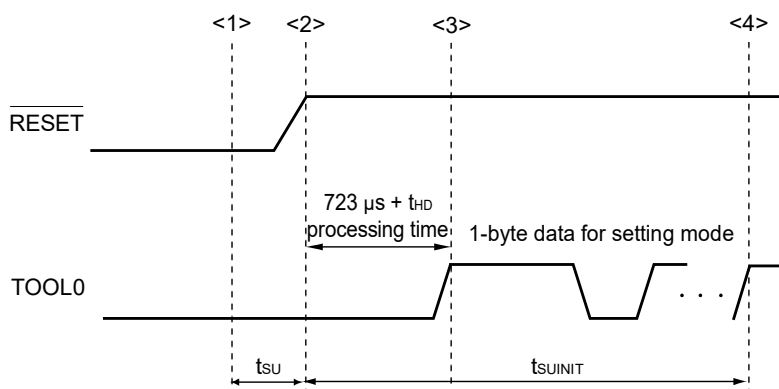
4. This temperature is the average value at which data are retained.

30.9 Dedicated Flash Memory Programmer Communication (UART)**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Transfer rate		During flash memory programming	115.2 k		1 M	bps

30.10 Timing Specs for Switching Flash Memory Programming Modes**($T_A = -40$ to $+105^\circ\text{C}$, $2.4\text{ V} \leq \text{EV}_{\text{DD0}} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, $\text{V}_{\text{SS}} = \text{EV}_{\text{SS0}} = 0\text{ V}$)**

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
How long from when an external reset ends until the initial communication settings are specified	t_{SUINIT}	POR and LVD reset must end before the external reset ends.			100	ms
How long from when the TOOL0 pin is placed at the low level until a external reset ends	t_{SU}	POR and LVD reset must end before the external reset ends.	10			μs
How long the TOOL0 pin must be kept at the low level after an external reset ends (except flash firmware processing time)	t_{HD}	POR and LVD reset must end before the external reset ends.	1			ms



- <1> The low level is input to the TOOL0 pin.
- <2> The pins reset ends (POR and LVD reset must end before the external reset ends.).
- <3> The TOOL0 pin is set to the high level.
- <4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

Remark t_{SUINIT} : The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.

t_{SU} : How long from when the TOOL0 pin is placed at the low level until a external reset ends

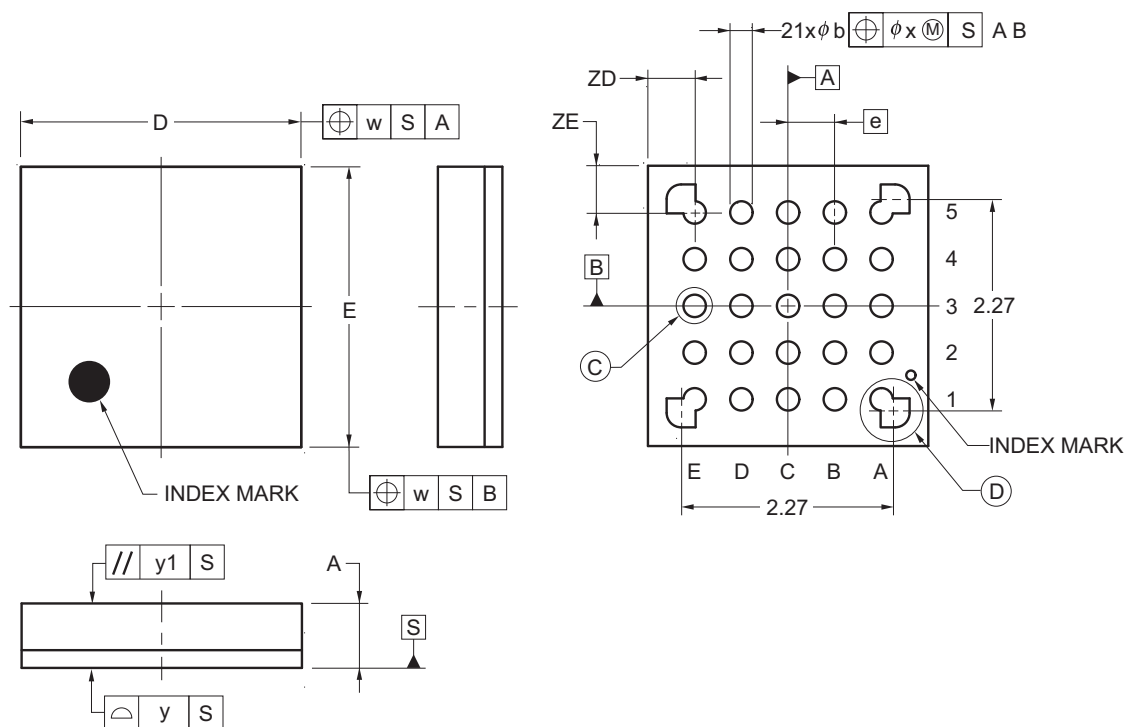
t_{HD} : How long to keep the TOOL0 pin at the low level from when the external resets end (except flash firmware processing time)

CHAPTER 31 PACKAGE DRAWINGS

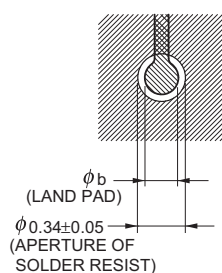
31.1 25-pin Products

JEITA Package Code	RENESAS Code	Previous Code	MASS (Typ) [g]
P-WFLGA25-3x3-0.50	PWLG0025KA-A	P25FC-50-2N2-3	0.01

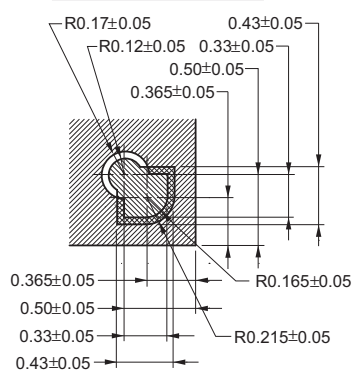
Unit: mm



DETAIL OF (C) PART



DETAIL OF (D) PART

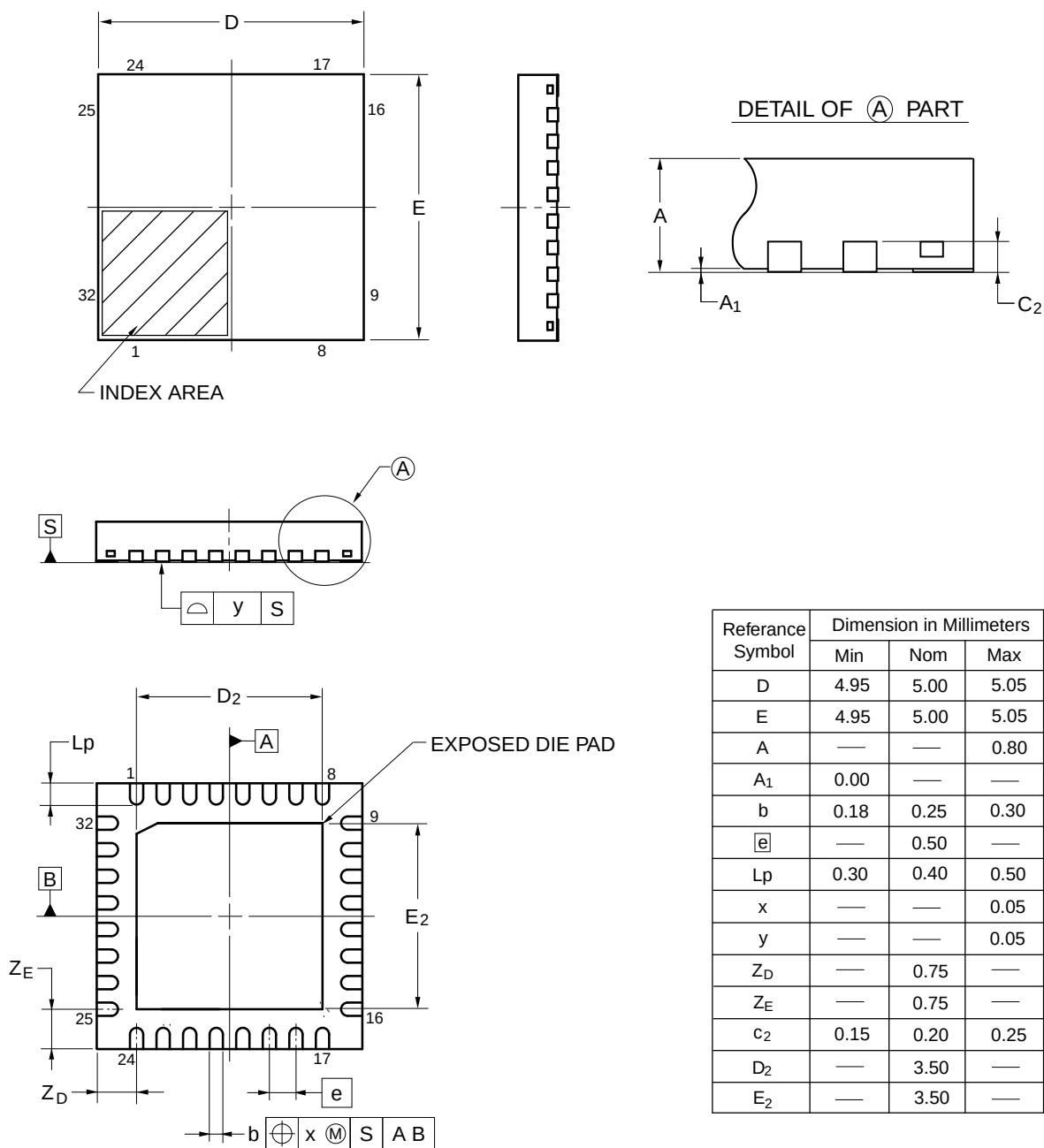


ITEM	DIMENSIONS
D	3.00±0.10
E	3.00±0.10
w	0.20
e	0.50
A	0.69±0.07
b	0.24±0.05
x	0.05
y	0.08
y1	0.20
ZD	0.50
ZE	0.50

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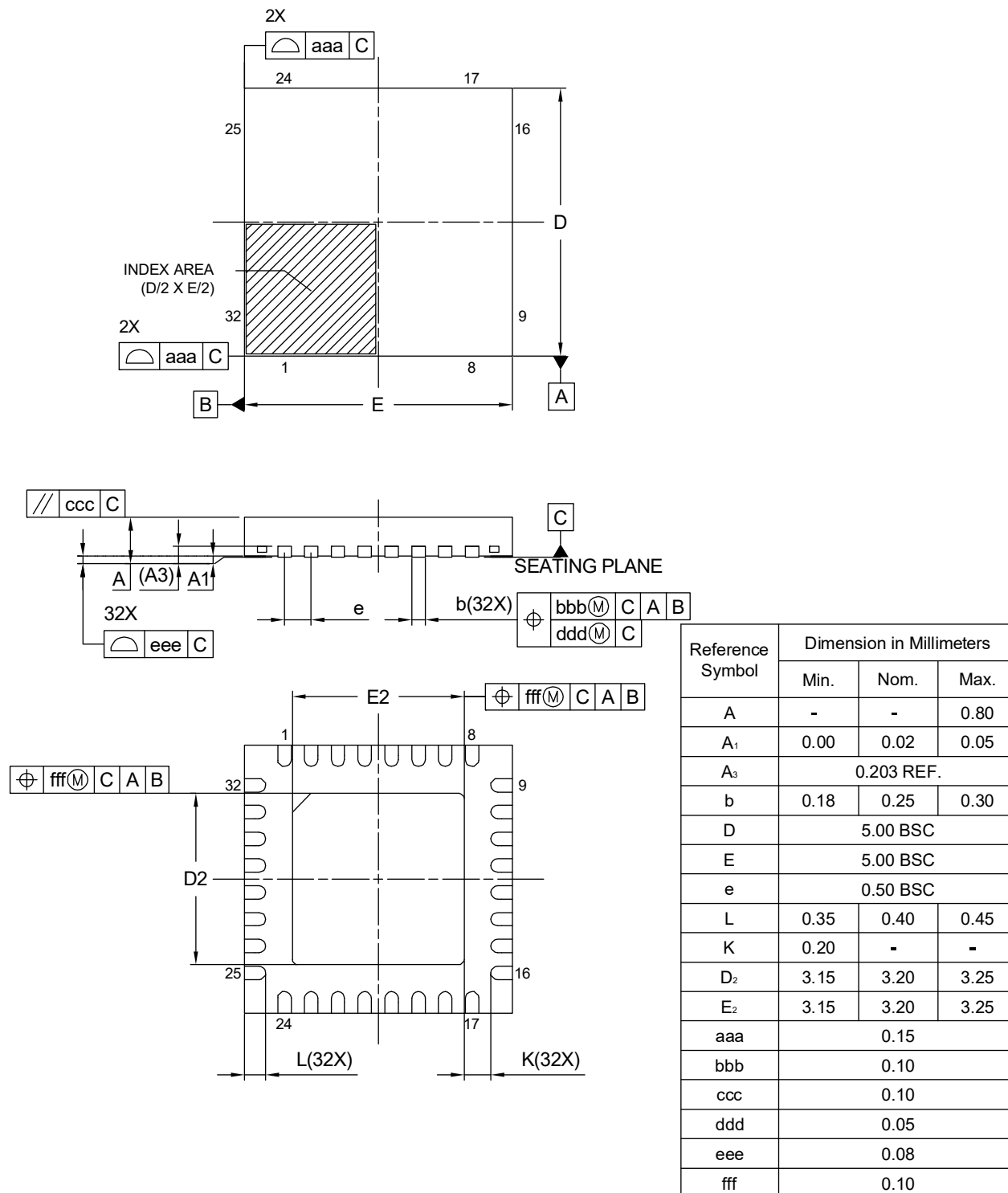
31.2 32-pin Products

JEITA Package code	RENESAS code	Previous code	MASS(TYP.)[g]
P-HWQFN32-5x5-0.50	PWQN0032KB-A	P32K8-50-3B4-5	0.06

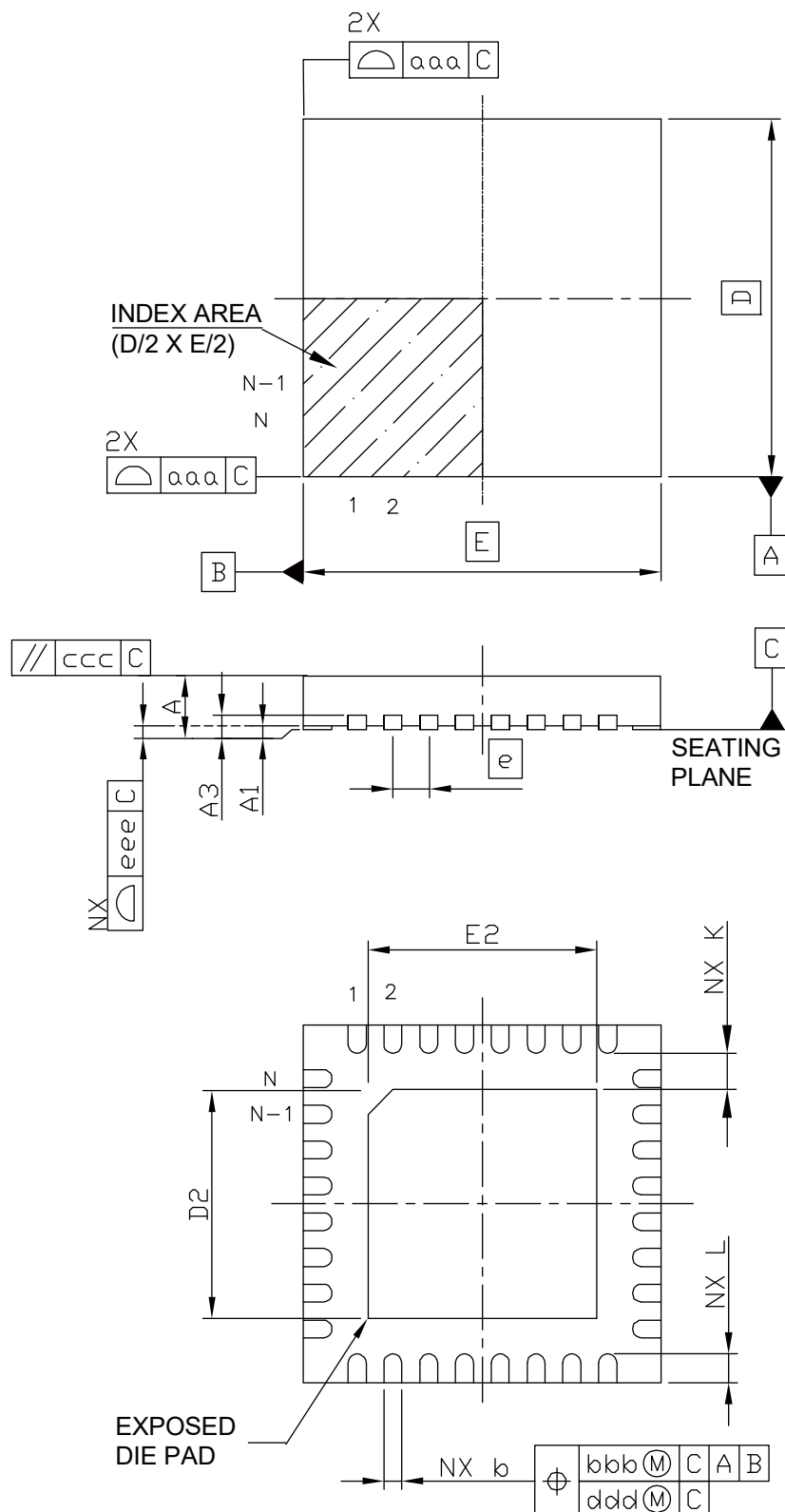


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JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-HWQFN032-5x5-0.50	PWQN0032KE-A	0.06



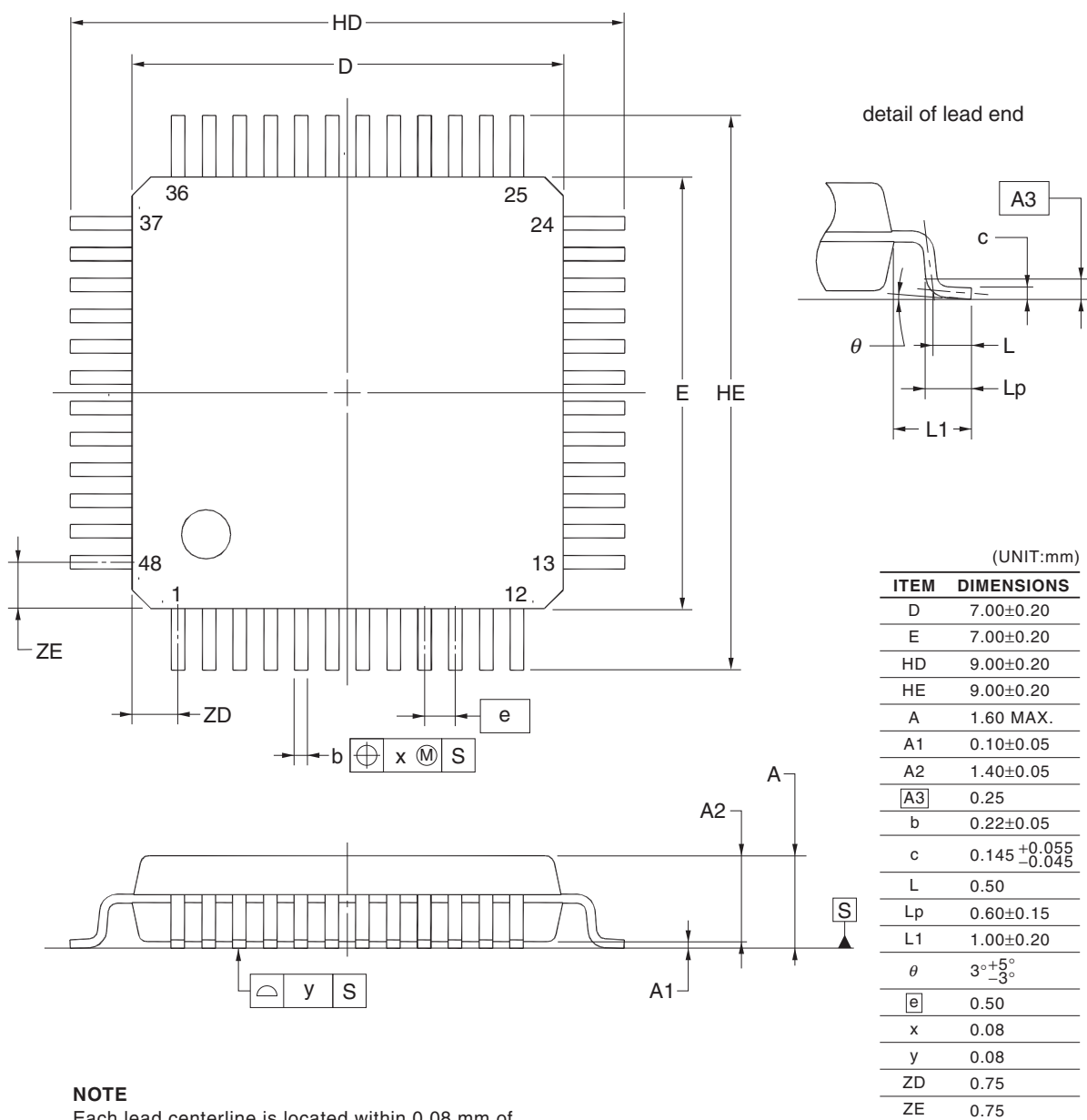
JEITA Package Code	RENESAS Code	MASS(Typ.)[g]
P-HWQFN32-5×5-0.50	PWQN0032KG-A	0.06



Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	—	—	0.80
A ₁	0.00	—	0.05
A ₃	0.20 REF.		
b	0.20	0.25	0.30
D	—	5.00	—
E	—	5.00	—
e	—	0.50	—
N	32		
L	0.30	0.40	0.50
K	0.20	—	—
D ₂	3.10	3.20	3.30
E ₂	3.10	3.20	3.30
aaa	—	—	0.15
bbb	—	—	0.10
ccc	—	—	0.10
ddd	—	—	0.05
eee	—	—	0.08

31.3 48-pin Products

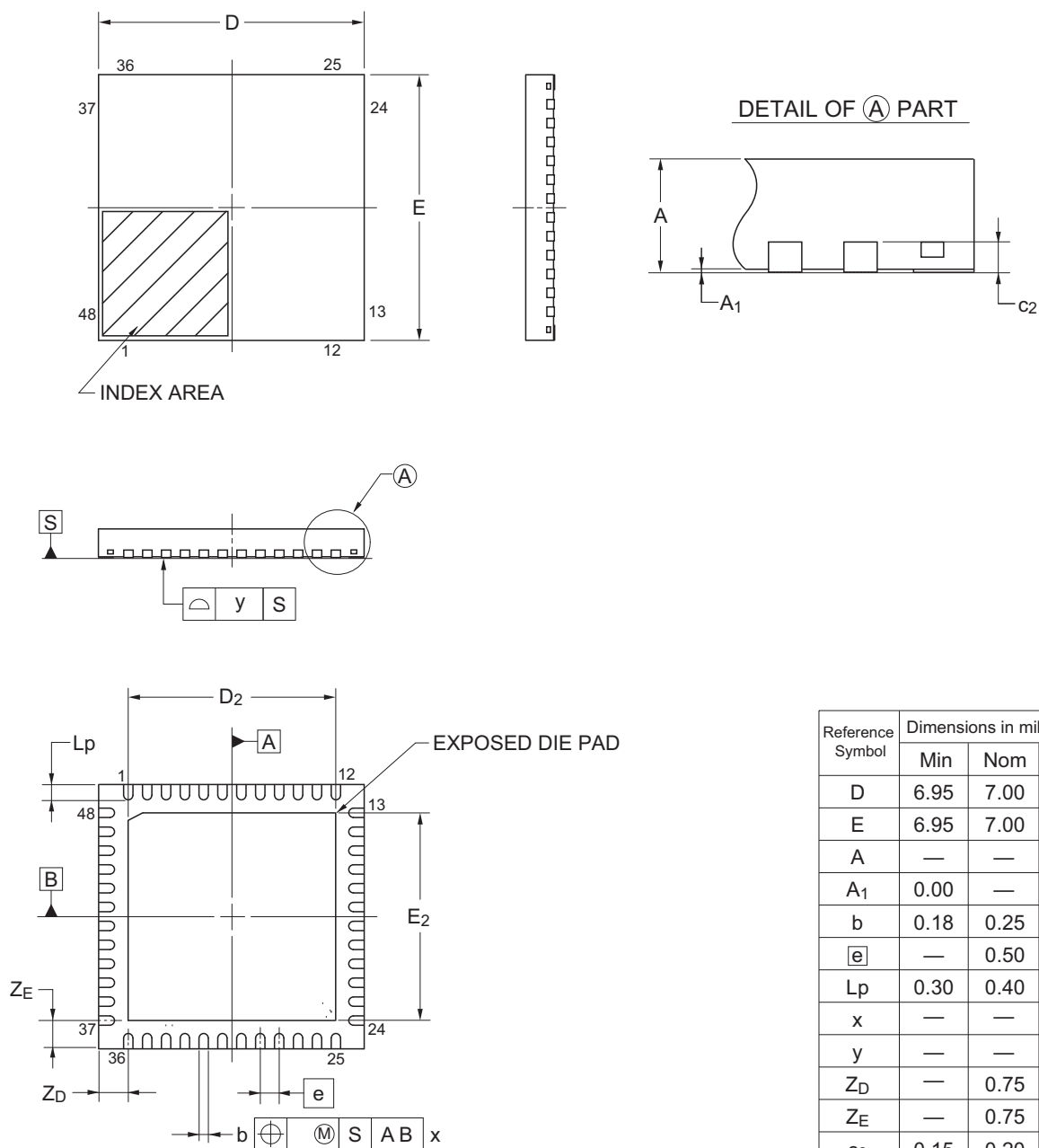
JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
P-LFQFP48-7x7-0.50	PLQP0048KF-A	P48GA-50-8EU-1	0.16



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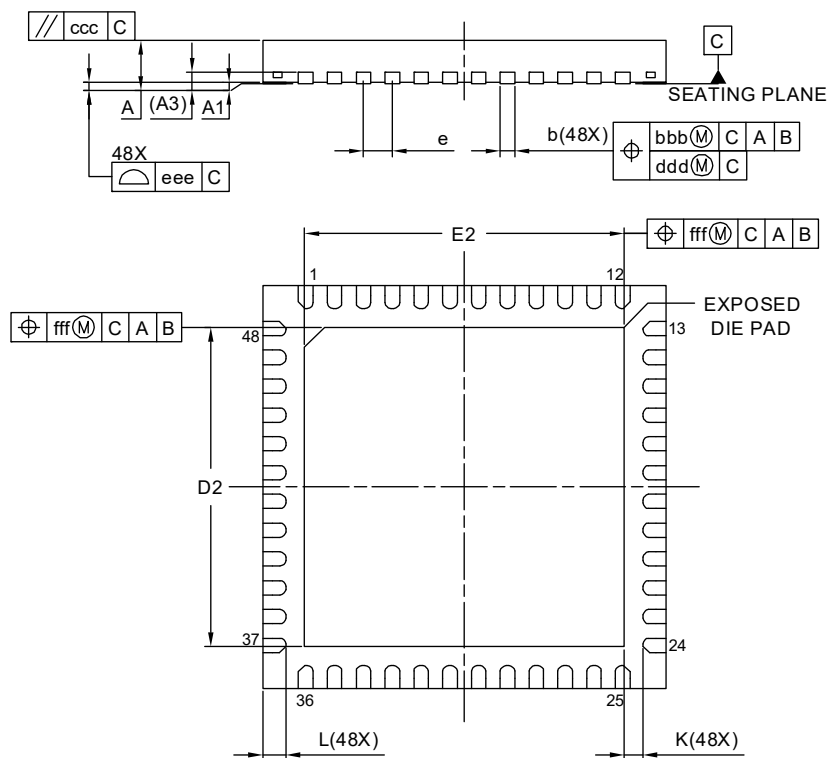
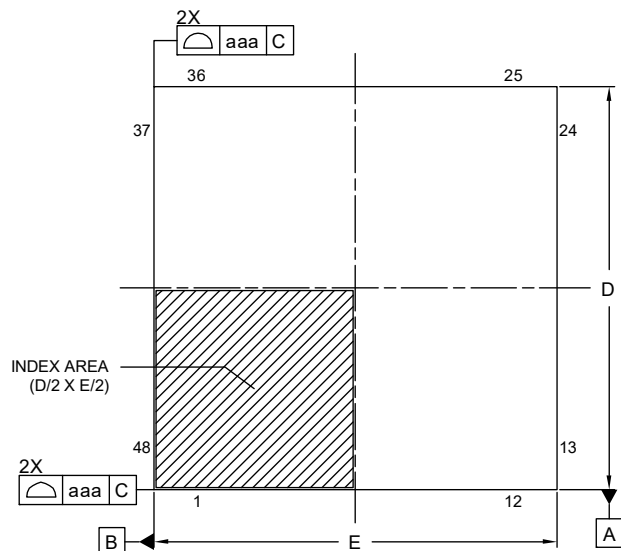
JEITA Package Code	RENESAS Code	Previous Code	MASS (Typ) [g]
P-HWQFN48-7x7-0.50	PWQN0048KB-A	48PJN-A P48K8-50-5B4-7	0.13

Unit: mm



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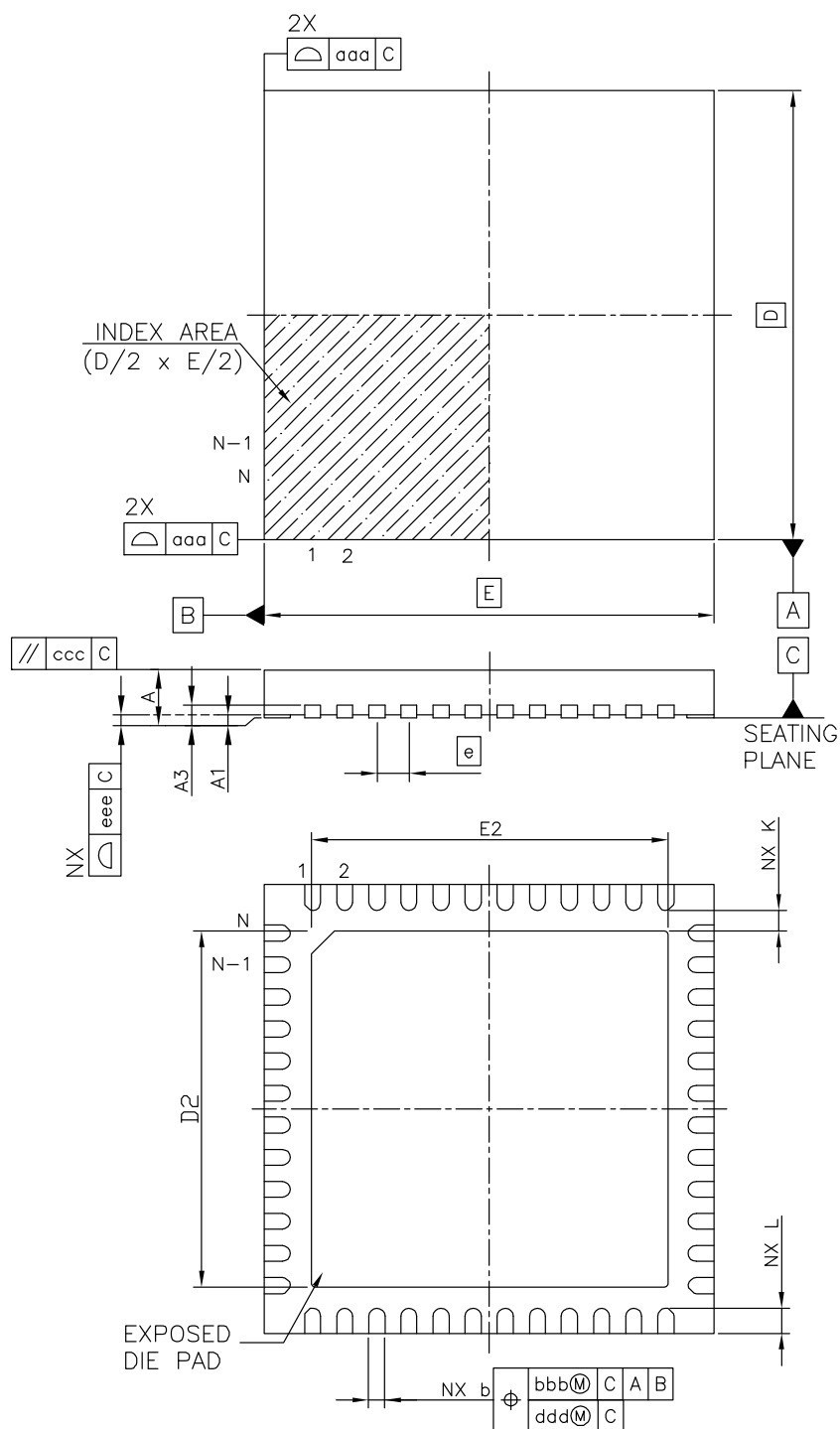
JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-HWQFN048-7x7-0.50	PWQN0048KE-A	0.13



Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	-	-	0.80
A ₁	0.00	0.02	0.05
A ₃	0.203 REF.		
b	0.20	0.25	0.30
D	7.00 BSC		
E	7.00 BSC		
e	0.50 BSC		
L	0.30	0.40	0.50
K	0.20	-	-
D ₂	5.50	5.55	5.60
E ₂	5.50	5.55	5.60
aaa	0.15		
bbb	0.10		
ccc	0.10		
ddd	0.05		
eee	0.08		
fff	0.10		

<R>

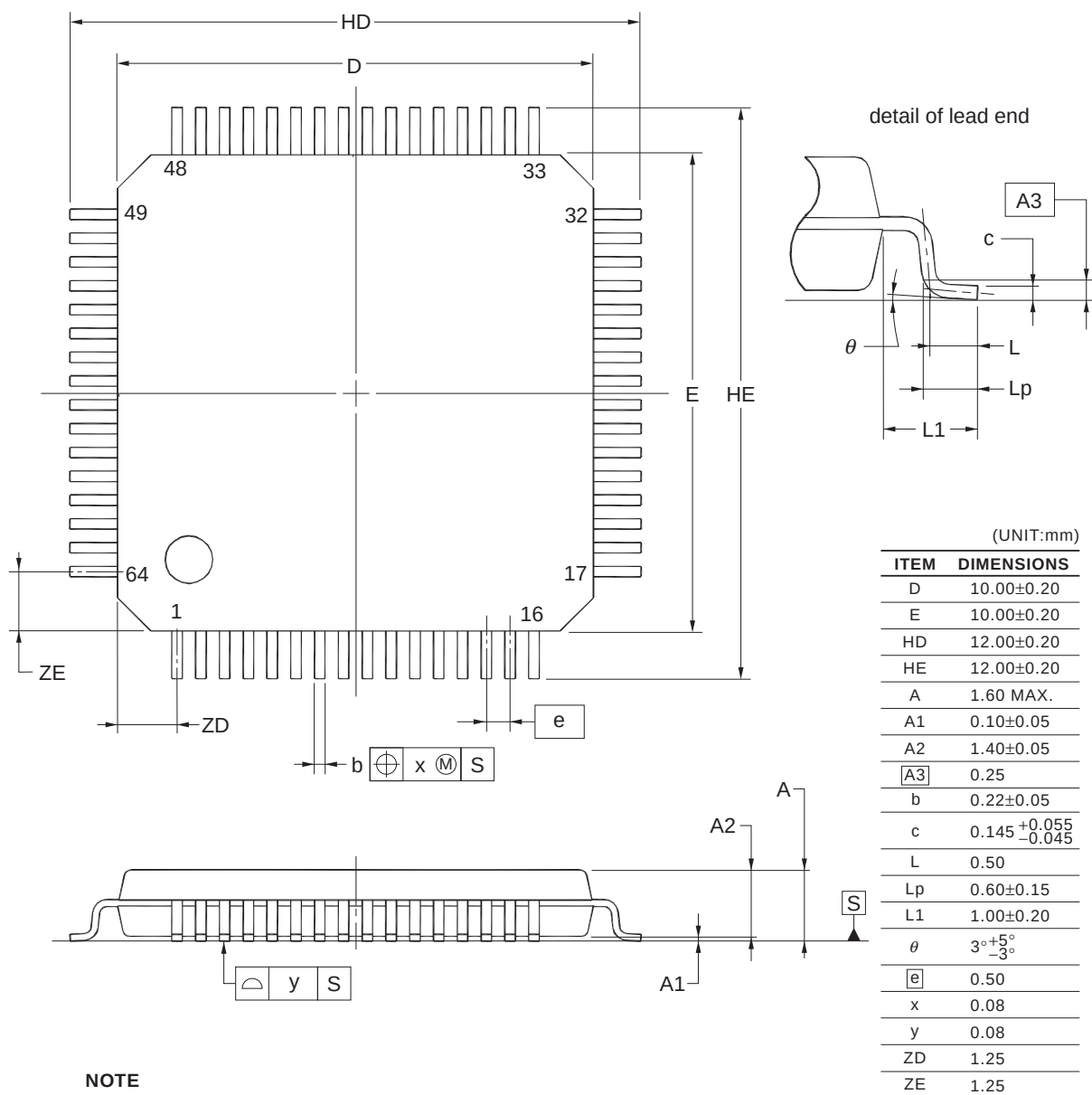
JEITA Package Code	RENESAS Code	MASS(Typ.)[g]
P-HWQFN48-7×7-0.50	PWQN0048KG-A	0.13



Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	—	—	0.80
A ₁	0.00	—	0.05
A ₃	0.20 REF.		
b	0.20	0.25	0.30
D	—	7.00	—
E	—	7.00	—
e	—	0.50	—
N	48		
L	0.30	0.40	0.50
K	0.20	—	—
D ₂	5.50	5.55	5.60
E ₂	5.50	5.55	5.60
aaa	—	—	0.15
bbb	—	—	0.10
ccc	—	—	0.10
ddd	—	—	0.05
eee	—	—	0.08

31.4 64-pin Products

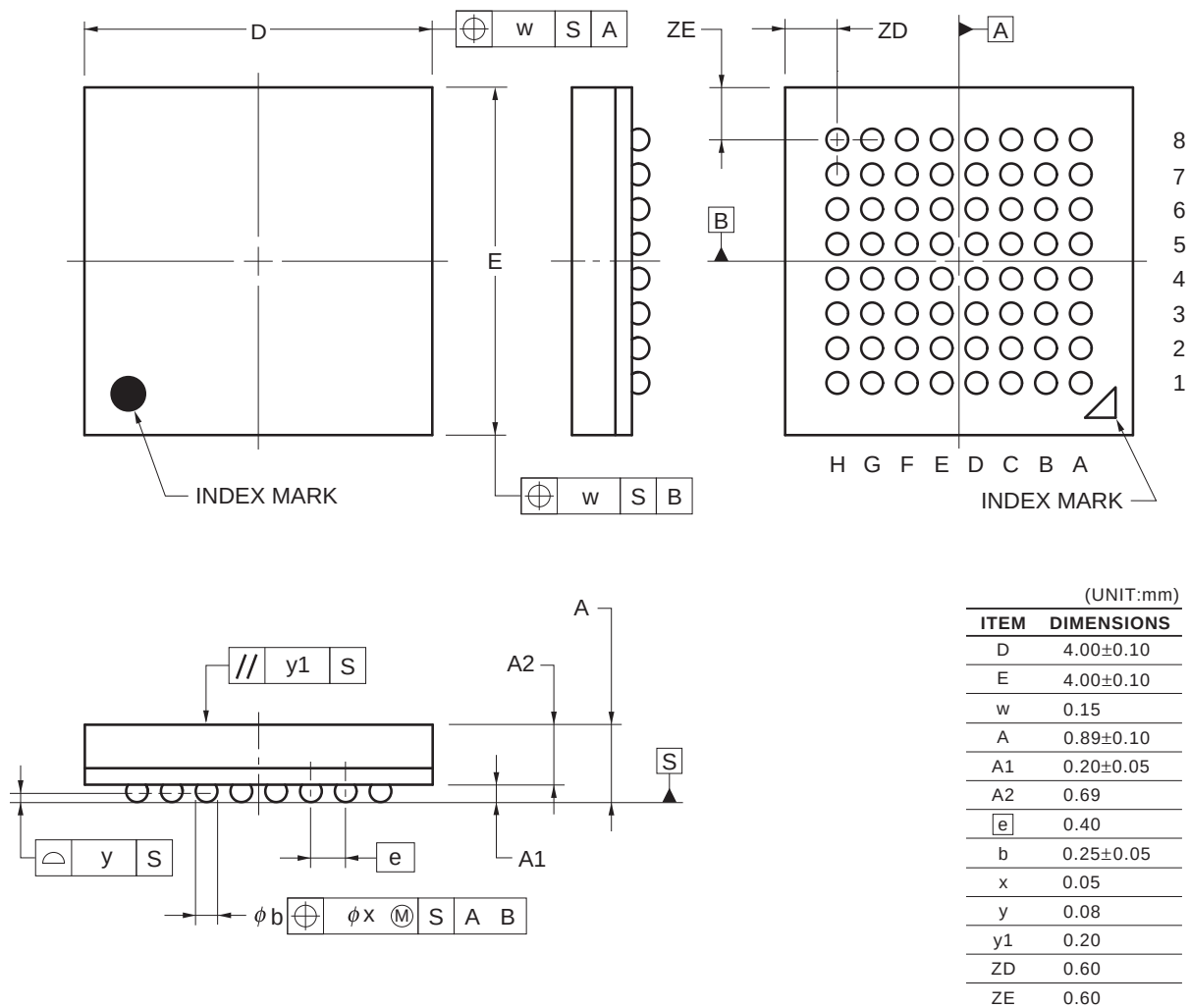
JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
P-LFQFP64-10x10-0.50	PLQP0064KF-A	P64GB-50-UEU-2	0.35



NOTE

Each lead centerline is located within 0.08 mm of its true position at maximum material condition.

JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
P-VFBGA64-4x4-0.40	PVBG0064LA-A	P64F1-40-AA2-2	0.03



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APPENDIX A REVISION HISTORY

A.1 Major Revisions in This Edition

Page	Description	Classification
CHAPTER 1 OUTLINE		
p.4	Modification of Figure 1-1. Part Number, Memory Size, and Package of RL78/G1A	(d)
p.5	Modification of Table 1-1. List of Ordering Part Numbers	(d)
CHAPTER 10 WATCHDOG TIMER		
p.339	Addition of Note in Table 10-3. Setting of Overflow Time of Watchdog Timer	(c)
p.341	Addition of Note in Table 10-4. Setting Window Open Period of Watchdog Timer	(c)
CHAPTER 22 SAFETY FUNCTIONS		
p.775	Modification of 22.1 Overview of Safety Functions	(c)
p.779	Modification of 22.3.2 CRC operation function (general-purpose CRC)	(c)
p.783	Modification of 22.3.4 RAM guard function	(c)
p.784	Modification of 22.3.5 SFR guard function	(c)
CHAPTER 25 FLASH MEMORY		
p.826	Addition of Cautions 4 in 25.8.3 Procedure for accessing data flash memory	(c)
CHAPTER 31 PACKAGE DRAWINGS		
p.963	Addition of PWQN0048KG-A in 31.3 48-pin Products	(d)

Remark "Classification" in the above table classifies revisions as follows.

- (a): Error correction, (b): Addition/change of specifications, (c): Addition/change of description or note, (d): Addition/change of package, part number, or management division, (e): Addition/change of related documents

A.2 Revision History of Preceding Editions

Here is the revision history of the preceding editions. Chapter indicates the chapter of each edition.

(1/27)		
Edition	Description	Chapter
Rev.2.20	"3-Wire Serial I/O" and "3-wire serial" were modified to "Simplified SPI"	All
	The module name for CSI was changed to Simplified SPI	
	"wait" for IIC was modified to "clock stretch"	
	Addition of Note 1 in 1 Features	CHAPTER 1 OUTLINE
	Modification of Table 1-1 List of Ordering Part Numbers	
	Addition of Note 1 in 4.4.5 Handling different potential (1.8 V or 2.5 V) by using I/O buffers	CHAPTER 4 PORT FUNCTIONS
	Modification of description in Figure 7-5. Format of Real-time Clock Control Register 1 (RTCC1) (2/2)	CHAPTER 7 REAL-TIME CLOCK
	Modification of caution in Figure 7-21. Procedure for Reading Real-time Clock	
	Modification of caution1 in Figure 7-22. Procedure for Writing Real-time Clock	
	Addition of Note 1 in CHAPTER 12 SERIAL ARRAY UNIT	CHAPTER 12 SERIAL ARRAY UNIT
	Modification of Figure 25-7. Setting of Flash Memory Programming Mode	CHAPTER 25 FLASH MEMORY
	Modification of note1, note4 and note5 in 29.3.2 Supply current characteristics ($T_A = -40$ to $+85^{\circ}\text{C}$, $1.6\text{ V} \leq E_{VDD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = E_{VSS0} = 0\text{ V}$) (1/3)	CHAPTER 29 ELECTRICAL SPECIFICATIONS ($T_A = -40$ to $+85^{\circ}\text{C}$)
	Modification of note1, note5 and note6 in 29.3.2 Supply current characteristics ($T_A = -40$ to $+85^{\circ}\text{C}$, $1.6\text{ V} \leq E_{VDD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = E_{VSS0} = 0\text{ V}$) (2/3)	
	Modification of figure in 29.10 Timing Specs for Switching Flash Memory Programming Modes	
Rev.2.11	Modification of note1, note4 and note5 in 30.3.2 Supply current characteristics ($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq E_{VDD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = E_{VSS0} = 0\text{ V}$) (1/3)	CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS $T_A = -40$ to $+105^{\circ}\text{C}$)
	Modification of note1, note5 and note6 in 30.3.2 Supply current characteristics ($T_A = -40$ to $+105^{\circ}\text{C}$, $2.4\text{ V} \leq E_{VDD0} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = E_{VSS0} = 0\text{ V}$) (2/3)	
	Modification of figure in 30.10 Timing Specs for Switching Flash Memory Programming Modes	
Rev.2.10	Addition of figure in 31.2 32-pin Products	CHAPTER 31 PACKAGE DRAWINGS
	Modification of Figure 1-1 Part Number, Memory Size, and Package of RL78/G1A	CHAPTER 1 OUTLINE
	Addition of title and modification of description in Table 1-1 List of Ordering Part Numbers	
Rev.2.10	Addition and modification of all in CHAPTER 31 PACKAGE DRAWINGS	CHAPTER 31 PACKAGE DRAWINGS
	Addition of description in 1.3.1 25-pin products to 1.3.4 64-pin products	CHAPTER 1 OUTLINE
	Modification of description in 1.6 Outline of Functions	
	Modification of 2.1.1 25-pin products to 2.1.4 64-pin products	
	Addition of caution in Figure 2-7 Pin Block Diagram for Pin Type 7-1-2	
	Addition of caution in Figure 2-9 Pin Block Diagram for Pin Type 7-3-2	
Rev.2.10	Addition of caution in Figure 2-10 Pin Block Diagram for Pin Type 8-1-1	CHAPTER 2 PIN FUNCTIONS

(2/27)

Edition	Description	Chapter
Rev.2.10	Addition of cautions 1 and 2 in Figure 2-11. Pin Block Diagram for Pin Type 8-1-2	CHAPTER 2 PIN FUNCTIONS
	Addition of cautions 1 and 2 in Figure 2-12 Pin Block Diagram for Pin Type 8-3-2	
	Addition of caution in Figure 2-13 Pin Block Diagram for Pin Type 12-1-1	
	Modification of Table 4-4. PMxx, Pxx, PUxx, PIMxx, POMxx, PMCxx registers and the bits mounted on each product	CHAPTER 4 PORT FUNCTIONS
	Modification of description in (1) Main system clock of 5.1 Functions of Clock Generator	CHAPTER 5 CLOCK GENERATOR
	Modification of caution 6 in Figure 5-4 Format of Clock Operation Status Control Register (CSC)	
	Modification of remark 1 in Figure 5-10. Format of High-Speed On-Chip Oscillator Trimming Register (HIOTRM)	
	Addition of caution in <5> in 5.6.2 Example of setting X1 oscillation clock	
	Modification of <1> in 5.6.3 Example of setting XT1 oscillation clock	
	Modification of Table 5-4. Changing CPU Clock	
	Modification of description in 5.6.7 Conditions before clock oscillation is stopped	
	Addition of remark 2 in (1) X1 oscillation of 5.7 Resonator and Oscillator Constants	
	Addition of remark in (2) XT1 oscillation: Crystal resonator of 5.7 Resonator and Oscillator Constants	
	Modification of description in 6.2.2 Timer data register mn (TDRmn)	CHAPTER 6 TIMER ARRAY UNIT
	Modification of description in Figure 6-11 Format of Timer Mode Register mn (TMRmn)	
	Modification of caution in Figure 6-16 Format of Timer Input Select register 0 (TIS0)	
	Modification of description in Figure 6-22. Format of Noise Filter Enable Register 1 (NFEN1)	
	Modification of description in 6.4.2 Basic rules of 8-bit timer operation function (channels 1 and 3 only)	
	Deletion of caution in Figure 6-37. TO0n Pin Statuses by Collective Manipulation of TO0n Bit	
	Modification of description in Figure 6-60. Operation Procedure When Input Signal High-/Low-Level Width Measurement Function Is Used	

(3/27)

Edition	Description	Chapter
Rev.2.10	Addition of notes 1 and 2 in Figure 7-5 Format of Real-time Clock Control Register 1 (RTCC1) (2/2)	CHAPTER 7 REAL-TIME CLOCK
	Modification of Figure 12-1. Block Diagram of Serial Array Unit 0	CHAPTER 12 SERIAL ARRAY UNIT
	Modification of Figure 12-2. Block Diagram of Serial Array Unit 1	
	Modification of note 2 in 12.2.2 Lower 8/9 bits of the serial data register mn (SDRmn)	
	Modification of caution 4 in Figure 12-8. Format of Serial Data Register mn (SDRmn)	
	Modification of Figure 12-17 Examples of Reverse Transmit Data	
	Modification of description in 12.5.7 SNOOZE mode function	
	Modification of description and note in Figure 12-70. Timing Chart of SNOOZE Mode Operation (Once Startup) (Type 1: DAPmn = 0, CKPmn = 0)	
	Modification of Figure 12-71 Timing Chart of SNOOZE Mode Operation (once startup) (Type 1: DAPmn = 0, CKPmn = 0)	
	Modification of description and note in Figure 12-72. Timing Chart of SNOOZE Mode Operation (Continuous Startup) (Type 1: DAPmn = 0, CKPmn = 0)	
	Modification of Figure 12-73 Timing Chart of SNOOZE Mode Operation (continuous startup) (Type 1: DAPmn = 0, CKPmn = 0)	
	Modification of description and Addition of caution 5 to 12.6.3 SNOOZE mode function	
	Modification of Figure 12-89 Timing Chart of SNOOZE Mode Operation (EOCm1 = 0, SSECm = 0/1)	
	Modification of Figure 12-90 Timing Chart of SNOOZE Mode Operation (EOCm1 = 1, SSECm = 0)	
	Modification of Figure 12-91. Flowchart of SNOOZE Mode Operation (EOCm1 = 0, SSECm = 0/1 or EOCm1 = 1, SSECm = 0)	
	Modification of Figure 12-92 Timing Chart of SNOOZE Mode Operation (EOCm1 = 1, SSECm = 1)	
	Modification of Figure 12-93. Flowchart of SNOOZE Mode Operation (EOCm1 = 1, SSECm = 1)	
	Addition of description in 13.3.6 IICA low-level width setting register 0 (IICWL0)	CHAPTER 13 SERIAL INTERFACE IICA
	Modification of description in 13.5.13 Wakeup function	
	Modification of description in 13.5.14 Communication reservation	
	Modification of note 1 in Figure 13-27 Communication Reservation Protocol	
	Modification of Figure 13-28 Master Operation in Single-Master System	
	Modification of Figure 13-29 Master Operation in Multi-Master System (1/4)	
	Modification of note in Figure 13-29 Master Operation in Multi-Master System (2/4)	
	Modification of Figure 13-30 Slave Operation Flowchart (1)	
	Modification of Table 16-5 Relationship Between Interrupt Requests Enabled for Multiple Interrupt Servicing During Interrupt Servicing	CHAPTER 16 INTERRUPT FUNCTIONS

(4/27)

Edition	Description	Chapter
Rev.2.10	Modification of Table 18-1. Operating Statuses in HALT Mode	CHAPTER 18 STANDBY FUNCTION
	Modification of Table 18-3. Operating Statuses in SNOOZE Mode	
	Modification of 19.1 Timing of Reset Operation	CHAPTER 19 RESET FUNCTION
	Modification of Figure 19-3. Timing of Reset Due to Watchdog Timer Overflow, Execution of Illegal Instruction, Detection of RAM Parity Error, or Detection of Illegal Memory Access	
	Modification of Figure 19-4. Format of Reset Control Flag Register (RESF)	
	Modification of Figure 19-5. Example of Procedure for Checking Reset Source	
	Modification of notes 3, 4 in Figure 20-2 (1) When the externally input reset signal on the RESET pin is used	CHAPTER 20 POWER-ON-RESET CIRCUIT
	Modification of note 3 in Figure 20-2. Timing of Generation of Internal Reset Signal by Power-on-reset Circuit and Voltage Detector (2/3)	
	Modification of description of Interrupt mode (LVIMDS1, LVIMDS0 = 0, 1)	CHAPTER 21 VOLTAGE DETECTOR
	Modification of description 21.4.2 When used as interrupt mode	CHAPTER 24 OPTION BYTE
	Modification of description in 24. 1. 1 (3) 000C2H/010C2H	
	Modification of description in Table 25-1. Wiring between RL78/G1A and Dedicated Flash Memory Programmer	CHAPTER 25 FLASH MEMORY
	Modification of description in Figure 25-2. Communication with Dedicated Flash Memory Programmer	
	Modification of remark 1 in 25.6 Self-Programming	
	Addition of description to 25.8.3 Procedure for accessing data flash memory	
	Modification of Table 26-1. On-Chip Debug Security ID	CHAPTER 26 ON-CHIP DEBUG FUNCTION
	Modification of conditions of 29.6.1 A/D converter characteristics	CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = -40 to +85°C)
	Renamed to 29.7 RAM Data Retention Characteristics , and modification of note and figure	
	Renamed to 30.7 RAM Data Retention Characteristics , and modification of note and figure	CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS T_A = -40 to +105°C)
	Addition of note 4 to 30.8 Flash Memory Programming Characteristics	
	Modification of package drawings in 31.1 25-pin Products	CHAPTER 31 PACKAGE DRAWINGS
	Modification of package drawings in 31.3 48-pin Products	

(5/27)

Edition	Description	Chapter
Rev.2.00	Modification of 1.1 Features	CHAPTER 1 OUTLINE
	Modification of Table 1-1. List of Ordering Part Numbers	
	Modification of Remark 3	
	Modification of 1.6 Outline of Functions	
	Modification of 2.1.1 25-pin products	CHAPTER 2 PIN FUNCTIONS
	Modification of 2.1.2 32-pin products	
	Modification of 2.1.3 48-pin products	
	Modification of 2.1.4 64-pin products	
	Modification of 2.2.2 Explanation of function	
	Modification of 2.3 Pin I/O Circuits and Recommended Connection of Unused Pins	
	Modification of Table 2-3. Connection of Unused Pins	
	Modification of Figures 2-1 to 2-13 in 2.4 Block Diagrams of Pins	
	Modification of 3.1.2 Mirror area	CHAPTER 3 CPU ARCHITECTURE
	Modification of 3.1.6 Data memory addressing	
	Modification of figure and Cautions 3 and 4 in Figure 3-9	
	Modification of Figures 3-11 and 3-12	
	Modification of Note 1 in Table 3-5	
	Modification of description and Note in Table 3-6. Extended SFR (2nd SFR) List	
	Modification of Table 3-6. Extended SFR (2nd SFR) List	
	Modification of Table 4-1. Port Configuration	CHAPTER 4 PORT FUNCTIONS
	Modification of 4.2.1 Port 0 and 4.2.2 Port 1	
	Modification of 4.2.3 Port 2 and 4.2.4 Port 3	
	Modification of 4.2.5 Port 4 and 4.2.6 Port 5	
	Modification of 4.2.8 Port 7 and 4.2.9 Port 12	
	Modification of 4.2.12 Port 15	
	Modification of 4.3.1 Port mode registers (PMxx)	
	Modification of 4.3.2 Port registers (Pxx)	
	Modification of 4.3.3 Pull-up resistor option registers (PUxx)	
	Modification of 4.3.4 Port input mode registers (PIMxx)	
	Modification of 4.3.5 Port output mode registers (POMxx)	
	Modification of 4.3.6 Port mode control registers (PMCxx)	
	Modification of 4.3.7 A/D port configuration register (ADPC)	
	Modification of 4.3.8 Peripheral I/O redirection register (PIOR)	
	Modification of 4.3.9 Global digital input disable register (GDIDIS)	
	Modification of 4.3.10 Global analog input disable register (GAIDIS)	
	Modification of 4.4.4 Handling different potential (1.8 V or 2.5 V) by using $EV_{DD} \leq V_{DD}$	
	Modification of 4.4.5 Handling different potential (1.8 V or 2.5 V) by using I/O buffers	
	Modification of 4.5 Register Settings When Using Alternate Function	
	Modification of 4.5.2 Register settings for alternate function whose output function is not used	
	Modification of 4.5.3 Register setting examples for used port and alternate functions	

(6/27)

Edition	Description	Chapter
Rev.2.00	Modification of Table 4-6. Setting Examples of Registers and Output Latches When Using Alternate Function	CHAPTER 4 PORT FUNCTIONS
	Modification of 4.6.2 Notes on specifying the pin settings	
	Modification of (3) Low-speed on-chip oscillator clock (Low-speed on-chip oscillator)	CHAPTER 5 CLOCK GENERATOR
	Modification of Table 5-1. Configuration of Clock Generator	
	Modification of Figure 5-1. Block Diagram of Clock Generator	
	Modification of 5.3 Registers Controlling Clock Generator	
	Modification of Caution 7	
	Modification of Figure 5-5. Format of Oscillation Stabilization Time Counter Status Register (OSTC)	
	Modification of 5.3.5 Oscillation stabilization time select register (OSTS)	
	Modification of Figure 5-6. Format of Oscillation Stabilization Time Select Register (OSTS)	
	Modification of 5.3.7 Subsystem clock supply mode control register (OSMC)	
	Modification of 5.3.8 High-speed on-chip oscillator frequency select register (HOCODIV)	
	Modification of Caution in Figure 5-12. Example of External Circuit of XT1 Oscillator	
	Modification of 5.4.4 Low-speed on-chip oscillator	
	Modification of 5.6.3 Example of setting XT1 oscillation clock	
	Modification of Table 5-3. CPU Clock Transition and SFR Register Setting Examples	
	Modification of 5.6.5 Condition before changing CPU clock and processing after changing CPU clock	
	Modification of Figure 5-16. External Oscillation Circuit Example	
	Modification of (1) X1 oscillation and (2) XT1 oscillation	
	Modification of 6.1.2 Simultaneous channel operation function	CHAPTER 6 TIMER ARRAY UNIT
	Modification of Table 6-1. Configuration of Timer Array Unit	
	Modification of Figure 6-3. Internal Block Diagram of Channels 1 and 3 of Timer Array Unit 0	
	Modification of Figure 6-9. Format of Peripheral Enable Register 0 (PER0)	
	Modification of 6.3.2 Timer clock select register m (TPSm)	
	Modification of Caution in Figure 6-10. Format of Timer Clock Select register m (TPSm)	
	Modification of Figure 6-21. Format of Input Switch Control Register (ISC)	
	Modification of 6.3.14 Noise filter enable register 1 (NFEN1)	
	Modification of 6.3.15 Registers controlling port functions of pins to be used for timer I/O	
	Modification of Remark in Figure 6-26. Operation Timing (In Event Counter Mode)	
	Modification of Remark 1	
	Modification of Figure 6-44. Operation Procedure of Interval Timer/Square Wave Output Function	
	Modification of Figure 6-48. Operation Procedure When External Event Counter Function Is Used	

(7/27)

Edition	Description	Chapter
Rev.2.00	Modification of Figure 6-51. Example of Set Contents of Registers During Operation as Frequency Divider	CHAPTER 6 TIMER ARRAY UNIT
	Modification of Figure 6-52. Operation Procedure When Frequency Divider Function Is Used	
	Modification of 6.8.4 Operation as input pulse interval measurement	
	Modification of Figure 6-56. Operation Procedure When Input Pulse Interval Measurement Function Is Used	
	Modification of Figure 6-57. Block Diagram of Operation as Input Signal High-/Low-Level Width Measurement	
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	Addition of Table 12-3. UART Reception Baud Rate Setting in the SNOOZE mode	
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	Addition of description in 12.6.3 (2) SNOOZE mode operation (EOCm1 = 1, SSECM = 0: error interrupt (INTSRE0) generation enable)	
	Modification of Figure 12-93. Flowchart of SNOOZE Mode Operation (EOCm1 = 0, SSECM = 0/1 or EOCm1 = 1, SSECM = 0)	
	Modification of 12.6.3 (3) SNOOZE mode operation (EOCm1 = 1, SSECM = 1: error interrupt (INTSRE0) generation stop)	
	Modification of Figure 12-95. Flowchart of SNOOZE Mode Operation (EOCm1 = 1, SSECM = 1)	
	Modification of 12.6.4 (2) Baud rate error during transmission	
	Modification of description in 14.4.1 Multiplication (unsigned) operation	CHAPTER 14 MULTIPLIER AND DIVIDER/MULTIPLY-ACCUMULATOR
	Modification of description in 14.4.2 Multiplication (signed) operation	
	Modification of description in 14.4.3 Multiply-accumulation (unsigned) operation	
	Modification of description in 14.4.4 Multiply-accumulation (signed) operation	
	Modification of Figure 14-9. Timing Diagram of Multiply-Accumulation (signed) Operation $(2 \times 3 + (-4) = 2 \rightarrow 32767 \times (-1) + (-2147483647) = -2147450882$ (overflow occurs.))	
	Modification of description in 14.4.5 Division operation	

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Rev.1.00	Addition of Note 5 to Table 16-1. Interrupt Source List	CHAPTER 16 INTERRUPT FUNCTION
	Modification of Table 18-1. Operating Statuses in HALT Mode	CHAPTER 18 STANDBY FUNCTION
	Modification of figure and note in Figure 18-4. HALT Mode Release by Reset	
	Modification of caution 1 in 18.3.2 (1) STOP mode setting and operating statuses	
	Deletion of caution 1 in Table 18-2. Operating Statuses in STOP Mode	
	Modification of note 2 and addition of remark 2 to Figure 18-5. STOP Mode Release by Interrupt Request Generation	
	Modification of figure and note in Figure 18-6. STOP Mode Release by Reset	
	Modification of description in 18.3.3 (1) SNOOZE mode setting and operating statuses	
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	Modification of description in Table 19-1. Operation Statuses During Reset Period	
	Modification of description and note 2 in Table 19-2. Hardware Statuses After Reset Acknowledgment	
	Modification of description and addition of note to 20.1 Functions of Power-on-reset Circuit	CHAPTER 20 POWER- ON-RESET CIRCUIT
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	Modification of description in 21.1 Functions of Voltage Detector	CHAPTER 21 VOLTAGE DETECTOR
	Modification of Figure 21-4. Timing of Voltage Detector Internal Reset Signal Generation (Option Byte LVIMDS1, LVIMDS0 = 1, 1)	
	Addition of note to 21.4.2 When used as interrupt mode	
	Modification of figure and addition of notes 2, 3 to Figure 21-5. Timing of Voltage Detector Internal Interrupt Signal Generation (Option Byte LVIMDS1, LVIMDS0 = 0, 1)	
	Addition of note to 21.4.3 When used as interrupt and reset mode	
	Modification of figure and addition of note 4 to Figure 21-6. Timing of Voltage Detector Reset Signal and Interrupt Signal Generation (Option Byte LVIMDS1, LVIMDS0 = 1, 0)	
	Modification of Figure 21-7. Processing Procedure After an Interrupt Is Generated	
	Modification of Figure 21-8. Initial Setting of Interrupt and Reset Mode	
	Modification of remark in 22.1 Overview of Safety Functions	CHAPTER 22 SAFETY FUNCTIONS
	Modification of caution and remarks 1 to 4 in Figure 22-7. Format of RAM Parity Error Control Register (RPECTL)	
	Addition of figure and note to Figure 22-10. Invalid access detection area	
	Modification of description and addition of caution to 24.1 Functions of Option Bytes	CHAPTER 24 OPTION BYTE
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	Modification of caution in Figure 24-1. Format of User Option Byte (000C0H/010C0H)	
	Addition of caution 2 to Figure 24-2. Format of User Option Byte (000C1H/010C1H)	
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	Modification of Table 28-5. Operation List	CHAPTER 28 INSTRUCTION SET

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Edition	Description	Chapter
Rev.1.00	Deletion of target in ELECTRICAL SPECIFICATIONS	CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = –40 to +85°C)
	Addition of target products	
	Modification of description and addition of remark 3 to 29.1 Absolute Maximum Ratings	
	Modification of description and note in 29.2.1 X1, XT1 oscillator characteristics	
	Modification of caution in 29.2.2 On-chip oscillator characteristics	
	Modification of note 3 in 29.3.1 Pin characteristics	
	Modification of description and notes in 29.3.2 Supply current characteristics	
	Addition of description and modification of remark in 29.4 AC Characteristics	
	Modification of 29.5.1 Serial array unit	
	Modification to 29.5.2 Serial interface IICA	
	Modification of 29.6.1 A/D converter characteristics	
	Addition of note to 29.6.3 POR circuit characteristics	
	Modification of LVD Detection Voltage of Interrupt & Reset Mode and Supply Voltage Rise Slope in 29.6.4 LVD circuit characteristics	
	Modification of 29.7 Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics	
	Modification of 29.9 Timing Specs for Switching Flash Memory Programming Modes	
	Addition of target products	CHAPTER 30 ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS T_A = –40 to +105°C) (TARGET)
	Addition of note 5 to 30.1 Absolute Maximum Ratings	
	Modification of value and note in 30.2.1 X1, XT1 oscillator characteristics	
	Modification of caution in 30.2.2 On-chip oscillator characteristics	
	Modification of note 3 in 30.3.1 Pin characteristics	
	Modification of description and notes in 30.3.2 Supply current characteristics	
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	Modification of 30.9 Timing Specs for Switching Flash Memory Programming Modes	
	Addition of the products	CHAPTER 31 PACKAGE DRAWINGS

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Rev.0.03	Renamed interval timer (unit) to 12-bit interval timer	Though out
	Renamed V_{LVI} , V_{LVIH} , V_{LVIL} to V_{LVD} , V_{LVDH} , V_{LVDL} (LVD detection voltage)	
	Renamed interrupt source of RAM parity error (RAMTOP) to RPE	
	Modification of 1.2 Ordering Information	CHAPTER 1 OUTLINE
	Addition of Figure 1-1. Part Number, Memory Size, and Package of RL78/G1A	
	Modification of 1.5.1 25-pin products to 1.5.4 64-pin products	
	Modification of Table 2-1. Pin I/O Buffer Power Supplies	CHAPTER 2 PIN FUNCTIONS
	Modification of 2.1 Port Function	
	Modification of description in 2.2 Functions other than port pins (Deletion of Description of Port Function)	
	Addition of remark to 2.3 Pin I/O Circuits and Recommended Connection of Unused Pins	
	Change of Table 2-3. Connection of Unused Pins (64-pin products) (2/2)	
	Addition of note 1 to Figures 3-1, 3-2	CHAPTER 3 CPU ARCHITECTURE
	Addition of caution to Figures 3-1 to 3-4	
	Modification of note in Figures 3-3, 3-4	
	Addition of remark to Table 3-1. Correspondence Between Address Values and Block Numbers in Flash Memory	
	Modification of caution 2 in 3.1.3 Internal data memory space	
	Addition of note 1 to Figures 3-6, 3-7	
	Addition of caution to Figures 3-6 to 3-9	
	Addition of note 1 to Figures 3-8, 3-9	
	Modification of caution 3 in 3.2.1 (3) Stack pointer (SP)	
	Deletion of caution 2 in 3.2.2 General-purpose registers	
	Modification of 4.1 Port Functions	CHAPTER 4 PORT FUNCTIONS
	Modification of block diagrams	
	Addition of description to 4.2.3 Port 2	
	Addition of description to 4.2.12 Port 15	
	Addition of caution to 4.3 Registers Controlling Port Function	
	Modification of Figure 4-39. Format of Port Register (64-pin products)	
	Modification of description and addition of caution to 4.3.3 Pull-up resistor option registers (PUxx)	
	Addition of 4.3.5 Port output mode registers (POMxx)	
	Addition of cautions 1 and 2 to Figure 4-43. Format of Port Mode Control Register	
	Addition of caution 1 to Figure 4-44. Format of A/D Port Configuration Register (ADPC)	
	Modification of description in 4.3.8 Peripheral I/O redirection register (PIOR)	

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	Modification of description in 4.4.1 (2) Input mode and 4.4.3 (2) Input mode	
	Addition of description to 4.4.4 (2) Setting procedure when using I/O pins of IIC00, IIC10, and IIC20 functions	
	Addition of caution to 4.5 Settings of Port Mode Register, and Output Latch When Using Alternate Function	
	Addition of 4.6.2 Notes on specifying the pin settings	
	Addition of 5.1 (1) <2> High-speed on-chip oscillator	CHAPTER 5 CLOCK GENERATOR
	Modification of Figure 5-1. Block Diagram of Clock Generator	
	Modification of caution 1 and addition of cautions 4 to 6 to Figure 5-2. Format of Clock Operation Mode Control Register (CMC)	
	Modification of cautions 1 to 3 in Figure 5-9. Format of High-speed On-chip Oscillator Frequency Select Register (HOCODIV)	
	Modification of note 3 in Figure 5-14. Clock Generator Operation When Power Supply Voltage Is Turned On	
	Addition of description to 5.6.2 Example of setting X1 oscillation clock	
	Addition of description to Figure 5-15. CPU Clock Status Transition Diagram	
	Modification of Table 5-3. CPU Clock Transition and SFR Register Setting Examples	
	Modification and deletion of description in Table 5-4. Changing CPU Clock	
	Modification of remark 2 to 5.6.6 Time required for switchover of CPU clock and system clock	
	Addition of 5.7 Recommended Oscillator Constants	
	Modification of description in 6.1.1 (7) Delay counter	CHAPTER 6 TIMER ARRAY UNIT
	Modification of caution in 6.1.2 (3) Multiple PWM (Pulse Width Modulation) output	
	Modification of Figure 6-2. Internal Block Diagram of Channels of Timer Array Unit 0, 2, 4, 6	
	Addition of Figures 6-3 to 6-6	
	Modification of Table 6-3. Timer Count Register mn (TCRmn) Read Value in Various Operation Modes	
	Modification of note and remark 2 and addition of caution to Figure 6-11. Format of Timer Clock Select register m (TPSm)	
	Modification of Figure 6-12. Format of Timer Mode Register mn (TMRmn)	
	Modification of description in Figure 6-18. Format of Timer Output Enable register m (TOEm)	
	Modification of description in 6.5.1 (1) When operation clock (f_{MCK}) specified by the CKS_{mn0} and CKS_{mn1} bits is selected (CCS_{mn} = 0)	
	Modification of description in Table 6-6. Operations from Count Operation Enabled State to Timer count Register mn (TCRmn) Count Start	
	Addition of title and remark to 6.5.3 Operation of counter	
	Modification of description, remark and addition note to Figure 6-29. Start Timing (In Capture Mode : Input Pulse Interval Measurement)	

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Rev.0.03	Modification of remark 1 in Figure 6-31. Operation Timing (In Capture & One-count Mode : High-level Width Measurement)	CHAPTER 6 TIMER ARRAY UNIT
	Modification of description in 6.6.2 TOMn Pin Output Setting	
	Modification of Figures 6-34 to 6-36	
	Modification of description in Figures 6-43, 6-47, 6-55, 6-59, 6-63, 6-68, 6-78 Example of Set Contents of Registers	
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	Modification of remark in 6.8.3 Operation as multiple PWM output function	
	Modification of 7.4.2 Shifting to HALT/STOP mode after starting operation	CHAPTER 7 REAL-TIME CLOCK
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	Modification of description and addition of note and caution in Table 11-3. A/D Conversion Time Selection	
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	Addition of note and caution 10 to Figure 11-11. Format of Analog Input Channel Specification Register (ADS)	
	Addition of note and caution to 11. 3.10 A/D test register (ADTES)	
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	Addition of note 1 to 11.4 A/D Converter Conversion Operations	
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	Modification of description in 11.8 SNOOZE Mode Function	
	Modification of description in 11.9 (1) Resolution	
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	Addition of note to 12.1.2 UART (UART0 to UART2)	
	Modification of Figures 12-1 and 12-2 block diagram of the serial array unit 0, 1	
	Modification of description in 12.2.2 Lower 8/9 bits of the serial data register mn (SDRmn)	
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	Modification of Figure 12-28, 29, 36, 37, 44, 45, 52, 53, 60, 61, 66, 67, 79, 80, 82, 84, 87, 88, 90, 93, 95, 106, 108, 111, 114, 116 (flow chart)	
	Modification of description in 12.5.7 SNOOZE mode function	
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	Modification of description and note in 12.7.1 LIN transmission and 12.7.2 LIN reception	
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	Modification of Figure 12-100. Flowchart for LIN Transmission	
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	Addition of description	CHAPTER 16 INTERRUPT FUNCTION

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Rev.0.03	Deletion of caution 2 in Figure 16-2. Format of Interrupt Request Flag Registers (IF0L, IF0H, IF1L, IF1H, IF2L, IF2H, IF3L) (128-pin)	CHAPTER 16 INTERRUPT FUNCTION
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Rev.0.03	Modification of description and addition of caution in 29.6.4 LVD circuit characteristics	CHAPTER 29 ELECTRICAL SPECIFICATIONS (T_A = –40 to +85°C) (TARGET)
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	Addition of the products of industrial application	CHAPTER 31 PACKAGE DRAWINGS
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