User's Manual

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RX610 Group

User's Manual: Hardware

RENESAS 32-Bit MCU
RX Family / RX600 Series

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General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins

   Handle unused pins in accord 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

5. Differences between Products

   Before changing from one product to another, i.e. to one with a different part number, confirm that the change will not lead to problems.

   — The characteristics of MPU/MCU in the same group but having different part numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different part numbers, implement a system-evaluation test for each of the products.

How to Use This Manual

1. Objective and Target Users

This manual was written to explain the hardware functions and electrical characteristics of this LSI to the target users, i.e. those who will be using this LSI in the design of application systems. Target users are expected to understand the fundamentals of electrical circuits, logic circuits, and microcomputers.
This manual is organized in the following items: an overview of the product, descriptions of the CPU, system control functions, and peripheral functions, electrical characteristics of the device, and usage notes.

When designing an application system that includes this LSI, take all points to note into account.
Points to note are given in their contexts and at the final part of each section, and in the section giving usage notes.

The list of revisions is a summary of major points of revision or addition for earlier versions. It does not cover all revised items. For details on the revised points, see the actual locations in the manual.

The following documents have been prepared for the RX610 Group. Before using any of the documents, please visit our web site to verify that you have the most up-to-date available version of the document.

Document Type	Contents	Document Title	Document No.
Short Sheet	Overview of hardware	—	—
Data Sheet	Overview of hardware and electrical characteristics	RX610 Group Data Sheet	—
User's manual: Hardware	Hardware specifications (pin assignments, memory maps, peripheral specifications, electrical characteristics, and timing charts) and descriptions of operation	RX610 Group User's manual: Hardware	This User's manual
User's manual: Software	Detailed descriptions of the CPU and instruction set	RX Family Series User's manual: Software	REJ09B0435
Application Note	Examples of applications and sample programs	—	—
Renesas Technical Update	Preliminary report on the specifications of a product, document, etc.	—	—

2. Description of Registers

Each register description includes a bit chart, illustrating the arrangement of bits, and a table of bits, describing the meanings of the bit settings. The standard format and notation for bit charts and tables are described below.

X.X.X ... Register

Address xxxx xxxxxh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	...	...	...	—	—	—	...
Value after reset	x	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	... 0	... Bit	0: ..... 1: Setting prohibited (3)	R/W (1)
b3 to b1	—	Reserved (2)	The read value is 0. The write value should always be 0.	R/W
b4	... 4	... Bit	0: 1:	R
b6, b5	... [1:0]	... Bi	0 0: ..... 0 1: ..... Settings other than above are prohibited. (3)	R/(W)*
b7	—	Reserved	The read value is undefined. Writing to this bit has no effect.	R

(1) R/W: The bit or field is readable and writable.
R/(W): The bit or field is readable and writable. However, writing to this bit or field has some limitations. For details on the limitations, see the description or notes of respective registers.
R: The bit or field is readable. Writing to this bit or field has no effect.

(2) Reserved. Make sure to use the specified value when writing to this bit or field; otherwise, the correct operation is not guaranteed.

(3) Setting prohibited. The correct operation is not guaranteed if such a setting is performed.

3. List of Abbreviations and Acronyms

Abbreviation	Full Form
ACIA	Asynchronous Communication Interface Adapter
bps	bits per second
CRC	Cyclic Redundancy Check
DMA	Direct Memory Access
DMAC	Direct Memory Access Controller
GSM	Global System for Mobile Communications
Hi-Z	High Impedance
IEBus	Inter Equipment Bus
I/O	Input / Output
IrDA	Infrared Data Association
LSB	Least Significant Bit
MSB	Most Significant Bit
NC	Non-Connect
PLL	Phase Locked Loop
PWM	Pulse Width Modulation
SIM	Subscriber Identity Module
UART	Universal Asynchronous Receiver / Transmitter
VCO	Voltage Controlled Oscillator

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Contents

1. Overview

1.1 Features

The RX610 Group is an MCU with the high-speed, high-performance RX CPU as its core.

One basic instruction is executable in one cycle of the system clock. Calculation functionality is further enhanced, with the inclusion of a single-precision floating-point calculation unit as well as a 32-bit multiplier and divider. Additionally, code efficiency is improved by instructions with lengths that are variable in byte units and by an enhanced range of addressing modes.

Timers, serial communication interfaces, I^2C bus interfaces, an A/D converter, and a D/A converter are incorporated as peripheral functions which are essential to embedded devices.

Facilities for connecting external memory are also included, enabling direct connection to memory and peripheral LSI circuits. The on-chip memory is flash memory capable of large-capacity, high-speed operation, and this significantly reduces the cost of configuring systems.

1.1.1 Applications

Office automation equipment and digital industrial equipment

1.1.2 Outline of Specifications

Table 1.1 lists the specifications of the RX610 Group in outline.

Table 1.1 Outline of Specifications

Classification	Module/Function	Description
CPU	CPU	• Maximum operating frequency: 100 MHz • 32-bit RX CPU • Minimum instruction execution time: One instruction in one state (in one system clock cycle) • Address space: 4-Gbyte linear address • Register set of the CPU General purpose: Sixteen 32-bit registers Control: Nine 32-bit registers Accumulator: One 64-bit register • Basic instructions: 73 • Floating-point operation instructions: 8 • DSP instructions: 9 • Addressing modes: 10 • Data arrangement Instructions: Little endian Data: Selectable as little endian or big endian • On-chip 32-bit multiplier: 32 x 32 → 64 bits • On-chip divider: 32 / 32 → 32 bits • Barrel shifter: 32 bits
	FPU	• Single precision (32-bit) floating point • Data types and floating-point exceptions conforming to the IEEE754 standard
Memory	Flash	• Flash capacity: 2 Mbytes (max.) • Three types of on-board programming modes SCI boot mode, user program mode, and user boot mode
	RAM	RAM capacity: 128 Kbytes
	Data flash	Data flash capacity: 32 Kbytes
MCU operating modes		Single-chip mode, on-chip ROM enabled extended mode, and on-chip ROM disabled extended mode
Clock	Clock generation circuit	• One main clock oscillation circuit • Includes a PLL circuit and frequency divider, so the operating frequency is selectable • System clock, peripheral module clock, and external bus clock are independently specifiable. The CPU, DMAC, DTC, ROM, and RAM run in synchronization with the system clock (ICLK): 8 to 100 MHz Peripheral modules run in synchronization with the peripheral module clock (PCLK): 8 to 50 MHz Devices connected to the external bus run in synchronization with the external bus clock (BCLK): 8 to 25 MHz
Power down	Power-down function	• Module stop function • Four power-down modes Sleep mode, all-module clock stop mode, software standby mode, and deep software standby mode

Classification	Module/Function	Description
Interrupt	Interrupt control unit	• Peripheral function interrupts: 116 • External interrupts: 16 (pins IRQ15 to IRQ0) • Non-maskable interrupt: 1 (the NMI pin) • Eight priority orders specifiable
External bus extension		• The external address space can be divided into eight areas (CS0 to CS7), each of which is independently controllable. Capacity of each area: 16 Mbytes Chip-select signals (CS0# to CS7#) can be output for each area. 8-bit or 16-bit bus space can be specified for each area. The data arrangement is selectable as little endian or big endian for each area. (only for data) • Separate bus system • Wait control • Write buffer programming
DMA	DMA controller	• 4-channel DMA transfer available • Activation sources: Software trigger, external interrupts, and interrupt requests from peripheral functions
	Data transfer controller	• Three transfer modes: Normal transfer, repeat transfer, and block transfer • Activated by interrupt requests (chain transfer enabled)
I/O ports	Programmable I/O ports	• I/O pins: 117 (144-pin LQFP), 140 (176-pin LFBGA) • Pull-up resistors: 40 • Open-drain outputs: 16 • 5-V tolerance: 10
Timer	16-bit timer pulse unit	• (16 bits x 6 channels) x 2 units • Up to 16 pulse inputs and outputs • Select from among 7 or 8 counter-input clocks for each channel • Input capture/output compare function • Maximum of 15-phase PWM output possible in PWM mode • Buffered operation, phase counting mode (two-phase encoder input), and cascaded operation (32 bits x 2 channels) settable for each channel • PPG output trigger can be generated • Conversion start trigger for the A/D converter can be generated
	Programmable pulse generator	• (4 bits x 4 groups) x 2 units • Provides pulse outputs by using the TPU output as a trigger • Maximum of 32-bit pulse output possible
	8-bit timer	• (8 bits x 2 channels) x 2 units • Select from among 8 clock sources (7 internal clocks and 1 external clock) • Allows the output of pulse trains with a desired duty cycle or PWM signals • Cascading of 2 channels enables it to be used as a 16-bit timer • Generation of trigger to start A/D converter conversion • Capable of generating baud rate clock for SCI5 and SCI6
	Compare match timer	• (16 bits x 2 channels) x 2 units • Select from among 4 counter-input clocks

Classification	Module/Function	Description
Watchdog timer		• 8 bits x 1 channel • Select from among 8 counter-input clocks • Switchable between watchdog timer mode and interval timer mode
Communication function	Serial communication interface	• 7 channels • Serial communication mode: Asynchronous, clock synchronous, and smart card interface • On-chip baud rate generator allows any bit rate to be selected • Choice of LSB-first or MSB-first transfer • Enables average transfer rate clock input from TMR (SCI5, SCI6)
	I^2C bus interface	• 2 channels • Communication format I^2C bus format/SMBus format Master/slave selectable (For multi-master operation) • Maximum transfer rate: 1 Mbps
A/D converter		• 4 units (1 unit x 4 channels) • 10-bit resolution • Conversion time: 1.0 μs per channel (at 50-MHz (PCLK) operation) • Two kinds of operating modes Single mode and scan mode (single scan mode or continuous scan mode) • Sample-and-hold function • Three types of A/D conversion start Conversion can be started by software, a conversion start trigger by the timer (TPU or TMR), or an external trigger signal.
D/A converter		• 2 channels • 10-bit resolution • Output voltage: 0 V to VREFH
CRC calculator		• CRC code generation for arbitrary data lengths in 8-bit units • One of three generating polynomials selectable $X^8 + X^2 + X + 1$, $X^{16} + X^{15} + X^2 + 1$, $X^{16} + X^{12} + X^5 + 1$ • CRC code generation for LSB-first or MSB-first communication selectable
Operating frequency		8 to 100 MHz
Power supply voltage		V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6V, VREFH = 3.0 to AV_{CC}
Supply current		50 mA (typ.) (regular specifications)
Operating temperature		−20 to +85 C (regular specifications), −40 to +85 C (wide-range specifications)
Package		176-pin LFBGA (PLBG0176GA-A) 144-pin LQFP (PLQP0144KA-A)

1.2 List of Products

Table 1.2 is the list of products, and figure 1.1 shows how to read the product part no.

Table 1.2 List of Products

Part No.	Package	ROM Capacity	RAM Capacity	Data Flash	Operating Frequency (Max.)
R5F56108VNFP	PLQP0144KA-A	2 Mbytes	128 Kbytes	32 Kbytes	100 MHz
R5F56108WNBG	PLBG0176GA-A	2 Mbytes	128 Kbytes	32 Kbytes	100 MHz
R5F56107VNFP	PLQP0144KA-A	1.5 Mbytes	128 Kbytes	32 Kbytes	100 MHz
R5F56107WNBG	PLBG0176GA-A	1.5 Mbytes	128 Kbytes	32 Kbytes	100 MHz
R5F56106VNFP	PLQP0144KA-A	1 Mbyte	128 Kbytes	32 Kbytes	100 MHz
R5F56106WNBG	PLBG0176GA-A	1 Mbyte	128 Kbytes	32 Kbytes	100 MHz
R5F56104VNFP	PLQP0144KA-A	768 Kbytes	128 Kbytes	32 Kbytes	100 MHz
R5F56104WNBG	PLBG0176GA-A	768 Kbytes	128 Kbytes	32 Kbytes	100 MHz

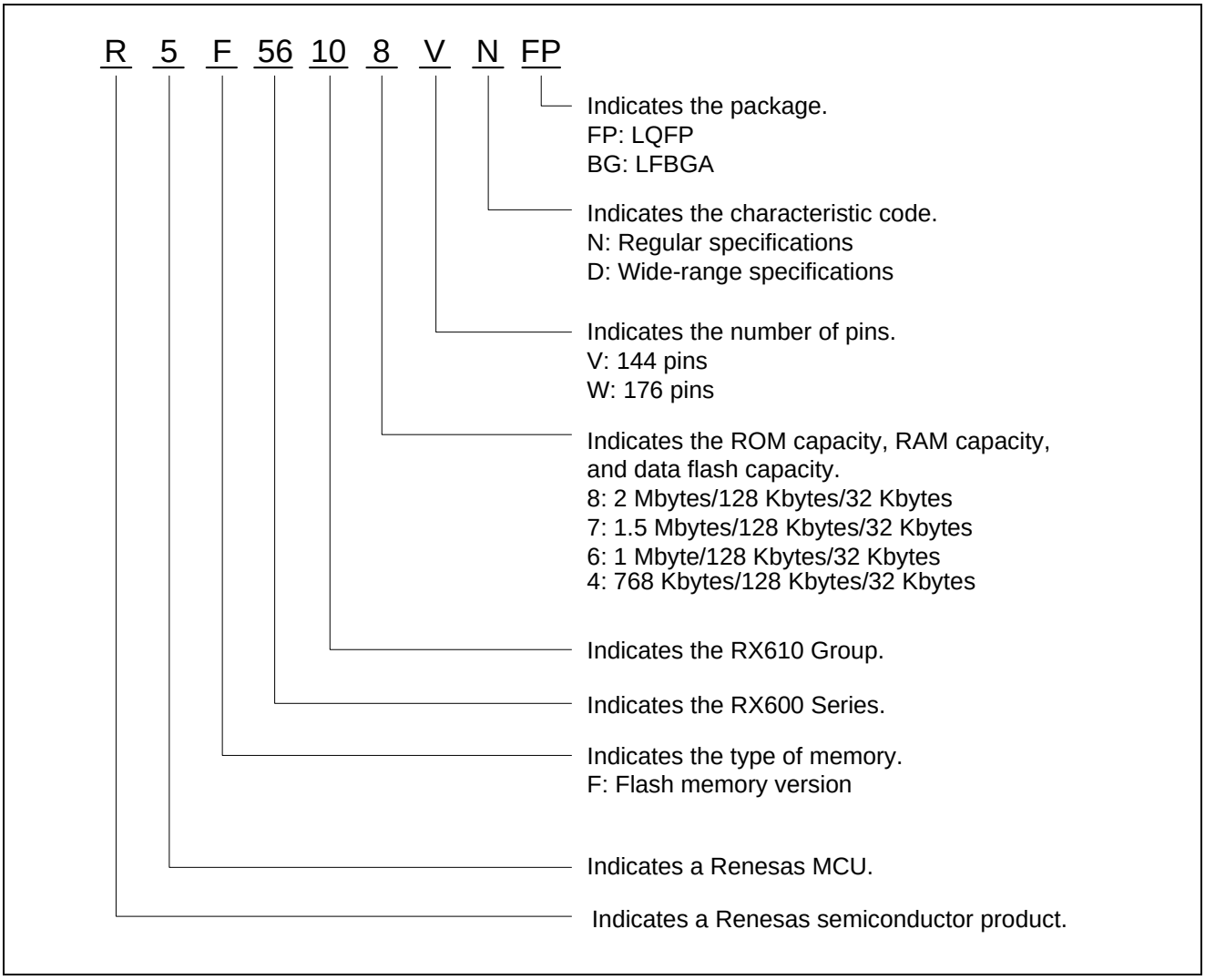
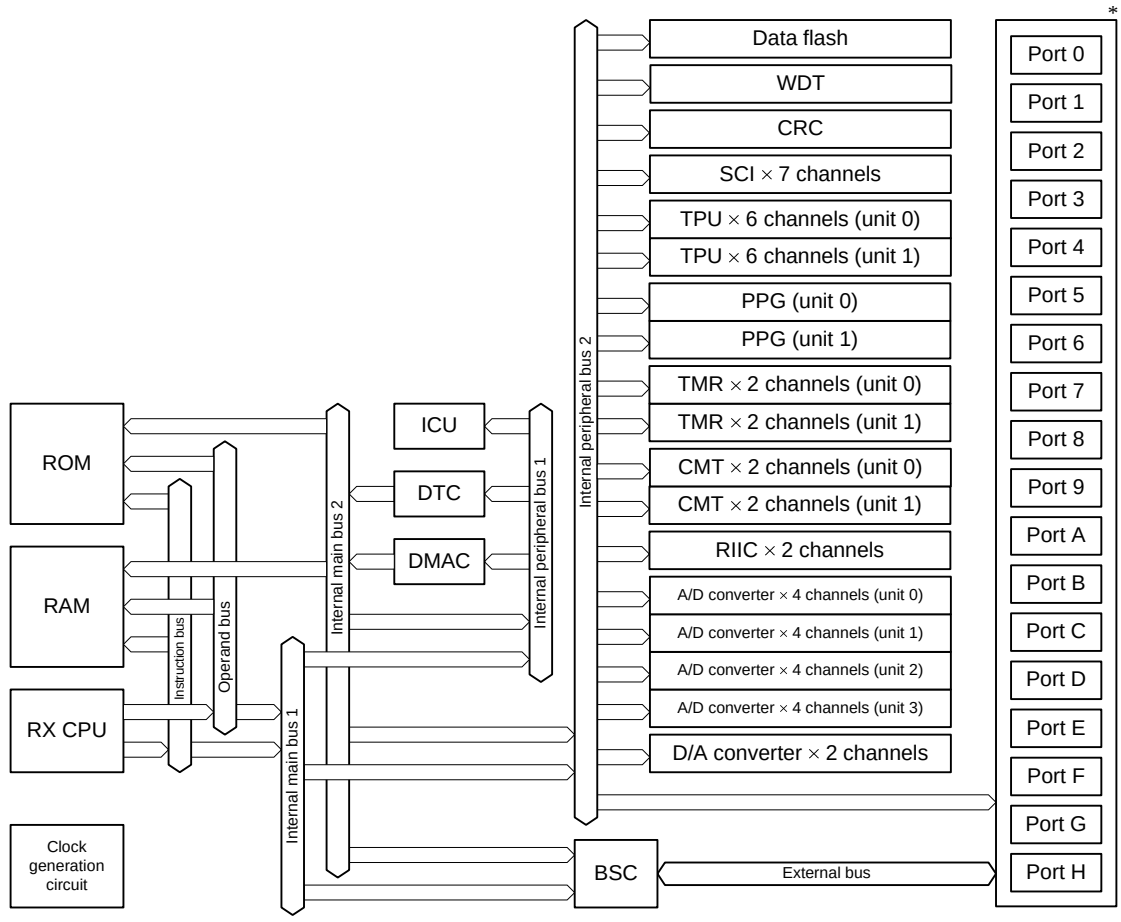


Figure 1.1 How to Read the Product Part No.

1.3 Block Diagram

Figure 1.2 shows a block diagram of the RX610 Group.



[Legend]

ICU:	Interrupt control unit	SCI:	Serial communications interfaces
DTC:	Data transfer controller	TPU:	16-bit timer pulse unit
DMAC:	DMA controller	PPG:	Programmable pulse generator
BSC:	Bus controller	TMR:	8-bit timer
WDT:	Watchdog timer	CMT:	Compare match timer
CRC:	CRC (Cyclic Redundancy Check) calculator	RIIC:	I^2C bus interface

Note: * Ports F and H are not included in the 144-pin LQFP package.

Figure 1.2 Block Diagram

1.4 Pin Assignments

Figures 1.3 and 1.4 show the pin assignments of the 176-pin LFBGA and the 144-pin LQFP, respectively. Figure 1.5 (assistance diagram) shows the pin assignment the 144-pin LQFP. Tables 1.3 and 1.4 show the lists of pins and pin functions of the 176-pin LFBGA and the 144-pin LQFP, respectively.

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	
15	PE0	PE2	PE5	PG5	VSS	PA1	PA5	PH1	P70	P74	PB3	PB6	PC1	VCC	PC3	15
14	PD6	PE1	PE3	PE7	PG6	PA0	PA4	PH0	VCC	P73	PB4	PC0	PC2	PC4	PC5	14
13	PD4	PD5	PD7	PE6	PG7	PA2	PA6	VSS	P71	PB1	PB5	VSS	PH2	PC6	P75	13
12	P63	VCC	VSS	PE4	VCC	PA3	PA7	PB0	P72	PB2	PB7	PC7	P76	P77	PH3	12
11	P60	P61	P62	P64								PH4	VSS	VCC	PH5	11
10	PD1	PD0	PD2	PD3								P51	P50	PH6	PH7	10
9	PG2	PG1	PG3	PG4								P81	P80	P52	P53	9
8	P97	P96	BSCANP	PG0								P83	VSS	VCC	P82	8
7	P93	P92	P94	P95								P57	P56	P54	P55	7
6	P90	VCC	VSS	P91								P37	P36	P84	P35	6
5	P46	P45	P47	P44								P14	P12	P11	P10	5
4	P43	P42	P41	P40	P00	MDE	P86	VSS	P34	P33	PF0	VSS	P16	P15	P13	4
3	VREFL	VREFH	P03	AVSS	EMLE	VCL	P85	EXTAL	PF6	P32	PF3	VCC	P20	PLLVCC	PLLVSS	3
2	AVCC	P05	P66	P01	WDTOVF#	MD0	XTAL	NMI	PF4	P30	PF1	P26	P24	P22	P17	2
1	P04	P67	P02	P65	VSS	MD1	RESN	VCC	PF5	P31	PF2	P27	P25	P23	P21	1
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	

RX610Group
PLBG0176GA-A
(176-pin LFBGA)
(Upper perspective view)

Figure 1.3 Pin Assignment of the 176-pin LFBGA

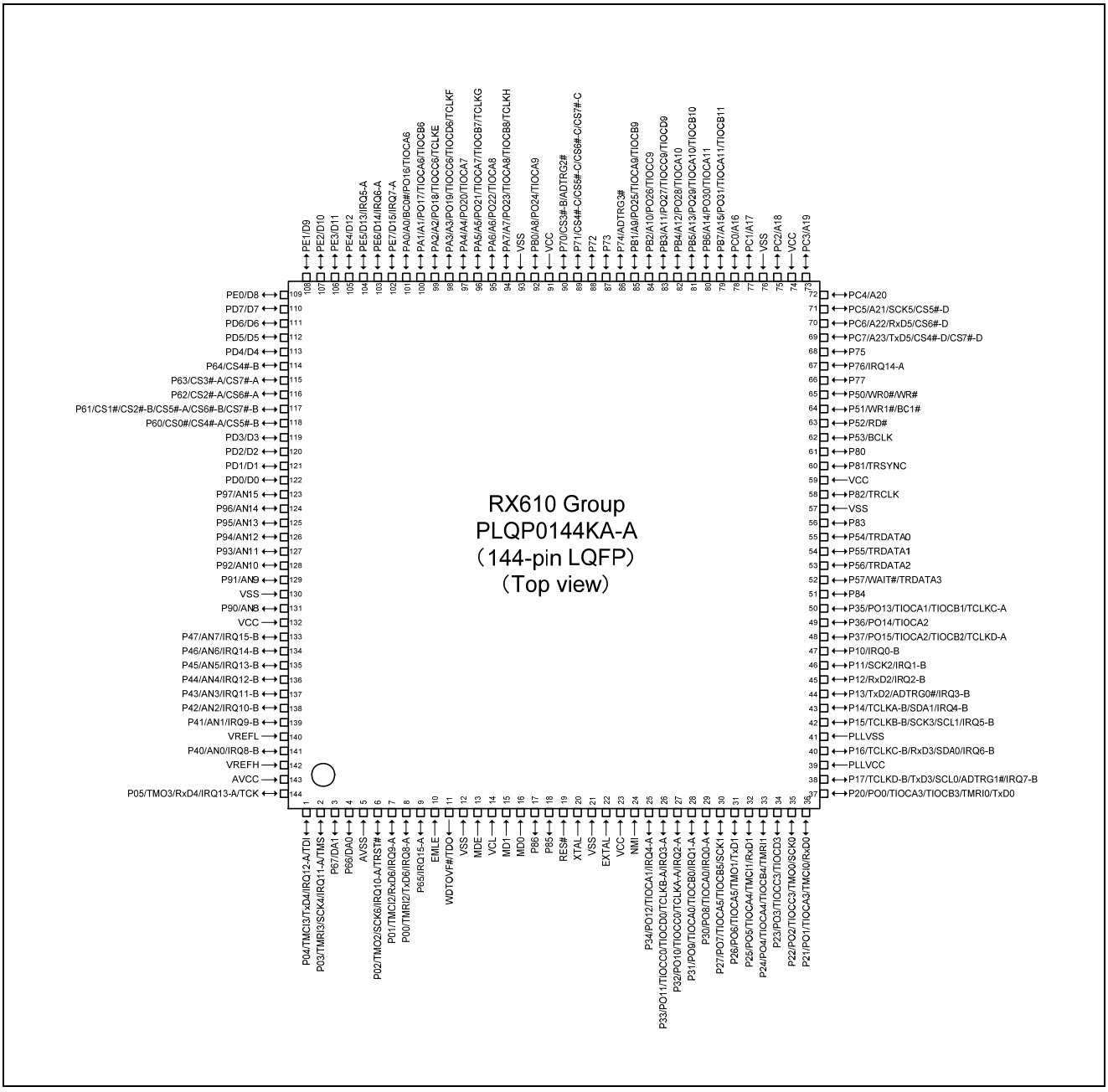


Figure 1.4 Pin Assignment of the 144-Pin LQFP

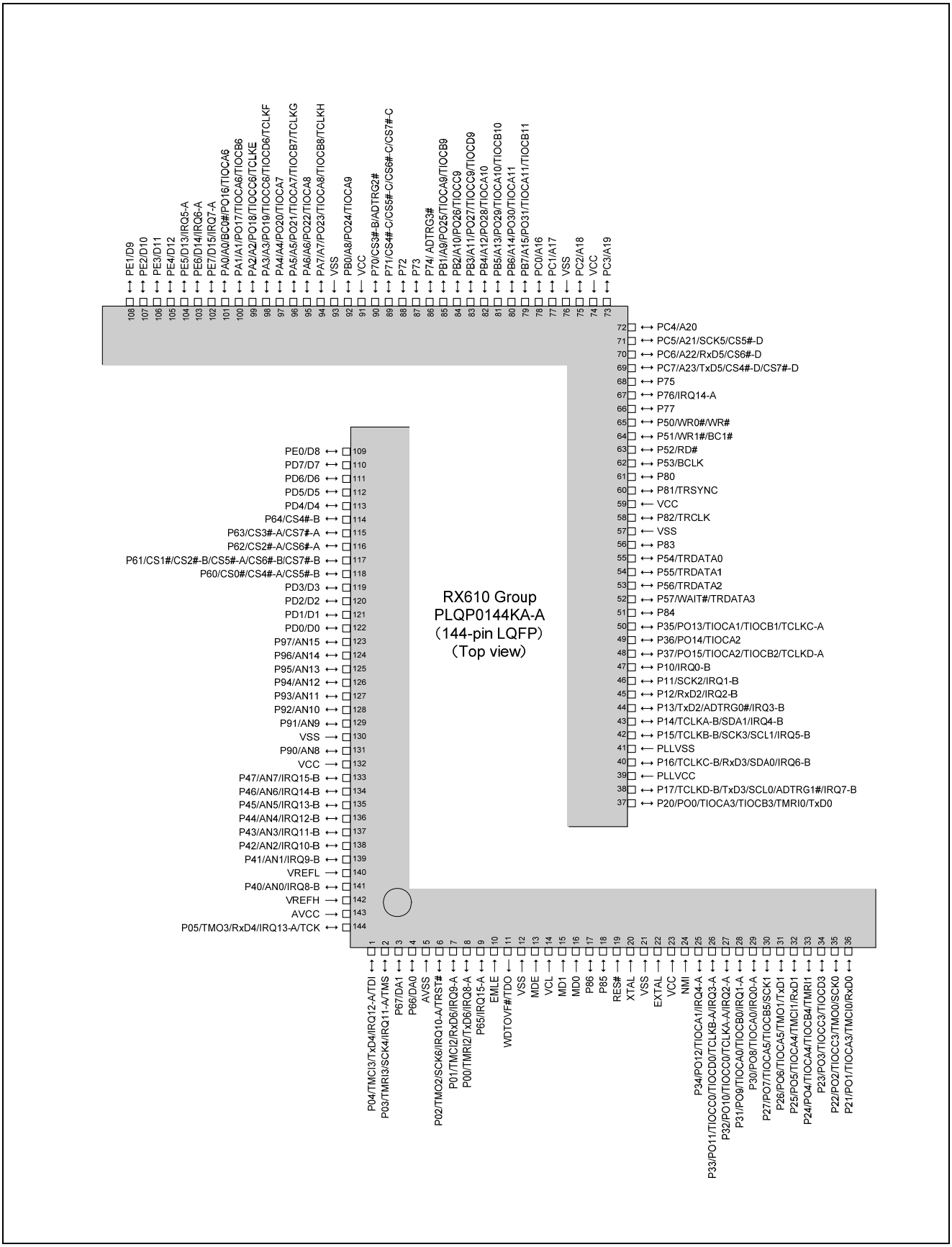


Figure 1.5 Pin Assignment (Assistance Diagram) of the 144-Pin LQFP

Table 1.3 List of Pins and Pin Functions (176-Pin LFBGA)

Pin No. 176-Pin LFBGA	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
A1		P04	IRQ12-A		TMCI3	TxD4		TDI
A2	AVCC							
A3	VREFL							
A4		P43	IRQ11-B				AN3	
A5		P46	IRQ14-B				AN6	
A6		P90					AN8	
A7		P93					AN11	
A8		P97					AN15	
A9		PG2						
A10		PD1		D1				
A11		P60		CS0#/ CS4#-A/ CS5#-B				
A12		P63		CS3#-A/ CS7#-A				
A13		PD4		D4				
A14		PD6		D6				
A15		PE0		D8				
B1		P67					DA1	
B2		P05	IRQ13-A		TMO3	RxD4		TCK
B3	VREFH							
B4		P42	IRQ10-B				AN2	
B5		P45	IRQ13-B				AN5	
B6	VCC							
B7		P92					AN10	
B8		P96					AN14	
B9		PG1						
B10		PD0		D0				
B11		P61		CS1#/ CS2#-B/ CS5#-A/ CS6#-B/ CS7#-B				
B12	VCC							
B13		PD5		D5				
B14		PE1		D9				
B15		PE2		D10				
C1		P02	IRQ10-A		TMO2	SCK6		TRST#
C2		P66					DA0	
C3		P03	IRQ11-A		TMRI3	SCK4		TMS
C4		P41	IRQ9-B				AN1	
C5		P47	IRQ15-B				AN7	

Pin No. 176-Pin LFBGA	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
C6	VSS							
C7		P94					AN12	
C8	BSCANP							
C9		PG3						
C10		PD2		D2				
C11		P62		CS2#-A/ CS6#-A				
C12	VSS							
C13		PD7		D7				
C14		PE3		D11				
C15		PE5	IRQ5-A	D13				
D1		P65	IRQ15-A					
D2		P01	IRQ9-A		TMCI2	RxD6		
D3	AVSS							
D4		P40	IRQ8-B				AN0	
D5		P44	IRQ12-B				AN4	
D6		P91					AN9	
D7		P95					AN13	
D8		PG0						
D9		PG4						
D10		PD3		D3				
D11		P64		CS4#-B				
D12		PE4		D12				
D13		PE6	IRQ6-A	D14				
D14		PE7	IRQ7-A	D15				
D15		PG5						
E1	VSS							
E2	WDTOVF#							TDO
E3	EMLE							
E4		P00	IRQ8-A		TMRI2	TxD6		
E12	VCC							
E13		PG7						
E14		PG6						
E15	VSS							
F1	MD1							
F2	MD0							
F3	VCL							
F4	MDE							
F12		PA3		A3	PO19/ TIOCC6/ TIOCD6/ TCLKF			

Pin No. 176-Pin LFBGA	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
F13		PA2		A2	PO18/ TIOCC6/ TCLKE			
F14		PA0		A0/BC0#	PO16/ TIOCA6			
F15		PA1		A1	PO17/ TIOCA6/ TIOCB6			
G1	RES#							
G2	XTAL							
G3		P85						
G4		P86						
G12		PA7		A7	PO23/ TIOCA8/ TIOCB8/ TCLKH			
G13		PA6		A6	PO22/ TIOCA8			
G14		PA4		A4	PO20/ TIOCA7			
G15		PA5		A5	PO21/ TIOCA7/ TIOCB7/ TCLKG			
H1	VCC							
H2			NMI					
H3	EXTAL							
H4	VSS							
H12		PB0		A8	PO24/ TIOCA9			
H13	VSS							
H14		PH0						
H15		PH1						
J1		PF5						
J2		PF4						
J3		PF6						
J4		P34	IRQ4-A		PO12/ TIOCA1			
J12		P72						
J13		P71		CS4#-C/ CS5#-C/ CS6#-C/ CS7#-C				
J14	VCC							

Pin No. 176-Pin LFBGA	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
J15		P70		CS3#-B			ADTRG2#	
K1		P31	IRQ1-A		PO9/ TIOCA0/ TIOCB0			
K2		P30	IRQ0-A		PO8/ TIOCA0			
K3		P32	IRQ2-A		PO10/ TIOCC0/ TCLKA-A			
K4		P33	IRQ3-A		PO11/ TIOCC0/ TIOCD0/ TCLKB-A			
K12		PB2		A10	PO26/ TIOCC9			
K13		PB1		A9	PO25/ TIOCA9/ TIOCB9			
K14		P73						
K15		P74					ADTRG3#	
L1		PF2						
L2		PF1						
L3		PF3						
L4		PF0						
L12		PB7		A15	PO31/ TIOCA11/ TIOCB11			
L13		PB5		A13	PO29/ TIOCA10/ TIOCB10			
L14		PB4		A12	PO28/ TIOCA10			
L15		PB3		A11	PO27/ TIOCC9/ TIOCD9			
M1		P27			PO7/ TIOCA5/ TIOCB5	SCK1		
M2		P26			PO6/ TIOCA5/ TMO1	TxD1		
M3	VCC							
M4	VSS							
M5		P14	IRQ4-B		TCLKA-B	SDA1		

Pin No. 176-Pin LFBGA	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
M6		P37			PO15/ TIOCA2/ TIOCB2/ TCLKD-A			
M7		P57		WAIT#				TRDATA3
M8		P83						
M9		P81						TRSYNC
M10		P51		WR1#/BC1#				
M11		PH4						
M12		PC7		A23/ CS4#-D/ CS7#-D		TxD5		
M13	VSS							
M14		PC0		A16				
M15		PB6		A14	PO30/ TIOCA11			
N1		P25			PO5/ TIOCA4/ TMCI1	RxD1		
N2		P24			PO4/ TIOCA4/ TIOCB4/ TMRI1			
N3		P20			PO0/ TIOCA3/ TIOCB3/ TMRI0	TxD0		
N4		P16	IRQ6-B		TCLKC-B	RxD3/SDA0		
N5		P12	IRQ2-B			RxD2		
N6		P36			PO14/ TIOCA2			
N7		P56						TRDATA2
N8	VSS							
N9		P80						
N10		P50		WR0#/WR#				
N11	VSS							
N12		P76	IRQ14-A					
N13		PH2						
N14		PC2		A18				
N15		PC1		A17				
P1		P23			PO3/ TIOCC3/ TIOCD3			

Pin No. 176-Pin LFBGA	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
P2		P22			PO2/ TIOCC3/ TMO0	SCK0		
P3	PLLVCC							
P4		P15	IRQ5-B		TCLKB-B	SCK3/SCL1		
P5		P11	IRQ1-B			SCK2		
P6		P84						
P7		P54						TRDATA0
P8	VCC							
P9		P52		RD#				
P10		PH6						
P11	VSS							
P12		P77						
P13		PC6		A22/ CS6#-D		RxD5		
P14		PC4		A20				
P15	VCC							
R1		P21			PO1/ TIOCA3/ TMCI0	RxD0		
R2		P17	IRQ7-B		TCLKD-B	TxD3/SCL0	ADTRG1#	
R3	PLLVSS							
R4		P13	IRQ3-B			TxD2	ADTRG0#	
R5		P10	IRQ0-B					
R6		P35			PO13/ TIOCA1/ TIOCB1/ TCLKC-A			
R7		P55						TRDATA1
R8		P82						TRCLK
R9	BCLK	P53						
R10		PH7						
R11		PH5						
R12		PH3						
R13		P75						
R14		PC5		A21/ CS5#-D		SCK5		
R15		PC3		A19				

Table 1.4 List of Pins and Pin Functions (144-Pin LQFP)

Pin No. 144-Pin LQFP	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
1		P04	IRQ12-A		TMCI3	TxD4		TDI
2		P03	IRQ11-A		TMRI3	SCK4		TMS
3		P67					DA1	
4		P66					DA0	
5	AVSS							
6		P02	IRQ10-A		TMO2	SCK6		TRST#
7		P01	IRQ9-A		TMCI2	RxD6		
8		P00	IRQ8-A		TMRI2	TxD6		
9		P65	IRQ15-A					
10	EMLE							
11	WDTOVF#							TDO
12	VSS							
13	MDE							
14	VCL							
15	MD1							
16	MD0							
17		P86						
18		P85						
19	RES#							
20	XTAL							
21	VSS							
22	EXTAL							
23	VCC							
24			NMI					
25		P34	IRQ4-A		PO12/ TIOCA1			
26		P33	IRQ3-A		PO11/ TIOCC0/ TIOCD0/ TCLKB-A			
27		P32	IRQ2-A		PO10/ TIOCC0/ TCLKA-A			
28		P31	IRQ1-A		PO9/ TIOCA0/ TIOCB0			
29		P30	IRQ0-A		PO8/ TIOCA0			
30		P27			PO7/ TIOCA5/ TIOCB5	SCK1		
31		P26			PO6/ TIOCA5/ TMO1	TxD1		

Pin No. 144-Pin LQFP	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
32		P25			PO5/ TIOCA4/ TMCI1	RxD1		
33		P24			PO4/ TIOCA4/ TIOCB4/ TMRI1			
34		P23			PO3/ TIOCC3/ TIOCD3			
35		P22			PO2/ TIOCC3/ TMO0	SCK0		
36		P21			PO1/ TIOCA3/ TMCI0	RxD0		
37		P20			PO0/ TIOCA3/ TIOCB3/ TMRI0	TxD0		
38		P17	IRQ7-B		TCLKD-B	TxD3/SCL0	ADTRG1#	
39	PLLVCC							
40		P16	IRQ6-B		TCLKC-B	RxD3/SDA0		
41	PLLVSS							
42		P15	IRQ5-B		TCLKB-B	SCK3/SCL1		
43		P14	IRQ4-B		TCLKA-B	SDA1		
44		P13	IRQ3-B			TxD2	ADTRG0#	
45		P12	IRQ2-B			RxD2		
46		P11	IRQ1-B			SCK2		
47		P10	IRQ0-B					
48		P37			PO15/ TIOCA2/ TIOCB2/ TCLKD-A			
49		P36			PO14/ TIOCA2			
50		P35			PO13/ TIOCA1/ TIOCB1/ TCLKC-A			
51		P84						
52		P57		WAIT#				TRDATA3
53		P56						TRDATA2
54		P55						TRDATA1

Pin No. 144-Pin LQFP	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
55		P54						TRDATA0
56		P83						
57	VSS							
58		P82						TRCLK
59	VCC							
60		P81						TRSYNC#
61		P80						
62	BCLK	P53						
63		P52		RD#				
64		P51		WR1#/BC1#				
65		P50		WR0#/WR#				
66		P77						
67		P76	IRQ14-A					
68		P75						
69		PC7		A23/ CS4#-D/ CS7#-D		TxD5		
70		PC6		A22/ CS6#-D		RxD5		
71		PC5		A21/ CS5#-D		SCK5		
72		PC4		A20				
73		PC3		A19				
74	VCC							
75		PC2		A18				
76	VSS							
77		PC1		A17				
78		PC0		A16				
79		PB7		A15	PO31/ TIOCA11/ TIOCB11			
80		PB6		A14	PO30/ TIOCA11			
81		PB5		A13	PO29/ TIOCA10/ TIOCB10			
82		PB4		A12	PO28/ TIOCA10			
83		PB3		A11	PO27/ TIOCC9/ TIOCD9			
84		PB2		A10	PO26/ TIOCC9			

Pin No. 144-Pin LQFP	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
85		PB1		A9	PO25/ TIOCA9/ TIOCB9			
86		P74					ADTRG3#	
87		P73						
88		P72						
89		P71		CS4#-C/ CS5#-C/ CS6#-C/ CS7#-C				
90		P70		CS3#-B			ADTRG2#	
91	VCC							
92		PB0		A8	PO24/ TIOCA9			
93	VSS							
94		PA7		A7	PO23/ TIOCA8/ TIOCB8/ TCLKH			
95		PA6		A6	PO22/ TIOCA8			
96		PA5		A5	PO21/ TIOCA7/ TIOCB7/ TCLKG			
97		PA4		A4	PO20/ TIOCA7			
98		PA3		A3	PO19/ TIOCC6/ TIOCD6/ TCLKF			
99		PA2		A2	PO18/ TIOCC6/ TCLKE			
100		PA1		A1	PO17/ TIOCA6/ TIOCB6			
101		PA0		A0/BC0#	PO16/ TIOCA6			
102		PE7	IRQ7-A	D15				
103		PE6	IRQ6-A	D14				
104		PE5	IRQ5-A	D13				
105		PE4		D12				
106		PE3		D11				
107		PE2		D10				

Pin No. 144-Pin LQFP	Power Supply Clock System Control	I/O Port	Interrupt	External Bus	Timer	Communi-cation	Analog	On-Chip Emulator
108		PE1		D9				
109		PE0		D8				
110		PD7		D7				
111		PD6		D6				
112		PD5		D5				
113		PD4		D4				
114		P64		CS4#-B				
115		P63		CS3#-A/ CS7#-A				
116		P62		CS2#-A/ CS6#-A				
117		P61		CS1#/ CS2#-B/ CS5#-A/ CS6#-B/ CS7#-B				
118		P60		CS0#/ CS4#-A/ CS5#-B				
119		PD3		D3				
120		PD2		D2				
121		PD1		D1				
122		PD0		D0				
123		P97					AN15	
124		P96					AN14	
125		P95					AN13	
126		P94					AN12	
127		P93					AN11	
128		P92					AN10	
129		P91					AN9	
130	VSS							
131		P90					AN8	
132	VCC							
133		P47	IRQ15-B				AN7	
134		P46	IRQ14-B				AN6	
135		P45	IRQ13-B				AN5	
136		P44	IRQ12-B				AN4	
137		P43	IRQ11-B				AN3	
138		P42	IRQ10-B				AN2	
139		P41	IRQ9-B				AN1	
140	VREFL							
141		P40	IRQ8-B				AN0	
142	VREFH							
143	AVCC							
144		P05	IRQ13-A		TMO3	RxD4		TCK

1.5 Pin Functions

Table 1.5 lists the pin functions.

Table 1.5 Pin Functions

Classifications	Pin Name	I/O	Description
Power supply	VCC	Input	Power supply pin. Connect it to the system power supply.
	VCL	Input	Connect this pin to VSS via a 0.1-μF capacitor. The capacitor should be placed close to the pin.
	VSS	Input	Ground pin. Connect it to the system power supply (0 V).
	PLLVCC	Input	Power supply pin for the PLL circuit. Connect it to the system power supply.
	PLLVSS	Input	Ground pin for the PLL circuit
Clock	XTAL	Input	Pins for a crystal resonator. An external clock signal can be input through the EXTAL pin.
	EXTAL	Input	
	BCLK	Output	Outputs the system clock for external devices.
Operating mode control	MD0, MD1, MDE	Input	Pins for setting the operating mode. The signal levels on these pins must not be changed during operation.
System control	RES#	Input	Reset signal input pin. This LSI enters the reset state when this signal goes low.
	EMLE	Input	Input pin to enable on-chip emulator signal. When the on-chip emulator is used, this pin should be driven high. When not used, it should be driven low.
	BSCANP	Input	Input pin to enable boundary-scan signal. When this pin is driven high, the boundary scan is enabled. When the boundary scan is not used, this pin should be driven low.
On-chip emulator	TRST#	Input	On-chip emulator pins. When the EMLE pin is driven high, these pins are dedicated for the on-chip emulator.
	TMS	Input	
	TDI	Input	
	TCK	Input	
	TDO	Output	
	TRCLK	Output	This pin outputs the clock for synchronization with the trace data.
	TRSYNC	Output	This pin indicates that output from the TRDATA0 to TRDATA3 pins is valid.
	TRDATA0 to TRDATA3	Output	These pins output the trace information.
Address bus	A0 to A23	Output	Output pins for the address
Data bus	D0 to D15	I/O	Input and output pins for the bidirectional data bus

Classifications	Pin Name	I/O	Description
Bus control	RD#	Output	Strobe signal which indicates that reading from the external bus interface space is in progress.
	WR0#	Output	Strobe signal which indicates that the lower-order byte (D0 to D7) is valid in writing to the external bus interface space, in byte strobe mode.
	WR1#	Output	Strobe signal which indicates that the higher-order byte (D8 to D15) is valid in writing to the external bus interface space, in byte strobe mode.
	WR#	Output	Strobe signal which indicates that writing to the external bus interface space is in progress, in 1-write strobe mode.
	BC0#	Output	Strobe signal which indicates that the lower-order byte (D0 to D7) is valid in access to the external bus interface space, in 1-write strobe mode.
	BC1#	Output	Strobe signal which indicates that the higher-order byte (D8 to D15) is valid in access to the external bus interface space, in 1- write strobe mode.
	CS0#, CS1# CS2#-A/CS2#-B CS3#-A/CS3#-B CS4#-A/CS4#-B/ CS4#-C/CS4#-D CS5#-A/CS5#-B/ CS5#-C/CS5#-D CS6#-A/CS6#-B/ CS6#-C/CS6#-D CS7#-A/CS7#-B/ CS7#-C/CS7#-D	Output	Select signals for areas 0 to 7
	WAIT#	Input	Requests wait cycles in access to the external space

Classifications	Pin Name	I/O	Description
Interrupt	NMI	Input	Non-maskable interrupt request signal
	IRQ0-A/IRQ0-B IRQ1-A/IRQ1-B IRQ2-A/IRQ2-B IRQ3-A/IRQ3-B IRQ4-A/IRQ4-B IRQ5-A/IRQ5-B IRQ6-A/IRQ6-B IRQ7-A/IRQ7-B IRQ8-A/IRQ8-B IRQ9-A/IRQ9-B IRQ10-A/IRQ10-B IRQ11-A/IRQ11-B IRQ12-A/IRQ12-B IRQ13-A/IRQ13-B IRQ14-A/IRQ14-B IRQ15-A/IRQ15-B	Input	Maskable request signals
16-bit timer pulse unit	TIOCA0, TIOCB0 TIOCC0, TIOCD0	I/O	Signals for TGRA0 to TGRD0. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA1, TIOCB1	I/O	Signals for TGRA1 and TGRB1. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA2, TIOCB2	I/O	Signals for TGRA2 and TGRB2. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA3, TIOCB3 TIOCC3, TIOCD3	I/O	Signals for TGRA3 to TGRD3. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA4, TIOCB4	I/O	Signals for TGRA4 and TGRB4. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA5, TIOCB5	I/O	Signals for TGRA5 and TGRB5. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA6, TIOCB6 TIOCC6, TIOCD6	I/O	Signals for TGRA6 to TGRD6. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA7, TIOCB7	I/O	Signals for TGRA7 and TGRB7. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA8, TIOCB8	I/O	Signals for TGRA8 and TGRB8. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA9, TIOCB9 TIOCC9, TIOCD9	I/O	Signals for TGRA9 to TGRD9. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA10, TIOCB10	I/O	Signals for TGRA10 and TGRB10. These pins are used as input capture inputs, output compare outputs, or PWM outputs.
	TIOCA11, TIOCB11	I/O	Signals for TGRA11 and TGRB11. These pins are used as input capture inputs, output compare outputs, or PWM outputs.

Classifications	Pin Name	I/O	Description
16-bit timer pulse unit	TCLKA-A/TCLKA-B TCLKB-A/TCLKB-B TCLKC-A/TCLKC-B TCLKD-A/TCLKD-B TCLKE, TCLKF TCLKG, TCLKH	Input	Input pins for external clock signals
Programmable pulse generator	PO0 to PO31	Output	Output pins for the pulse signals
8-bit timer	TMO0 to TMO3	Output	Output pins for the compare match signals
	TMCI0 to TMCI3	Input	Input pins for the external clock signals that drive for the counters
	TMRI0 to TMRI3	Input	Input pins for the counter-reset signals
Watchdog timer	WDTOVF#	Output	Output pin for the counter-overflow signal in watchdog-timer mode
Serial communication interface	TxD0, TxD1, TxD2, TxD3, TxD4, TxD5, TxD6	Output	Output pins for data transmission
	RxD0, RxD1, RxD2, RxD3, RxD4, RxD5, RxD6	Input	Input pins for data reception
	SCK0, SCK1, SCK2, SCK3, SCK4, SCK5, SCK6	I/O	Input/output pins for clock signals
I^2C bus interface	SCL0, SCL1	I/O	Input/output pins for RIIC clocks. Bus can be directly driven by the NMOS open drain output.
	SDA0, SDA1	I/O	Input/output pins for RIIC data. Bus can be directly driven by the NMOS open drain output.
A/D converter	AN0 to AN15	Input	Input pins for the analog signals to be processed by the A/D converter
	ADTRG0# to ADTRG3#	Input	Input pins for the external trigger signals that start the A/D conversion
D/A converter	DA0, DA1	Output	Output pins for the analog signals from the D/A converter

Classifications	Pin Name	I/O	Description
Analog power supply	AVCC	Input	Analog power supply pin for the A/D and D/A converters. When the A/D and D/A converters are not in use, connect this pin to the system power supply.
	AVSS	Input	Ground pin for the A/D and D/A converters. Connect this pin to the system power supply (0 V).
	VREFH	Input	Reference power supply pin for the A/D and D/A converters. When the A/D and D/A converters are not in use, connect this pin to the system power supply.
	VREFL	Input	Reference ground pin for the A/D and D/A converters. Make sure to connect this pin to the analog reference power supply (0 V). When the A/D and D/A converters are not in use, connect this pin to the system power supply (0 V). For details, see section 23.6.7, Ranges of Settings for Analog Power Supply and Other Pins.
I/O ports	P00 to P05	I/O	6-bit input/output pins
	P10 to P17	I/O	8-bit input/output pins
	P20 to P27	I/O	8-bit input/output pins
	P30 to P37	I/O	8-bit input/output pins
	P40 to P47	I/O	8-bit input/output pins
	P50 to P57	I/O	8-bit input/output pins. (P53 is an input-only pin.)
	P60 to P67	I/O	8-bit input/output pins
	P70 to P77	I/O	8-bit input/output pins
	P80 to P86	I/O	7-bit input/output pins
	P90 to P97	I/O	8-bit input/output pins
	PA0 to PA7	I/O	8-bit input/output pins
	PB0 to PB7	I/O	8-bit input/output pins
	PC0 to PC7	I/O	8-bit input/output pins
	PD0 to PD7	I/O	8-bit input/output pins
	PE0 to PE7	I/O	8-bit input/output pins
	PF0 to PF6	I/O	7-bit input/output pins
	PG0 to PG7	I/O	8-bit input/output pins
	PH0 to PH7	I/O	8-bit input/output pins

2. CPU

The RX610 Group is an MCU with the high-speed, high-performance RX CPU as its core.

A variable-length instruction format has been adopted for the RX CPU. Allocating the more frequently used instructions to the shorter instruction lengths facilitates the development of efficient programs that take up less memory.

The CPU has 73 basic instructions and 8 floating-point operation instructions, and 9 DSP instructions, for a total of 90 instructions. It has 10 addressing modes and caters to register–register operations, register–memory operations, immediate–register operations, immediate–memory operations, memory–memory transfer, and bitwise operations. High-speed operation was realized by achieving execution in a single cycle not only for register–register operations, but also for other types of multiple instructions. The CPU includes an internal multiplier and an internal divider for high-speed multiplication and division.

The RX CPU has a five-stage pipeline for processing instructions. The stages are instruction fetching, instruction decoding, execution, memory access, and write-back. In cases where pipeline processing is drawn-out by memory access, subsequent operations may in fact be executed earlier. By adopting "out-of-order completion" of this kind, the execution of instructions is controlled to optimize numbers of clock cycles.

2.1 Features

- High instruction execution rate: One instruction in one clock cycle
- Address space: 4-Gbyte linear
- Register set of the CPU
  General purpose: Sixteen 32-bit registers
  Control: Nine 32-bit registers
  Accumulator: One 64-bit register
- Basic instructions: 73 (arithmetic/logic instructions, data-transfer instructions, branch instructions, bit-manipulation instructions, string-manipulation instructions, and system-manipulation instructions)
  Relative branch instructions to suit branch distances
  Variable-length instruction format (lengths from one to eight bytes)
  Short formats for frequently used instructions
- Floating-point operation instructions: 8
- DSP instructions (as an optional function): 9
  Supports 16-bit x 16-bit multiplication and multiply-and-accumulate operations.
  Rounds the data in the accumulator.
- Addressing modes: 10
- Five-stage pipeline
  Adoption of out-of-order completion
- Processor modes
  A supervisor mode and a user mode are supported.
- Floating-point operation unit
  Supports single-precision (32-bit) floating point
  Supports data types and exceptions in conformance with the IEEE754 standard
- Data arrangement
  Selectable as little endian or big endian

2.2 Register Set of the CPU

The RX CPU has sixteen general-purpose registers, nine control registers, and one accumulator used for DSP instructions.

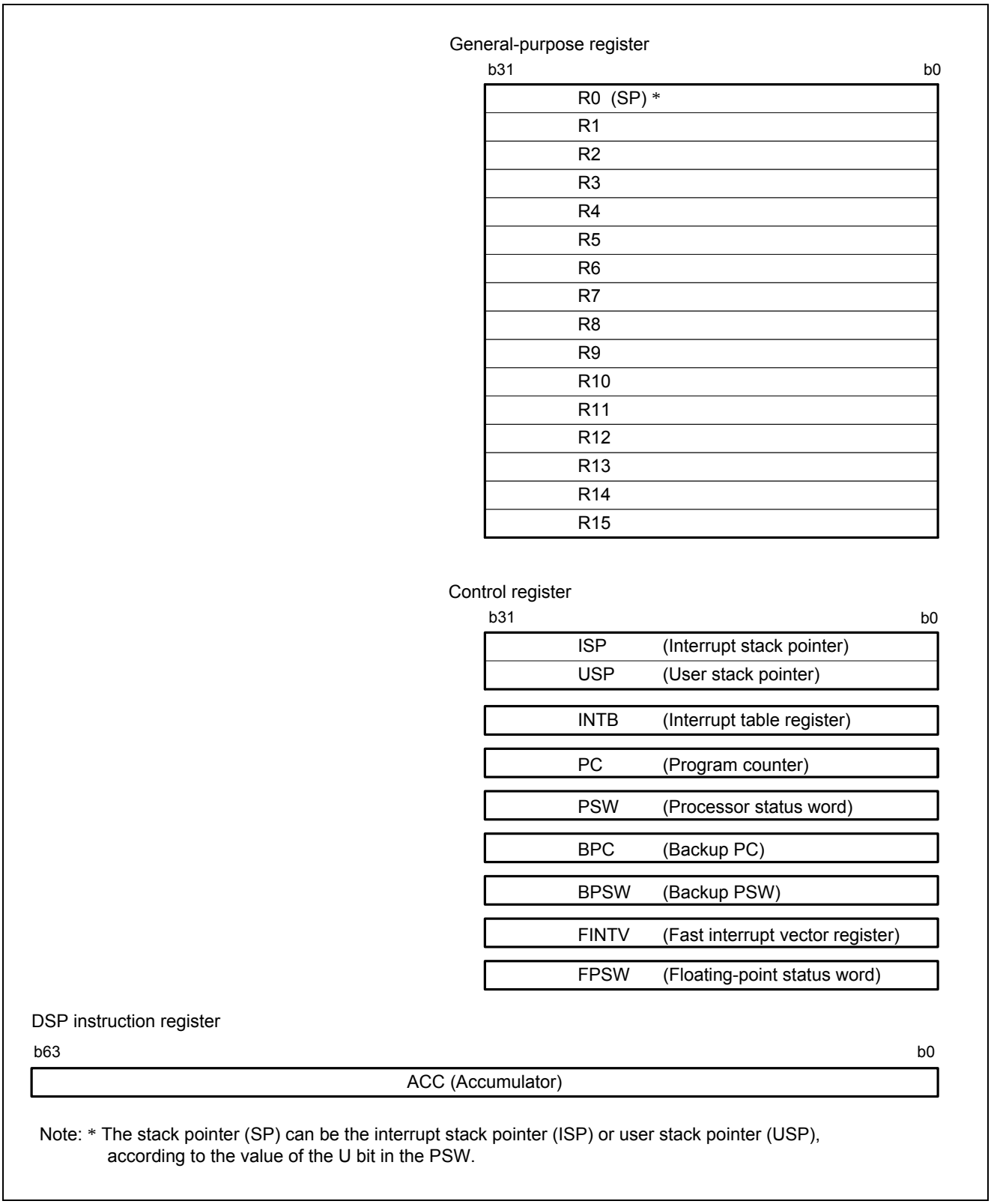


Figure 2.1 Register Set of the CPU

2.2.1 General-Purpose Registers (R0 to R15)

This CPU has sixteen general-purpose registers (R0 to R15). R1 to R15 can be used as data registers or address registers.

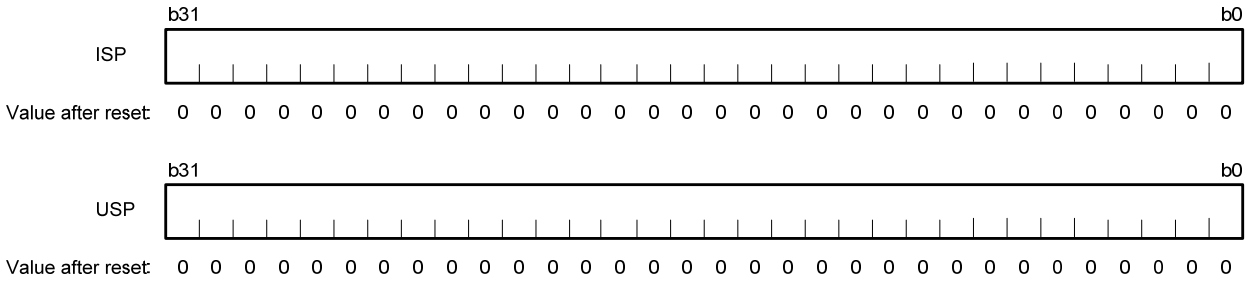
R0, a general-purpose register, also functions as the stack pointer (SP). The stack pointer is switched to operate as the interrupt stack pointer (ISP) or user stack pointer (USP) by the value of the stack pointer select bit (U) in the processor status word (PSW).

2.2.2 Control Registers

This CPU has the following nine control registers.

- Interrupt stack pointer (ISP)
- User stack pointer (USP)
- Interrupt table register (INTB)
- Program counter (PC)
- Processor status word (PSW)
- Backup PC (BPC)
- Backup PSW (BPSW)
- Fast interrupt vector register (FINTV)
- Floating-point status word (FPSW)

2.2.2.1 Interrupt Stack Pointer (ISP)/User Stack Pointer (USP)



The stack pointer (SP) can be either of two types, the interrupt stack pointer (ISP) or the user stack pointer (USP). Whether the stack pointer operates as the ISP or USP depends on the value of the stack pointer select bit (U) in the processor status word (PSW).

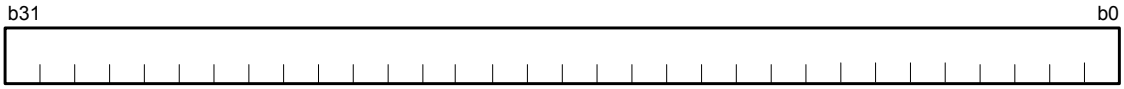
Set the ISP or USP to a multiple of four, as this reduces the numbers of cycles required to execute interrupt sequences and instructions entailing stack manipulation.

2.2.2.2 Interrupt Table Register (INTB)

Value after reset: Undefined

The interrupt table register (INTB) specifies the address where the relocatable vector table starts.

2.2.2.3 Program Counter (PC)



Value after reset: Value allocated to addresses in the range from FFFFFFFCh to FFFFFFFFh

The program counter (PC) indicates the address of the instruction being executed.

2.2.2.4 Processor Status Word (PSW)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	IPL[2:0] *			—	—	—	PM	—	—	U	I
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—	—	—	—	—	O	S	Z	C
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: * The MVTIPL instruction is not supported in the RX610 Group. When writing to PSW.IPL[2:0], use the MVTC instruction.

Bit	Symbol	Bit Name	Description	R/W
b0	C	Carry Flag	0: No carry has occurred. 1: A carry has occurred.	R/W
b1	Z	Zero Flag	0: Result is non-zero. 1: Result is 0.	R/W
b2	S	Sign Flag	0: Result is a positive value or 0. 1: Result is a negative value.	R/W
b3	O	Overflow Flag	0: No overflow has occurred. 1: An overflow has occurred.	R/W
b15 to b4	—	Reserved	The value read is always 0. When writing, write 0 to these bits.	R/W
b16	I*1	Interrupt Enable	0: Interrupt disabled. 1: Interrupt enabled.	R/W
b17	U*1	Stack Pointer Select	0: Interrupt stack pointer (ISP) is selected. 1: User stack pointer (USP) is selected.	R/W
b19, b18	—	Reserved	The value read is always 0. When writing, write 0 to these bits.	R/W
b20	PM*1*2*3	Processor Mode Select	0: Supervisor mode is selected. 1: User mode is selected.	R/W
b23 to b21	—	Reserved	The value read is always 0. When writing, write 0 to these bits.	R/W
b26 to b24	IPL[2:0]*1*4	Processor Interrupt Priority Level	b26 b24 0 0 0: Priority level 0 (lowest) 0 0 1: Priority level 1 0 1 0: Priority level 2 0 1 1: Priority level 3 1 0 0: Priority level 4 1 0 1: Priority level 5 1 1 0: Priority level 6 1 1 1: Priority level 7 (highest)	R/W
b31 to b27	—	Reserved	The value read is always 0. When writing, write 0 to these bits.	R/W

Notes: 1. In user mode, writing to the IPL[2:0], PM, U, and I bits by an MVTC or a POPC instruction is ignored.

2. In supervisor mode, writing to the PM bit by an MVTC or a POPC instruction is ignored, but writing to the other bits is possible.
3. Switching from supervisor mode to user mode requires execution of an RTE instruction after having set the PM bit in the PSW saved on the stack to 1 or executing an RTFI instruction after having set the PM bit in the BPSW to 1.
4. The MVTIPL instruction is not supported in the RX610 Group. When writing to PSW.IPL[2:0], use the MVTC instruction.

The processor status word (PSW) indicates results of instruction execution or the state of the CPU.

C Flag (Carry Flag)

This flag indicates whether a carry, borrow, or shift-out has occurred as the result of an operation.

Z Flag (Zero Flag)

This flag indicates that the result of an operation was 0.

S Flag (Sign Flag)

This flag indicates that the result of an operation was negative.

O Flag (Overflow Flag)

This flag indicates that an overflow occurred during an operation.

I Bit (Interrupt Enable)

This bit enables interrupt requests. When an exception is accepted, the value of this bit becomes 0.

U Bit (Stack Pointer Select)

This bit specifies the stack pointer as either the ISP or USP. When an exception request is accepted, this bit is set to 0. When the processor mode is switched from supervisor mode to user mode, this bit is set to 1.

PM Bit (Processor Mode Select)

This bit specifies the processor mode. When an exception is accepted, the value of this bit becomes 0.

IPL[2:0] Bits (Processor Interrupt Priority Level)

The IPL[2:0] bits specify the processor interrupt priority level as one of eight levels from zero to seven, wherein priority level zero is the lowest and priority level seven the highest. When the priority level of a requested interrupt is higher than the processor interrupt priority level, the interrupt is enabled. Setting the IPL[2:0] bits to level seven (111b) disables all interrupt requests. The IPL[2:0] bits are set to level seven (111b) when a non-maskable interrupt is generated. When interrupts in general are generated, the bits are set to the priority levels of accepted interrupts.

2.2.2.5 Backup PC (BPC)

Value after reset: Undefined

The backup PC (BPC) is provided to speed up response to interrupts.

After a fast interrupt has been generated, the contents of the program counter (PC) are saved in the BPC.

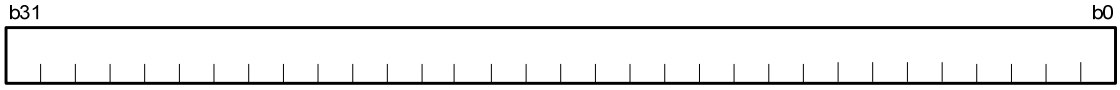
2.2.2.6 Backup PSW (BPSW)

Value after reset: Undefined

The backup PSW (BPSW) is provided to speed up response to interrupts.

After a fast interrupt has been generated, the contents of the processor status word (PSW) are saved in the BPSW. The allocation of bits in the BPSW corresponds to that in the PSW.

2.2.2.7 Fast Interrupt Vector Register (FINTV)



Value after reset: Undefined

The fast interrupt vector register (FINTV) is provided to speed up response to interrupts.

The FINTV specifies a branch destination address when a fast interrupt has been generated.

2.2.2.8 Floating-Point Status Word (FPSW)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	FS	FX	FU	FZ	FO	FV	—	—	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	EX	EU	EZ	EO	EV	—	DN	CE	CX	CU	CZ	CO	CV	RM[1:0]	
Value after reset:	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	RM[1:0]	Floating-Point Rounding-Mode Setting	b1 b0 0 0: Rounding to the nearest value 0 1: Rounding to 0 1 0: Rounding to +∞ 1 1: Rounding to –∞	R/W
b2	CV	Invalid Operation Cause Flag	0: No invalid operation has been encountered. 1: Invalid operation has been encountered.	R/(W)*1
b3	CO	Overflow Cause Flag	0: No overflow has occurred. 1: Overflow has occurred.	R/(W)*1
b4	CZ	Division-by-Zero Cause Flag	0: No division-by-zero has occurred. 1: Division-by-zero has occurred.	R/(W)*1
b5	CU	Underflow Cause Flag	0: No underflow has occurred. 1: Underflow has occurred.	R/(W)*1
b6	CX	Inexact Cause Flag	0: No inexact exception has been generated. 1: Inexact exception has been generated.	R/(W)*1
b7	CE	Un-Implemented Processing Cause Flag	0: No un-implemented processing has been encountered. 1: Un-implemented process has been encountered.	R/(W)*1
b8	DN	0 Flush Bit of Denormalized Number	0: A denormalized number is handled as a denormalized number. 1: A denormalized number is handled as 0.*2	R/W
b9	—	Reserved	The value read is always 0. When writing, write 0 to this bit.	R/W
b10	EV	Invalid Operation Exception Enable	0: Invalid operation exception is masked. 1: Invalid operation exception is enabled.	R/W
b11	EO	Overflow Exception Enable	0: Overflow exception is masked. 1: Overflow exception is enabled.	R/W
b12	EZ	Division-by-Zero Exception Enable	0: Division-by-zero exception is masked. 1: Division-by-zero exception is enabled.	R/W
b13	EU	Underflow Exception Enable	0: Underflow exception is masked. 1: Underflow exception is enabled.	R/W
b14	EX	Inexact Exception Enable	0: Inexact exception is masked. 1: Inexact exception is enabled.	R/W
b25 to b15	—	Reserved	The value read is always 0. When writing, write 0 to these bits.	R/W

Bit	Symbol	Bit Name	Description	R/W
b26	FV*3	Invalid Operation Flag	0: No invalid operation has been encountered. 1: Invalid operation has been encountered.*8	R/W
b27	FO*4	Overflow Flag	0: No overflow has occurred. 1: Overflow has occurred.*8	R/W
b28	FZ*5	Division-by-Zero Flag	0: No division-by-zero has occurred. 1: Division-by-zero has occurred.*8	R/W
b29	FU*6	Underflow Flag	0: No underflow has occurred. 1: Underflow has occurred.*8	R/W
b30	FX*7	Inexact Flag	0: No inexact exception has been generated. 1: Inexact exception has been generated.*8	R/W
b31	FS	Floating-Point Error Summary Flag	This bit reflects the logical OR of the FU, FZ, FO, and FV flags.	R

Notes: 1. Writing 0 to the bit clears it. Writing 1 to the bit does not affect its value.
2. Positive denormalized numbers are treated as +0, negative denormalized numbers as –0.
3. When the EV bit is set to 0, the FV flag is enabled.
4. When the EO bit is set to 0, the FO flag is enabled.
5. When the EZ bit is set to 0, the FZ flag is enabled.
6. When the EU bit is set to 0, the FU flag is enabled.
7. When the EX bit is set to 0, the FX flag is enabled.
8. Once the bit has been set to 1, this value is retained until it is cleared to 0 by software.

The floating-point status word (FPSW) indicates the results of floating-point operations.

When an exception handling enable bit (Ej) enables the exception handling (Ej = 1), the corresponding Cj flag indicates the source of the exception within the exception handling routine. If the exception handling is masked (Ej = 0), check the Fj flag at the end of a series of processing whether an exception is generated or not. The Fj flag is the accumulation type flag (j = X, U, Z, O, or V).

RM[1:0] Bits (Floating-Point Rounding-Mode Setting)

These bits specify the floating-point rounding-mode.

Explanation of Floating-Point Rounding Modes

- Rounding to the nearest value (the default behavior): An inexact result is rounded to the available value that is closest to the result which would be obtained with an infinite number of digits. If two available values are equally close, rounding is to the even alternative.
- Rounding towards 0: An inexact result is rounded to the smallest available absolute value, i.e. in the direction of zero (simple truncation).
- Rounding towards +∞: An inexact result is rounded to the nearest available value in the direction of positive infinity.
- Rounding towards –∞: An inexact result is rounded to the nearest available value in the direction of negative infinity.

(1) Rounding to the nearest value is specified as the default mode and returns the most accurate value.

(2) Modes such as rounding towards 0, rounding towards +∞, and rounding towards –∞ are used to ensure precision when interval arithmetic is employed.

CV Flag (Invalid Operation Cause Flag), CO Flag (Overflow Cause Flag), CZ Flag (Division-by-Zero Cause Flag), CU Flag (Underflow Cause Flag), CX Flag (Inexact Cause Flag), and CE Flag (Un-Implemented Processing Cause Flag)

Floating-point exceptions include the five specified in the IEEE754 standard, namely overflow, underflow, inexact, division-by-zero, and invalid operation. For a further floating-point exception that is generated upon detection of unimplemented processing, the corresponding flag (CE) is set to 1.

- The bit that has been set to 1 is cleared to 0 when the FPU instruction is executed.
- When 0 is written to the bit by the MVTC and POPC instructions, the bit is set to 0; the bit retains the previous value when 1 is written by the instruction.

DN Flag (0 Flush Bit of Denormalized Number)

When this bit is set to 0, a denormalized number is handled as a denormalized number. When this bit is set to 1, a denormalized number is handled as 0.

EV Bit (Invalid Operation Exception Enable), EO Bit (Overflow Exception Enable), EZ Bit (Division-by-Zero Exception Enable), EU Bit (Underflow Exception Enable), and EX Bit (Inexact Exception Enable)

When any of five floating-point exceptions specified in the IEEE754 standard is generated by the FPU instruction, the bit decides whether the CPU will start handling the exception. When the bit is set to 0, the exception handling is masked; when the bit is set to 1, the exception handling is enabled.

FV Flag (Invalid Operation flag), FO Flag (Overflow Flag), FZ Flag (Division-by-Zero Flag), FU Flag (Underflow Flag), and FX Flag (Inexact Flag)

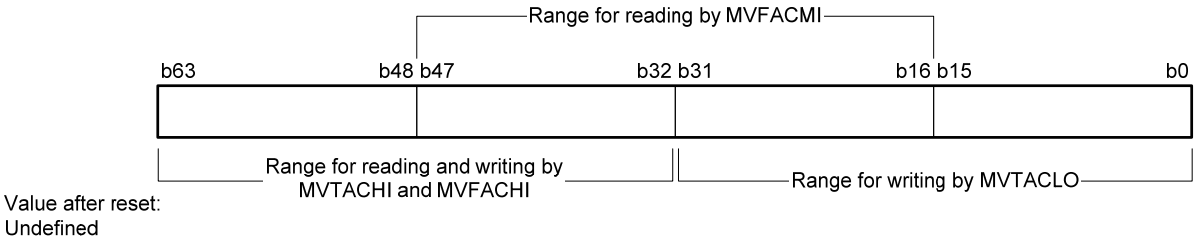
While the exception handling enable bit (Ej) is 0 (exception handling is masked), if any of five floating-point exceptions specified in the IEEE754 standard is generated, the corresponding bit is set to 1.

- When Ej is 1 (exception handling is enabled), the value of the flag remains.
- When the corresponding flag is set to 1, it remains 1 until it is cleared to 0 by software. (Accumulation flag)

FS Flag (Floating-Point Error Summary Flag)

This bit reflects the logical OR of the FU, FZ, FO, and FV flags.

2.2.2.9 Accumulator (ACC)



The accumulator (ACC) is a 64-bit register used for DSP instructions. The accumulator is also used for the multiply and multiply-and-accumulate instructions; EMUL, EMULU, FMUL, MUL, and RMPA, in which case the prior value in the accumulator is modified by execution of the instruction.

Use the MVTACHI and MVTACLO instructions for writing to the accumulator. The MVTACHI and MVTACLO instructions write data to the higher-order 32 bits (bits 63 to 32) and the lower-order 32 bits (bits 31 to 0), respectively.

Use the MVFACHI and MVFACMI instructions for reading data from the accumulator. The MVFACHI and MVFACMI instructions read data from the higher-order 32 bits (bits 63 to 32) and the middle 32 bits (bits 47 to 16), respectively.

2.3 Processor Mode

The RX CPU supports two processor modes, supervisor and user. These processor modes enable the realization of a hierarchical CPU resource protection.

Each processor mode imposes a level on rights of access to the CPU resource and the instructions that can be executed. Supervisor mode carries greater rights than those of user mode.

The initial state after a reset is supervisor mode.

2.3.1 Supervisor Mode

In supervisor mode, all CPU resources are accessible and all instructions are available. However, writing to the processor mode select bit (PM) in the processor status word (PSW) by executing an MVTC or a POPC instruction will be ignored. For details on how to write to the PM bit, refer to section 2.2.2.4, Processor Status Word (PSW).

2.3.2 User Mode

In user mode, write access to the CPU resources listed below is restricted. The restriction applies to any instruction capable of write access.

- Some bits (bits IPL[2:0], PM, U, and I) in the processor status word (PSW)
- Interrupt stack pointer (ISP)
- Interrupt table register (INTB)
- Backup PSW (BPSW)
- Backup PC (BPC)
- Fast interrupt vector register (FINTV)

2.3.3 Privileged Instruction

Privileged instructions can only be executed in supervisor mode. Executing a privileged instruction in user mode produces a privileged instruction exception. Privileged instructions include the RTFI, RTE, and WAIT instructions.

2.3.4 Switching Between Processor Modes

Manipulating the processor mode select bit (PM) in the processor status word (PSW) switches the processor mode. However, rewriting to the PM bit by executing an MVTC or a POPC instruction is prohibited. Switch the processor mode by following the procedures described below.

(1) Switching from user mode to supervisor mode

After an exception has been generated, the PM bit in the PSW is set to 0 and the CPU switches to supervisor mode. The pre-processing by hardware is executed in supervisor mode. The state of the processor mode before the exception was generated is retained in the PM bit in the copy of the PSW that is saved on the stack.

(2) Switching from supervisor mode to user mode

Executing an RTE instruction when the value of the copy of the PM bit in the PSW that has been preserved on the stack is "1" or an RTFI instruction when the value of the copy of the PM bit in the PSW that has been preserved in the backup PSW (BPSW) is "1" causes a transition to user mode. In the transition to user mode, the value of the stack pointer designation bit (the U bit in the PSW) becomes "1".

2.4 Data Types

The RX CPU can handle four types of data: integer, floating-point, bit, and string.

2.4.1 Integer

An integer can be signed or unsigned. For signed integers, negative values are represented by two's complements.

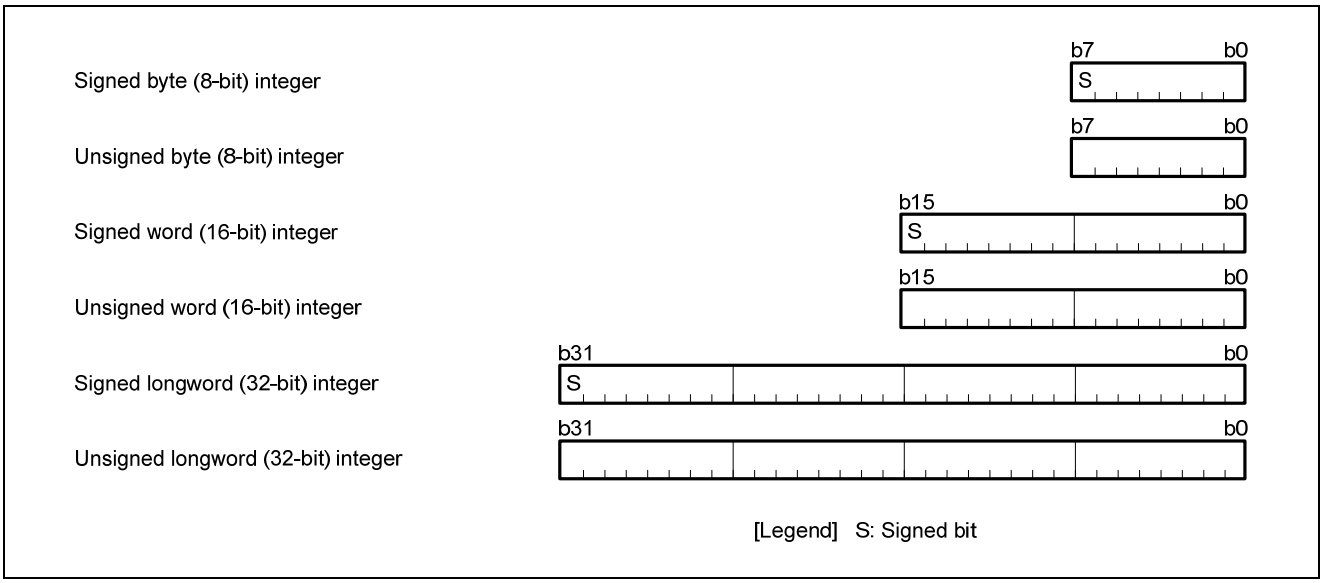


Figure 2.2 Integer

2.4.2 Floating-Point

Floating-point support is for the single-precision floating-point type specified in IEEE754; operands of this type can be used in eight floating-point operation instructions: FADD, FCMP, FDIV, FMUL, FSUB, FTOI, ITOF, and ROUND.

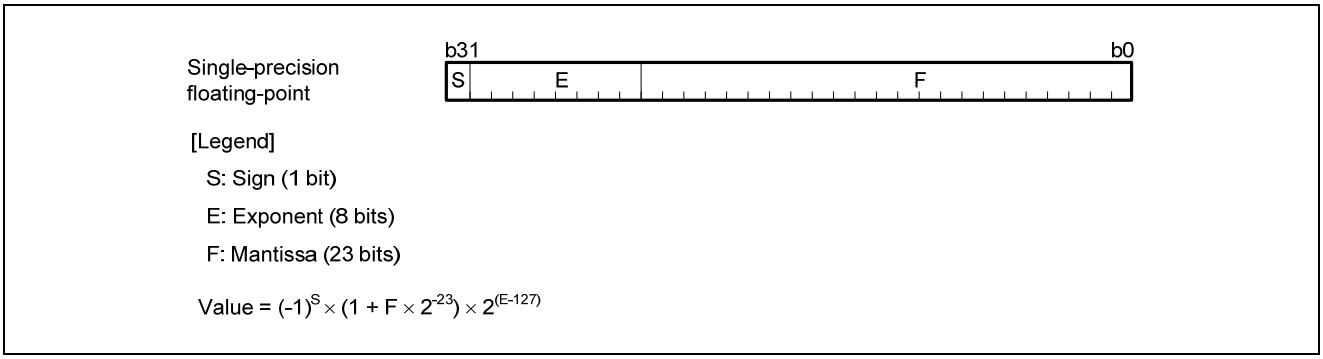


Figure 2.3 Floating-Point

The floating-point format supports the values listed below.

- 0 < E < 255 (normal numbers)
- E = 0 and F = 0 (signed zero)
- E = 0 and F > 0 (denormalized numbers)

Note: The number is treated as 0 when the DN bit in the FPSW is 1. When the DN bit is 0, an un-implemented processing exception is generated.

- E = 255 and F = 0 (infinity)
- E = 255 and F > 0 (NaN: Not-a-Number)

2.4.3 Bitwise Operations

Five bit-manipulation instructions are provided for bitwise operations: BCLR, BM*Cnd*, BNOT, BSET, and BTST.

A bit in a register is specified as the destination register and a bit number in the range from 31 to 0.

A bit in memory is specified as the destination address and a bit number from 7 to 0. The addressing modes available to specify addresses are register indirect and register relative.

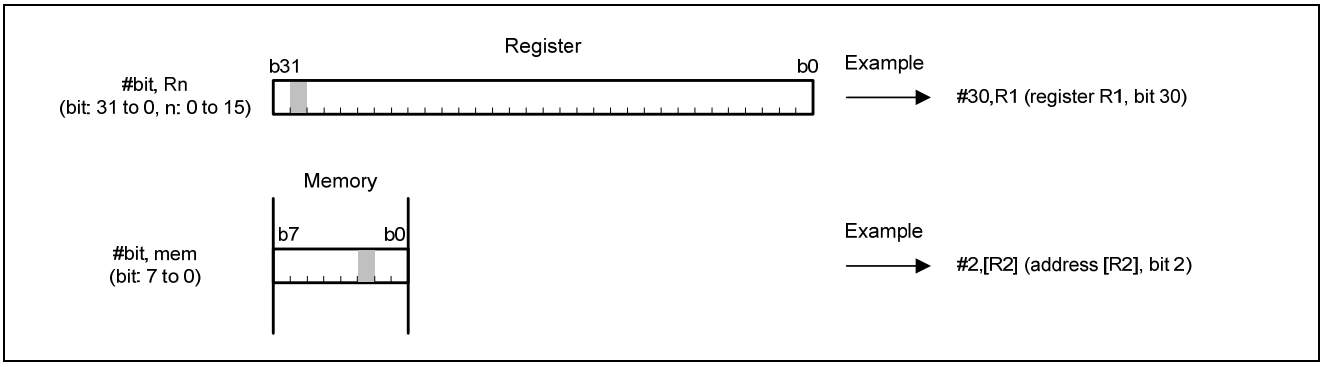


Figure 2.4 Bit

2.4.4 Strings

The string data type consists of an arbitrary number of consecutive byte (8-bit), word (16-bit), or longword (32-bit) units.

Seven string manipulation instructions are provided for use with strings: SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, and SWHILE.

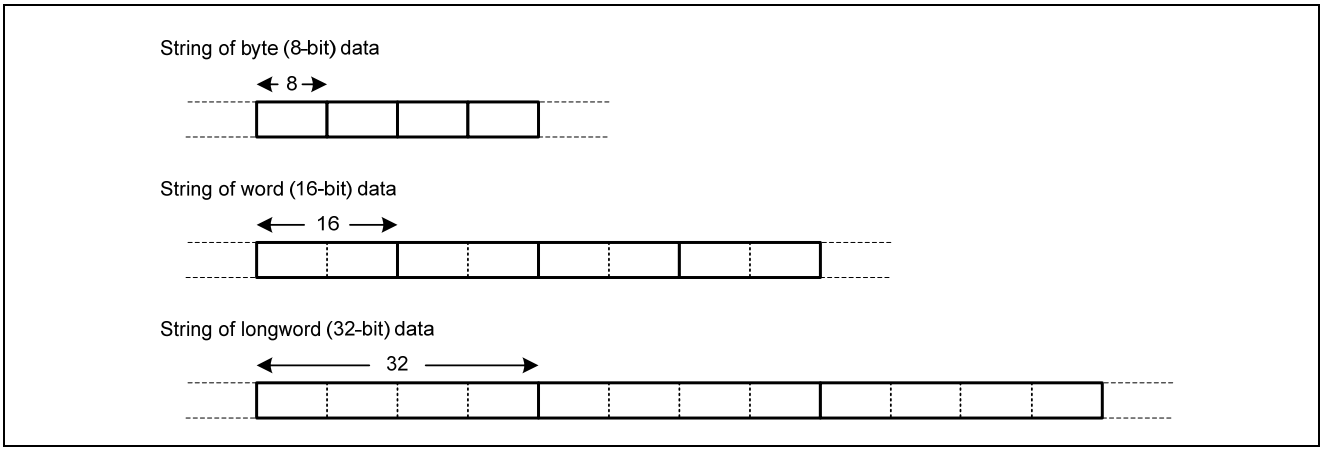


Figure 2.5 String

2.5 Endian

For the RX CPU, instructions are always little endian, but the treatment of data is selectable as little or big endian.

2.5.1 Switching the Endian

As arrangements of bytes, the RX610 Group supports both big endian, where the higher-order byte (MSB) is at location 0, and little endian, where the lower-order byte (LSB) is at location 0.

The endian is switched by changing the setting on a mode pin (MDE). For details on the endian setting, see section 3, Operating Modes.

Operations for access differ according to the endian setting and, depending on the instruction, whether 8-, 16- or 32-bit access has been selected. Operations for access in the various possible cases are described in tables 2.1 to 2.12.

In the tables, LL indicates bits D7 to D0 of the general register,
LH indicates bits D15 to D8 of the general register,
HL indicates bits D23 to D16 of the general register, and
HH indicates bits D31 to D24 of the general register.

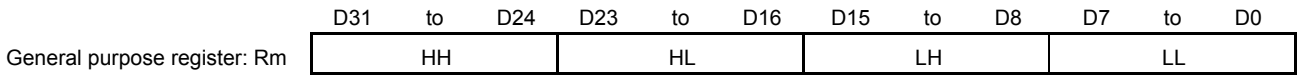


Table 2.1 32-Bit Read Operations when Little Endian has been Selected

Operation / Address of src	Reading a 32-bit unit from address 0	Reading a 32-bit unit from address 1	Reading a 32-bit unit from address 2	Reading a 32-bit unit from address 3	Reading a 32-bit unit from address 4
Address 0	Transfer to LL	—	—	—	—
Address 1	Transfer to LH	Transfer to LL	—	—	—
Address 2	Transfer to HL	Transfer to LH	Transfer to LL	—	—
Address 3	Transfer to HH	Transfer to HL	Transfer to LH	Transfer to LL	—
Address 4	—	Transfer to HH	Transfer to HL	Transfer to LH	Transfer to LL
Address 5	—	—	Transfer to HH	Transfer to HL	Transfer to LH
Address 6	—	—	—	Transfer to HH	Transfer to HL
Address 7	—	—	—	—	Transfer to HH

Table 2.2 32-Bit Read Operations when Big Endian has been Selected

Operation / Address of src	Reading a 32-bit unit from address 0	Reading a 32-bit unit from address 1	Reading a 32-bit unit from address 2	Reading a 32-bit unit from address 3	Reading a 32-bit unit from address 4
Address 0	Transfer to HH	—	—	—	—
Address 1	Transfer to HL	Transfer to HH	—	—	—
Address 2	Transfer to LH	Transfer to HL	Transfer to HH	—	—
Address 3	Transfer to LL	Transfer to LH	Transfer to HL	Transfer to HH	—
Address 4	—	Transfer to LL	Transfer to LH	Transfer to HL	Transfer to HH
Address 5	—	—	Transfer to LL	Transfer to LH	Transfer to HL
Address 6	—	—	—	Transfer to LL	Transfer to LH
Address 7	—	—	—	—	Transfer to LL

Table 2.3 32-Bit Write Operations when Little Endian has been Selected

Operation / Address of dest	Writing a 32-bit unit to address 0	Writing a 32-bit unit to address 1	Writing a 32-bit unit to address 2	Writing a 32-bit unit to address 3	Writing a 32-bit unit to address 4
Address 0	Transfer from LL	—	—	—	—
Address 1	Transfer from LH	Transfer from LL	—	—	—
Address 2	Transfer from HL	Transfer from LH	Transfer from LL	—	—
Address 3	Transfer from HH	Transfer from HL	Transfer from LH	Transfer from LL	—
Address 4	—	Transfer from HH	Transfer from HL	Transfer from LH	Transfer from LL
Address 5	—	—	Transfer from HH	Transfer from HL	Transfer from LH
Address 6	—	—	—	Transfer from HH	Transfer from HL
Address 7	—	—	—	—	Transfer from HH

Table 2.4 32-Bit Write Operations when Big Endian has been Selected

Operation / Address of dest	Writing a 32-bit unit to address 0	Writing a 32-bit unit to address 1	Writing a 32-bit unit to address 2	Writing a 32-bit unit to address 3	Writing a 32-bit unit to address 4
Address 0	Transfer from HH	—	—	—	—
Address 1	Transfer from HL	Transfer from HH	—	—	—
Address 2	Transfer from LH	Transfer from HL	Transfer from HH	—	—
Address 3	Transfer from LL	Transfer from LH	Transfer from HL	Transfer from HH	—
Address 4	—	Transfer from LL	Transfer from LH	Transfer from HL	Transfer from HH
Address 5	—	—	Transfer from LL	Transfer from LH	Transfer from HL
Address 6	—	—	—	Transfer from LL	Transfer from LH
Address 7	—	—	—	—	Transfer from LL

Table 2.5 16-Bit Read Operations when Little Endian has been Selected

Operation / Address of src	Reading a 16-bit unit from address 0	Reading a 16-bit unit from address 1	Reading a 16-bit unit from address 2	Reading a 16-bit unit from address 3	Reading a 16-bit unit from address 4	Reading a 16-bit unit from address 5	Reading a 16-bit unit from address 6
Address 0	Transfer to LL	—	—	—	—	—	—
Address 1	Transfer to LH	Transfer to LL	—	—	—	—	—
Address 2	—	Transfer to LH	Transfer to LL	—	—	—	—
Address 3	—	—	Transfer to LH	Transfer to LL	—	—	—
Address 4	—	—	—	Transfer to LH	Transfer to LL	—	—
Address 5	—	—	—	—	Transfer to LH	Transfer to LL	—
Address 6	—	—	—	—	—	Transfer to LH	Transfer to LL
Address 7	—	—	—	—	—	—	Transfer to LH

Table 2.6 16-Bit Read Operations when Big Endian has been Selected

Operation / Address of src	Reading a 16-bit unit from address 0	Reading a 16-bit unit from address 1	Reading a 16-bit unit from address 2	Reading a 16-bit unit from address 3	Reading a 16-bit unit from address 4	Reading a 16-bit unit from address 5	Reading a 16-bit unit from address 6
Address 0	Transfer to LH	—	—	—	—	—	—
Address 1	Transfer to LL	Transfer to LH	—	—	—	—	—
Address 2	—	Transfer to LL	Transfer to LH	—	—	—	—
Address 3	—	—	Transfer to LL	Transfer to LH	—	—	—
Address 4	—	—	—	Transfer to LL	Transfer to LH	—	—
Address 5	—	—	—	—	Transfer to LL	Transfer to LH	—
Address 6	—	—	—	—	—	Transfer to LL	Transfer to LH
Address 7	—	—	—	—	—	—	Transfer to LL

Table 2.7 16-Bit Write Operations when Little Endian has been Selected

Operation / Address of dest	Writing a 16-bit unit to address 0	Writing a 16-bit unit to address 1	Writing a 16-bit unit to address 2	Writing a 16-bit unit to address 3	Writing a 16-bit unit to address 4	Writing a 16-bit unit to address 5	Writing a 16-bit unit to address 6
Address 0	Transfer from LL	—	—	—	—	—	—
Address 1	Transfer from LH	Transfer from LL	—	—	—	—	—
Address 2	—	Transfer from LH	Transfer from LL	—	—	—	—
Address 3	—	—	Transfer from LH	Transfer from LL	—	—	—
Address 4	—	—	—	Transfer from LH	Transfer from LL	—	—
Address 5	—	—	—	—	Transfer from LH	Transfer from LL	—
Address 6	—	—	—	—	—	Transfer from LH	Transfer from LL
Address 7	—	—	—	—	—	—	Transfer from LH

Table 2.8 16-Bit Write Operations when Big Endian has been Selected

Operation / Address of dest	Writing a 16-bit unit to address 0	Writing a 16-bit unit to address 1	Writing a 16-bit unit to address 2	Writing a 16-bit unit to address 3	Writing a 16-bit unit to address 4	Writing a 16-bit unit to address 5	Writing a 16-bit unit to address 6
Address 0	Transfer from LH	—	—	—	—	—	—
Address 1	Transfer from LL	Transfer from LH	—	—	—	—	—
Address 2	—	Transfer from LL	Transfer from LH	—	—	—	—
Address 3	—	—	Transfer from LL	Transfer from LH	—	—	—
Address 4	—	—	—	Transfer from LL	Transfer from LH	—	—
Address 5	—	—	—	—	Transfer from LL	Transfer from LH	—
Address 6	—	—	—	—	—	Transfer from LL	Transfer from LH
Address 7	—	—	—	—	—	—	Transfer from LL

Table 2.9 8-Bit Read Operations when Little Endian has been Selected

Operation / Address of src	Reading an 8-bit unit from address 0	Reading an 8-bit unit from address 1	Reading an 8-bit unit from address 2	Reading an 8-bit unit from address 3
Address 0	Transfer to LL	—	—	—
Address 1	—	Transfer to LL	—	—
Address 2	—	—	Transfer to LL	—
Address 3	—	—	—	Transfer to LL

Table 2.10 8-Bit Read Operations when Big Endian has been Selected

Operation / Address of src	Reading an 8-bit unit from address 0	Reading an 8-bit unit from address 1	Reading an 8-bit unit from address 2	Reading an 8-bit unit from address 3
Address 0	Transfer to LL	—	—	—
Address 1	—	Transfer to LL	—	—
Address 2	—	—	Transfer to LL	—
Address 3	—	—	—	Transfer to LL

Table 2.11 8-Bit Write Operations when Little Endian has been Selected

Operation / Address of dest	Writing an 8-bit unit to address 0	Writing an 8-bit unit to address 1	Writing an 8-bit unit to address 2	Writing an 8-bit unit to address 3
Address 0	Transfer from LL	—	—	—
Address 1	—	Transfer from LL	—	—
Address 2	—	—	Transfer from LL	—
Address 3	—	—	—	Transfer from LL

Table 2.12 8-Bit Write Operations when Big Endian has been Selected

Operation / Address of dest	Writing an 8-bit unit to address 0	Writing an 8-bit unit to address 1	Writing an 8-bit unit to address 2	Writing an 8-bit unit to address 3
Address 0	Transfer from LL	—	—	—
Address 1	—	Transfer from LL	—	—
Address 2	—	—	Transfer from LL	—
Address 3	—	—	—	Transfer from LL

2.5.2 Access to I/O Registers

The addresses of I/O registers are fixed, and this is regardless of whether the setting on the MDE pin is for little endian or big endian. Accordingly, changes to the endian do not affect access to I/O registers. For the arrangements of I/O registers, refer to the descriptions of registers in the relevant sections.

2.5.3 Notes on Access to I/O Registers

Ensure that access to I/O registers is in accord with the following rules.

- For I/O registers designated as having a bus width of eight bits, use instructions for an eight-bit bus width.
- For I/O registers designated as having a bus width of 16 bits, use instructions for a 16-bit bus width.
- For I/O registers designated as having a bus width of 32 bits, use instructions for a 32-bit bus width.

2.5.4 Data Arrangement

2.5.4.1 Data Arrangement in Registers

Figure 2.6 shows the relation between the sizes of registers and bit numbers.

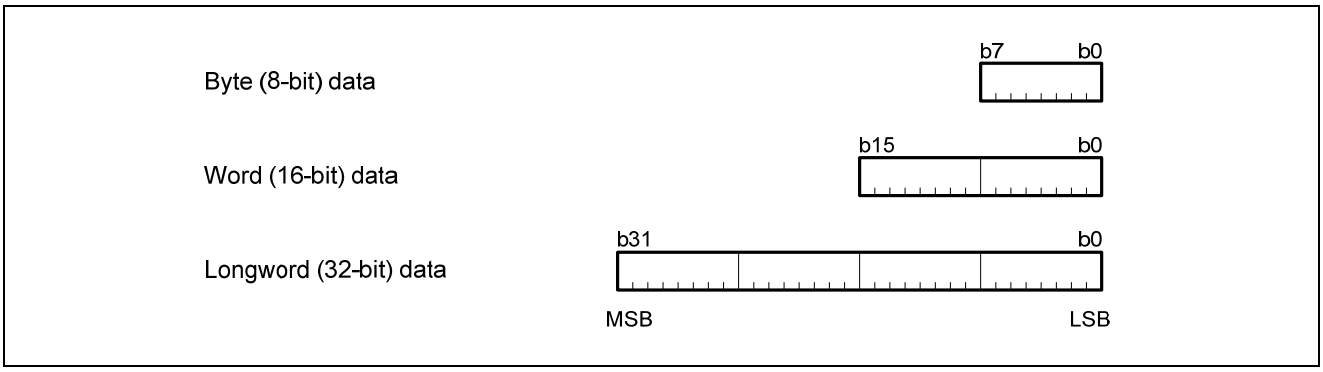


Figure 2.6 Data Arrangement in Registers

2.5.4.2 Data Arrangement in Memory

Data in memory have three sizes: byte (8-bit), word (16-bit), and longword (32-bit). The data arrangement is selectable as little endian or big endian. Figure 2.7 shows the arrangement of data in memory.

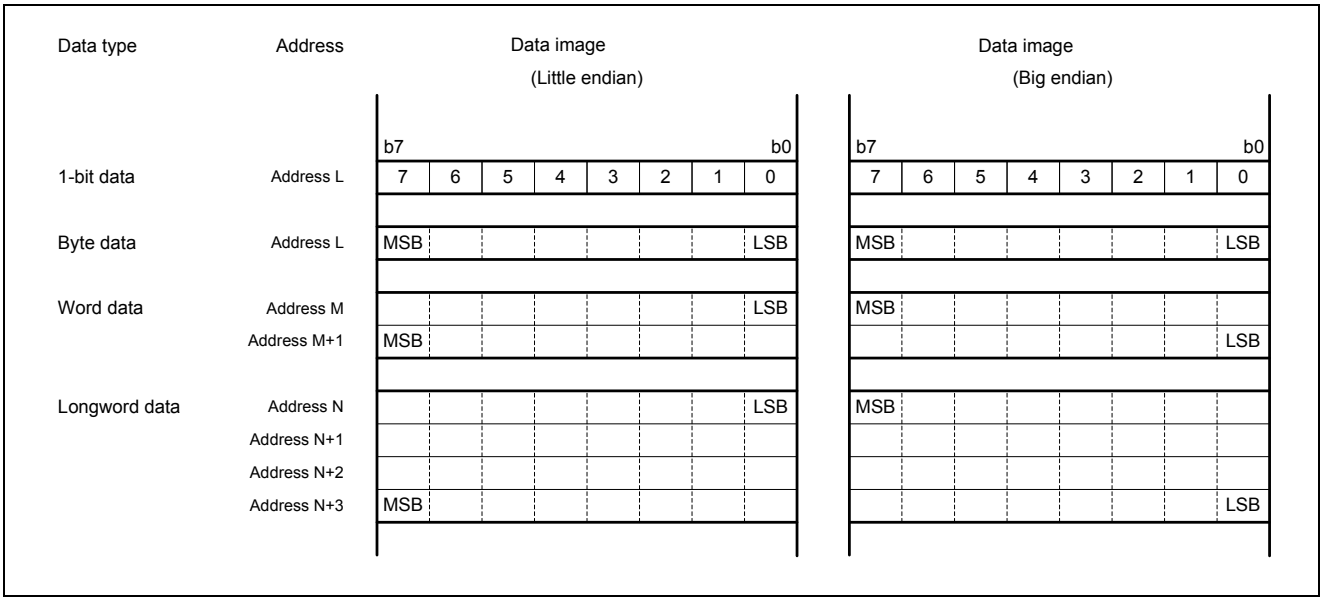


Figure 2.7 Data Arrangement in Memory

2.5.5 Notes on Arrangement of Instruction Code

When the endian setting for the external space is different from that for the chip, no instruction code can be arranged in the area. The instruction code should be arranged in the external space whose endian setting is the same as that for the chip

2.6 Vector Table

There are two types of vector table: fixed and relocatable. Each vector in the vector table consists of four bytes and specifies the address where the corresponding exception processing routine starts.

2.6.1 Fixed Vector Table

The fixed vector table is allocated to a fixed address range. The individual vectors for the privileged instruction exception, undefined instruction exception, floating-point exception, non-maskable interrupt, and reset are allocated to addresses in the range from FFFFFF80h to FFFFFFFFh. Figure 2.8 shows the fixed vector table.

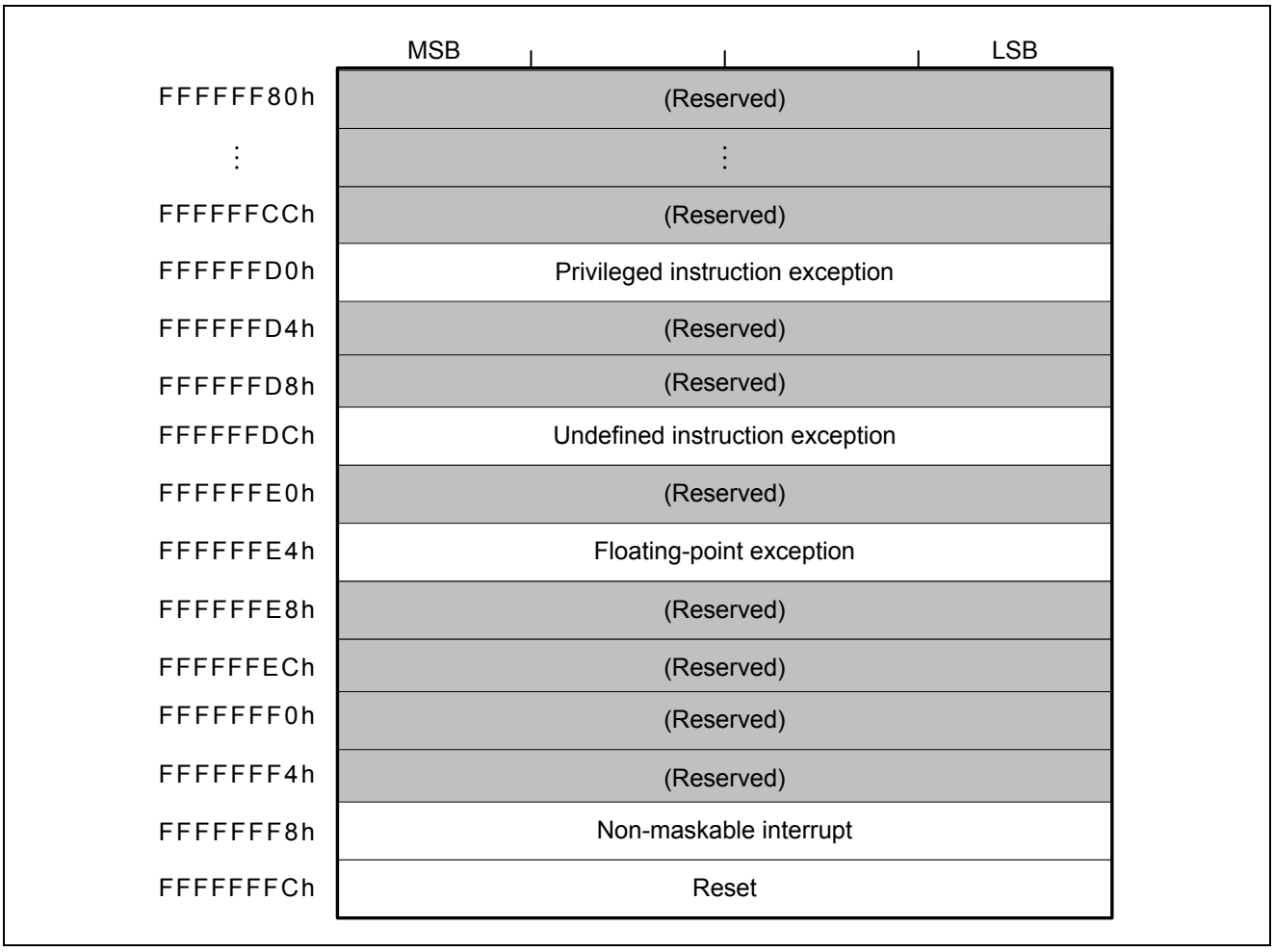


Figure 2.8 Fixed Vector Table

2.6.2 Relocatable Vector Table

The address where the relocatable vector table is placed can be adjusted. The table is a 1,024-byte region that contains all vectors for unconditional traps and interrupts and starts at the address (IntBase) specified in the interrupt table register (INTB). Figure 2.9 shows the relocatable vector table.

Each vector in the relocatable vector table has a vector number from 0 to 255. Each of the INT instructions, which act as the sources of unconditional traps, is allocated to the vector that has the same number as that of the instruction itself (from 0 to 255). The BRK instruction is allocated to the vector with number 0. Furthermore, vector numbers within the set from 0 to 255 may also be allocated to other interrupt sources on a per-product basis. For more on the interrupt vector numbers, see section 10.3.1, Interrupt Vector Table.

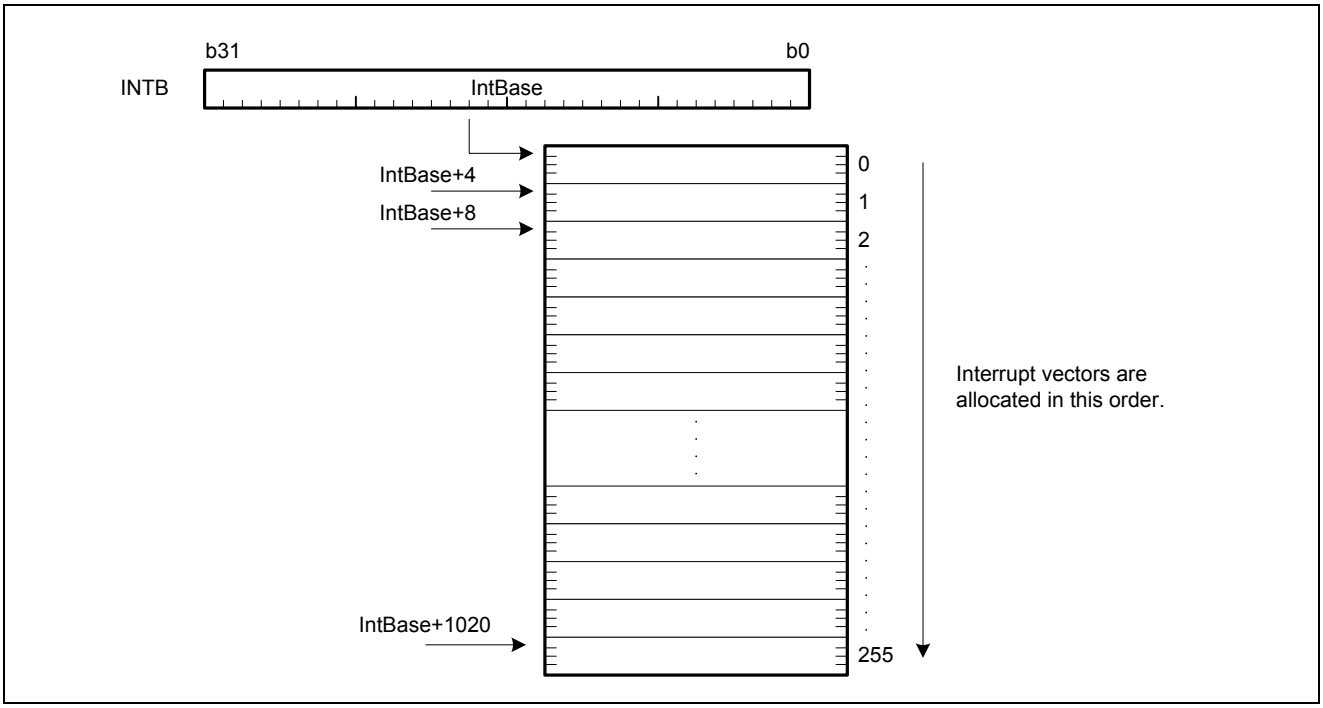


Figure 2.9 Relocatable Vector Table

2.7 Operation of Instructions

2.7.1 Data Prefetching by the RMPA Instruction and the String-Manipulation Instructions

The RMPA instruction and the string-manipulation instructions (SCMPU, SMOVB, SMOVF, SMOVU, SUNTIL, SWHILE, and SSTR instructions are not included) may prefetch data from the memory to speed up the read processing. Data is prefetched from the prefetching start position with three bytes as the upper limit. The prefetching start positions of each operation are shown below.

- RMPA instruction: The multiplicand address specified by R1, and the multiplier address specified by R2
- SCMPU instruction: The source address specified by R1 for comparison, and the destination address specified by R2 for comparison
- SUNTIL and SWHILE instructions: The destination address specified by R1 for comparison
- SMOVB, SMOVF, and SMOVU instructions: The source address specified by R2 for transfer

2.8 Pipeline

2.8.1 Overview

The RX CPU has 5-stage pipeline structure. The RX CPU instruction is converted into one or more micro-operations, which are then executed in pipeline processing. In the pipeline stage, the IF stage is executed in the unit of instructions, while the D and subsequent stages are executed in the unit of micro-operations.

The operation of pipeline and respective stages is described below.

(1) IF stage (instruction fetch stage)

In the IF stage, the CPU fetches instructions from the memory. As the RX CPU has four 8-byte instruction queues, it fetches instructions until the instruction queue is full, regardless of the completion of decoding in the D (decoding) stage.

(2) D stage (decoding stage)

The CPU decodes instructions in the D stage and converts them into micro-operations. The CPU reads the register information (RF) in this stage and executes a bypass process (BYP) if the result of the preceding instruction will be used in a subsequent instruction. The write of operation result to the register (RW) can be executed with the register reference by using the bypass process.

(3) E stage (execution stage)

Operations and address calculations (OP) are processed in the E stage.

(4) M stage (memory access stage)

Operand memory accesses (OA) are processed in the M stage. This stage is used only when the memory is accessed, and is divided into two sub-stages, M1 and M2. The RX CPU enables respective memory accesses for M1 and M2.

- M1 stage (memory-access stage 1)
  Operand memory access (OA1, OA2) is processed.

  Store operation: The pipeline processing ends when a write request is received via the bus.

  Load operation: The operation proceeds to the M2 stage when a read request is received via the bus. If a request and load data are received at the same timing (no-wait memory access), the operation proceeds to the WB stage.

- M2 stage (memory-access stage 2)
  Operand memory access (OA2) is processed. The CPU waits for the load data in the M2 stage. When the load data is received, the operation proceeds to the WB stage.

(5) WB stage (write-back stage)

The operation result and the data read from memory are written to the register (RW) in the WB stage. The data read from memory and the other type of data, such as the operation result, can be written to the register in the same clock cycles.

Figure 2.10 shows the pipeline configuration and its operation.

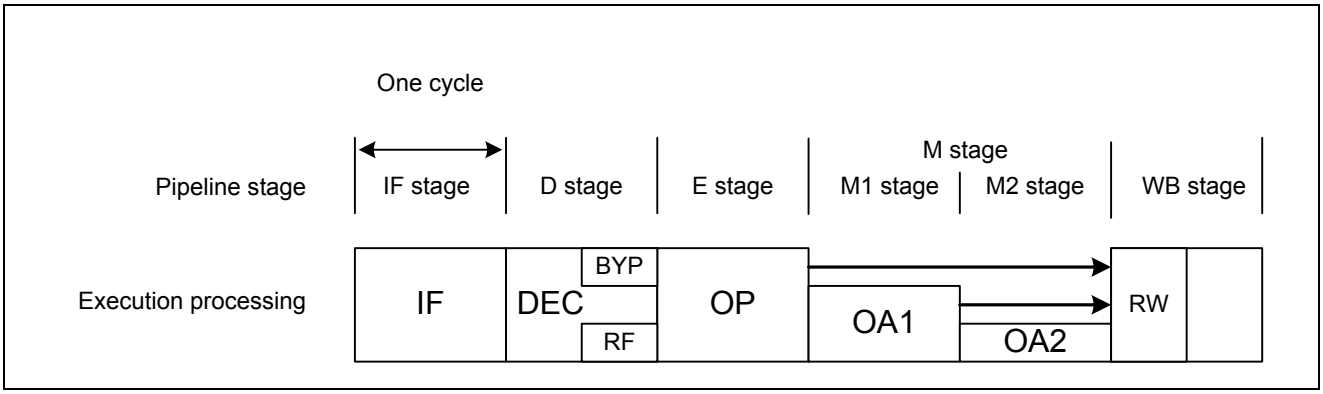


Figure 2.10 Pipeline Configuration and its Operation

2.8.2 Instructions and Pipeline Processing

The operands in the table below indicate the following meaning.

#IMM: Immediate
Rs, Rs2, Rd, Rd2, Ri, Rb: General-purpose register, CR: Control register
dsp: dsp5, dsp8, dsp16, dsp24
pcdsp: pcdsp3, pcdsp8, pcdsp16, pcdsp24

2.8.2.1 Instructions Converted into Single Micro-Operation and Pipeline Processing

The table below lists the instructions that are converted into a single micro-operation. The number of cycles in the table indicates the number of cycles during no-wait memory access.

Table 2.13 Instructions that are Converted into a Single Micro-Operation

Instruction	Mnemonic (indicates the common operation when the size is omitted)	Reference Figure	Number of Cycles
Arithmetic/logic instructions (register-register, immediate-register) Except EMUL, EMULU, RMPA, DIV, and DIVU	• {ABS, ADC (omitted), XOR} “#IMM, Rd”/“Rd” /“Rs, Rd”/“Rs, Rs2, Rd”	Figure 2.11	1
Arithmetic/logic instructions (division)	• DIV “#IMM, Rd”/“Rs, Rd”	Figure 2.11	3 to 20*1
	• DIVU “#IMM, Rd”/“Rs, Rd”	Figure 2.11	2 to 18*1
Data transfer instructions (register-register, immediate-register)	• {MOV, MOVU, REVL, REVW} “#IMM, Rd”/“Rs, Rd” • SCCnd “Rd” • {STNZ, STZ} “#IMM, Rd”	Figure 2.11	1
Transfer instructions (load operation)	• {MOV, MOVU} “[Rs], Rd”/“dsp[Rs], Rd” /“[Rs+], Rd”/“[-Rs], Rd”/“Rs, [Ri, Rb]” • POP “Rd”	Figure 2.12	Throughput: 1 Latency: 2*2
Transfer instructions (store operation)	• MOV “Rs, [Rd]”/“Rs, dsp[Rd]”/“Rs, [Rd+]” /“Rs, [-Rd]”/“Rs, [Ri, Rb]” • PUSH “Rs” • PUSHC “CR”	Figure 2.13	1
Bit manipulation instructions (register)	• {BCLR, BNOT, BSET, BTST} “#IMM, Rd”/“Rs, Rd” • BMCnd “#IMM, Rd”	Figure 2.11	1
Branch instructions	• BCnd “pcdsp” • {BRA, BSR} “pcdsp”/“Rs” • {JMP, JSR} “Rs”	Figure 2.22	Branch taken: 3 Branch not taken: 1
Floating-point operation instructions (register-register, immediate-register)	• FCMP “#IMM, Rd”/“Rs, Rd”	Figure 2.11	1
System manipulation instructions	• CLRPSW, SETPSW “#IMM” • MVTC “#IMM, CR”/“Rs, CR” • MVFC “CR, Rd”	—	1

Notes: 1. The number of cycles for the dividing instruction varies according to the divisor and dividend.
2. For the number of cycles for throughput and latency, see section 2.8.3, Calculation of the Instruction Processing Time.

Figures 2.11 to 2.13 show the operation of instructions that are converted into a basic single micro-operation.

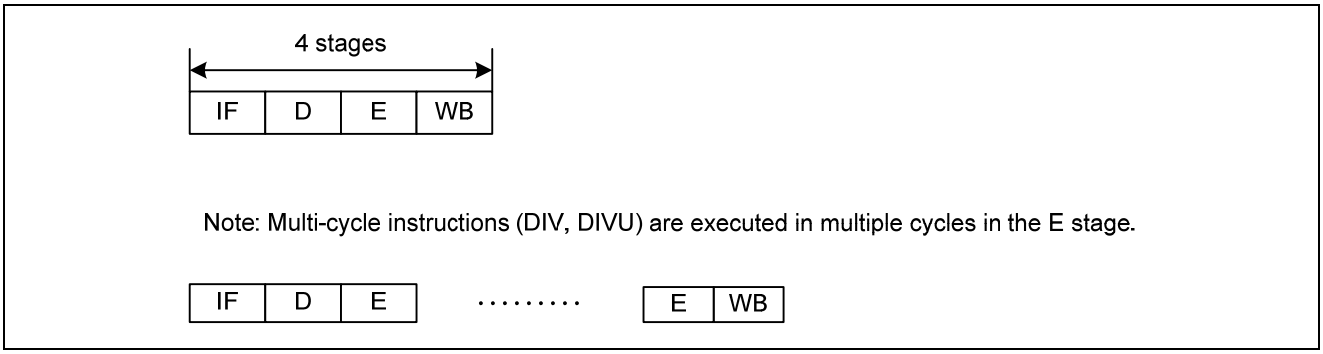


Figure 2.11 Operation for Register-Register, Immediate-Register

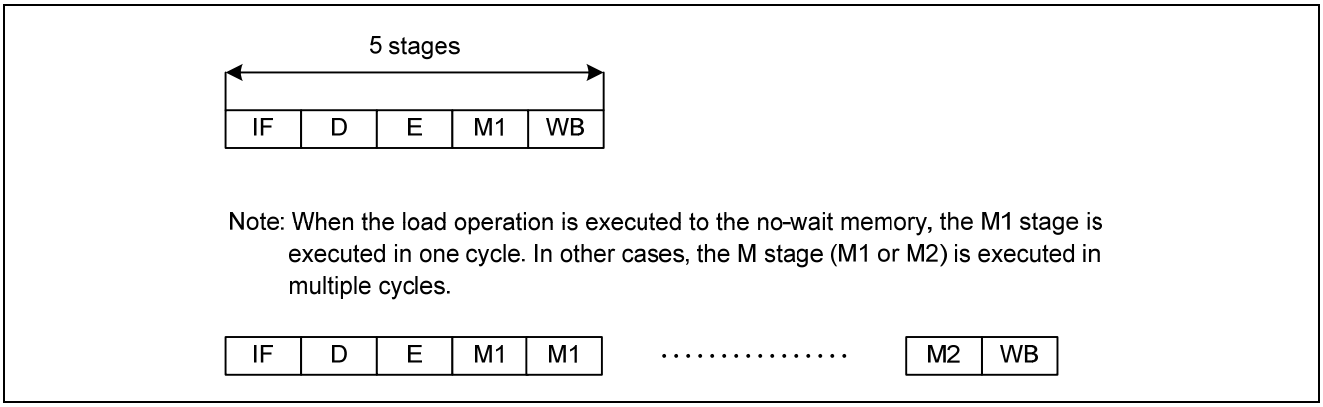


Figure 2.12 Load Operation

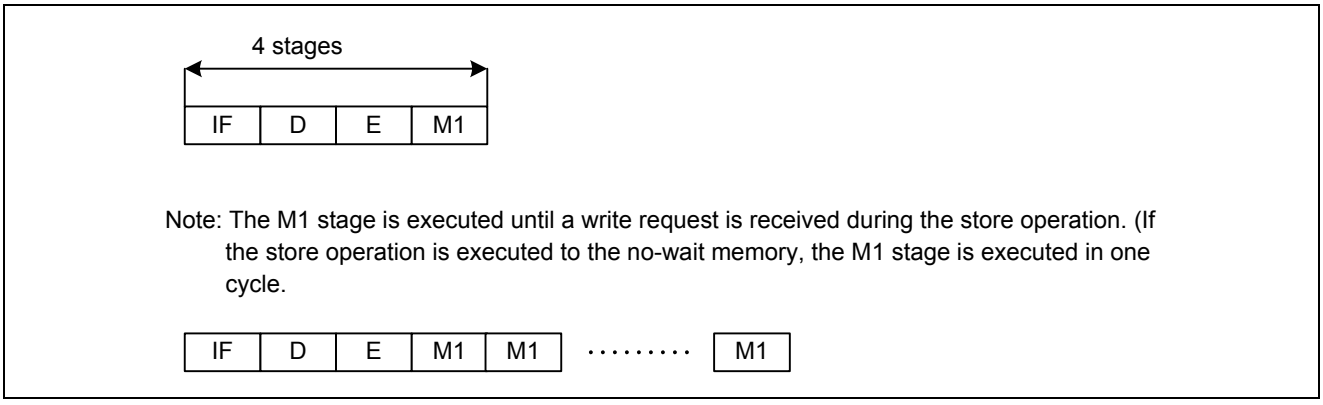


Figure 2.13 Store Operation

2.8.2.2 Instructions Converted into Multiple Micro-Operations and Pipeline Processing

The table below lists the instructions that are converted into multiple micro-operations. The number of cycles in the table indicates the number of cycles during no-wait memory access.

Table 2.14 Instructions that are Converted into Multiple Micro-Operations

Instruction	Mnemonic (indicates the common operation when the size is omitted)	Reference Figure	Number of Cycles
Arithmetic/logic instructions (memory source operand)	• ADC, ADD (omitted), XOR} "[Rs], Rd" /"dsp[Rs], Rd"	Figure 2.14	3
Arithmetic/logic instructions (division)	• DIV "[Rs], Rd / dsp[Rs], Rd"	—	5 to 22
	• DIVU "[Rs], Rd / dsp[Rs], Rd"	—	4 to 20
Arithmetic/logic instructions (multiplier: 32 x 32 → 64 bits) (register-register, register-immediate)	• {EMUL, EMULU} "#IMM, Rd"/"Rs, Rd"	Figure 2.16	2
Arithmetic/logic instructions (multiply-and-accumulate operation)	• RMPA.B	—	6+7×floor(n/4)+4×(n%4) n: Number of processing bytes*1
	• RMPA.W	—	6+5×floor(n/2)+4×(n%2) n: Number of processing words*1
	• RMPA.L	—	6+4n n: Number of processing longwords*1
Data transfer instructions (memory-memory transfer)	• MOV "[Rs], [Rd]"/"dsp[Rs], [Rd]" /"[Rs], dsp[Rd]"/"dsp[Rs], [Rd]" • PUSH "[Rs]"/"dsp[Rs]"	Figure 2.15	3
Bit manipulation instructions (memory source operand)	• {BCLR, BNOT, BSET, BTST} "#IMM, [Rd]" /"#IMM, dsp[Rd]" • BMCnd "#IMM, [Rd]"/"#IMM, dsp[Rd]"	Figure 2.15	3
Transfer instructions (load operation)	• POPC "CR"	—	Throughput: 3 Latency: 4*2
Transfer instructions (store operation of multiple registers)	• PUSHM "Rs-Rs2"	—	n n: Number of registers*3
Transfer instructions (store operation of multiple registers)	• POPM "Rs-Rs2"	—	Throughput: n Latency: n + 1 n: Number of registers*2*4
Transfer instructions (register-register)	• XCHG "Rs, Rd"	Figure 2.17	2
Transfer instructions (memory-register)	• XCHG "[Rs], Rd"/"dsp[Rs], Rd"	Figure 2.18	2
Branch instructions	• RTS	—	5
	• RTSD "#IMM"	—	5
	• RTSD "#IMM, Rd-Rd2"	—	Throughput: n<5?5:1+n Latency: n<4?5:2+n n: Number of registers*2

Instruction	Mnemonic (indicates the common operation when the size is omitted)	Reference Figure	Number of Cycles
String manipulation instructions*5	• SCMPU	—	2+4×floor(n/4)+4×(n%4) n: Number of comparison bytes*1
	• SMOVB	—	n>3? 6+3×floor(n/4)+3×(n%4): 2+3n n: Number of transfer bytes*1
	• SMOVF, SMOVU	—	2+3×floor(n/4)+3×(n%4) n: Number of transfer bytes*1
	• SSTR.B	—	2+floor(n/4)+n%4 n: Number of transfer bytes*1
	• SSTR.W	—	2+floor(n/2)+n%2 n: Number of transfer words*1
	• SSTR.L	—	2+n n: Number of transfer longwords
	• SUNTIL.B, SWHILE.B	—	3+3×floor(n/4)+3×(n%4) n: Number of comparison bytes*1
	• SUNTIL.W, SWHILE.W	—	3+3×floor(n/2)+3×(n%2) n: Number of comparison words*1
	• SUNTIL.L, SWHILE.L	—	3+3×n n: Number of comparison longwords
Floating-point operation instructions (register-register, immediate-register)	• {FADD, FSUB} “#IMM, Rd”/ “Rs, Rd”	Figure 2.19	4
	• FMUL “#IMM, Rd”/“Rs, Rd”	—	3
	• FDIV “#IMM, Rd”/“Rs, Rd”	—	16
	• {FTOI, ROUND, ITOF} “Rs, Rd”	—	2
Floating-point operation instructions (memory source operand)	• {FADD, FSUB} “[Rs], Rd”/“dsp[Rs], Rd”	—	6
	• FMUL “[Rs], Rd”/“dsp[Rs], Rd”	—	5
	• FDIV “[Rs], Rd”/“dsp[Rs], Rd”	—	1
	• {FTOI, ROUND, ITOF} “[Rs], Rd” /“dsp[Rs], Rd”	—	4
System manipulation instructions	• RTE	—	6
	• RTFI	—	3

Notes: 1. floor(x): Max. integer that is smaller than x

2. For the number of cycles for throughput and latency, see section 2.8.3, Calculation of the Instruction Processing Time.
3. The PUSHM instruction is converted into multiple store operations. The pipeline processing is the same as the one for the store operations of the MOV instruction, where the operation is repeated for the number of specified registers.
4. The POPM instruction is converted into multiple store operations. The pipeline processing is the same as the one for the store operations of the MOV instruction, where the operation is repeated for the number of specified registers.
5. Each of the SCMPU, SMOVU, SWHILE, and SUNTIL instructions ends the execution regardless of the specified cycles, if the end condition is satisfied during execution.

Figures 2.14 to 2.19 show the operation of instructions that are converted into basic multiple micro-operations. Small letters in figures below indicate micro-operations.

[Legend]
mop: Micro-operation, stall: Pipeline stall

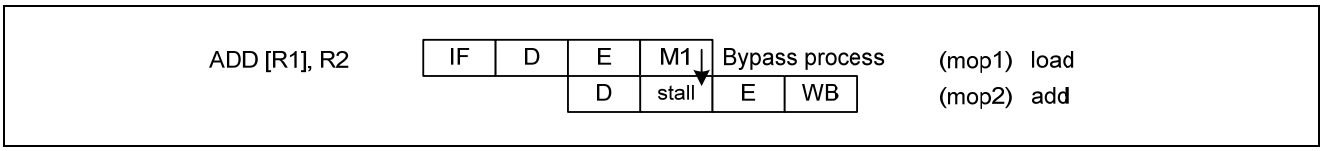


Figure 2.14 Arithmetic/Logic Instruction (Memory Source Operand)

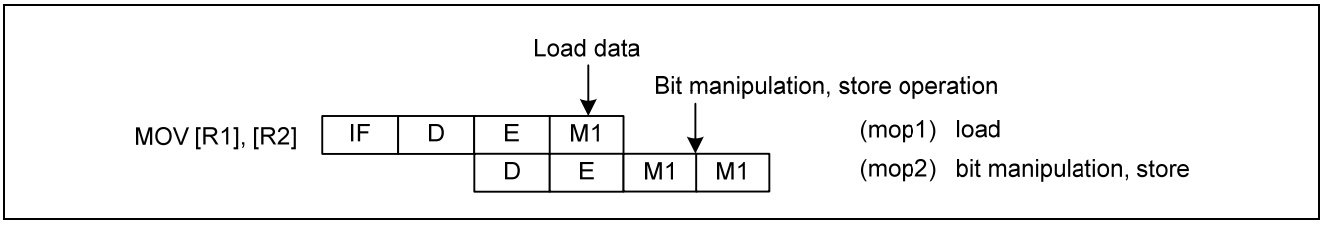


Figure 2.15 MOV Instruction (Memory-Memory), Bit Manipulation Instruction (Memory Source Operand)

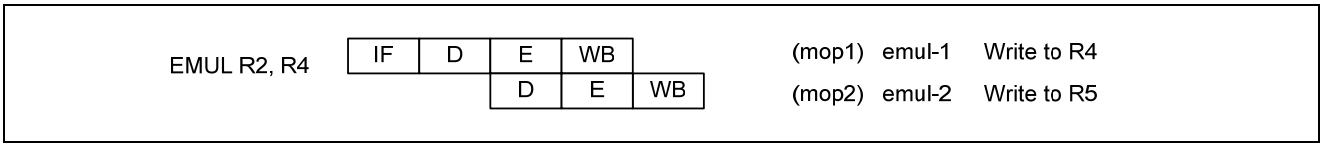


Figure 2.16 EMUL, EMULU Instructions (Register- Register, Register-Immediate)

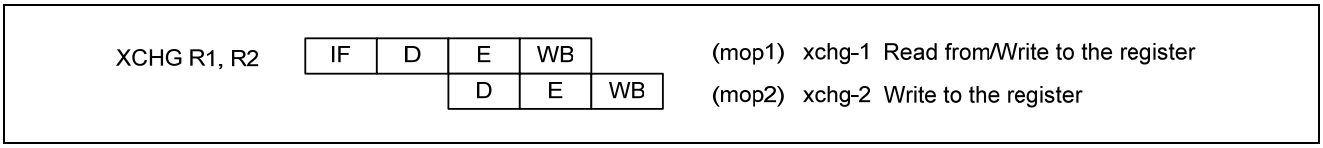


Figure 2.17 XCHG Instruction (Registers)

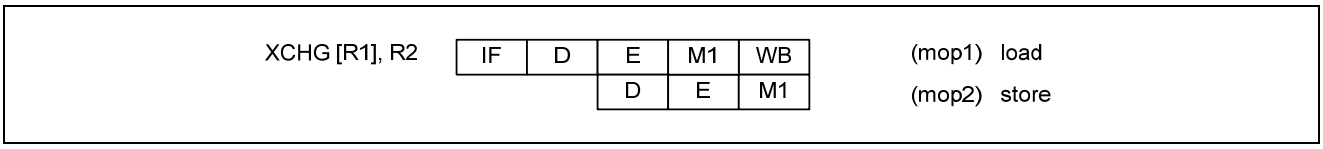


Figure 2.18 XCHG Instruction (Memory Source Operand)

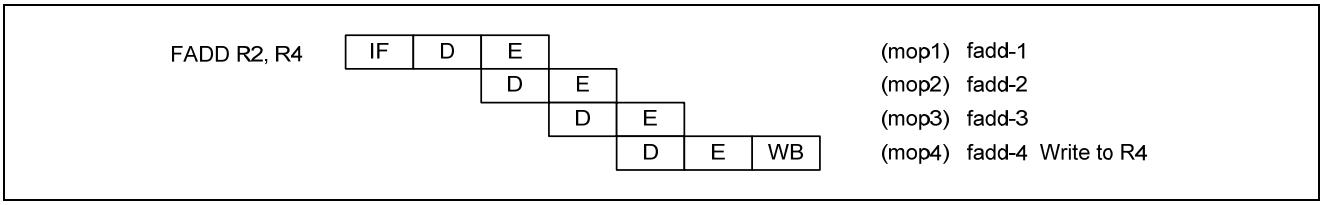


Figure 2.19 Floating-Point Operation Instruction (Register-Register, Immediate-Register)

2.8.2.3 Pipeline Basic Operation

In the ideal pipeline processing, each stage is executed in one cycle, though all instructions may not be pipelined in due to the processing and the branch execution.

The CPU controls the pipeline stage with the IF stage in the unit of instructions, while the D and subsequent stages in the unit of micro-operations.

The figures below show the pipeline processing of typical cases. Small letters in figures indicate micro-operations.

[Legend]
mop: Micro-operation, stall: Pipeline stall

(1) Pipeline Flow with Stalls

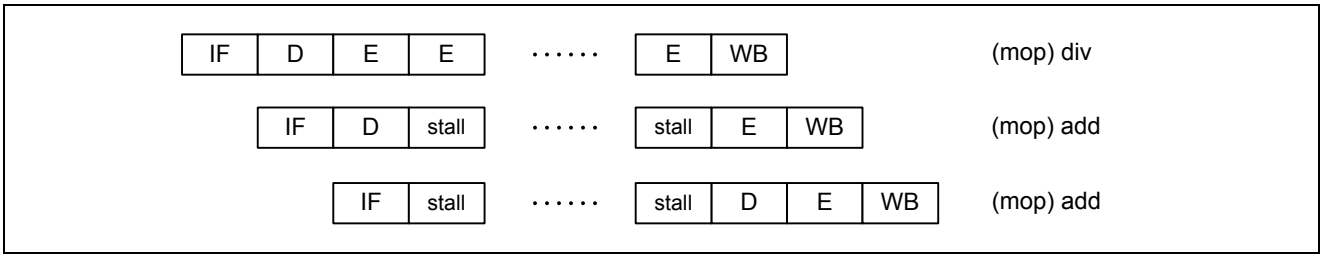


Figure 2.20 When an Instruction which Requires Multiple Cycles is Executed in the E Stage

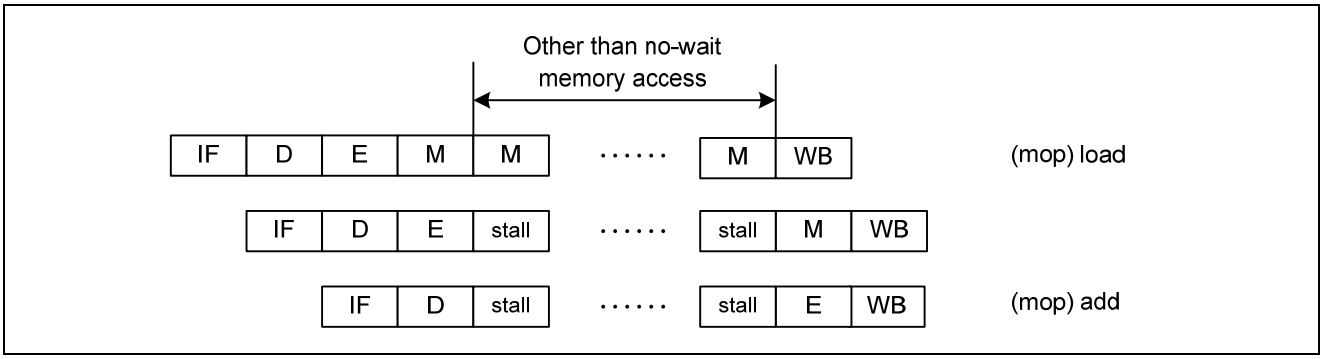


Figure 2.21 When an Instruction which Requires more than One Cycle for its Operand Access is Executed

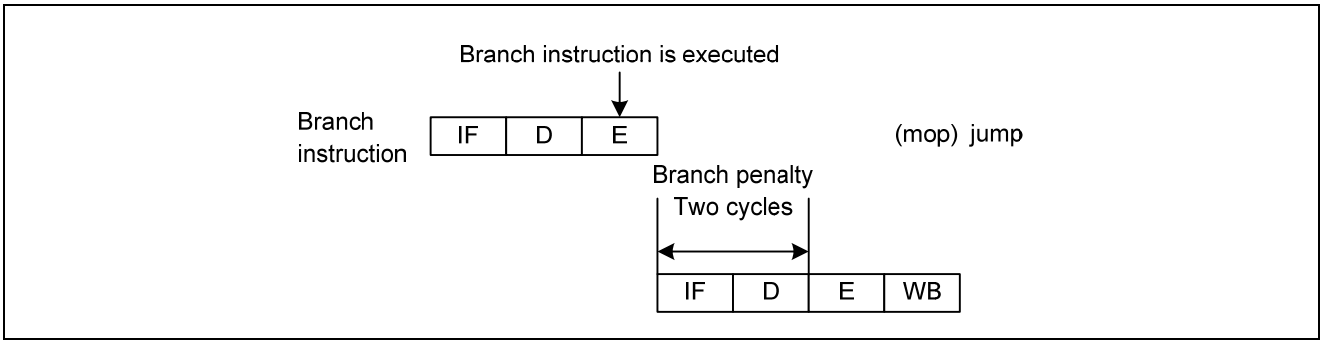


Figure 2.22 When a Branch Instruction is Executed (While the Condition is Satisfied for Unconditional/Conditional Branch Instruction)

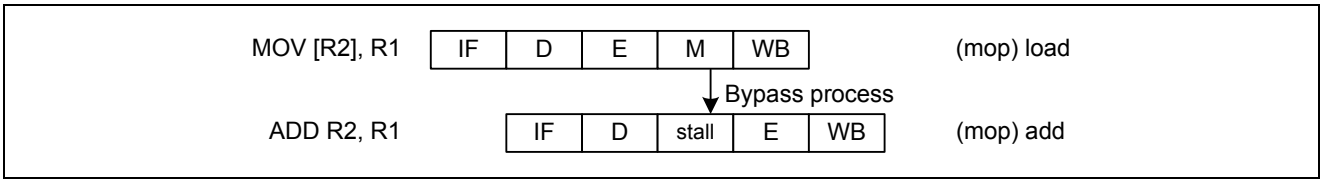


Figure 2.23 When the Subsequent Instruction Uses an Operand Read from the Memory

(2) Pipeline Flow with no Stall

(a) Bypass process

Even when the result of the preceding instruction will be used in a subsequent instruction, the operation processing between registers is pipelined in by the bypass process.

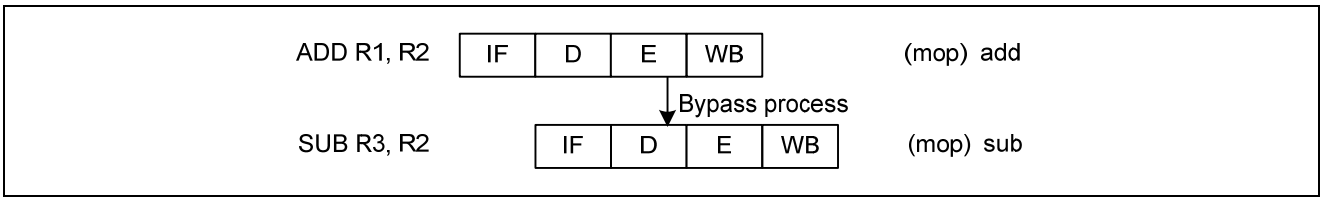


Figure 2.24 Bypass Process

(b) When WB stages for the memory load and for the operation are overlapped

Even when the WB stages for the memory load and for the operation are overlapped, the operation processing is pipelined in, because the load data and the operation result can be written to the register at the same timing.

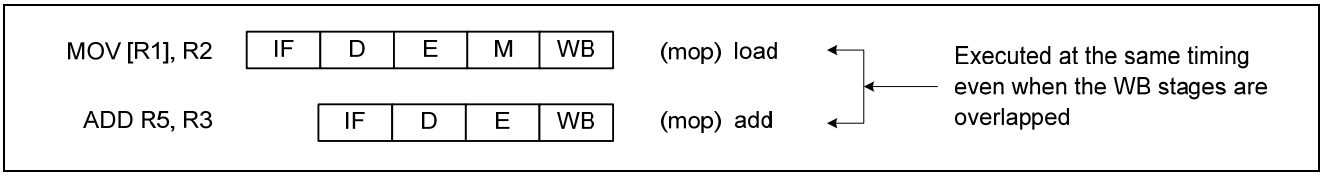


Figure 2.25 When WB Stages for the Memory Load and for the Operation are Overlapped

(c) When subsequent instruction writes to the same register before the end of memory load

Even when the subsequent instruction writes to the same register before the end of memory load, the operation processing is pipelined in, because the WB stage for the memory load is canceled.

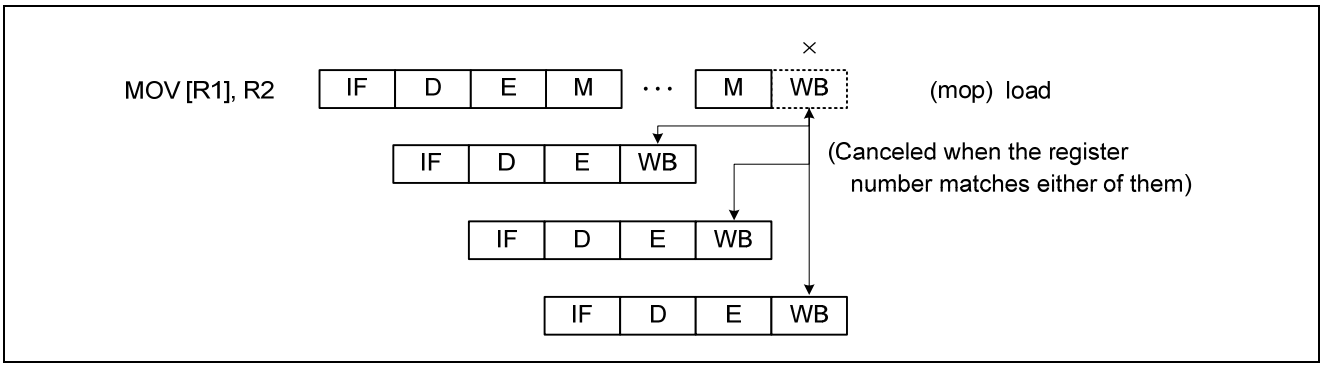


Figure 2.26 When Subsequent Instruction Writes to the Same Register before the End of Memory Load

(d) When the load data is not used by the subsequent instruction

When the load data is not used by the subsequent instruction, the subsequent operations are in fact executed earlier and the operation processing ends (out-of-order completion).

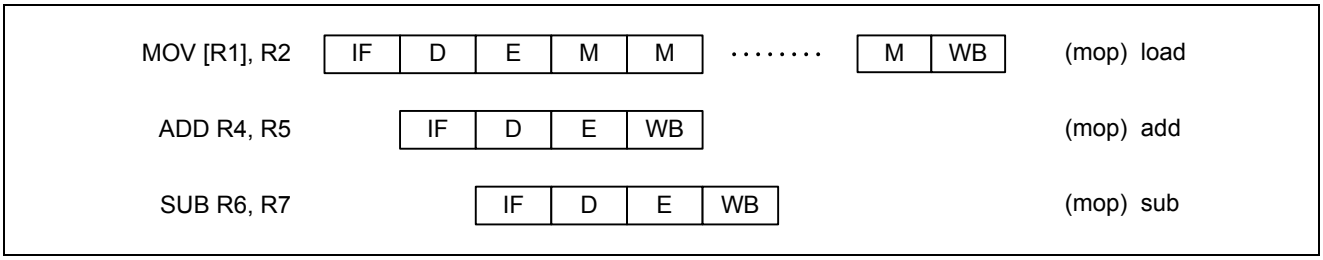


Figure 2.27 When Load Data is not Used by the Subsequent Instruction

2.8.3 Calculation of the Instruction Processing Time

Though the instruction processing time of the CPU varies according to the pipeline processing, the approximate time can be calculated in the following methods.

- Count the number of cycles (see tables 2.13 and 2.14)
  When the load data is used by the subsequent instruction, the number of cycles described as " latency" is counted as the number of cycles for the memory load instruction. For the cycles other than the memory load instruction, the number of cycles described as "throughput" is counted.
- If the instruction fetch stall is generated, the number of cycles increments.
- Depending on the system configuration, multiple cycles are required for the memory access. The number of memory access cycles in the RX610 Group is on a per-product basis.

2.8.4 Numbers of Cycles for Response to Interrupts

Table 2.15 lists numbers of cycles taken by processing for response to interrupts.

Table 2.15 Numbers of Cycles for Response to Interrupts

Type of Interrupt Request/Details of Processing	Fast Interrupt	Other Interrupts
ICU Judgment of priority order	2 cycles	2 cycles
CPU Number of cycles from notification to acceptance of the interrupt request	N cycles (varies with the instruction being executed at the time the interrupt was received)	
CPU—Pre-processing by hardware Saving the current PC and PSW values in RAM (or in control registers in the case of the fast interrupt) Reading of the vector Branching to the start of the interrupt Exception handling routine	4 cycles	6 cycles

Times calculated from the values in table 2.15 will be applicable when access to memory from the CPU is always processed with no waiting. The on-chip RAM and ROM in products of the RX62N/RX621 Groups always allows such access. Numbers of cycles for response to interrupts can be minimized by placing program code (and vectors) in on-chip ROM and the stack in on-chip RAM. Furthermore, place the addresses where handlers start on eight-byte boundaries.

For information on the number of cycles from notification to acceptance of the interrupt request, indicated by N in the table above, see tables 2.13, Instructions that are Converted into a Single Micro-Operation, and 2.14, Instructions that are Converted into Multiple Micro-Operations.

The timing of interrupt acceptance depends on the state of the CPU's pipelines. For more information on this, see section 9.3.1, Timing of Acceptance and Saved PC Values.

3. Operating Modes

3.1 Operating Mode Types and Selection

Operating modes are specified by the MD1 and MD0 pins and the ROME and EXBE bits in the system control register 0 (SYSCR0).

The endian can be selected in each operating mode. Endian is specified by the MDE pin. For details on the endian, see section 11, Buses.

Note:Do not change the state of pins MDE, MD1, and MD0 while the LSI is working. Do not select any combination other than those specified in table 3.1.

Table 3.1 Selection of Operating Modes by the Mode Pins

Mode Pin		SYSCR0 Initial State				
MD1	**MD0**	**ROME**	**EXBE**	**Operating Mode**	**On-Chip ROM***	**External Bus**
0	1	1	0	Boot mode	Enabled	Disabled
1	0	1	0	User boot mode	Enabled	Disabled
1	1	1	0	Single-chip mode	Enabled	Disabled

Note: * The on-chip ROM is classified into two flash memories: ROM and data flash. For details, see section 26, ROM (Flash Memory for Code Storage), and section 27, Data Flash (Flash Memory for Data Storage).

Table 3.2 Selection of Operating Modes by Register Setting

SYSCR0				
ROME	**EXBE**	**Operating Mode**	**On-Chip ROM***	**External Bus**
0	0	Single-chip mode, user boot mode	Disabled	Disabled
1	0		Enabled	Disabled
0	1	On-chip ROM disabled extended mode	Disabled	Enabled
1	1	On-chip ROM enabled extended mode	Enabled	Enabled

Note: * The on-chip ROM is classified into two flash memories: ROM and data flash. For details, see section 26, ROM (Flash Memory for Code Storage), and section 27, Data Flash (Flash Memory for Data Storage).

Table 3.3 Selection of Endian

Mode Pin	
MDE	**Endian**
0	Little endian
1	Big endian

3.2 Register Descriptions

Table 3.4 lists the registers related to operating modes.

Table 3.4 Registers Related to Operating Modes

Register Name	Symbol	Value after Reset	Address	Access Size
Mode monitor register	MDMONR	10000000 x00000xxb	0008 0000h	16
Mode status register	MDSR	00000000 00001001b	0008 0002h	16
System control register 0	SYSCR0	00000000 00000001b	0008 0006h	16
System control register 1	SYSCR1	00000000 00000001b	0008 0008h	16

3.2.1 Mode Monitor Register (MDMONR)

Address: 0008 0000h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	1	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	MDE	—	—	—	—	—	MD1	MD0
Value after reset:	x*	0	0	0	0	0	x*	x*

Note: * Depends on the setting of the mode pins (MDE, MD1, and MD0).

Bit	Symbol	Bit Name	Description	R/W
b0	MD0	MD0 Status Flag	0: The MD0 pin is 0 1: The MD0 pin is 1	R
b1	MD1	MD1 Status Flag	0: The MD1 pin is 0 1: The MD1 pin is 1	R
b6 to b2	—	Reserved	These bits are always read as 0 and cannot be modified.	R
b7	MDE	MDE Status Flag	0: The MDE pin is 0 (little endian) 1: The MDE pin is 1 (big endian)	R
b14 to b8	—	Reserved	These bits are always read as 0 and cannot be modified.	R
b15	—	Reserved	This bit is always read as 1 and cannot be modified.	R

MDMONR indicates the status of the mode pins.

3.2.2 Mode Status Register (MDSR)

Address: 0008 0002h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	UBTS	—	BOTS	BSW[1:0]		EXB	IROM
Value after reset:	0	0	0	0	1	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	IROM	On-Chip ROM Startup Status Flag	0: The on-chip ROM is disabled at startup 1: The on-chip ROM is enabled at startup	R
b1	EXB	External Bus Startup Status Flag	0: The external bus is disabled at startup 1: The external bus is enabled at startup	R
b3, b2	BSW[1:0]	External Bus Width Flags	0 0: The 16-bit bus is activated 0 1: Reserved 1 0: The 8-bit bus is activated 1 1: Reserved	R
b4	BOTS	Boot Mode Startup Flag	0: Started with a mode except boot mode 1: Started with boot mode	R
b5	—	Reserved	This bit is always read as 0 and cannot be modified.	R
b6	UBTS	User Boot Mode Startup Flag	0: Started with a mode except user boot mode 1: Started with user boot mode	R
b15 to b7	—	Reserved	These bits are always read as 0 and cannot be modified.	R

MDSR indicates the internal status of this LSI at startup.

3.2.3 System Control Register 0 (SYSCR0)

Address: 0008 0006h

	b15	b14	b13	b12	b11	b10	b9	b8
	KEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	EXBE	ROME
Value after reset:	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	ROME	On-Chip FLASH Enable	0: The on-chip FLASH is disabled 1: The on-chip ROM is enabled	R/W
b1	EXBE	External Bus Enable	0: The external bus is disabled 1: The external bus is enabled	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	KEY[7:0]	SYSCR0 Key Code	5Ah: Modifying SYSCR0 is enabled Other codes: Modifying SYSCR0 is disabled These bits are always read as 00h.	R/W

SYSCR0 is used to enable or disable the on-chip ROM and the external bus.

ROME Bit (On-Chip FLASH Enable)

The ROME bit enables or disables the on-chip ROM (ROM, data flash).

While this bit is 1, it can be cleared to 0. While this bit is 0, it cannot be set to 1. Once the on-chip ROM is disabled by clearing this bit to 0, the on-chip ROM can no longer be enabled with the ROME bit. A 0 should not be written to this bit during access to the on-chip ROM.

After writing a 0 to this bit to disable the on-chip ROM, always make sure that the ROME bit has been changed to 0 before proceeding to the next processing.

EXBE Bit (External Bus Enable)

The EXBE bit enables* or disables the external bus.

Write 0 to this bit while the external bus cycle is not performed.

Be careful when disabling the external bus because the external bus and the internal bus are concurrently activated in some cases. When the EXBE bit is changed, the bus should be accessed after the change in the EXBE bit is completed.

When the EXBE bit is changed, the I/O port setting should also be changed simultaneously. For details, see section 14, I/O Ports.

KEY[7:0] Bits (SYSCR0 Key Code)

The KEY[7:0] bits enable or disable modifying SYSCR0.

When writing a value to the ROME or EXBE bit, write 5Ah to the KEY[7:0] bits simultaneously. If SYSCR0 is modified with a KEY[7:0] value other than 5Ah, the ROME and EXBE values remain unchanged.

3.2.4 System Control Register 1 (SYSCR1)

Address: 0008 0008h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	RAME
Value after reset:	0	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	RAME	RAM Enable	0: The on-chip RAM is disabled 1: The on-chip RAM is enabled	R/W
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SYSCR1 is used to enable or disable the on-chip RAM.

RAME Bit (RAM Enable)

The RAME bit enables or disables the on-chip RAM.

The RAME bit is initialized to 1 after a reset is released.

A 0 should not be written to this bit during access to the on-chip RAM.

When accessing the on-chip RAM immediately after changing the RAME bit from 0 (on-chip RAM disabled) to 1 (on-chip RAM enabled), always make sure that the RAME bit is 1 before the access.

Even when the RAME bit is cleared to 0, the on-chip RAM retains its value*.

To retain the value in the on-chip RAM, keep the specified RAM standby voltage (VRAM). For details, see section 29, Electrical Characteristics.

3.3 Details of Operating Modes

3.3.1 Single-Chip Mode

In this mode, the on-chip ROM is enabled or disabled, the external bus is disabled (EXBE bit = 0 in SYSCR0), and all I/O ports can be used as input/output ports.

The on-chip ROM is enabled when this LSI is started. While the on-chip ROM is enabled (ROME bit = 1 in SYSCR0), it can be disabled by clearing the ROME bit to 0. While the on-chip ROM is disabled (ROME bit = 0), it cannot be enabled by setting the ROME bit to 1.

Setting the EXBE bit in SYSCR0 to 1 causes a transition to on-chip ROM enabled extended mode or on-chip ROM disabled extended mode where the external bus is available.

3.3.2 On-Chip ROM Enabled Extended Mode

In this mode, the on-chip ROM is enabled (ROME bit = 1 in SYSCR0) and the external bus is available as external extended mode (EXBE bit = 1 in SYSCR0). This mode allows some I/O ports to be used as data bus input/output, address bus output, or bus control signal input/output. For details, see section 14, I/O Ports.

The external bus width can be changed by the setting of external bus width selection (BSIZE[1:0] bits in CSiCNT (i = 0 to 7)). For details, see section 11, Buses.

Writing 0 to the EXBE bit causes a transition to single-chip mode (on-chip ROM enabled).

Writing 0 to the ROME bit causes a transition to on-chip ROM disabled extended mode.

3.3.3 On-Chip ROM Disabled Extended Mode

In this mode, the on-chip ROM is disabled (ROME bit = 0 in SYSCR0) and the external bus is available as external extended mode (EXBE bit = 1 in SYSCR0). This mode allows some I/O ports to be used as data bus input/output, address bus output, or bus control signal input/output. For details, see section 14, I/O Ports.

The external bus width can be changed by the setting of external bus width selection (BSIZE[1:0] bits in CSiCNT (i = 0 to 7)). For details, see section 11, Buses.

In this mode, the on-chip ROM cannot be enabled by setting the ROME bit to 1.

Writing 0 to the EXBE bit causes a transition to single-chip mode (on-chip ROM disabled).

3.3.4 Boot Mode

Boot mode is provided for the flash memory. This mode functions in the same manner as single-chip mode except for data write/erase to the flash memory. For details, see section 26, ROM (Flash Memory for Code Storage), and section 27, Data Flash (Flash Memory for Data Storage).

3.3.5 User Boot Mode

User boot mode is provided for the flash memory. This mode functions in the same manner as single-chip mode except for data write/erase to the flash memory. For details, see section 26, ROM (Flash Memory for Code Storage), and section 27, Data Flash (Flash Memory for Data Storage).

3.4 Transitions of Operating Modes

3.4.1 Operating Mode Transitions According to Mode Pin Setting

Figure 3.1 shows operating mode transitions according to the setting of pins MD1 and MD0. Operating modes can shift in the direction of arrow.

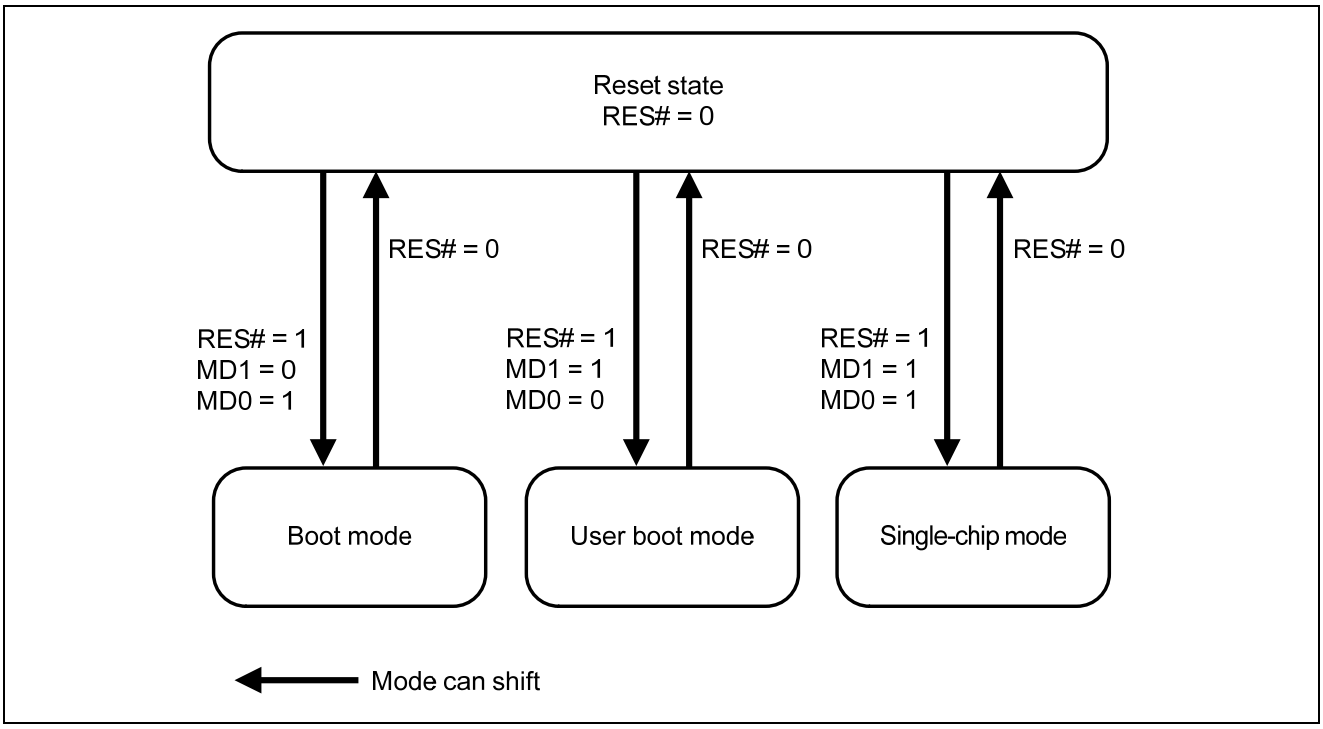


Figure 3.1 Setting of Pins MD1 and MD0 and Operating Modes

3.4.2 Operating Mode Transitions According to Register Setting

Figure 3.2 shows operating mode transitions according to the setting of the ROME and EXBE bits in SYSCR0. Operating modes can shift in the direction of arrow.

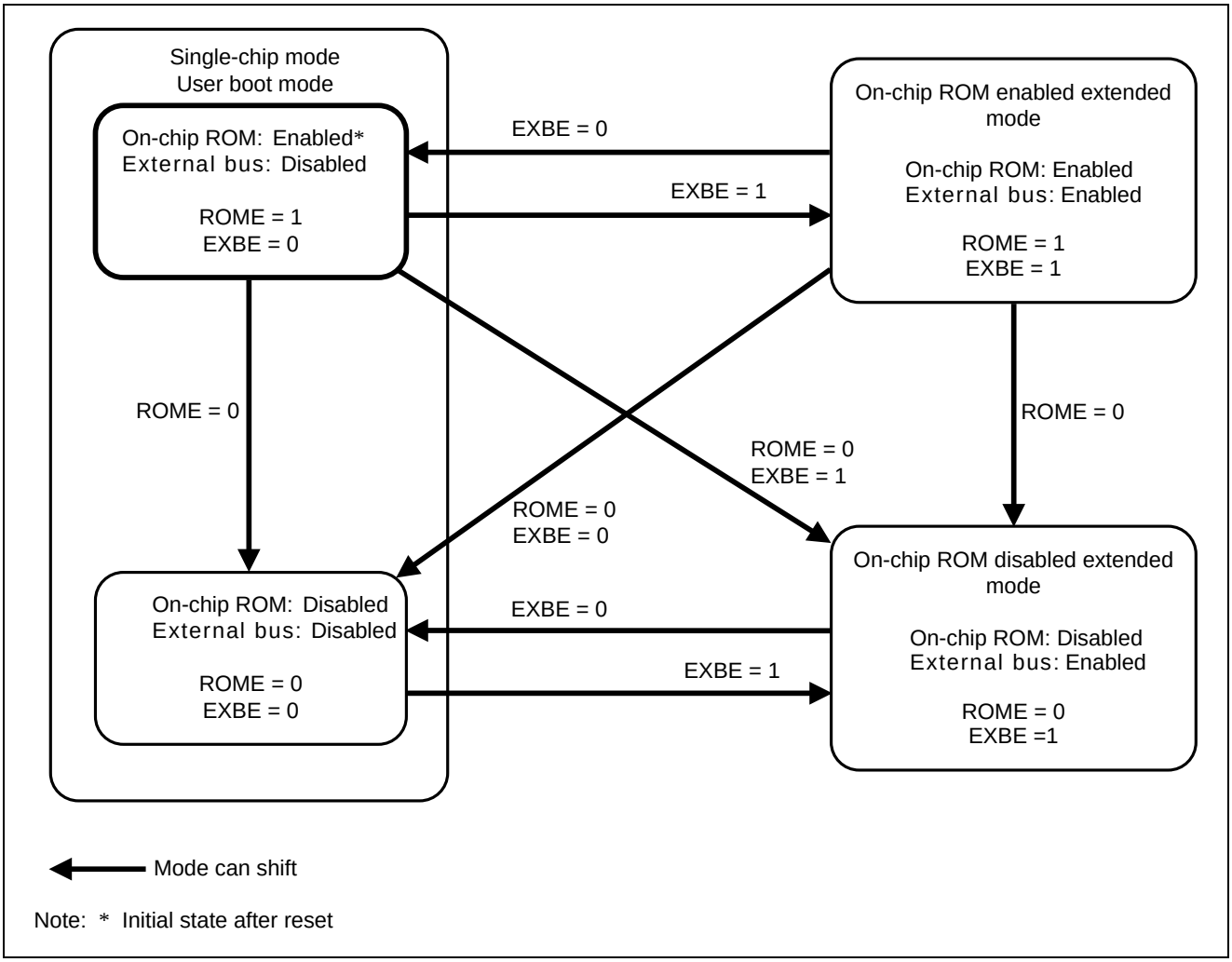


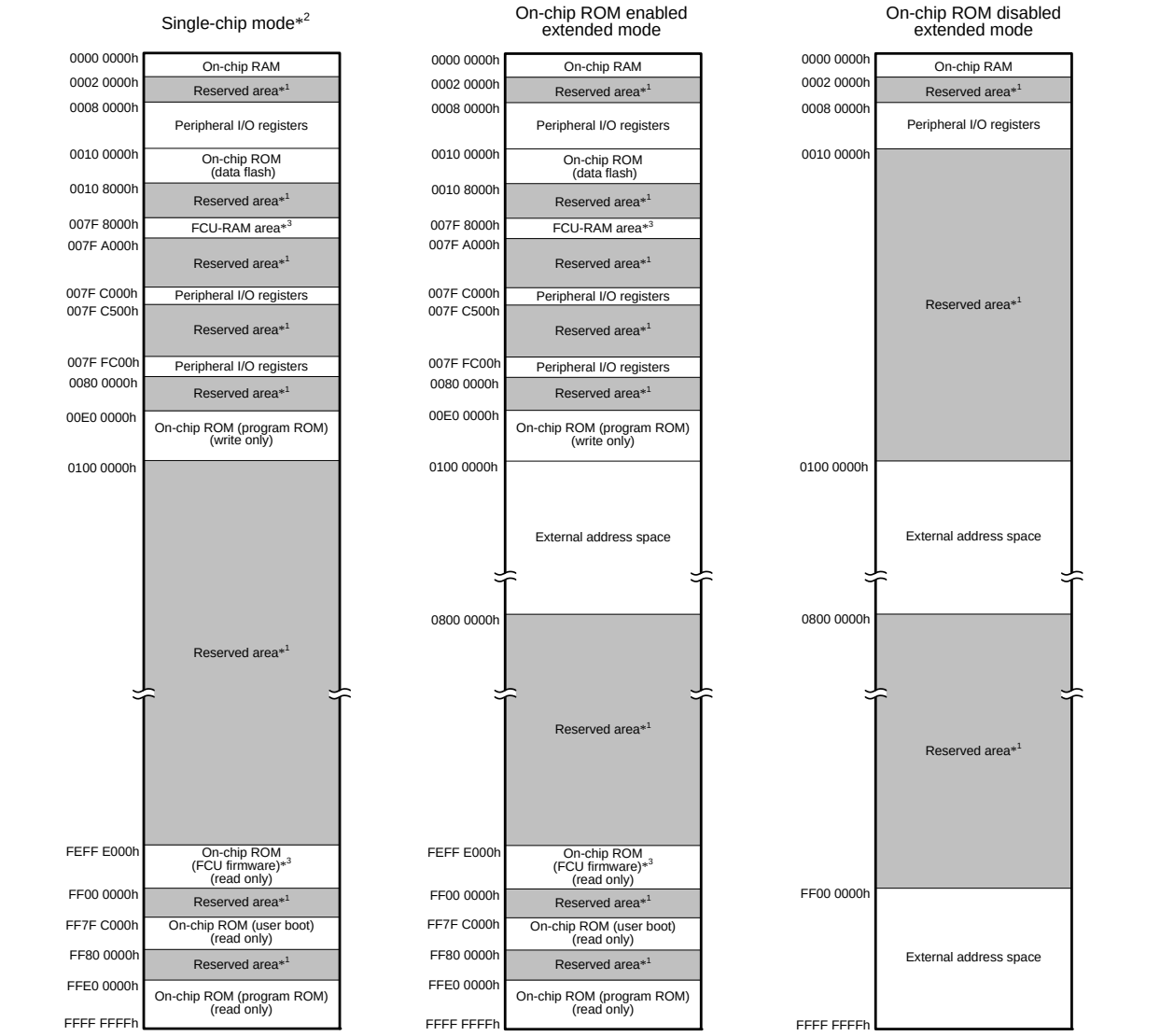
Figure 3.2 Setting of Bits ROME and EXBE and Operating Modes

4. Address Space

4.1 Address Space

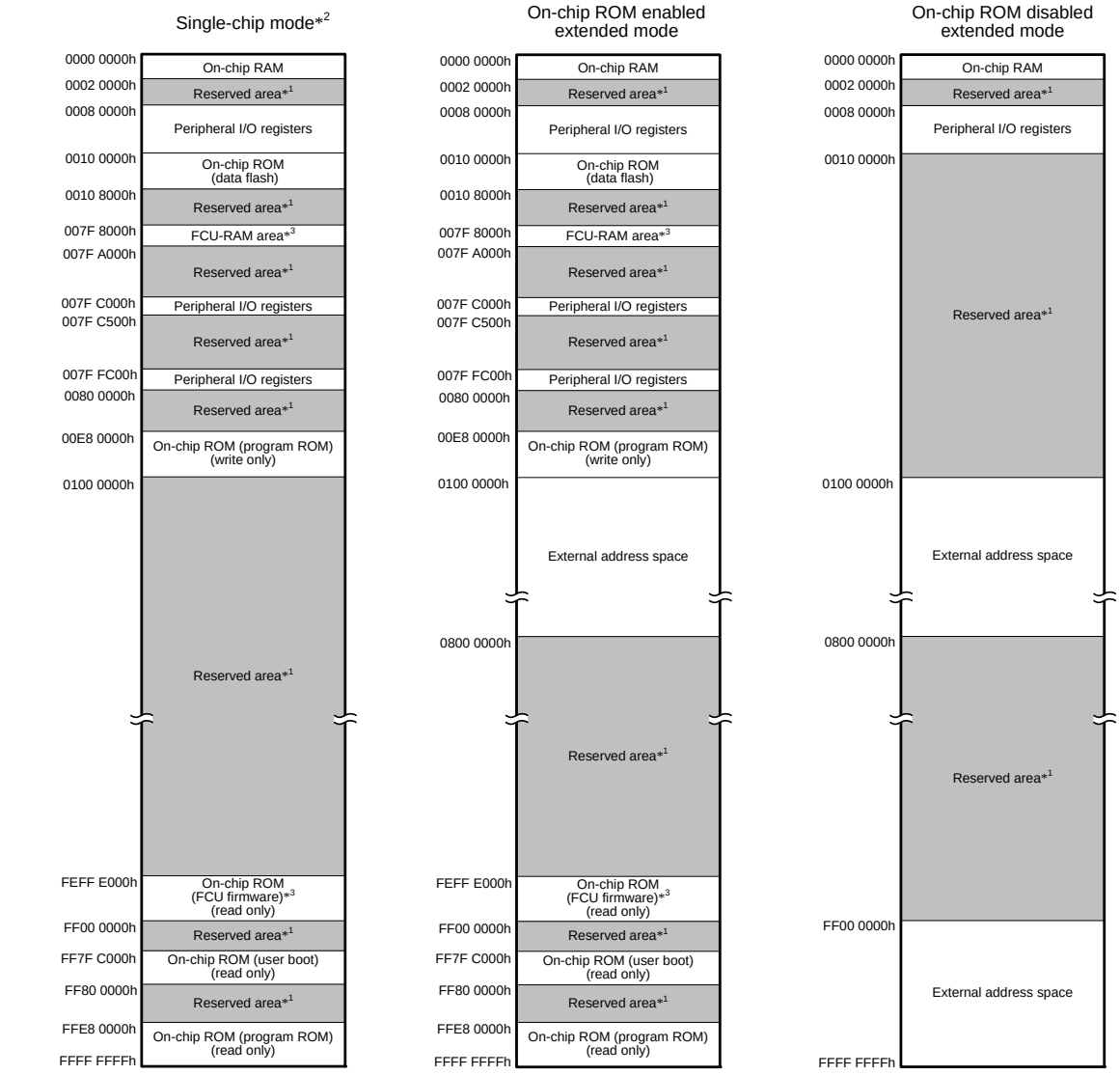
This MCU has a 4-Gbyte address space, consisting of the range of addresses from 0000 0000h to FFFF FFFFh. That is, linear access to an address space of up to 4 Gbytes is possible, and this contains both program and data areas.

Figures 4.1 to 4.4 show the memory maps in the respective operating modes of each product. Accessible areas will differ according to the operating mode and states of control bits.



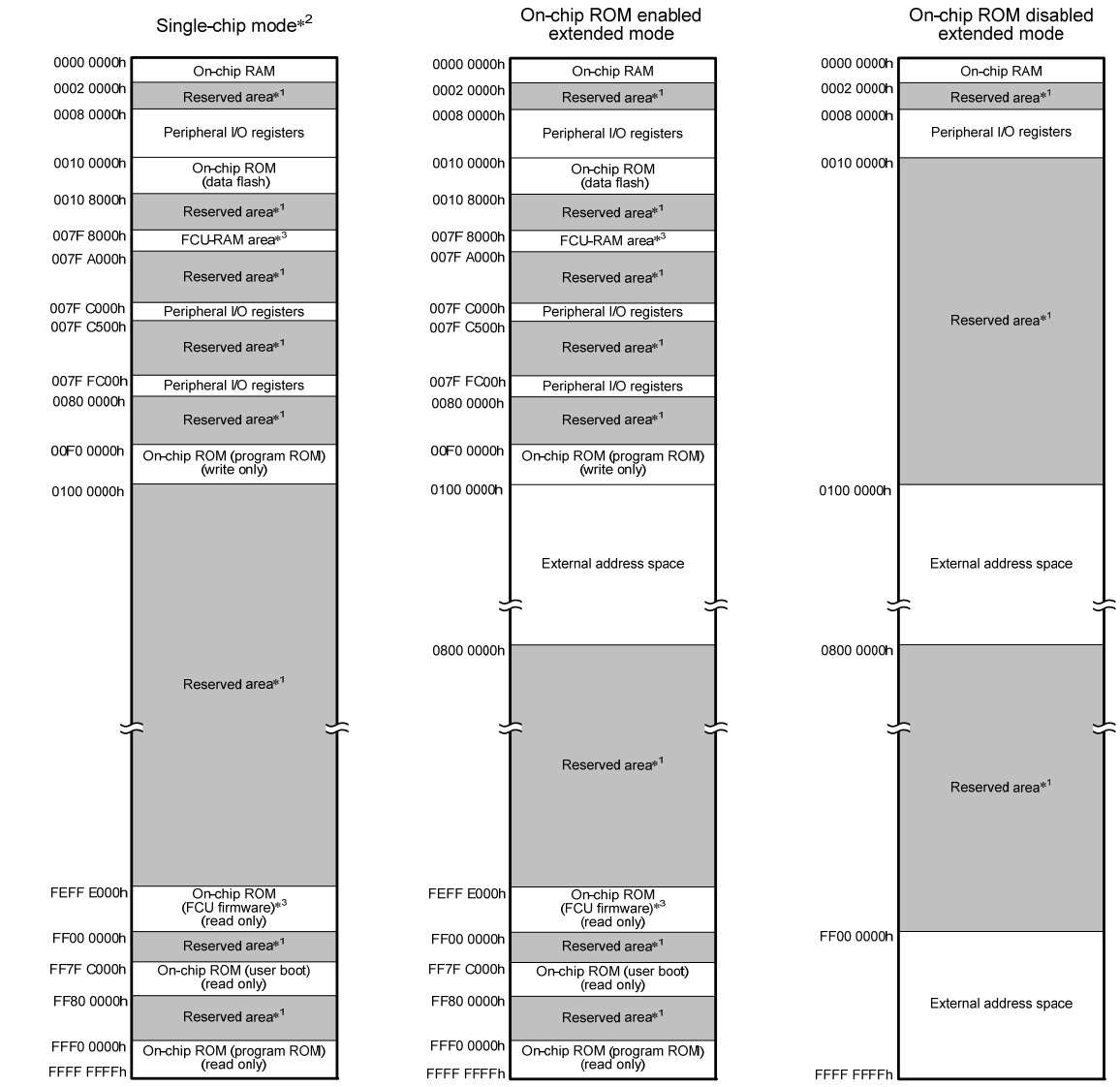
Notes: 1. A reserved area should not be accessed.
2. The address space in boot mode and user boot mode is the same as the address space in single-chip mode.
3. For details on the FCU, see section 26, ROM (Flash Memory for Code Storage) and sec ion 27, Data Flash (Flash Memory for Data Storage).

Figure 4.1 Memory Map of the R5F56108



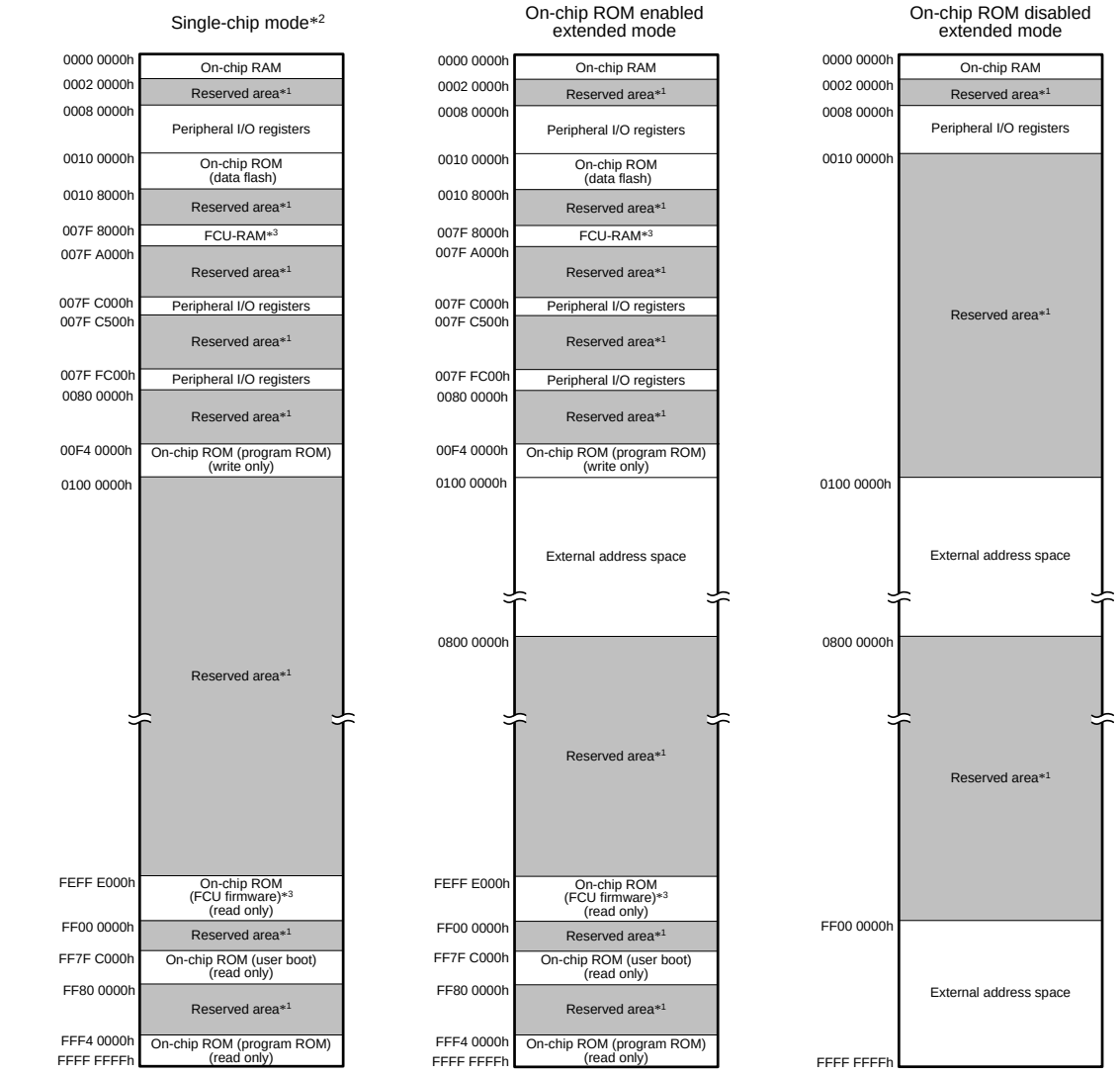
Notes: 1. A reserved area should not be accessed.
2. The address space in boot mode and user boot mode is the same as the address space in single-chip mode.
3. For details on the FCU, see section 26, ROM (Flash Memory for Code Storage) and section 27, Data Flash (Flash Memory for Data Storage).

Figure 4.2 Memory Map of the R5F56107



Notes: 1. A reserved area should not be accessed.
2. The address space in boot mode and user boot mode is the same as the address space in single-chip mode.
3. For details on the FCU, see section 26, ROM (Flash Memory for Code Storage) and section 27, Data Flash (Flash Memory for Data Storage).

Figure 4.3 Memory Map of the R5F56106



Notes: 1. A reserved area should not be accessed.
2. The address space in boot mode and user boot mode is the same as he address space in single-chip mode.
3. For details on the FCU, see section 26, ROM (Flash Memory for Code Storage) and section 27, Data Flash (Flash Memory for Data Storage).

Figure 4.4 Memory Map of the R5F56104

4.2 External Address Space

The external address space is divided into up to 8 areas, each corresponding to the CSi# signal output from a CSi# (i = 0 to 7) pin. Figure 4.5 shows the address ranges corresponding to the individual CSi# signals (CSi areas, i = 0 to 7) in on-chip ROM disabled external extended mode.

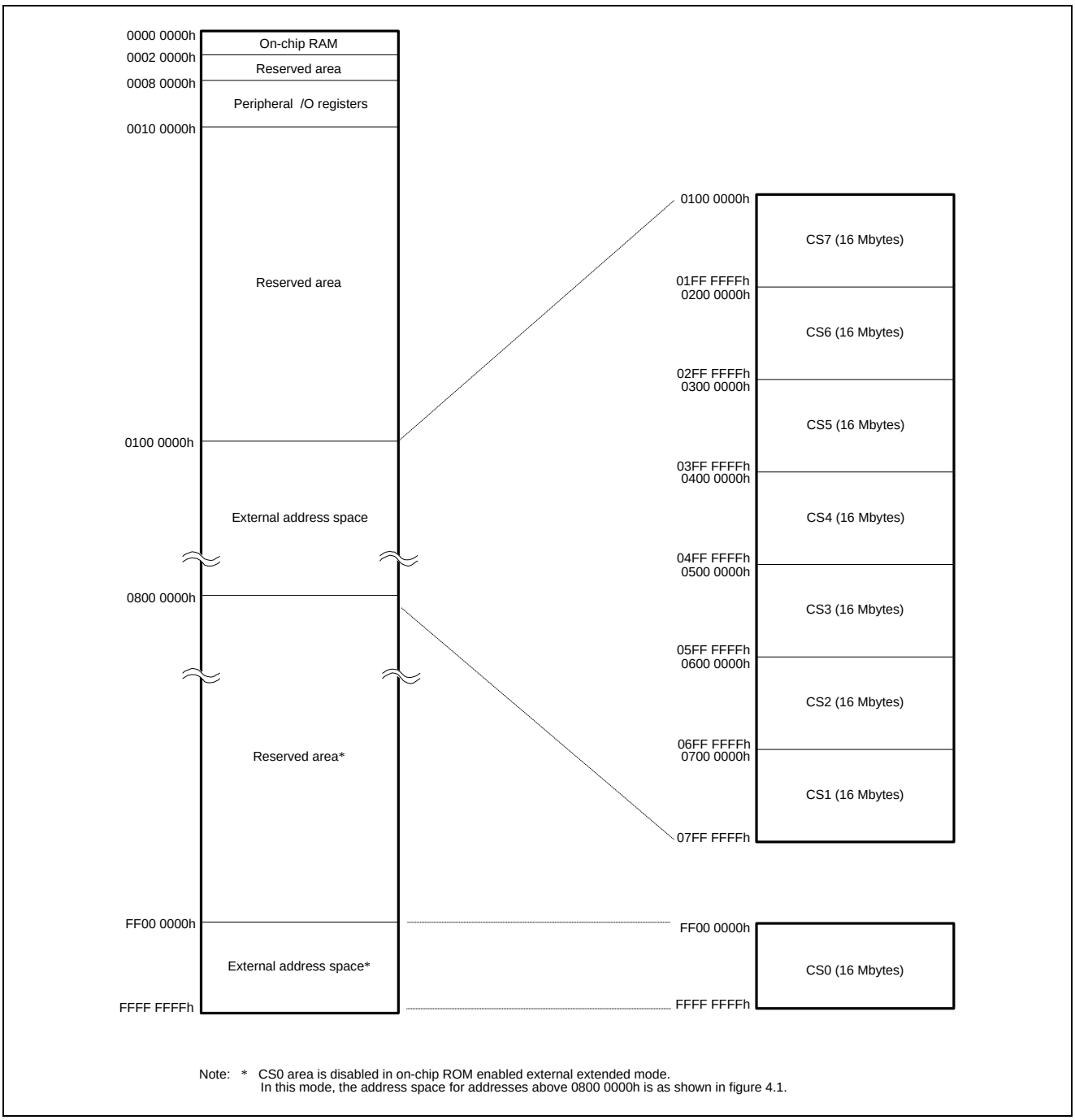


Figure 4.5 Correspondence between External Address Spaces and CSi Areas (In On-Chip ROM Disabled External Extended Mode)

5. I/O Registers

This section gives information on the on-chip I/O register addresses and bit configurations. The information is given as shown below. Notes on writing to registers are also given at the end.

1. I/O register addresses (address order)

- Registers are listed from the lower allocation addresses.
- Registers are classified according to functional modules (abbreviations).
- The number of access cycles indicates the number of states based on the specified reference clock.
- Among the I/O register area, addresses not listed in the list of registers are reserved. Reserved addresses must not be accessed. Do not access these addresses; otherwise, the operation when accessing these bits and subsequent operations cannot be guaranteed.
- The access size is specified for each register. The registers must be accessed with the specified access size.

2. I/O register bits

- Bit configurations of the registers are listed in the same order as the register addresses.
- Reserved bits are indicated by "—" in the bit name column.
- Space in the bit name field indicates that the entire register is allocated to either the counter or data.
- For the registers of 16 or 32 bits, the MSB is listed first.

3. Notes on writing to I/O registers

When writing to an I/O register, the CPU starts executing the subsequent instruction before completing I/O register write. This may cause the subsequent instruction to be executed before the post-update I/O register value is reflected on the operation.

As described in the following examples, special care is required for the cases in which the subsequent instruction must be executed after the post-update I/O register value is actually reflected.

[Examples of cases requiring special care]

- The subsequent instruction must be executed while an interrupt request is disabled with the IENj bit in IERm of the ICU (interrupt request enable bit) cleared to 0.
- A WAIT instruction is executed immediately after the preprocessing for causing a transition to the low power consumption state.

In the above cases, after writing to an I/O register, wait until the write operation is completed using the following procedure and then execute the subsequent instruction.

(a) Write to an I/O register.

(b) Read the value from the I/O register to a general register.

(c) Execute the operation using the value read.

(d) Execute the subsequent instruction.

[Instruction examples]

- Byte-size I/O registers

```
MOV.L   #SFR_ADDR, R1
MOV.B   #SFR_DATA, [R1]
CMP     [R1].UB, R1
;; Next process
```

- Word-size I/O registers

```
MOV.L   #SFR_ADDR, R1
MOV.W   #SFR_DATA, [R1]
CMP     [R1].W, R1
;; Next process
```

- Longword-size I/O registers

```
MOV.L   #SFR_ADDR, R1
MOV.L   #SFR_DATA, [R1]
CMP     [R1].L, R1
;; Next process
```

If multiple registers are written to and a subsequent instruction should be executed after the write operations are entirely completed, only read the I/O register that was last written to and execute the operation using the value; it is not necessary to read or execute operation for al the registers that were written to.

4. Number of Access Cycles to I/O Registers

The number of access cycles to I/O registers is obtained by following equation.*

Number of access cycles to I/O registers = Number of bus cycles for internal main bus 1 +
Number of divided cycles for clock synchronization +
Number of bus cycles for internal peripheral bus 1 (or 2)

The number of bus cycles of internal peripheral bus 1 (or 2) differs according to the register to be accessed. For the number of access cycles to each I/O register, see table 5.1, List of I/O Registers.

When peripheral functions connected to internal peripheral bus 2 or registers for the external bus control unit (except for bus error related registers) are accessed, the number of divided cycles for clock synchronization is added.

Although the number of divided cycles for clock synchronization differs depending on the number of frequency ratio or bus access timing, the sum of the number of bus cycles for internal main bus 1 and the number of divided cycles for clock synchronization will be one PCLK (or BCLK) at a maximum. Therefore, one PCLK (or BCLK) is added to the number of access cycles shown in table 5.1.

Note: * This applies to the number of cycles when the access from the CPU does not conflict with the instruction fetching to the external memory or bus access from the different bus master (DMAC or DTC).

5.1 I/O Register Addresses (Address Order)

Table 5.1 List of I/O Registers (Address Order)

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 0000h	SYSTEM	Mode monitor register	MDMONR	16	16	3 ICLK
0008 0002h	SYSTEM	Mode status register	MDSR	16	16	3 ICLK
0008 0006h	SYSTEM	System control register 0	SYSCR0	16	16	3 ICLK
0008 0008h	SYSTEM	System control register 1	SYSCR1	16	16	3 ICLK
0008 000Ch	SYSTEM	Standby control register	SBYCR	16	16	3 ICLK
0008 0010h	SYSTEM	Module stop control register A	MSTPCRA	32	32	3 ICLK
0008 0014h	SYSTEM	Module stop control register B	MSTPCRB	32	32	3 ICLK
0008 0018h	SYSTEM	Module stop control register C	MSTPCRC	32	32	3 ICLK
0008 0020h	SYSTEM	System clock control register	SCKCR	32	32	3 ICLK
0008 1300h	BSC	Bus error source clear register	BERCLR	8	8	2 ICLK
0008 1304h	BSC	Bus error monitor enable register	BEREN	8	8	2 ICLK
0008 1306h	BSC	Bus error interrupt enable register	BERIE	8	8	2 ICLK
0008 2000h	DMAC0	DMA current transfer source address register	DMCSA	32	32	4 to 5 ICLK
0008 2004h	DMAC0	DMA current transfer destination address register	DMCDA	32	32	4 to 5 ICLK
0008 2008h	DMAC0	DMA current transfer byte count register	DMCBC	32	32	4 to 5 ICLK
0008 200Ch	DMAC0	DMA mode register	DMMOD	32	32	4 to 5 ICLK
0008 2010h	DMAC1	DMA current transfer source address register	DMCSA	32	32	4 to 5 ICLK
0008 2014h	DMAC1	DMA current transfer destination address register	DMCDA	32	32	4 to 5 ICLK
0008 2018h	DMAC1	DMA current transfer byte count register	DMCBC	32	32	4 to 5 ICLK
0008 201Ch	DMAC1	DMA mode register	DMMOD	32	32	4 to 5 ICLK
0008 2020h	DMAC2	DMA current transfer source address register	DMCSA	32	32	4 to 5 ICLK
0008 2024h	DMAC2	DMA current transfer destination address register	DMCDA	32	32	4 to 5 ICLK
0008 2028h	DMAC2	DMA current transfer byte count register	DMCBC	32	32	4 to 5 ICLK
0008 202Ch	DMAC2	DMA mode register	DMMOD	32	32	4 to 5 ICLK
0008 2030h	DMAC3	DMA current transfer source address register	DMCSA	32	32	4 to 5 ICLK
0008 2034h	DMAC3	DMA current transfer destination address register	DMCDA	32	32	4 to 5 ICLK
0008 2038h	DMAC3	DMA current transfer byte count register	DMCBC	32	32	4 to 5 ICLK
0008 203Ch	DMAC3	DMA mode register	DMMOD	32	32	4 to 5 ICLK
0008 2200h	DMAC0	DMA reload transfer source address register	DMRSA	32	32	4 to 5 ICLK *8
0008 2204h	DMAC0	DMA reload transfer destination address register	DMRDA	32	32	4 to 5 ICLK *8
0008 2208h	DMAC0	DMA reload transfer byte count register	DMRBC	32	32	4 to 5 ICLK *8
0008 2210h	DMAC1	DMA reload transfer source address register	DMRSA	32	32	4 to 5 ICLK *8
0008 2214h	DMAC1	DMA reload transfer destination address register	DMRDA	32	32	4 to 5 ICLK *8
0008 2218h	DMAC1	DMA reload transfer byte count register	DMRBC	32	32	4 to 5 ICLK *8
0008 2220h	DMAC2	DMA reload transfer source address register	DMRSA	32	32	4 to 5 ICLK *8
0008 2224h	DMAC2	DMA reload transfer destination address register	DMRDA	32	32	4 to 5 ICLK *8
0008 2228h	DMAC2	DMA reload transfer byte count register	DMRBC	32	32	4 to 5 ICLK *8
0008 2230h	DMAC3	DMA reload transfer source address register	DMRSA	32	32	4 to 5 ICLK *8
0008 2234h	DMAC3	DMA reload transfer destination address register	DMRDA	32	32	4 to 5 ICLK *8
0008 2238h	DMAC3	DMA reload transfer byte count register	DMRBC	32	32	4 to 5 ICLK *8

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 2400h	DMAC0	DMA control register A	DMCRA	32	32	3 ICLK
0008 2404h	DMAC0	DMA control register B	DMCRB	8	8	3 ICLK
0008 2405h	DMAC0	DMA control register C	DMCRC	8	8	3 ICLK
0008 2406h	DMAC0	DMA control register D	DMCRD	8	8	3 ICLK
0008 2407h	DMAC0	DMA control register E	DMCRE	8	8	3 ICLK
0008 2408h	DMAC1	DMA control register A	DMCRA	32	32	3 ICLK
0008 240Ch	DMAC1	DMA control register B	DMCRB	8	8	3 ICLK
0008 240Dh	DMAC1	DMA control register C	DMCRC	8	8	3 ICLK
0008 240Eh	DMAC1	DMA control register D	DMCRD	8	8	3 ICLK
0008 240Fh	DMAC1	DMA control register E	DMCRE	8	8	3 ICLK
0008 2410h	DMAC2	DMA control register A	DMCRA	32	32	3 ICLK
0008 2414h	DMAC2	DMA control register B	DMCRB	8	8	3 ICLK
0008 2415h	DMAC2	DMA control register C	DMCRC	8	8	3 ICLK
0008 2416h	DMAC2	DMA control register D	DMCRD	8	8	3 ICLK
0008 2417h	DMAC2	DMA control register E	DMCRE	8	8	3 ICLK
0008 2418h	DMAC3	DMA control register A	DMCRA	32	32	3 ICLK
0008 241Ch	DMAC3	DMA control register B	DMCRB	8	8	3 ICLK
0008 241Dh	DMAC3	DMA control register C	DMCRC	8	8	3 ICLK
0008 241Eh	DMAC3	DMA control register D	DMCRD	8	8	3 ICLK
0008 241Fh	DMAC3	DMA control register E	DMCRE	8	8	3 ICLK
0008 2502h	DMAC common	DMA start control register	DMSCNT	8	8	3 ICLK
0008 250Bh	DMAC common	DMA interrupt control register	DMICNT	8	8	3 ICLK
0008 2517h	DMAC common	DMA transfer end detect register	DMEDET	8	8	3 ICLK
0008 251Bh	DMAC common	DMA arbitration status register	DMASTS	8	8	3 ICLK
0008 3002h	BSC	CS0 mode register	CS0MOD	16	16	1 to 2 BCLK *7
0008 3004h	BSC	CS0 wait control register 1	CS0WCNT1	32	32	1 to 2 BCLK *7
0008 3008h	BSC	CS0 wait control register 2	CS0WCNT2	32	32	1 to 2 BCLK *7
0008 3012h	BSC	CS1 mode register	CS1MOD	16	16	1 to 2 BCLK *7
0008 3014h	BSC	CS1 wait control register 1	CS1WCNT1	32	32	1 to 2 BCLK *7
0008 3018h	BSC	CS1 wait control register 2	CS1WCNT2	32	32	1 to 2 BCLK *7
0008 3022h	BSC	CS2 mode register	CS2MOD	16	16	1 to 2 BCLK *7
0008 3024h	BSC	CS2 wait control register 1	CS2WCNT1	32	32	1 to 2 BCLK *7
0008 3028h	BSC	CS2 wait control register 2	CS2WCNT2	32	32	1 to 2 BCLK *7
0008 3032h	BSC	CS3 mode register	CS3MOD	16	16	1 to 2 BCLK *7
0008 3034h	BSC	CS3 wait control register 1	CS3WCNT1	32	32	1 to 2 BCLK *7
0008 3038h	BSC	CS3 wait control register 2	CS3WCNT2	32	32	1 to 2 BCLK *7
0008 3042h	BSC	CS4 mode register	CS4MOD	16	16	1 to 2 BCLK *7
0008 3044h	BSC	CS4 wait control register 1	CS4WCNT1	32	32	1 to 2 BCLK *7
0008 3048h	BSC	CS4 wait control register 2	CS4WCNT2	32	32	1 to 2 BCLK *7
0008 3052h	BSC	CS5 mode register	CS5MOD	16	16	1 to 2 BCLK *7
0008 3054h	BSC	CS5 wait control register 1	CS5WCNT1	32	32	1 to 2 BCLK *7
0008 3058h	BSC	CS5 wait control register 2	CS5WCNT2	32	32	1 to 2 BCLK *7
0008 3062h	BSC	CS6 mode register	CS6MOD	16	16	1 to 2 BCLK *7
0008 3064h	BSC	CS6 wait control register 1	CS6WCNT1	32	32	1 to 2 BCLK *7
0008 3068h	BSC	CS6 wait control register 2	CS6WCNT2	32	32	1 to 2 BCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 3072h	BSC	CS7 mode register	CS7MOD	16	16	1 to 2 BCLK *7
0008 3074h	BSC	CS7 wait control register 1	CS7WCNT1	32	32	1 to 2 BCLK *7
0008 3078h	BSC	CS7 wait control register 2	CS7WCNT2	32	32	1 to 2 BCLK *7
0008 3802h	BSC	CS0 control register	CS0CNT	16	16	1 to 2 BCLK *7
0008 380Ah	BSC	CS0 recovery cycle register	CS0REC	16	16	1 to 2 BCLK *7
0008 3812h	BSC	CS1 control register	CS1CNT	16	16	1 to 2 BCLK *7
0008 381Ah	BSC	CS1 recovery cycle register	CS1REC	16	16	1 to 2 BCLK *7
0008 3822h	BSC	CS2 control register	CS2CNT	16	16	1 to 2 BCLK *7
0008 382Ah	BSC	CS2 recovery cycle register	CS2REC	16	16	1 to 2 BCLK *7
0008 3832h	BSC	CS3 control register	CS3CNT	16	16	1 to 2 BCLK *7
0008 383Ah	BSC	CS3 recovery cycle register	CS3REC	16	16	1 to 2 BCLK *7
0008 3842h	BSC	CS4 control register	CS4CNT	16	16	1 to 2 BCLK *7
0008 384Ah	BSC	CS4 recovery cycle register	CS4REC	16	16	1 to 2 BCLK *7
0008 3852h	BSC	CS5 control register	CS5CNT	16	16	1 to 2 BCLK *7
0008 385Ah	BSC	CS5 recovery cycle register	CS5REC	16	16	1 to 2 BCLK *7
0008 3862h	BSC	CS6 control register	CS6CNT	16	16	1 to 2 BCLK *7
0008 386Ah	BSC	CS6 recovery cycle register	CS6REC	16	16	1 to 2 BCLK *7
0008 3872h	BSC	CS7 control register	CS7CNT	16	16	1 to 2 BCLK *7
0008 387Ah	BSC	CS7 recovery cycle register	CS7REC	16	16	1 to 2 BCLK *7
0008 7010h	ICU	Interrupt request register 016	IR016	8	8	2 ICLK
0008 7015h	ICU	Interrupt request register 021	IR021	8	8	2 ICLK
0008 7017h	ICU	Interrupt request register 023	IR023	8	8	2 ICLK
0008 701Ch	ICU	Interrupt request register 028	IR028	8	8	2 ICLK
0008 701Dh	ICU	Interrupt request register 029	IR029	8	8	2 ICLK
0008 701Eh	ICU	Interrupt request register 030	IR030	8	8	2 ICLK
0008 701Fh	ICU	Interrupt request register 031	IR031	8	8	2 ICLK
0008 7040h	ICU	Interrupt request register 064	IR064	8	8	2 ICLK
0008 7041h	ICU	Interrupt request register 065	IR065	8	8	2 ICLK
0008 7042h	ICU	Interrupt request register 066	IR066	8	8	2 ICLK
0008 7043h	ICU	Interrupt request register 067	IR067	8	8	2 ICLK
0008 7044h	ICU	Interrupt request register 068	IR068	8	8	2 ICLK
0008 7045h	ICU	Interrupt request register 069	IR069	8	8	2 ICLK
0008 7046h	ICU	Interrupt request register 070	IR070	8	8	2 ICLK
0008 7047h	ICU	Interrupt request register 071	IR071	8	8	2 ICLK
0008 7048h	ICU	Interrupt request register 072	IR072	8	8	2 ICLK
0008 7049h	ICU	Interrupt request register 073	IR073	8	8	2 ICLK
0008 704Ah	ICU	Interrupt request register 074	IR074	8	8	2 ICLK
0008 704Bh	ICU	Interrupt request register 075	IR075	8	8	2 ICLK
0008 704Ch	ICU	Interrupt request register 076	IR076	8	8	2 ICLK
0008 704Dh	ICU	Interrupt request register 077	IR077	8	8	2 ICLK
0008 704Eh	ICU	Interrupt request register 078	IR078	8	8	2 ICLK
0008 704Fh	ICU	Interrupt request register 079	IR079	8	8	2 ICLK
0008 7060h	ICU	Interrupt request register 096	IR096	8	8	2 ICLK
0008 7062h	ICU	Interrupt request register 098	IR098	8	8	2 ICLK
0008 7063h	ICU	Interrupt request register 099	IR099	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7064h	ICU	Interrupt request register 100	IR100	8	8	2 ICLK
0008 7065h	ICU	Interrupt request register 101	IR101	8	8	2 ICLK
0008 7068h	ICU	Interrupt request register 104	IR104	8	8	2 ICLK
0008 7069h	ICU	Interrupt request register 105	IR105	8	8	2 ICLK
0008 706Ah	ICU	Interrupt request register 106	IR106	8	8	2 ICLK
0008 706Bh	ICU	Interrupt request register 107	IR107	8	8	2 ICLK
0008 706Ch	ICU	Interrupt request register 108	IR108	8	8	2 ICLK
0008 706Fh	ICU	Interrupt request register 111	IR111	8	8	2 ICLK
0008 7070h	ICU	Interrupt request register 112	IR112	8	8	2 ICLK
0008 7073h	ICU	Interrupt request register 115	IR115	8	8	2 ICLK
0008 7074h	ICU	Interrupt request register 116	IR116	8	8	2 ICLK
0008 7075h	ICU	Interrupt request register 117	IR117	8	8	2 ICLK
0008 7076h	ICU	Interrupt request register 118	IR118	8	8	2 ICLK
0008 7078h	ICU	Interrupt request register 120	IR120	8	8	2 ICLK
0008 7079h	ICU	Interrupt request register 121	IR121	8	8	2 ICLK
0008 707Ah	ICU	Interrupt request register 122	IR122	8	8	2 ICLK
0008 707Bh	ICU	Interrupt request register 123	IR123	8	8	2 ICLK
0008 707Ch	ICU	Interrupt request register 124	IR124	8	8	2 ICLK
0008 707Dh	ICU	Interrupt request register 125	IR125	8	8	2 ICLK
0008 707Eh	ICU	Interrupt request register 126	IR126	8	8	2 ICLK
0008 707Fh	ICU	Interrupt request register 127	IR127	8	8	2 ICLK
0008 7080h	ICU	Interrupt request register 128	IR128	8	8	2 ICLK
0008 7083h	ICU	Interrupt request register 131	IR131	8	8	2 ICLK
0008 7084h	ICU	Interrupt request register 132	IR132	8	8	2 ICLK
0008 7085h	ICU	Interrupt request register 133	IR133	8	8	2 ICLK
0008 7086h	ICU	Interrupt request register 134	IR134	8	8	2 ICLK
0008 7088h	ICU	Interrupt request register 136	IR136	8	8	2 ICLK
0008 7089h	ICU	Interrupt request register 137	IR137	8	8	2 ICLK
0008 708Ah	ICU	Interrupt request register 138	IR138	8	8	2 ICLK
0008 708Bh	ICU	Interrupt request register 139	IR139	8	8	2 ICLK
0008 708Ch	ICU	Interrupt request register 140	IR140	8	8	2 ICLK
0008 708Dh	ICU	Interrupt request register 141	IR141	8	8	2 ICLK
0008 708Eh	ICU	Interrupt request register 142	IR142	8	8	2 ICLK
0008 7091h	ICU	Interrupt request register 145	IR145	8	8	2 ICLK
0008 7092h	ICU	Interrupt request register 146	IR146	8	8	2 ICLK
0008 7095h	ICU	Interrupt request register 149	IR149	8	8	2 ICLK
0008 7096h	ICU	Interrupt request register 150	IR150	8	8	2 ICLK
0008 7097h	ICU	Interrupt request register 151	IR151	8	8	2 ICLK
0008 7098h	ICU	Interrupt request register 152	IR152	8	8	2 ICLK
0008 709Ah	ICU	Interrupt request register 154	IR154	8	8	2 ICLK
0008 709Bh	ICU	Interrupt request register 155	IR155	8	8	2 ICLK
0008 709Ch	ICU	Interrupt request register 156	IR156	8	8	2 ICLK
0008 709Dh	ICU	Interrupt request register 157	IR157	8	8	2 ICLK
0008 709Eh	ICU	Interrupt request register 158	IR158	8	8	2 ICLK
0008 709Fh	ICU	Interrupt request register 159	IR159	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 70A0h	ICU	Interrupt request register 160	IR160	8	8	2 ICLK
0008 70A1h	ICU	Interrupt request register 161	IR161	8	8	2 ICLK
0008 70A2h	ICU	Interrupt request register 162	IR162	8	8	2 ICLK
0008 70A5h	ICU	Interrupt request register 165	IR165	8	8	2 ICLK
0008 70A6h	ICU	Interrupt request register 166	IR166	8	8	2 ICLK
0008 70A7h	ICU	Interrupt request register 167	IR167	8	8	2 ICLK
0008 70A8h	ICU	Interrupt request register 168	IR168	8	8	2 ICLK
0008 70AAh	ICU	Interrupt request register 170	IR170	8	8	2 ICLK
0008 70ABh	ICU	Interrupt request register 171	IR171	8	8	2 ICLK
0008 70AEh	ICU	Interrupt request register 174	IR174	8	8	2 ICLK
0008 70AFh	ICU	Interrupt request register 175	IR175	8	8	2 ICLK
0008 70B0h	ICU	Interrupt request register 176	IR176	8	8	2 ICLK
0008 70B1h	ICU	Interrupt request register 177	IR177	8	8	2 ICLK
0008 70B2h	ICU	Interrupt request register 178	IR178	8	8	2 ICLK
0008 70B3h	ICU	Interrupt request register 179	IR179	8	8	2 ICLK
0008 70B4h	ICU	Interrupt request register 180	IR180	8	8	2 ICLK
0008 70B5h	ICU	Interrupt request register 181	IR181	8	8	2 ICLK
0008 70B6h	ICU	Interrupt request register 182	IR182	8	8	2 ICLK
0008 70B7h	ICU	Interrupt request register 183	IR183	8	8	2 ICLK
0008 70B8h	ICU	Interrupt request register 184	IR184	8	8	2 ICLK
0008 70B9h	ICU	Interrupt request register 185	IR185	8	8	2 ICLK
0008 70C6h	ICU	Interrupt request register 198	IR198	8	8	2 ICLK
0008 70C7h	ICU	Interrupt request register 199	IR199	8	8	2 ICLK
0008 70C8h	ICU	Interrupt request register 200	IR200	8	8	2 ICLK
0008 70C9h	ICU	Interrupt request register 201	IR201	8	8	2 ICLK
0008 70D6h	ICU	Interrupt request register 214	IR214	8	8	2 ICLK
0008 70D7h	ICU	Interrupt request register 215	IR215	8	8	2 ICLK
0008 70D8h	ICU	Interrupt request register 216	IR216	8	8	2 ICLK
0008 70D9h	ICU	Interrupt request register 217	IR217	8	8	2 ICLK
0008 70DAh	ICU	Interrupt request register 218	IR218	8	8	2 ICLK
0008 70DBh	ICU	Interrupt request register 219	IR219	8	8	2 ICLK
0008 70DCh	ICU	Interrupt request register 220	IR220	8	8	2 ICLK
0008 70DDh	ICU	Interrupt request register 221	IR221	8	8	2 ICLK
0008 70DEh	ICU	Interrupt request register 222	IR222	8	8	2 ICLK
0008 70DFh	ICU	Interrupt request register 223	IR223	8	8	2 ICLK
0008 70E0h	ICU	Interrupt request register 224	IR224	8	8	2 ICLK
0008 70E1h	ICU	Interrupt request register 225	IR225	8	8	2 ICLK
0008 70E2h	ICU	Interrupt request register 226	IR226	8	8	2 ICLK
0008 70E3h	ICU	Interrupt request register 227	IR227	8	8	2 ICLK
0008 70E4h	ICU	Interrupt request register 228	IR228	8	8	2 ICLK
0008 70E5h	ICU	Interrupt request register 229	IR229	8	8	2 ICLK
0008 70E6h	ICU	Interrupt request register 230	IR230	8	8	2 ICLK
0008 70E7h	ICU	Interrupt request register 231	IR231	8	8	2 ICLK
0008 70E8h	ICU	Interrupt request register 232	IR232	8	8	2 ICLK
0008 70E9h	ICU	Interrupt request register 233	IR233	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 70EAh	ICU	Interrupt request register 234	IR234	8	8	2 ICLK
0008 70EBh	ICU	Interrupt request register 235	IR235	8	8	2 ICLK
0008 70ECh	ICU	Interrupt request register 236	IR236	8	8	2 ICLK
0008 70EDh	ICU	Interrupt request register 237	IR237	8	8	2 ICLK
0008 70EEh	ICU	Interrupt request register 238	IR238	8	8	2 ICLK
0008 70EFh	ICU	Interrupt request register 239	IR239	8	8	2 ICLK
0008 70F0h	ICU	Interrupt request register 240	IR240	8	8	2 ICLK
0008 70F1h	ICU	Interrupt request register 241	IR241	8	8	2 ICLK
0008 70F6h	ICU	Interrupt request register 246	IR246	8	8	2 ICLK
0008 70F7h	ICU	Interrupt request register 247	IR247	8	8	2 ICLK
0008 70F8h	ICU	Interrupt request register 248	IR248	8	8	2 ICLK
0008 70F9h	ICU	Interrupt request register 249	IR249	8	8	2 ICLK
0008 70FAh	ICU	Interrupt request register 250	IR250	8	8	2 ICLK
0008 70FBh	ICU	Interrupt request register 251	IR251	8	8	2 ICLK
0008 70FCh	ICU	Interrupt request register 252	IR252	8	8	2 ICLK
0008 70FDh	ICU	Interrupt request register 253	IR253	8	8	2 ICLK
0008 711Ch	ICU	Interrupt request destination setting register 028	ISELR028	8	8	2 ICLK
0008 711Dh	ICU	Interrupt request destination setting register 029	ISELR029	8	8	2 ICLK
0008 711Eh	ICU	Interrupt request destination setting register 030	ISELR030	8	8	2 ICLK
0008 711Fh	ICU	Interrupt request destination setting register 031	ISELR031	8	8	2 ICLK
0008 7140h	ICU	Interrupt request destination setting register 064	ISELR064	8	8	2 ICLK
0008 7141h	ICU	Interrupt request destination setting register 065	ISELR065	8	8	2 ICLK
0008 7142h	ICU	Interrupt request destination setting register 066	ISELR066	8	8	2 ICLK
0008 7143h	ICU	Interrupt request destination setting register 067	ISELR067	8	8	2 ICLK
0008 7144h	ICU	Interrupt request destination setting register 068	ISELR068	8	8	2 ICLK
0008 7145h	ICU	Interrupt request destination setting register 069	ISELR069	8	8	2 ICLK
0008 7146h	ICU	Interrupt request destination setting register 070	ISELR070	8	8	2 ICLK
0008 7147h	ICU	Interrupt request destination setting register 071	ISELR071	8	8	2 ICLK
0008 7148h	ICU	Interrupt request destination setting register 072	ISELR072	8	8	2 ICLK
0008 7149h	ICU	Interrupt request destination setting register 073	ISELR073	8	8	2 ICLK
0008 714Ah	ICU	Interrupt request destination setting register 074	ISELR074	8	8	2 ICLK
0008 714Bh	ICU	Interrupt request destination setting register 075	ISELR075	8	8	2 ICLK
0008 714Ch	ICU	Interrupt request destination setting register 076	ISELR076	8	8	2 ICLK
0008 714Dh	ICU	Interrupt request destination setting register 077	ISELR077	8	8	2 ICLK
0008 714Eh	ICU	Interrupt request destination setting register 078	ISELR078	8	8	2 ICLK
0008 714Fh	ICU	Interrupt request destination setting register 079	ISELR079	8	8	2 ICLK
0008 7162h	ICU	Interrupt request destination setting register 098	ISELR098	8	8	2 ICLK
0008 7163h	ICU	Interrupt request destination setting register 099	ISELR099	8	8	2 ICLK
0008 7164h	ICU	Interrupt request destination setting register 100	ISELR100	8	8	2 ICLK
0008 7165h	ICU	Interrupt request destination setting register 101	ISELR101	8	8	2 ICLK
0008 7168h	ICU	Interrupt request destination setting register 104	ISELR104	8	8	2 ICLK
0008 7169h	ICU	Interrupt request destination setting register 105	ISELR105	8	8	2 ICLK
0008 716Ah	ICU	Interrupt request destination setting register 106	ISELR106	8	8	2 ICLK
0008 716Bh	ICU	Interrupt request destination setting register 107	ISELR107	8	8	2 ICLK
0008 716Fh	ICU	Interrupt request destination setting register 111	ISELR111	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7170h	ICU	Interrupt request destination setting register 112	ISELR112	8	8	2 ICLK
0008 7175h	ICU	Interrupt request destination setting register 117	ISELR117	8	8	2 ICLK
0008 7176h	ICU	Interrupt request destination setting register 118	ISELR118	8	8	2 ICLK
0008 717Ah	ICU	Interrupt request destination setting register 122	ISELR122	8	8	2 ICLK
0008 717Bh	ICU	Interrupt request destination setting register 123	ISELR123	8	8	2 ICLK
0008 717Ch	ICU	Interrupt request destination setting register 124	ISELR124	8	8	2 ICLK
0008 717Dh	ICU	Interrupt request destination setting register 125	ISELR125	8	8	2 ICLK
0008 717Fh	ICU	Interrupt request destination setting register 127	ISELR127	8	8	2 ICLK
0008 7180h	ICU	Interrupt request destination setting register 128	ISELR128	8	8	2 ICLK
0008 7185h	ICU	Interrupt request destination setting register 133	ISELR133	8	8	2 ICLK
0008 7186h	ICU	Interrupt request destination setting register 134	ISELR134	8	8	2 ICLK
0008 718Ah	ICU	Interrupt request destination setting register 138	ISELR138	8	8	2 ICLK
0008 718Bh	ICU	Interrupt request destination setting register 139	ISELR139	8	8	2 ICLK
0008 718Ch	ICU	Interrupt request destination setting register 140	ISELR140	8	8	2 ICLK
0008 718Dh	ICU	Interrupt request destination setting register 141	ISELR141	8	8	2 ICLK
0008 7191h	ICU	Interrupt request destination setting register 145	ISELR145	8	8	2 ICLK
0008 7192h	ICU	Interrupt request destination setting register 146	ISELR146	8	8	2 ICLK
0008 7197h	ICU	Interrupt request destination setting register 151	ISELR151	8	8	2 ICLK
0008 7198h	ICU	Interrupt request destination setting register 152	ISELR152	8	8	2 ICLK
0008 719Ch	ICU	Interrupt request destination setting register 156	ISELR156	8	8	2 ICLK
0008 719Dh	ICU	Interrupt request destination setting register 157	ISELR157	8	8	2 ICLK
0008 719Eh	ICU	Interrupt request destination setting register 158	ISELR158	8	8	2 ICLK
0008 719Fh	ICU	Interrupt request destination setting register 159	ISELR159	8	8	2 ICLK
0008 71A1h	ICU	Interrupt request destination setting register 161	ISELR161	8	8	2 ICLK
0008 71A2h	ICU	Interrupt request destination setting register 162	ISELR162	8	8	2 ICLK
0008 71A7h	ICU	Interrupt request destination setting register 167	ISELR167	8	8	2 ICLK
0008 71A8h	ICU	Interrupt request destination setting register 168	ISELR168	8	8	2 ICLK
0008 71AEh	ICU	Interrupt request destination setting register 174	ISELR174	8	8	2 ICLK
0008 71AFh	ICU	Interrupt request destination setting register 175	ISELR175	8	8	2 ICLK
0008 71B1h	ICU	Interrupt request destination setting register 177	ISELR177	8	8	2 ICLK
0008 71B2h	ICU	Interrupt request destination setting register 178	ISELR178	8	8	2 ICLK
0008 71B4h	ICU	Interrupt request destination setting register 180	ISELR180	8	8	2 ICLK
0008 71B5h	ICU	Interrupt request destination setting register 181	ISELR181	8	8	2 ICLK
0008 71B7h	ICU	Interrupt request destination setting register 183	ISELR183	8	8	2 ICLK
0008 71B8h	ICU	Interrupt request destination setting register 184	ISELR184	8	8	2 ICLK
0008 71C6h	ICU	Interrupt request destination setting register 198	ISELR198	8	8	2 ICLK
0008 71C7h	ICU	Interrupt request destination setting register 199	ISELR199	8	8	2 ICLK
0008 71C8h	ICU	Interrupt request destination setting register 200	ISELR200	8	8	2 ICLK
0008 71C9h	ICU	Interrupt request destination setting register 201	ISELR201	8	8	2 ICLK
0008 71D7h	ICU	Interrupt request destination setting register 215	ISELR215	8	8	2 ICLK
0008 71D8h	ICU	Interrupt request destination setting register 216	ISELR216	8	8	2 ICLK
0008 71DBh	ICU	Interrupt request destination setting register 219	ISELR219	8	8	2 ICLK
0008 71DCh	ICU	Interrupt request destination setting register 220	ISELR220	8	8	2 ICLK
0008 71DFh	ICU	Interrupt request destination setting register 223	ISELR223	8	8	2 ICLK
0008 71E0h	ICU	Interrupt request destination setting register 224	ISELR224	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 71E3h	ICU	Interrupt request destination setting register 227	ISELR227	8	8	2 ICLK
0008 71E4h	ICU	Interrupt request destination setting register 228	ISELR228	8	8	2 ICLK
0008 71E7h	ICU	Interrupt request destination setting register 231	ISELR231	8	8	2 ICLK
0008 71E8h	ICU	Interrupt request destination setting register 232	ISELR232	8	8	2 ICLK
0008 71EBh	ICU	Interrupt request destination setting register 235	ISELR235	8	8	2 ICLK
0008 71ECh	ICU	Interrupt request destination setting register 236	ISELR236	8	8	2 ICLK
0008 71EFh	ICU	Interrupt request destination setting register 239	ISELR239	8	8	2 ICLK
0008 71F0h	ICU	Interrupt request destination setting register 240	ISELR240	8	8	2 ICLK
0008 71F7h	ICU	Interrupt request destination setting register 247	ISELR247	8	8	2 ICLK
0008 71F8h	ICU	Interrupt request destination setting register 248	ISELR248	8	8	2 ICLK
0008 71FBh	ICU	Interrupt request destination setting register 251	ISELR251	8	8	2 ICLK
0008 71FCh	ICU	Interrupt request destination setting register 252	ISELR252	8	8	2 ICLK
0008 71FDh	ICU	Interrupt request destination setting register 253	ISELR253	8	8	2ICLK
0008 7202h	ICU	Interrupt request enable register 02	IER02	8	8	2 ICLK
0008 7203h	ICU	Interrupt request enable register 03	IER03	8	8	2 ICLK
0008 7208h	ICU	Interrupt request enable register 08	IER08	8	8	2 ICLK
0008 7209h	ICU	Interrupt request enable register 09	IER09	8	8	2 ICLK
0008 720Ch	ICU	Interrupt request enable register 0C	IER0C	8	8	2 ICLK
0008 720Dh	ICU	Interrupt request enable register 0D	IER0D	8	8	2 ICLK
0008 720Eh	ICU	Interrupt request enable register 0E	IER0E	8	8	2 ICLK
0008 720Fh	ICU	Interrupt request enable register 0F	IER0F	8	8	2 ICLK
0008 7210h	ICU	Interrupt request enable register 10	IER10	8	8	2 ICLK
0008 7211h	ICU	Interrupt request enable register 11	IER11	8	8	2 ICLK
0008 7212h	ICU	Interrupt request enable register 12	IER12	8	8	2 ICLK
0008 7213h	ICU	Interrupt request enable register 13	IER13	8	8	2 ICLK
0008 7214h	ICU	Interrupt request enable register 14	IER14	8	8	2 ICLK
0008 7215h	ICU	Interrupt request enable register 15	IER15	8	8	2 ICLK
0008 7216h	ICU	Interrupt request enable register 16	IER16	8	8	2 ICLK
0008 7217h	ICU	Interrupt request enable register 17	IER17	8	8	2 ICLK
0008 7218h	ICU	Interrupt request enable register 18	IER18	8	8	2 ICLK
0008 7219h	ICU	Interrupt request enable register 19	IER19	8	8	2 ICLK
0008 721Ah	ICU	Interrupt request enable register 1A	IER1A	8	8	2 ICLK
0008 721Bh	ICU	Interrupt request enable register 1B	IER1B	8	8	2 ICLK
0008 721Ch	ICU	Interrupt request enable register 1C	IER1C	8	8	2 ICLK
0008 721Dh	ICU	Interrupt request enable register 1D	IER1D	8	8	2 ICLK
0008 721Eh	ICU	Interrupt request enable register 1E	IER1E	8	8	2 ICLK
0008 721Fh	ICU	Interrupt request enable register 1F	IER1F	8	8	2 ICLK
0008 7300h	ICU	Interrupt priority register 00	IPR00	8	8	2 ICLK
0008 7301h	ICU	Interrupt priority register 01	IPR01	8	8	2 ICLK
0008 7302h	ICU	Interrupt priority register 02	IPR02	8	8	2 ICLK
0008 7304h	ICU	Interrupt priority register 04	IPR04	8	8	2 ICLK
0008 7305h	ICU	Interrupt priority register 05	IPR05	8	8	2 ICLK
0008 7306h	ICU	Interrupt priority register 06	IPR06	8	8	2 ICLK
0008 7307h	ICU	Interrupt priority register 07	IPR07	8	8	2 ICLK
0008 7320h	ICU	Interrupt priority register 20	IPR20	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7321h	ICU	Interrupt priority register 21	IPR21	8	8	2 ICLK
0008 7322h	ICU	Interrupt priority register 22	IPR22	8	8	2 ICLK
0008 7323h	ICU	Interrupt priority register 23	IPR23	8	8	2 ICLK
0008 7324h	ICU	Interrupt priority register 24	IPR24	8	8	2 ICLK
0008 7325h	ICU	Interrupt priority register 25	IPR25	8	8	2 ICLK
0008 7326h	ICU	Interrupt priority register 26	IPR26	8	8	2 ICLK
0008 7327h	ICU	Interrupt priority register 27	IPR27	8	8	2 ICLK
0008 7328h	ICU	Interrupt priority register 28	IPR28	8	8	2 ICLK
0008 7329h	ICU	Interrupt priority register 29	IPR29	8	8	2 ICLK
0008 732Ah	ICU	Interrupt priority register 2A	IPR2A	8	8	2 ICLK
0008 732Bh	ICU	Interrupt priority register 2B	IPR2B	8	8	2 ICLK
0008 732Ch	ICU	Interrupt priority register 2C	IPR2C	8	8	2 ICLK
0008 732Dh	ICU	Interrupt priority register 2D	IPR2D	8	8	2 ICLK
0008 732Eh	ICU	Interrupt priority register 2E	IPR2E	8	8	2 ICLK
0008 732Fh	ICU	Interrupt priority register 2F	IPR2F	8	8	2 ICLK
0008 7340h	ICU	Interrupt priority register 40	IPR40	8	8	2 ICLK
0008 7344h	ICU	Interrupt priority register 44	IPR44	8	8	2 ICLK
0008 7345h	ICU	Interrupt priority register 45	IPR45	8	8	2 ICLK
0008 7346h	ICU	Interrupt priority register 46	IPR46	8	8	2 ICLK
0008 7347h	ICU	Interrupt priority register 47	IPR47	8	8	2 ICLK
0008 734Ch	ICU	Interrupt priority register 4C	IPR4C	8	8	2 ICLK
0008 734Dh	ICU	Interrupt priority register 4D	IPR4D	8	8	2 ICLK
0008 734Eh	ICU	Interrupt priority register 4E	IPR4E	8	8	2 ICLK
0008 734Fh	ICU	Interrupt priority register 4F	IPR4F	8	8	2 ICLK
0008 7350h	ICU	Interrupt priority register 50	IPR50	8	8	2 ICLK
0008 7351h	ICU	Interrupt priority register 51	IPR51	8	8	2 ICLK
0008 7352h	ICU	Interrupt priority register 52	IPR52	8	8	2 ICLK
0008 7353h	ICU	Interrupt priority register 53	IPR53	8	8	2 ICLK
0008 7354h	ICU	Interrupt priority register 54	IPR54	8	8	2 ICLK
0008 7355h	ICU	Interrupt priority register 55	IPR55	8	8	2 ICLK
0008 7356h	ICU	Interrupt priority register 56	IPR56	8	8	2 ICLK
0008 7357h	ICU	Interrupt priority register 57	IPR57	8	8	2 ICLK
0008 7358h	ICU	Interrupt priority register 58	IPR58	8	8	2 ICLK
0008 7359h	ICU	Interrupt priority register 59	IPR59	8	8	2 ICLK
0008 735Ah	ICU	Interrupt priority register 5A	IPR5A	8	8	2 ICLK
0008 735Bh	ICU	Interrupt priority register 5B	IPR5B	8	8	2 ICLK
0008 735Ch	ICU	Interrupt priority register 5C	IPR5C	8	8	2 ICLK
0008 735Dh	ICU	Interrupt priority register 5D	IPR5D	8	8	2 ICLK
0008 735Eh	ICU	Interrupt priority register 5E	IPR5E	8	8	2 ICLK
0008 735Fh	ICU	Interrupt priority register 5F	IPR5F	8	8	2 ICLK
0008 7360h	ICU	Interrupt priority register 60	IPR60	8	8	2 ICLK
0008 7361h	ICU	Interrupt priority register 61	IPR61	8	8	2 ICLK
0008 7362h	ICU	Interrupt priority register 62	IPR62	8	8	2 ICLK
0008 7363h	ICU	Interrupt priority register 63	IPR63	8	8	2 ICLK
0008 7368h	ICU	Interrupt priority register 68	IPR68	8	8	2 ICLK

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 7369h	ICU	Interrupt priority register 69	IPR69	8	8	2 ICLK
0008 736Ah	ICU	Interrupt priority register 6A	IPR6A	8	8	2 ICLK
0008 736Bh	ICU	Interrupt priority register 6B	IPR6B	8	8	2 ICLK
0008 7370h	ICU	Interrupt priority register 70	IPR70	8	8	2 ICLK
0008 7371h	ICU	Interrupt priority register 71	IPR71	8	8	2 ICLK
0008 7372h	ICU	Interrupt priority register 72	IPR72	8	8	2 ICLK
0008 7373h	ICU	Interrupt priority register 73	IPR73	8	8	2 ICLK
0008 7380h	ICU	Interrupt priority register 80	IPR80	8	8	2 ICLK
0008 7381h	ICU	Interrupt priority register 81	IPR81	8	8	2 ICLK
0008 7382h	ICU	Interrupt priority register 82	IPR82	8	8	2 ICLK
0008 7383h	ICU	Interrupt priority register 83	IPR83	8	8	2 ICLK
0008 7384h	ICU	Interrupt priority register 84	IPR84	8	8	2 ICLK
0008 7385h	ICU	Interrupt priority register 85	IPR85	8	8	2 ICLK
0008 7386h	ICU	Interrupt priority register 86	IPR86	8	8	2 ICLK
0008 7388h	ICU	Interrupt priority register 88	IPR88	8	8	2 ICLK
0008 7389h	ICU	Interrupt priority register 89	IPR89	8	8	2 ICLK
0008 738Ah	ICU	Interrupt priority register 8A	IPR8A	8	8	2 ICLK
0008 738Bh	ICU	Interrupt priority register 8B	IPR8B	8	8	2 ICLK
0008 738Ch	ICU	Interrupt priority register 8C	IPR8C	8	8	2 ICLK
0008 738Dh	ICU	Interrupt priority register 8D	IPR8D	8	8	2 ICLK
0008 738Eh	ICU	Interrupt priority register 8E	IPR8E	8	8	2 ICLK
0008 738Fh	ICU	Interrupt priority register 8F	IPR8F	8	8	2 ICLK
0008 73F0h	ICU	Fast interrupt register	FIR	16	16	2 ICLK
0008 7400h	DTC	DTC control register	DTCCR	8	8	2 ICLK
0008 7404h	DTC	DTC vector base register	DTCVBR	32	32	2 ICLK
0008 7408h	DTC	DTC address mode register	DTCADMOD	8	8	2 ICLK
0008 740Ch	DTC	DTC module start register	DTCST	8	8	2 ICLK
0008 8000h	CMT (unit 0)	Compare match timer start register 0	CMSTR0	16	16	2 to 3 PCLK *7
0008 8002h	CMT0	Compare match timer control register	CMCR	16	16	2 to 3 PCLK *7
0008 8004h	CMT0	Compare match timer counter	CMCNT	16	16	2 to 3 PCLK *7
0008 8006h	CMT0	Compare match timer constant register	CMCOR	16	16	2 to 3 PCLK *7
0008 8008h	CMT1	Compare match timer control register	CMCR	16	16	2 to 3 PCLK *7
0008 800Ah	CMT1	Compare match timer counter	CMCNT	16	16	2 to 3 PCLK *7
0008 800Ch	CMT1	Compare match timer constant register	CMCOR	16	16	2 to 3 PCLK *7
0008 8010h	CMT (unit 1)	Compare match timer start register 1	CMSTR1	16	16	2 to 3 PCLK *7
0008 8012h	CMT2	Compare match timer control register	CMCR	16	16	2 to 3 PCLK *7
0008 8014h	CMT2	Compare match timer counter	CMCNT	16	16	2 to 3 PCLK *7
0008 8016h	CMT2	Compare match timer constant register	CMCOR	16	16	2 to 3 PCLK *7
0008 8018h	CMT3	Compare match timer control register	CMCR	16	16	2 to 3 PCLK *7
0008 801Ah	CMT3	Compare match timer counter	CMCNT	16	16	2 to 3 PCLK *7
0008 801Ch	CMT3	Compare match timer constant register	CMCOR	16	16	2 to 3 PCLK *7
0008 8028h	WDT	Timer control/status register	TCSR	8	8	2 to 3 PCLK *7
0008 8028h	WDT	Write window A register	WINA	16	16	2 to 3 PCLK *7
0008 8029h	WDT	Timer counter	TCNT	8	8	2 to 3 PCLK *7
0008 802Ah	WDT	Write window B register	WINB	16	16	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 802Bh	WDT	Reset control/status register	RSTCSR	8	8	2 to 3 PCLK *7
0008 8040h	AD0	A/D data register A	ADDRA	16	16	2 to 3 PCLK *7
0008 8042h	AD0	A/D data register B	ADDRB	16	16	2 to 3 PCLK *7
0008 8044h	AD0	A/D data register C	ADDRC	16	16	2 to 3 PCLK *7
0008 8046h	AD0	A/D data register D	ADDRD	16	16	2 to 3 PCLK *7
0008 8050h	AD0	A/D control/status register	ADCSR	8	8	2 to 3 PCLK *7
0008 8051h	AD0	A/D control register	ADCR	8	8	2 to 3 PCLK *7
0008 8052h	AD0	ADDRy format select register	ADDPR	8	8	2 to 3 PCLK *7
0008 8053h	AD0	A/D sampling state register	ADSSTR	8	8	2 to 3 PCLK *7
0008 8060h	AD1	A/D data register A	ADDRA	16	16	2 to 3 PCLK *7
0008 8062h	AD1	A/D data register B	ADDRB	16	16	2 to 3 PCLK *7
0008 8064h	AD1	A/D data register C	ADDRC	16	16	2 to 3 PCLK *7
0008 8066h	AD1	A/D data register D	ADDRD	16	16	2 to 3 PCLK *7
0008 8070h	AD1	A/D control/status register	ADCSR	8	8	2 to 3 PCLK *7
0008 8071h	AD1	A/D control register	ADCR	8	8	2 to 3 PCLK *7
0008 8072h	AD1	ADDRy format select register	ADDPR	8	8	2 to 3 PCLK *7
0008 8073h	AD1	A/D sampling state register	ADSSTR	8	8	2 to 3 PCLK *7
0008 8080h	AD2	A/D data register A	ADDRA	16	16	2 to 3 PCLK *7
0008 8082h	AD2	A/D data register B	ADDRB	16	16	2 to 3 PCLK *7
0008 8084h	AD2	A/D data register C	ADDRC	16	16	2 to 3 PCLK *7
0008 8086h	AD2	A/D data register D	ADDRD	16	16	2 to 3 PCLK *7
0008 8090h	AD2	A/D control/status register	ADCSR	8	8	2 to 3 PCLK *7
0008 8091h	AD2	A/D control register	ADCR	8	8	2 to 3 PCLK *7
0008 8092h	AD2	ADDRy format select register	ADDPR	8	8	2 to 3 PCLK *7
0008 8093h	AD2	A/D sampling state register	ADSSTR	8	8	2 to 3 PCLK *7
0008 80A0h	AD3	A/D data register A	ADDRA	16	16	2 to 3 PCLK *7
0008 80A2h	AD3	A/D data register B	ADDRB	16	16	2 to 3 PCLK *7
0008 80A4h	AD3	A/D data register C	ADDRC	16	16	2 to 3 PCLK *7
0008 80A6h	AD3	A/D data register D	ADDRD	16	16	2 to 3 PCLK *7
0008 80B0h	AD3	A/D control/status register	ADCSR	8	8	2 to 3 PCLK *7
0008 80B1h	AD3	A/D control register	ADCR	8	8	2 to 3 PCLK *7
0008 80B2h	AD3	ADDRy format select register	ADDPR	8	8	2 to 3 PCLK *7
0008 80B3h	AD3	A/D sampling state register	ADSSTR	8	8	2 to 3 PCLK *7
0008 80C0h	D/A	D/A data register 0	DADR0	16	16	2 to 3 PCLK *7
0008 80C2h	D/A	D/A data register 1	DADR1	16	16	2 to 3 PCLK *7
0008 80C4h	D/A	D/A control register	DACR	8	8	2 to 3 PCLK *7
0008 80C5h	D/A	DADRy format select register	DADPR	8	8	2 to 3 PCLK *7
0008 8100h	TPU (unit 0)	Timer start register	TSTRA	8	8	2 to 3 PCLK *7
0008 8101h	TPU (unit 0)	Timer synchronous register	TSYRA	8	8	2 to 3 PCLK *7
0008 8110h	TPU0	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8111h	TPU0	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8112h	TPU0	Timer I/O control register H	TIORH	8	8	2 to 3 PCLK *7
0008 8113h	TPU0	Timer I/O control register L	TIORL	8	8	2 to 3 PCLK *7
0008 8114h	TPU0	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8115h	TPU0	Timer status register	TSR	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 8116h	TPU0	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8118h	TPU0	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 811Ah	TPU0	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 811Ch	TPU0	Timer general register C	TGRC	16	16	2 to 3 PCLK *7
0008 811Eh	TPU0	Timer general register D	TGRD	16	16	2 to 3 PCLK *7
0008 8120h	TPU1	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8121h	TPU1	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8122h	TPU1	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 8124h	TPU1	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8125h	TPU1	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 8126h	TPU1	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8128h	TPU1	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 812Ah	TPU1	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 8130h	TPU2	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8131h	TPU2	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8132h	TPU2	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 8134h	TPU2	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8135h	TPU2	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 8136h	TPU2	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8138h	TPU2	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 813Ah	TPU2	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 8140h	TPU3	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8141h	TPU3	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8142h	TPU3	Timer I/O control register H	TIORH	8	8	2 to 3 PCLK *7
0008 8143h	TPU3	Timer I/O control register L	TIORL	8	8	2 to 3 PCLK *7
0008 8144h	TPU3	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8145h	TPU3	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 8146h	TPU3	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8148h	TPU3	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 814Ah	TPU3	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 814Ch	TPU3	Timer general register C	TGRC	16	16	2 to 3 PCLK *7
0008 814Eh	TPU3	Timer general register D	TGRD	16	16	2 to 3 PCLK *7
0008 8150h	TPU4	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8151h	TPU4	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8152h	TPU4	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 8154h	TPU4	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8155h	TPU4	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 8156h	TPU4	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8158h	TPU4	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 815Ah	TPU4	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 8160h	TPU5	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8161h	TPU5	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8162h	TPU5	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 8164h	TPU5	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8165h	TPU5	Timer status register	TSR	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 8166h	TPU5	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8168h	TPU5	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 816Ah	TPU5	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 8170h	TPU (unit 1)	Timer start register	TSTRB	8	8	2 to 3 PCLK *7
0008 8171h	TPU (unit 1)	Timer synchronous register	TSYRB	8	8	2 to 3 PCLK *7
0008 8180h	TPU6	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8181h	TPU6	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8182h	TPU6	Timer I/O control register H	TIORH	8	8	2 to 3 PCLK *7
0008 8183h	TPU6	Timer I/O control register L	TIORL	8	8	2 to 3 PCLK *7
0008 8184h	TPU6	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8185h	TPU6	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 8186h	TPU6	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8188h	TPU6	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 818Ah	TPU6	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 818Ch	TPU6	Timer general register C	TGRC	16	16	2 to 3 PCLK *7
0008 818Eh	TPU6	Timer general register D	TGRD	16	16	2 to 3 PCLK *7
0008 8190h	TPU7	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8191h	TPU7	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 8192h	TPU7	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 8194h	TPU7	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 8195h	TPU7	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 8196h	TPU7	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 8198h	TPU7	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 819Ah	TPU7	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 81A0h	TPU8	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 81A1h	TPU8	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 81A2h	TPU8	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 81A4h	TPU8	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 81A5h	TPU8	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 81A6h	TPU8	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 81A8h	TPU8	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 81AAh	TPU8	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 81B0h	TPU9	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 81B1h	TPU9	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 81B2h	TPU9	Timer I/O control register H	TIORH	8	8	2 to 3 PCLK *7
0008 81B3h	TPU9	Timer I/O control register L	TIORL	8	8	2 to 3 PCLK *7
0008 81B4h	TPU9	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 81B5h	TPU9	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 81B6h	TPU9	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 81B8h	TPU9	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 81BAh	TPU9	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 81BCh	TPU9	Timer general register C	TGRC	16	16	2 to 3 PCLK *7
0008 81BEh	TPU9	Timer general register D	TGRD	16	16	2 to 3 PCLK *7
0008 81C0h	TPU10	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 81C1h	TPU10	Timer mode register	TMDR	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 81C2h	TPU10	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 81C4h	TPU10	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 81C5h	TPU10	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 81C6h	TPU10	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 81C8h	TPU10	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 81CAh	TPU10	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 81D0h	TPU11	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 81D1h	TPU11	Timer mode register	TMDR	8	8	2 to 3 PCLK *7
0008 81D2h	TPU11	Timer I/O control register	TIOR	8	8	2 to 3 PCLK *7
0008 81D4h	TPU11	Timer interrupt enable register	TIER	8	8	2 to 3 PCLK *7
0008 81D5h	TPU11	Timer status register	TSR	8	8	2 to 3 PCLK *7
0008 81D6h	TPU11	Timer counter	TCNT	16	16	2 to 3 PCLK *7
0008 81D8h	TPU11	Timer general register A	TGRA	16	16	2 to 3 PCLK *7
0008 81DAh	TPU11	Timer general register B	TGRB	16	16	2 to 3 PCLK *7
0008 81E6h	PPG0	PPG output control register	PCR	8	8	2 to 3 PCLK *7
0008 81E7h	PPG0	PPG output mode register	PMR	8	8	2 to 3 PCLK *7
0008 81E8h	PPG0	Next data enable register H	NDERH	8	8	2 to 3 PCLK *7
0008 81E9h	PPG0	Next data enable register L	NDERL	8	8	2 to 3 PCLK *7
0008 81EAh	PPG0	Output data register H	PODRH	8	8	2 to 3 PCLK *7
0008 81EBh	PPG0	Output data register L	PODRL	8	8	2 to 3 PCLK *7
0008 81Ech*1	PPG0	Next data register H	NDRH	8	8	2 to 3 PCLK *7
0008 81EDh*2	PPG0	Next data register L	NDRL	8	8	2 to 3 PCLK *7
0008 81EEh*1	PPG0	Next data register H	NDRH	8	8	2 to 3 PCLK *7
0008 81EFh*2	PPG0	Next data register L	NDRL	8	8	2 to 3 PCLK *7
0008 81F0h	PPG1	PPG trigger select register	PTRSLR	8	8	2 to 3 PCLK *7
0008 81F6h	PPG1	PPG output control register	PCR	8	8	2 to 3 PCLK *7
0008 81F7h	PPG1	PPG output mode register	PMR	8	8	2 to 3 PCLK *7
0008 81F8h	PPG1	Next data enable register H	NDERH	8	8	2 to 3 PCLK *7
0008 81F9h	PPG1	Next data enable register L	NDERL	8	8	2 to 3 PCLK *7
0008 81FAh	PPG1	Output data register H	PODRH	8	8	2 to 3 PCLK *7
0008 81FBh	PPG1	Output data register L	PODRL	8	8	2 to 3 PCLK *7
0008 81FCh*3	PPG1	Next data register H	NDRH	8	8	2 to 3 PCLK *7
0008 81FDh*4	PPG1	Next data register L	NDRL	8	8	2 to 3 PCLK *7
0008 81FEh*3	PPG1	Next data register H	NDRH	8	8	2 to 3 PCLK *7
0008 81FFh*4	PPG1	Next data register L	NDRL	8	8	2 to 3 PCLK *7
0008 8200h	TMR0	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8201h	TMR1	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8202h	TMR0	Timer control/status register	TCSR	8	8	2 to 3 PCLK *7
0008 8203h	TMR1	Timer control/status register	TCSR	8	8	2 to 3 PCLK *7
0008 8204h	TMR0	Time constant register A	TCORA	8	8 or 16	2 to 3 PCLK *7
0008 8205h	TMR1	Time constant register A	TCORA	8	8 or 16*5	2 to 3 PCLK *7
0008 8206h	TMR0	Time constant register B	TCORB	8	8 or 16	2 to 3 PCLK *7
0008 8207h	TMR1	Time constant register B	TCORB	8	8 or 16*5	2 to 3 PCLK *7
0008 8208h	TMR0	Timer counter	TCNT	8	8 or 16	2 to 3 PCLK *7
0008 8209h	TMR1	Timer counter	TCNT	8	8 or 16*5	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 820Ah	TMR0	Timer counter control register	TCCR	8	8 or 16	2 to 3 PCLK *7
0008 820Bh	TMR1	Timer counter control register	TCCR	8	8 or 16	2 to 3 PCLK *7
0008 8210h	TMR2	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8211h	TMR3	Timer control register	TCR	8	8	2 to 3 PCLK *7
0008 8212h	TMR2	Timer control/status register	TCSR	8	8	2 to 3 PCLK *7
0008 8213h	TMR3	Timer control/status register	TCSR	8	8	2 to 3 PCLK *7
0008 8214h	TMR2	Time constant register A	TCORA	8	8 or 16	2 to 3 PCLK *7
0008 8215h	TMR3	Time constant register A	TCORA	8	8 or 16*5	2 to 3 PCLK *7
0008 8216h	TMR2	Time constant register B	TCORB	8	8 or 16	2 to 3 PCLK *7
0008 8217h	TMR3	Time constant register B	TCORB	8	8 or 16*5	2 to 3 PCLK *7
0008 8218h	TMR2	Timer counter	TCNT	8	8 or 16	2 to 3 PCLK *7
0008 8219h	TMR3	Timer counter	TCNT	8	8 or 16*5	2 to 3 PCLK *7
0008 821Ah	TMR2	Timer counter control register	TCCR	8	8 or 16	2 to 3 PCLK *7
0008 821Bh	TMR3	Timer counter control register	TCCR	8	8 or 16	2 to 3 PCLK *7
0008 8240h	SCI0	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8241h	SCI0	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 8242h	SCI0	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 8243h	SCI0	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 8244h	SCI0	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 8245h	SCI0	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 8246h	SCI0	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7
0008 8247h	SCI0	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8248h	SCI1	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8249h	SCI1	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 824Ah	SCI1	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 824Bh	SCI1	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 824Ch	SCI1	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 824Dh	SCI1	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 824Eh	SCI1	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7
0008 824Fh	SCI1	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8250h	SCI2	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8251h	SCI2	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 8252h	SCI2	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 8253h	SCI2	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 8254h	SCI2	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 8255h	SCI2	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 8256h	SCI2	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7
0008 8257h	SCI2	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8258h	SCI3	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8259h	SCI3	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 825Ah	SCI3	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 825Bh	SCI3	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 825Ch	SCI3	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 825Dh	SCI3	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 825Eh	SCI3	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 825Fh	SCI3	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8260h	SCI4	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8261h	SCI4	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 8262h	SCI4	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 8263h	SCI4	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 8264h	SCI4	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 8265h	SCI4	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 8266h	SCI4	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7
0008 8267h	SCI4	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8268h	SCI5	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8269h	SCI5	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 826Ah	SCI5	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 826Bh	SCI5	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 826Ch	SCI5	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 826Dh	SCI5	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 826Eh	SCI5	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7
0008 826Fh	SCI5	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8270h	SCI6	Serial mode register	SMR*6	8	8	2 to 3 PCLK *7
0008 8271h	SCI6	Bit rate register	BRR	8	8	2 to 3 PCLK *7
0008 8272h	SCI6	Serial control register	SCR*6	8	8	2 to 3 PCLK *7
0008 8273h	SCI6	Transmit data register	TDR	8	8	2 to 3 PCLK *7
0008 8274h	SCI6	Serial status register	SSR*6	8	8	2 to 3 PCLK *7
0008 8275h	SCI6	Receive data register	RDR	8	8	2 to 3 PCLK *7
0008 8276h	SCI6	Smart card mode register	SCMR	8	8	2 to 3 PCLK *7
0008 8277h	SCI6	Serial extended mode register	SEMR	8	8	2 to 3 PCLK *7
0008 8280h	CRC	CRC control register	CRCCR	8	8	2 to 3 PCLK *7
0008 8281h	CRC	CRC data input register	CRCDIR	8	8	2 to 3 PCLK *7
0008 8282h	CRC	CRC data output register	CRCDOR	16	16	2 to 3 PCLK *7
0008 8300h	RIIC0	I2C bus control register 1	ICCR1	8	8	2 to 3 PCLK *7
0008 8301h	RIIC0	I2C bus control register 2	ICCR2	8	8	2 to 3 PCLK *7
0008 8302h	RIIC0	I2C bus mode register 1	ICMR1	8	8	2 to 3 PCLK *7
0008 8303h	RIIC0	I2C bus mode register 2	ICMR2	8	8	2 to 3 PCLK *7
0008 8304h	RIIC0	I2C bus mode register 3	ICMR3	8	8	2 to 3 PCLK *7
0008 8305h	RIIC0	I2C bus function enable register	ICFER	8	8	2 to 3 PCLK *7
0008 8306h	RIIC0	I2C bus status enable register	ICSER	8	8	2 to 3 PCLK *7
0008 8307h	RIIC0	I2C bus interrupt enable register	ICIER	8	8	2 to 3 PCLK *7
0008 8308h	RIIC0	I2C bus status register 1	ICSR1	8	8	2 to 3 PCLK *7
0008 8309h	RIIC0	I2C bus status register 2	ICSR2	8	8	2 to 3 PCLK *7
0008 830Ah	RIIC0	Slave address register L0	SARL0	8	8	2 to 3 PCLK *7
0008 830Bh	RIIC0	Slave address register U0	SARU0	8	8	2 to 3 PCLK *7
0008 830Ch	RIIC0	Slave address register L1	SARL1	8	8	2 to 3 PCLK *7
0008 830Dh	RIIC0	Slave address register U1	SARU1	8	8	2 to 3 PCLK *7
0008 830Eh	RIIC0	Slave address register L2	SARL2	8	8	2 to 3 PCLK *7
0008 830Fh	RIIC0	Slave address register U2	SARU2	8	8	2 to 3 PCLK *7
0008 8310h	RIIC0	I2C bus bit rate low-level register	ICBRL	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 8311h	RIIC0	I2C bus bit rate high-level register	ICBRH	8	8	2 to 3 PCLK *7
0008 8312h	RIIC0	I2C bus transmit data register	ICDRT	8	8	2 to 3 PCLK *7
0008 8313h	RIIC0	I2C bus receive data register	ICDRR	8	8	2 to 3 PCLK *7
0008 8320h	RIIC1	I2C bus control register 1	ICCR1	8	8	2 to 3 PCLK *7
0008 8321h	RIIC1	I2C bus control register 2	ICCR2	8	8	2 to 3 PCLK *7
0008 8322h	RIIC1	I2C bus mode register 1	ICMR1	8	8	2 to 3 PCLK *7
0008 8323h	RIIC1	I2C bus mode register 2	ICMR2	8	8	2 to 3 PCLK *7
0008 8324h	RIIC1	I2C bus mode register 3	ICMR3	8	8	2 to 3 PCLK *7
0008 8325h	RIIC1	I2C bus function enable register	ICFER	8	8	2 to 3 PCLK *7
0008 8326h	RIIC1	I2C bus status enable register	ICSER	8	8	2 to 3 PCLK *7
0008 8327h	RIIC1	I2C bus interrupt enable register	ICIER	8	8	2 to 3 PCLK *7
0008 8328h	RIIC1	I2C bus status register 1	ICSR1	8	8	2 to 3 PCLK *7
0008 8329h	RIIC1	I2C bus status register 2	ICSR2	8	8	2 to 3 PCLK *7
0008 832Ah	RIIC1	Slave address register L0	SARL0	8	8	2 to 3 PCLK *7
0008 832Bh	RIIC1	Slave address register U0	SARU0	8	8	2 to 3 PCLK *7
0008 832Ch	RIIC1	Slave address register L1	SARL1	8	8	2 to 3 PCLK *7
0008 832Dh	RIIC1	Slave address register U1	SARU1	8	8	2 to 3 PCLK *7
0008 832Eh	RIIC1	Slave address register L2	SARL2	8	8	2 to 3 PCLK *7
0008 832Fh	RIIC1	Slave address register U2	SARU2	8	8	2 to 3 PCLK *7
0008 8330h	RIIC1	I2C bus bit rate low-level register	ICBRL	8	8	2 to 3 PCLK *7
0008 8331h	RIIC1	I2C bus bit rate high-level register	ICBRH	8	8	2 to 3 PCLK *7
0008 8332h	RIIC1	I2C bus transmit data register	ICDRT	8	8	2 to 3 PCLK *7
0008 8333h	RIIC1	I2C bus receive data register	ICDRR	8	8	2 to 3 PCLK *7
0008 C000h	P0	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C001h	P1	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C002h	P2	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C003h	P3	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C004h	P4	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C005h	P5	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C006h	P6	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C007h	P7	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C008h	P8	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C009h	P9	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C00Ah	PA	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C00Bh	PB	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C00Ch	PC	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C00Dh	PD	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C00Eh	PE	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C00Fh	PF	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C010h	PG	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C011h	PH	Data direction register	DDR	8	8	2 to 3 PCLK *7
0008 C020h	P0	Data register	DR	8	8	2 to 3 PCLK *7
0008 C021h	P1	Data register	DR	8	8	2 to 3 PCLK *7
0008 C022h	P2	Data register	DR	8	8	2 to 3 PCLK *7
0008 C023h	P3	Data register	DR	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 C024h	P4	Data register	DR	8	8	2 to 3 PCLK *7
0008 C025h	P5	Data register	DR	8	8	2 to 3 PCLK *7
0008 C026h	P6	Data register	DR	8	8	2 to 3 PCLK *7
0008 C027h	P7	Data register	DR	8	8	2 to 3 PCLK *7
0008 C028h	P8	Data register	DR	8	8	2 to 3 PCLK *7
0008 C029h	P9	Data register	DR	8	8	2 to 3 PCLK *7
0008 C02Ah	PA	Data register	DR	8	8	2 to 3 PCLK *7
0008 C02Bh	PB	Data register	DR	8	8	2 to 3 PCLK *7
0008 C02Ch	PC	Data register	DR	8	8	2 to 3 PCLK *7
0008 C02Dh	PD	Data register	DR	8	8	2 to 3 PCLK *7
0008 C02Eh	PE	Data register	DR	8	8	2 to 3 PCLK *7
0008 C02Fh	PF	Data register	DR	8	8	2 to 3 PCLK *7
0008 C030h	PG	Data register	DR	8	8	2 to 3 PCLK *7
0008 C031h	PH	Data register	DR	8	8	2 to 3 PCLK *7
0008 C040h	P0	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C041h	P1	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C042h	P2	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C043h	P3	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C044h	P4	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C045h	P5	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C046h	P6	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C047h	P7	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C048h	P8	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C049h	P9	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C04Ah	PA	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C04Bh	PB	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C04Ch	PC	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C04Dh	PD	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C04Eh	PE	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C04Fh	PF	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C050h	PG	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C051h	PH	Port register	PORT	8	8	2 to 3 PCLK *7
0008 C060h	P0	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C061h	P1	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C062h	P2	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C063h	P3	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C064h	P4	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C065h	P5	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C066h	P6	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C067h	P7	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C068h	P8	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C069h	P9	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C06Ah	PA	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C06Bh	PB	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C06Ch	PC	Input buffer control register	ICR	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 C06Dh	PD	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C06Eh	PE	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C06Fh	PF	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C070h	PG	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C071h	PH	Input buffer control register	ICR	8	8	2 to 3 PCLK *7
0008 C082h	P2	Open drain control register	ODR	8	8	2 to 3 PCLK *7
0008 C08Ch	PC	Open drain control register	ODR	8	8	2 to 3 PCLK *7
0008 C0CAh	PA	Pull-Up resistor control register	PCR	8	8	2 to 3 PCLK *7
0008 C0CBh	PB	Pull-Up resistor control register	PCR	8	8	2 to 3 PCLK *7
0008 C0CCh	PC	Pull-Up resistor control register	PCR	8	8	2 to 3 PCLK *7
0008 C0CDh	PD	Pull-Up resistor control register	PCR	8	8	2 to 3 PCLK *7
0008 C0CEh	PE	Pull-Up resistor control register	PCR	8	8	2 to 3 PCLK *7
0008 C100h	I/O PORT	Port function control register 0	PFCR0	8	8	2 to 3 PCLK *7
0008 C101h	I/O PORT	Port function control register 1	PFCR1	8	8	2 to 3 PCLK *7
0008 C102h	I/O PORT	Port function control register 2	PFCR2	8	8	2 to 3 PCLK *7
0008 C103h	I/O PORT	Port function control register 3	PFCR3	8	8	2 to 3 PCLK *7
0008 C104h	I/O PORT	Port function control register 4	PFCR4	8	8	2 to 3 PCLK *7
0008 C105h	I/O PORT	Port function control register 5	PFCR5	8	8	2 to 3 PCLK *7
0008 C106h	I/O PORT	Port function control register 6	PFCR6	8	8	2 to 3 PCLK *7
0008 C107h	I/O PORT	Port function control register 7	PFCR7	8	8	2 to 3 PCLK *7
0008 C108h	I/O PORT	Port function control register 8	PFCR8	8	8	2 to 3 PCLK *7
0008 C109h	I/O PORT	Port function control register 9	PFCR9	8	8	2 to 3 PCLK *7
0008 C280h	SYSTEM	Deep standby control register	DPSBYCR	8	8	4 to 5 PCLK *7
0008 C281h	SYSTEM	Deep standby wait control register	DPSWCR	8	8	4 to 5 PCLK *7
0008 C282h	SYSTEM	Deep standby interrupt enable register	DPSIER	8	8	4 to 5 PCLK *7
0008 C283h	SYSTEM	Deep standby interrupt flag register	DPSIFR	8	8	4 to 5 PCLK *7
0008 C284h	SYSTEM	Deep standby interrupt edge register	DPSIEGR	8	8	4 to 5 PCLK *7
0008 C285h	SYSTEM	Reset status register	RSTSR	8	8	4 to 5 PCLK *7
0008 C289h	FLASH	Flash write erase protection register	FWEPROR	8	8	4 to 5 PCLK *7
0008 C290h	SYSTEM	Deep standby backup register 0	DPSBKR0	8	8	4 to 5 PCLK *7
0008 C291h	SYSTEM	Deep standby backup register 1	DPSBKR1	8	8	4 to 5 PCLK *7
0008 C292h	SYSTEM	Deep standby backup register 2	DPSBKR2	8	8	4 to 5 PCLK *7
0008 C293h	SYSTEM	Deep standby backup register 3	DPSBKR3	8	8	4 to 5 PCLK *7
0008 C294h	SYSTEM	Deep standby backup register 4	DPSBKR4	8	8	4 to 5 PCLK *7
0008 C295h	SYSTEM	Deep standby backup register 5	DPSBKR5	8	8	4 to 5 PCLK *7
0008 C296h	SYSTEM	Deep standby backup register 6	DPSBKR6	8	8	4 to 5 PCLK *7
0008 C297h	SYSTEM	Deep standby backup register 7	DPSBKR7	8	8	4 to 5 PCLK *7
0008 C298h	SYSTEM	Deep standby backup register 8	DPSBKR8	8	8	4 to 5 PCLK *7
0008 C299h	SYSTEM	Deep standby backup register 9	DPSBKR9	8	8	4 to 5 PCLK *7
0008 C29Ah	SYSTEM	Deep standby backup register 10	DPSBKR10	8	8	4 to 5 PCLK *7
0008 C29Bh	SYSTEM	Deep standby backup register 11	DPSBKR11	8	8	4 to 5 PCLK *7
0008 C29Ch	SYSTEM	Deep standby backup register 12	DPSBKR12	8	8	4 to 5 PCLK *7
0008 C29Dh	SYSTEM	Deep standby backup register 13	DPSBKR13	8	8	4 to 5 PCLK *7
0008 C29Eh	SYSTEM	Deep standby backup register 14	DPSBKR14	8	8	4 to 5 PCLK *7
0008 C29Fh	SYSTEM	Deep standby backup register 15	DPSBKR15	8	8	4 to 5 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 C2A0h	SYSTEM	Deep standby backup register 16	DPSBKR16	8	8	4 to 5 PCLK *7
0008 C2A1h	SYSTEM	Deep standby backup register 17	DPSBKR17	8	8	4 to 5 PCLK *7
0008 C2A2h	SYSTEM	Deep standby backup register 18	DPSBKR18	8	8	4 to 5 PCLK *7
0008 C2A3h	SYSTEM	Deep standby backup register 19	DPSBKR19	8	8	4 to 5 PCLK *7
0008 C2A4h	SYSTEM	Deep standby backup register 20	DPSBKR20	8	8	4 to 5 PCLK *7
0008 C2A5h	SYSTEM	Deep standby backup register 21	DPSBKR21	8	8	4 to 5 PCLK *7
0008 C2A6h	SYSTEM	Deep standby backup register 22	DPSBKR22	8	8	4 to 5 PCLK *7
0008 C2A7h	SYSTEM	Deep standby backup register 23	DPSBKR23	8	8	4 to 5 PCLK *7
0008 C2A8h	SYSTEM	Deep standby backup register 24	DPSBKR24	8	8	4 to 5 PCLK *7
0008 C2A9h	SYSTEM	Deep standby backup register 25	DPSBKR25	8	8	4 to 5 PCLK *7
0008 C2AAh	SYSTEM	Deep standby backup register 26	DPSBKR26	8	8	4 to 5 PCLK *7
0008 C2ABh	SYSTEM	Deep standby backup register 27	DPSBKR27	8	8	4 to 5 PCLK *7
0008 C2ACh	SYSTEM	Deep standby backup register 28	DPSBKR28	8	8	4 to 5 PCLK *7
0008 C2ADh	SYSTEM	Deep standby backup register 29	DPSBKR29	8	8	4 to 5 PCLK *7
0008 C2AEh	SYSTEM	Deep standby backup register 30	DPSBKR30	8	8	4 to 5 PCLK *7
0008 C2AFh	SYSTEM	Deep standby backup register 31	DPSBKR31	8	8	4 to 5 PCLK *7
0008 C300h	ICU	IRQ detection enable registrar 0	IRQER0	8	8	2 to 3 PCLK *7
0008 C301h	ICU	IRQ detection enable registrar 1	IRQER1	8	8	2 to 3 PCLK *7
0008 C302h	ICU	IRQ detection enable registrar 2	IRQER2	8	8	2 to 3 PCLK *7
0008 C303h	ICU	IRQ detection enable registrar 3	IRQER3	8	8	2 to 3 PCLK *7
0008 C304h	ICU	IRQ detection enable registrar 4	IRQER4	8	8	2 to 3 PCLK *7
0008 C305h	ICU	IRQ detection enable registrar 5	IRQER5	8	8	2 to 3 PCLK *7
0008 C306h	ICU	IRQ detection enable registrar 6	IRQER6	8	8	2 to 3 PCLK *7
0008 C307h	ICU	IRQ detection enable registrar 7	IRQER7	8	8	2 to 3 PCLK *7
0008 C308h	ICU	IRQ detection enable registrar 8	IRQER8	8	8	2 to 3 PCLK *7
0008 C309h	ICU	IRQ detection enable registrar 9	IRQER9	8	8	2 to 3 PCLK *7
0008 C30Ah	ICU	IRQ detection enable registrar 10	IRQER10	8	8	2 to 3 PCLK *7
0008 C30Bh	ICU	IRQ detection enable registrar 11	IRQER11	8	8	2 to 3 PCLK *7
0008 C30Ch	ICU	IRQ detection enable registrar 12	IRQER12	8	8	2 to 3 PCLK *7
0008 C30Dh	ICU	IRQ detection enable registrar 13	IRQER13	8	8	2 to 3 PCLK *7
0008 C30Eh	ICU	IRQ detection enable registrar 14	IRQER14	8	8	2 to 3 PCLK *7
0008 C30Fh	ICU	IRQ detection enable registrar 15	IRQER15	8	8	2 to 3 PCLK *7
0008 C320h	ICU	IRQ control register 0	IRQCR0	8	8	2 to 3 PCLK *7
0008 C321h	ICU	IRQ control register 1	IRQCR1	8	8	2 to 3 PCLK *7
0008 C322h	ICU	IRQ control register 2	IRQCR2	8	8	2 to 3 PCLK *7
0008 C323h	ICU	IRQ control register 3	IRQCR3	8	8	2 to 3 PCLK *7
0008 C324h	ICU	IRQ control register 4	IRQCR4	8	8	2 to 3 PCLK *7
0008 C325h	ICU	IRQ control register 5	IRQCR5	8	8	2 to 3 PCLK *7
0008 C326h	ICU	IRQ control register 6	IRQCR6	8	8	2 to 3 PCLK *7
0008 C327h	ICU	IRQ control register 7	IRQCR7	8	8	2 to 3 PCLK *7
0008 C328h	ICU	IRQ control register 8	IRQCR8	8	8	2 to 3 PCLK *7
0008 C329h	ICU	IRQ control register 9	IRQCR9	8	8	2 to 3 PCLK *7
0008 C32Ah	ICU	IRQ control register 10	IRQCR10	8	8	2 to 3 PCLK *7
0008 C32Bh	ICU	IRQ control register 11	IRQCR11	8	8	2 to 3 PCLK *7
0008 C32Ch	ICU	IRQ control register 12	IRQCR12	8	8	2 to 3 PCLK *7

Address	Module Abbreviation	Register Name	Register Abbreviation	Number of Bits	Access Size	Number of Access Cycles
0008 C32Dh	ICU	IRQ control register 13	IRQCR13	8	8	2 to 3 PCLK *7
0008 C32Eh	ICU	IRQ control register 14	IRQCR14	8	8	2 to 3 PCLK *7
0008 C32Fh	ICU	IRQ control register 15	IRQCR15	8	8	2 to 3 PCLK *7
0008 C340h	ICU	Software standby release IRQ enable register	SSIER	16	16	2 to 3 PCLK *7
0008 C350h	ICU	Non-maskable interrupt enable register	NMIER	8	8	2 to 3 PCLK *7
0008 C351h	ICU	NMI pin interrupt control register	NMICR	8	8	2 to 3 PCLK *7
0008 C352h	ICU	Non-maskable interrupt status register	NMISR	8	8	2 to 3 PCLK *7
0008 C353h	ICU	Non-maskable interrupt clear register	NMICLR	8	8	2 to 3 PCLK *7
007F C402h	FLASH	Flash mode register	FMODR	8	8	2 to 3 PCLK *7
007F C410h	FLASH	Flash access status register	FASTAT	8	8	2 to 3 PCLK *7
007F C411h	FLASH	Flash access error interrupt enable register	FAEINT	8	8	2 to 3 PCLK *7
007F C412h	FLASH	Flash ready interrupt enable register	FRDYIE	8	8	2 to 3 PCLK *7
007F C440h	FLASH	Data flash read enable register	DFLRE	16	16	2 to 3 PCLK *7
007F C450h	FLASH	Data flash programming/erasure enable register	DFLWE	16	16	2 to 3 PCLK *7
007F C454h	FLASH	FCU RAM enable register	FCURAME	16	16	2 to 3 PCLK *7
007F FFB0h	FLASH	Flash status register 0	FSTATR0	8	8	2 to 3 PCLK *7
007F FFB1h	FLASH	Flash status register 1	FSTATR1	8	8	2 to 3 PCLK *7
007F FFB2h	FLASH	Flash P/E mode entry register	FENTRYR	16	16	2 to 3 PCLK *7
007F FFB4h	FLASH	Flash protection register	FPROTR	16	16	2 to 3 PCLK *7
007F FFB6h	FLASH	Flash reset register	FRESETR	16	16	2 to 3 PCLK *7
007F FFBAh	FLASH	FCU command register	FCMDR	16	16	2 to 3 PCLK *7
007F FFC8h	FLASH	FCU processing switching register	FCPSR	16	16	2 to 3 PCLK *7
007F FFCAh	FLASH	Data flash blank check control register	DFLBCCNT	16	16	2 to 3 PCLK *7
007F FFCCh	FLASH	Flash P/E status register	FPESTAT	16	16	2 to 3 PCLK *7
007F FFCEh	FLASH	Data flash blank check status register	DFLBCSTAT	16	16	2 to 3 PCLK *7
007F FFE8h	FLASH	Peripheral clock notification register	PCKAR	16	16	2 to 3 PCLK *7

Notes:
1. When the same output trigger is specified for pulse output groups 2 and 3 by the PPG0.PCR setting, the PPG0.NDRH address is 000881ECh. When different output triggers are specified, the PPG0.NDRH addresses for pulse output groups 2 and 3 are 000881EEh and 000881ECh, respectively.
2. When the same output trigger is specified for pulse output groups 0 and 1 by the PPG0.PCR setting, the PPG0.NDRL address is 000881EDh. When different output triggers are specified, the PPG0.NDRL addresses for pulse output groups 0 and 1 are 000881EFh and 000881EDh, respectively.
3. When the same output trigger is specified for pulse output groups 6 and 7 by the PPG1.PCR setting, the PPG1.NDRH address is 000881FCh. When different output triggers are specified, the PPG1.NDRH addresses for pulse output groups 6 and 7 are 000881FEh and 000881FCh, respectively.
4. When the same output trigger is specified for pulse output groups 4 and 5 by the PPG1.PCR setting, the PPG1.NDRL address is 000881FDh. When different output triggers are specified, the PPG1.NDRL addresses for pulse output groups 4 and 5 are 000881FFh and 000881FDh, respectively.
5. 16-bit access to odd addresses is proh bited. When 16-bit access is required, access is at the address corresponding to TMR0 or TMR2.
6. For certain bits, functions differ according to whether the mode is serial communications or smart card interface.
7. The number of access cycles varies depending on the number of divided cycles for clock synchronization (0 to one PCLK).
8. The number of access cycles may be 5 ICLK if the register is accessed during the DMAC operation.

5.2 I/O Register Bits

Register addresses and bit names of the peripheral modules are described below.

Each line cover eight bits, and 16-bit and 32-bit registers are shown as 2 or 4 lines, respectively.

Table 5.2 List of I/O Registers (Bit Order)

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
SYSTEM	MDMONR	—	—	—	—	—	—	—	—
		MDE	—	—	—	—	—	MD1	MD0
SYSTEM	MDSR	—	—	—	—	—	—	—	—
		—	UBTS	—	BOTS	BSW[1:0]		EXB	IROM
SYSTEM	SYSCR0	KEY[7:0]							
		—	—	—	—	—	—	EXBE	ROME
SYSTEM	SYSCR1	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	RAME
SYSTEM	SBYCR	SSBY	OPE	—	STS[4:0]				
		—	—	—	—	—	—	—	—
SYSTEM	MSTPCRA	ACSE	—	—	MSTPA28	MSTPA27	—	—	—
		MSTPA23	MSTPA22	MSTPA21	MSTPA20	MSTPA19	—	—	—
		MSTPA15	MSTPA14	MSTPA13	MSTPA12	MSTPA11	MSTPA10	—	—
		—	—	MSTPA5	MSTPA4	—	—	—	—
SYSTEM	MSTPCRB	MSTPB31	MSTPB30	MSTPB29	MSTPB28	MSTPB27	MSTPB26	MSTPB25	—
		MSTPB23	—	MSTPB21	MSTPB20	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
SYSTEM	MSTPCRC	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	—
		—	—	—	—	—	—	MSTPC1	MSTPC0
SYSTEM	SCKCR	—	—	—	—	ICK[3:0]			
		PSTOP1	—	—	—	BCK[3:0]			
		—	—	—	—	PCK[3:0]			
		—	—	—	—	—	—	—	—
BSC	BERCLR	—	—	—	—	—	—	—	STSCLR
BSC	BEREN	—	—	—	—	—	—	TOEN	IGAEN
BSC	BERIE	—	—	—	—	—	—	—	CPEN
DMAC0	DMCSA								
DMAC0	DMCDA								
DMAC0	DMCBC	—	—	—	—	—	—		

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
DMAC0	DMMOD	—	—	—	—	OPSEL[3:0]			
		—	—	—	—	—	SZSEL[2:0]		
		—	SMOD[2:0]			—	DMOD[2:0]		
		—	—	—	—	—	—	—	—
DMAC1	DMCSA								
DMAC1	DMCDA								
DMAC1	DMCBC	—	—	—	—	—	—		
DMAC1	DMMOD	—	—	—	—	OPSEL[3:0]			
		—	—	—	—	—	SZSEL[2:0]		
		—	SMOD[2:0]			—	DMOD[2:0]		
		—	—	—	—	—	—	—	—
DMAC2	DMCSA								
DMAC2	DMCDA								
DMAC2	DMCBC	—	—	—	—	—	—		
DMAC2	DMMOD	—	—	—	—	OPSEL[3:0]			
		—	—	—	—	—	SZSEL[2:0]		
		—	SMOD[2:0]			—	DMOD[2:0]		
		—	—	—	—	—	—	—	—
DMAC3	DMCSA								
DMAC3	DMCDA								

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
DMAC3	DMCBC	—	—	—	—	—	—		
DMAC3	DMMOD	—	—	—	—	OPSEL[3:0]			
		—	—	—	—	—	SZSEL[2:0]		
		—	SMOD[2:0]			—	DMOD[2:0]		
		—	—	—	—	—	—	—	—
DMAC0	DMRSA								
DMAC0	DMRDA								
DMAC0	DMRBC	—	—	—	—	—	—		
DMAC1	DMRSA								
DMAC1	DMRDA								
DMAC1	DMRBC	—	—	—	—	—	—		
DMAC2	DMRSA								
DMAC2	DMRDA								
DMAC2	DMRBC	—	—	—	—	—	—		

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
DMAC3	DMRSA								
DMAC3	DMRDA								
DMAC3	DMRBC	—	—	—	—	—	—		
DMAC0	DMCRA	—	—	—	—	—	—	DSEL[1:0]	
		—	—	—	—	—	—	—	—
		—	—	—	—	—	BRLOD	SRLOD	DRLOD
		—	—	DCTG[5:0]					
DMAC0	DMCRB	—	—	—	—	—	—	—	DSCLR
DMAC0	DMCRC	—	—	—	—	—	—	—	ECLR
DMAC0	DMCRD	—	—	—	—	—	—	—	DREQ
DMAC0	DMCRE	—	—	—	—	—	—	—	DEN
DMAC1	DMCRA	—	—	—	—	—	—	DSEL[1:0]	
		—	—	—	—	—	—	—	—
		—	—	—	—	—	BRLOD	SRLOD	DRLOD
		—	—	DCTG[5:0]					
DMAC1	DMCRB	—	—	—	—	—	—	—	DSCLR
DMAC1	DMCRC	—	—	—	—	—	—	—	ECLR
DMAC1	DMCRD	—	—	—	—	—	—	—	DREQ
DMAC1	DMCRE	—	—	—	—	—	—	—	DEN
DMAC2	DMCRA	—	—	—	—	—	—	DSEL[1:0]	
		—	—	—	—	—	—	—	—
		—	—	—	—	—	BRLOD	SRLOD	DRLOD
		—	—	DCTG[5:0]					
DMAC2	DMCRB	—	—	—	—	—	—	—	DSCLR
DMAC2	DMCRC	—	—	—	—	—	—	—	ECLR
DMAC2	DMCRD	—	—	—	—	—	—	—	DREQ
DMAC2	DMCRE	—	—	—	—	—	—	—	DEN
DMAC3	DMCRA	—	—	—	—	—	—	DSEL[1:0]	
		—	—	—	—	—	—	—	—
		—	—	—	—	—	BRLOD	SRLOD	DRLOD
		—	—	DCTG[5:0]					
DMAC3	DMCRB	—	—	—	—	—	—	—	DSCLR
DMAC3	DMCRC	—	—	—	—	—	—	—	ECLR
DMAC3	DMCRD	—	—	—	—	—	—	—	DREQ
DMAC3	DMCRE	—	—	—	—	—	—	—	DEN

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
Common to all DMAC channels	DMSCNT	—	—	—	—	—	—	—	DMST
Common to all DMAC channels	DMICNT	DINTM0	DINTM1	DINTM2	DINTM3	—	—	—	—
Common to all DMAC channels	DMEDET	DEDET0	DEDET1	DEDET2	DEDET3	—	—	—	—
Common to all DMAC channels	DMASTS	DASTS0	DASTS1	DASTS2	DASTS3	—	—	—	—
BSC	CS0MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS0WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		
BSC	CS0WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS1MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS1WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		
BSC	CS1WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS2MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS2WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		
BSC	CS2WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS3MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
BSC	CS3WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		
BSC	CS3WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS4MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS4WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT [2:0]		
BSC	CS4WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS5MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS5WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		
BSC	CS5WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS6MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS6WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		
BSC	CS6WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS7MOD	PRMOD	—	—	—	—	—	PWENB	PRENB
		—	—	—	—	EWENB	—	—	WRMOD
BSC	CS7WCNT1	—	—	—	CSRWAIT[4:0]				
		—	—	—	CSWWAIT[4:0]				
		—	—	—	—	—	CSPRWAIT[2:0]		
		—	—	—	—	—	CSPWWAIT[2:0]		

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
BSC	CS7WCNT2	—	CSON[2:0]			—	WDON[2:0]		
		—	WRON[2:0]			—	RDON[2:0]		
		—	—	—	—	—	WDOFF[2:0]		
		—	CSWOFF[2:0]			—	CSROFF[2:0]		
BSC	CS0CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS0REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS1CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS1REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS2CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS2REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS3CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS3REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS4CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS4REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS5CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS5REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS6CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS6REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
BSC	CS7CNT	—	—	—	—	—	—	—	EMODE
		—	—	BSIZE[1:0]		—	—	—	EXENB
BSC	CS7REC	—	—	—	—	WRCV[3:0]			
		—	—	—	—	RRCV[3:0]			
ICU	IR016	—	—	—	—	—	—	—	IR
ICU	IR021	—	—	—	—	—	—	—	IR
ICU	IR023	—	—	—	—	—	—	—	IR
ICU	IR028	—	—	—	—	—	—	—	IR
ICU	IR029	—	—	—	—	—	—	—	IR
ICU	IR030	—	—	—	—	—	—	—	IR
ICU	IR031	—	—	—	—	—	—	—	IR
ICU	IR064	—	—	—	—	—	—	—	IR
ICU	IR065	—	—	—	—	—	—	—	IR

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IR066	—	—	—	—	—	—	—	IR
ICU	IR067	—	—	—	—	—	—	—	IR
ICU	IR068	—	—	—	—	—	—	—	IR
ICU	IR069	—	—	—	—	—	—	—	IR
ICU	IR070	—	—	—	—	—	—	—	IR
ICU	IR071	—	—	—	—	—	—	—	IR
ICU	IR072	—	—	—	—	—	—	—	IR
ICU	IR073	—	—	—	—	—	—	—	IR
ICU	IR074	—	—	—	—	—	—	—	IR
ICU	IR075	—	—	—	—	—	—	—	IR
ICU	IR076	—	—	—	—	—	—	—	IR
ICU	IR077	—	—	—	—	—	—	—	IR
ICU	IR078	—	—	—	—	—	—	—	IR
ICU	IR079	—	—	—	—	—	—	—	IR
ICU	IR096	—	—	—	—	—	—	—	IR
ICU	IR098	—	—	—	—	—	—	—	IR
ICU	IR099	—	—	—	—	—	—	—	IR
ICU	IR100	—	—	—	—	—	—	—	IR
ICU	IR101	—	—	—	—	—	—	—	IR
ICU	IR104	—	—	—	—	—	—	—	IR
ICU	IR105	—	—	—	—	—	—	—	IR
ICU	IR106	—	—	—	—	—	—	—	IR
ICU	IR107	—	—	—	—	—	—	—	IR
ICU	IR108	—	—	—	—	—	—	—	IR
ICU	IR111	—	—	—	—	—	—	—	IR
ICU	IR112	—	—	—	—	—	—	—	IR
ICU	IR115	—	—	—	—	—	—	—	IR
ICU	IR116	—	—	—	—	—	—	—	IR
ICU	IR117	—	—	—	—	—	—	—	IR
ICU	IR118	—	—	—	—	—	—	—	IR
ICU	IR120	—	—	—	—	—	—	—	IR
ICU	IR121	—	—	—	—	—	—	—	IR
ICU	IR122	—	—	—	—	—	—	—	IR
ICU	IR123	—	—	—	—	—	—	—	IR
ICU	IR124	—	—	—	—	—	—	—	IR
ICU	IR125	—	—	—	—	—	—	—	IR
ICU	IR126	—	—	—	—	—	—	—	IR
ICU	IR127	—	—	—	—	—	—	—	IR
ICU	IR128	—	—	—	—	—	—	—	IR
ICU	IR131	—	—	—	—	—	—	—	IR
ICU	IR132	—	—	—	—	—	—	—	IR
ICU	IR133	—	—	—	—	—	—	—	IR
ICU	IR134	—	—	—	—	—	—	—	IR
ICU	IR136	—	—	—	—	—	—	—	IR
ICU	IR137	—	—	—	—	—	—	—	IR

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IR138	—	—	—	—	—	—	—	IR
ICU	IR139	—	—	—	—	—	—	—	IR
ICU	IR140	—	—	—	—	—	—	—	IR
ICU	IR141	—	—	—	—	—	—	—	IR
ICU	IR142	—	—	—	—	—	—	—	IR
ICU	IR145	—	—	—	—	—	—	—	IR
ICU	IR146	—	—	—	—	—	—	—	IR
ICU	IR149	—	—	—	—	—	—	—	IR
ICU	IR150	—	—	—	—	—	—	—	IR
ICU	IR151	—	—	—	—	—	—	—	IR
ICU	IR152	—	—	—	—	—	—	—	IR
ICU	IR154	—	—	—	—	—	—	—	IR
ICU	IR155	—	—	—	—	—	—	—	IR
ICU	IR156	—	—	—	—	—	—	—	IR
ICU	IR157	—	—	—	—	—	—	—	IR
ICU	IR158	—	—	—	—	—	—	—	IR
ICU	IR159	—	—	—	—	—	—	—	IR
ICU	IR160	—	—	—	—	—	—	—	IR
ICU	IR161	—	—	—	—	—	—	—	IR
ICU	IR162	—	—	—	—	—	—	—	IR
ICU	IR165	—	—	—	—	—	—	—	IR
ICU	IR166	—	—	—	—	—	—	—	IR
ICU	IR167	—	—	—	—	—	—	—	IR
ICU	IR168	—	—	—	—	—	—	—	IR
ICU	IR170	—	—	—	—	—	—	—	IR
ICU	IR171	—	—	—	—	—	—	—	IR
ICU	IR174	—	—	—	—	—	—	—	IR
ICU	IR175	—	—	—	—	—	—	—	IR
ICU	IR176	—	—	—	—	—	—	—	IR
ICU	IR177	—	—	—	—	—	—	—	IR
ICU	IR178	—	—	—	—	—	—	—	IR
ICU	IR179	—	—	—	—	—	—	—	IR
ICU	IR180	—	—	—	—	—	—	—	IR
ICU	IR181	—	—	—	—	—	—	—	IR
ICU	IR182	—	—	—	—	—	—	—	IR
ICU	IR183	—	—	—	—	—	—	—	IR
ICU	IR184	—	—	—	—	—	—	—	IR
ICU	IR185	—	—	—	—	—	—	—	IR
ICU	IR198	—	—	—	—	—	—	—	IR
ICU	IR199	—	—	—	—	—	—	—	IR
ICU	IR200	—	—	—	—	—	—	—	IR
ICU	IR201	—	—	—	—	—	—	—	IR
ICU	IR214	—	—	—	—	—	—	—	IR
ICU	IR215	—	—	—	—	—	—	—	IR
ICU	IR216	—	—	—	—	—	—	—	IR

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	IR217	—	—	—	—	—	—	—	IR
ICU	IR218	—	—	—	—	—	—	—	IR
ICU	IR219	—	—	—	—	—	—	—	IR
ICU	IR220	—	—	—	—	—	—	—	IR
ICU	IR221	—	—	—	—	—	—	—	IR
ICU	IR222	—	—	—	—	—	—	—	IR
ICU	IR223	—	—	—	—	—	—	—	IR
ICU	IR224	—	—	—	—	—	—	—	IR
ICU	IR225	—	—	—	—	—	—	—	IR
ICU	IR226	—	—	—	—	—	—	—	IR
ICU	IR227	—	—	—	—	—	—	—	IR
ICU	IR228	—	—	—	—	—	—	—	IR
ICU	IR229	—	—	—	—	—	—	—	IR
ICU	IR230	—	—	—	—	—	—	—	IR
ICU	IR231	—	—	—	—	—	—	—	IR
ICU	IR232	—	—	—	—	—	—	—	IR
ICU	IR233	—	—	—	—	—	—	—	IR
ICU	IR234	—	—	—	—	—	—	—	IR
ICU	IR235	—	—	—	—	—	—	—	IR
ICU	IR236	—	—	—	—	—	—	—	IR
ICU	IR237	—	—	—	—	—	—	—	IR
ICU	IR238	—	—	—	—	—	—	—	IR
ICU	IR239	—	—	—	—	—	—	—	IR
ICU	IR240	—	—	—	—	—	—	—	IR
ICU	IR241	—	—	—	—	—	—	—	IR
ICU	IR246	—	—	—	—	—	—	—	IR
ICU	IR247	—	—	—	—	—	—	—	IR
ICU	IR248	—	—	—	—	—	—	—	IR
ICU	IR249	—	—	—	—	—	—	—	IR
ICU	IR250	—	—	—	—	—	—	—	IR
ICU	IR251	—	—	—	—	—	—	—	IR
ICU	IR252	—	—	—	—	—	—	—	IR
ICU	IR253	—	—	—	—	—	—	—	IR
ICU	ISELR028	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR029	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR030	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR031	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR064	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR065	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR066	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR067	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR068	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR069	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR070	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR071	—	—	—	—	—	—	ISEL[1:0]	

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ICU	ISELR072	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR073	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR074	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR075	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR076	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR077	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR078	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR079	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR098	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR099	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR100	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR101	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR104	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR105	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR106	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR107	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR111	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR112	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR117	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR118	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR122	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR123	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR124	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR125	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR127	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR128	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR133	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR134	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR138	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR139	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR140	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR141	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR145	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR146	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR151	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR152	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR156	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR157	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR158	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR159	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR161	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR162	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR167	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR168	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR174	—	—	—	—	—	—	ISEL[1:0]	

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
ICU	ISELR175	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR177	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR178	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR180	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR181	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR183	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR184	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR198	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR199	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR200	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR201	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR215	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR216	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR219	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR220	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR223	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR224	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR227	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR228	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR231	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR232	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR235	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR236	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR239	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR240	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR247	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR248	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR251	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR252	—	—	—	—	—	—	ISEL[1:0]	
ICU	ISELR253	—	—	—	—	—	—	ISEL[1:0]	
ICU	IER02	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER03	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER08	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER09	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0C	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0D	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0E	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER0F	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER10	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER11	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER12	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER13	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER14	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER15	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER16	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0

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ICU	IER17	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER18	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER19	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1A	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1B	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1C	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1D	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1E	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IER1F	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
ICU	IPR00	—	—	—	—	—	IPR[2:0]		
ICU	IPR01	—	—	—	—	—	IPR[2:0]		
ICU	IPR02	—	—	—	—	—	IPR[2:0]		
ICU	IPR04	—	—	—	—	—	IPR[2:0]		
ICU	IPR05	—	—	—	—	—	IPR[2:0]		
ICU	IPR06	—	—	—	—	—	IPR[2:0]		
ICU	IPR07	—	—	—	—	—	IPR[2:0]		
ICU	IPR20	—	—	—	—	—	IPR[2:0]		
ICU	IPR21	—	—	—	—	—	IPR[2:0]		
ICU	IPR22	—	—	—	—	—	IPR[2:0]		
ICU	IPR23	—	—	—	—	—	IPR[2:0]		
ICU	IPR24	—	—	—	—	—	IPR[2:0]		
ICU	IPR25	—	—	—	—	—	IPR[2:0]		
ICU	IPR26	—	—	—	—	—	IPR[2:0]		
ICU	IPR27	—	—	—	—	—	IPR[2:0]		
ICU	IPR28	—	—	—	—	—	IPR[2:0]		
ICU	IPR29	—	—	—	—	—	IPR[2:0]		
ICU	IPR2A	—	—	—	—	—	IPR[2:0]		
ICU	IPR2B	—	—	—	—	—	IPR[2:0]		
ICU	IPR2C	—	—	—	—	—	IPR[2:0]		
ICU	IPR2D	—	—	—	—	—	IPR[2:0]		
ICU	IPR2E	—	—	—	—	—	IPR[2:0]		
ICU	IPR2F	—	—	—	—	—	IPR[2:0]		
ICU	IPR40	—	—	—	—	—	IPR[2:0]		
ICU	IPR44	—	—	—	—	—	IPR[2:0]		
ICU	IPR45	—	—	—	—	—	IPR[2:0]		
ICU	IPR46	—	—	—	—	—	IPR[2:0]		
ICU	IPR47	—	—	—	—	—	IPR[2:0]		
ICU	IPR4C	—	—	—	—	—	IPR[2:0]		
ICU	IPR4D	—	—	—	—	—	IPR[2:0]		
ICU	IPR4E	—	—	—	—	—	IPR[2:0]		
ICU	IPR4F	—	—	—	—	—	IPR[2:0]		
ICU	IPR50	—	—	—	—	—	IPR[2:0]		
ICU	IPR51	—	—	—	—	—	IPR[2:0]		
ICU	IPR52	—	—	—	—	—	IPR[2:0]		
ICU	IPR53	—	—	—	—	—	IPR[2:0]		

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ICU	IPR54	—	—	—	—	—	IPR[2:0]		
ICU	IPR55	—	—	—	—	—	IPR[2:0]		
ICU	IPR56	—	—	—	—	—	IPR[2:0]		
ICU	IPR57	—	—	—	—	—	IPR[2:0]		
ICU	IPR58	—	—	—	—	—	IPR[2:0]		
ICU	IPR59	—	—	—	—	—	IPR[2:0]		
ICU	IPR5A	—	—	—	—	—	IPR[2:0]		
ICU	IPR5B	—	—	—	—	—	IPR[2:0]		
ICU	IPR5C	—	—	—	—	—	IPR[2:0]		
ICU	IPR5D	—	—	—	—	—	IPR[2:0]		
ICU	IPR5E	—	—	—	—	—	IPR[2:0]		
ICU	IPR5F	—	—	—	—	—	IPR[2:0]		
ICU	IPR60	—	—	—	—	—	IPR[2:0]		
ICU	IPR61	—	—	—	—	—	IPR[2:0]		
ICU	IPR62	—	—	—	—	—	IPR[2:0]		
ICU	IPR63	—	—	—	—	—	IPR[2:0]		
ICU	IPR68	—	—	—	—	—	IPR[2:0]		
ICU	IPR69	—	—	—	—	—	IPR[2:0]		
ICU	IPR6A	—	—	—	—	—	IPR[2:0]		
ICU	IPR6B	—	—	—	—	—	IPR[2:0]		
ICU	IPR70	—	—	—	—	—	IPR[2:0]		
ICU	IPR71	—	—	—	—	—	IPR[2:0]		
ICU	IPR72	—	—	—	—	—	IPR[2:0]		
ICU	IPR73	—	—	—	—	—	IPR[2:0]		
ICU	IPR80	—	—	—	—	—	IPR[2:0]		
ICU	IPR81	—	—	—	—	—	IPR[2:0]		
ICU	IPR82	—	—	—	—	—	IPR[2:0]		
ICU	IPR83	—	—	—	—	—	IPR[2:0]		
ICU	IPR84	—	—	—	—	—	IPR[2:0]		
ICU	IPR85	—	—	—	—	—	IPR[2:0]		
ICU	IPR86	—	—	—	—	—	IPR[2:0]		
ICU	IPR89	—	—	—	—	—	IPR[2:0]		
ICU	IPR8A	—	—	—	—	—	IPR[2:0]		
ICU	IPR8B	—	—	—	—	—	IPR[2:0]		
ICU	IPR8C	—	—	—	—	—	IPR[2:0]		
ICU	IPR8D	—	—	—	—	—	IPR[2:0]		
ICU	IPR8E	—	—	—	—	—	IPR[2:0]		
ICU	IPR8F	—	—	—	—	—	IPR[2:0]		
ICU	FIR	FIEN	—	—	—	—	—	—	—
		FVCT[7:0]							
DTC	DTCCR	—	—	—	RRS	RCHNE	—	—	ERR
DTC	DTCVBR								
						0	0	0	0
		0	0	0	0	0	0	0	0

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DTC	DTCADMOD	—	—	—	—	—	—	—	SHORT
DTC	DTCST	—	—	—	—	—	—	—	DTCST
CMT (unit 0)	CMSTR0	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	STR1	STR0
CMT0	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT0	CMCNT								
CMT0	CMCOR								
CMT1	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT1	CMCNT								
CMT1	CMCOR								
CMT (unit 1)	CMSTR1	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	STR3	STR2
CMT2	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT2	CMCNT								
CMT2	CMCOR								
CMT3	CMCR	—	—	—	—	—	—	—	—
		—	CMIE	—	—	—	—	CKS[1:0]	
CMT3	CMCNT								
CMT3	CMCOR								
WDT	TCSR	—	TMS	TME	—	—	CKS[2:0]		
WDT	WINA								
WDT	TCNT								
WDT	WINB								
WDT	RSTCSR	WOVF	RSTE	—	—	—	—	—	—
AD0	ADDRA								
AD0	ADDRB								
AD0	ADDRC								
AD0	ADDRD								

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AD0	ADCSR	—	ADIE	ADST	—	CH[3:0]			
AD0	ADCR	TRGS[2 0]			—	CKS[1:0]		MODE[1:0]	
AD0	ADDPR	DPSEL	—	—	—	—	—	—	—
AD0	ADSSTR								
AD1	ADDRA								
AD1	ADDRB								
AD1	ADDRC								
AD1	ADDRD								
AD1	ADCSR	—	ADIE	ADST	—	CH[3:0]			
AD1	ADCR	TRGS[2 0]			—	CKS[1:0]		MODE[1:0]	
AD1	ADDPR	DPSEL	—	—	—	—	—	—	—
AD1	ADSSTR								
AD2	ADDRA								
AD2	ADDRB								
AD2	ADDRC								
AD2	ADDRD								
AD2	ADCSR	—	ADIE	ADST	—	CH[3:0]			
AD2	ADCR	TRGS[2 0]			—	CKS[1:0]		MODE[1:0]	
AD2	ADDPR	DPSEL	—	—	—	—	—	—	—
AD2	ADSSTR								
AD3	ADDRA								
AD3	ADDRB								
AD3	ADDRC								
AD3	ADDRD								
AD3	ADCSR	—	ADIE	ADST	—	CH[3:0]			
AD3	ADCR	TRGS[2 0]			—	CKS[1:0]		MODE[1:0]	
AD3	ADDPR	DPSEL	—	—	—	—	—	—	—
AD3	ADSSTR								
D/A	DADR0								
D/A	DADR1								
D/A	DACR	DAOE1	DAOE0	DAE	—	—	—	—	—

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D/A	DADPR	DPSEL	—	—	—	—	—	—	—
TPU (unit 0)	TSTRA	—	—	CST5	CST4	CST3	CST2	CST1	CST0
TPU (unit 0)	TSYRA	—	—	SYNC5	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0
TPU0	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU0	TMDR	ICSELD	ICSELB	BFB	BFA	MD[3:0]			
TPU0	TIORH	IOB[3:0]				IOA[3:0]			
TPU0	TIORL	IOD[3:0]				IOC[3:0]			
TPU0	TIER	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
TPU0	TSR	—	—	—	—	—	—	—	—
TPU0	TCNT								
TPU0	TGRA								
TPU0	TGRB								
TPU0	TGRC								
TPU0	TGRD								
TPU1	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU1	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU1	TIOR	IOB[3:0]				IOA[3:0]			
TPU1	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU1	TSR	TCFD	—	—	—	—	—	—	—
TPU1	TCNT								
TPU1	TGRA								
TPU1	TGRB								
TPU2	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU2	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU2	TIOR	IOB[3:0]				IOA[3:0]			
TPU2	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU2	TSR	TCFD	—	—	—	—	—	—	—
TPU2	TCNT								
TPU2	TGRA								
TPU2	TGRB								
TPU3	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU3	TMDR	ICSELD	ICSELB	BFB	BFA	MD[3:0]			

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TPU3	TIORH	IOB[3:0]				IOA[3:0]			
TPU3	TIORL	IOD[3:0]				IOC[3:0]			
TPU3	TIER	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
TPU3	TSR	—	—	—	—	—	—	—	—
TPU3	TCNT								
TPU3	TGRA								
TPU3	TGRB								
TPU3	TGRC								
TPU3	TGRD								
TPU4	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU4	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU4	TIOR	IOB[3:0]				IOA[3:0]			
TPU4	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU4	TSR	TCFD	—	—	—	—	—	—	—
TPU4	TCNT								
TPU4	TGRA								
TPU4	TGRB								
TPU5	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU5	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU5	TIOR	IOB[3:0]				IOA[3:0]			
TPU5	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU5	TSR	TCFD	—	—	—	—	—	—	—
TPU5	TCNT								
TPU5	TGRA								
TPU5	TGRB								
TPU (unit 1)	TSTRB	—	—	CST5	CST4	CST3	CST2	CST1	CST0
TPU (unit 1)	TSYRB	—	—	SYNC5	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0
TPU6	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU6	TMDR	ICSELD	ICSELB	BFB	BFA	MD[3:0]			
TPU6	TIORH	IOB[3:0]				IOA[3:0]			
TPU6	TIORL	IOD[3:0]				IOC[3:0]			
TPU6	TIER	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA

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TPU6	TSR	—	—	—	—	—	—	—	—
TPU6	TCNT								
TPU6	TGRA								
TPU6	TGRB								
TPU6	TGRC								
TPU6	TGRD								
TPU7	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU7	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU7	TIOR	IOB[3:0]				IOA[3:0]			
TPU7	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU7	TSR	TCFD	—	—	—	—	—	—	—
TPU7	TCNT								
TPU7	TGRA								
TPU7	TGRB								
TPU8	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU8	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU8	TIOR	IOB[3:0]				IOA[3:0]			
TPU8	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU8	TSR	TCFD	—	—	—	—	—	—	—
TPU8	TCNT								
TPU8	TGRA								
TPU8	TGRB								
TPU9	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU9	TMDR	ICSELD	ICSELB	BFB	BFA	MD[3:0]			
TPU9	TIORH	IOB[3:0]				IOA[3:0]			
TPU9	TIORL	IOD[3:0]				IOC[3:0]			
TPU9	TIER	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
TPU9	TSR	—	—	—	—	—	—	—	—
TPU9	TCNT								
TPU9	TGRA								
TPU9	TGRB								

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TPU9	TGRC								
TPU9	TGRD								
TPU10	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU10	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU10	TIOR	IOB[3:0]				IOA[3:0]			
TPU10	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU10	TSR	TCFD	—	—	—	—	—	—	—
TPU10	TCNT								
TPU10	TGRA								
TPU10	TGRB								
TPU11	TCR	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
TPU11	TMDR	—	ICSELB	—	—	MD[3:0]			
TPU11	TIOR	IOB[3:0]				IOA[3:0]			
TPU11	TIER	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
TPU11	TSR	TCFD	—	—	—	—	—	—	—
TPU11	TCNT								
TPU11	TGRA								
TPU11	TGRB								
PPG0	PCR	G3CMS[1:0]		G2CMS[1:0]		G1CMS[1:0]		G0CMS[1:0]	
PPG0	PMR	G3INV	G2INV	G1INV	G0INV	G3NOV	G2NOV	G1NOV	G0NOV
PPG0	NDERH	NDER15	NDER14	NDER13	NDER12	NDER11	NDER10	NDER9	NDER8
PPG0	NDERL	NDER7	NDER6	NDER5	NDER4	NDER3	NDER2	NDER1	NDER0
PPG0	PODRH	POD15	POD14	POD13	POD12	POD11	POD10	POD9	POD8
PPG0	PODRL	POD7	POD6	POD5	POD4	POD3	POD2	POD1	POD0
PPG0	NDRH*1	NDR15	NDR14	NDR13	NDR12	NDR11 (—)	NDR10 (—)	NDR9 (—)	NDR8 (—)
PPG0	NDRL*2	NDR7	NDR6	NDR5	NDR4	NDR3 (—)	NDR2 (—)	NDR1 (—)	NDR0 (—)
PPG0	NDRH*1	—	—	—	—	NDR11	NDR10	NDR9	NDR8
PPG0	NDRL*2	—	—	—	—	NDR3	NDR2	NDR1	NDR0
PPG1	PTRSLR	—	—	—	—	—	—	—	PTRSL
PPG1	PCR	G3CMS[1:0]		G2CMS[1:0]		G1CMS[1:0]		G0CMS[1:0]	
PPG1	PMR	G3INV	G2INV	G1INV	G0INV	G3NOV	G2NOV	G1NOV	G0NOV
PPG1	NDERH	NDER31	NDER30	NDER29	NDER28	NDER27	NDER26	NDER25	NDER24
PPG1	NDERL	NDER23	NDER22	NDER21	NDER20	NDER19	NDER18	NDER17	NDER16
PPG1	PODRH	POD31	POD30	POD29	POD28	POD27	POD26	POD25	POD24

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PPG1	PODRL	POD23	POD22	POD21	POD20	POD19	POD18	POD17	POD16
PPG1	NDRH*3	NDR31	NDR30	NDR29	NDR28	NDR27 (—)	NDR26 (—)	NDR25 (—)	NDR24 (—)
PPG1	NDRL*4	NDR23	NDR22	NDR21	NDR20	NDR19 (—)	NDR18 (—)	NDR17 (—)	NDR16 (—)
PPG1	NDRH*3	—	—	—	—	NDR27	NDR26	NDR25	NDR24
PPG1	NDRL*4	—	—	—	—	NDR19	NDR18	NDR17	NDR16
TMR0	TCR	CMIEB	CMIEA	OVIE	CCLR[1:0]		—	—	—
TMR1	TCR	CMIEB	CMIEA	OVIE	CCLR[1:0]		—	—	—
TMR0	TCSR	—	—	—	ADTE	OSB[1:0]		OSA[1:0]	
TMR1	TCSR	—	—	—	—	OSB[1:0]		OSA[1:0]	
TMR0	TCORA								
TMR1	TCORA								
TMR0	TCORB								
TMR1	TCORB								
TMR0	TCNT								
TMR1	TCNT								
TMR0	TCCR	TMRIS	—	—	CSS[1:0]		CKS[2:0]		
TMR1	TCCR	TMRIS	—	—	CSS[1:0]		CKS[2:0]		
TMR2	TCR	CMIEB	CMIEA	OVIE	CCLR[1:0]		—	—	—
TMR3	TCR	CMIEB	CMIEA	OVIE	CCLR[1:0]		—	—	—
TMR2	TCSR	—	—	—	ADTE	OSB[1:0]		OSA[1:0]	
TMR3	TCSR	—	—	—	—	OSB[1:0]		OSA[1:0]	
TMR2	TCORA								
TMR3	TCORA								
TMR2	TCORB								
TMR3	TCORB								
TMR2	TCNT								
TMR3	TCNT								
TMR2	TCCR	TMRIS	—	—	CSS[1:0]		CKS[2:0]		
TMR3	TCCR	TMRIS	—	—	CSS[1:0]		CKS[2:0]		
SCI0	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI0	BRR								
SCI0	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI0	TDR								
SCI0	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI0	RDR								
SCI0	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI0	SEMR	—	—	—	ABCS	—	—	—	ACS0
SCI1	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI1	BRR								
SCI1	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI1	TDR								

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
SCI1	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI1	RDR								
SCI1	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI1	SEMR	—	—	—	ABCS	—	—	—	ACS0
SCI2	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI2	BRR								
SCI2	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI2	TDR								
SCI2	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI2	RDR								
SCI2	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI2	SEMR	—	—	—	ABCS	—	—	—	ACS0
SCI3	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI3	BRR								
SCI3	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI3	TDR								
SCI3	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI3	RDR								
SCI3	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI3	SEMR	—	—	—	ABCS	—	—	—	ACS0
SCI4	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI4	BRR								
SCI4	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI4	TDR								
SCI4	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI4	RDR								
SCI4	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI4	SEMR	—	—	—	ABCS	—	—	—	ACS0
SCI5	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI5	BRR								
SCI5	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI5	TDR								
SCI5	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI5	RDR								

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SCI5	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI5	SEMR	—	—	—	ABCS	—	—	—	ACS0
SCI6	SMR*5	CM (GM)	CHR (BLK)	PE (PE)	PM (PM)	STOP (BCP[1:0])	—	CKS[1:0] (CKS[1:0])	
SCI6	BRR								
SCI6	SCR*5	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
SCI6	TDR								
SCI6	SSR*5	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	— (—)	— (—)
SCI6	RDR								
SCI6	SCMR	BCP2	—	—	—	SDIR	SINV	—	SMIF
SCI6	SEMR	—	—	—	ABCS	—	—	—	ACS0
CRC	CRCCR	DORCLR	—	—	—	—	LMS	GPS[1:0]	
CRC	CRCDIR								
CRC	CRCDOR								
RIIC0	ICCR1	ICE	IICRST	CLO	SOWP	SCLO	SDAO	SCLI	SDAI
RIIC0	ICCR2	BBSY	MST	TRS	—	SP	RS	ST	—
RIIC0	ICMR1	MTWP	CKS[2:0]			BCWP	BC[2:0]		
RIIC0	ICMR2	DLCS	SDDL[2:0]			—	TMOH	TMOL	TMOS
RIIC0	ICMR3	SMBS	WAIT	RDRFS	ACKWP	ACKBT	ACKBR	NF[1:0]	
RIIC0	ICFER	FMPE	SCLE	NFE	NACKE	SALE	NALE	MALE	TMOE
RIIC0	ICSER	HOAE	—	DIDE	—	GCAE	SAR2E	SAR1E	SAR0E
RIIC0	ICIER	TIE	TEIE	RIE	NAKIE	SPIE	STIE	ALIE	TMOIE
RIIC0	ICSR1	HOA	—	DID	—	GCA	AAS2	AAS1	AAS0
RIIC0	ICSR2	TDRE	TEND	RDRF	NACKF	STOP	START	AL	TMOF
RIIC0	SARL0	SVA[7:1]							SVA0
RIIC0	SARU0	—	—	—	—	—	SVA[9:8]		FS
RIIC0	SARL1	SVA[7:1]							SVA0
RIIC0	SARU1	—	—	—	—	—	SVA[9:8]		FS
RIIC0	SARL2	SVA[7:1]							SVA0
RIIC0	SARU2	—	—	—	—	—	SVA[9:8]		FS
RIIC0	ICBRL	—	—	—	BRL[4:0]				
RIIC0	ICBRH	—	—	—	BRH[4:0]				
RIIC0	ICDRT								
RIIC0	ICDRR								
RIIC1	ICCR1	ICE	IICRST	CLO	SOWP	SCLO	SDAO	SCLI	SDAI
RIIC1	ICCR2	BBSY	MST	TRS	—	SP	RS	ST	—
RIIC1	ICMR1	MTWP	CKS[2:0]			BCWP	BC[2:0]		
RIIC1	ICMR2	DLCS	SDDL[2:0]			—	TMOH	TMOL	TMOS
RIIC1	ICMR3	SMBS	WAIT	RDRFS	ACKWP	ACKBT	ACKBR	NF[1:0]	
RIIC1	ICFER	FMPE	SCLE	NFE	NACKE	SALE	NALE	MALE	TMOE
RIIC1	ICSER	HOAE	—	DIDE	—	GCAE	SAR2E	SAR1E	SAR0E

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
RIIC1	ICIER	TIE	TEIE	RIE	NAKIE	SPIE	STIE	ALIE	TMOIE
RIIC1	ICSR1	HOA	—	DID	—	GCA	AAS2	AAS1	AAS0
RIIC1	ICSR2	TDRE	TEND	RDRF	NACKF	STOP	START	AL	TMOF
RIIC1	SARL0	SVA[7:1]							SVA0
RIIC1	SARU0	—	—	—	—	—	SVA[9:8]		FS
RIIC1	SARL1	SVA[7:1]							SVA0
RIIC1	SARU1	—	—	—	—	—	SVA[9:8]		FS
RIIC1	SARL2	SVA[7:1]							SVA0
RIIC1	SARU2	—	—	—	—	—	SVA[9:8]		FS
RIIC1	ICBRL	—	—	—	BRL[4:0]				
RIIC1	ICBRH	—	—	—	BRH[4:0]				
RIIC1	ICDRT								
RIIC1	ICDRR								
P0	DDR	—	—	B5	B4	B3	B2	B1	B0
P1	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P2	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P3	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P4	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P5	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P6	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P7	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P8	DDR	—	B6	B5	B4	B3	B2	B1	B0
P9	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PA	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PB	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PC	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PD	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PE	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PF	DDR	—	B6	B5	B4	B3	B2	B1	B0
PG	DDR	B7	B6	B5	B4	B3	B2	B1	B0
PH	DDR	B7	B6	B5	B4	B3	B2	B1	B0
P0	DR	—	—	B5	B4	B3	B2	B1	B0
P1	DR	B7	B6	B5	B4	B3	B2	B1	B0
P2	DR	B7	B6	B5	B4	B3	B2	B1	B0
P3	DR	B7	B6	B5	B4	B3	B2	B1	B0
P4	DR	B7	B6	B5	B4	B3	B2	B1	B0
P5	DR	B7	B6	B5	B4	B3	B2	B1	B0
P6	DR	B7	B6	B5	B4	B3	B2	B1	B0
P7	DR	B7	B6	B5	B4	B3	B2	B1	B0
P8	DR	—	B6	B5	B4	B3	B2	B1	B0
P9	DR	B7	B6	B5	B4	B3	B2	B1	B0
PA	DR	B7	B6	B5	B4	B3	B2	B1	B0
PB	DR	B7	B6	B5	B4	B3	B2	B1	B0
PC	DR	B7	B6	B5	B4	B3	B2	B1	B0

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
PD	DR	B7	B6	B5	B4	B3	B2	B1	B0
PE	DR	B7	B6	B5	B4	B3	B2	B1	B0
PF	DR	—	B6	B5	B4	B3	B2	B1	B0
PG	DR	B7	B6	B5	B4	B3	B2	B1	B0
PH	DR	B7	B6	B5	B4	B3	B2	B1	B0
P0	PORT	—	—	B5	B4	B3	B2	B1	B0
P1	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P2	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P3	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P4	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P5	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P6	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P7	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P8	PORT	—	B6	B5	B4	B3	B2	B1	B0
P9	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PA	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PB	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PC	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PD	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PE	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PF	PORT	—	B6	B5	B4	B3	B2	B1	B0
PG	PORT	B7	B6	B5	B4	B3	B2	B1	B0
PH	PORT	B7	B6	B5	B4	B3	B2	B1	B0
P0	ICR	—	—	B5	B4	B3	B2	B1	B0
P1	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P2	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P3	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P4	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P5	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P6	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P7	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P8	ICR	—	B6	B5	B4	B3	B2	B1	B0
P9	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PA	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PB	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PC	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PD	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PE	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PF	ICR	—	B6	B5	B4	B3	B2	B1	B0
PG	ICR	B7	B6	B5	B4	B3	B2	B1	B0
PH	ICR	B7	B6	B5	B4	B3	B2	B1	B0
P2	ODR	B7	B6	B5	B4	B3	B2	B1	B0
PC	ODR	B7	B6	B5	B4	B3	B2	B1	B0
PA	PCR	B7	B6	B5	B4	B3	B2	B1	B0
PB	PCR	B7	B6	B5	B4	B3	B2	B1	B0

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
PC	PCR	B7	B6	B5	B4	B3	B2	B1	B0
PD	PCR	B7	B6	B5	B4	B3	B2	B1	B0
PE	PCR	B7	B6	B5	B4	B3	B2	B1	B0
I/O PORT	PFCR0	CS7E	CS6E	CS5E	CS4E	CS3E	CS2E	CS1E	CS0E
I/O PORT	PFCR1	CS7S[1:0]		CS6S[1:0]		CS5S[1:0]		CS4S[1:0]	
I/O PORT	PFCR2	CS3S	CS2S	—	—	—	—	—	—
I/O PORT	PFCR3	A23E	A22E	A21E	A20E	A19E	A18E	A17E	A16E
I/O PORT	PFCR4	A15E	A14E	A13E	A12E	A11E	A10E	A9E	A8E
I/O PORT	PFCR5	—	WR1BC1E	—	DHE	TCLKS	—	—	—
I/O PORT	PFCR6	TPUMS5	TPUMS4	TPUMS3A	TPUMS3B	TPUMS2	TPUMS1	TPUMS0A	TPUMS0B
I/O PORT	PFCR7	TPUMS11	TPUMS10	TPUMS9A	TPUMS9B	TPUMS8	TPUMS7	TPUMS6A	TPUMS6B
I/O PORT	PFCR8	ITS15	ITS14	ITS13	ITS12	ITS11	ITS10	ITS9	ITS8
I/O PORT	PFCR9	ITS7	ITS6	ITS5	ITS4	ITS3	ITS2	ITS1	ITS0
SYSTEM	DPSBYCR	DPSBY	IOKEEP	RAMCUT2	RAMCUT1	—	—	—	RAMCUT0
SYSTEM	DPSWCR	—	—	WTSTS[5:0]					
SYSTEM	DPSIER	DNMIE	—	—	—	DIRQ3E	DIRQ2E	DIRQ1E	DIRQ0E
SYSTEM	DPSIFR	DNMIF	—	—	—	DIRQ3F	DIRQ2F	DIRQ1F	DIRQ0F
SYSTEM	DPSIEGR	DNMIEG	—	—	—	DIRQ3EG	DIRQ2EG	DIRQ1EG	DIRQ0EG
SYSTEM	RSTSR	DPSRSTF	—	—	—	—	—	—	—
FLASH	FWEPROR	—	—	—	—	—	—	FLWE[1:0]	
SYSTEM	DPSBKR0	BKUP07	BKUP06	BKUP05	BKUP04	BKUP03	BKUP02	BKUP01	BKUP00
SYSTEM	DPSBKR1	BKUP17	BKUP16	BKUP15	BKUP14	BKUP13	BKUP12	BKUP11	BKUP10
SYSTEM	DPSBKR2	BKUP27	BKUP26	BKUP25	BKUP24	BKUP23	BKUP22	BKUP21	BKUP20
SYSTEM	DPSBKR3	BKUP37	BKUP36	BKUP35	BKUP34	BKUP33	BKUP32	BKUP31	BKUP30
SYSTEM	DPSBKR4	BKUP47	BKUP46	BKUP45	BKUP44	BKUP43	BKUP42	BKUP41	BKUP40
SYSTEM	DPSBKR5	BKUP57	BKUP56	BKUP55	BKUP54	BKUP53	BKUP52	BKUP51	BKUP50
SYSTEM	DPSBKR6	BKUP67	BKUP66	BKUP65	BKUP64	BKUP63	BKUP62	BKUP61	BKUP60
SYSTEM	DPSBKR7	BKUP77	BKUP76	BKUP75	BKUP74	BKUP73	BKUP72	BKUP71	BKUP70
SYSTEM	DPSBKR8	BKUP87	BKUP86	BKUP85	BKUP84	BKUP83	BKUP82	BKUP81	BKUP80
SYSTEM	DPSBKR9	BKUP97	BKUP96	BKUP95	BKUP94	BKUP93	BKUP92	BKUP91	BKUP90
SYSTEM	DPSBKR10	BKUP107	BKUP106	BKUP105	BKUP104	BKUP103	BKUP102	BKUP101	BKUP100
SYSTEM	DPSBKR11	BKUP117	BKUP116	BKUP115	BKUP114	BKUP113	BKUP112	BKUP111	BKUP110
SYSTEM	DPSBKR12	BKUP127	BKUP126	BKUP125	BKUP124	BKUP123	BKUP122	BKUP121	BKUP120
SYSTEM	DPSBKR13	BKUP137	BKUP136	BKUP135	BKUP134	BKUP133	BKUP132	BKUP131	BKUP130
SYSTEM	DPSBKR14	BKUP147	BKUP146	BKUP145	BKUP144	BKUP143	BKUP142	BKUP141	BKUP140
SYSTEM	DPSBKR15	BKUP157	BKUP156	BKUP155	BKUP154	BKUP153	BKUP152	BKUP151	BKUP150
SYSTEM	DPSBKR16	BKUP167	BKUP166	BKUP165	BKUP164	BKUP163	BKUP162	BKUP161	BKUP160
SYSTEM	DPSBKR17	BKUP177	BKUP176	BKUP175	BKUP174	BKUP173	BKUP172	BKUP171	BKUP170
SYSTEM	DPSBKR18	BKUP187	BKUP186	BKUP185	BKUP184	BKUP183	BKUP182	BKUP181	BKUP180
SYSTEM	DPSBKR19	BKUP197	BKUP196	BKUP195	BKUP194	BKUP193	BKUP192	BKUP191	BKUP190
SYSTEM	DPSBKR20	BKUP207	BKUP206	BKUP205	BKUP204	BKUP203	BKUP202	BKUP201	BKUP200
SYSTEM	DPSBKR21	BKUP217	BKUP216	BKUP215	BKUP214	BKUP213	BKUP212	BKUP211	BKUP210
SYSTEM	DPSBKR22	BKUP227	BKUP226	BKUP225	BKUP224	BKUP223	BKUP222	BKUP221	BKUP220
SYSTEM	DPSBKR23	BKUP237	BKUP236	BKUP235	BKUP234	BKUP233	BKUP232	BKUP231	BKUP230
SYSTEM	DPSBKR24	BKUP247	BKUP246	BKUP245	BKUP244	BKUP243	BKUP242	BKUP241	BKUP240

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
SYSTEM	DPSBKR25	BKUP257	BKUP256	BKUP255	BKUP254	BKUP253	BKUP252	BKUP251	BKUP250
SYSTEM	DPSBKR26	BKUP267	BKUP266	BKUP265	BKUP264	BKUP263	BKUP262	BKUP261	BKUP260
SYSTEM	DPSBKR27	BKUP277	BKUP276	BKUP275	BKUP274	BKUP273	BKUP272	BKUP271	BKUP270
SYSTEM	DPSBKR28	BKUP287	BKUP286	BKUP285	BKUP284	BKUP283	BKUP282	BKUP281	BKUP280
SYSTEM	DPSBKR29	BKUP297	BKUP296	BKUP295	BKUP294	BKUP293	BKUP292	BKUP291	BKUP290
SYSTEM	DPSBKR30	BKUP307	BKUP306	BKUP305	BKUP304	BKUP303	BKUP302	BKUP301	BKUP300
SYSTEM	DPSBKR31	BKUP317	BKUP316	BKUP315	BKUP314	BKUP313	BKUP312	BKUP311	BKUP310
ICU	IRQER0	—	—	—	—	—	—	—	IRQEN
ICU	IRQER1	—	—	—	—	—	—	—	IRQEN
ICU	IRQER2	—	—	—	—	—	—	—	IRQEN
ICU	IRQER3	—	—	—	—	—	—	—	IRQEN
ICU	IRQER4	—	—	—	—	—	—	—	IRQEN
ICU	IRQER5	—	—	—	—	—	—	—	IRQEN
ICU	IRQER6	—	—	—	—	—	—	—	IRQEN
ICU	IRQER7	—	—	—	—	—	—	—	IRQEN
ICU	IRQER8	—	—	—	—	—	—	—	IRQEN
ICU	IRQER9	—	—	—	—	—	—	—	IRQEN
ICU	IRQER10	—	—	—	—	—	—	—	IRQEN
ICU	IRQER11	—	—	—	—	—	—	—	IRQEN
ICU	IRQER12	—	—	—	—	—	—	—	IRQEN
ICU	IRQER13	—	—	—	—	—	—	—	IRQEN
ICU	IRQER14	—	—	—	—	—	—	—	IRQEN
ICU	IRQER15	—	—	—	—	—	—	—	IRQEN
ICU	IRQCR0	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR1	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR2	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR3	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR4	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR5	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR6	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR7	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR8	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR9	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR10	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR11	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR12	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR13	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR14	—	—	—	—	IRQMD[1:0]		—	—
ICU	IRQCR15	—	—	—	—	IRQMD[1:0]		—	—
ICU	SSIER	SSI15	SSI14	SSI13	SSI12	SSI11	SSI10	SSI9	SSI8
		SSI7	SSI6	SSI5	SSI4	SSI3	SSI2	SSI1	SSI0
ICU	NMIER	—	—	—	—	—	—	—	NMIEN
ICU	NMICR	—	—	—	—	NMIMD	—	—	—
ICU	NMISR	—	—	—	—	—	—	—	NMIST
ICU	NMICLR	—	—	—	—	—	—	—	NMICLR

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
FLASH	FMODR	—	—	—	FRDMD	—	—	—	—
FLASH	FASTAT	ROMAE	—	—	CMDLK	DFLAE	—	DFLRPE	DFLWPE
FLASH	FAEINT	ROMAEIE	—	—	CMDLKIE	DFLAEIE	—	DFLRPEIE	DFLWPEIE
FLASH	FRDYIE	—	—	—	—	—	—	—	FRDYIE
FLASH	DFLRE	KEY[7:0]							
		—	—	—	—	DBRE3	DBRE2	DBRE1	DBRE0
FLASH	DFLWE	KEY[7:0]							
		—	—	—	—	DBWE3	DBWE2	DBWE1	DBWE0

Module Abbreviation	Register Abbreviation	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
FLASH	FCURAME	KEY[7:0]							
		—	—	—	—	—	—	—	FCRME
FLASH	FSTATR0	FRDY	ILGLERR	ERSERR	PRGERR	SUSRDY	—	ERSSPD	PRGSPD
FLASH	FSTATR1	FCUERR	—	—	FLOCKST	—	—	—	—
FLASH	FENTRYR	FEKEY[7:0]							
		FENTRYD	—	—	—	—	—	FENTRY1	FENTRY0
FLASH	FPROTR	FPKEY[7:0]							
		—	—	—	—	—	—	—	FPROTCN
FLASH	FRESETR	FRKEY[7:0]							
		—	—	—	—	—	—	—	FRESET
FLASH	FCMDR	CMDR[7:0]							
		PCMDR[7 0]							
FLASH	FCPSR	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	ESUSPMD
FLASH	DFLBCCNT	—	—	—	BCADR[9:0]				
		BCADR[9:0]					—	—	BCSIZE
FLASH	FPESTAT	—	—	—	—	—	—	—	—
		PEERRST[7:0]							
FLASH	DFLBCSTAT	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	BCST
FLASH	PCKAR	—	—	—	—	—	—	—	—
		PCKA[7:0]							

Notes:
1. When the same output trigger is specified for pulse output groups 2 and 3 by the PPG0.PCR setting, the PPG0.NDRH address is 000881ECh. When different output triggers are specified, the PPG0.NDRH addresses for pulse output groups 2 and 3 are 000881EEh and 000881ECh, respectively.
2. When the same output trigger is specified for pulse output groups 0 and 1 by the PPG0.PCR setting, the PPG0.NDRL address is 000881EDh. When different output triggers are specified, the PPG0.NDRL addresses for pulse output groups 0 and 1 are 000881EFh and 000881EDh, respectively.
3. When the same output trigger is specified for pulse output groups 6 and 7 by the PPG1.PCR setting, the PPG1.NDRH address is 000881FCh. When different output triggers are specified, the PPG1.NDRH addresses for pulse output groups 6 and 7 are 000881FEh and 000881FCh, respectively.
4. When the same output trigger is specified for pulse output groups 4 and 5 by the PPG1.PCR setting, the PPG1.NDRL address is 000881FDh. When different output triggers are specified, the PPG1.NDRL addresses for pulse output groups 4 and 5 are 000881FFh and 000881FDh, respectively.
5. For certain bits, functions differ according to whether the mode is serial communications or smart card interface.

6. Resets

6.1 Overview

There are three types of reset: pin reset, deep software standby reset, and watchdog timer reset. Table 6.1 lists the reset names and sources.

Table 6.1 Reset Names and Sources

Reset Name	Source
Pin reset	The RES# pin input voltage is driven low.
Deep software standby reset	Deep software standby mode is canceled by an interrupt.
Watchdog timer reset	The watchdog timer overflows.

The internal state and pins of the LSI are initialized by a reset. Figure 6.1 shows the targets to be initialized by each reset.

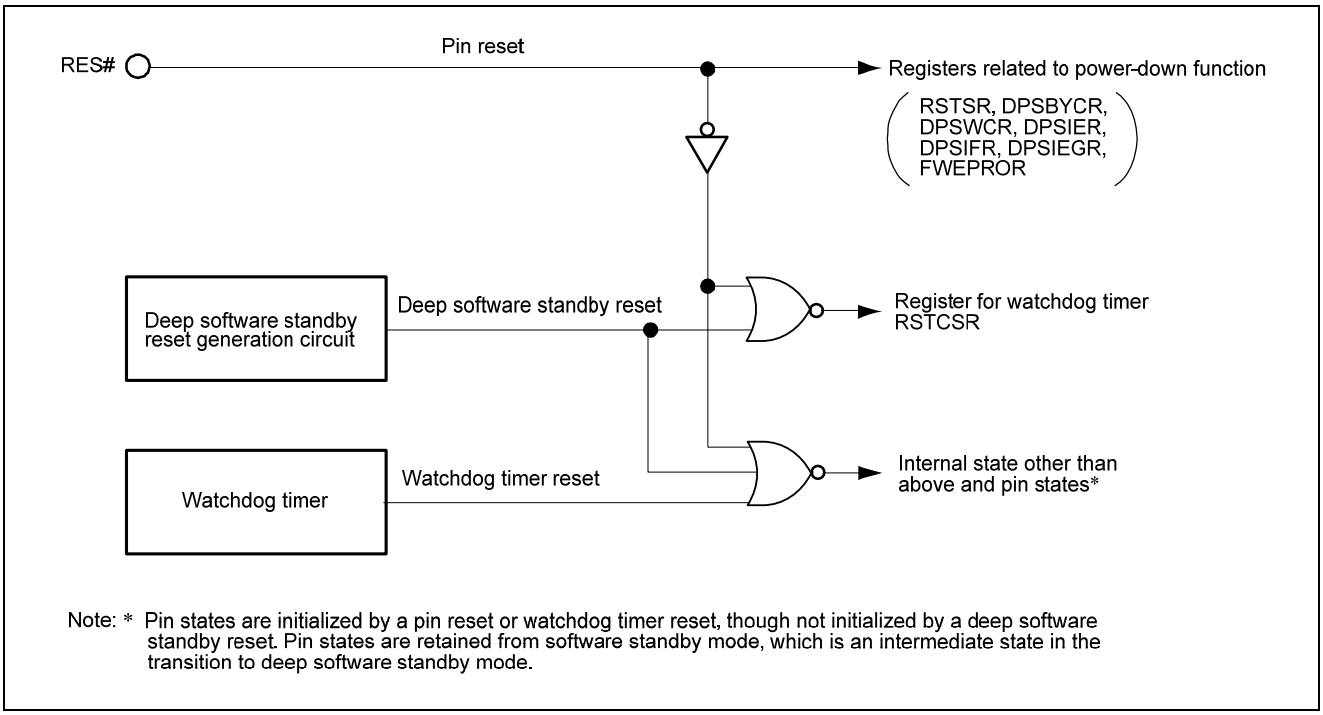


Figure 6.1 Block Diagram of Reset Circuit

Table 6.2 Targets to be Initialized by Each Reset Type

	Reset Type		
Reset Target	**Pin Reset**	**Deep Software Standby Reset**	**Watchdog Timer Reset**
Registers related to the power-down function (RSTSR, DPSBYCR, DPSWCR, DPSIER, DPSIFR, DPSIEGR, FWEPROR)	Reset	—	—
Register for the watchdog timer RSTCSR	Reset	Reset	—
Registers other than above and internal state	Reset	Reset	Reset
Pin states	Reset	—	Reset

When a reset is released, the reset exception handling is started. For the reset exception handling, see section 9, Exceptions.

Table 6.3 shows the pin related to reset.

Table 6.3 Pin Configuration

Pin Name	I/O	Function
RES#	Input	Reset pin

6.2 Register Descriptions

Table 6.4 lists registers related to reset.

Table 6.4 Registers Related to Reset

Register Name	Symbol	Value after Reset	Address	Access Size
Reset status register	RSTSR	00h	0008 C285h	8
Reset control/status register	RSTCSR	1Fh	0008 802Bh	8

6.2.1 Reset Status Register (RSTSR)

Address: 0008 C285h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSRSTF	–	–	–	–	–	–	–
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DPSRSTF	Deep Software Standby Reset Flag	0: An external interrupt source to cancel the deep software standby reset is not generated 1: An external interrupt source to cancel the deep software standby reset is generated	R/(W)*

Note: * Only 0 can be written to this bit.

RSTSR indicates a source for generating an internal reset.

DPSRSTF Flag (Deep Software Standby Reset Flag)

The DPSRSTF flag indicates that deep software standby mode is canceled by an external interrupt source specified with the deep standby interrupt enable register (DPSIER) or the deep standby interrupt flag register (DPSIFR) and an internal reset is generated.

The DPSRSTF flag is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that is used to cancel deep software standby mode.

[Setting condition]

- When deep software standby mode is canceled by an external interrupt source

[Clearing condition]

- When this bit is read as 1 and then written by 0

6.2.2 Reset Control/Status Register (RSTCSR)

Address: 0008 802Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	WOVF	RSTE	–	–	–	–	–	–
Value after reset:	0	0	0	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b5	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6	RSTE	Reset Enable	0: The LSI is not reset internally when TCNT overflows in watchdog timer mode. (TCNT and TCSR of the WDT are reset.) 1: The LSI is internally reset when TCNT overflows in watchdog timer mode.	R/W
b7	WOVF	Watchdog Timer Overflow Flag	0: TCNT has not overflowed in watchdog timer mode. 1: TCNT has overflowed in watchdog timer mode.	R/(W)*

Note: * Only 0 can be written to this bit.

RSTCSR controls the generation of the internal reset signal when TCNT overflows, and selects the type of internal reset signal.
RSTCSR is initialized to 1Fh by a reset signal from the RES# pin or a deep software standby reset, but not by the WDT internal reset signal caused by a WDT overflow.
To read this register, use 8-bit access.
To write to this register, write data in WINB in 16 bits.
For details, see section 19.5.1, Notes on Register Access.

RSTE Bit (Reset Enable)

Selects whether or not this LSI is internally reset when TCNT overflows in watchdog timer mode.

WOVF Flag (Watchdog Timer Overflow)

Indicates that TCNT overflows in watchdog timer mode. This bit cannot be set to 1 in interval timer mode.

[Setting condition]

- When TCNT overflows (changed form FFh to 00h) in watchdog timer mode

[Clearing condition]

- Reading RSTCSR when WOVF = 1, and then writing 0 to WOVF

6.3 Operation

6.3.1 Pin Reset

This is a reset generated by the RES# pin.

When the RES# pin is driven low, all the processing in progress is terminated and this LSI enters a reset state.

To reset this LSI without fail, the specified oscillation settling time should be observed at power-on and then the RES# pin should be held low. While this LSI is working, the RES# pin should be held low while observing the specified reset pulse width. For details, see section 28, Electrical Characteristics.

6.3.2 Deep Software Standby Reset

This is an internal reset generated when deep software standby mode is canceled by an interrupt.

When deep software standby mode is canceled, clock oscillation starts and a deep software standby reset is generated at the same time. After the time specified with the deep software standby wait time bits (WTSTS[5:0] in DPSWCR) has passed, the deep software standby reset is released.

For details on the deep software standby reset, see section 8, Low Power Consumption.

6.3.3 Watchdog Timer Reset

This is an internal reset generated by the watchdog timer.

While the RSTE bit in RSTCSR is set to 1, a watchdog timer reset is generated by a watchdog timer overflow. After a predetermined time has passed, the watchdog timer reset is released.

For details on the watchdog timer reset, see section 19, Watchdog Timer (WDT).

6.4 Determining Reset Generation Source

Reading RSTCSR and RSTSR allows the LSI to determine which reset was used to execute the reset exception handling. Figure 6.2 shows an example of flow to identify a reset generation source.

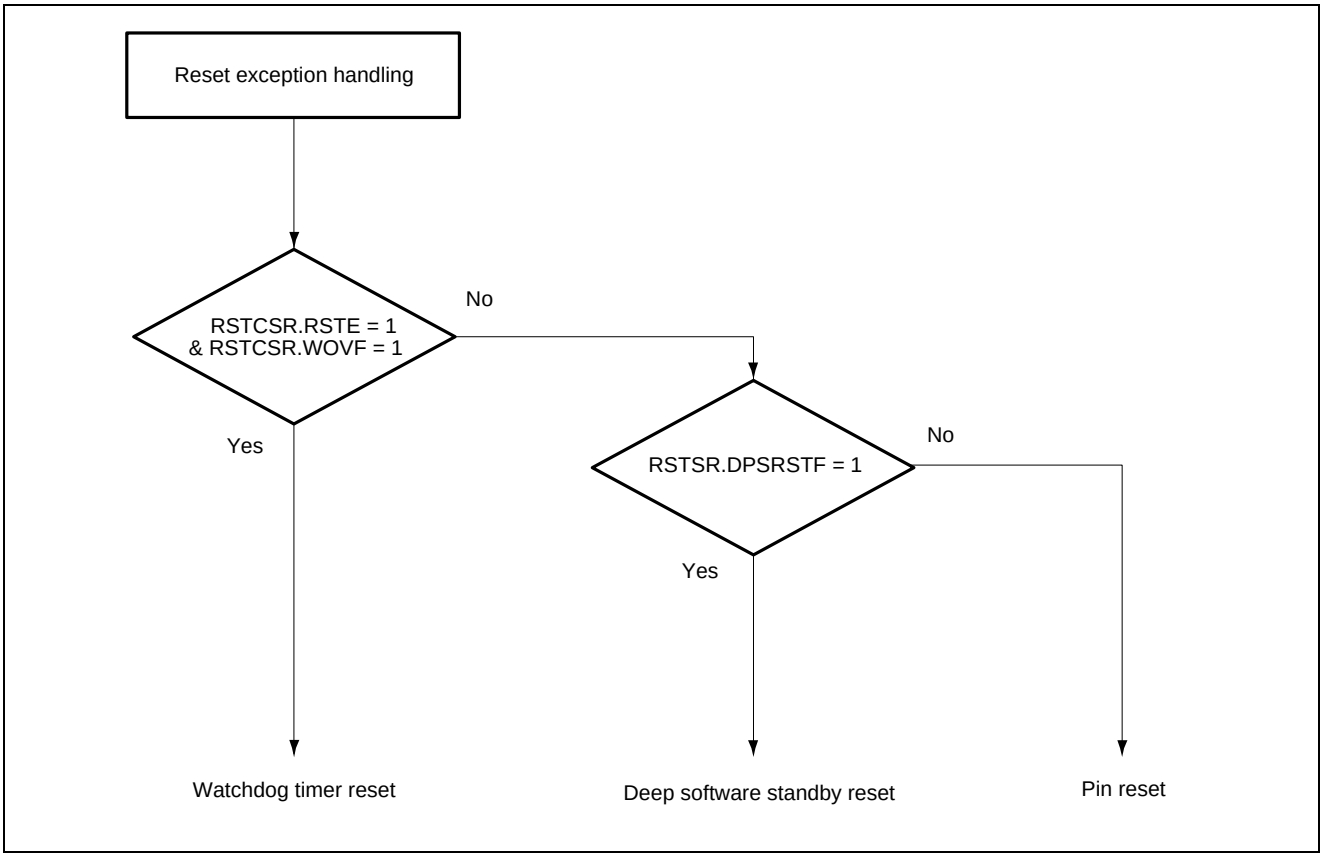


Figure 6.2 Example of Flow to Identify a Reset Generation Source

6.5 Usage Notes

6.5.1 Notes on Design of Board

The XTAL pin and the reset pin are crossly arranged on the RX610 Group. Therefore, to avoid the reference from the clock signal, the reset signal should be guarded by GND.

7. Clock Generation Circuit

7.1 Overview

The RX610 Group has a clock generation circuit that generates the system clock (ICLK), peripheral module clock (PCLK), and external bus clock (BCLK).

The clock generation circuit consists of a main clock oscillator, phase-locked loop (PLL) circuit, frequency divider, and selector circuit.

Table 7.1 lists the specifications of the clock generation circuit. Figure 7.1 shows a block diagram of the clock generation circuit.

Table 7.1 Specifications of Clock Generation Circuit

Item	Specification
Use	• Generates the system clock (ICLK) to be supplied to the CPU, DTC, DMAC, ROM, and RAM. • Generates the peripheral module clock (PCLK) to be supplied to peripheral modules. • Generates the external bus clock (BCLK) to be supplied to the external bus.
Input clock (EXTAL) frequency	8 to 14 MHz
Selection of ICLK, PCLK, or BCLK	The ICLK, PCLK, or BCLK is selectable independently from EXTAL ×8, ×4, ×2, and ×1.
Operating frequency	ICLK: 8 to 100 MHz PCLK: 8 to 50 MHz BCLK: 8 to 25 MHz Restrictions for setting clock frequencies: ICLK ≥ PCLK and ICLK ≥ BCLK
Connectable resonator or additional circuit	Crystal resonator
Pins for connection to the resonator or additional circuit	EXTAL and XTAL
BCLK output control function	BCLK output or high-level output is selectable.

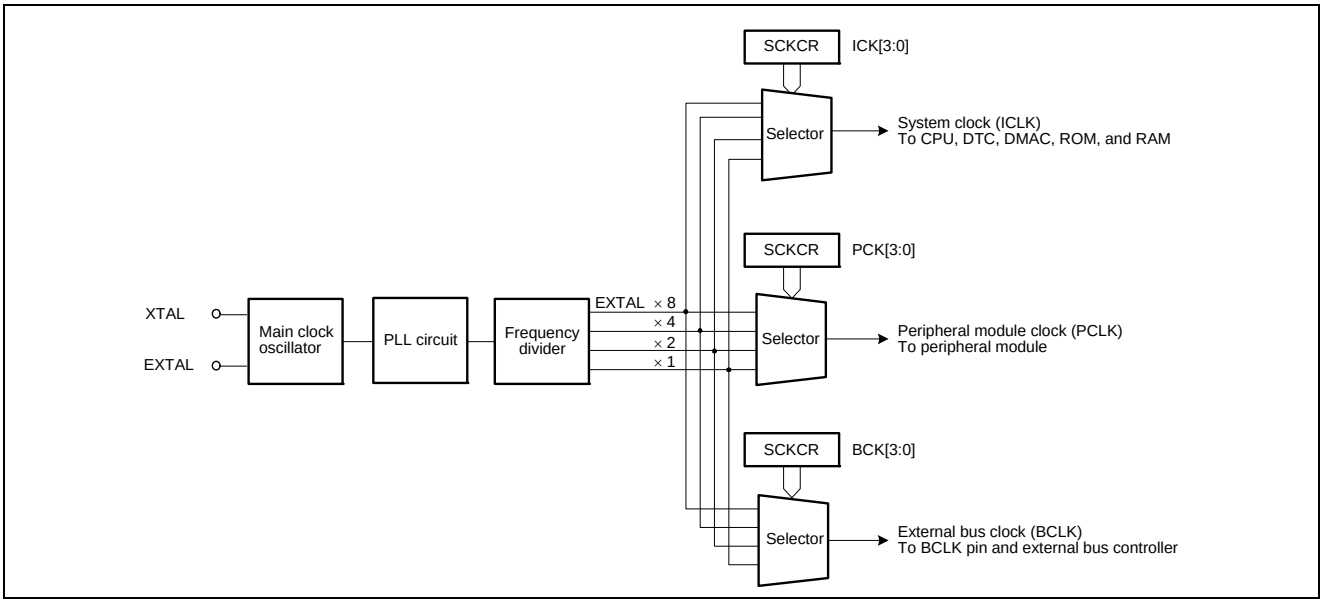


Figure 7.1 Block Diagram of Clock Generation Circuit

Table 7.2 lists the input/output pins of the clock generation circuit.

Table 7.2 Pin Configuration

Pin Name	I/O	Description
XTAL	Input	These pins are used to connect a crystal resonator. The EXTAL pin can also be used to input an external clock. For details, see section 7.3.2, External Clock Input.
EXTAL	Input	
BCLK	Output	This pin is used to supply external devices with the external bus clock (BCLK).

7.2 Register Descriptions

Table 7.3 shows the register of the clock generation circuit.

Table 7.3 Register of Clock Generation Circuit

Register Name	Symbol	Value after Reset	Address	Access Size
System clock control register	SCKCR	0202 0200h	0008 0020h	32

7.2.1 System Clock Control Register (SCKCR)

Address: 0008 0020h

	b31	b30	b29	b28	b27	b26	b25	b24
	–	–	–	–	ICK[3:0]			
Value after reset:	0	0	0	0	0	0	1	0

	b23	b22	b21	b20	b19	b18	b17	b16
	PSTOP1	–	–	–	BCK[3:0]			
Value after reset:	0	0	0	0	0	0	1	0

	b15	b14	b13	b12	b11	b10	b9	b8
	–	–	–	–	PCK[3:0]			
Value after reset:	0	0	0	0	0	0	1	0

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	–
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b11 to b8	PCK[3:0]*1	Peripheral Module Clock (PCLK) Select	b11 b8 0 0 0 0: ×8 0 0 0 1: ×4 0 0 1 0: ×2 0 0 1 1: ×1 Settings other than above are prohibited.	R/W
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b19 to b16	BCK[3:0]*1	External Bus Clock (BCLK) Select	b19 b16 0 0 0 0: ×8 0 0 0 1: ×4 0 0 1 0: ×2 0 0 1 1: ×1 Settings other than above are prohibited.	R/W
b22 to b20	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b23	PSTOP1	BCLK Output Stop	0: BCLK output 1: Fixed high	R/W
b27 to b24	ICK[3:0]*2	System Clock (ICLK) Select	b27 b24 0 0 0 0: ×8 0 0 0 1: ×4 0 0 1 0: ×2 0 0 1 1: ×1 Settings other than above are prohibited.	R/W
b31 to b28	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Notes: 1. Do not set a frequency higher than the system clock (ICLK). If such a frequency is set, the clock frequency will be the same as the ICLK.

2. Do not set a frequency lower than the peripheral module clock (PCLK) and external bus clock (BCLK). If such a frequency is set, the frequency of the PCLK and BCLK will change to the system clock (ICLK) frequency.

The SCKCR register is used to control the BCLK output and select the frequencies of the system clock (ICLK), peripheral module clock (PCLK), and external bus clock (BCLK).

PCK[3:0] Bits (Peripheral Module Clock (PCLK) Select)

These bits select the PCLK frequency.

The value of these bits indicates a multiplication factor of the input clock (EXTAL).

BCK[3:0] Bits (External Bus Clock (BCLK) Select)

These bits select the BCLK frequency.

The value of these bits indicates a multiplication factor of the input clock (EXTAL).

PSTOP1 Bit (BCLK Output Stop)

This bit controls the BCLK output from P53.

ICK[3:0] Bits (System Clock (ICLK) Select)

These bits select the frequency of the CPU, DMAC, DTC, and system clock (ICLK).

The value of these bits indicates a multiplication factor of the input clock (EXTAL).

7.3 Main Clock Oscillator

Clock pulses can be supplied by connecting a crystal resonator or by inputting an external clock.

7.3.1 Connecting a Crystal Resonator

Figure 7.2 shows an example of connecting a crystal resonator. Table 7.4 shows reference values of the damping resistance (Rd). An AT-cut parallel-resonance type should be used for the crystal resonator.

When supplying the clock from the crystal resonator, the frequency of the resonator should be in the range of 8 to 14 MHz.

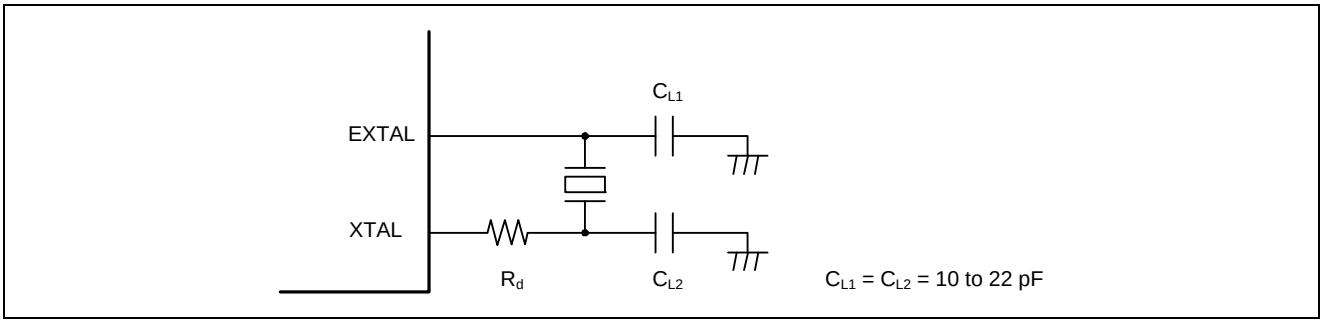


Figure 7.2 Example of Crystal Resonator Connection

Table 7.4 Damping Resistance (Reference Values)

Frequency (MHz)	8	10	12	14
Rd (Ω)	200	100	0	0

Figure 7.3 shows an equivalent circuit of the crystal resonator. Use a crystal resonator that has the characteristics shown in table 7.5.

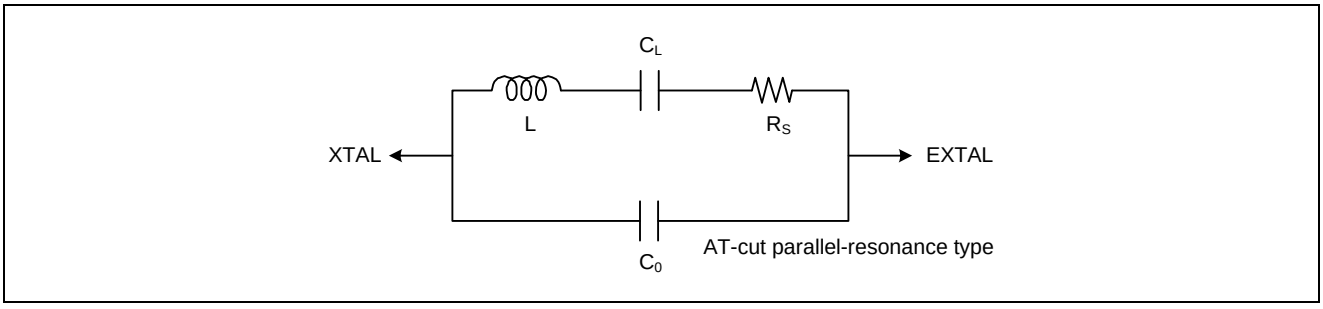


Figure 7.3 Equivalent Circuit of Crystal Resonator

Table 7.5 Crystal Resonator Characteristics (Reference Values)

Frequency (MHz)	8	10	12	14
Rs max (Ω)	80	70	60	50
C0 max (pF)	7			

7.3.2 External Clock Input

Figure 7.4 shows examples of external clock input. To leave the XTAL pin open, make the parasitic capacitance less than 10 pF. When the counter-phase clock is input to the XTAL pin, hold the external clock in high level during standby mode.

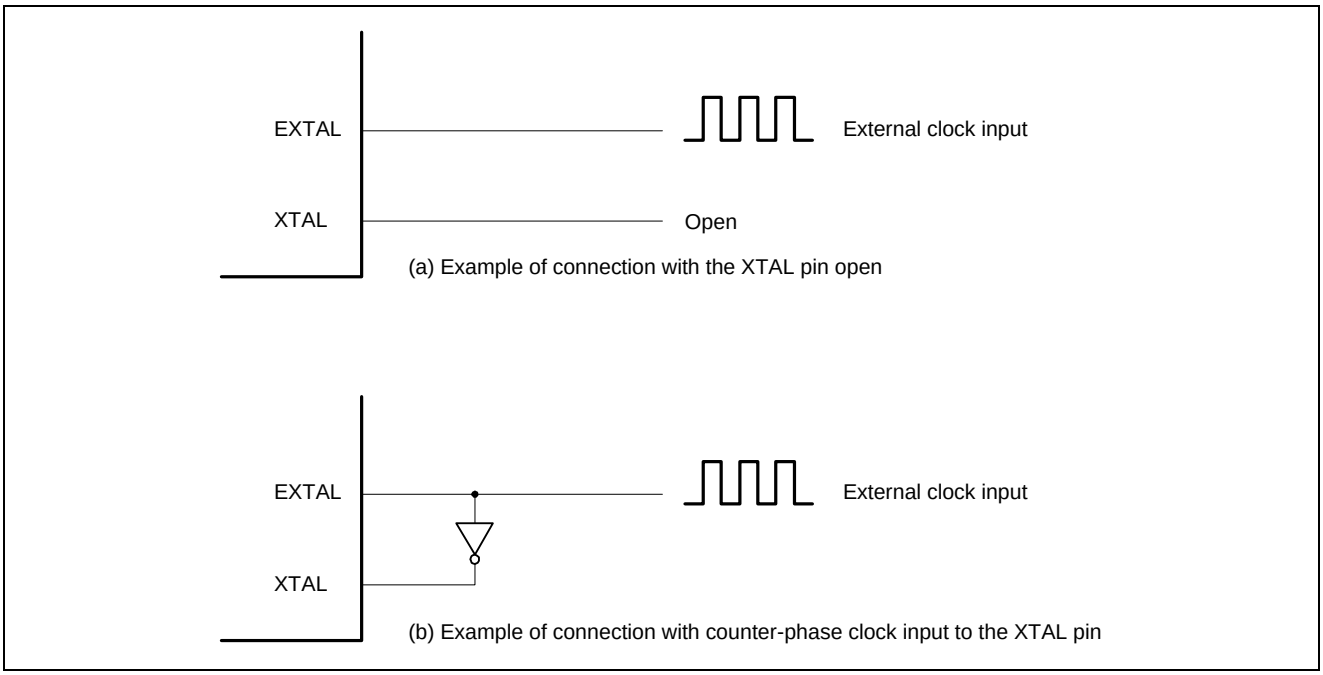


Figure 7.4 Examples of External Clock Input

7.4 PLL Circuit

The PLL circuit has a function to multiply the frequency from the oscillator by a factor of up to 8.

7.5 Frequency Divider

The frequency divider divides the PLL clock to generate 1/2, 1/4, or 1/8 clock. After the ICK[3:0], PCK[3:0], and BCK[3:0] bits in SCKCR are updated, this LSI operates with the updated frequencies.

7.6 Internal Clock

The internal clock is generated by multiplying the external input clock (EXTAL) by 8 with the PLL circuit, and then by dividing the multiplied clock by 1, 2, 4, or 8 with the frequency divider.

There are following three types of internal clock.

- Operating clock of the CPU, DMAC, and DTC: System clock (ICLK)
- Operating clock of peripheral modules: Peripheral module clock (PCLK)
- Clock for the external bus controller and external pin output: External bus clock (BCLK)

The frequencies are set by bits ICK[3:0], PCK[3:0], and BCK[3:0] in SCKCR, respectively.

7.6.1 System Clock (ICLK)

The system clock (ICLK) is used as the operating clock of the CPU, DMAC, DTC, ROM, and RAM.

The ICLK frequency is specified by the ICK[3:0] bits in SCKCR.

A frequency lower than the peripheral module clock (PCLK) and external bus clock (BCLK) should not be set for the ICLK. If such a frequency is set, the frequency of ICLS will be the same as that of the PCLK or BCLK.

7.6.2 Peripheral Module Clock (PCLK)

The peripheral module clock (PCLK) is the operating clock for peripheral modules.

The PCLK frequency is specified by the PCK[3:0] bits in SCKCR.

A frequency higher than the system clock (ICLK) should not be set for the PCLK. If such a frequency is set, the clock frequency will be the same as the ICLK.

7.6.3 External Bus Clock (BCLK)

The external bus clock (BCLK) is output on an external pin as the clock signal for the external connection bus.

Setting the PSTOP1 bit in SCKCR to 0 and the B3 bit in DDR for port 5 (P5.DDR) to 1 selects output of the BCLK on the BCLK output pin. However, note that the order of setting for these bits requires care. Specifically, change the value of the B3 bit in P5.DDR while the value of the PSTOP1 bit in SCKCR is 1.

The BCLK frequency is specified by the BCK[3:0] bits in SCKCR.

A frequency higher than the system clock (ICLK) should not be set for the BCLK. If such a frequency is set, the clock frequency will be the same as the ICLK.

7.7 Usage Notes

7.7.1 Notes on the Clock Generation Circuit

1. The frequencies of the system clock (ICLK), peripheral module clock (PCLK), and external bus clock (BCLK) supplied to each module are selected according to the setting of SCKCR. Select each frequency that is within the operation guaranteed range of clock cycle time (tcyc) specified in AC characteristics of electrical characteristics. Each frequency should meet the following:

   ICLK = 8 to 100 MHz, PCLK = 8 to 50 MHz, BCLK = 8 to 25 MHz

   All peripheral modules (except for the DMAC and DTC) operate on the PCLK. Note therefore that the operating speed of modules such as the timer and SCI varies before and after the frequency is changed.
   In addition, the waiting time for canceling software standby mode varies with the frequency change. For details, see section 8.5.3.3, Setting Oscillation Settling Time after Software Standby Mode is Canceled.

2. The relationship among the system clock (ICLK), peripheral module clock (PCLK), and external bus clock (BCLK) is ICLK ≥ PCLK and ICLK ≥ BCLK, and the ICLK has the highest priority. For this reason, if a setting that does not meet these conditions is made, the PCLK and BCLK may have the clock frequency set by the ICK[3:0] bits in SCKCR regardless of the settings of the PCK[3:0] and BCK[3:0] bits in SCKCR.

3. Note that when changing a clock frequency, it may change during an access to the external bus.

4. After writing to the SCKCR, further writing to the same register before completion of the change in frequency is ignored. In the case of continued writing to the SCKCR, confirm that values read from the SCKCR are actually the most recently written values.

5. After writing to the SCKCR, transitions to software standby mode are prohibited until completion of the change in frequency. Subsequent operation is not guaranteed if a transition to software standby mode is attempted while the frequency is being changed. The interval between writing to the SCKCR and issuing of the WAIT instruction must take up at least 11 cycles of the system clock.

7.7.2 Notes on Resonator

Since various resonator characteristics relate closely to the user's board design, adequate evaluation is required on the user side before use, referencing the resonator connection example shown in this section. The circuit constants for the resonator depend on the resonator to be used and the stray capacitance of the mounting circuit. Therefore, the circuit constants should be determined in full consultation with the resonator manufacturer. The voltage to be applied between the resonator pins must be within the absolute maximum rating.

7.7.3 Notes on Board Design

When using a crystal resonator, place the resonator and its capacitors as close to the XTAL and EXTAL pins as possible. Other signal lines should be routed away from the oscillation circuit as shown in figure 7.5 to prevent induction from interfering with correct oscillation.

The XTAL pin and the reset pin are crossly arranged on the RX610 Group. Therefore, to avoid the reference from the clock signal, the reset signal should be guarded by GND.

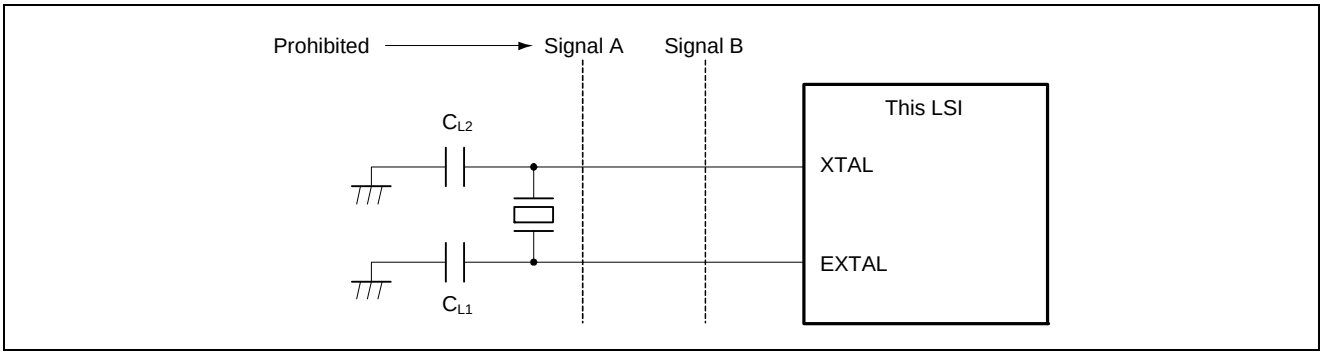


Figure 7.5 Notes on Board Design for Oscillation Circuit

Figure 7.6 shows a recommended external circuit for the PLL circuit. Separate pins PLLVcc, PLLVss, Vcc, and Vss from the board power supply source, and be sure to insert bypass capacitors CPB and CB close to the pins.

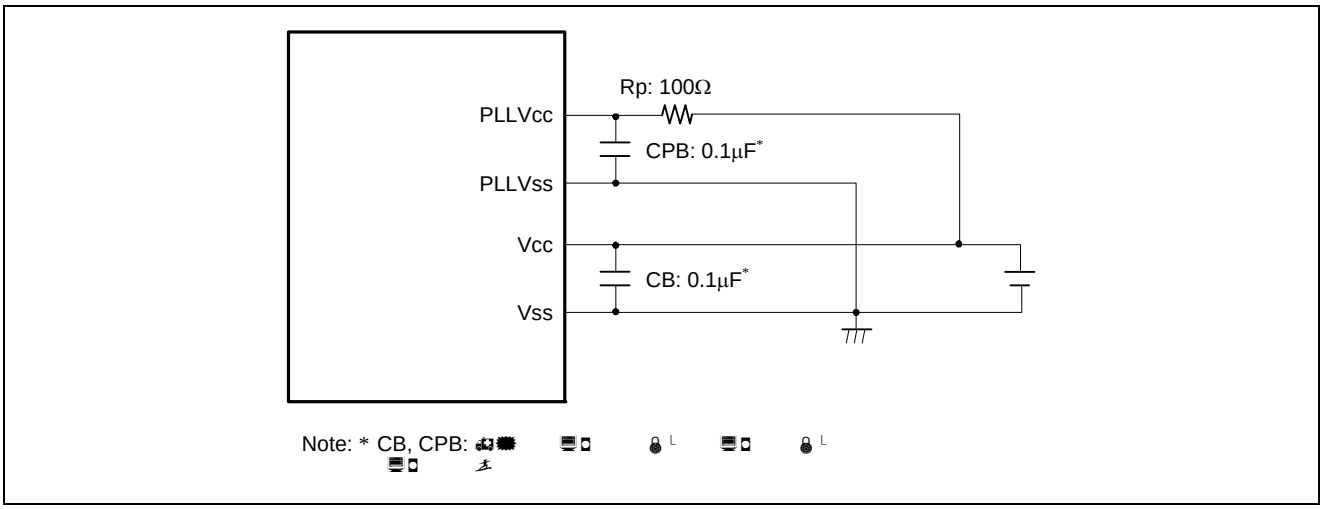


Figure 7.6 Recommended External Circuit for PLL Circuit

8. Low Power Consumption

8.1 Overview

The RX610 Group has functions to reduce power consumption, including a multi-clock function, BCLK output stop function, module stop function, and a function for transition to low power consumption mode.

Table 8.1 lists the specifications of low power consumption. Table 8.2 shows the conditions to shift to low power consumption mode, states of the CPU and peripheral modules, and mode canceling method.
After the reset state, this LSI enters the normal program execution state, but modules except the DTC and DMAC do not operate.

Table 8.1 Specifications of Low Power Consumption

Item	Description
Multi-clock function	The frequency division ratio is settable independently for the system clock (ICLK), peripheral module clock (PCLK), and external bus clock (BCLK).
BCLK output stop function	BCLK output and high-output are selectable.
Module stop function	Functions can be stopped for each peripheral module.
Function for transition to low power consumption mode	Transition to low power consumption mode is enabled to stop the CPU, peripheral modules, and oscillator.
Four low power consumption modes	Sleep mode All-module clock stop mode Software standby mode Deep software standby mode

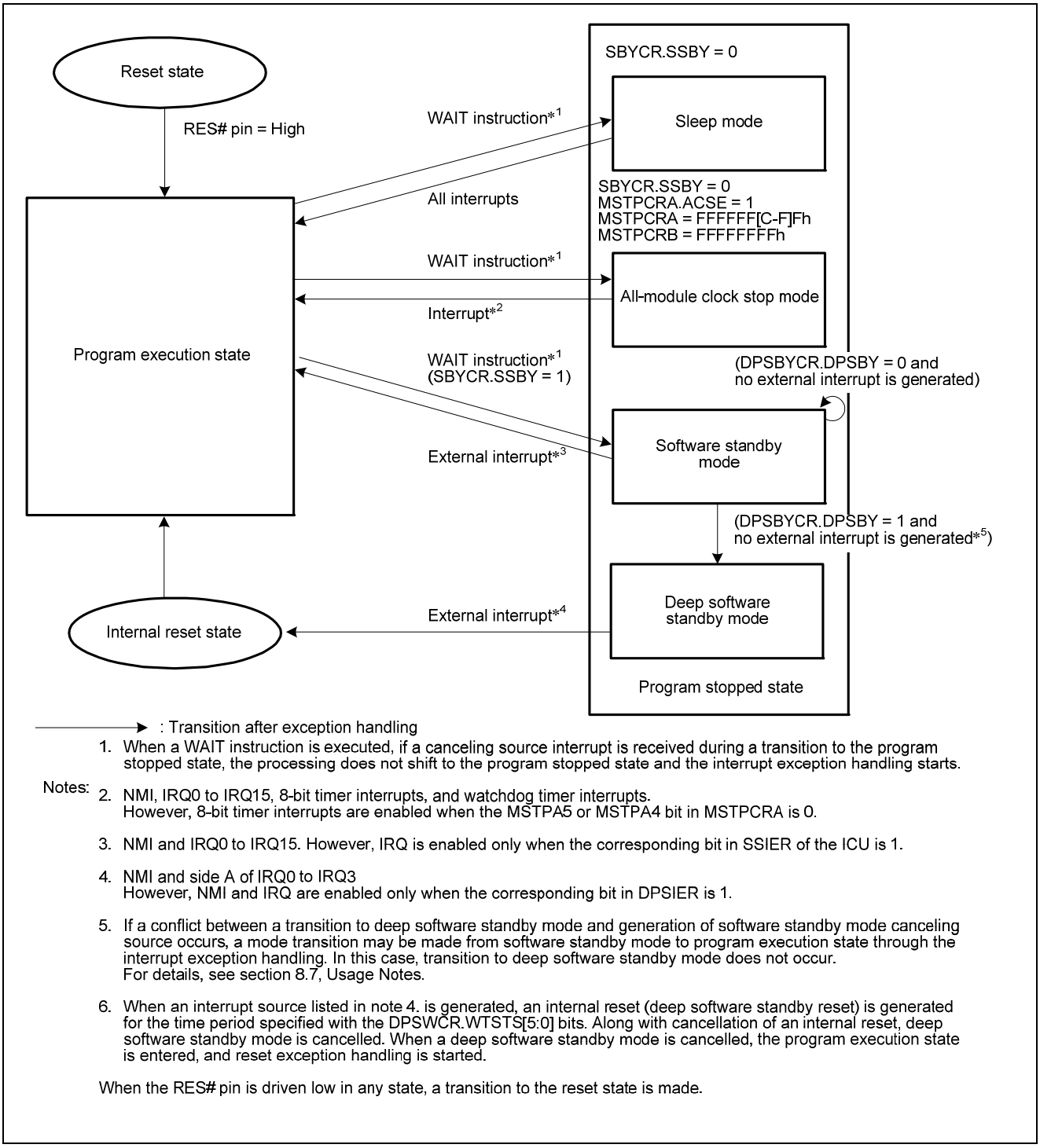
Table 8.2 Transition and Cancellation of the Mode and the State of Operation

Transition and Cancellation of the Mode and the State of Operation	Sleep Mode	All-Module Clock Stop Mode	Software Standby Mode	Deep Software Standby Mode
Transition method	Control register + instruction	Control register + instruction	Control register + instruction	Control register + instruction
Canceling method	Interrupt	Interrupt*1	External interrupt	External interrupt*2
State after cancellation*3	Program execution state (interrupt processing)	Program execution state (interrupt processing)	Program execution state (interrupt processing)	Program execution state (reset processing)
Oscillator	Operating	Operating	Stopped	Stopped
CPU	Stopped (Retained)	Stopped (Retained)	Stopped (Retained)	Stopped (Undefined)
On-chip RAM 1 (0001 0000h to 0001 FFFFh)	Operating (Retained)	Stopped (Retained)	Stopped (Retained)	Stopped (Undefined)
On-chip RAM 0 (0000 0000h to 0000 FFFFh)	Operating (Retained)	Stopped (Retained)	Stopped (Retained)	Stopped (Retained/ Undefined)*4
Watchdog timer	Operating	Operating	Stopped (Retained)	Stopped (Undefined)
8-bit timer (unit 0, unit 1)	Operating	Operating*5	Stopped (Retained)	Stopped (Undefined)
Peripheral modules	Operating	Stopped*6	Stopped*6	Stopped (Undefined)
I/O ports	Operating	Retained*7	Retained*8	Retained*8

Notes: "Stopped (Retained)" means that internal register values are retained and internal operations are suspended.

"Stopped (Undefined)" means that internal register values are undefined and power is not supplied to the internal circuit.

1. External interrupt and some internal interrupts (8-bit timer and watchdog timer)
2. NMI and only side A of IRQ0 to IRQ3. However, NMI and IRQ are enabled only when the corresponding bit in DPSIER is set to 1.
3. Cancellation by the RES# pin is excluded. When canceled by the RES# pin, this LSI enters the reset state.
4. "Retained" or "Undefined" can be selected by the settings of the on-chip RAM Off 2, on-chip RAM Off 1, and on-chip RAM Off 0 bits (RAMCUT2/RAMCUT1/RAMCUT0) in DPSBYC.
5. "Run" or "stop" can be selected by the settings of the 8-bit timer 3/2 (unit 1) module stop and 8-bit timer 1/0 (unit 0) module stop bits (MSTPA5/MSTPA4) in MSTPCRA.
6. Peripheral modules retain the state.
7. When P53 is set as the BCLK output, the I/O port continues to operate as the BCLK output. For details, see section 8.6, BCLK Output Control.
8. "Retained" or "High impedance" for the address bus and bus control signals (CS0# to CS7#, RD#, WR0#, WR1#, WR#, BC0#, and BC1#) can be selected by the setting of the output port enable bit (OPE) in SBYCR.



Notes:
1. When a WAIT instruction is executed, if a canceling source interrupt is received during a transition to the program stopped state, the processing does not shift to the program stopped state and the interrupt exception handling starts.
2. NMI, IRQ0 to IRQ15, 8-bit timer interrupts, and watchdog timer interrupts.
However, 8-bit timer interrupts are enabled when the MSTPA5 or MSTPA4 bit in MSTPCRA is 0.
3. NMI and IRQ0 to IRQ15. However, IRQ is enabled only when the corresponding bit in SSIER of the ICU is 1.
4. NMI and side A of IRQ0 to IRQ3
However, NMI and IRQ are enabled only when the corresponding bit in DPSIER is 1.
5. If a conflict between a transition to deep software standby mode and generation of software standby mode canceling source occurs, a mode transition may be made from software standby mode to program execution state through the interrupt exception handling. In this case, transition to deep software standby mode does not occur.
For details, see section 8.7, Usage Notes.
6. When an interrupt source listed in note 4. is generated, an internal reset (deep software standby reset) is generated for the time period specified with the DPSWCR.WTSTS[5:0] bits. Along with cancellation of an internal reset, deep software standby mode is cancelled. When a deep software standby mode is cancelled, the program execution state is entered, and reset exception handling is started.

When the RES# pin is driven low in any state, a transition to the reset state is made.

Figure 8.1 Mode Transitions

8.2 Register Descriptions

Table 8.3 is the list of low power consumption registers. For details on the system clock control register (SCKCR), see section 7.2.1, System Clock Control Register (SCKCR).

Table 8.3 List of Low Power Consumption Registers

Register Name	Symbol	Value after Reset	Address	Access Size
Standby control register	SBYCR	4F00h	0008 000Ch	16
Module stop control register A	MSTPCRA	67FF FFFFh	0008 0010h	32
Module stop control register B	MSTPCRB	FFFF FFFFh	0008 0014h	32
Module stop control register C	MSTPCRC	FFFF 0000h	0008 0018h	32
Deep standby control register	DPSBYCR	31h	0008 C280h	8
Deep standby wait control register	DPSWCR	0Fh	0008 C281h	8
Deep standby interrupt enable register	DPSIER	00h	0008 C282h	8
Deep standby interrupt flag register	DPSIFR	00h	0008 C283h	8
Deep standby interrupt edge register	DPSIEGR	00h	0008 C284h	8
Reset status register	RSTSR	00h	0008 C285h	8
Deep standby backup register 0	DPSBKR0	xxh*	0008 C290h	8
Deep standby backup register 1	DPSBKR1	xxh*	0008 C291h	8
Deep standby backup register 2	DPSBKR2	xxh*	0008 C292h	8
Deep standby backup register 3	DPSBKR3	xxh*	0008 C293h	8
Deep standby backup register 4	DPSBKR4	xxh*	0008 C294h	8
Deep standby backup register 5	DPSBKR5	xxh*	0008 C295h	8
Deep standby backup register 6	DPSBKR6	xxh*	0008 C296h	8
Deep standby backup register 7	DPSBKR7	xxh*	0008 C297h	8
Deep standby backup register 8	DPSBKR8	xxh*	0008 C298h	8
Deep standby backup register 9	DPSBKR9	xxh*	0008 C299h	8
Deep standby backup register 10	DPSBKR10	xxh*	0008 C29Ah	8
Deep standby backup register 11	DPSBKR11	xxh*	0008 C29Bh	8
Deep standby backup register 12	DPSBKR12	xxh*	0008 C29Ch	8
Deep standby backup register 13	DPSBKR13	xxh*	0008 C29Dh	8
Deep standby backup register 14	DPSBKR14	xxh*	0008 C29Eh	8
Deep standby backup register 15	DPSBKR15	xxh*	0008 C29Fh	8
Deep standby backup register 16	DPSBKR16	xxh*	0008 C2A0h	8
Deep standby backup register 17	DPSBKR17	xxh*	0008 C2A1h	8
Deep standby backup register 18	DPSBKR18	xxh*	0008 C2A2h	8
Deep standby backup register 19	DPSBKR19	xxh*	0008 C2A3h	8
Deep standby backup register 20	DPSBKR20	xxh*	0008 C2A4h	8
Deep standby backup register 21	DPSBKR21	xxh*	0008 C2A5h	8
Deep standby backup register 22	DPSBKR22	xxh*	0008 C2A6h	8
Deep standby backup register 23	DPSBKR23	xxh*	0008 C2A7h	8
Deep standby backup register 24	DPSBKR24	xxh*	0008 C2A8h	8
Deep standby backup register 25	DPSBKR25	xxh*	0008 C2A9h	8
Deep standby backup register 26	DPSBKR26	xxh*	0008 C2AAh	8
Deep standby backup register 27	DPSBKR27	xxh*	0008 C2ABh	8
Deep standby backup register 28	DPSBKR28	xxh*	0008 C2ACh	8

Register Name	Symbol	Value after Reset	Address	Access Size
Deep standby backup register 29	DPSBKR29	xxh*	0008 C2ADh	8
Deep standby backup register 30	DPSBKR30	xxh*	0008 C2AEh	8
Deep standby backup register 31	DPSBKR31	xxh*	0008 C2AFh	8

Note: * DPSBKR0 to DPSBKR31 are not initialized and their values are undefined immediately after power-on.

8.2.1 Standby Control Register (SBYCR)

Address: 0008 000Ch

	b15	b14	b13	b12	b11	b10	b9	b8
	SSBY	OPE	—			STS[4:0]		
Value after reset:	0	1	0	0	1	1	1	1

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b12 to b8	STS[4:0]	Standby Timer Select	b12 b8 0 0 1 0 1: Waiting time = 64 states 0 0 1 1 0: Waiting time = 512 states 0 0 1 1 1: Waiting time = 1024 states 0 1 0 0 0: Waiting time = 2048 states 0 1 0 0 1: Waiting time = 4096 states 0 1 0 1 0: Waiting time = 16384 states 0 1 0 1 1: Waiting time = 32768 states 0 1 1 0 0: Waiting time = 65536 states 0 1 1 0 1: Waiting time = 131072 states 0 1 1 1 0: Waiting time = 262144 states 0 1 1 1 1: Waiting time = 524288 states Settings other than above are prohibited.	R/W
b13	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b14	OPE	Output Port Enable	0: In software standby mode or deep software standby mode, the address bus and bus control signals are set to the high-impedance state. 1: In software standby mode or deep software standby mode, the address bus and bus control signals retain the output state.	R/W
b15	SSBY	Software Standby	0: Shifts to sleep mode or all-module clock stop mode after the WAIT instruction is executed 1: Shifts to software standby mode after the WAIT instruction is executed	R/W

SBYCR is used to control software standby mode.

STS[4:0] Bits (Standby Timer Select)

These bits select the time for this LSI to wait until the clock is stabilized when software standby mode is canceled by an external interrupt.

In the case of crystal oscillation, see table 8.4 and make a selection according to the operating frequency so that the waiting time is no less than the oscillation settling time. When an external clock is used, the PLL circuit settling time is necessary. Select a waiting time referring to table 8.4.

During the oscillation settling time, the standby timer is counted on the peripheral module clock (PCLK) frequency. Note this in multi-clock mode.

OPE Bit (Output Port Enable)

The OPE bit specifies whether to retain the output of the address bus and bus control signals (CS0# to CS7#, RD#, WR0#, WR1#, WR#, BC0#, and BC1#) in software standby mode or deep software standby mode, or to set the output to the high-impedance state.

SSBY Bit (Software Standby)

The SSBY bit specifies the transition destination after the WAIT instruction is executed.

When the SSBY bit is set to 0, the LSI enters either sleep mode or all-module clock stop mode after execution of the WAIT instruction, according to the setting of the MSTPCRA and MSTPCRB registers. When the SSBY bit is set to 1, the LSI enters software standby mode after execution of the WAIT instruction. In this case, when the DPSBY bit in DPSBYCR is 1, the LSI enters deep software standby mode after software standby mode. For details, see section 8.5, Low Power Consumption Modes.

This bit is not cleared to 0 when software standby mode is canceled by an external interrupt and the LSI enters normal mode. Write 0 to this bit to clear.

When the WDT is used in watchdog timer mode, the setting of this bit is invalid and the LSI always enters sleep mode or all-module clock stop mode after the WAIT instruction is executed.

8.2.2 Module Stop Control Register A (MSTPCRA)

Address: 0008 0010h

	b31	b30	b29	b28	b27	b26	b25	b24
	ACSE	—	—	MSTPA28	MSTPA27	—	—	—
Value after reset:	0	1	1	0	0	1	1	1

	b23	b22	b21	b20	b19	b18	b17	b16
	MSTPA23	MSTPA22	MSTPA21	MSTPA20	MSTPA19	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8
	MSTPA15	MSTPA14	MSTPA13	MSTPA12	MSTPA11	MSTPA10	—	—
Value after reset:	1	1	1	1	1	1	1	1

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	MSTPA5	MSTPA4	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b4	MSTPA4	8-Bit Timer 3/2 (Unit 1) Module Stop	Target module: TMR3/TMR2 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b5	MSTPA5	8-Bit Timer 1/0 (Unit 0) Module Stop	Target module: TMR1/TMR0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b9 to b6	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b10	MSTPA10	Programmable Pulse Generator 1 (Unit 1) Module Stop	Target module: PPG1 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b11	MSTPA11	Programmable Pulse Generator 0 (Unit 0) Module Stop	Target module: PPG0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b12	MSTPA12	16-Bit Timer Pulse Unit 1 (Unit 1) Module Stop	Target module: TPU unit 1 (TPU6 to TPU11) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b13	MSTPA13	16-Bit Timer Pulse Unit 0 (Unit 0) Module Stop	Target module: TPU unit 0 (TPU0 to TPU5) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b14	MSTPA14	Compare Match Timer 1 (Unit 1) Module Stop	Target module: CMT unit 1 (CMT2, CMT3) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W

Bit	Symbol	Bit Name	Description	R/W
b15	MSTPA15	Compare Match Timer 0 (Unit 0) Module Stop	Target module: CMT unit 0 (CMT0, CMT1) 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b18 to b16	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b19	MSTPA19	D/A Converter Module Stop	Target module: DA 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b20	MSTPA20	A/D Converter (Unit 3) Module Stop	Target module: AD3 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b21	MSTPA21	A/D Converter (Unit 2) Module Stop	Target module: AD2 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b22	MSTPA22	A/D Converter (Unit 1) Module Stop	Target module: AD1 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b23	MSTPA23	A/D Converter (Unit 0) Module Stop	Target module: AD0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b26 to b24	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b27	MSTPA27	Data Transfer Controller Module Stop	Target module: DTC 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b28	MSTPA28	DMA Controller Module Stop	Target module: DMAC 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b30, b29	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b31	ACSE[*1]	All-Module Clock Stop Mode Enable	0: All-module clock stop mode is disabled 1: All-module clock stop mode is enabled	R/W

MSTPCRA is used to control the module stop state.

ACSE Bit (All-Module Clock Stop Mode Enable)

The ACSE bit enables or disables all-module clock stop mode for reducing supply current by stopping the bus controller and I/O ports when the CPU executes the WAIT instruction after the module stop state has been specified for all modules[*2] controlled by MSTPCRA and MSTPCRB.

Notes: 1. When the SBYCR.SSBY and MSTPCRA.ACSE bits are both 0, sleep mode is entered after WAIT instruction execution.

2. Whether to stop the 8-bit timers or not can be selected by the MSTPA5 and MSTPA 4 bits.

8.2.3 Module Stop Control Register B (MSTPCRB)

Address: 0008 0014h

	b31	b30	b29	b28	b27	b26	b25	b24
	MSTPB31	MSTPB30	MSTPB29	MSTPB28	MSTPB27	MSTPB26	MSTPB25	—
Value after reset:	1	1	1	1	1	1	1	1

	b23	b22	b21	b20	b19	b18	b17	b16
	MSTPB23	—	MSTPB21	MSTPB20	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b19 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b20	MSTPB20	I^2C Bus Interface 1 (Unit 1) Module Stop	Target module: RIIC1 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b21	MSTPB21	I^2C Bus Interface 0 (Unit 0) Module Stop	Target module: RIIC0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b22	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b23	MSTPB23	CRC Calculator Module Stop	Target module: CRC 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b24	—	Reserved	This bit is always read as 1. The write value should always be 1.	R/W
b25	MSTPB25	Serial Communication Interface 6 Module Stop	Target module: SCI6 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b26	MSTPB26	Serial Communication Interface 5 Module Stop	Target module: SCI5 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b27	MSTPB27	Serial Communication Interface 4 Module Stop	Target module: SCI4 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W

Bit	Symbol	Bit Name	Description	R/W
b28	MSTPB28	Serial Communication Interface 3 Module Stop	Target module: SCI3 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b29	MSTPB29	Serial Communication Interface 2 Module Stop	Target module: SCI2 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b30	MSTPB30	Serial Communication Interface 1 Module Stop	Target module: SCI1 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W
b31	MSTPB31	Serial Communication Interface 0 Module Stop	Target module: SCI0 0: The module stop state is canceled 1: Transition to the module stop state is made	R/W

MSTPCRB is used to control the module stop state.

8.2.4 Module Stop Control Register C (MSTPCRC)

Address: 0008 0018h

	b31	b30	b29	b28	b27	b26	b25	b24
	—	—	—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	MSTPC1	MSTPC0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	MSTPC0*	RAM0 Module Stop	Target module: RAM0 (0000 0000h to 0000 FFFFh) 0: RAM0 run 1: RAM0 stop	R/W
b1	MSTPC1*	RAM1 Module Stop	Target module: RAM1 (0001 0000h to 0001 FFFFh) 0: RAM1 run 1: RAM1 stop	R/W
b15 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b31 to b16	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

Note: * The MSTPC0 or MSTPC1 bit should not be set to 1 during access to the on-chip RAM0 or RAM1. The on-chip RAM 0 or RAM 1 should not be accessed with the MSTPC0 or MSTPC1 bit set to 1.

MSTPCRC is used to control the module stop state.

8.2.5 Deep Standby Control Register (DPSBYCR)

Address: 0008 C280h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSBY	IOKEEP	RAMCUT2	RAMCUT1	—	—	—	RAMCUT0
Value after reset:	0	0	1	1	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	RAMCUT0	On-Chip RAM Off 0	b5 b4 b0 0 0 0: Power is supplied to the on-chip RAM (RAM0*) in deep software standby mode 1 1 1: Power is not supplied to the on-chip RAM (RAM0*) in deep software standby mode Settings other than above are prohibited.	R/W
b3 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	RAMCUT1	On-Chip RAM Off 1	See the description of the RAMCUT0 bit	R/W
b5	RAMCUT2	On-Chip RAM Off 2	See the description of the RAMCUT0 bit	R/W
b6	IOKEEP	I/O Port Retention	0: Deep software standby mode and I/O port retention are canceled simultaneously 1: I/O port retention is canceled when 0 is written to the IOKEEP bit after deep software standby mode is canceled	R/W
b7	DPSBY	Deep Software Standby	SSBY b7 0 0: Transition to sleep mode is made after the WAIT instruction is executed 0 1: Transition to sleep mode is made after the WAIT instruction is executed 1 0: Transition to software standby mode is made after the WAIT instruction is executed 1 1: Transition to deep software standby mode is made after the WAIT instruction is executed	R/W

Note: * For the on-chip RAM address space, see table 8.2.

DPSBYCR is used to control deep software standby mode.

DPSBYCR is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.

RAMCUTj Bits (On-Chip RAM Off j) (j = 0 to 2)

These bits control the internal power supply to the on-chip RAM modules in deep software standby mode.

The on-chip RAM address space is divided into the RAM 0 area and RAM 1 area. For the on-chip RAM address space, see table 8.2.

Only the internal power supply of RAM0 can be controlled by the setting of bits RAMCUT0, RAMCUT1, and RAMCUT2.

The internal power supply of RAM1 is stopped in deep software standby mode regardless of the setting of bits RAMCUT0, RAMCUT1, and RAMCUT2.

IOKEEP Bit (I/O Port Retention)

In deep software standby mode, I/O ports keep retaining the same states from software standby mode. The IOKEEP bit specifies whether to keep retaining the I/O port states from deep software standby mode even after deep software standby mode is canceled, or to cancel retaining the I/O port states.

DPSBY Bit (Deep Software Standby)

The DPSBY bit controls transitions to deep software standby mode.

When the WAIT instruction is executed while the SSBY and DPSBY bits in SBYCR are 1, the LSI enters deep software standby mode through software standby mode.

This bit is not cleared to 0 when deep software standby mode is canceled by the external interrupt pin. Write 0 to this bit to clear.

When the WDT is used in watchdog timer mode, the setting of this bit is invalid. In this case, even when the SSBY and DPSBY bits in SBYCR are set to 1, the LSI always enters sleep mode or all-module clock stop mode after the WAIT instruction is executed.

8.2.6 Deep Standby Wait Control Register (DPSWCR)

Address: 0008 C281h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	WTSTS[5:0]					
Value after reset:	0	0	0	0	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	WTSTS[5:0]	Deep Software Standby Waiting Time	b5 b0 0 0 0 1 0 1: Waiting time = 64 states 0 0 0 1 1 0: Waiting time = 512 states 0 0 0 1 1 1: Waiting time = 1024 states 0 0 1 0 0 0: Waiting time = 2048 states 0 0 1 0 0 1: Waiting time = 4096 states 0 0 1 0 1 0: Waiting time = 16384 states 0 0 1 0 1 1: Waiting time = 32768 states 0 0 1 1 0 0: Waiting time = 65536 states 0 0 1 1 0 1: Waiting time = 131072 states 0 0 1 1 1 0: Waiting time = 262144 states 0 0 1 1 1 1: Waiting time = 524288 states	R/W
b7, b6	—	Reserved	These bits are always read as 0.The write value should always be 0.	R/W

DPSWCR is used to select the time for this LSI to wait until the clock is stabilized when deep software standby mode is canceled by the external interrupt pin.

DPSWCR is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.

WTSTS[5:0] Bits (Deep Software Standby Waiting Time)

These bits select the time for this LSI to wait until the clock is stabilized when deep software standby mode is canceled by the external interrupt pin. When using deep software standby mode, set the WTSTS[5:0] bits before a transition to deep software standby mode is made.

In the case of crystal oscillation, see table 8.5 and make a selection according to the operating frequency so that the waiting time is no less than the oscillation settling time. When an external clock is used, the PLL circuit settling time is necessary. Select a waiting time referring to table 8.5.

During the oscillation settling time, the counter is counted on the EXTAL input clock frequency.

8.2.7 Deep Standby Interrupt Enable Register (DPSIER)

Address: 0008 C282h

	b7	b6	b5	b4	b3	b2	b1	b0
	DNMIE	—	—	—	DIRQ3E	DIRQ2E	DIRQ1E	DIRQ0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DIRQ0E	IRQ0 Pin Enable	0: Canceling deep software standby mode by the IRQ0 pin is disabled 1: Canceling deep software standby mode by the IRQ0 pin is enabled	R/W
b1	DIRQ1E	IRQ1 Pin Enable	0: Canceling deep software standby mode by the IRQ1 pin is disabled 1: Canceling deep software standby mode by the IRQ1 pin is enabled	R/W
b2	DIRQ2E	IRQ2 Pin Enable	0: Canceling deep software standby mode by the IRQ2 pin is disabled 1: Canceling deep software standby mode by the IRQ2 pin is enabled	R/W
b3	DIRQ3E	IRQ3 Pin Enable	0: Canceling deep software standby mode by the IRQ3 pin is disabled 1: Canceling deep software standby mode by the IRQ3 pin is enabled	R/W
b6 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DNMIE	NMI Pin Enable	0: Canceling deep software standby mode by the NMI pin is disabled 1: Canceling deep software standby mode by the NMI pin is enabled	R/(W)*

Note: * A 1 can be written only once. Once 1 is written to the DNMIE bit, subsequent write accesses are disabled.

DPSIER is used to enable or disable the external interrupt pin that cancels deep software standby mode.

DPSIER is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.

Note that modifying the DPSIER register setting may internally produce an edge on some pin even if the PnICR register value is 0 and may cause the DPSIFR register value to be 1. Before causing a shift to deep software standby mode, set the DPSIFR register value to 0.

Also note that causing a shift to deep software standby mode may internally produce a rising edge on some pin even if the DPSIER register value is 0 and may cause the DPSIFR register value to be 1. In this case, however, if the DPSIEGR register value is 0, no rising edges are detected and thus the DPSIFR register value will not be 1.

8.2.8 Deep Standby Interrupt Flag Register (DPSIFR)

Address: 0008 C283h

	b7	b6	b5	b4	b3	b2	b1	b0
	DNMIF	—	—	—	DIRQ3F	DIRQ2F	DIRQ1F	DIRQ0F
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DIRQ0F	IRQ0 Deep Standby Cancel Flag	0: No cancel request by the IRQ0 pin is generated 1: A cancel request by the IRQ0 pin is generated	R/(W)*
b1	DIRQ1F	IRQ1 Deep Standby Cancel Flag	0: No cancel request by the IRQ1 pin is generated 1: A cancel request by the IRQ1 pin is generated	R/(W)*
b2	DIRQ2F	IRQ2 Deep Standby Cancel Flag	0: No cancel request by the IRQ2 pin is generated 1: A cancel request by the IRQ2 pin is generated	R/(W)*
b3	DIRQ3F	IRQ3 Deep Standby Cancel Flag	0: No cancel request by the IRQ3 pin is generated 1: A cancel request by the IRQ3 pin is generated	R/(W)*
b6 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DNMIF	NMI Deep Standby Cancel Flag	0: No cancel request by the NMI pin is generated 1: A cancel request by the NMI pin is generated	R/(W)*

Note: * Only 0 can be written to this bit.

DPSIFR is used to hold the request for canceling deep software standby mode.

Each flag is set to 1 when a cancel request specified by the deep standby interrupt edge register (DPSIEGR) is generated. Since each flag is set to 1 when a cancel request is generated in any mode, a transition to deep software standby mode should be made after DPSIFR is cleared to 0. Furthermore, changing the corresponding P3.ICR or DPSIER setting may lead to a flag being set to 1. When clearing DPSIFR to 0 after changing the P3.ICR or DPSIER setting, wait for at least 6 cycles of the PCLK before reading DPSIFR and then writing 0 to DPSIFR. For example, reading DPSIER secures at least 6 cycles of the PCLK.

DPSIFR is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.

DIRQnF Flags (IRQn Deep Standby Cancel Flag) (n = 0 to 3)

These flags indicate that a cancel request by the IRQn pin has been generated.

[Setting condition]

- When a cancel request by the IRQn pin specified by DPSIEGR is generated

[Clearing condition]

- When each bit is read as 1 and then written by 0

DNMIF Flag (NMI Deep Standby Cancel Flag)

This flag indicates that a cancel request by the NMI pin has been generated.

[Setting condition]

- When a cancel request by the NMI pin specified by DPSIEGR is generated

[Clearing condition]

- When this bit is read as 1 and then written by 0

8.2.9 Deep Standby Interrupt Edge Register (DPSIEGR)

Address: 0008 C284h

	b7	b6	b5	b4	b3	b2	b1	b0
	DNMIEG	—	—	—	DIRQ3EG	DIRQ2EG	DIRQ1EG	DIRQ0EG
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DIRQ0EG	IRQ0 Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W
b1	DIRQ1EG	IRQ1 Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W
b2	DIRQ2EG	IRQ2 Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W
b3	DIRQ3EG	IRQ3 Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W
b6 to b4	—	Reserved	These bits are always read as 0.The write value should always be 0.	R/W
b7	DNMIEG	NMI Edge Select	0: A cancel request is generated at a falling edge 1: A cancel request is generated at a rising edge	R/W

DPSIEGR is used to select an edge of the cancel signal for canceling deep software standby mode.

DPSIEGR is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.

8.2.10 Reset Status Register (RSTSR)

Address: 0008 C285h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSRSTF	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DPSRSTF	Deep Software Standby Reset Flag	0: No deep software standby mode canceling source by an external interrupt is generated 1: A deep software standby mode canceling source by an external interrupt is generated	R/(W)*

Note: * Only 0 can be written to clear the flag.

RSTSR indicates an internal reset generation source.

DPSRSTF Flag (Deep Software Standby Reset Flag)

The DPSRSTF flag indicates that deep software standby mode has been canceled by an external interrupt source specified by DPSIER and DPSIEGR and an internal reset has been generated.

This flag is initialized by the reset signal from the RES# pin, but is not initialized by the internal reset signal that cancels deep software standby mode.

[Setting condition]

- When deep software standby mode is canceled by an external interrupt source

[Clearing condition]

- When this bit is read as 1 and then written by 0

8.2.11 Deep Standby Backup Register (DPSBKRy) (y = 0 to 31)

Address: 0008 C290h to 0008 C2AFh

	b7	b6	b5	b4	b3	b2	b1	b0
	BKUPm7	BKUPm6	BKUPm5	BKUPm4	BKUPm3	BKUPm2	BKUPm1	BKUPm0
Value after reset:	x	x	x	x	x	x	x	x

DPSBKRy is an 8-bit readable/writable register to store data during deep software standby mode.

The value of this register is retained even in deep software standby mode where on-chip RAM data is not retained.

DPSBKRy is not initialized and the register value is undefined immediately after power-on.

8.3 Multi-Clock Function

When the ICK[3:0], BCK[3:0], and PCK[3:0] bits in SCKCR are set, the clock frequency changes.

The CPU and bus masters operate on the operating clock specified by the ICK[3:0] bits. Peripheral modules operate on the operating clock specified by the PCK[3:0] bits. The external bus operates on the operating clock specified by the BCK[3:0] bits. For details, see section 7, Clock Generation Circuit.

8.4 Module Stop Function

The module stop function can be set for each on-chip peripheral module.

When the MSTPyj bit (y = A to C, j = 0 to 31) in MSTPCRA to MSTPCRC is set to 1, the specified module stops operating and enters the module stop state, but the CPU continues to operate independently. Clearing the MSTPmi bit to 0 cancels the module stop state, allowing the module to restart operating at the end of the bus cycle.

The internal states of modules are retained in the module stop state.

After a reset, all modules other than the DMAC, DTC, and on-chip RAM are placed in the module stop state. No read/write access can be made to the registers of the module that are in the module stop state.

8.5 Low Power Consumption Modes

8.5.1 Sleep Mode

8.5.1.1 Transition to Sleep Mode

When the WAIT instruction is executed while the SSBY bit in SBYCR is 0, the CPU enters sleep mode.

In sleep mode, the CPU stops operating but the contents of its internal registers are retained. Other peripheral functions do not stop.

8.5.1.2 Canceling Sleep Mode

Sleep mode is canceled by any interrupt, reset signal from the RES# pin, or a reset caused by a watchdog timer overflow.

- Canceling by an interrupt

  When an interrupt occurs, sleep mode is canceled and the interrupt exception handling starts. If a maskable interrupt has been masked by the CPU (the priority level*[1] of the interrupt has been set to a value lower than that of the IPL[2:0] bits*[2] in PSW of the CPU), sleep mode is not canceled.

Notes: 1. For details, see section 10, Interrupt Control Unit (ICU).
2. For details, see section 2, CPU.

- Canceling by the RES# pin

  When the RES# pin is driven low, the LSI enters the reset state. When the RES# pin is driven high after the reset signal is input for a predetermined time period, the CPU starts the reset exception handling.
- Canceling by a watchdog timer overflow reset

  Sleep mode is canceled by an internal reset generated by a watchdog timer overflow.

8.5.2 All-Module Clock Stop Mode

8.5.2.1 Transitions to All-Module Clock Stop Mode

When the following two conditions are satisfied, executing the WAIT instruction with the SSBY bit in SBYCR cleared to 0 will cause the transition to all-module clock stop mode at the end of the bus cycle.*[1]

- The ACSE bit in MSTPCRA is set to 1.
- All the modules controlled by the MSTPCRA and MSTPCRB registers except for the 8-bit timers (units 0 and 1) are set in the module stop state (MSTPCRA = FFFFFF[C to F]Fh, MSTPCRB = FFFFFFFFh).

In all-module clock stop mode, the CPU, the bus controller, the I/O ports, and all the peripheral modules except for the 8-bit timers*[2] and the watchdog timers are stopped.

If a further reduction in supply current is required beyond that in all-module clock stop mode, stop the target modules for which operation or stopping is controlled by MSTPCRC.

When all-module clock stop mode is in use, issue a WAIT instruction after making the following settings.

1. Clear the I bit*[3] in PSW of the CPU to 0.
2. Set the priority*[4] of the interrupt to be used for recovery from all-module clock stop mode to a level higher than the setting of the IPL[2:0] bits*[3] in PSW.
3. Set the IENj bit*[4] in IERm for the interrupt to be used for recovery from all-module clock stop mode to 1.
4. Make either of the following settings for interrupts that are not to be used for recovery from all-module clock stop mode.
   - Set the priority*[4] of interrupts*[5] that are not to be used for recovery from all-module clock stop mode to a level lower than the setting of the IPL[2:0] bits*[3] in PSW of the CPU.
   - Set the IENj bit*[4] in IERm for the interrupt*[5] that is not to be used for recovery from all-module clock stop mode to 0.
5. Execute a WAIT instruction (executing a WAIT instruction causes automatic setting of the I bit*[3] in PSW of the CPU to 1).

Notes:
1. The state of DTC or DMAC operations can make transitions to module stop mode impossible. Before setting the MSTPA28 or MSTPA27 bits in MSTPCRA to 1, clear the DMST bit in DMSCNT of the DMAC and the DTCST bit in DTCST of the DTC to 0 so that the DTC or DMAC is not initiated.
2. The MSTPA4 and MSTPA5 bits of the MSTPCRA register select operation or stopping of these modules.
3. For details, see section 2, CPU.
4. For details, see section 10, Interrupt Control Unit (ICU).
5. Executing a WAIT instruction while a peripheral module is operating creates a possibility of recovery from all-module clock-stop mode being triggered by an interrupt that could not normally act as a trigger for recovery. Interrupts that can act as triggers for recovery thus include all interrupts which can be set by the various IERm.IENj bits and the PSW.IPL[2:0] bits, as well as the interrupts that are intended to act as triggers for recovery.

8.5.2.2 Release from All-Module Clock Stop Mode

Release from all-module clock stop mode is triggered by an external interrupt (the NMI pin or any pin from among IRQ0 to IRQ15), the signal on the RES# pin, or an internal interrupt (from an 8-bit timer*[1] or the watchdog timer), and normal program execution resumes once handling of the given exception is complete. However, note that in cases where a maskable interrupt has been masked by the CPU (the priority level*[2] of the interrupt has been set to a value lower than that of the IPL[2:0] bits*[3] in PSW of the CPU) or a maskable interrupt has been set up as a trigger for transfer by the DTC or DMAC, the interrupt will not trigger release from all-module clock stop mode.

Notes: 1. The MSTPA4 and MSTPA5 bits of register MSTPCRA select operation or stopping of these modules.
2. For details, see section 10, Interrupt Control Unit (ICU).
3. For details, see section 2, CPU.

8.5.3 Software Standby Mode

8.5.3.1 Transition to Software Standby Mode

When the WAIT instruction is executed with the SSBY bit in SBYCR set to 1 and the DPSBY bit in DPSBYCR cleared to 0, a transition to software standby mode is made. In this mode, the CPU, on-chip peripheral functions, and all the oscillator functions stop. However, the contents of the CPU internal registers, on-chip RAM data, on-chip peripheral functions, and the states of the I/O ports are retained. Whether the address bus and bus control signals are placed in the high-impedance state or the output state is retained can be specified by the OPE bit in SBYCR. This mode allows significant reduction in power consumption because the oscillator stops in this mode.

When a transition to software standby mode is made, the system clock (ICLK) and peripheral module clock (PCLK) should be operating at the same frequency. If not, be sure to change the system clock (ICLK) or peripheral module clock (PCLK) setting, before executing a WAIT instruction.

In addition, before executing a WAIT instruction, be sure to clear both the DMST bit in DMSCNT of the DMAC and the DTCST bit in DTCST in the DTC to 0.

When the WDT is used in watchdog timer mode, no transition to software standby mode is made. Stop the WDT before executing the WAIT instruction.

When software standby mode is in use, issue a WAIT instruction after making the following settings.

1. Clear the I bit*1 in PSW of the CPU to 0.
2. Set the priority*2 of the interrupt to be used for recovery from software standby mode to a level higher than the setting of the IPL[2:0] bits*1 in PSW.
3. Set the IENj bit*2 in IERm for the interrupt to be used for recovery from software standby mode to 1.
4. Make either of the following settings for interrupts that are not to be used for recovery from software standby mode.
   - Set the priority*2 of interrupts*3 that are not to be used for recovery from software standby mode to a level lower than the setting of the IPL[2:0] bits*1 in PSW of the CPU.
   - Set the IENj bit*2 in IERm for the interrupt*3 that is not to be used for recovery from software standby mode to 0.
5. Execute a WAIT instruction (executing a WAIT instruction causes automatic setting of the I bit*1 in PSW of the CPU to 1).

Notes: 1. For details, see section 2, CPU.
2. For details, see section 10, Interrupt Control Unit (ICU).
3. Executing a WAIT instruction while a peripheral module is operating creates a possibility of recovery from software standby mode being triggered by an interrupt that could not normally act as a trigger for recovery. In addition, the interrupt status flag of an interrupt IRQ0 to IRQ15, which is not specified as a trigger for recovery, might be set in software standby mode, and thus an unexpected exception handling that is not the trigger for recovery will be started.
   Interrupts that can act as triggers for recovery thus includes all interrupts which can be set by the various IERi.IENj bits and the PSW.IPL[2:0] bits, as well as the interrupts that are intended to act as triggers for recovery.

8.5.3.2 Canceling Software Standby Mode

Software standby mode is canceled by an external interrupt (NMI or IRQ0 to IRQ15*[1]) or the reset signal from the RES# pin.

1. Canceling by an interrupt

   When an NMI or IRQ0 to IRQ15*[1] interrupt request signal is input, clock oscillation starts, and stable clocks are supplied to the entire LSI after the time selected by the STS[4:0] bits in SBYCR has passed, software standby mode is canceled, and the interrupt exception handling is started.

   To cancel software standby mode by an interrupt IRQ0 to IRQ15*[1], set the corresponding enable bit (IENj bit in IERm)*[2] to 1 and mask interrupts with a higher priority than interrupts IRQ0 to IRQ15*[1].

   To cancel software standby mode by an interrupt IRQ0 to IRQ15 for which edge detection is set, 0 should be written to the status flag (the IR bit in IRn of the ICU) of the corresponding interrupt at the beginning of the exception handler for the interrupt.

   In addition, the interrupt status flag of an interrupt IRQ0 to IRQ15, which is not specified as a trigger for recovery, might be set in software standby mode*[3]. Therefore, clear the IR flag after the recovery from software standby mode.

Notes: 1 An interrupt from among IRQ0 to IRQ15 cannot be used as a trigger for release from software standby mode if the corresponding SSIj bit (j = 15 to 0) in SSIER of the ICU has been set to 0. For details, see section 10, Interrupt Control Unit (ICU).

2 For details, see section 10, Interrupt Control Unit (ICU).

3. For details, see section 10.6.2, Return from Software Standby Mode.

2. Canceling by the RES# pin

   When the RES# pin is driven low, clock oscillation starts and at the same time the clocks are supplied to the entire LSI. Be sure to hold the RES# pin low until the clock oscillation settles. When the RES# pin is driven high, the CPU begins the reset exception handling.

8.5.3.3 Setting Oscillation Settling Time after Software Standby Mode is Canceled

Set the STS[4:0] bits in SBYCR as follows:

1. When using a crystal resonator
   Set the STS[4:0] bits so that the waiting time is no less than the oscillation settling time.
   Table 8.4 shows operating frequencies and waiting time corresponding to each setting of the STS[4:0] bits.
2. When using an external clock
   The PLL circuit settling time is necessary. Set the waiting time referring to table 8.4.

Table 8.4 Oscillation Settling Time Setting

					Waiting Time	PCLK* (MHz)			
STS4	STS3	STS2	STS1	STS0	(States)	50	25	8	Unit
0	0	0	0	0	Reserved	—	—	—	μs
				1	Reserved	—	—	—	
			1	0	Reserved	—	—	—	
				1	Reserved	—	—	—	
		1	0	0	Reserved	—	—	—	
				1	64	1.3	2.6	8.0	
			1	0	512	10.25	20.5	64.0	
				1	1024	20.5	41.0	128.0	
	1	0	0	0	2048	40.95	81.9	256.0	
				1	4096	0.08	0.16	0.51	ms
			1	0	16384	0.33	0.66	2.05	
				1	32768	0.655	1.31	4.10	
		1	0	0	65536	1.31	2.62	8.19	
				1	131072	2.62	5.24	16.38	
			1	0	262144	5.25	10.49	32.77	
				1	524288	10.49	20.97	65.54	
1	x	x	x	x	Reserved	—	—	—	

: Recommended time setting when an external clock is used

: Recommended time setting when a crystal resonator is used

Note: * The PCLK is the output of the peripheral module frequency divider.
The oscillation settling time (including oscillator's unstable oscillation time) depends on the resonator characteristics.
The PCLK values in this table are reference values.

8.5.3.4 Example of Software Standby Mode Application

Figure 8.2 shows an example where a transition to software standby mode is made at the falling edge on the IRQ pin, and software standby mode is canceled at the rising edge on the IRQ pin.

In this example, an IRQ interrupt is accepted with the IRQMD[1:0] bits in IRQCRi of the ICU set to 01b (falling edge), and then the IRQMD[1:0] bits are set to 10b (rising edge). After that, the SSIi bit in SSIER of the ICU and the SSBY bit in SBYCR are set to 1, and then the WAIT instruction is executed. Thus a transition to software standby mode is made.

After that, software standby mode is canceled at the rising edge on the IRQ pin.

To return from the software standby mode, settings of the interrupt control unit (ICU) are also necessary. For details, see section 10, Interrupt Control Unit (ICU).

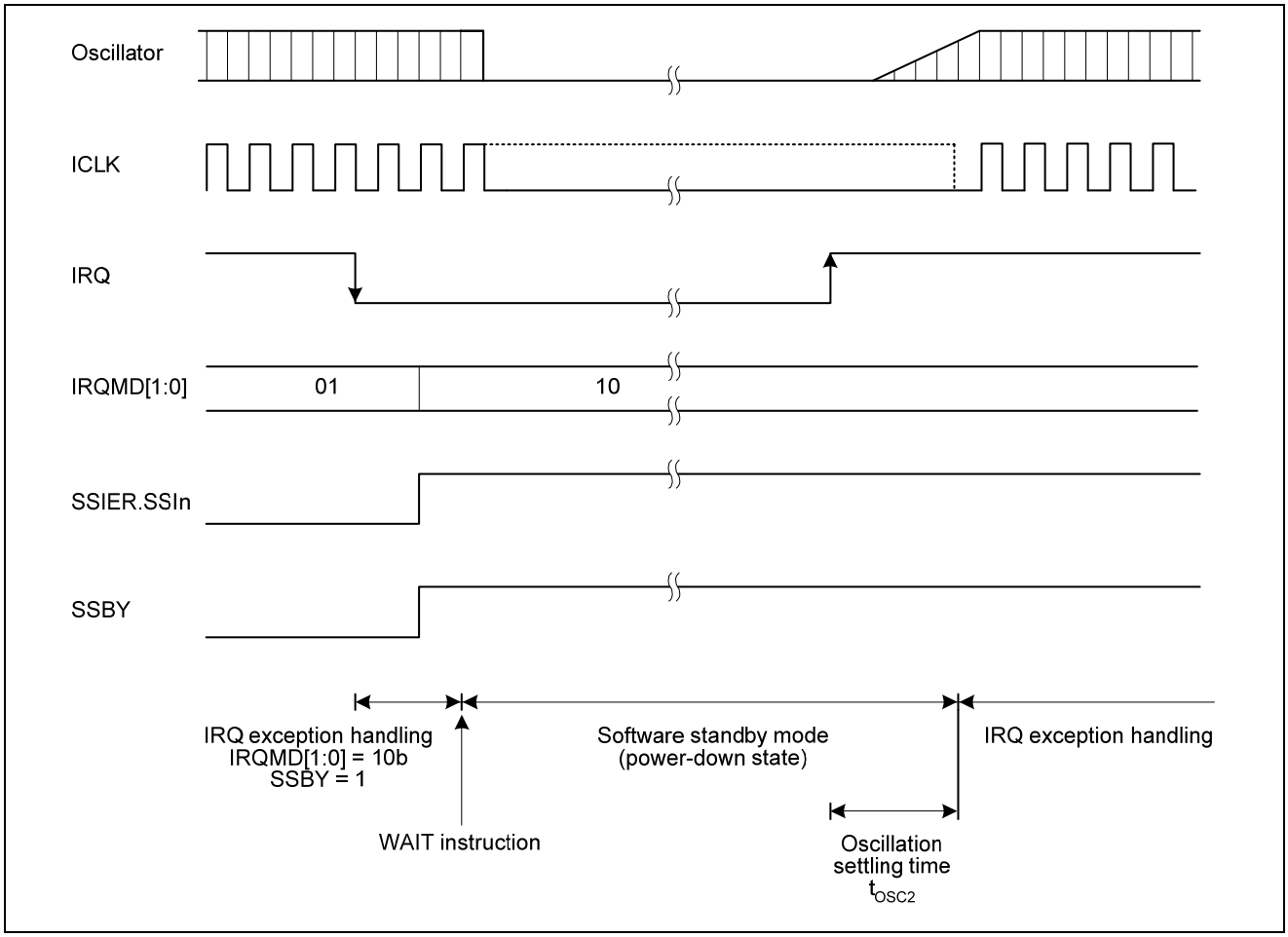


Figure 8.2 Example of Software Standby Mode Application

8.5.4 Deep Software Standby Mode

8.5.4.1 Transition to Deep Software Standby Mode

When the WAIT instruction is executed with the SSBY bit in SBYCR set to 1, a transition to software standby mode*[1] is made. At this time, when the DPSBY bit in DPSBYCR is set to 1, a transition to deep software standby mode is made. However, if a software standby mode canceling source (NMI or IRQ0 to IRQ15) is generated concurrently when a transition to software standby mode is made, software standby mode is canceled regardless of the DPSBY setting, and the interrupt exception handling starts after the oscillation settling time for software standby mode specified by the STS[4:0] bits in SBYCR has passed*[2].

When the SSBY and DPSBY bits are set to 1 and no software standby mode canceling source is generated, a transition to deep software standby mode is made immediately after transition to software standby mode.

In deep software standby mode, the CPU, on-chip peripheral functions, on-chip RAM 1*[3], and all the oscillator functions stop. Furthermore, the internal power supply to these modules stops, allowing significant reduction in power consumption. At this time, the contents of all the registers of the CPU and on-chip peripheral functions become undefined. All the on-chip RAM 1*[3] data becomes undefined regardless of the setting of the RAMCUT2 to RAMCUT0 bits in DPSBYCR.

The on-chip RAM 0*[3] data can be retained by clearing the RAMCUT2 to RAMCUT0 bits to all 0 beforehand. Setting all of these bits to 1 will stop the internal power supply to the on-chip RAM 0*[2], allowing further reduction in power consumption. At this time, the on-chip RAM 0*[3] data is undefined.

The I/O port states remain unchanged from software standby mode.

Notes: 1. Conditions on the DTC, DMAC, and WDT for transition to software standby mode should be met before the WAIT instruction is executed. For details, see section 8.5.3, Software Standby Mode.
2. To cancel software standby mode by an interrupt IRQ0 to IRQ15 for which edge detection is set, 0 should be written to the status flag (the IR bit in IRi of the ICU) of the corresponding interrupt at the beginning of the exception handling routine for the interrupt.
3. The on-chip RAM address space is divided into the RAM 0 area and RAM 1 area. For the on-chip RAM address space, see table 8.2.

8.5.4.2 Canceling Deep Software Standby Mode

Deep software standby mode is canceled by an external interrupt (NMI or IRQ0-A to IRQ3-A pins) or the reset signal from the RES# pin.

1. Canceling by an external interrupt
   The DPSIFR holds the cancelation cause of deep software standby mode and the bits in this register are set to 1 when the corresponding cancelation requests are generated. When a bit is set to 1 and the corresponding cancelation cause is enabled in the DPSIER register, deep software standby mode is canceled.
   Deep software standby mode is canceled when any of the DNMIF flag in DPSIFR and the DIRQnF flag (n = 3 to 0) in DPSIFR is set to 1. The DNMIF or DIRQnF flag is set to 1 when an edge is generated on the NMI pin or IRQ0-A to IRQ3-A pins enabled by the DNMIE bit in DPSIER or the DIRQnE bit (n = 3 to 0) in DPSIER. Rising edge or falling edge is selectable with DPSIEGR for each pin.
   When a deep software standby mode canceling source is generated, clock oscillation starts and the internal power supply begins at the same time, and then the internal reset signal is generated throughout the LSI. After the time specified by the WTSTS[5:0] bits in DPSWCR has passed, stable clocks are supplied to the entire LSI and the internal reset is released. At the same time, deep software standby mode is canceled and the reset exception handling starts.
   When deep software standby mode is canceled by an external interrupt, the DPSRSTF flag in RSTSR is set to 1.
2. Canceling by the RES# pin
   When the RES# pin is driven low, clock oscillation starts and the internal power supply begins at the same time. Clocks are supplied to the LSI simultaneously with the start of clock oscillation. Be sure to hold the RES# pin low until the clock oscillation settles. When the RES# pin is driven high, the CPU begins the reset exception handling.

8.5.4.3 Pin States when Deep Software Standby Mode is Canceled

In deep software standby mode, I/O ports retain the same states from software standby mode. The inside of the LSI is initialized by an internal reset generated when deep software standby mode is canceled. Upon cancellation of deep software standby mode, the reset exception handling starts. The following shows the states of I/O ports at this time.

Whether to initialize the I/O ports or to keep retaining the I/O port states at the time of software standby mode can be selected by the IOKEEP bit in DPSBYCR.

- When IOKEEP = 0
  I/O ports are initialized by an internal reset generated when deep software standby mode is canceled.
- When IOKEEP = 1
  Although the inside of the LSI is initialized by an internal reset generated when deep software standby mode is canceled, I/O ports keep retaining their states from software standby mode regardless of the LSI internal state. At this time, the I/O port states remain unchanged from software standby mode even if settings of I/O ports or peripheral modules are made. Then the retained I/O port states are released by clearing the IOKEEP bit to 0, and the LSI operates according to the internal state.

The IOKEEP bit is not initialized by an internal reset generated when deep software standby mode is canceled.

8.5.4.4 Setting Oscillation Settling Time after Deep Software Standby Mode is Canceled

Set the WTSTS[5:0] bits in DPSWCR as follows:

1. When using a crystal resonator
   Set the WTSTS[5:0] bits so that the waiting time is no less than the oscillation settling time.
   Table 8.5 shows EXTAL input clock frequencies and waiting time corresponding to each setting of the WTSTS[5:0] bits.
2. When using an external clock
   The PLL circuit settling time is necessary. Set the waiting time referring to table 8.5.

Table 8.5 Oscillation Settling Time Setting

							EXTAL Input Clock Frequency* (MHz)		
WTSTS5	WTSTS4	WTSTS3	WTSTS2	WTSTS1	WTSTS0	Waiting Time (States)	12	8	Unit
0	0	0	0	0	0	Reserved	—	—	μs
					1	Reserved	—	—	
				1	0	Reserved	—	—	
					1	Reserved	—	—	
			1	0	0	Reserved	—	—	
					1	64	5.3	8.0	
				1	0	512	42.7	64.0	
					1	1024	85.3	128.0	
		1	0	0	0	2048	170.7	256.0	
					1	4096	0.34	0.51	ms
				1	0	16384	1.37	2.05	
					1	32768	2.73	4.10	
			1	0	0	65536	5.46	8.19	
					1	131072	10.92	16.38	
				1	0	262144	21.85	32.77	
					1	524288	43.69	65.54	
	1	×	×	×	×	Reserved	—	—	
1	×	×	×	×	×	Reserved	—	—	

: Recommended time setting when an external clock is used

: Recommended time setting when a crystal resonator is used

Note: * The oscillation settling time (including oscillator's unstable oscillation time) depends on the resonator characteristics.
The values of the EXTAL input clock frequency in this table are reference values.

8.5.4.5 Example of Deep Software Standby Mode Application

Figure 8.3 shows an example where a transition to deep software standby mode is made at the falling edge on the IRQ pin, and deep software standby mode is canceled at the rising edge on the IRQ pin.

In this example, an IRQ interrupt is accepted with the IRQMD[1:0] bits in IRQCRi of the ICU set to 01 (falling edge), and then the DIRQnEG bit in DPSIEGR is set to 1 (rising edge). After that, the SSBY bit in SBYCR and the DPSBY bit in DPSBYCR are set to 1, and then the WAIT instruction is executed. Thus a transition to deep software standby mode is made.

After that, deep software standby mode is canceled at the rising edge on the IRQ pin.

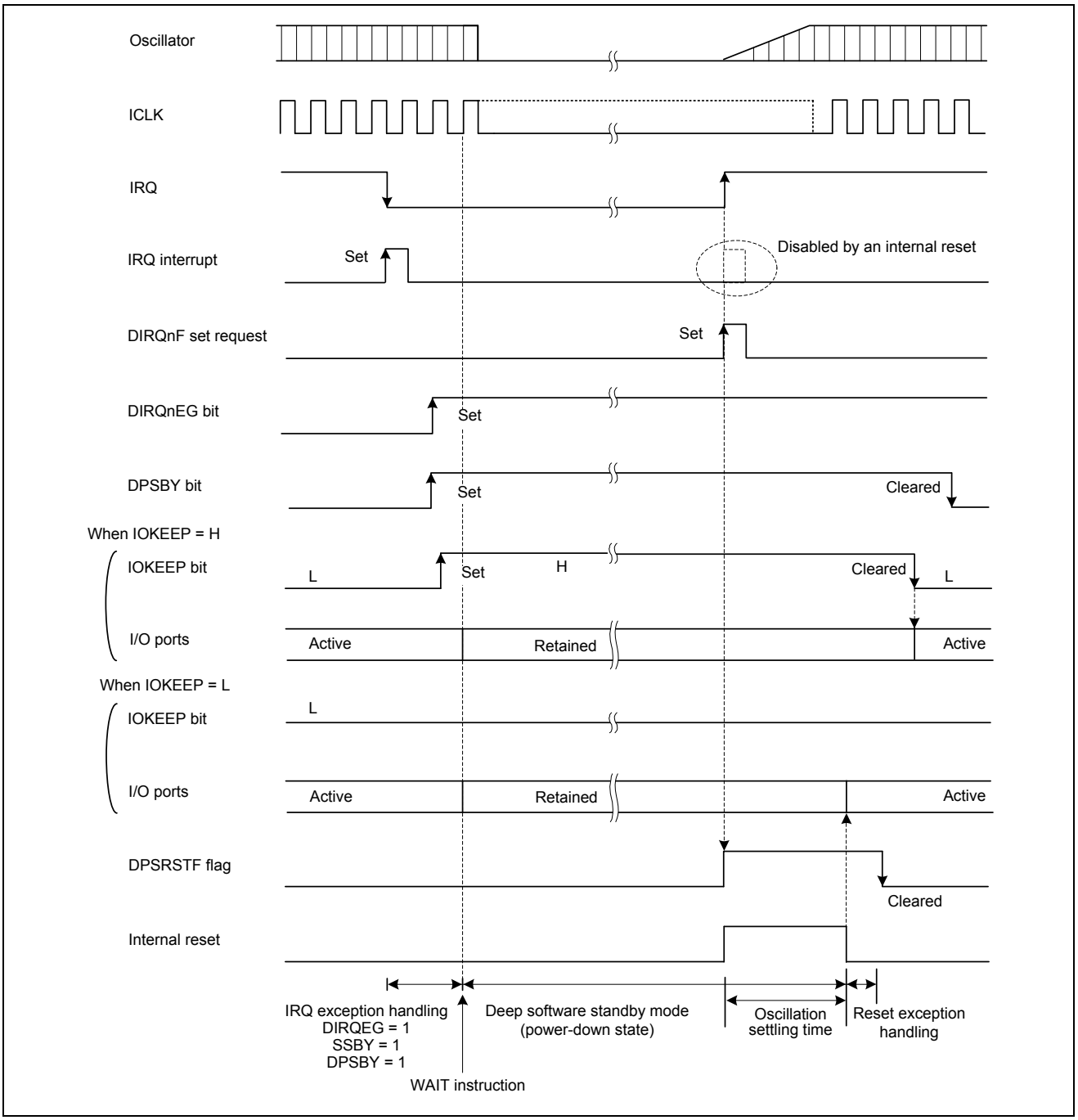


Figure 8.3 Example of Deep Software Standby Mode Application

8.5.4.6 Flowchart to Use Deep Software Standby Mode

Figure 8.4 shows an example of flowchart to use deep software standby mode.

In this example, the DPSRSTF flag in RSTSR of the reset function is read after the reset exception handling to determine whether a reset was generated by the RES# pin or by the cancellation of deep software standby mode.

In the case of a reset by the RES# pin, a transition to deep software standby mode is made after required register settings.

In the case of a reset by the cancellation of deep software standby mode, the IOKEEP bit in DPSBYCR is cleared to 0 after the I/O port settings.

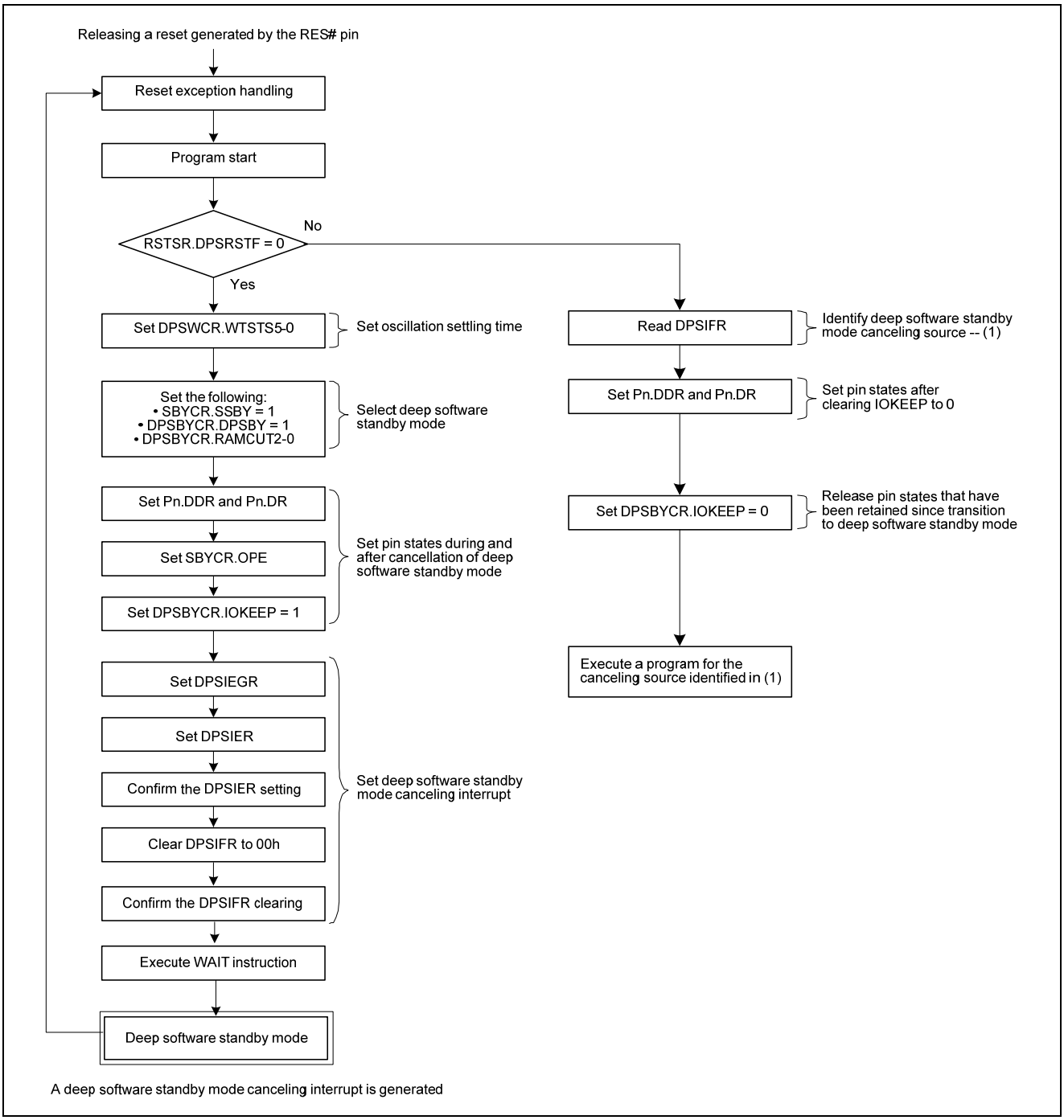


Figure 8.4 Example of Flowchart to Use Deep Software Standby Mode

8.6 BCLK Output Control

The BCLK output can be controlled with the PSTOP1 bit in SCKCR and the B3 bit in P5.DDR of corresponding P53.

When the PSTOP1 bit is cleared to 0, P53 functions as the BCLK output. When the PSTOP1 bit is set to 1, the BCLK output stops at the end of the bus cycle and goes high. When the B3 bit in P5.DDR of P53 is cleared to 0, the BCLK output is disabled and the pin functions as an input port.

Table 8.6 shows the BCLK pin state in each operating mode.

Table 8.6 BCLK Pin (P53) State in Each Operating Mode

Register Settings		Normal Operating Mode	Sleep Mode	All-Module Clock Stop Mode	Software Standby Mode		Deep Software Standby Mode	
DDR	PSTOP1				OPE = 0	OPE = 1	IOKEE P= 0	IOKEEP = 1
0	×	Hi-Z	Hi-Z	Hi-Z	Hi-Z	Hi-Z	Hi-Z	Hi-Z
1	0	BCLK output	BCLK output	BCLK output	High	High	High	High
1	1	High	High	High	High	High	High	High

8.7 Usage Notes

8.7.1 I/O Port States

I/O port states are retained in software standby mode and deep software standby mode. Therefore, supply current is not reduced while output signals are held high.

8.7.2 Module Stop State of the DMAC and DTC

Before setting the MSTPA28 or MSTPA27 bits in MSTPCRA to 1, clear the DMST bit in DMSCNT of the DMAC and the DTCST bit in DTCST of the DTC to 0 so that initiating transfer by the DTC or DMAC is not possible. For details, see section 12, DMA Controller (DMAC) and section 13, Data Transfer Controller (DTC).

8.7.3 On-Chip Peripheral Module Interrupts

Operation of relevant interrupt is disabled in the module stop state. Therefore, if the module stop state is made with an interrupt request pending, a CPU interrupt source or a DMAC (or DTC) startup source cannot be cleared. For this reason, disable interrupts before entering the module stop state.

8.7.4 Write-Access to MSTPCRA, MSTPCRB, and MSTPCRC

Write-accesses to MSTPCRA, MSTPCRB, and MSTPCRC should be made only by the CPU.

8.7.5 Input Buffer Control by DIRQnE Bit (n = 3 to 0)

The input buffers for the P30/IRQ0-A to P33/IRQ3-A pins are enabled by setting the DIRQnE bit (n = 3 to 0) in DPSIER to 1. Therefore, note that inputs to these pins are reflected in the DIRQnF flag (n = 3 to 0) in DPSIFR, but are not transferred to the interrupt control unit, peripheral modules, and I/O ports. Inputs to the interrupt control unit, peripheral modules, and I/O ports should be controlled by each Pn.ICR.

8.7.6 Conflict between Transition to Deep Software Standby Mode and Interrupt

If a conflict occurs between a transition to deep software standby mode and generation of a software standby mode canceling source, the transition to deep software standby mode is not realized but the software standby mode canceling sequence is started. After the oscillation settling time specified by the STS[4:0] bits in SBYCR for software standby mode has passed, the interrupt exception handling is started.

Note that if a conflict occurs between a transition to deep software standby mode and generation of an NMI interrupt, the NMI interrupt exception handling routine is required.

If a conflict occurs between a transition to deep software standby mode and generation of an interrupt of IRQ0 to IRQ15, a transition to deep software standby mode can be made by clearing the SSIj bit (j = 15 to 0) in SSIER of the ICU to 0 beforehand without starting the interrupt exception handling.

8.7.7 Timing of Wait Instructions

The WAIT instruction is executed before completion of the preceding register write; it may be executed before the register modification is reflected, causing unintended operation. To avoid this, execute the WAIT instruction after confirming that the last write to the register has been completed.

9. Exceptions

9.1 Types of Exceptions

During the execution of a program by the CPU, the occurrence of certain events may necessitate suspending execution of the main flow of the program and starting the execution of another flow. Such events are called exceptions.

The RX CPU supports the seven types of exceptions listed in figure 9.1.

The occurrence of an exception causes the processor mode to switch to supervisor mode.

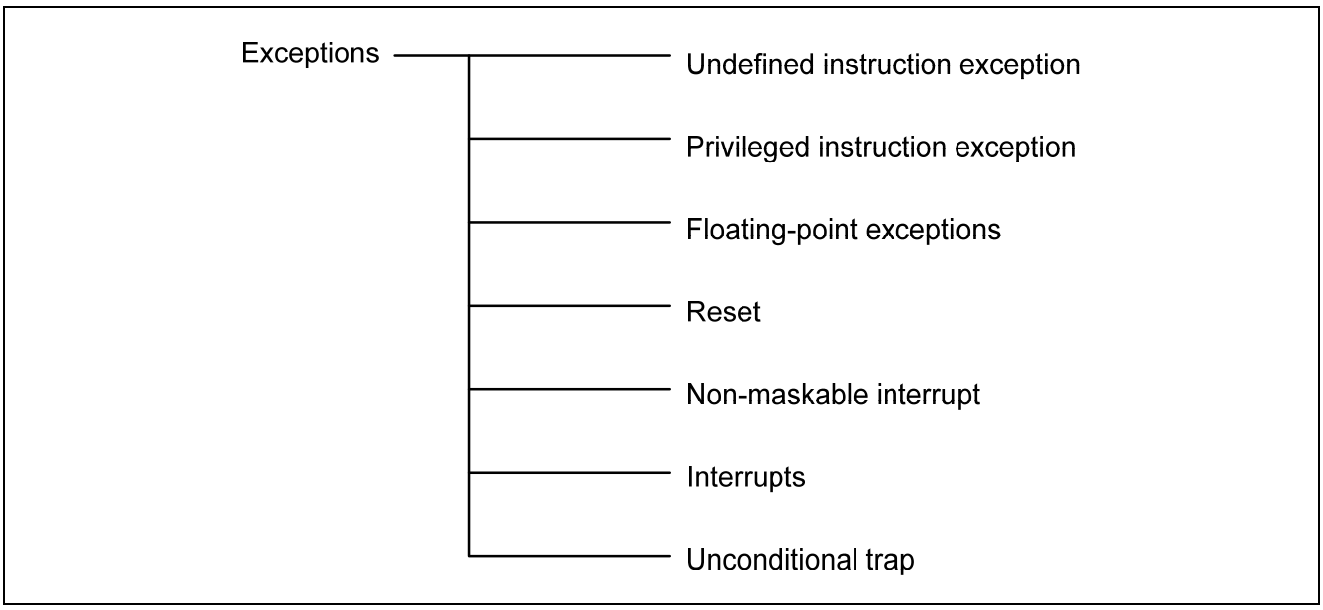


Figure 9.1 Types of Exception

9.1.1 Undefined Instruction Exception

An undefined instruction exception occurs when execution of an undefined instruction (an instruction not implemented) is detected.

9.1.2 Privileged Instruction Exception

A privileged instruction exception occurs when execution of a privileged instruction is detected while operation is in user mode. Privileged instructions can only be executed in supervisor mode.

9.1.3 Floating-Point Exceptions

Floating-point exceptions include the five specified in the IEEE754 standard, namely overflow, underflow, inexact, division-by-zero, and invalid operation, and a further floating-point exception that is generated on the detection of unimplemented processing. The exception processing of floating-point exceptions is masked when the EX, EU, EZ, EO, or EV bit in FPSW is 0.

9.1.4 Reset

A reset through input of the reset signal to the CPU causes the exception request. This has the highest priority of any exception and is always accepted.

9.1.5 Non-Maskable Interrupt

The non-maskable interrupt is generated by input of the non-maskable interrupt signal to the CPU and is only used when a fatal fault is considered to have occurred in the system. Never end the exception handling routine for the non-maskable interrupt with an attempt to return to the program that was being executed at the time of interrupt generation.

9.1.6 Interrupts

Interrupts are generated by the input of interrupt signals to the CPU. The interrupt with the highest priority can be selected for handling as a fast interrupt. The exception processing of interrupts is masked when the I bit in the PSW is 0.

9.1.7 Unconditional Trap

An unconditional trap is generated when the INT or BRK instruction is executed.

9.2 Exception Handling Procedure

For exception handling, part of the processing is handled automatically by hardware and part is handled by a program (the exception handling routine) that has been written by the user. Figure 9.2 shows the handling procedure when an exception other than a reset is accepted.

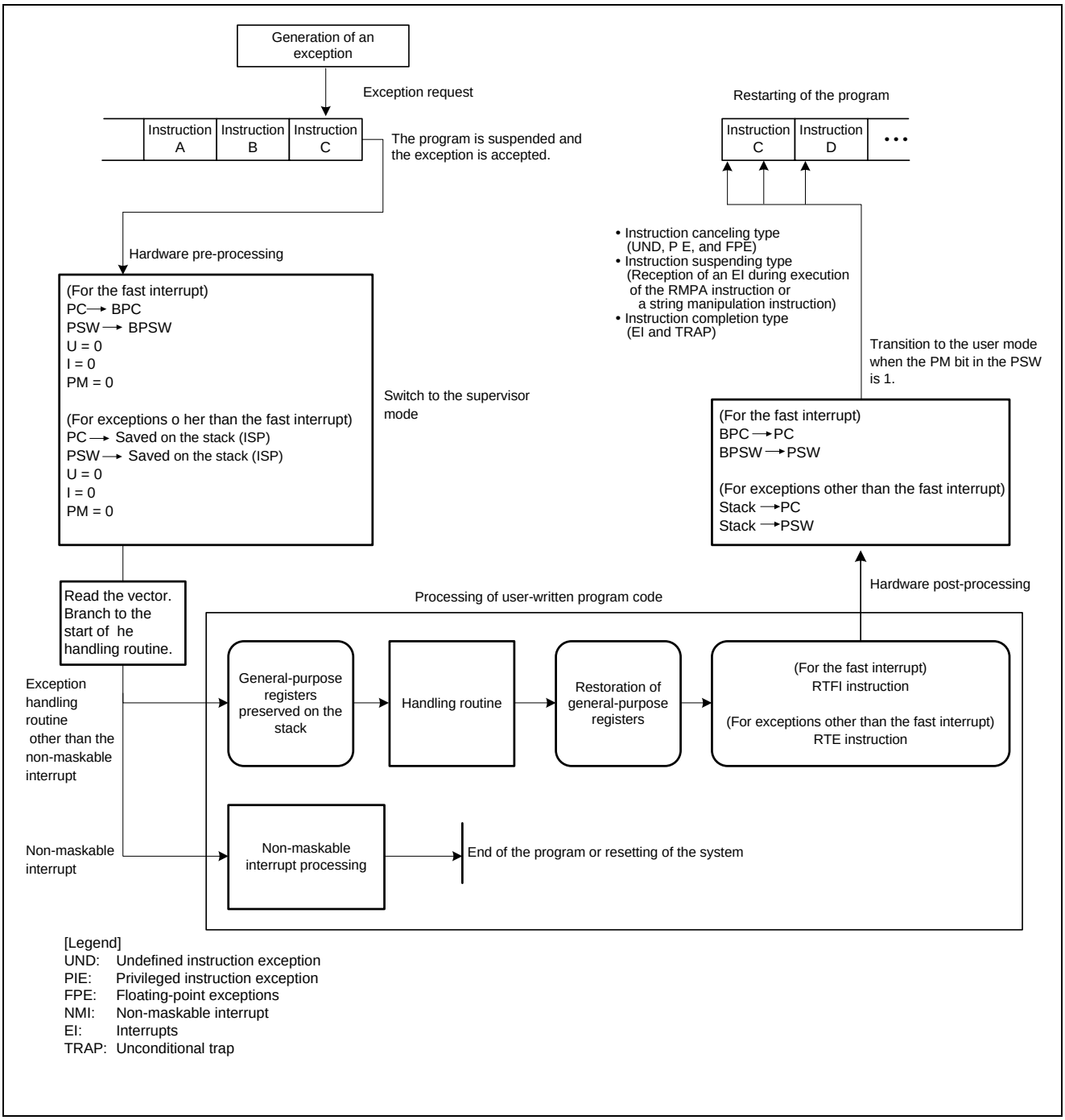


Figure 9.2 Outline of the Exception Handling Procedure

When an exception is accepted, hardware processing by the RX CPU is followed by vector access to acquire the address of the branch destination. A vector address is allocated to each exception. The branch destination address of the handler for the given exception is written to each vector address. The combination is referred to as a vector.

Hardware pre-processing by the RX CPU handles saving of the contents of the program counter (PC) and processor status word (PSW). In the case of the fast interrupt, the contents are saved in the backup PC (BPC) and the backup PSW (BPSW), respectively. In the case of other exceptions, the contents are preserved in the stack area.

General purpose registers and control registers other than the PC and PSW that are to be used within the exception handling routine must be preserved on the stack by user program code at the start of the exception handling routine.

On completion of processing by most exception processing handlers, registers preserved under program control are restored and the RTE instruction is executed to restore execution from the exception handling routine to the original program. For return from the fast interrupt, the RTFI instruction is used instead. In the case of the non-maskable interrupt, however, end the program or reset the system without returning to the original program.

Hardware post-processing by the RX CPU handles restoration of the pre-exception contents of the PC and PSW. In the case of the fast interrupt, the contents of the BPC and BPSW are restored to the PC and PSW, respectively. In the case of other exceptions, the contents are restored from the stack area to the PC and PSW.

9.3 Acceptance of Exceptions

When an exception occurs, the CPU suspends the execution of the program and processing branches to the start of the exception handling routine.

9.3.1 Timing of Acceptance and Saved PC Values

Table 9.1 lists the timing of acceptance and program counter (PC) value to be saved for each type of exception event.

Table 9.1 Timing of Acceptance and Saved PC Value

Exception		Type of Handling	Timing of Acceptance	Value Saved in the BPC/ on the Stack
Undefined instruction exception		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Privileged instruction exception		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Floating-point exceptions		Instruction canceling type	During instruction execution	PC value of the instruction that generated the exception
Reset		Program abandonment type	Any machine cycle	None
Non-maskable interrupt	During execution of the RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, and SWHILE instructions	Instruction suspending type	During instruction execution	PC value of the instruction being executed
	Other than the above	Instruction completion type	At the next break between instructions	PC value of the next instruction
Interrupts	During execution of the RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, and SWHILE instructions	Instruction suspending type	During instruction execution	PC value of the instruction being executed
	Other than the above	Instruction completion type	At the next break between instructions	PC value of the next instruction
Unconditional trap		Instruction completion type	At the next break between instructions	PC value of the next instruction

9.3.2 Vector and Site for Saving the Values in the PC and PSW

The vector for each type of exception and the site for saving the values of the program counter (PC) and processor status word (PSW) are listed in table 9.2.

Table 9.2 Vector and Site for Saving the Values in the PC and PSW

Exception		Vector	Site for Saving the Values in the PC and PSW
Undefined instruction exception		Fixed vector table	Stack
Privileged instruction exception		Fixed vector table	Stack
Floating-point exceptions		Fixed vector table	Stack
Reset		Fixed vector table	Nowhere
Non-maskable interrupt		Fixed vector table	Stack
Interrupts	Fast interrupt	FINTV	BPC and BPSW
	Other than the above	Relocatable vector table (INTB)	Stack
Unconditional trap		Relocatable vector table (INTB)	Stack

9.4 Hardware Processing for Accepting and Returning from Exceptions

This section describes the hardware processing for accepting and returning from exceptions other than a reset.

(1) Hardware pre-processing for accepting an exception

(a) Saving the values in the PSW

- For the fast interrupt
  PSW → BPSW
- For other exceptions
  PSW → Stack area

Note: The values in the FPSW are not saved by hardware pre-processing. Therefore, if floating-point instructions are to be used within an exception handling routine, the user must ensure that these values are saved on the stack.

(b) Updating of the PM, U, and I bits in the PSW

I: Cleared
I: Cleared
PM: Cleared

(c) Saving the values in the PC

- For the fast interrupt
  PC → BPC
- For other exceptions
  PC → Stack area

(d) Set the branch-destination address of the exception handling routine in the PC

Processing is shifted to the exception handling routine by acquiring the vector corresponding to the exception and branching accordingly.

(2) Hardware post-processing for execution of RTE and RTFI instructions

(a) Restoring the values in the PSW

- For the fast interrupt
  BPSW → PSW
- For other exceptions
  Stack area→ PSW

(b) Restoring the values in the PC

- For the fast interrupt
  BPC → PC
- For other exceptions
  Stack area→ PC

9.5 Hardware Pre-Processing

The sequences of hardware pre-processing from reception of each exception request to execution of the associated exception handling routine are explained below.

9.5.1 Undefined Instruction Exception

1. The value of the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFDCh.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

9.5.2 Privileged Instruction Exception

1. The value in the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFD0h.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

9.5.3 Floating-Point Exceptions

1. The value in the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) is saved on the stack (ISP).
4. The address of the processing routine is fetched from the vector address, FFFFFFE4h.
5. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

9.5.4 Reset

1. The control registers are initialized.
2. The address of the processing routine is fetched from the vector address, FFFFFFFCh.
3. The PC is set to the fetched address.

9.5.5 Non-Maskable Interrupt

1. The value of the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. If the interrupt was generated during the execution of an RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, or SWHILE instruction, the value of the program counter (PC) for that instruction is saved on the stack (ISP). For other instructions, the PC value of the next instruction is saved.
4. The processor interrupt priority level bits (IPL[2:0]) in the PSW are set to 111b.
5. The address of the processing routine is fetched from the vector address, FFFFFFF8h.
6. The PC is set to the fetched address and the processing branches to the start of the exception handling routine.

9.5.6 Interrupts

1. The value of the processor status word (PSW) is saved on the stack (ISP) or, for the fast interrupt, in the backup PSW (BPSW).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. If the interrupt was generated during the execution of an RMPA, SCMPU, SMOVB, SMOVF, SMOVU, SSTR, SUNTIL, or SWHILE instruction, the value of the program counter (PC) for that instruction is saved. For other instructions, the PC value of the next instruction is saved. Saving of the PC is in the backup PC (BPC) for fast interrupts.
4. The processor interrupt priority level bits (IPL[2:0]) in the PSW indicate the interrupt priority level of the interrupt.
5. The address of the processing routine for an interrupt source other than the fast interrupt is fetched from the relocatable vector table. For the fast interrupt, the address is fetched from the fast interrupt vector register (FINTV).
6. The PC is set to the fetched address and processing branches to the start of the exception handling routine.

9.5.7 Unconditional Trap

1. The value in the processor status word (PSW) is saved on the stack (ISP).
2. The processor mode select bit (PM), the stack pointer select bit (U), and the interrupt enable bit (I) in the PSW are cleared to 0.
3. The value of the program counter (PC) for the next instruction is saved on the stack (ISP).
4. For the INT instruction, the value at the vector corresponding to the INT instruction number is fetched from the relocatable vector table.
   For the BRK instruction, the value at the vector from the start address is fetched from the relocatable vector table.
5. The PC is set to the fetched address and the processing branches to the start of the exception handling routine.

9.6 Return from Exception Handling Routines

Executing the instructions listed in table 9.3 at the end of the corresponding exception handling routines restores the values of the program counter (PC) and processor status word (PSW) that were saved on the stack or in the control registers (BPC and BPSW) immediately before the exception handling sequence.

Table 9.3 Return from Exception Handling Routines

Exception		Instruction for Return
Undefined instruction exception		RTE
Privileged instruction exception		RTE
Floating-point exceptions		RTE
Reset		Return is impossible
Non-maskable interrupt		Return is impossible
Interrupts	Fast interrupt	RTFI
	Other than the above	RTE
Unconditional trap		RTE

9.7 Order of Priority for Exceptions

The order of priority for exceptions is given in table 9.4. When multiple exceptions are generated at the same time, the exception with the highest priority is accepted first.

Table 9.4 Order of Priority for Exceptions

Order of Priority		Exception
High	1	Reset
↑	2	Non-maskable interrupt
	3	Interrupts
	4	Undefined instruction exception Privileged instruction exception
	5	Unconditional trap
Low	6	Floating-point exceptions

10. Interrupt Control Unit (ICU)

10.1 Overview

The interrupt control unit (ICU) responds to interrupt signals from peripheral modules and external pins to convey interrupt requests to the CPU and activate the DTC and DMAC.

Table 10.1 lists the specifications of the interrupt control unit, and figure 10.1 shows a block diagram of the interrupt control unit.

Table 10.1 Specifications of the Interrupt Control Unit

Item		Description
Interrupts	Peripheral function interrupts	Interrupts from peripheral modules • Number of sources: 116 • Interrupt detection: Edge detection/level detection Edge detection or level detection is determined for each source of connected peripheral modules.
	External interrupts	Interrupts from pins IRQ15 to IRQ0 • Number of sources: 16 • Interrupt detection: Low level/falling edge/rising edge/rising and falling edges One of these detection methods can be set for each source.
Non-maskable interrupt	NMI pin interrupts	Interrupts from the NMI pin • Number of sources: 1 • Interrupt detection: Falling edge/rising edge
Interrupt priority		Specified by registers.
Vector address		Since a vector address is allocated to each interrupt source, interrupt sources need not be identified by the software program.
Fast interrupt function		Faster interrupt processing of the CPU can be set only for a single interrupt source.
DTC/DMAC control		The DTC and DMAC can be activated by interrupt sources. • Number of DTC activating sources: 86 (70 peripheral function interrupts + 16 external interrupts) • Number of DMAC activating sources: 42 (38 peripheral function interrupts + 4 external interrupts)
Return from low power consumption modes		• Sleep mode: Return is initiated by NMI pin interrupts or any other interrupts. • All-module clock stop mode: Return is initiated by NMI pin interrupts, external interrupts, or peripheral module interrupts (WDT and TMR) • Software standby mode: Return is initiated by NMI pin interrupts or external interrupts.

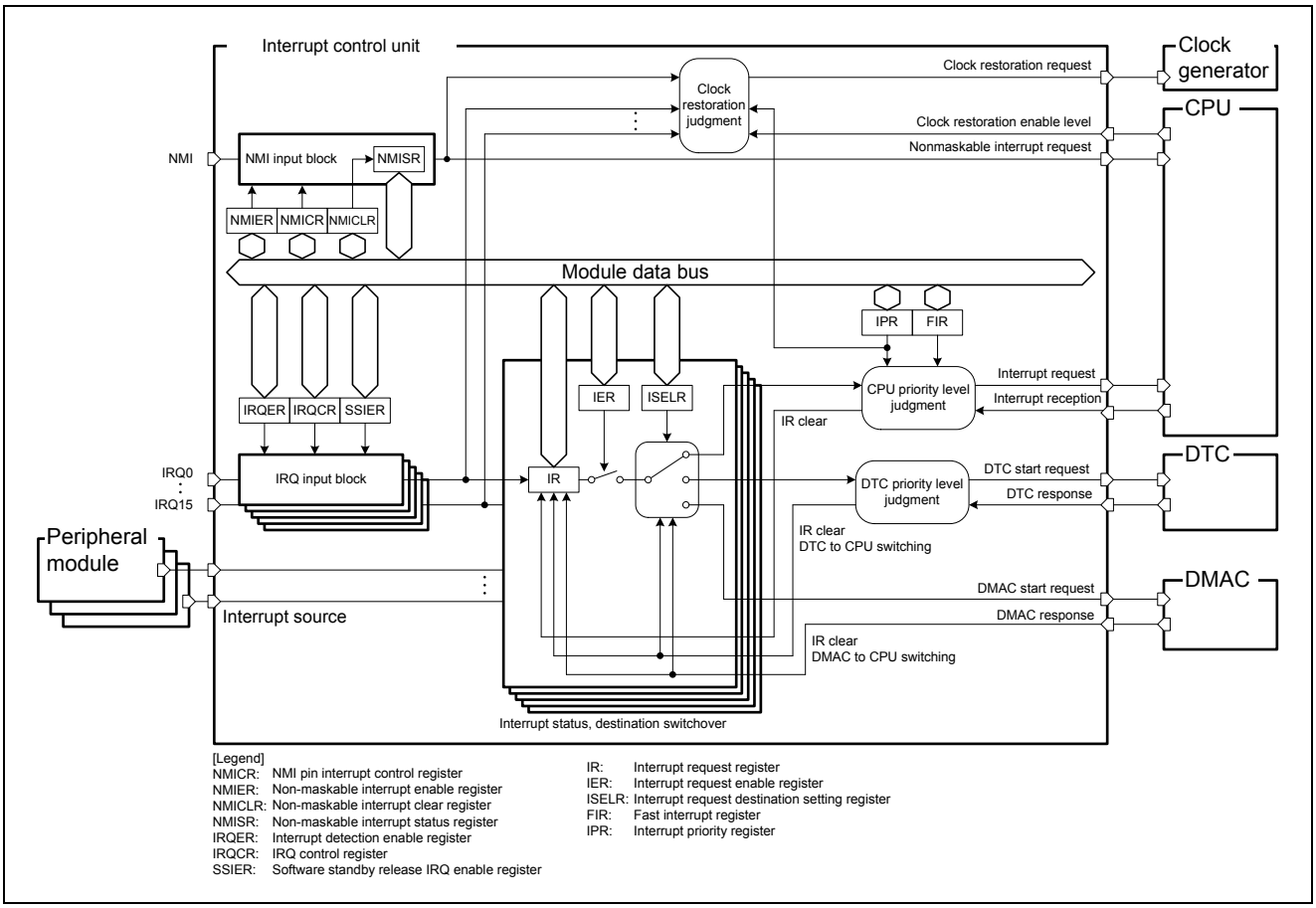


Figure 10.1 Block Diagram of Interrupt Control Unit

Table 10.2 shows the input/output pins of the interrupt control unit.

Table 10.2 Pin Configuration of ICU

Pin Name	I/O	Description
NMI	Input	Non-maskable interrupt request pin
IRQ15 to IRQ0	Input	External interrupt request pins

10.2 Register Descriptions

Table 10.3 lists the registers of the interrupt control unit.

Table 10.3 Registers of the Interrupt Control Unit

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt request register 016	IR016	00h	0008 7010h	8
Interrupt request register 021	IR021	00h	0008 7015h	8
Interrupt request register 023	IR023	00h	0008 7017h	8
Interrupt request register 028	IR028	00h	0008 701Ch	8
Interrupt request register 029	IR029	00h	0008 701Dh	8
Interrupt request register 030	IR030	00h	0008 701Eh	8
Interrupt request register 031	IR031	00h	0008 701Fh	8
Interrupt request register 064	IR064	00h	0008 7040h	8
Interrupt request register 065	IR065	00h	0008 7041h	8
Interrupt request register 066	IR066	00h	0008 7042h	8
Interrupt request register 067	IR067	00h	0008 7043h	8
Interrupt request register 068	IR068	00h	0008 7044h	8
Interrupt request register 069	IR069	00h	0008 7045h	8
Interrupt request register 070	IR070	00h	0008 7046h	8
Interrupt request register 071	IR071	00h	0008 7047h	8
Interrupt request register 072	IR072	00h	0008 7048h	8
Interrupt request register 073	IR073	00h	0008 7049h	8
Interrupt request register 074	IR074	00h	0008 704Ah	8
Interrupt request register 075	IR075	00h	0008 704Bh	8
Interrupt request register 076	IR076	00h	0008 704Ch	8
Interrupt request register 077	IR077	00h	0008 704Dh	8
Interrupt request register 078	IR078	00h	0008 704Eh	8
Interrupt request register 079	IR079	00h	0008 704Fh	8
Interrupt request register 096	IR096	00h	0008 7060h	8
Interrupt request register 098	IR098	00h	0008 7062h	8
Interrupt request register 099	IR099	00h	0008 7063h	8
Interrupt request register 100	IR100	00h	0008 7064h	8
Interrupt request register 101	IR101	00h	0008 7065h	8
Interrupt request register 104	IR104	00h	0008 7068h	8
Interrupt request register 105	IR105	00h	0008 7069h	8
Interrupt request register 106	IR106	00h	0008 706Ah	8
Interrupt request register 107	IR107	00h	0008 706Bh	8
Interrupt request register 108	IR108	00h	0008 706Ch	8
Interrupt request register 111	IR111	00h	0008 706Fh	8
Interrupt request register 112	IR112	00h	0008 7070h	8
Interrupt request register 115	IR115	00h	0008 7073h	8
Interrupt request register 116	IR116	00h	0008 7074h	8
Interrupt request register 117	IR117	00h	0008 7075h	8
Interrupt request register 118	IR118	00h	0008 7076h	8
Interrupt request register 120	IR120	00h	0008 7078h	8
Interrupt request register 121	IR121	00h	0008 7079h	8

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt request register 122	IR122	00h	0008 707Ah	8
Interrupt request register 123	IR123	00h	0008 707Bh	8
Interrupt request register 124	IR124	00h	0008 707Ch	8
Interrupt request register 125	IR125	00h	0008 707Dh	8
Interrupt request register 126	IR126	00h	0008 707Eh	8
Interrupt request register 127	IR127	00h	0008 707Fh	8
Interrupt request register 128	IR128	00h	0008 7080h	8
Interrupt request register 131	IR131	00h	0008 7083h	8
Interrupt request register 132	IR132	00h	0008 7084h	8
Interrupt request register 133	IR133	00h	0008 7085h	8
Interrupt request register 134	IR134	00h	0008 7086h	8
Interrupt request register 136	IR136	00h	0008 7088h	8
Interrupt request register 137	IR137	00h	0008 7089h	8
Interrupt request register 138	IR138	00h	0008 708Ah	8
Interrupt request register 139	IR139	00h	0008 708Bh	8
Interrupt request register 140	IR140	00h	0008 708Ch	8
Interrupt request register 141	IR141	00h	0008 708Dh	8
Interrupt request register 142	IR142	00h	0008 708Eh	8
Interrupt request register 145	IR145	00h	0008 7091h	8
Interrupt request register 146	IR146	00h	0008 7092h	8
Interrupt request register 149	IR149	00h	0008 7095h	8
Interrupt request register 150	IR150	00h	0008 7096h	8
Interrupt request register 151	IR151	00h	0008 7097h	8
Interrupt request register 152	IR152	00h	0008 7098h	8
Interrupt request register 154	IR154	00h	0008 709Ah	8
Interrupt request register 155	IR155	00h	0008 709Bh	8
Interrupt request register 156	IR156	00h	0008 709Ch	8
Interrupt request register 157	IR157	00h	0008 709Dh	8
Interrupt request register 158	IR158	00h	0008 709Eh	8
Interrupt request register 159	IR159	00h	0008 709Fh	8
Interrupt request register 160	IR160	00h	0008 70A0h	8
Interrupt request register 161	IR161	00h	0008 70A1h	8
Interrupt request register 162	IR162	00h	0008 70A2h	8
Interrupt request register 165	IR165	00h	0008 70A5h	8
Interrupt request register 166	IR166	00h	0008 70A6h	8
Interrupt request register 167	IR167	00h	0008 70A7h	8
Interrupt request register 168	IR168	00h	0008 70A8h	8
Interrupt request register 170	IR170	00h	0008 70AAh	8
Interrupt request register 171	IR171	00h	0008 70ABh	8
Interrupt request register 174	IR174	00h	0008 70AEh	8
Interrupt request register 175	IR175	00h	0008 70AFh	8
Interrupt request register 176	IR176	00h	0008 70B0h	8
Interrupt request register 177	IR177	00h	0008 70B1h	8
Interrupt request register 178	IR178	00h	0008 70B2h	8
Interrupt request register 179	IR179	00h	0008 70B3h	8
Interrupt request register 180	IR180	00h	0008 70B4h	8
Interrupt request register 181	IR181	00h	0008 70B5h	8

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt request register 182	IR182	00h	0008 70B6h	8
Interrupt request register 183	IR183	00h	0008 70B7h	8
Interrupt request register 184	IR184	00h	0008 70B8h	8
Interrupt request register 185	IR185	00h	0008 70B9h	8
Interrupt request register 198	IR198	00h	0008 70C6h	8
Interrupt request register 199	IR199	00h	0008 70C7h	8
Interrupt request register 200	IR200	00h	0008 70C8h	8
Interrupt request register 201	IR201	00h	0008 70C9h	8
Interrupt request register 214	IR214	00h	0008 70D6h	8
Interrupt request register 215	IR215	00h	0008 70D7h	8
Interrupt request register 216	IR216	00h	0008 70D8h	8
Interrupt request register 217	IR217	00h	0008 70D9h	8
Interrupt request register 218	IR218	00h	0008 70DAh	8
Interrupt request register 219	IR219	00h	0008 70DBh	8
Interrupt request register 220	IR220	00h	0008 70DCh	8
Interrupt request register 221	IR221	00h	0008 70DDh	8
Interrupt request register 222	IR222	00h	0008 70DEh	8
Interrupt request register 223	IR223	00h	0008 70DFh	8
Interrupt request register 224	IR224	00h	0008 70E0h	8
Interrupt request register 225	IR225	00h	0008 70E1h	8
Interrupt request register 226	IR226	00h	0008 70E2h	8
Interrupt request register 227	IR227	00h	0008 70E3h	8
Interrupt request register 228	IR228	00h	0008 70E4h	8
Interrupt request register 229	IR229	00h	0008 70E5h	8
Interrupt request register 230	IR230	00h	0008 70E6h	8
Interrupt request register 231	IR231	00h	0008 70E7h	8
Interrupt request register 232	IR232	00h	0008 70E8h	8
Interrupt request register 233	IR233	00h	0008 70E9h	8
Interrupt request register 234	IR234	00h	0008 70EAh	8
Interrupt request register 235	IR235	00h	0008 70EBh	8
Interrupt request register 236	IR236	00h	0008 70ECh	8
Interrupt request register 237	IR237	00h	0008 70EDh	8
Interrupt request register 238	IR238	00h	0008 70EEh	8
Interrupt request register 239	IR239	00h	0008 70EFh	8
Interrupt request register 240	IR240	00h	0008 70F0h	8
Interrupt request register 241	IR241	00h	0008 70F1h	8
Interrupt request register 246	IR246	00h	0008 70F6h	8
Interrupt request register 247	IR247	00h	0008 70F7h	8
Interrupt request register 248	IR248	00h	0008 70F8h	8
Interrupt request register 249	IR249	00h	0008 70F9h	8
Interrupt request register 250	IR250	00h	0008 70FAh	8
Interrupt request register 251	IR251	00h	0008 70FBh	8
Interrupt request register 252	IR252	00h	0008 70FCh	8
Interrupt request register 253	IR253	00h	0008 70FDh	8
Interrupt request destination setting register 028	ISELR028	00h	0008 711Ch	8
Interrupt request destination setting register 029	ISELR029	00h	0008 711Dh	8
Interrupt request destination setting register 030	ISELR030	00h	0008 711Eh	8

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt request destination setting register 031	ISELR031	00h	0008 711Fh	8
Interrupt request destination setting register 064	ISELR064	00h	0008 7140h	8
Interrupt request destination setting register 065	ISELR065	00h	0008 7141h	8
Interrupt request destination setting register 066	ISELR066	00h	0008 7142h	8
Interrupt request destination setting register 067	ISELR067	00h	0008 7143h	8
Interrupt request destination setting register 068	ISELR068	00h	0008 7144h	8
Interrupt request destination setting register 069	ISELR069	00h	0008 7145h	8
Interrupt request destination setting register 070	ISELR070	00h	0008 7146h	8
Interrupt request destination setting register 071	ISELR071	00h	0008 7147h	8
Interrupt request destination setting register 072	ISELR072	00h	0008 7148h	8
Interrupt request destination setting register 073	ISELR073	00h	0008 7149h	8
Interrupt request destination setting register 074	ISELR074	00h	0008 714Ah	8
Interrupt request destination setting register 075	ISELR075	00h	0008 714Bh	8
Interrupt request destination setting register 076	ISELR076	00h	0008 714Ch	8
Interrupt request destination setting register 077	ISELR077	00h	0008 714Dh	8
Interrupt request destination setting register 078	ISELR078	00h	0008 714Eh	8
Interrupt request destination setting register 079	ISELR079	00h	0008 714Fh	8
Interrupt request destination setting register 098	ISELR098	00h	0008 7162h	8
Interrupt request destination setting register 099	ISELR099	00h	0008 7163h	8
Interrupt request destination setting register 100	ISELR100	00h	0008 7164h	8
Interrupt request destination setting register 101	ISELR101	00h	0008 7165h	8
Interrupt request destination setting register 104	ISELR104	00h	0008 7168h	8
Interrupt request destination setting register 105	ISELR105	00h	0008 7169h	8
Interrupt request destination setting register 106	ISELR106	00h	0008 716Ah	8
Interrupt request destination setting register 107	ISELR107	00h	0008 716Bh	8
Interrupt request destination setting register 111	ISELR111	00h	0008 716Fh	8
Interrupt request destination setting register 112	ISELR112	00h	0008 7170h	8
Interrupt request destination setting register 117	ISELR117	00h	0008 7175h	8
Interrupt request destination setting register 118	ISELR118	00h	0008 7176h	8
Interrupt request destination setting register 122	ISELR122	00h	0008 717Ah	8
Interrupt request destination setting register 123	ISELR123	00h	0008 717Bh	8
Interrupt request destination setting register 124	ISELR124	00h	0008 717Ch	8
Interrupt request destination setting register 125	ISELR125	00h	0008 717Dh	8
Interrupt request destination setting register 127	ISELR127	00h	0008 717Fh	8
Interrupt request destination setting register 128	ISELR128	00h	0008 7180h	8
Interrupt request destination setting register 133	ISELR133	00h	0008 7185h	8
Interrupt request destination setting register 134	ISELR134	00h	0008 7186h	8
Interrupt request destination setting register 138	ISELR138	00h	0008 718Ah	8
Interrupt request destination setting register 139	ISELR139	00h	0008 718Bh	8
Interrupt request destination setting register 140	ISELR140	00h	0008 718Ch	8
Interrupt request destination setting register 141	ISELR141	00h	0008 718Dh	8
Interrupt request destination setting register 145	ISELR145	00h	0008 7191h	8
Interrupt request destination setting register 146	ISELR146	00h	0008 7192h	8
Interrupt request destination setting register 151	ISELR151	00h	0008 7197h	8
Interrupt request destination setting register 152	ISELR152	00h	0008 7198h	8
Interrupt request destination setting register 156	ISELR156	00h	0008 719Ch	8
Interrupt request destination setting register 157	ISELR157	00h	0008 719Dh	8

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt request destination setting register 158	ISELR158	00h	0008 719Eh	8
Interrupt request destination setting register 159	ISELR159	00h	0008 719Fh	8
Interrupt request destination setting register 161	ISELR161	00h	0008 71A1h	8
Interrupt request destination setting register 162	ISELR162	00h	0008 71A2h	8
Interrupt request destination setting register 167	ISELR167	00h	0008 71A7h	8
Interrupt request destination setting register 168	ISELR168	00h	0008 71A8h	8
Interrupt request destination setting register 174	ISELR174	00h	0008 71AEh	8
Interrupt request destination setting register 175	ISELR175	00h	0008 71AFh	8
Interrupt request destination setting register 177	ISELR177	00h	0008 71B1h	8
Interrupt request destination setting register 178	ISELR178	00h	0008 71B2h	8
Interrupt request destination setting register 180	ISELR180	00h	0008 71B4h	8
Interrupt request destination setting register 181	ISELR181	00h	0008 71B5h	8
Interrupt request destination setting register 183	ISELR183	00h	0008 71B7h	8
Interrupt request destination setting register 184	ISELR184	00h	0008 71B8h	8
Interrupt request destination setting register 198	ISELR198	00h	0008 71C6h	8
Interrupt request destination setting register 199	ISELR199	00h	0008 71C7h	8
Interrupt request destination setting register 200	ISELR200	00h	0008 71C8h	8
Interrupt request destination setting register 201	ISELR201	00h	0008 71C9h	8
Interrupt request destination setting register 215	ISELR215	00h	0008 71D7h	8
Interrupt request destination setting register 216	ISELR216	00h	0008 71D8h	8
Interrupt request destination setting register 219	ISELR219	00h	0008 71DBh	8
Interrupt request destination setting register 220	ISELR220	00h	0008 71DCh	8
Interrupt request destination setting register 223	ISELR223	00h	0008 71DFh	8
Interrupt request destination setting register 224	ISELR224	00h	0008 71E0h	8
Interrupt request destination setting register 227	ISELR227	00h	0008 71E3h	8
Interrupt request destination setting register 228	ISELR228	00h	0008 71E4h	8
Interrupt request destination setting register 231	ISELR231	00h	0008 71E7h	8
Interrupt request destination setting register 232	ISELR232	00h	0008 71E8h	8
Interrupt request destination setting register 235	ISELR235	00h	0008 71EBh	8
Interrupt request destination setting register 236	ISELR236	00h	0008 71ECh	8
Interrupt request destination setting register 239	ISELR239	00h	0008 71EFh	8
Interrupt request destination setting register 240	ISELR240	00h	0008 71F0h	8
Interrupt request destination setting register 247	ISELR247	00h	0008 71F7h	8
Interrupt request destination setting register 248	ISELR248	00h	0008 71F8h	8
Interrupt request destination setting register 251	ISELR251	00h	0008 71FBh	8
Interrupt request destination setting register 252	ISELR252	00h	0008 71FCh	8
Interrupt request enable register 02	IER02	00h	0008 7202h	8
Interrupt request enable register 03	IER03	00h	0008 7203h	8
Interrupt request enable register 08	IER08	00h	0008 7208h	8
Interrupt request enable register 09	IER09	00h	0008 7209h	8
Interrupt request enable register 0C	IER0C	00h	0008 720Ch	8
Interrupt request enable register 0D	IER0D	00h	0008 720Dh	8
Interrupt request enable register 0E	IER0E	00h	0008 720Eh	8
Interrupt request enable register 0F	IER0F	00h	0008 720Fh	8
Interrupt request enable register 10	IER10	00h	0008 7210h	8
Interrupt request enable register 11	IER11	00h	0008 7211h	8
Interrupt request enable register 12	IER12	00h	0008 7212h	8

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt request enable register 13	IER13	00h	0008 7213h	8
Interrupt request enable register 14	IER14	00h	0008 7214h	8
Interrupt request enable register 15	IER15	00h	0008 7215h	8
Interrupt request enable register 16	IER16	00h	0008 7216h	8
Interrupt request enable register 17	IER17	00h	0008 7217h	8
Interrupt request enable register 18	IER18	00h	0008 7218h	8
Interrupt request enable register 19	IER19	00h	0008 7219h	8
Interrupt request enable register 1A	IER1A	00h	0008 721Ah	8
Interrupt request enable register 1B	IER1B	00h	0008 721Bh	8
Interrupt request enable register 1C	IER1C	00h	0008 721Ch	8
Interrupt request enable register 1D	IER1D	00h	0008 721Dh	8
Interrupt request enable register 1E	IER1E	00h	0008 721Eh	8
Interrupt request enable register 1F	IER1F	00h	0008 721Fh	8
Interrupt priority register 00	IPR00	00h	0008 7300h	8
Interrupt priority register 01	IPR01	00h	0008 7301h	8
Interrupt priority register 02	IPR02	00h	0008 7302h	8
Interrupt priority register 04	IPR04	00h	0008 7304h	8
Interrupt priority register 05	IPR05	00h	0008 7305h	8
Interrupt priority register 06	IPR06	00h	0008 7306h	8
Interrupt priority register 07	IPR07	00h	0008 7307h	8
Interrupt priority register 20	IPR20	00h	0008 7320h	8
Interrupt priority register 21	IPR21	00h	0008 7321h	8
Interrupt priority register 22	IPR22	00h	0008 7322h	8
Interrupt priority register 23	IPR23	00h	0008 7323h	8
Interrupt priority register 24	IPR24	00h	0008 7324h	8
Interrupt priority register 25	IPR25	00h	0008 7325h	8
Interrupt priority register 26	IPR26	00h	0008 7326h	8
Interrupt priority register 27	IPR27	00h	0008 7327h	8
Interrupt priority register 28	IPR28	00h	0008 7328h	8
Interrupt priority register 29	IPR29	00h	0008 7329h	8
Interrupt priority register 2A	IPR2A	00h	0008 732Ah	8
Interrupt priority register 2B	IPR2B	00h	0008 732Bh	8
Interrupt priority register 2C	IPR2C	00h	0008 732Ch	8
Interrupt priority register 2D	IPR2D	00h	0008 732Dh	8
Interrupt priority register 2E	IPR2E	00h	0008 732Eh	8
Interrupt priority register 2F	IPR2F	00h	0008 732Fh	8
Interrupt priority register 40	IPR40	00h	0008 7340h	8
Interrupt priority register 44	IPR44	00h	0008 7344h	8
Interrupt priority register 45	IPR45	00h	0008 7345h	8
Interrupt priority register 46	IPR46	00h	0008 7346h	8
Interrupt priority register 47	IPR47	00h	0008 7347h	8
Interrupt priority register 4C	IPR4C	00h	0008 734Ch	8
Interrupt priority register 4D	IPR4D	00h	0008 734Dh	8
Interrupt priority register 4E	IPR4E	00h	0008 734Eh	8
Interrupt priority register 4F	IPR4F	00h	0008 734Fh	8
Interrupt priority register 50	IPR50	00h	0008 7350h	8
Interrupt priority register 51	IPR51	00h	0008 7351h	8

Register Name	Symbol	Value after Reset	Address	Access Size
Interrupt priority register 52	IPR52	00h	0008 7352h	8
Interrupt priority register 53	IPR53	00h	0008 7353h	8
Interrupt priority register 54	IPR54	00h	0008 7354h	8
Interrupt priority register 55	IPR55	00h	0008 7355h	8
Interrupt priority register 56	IPR56	00h	0008 7356h	8
Interrupt priority register 57	IPR57	00h	0008 7357h	8
Interrupt priority register 58	IPR58	00h	0008 7358h	8
Interrupt priority register 59	IPR59	00h	0008 7359h	8
Interrupt priority register 5A	IPR5A	00h	0008 735Ah	8
Interrupt priority register 5B	IPR5B	00h	0008 735Bh	8
Interrupt priority register 5C	IPR5C	00h	0008 735Ch	8
Interrupt priority register 5D	IPR5D	00h	0008 735Dh	8
Interrupt priority register 5E	IPR5E	00h	0008 735Eh	8
Interrupt priority register 5F	IPR5F	00h	0008 735Fh	8
Interrupt priority register 60	IPR60	00h	0008 7360h	8
Interrupt priority register 61	IPR61	00h	0008 7361h	8
Interrupt priority register 62	IPR62	00h	0008 7362h	8
Interrupt priority register 63	IPR63	00h	0008 7363h	8
Interrupt priority register 68	IPR68	00h	0008 7368h	8
Interrupt priority register 69	IPR69	00h	0008 7369h	8
Interrupt priority register 6A	IPR6A	00h	0008 736Ah	8
Interrupt priority register 6B	IPR6B	00h	0008 736Bh	8
Interrupt priority register 70	IPR70	00h	0008 7370h	8
Interrupt priority register 71	IPR71	00h	0008 7371h	8
Interrupt priority register 72	IPR72	00h	0008 7372h	8
Interrupt priority register 73	IPR73	00h	0008 7373h	8
Interrupt priority register 80	IPR80	00h	0008 7380h	8
Interrupt priority register 81	IPR81	00h	0008 7381h	8
Interrupt priority register 82	IPR82	00h	0008 7382h	8
Interrupt priority register 83	IPR83	00h	0008 7383h	8
Interrupt priority register 84	IPR84	00h	0008 7384h	8
Interrupt priority register 85	IPR85	00h	0008 7385h	8
Interrupt priority register 86	IPR86	00h	0008 7386h	8
Interrupt priority register 88	IPR88	00h	0008 7388h	8
Interrupt priority register 89	IPR89	00h	0008 7389h	8
Interrupt priority register 8A	IPR8A	00h	0008 738Ah	8
Interrupt priority register 8B	IPR8B	00h	0008 738Bh	8
Interrupt priority register 8C	IPR8C	00h	0008 738Ch	8
Interrupt priority register 8D	IPR8D	00h	0008 738Dh	8
Interrupt priority register 8E	IPR8E	00h	0008 738Eh	8
Interrupt priority register 8F	IPR8F	00h	0008 738Fh	8
Fast interrupt register	FIR	0000h	0008 73F0h	16
IRQ detection enable register 0	IRQER0	00h	0008 C300h	8
IRQ detection enable register 1	IRQER1	00h	0008 C301h	8
IRQ detection enable register 2	IRQER2	00h	0008 C302h	8
IRQ detection enable register 3	IRQER3	00h	0008 C303h	8
IRQ detection enable register 4	IRQER4	00h	0008 C304h	8

Register Name	Symbol	Value after Reset	Address	Access Size
IRQ detection enable register 5	IRQER5	00h	0008 C305h	8
IRQ detection enable register 6	IRQER6	00h	0008 C306h	8
IRQ detection enable register 7	IRQER7	00h	0008 C307h	8
IRQ detection enable register 8	IRQER8	00h	0008 C308h	8
IRQ detection enable register 9	IRQER9	00h	0008 C309h	8
IRQ detection enable register 10	IRQER10	00h	0008 C30Ah	8
IRQ detection enable register 11	IRQER11	00h	0008 C30Bh	8
IRQ detection enable register 12	IRQER12	00h	0008 C30Ch	8
IRQ detection enable register 13	IRQER13	00h	0008 C30Dh	8
IRQ detection enable register 14	IRQER14	00h	0008 C30Eh	8
IRQ detection enable register 15	IRQER15	00h	0008 C30Fh	8
IRQ control register 0	IRQCR0	00h	0008 C320h	8
IRQ control register 1	IRQCR1	00h	0008 C321h	8
IRQ control register 2	IRQCR2	00h	0008 C322h	8
IRQ control register 3	IRQCR3	00h	0008 C323h	8
IRQ control register 4	IRQCR4	00h	0008 C324h	8
IRQ control register 5	IRQCR5	00h	0008 C325h	8
IRQ control register 6	IRQCR6	00h	0008 C326h	8
IRQ control register 7	IRQCR7	00h	0008 C327h	8
IRQ control register 8	IRQCR8	00h	0008 C328h	8
IRQ control register 9	IRQCR9	00h	0008 C329h	8
IRQ control register 10	IRQCR10	00h	0008 C32Ah	8
IRQ control register 11	IRQCR11	00h	0008 C32Bh	8
IRQ control register 12	IRQCR12	00h	0008 C32Ch	8
IRQ control register 13	IRQCR13	00h	0008 C32Dh	8
IRQ control register 14	IRQCR14	00h	0008 C32Eh	8
IRQ control register 15	IRQCR15	00h	0008 C32Fh	8
Software standby release IRQ enable register	SSIER	0000h	0008 C340h	16
Non-maskable interrupt enable register	NMIER	00h	0008 C350h	8
NMI pin interrupt control register	NMICR	00h	0008 C351h	8
Non-maskable interrupt status register	NMISR	00h	0008 C352h	8
Non-maskable interrupt clear register	NMICLR	00h	0008 C353h	8

10.2.1 Interrupt Request Register i (IRi) (i = interrupt vector number)

Addresses: 0008 7010h to 0008 70FDh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	IR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	IR	Interrupt Status Flag	0: No interrupt request is generated 1: An interrupt request is generated	R/(W)*
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note: * In the case of the edge detection, only 0 can be written to clear the flag.
Writing 1 is enabled under the conditions described in section 10.7.3, Notes on DMAC/DTC Transfer using Communication Function (SCI, RIIC).
In the case of the level detection, writing to this flag is disabled.

The IRi register indicates interrupt request status.

IRi is provided for each interrupt source, where "i" shows an interrupt vector number.

For the correspondence between interrupt sources and interrupt vector numbers, see table 10.4, Interrupt Vector Table.

IR Flag (Interrupt Status Flag)

This bit is the status flag for the corresponding interrupt request. If the flag is set to 1 while interrupt requests are enabled by the IENj bit in IERi, an interrupt request signal is output to the destination that has been specified by the ISEL[1:0] bits in ISELRi.

When an interrupt request from the source is detected in the source of interrupt generation, the flag is set to 1. For the actual interrupt to be generated, the interrupt enable bit of the corresponding peripheral module must be set to enable interrupt output or detection of the interrupt signal on the given pin must be enabled by the IRQEN bit in IRQERn for interrupts on pin IRQn.

Interrupts are detected as either an edge or level of the interrupt signal. For details on interrupt detection, see section 10.4.2, Interrupt Status Flag.

- Peripheral module interrupts (except IR064 to IR079)

  Edge detection

  [Setting condition]

  - Generation of the interrupt signal from the source

  [Clearing conditions]

  - Writing of a 0 to the flag
    However, when the DTC or the DMAC is specified as an interrupt request destination, writing 0 to the IR flag is prohibited.
  - If the setting of the ISEL[1:0] bits in ISELRi is 00b, interrupt exception handling by the CPU
  - If the setting of the ISEL[1:0] bits in ISELRi is 01b and the setting of the DISEL bit in MRB of the DTC is 0, activation of the DTC

- If the setting of the ISEL[1:0] bits in ISELRi is 10b, activation of the DMAC

Level detection

[Setting condition]

- Generation of the interrupt signal from the source

[Clearing conditions]

- Clearing the status flag of the interrupt source
- Setting the interrupt enable bit of the corresponding interrupt source to disable the output of interrupt requests

- External interrupts (IR064 to IR079)

Edge detection (IRQMD[1:0] bits in IRQCRn = 01b/10b/11b)

[Setting condition]

- Generation of the interrupt signal from the source

[Clearing condition]

- Writing of a 0 to the flag
- If the setting of the ISEL[1:0] bits in ISELRi is 00b, interrupt exception handling by the CPU
- If the setting of the ISEL[1:0] bits in ISELRi is 01b and the setting of the DISEL bit in MRB of the DTC is 0, activation of the DTC
- If the setting of the ISEL[1:0] bits in ISELRi is 10b, activation of the DMAC

Level detection (IRQMD[1:0] bits in IRQCRn = 00b)

[Setting condition]

- Generation of the interrupt signal from the source

[Clearing conditions]

- Writing of 0 with the IRQn pin at the high level *1, *2
- Disabling the detection of interrupts by the setting of the IRQEN bit in IRQERn of pin IRQn

Notes: 1. For details on clearing in the case of level-detected external interrupts, see section 10.4.2.2, Interrupt Status Flag in Level Detection.

2. Do not write 0 to the corresponding IR flag while the signal on an IRQn pin is at the low level. While doing so temporarily clears the IR flag to 0 and withdraws the interrupt request, the IR flag is returned to 1 to generate the interrupt request again after two clock cycles of PCLK have elapsed.

10.2.2 Interrupt Request Destination Setting Register i (ISELRi) (i = interrupt vector number)

Addresses: 0008 711Ch to 0008 71FDh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	ISEL[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	ISEL[1:0]	Interrupt Destination	b1 b0 0 0: The request is sent to the CPU. 0 1: The request activates the DTC and is passed to the CPU on completion of data transfer. *1 1 0: The request activates the DMAC. 1 1: The request activates the DMAC and is then passed to the CPU. *1	R/W*2
b7 to b2	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Notes: 1. The ISEL[1:0] bits are automatically cleared to 00b on completion of DTC data transfer or DMAC activation. For details, refer to section 10.4.3, Selecting Interrupt Request Destinations.

2. The DMAC cannot be selected as an interrupt request destination for some interrupt sources. In such cases, the lowest 1 bit is valid and the upper 7 bits are reserved. The reserved bits are read as 0. The write value to the reserved bits should always be 0.

The ISELRi register is used to set the destination of an interrupt request.

ISEL[1:0] Bits (Interrupt Destination)

These bits specify the destination of an interrupt request.

The ISEL[1:0] bits should be modified after the interrupt request is disabled by the setting of the IENj bit in IERi.

The interrupt request destinations available for specification by the ISEL[1:0] bits depend on the interrupt source. For the correspondence between specifiable interrupt request destinations and interrupt sources, see table 10.4, Interrupt Vector Table.

If the setting of the IENj bit in IERi enables the interrupt request and the IR flag in the corresponding IRi is set to 1, the interrupt request is output to the destination that has been specified by the ISEL[1:0] bits. For details, see section 10.4.3, Selecting Interrupt Request Destinations.

10.2.3 Interrupt Request Enable Register m (IERi) (i = 02h to 1Fh)

Addresses: 0008 7202h to 0008 721Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	IEN7	IEN6	IEN5	IEN4	IEN3	IEN2	IEN1	IEN0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W*
b0	IEN0	Interrupt Request Enable 0	0: Interrupt request is disabled 1: Interrupt request is enabled	R/W
b1	IEN1	Interrupt Request Enable 1		R/W
b2	IEN2	Interrupt Request Enable 2		R/W
b3	IEN3	Interrupt Request Enable 3		R/W
b4	IEN4	Interrupt Request Enable 4		R/W
b5	IEN5	Interrupt Request Enable 5		R/W
b6	IEN6	Interrupt Request Enable 6		R/W
b7	IEN7	Interrupt Request Enable 7		R/W

Note: * Write 0 to the bit that corresponds to the interrupt source for reservation. Such a bit is read as 0.

The IERm register is used to enable or disable an interrupt request to the CPU and DMAC/DTC activation request.

IENj Bits (Interrupt Request Enable) (j = 0 to 7)

There is an interrupt request enable bit for each interrupt source.

For the correspondence between interrupt sources and interrupt request enable bits, see table 10.4, Interrupt Vector Table.

When an IENj bit is 1, the corresponding interrupt request is enabled. When an IENj bit is 0, the corresponding interrupt request is disabled.

The IRi.IR flag is not affected by the IENj bit. Even if the IENj bit is 0, the IR flag changes under the conditions described in section 10.2.1, Interrupt Request Register i (IRi) (i = interrupt vector number). The correspondence between the interrupt sources and the IERm.IENj bits, refer to table 10.4, Interrupt Vector Table. For IERm.IENj bit setting procedure for selection of the interrupt request destination, refer to section 10.4.3, Selecting Interrupt Request Destinations.

10.2.4 Interrupt Priority Register i (IPRi) (i = 00h to 8Fh)

Addresses: 0008 7300h to 0008 738Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	IPR[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	IPR[2:0]	Interrupt Priority Level Select	b2 b0 0 0 0: Level 0 (interrupt prohibited) 0 0 1: Level 1 0 1 0: Level 2 0 1 1: Level 3 1 0 0: Level 4 1 0 1: Level 5 1 1 0: Level 6 1 1 1: Level 7 (highest)	R/W
b7 to b3	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The IPRi register is used to set the priority level of an interrupt source.

IPRi is provided for each interrupt source group, where "i" is a serial number (00 to 8F) in hexadecimal notation.

For the correspondence between interrupt sources and groups, see table 10.4, Interrupt Vector Table.

IPR[2:0] Bits (Interrupt Priority Level Select)

These bits specify the priority level of interrupt requests.

Priority levels specified by the IPR[2:0] bits are used only to determine the priority of interrupt requests to the CPU, and do not affect activation requests to the DTC and DMAC.

The CPU accepts only interrupt requests higher than the priority level specified by the IPL[2:0] bits in PSW, and handles accepted interrupts.

If two or more interrupt requests are generated at the same time, their priority levels are compared with the value of the IPR[2:0] bits. If interrupt requests of the same priority level are generated at the same time, an interrupt request with a smaller vector number takes precedence.

Write to these bits while the interrupt request is disabled (IERm.IENj bit is 0).

10.2.5 Fast Interrupt Register (FIR)

Address: 0008 73F0h

	b15	b14	b13	b12	b11	b10	b9	b8
	FIEN	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	FVCT[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	FVCT[7:0]	Fast Interrupt Vector Number	Specify the vector number of an interrupt source to be a fast interrupt.	R/W
b14 to b8	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W
b15	FIEN	Fast Interrupt Enable	0: Fast interrupt is disabled 1: Fast interrupt is enabled	R/W

The FIR register is used to set up the fast interrupt.

The fast interrupt settings are only applicable to an interrupt request for the CPU. That is, they do not affect activation requests for the DTC and DMAC.

Write to these bits while the interrupt request is disabled (IERm.IENj bit is 0).

FVCT[7:0] Bits (Fast Interrupt Vector Number)

The FVCT[7:0] bits specify the vector number of a source for use as the fast interrupt.

When the CPU is the interrupt request destination and an interrupt request corresponding to the vector number specified with the FVCT[7:0] bits is generated while the FIEN bit is 1, the interrupt request is output to the CPU as the fast interrupt regardless of the setting of the IPRi register. However, to use a fast interrupt for recovery from software standby mode, refer to section 10.6.2, Returning from Software Standby Mode.

When the setting of the IENj bit in IERi has disabled interrupt requests from the interrupt source, such interrupt requests are not output to the CPU.

For settable vector numbers, see table 10.4, Interrupt Vector Table.

Do not write a reserved vector number to these bits.

FIEN Bit (Fast Interrupt Enable)

This bit enables the fast interrupt.

Setting this bit to 1 makes the interrupt request corresponding to the vector number specified in the FVCT[7:0] bits operate as the fast interrupt.

For details on the fast interrupt, see sections 9, Exceptions and 10.4.5, Fast Interrupt.

10.2.6 IRQ Detection Enable Register n (IRQERn) (n = 0 to 15)

Addresses: 0008 C300h to 0008 C30Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	IRQEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	IRQEN	IRQ Detection Enable	0: Detection of the signal on the corresponding IRQn pin as an external interrupt source is disabled 1: Detection of the signal on the corresponding IRQn pin as an external interrupt source is enabled (n = 0 to 15)	R/W
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The IRQERn register is used to enable or disable the detection of the corresponding external interrupt source (interrupt on the corresponding IRQn pin; n = 0 to 15).

IRQEN Bit (IRQ Enable)

This bit specifies whether to enable or disable the detection of the corresponding external interrupt source (interrupt on the corresponding IRQn pin; n = 0 to 15).

10.2.7 IRQ Control Register n (IRQCRn) (n = 0 to 15)

Addresses: 0008 C320h to 0008 C32Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	IRQMD[1:0]		—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W
b3, b2	IRQMD[1:0]	IRQ Detection Select	b3 b2 0 0: Low level 0 1: Falling edge 1 0: Rising edge 1 1: Rising and falling edges	R/W
b7 to b4	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The IRQCRn register is used to set up the external interrupt IRQn pin (n = 0 to 15).

The contents of this register should be modified while the corresponding interrupt request enable bit is set to disable an interrupt request (IERm.IENj bit is 0). After modification of the contents of this register, the IR flag should be cleared, and then the interrupt request enable bit should be set to enable the interrupt request.

IRQMD[1:0] Bits (IRQ Detection Sense Select)

These bits select the detection method for external interrupt source IRQn, where n = 0 to 15.

For setting to detect the corresponding external interrupt source, see section 10.4.6, External Interrupts.

10.2.8 Non-maskable Interrupt Enable Register (NMIER)

Address: 0008 C350h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	NMIEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NMIEN	NMI Enable	0: NMI pin interrupt is disabled 1: NMI pin interrupt is enabled	R/W*
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note: * A 1 can be written to this bit only once, and subsequent write accesses are no longer enabled.

The NMIER register is used to enable the non-maskable interrupt.

NMIEN Bit (NMI Enable)

This bit enables interrupts by the signal on the NMI pin.

A 1 can be written to this bit only once. Once the interrupt has been enabled, further write access is not possible.

Do not write 0 to this bit. The NMI cannot be disabled once it has been enabled.

10.2.9 NMI Pin Interrupt Control Register (NMICR)

Address: 0008 C351h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	NMIMD	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W
b3	NMIMD	NMI Detection Select	0: Falling edge 1: Rising edge	R/W
b7 to b4	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

The NMICR register is used to set up the NMI (interrupt on the NMI pin).

Change the setting before enabling the NMI (setting the NMIEN bit in NMIER to 1).

NMIMD Bit (NMI Detection Sense Select)

This bit sets the detection method for the NMI.

10.2.10 Non-maskable Interrupt Status Register (NMISR)

Address: 0008 C352h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	NMIST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NMIST	NMI Status Flag	0: No NMI pin request is generated 1: An NMI pin request is generated	R
b7 to b1	—	Reserved	These bits are read as 0 and cannot be modified.	R

The NMISR register is used to monitor the non-maskable interrupt status.

To clear the NMISR.NMIST flag to 0, set the NMICLR.NMICLR bit to 1. After that, confirm that the NMISR.NMIST flag is 0, and then execute the next instruction.

NMIST Flag (NMI Status Flag)

The NMIST flag indicates the NMI pin interrupt request.

This is a read-only flag and is cleared by the NMICR bit in NMICLR.

[Setting condition]

- This flag is set to 1 when an edge specified by the NMIMD bit in NMICR is input to the NMI pin while the NMIEN bit in NMIER is 1 (NMI pin interrupt enable).

[Clearing condition]

- This flag is cleared to 0 by writing 1 to the NMICLR bit in NMICLR.

10.2.11 Non-maskable Interrupt Clear Register (NMICLR)

Address: 0008 C353h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	NMICLR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	NMICLR	NMI Clear	This bit is always read as 0. Writing 1 to this bit clears the NMIST flag in NMISR. Writing 0 to this bit has no effect.	R/W*
b7 to b1	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note: * Only 1 can be written to this bit.

The NMICLR register is used to clear the non-maskable interrupt status register (NMISR).

NMICLR Bit (NMI Clear)

Writing 1 to this bit clears the NMIST flag in NMISR.

The NMICLR bit does not retain the "1" state. This bit is always read as 0.

10.2.12 Software Standby Release IRQ Enable Register (SSIER)

Address: 0008 C340h

	b15	b14	b13	b12	b11	b10	b9	b8
	SSI15	SSI14	SSI13	SSI12	SSI11	SSI10	SSI9	SSI8
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	SSI7	SSI6	SSI5	SSI4	SSI3	SSI2	SSI1	SSI0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SSI0	Software Standby Release IRQ	0: The signal on the corresponding IRQn pin as an external interrupt source is not sampled in the software standby state. 1: When the signal on the corresponding IRQn pin as an external interrupt source is generated in the software standby state, the interrupt control unit returns from the software standby state after the oscillation settling time. (n = 0 to 15)	R/W
b1	SSI1			R/W
b2	SSI2			R/W
b3	SSI3			R/W
b4	SSI4			R/W
b5	SSI5			R/W
b6	SSI6			R/W
b7	SSI7			R/W
b8	SSI8			R/W
b9	SSI9			R/W
b10	SSI10			R/W
b11	SSI11			R/W
b12	SSI12			R/W
b13	SSI13			R/W
b14	SSI14			R/W
b15	SSI15			R/W

The SSIER register is used to set whether to use the IRQn pin (n = 0 to 15) as a source that allows the interrupt control unit to return from the software standby state.

SSIj Bits (j = 0 to 15) (Software Standby Release IRQ)

These bits specify whether to use the IRQn pin corresponding to the bit number as a source that allows the interrupt control unit to return from the software standby state.

For how to set up return from the software standby state, see section 10.6.2, Returning from Software Standby Mode.

10.3 Vector Table

The interrupt control unit detects two types of interrupt exceptions: maskable interrupts and the non-maskable interrupt.

When the CPU accepts an interrupt or non-maskable interrupt, it acquires a four-byte vector address from the vector table.

10.3.1 Interrupt Vector Table

The interrupt vector table is placed in the 1024-byte range (4 bytes x 256 sources) beginning at the address specified in the interrupt table register (INTB) of the CPU. Write a value to the INTB register before enabling interrupts. Setting this to a multiple of four speeds up the execution of interrupt exception handling.

Table 10.4 shows the interrupt vector table. "Sstb recovery" means recovery from software (S/W) standby mode, and "Sacs recovery" means recovery from all-module clock stop mode.

Table 10.4 Interrupt Vector Table

Priority	Interrupt Request Source	Name	Vector Number	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination					IER	IPR
						CPU	DTC	DMAC	Sstb Recovery	Sacs Recovery		
High	—	Reserved	0	0000h	—	×	×	×	×	×	—	—
↑		Reserved	1	0004h	—	×	×	×	×	×	—	—
		Reserved	2	0008h	—	×	×	×	×	×	—	—
		Reserved	3	000Ch	—	×	×	×	×	×	—	—
		Reserved	4	0010h	—	×	×	×	×	×	—	—
		Reserved	5	0014h	—	×	×	×	×	×	—	—
		Reserved	6	0018h	—	×	×	×	×	×	—	—
		Reserved	7	001Ch	—	×	×	×	×	×	—	—
		Reserved	8	0020h	—	×	×	×	×	×	—	—
		Reserved	9 to 15	0024h to 003Ch	—	×	×	×	×	×	—	—
	Bus error	BUSERR	16	0040h	Level	√	×	×	×	×	IER02.IEN0	IPR00
	—	Reserved	17	0044h	—	×	×	×	×	×	IER02. EN1	—
		Reserved	18	0048h	—	×	×	×	×	×	IER02. EN2	—
		Reserved	19	004Ch	—	×	×	×	×	×	IER02. EN3	—
		Reserved	20	0050h	—	×	×	×	×	×	IER02. EN4	—
	FCU	FIFERR	21	0054h	Level	√	×	×	×	×	IER02.IEN5	IPR01
		Reserved	22	0058h	—	×	×	×	×	×	IER02.IEN6	—
		FRDYI	23	005Ch	Edge	√	×	×	×	×	IER02.IEN7	IPR02
	—	Reserved	24	0060h	—	×	×	×	×	×	IER03.IEN0	—
		Reserved	25	0064h	—	×	×	×	×	×	IER03.IEN1	—
		Reserved	26	0068h	—	×	×	×	×	×	IER03.IEN2	—
		Reserved	27	006Ch	—	×	×	×	×	×	IER03.IEN3	—
	CMT unit 0	CMT0	28	0070h	Edge	√	√	√	×	×	IER03.IEN4	IPR04
		CMT1	29	0074h	Edge	√	√	√	×	×	IER03.IEN5	IPR05
	CMT unit 1	CMT2	30	0078h	Edge	√	√	√	×	×	IER03.IEN6	IPR06
↓		CMT3	31	007Ch	Edge	√	√	√	×	×	IER03.IEN7	IPR07
Low	—	Reserved	32 to 63	0080h to 00FCh	—	×	×	×	×	×	—	—

Priority	Interrupt Request Source	Name	Vector Number	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination					IER	IPR
						CPU	DTC	DMAC	Sstb Recovery	Sacs Recovery		
High	External	IRQ0	64	0100h	Edge/Level	√	√	√	√	√	IER08.IEN0	IPR20
↑	pin	IRQ1	65	0104h	Edge/Level	√	√	√	√	√	IER08.IEN1	IPR21
		IRQ2	66	0108h	Edge/Level	√	√	√	√	√	IER08.IEN2	IPR22
		IRQ3	67	010Ch	Edge/Level	√	√	√	√	√	IER08.IEN3	IPR23
		IRQ4	68	0110h	Edge/Level	√	√	×	√	√	IER08.IEN4	IPR24
		IRQ5	69	0114h	Edge/Level	√	√	×	√	√	IER08.IEN5	IPR25
		IRQ6	70	0118h	Edge/Level	√	√	×	√	√	IER08.IEN6	IPR26
		IRQ7	71	011Ch	Edge/Level	√	√	×	√	√	IER08.IEN7	IPR27
		IRQ8	72	0120h	Edge/Level	√	√	×	√	√	IER09.IEN0	IPR28
		IRQ9	73	0124h	Edge/Level	√	√	×	√	√	IER09.IEN1	IPR29
		IRQ10	74	0128h	Edge/Level	√	√	×	√	√	IER09.IEN2	IPR2A
		IRQ11	75	012Ch	Edge/Level	√	√	×	√	√	IER09.IEN3	IPR2B
		IRQ12	76	0130h	Edge/Level	√	√	×	√	√	IER09.IEN4	IPR2C
		IRQ13	77	0134h	Edge/Level	√	√	×	√	√	IER09.IEN5	IPR2D
		IRQ14	78	0138h	Edge/Level	√	√	×	√	√	IER09.IEN6	IPR2E
		IRQ15	79	013Ch	Edge/Level	√	√	×	√	√	IER09.IEN7	IPR2F
	—	Reserved	80 to 95	0140h to 017Ch	—	×	×	×	×	×	—	—
	WDT	WOVI	96	0180h	Edge	√	×	×	×	√	IER0C.IEN0	IPR40
		Reserved	97	0184h	—	×	×	×	×	×	IER0C.IEN1	—
	AD0	ADI0	98	0188h	Edge	√	√	√	×	×	IER0C.IEN2	IPR44
	AD1	ADI1	99	018Ch	Edge	√	√	√	×	×	IER0C.IEN3	IPR45
	AD2	ADI2	100	0190h	Edge	√	√	√	×	×	IER0C.IEN4	IPR46
	AD3	ADI3	101	0194h	Edge	√	√	√	×	×	IER0C.IEN5	IPR47
	—	Reserved	102	0198h	—	×	×	×	×	×	IER0C.IEN6	—
		Reserved	103	019Ch	—	×	×	×	×	×	IER0C.IEN7	—
	TPU0	TGI0A	104	01A0h	Edge	√	√	√	×	×	IER0D.IEN0	IPR4C
		TGI0B	105	01A4h	Edge	√	√	×	×	×	IER0D.IEN1	
		TGI0C	106	01A8h	Edge	√	√	×	×	×	IER0D.IEN2	
		TGI0D	107	01ACh	Edge	√	√	×	×	×	IER0D.IEN3	
		TCI0V	108	01B0h	Edge	√	×	×	×	×	IER0D.IEN4	IPR4D
		Reserved	109	01B4h	—	×	×	×	×	×	IER0D.IEN5	—
		Reserved	110	01B8h	—	×	×	×	×	×	IER0D.IEN6	—
	TPU1	TGI1A	111	01BCh	Edge	√	√	√	×	×	IER0D.IEN7	IPR4E
		TGI1B	112	01C0h	Edge	√	√	×	×	×	IER0E.IEN0	
		Reserved	113	01C4h	—	×	×	×	×	×	IER0E.IEN1	—
		Reserved	114	01C8h	—	×	×	×	×	×	IER0E.IEN2	—
		TCI1V	115	01CCh	Edge	√	×	×	×	×	IER0E.IEN3	IPR4F
		TCI1U	116	01D0h	Edge	√	×	×	×	×	IER0E.IEN4	
	TPU2	TGI2A	117	01D4h	Edge	√	√	√	×	×	IER0E.IEN5	IPR50
		TGI2B	118	01D8h	Edge	√	√	×	×	×	IER0E.IEN6	
		Reserved	119	01DCh	—	×	×	×	×	×	IER0E.IEN7	—
↓		TCI2V	120	01E0h	Edge	√	×	×	×	×	IER0F. EN0	IPR51
Low		TCI2U	121	01E4h	Edge	√	×	×	×	×	IER0F. EN1	

Priority	Interrupt Request Source	Name	Vector Number	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination					IER	IPR
						CPU	DTC	DMAC	Sstb Recovery	Sacs Recovery		
High ↑	TPU3	TGI3A	122	01E8h	Edge	√	√	√	×	×	IER0F. EN2	IPR52
		TGI3B	123	01ECh	Edge	√	√	×	×	×	IER0F. EN3	
		TGI3C	124	01F0h	Edge	√	√	×	×	×	IER0F. EN4	
		TGI3D	125	01F4h	Edge	√	√	×	×	×	IER0F. EN5	
		TCI3V	126	01F8h	Edge	√	×	×	×	×	IER0F. EN6	IPR53
	TPU4	TGI4A	127	01FCh	Edge	√	√	√	×	×	IER0F. EN7	IPR54
		TGI4B	128	0200h	Edge	√	√	×	×	×	IER10.IEN0	
		Reserved	129	0204h	—	×	×	×	×	×	IER10.IEN1	—
		Reserved	130	0208h	—	×	×	×	×	×	IER10.IEN2	—
		TCI4V	131	020Ch	Edge	√	×	×	×	×	IER10.IEN3	IPR55
		TCI4U	132	0210h	Edge	√	×	×	×	×	IER10.IEN4	
	TPU5	TGI5A	133	0214h	Edge	√	√	√	×	×	IER10.IEN5	IPR56
		TGI5B	134	0218h	Edge	√	√	×	×	×	IER10.IEN6	
		Reserved	135	021Ch	—	×	×	×	×	×	IER10.IEN7	—
		TCI5V	136	0220h	Edge	√	×	×	×	×	IER11.IEN0	IPR57
		TCI5U	137	0224h	Edge	√	×	×	×	×	IER11.IEN1	
	TPU6	TGI6A	138	0228h	Edge	√	√	√	×	×	IER11.IEN2	IPR58
		TGI6B	139	022Ch	Edge	√	√	×	×	×	IER11.IEN3	
		TGI6C	140	0230h	Edge	√	√	×	×	×	IER11.IEN4	
		TGI6D	141	0234h	Edge	√	√	×	×	×	IER11.IEN5	
		TCI6V	142	0238h	Edge	√	×	×	×	×	IER11.IEN6	IPR59
		Reserved	143	023Ch	—	×	×	×	×	×	IER11.IEN7	—
		Reserved	144	0240h	—	×	×	×	×	×	IER12.IEN0	—
	TPU7	TGI7A	145	0244h	Edge	√	√	√	×	×	IER12.IEN1	IPR5A
		TGI7B	146	0248h	Edge	√	√	×	×	×	IER12.IEN2	
		Reserved	147	024Ch	—	×	×	×	×	×	IER12.IEN3	—
		Reserved	148	0250h	—	×	×	×	×	×	IER12.IEN4	—
		TCI7V	149	0254h	Edge	√	×	×	×	×	IER12.IEN5	IPR5B
		TCI7U	150	0258h	Edge	√	×	×	×	×	IER12.IEN6	
	TPU8	TGI8A	151	025Ch	Edge	√	√	√	×	×	IER12.IEN7	IPR5C
		TGI8B	152	0260h	Edge	√	√	×	×	×	IER13.IEN0	
		Reserved	153	0264h	—	×	×	×	×	×	IER13.IEN1	—
		TCI8V	154	0268h	Edge	√	×	×	×	×	IER13.IEN2	IPR5D
		TCI8U	155	026Ch	Edge	√	×	×	×	×	IER13.IEN3	
	TPU9	TGI9A	156	0270h	Edge	√	√	√	×	×	IER13.IEN4	IPR5E
		TGI9B	157	0274h	Edge	√	√	×	×	×	IER13.IEN5	
		TGI9C	158	0278h	Edge	√	√	×	×	×	IER13.IEN6	
		TGI9D	159	027Ch	Edge	√	√	×	×	×	IER13.IEN7	
		TCI9V	160	0280h	Edge	√	×	×	×	×	IER14.IEN0	IPR5F
	TPU10	TGI10A	161	0284h	Edge	√	√	√	×	×	IER14. EN1	IPR60
		TGI10B	162	0288h	Edge	√	√	×	×	×	IER14.IEN2	
		Reserved	163	028Ch	—	×	×	×	×	×	IER14.IEN3	—
		Reserved	164	0290h	—	×	×	×	×	×	IER14.IEN4	—
↓ Low		TCI10V	165	0294h	Edge	√	×	×	×	×	IER14.IEN5	IPR61
		TCI10U	166	0298h	Edge	√	×	×	×	×	IER14.IEN6	

Priority	Interrupt Request Source	Name	Vector Number	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination					IER	IPR
						CPU	DTC	DMAC	Sstb Recovery	Sacs Recovery		
High ↑	TPU11	TGI11A	167	029Ch	Edge	√	√	√	×	×	IER14. EN7	PR62
		TGI11B	168	02A0h	Edge	√	√	×	×	×	IER15. EN0	
		Reserved	169	02A4h	—	×	×	×	×	×	IER15. EN1	—
		TCI11V	170	02A8h	Edge	√	×	×	×	×	IER15. EN2	IPR63
		TCI11U	171	02ACh	Edge	√	×	×	×	×	IER15. EN3	
	—	Reserved	172	02B0h	—	×	×	×	×	×	IER15. EN4	—
		Reserved	173	02B4h	—	×	×	×	×	×	IER15. EN5	—
	TMR0	CMIA0	174	02B8h	Edge	√	√	×	×	√	IER15. EN6	IPR68
		CMIB0	175	02BCh	Edge	√	√	×	×	√	IER15. EN7	
		OV 0	176	02C0h	Edge	√	×	×	×	√	IER16. EN0	
	TMR1	CMIA1	177	02C4h	Edge	√	√	×	×	√	IER16. EN1	IPR69
		CMIB1	178	02C8h	Edge	√	√	×	×	√	IER16. EN2	
		OVI1	179	02CCh	Edge	√	×	×	×	√	IER16. EN3	
	TMR2	CMIA2	180	02D0h	Edge	√	√	×	×	√	IER16. EN4	IPR6A
		CMIB2	181	02D4h	Edge	√	√	×	×	√	IER16. EN5	
		OVI2	182	02D8h	Edge	√	×	×	×	√	IER16. EN6	
	TMR3	CMIA3	183	02DCh	Edge	√	√	×	×	√	IER16. EN7	IPR6B
		CMIB3	184	02E0h	Edge	√	√	×	×	√	IER17. EN0	
		OVI3	185	02E4h	Edge	√	×	×	×	√	IER17. EN1	
	—	Reserved	186	02E8h	—	×	×	×	×	×	IER17. EN2	—
		Reserved	187	02ECh	—	×	×	×	×	×	IER17. EN3	—
		Reserved	188	02F0h	—	×	×	×	×	×	IER17. EN4	—
		Reserved	189	02F4h	—	×	×	×	×	×	IER17. EN5	—
		Reserved	190	02F8h	—	×	×	×	×	×	IER17. EN6	—
		Reserved	191	02FCh	—	×	×	×	×	×	IER17. EN7	—
		Reserved	192	0300h	—	×	×	×	×	×	IER18. EN0	—
		Reserved	193	0304h	—	×	×	×	×	×	IER18. EN1	—
		Reserved	194	0308h	—	×	×	×	×	×	IER18. EN2	—
		Reserved	195	030Ch	—	×	×	×	×	×	IER18. EN3	—
		Reserved	196	0310h	—	×	×	×	×	×	IER18. EN4	—
		Reserved	197	0314h	—	×	×	×	×	×	IER18. EN5	—
	DMAC	DMTEND0	198	0318h	Edge	√	√	×	×	×	IER18. EN6	PR70
		DMTEND1	199	031Ch	Edge	√	√	×	×	×	IER18. EN7	PR71
		DMTEND2	200	0320h	Edge	√	√	×	×	×	IER19. EN0	PR72
		DMTEND3	201	0324h	Edge	√	√	×	×	×	IER19. EN1	PR73
	—	Reserved	202	0328h	—	×	×	×	×	×	IER19. EN2	—
		Reserved	203	032Ch	—	×	×	×	×	×	IER19. EN3	—
		Reserved	204	0330h	—	×	×	×	×	×	IER19. EN4	—
		Reserved	205	0334h	—	×	×	×	×	×	IER19. EN5	—
↓ Low		Reserved	206	0338h	—	×	×	×	×	×	IER19. EN6	—

Priority	Interrupt Request Source	Name	Vector Number	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination					IER	IPR
						CPU	DTC	DMAC	Sstb Recovery	Sacs Recovery		
High ↑	—	Reserved	207	033Ch	—	×	×	×	×	×	IER19. EN7	—
		Reserved	208	0340h	—	×	×	×	×	×	IER1A.IEN0	—
		Reserved	209	0344h	—	×	×	×	×	×	IER1A.IEN1	—
		Reserved	210	0348h	—	×	×	×	×	×	IER1A.IEN2	—
		Reserved	211	034Ch	—	×	×	×	×	×	IER1A.IEN3	—
		Reserved	212	0350h	—	×	×	×	×	×	IER1A.IEN4	—
		Reserved	213	0354h	—	×	×	×	×	×	IER1A.IEN5	—
	SCI0	ERI0	214	0358h	Level	√	×	×	×	×	IER1A.IEN6	IPR80
		RXI0	215	035Ch	Edge	√	√	√	×	×	IER1A.IEN7	
		TXI0	216	0360h	Edge	√	√	√	×	×	IER1B.IEN0	
		TEI0	217	0364h	Level	√	×	×	×	×	IER1B.IEN1	
	SCI1	ERI1	218	0368h	Level	√	×	×	×	×	IER1B.IEN2	IPR81
		RXI1	219	036Ch	Edge	√	√	√	×	×	IER1B.IEN3	
		TXI1	220	0370h	Edge	√	√	√	×	×	IER1B.IEN4	
		TEI1	221	0374h	Level	√	×	×	×	×	IER1B.IEN5	
	SCI2	ERI2	222	0378h	Level	√	×	×	×	×	IER1B.IEN6	IPR82
		RXI2	223	037Ch	Edge	√	√	√	×	×	IER1B.IEN7	
		TXI2	224	0380h	Edge	√	√	√	×	×	IER1C. EN0	
		TEI2	225	0384h	Level	√	×	×	×	×	IER1C. EN1	
	SCI3	ERI3	226	0388h	Level	√	×	×	×	×	IER1C. EN2	IPR83
		RXI3	227	038Ch	Edge	√	√	√	×	×	IER1C. EN3	
		TXI3	228	0390h	Edge	√	√	√	×	×	IER1C. EN4	
		TEI3	229	0394h	Level	√	×	×	×	×	IER1C. EN5	
	SCI4	ERI4	230	0398h	Level	√	×	×	×	×	IER1C. EN6	IPR84
		RXI4	231	039Ch	Edge	√	√	√	×	×	IER1C. EN7	
		TXI4	232	03A0h	Edge	√	√	√	×	×	IER1D. EN0	
		TEI4	233	03A4h	Level	√	×	×	×	×	IER1D. EN1	
	SCI5	ERI5	234	03A8h	Level	√	×	×	×	×	IER1D. EN2	IPR85
		RXI5	235	03ACh	Edge	√	√	√	×	×	IER1D. EN3	
		TXI5	236	03B0h	Edge	√	√	√	×	×	IER1D. EN4	
		TEI5	237	03B4h	Level	√	×	×	×	×	IER1D. EN5	
	SCI6	ERI6	238	03B8h	Level	√	×	×	×	×	IER1D. EN6	IPR86
		RXI6	239	03BCh	Edge	√	√	√	×	×	IER1D. EN7	
		TXI6	240	03C0h	Edge	√	√	√	×	×	IER1E.IEN0	
		TEI6	241	03C4h	Level	√	×	×	×	×	IER1E.IEN1	
	—	Reserved	242	03C8h	—	×	×	×	×	×	IER1E.IEN2	—
		Reserved	243	03CCh	—	×	×	×	×	×	IER1E.IEN3	—
↓		Reserved	244	03D0h	—	×	×	×	×	×	IER1E.IEN4	—
Low		Reserved	245	03D4h	—	×	×	×	×	×	IER1E.IEN5	—

Priority	Interrupt Request Source	Name	Vector Number	Vector Address Offset	Form of Detection	Selectable Interrupt Request Destination					IER	IPR
						CPU	DTC	DMAC	Sstb Recovery	Sacs Recovery		
High ↑	RIIC0	ICEEI0	246	03D8h	Level	√	×	×	×	×	IER1E.IEN6	PR88
		ICRXI0	247	03DCh	Edge	√	√	√	×	×	IER1E.IEN7	PR89
		ICTXI0	248	03E0h	Edge	√	√	√	×	×	IER1F.IEN0	PR8A
		ICTEI0	249	03E4h	Level	√	×	×	×	×	IER1F.IEN1	PR8B
	RIIC1	ICEEI1	250	03E8h	Level	√	×	×	×	×	IER1F.IEN2	PR8C
		ICRXI1	251	03ECh	Edge	√	√	√	×	×	IER1F.IEN3	PR8D
		ICTXI1	252	03F0h	Edge	√	√	√	×	×	IER1F.IEN4	PR8E
		ICTEI1	253	03F4h	Level	√	×	×	×	×	IER1F.IEN5	PR8F
	—	Reserved	254	03F8h	—	×	×	×	×	×	IER1F.IEN6	—
↓ Low		Reserved	255	03FCh	—	×	×	×	×	×	IER1F.IEN7	—

[Legend] √: Selectable ×: Not selectable

10.3.2 Fast Interrupt Vector Address

The vector address for the interrupt that corresponds to the vector number setting of the fast interrupt is placed in the fast interrupt vector register (FINTV) of the CPU.

10.3.3 Non-maskable Interrupt Vector Address

The vector address of the non-maskable interrupt is FFFF FFF8h.

10.4 Operation

The interrupt control unit determines priority levels of interrupts and non-maskable interrupts and outputs interrupt request signals to the CPU, DTC and/or DMAC.

When the condition for the interrupt source is generated, the corresponding interrupt status flag (IR flag in IRi) is set and interrupt request signal is output to the request destination. For the interrupt request signals to be output to the interrupt request destination, the setting of the IENj bit in IERi must enable the interrupt. If multiple IR flags in IRi are set to 1 at the same time, the interrupt request signals from the highest priority sources for the respective interrupt request destinations are output to the CPU and/or DTC.*

Note: * When multiple interrupt requests that have been set up to activate the DMAC are generated simultaneously, the priority of the sources is determined by the DMAC.

10.4.1 Enabling and Disabling Interrupts

The following settings are required to enable an interrupt requests.

- In the case of interrupt requests from peripheral modules, enabling of interrupt output for the corresponding source by the setting of the interrupt enable bit (or bits) of the peripheral module
- In the case of external interrupts, enabling of interrupt output in response to signals on the corresponding IRQn pin by the setting of the IRQEN bit in IRQERn
- Enabling of the interrupt by the corresponding IENj bit in IERi

When an interrupt signal is generated while output for that interrupt source is enabled at the source for interrupt generation, the IR flag in the corresponding IRi register will be set.

If the corresponding IENj bit in IERi allows output of the interrupt request, the interrupt request corresponding to the IR flag in IRi is conveyed to the selected destination. If the IENj bit in IERi has been set to disable the interrupt request, the interrupt request corresponding to the IR flag in IRi retains the indication that the interrupt signal was generated.

That is, the setting of the IENj bit in IERi does not affect the operation of the IR flag in IRi.

10.4.2 Interrupt Status Flag

The interrupt status flag (IR flag) in IRi detects the corresponding interrupt signal and retains an indication that the request was generated.

There are two ways to detect interrupt sources: level detection and edge detection.

For interrupts from peripheral modules, detection is by either edge or level according to the source.

For the IRQn pins (n = 0 to 15) as interrupt sources, edge or level detection can be selected by the setting of the IRQMD[1:0] bits in IRQCRn.

For the interrupt request and the corresponding detection method of each interrupt request source, see table 10.4, Interrupt Vector Table.

10.4.2.1 Interrupt Status Flag in Edge Detection

Figure 10.2 shows the operation of the IR flag in IRi in the case of edge detection of peripheral module interrupts and external interrupts.

When an interrupt signal is generated, the IR flag in IRi is set to 1 and the interrupt request is conveyed to the selected destination immediately after the point of transition of the interrupt signal. If the destination accepts the interrupt request, the IR flag in IRi is automatically cleared to 0. Therefore, the software being executed does not have to clear the IR flag.

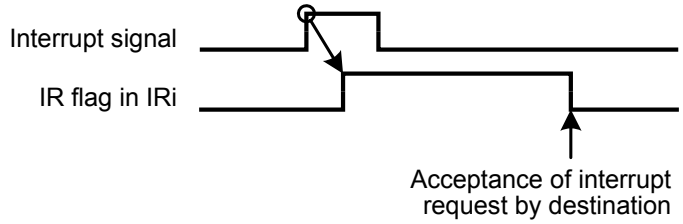


Figure 10.2 Operation of the IR Flag in IRi in the Case of Edge Detection

While the IR flag in IRi is set to 1 because an interrupt signal has been generated, re-generation of the interrupt signal is ignored. If the interrupt signal is generated after the IR flag in IRi has been cleared, the IR flag in IRi is re-set. Figure 10.3 shows the timing for re-setting of the IR flag in IRi.

When the communication function (SCI/RIIC) is combined with DTC/DMAC function, an interrupt request is ignored, and a transfer request may be lost. For details, refer to section 10.7.3, Notes on Transferring DMAC/DTC Using Communication Function (SCI, RIIC).

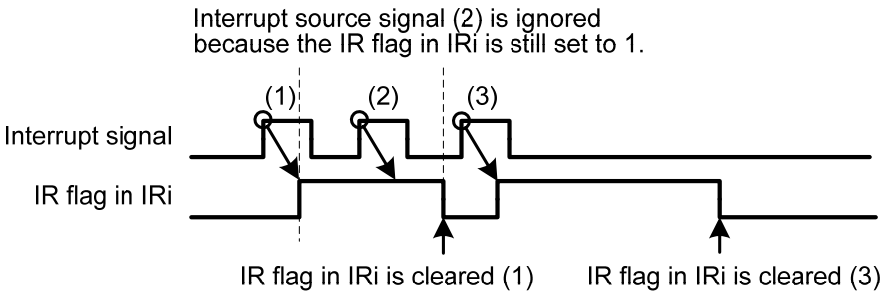


Figure 10.3 Timing for Re-setting the IR Flag in IRi

Once the IR flag in IRi has been set to 1, even if the interrupt is disabled at its source, that is, if output of the interrupt is disabled by the interrupt enable bit of the corresponding peripheral module or detection of an external interrupt on pin IRQn is disabled by the IRQEN bit in IRQERn, the IR flag in IRi is not affected and retains its value. Figure 10.4 shows operation when the interrupt is disabled at its source.

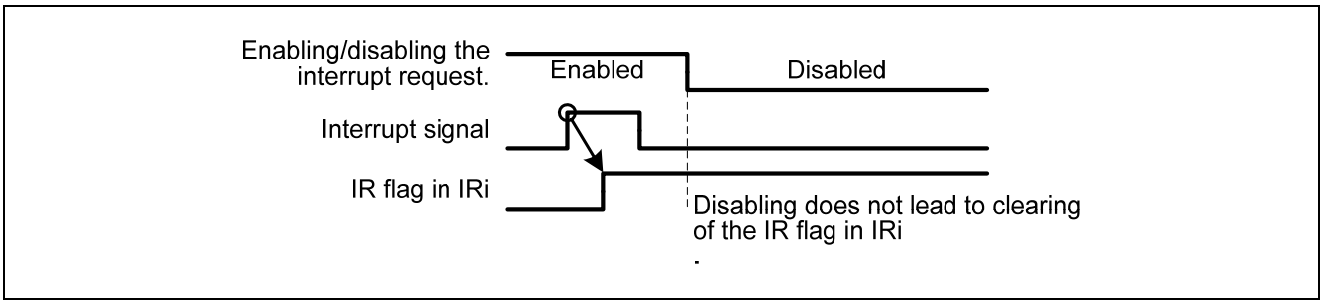


Figure 10.4 Relation between the IR Flag in IRi and Disabling of the Interrupt Sources

10.4.2.2 Interrupt Status Flag in Level Detection

Operation is individually described for the cases of level detection of peripheral module interrupts and external interrupts.

Figure 10.5 shows how the IR flag in IRi operates in the case of level detection of an interrupt from a peripheral function.

When the IR flag in IRi for an interrupt from a peripheral module has been set to 1, this setting is maintained while generation of the interrupt signal by the source continues. To clear the IR flag in IRi, software should clear the status flag at the source of the interrupt or change the interrupt enable bit at the source of the interrupt to disable interrupt generation. Also, after clearing the source of the interrupt, confirm that the IR flag in IRi has actually been cleared before executing further instructions.

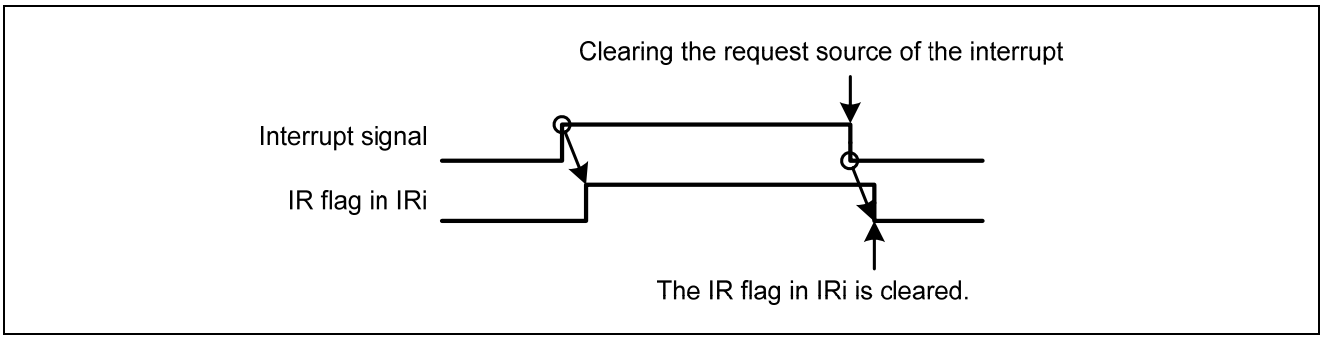


Figure 10.5 Operation of the IR Flag in IRi in the Case of Level Detection of a Peripheral Module Interrupt

Figure 10.6 shows how the IR flag in IRi operates in the case of level detection of an external interrupt.

If the setting of the IRQMD[1:0] bits in IRQCRn is for detection of the external interrupt as the low level of the signal, the interrupt source should maintain the low level on the IRQn pin until handling of the given interrupt. After that, the interrupt exception handling routine should return the input on the IRQn pin to the high level, which leads to clearing of the IR flag in IRi to 0 after four cycles of the PCLK clock. At least four cycles of PCLK can be secured by, for example, reading the Bj bit in Pm.PORT for the corresponding I/O pin and checking twice for the high level on the IRQn pin.

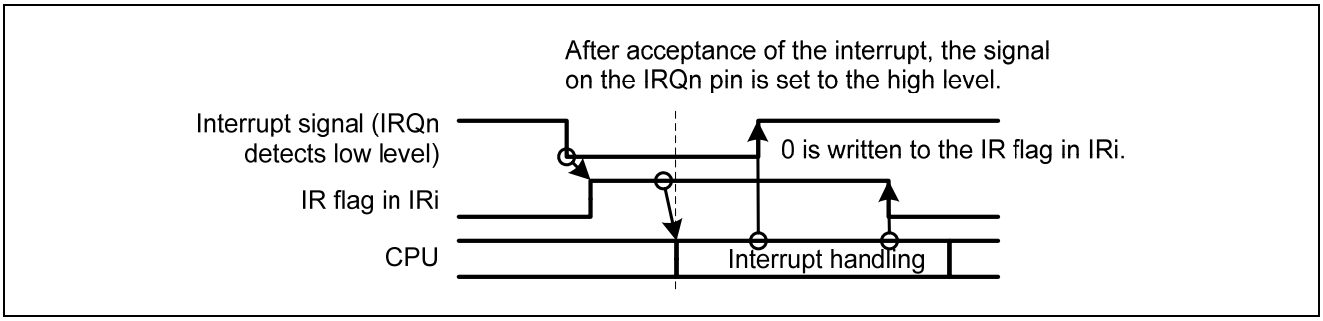


Figure 10.6 Operation of the IR Flag in IRi in the Case of Level Detection of an External Interrupt

Once the IR flag in IRi has been set to 1, if the interrupt is disabled at its source, that is, if output of the interrupt is disabled by the interrupt enable bit of the corresponding peripheral module or detection of an external interrupt on pin IRQn is disabled by the IRQEN bit in IRQERn, the IR flag in IRi is cleared. Figure 10.7 shows operation when the interrupt is disabled at its source.

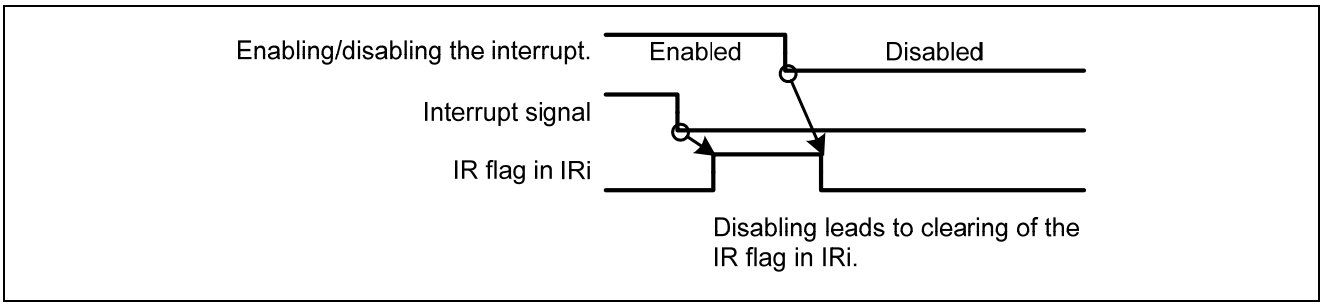


Figure 10.7 Relation between the IR Flag in IRi and Disabling of the Interrupt Source

10.4.3 Selecting Interrupt Request Destinations

Sources that can act as interrupts or activate the DTC and DMAC have ISEL[1:0] bits in the corresponding ISELRi for setting the destination of interrupt requests. The selectable destinations for each of the interrupt sources are fixed and they are listed in table 10.4, Interrupt Vector Table. Do not select a destination which is not indicated in the table.

The following four types of request-destination settings for the ISEL[1:0] bits in ISELRi are available.

1. Interrupt request for the CPU
2. Activate the DTC and convey the interrupt request to the CPU on completion of data transfer.
3. Request to activate the DMAC
4. Activate the DMAC and then convey the interrupt request to the CPU (without waiting for the completion of DMA transfer).

If the source is to activate the DTC or DMAC, use edge detection of the interrupt.

For most interrupts from peripheral modules, only edge detection is available.

If edge detection is to be used for an external interrupt, make the setting for edge detection in the IRQMD[1:0] bits in IRQCRn.

If the setting of the ISEL[1:0] bits in ISELRi is 00b, the interrupt control unit conveys interrupt requests to the CPU.

If the setting of the ISEL[1:0] bits in ISELRi is 01b, the interrupt control unit conveys an activation request to the DTC. Further operation is as follows, according to the setting of the DISEL bit in MRB of the DTC.

- When the DISEL bit in MRB of the DTC is set to 0, the DTC performs the specified number of data transfers. The value of the ISEL[1:0] bits in ISELRi is kept at 01b until the transfer counter reaches 0. On completion of data transfer (i.e. when the transfer counter reaches 0), the ISEL[1:0] bits are automatically updated to 00b. At this point, the interrupt control unit conveys the interrupt request to the CPU.
- When the DISEL bit in MRB of the DTC is set to 1, the ISEL[1:0] bits in ISELRi are automatically updated to 00b on completion of an individual data transfer, regardless of the transfer counter. At this point, the interrupt control unit conveys the interrupt request to the CPU.

In cases where the ISEL[1:0] bits in ISELRi are to be re-set to 01b after having been updated to 00b, modify the value of the bits within the corresponding interrupt exception handler. Furthermore, if re-activation of the DTC is required, ensure that generation of the interrupt signal is possible after setting the ISEL[1:0] bits in ISELRi to 01b.

If the setting of the ISEL[1:0] bits in ISELRi is 10b, the interrupt control unit conveys an activation request to the DMAC.

After DMAC activation, the value of the ISEL[1:0] bits in ISELRi is kept at 10b.

When the selected form of DMA transfer is consecutive-operand transfer or the same interrupt source activates multiple channels, regardless of the type of DMA transfer, enable the generation of further interrupts with the timing described below.

- When the form of DMA transfer is consecutive-operand transfer, make settings to enable the generation of a next interrupt by the source on completion of all DMA transfer on activated channels.[*1]
- When the same interrupt source activates multiple channels, regardless of the type of DMA transfer, make settings to enable the generation of a next interrupt by the source on completion of transfer on all channels.[*2]

Notes: 1. Single-operand transfer is transfer for a single operand per activation request. The IR flag in IRi is cleared by activation of transfer for the single operand. In nonstop transfer, one round of DMA transfer proceeds per activation request. The IR flag in IRi is cleared by activation of the DMA transfer. In consecutive-operand transfer, on the other hand, transfer for multiple operands per activation request is possible. The IR flag in IRi is cleared every operand transfer. If the source generates a further interrupt signal before transfer for all operands is complete, once the IR flag in IRi has been set to 1, it is cleared after transfer for individual operands.

2. In cases where the same interrupt source activates multiple channels of the DMAC, all specified channels are activated per activation request regardless of the form of DMA transfer. The IR flag in IRi is cleared every transfer on individual channels. If the source generates a further interrupt signal before transfer for all operands on all channels is complete, once the IR flag in IRi has been set to 1, it is cleared after transfer on individual channels.

If the setting of the ISEL[1:0] bits in ISELRi is 11b, the interrupt control unit activates the DAMC and then automatically updates the ISEL[1:0] bits in ISELRi to 00b without waiting for the completion of data transfer. At this point, the IR flag in IRi is not cleared and the interrupt request is conveyed to the CPU.

In cases where the ISEL[1:0] bits in ISELRi are to be re-set to 01b after having been updated to 00b, modify the value of the bits with the following timing.

- When the selected form of DMA transfer is single-operand transfer or nonstop transfer, modify the value of the bits within the corresponding interrupt exception handler.
- When the selected form of DMA transfer is consecutive-operand transfer, modify the value of the bits on completion of all DMA transfer on activated channels.[*1]
- When the same interrupt source is activating multiple channels, regardless of the type of DMA transfer, modify the value of the bits on completion of transfer on all channels.[*2]

Furthermore, if re-activation of the DMAC is required, ensure that generation of the interrupt signal is possible after setting the ISEL[1:0] bits in ISELRi to 11b.

Notes: 1. Single-operand transfer is transfer for a single operand per activation request. The ISEL[1:0] bits in ISELRi are automatically updated to 00b by activation of transfer for the single operand. In nonstop transfer, one round of DMA transfer proceeds per activation request. The ISEL[1:0] bits in ISELRi are automatically updated to 00b by activation of the DMA transfer. In consecutive-operand transfer, on the other hand, transfer for multiple operands per activation request is possible. The ISEL[1:0] bits in ISELRi are automatically updated to 00 every operand transfer. If the ISEL[1:0] bits in ISELRi are re-set to 11b before transfer for all operands is complete, the ISEL[1:0] bits in ISELRi are updated to 00b after transfer for individual operands.

2. In cases where the same interrupt source activates multiple channels of the DMAC, all specified channels are activated per activation request regardless of the form of DMA transfer. The ISEL[1:0] bits in ISELRi are automatically updated to 00b after transfer on individual channels. If the ISEL[1:0] bits in ISELRi are re-set to 11b before transfer for all operands on all channels is complete, the ISEL[1:0] bits in ISELRi are updated to 00b after transfer on individual channels.

10.4.4 Determining Priority

The interrupt control unit determines interrupt priority for each interrupt destination.

If multiple interrupt requests are generated for the same destination, the interrupt from the highest priority source is accepted. The method used to determine the priority depends on the interrupt request destination.

(1) Determining Priority when Interrupt Request Destination is CPU

For a group for which the ISEL[1:0] bits in ISELRi are set to 00b, the interrupt source with the larger value of the interrupt priority level select bits IPR[2:0] in IPRi takes precedence. If multiple interrupt sources that have the same priority level (same values of the IPR[2:0] bits in IPRi) are generated, the interrupt source with the smallest vector number takes precedence.

When an interrupt source specified as the fast interrupt (described in a later section) is generated, the interrupt request is conveyed to the CPU as an interrupt with the highest priority level (7), regardless of the value of the corresponding IPR[2:0] bits in IPRi and vector number.

(2) Determining Priority when the DTC is the Destination of the Interrupt Request

The IPR[2:0] bits in IPRi have no effect on a group for which 01b is set in the ISEL[1:0] bits in ISELRi. An interrupt source with a smaller vector number takes precedence.

(3) Determining Priority when the DMAC is the Destination of the Interrupt Request

For a group for which 10b or 11b is set in the ISEL[1:0] bits in ISELRi, the IPR[2:0] bits in IPRi have no effect. The interrupt priority is determined by the setting of the DMAC. See section 12, DMA Controller (DMAC).

10.4.5 Fast Interrupt

The fast interrupt is a facility for faster interrupt processing by the CPU. This function has no effect on activation requests for the DTC and DMAC.

By setting the FIEN bit in FIR to 1 and then setting the vector number of the interrupt source to be defined as the fast interrupt in the FVCT[7:0] bits of FIR, interrupts from the source thus defined are output to the CPU for handling as the fast interrupt.

The interrupt source selected for the fast interrupt has the highest priority regardless of the setting of the IPR[2:0] bits in IPRi. When the CPU is engaged in processing for a non-maskable interrupt or a level-7 interrupt, it accepts the fast interrupt after it has completed the current interrupt processing.

For details on the fast interrupt, see section 9, Exceptions.

10.4.6 External Interrupts

External interrupts are interrupts that have the signals on the IRQn pins (n = 0 to 15) as sources. Figure 10.8 is a block diagram of the circuit for an external interrupt.

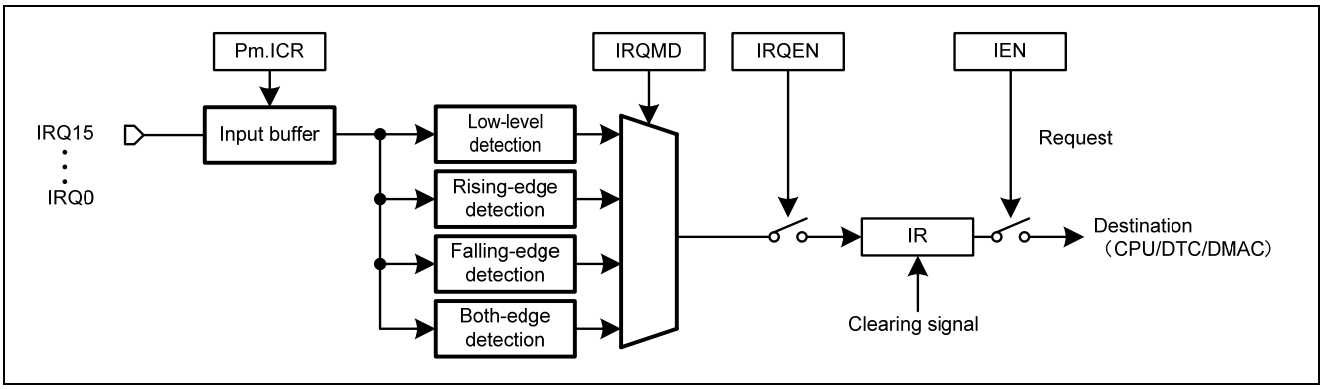


Figure 10.8 Block Diagram of External Interrupts

For external interrupts, level detection (low level) or edge detection (falling edge, rising edge, or both edges) is selected by the IRQMD[1:0] bits in IRQCRn.

To set the IRQMD[1:0] bits in IRQCRn, follow the procedure below.

1. Use the IRQEN bit in IRQERn and the IENj bit in IERi to disable detection and requesting of the external interrupt.
2. Set the IRQMD[1:0] bits in IRQCRn.
3. Clear the IR flag in IRi.
4. Use the IRQEN bit in IRQERn and IENj bit in IERi to enable detection and requesting of the external interrupt.

For details on operation in the cases of edge- and level-detected external interrupts, see section 10.4.2, Interrupt Status Flag.

When an external interrupt is in use, the input buffer of the IRQn pin should be enabled by the corresponding Bj bit in Pm.ICR.

When modifying the value of the Bj bit in Pm.ICR, follow the procedure below.

1. Use the IRQEN bit in IRQERn and the IENj bit in IERi to disable detection and requesting of the external interrupt.
2. Modify the setting of the Bj bit in Pm.ICR.
3. Clear the IR flag in IRi after four cycles of the PCLK clock.
4. Use the IRQEN bit in IRQERn and the IENj bit in IERi to enable detection and requesting of the external interrupt.

For the correspondence between the IRQn pins and the Bj bits in Pm.ICR, see section 14, I/O Ports.

10.5 Non-maskable Interrupt Operation

The interrupt on the non-maskable interrupt (NMI) pin serves as an NMI. Specifically, a rising or falling edge of the signal on the NMI pin issues an NMI request for the CPU. The DTC and DMAC are not selectable as destinations for the NMI. The NMI takes precedence over all other interrupts, including the fast interrupt.

Upon detection of an NMI, the NMI status flag (NMIST bit) in NMISR is set to 1, and an NMI request is issued for the CPU. An NMI request is accepted regardless of the settings of the I bit (interrupt enable bit) and IPL[2:0] bits (processor interrupt priority level) in the PSW of the CPU.

To clear the NMIST flag in NMISR, write 1 to the NMICLR bit in NMICLR. Then, before executing the next instruction, confirm that the NMIST flag in NMISR has been cleared.

To prevent malfunctions in systems that do not require interrupts via the NMI pin, the NMI is disabled by default. If a system is to use the NMI, the procedure below must be included at the beginning of processing by all programs.

Procedure for Using the NMI

1. Set the stack pointer (SP).
2. Make the detection setting for the NMI in the NMIMD bit.
3. Clear the NMIST flag in NMISR by writing 1 to the NMICLR bit in NMICLR, and then confirm that the flag is actually cleared.
4. Write 1 to the NMIEN bit in NMIER to enable the NMI.

After the NMIEN bit in NMIER is set to 1, subsequent write access to the bit is ignored. The NMI cannot be disabled.

This feature is essential if the NMI is in use, since it prevents unintentional disabling of the NMI due to a program crashing.

For the flow of non-maskable interrupt processing, see section 9, Exceptions.

10.6 Returning from Low Power Consumption Modes

The interrupt control unit is capable of returning operation from low power consumption modes in response to interrupts.

Table 10.5 shows the correspondence between low power consumption modes and the interrupt sources that are capable of initiating return from the individual modes.

Table 10.5 List of Interrupt Sources

Low Power Consumption Mode	Capable Interrupt Sources	Interrupt Control Unit Clock
Sleep	All interrupts including NMI pin interrupts	Runs
All-module clock stop	Peripheral function interrupts (WDT, TMR*), external interrupts, NMI pin interrupts	Runs
Software standby	External interrupts, NMI pin interrupts	Stopped

Note: * For details, see section 8, Low Power Consumption.

10.6.1 Returning from Sleep Mode and All-Module Clock Stop Mode

The interrupt control unit can return operation from sleep mode or all-module clock stop mode in response to any interrupts.

The following conditions apply.

1. The interrupt destination is the CPU.
2. The given interrupt request is enabled by the IENj bit in IERi.
3. The priority level of the interrupt is higher than that set by the IPL[2:0] bits in the PSW of the CPU.

10.6.2 Returning from Software Standby Mode

The interrupt control unit can return operation from software standby mode in response to the NMI or an external interrupt on the IRQn pins (n = 0 to 15).

When the NMI or an IRQn (n = 0 to 15) external interrupt is generated, the clock starts oscillating and the clock signal is supplied throughout the LSI, and interrupt processing starts.

For the NMI to act as the trigger for return from software standby mode, the NMIEN bit in NMIER must be set to 1 (enabling the NMI).

For an IRQn (n = 0 to 15) external interrupt to act as the trigger for return from software standby mode, the following conditions apply.

1. The SSIj (j = 0 to 15) bit in SSIER enables the source as a trigger for return.
2. The IRQEN bit in IRQERn enables the detection of external interrupts on the given IRQn pin.
3. The IENj bit in IERi enables the given IRQn pin interrupt request.
4. The ISEL[1:0] bits in ISELRi specify the CPU as the destination of the interrupt request.
5. The IPR[2:0] bits in IPRi specify a priority level higher than that set by the IPL[2:0] bits in the PSW of the CPU.*

Note: * An interrupt source which has been specified as the fast interrupt is the highest-priority interrupt (other than the NMI) regardless of the setting of the IPR[2:0] bits in IPRi. However, if the interrupt source specified as the fast interrupt is to be used as a trigger for return from software standby mode, the setting of the IPR[2:0] bits in IPRi for that interrupt source must satisfy the above relevant condition above.

To cancel software standby mode by an interrupt IRQ0 to IRQ15 for which edge detection is set, 0 should be written to the status flag (the IR bit in IRi of the ICU) of the corresponding interrupt at the beginning of the exception handling routine for the interrupt.

In addition, when an interrupt IRQ0 to IRQ15 is not set as a trigger for return from software standby mode, the input buffer of the corresponding pin becomes invalid in software standby mode and thus the input signal to the LSI is fixed high. In such a case, the interrupt status flag (ICU.IRi.IR) might be set to 1 depending on the state of the pin. Therefore, be sure to execute the WAIT instruction after an interrupt IRQ0 to IRQ15 that is not set as a trigger for cancelation source is masked by the IERi.IENj bit, or its interrupt priority level is made lower by the IPRi.IPR bit. Moreover, clear the interrupt status flag after returning from software standby mode.

For details on the low power consumption states, see section 8, Low Power Consumption.

10.7 Usage Notes

10.7.1 Notes when writing to the Register of the Interrupt Control Unit

The CPU executes the following instruction without waiting for the completion of previous writing to the register of the interrupt control unit. Thus, the following instruction might be executed before the previously written value is stored in the register. To prevent this, be sure to check the completion of writing to the register. In case when multiple registers are successively written to, be sure to check the completion of last writing. For details on checking the completion of writing, see section 5, I/O Registers.

For instance, when masking the interrupt that is not set as a trigger for return from software standby mode, set 0 to the IERi.IEj bit and execute the WAIT instruction before shifting to the software standby state. In this case, if the operation is shifted to the software standby state without waiting for the completion of previous writing, the masked interrupt might be used as a trigger for return. Be sure to check the completion of writing to the IERi.IEj bit before the WAIT instruction is executed.

10.7.2 Notes on the WAIT Instruction when the NMI Pin Interrupt is Used

The WAIT instruction should not be executed while the NMISR.NMIST flag is 1. Be sure to check that the NMISR.NMIST flag is 0 before executing the WAIT instruction.

10.7.3 Notes on Transferring DMAC/DTC Using Communication Function (SCI, RIIC)

When the DMAC/DTC is activated using an interrupt from the communication function, the DMAC/DTC cannot accept an activation request from the communication function and may not perform DMAC/DTC transfer. In this phenomenon, when the next transfer request is issued by the time that the interrupt status flag (IR flag) is automatically cleared after data transfer (reading reception data or writing transmit data) using the DMAC/DTC, the transfer request is lost.

For example, when the DTC is activated using the SCI reception interrupt with CPU interrupt (DISEL = 1) for every transfer, the IR flag is set to 1 in a first receiving operation and the DTC is activated. After the DTC transfer, the IR flag is retained at 1 until the CPU interrupt is received. In the meantime, if a second receiving operation is completed, a setting of the IR flag that is the transfer request is ignored. Therefore, the DTC cannot be activated, and the data received in second receiving operation cannot be transferred.

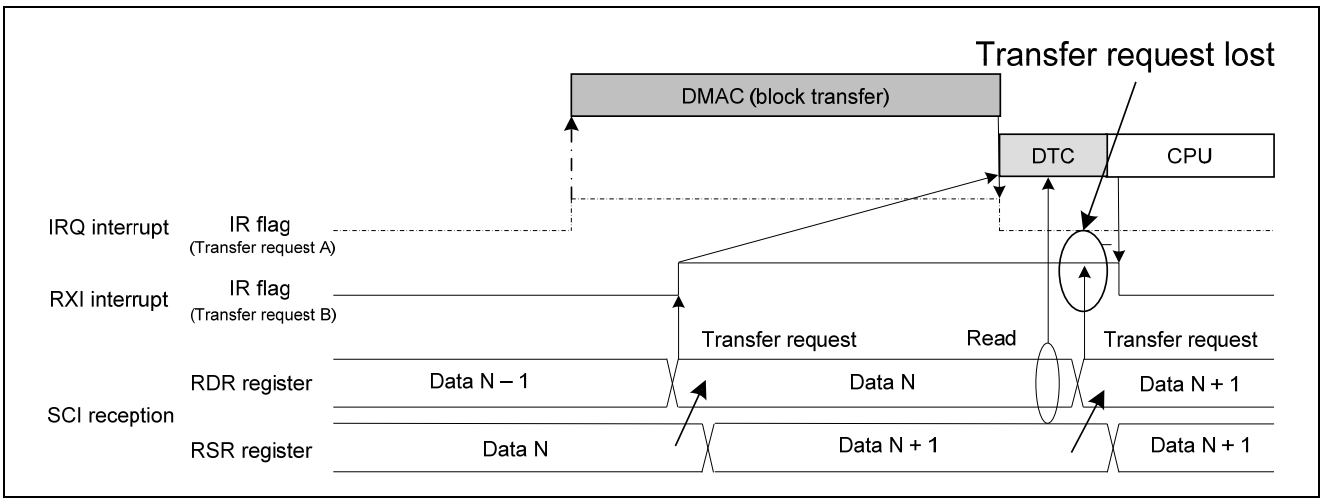


Figure 10.9 Example of SCI Reception + DTC Transfer (CPU Interrupt (DISEL = 1) for Every Transfer), and a DMAC Block Transfer Using the IRQ Interrupt

Table 10.6 Setting Conditions of the DMAC/DTC and Occurrence of the Phenomenon

Destination of Interrupt Request from Communication Function	Chain Transfer Used or Not Used	No.	Communication Interrupts to CPU Issued or Not Issued	Possibility of Problem Occurrence
DMAC	– (Chain transfer not provided)	1	No CPU interrupt (ISEL[1:0] = 10b)	Impossible
		2	CPU interrupt (ISEL[1:0] = 11b)	Possible
DTC	Chain transfer not used	3	No CPU interrupt (DISEL = 0)	Impossible
		4	CPU interrupt (DISEL = 1)	Possible
	Chain transfer used	5	No CPU interrupt (DISEL = 0)	Impossible
		6	CPU interrupt (DISEL = 1)	Possible

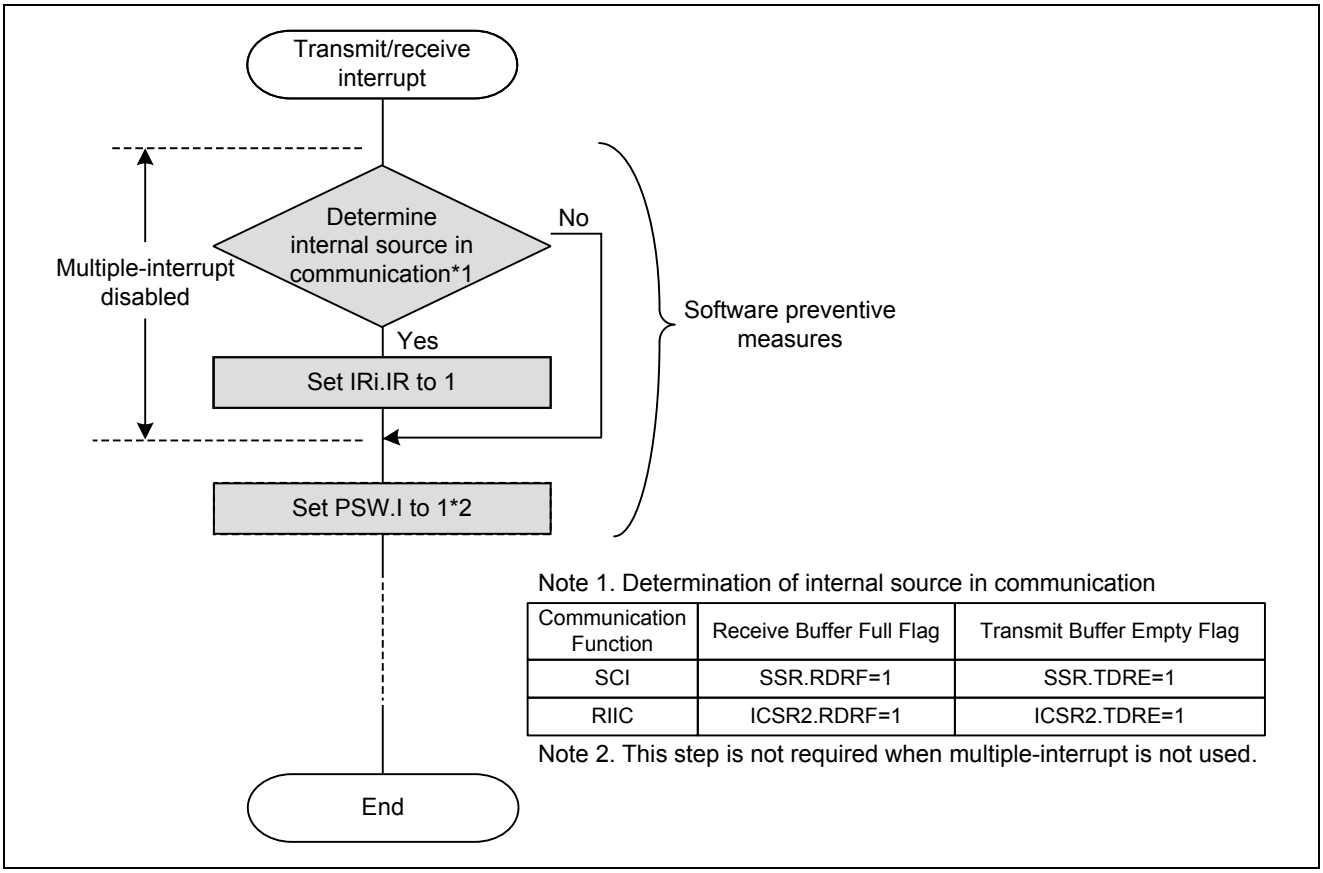
Note 1. Communication interrupts include transmit data empty and receive data full interrupts from SCI and RIIC.

Note 2. In the final transfer, if the DTC is re-set too late for the transfer request of the next packet to be transmitted/received, the same problem may occur as with the case in DESEL = 1.

- When the DMAC is used with ISEL[1:0] ＝ 11b, use the DTC with DISEL = 1 and implement the following preventive measures.
- When the DTC is used with DISEL = 1, it should be used such that the transfer request is not lost, or implement the software preventive measures of the DTC to prevent the transfer request from being lost.

(1) Software Preventive Measures

Figure 10.10 shows the flowchart for software preventive measures to be taken for the DTC.



Note 1. Determination of internal source in communication

Communication Function	Receive Buffer Full Flag	Transmit Buffer Empty Flag
SCI	SSR.RDRF=1	SSR.TDRE=1
RIIC	ICSR2.RDRF=1	ICSR2.TDRE=1

Note 2. This step is not required when multiple-interrupt is not used.

Figure 10.10 Flowchart for Measures with DISEL = 1

11. Buses

11.1 Overview

Table 11.1 lists the bus specifications and figure 11.1 shows the bus configuration.

Table 11.1 Bus Specifications

Bus Type		Description
CPU bus	Instruction bus	• Connected to the CPU (for instructions) • Connected to on-chip memory (on-chip RAM, on-chip ROM) • Operates in synchronization with the system clock (ICLK)
	Operand bus	• Connected to the CPU (for operands) • Connected to on-chip memory (on-chip RAM, on-chip ROM) • Operates in synchronization with the system clock (ICLK)
Internal main bus	Internal main bus 1	• Connected to the CPU • Operates in synchronization with the system clock (ICLK)
	Internal main bus 2	• Connected to the DMAC and DTC • Connected to on-chip memory (on-chip RAM, on-chip ROM) • Operates in synchronization with the system clock (ICLK)
Internal peripheral bus	Internal peripheral bus 1	• Connected to peripheral modules • Operates in synchronization with the system clock (ICLK)
	Internal peripheral bus 2	• Connected to peripheral modules, on-chip ROM (for programming and erasure), and data-flash memory • Operates in synchronization with the peripheral-module clock (PCLK)
External bus		• Connected to the external devices • Operates in synchronization with the external-bus clock (BCLK)

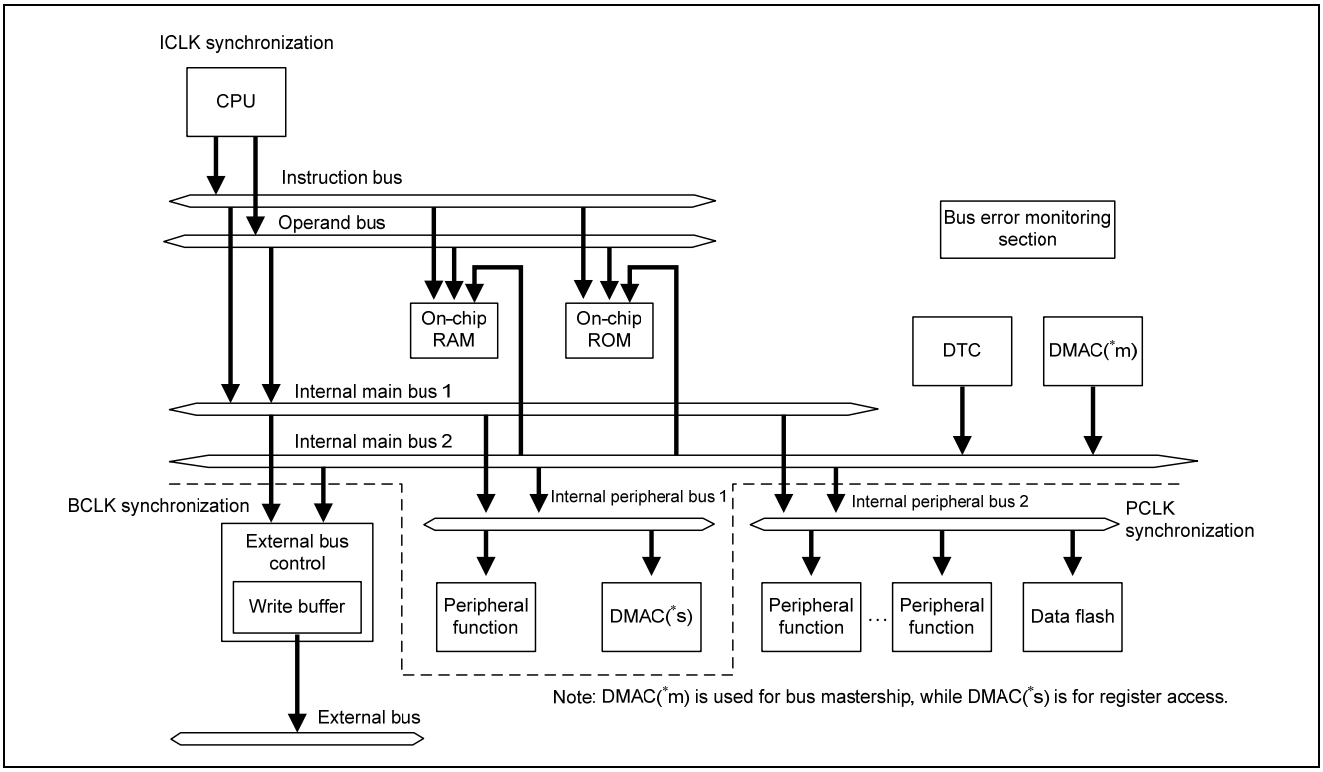


Figure 11.1 Bus Configuration

11.2 Description of Buses

11.2.1 CPU Buses

The CPU buses consist of the instruction and operand buses, which are connected to internal main bus 1. As the names suggest, the instruction bus is used to fetch instructions for the CPU, while the operand bus is used for operand access.

Connection of the instruction and operand buses to on-chip RAM and on-chip ROM provides the CPU with direct access to these areas, i.e. access is not via internal main bus 1. However, only reading is possible in direct access to on-chip ROM by the CPU; programming and erasure are handled via an internal peripheral bus.

Units for the arbitration of bus requests for instruction fetching and operand access are on-chip RAM, on-chip ROM, and internal main bus 1. The order of priority is operand access then instruction fetching.

If requests for access via the instruction bus, operand bus, and internal main bus 1 are for different slave modules, the various forms of access can proceed at the same time. For example, parallel access to on-chip ROM and on-chip RAM or to on-chip ROM and external space is possible.

11.2.2 Internal Main Buses

The internal main buses consist of a bus for use by the CPU (internal main bus 1) and a bus for use by the other bus-master modules, i.e. the DMAC and DTC (internal main bus 2). Requests for bus mastership from the DMAC and DTC are arbitrated by internal main bus 2. The order of priority is DMAC and then DTC, as shown in table 11.2.

Units for the arbitration of bus requests from the two internal main buses are slave devices on the external and peripheral buses, and on-chip memory. If the CPU and another bus master are requesting access to different slave modules, the respective bus-access operations can proceed simultaneously.

Internal main bus 2 (for bus masters other than the CPU) has priority over internal main bus 1 (for the CPU). However, when the CPU executes the XCHG instruction, requests for bus access from masters other than the CPU are not accepted until data transfer for the XCHG instruction is completed. Furthermore, requests for bus access from masters other than the DTC are not accepted during reading and writing-back of transfer control information for the DTC.

Table 11.2 Order of Priority for Bus Masters

Priority	Bus Master
High ↑	DMA destination
	DMA source
	DTC
Low	CPU

11.2.3 Internal Peripheral Buses

Connection of peripheral modules to the internal peripheral buses is as described in table 11.3.

Table 11.3 Connection of Peripheral Modules to the Internal Peripheral Buses

Type of Bus	Peripheral Modules
Internal peripheral bus 1	• DMAC • Interrupt controller
Internal peripheral bus 2	• Peripheral modules other than those connected to internal peripheral bus 1

11.2.4 External Bus

Table 11.4 lists the specifications of the external bus.

Table 11.4 Specifications of the External Bus

Item	Description
External address space	• An external address space is divided into eight areas (CS0 to CS7) for management. • Chip select signals can be output for each area. • An 8-bit bus space or a 16-bit bus space is selectable for each area. • An endian mode can be specified for each area.
Wait control function	• Recovery cycles can be inserted. Read recovery: Up to 15 cycles Write recovery: Up to 15 cycles • Cycle wait function: Wait for up to 31 cycles (page access: up to 7 cycles) • Wait control can be used to set up the following. Timing of assertion and negation for chip-select signals (CS0# to CS7#) The timing of assertion of the read signal (RD#) and write signals (WR0#, WR1#, and WR#) The timing with which data output starts and ends • Write access mode: Single write strobe mode/byte strobe mode
Write buffer function	• When write data from the bus master has been written to the write buffer, write access by the bus master is completed.
Frequency	• The external bus operates in synchronization with the external bus clock (BCLK).

Table 11.5 shows the input/output pins of the external bus.

Table 11.5 Pin Configuration of the External Bus

Pin Name	I/O	Description
A23 to A0[*1]	Output	Address output pins
BC0#[*1 *2]	Output	A strobe signal; (the BC0# signal being at the low level) during access to an external address space in single write strobe mode indicates that the lower-order byte (D7 to D0) is valid. When an 8-bit bus space is specified, this output pin is always held low regardless of write access mode.
BC1#[*2]	Output	A strobe signal; (the BC1# signal being at the low level) during access to an external address space in single write strobe mode indicates that the higher-order byte (D15 to D8) is valid. This pin is not used when the 8-bit bus space is specified.
D15 to D0	I/O	Data input/output pins D15 to D0 pins are enabled when the 16-bit bus space is specified, but D7 to D0 pins are enabled when the 8-bit bus space is specified.
CS0#	Output	A strobe signal indicating that area 0 (CS0) is selected
CS1#	Output	A strobe signal indicating that area 1 (CS1) is selected
CS2#	Output	A strobe signal indicating that area 2 (CS2) is selected
CS3#	Output	A strobe signal indicating that area 3 (CS3) is selected
CS4#	Output	A strobe signal indicating that area 4 (CS4) is selected
CS5#	Output	A strobe signal indicating that area 5 (CS5) is selected
CS6#	Output	A strobe signal indicating that area 6 (CS6) is selected
CS7#	Output	A strobe signal indicating that area 7 (CS7) is selected
RD#	Output	A strobe signal indicating that reading from an external address space is in progress
WR0#	Output	A strobe signal; (the WR0# signal being at the low level) during writing to an external address space in byte strobe mode indicates that the higher-order byte (D7 to D0) is valid. This strobe signal also indicates writing to an external address space is in progress in single write strobe mode. When an 8-bit bus space is specified, this output pin is held low during a write access regardless of write access mode.
WR1#	Output	A strobe signal; (the WR1# signal being at the low level) during writing to an external address space in byte strobe mode indicates that the higher-order byte (D15 to D8) is valid. The BC1# signal is output in single write strobe mode. This pin is not used when the 8-bit bus space is specified.
WR#	Output	A strobe signal to indicate writing to an external address space in single write strobe mode
WAIT#	Input	A wait request signal when accessing the external address space (Low: Wait request)

Note 1. The A0 and BC0# pin functions share the same pin, and either becomes effective according to the area, with the function being A0 in byte-writing mode and BC0# in single write strobe mode. In single write strobe mode, setting 8-bit external bus width is prohibited. For information on other multiplexed pin functions, see section 14, I/O Ports.

Note 2. The BC0# and BC1# signals are readable/writable signals.

11.2.5 Parallel Operation

Parallel operation is possible when different bus-master modules are requesting access to different slave modules. For example, if the CPU is fetching an instruction from on-chip ROM and an operand from on-chip RAM, the DMAC is able to handle transfer between a peripheral bus and the external bus at the same time.

An example of parallel operations is given in figure 11.2. In this example, the CPU is able to employ the instruction and operand buses for simultaneous access to on-chip ROM and on-chip RAM, respectively. Furthermore, the DMAC simultaneously employs internal main bus 2 for access to a peripheral bus or the external bus during access to on-chip RAM and ROM by the CPU.

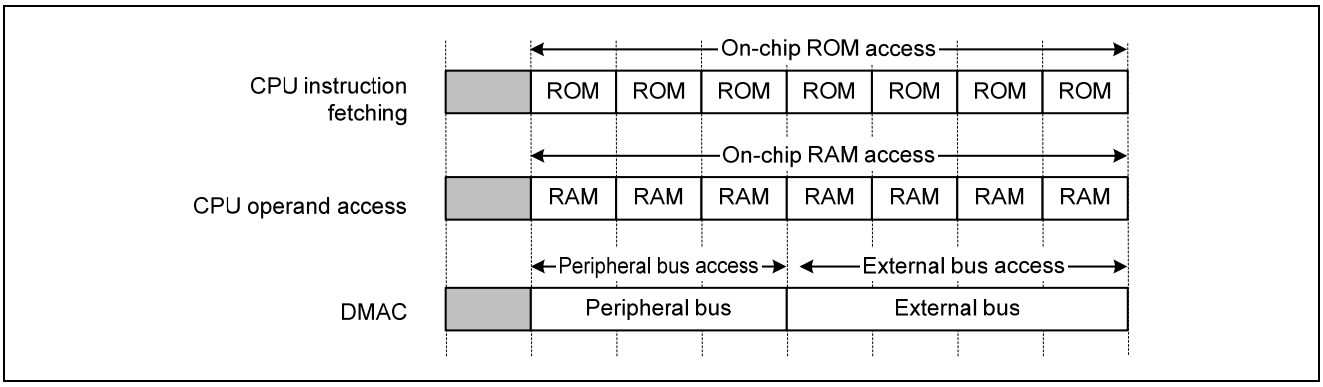


Figure 11.2 Example of Parallel Operations

11.3 Register Descriptions

Table 11.6 lists the registers of the external bus controller.

Table 11.6 Registers of the External Bus Controller

Register Name	Symbol	Value after Reset	Address	Access Size
CS0 control register	CS0CNT	0021h	0008 3802h	16
CS0 recovery cycle register	CS0REC	0000h	0008 380Ah	16
CS1 control register	CS1CNT	0000h	0008 3812h	16
CS1 recovery cycle register	CS1REC	0000h	0008 381Ah	16
CS2 control register	CS2CNT	0000h	0008 3822h	16
CS2 recovery cycle register	CS2REC	0000h	0008 382Ah	16
CS3 control register	CS3CNT	0000h	0008 3832h	16
CS3 recovery cycle register	CS3REC	0000h	0008 383Ah	16
CS4 control register	CS4CNT	0000h	0008 3842h	16
CS4 recovery cycle register	CS4REC	0000h	0008 384Ah	16
CS5 control register	CS5CNT	0000h	0008 3852h	16
CS5 recovery cycle register	CS5REC	0000h	0008 385Ah	16
CS6 control register	CS6CNT	0000h	0008 3862h	16
CS6 recovery cycle register	CS6REC	0000h	0008 386Ah	16
CS7 control register	CS7CNT	0000h	0008 3872h	16
CS7 recovery cycle register	CS7REC	0000h	0008 387Ah	16
CS0 mode register	CS0MOD	0000h	0008 3002h	16
CS0 wait control register 1	CS0WCNT1	0707 0707h	0008 3004h	32
CS0 wait control register 2	CS0WCNT2	0000 0007h	0008 3008h	32
CS1 mode register	CS1MOD	0000h	0008 3012h	16
CS1 wait control register 1	CS1WCNT1	0707 0707h	0008 3014h	32
CS1 wait control register 2	CS1WCNT2	0000 0007h	0008 3018h	32
CS2 mode register	CS2MOD	0000h	0008 3022h	16
CS2 wait control register 1	CS2WCNT1	0707 0707h	0008 3024h	32
CS2 wait control register 2	CS2WCNT2	0000 0007h	0008 3028h	32
CS3 mode register	CS3MOD	0000h	0008 3032h	16
CS3 wait control register 1	CS3WCNT1	0707 0707h	0008 3034h	32
CS3 wait control register 2	CS3WCNT2	0000 0007h	0008 3038h	32
CS4 mode register	CS4MOD	0000h	0008 3042h	16
CS4 wait control register 1	CS4WCNT1	0707 0707h	0008 3044h	32
CS4 wait control register 2	CS4WCNT2	0000 0007h	0008 3048h	32
CS5 mode register	CS5MOD	0000h	0008 3052h	16
CS5 wait control register 1	CS5WCNT1	0707 0707h	0008 3054h	32
CS5 wait control register 2	CS5WCNT2	0000 0007h	0008 3058h	32

Register Name	Symbol	Value after Reset	Address	Access Size
CS6 mode register	CS6MOD	0000h	0008 3062h	16
CS6 wait control register 1	CS6WCNT1	0707 0707h	0008 3064h	32
CS6 wait control register 2	CS6WCNT2	0000 0007h	0008 3068h	32
CS7 mode register	CS7MOD	0000h	0008 3072h	16
CS7 wait control register 1	CS7WCNT1	0707 0707h	0008 3074h	32
CS7 wait control register 2	CS7WCNT2	0000 0007h	0008 3078h	32
Bus error source clear register	BERCLR	00h	0008 1300h	8
Bus error monitoring enable register	BEREN	00h	0008 1304h	8
Bus error interrupt enable register	BERIE	00h	0008 1306h	8

11.3.1 CSi Control Register (CSiCNT) (i = 0 to 7)

Address: 0008 3802h (CS0CNT)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	EMODE	–	–	BSIZE[1:0]		–	–	–	EXENB
Value after reset:	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1

Addresses: 0008 3812h to 0008 3872h (CS1CNT to CS7CNT)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	EMODE	–	–	BSIZE[1:0]		–	–	–	EXENB
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	EXENB	Operation Enable	0: Operation is disabled 1: Operation is enabled	R/W*1
b3 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b5, b4	BSIZE[1:0]	External Bus Width Select	b5 b4 0 0: A 16-bit bus space is selected 0 1: Setting prohibited 1 0: An 8-bit bus space is selected 1 1: Setting prohibited	R/W*2
b7, b6	—	Reserved	These bits are always read as 0 and cannot be modified.	R
b8	EMODE	Endian Mode	0: Endian of area i (i = 0 to 7) is the same as the endian of operating mode. 1: Endian of area i (i = 0 to 7) is not the endian of operating mode.	R/W
b15 to b9	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Notes: 1. After a reset, the value of the EXENB bit in CS0CNT is 1 and the value of the EXENB bit in CSiCNT (i = 1 to 7) is 0.

2. The value of the BSIZE[1:0] bits in CS0CNT after a reset is 10.

CSiCNT is used to set enabling/disabling of the operation, data bus width, and endian for each area in the external address space.

EXENB Bit (Operation Enable)

This bit enables or disables operation of the respective CS areas.

After this LSI is reset, operation is only enabled (EXENB = 1) for area 0; operation in other areas is disabled (EXENB = 0).

An attempt at access to an area for which operation has been disabled does not lead to access via the external bus. However, if the illegal address access detection enable bit in the bus error monitoring enable register has been set to enable detection (BEREN.IGAEN = 1), such an attempt will lead to an illegal-access error.

BSIZE[1:0] Bits (External Bus Width Select)

These bits specify the data bus width of each area. The data bus width of area 0 after a reset is 8 bits.

EMODE Bit (Endian Mode)

This bit specifies the endian of each area.

When the endian setting for each area is different from that for the chip, no instruction code can be allocated in the area. If the instruction code is allocated to the external space, it must be allocated to areas where the endian setting is the same as that for the chip.

11.3.2 CSi Recovery Cycle Register (CSiREC) (i = 0 to 7)

Addresses: 0008 380Ah to 0008 387Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	WRCV[3:0]				—	—	—	—	RRCV[3:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	RRCV[3:0]	Read Recovery	b3 b2 b1 b0	R/W
			0 0 0 0: No recovery cycle is inserted.	
			0 0 0 1: One recovery cycle is inserted.	
			0 0 1 0: Two recovery cycles are inserted.	
			0 0 1 1: Three recovery cycles are inserted.	
			0 1 0 0: Four recovery cycles are inserted.	
			0 1 0 1: Five recovery cycles are inserted.	
			0 1 1 0: Six recovery cycles are inserted.	
			0 1 1 1: Seven recovery cycles are inserted.	
			1 0 0 0: Eight recovery cycles are inserted.	
			1 0 0 1: Nine recovery cycles are inserted.	
			1 0 1 0: Ten recovery cycles are inserted.	
			1 0 1 1: Eleven recovery cycles are inserted.	
			1 1 0 0: Twelve recovery cycles are inserted.	
			1 1 0 1: Thirteen recovery cycles are inserted.	
			1 1 1 0: Fourteen recovery cycles are inserted.	
			1 1 1 1: Fifteen recovery cycles are inserted.	
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b11 to b8	WRCV[3:0]	Write Recovery	b11 b10 b9 b8	R/W
			0 0 0 0: No recovery cycle is inserted.	
			0 0 0 1: One recovery cycle is inserted.	
			0 0 1 0: Two recovery cycles are inserted.	
			0 0 1 1: Three recovery cycles are inserted.	
			0 1 0 0: Four recovery cycles are inserted.	
			0 1 0 1: Five recovery cycles are inserted.	
			0 1 1 0: Six recovery cycles are inserted.	
			0 1 1 1: Seven recovery cycles are inserted.	
			1 0 0 0: Eight recovery cycles are inserted.	
			1 0 0 1: Nine recovery cycles are inserted.	
			1 0 1 0: Ten recovery cycles are inserted.	
			1 0 1 1: Eleven recovery cycles are inserted.	
			1 1 0 0: Twelve recovery cycles are inserted.	
			1 1 0 1: Thirteen recovery cycles are inserted.	
			1 1 1 0: Fourteen recovery cycles are inserted.	
			1 1 1 1: Fifteen recovery cycles are inserted.	
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CSiREC is used to set the number of recovery cycles to be inserted after a write access and read access of each area in the external address space.

RRCV[3:0] Bits (Read Recovery)

These bits specify the number of recovery cycles to be inserted after a read access to the external bus.

When a value except 0000b is written to these bits, one to 15 recovery cycles are inserted in the following cases.

- When a write access is made to the external bus after a read access to the external bus
  (Recovery cycles are also inserted when consecutive accesses are made in the same area.)
- When a read access is made to another area after a read access to the external bus
  (No recovery cycle is inserted when consecutive accesses are made in the same area.)

WRCV[3:0] Bits (Write Recovery)

These bits specify the number of recovery cycles to be inserted after a write access to the external bus.

When a value except 0000b is written to these bits, one to 15 recovery cycles are inserted in the following cases.

- When a read access is made to the external bus after a write access to the external bus
  (Recovery cycles are also inserted when consecutive accesses are made in the same area.)

No recovery cycle is inserted during a write access after a write access.

Table 11.7 Insertion of Recovery Cycles

Access Type	External Address Space	Insertion of Recovery Cycles
Read access after write access	Same area	Recovery cycles specified by the WRCV[3:0] bits are inserted.
	Different area	Recovery cycles specified by the WRCV[3:0] bits are inserted.
Write access after write access	Same area	No recovery cycle is inserted.
	Different area	No recovery cycle is inserted.
Write access after read access	Same area	Recovery cycles specified by the RRCV[3:0] bits are inserted.
	Different area	Recovery cycles specified by the RRCV[3:0] bits are inserted.
Read access after read access	Same area	No recovery cycle is inserted.
	Different area	Recovery cycles specified by the RRCV[3:0] bits are inserted.

11.3.3 CSi Mode Register (CSiMOD) (i = 0 to 7)

Addresses: 0008 3002h to 0008 3072h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	PRMOD	—	—	—	—	—	PWENB	PRENB	—	—	—	—	EWENB	—	—	WRMOD
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	WRMOD	Write Access Mode Select	0: Byte strobe mode 1: Single write strobe mode	R/W
b2, b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b3	EWENB	External Wait Enable	0: External wait is disabled 1: External wait is enabled	R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b8	PRENB	Page Read Access Enable	0: Page read access is disabled 1: Page read access is enabled	R/W
b9	PWENB	Page Write Access Enable	0: Page write access is disabled 1: Page write access is enabled	R/W
b14 to b10	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15	PRMOD	Page Read Access Mode Select	0: Normal access compatible mode 1: External data read continuous assertion mode	R/W

CSiMOD is used to set access modes of each area in the external address space.

WRMOD Bit (Write Access Mode Select)

This bit selects a write access operating mode.

Writing 0 to this bit selects byte strobe mode where data write operation is controlled by the WR0# and WR1# signals corresponding to the respective byte positions.

Writing 1 to this bit selects single write strobe mode where data write operation is controlled by the BCi# (i = 1, 0) signals and WR# signal corresponding to respective byte positions.

Table 11.8 shows whether the control signals are enabled or disabled in each write access mode.

Table 11.8 Control Signals for Write Access Mode

	Data Write Signal			Byte Control Signal	
Write Access Mode	**WR0#**	**WR1#**	**WR#**	**BC0#**	**BC1#**
Byte strobe mode	Enabled	Enabled	Disabled	Disabled	Disabled
Single write strobe mode	Disabled	Disabled	Enabled	Enabled	Enabled

EWENB Bit (External Wait Enable)

This bit enables or disables external wait.

Writing 1 to this bit selects external wait and allows control of the number of waits in each cycle with the WAIT# signal. In this state, wait cycles are inserted while the WAIT# signal is at the low level.

Writing 0 to this bit disables the WAIT# signal.

PRENB Bit (Page Read Access Enable)

This bit enables or disables page read accesses.

PWENB Bit (Page Write Access Enable)

This bit enables or disables page write accesses.

PRMOD Bit (Page Read Access Mode Select)

This bit selects a page read access operating mode.

Writing 0 to this bit selects normal access compatible mode where the RD# signal is negated and RD assert wait is inserted each time a piece of data is read. However, when there is no RD assert wait, the RD# signal is negated only when the last data is transferred on the external bus.

Writing 1 to this bit selects external data read continuous assertion mode where RD assert wait is inserted and the RD# signal is continuously asserted during this time period.

11.3.4 CSi Wait Control Register 1 (CSiWCNT1) (i = 0 to 7)

Addresses: 0008 3004h to 0008 3074h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	CSRWAIT[4:0]					—	—	—	CSWWAIT[4:0]				
Value after reset:	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	CSPRWAIT[2:0]			—	—	—	—	—	CSPWWAIT[2:0]		
Value after reset:	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	CSPWWAIT[2:0]	Page Write Cycle Wait Select*1	b2 b0 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b10 to b8	CSPRWAIT[2:0]	Page Read Cycle Wait Select*2	b10 b8 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b15 to b11	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b20 to b16	CSWWAIT[4:0]	Normal Write Cycle Wait Select	b20 b16 0 0 0 0 0: No wait is inserted. 0 0 0 0 1: Wait with a length of 1 clock cycle is inserted. 0 0 0 1 0: Wait with a length of 2 clock cycles is inserted. 0 0 0 1 1: Wait with a length of 3 clock cycles is inserted. 0 0 1 0 0: Wait with a length of 4 clock cycles is inserted. 0 0 1 0 1: Wait with a length of 5 clock cycles is inserted. 0 0 1 1 0: Wait with a length of 6 clock cycles is inserted. 0 0 1 1 1: Wait with a length of 7 clock cycles is inserted. 0 1 0 0 0: Wait with a length of 8 clock cycles is inserted. 0 1 0 0 1: Wait with a length of 9 clock cycles is inserted. 0 1 0 1 0: Wait with a length of 10 clock cycles is inserted. 0 1 0 1 1: Wait with a length of 11 clock cycles is inserted. 0 1 1 0 0: Wait with a length of 12 clock cycles is inserted. 0 1 1 0 1: Wait with a length of 13 clock cycles is inserted. 0 1 1 1 0: Wait with a length of 14 clock cycles is inserted. 0 1 1 1 1: Wait with a length of 15 clock cycles is inserted. 1 0 0 0 0: Wait with a length of 16 clock cycles is inserted. 1 0 0 0 1: Wait with a length of 17 clock cycles is inserted. 1 0 0 1 0: Wait with a length of 18 clock cycles is inserted. 1 0 0 1 1: Wait with a length of 19 clock cycles is inserted. 1 0 1 0 0: Wait with a length of 20 clock cycles is inserted. 1 0 1 0 1: Wait with a length of 21 clock cycles is inserted. 1 0 1 1 0: Wait with a length of 22 clock cycles is inserted. 1 0 1 1 1: Wait with a length of 23 clock cycles is inserted. 1 1 0 0 0: Wait with a length of 24 clock cycles is inserted. 1 1 0 0 1: Wait with a length of 25 clock cycles is inserted. 1 1 0 1 0: Wait with a length of 26 clock cycles is inserted. 1 1 0 1 1: Wait with a length of 27 clock cycles is inserted. 1 1 1 0 0: Wait with a length of 28 clock cycles is inserted. 1 1 1 0 1: Wait with a length of 29 clock cycles is inserted. 1 1 1 1 0: Wait with a length of 30 clock cycles is inserted. 1 1 1 1 1: Wait with a length of 31 clock cycles is inserted.	R/W
b23 to b21	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b28 to b24	CSRWAIT[4:0]	Normal Read Cycle Wait Select	b28 b24 0 0 0 0: No wait is inserted. 0 0 0 0: Wait with a length of 1 clock cycle is inserted. 0 0 0 1: Wait with a length of 2 clock cycles is inserted. 0 0 0 1: Wait with a length of 3 clock cycles is inserted. 0 0 1 0: Wait with a length of 4 clock cycles is inserted. 0 0 1 0: Wait with a length of 5 clock cycles is inserted. 0 0 1 1: Wait with a length of 6 clock cycles is inserted. 0 0 1 1: Wait with a length of 7 clock cycles is inserted. 0 1 0 0: Wait with a length of 8 clock cycles is inserted. 0 1 0 0: Wait with a length of 9 clock cycles is inserted. 0 1 0 1: Wait with a length of 10 clock cycles is inserted. 0 1 0 1: Wait with a length of 11 clock cycles is inserted. 0 1 1 0: Wait with a length of 12 clock cycles is inserted. 0 1 1 0: Wait with a length of 13 clock cycles is inserted. 0 1 1 1: Wait with a length of 14 clock cycles is inserted. 0 1 1 1: Wait with a length of 15 clock cycles is inserted. 1 0 0 0: Wait with a length of 16 clock cycles is inserted. 1 0 0 0: Wait with a length of 17 clock cycles is inserted. 1 0 0 1: Wait with a length of 18 clock cycles is inserted. 1 0 0 1: Wait with a length of 19 clock cycles is inserted. 1 0 1 0: Wait with a length of 20 clock cycles is inserted. 1 0 1 0: Wait with a length of 21 clock cycles is inserted. 1 0 1 1: Wait with a length of 22 clock cycles is inserted. 1 0 1 1: Wait with a length of 23 clock cycles is inserted. 1 1 0 0: Wait with a length of 24 clock cycles is inserted. 1 1 0 0: Wait with a length of 25 clock cycles is inserted. 1 1 0 1: Wait with a length of 26 clock cycles is inserted. 1 1 0 1: Wait with a length of 27 clock cycles is inserted. 1 1 1 0: Wait with a length of 28 clock cycles is inserted. 1 1 1 0: Wait with a length of 29 clock cycles is inserted. 1 1 1 1: Wait with a length of 30 clock cycles is inserted. 1 1 1 1: Wait with a length of 31 clock cycles is inserted.	R/W
b31 to b29	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Notes: 1. The CSPWWAIT[2:0] value is valid only when the PWENB bit in CSiMOD is set to 1.

2. The CSPRWAIT[2:0] value is valid only when the PRENB bit in CSiMOD is set to 1.

CSiWCNT1 is used to select the number of wait cycles of each area in the external address space.

CSPWWAIT[2:0] Bits (Page Write Cycle Wait Select)

These bits specify the number of wait cycles to be inserted into the second and subsequent accesses during a page write cycle.

This setting is enabled when the PWENB bit in CSiMOD is set to 1.

Note: Set these bits so that 1 ≤ WDON[2:0] ≤ WRON[2:0] ≤ CSPWWAIT[2:0] or CSON[2:0] ≤ WRON[2:0] ≤ CSPWWAIT[2:0] is satisfied.

CSPRWAIT[2:0] Bits (Page Read Cycle Wait Select)

These bits specify the number of wait cycles to be inserted into the second and subsequent accesses during a page read cycle.

This setting is enabled when the PRENB bit in CSiMOD is set to 1.

Note: Set these bits so that CSON[2:0] ≤ RDON[2:0] ≤ CSPRWAIT[2:0] is satisfied.

CSWWAIT[4:0] Bits (Normal Write Cycle Wait Select)

These bits specify the number of wait cycles to be inserted into the first access during a normal write cycle or page write cycle.

Note: Set these bits so that 1 ≤ WDON[2:0] ≤ WRON[2:0] ≤ CSWWAIT[4:0] or CSON[2:0] ≤ WRON[2:0] ≤ CSWWAIT[4:0] is satisfied.

CSRWAIT[4:0] Bits (Normal Read Cycle Wait Select)

These bits specify the number of wait cycles to be inserted into the first access during a normal read cycle or page read cycle.

Note: Set these bits so that CSON[2:0] ≤ RDON[2:0] ≤ CSRWAIT[4:0] is satisfied.

Note: Set each of these bits within a range of the restrictions described in section 11.5.5.1, Limitations at the Time of Normal and Page Access.

11.3.5 CSi Wait Control Register 2 (CSiWCNT2) (i = 0 to 7)

Addresses: 0008 3008h to 0008 3078h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	CSON[2:0]			—	WDON[2:0]			—	WRON[2:0]			—	RDON[2:0]		
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	WDOFF[2:0]			—	CSWOFF[2:0]			—	CSROFF[2:0]		
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	CSROFF[2:0]	Read-Access CS Extension Cycle Select	b2 b0 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b3	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6 to b4	CSWOFF[2:0]	Write-Access CS Extension Cycle Select	b6 b4 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b7	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b10 to b8	WDOFF[2:0]	Write Data Output Extension Cycle Select	b10 b8 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b15 to b11	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b18 to b16	RDON[2:0]	RD Assert Wait Select	b18 b16 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b19	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b22 to b20	WRON[2:0]	WR Assert Wait Select	b22 b20 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b23	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b26 to b24	WDON[2:0]	Write Data Output Wait Select	b26 b24 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b27	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b30 to b28	CSON[2:0]	CS Assert Wait Select	b30 b28 0 0: No wait is inserted. 0 0: Wait with a length of 1 clock cycle is inserted. 0 1: Wait with a length of 2 clock cycles is inserted. 0 1: Wait with a length of 3 clock cycles is inserted. 1 0: Wait with a length of 4 clock cycles is inserted. 1 0: Wait with a length of 5 clock cycles is inserted. 1 1: Wait with a length of 6 clock cycles is inserted. 1 1: Wait with a length of 7 clock cycles is inserted.	R/W
b31	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W

CSiWCNT2 is used to select the number of wait cycles of each area in the external address space.

CSROFF[2:0] Bits (Read-Access CS Extension Cycle Select)

These bits specify the number of wait cycles to be inserted in a time period from the end of a wait cycle (RD# signal negated) until the CSi# signal (i = 0 to 7) is negated in read access mode.

CSWOFF[2:0] Bits (Write-Access CS Extension Cycle Select)

These bits specify the number of wait cycles to be inserted in a time period from the end of a wait cycle (WR0#, WR1#, or WR# signal negated) until the CSi# signal (i = 0 to 7) is negated in write access mode.

Note: Set these bits so that 1 ≤ WDOFF[2:0] ≤ CSWOFF[2:0] is satisfied.

WDOFF[2:0] Bits (Write Data Output Extension Cycle Select)

These bits specify the number of wait cycles to be inserted in a time period from the end of a wait cycle (WR0#, WR1#, or WR# signal negated) until the write data output is completed in write access mode.

Note: Set these bits so that 1 ≤ WDOFF[2:0] ≤ CSWOFF[2:0] is satisfied.

RDON[2:0] Bits (RD Assert Wait Select)

These bits specify the number of wait cycles to be inserted before the RD# signal is asserted.

Note: Set these bits so that the following conditions are satisfied:
CSON[2:0] ≤ RDON[2:0] ≤ CSRWAIT[4:0] in normal read access
CSON[2:0] ≤ RDON[2:0] ≤ CSPRWAIT[2:0] in page read access

WRON[2:0] Bits (WR Assert Wait Select)

These bits specify the number of wait cycles to be inserted before the WR0#, WR1#, or WR# signal is asserted.

Note: Set these bits so that the following conditions are satisfied:
1 ≤ WDON[2:0] ≤ WRON[2:0] ≤ CSWWAIT[4:0] or CSON[2:0] ≤ WRON[2:0] ≤ CSWWAIT[4:0] in normal write access
1 ≤ WDON[2:0] ≤ WRON[2:0] ≤ CSPWWAIT[2:0] or CSON[2:0] ≤ WRON[2:0] ≤ CSPWWAIT[2:0] in page write access

WDON[2:0] Bits (Write Data Output Wait Select)

These bits specify the number of wait cycles to be inserted before the write data is output.

Note: Set these bits so that the following conditions are satisfied:
1 ≤ WDON[2:0] ≤ WRON[2:0] ≤ CSWWAIT[4:0] in normal write access
1 ≤ WDON[2:0] ≤ WRON[2:0] ≤ CSPWWAIT[2:0] in page write access

CSON[2:0] Bits (CS Assert Wait Select)

These bits specify the number of wait cycles to be inserted before the CSi# signal (i = 0 to 7) is asserted.

Note: Set these bits so that the following conditions are satisfied:
CSON[2:0] ≤ RDON[2:0] ≤ CSRWAIT[4:0] in normal read access
CSON[2:0] ≤ RDON[2:0] ≤ CSPRWAIT[2:0] in page read access
CSON[2:0] ≤ WRON[2:0] ≤ CSWWAIT[4:0] in normal write access
CSON[2:0] ≤ WRON[2:0] ≤ CSPWWAIT[2:0] in page write access

Note: Set each of these bits within a range of the restrictions described in section 11.5.5.1, Limitations at the Time of Normal and Page Access.

11.3.6 Bus Error Source Clear Register (BERCLR)

Address: 0008 1300h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	STSCLR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
0	STSCLR	Bus Error Source Clear	0: No effect 1: Clears the bus-error source signals	R/(W)*
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Note: * Only the writing of 1 is effective; i.e. writing 0 has no effect.

STSCLR Bit (Bus Error Source Clear)

Writing 1 to this bit clears the internal bus-error source signals. Clear the bus-error source signals being retained by the bus from within the handling routine for bus-error interrupts.

Writing 0 to this bit has no effect. The value 0 is always read from this bit.

11.3.7 Bus Error Monitoring Enable Register (BEREN)

Address: 0008 1304h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	TOEN	IGAEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
0	IGAEN	Illegal Address Access Detection Enable	0: Illegal address access detection is disabled. 1: Illegal address access detection is enabled.	R/W
1	TOEN	Time-out Detection Enable*1*2	0: Time-out detection is disabled. 1: Time-out detection is enabled.	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Notes: 1. When detection is disabled (the TOEN bit is cleared to 0), bus access can cause the bus to freeze.

2. Do not set the TOEN bit to the value that disables detection while time-out errors are being detected.

IGAEN Bit (Illegal Address Access Detection Enable)

This bit enables or disables detection of access to illegal addresses.

TOEN Bit (Time-out Detection Enable)

This bit enables or disables detection of time-out for bus operations.

11.3.8 Bus Error Interrupt Enable Register (BERIE)

Address: 0008 1306h

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	CPEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CPEN	CPU Bus Error Notification Control	0: Bus-error interrupts are not conveyed to the CPU. 1: Bus-error interrupts are conveyed to the CPU.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CPEN Bit (CPU Bus Error Notification Control)

This bit controls whether the interrupt controller is (1) or is not (0) notified when bus errors are detected.

11.4 Endian and Data Alignment

Eight, 16, and 32 bits are the units of access by the CPU and other internal bus-master modules. The external bus controller has a data-alignment facility, and this can control whether access is to bits D15 to D8 or to bits D7 to D0, the bus specification (8-bit or 16-bit bus space), the unit of access, and the endian for areas of the external address space.

11.4.1 16-Bit Bus Space

When a 16-bit width is selected for a bus space by the BSIZE[1:0] bits in CSiCNT, the address bus (A23 to A1) output signals for access to 16-bit units are enabled, but the A0 signal is always 0.

When byte strobe mode (the WRMOD bit = 0 in CSiMOD) is selected, the WRi# (i = 0, 1) pins are enabled, but the BCi# (i = 0, 1) pins are not used.

When single write strobe mode (the WRMOD bit = 1 in CSiMOD) is selected, the WR# pin is enabled and always outputs the low level during write access, regardless of the unit of access. The valid byte position is indicated by the BCi# (i = 0, 1) pins. The WRi# (i = 0, 1) pins are not used.

Page access can occur in access to data in 32-bit units. The situations in which page access occurs are indicated by the letter "(p)" in figures 11.3 and 11.4.

The valid positions of data external to the chip and of control signals differ according to whether the endian is big or little.

Data Size	Access Address	Number of Access	Bus Cycle	Unit of Data	Address		WR1#/BC1# | WR0#/BC0# RD# Data Bus D15 D8 D7 D0
8 bits	4n	One	First	8 bits	4n		7 0
	4n+1	One	First	8 bits	4n		7 0
	4n+2	One	First	8 bits	4n+2		7 0
	4n+3	One	First	8 bits	4n+2		7 0
16 bits	4n	One	First	16 bits	4n		15 8 | 7 0
	4n+1	Two	First	8 bits	4n		7 0
			Second	8 bits	4n+2		15 8
	4n+2	One	First	16 bits	4n+2		15 8 | 7 0
	4n+3	Two	First	8 bits	4n+2		7 0
			Second	8 bits	4n+4		15 8
32 bits	4n	Two	First	16 bits	4n		15 8 | 7 0
			Second	16 bits	4n+2	(p)	31 24 | 23 16
	4n+1	Three	First	8 bits	4n		7 0
			Second	16 bits	4n+2		23 16 | 15 8
			Third	8 bits	4n+4		31 24
	4n+2	Two	First	16 bits	4n+2		15 8 | 7 0
			Second	16 bits	4n+4		31 24 | 23 16
	4n+3	Three	First	8 bits	4n+2		7 0
			Second	16 bits	4n+4		23 16 | 15 8
			Third	8 bits	4n+6		31 24

[Legend]
(p): Page access (only when page access is enabled with the PRENB and PWENB bits in CSiMOD)

Figure 11.3 Data Alignment (Little Endian) in 16-Bit Bus Space

Data Size	Access Address	Number of Access	Bus Cycle	Unit of Data	Address		WR1#/BC1# WR0#/BC0# RD# Data Bus D15 D8 D7 D0
8 bits	4n	One	First	8 bits	4n		7 0
	4n+1	One	First	8 bits	4n		7 0
	4n+2	One	First	8 bits	4n+2		7 0
	4n+3	One	First	8 bits	4n+2		7 0
16 bits	4n	One	First	16 bits	4n		15 8 7 0
	4n+1	Two	First	8 bits	4n		15 8
			Second	8 bits	4n+2		7 0
	4n+2	One	First	16 bits	4n+2		15 8 7 0
	4n+3	Two	First	8 bits	4n+2		15 8
			Second	8 bits	4n+4		7 0
32 bits	4n	Two	First	16 bits	4n		31 24 23 16
			Second	16 bits	4n+2	(p)	15 8 7 0
	4n+1	Three	First	8 bits	4n		31 24
			Second	16 bits	4n+2		23 16 15 8
			Third	8 bits	4n+4		7 0
	4n+2	Two	First	16 bits	4n+2		31 24 23 16
			Second	16 bits	4n+4		15 8 7 0
	4n+3	Three	First	8 bits	4n+2		31 24
			Second	16 bits	4n+4		23 16 15 8
			Third	8 bits	4n+6		7 0

[Legend]
(p): Page access (only when page access is enabled with the PRENB and PWENB bits in CSiMOD)

Figure 11.4 Data Alignment (Big Endian) in 16-Bit Bus Space

11.4.2 8-Bit Bus Space

When an 8-bit bus space is selected by the BSIZE[1:0] bits in CSiCNT, the address bus (A23 to A0) output signals for access to byte units are enabled.

When byte strobe mode is selected, the WR0# pin is valid, and when single write strobe mode is selected, the WR# pin is valid. In write access, the low level is always output on the WR0# and WR# pins. The BC0#, WR1#, and BC1# pins are not used.

Page access can occur in access to data in 16- or 32-bit units. The situations in which page access occurs are indicated by the letter "(p)" in figures 11.5 and 11.6.

The valid positions of data external to the chip and of the control signals are not affected by the endian.

Data Size	Access Address	Number of Access	Bus Cycle	Unit of Data	Address		WR1#/BC1# D15–D8	WR0#/BC0# D7–D0
							RD# Data Bus	
8 bits	4n	One	First	8 bits	4n			7 0
	4n+1	One	First	8 bits	4n+1			7 0
	4n+2	One	First	8 bits	4n+2			7 0
	4n+3	One	First	8 bits	4n+3			7 0
16 bits	4n	Two	First	8 bits	4n			7 0
			Second	8 bits	4n+1	(p)		15 8
	4n+1	Two	First	8 bits	4n+1			7 0
			Second	8 bits	4n+2	(p)		15 8
	4n+2	Two	First	8 bits	4n+2			7 0
			Second	8 bits	4n+3	(p)		15 8
	4n+3	Two	First	8 bits	4n+3			7 0
			Second	8 bits	4n+4			15 8
32 bits	4n	Four	First	8 bits	4n			7 0
			Second	8 bits	4n+1	(p)		15 8
			Third	8 bits	4n+2	(p)		23 16
			Fourth	8 bits	4n+3	(p)		31 24
	4n+1	Four	First	8 bits	4n+1			7 0
			Second	8 bits	4n+2	(p)		15 8
			Third	8 bits	4n+3	(p)		23 16
			Fourth	8 bits	4n+4			31 24
	4n+2	Four	First	8 bits	4n+2			7 0
			Second	8 bits	4n+3	(p)		15 8
			Third	8 bits	4n+4			23 16
			Fourth	8 bits	4n+5	(p)		31 24
	4n+3	Four	First	8 bits	4n+3			7 0
			Second	8 bits	4n+4			15 8
			Third	8 bits	4n+5	(p)		23 16
			Fourth	8 bits	4n+6	(p)		31 24

[Legend]
(p): Page access (only when page access is enabled with the PRENB and PWENB bits in CSiMOD)

Figure 11.5 Data Alignment (Little Endian) in 8-Bit Bus Space

Data Size	Access Address	Number of Access	Bus Cycle	Unit of Data	Address		WR1#/BC1# D15–D8	WR0#/BC0# D7–D0
8 bits	4n	One	First	8 bits	4n			7 0
	4n+1	One	First	8 bits	4n+1			7 0
	4n+2	One	First	8 bits	4n+2			7 0
	4n+3	One	First	8 bits	4n+3			7 0
16 bits	4n	Two	First	8 bits	4n			15 8
			Second	8 bits	4n+1	(p)		7 0
	4n+1	Two	First	8 bits	4n+1			15 8
			Second	8 bits	4n+2	(p)		7 0
	4n+2	Two	First	8 bits	4n+2			15 8
			Second	8 bits	4n+3	(p)		7 0
	4n+3	Two	First	8 bits	4n+3			15 8
			Second	8 bits	4n+4			7 0
32 bits	4n	Four	First	8 bits	4n			31 24
			Second	8 bits	4n+1	(p)		23 16
			Third	8 bits	4n+2	(p)		15 8
			Fourth	8 bits	4n+3	(p)		7 0
	4n+1	Four	First	8 bits	4n+1			31 24
			Second	8 bits	4n+2	(p)		23 16
			Third	8 bits	4n+3	(p)		15 8
			Fourth	8 bits	4n+4			7 0
	4n+2	Four	First	8 bits	4n+2			31 24
			Second	8 bits	4n+3	(p)		23 16
			Third	8 bits	4n+4			15 8
			Fourth	8 bits	4n+5	(p)		7 0
	4n+3	Four	First	8 bits	4n+3			31 24
			Second	8 bits	4n+4			23 16
			Third	8 bits	4n+5	(p)		15 8
			Fourth	8 bits	4n+6	(p)		7 0

RD#

Data Bus

[Legend]
(p): Page access (only when page access is enabled with the PRENB and PWENB bits in CSiMOD)

Figure 11.6 Data Alignment (Big Endian) in 8-Bit Bus Space

11.5 Operation

11.5.1 Timing of External Bus Access

The various periods in the timing charts are described below.

(1) Tw1 to Twn (clock cycles of waiting for a normal read cycle or normal write cycle)

The period Tw1 to Twn is made up of the number of clock cycles between the start of access via the external bus and the cycle where waiting is completed (described below). The number of cycles is selectable within the range from zero to 31. Within this period, the timing of CSi#, RD#, WRi#, and WR# assertion (placing the signals at the low level) is determined by the respective wait settings. Specifically, the periods of waiting are controlled by the CS assertion wait (CSON), RD assertion wait (RDON), WR assertion wait (WRON), and write-data output wait (WDON) bits of CSi wait control register 2 (CSiWCNT2). The number of clock cycles for each of these periods of waiting is selectable as a value from zero to seven counted from the start of bus access. Selectable numbers of cycles are also within the overall number of clock cycles of waiting for reading or writing.

(2) Tend (clock cycle where the strobe signal is valid)

Tend is the next clock cycle after completion of the period of waiting for a normal cycle of reading or writing or for a cycle of page reading or page writing. If the number of clock cycles in the period of waiting for a normal cycle of reading or writing or for a cycle of page reading or page writing is zero, the clock cycle where bus access starts is the clock cycle where the strobe signal is valid. The RD#, WRi#, and WR# signals are negated in the next clock cycle after the cycle where the strobe signal is valid. In the case of read access, the clock cycle where the strobe signal is valid becomes the clock cycle where the data to be read are sampled.

If an external wait is enabled, the wait signal is sampled at the time of the cycle where the strobe signal is valid. The bus cycle is extended if the wait signal is at the low level. The bus cycle is completed in the next clock cycle if the wait signal is at the high level. Tend indicates the cycle where sampling of the wait signal starts.

After the first cycle where the strobe signal is valid during page access, second and subsequent page access operations (point 6. below) start in the next cycle except in cases of write access where a setting (other than zero) for write-data output extension clock cycles (point 5. below) has been made. If the setting for the RD or WR assertion wait is a value other than zero, the RD#, WRi#, and WR# signals are negated in the next clock cycle. If the setting is zero, assertion continues. Furthermore, the CSi# signal continues to be asserted rather than being negated.

(3) Tn1 to Tnm (clock cycles of CS extension)

In the case of normal access, Tn1 to Tnm represent the clock cycles of the period following the cycle where the strobe signal is valid (Tend) up to negation of the CSi# signal. For read or write access, the timing of negation is controlled by the CS extension cycles setting for reading (CSROFF) or the CS extension cycles setting for writing (CSROFF) in CSi wait control register 2 (CSiWCNT2).

The number of cycles is counted from the cycle following the cycle where the strobe signal is valid.

In the case of page access, Tn1 to Tnm represent the clock cycles of the period for the cycle following the last cycle where the strobe signal is valid up to negation of the CSi# signal.

For write access, the setting for write data output extension cycles (WDOFF) controls extension of the period where the address and output data are valid.

(4) Th (address hold time)

In the clock cycle that follows the end of the cycles of CS extension, the value for the address is retained from the previous access. However, when two or more rounds of external bus access are required in response to a request for transfer from a bus master, only the value from the final bus access of the divided-up operation is retained. In bus access other than the final bus access, the address value is updated to that for the next access operation at the time of negation of the CS# signal. In the case of normal access, one clock cycle is inserted as the period of negation of the CSi# signal. In the case of page access, a period for negation of the CS# signal is not inserted (see figures 11.10 and 11.11).

(5) Tdw1 to Tdwn (write-data output extension clock cycles)

For write access, if the setting for write-data output extension wait is a value other than zero, clock cycles of write-data output extension are inserted from the cycle that follows the cycle where the strobe signal is valid (Tend).

In the case of normal access, this is inserted within the period of clock cycles of CS extension (point 3. above).

In the case of page access, this is inserted within the period of the cycle where the strobe signal is valid and subsequent page access or within the period of clock cycles of CS extension (point 3. above). Valid address and data output are extended over this period, and the WRi# and WR# signals are negated.

(6) Tpw1 to Tpwn (page-read cycle or page-write cycle wait)

For the second and subsequent cycles of the bus clock during page access, the values for a page-read cycle wait or page-write cycle wait are used instead of the settings for a normal read or write cycle wait. The setting for the wait until WR assertion becomes effective is in a similar way as for the first round of access. How the setting for RD assertion controls operation differs with the setting for page-read access mode (CSiMOD.PRMOD) as described below.

CSiMOD.PRMOD = 0: A wait until RD assertion is inserted in a similar way as for the first round of access, and the RD# signal is negated.

CSiMOD.PRMOD = 1: Although a wait until RD assertion is inserted in a similar way as for normal-access compatibility mode, the RD# signal continues to be asserted over this period.

(7) Tr1 to Trn (clock cycles of recovery)

Clock cycles of recovery can be inserted from the point where a bus cycle is completed. The number of clock cycles is controlled by the setting of the read recovery (RRCV) or write recovery (WRCV) bits in the CSi recovery cycle setting register (CSiREC). Both numbers of clock cycles of recovery are counted from the next cycle after the address hold time and have values in the range from zero to 15 (clock cycles). For details on the clock cycles of recovery, see section 11.5.3, Insertion of Recovery Cycles.

11.5.1.1 Normal Access

When the PRENB and PWENB bits in CSiMOD are set to 0 to disable page-reading and page-writing access, respectively, all bus access will take the form of normal read and write operations.

Even when the PRENB and PWENB bits in CSiMOD are set to 1 to enable page-reading and page-writing access, respectively, bus access other than page access will take the form of normal read and write operations.

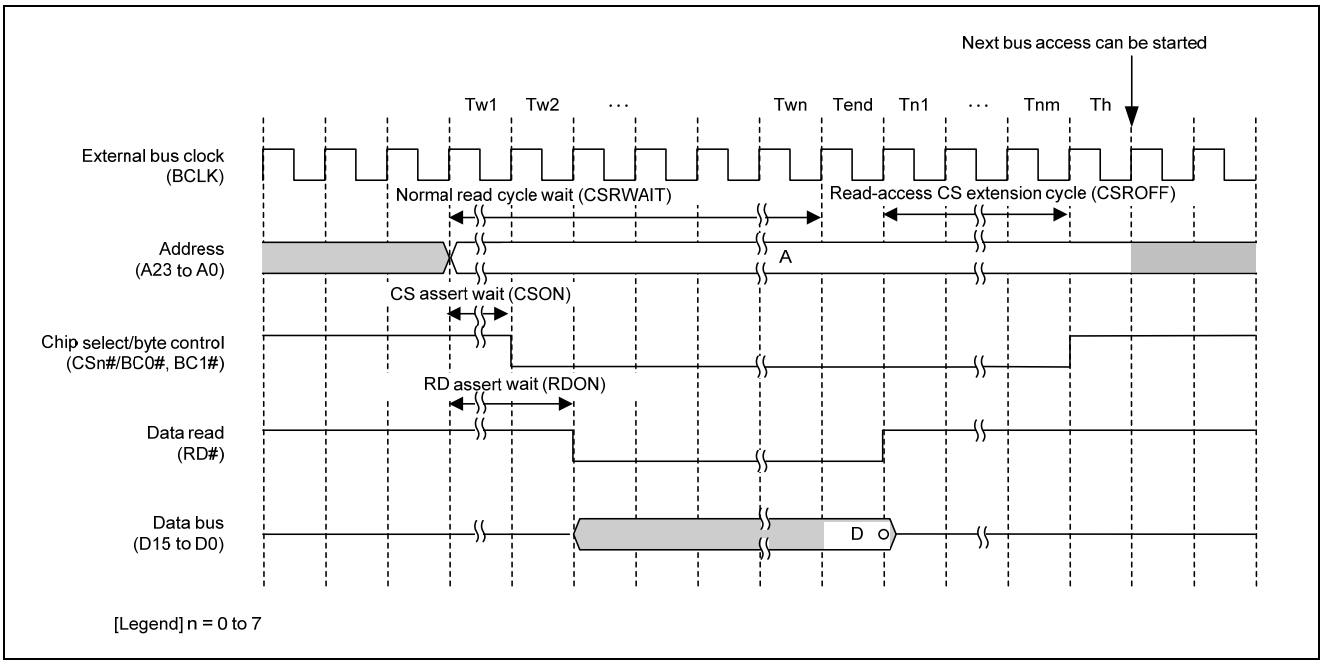


Figure 11.7 Bus Timing (Normal-Read Operation)

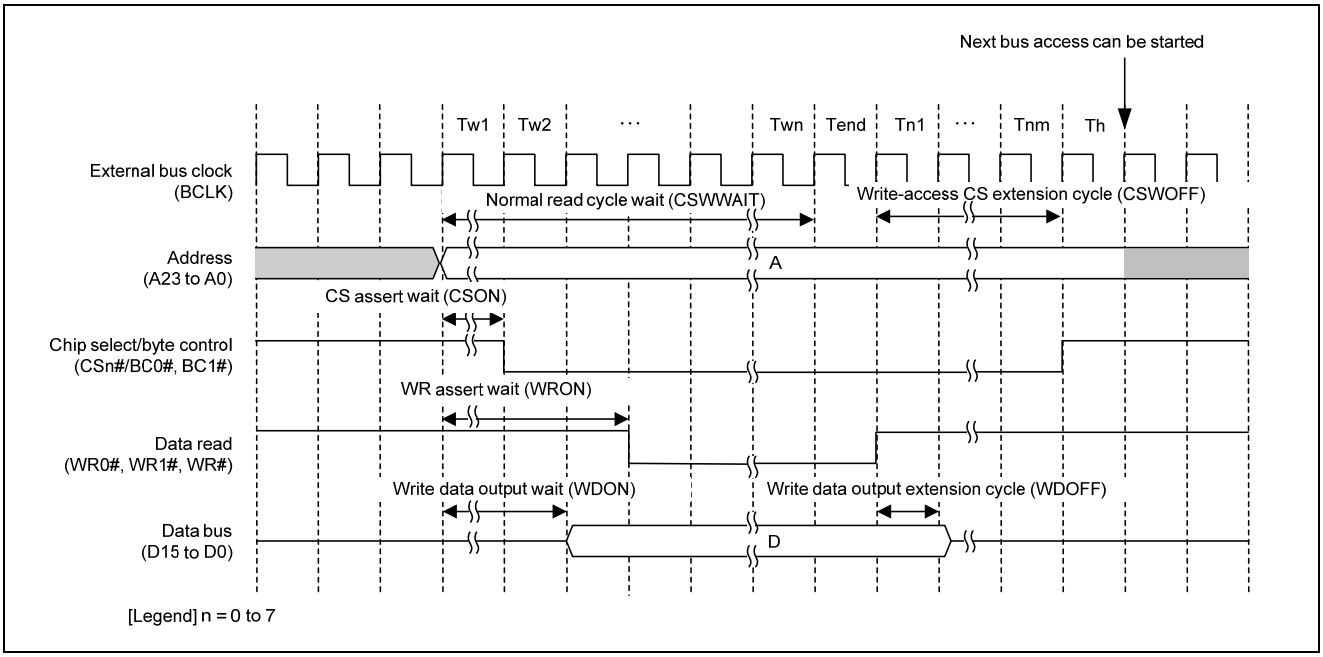


Figure 11.8 Bus Timing (Normal-Write Operation)

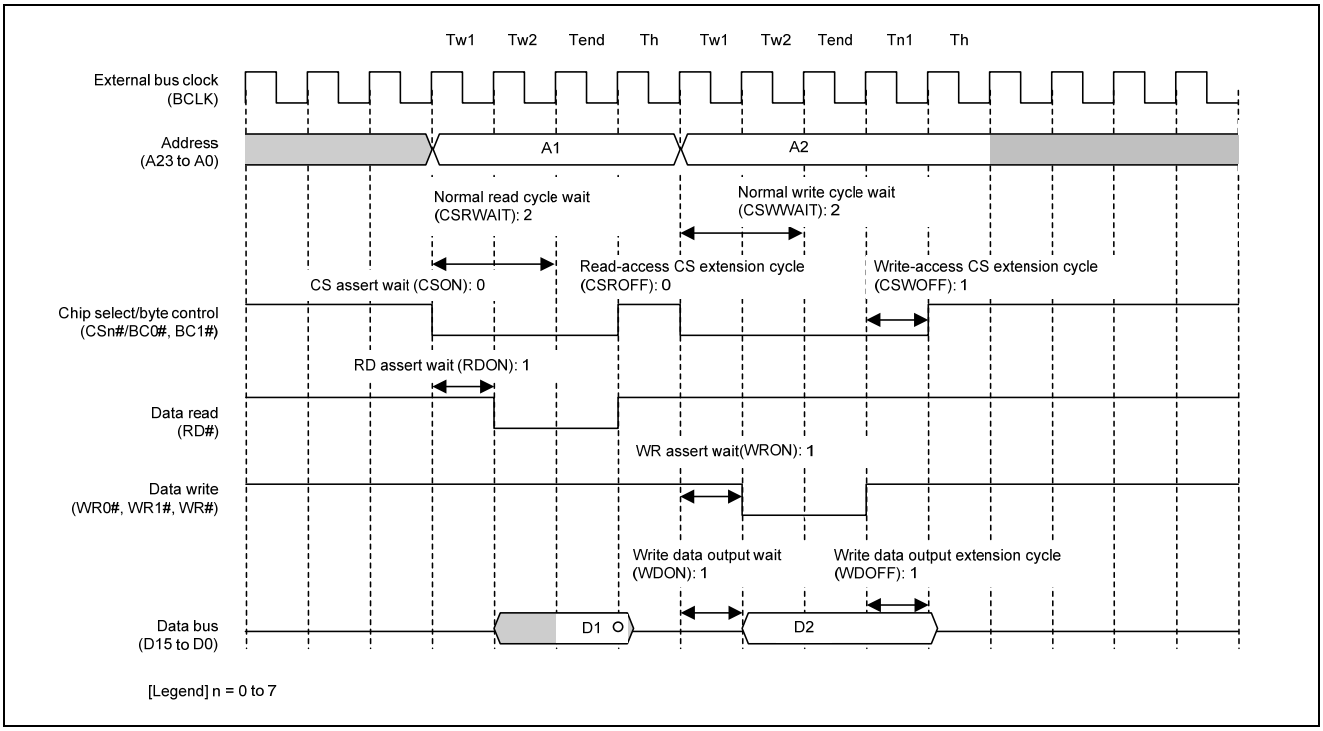


Figure 11.9 Example of Normal Access Operation (Read/Write)

When two or more rounds of external bus access are required in response to a single request for transfer from a bus master, normal access operations (points 1. to 4. above) are repeated. Figures 11.10 and 11.11 show examples of operations when two rounds of bus access are generated in response to a single request for transfer. The values of the wait control registers are example settings. In practice, the register settings will correspond to the specifications of connected devices.

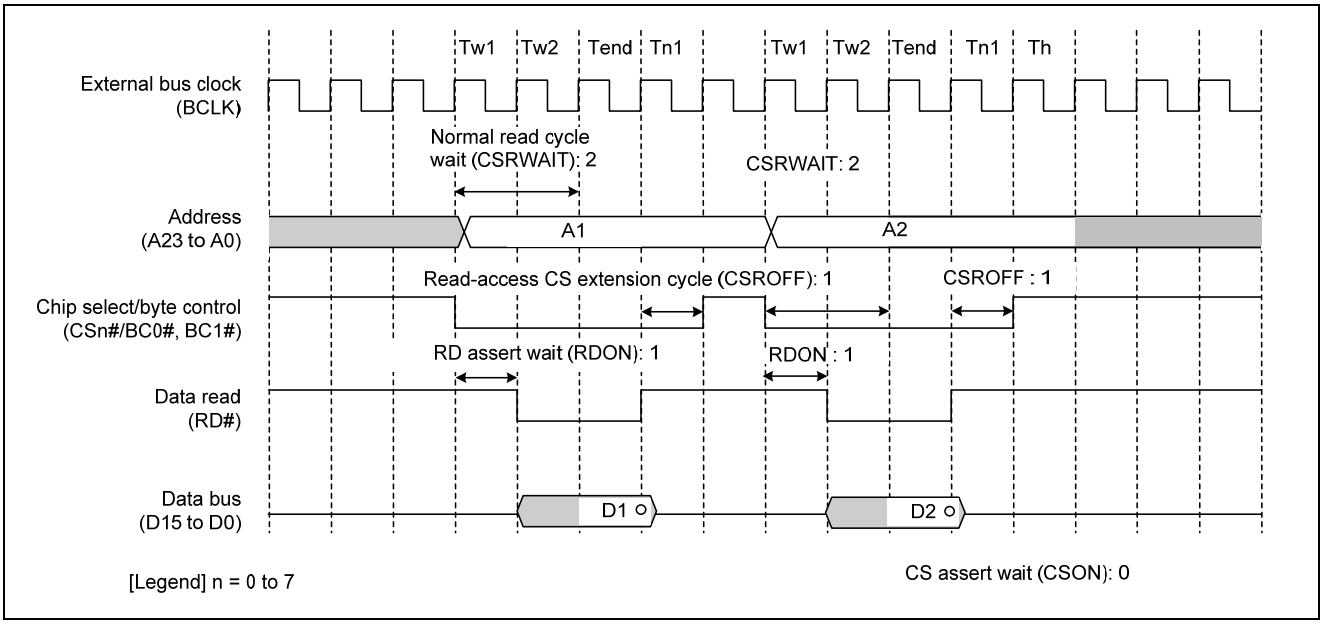


Figure 11.10 Example of Normal-Read Operation (when Two Rounds of Bus Access are Generated in Response to a Single Request for Transfer)

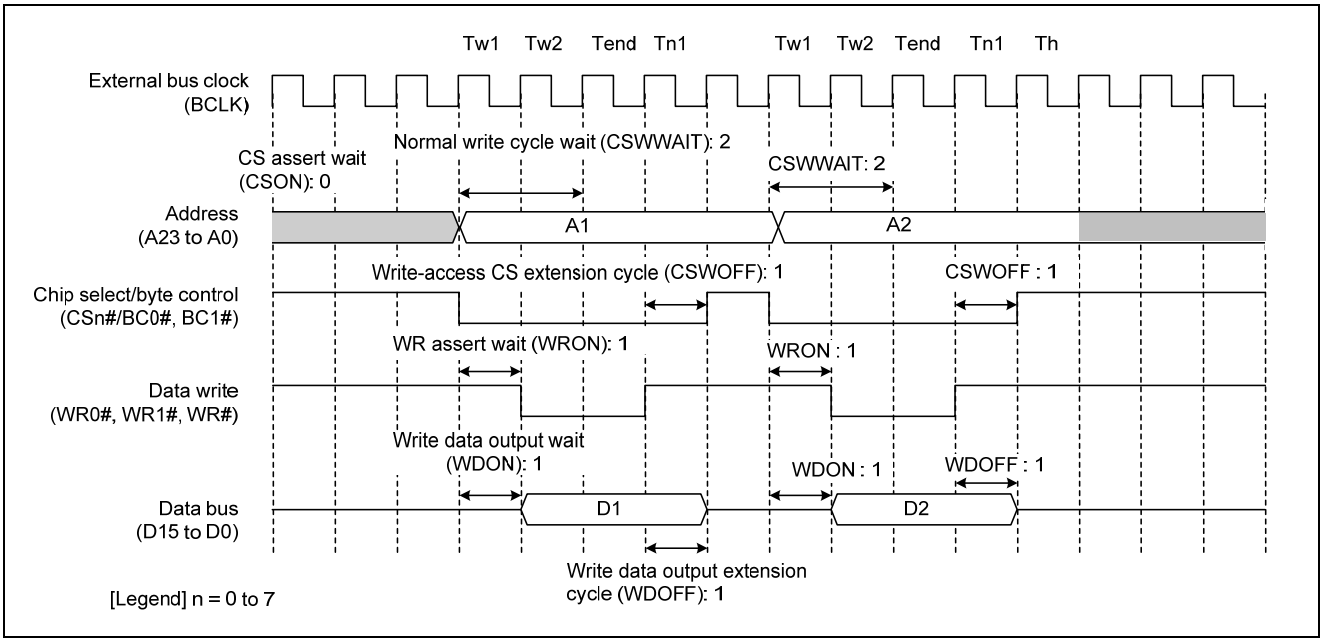


Figure 11.11 Example of Normal-Write Operation (when Two Rounds of Bus Access are Generated in Response to a Single Request for Transfer)

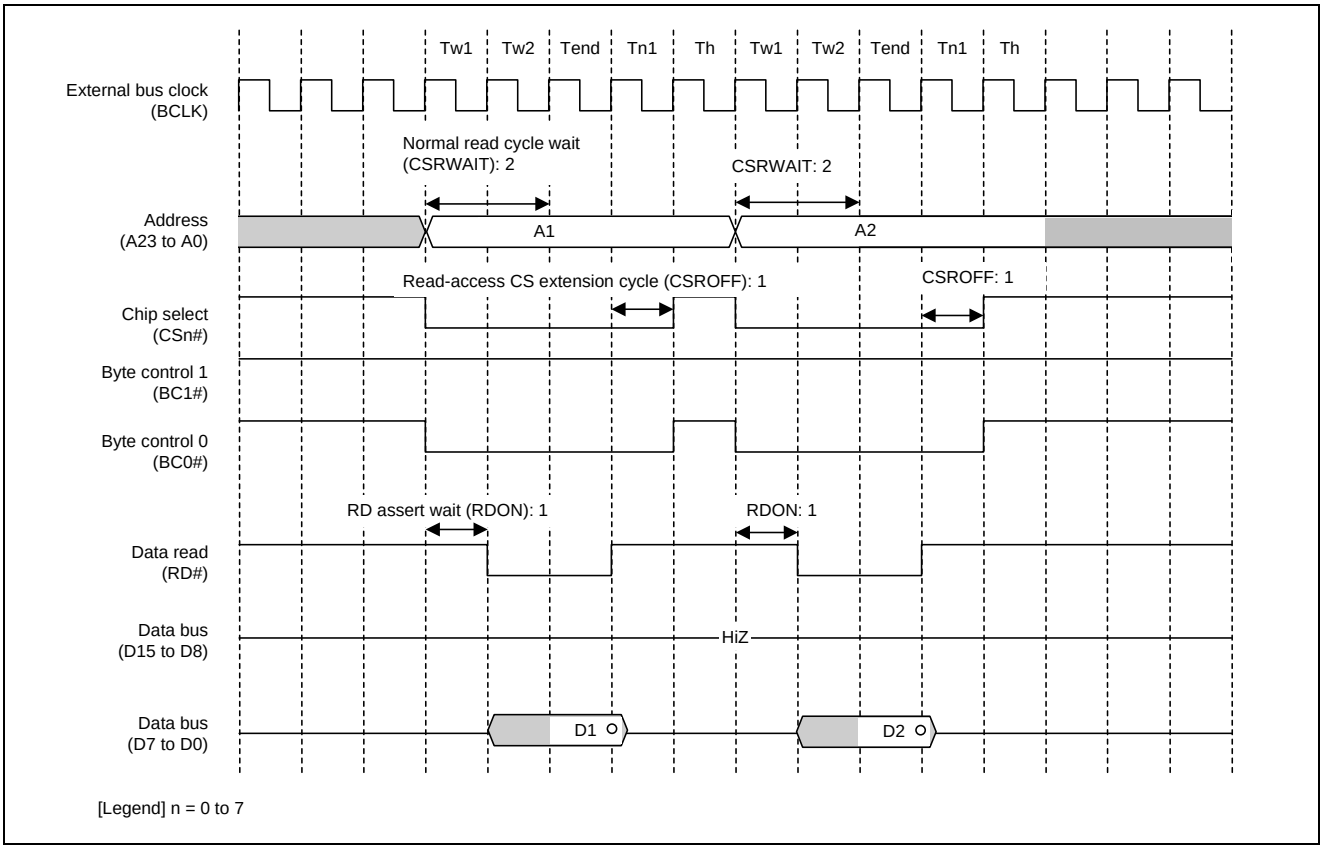


Figure 11.12 Example of Normal-Read Operation (when 16-Bit Bus Space is Accessed in 8 Bits)

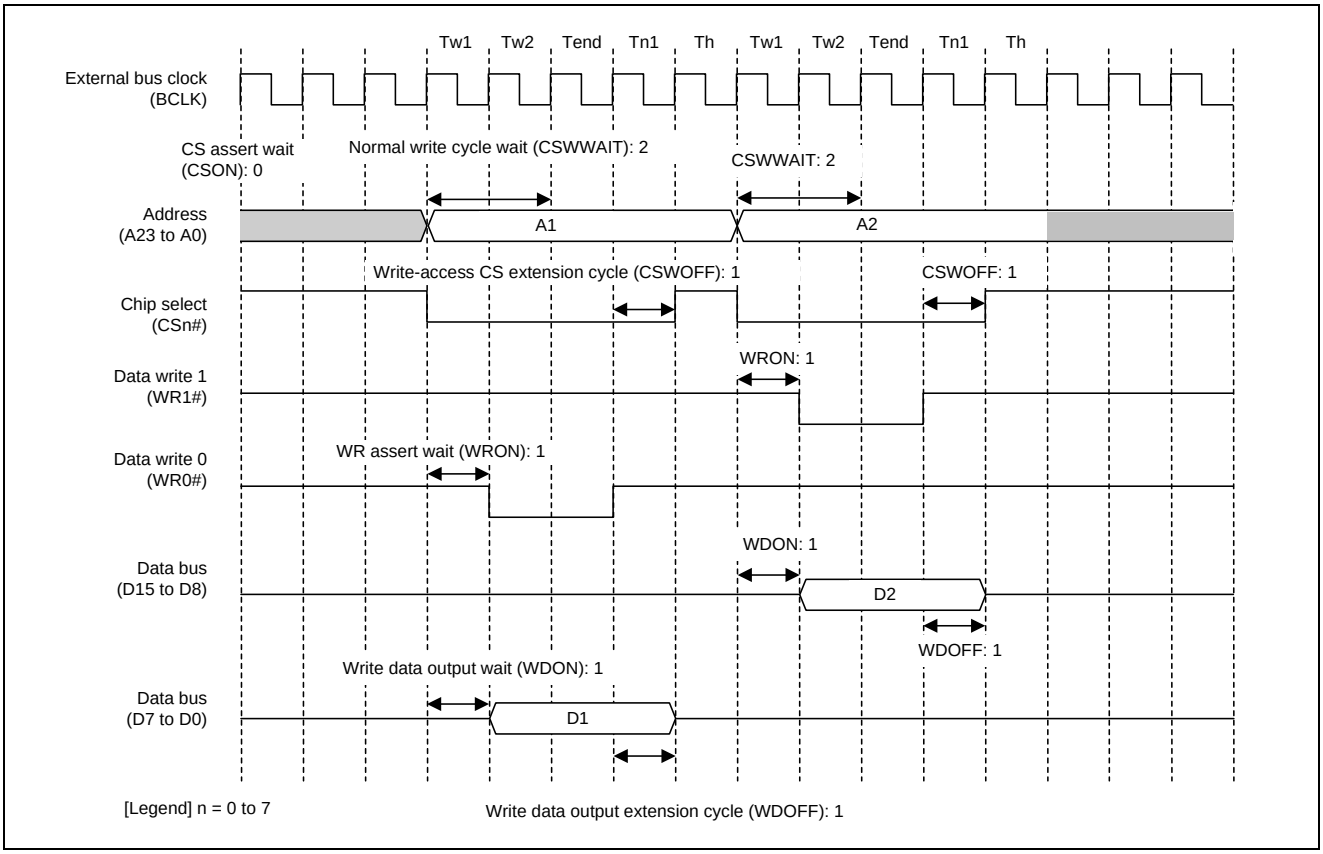


Figure 11.13 Example of Normal-Write Operation (when 16-Bit Bus Space is Accessed in 8 Bits, in Byte Strobe Mode)

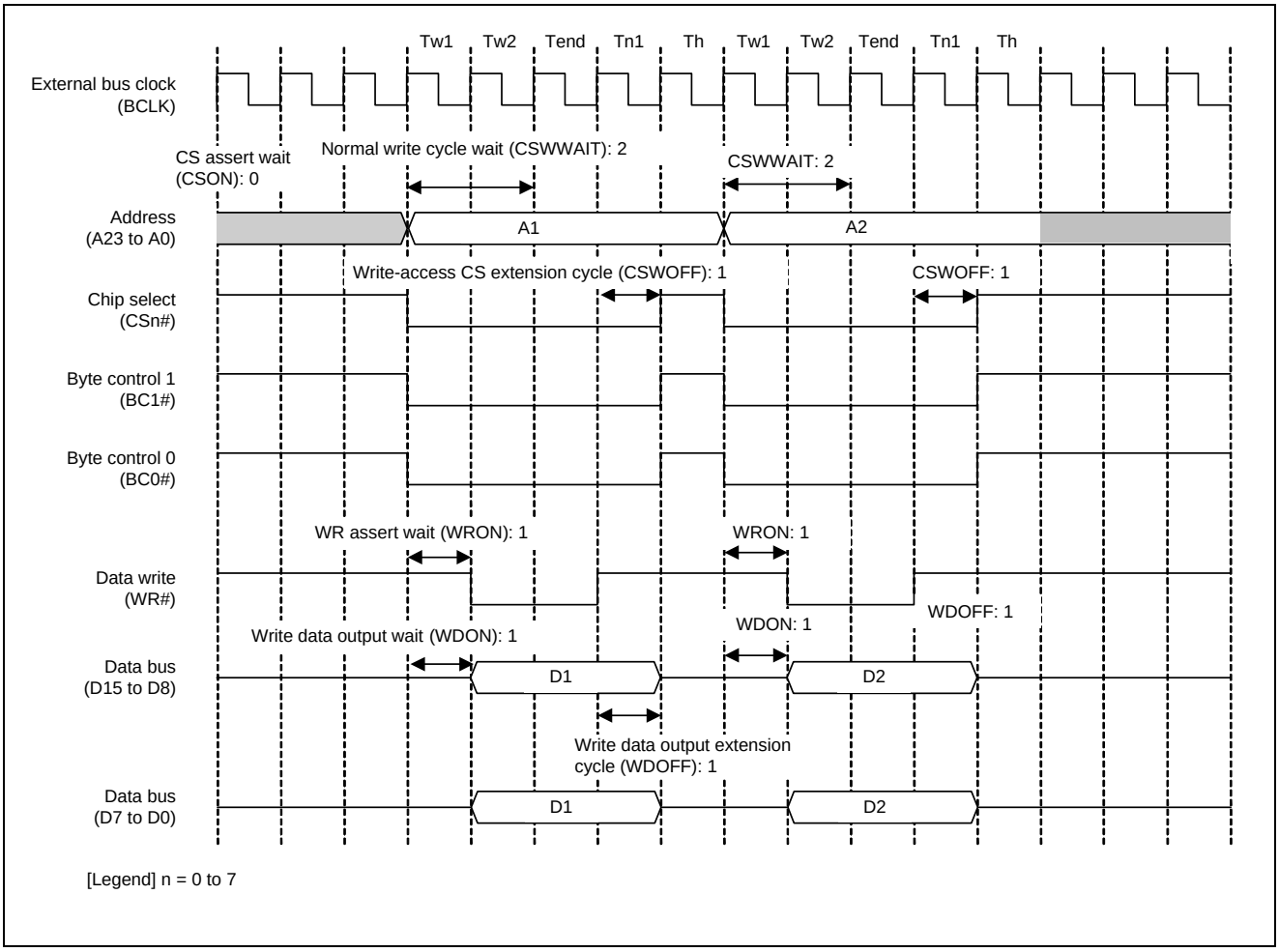


Figure 11.14 Example of Normal-Write Operation (when 16-Bit Bus Space is Accessed in 16 Bits, in Single Write Strobe Mode)

11.5.1.2 Page Access

When the PRENB and PWENB bits in CSiMOD are set to 1 to enable page-reading and page-writing access, respectively, the bus access for page access operations becomes page reading and writing. Page access is made when two or more rounds of external bus access are required for a single transfer request from the bus master. See figures 11.15 to 11.18 for the conditions under which page access occurs.

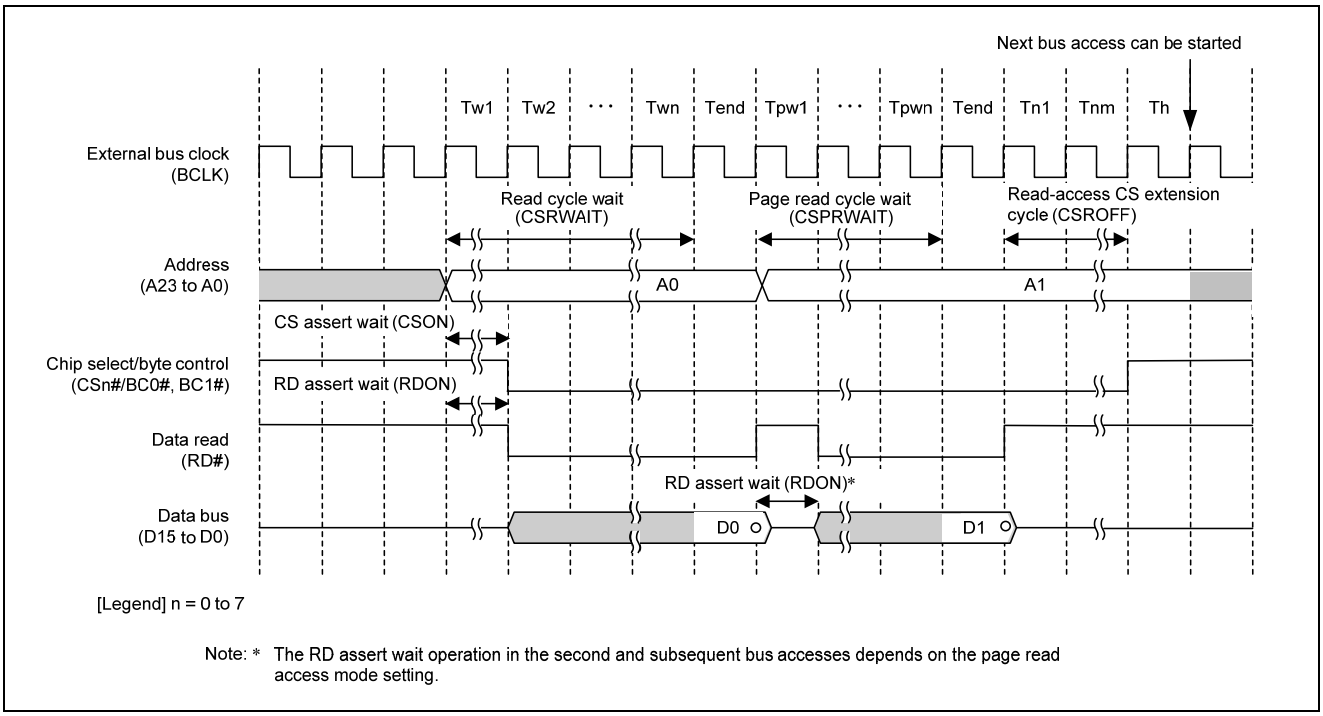


Figure 11.15 Page-Read Access Timing

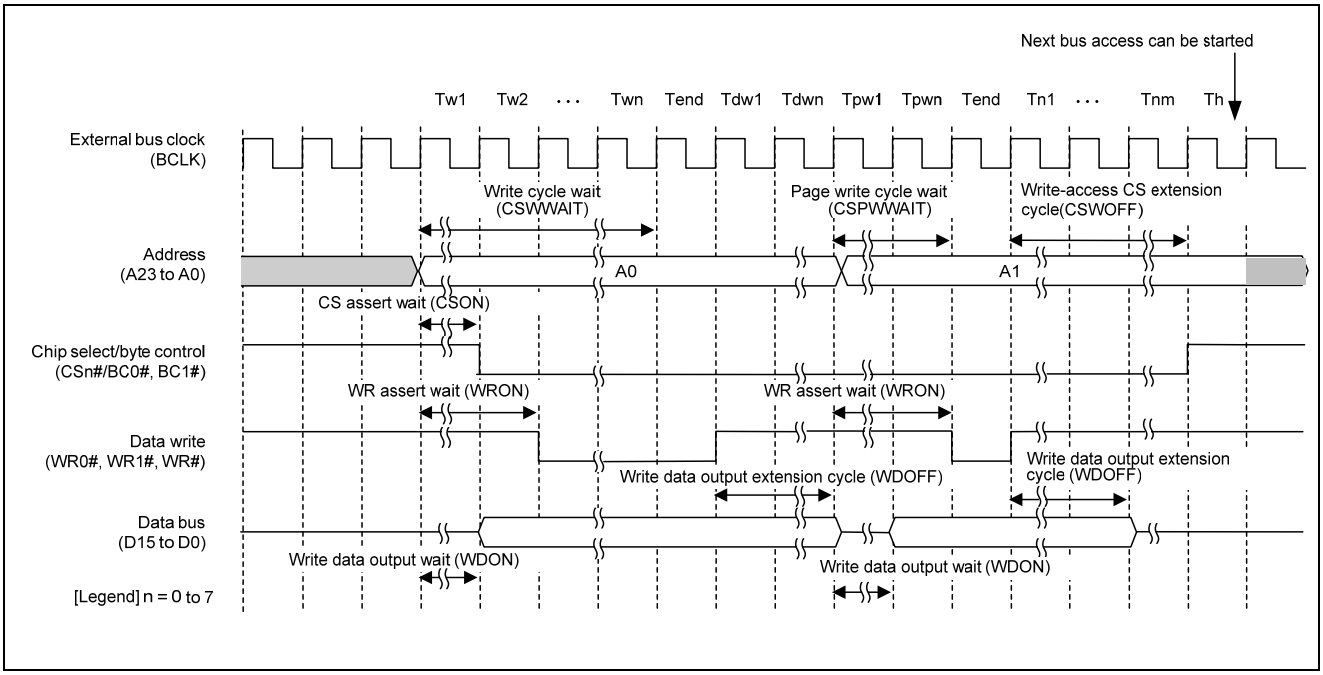


Figure 11.16 Page-Write Access Timing

Figures 11.17 and 11.18 depict examples of operations for access to a 16-bit bus space in 32 bits. The values of the wait control registers are example settings. In practice, the register settings will correspond to the specifications of connected devices.

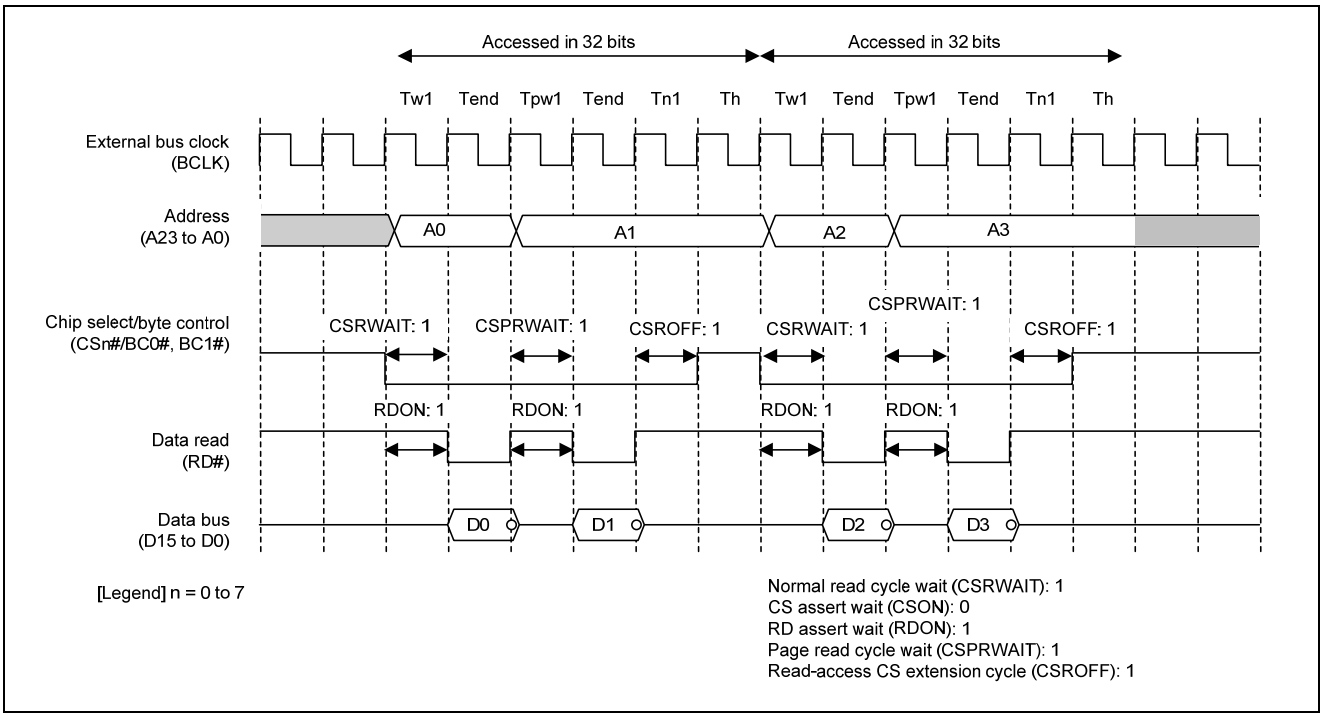


Figure 11.17 Example of Page-Read Access Operation (when 16-Bit Bus Space is Accessed in 32 Bits)

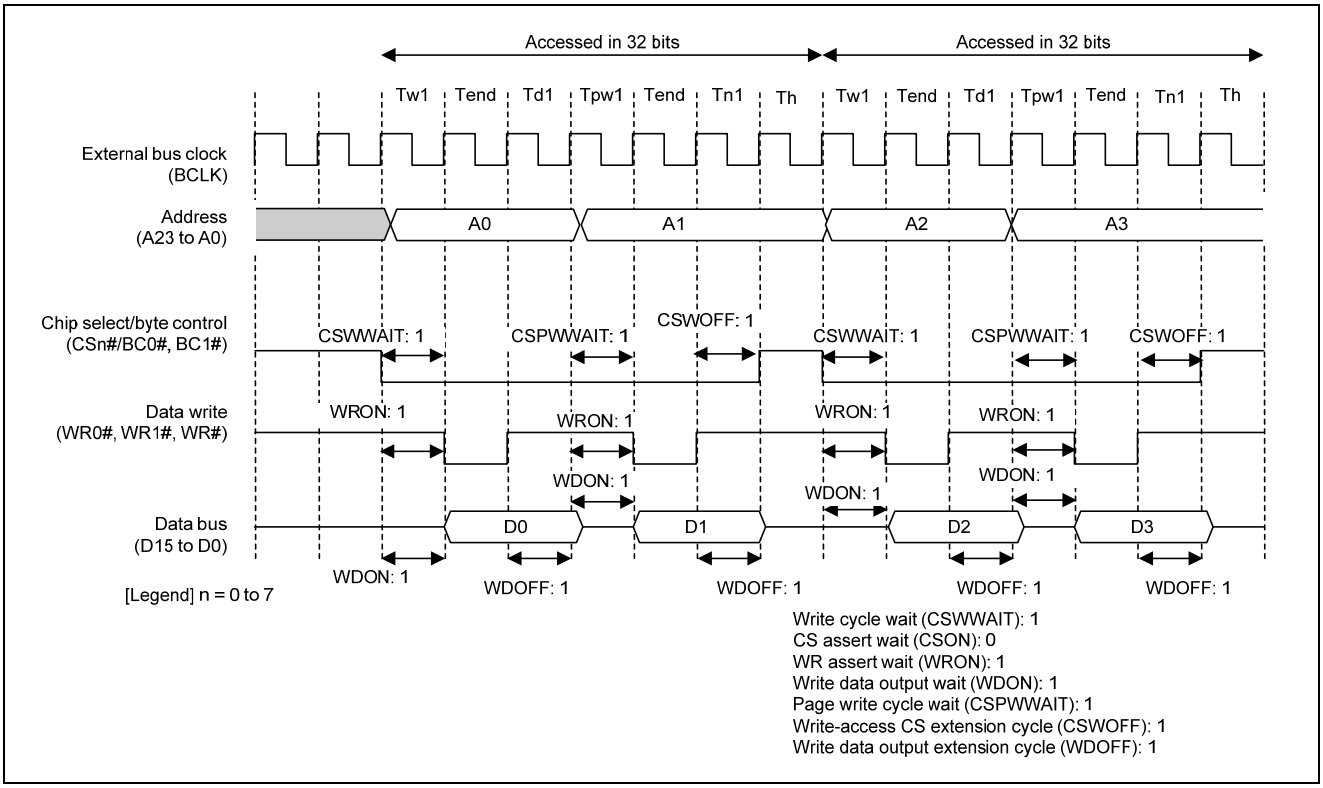


Figure 11.18 Example of Page-Write Access Operation (when 16-Bit Bus Space is Accessed in 32 Bits)

11.5.2 External Wait Function

Wait cycles can be extended by the WAIT# signal over the length of normal access cycle wait (specified by the CSRWAIT[4:0] and CSWWAIT[4:0] bits in CSiWCNT1) and page access cycle wait (specified by the CSPRWAIT[2:0] and CSPWWAIT[2:0] bits in CSiWCNT1).

When external wait is enabled (the EWENB bit = 1 in CSiMOD), wait cycles are inserted while the WAIT# signal is held low. When external wait is disabled (the EWENB bit = 0 in CSiMOD), the WAIT# signal has no effect.

All wait cycles specified in CSiWCNT1 are inserted independently of the WAIT# signal.

11.5.2.1 Normal Access

Sampling of the WAIT# signal begins upon completion of the wait cycle (Tend) specified in CSiWCNT1. The bus cycle is extended while the WAIT# signal is held low. The wait cycle ends (Tend) at the next cycle after the WAIT# signal becomes high.

11.5.2.2 Page Access

The first data read or data write operation is the same as the normal read or write operation. Sampling of the WAIT# signal begins upon completion of the wait cycle (Tend) specified in the CSiWCNT1 register. The bus cycle is extended while the WAIT# signal is held low. The wait cycle ends (Tend) at the next cycle after the WAIT# signal becomes high.

With respect to the second and subsequent read accesses, sampling of the WAIT# signal begins upon completion of the wait cycle of the page access. The wait cycle of the page access is extended while the WAIT# signal is held low, and ends (Tend) at the next cycle after the WAIT# signal becomes high.

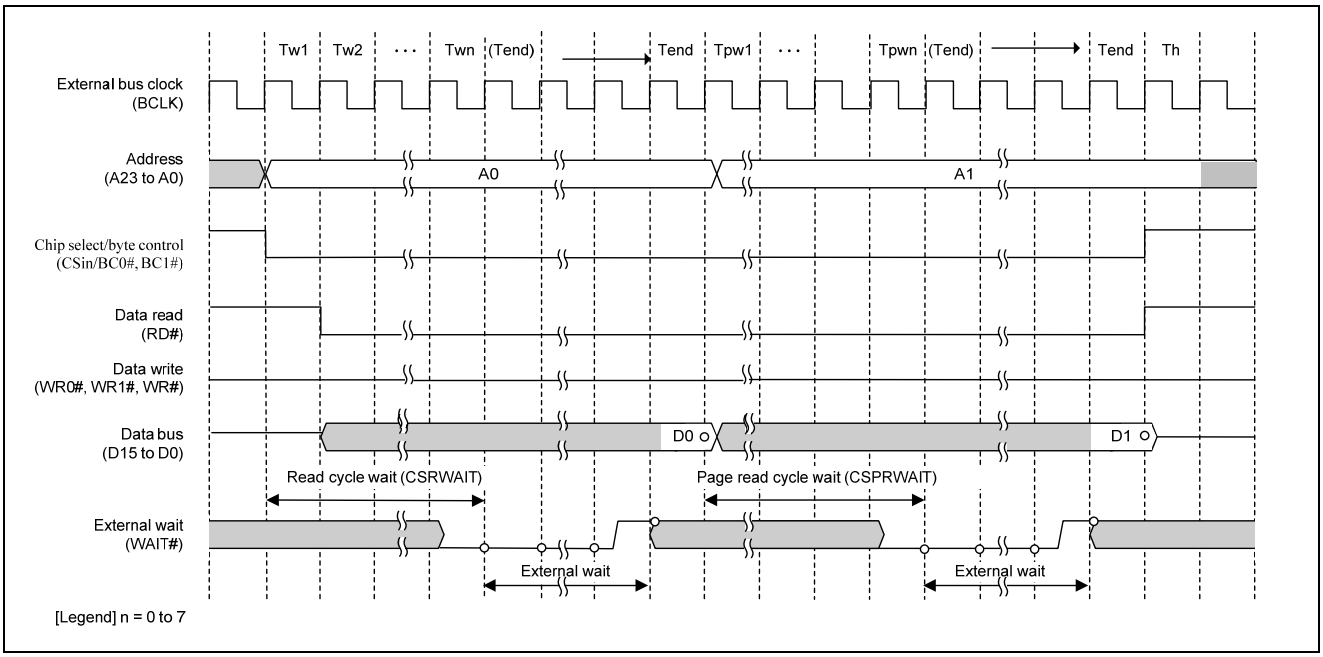


Figure 11.19 Example of External Wait Timing (Page-Read Access to 16-Bit Bus Space)

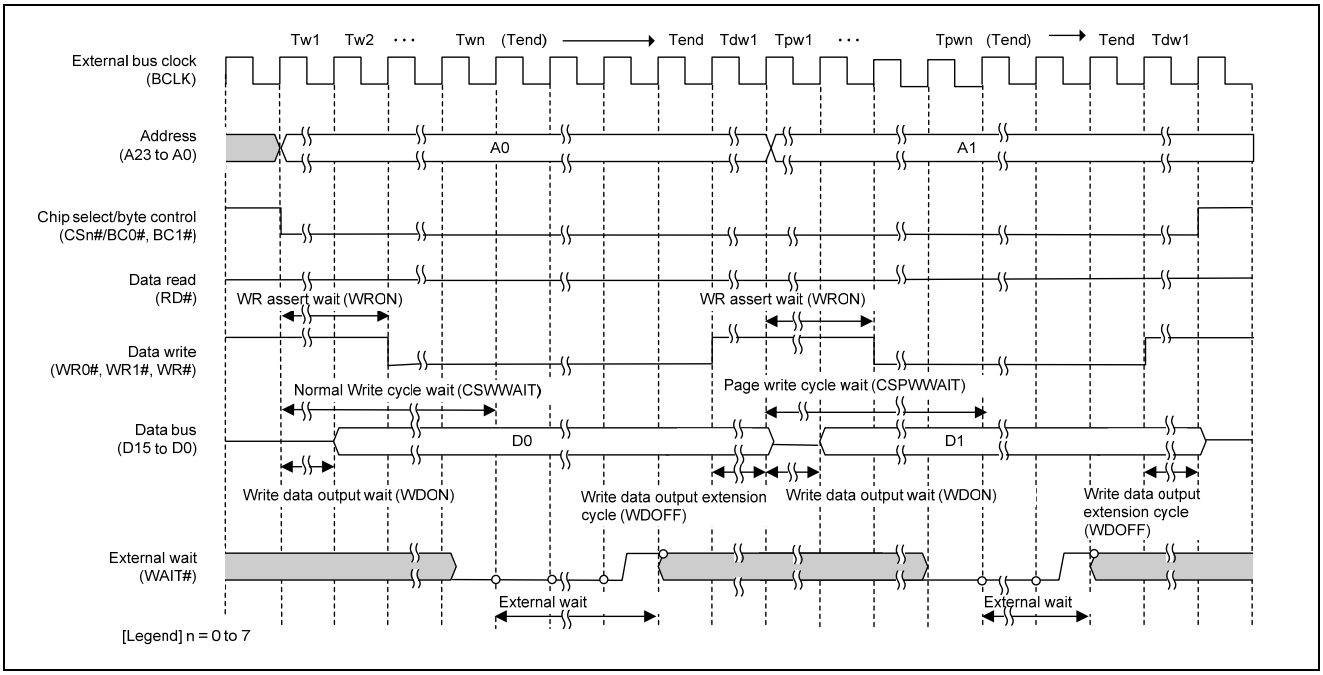


Figure 11.20 Example of External Wait Timing (Page-Write Access to 16-Bit Bus Space)

11.5.3 Insertion of Recovery Cycles

Clock cycles of recovery can be inserted between consecutive rounds of external bus access. Conditions where cycles of recovery can be inserted are described below.

- Write access via the external bus follows read access via the external bus.
- Read access via the external bus follows read access to a different area via the external bus.
- Read access via the external bus follows write access via the external bus.

Clock cycles of recovery are not inserted between write access and subsequent write access.

Separate numbers of clock cycles for recovery can be set up for insertion after cycles of reading or writing. The number of bus-clock cycles to be inserted for recovery following a write cycle is set by the WRCV[3:0] bits in CSiREC for the area to which a write access has been performed in the preceding bus cycle, and the number of bus-clock cycles to be inserted as the recovery cycle that follows a read cycle is set by the RRCV[3:0] bits in CSiREC for the area to which a read access has been performed in the preceding bus cycle. In other words, when a read access is made to CS0 and then to CS1, the number of recovery cycles to be inserted between these two accesses is determined by the PRCV[3:0] bits in CS0REC.

The clock cycles of recovery begin at the end of the preceding bus cycle, i.e. when the CSi# signal (i = 0 to 7) is negated. From this point, the selected period over which the CSi# signal is at the high level (i.e. the recovery period) is inserted.

After the end of the clock cycles of recovery, the CSi# signal is asserted for the next round of bus access after the insertion of no less than one bus-clock cycle as an idle cycle. Even if the next request for access to an external space is generated during the recovery period, the next round of access over the external bus will only start after one bus-clock cycle has been inserted as an idle cycle following the end of the recovery period.

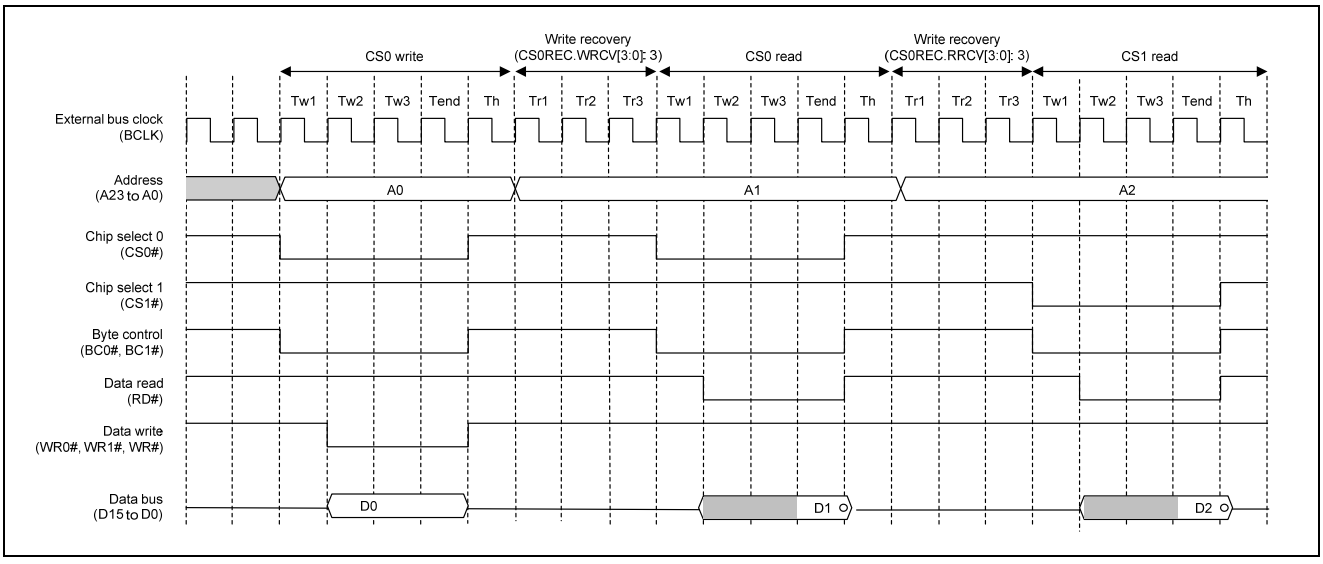


Figure 11.21 Example of Recovery Timing

11.5.4 Write Buffer Function

The internal main bus is released by writing data to the write buffer before the write access is completed, which allows the next round of bus access to start. However, if the following round of bus access is to an external address space or to a control register for the external bus, it is suspended until the external bus operations already in progress are completed.

Figure 11.22 shows an example of operation when the write-buffer function is in use. When this function is in use, if the next operation after an external write is internal access, the internal access (access to on-chip memory or a peripheral module) is executed in parallel with the external write, i.e. without waiting for completion of the latter operation.

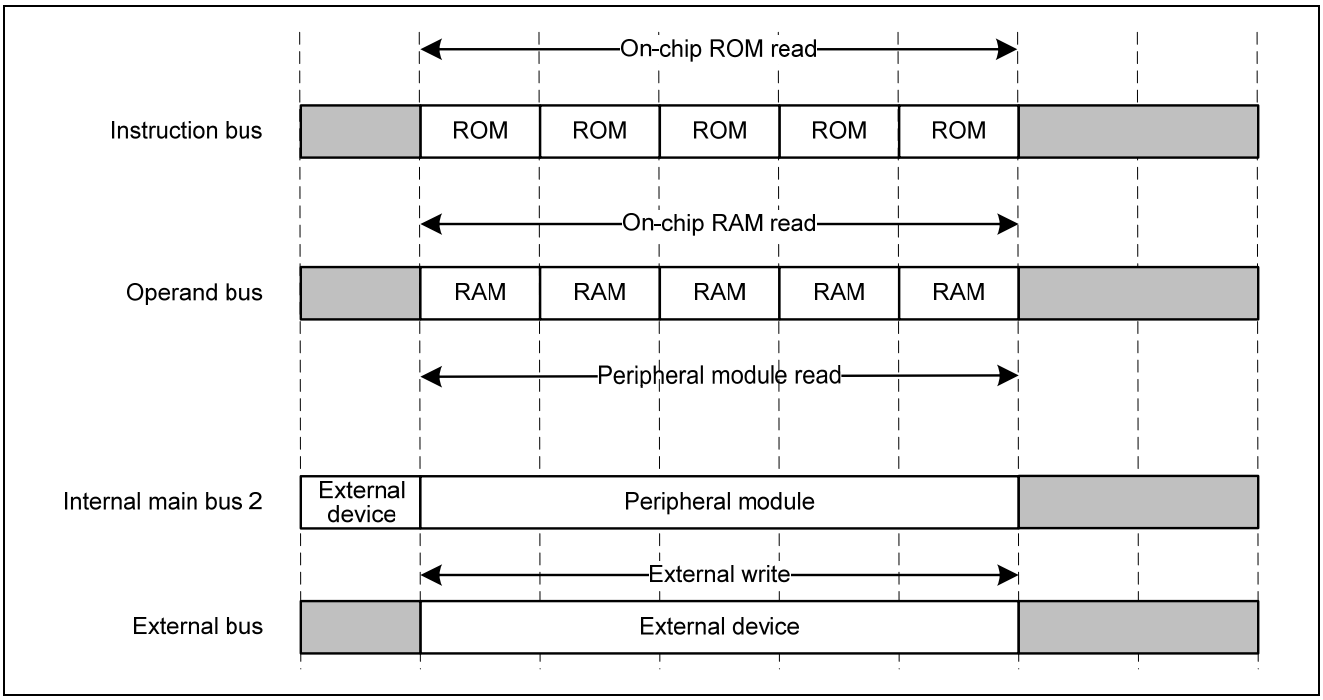


Figure 11.22 Example of Operation when the Write-Buffer Function is in Use

11.5.5 Notes on Usage

11.5.5.1 Limitations at the Time of Normal and Page Access

Limitations that apply to various bits of CSi wait control register 1 (CSiWCNT1) and CSi wait control register 2 (CSiWCNT2) at the times of normal and page access are listed in table 11.9.

If the setting of the page-read access enable bit in the CSi mode register or the page-write access enable bit in the CSi mode register selects permission (CSiMOD.PRENB = 1 or CSiMOD.PWENB = 1), the limitations on normal access must be satisfied in the first round of access for page access or in access that does not fall within the scope of page access and thus leads to normal access operations. For details on the situations that are not within the scope of page access, see section 11.5.1, Timing of External Bus Access.

Table 11.9 Limitations at the Time of Normal and Page Access

Limitations at the Time of Normal Access		Limitations at the Time of Page Access	
Reading	**Writing**	**Reading**	**Writing**
CSON[2:0] ≤ CSRWAIT	CSON[2:0] ≤ CSWWAIT	CSON[2:0] ≤ CSPRWAIT	CSON[2:0] ≤ CSPWWAIT
RDON[2:0] ≤ CSRWAIT	WRON[2:0] ≤ CSWWAIT	RDON[2:0] ≤ CSPRWAIT	WRON[2:0] ≤ CSPWWAIT
CSON[2:0] ≤ RDON	WDON[2:0] ≤ CSWWAIT	CSON[2:0] ≤ RDON	WDON[2:0] ≤ CSPWWAIT
	WDOFF[2:0] ≤ CSWOFF		WDOFF[2:0] ≤ CSWOFF
	WDON[2:0] ≤ WRON		WDON[2:0] ≤ WRON
	CSON[2:0] ≤ WRON		CSON[2:0] ≤ WRON

11.5.5.2 Prohibition of Access that Spans Areas of Address Space

Single access operations that span areas of the address space are prohibited, and operation in the case of attempts at such access is not guaranteed. In cases where access to a single word or longword would produce access that crosses a boundary between areas, split the instruction so that separate instructions are used for access to each of the areas.

11.5.5.3 Restrictions in Relation to RMPA and String-Manipulation Instructions

- Although the external space has a per-area ending-switching facility (only for data), the allocation of data to be handled by RMPA or string-manipulation instructions to an area where the endian differs from that of the chip is prohibited, and operation is not guaranteed if this restriction is not observed. If data to be handled by RMPA or string-manipulation instructions are allocated to the external space, they must be allocated to areas where the endian setting is the same as that for the chip.
- The allocation of data to be handled by RMPA or string-manipulation instructions to I/O registers is prohibited, and operation is not guaranteed if this restriction is not observed.

11.5.5.4 Point for Caution Regarding Register Settings

- Note on setting that affects the write data hold time (tWDH)
  To secure the write data hold time, ensure that the setting of the CSiWCNT2.WDOFF[2:0] bits (write data output extension cycle select bits) is at least 1. Take care to ensure that this condition is met, since not meeting the condition may make securing the write data hold time impossible.

11.5.5.5 Restriction on Instruction Code

When the endian setting for an area is different from that for the chip, no instruction code can be arranged in the area. The instruction code should be arranged in the external space whose endian setting is the same as that for the chip.

11.6 Bus Error Monitoring Section

The bus-error monitoring section monitors the individual areas for bus errors, and generates an interrupt when it detects a bus error.

11.6.1 Types of Bus Error

There are two types of bus error: illegal address access and time-out.

Illegal address access is the detection of illegal access to an area, and time-out is the detection of a bus-access operation not being completed within 768 cycles.

11.6.1.1 Illegal Address Access

When the illegal address access detection enable bit in the bus-error enable register is set (BEREN.IGAEN = 1), access of the following types leads to illegal address access errors.

- Access to areas of external space for which operation has been disabled (CSiCNT.EXENB = 0; i = 0 to 7)
- Access to illegal address ranges other than in areas for which operation has been disabled

The address ranges where access will lead to illegal address access errors are indicated in table 11.10.

11.6.1.2 Time-out

When the time-out detection enable bit in the bus-error enable register is set (BEREN.TOEN = 1), bus access that is not completed within 768 cycles leads to a time-out error. Cycles of the operating clock of the relevant slave are counted as the number of cycles.

- External space: Once a bus-access operation has started, access is not completed (the WAIT# signal is not negated) within 768 cycles.

Note: In products of the RX610 Group, time-out errors are only generated for access to external space.

11.6.2 Operations When a Bus Error Occurs

Generation of an interrupt (BUSERR) can be selected by setting the bus error notification bit (BERIE.CPEN = 1).

11.6.3 Conditions Leading to Bus Errors

Table 11.10 lists the types of bus errors for each area in the respective address space.

Table 11.10 Types of Bus Errors

Address	Type of Area		Type of Error			
			Illegal Address Access		Time-out	
	On-chip ROM Mode		On-chip ROM mode		On-chip ROM Mode	
	Enabled	Disabled	Enabled	Disabled	Enabled	Disabled
0000 0000h to 0001 FFFFh	On-chip RAM		—		—	
0002 0000h to 0007 FFFFh	Reserved area					
0008 0000h to 0008 FFFFh	Peripheral I/O registers		—		—	
0009 0000h to 000F FFFFh			✓		—	
0010 0000h to 0011 FFFFh	Data flash	Reserved area	—	✓	—	—
0012 0000h to 007F 7FFFh	Reserved area		✓		—	
007F 8000h to 007F 9FFFh	FCU-RAM		—		—	
007F A000h to 007F BFFFh	Reserved area		✓		—	
007F C000h to 007F C4FFh	Peripheral I/O registers		—		—	
007F C500h to 007F FBFFh	Reserved area		✓		—	
007F FC00h to 00FF FFFFh	Peripheral I/O registers		—		—	
0080 0000h to 00DF FFFFh	Reserved area					
00E0 0000h to 00FF FFFFh	On-chip ROM (dedicated area for writing)					
0100 0000h to 07FF FFFFh	External address space (CS1 to CS7)		✓*1		✓*2	
0800 0000h to 7FFF FFFFh	Reserved area		✓		—	
8000 0000h to FEFF FFFFh	On-chip ROM (dedicated area for reading)	Reserved area	—	✓	—	—
FF00 0000h to FFFF FFFFh		External address space (CS0)		✓*1		✓*2

[Legend] —: A bus error is not produced.
✓: A bus error is produced.
1. Access to this area leads to the detection of a bus error if operation has been disabled (CSiCNT.EXENB = 0; i = 0 to 7).
2. Bus access not being completed (the WAIT# signal not being negated) within 768 cycles leads to detection of a bus error.

12. DMA Controller (DMAC)

The RX610 Group incorporates a 4-channel direct memory access controller (DMAC).

The DMAC is a module to transfer data without the CPU.

When a DMA transfer request is generated, the DMAC transfers data stored at the transfer source address to the transfer destination address.

12.1 Overview

Table 12.1 lists the specifications of the DMAC, and figure 12.1 shows a block diagram of the DMAC.

Table 12.1 Specifications of DMAC

Item		Description	
Number of channels		4 (DMACm (m = 0 to 3))	
Transfer space		4 Gbytes (00000000h to FFFFFFFFh excluding reserved areas)	
Maximum transfer volume		64 Mbytes	
DMA activation source		Software trigger Trigger input to external pin interrupts Interrupt requests from peripheral functions	
Channel priority		Channel 0 > Channel 1 > Channel 2 > Channel 3 (Channel 0: Highest)	
Transfer data	Single data	Bit length: 8, 16, 32 bits	
	Single operand	Data count: 1, 2, 4, 8, 16, 32, 64, 128	
Transfer system	Operand transfer system	Single	Data of a single operand is transferred per DMA transfer request. Channel arbitration is made after a single-operand transfer. A DMA transfer request is necessary at each end of single-operand transfer until the DMA transfer end.
		Consecutive	Data is transferred continuously in operand units until the DMA transfer end per DMA transfer request. Channel arbitration is made after a single-operand transfer. A DMA transfer request is made first only once.
	Nonstop transfer system	Data is transferred continuously until the DMA transfer ends per DMA transfer request. Channel arbitration is made when DMA transfer is completed. A DMA transfer request is made first only once.	
DMA transfer start condition		DMA transfer starts when all the following conditions are met. The DEN bit in DMCRE of DMACm is 1 (DMA transfer enabled). The DMST bit in DMSCNT is 1 (DMAC start). When a DMA transfer request of channel m (DMACm) is generated and the execution authority is obtained by the channel arbitration.	
DMA transfer end condition		When the DMCBC register of DMACm is decremented to 0000000h	
Interrupt request generation timing		When the DMCBC register of DMACm is decremented to 0000000h	
Single-data transfer time		Three bus clock cycles or more	

Item	Description
Selective function	Reload function Reloads the values in reload registers (transfer source address, transfer destination address, transfer byte count) to current registers (transfer source address, transfer destination address, transfer byte count) at the end of DMA transfer.

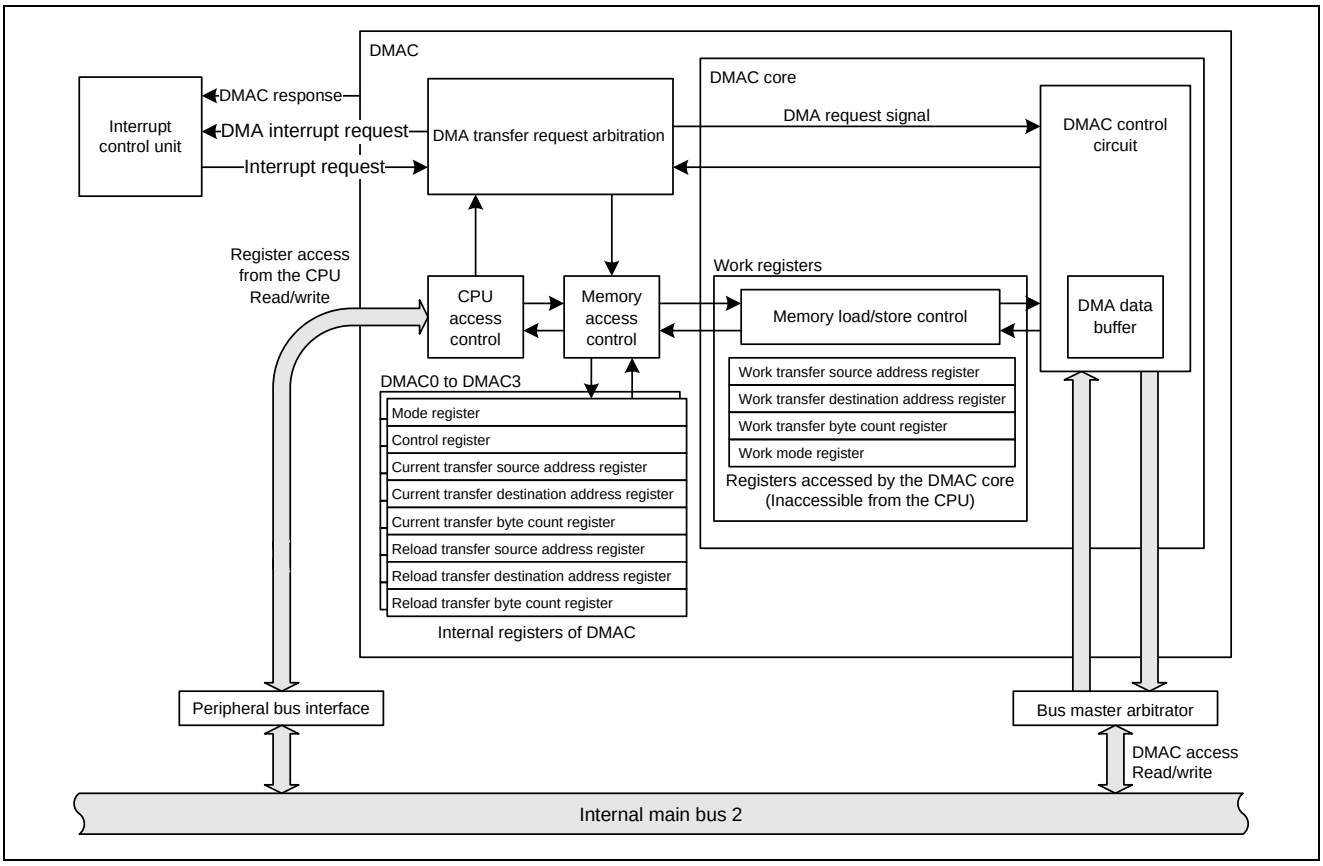


Figure 12.1 Block Diagram of DMAC

12.2 Register Descriptions

Table 12.2 lists the registers of the DMAC. Registers of DMAC0 to DMAC3 have same functions.

Table 12.2 Registers of DMAC

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
DMAC0	DMA mode register	DMMOD	0x0x xx00h	0008 200Ch	32
	DMA control register A	DMCRA	0000 0000h	0008 2400h	32
	DMA control register B	DMCRB	00h	0008 2404h	8
	DMA control register C	DMCRC	00h	0008 2405h	8
	DMA control register D	DMCRD	00h	0008 2406h	8
	DMA control register E	DMCRE	00h	0008 2407h	8
	DMA current transfer source address register	DMCSA	xxxx xxxxh	0008 2000h	32
	DMA current transfer destination address register	DMCDA	xxxx xxxxh	0008 2004h	32
	DMA current transfer byte count register	DMCBC	0xxx xxxxh	0008 2008h	32
	DMA reload transfer source address register	DMRSA	xxxx xxxxh	0008 2200h	32
	DMA reload transfer destination address register	DMRDA	xxxx xxxxh	0008 2204h	32
	DMA reload transfer byte count register	DMRBC	0xxx xxxxh	0008 2208h	32
DMAC1	DMA mode register	DMMOD	0x0x xx00h	0008 201Ch	32
	DMA control register A	DMCRA	0000 0000h	0008 2408h	32
	DMA control register B	DMCRB	00h	0008 240Ch	8
	DMA control register C	DMCRC	00h	0008 240Dh	8
	DMA control register D	DMCRD	00h	0008 240Eh	8
	DMA control register E	DMCRE	00h	0008 240Fh	8
	DMA current transfer source address register	DMCSA	xxxx xxxxh	0008 2010h	32
	DMA current transfer destination address register	DMCDA	xxxx xxxxh	0008 2014h	32
	DMA current transfer byte count register	DMCBC	0xxx xxxxh	0008 2018h	32
	DMA reload transfer source address register	DMRSA	xxxx xxxxh	0008 2210h	32
	DMA reload transfer destination address register	DMRDA	xxxx xxxxh	0008 2214h	32
	DMA reload transfer byte count register	DMRBC	0xxx xxxxh	0008 2218h	32
DMAC2	DMA mode register	DMMOD	0x0x xx00h	0008 202Ch	32
	DMA control register A	DMCRA	0000 0000h	0008 2410h	32
	DMA control register B	DMCRB	00h	0008 2414h	8
	DMA control register C	DMCRC	00h	0008 2415h	8
	DMA control register D	DMCRD	00h	0008 2416h	8
	DMA control register E	DMCRE	00h	0008 2417h	8
	DMA current transfer source address register	DMCSA	xxxx xxxxh	0008 2020h	32
	DMA current transfer destination address register	DMCDA	xxxx xxxxh	0008 2024h	32
	DMA current transfer byte count register	DMCBC	0xxx xxxxh	0008 2028h	32
	DMA reload transfer source address register	DMRSA	xxxx xxxxh	0008 2220h	32
	DMA reload transfer destination address register	DMRDA	xxxx xxxxh	0008 2224h	32
	DMA reload transfer byte count register	DMRBC	0xxx xxxxh	0008 2228h	32

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
DMAC3	DMA mode register	DMMOD	0x0x xx00h	0008 203Ch	32
	DMA control register A	DMCRA	0000 0000h	0008 2418h	32
	DMA control register B	DMCRB	00h	0008 241Ch	8
	DMA control register C	DMCRC	00h	0008 241Dh	8
	DMA control register D	DMCRD	00h	0008 241Eh	8
	DMA control register E	DMCRE	00h	0008 241Fh	8
	DMA current transfer source address register	DMCSA	xxxx xxxxh	0008 2030h	32
	DMA current transfer destination address register	DMCDA	xxxx xxxxh	0008 2034h	32
	DMA current transfer byte count register	DMCBC	0xxx xxxxh	0008 2038h	32
	DMA reload transfer source address register	DMRSA	xxxx xxxxh	0008 2230h	32
	DMA reload transfer destination address register	DMRDA	xxxx xxxxh	0008 2234h	32
	DMA reload transfer byte count register	DMRBC	0xxx xxxxh	0008 2238h	32
DMAC0 to DMAC3	DMA interrupt control register	DMICNT	00h	0008 250Bh	8
	DMA start control register	DMSCNT	00h	0008 2502h	8
	DMA arbitration status register	DMASTS	00h	0008 251Bh	8
	DMA transfer end detect register	DMEDET	00h	0008 2517h	8

Note: x: Undefined

12.2.1 DMA Mode Register (DMMOD)

Addresses: DMAC0.DMMOD 0008 200Ch, DMAC1.DMMOD 0008 201Ch
DMAC2.DMMOD 0008 202Ch, DMAC3.DMMOD 0008 203Ch

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	OPSEL[3:0]				—	—	—	—	—	SZSEL[2:0]		
Value after reset:	0	0	0	0	x	x	x	x	0	0	0	0	0	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	SMOD[2:0]			—	DMOD[2:0]			—	—	—	—	—	—	—	—
Value after reset:	0	x	x	x	0	x	x	x	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b10 to b8	DMOD[2:0]	Transfer Destination Address Addition Direction Select	b10 b9 b8 0 0 0: Fixed 0 0 1: Plus 0 1 0: Minus 0 1 1: Rotate Do not write other values.	R/W
b11	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b14 to b12	SMOD[2:0]	Transfer Source Address Addition Direction Select	b14 b13 b12 0 0 0: Fixed 0 0 1: Plus 0 1 0: Minus 0 1 1: Rotate Do not write other values.	R/W
b15	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b18 to b16	SZSEL[2:0]	Transfer Data Size Select	b18 b17 b16 0 0 0: 8 bits 0 0 1: 16 bits 0 1 0: 32 bits Do not write other values.	R/W
b23 to b19	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b27 to b24	OPSEL[3:0]	Operand Transfer Data Count Select	b27 b26 b25 b24 0 0 0 0: Single data 0 0 0 1: 2 data 0 0 1 0: 4 data 0 0 1 1: 8 data 0 1 0 0: 16 data 0 1 0 1: 32 data 0 1 1 0: 64 data 0 1 1 1: 128 data Do not write other values.	R/W
b31 to b28	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMMOD is used to set the addition direction of transfer source and destination addresses and to set the size of transfer data.

Do not set DMMOD during data transfer, but set it while the DMAC is not active or DMA transfer is disabled.

Access this register with 32 bits.

DMOD[2:0] Bits (Transfer Destination Address Addition Direction Select)
SMOD[2:0] Bits (Transfer Source Address Addition Direction Select)

These bits select the addition direction of transfer source and destination addresses during DMA transfer.

When "rotate" is selected, address is added in the plus direction and is returned to the value specified at the beginning of DMA transfer when single-operand transfer is completed.

Transfer source and destination addresses increase or decrease according to the addition direction and data size settings as shown in table 12.3.

Table 12.3 Address Increase/Decrease According to Addition Direction and Data Size

SZSEL[2:0] Bits	SMOD[2:0] Bits/DMOD[2:0] Bits			
	000b (Fixed)	001b (Plus)	010b (Minus)	011b (Rotate)
000b (8 bits)	±0	+1	-1	+1
001b (16 bits)	±0	+2	-2	+2
010b (32 bits)	±0	+4	-4	+4

SZSEL[2:0] Bits (Transfer Data Size Select)

The SZSEL[2:0] bits select the bit length of transfer data.

OPSEL[3:0] Bits (Operand Transfer Data Count Select)

The OPSEL[3:0] bits select the data count of single-operand transfer.

When the operand transfer system is used, data of the volume specified by the OPSEL[3:0] bits is continuously transferred as a single operand.

When the nonstop transfer system is used, data of the volume specified by the DMA current transfer byte count register (DMCBC) of DMACm is continuously transferred independently of the OPSEL[3:0] setting.

12.2.2 DMA Control Register A (DMCRA)

Addresses: DMAC0.DMCRA 0008 2400h, DMAC1.DMCRA 0008 2408h
DMAC2.DMCRA 0008 2410h, DMAC3.DMCRA 0008 2418h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—	DSEL[1:0]		—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	BRLOD	SRLOD	DRLOD	—	—			DCTG[5:0]			
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	DCTG[5:0]	DMA Activation Source Select	Select a DMA activation source. (See table 12.4.)	R/W
b7, b6	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b8	DRLOD	Transfer Destination Address Reload Function Select	0: Transfer destination address reload function is not used 1: Transfer destination address reload function is used	R/W
b9	SRLOD	Transfer Source Address Reload Function Select	0: Transfer source address reload function is not used 1: Transfer source address reload function is used	R/W
b10	BRLOD	Transfer Byte Count Reload Function Select	0: Transfer byte count reload function is not used 1: Transfer byte count reload function is used	R/W
b23 to b11	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b25, b24	DSEL[1:0]	Transfer System Select	b25 b24 0 0: Single-operand transfer 0 1: Consecutive-operand transfer 1 0: Setting prohibited 1 1: Nonstop transfer	R/W
b31 to b26	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMCRA is used to control DMAC functions.

DCTG[5:0] Bits (DMA Activation Source Select)

The DCTG[5:0] bits select a DMA activation source.

Do not set these bits during data transfer, but set them while the DMAC is not active or DMA transfer is disabled. After these bits are set, be sure to set the DREQ bit in DMCRD of DMACm to 0 (no DMA transfer request) and then activate the DMAC and enable DMA transfer.

Table 12.4 shows the setting of the DCTG[5:0] bits.

Table 12.4 Setting of DCTG[5:0] Bits

	DMA Activation Source			
DCTG[5:0] Bits	**DMA0**	**DMA1**	**DMA2**	**DMA3**
000000	Software trigger			
000001	CMI0 (CMT0 compare match interrupt of compare match timer unit 0)			
000010	CMI1 (CMT1 compare match interrupt of compare match timer unit 0)			
000011	CMI2 (CMT2 compare match interrupt of compare match timer unit 1)			
000100	CMI3 (CMT3 compare match interrupt of compare match timer unit 1)			
000101	IRQ0 (external pin interrupt)			
000110	IRQ1 (external pin interrupt)			
000111	IRQ2 (external pin interrupt)			
001000	IRQ3 (external pin interrupt)			
001001	ADI0 (ADC interrupt of A/D converter unit 0)			
001010	ADI1 (ADC interrupt of A/D converter unit 1)			
001011	ADI2 (ADC interrupt of A/D converter unit 2)			
001100	ADI3 (ADC interrupt of A/D converter unit 3)			
001101	TGI0A (TPU0 input capture/compare match interrupt of 16-bit timer pulse unit 0)			
001110	TGI1A (TPU1 input capture/compare match interrupt of 16-bit timer pulse unit 0)			
001111	TGI2A (TPU2 input capture/compare match interrupt of 16-bit timer pulse unit 0)			
010000	TGI3A (TPU3 input capture/compare match interrupt of 16-bit timer pulse unit 0)			
010001	TGI4A (TPU4 input capture/compare match interrupt of 16-bit timer pulse unit 0)			
010010	TGI5A (TPU5 input capture/compare match interrupt of 16-bit timer pulse unit 0)			
010011	TGI6A (TPU6 input capture/compare match interrupt of 16-bit timer pulse unit 1)			
010100	TGI7A (TPU7 input capture/compare match interrupt of 16-bit timer pulse unit 1)			
010101	TGI8A (TPU8 input capture/compare match interrupt of 16-bit timer pulse unit 1)			
010110	TGI9A (TPU9 input capture/compare match interrupt of 16-bit timer pulse unit 1)			
010111	TGI10A (TPU10 input capture/compare match interrupt of 16-bit timer pulse unit 1)			
011000	TGI11A (TPU11 input capture/compare match interrupt of 16-bit timer pulse unit 1)			
011001	RXI0 (receive data full interrupt of serial communications interface SCI0)			
011010	TXI0 (transmit data empty interrupt of serial communications interface SCI0)			
011011	RXI1 (receive data full interrupt of serial communications interface SCI1)			
011100	TXI1 (transmit data empty interrupt of serial communications interface SCI1)			
011101	RXI2 (receive data full interrupt of serial communications interface SCI2)			
011110	TXI2 (transmit data empty interrupt of serial communications interface SCI2)			
011111	RXI3 (receive data full interrupt of serial communications interface SCI3)			
100000	TXI3 (transmit data empty interrupt of serial communications interface SCI3)			
100001	RXI4 (receive data full interrupt of serial communications interface SCI4)			
100010	TXI4 (transmit data empty interrupt of serial communications interface SCI4)			
100011	RXI5 (receive data full interrupt of serial communications interface SCI5)			
100100	TXI5 (transmit data empty interrupt of serial communications interface SCI5)			
100101	RXI6 (receive data full interrupt of serial communications interface SCI6)			
100110	TXI6 (transmit data empty interrupt of serial communications interface SCI6)			
100111	ICRXI0 (receive data full interrupt of I^2C bus interface RIIC0)			
101000	ICTXI0 (transmit data empty interrupt of I^2C bus interface RIIC0)			
101001	ICRXI1 (receive data full interrupt of I^2C bus interface RIIC1)			
101010	ICTXI1 (transmit data empty interrupt of I^2C bus interface RIIC1)			
101011 to 111111	(Nothing is assigned. These settings are prohibited.)			

To make an interrupt request effective as a source of DMA requests, the corresponding bit of the relevant interrupt

enabling register in the ICU (IERi; i = 02h to 1Fh) must be set to 1, and the relevant interrupt destination setting register of the ICU (ISELRi, where n is the interrupt vector number) must be set to select the DMAC as the destination of the interrupt signal. For details, see the sections on the interrupt controller and various peripheral modules listed below.

- Section 10, Interrupt Control Unit (ICU)
- Section 15, 16-Bit Timer Pulse Unit (TPU)
- Section 18, Compare Match Timer (CMT)
- Section 20, Serial Communications Interface (SCI)
- Section 22, I^2C Bus Interface Unit (RIIC)
- Section 23, A/D Converter

DRLOD Bit (Transfer Destination Address Reload Function Select)

This bit controls the transfer destination address reload function.

When the DRLOD bit is set to 1, the value of the DMA reload transfer destination address register (DMRDA) of DMACm is reloaded to the DMA current transfer destination address register (DMCDA) of DMACm at the end of DMA transfer.

When this reload function is not used, set the ECLR bit in DMCRC of DMACm to 1 (the DEN bit is cleared to 0 at the end of DMA transfer) to clear the DEN bit in DMCRE of DMACm to 0 (DMA transfer disabled).

SRLOD Bit (Transfer Source Address Reload Function Select)

This bit controls the transfer source address reload function.

When the SRLOD bit is set to 1, the value of the DMA reload transfer source address register (DMRSA) of DMACm is reloaded to the DMA current transfer source address register (DMCSA) of DMACm at the end of DMA transfer.

When this reload function is not used, set the ECLR bit in DMCRC of DMACm to 1 to clear the DEN bit in DMCRE of DMACm to 0.

BRLOD Bit (Transfer Byte Count Reload Function Select)

This bit controls the transfer byte count reload function.

When the BRLOD bit is set to 1, the value of the DMA reload transfer byte count register (DMRBC) of DMACm is reloaded to the DMA current transfer byte count register (DMCBC) of DMACm at the end of DMA transfer.

When this reload function is not used, set the ECLR bit in DMCRC of DMACm to 1 to clear the DEN bit in DMCRE of DMACm to 0.

DSEL[1:0] Bits (Transfer System Select)

The DSEL[1:0] bits select a transfer system.

Do not set these bits during data transfer, but set them while the DMAC is not active or DMA transfer is disabled.

12.2.3 DMA Control Register B (DMCRB)

Addresses: DMAC0.DMCRB 0008 2404h, DMAC1.DMCRB 0008 240Ch
DMAC2.DMCRB 0008 2414h, DMAC3.DMCRB 0008 241Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DSCLR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DSCLR	DMAC Internal Status Clear	Writing 1 to this bit initializes the DMAC internal status. Do not write 0 to this bit. This bit is always read as 0.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMCRB is used to control DMA transfer.

DSCLR Bit (DMAC Internal Status Clear)

This bit initializes the internal status of the DMAC.

Setting the DSCLR bit to 1 when DMA has been suspended cancels the remainder of the DMA transfer and initializes the DMAC's internal transfer state. However, no registers are initialized. Since a written "1" is not retained, this bit is always read as 0. Writing 0 has no effect.

Do not set the DSCLR bit during data transfer. Only set it while the DMAC is not active or DMA transfer is disabled.

12.2.4 DMA Control Register C (DMCRC)

Addresses: DMAC0.DMCRE 0008 2407h, DMAC1.DMCRE 0008 240Fh
DMAC2.DMCRE 0008 2417h, DMAC3.DMCRE 0008 241Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	DEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ECLR	DMA Transfer Enable Clear	0: The DEN bit is not cleared to 0 at the end of DMA transfer. 1: The DEN bit is cleared to 0 at the end of DMA transfer.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMCRC is used to control DMA transfer.

ECLR Bit (DMA Transfer Enable Clear)

The ECLR bit controls behavior of the DEN bit in DMCRE of the given DMACm at the end of DMA transfer.

When the value of the ECLR bit is 1, the DEN bit is cleared to 0 at the end of DMA transfer, disabling subsequent DMA transfer on the given channel.

When reloading is not in use, set this bit to 1 so that the DEN bit is cleared to 0 at the end of DMA transfer.

Do not set the ECLR bit during data transfer.

12.2.5 DMA Control Register D (DMCRD)

Addresses: DMAC0.DMCRD 0008 2406h, DMAC1.DMCRD 0008 240Eh
DMAC2.DMCRD 0008 2416h, DMAC3.DMCRD 0008 241Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DREQ
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DREQ	DMA Transfer Request	0: No DMA transfer request is generated 1: A DMA transfer request is generated	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMCRD is used to control DMA transfer.

DREQ Bit (DMA Transfer Request)

The DREQ bit indicates whether a DMA transfer request is present or not.

The value of the DREQ bit varies according to the presence or absence of a DMA transfer request even when the DMAC is stopped or DMA transfer is disabled.

If software triggering is specified as a source of DMA transfer requests, the program generates a DMA transfer request by writing 1 to this bit.

If software triggering is not specified as a source of DMA transfer requests, the program should not write 1 to this bit.

Write 0 to the DREQ bit while data transfer is not in progress, i.e. while the DMAC is stopped or DMA transfer is disabled. Writing of 1 can proceed regardless of the state of DMA transfer.

The DREQ bit is set to 1 or cleared to 0 according to the source of DMA transfer requests as described below.

(1) When the source of DMA transfer requests is a software trigger

[Setting condition]

- The program writing 1 to the bit

[Clearing conditions]

- The program writing 0 to the bit
- The start of data transfer following acceptance of a DMA transfer request

(2) When the source of DMA transfer requests is other than a software trigger

[Setting condition]

- Detection of a source of DMA transfer requests that has been selected in the corresponding DMACm.DMCRA.DCTG[5:0] bits

[Clearing conditions]

- The program writing 0 to the bit
- The start of data transfer following acceptance of a DMA transfer request

12.2.6 DMA Control Register E (DMCRE)

Addresses: DMAC0.DMCRE 0008 2407h, DMAC1.DMCRE 0008 240Fh
DMAC2.DMCRE 0008 2417h, DMAC3.DMCRE 0008 241Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DEN	DMA Transfer Enable	0: DMA transfer is disabled 1: DMA transfer is enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMCRE is used to control DMA transfer.

DEN Bit (DMA Transfer Enable)

The DEN bit enables DMA transfer.

While the ECLR bit is 1, the DEN bit is automatically cleared to 0 at the end of DMA transfer.

When the DEN bit is cleared to 0 in operand transfer mode, DMA transfer on the given channel is suspended after the current single-operand transfer is completed. The DMA transfer is restarted by setting the DEN bit to 1 again.

In nonstop transfer mode, DMA transfer is not suspended by clearing the DEN bit to 0. Instead, DMA transfer continues until it is completed.

12.2.7 DMA Current Transfer Source Address Register (DMCSA)

Addresses: DMAC0.DMCSA 0008 2000h, DMAC1.DMCSA 0008 2010h
DMAC2.DMCSA 0008 2020h, DMAC3.DMCSA 0008 2030h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: x: Undefined

Bit	Description	Setting Range	R/W
b31 to b0	Transfer source start address	00000000h to FFFFFFFFh (4 Gbytes)	R/W

DMCSA is used to set the start address of the transfer source.

Do not set the DMCSA register of DMACm during data transfer, but set it while the DMAC is not active or DMA transfer is disabled.

Access the DMCSA register of DMACm with 32 bits.

Write a multiple of 2 (for 16-bit data size) or a multiple of 4 (for 32-bit data size) to this register so that b31 to b0 correspond to A31 to A0.

The value written to this register is transferred to the work register in the DMAC core at the beginning of DMA transfer, and the work register value is reloaded at the end of single-operand transfer or DMA transfer. However, when the SMOD[2:0] value in DMMOD of DMACm is 011b (rotate), the work register value is not reloaded and the DMCSA register value remains unchanged retaining the value that was set at the beginning of DMA transfer. When the SRLOD bit in DMCRA of DMACm is set to 1 (the transfer source address reload function is used), the value of the DMRSA register of DMACm is reloaded at the end of DMA transfer.

12.2.8 DMA Current Transfer Destination Address Register (DMCDA)

Addresses: DMAC0.DMCDA 0008 2004h, DMAC1.DMCDA 0008 2014h
DMAC2.DMCDA 0008 2024h, DMAC3.DMCDA 0008 2034h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: x: Undefined

Bit	Description	Setting Range	R/W
b31 to b0	Transfer destination start address	00000000h to FFFFFFFFh (4 Gbytes)	R/W

DMCDA is used to set the start address of the transfer destination.

Do not set the DMCDA register of DMACm during data transfer, but set it while the DMAC is not active or DMA transfer is disabled.

Access the DMCDA register of DMACm with 32 bits.

Write a multiple of 2 (for 16-bit data size) or a multiple of 4 (for 32-bit data size) to this register so that b31 to b0 correspond to A31 to A0.

The value written to this register is transferred to the work register in the DMAC core at the beginning of DMA transfer, and the work register value is reloaded at the end of single-operand transfer or DMA transfer. However, when the DMOD[2:0] value in DMMOD of DMACm is 011b (rotate), the work register value is not reloaded and the DMCSA register value remains unchanged retaining the value that was set at the beginning of DMA transfer. When the DRLOD bit in DMCRA of DMACm is set to 1 (the transfer destination address reload function is used), the value of the DMRDA register of DMACm is reloaded at the end of DMA transfer.

12.2.9 DMA Current Transfer Byte Count Register (DMCBC)

Addresses: DMAC0.DMCBC 0008 2008h, DMAC1.DMCBC 0008 2018h
DMAC2.DMCBC 0008 2028h, DMAC3.DMCBC 0008 2038h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	–	–	–	–	–	–										
Value after reset:	0	0	0	0	0	0	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: x: Undefined

Bit	Description	Setting Range	R/W
b25 to b0	Number of DMA transfer bytes	0000000h to 3FFFFFFh	R/W
b31 to b26	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMCBC is used to set the number of DMA transfer bytes.

Do not set the DMCBC register of DMACm during data transfer, but set it while the DMAC is not active or DMA transfer is disabled.

Access the DMCBC register of DMACm with 32 bits.

Write a multiple of 2 (for 16-bit data size) or a multiple of 4 (for 32-bit data size) to this register. Writing 0000000h to this register makes the transfer byte count 64 Mbytes.

The value written to this register is transferred to the work register in the DMAC core at the beginning of DMA transfer. The work register value decreases by the transfer byte count (1 for 8-bit data size, 2 for 16-bit data size, or 4 for 32-bit data size) each time a single data block is transferred. When the work register value decreases to 0000000h, the DMA transfer ends. The DMCBC register of DMACm is reloaded with the value from the working register on completion of a single-operand transfer or of DMA transfer. However, when the BRLOD bit in DMCRA of DMACm is set to 1 (the transfer byte count reload function is used), the value of the DMRBC register of DMACm is reloaded at the end of DMA transfer.

12.2.10 DMA Reload Transfer Source Address Register (DMRSA)

Addresses: DMAC0.DMRSA 0008 2200h, DMAC1.DMRSA 0008 2210h
DMAC2.DMRSA 0008 2220h, DMAC3.DMRSA 0008 2230h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: x: Undefined

Bit	Description	Setting Range	R/W
b31 to b0	Set an address value to be reloaded to the DMCSA register of DMACm	00000000h to FFFFFFFFh (4 Gbytes)	R/W

DMRSA is used to set an address value to be reloaded to the DMCSA register of DMACm.

Access the DMRSA register of DMACm with 32 bits.

When the SRLOD bit in DMCRA of DMACm is set to 1 (the transfer source address reload function is used), the value of the DMRSA register of DMACm is reloaded to the DMCSA register of DMACm at the end of DMA transfer.

Write a multiple of 2 (for 16-bit data size) or a multiple of 4 (for 32-bit data size) to this register so that b31 to b0 correspond to A31 to A0.

12.2.11 DMA Reload Transfer Destination Address Register (DMRDA)

Addresses: DMAC0.DMRDA 0008 2204h, DMAC1.DMRDA 0008 2214h
DMAC2.DMRDA 0008 2224h, DMAC3.DMRDA 0008 2234h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: x: Undefined

Bit	Description	Setting Range	R/W
b31 to b0	Set an address value to be reloaded to the DMCDA register of DMACm	00000000h to FFFFFFFFh (4 Gbytes)	R/W

DMRDA is used to set an address value to be reloaded to the DMCDA register of DMACm.

Access the DMRDA register of DMACm with 32 bits.

When the DRLOD bit in DMCRA of DMACm is set to 1 (the transfer destination address reload function is used), the value of the DMRDA register of DMACm is reloaded to the DMCDA register of DMACm at the end of DMA transfer.

Write a multiple of 2 (for 16-bit data size) or a multiple of 4 (for 32-bit data size) to this register so that b31 to b0 correspond to A31 to A0.

12.2.12 DMA Reload Transfer Byte Count Register (DMRBC)

Addresses: DMAC0.DMRBC 0008 2208h, DMAC1.DMRBC 0008 2218h
DMAC2.DMRBC 0008 2228h, DMAC3.DMRBC 0008 2238h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
	—	—	—	—	—	—										
Value after reset:	0	0	0	0	0	0	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: x: Undefined

Bit	Description	Setting Range	R/W
b25 to b0	Set the number of DMA transfer bytes to be reloaded to the DMCBC register of DMACm	0000000h to 3FFFFFFh	R/W
b31 to b26	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMRBC is used to set the number of DMA transfer bytes to be reloaded to the DMCBC register of DMACm.

Access the DMRBC register of DMACm with 32 bits.

When the BRLOD bit in DMCRA of DMACm is set to 1 (the transfer byte count reload function is used), the value of the DMRBC register of DMACm is reloaded to the DMCBC register of DMACm at the end of DMA transfer.

Write a multiple of 2 (for 16-bit data size) or a multiple of 4 (for 32-bit data size) to this register. Writing 0000000h to this register makes the transfer byte count 64 Mbytes.

12.2.13 DMA Interrupt Control Register (DMICNT)

Address: 0008 250Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	DINTM0	DINTM1	DINTM2	DINTM3	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	DINTM3	DMA3 Interrupt Enable	0: DMAm interrupts are disabled	R/W
b5	DINTM2	DMA2 Interrupt Enable	1: DMAm interrupts are enabled	R/W
b6	DINTM1	DMA1 Interrupt Enable		R/W
b7	DINTM0	DMA0 Interrupt Enable		R/W

DMICNT is used to enable a DMAm (m = 0 to 3) interrupt request (DMTENDm).

DINTMn Bits (DMAm Interrupt Enable) (m = 0 to 3)

Setting the DINTMm bit to 1 enables a DMAm interrupt request (DMTENDm) to occur at the end of DMA transfer of channel m. When the DINTMm bit is set to 0, no DMAm interrupt request (DMTENDm) is generated.

12.2.14 DMA Start Register (DMSCNT)

Address: 0008 2502h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	DMST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DMST	DMAC Start	0: DMAC stop 1: DMAC start	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DMSCNT is used to start the DMAC.

DMST Bit (DMAC Start)

When the DMST bit is set to 1, the DMAC is activated.

When the DMST bit is cleared to 0 during DMA transfer in operand transfer mode, DMA transfer of all channels is suspended after the ongoing single-operand transfer is completed. The DMA transfer is restarted by setting this bit to 1 again.

In nonstop transfer mode, DMA transfer is not suspended by clearing the DMST bit to 0 and continues until the DMA transfer is completed.

To make transitions to the module-stop function for the DMAC, all-module clock-stop mode, software-standby mode, or deep software-standby mode, set the DMST bit to 0 (DMAC stop).

See section 8, Power-Down Modes, for further information on the module-stop function for the DMAC, all-module clock-stop mode, software-standby mode, and deep software-standby mode.

12.2.15 DMA Arbitration Status Register (DMASTS)

Address: 0008 251Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	DASTS0	DASTS1	DASTS2	DASTS3	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. Do not write to this bit.	R
b4	DASTS3	Channel 3 Arbitration Status Flag	0: Data transfer is not in progress	R
b5	DASTS2	Channel 2 Arbitration Status Flag	1: Data transfer is in progress	R
b6	DASTS1	Channel 1 Arbitration Status Flag	(during operand transfer or nonstop transfer)	R
b7	DASTS0	Channel 0 Arbitration Status Flag		R

DMASTS indicates data transfer status of each channel.

DASTSm Flag (Channel m Arbitration Status Flag) (m = 0 to 3)

When data transfer (single-operand transfer or nonstop transfer) of channel m is started, the corresponding DASTSm flag is set to 1 and is cleared to 0 when the data transfer is completed.

[Setting conditions]

- In the case of operand transfer, the start of transfer for an operand
- In the case of non-stop transfer, the start of DMA transfer

[Clearing condition]

- The completion of transfer for a single operand or of DMA transfer

12.2.16 DMA Transfer End Detect Register (DMEDET)

Address: 0008 2517h

	b7	b6	b5	b4	b3	b2	b1	b0
	DEDET0	DEDET1	DEDET2	DEDET3	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	DEDET3	Channel 3 DMA Transfer End Detect Flag	Read: 0: Not detected 1: Detected Write: 0: Disabled 1: The DEDETm flag (m = 0 to 3) is cleared to 0	R/W
b5	DEDET2	Channel 2 DMA Transfer End Detect Flag		R/W
b6	DEDET1	Channel 1 DMA Transfer End Detect Flag		R/W
b7	DEDET0	Channel 0 DMA Transfer End Detect Flag		R/W

DMEDET indicates the DMA transfer end of each channel.

DEDETm Flags (Channel m DMA Transfer End Detect Flags) (m = 0 to 3)

Upon completion of DMA transfer of channel m, the DEDETm flag is set to 1. Once the DEDETm flag is set to 1, it is not cleared to 0 automatically. To clear the DEDETm flag to 0, write 1 to the flag by the program. This written value of 1 is not retained. Writing 0 to these bits has no effect.

To use a DMAm interrupt (DMTENDm), write 1 to the DEDETm flag of a channel in which a DMA interrupt request is generated in the interrupt routine.

[Setting condition]

- Completion of DMA transfer

[Clearing condition]

- Writing of a "1" to the relevant DEDETm bit

Do not use any bit manipulation instruction such as BSET instruction to clear the DEDETm flags. To clear the DEDETm flags, set only the bit of a channel to be cleared to 1 using the MOV instruction, and write to the DMEDET register.

12.3 Operation

12.3.1 Bus Mastership Release Timing

The DMAC must release bus mastership for an interval of at least one cycle per single operation of data reading and writing. The bus is thus accessible by another master (CPU or DTC) during this interval.

Furthermore, access by the CPU (except with the DMAC as the target) is possible during access by the DMAC. However, when the external bus is set as the source or destination for transfer by the DMAC, access over the internal bus by the CPU and DTC may become impossible due to the relation between the clock and the timing of access. In such cases, divided up the data for transfer by the DMAC into smaller units and handle transfer in these units so that the CPU and DTC become able to accept access requests when transfer-completed interrupts are conveyed to the CPU and DTC. For details, refer to section 11, Bus.

Figure 12.2 shows an example of how bus mastership passes between the DMAC and other bus masters.

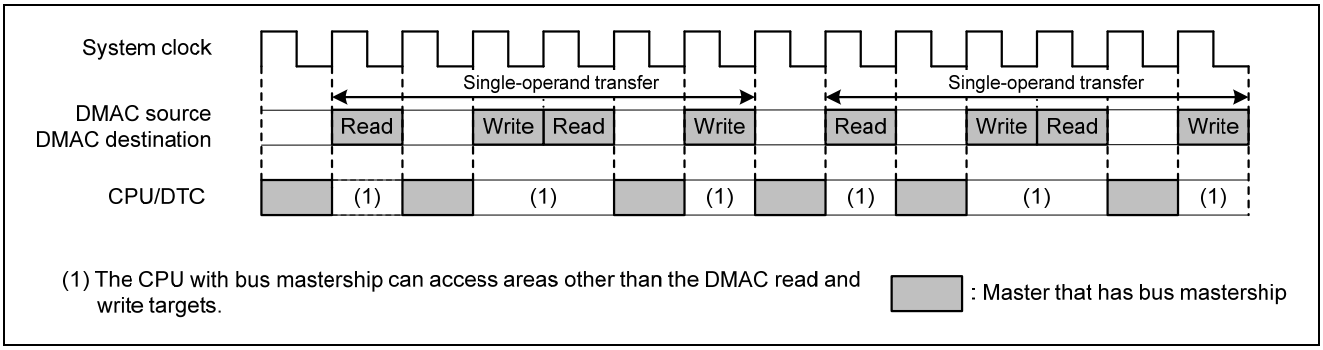


Figure 12.2 Example of how Bus Mastership Passes between the DMAC and Other Bus Masters

12.3.2 Transfer System

The DMA transfer system includes operand transfer and nonstop transfer.

The operand transfer system includes single-operand transfer and consecutive-operand transfer. The single-operand transfer allows transfer of a single operand per DMA transfer request, and the consecutive-operand transfer allows transfer in operand units upon a DMA transfer request until the DMA transfer ends.

The nonstop transfer allows continuous data transfer upon a DMA transfer request until the DMA transfer ends.

Regardless of transfer system, data of the byte count specified in the DMACm.DMCBC register is transferred during a single DMA transfer. When the DMCBC register value of DMACm is decreased to 0000000h, the DMA transfer is completed.

Table 12.5 lists transfer systems.

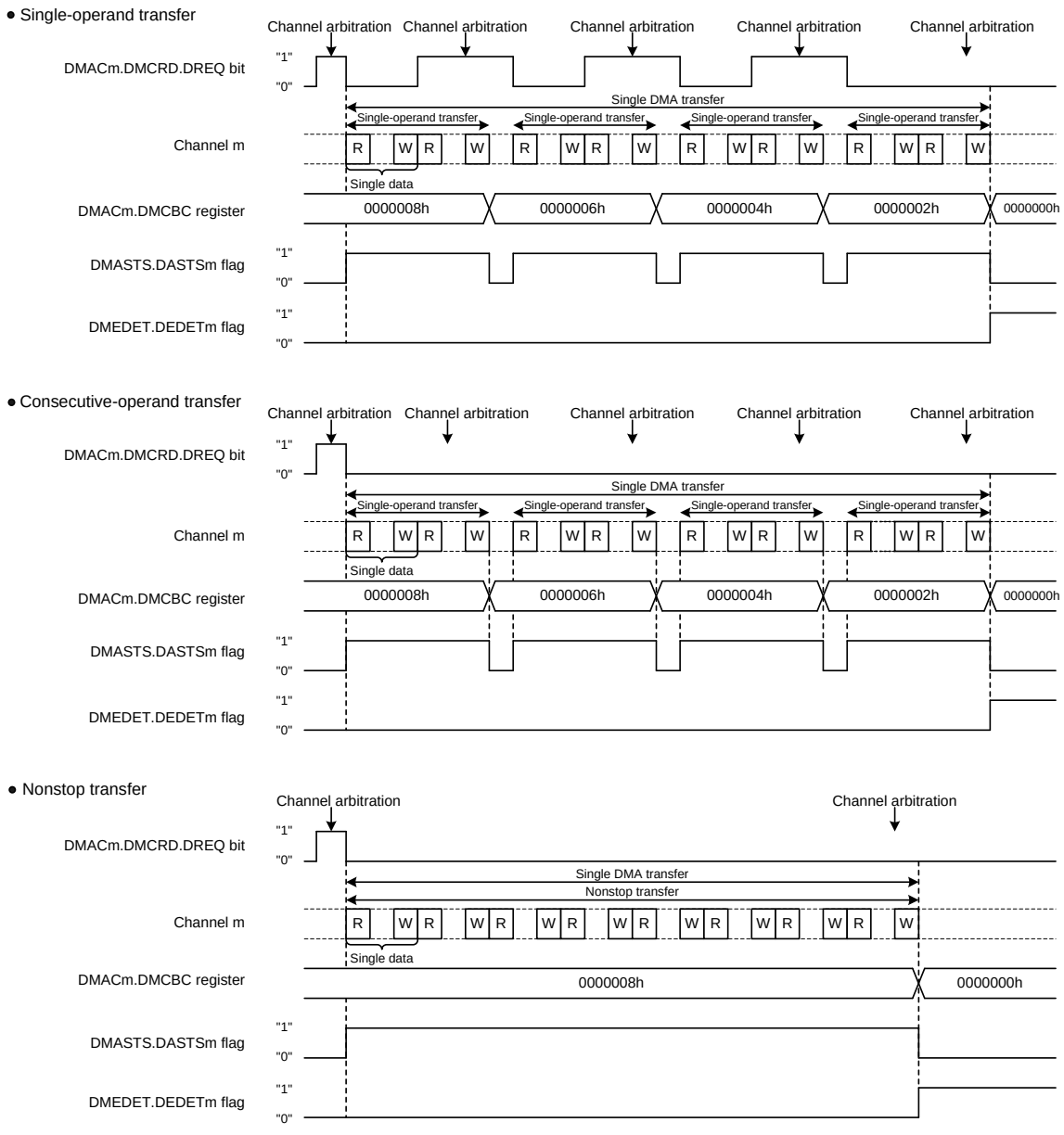
Table 12.5 Transfer Systems

DSEL[1:0] Bits in DMCRA of DMACm	Transfer System	Byte Count Transferred per DMA Transfer Request
00b (Single-operand transfer)	• Single-operand data is transferred during DMA transfer. • Single-operand data is transferred at each DMA transfer request until DMA transfer ends. • Channel arbitration is made at the end of single-operand transfer. • DMA transfer request is necessary each time single-operand transfer is completed.	Byte count corresponding to single-operand data count × bit length
01b (Consecutive-operand transfer)	• Single-operand data is transferred during DMA transfer. • Data is transferred in operand units until DMA transfer ends. • Channel arbitration is made each time single-operand transfer is completed. • A DMA transfer request is generated first only once.	Byte count specified by the DMCBC register of DMACm
11b (Nonstop transfer)	• Data is transferred continuously during DMA transfer. • Data is transferred continuously until DMA transfer ends. • Channel arbitration is made at the end of DMA transfer. • A DMA transfer request is generated first only once.	Byte count specified by the DMCBC register of DMACm

In the operand transfer system, when there is a DMA transfer request of higher-priority channel in the channel arbitration that is made at the end of single-operand transfer, DMA transfer of the higher-priority channel is performed. When there is no such DMA transfer request, the following operand is transferred continuously. However, when there is no DMA transfer request in single-operand transfer mode, the following operand is not transferred.

In the nonstop transfer system, data is transferred continuously from the start to the end of DMA transfer. Therefore, even if a DMA transfer request of higher-priority channel is generated during DMA transfer, the request is not accepted.

Figure 12.3 shows examples of DMA transfer in each transfer system.



These figures show examples of DMA transfer under the following conditions.
- SZSEL[2 0] bits in DMMOD of DMACm = 000b (8 bits), OPSEL[3:0] bits in DMMOD of DMACm = 0001b (2 data)
- BRLOD bit in DMCRA of DMACm = 0 (the transfer byte count reload function is not used)
- MDSEL[1 0] bits in DMMOD of DMACm = 00b (cycle steal transfer mode)
- DMCBC register of DMACm = 0000008h (8 bytes)
- No DMA transfer request other than that of channel m

Figure 12.3 Examples of DMA Transfer in Each Transfer System

12.3.3 Activating the DMAC

Figure 12.4 shows the register setting procedure.

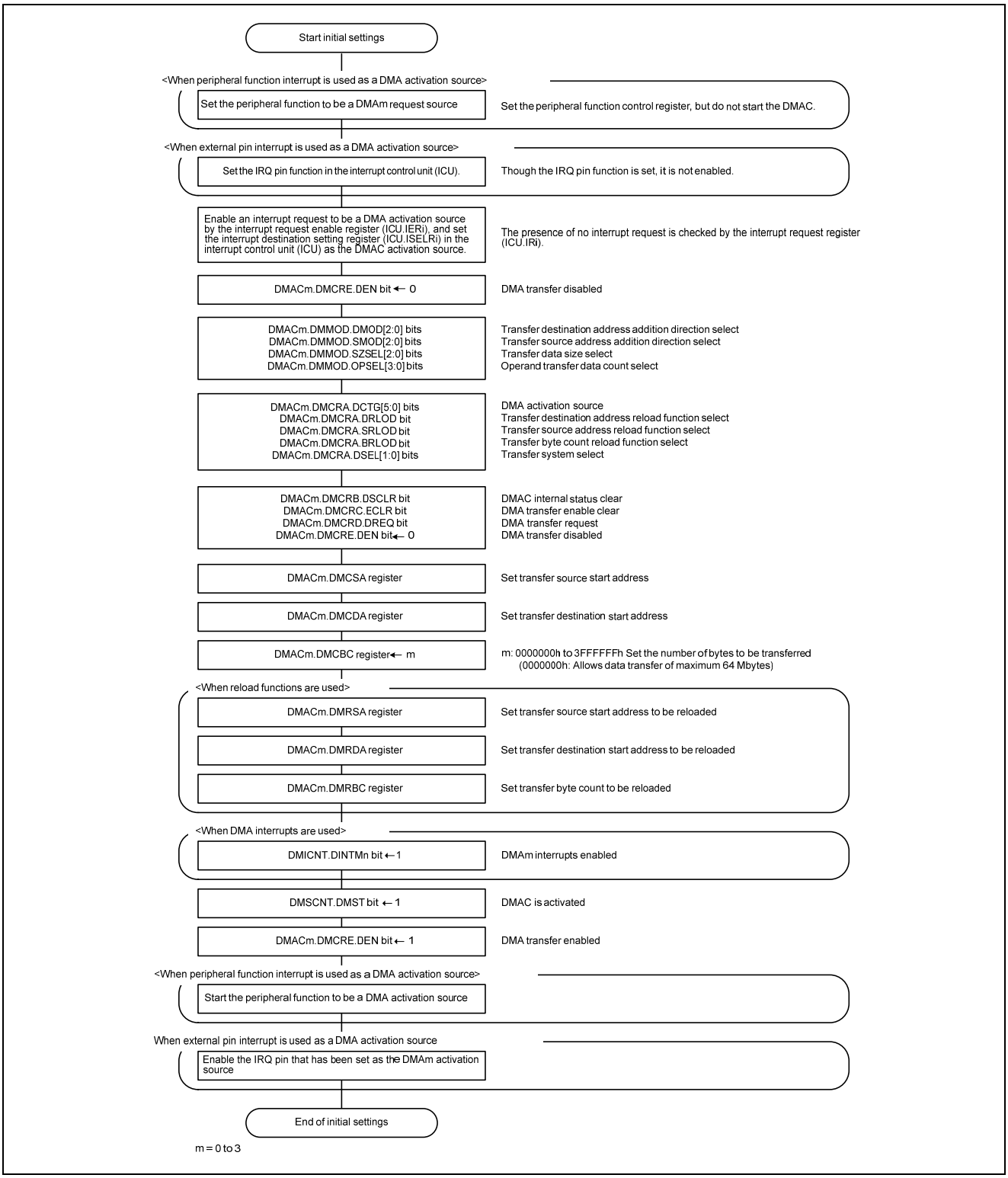


Figure 12.4 Register Setting Procedure

12.3.4 Starting DMA Transfer

Setting the DEN bit in DMCRE of DMACm to 1 (DMA transfer enabled) and setting the DMST bit in DMSCNT to 1 (DMAC start) enable DMA transfer of channel m (m = 0 to 3).

When DMA transfer requests are generated, channel arbitration is made where a DMA transfer request of higher-priority channel is accepted and DMA transfer of the channel starts. When a DMA transfer request is accepted and DMA transfer starts, the DASTSm flag in DMASTS is set to 1 (data transfer is in progress).

12.3.5 Ending DMA Transfer

When the DMCBC register value of DMACm is decreased to 0000000h, DMA transfer of channel m (m = 0 to 3) ends and the DMAC performs the following processing.

- The DEDETm flag in DMEDET is set to 1 (DMA transfer end detected).
- When the DINTMm bit in DMICNT is 1 (interrupts enabled), a DMAm interrupt request (DMTENDm) request occurs.
- When the value of the ECLR bit in DMCRC for DMACm is "1" causing the DEN bit in DMCRE for DMACm to be cleared to "0" on completion of DMA transfer, subsequent DMA transfer on channel m does not proceed once the value of the DEN bit has become "1" (disabling DMA transfer).
- When the reload functions are used, reload register values are reloaded to the current registers respectively.

12.3.6 Suspending, Restarting, and Canceling DMA Transfer

(1) Suspending DMA transfer

DMA transfer by operand transfer can be suspended by clearing the DMST (DMAC stop) bit in DMSCNT or the DEN bit in DMCRE for DMACm to 0 (disabling DMA transfer on that channel).

Suspension applies to all channels when the DMST bit is 0 or the corresponding channel n when DEN bit is 0, and becomes effective on completion of the transfer for the operand for which transfer was in progress.

Nonstop DMA transfer is not suspended even when the DMST or DEN bit is cleared to 0; instead, DMA transfer continues until it is completed.

In advance of transitions of the DMAC to the module-stop state or of the overall device to all-module clock stop mode, software standby mode, or deep software standby mode, clear the DMST bit to 0 (stopping the DMAC).

(2) Restarting DMA transfer

Suspended DMA transfer on a channel is restarted by setting the DMST bit in DMSCNT or the DEN bit in DMCRE of the given DMACm to 1.

After returning the DMAC from the module-stop state or the overall device from all-module clock stop mode, software standby mode, or deep software standby mode, setting the DMST bit to 1 restarts DMA transfer on channels where transfer had been suspended.

(3) Canceling DMA transfer

If the DSCLR bit in DMCRB of DMACm is set to 1 with DMA transfer of the channel suspended, the DMA transfer is canceled and the internal state of the DMAC is initialized. However, only the transfer state of the DMAC's internal circuits is initialized at this time; that is, all registers are not initialized.

12.3.7 DMA Activation Source

Interrupt signals from peripheral functions and interrupt signals on external pins for which the appropriate software-trigger and interrupt control unit (ICU) settings have been made are selectable as DMA activation sources.

12.3.7.1 Software Trigger

When software trigger is selected as a DMA activation source and the DREQ bit in DMCRD of DMACm is set to 1 (a DMA transfer request is generated) by the program, a DMA transfer request is generated. The DREQ bit can be set to 1 independently of the DMA transfer status, but be sure to clear the DREQ bit to 0 (no DMA transfer request is generated) while the DMAC is not active or DMA transfer is disabled (except during DMA transfer).

12.3.7.2 Interrupt Signals on External Pins and Peripheral Function Interrupts

When the corresponding bit of the relevant interrupt enabling register in the ICU (IERi; i = 02h to 1Fh) has been set to 1 (enabling an interrupt signal on an external pin or an interrupt signal from a peripheral module), the interrupt destination setting bits (ISEL[1:0]) in the interrupt destination setting register (ISELR) of the interrupt control unit (ICU) have been set to select the DMAC as the destination, and the DTCG[5:0] bits in DMCRA of DMACm have been set so that the corresponding source of interrupt requests acts as a source of DMA transfer requests, generation of the conditions for the selected request leads to the generation of a DMA transfer request.

When a DMA transfer request is detected, the DREQ bit in DMCRD of DMACm is set to "1" to indicate the presence of the DMA transfer request, and the value of the DREQ remains unchanged even if the input level subsequently changes until a "0" (indicating that there is not DMA transfer request) is written to this bit by the program or until the DMA transfer request is accepted.

Since the value of the DREQ bit that indicates the DMA transfer request is retained, a DMA transfer request that is issued while the value of the DREQ bit is still "1" will be ignored.

Figure 12.5 shows the timing of the DREQ bit.

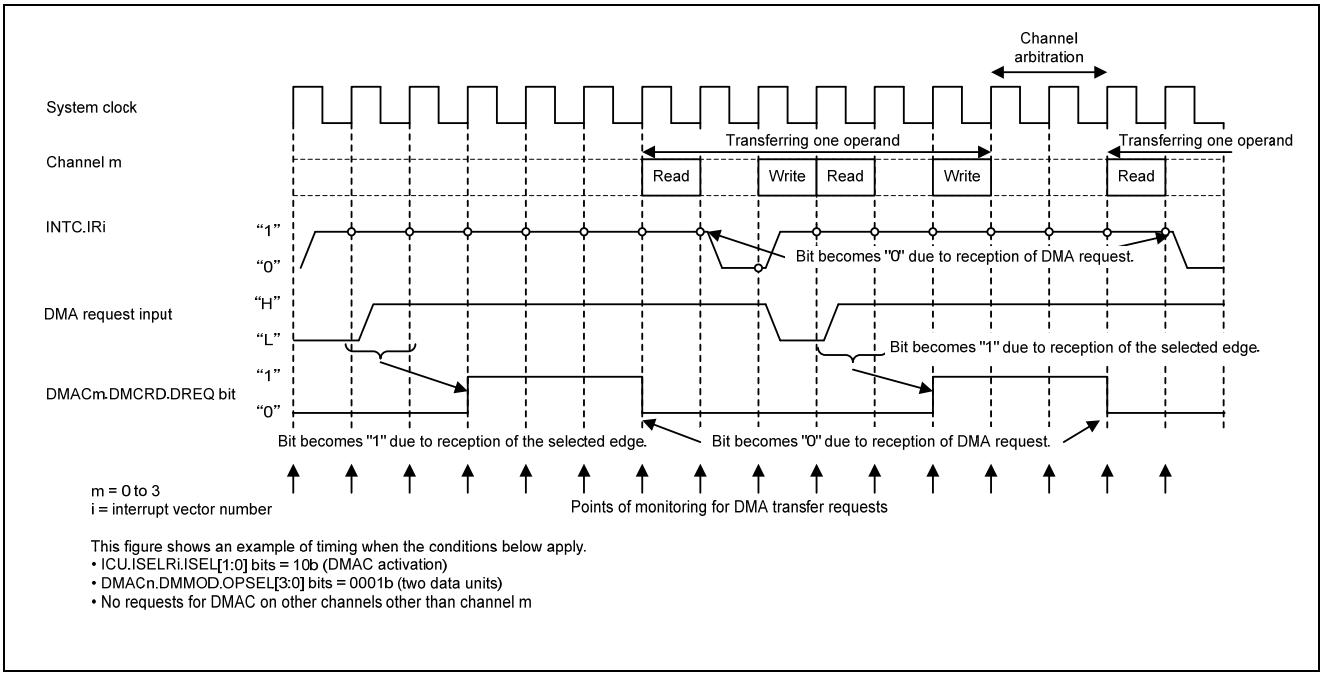


Figure 12.5 Timing of DMACm.DMCRD.DREQ Bit Transitions

12.3.8 Channel Arbitration

When multiple DMA transfer requests are present, the DMAC determines the priority of channels that have DMA transfer requests. The channel priority is fixed as channel 0 > channel 1 > channel 2 > channel 3 (channel 0: highest).

When a DMA transfer request is generated during data transfer, channel arbitration is started at the beginning of final data write access. Therefore, when another DMA transfer request of higher-priority channel is generated during the data transfer, DMA transfer of the higher-priority channel starts after the current data transfer is completed.

12.3.9 Reload Function

The reload function reloads values of the reload registers (DMRSA, DMRDA, and DMRBC of DMACm) to the current registers (DMCSA, DMCDA, and DMCBC of DMACm) respectively at the end of DMA transfer, and is available for reloading transfer source addresses, transfer destination addresses, and transfer byte counts. The reload function allows continuous transfer of separately allocated blocks. That is, multiple transfer blocks with different transfer area and/or data size can be transferred continuously in the same channel. Furthermore, by writing a value to a reload register before the data transfer ends, the next transfer can be prepared without affecting the current register engaged in DMA transfer.

To use the reload function, write data to the corresponding reload registers and current registers. Set reload registers to be used before the final data transfer starts. If they are set after the final data transfer starts, the settings may not be reflected in the reload operation after the DMA transfer ends.

When the reload function is not used, set the ECLR bit in DMCRC of DMACm to 1 (the DEN bit is cleared to 0 at the end of DMA transfer) to clear the DEN bit in DMCRE of DMACm.

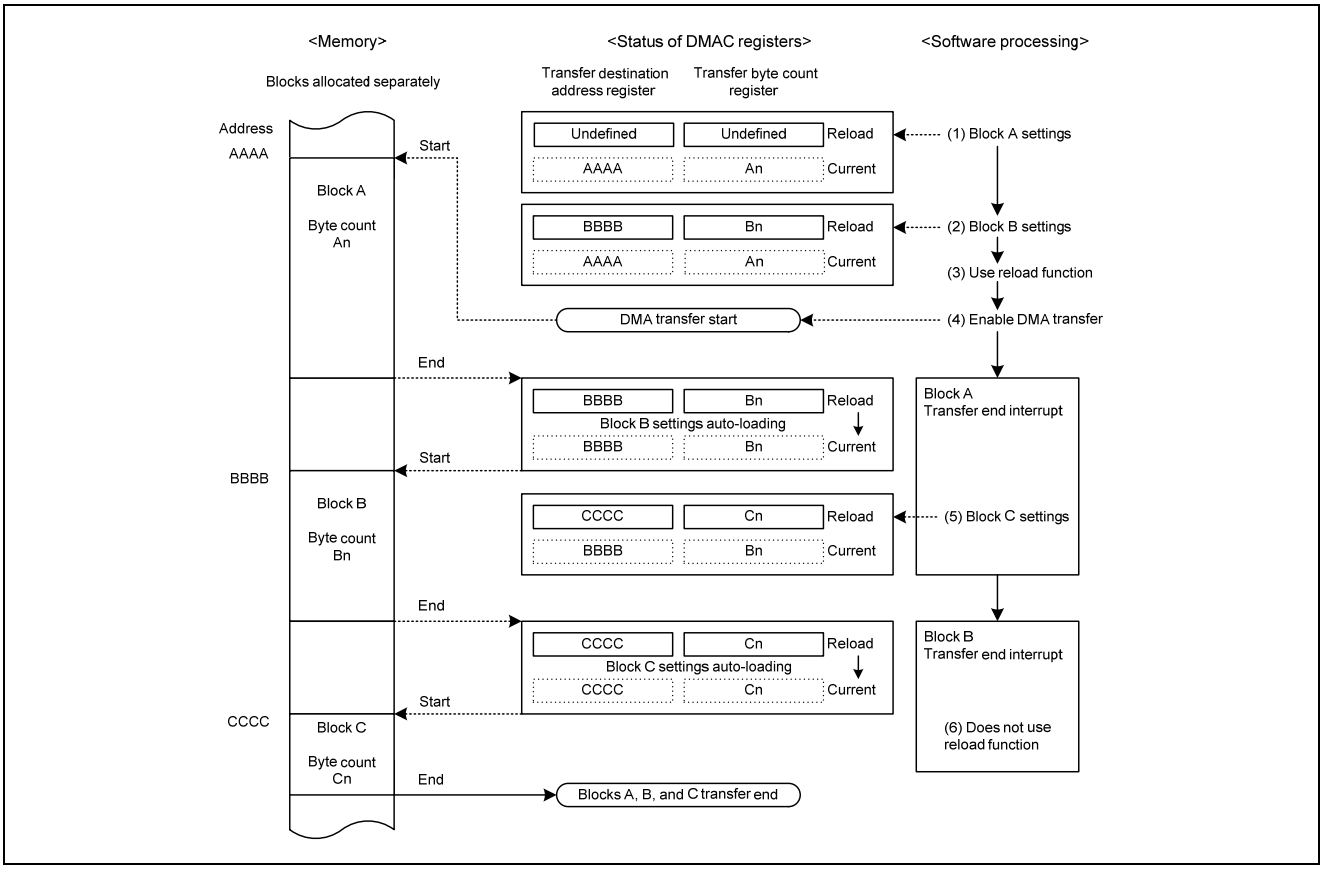


Figure 12.6 Example of DMA Transfer Using the Reload Function

12.3.10 Rotate

When "rotate" is selected with the DMOD[2:0] and SMOD[2:0] bits in DMMOD of DMACm, transfer destination and source addresses are automatically increased during data transfer. The values written at the beginning of DMA transfer are reloaded to the address registers when single-operand transfer is completed.

Figure 12.7 shows an example of "rotate" transfer.

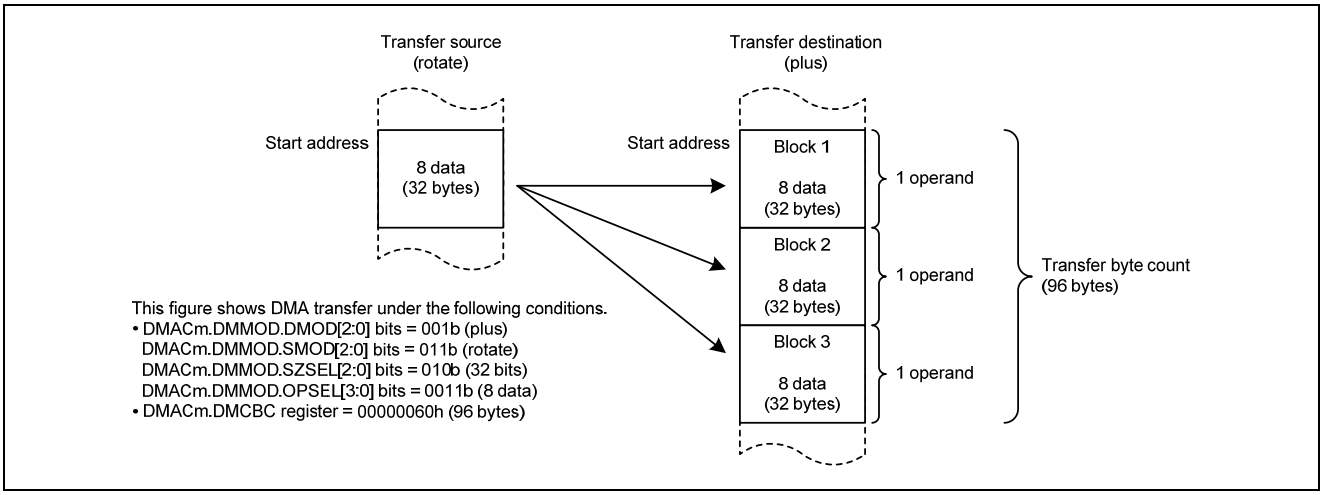


Figure 12.7 Example of "Rotate" Transfer

12.4 Interrupts

When the DINTMm bit (m = 0 to 3) in DMICNT is set to 1 (DMAm interrupts enabled), a DMAm interrupt request (DMTENDm) is generated upon completion of channel-m DMA transfer. Figure 12.8 shows the schematic logic diagram of interrupt outputs.

To use a DMAm interrupt, write 1 to the DEDETm flag in DMEDET of a channel in which a DMA interrupt request is generated in the interrupt routine. Setting the DINTMm bit in DMICNT to 1 from 0 while the DEDETm flag in DMEDET is set to 1 generates a DMAm interrupt request (DMTENDm) regardless of the DMAC transfer status.

The interrupt control unit (ICU) can be set to select a DMAm interrupt as a source for activation of the data transfer controller (DTC). For details, refer to section 10, Interrupt Control Unit (ICU).

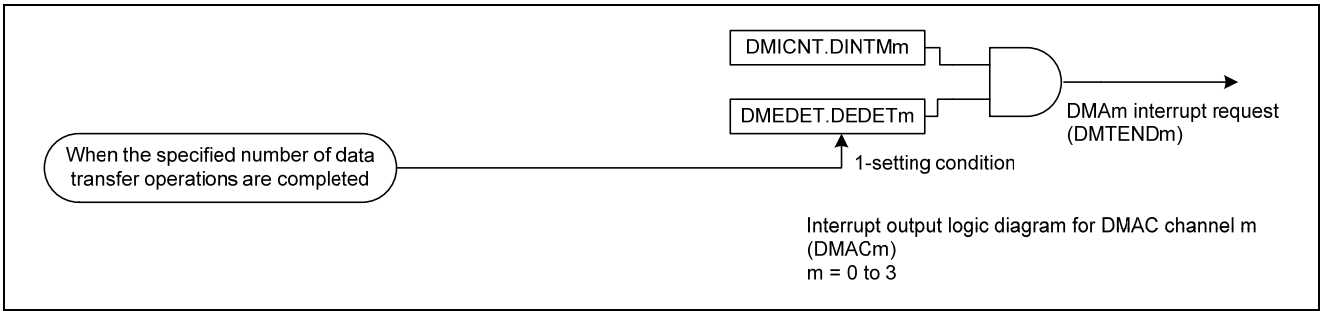


Figure 12.8 Schematic Logic Diagram of Interrupt Outputs

12.5 Low-Power Consumption

If the DMAC is to be placed in any low power-consumption state (module-stop state, all-module clock-stop mode, software-standby mode, or deep software-standby mode), DMAC transfer in progress when the request for transition to the low-power state was accepted must be suspended.

Specifically, clear the DMST bit in DMSCNT to 0 (stopping the DMAC) in advance of transitions of the DMAC to the module-stop state or of the overall device to all-module clock stop mode, software standby mode, or deep software standby mode.

(1) Module Stop

After "0" has been written to the DMSCNT.DMST (DMAC stop) bit, writing a "1" to the MSTPA28 bit (transition to the module-stop state) in MSTPCRA places the DMAC in the module-stop state. If DMA transfer is in progress at the time a "1" is written to the MSTPA28 bit, the transition to the module-stop state proceeds after DMAC transfer has been suspended. Furthermore, the internal registers of the DMAC become inaccessible at the time a "1" is written to the MSTPA28 bit, regardless of the state of DMA transfer.

Writing a "0" to the MSTPA28 bit releases the DMAC from the module-stop state. The registers of the DMAC become accessible again once the DMAC is supplied with a clock signal.

(2) All-Module Clock-Stop Mode

After writing "0" to the DMSCNT.DMST (DMAC stop) bit, and then writing a "1" to the ACSE bit (permitting all-module clock-stop mode) in MSTPCRA, writing "1" to all bits in MSTPCRA and MSTPCRB, including the MSTPA28 bit (module-stop bit for the DMAC), and confirming that "1" has been written to all bits of the MSTPCRA and MSTPCRB registers, executing a WAIT instruction causes a transition to the all-module clock-stop mode. However, if DMA transfer is in progress at the time the WAIT instruction is executed, the transition to all-module clock stop mode becomes possible after the suspension of DMA transfer.

Release from all-module clock stop mode is triggered by an external interrupt (the NMI or any of IRQ0 to IRQ15), a reset by the signal on the RES# pin, or an internal interrupt (from an 8-bit timer or the watchdog timer).

(3) Software Standby and Deep Software Standby Modes

After writing "0" to the DMSCNT.DMST (DMAC stop) bit, and then writing a "1" to the SBYCR.SSBY bit (selecting a transition to software standby mode following the execution of a WAIT instruction) and a "0" to the DPSBYCR.DPSBY bit (so that the transition is not to deep software standby mode following the execution of a WAIT instruction), executing a WAIT instruction places the chip in software standby mode.

However, if DMA transfer is in progress at the time the WAIT instruction is executed, the transition to software-standby mode becomes possible after the suspension of DMA transfer.

Release from software-standby mode is triggered by an external interrupt (the NMI or any of IRQ0 to IRQ15), a reset by the signal on the RES# pin, or an internal interrupt (from an eight-bit timer or the watchdog timer).

If the setting of the DPSBY bit is "1" (selecting a transition to deep software standby mode after execution of a WAIT instruction), the transition is to deep software standby mode.

12.6 Usage Notes

12.6.1 Register Settings

(1) When setting the bits or registers below, set them when the DASTSm flag (m = 0 to 3) in DMASTS is 0 (data transfer is not in progress) and the DEN bit in DMCRE of DMACm is 0 (DMA transfer disabled) or when the DMST bit in DMSCNT is 0 (DMAC stop) for the target channel.

Registers: DMMOD, DMCRB, DMCRC, DMCDA, and DMCBC of DMACm
Bits: DSEL[1:0] bits and DCTG[5:0] bits in the DMCRA register of DMACm

Write 0 to the DREQ bit in DMCRD of DMACm (However, the DREQ bit can be set to 1 independently of the DMA transfer status.)

(2) Access the following registers with 32 bits.
DMMOD, DMCSA, DMCDA, DMCBC, DMRSA, and DMRDA of DMACm

(3) Modify the ECLR bit in DMCRC of DMACm while the DASTSm flag (m = 0 to 3) in DMASTS is 0 (data transfer is not in progress). When the reload function is not used, set the ECLR bit to 1 (the DEN bit is cleared to 0 at the end of DMA transfer) to clear the DEN bit in DMCRE of DMACm.

(4) When the DCTG[5:0] in DMCRA of DMACm is set to 1, be sure to clear the DREQ bit in DMCRD of DMACm and then set the DMST bit in DMSCNT to 1 (DMAC start) and the DEN bit in DMCRE of DMACm to 1 (DMA transfer enabled) for the selected channel.

(5) The DREQ bit in DMCRD of DMACm varies with the presence or absence of DMA transfer request regardless of the setting of the DMST bit in DMSCNT and the DEN bit in DMCRE of DMACm. Unless software trigger is selected as a DMA activation source, do not write 1 to the DREQ bit by the program.

(6) Set each address register and transfer byte count register to an aligned value according to data size. Table 12.6 lists alignment and the lower 2 bits of each register according to data size.

(7) Do not use any bit manipulation instruction such as BSET instruction to clear the DEDETm flags in DMEDET. To clear the DEDETm flags, set only the bit of a channel to be cleared to 1 using the MOV instruction, and write to the DMEDET register.

Table 12.6 Alignment and the Lower 2 Bits of Each Register According to Data Size

SZSEL[2:0] Bits in DMMOD of DMACm	Alignment	Address Registers		Transfer Byte Count Registers	
		b1	b0	b1	b0
000b (8 bits)	Integer multiple	—	—	—	—
001b (16 bits)	Multiple of 2	—	0	—	0
010b (32 bits)	Multiple of 4	0	0	0	0

[Legend] —: Either 0 or 1

12.6.2 DMA Transfer to External Devices

When DMA transfer to an external device is performed, the DASTSm flag (m = 0 to 3) in DMASTS is cleared to 0 (data transfer is not in progress) before the external bus access ends after the final data write is started in some cases.

13. Data Transfer Controller (DTC)

The RX610 Group incorporates a data transfer controller (DTC).

The DTC is activated by an interrupt request and controls data transfer.

13.1 Overview

Table 13.1 lists the specifications of the DTC, and figure 13.1 shows a block diagram of the DTC.

Table 13.1 DTC Specifications

Item	Description
Transfer mode	• Normal transfer mode • Repeat transfer mode • Block transfer mode
Transfer of arbitrary channels	• Data of multiple channels can be transferred on a single startup source (chain transfer). • Execution of chain transfer after data transfer can be set.
Short-address mode/ Full-address mode	• Transfer data is packed in 3 longwords (short-address mode) or in 4 longwords (full-address mode). • In short-address mode, transfer source address and transfer destination address can be specified with 24 bits, and a 16-Mbyte address space can be directly specified for repeat transfer. • In full-address mode, transfer source address and transfer destination address can be specified with 32 bits, and a 4-Gbyte address space can be directly specified for normal transfer.
Data transfer units	• Byte, word, or longword Transfer of units that are not aligned with the corresponding boundary is possible. However, see selection 11, Buses, for details on the allowable range for the transfer of a word or longword unit for which an odd address is specified, or of a longword unit with an address of the form 4n + 2 (n = 0, 1, 2 …).
Interrupt source	• An interrupt request is output to the CPU after a single data transfer. • An interrupt request is output to the CPU after data transfer of specified volume.

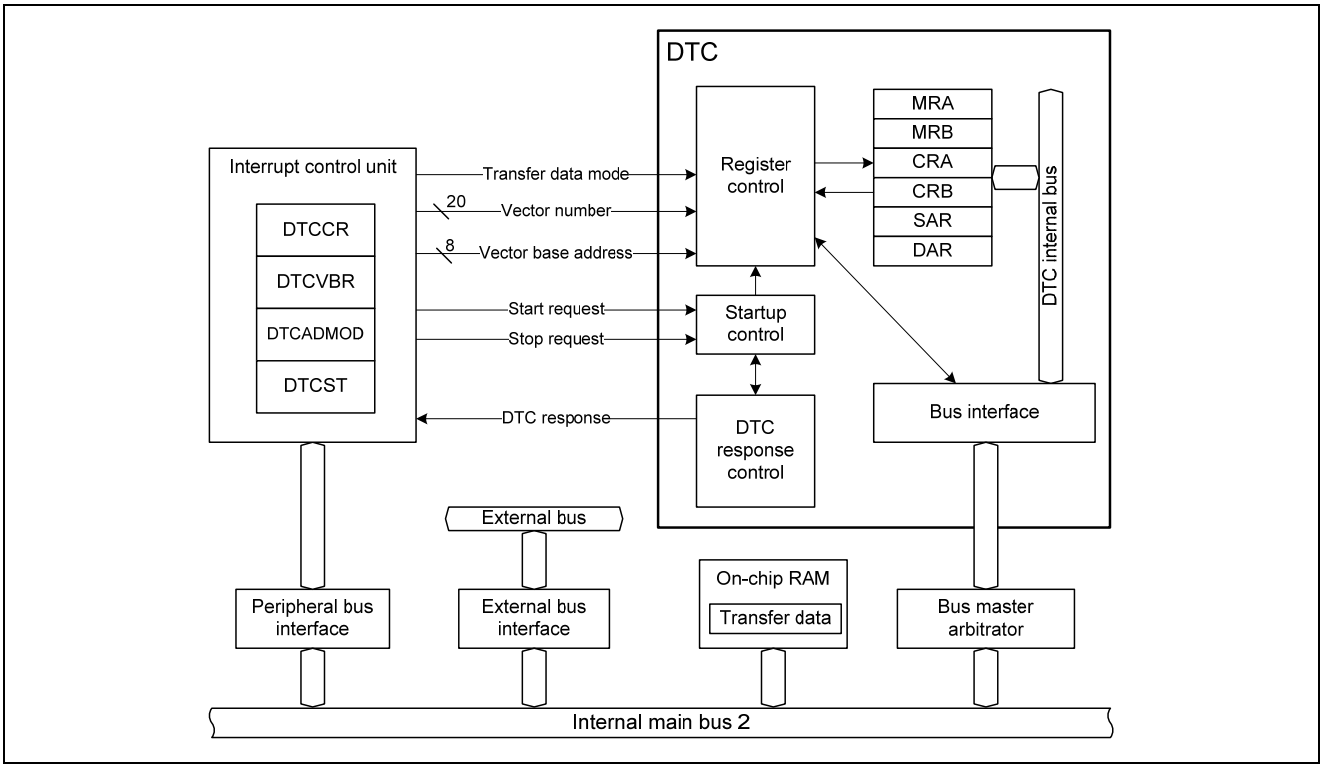


Figure 13.1 Block Diagram of the DTC

13.2 Register Descriptions

Table 13.2 lists the registers of the DTC.

Registers MRA, MRB, SAR, DAR, CRA, and CRB cannot be accessed directly from the CPU. They are located in the data area as transfer data.

When a DTC activation request is generated, the transfer data start address is read according to the vector address determined for each startup source, and arbitrary transfer data is transferred in the DTC. Upon completion of the data transfer, the values of these registers are written back.

Table 13.2 Registers of the DTC

Register Name	Symbol	Value after Reset	Address	Access Size
DTC mode register A	MRA	xxh	—	8 bits
DTC mode register B	MRB	xxh	—	8 bits
DTC source address register	SAR	xxxxxxxxh	—	32 bits
DTC destination address register	DAR	xxxxxxxxh	—	32 bits
DTC transfer count register A	CRA	xxxxh	—	16 bits
DTC transfer count register B	CRB	xxxxh	—	16 bits
DTC control register	DTCCR	00h	0008 7400h	8 bits
DTC vector base register	DTCVBR	00000000h	0008 7404h	32 bits
DTC address mode register	DTCADMOD	00h	0008 7408h	8 bits
DTC module start register	DTCST	00h	0008 740Ch	8 bits

Note: To activate the DTC, a setting of the ISELRi.ISEL[1:0] and IERi.IENj bits in the interrupt control unit (ICU) is required. For details, refer to section 10, Interrupt Control Unit (ICU).

[Legend]

x: Undefined value

13.2.1 DTC Mode Register A (MRA)

Address (inaccessible directly from the CPU)

	b7	b6	b5	b4	b3	b2	b1	b0
	MD[1:0]		SZ[1:0]		SM[1:0]		–	–
Value after reset:	x	x	x	x	x	x	x	x

[Legend] x: Undefined

Bit	Symbol	Bit	Symbol	R/W
b1, b0	—	Reserved	The read data is undefined. The write value should be 0.	—
b3, b2	SM[1:0]	SAR Transfer Source Address Addressing Mode	b3 b2 0 0: SAR address is fixed (Write-back to SAR is skipped) 0 1: SAR address is fixed (Write-back to SAR is skipped) 1 0: SAR value is incremented after data transfer (+1 when SZ[1:0] bits = 00b, +2 when SZ[1:0] bits = 01b, +4 when SZ[1:0] bits = 10b) 1 1: SAR value is decremented after data transfer (-1 when SZ[1:0] bits = 00b, -2 when SZ[1:0] bits = 01b, -4 when SZ[1:0] bits = 10b)	—
b5, b4	SZ[1:0]	DTC Data Transfer Size	b5 b4 0 0: Byte transfer 0 1: Word transfer 1 0: Longword transfer 1 1: Setting prohibited	—
b7, b6	MD[1:0]	DTC Mode	b7 b6 0 0: Normal transfer mode 0 1: Repeat transfer mode 1 0: Block transfer mode 1 1: Setting prohibited	—

MRA is used to select the operating mode of the DTC.

MRA cannot be accessed directly from the CPU.

SM[1:0] Bits (SAR Transfer Source Address Addressing Mode)

These bits specify the SAR operation after data transfer.

SZ[1:0] Bits (DTC Data Transfer Size)

These bits specify the transfer data size.

MD[1:0] Bits (DTC Mode)

These bits specify the transfer mode of the DTC.

13.2.2 DTC Mode Register B (MRB)

Address (inaccessible directly from the CPU)

	b7	b6	b5	b4	b3	b2	b1	b0
	CHNE	CHNS	DISEL	DTS	DM[1:0]		—	—
Value after reset:	x	x	x	x	x	x	x	x

[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	The read data is undefined. The write value should be 0.	—
b3, b2	DM[1:0]	DAR Transfer Destination Address Addressing Mode	b3 b2 0 0: DAR address is fixed (Write-back to DAR is skipped) 0 1: DAR address is fixed (Write-back to DAR is skipped) 1 0: DAR value is incremented after data transfer (+1 when SZ[1:0] bits in MRA = 00b, +2 when SZ[1:0] bits = 01b, +4 when SZ[1:0] bits = 10b) 1 1: DAR value is decremented after data transfer (-1 when SZ[1:0] bits in MRA = 00b, -2 when SZ[1:0] bits = 01b, -4 when SZ[1:0] bits = 10b)	—
b4	DTS	DTC Transfer Mode Select	0: Destination side is repeat area or block area 1: Source side is repeat area or block area	—
b5	DISEL	DTC Interrupt Select	0: An interrupt request to the CPU is generated when specified data transfer is completed 1: An interrupt request to the CPU is generated each time DTC data transfer is performed	—
b6	CHNS	DTC Chain Transfer Select	0: Chain transfer is performed continuously 1: Chain transfer is performed only when the transfer counter is 0	—
b7	CHNE	DTC Chain Transfer Enable	0: Chain transfer is disabled 1: Chain transfer is enabled	—

MRB is used to select the operating mode of the DTC.

MRB cannot be accessed directly from the CPU.

DM[1:0] Bits (DAR Transfer Destination Address Addressing Mode)

These bits specify the DAR operation after data transfer.

DTS Bit (DTC Transfer Mode Select)

The DTS bit specifies the side (transfer source or destination) to be a repeat area or block area in repeat transfer mode or block transfer mode.

DISEL Bit (DTC Interrupt Select)

The DISEL bit specifies whether to generate an interrupt request to the CPU each time DTC data transfer is performed or when specified data transfer is completed.

CHNS Bit (DTC Chain Transfer Select)

The CHNS bit selects the chain transfer condition.

When the next transfer is chain transfer, completion of specified transfer count is not checked and the startup source flag is not cleared. Moreover, an interrupt request to the CPU is not generated.

CHNE Bit (DTC Chain Transfer Enable)

The CHNE bit enables or disables chain transfer.

The chain transfer condition is selected by the CHNS bit.

For details of chain transfer, see section 13.4.6, Chain Transfer.

13.2.3 DTC Source Address register (SAR)

Address (inaccessible directly from the CPU)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

[Legend] x: Undefined

SAR is used to set the transfer source start address.

In full-address mode, 32 bits are valid.

In short-address mode, lower 24 bits are valid and upper 8 bits (b31 to b24) are ignored. The address of this register is extended by the value specified by b23.

SAR cannot be accessed directly from the CPU.

13.2.4 DTC Destination Address Register (DAR)

Address (inaccessible directly from the CPU)

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

[Legend] x: Undefined

DAR is used to set the transfer destination start address.

In full-address mode, 32 bits are valid.

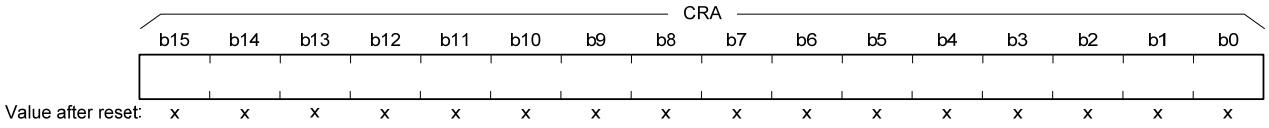
In short-address mode, lower 24 bits are valid and upper 8 bits (b31 to b24) are ignored. The address of this register is extended by the value specified by b23.

DAR cannot be accessed directly from the CPU.

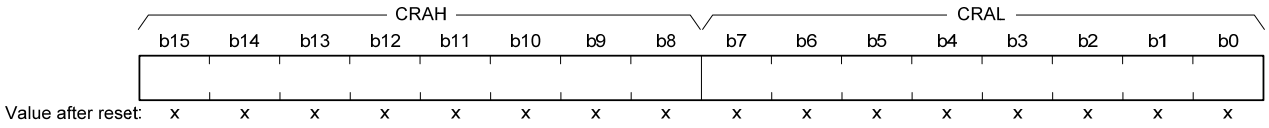
13.2.5 DTC Transfer Count Register A (CRA)

Address (inaccessible directly from the CPU)

- Normal transfer mode



- Repeat transfer mode/block transfer mode



Notes: 1. The function depends on transfer mode.
2. x: Undefined

Symbol	Register Name	Description	R/W
CRAL	Transfer Counter A Lower Register	Set transfer count.	—
CRAH	Transfer Counter A Upper Register		—

Note: Set CRAH and CRAL to the same value in repeat transfer mode and block transfer mode.

CRA is used to set the transfer count of the DTC.

The function of this register depends on transfer mode.

CRA cannot be accessed directly from the CPU.

(1) Normal transfer mode (MD[1:0] bits in MRA = 00b)

CRA functions as a 16-bit transfer counter in normal transfer mode.

The transfer count is 1, 65535, and 65536 when the set value is 0001h, FFFFh, and 0000h, respectively.

The CRA value is decremented (-1) at each data transfer.

(2) Repeat transfer mode (MD[1:0] bits in MRA = 01b)

The CRAH register retains transfer count and the CRAL register functions as an 8-bit transfer counter.

The transfer count is 1, 255, and 256 when the set value is 01h, FFh, and 00h, respectively.

The CRAL value is decremented (-1) at each data transfer. When it reaches 00h, the CRAH value is transferred to CRAL.

(3) Block transfer mode (MD[1:0] bits in MRA = 10b)

The CRAH register retains block size and the CRAL register functions as an 8-bit block size counter.

The transfer count is 1, 255, and 256 when the set value is 01h, FFh, and 00h, respectively.

The CRAL value is decremented (-1) at each data transfer. When it reaches 00h, the CRAH value is transferred to CRAL.

13.2.6 DTC Transfer Count Register B (CRB)

Address (inaccessible directly from the CPU)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

[Legend] x: Undefined

CRB is used to set the block transfer count for block transfer mode.

The transfer count is 1, 65535, and 65536 when the set value is 0001h, FFFFh, and 0000h, respectively. The CRB value is decremented (-1) at each data transfer.

When normal transfer mode or repeat transfer mode is selected, this register is not used and the set value is ignored.

CRB cannot be accessed directly from the CPU.

13.2.7 DTC Control Register (DTCCR)

Address: 0008 7400h

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	RRS	RCHNE	–	–	ERR
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ERR*	Transfer Stop Flag	0: No DTC transfer stop request is generated 1: A DTC transfer stop request is generated	R
b2, b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b3	RCHNE	Chain Transfer Enable after DTC Repeat Transfer	0: Chain transfer after repeat transfer is disabled 1: Chain transfer after repeat transfer is enabled	R/W
b4	RRS	DTC Transfer Data Read Skip Enable	0: Transfer data read is not skipped 1: Transfer data read is skipped when vector numbers match.	R/W
b7 to b5	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

Note: * The DTC will not be activated as long as the value of the ERR bit is 1.

To activate the DTC when transfer has stopped because of a nonmaskable interrupt, clear the interrupt source flag. When transfer has stopped because of the bus error generation, which is not a nonmaskable interrupt, clear the interrupt source by the bus error source clear register (BERCLR) in the bus error monitoring section. For details on nonmaskable interrupts, see section 10, Interrupt Control Unit (ICU). For details on bus errors, see section 11, Buses.

DTCCR is used to specify the control of the DTC.

ERR Flag (Transfer Stop Flag)

The ERR flag indicates that a DTC transfer stop request is present due to a bus error or nonmaskable interrupt.

When the DTC accepts a transfer stop request, it stops data transfer.

[Setting condition]

- When a nonmaskable interrupt is generated, or when a bus error is generated

[Clearing condition]

- When the corresponding source flag is cleared on completion of processing for the nonmaskable interrupt, or when the bus error source is cleared on completion of processing for the bus error interrupt

RCHNE Bit (Chain Transfer Enable after DTC Repeat Transfer)

The RCHNE bit enables or disables chain transfer when data transfer of the specified count ends (transfer counter = 0) in repeat transfer mode.

When the transfer counter CRAL becomes 00h in repeat transfer mode, chain transfer is not performed because the CRAH value is written to CRAL. Writing 1 to the RCHNE bit enables chain transfer when the transfer counter is rewritten.

RRS Bit (DTC Transfer Data Read Skip Enable)

The DTC vector number is always compared with the vector number in the previous startup process.

When these vector numbers match and the RRS bit is set to 1, DTC data transfer is performed without reading the transferred data. However, when the previous transfer was chain transfer, the transferred data is always read regardless of the value of RRS bit.

Furthermore, when the transfer counter (CRA register) became 0 during the previous normal transfer and when the transfer counter (CRB register) became 0 during the previous block transfer, the transferred data is always read regardless of the value of RRS bit.

13.2.8 DTC Vector Base Register (DTCVBR)

Address: 0008 7404h

	b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
					0	0	0	0	0	0	0	0	0	0	0	0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DTCVBR is used to set the base address for calculating the DTC vector table address.

The lower 12 bits (b11 to b0) are always 0 and cannot be modified.

The upper 4 bits (b31 to b28) are ignored, and the address of this register is extended by the value specified by b27.

13.2.9 DTC Address Mode Register (DTCADMOD)

Address: 0008 7408h

	b7	b6	b5	b4	b3	b2	b1	b0
	?	?	?	?	?	?	?	SHORT
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SHORT	Short-Address Mode	0: Full-address mode 1: Short-address mode	R/W
b7 to b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

DTCADMOD is used to select an address mode that specifies DTC's accessible area.

SHORT Bit (Short-Address Mode)

Full-address mode allows the DTC to access to a 4-Gbyte space (00000000h to FFFFFFFFh).

Short-address mode allows the DTC to access to a 16-Mbyte space (00000000h to 007FFFFFh and FF800000h to FFFFFFFFh).

13.2.10 DTC Module Start Register (DTCST)

Address: 0008 740Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	DTCST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DTCST	DTC Module Start	0: DTC module stop 1: DTC module start	R/W
b7 to b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W

DTCST is used to start or stop the DTC module.

DTCST Bit (DTC Module Start)

Set the DTCST bit to 1 to enable the DTC to accept start requests. When this bit is cleared to 0, start requests are no longer accepted.

If this bit is cleared to 0 during data transfer, the accepted start request is active until the processing is completed.

To enable transitions to the module-stop state, all-module clock-stop state, software-standby mode, or deep software-standby mode, the DTCST bit must be set to "0".

For details on the facilities for transitions to the module-stop state, all-module clock-stop state, software-standby mode, and deep software-standby mode, refer to section 13.8.1, Setting the DTC Module Start Register, and section 8, Low Power Consumption.

13.3 Sources of Activation

The DTC is activated by an interrupt request. Setting ISEL[1:0] bits in an ISELRi register (where i is the interrupt vector number of the given interrupt) of the ICU to 01b selects the corresponding interrupt as an activation source for the DTC, and clearing the same bits to 00b selects the interrupt as a source of interrupts for the CPU.

On completion of a single round of data transfer (or the last of the consecutive transfers in the case of a chained transfer), the flag for the interrupt that was the source of activation and the ISEL[1:0] bits in the corresponding ISELRi register are cleared to 00b.

13.3.1 Allocating Transfer Data and DTC Vector Table

Transfer data is allocated in the data area. Be sure to set multiples of 4 for the transfer data start addresses in the vector table. Because, such addresses are accessed with their lowest 2 bits fixed at 00b.

Transfer data can be allocated with 3 longwords (short-address mode) or 4 longwords (full-address mode). Use the SHORT bit in DTCADMOD to select short-address mode (SHORT bit = 1) or full-address mode (SHORT bit = 0).

Figure 13.2 shows the allocation of transfer data in the data area. The DTC reads the transfer data start address for each startup source, and then reads the transfer data from this start address. Figure 13.3 shows the DTC vector table and transfer data.

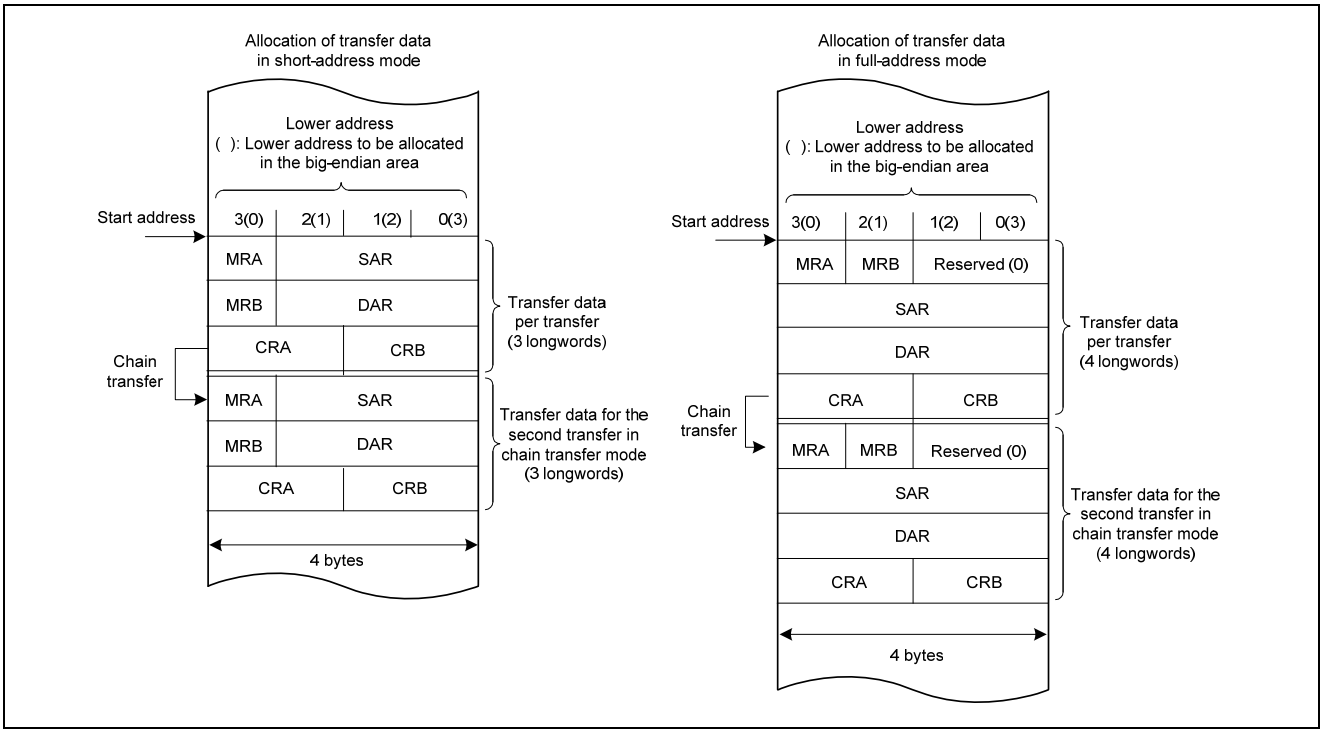


Figure 13.2 Allocation of Transfer Data in the Data Area

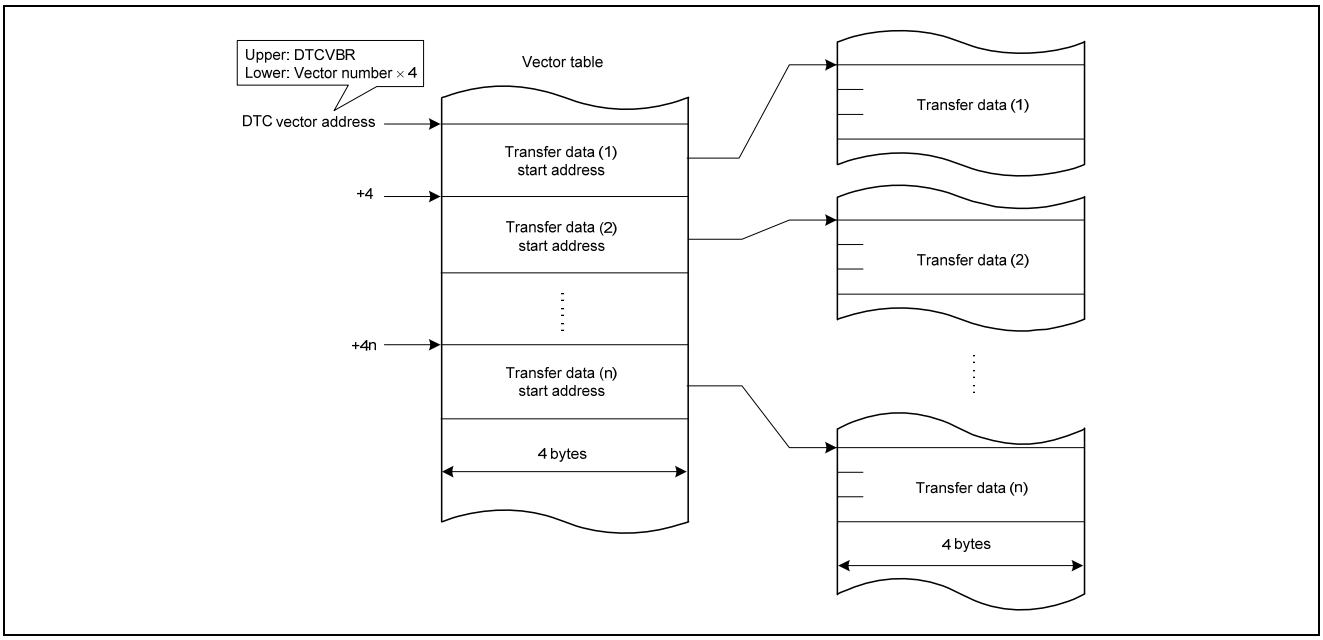


Figure 13.3 DTC Vector Table and Transfer Data

13.3.2 Startup source and Vector Address

Table 13.3 shows the correspondence between DTC startup sources and vector addresses.

Table 13.3 Correspondence between Interrupt Sources, DTC Vector Addresses, and the ISELRi Register of the ICU

Activation Request Generation Source	Activation Source	Vector Number	DTC Vector Address Offset	ISELRi Register of the ICU	Priority
CMT Unit 0	CMT0	28	0070h	ISELR028	High
	CMT1	29	0074h	ISELR029	
CMT Unit 1	CMT2	30	0078h	ISELR030	
	CMT3	31	007Ch	ISELR031	
External pins	IRQ0	64	0100h	ISELR064	
	IRQ1	65	0104h	ISELR065	
	IRQ2	66	0108h	ISELR066	
	IRQ3	67	010Ch	ISELR067	
	IRQ4	68	0110h	ISELR068	
	IRQ5	69	0114h	ISELR069	
	IRQ6	70	0118h	ISELR070	
	IRQ7	71	011Ch	ISELR071	
	IRQ8	72	0120h	ISELR072	
	IRQ9	73	0124h	ISELR073	
	IRQ10	74	0128h	ISELR074	
	IRQ11	75	012Ch	ISELR075	
	IRQ12	76	0130h	ISELR076	
	IRQ13	77	0134h	ISELR077	
	IRQ14	78	0138h	ISELR078	
	IRQ15	79	013Ch	ISELR079	
AD0	ADI0	98	0188h	ISELR098	
AD1	ADI1	99	018Ch	ISELR099	
AD2	ADI2	100	0190h	ISELR100	
AD3	ADI3	101	0194h	ISELR101	
TPU0	TGI0A	104	01A0h	ISELR104	
	TGI0B	105	01A4h	ISELR105	
	TGI0C	106	01A8h	ISELR106	
	TGI0D	107	01ACh	ISELR107	
TPU1	TGI1A	111	01BCh	ISELR111	
	TGI1B	112	01C0h	ISELR112	
TPU2	TGI2A	117	01D4h	ISELR117	
	TGI2B	118	01D8h	ISELR118	
TPU3	TGI3A	122	01E8h	ISELR122	
	TGI3B	123	01ECh	ISELR123	
	TGI3C	124	01F0h	ISELR124	
	TGI3D	125	01F4h	ISELR125	
TPU4	TGI4A	127	01FCh	ISELR127	
	TGI4B	128	0200h	ISELR128	Low

Activation Request Generation Source	Activation Source	Vector Number	DTC Vector Address Offset	ISELRi Register of the ICU	Priority
TPU5	TGI5A	133	0214h	ISELR133	High
	TGI5B	134	0218h	ISELR134	
TPU6	TGI6A	138	0228h	ISELR138	
	TGI6B	139	022Ch	ISELR139	
	TGI6C	140	0230h	ISELR140	
	TGI6D	141	0234h	ISELR141	
TPU7	TGI7A	145	0244h	ISELR145	
	TGI7B	146	0248h	ISELR146	
TPU8	TGI8A	151	025Ch	ISELR151	
	TGI8B	152	0260h	ISELR152	
TPU9	TGI9A	156	0270h	ISELR156	
	TGI9B	157	0274h	ISELR157	
	TGI9C	158	0278h	ISELR158	
	TGI9D	159	027Ch	ISELR159	
TPU10	TGI10A	161	0284h	ISELR161	
	TGI10B	162	0288h	ISELR162	
TPU11	TGI11A	167	029Ch	ISELR167	
	TGI11B	168	02A0h	ISELR168	
TMR0	CMIA0	174	02B8h	ISELR174	
	CMIB0	175	02BCh	ISELR175	
TMR1	CMIA1	177	02C4h	ISELR177	
	CMIB1	178	02C8h	ISELR178	
TMR2	CMIA2	180	02D0h	ISELR180	
	CMIB2	181	02D4h	ISELR181	
TMR3	CMIA3	183	02DCh	ISELR183	
	CMIB3	184	02E0h	ISELR184	
DMAC	DMTEND0	198	0318h	ISELR198	
	DMTEND1	199	031Ch	ISELR199	
	DMTEND2	200	0320h	ISELR200	
	DMTEND3	201	0324h	ISELR201	
SCI0	RXI0	215	035Ch	ISELR215	
	TXI0	216	0360h	ISELR216	
SCI1	RXI1	219	036Ch	ISELR219	
	TXI1	220	0370h	ISELR220	
SCI2	RXI2	223	037Ch	ISELR223	
	TXI2	224	0380h	ISELR224	
SCI3	RXI3	227	038Ch	ISELR227	
	TXI3	228	0390h	ISELR228	
SCI4	RXI4	231	039Ch	ISELR231	
	TXI4	232	03A0h	ISELR232	
SCI5	RXI5	235	03ACh	ISELR235	
	TXI5	236	03B0h	ISELR236	Low

Activation Request Generation Source	Activation Source	Vector Number	DTC Vector Address Offset	ISELRi Register of the ICU	Priority
SCI6	RXI6	239	03BCh	ISELR239	High
	TXI6	240	03C0h	ISELR240	
RIIC0	RXI0	247	03DCh	ISELR247	
	TXI0	248	03E0h	ISELR248	
RIIC1	RXI1	251	03ECh	ISELR251	
	TXI1	252	03F0h	ISELR252	Low

13.4 Operation

The DTC stores transfer data in the data area.

When the DTC is activated, it reads the DTC vector corresponding to the vector number. Then the DTC reads transfer data from the transfer data store address pointed by the DTC vector, transfers data, and then writes back the transfer data after the data transfer. Storing transfer data in the data area allows data transfer of arbitrary number of channels.

There are three transfer modes: normal transfer mode, repeat transfer mode, and block transfer mode.

The DTC specifies a transfer source address in SAR and a transfer destination address in DAR. The values of these registers are incremented, decremented, or remain unchanged independently after data transfer.

Table 13.4 lists transfer modes of the DTC.

Table 13.4 Transfer Modes of the DTC

Transfer Mode	Data Size Transferred on a Single Transfer Request	Increment/Decrement of Memory Address	Settable Transfer Count
Normal transfer mode	One byte/word/longword	Incremented/decremented by 1, 2, or 4 or address fixed	1 to 65536
Repeat transfer mode*1	One byte/word/longword	Incremented/decremented by 1, 2 or, 4 or address fixed	1 to 256*3
Block transfer mode*2	Block size specified in CRAH (1 to 256 bytes/words/longwords)	Incremented/decremented by 1, 2 or, 4 or address fixed	1 to 65536

Notes: 1. Set transfer source or transfer destination in the repeat area.
2. Set transfer source or transfer destination in the block area.
3. After data transfer of the specified count, the initial state is restored and the operation is continued (repeated).

Setting the CHNE bit in MRB to 1 allows multiple transfers (chain transfer) on a single startup source. Chain transfer is enabled when transfer counter = 0 by setting the CHNS bit in MRB to 1.

Figure 13.4 shows the operation flowchart of the DTC. Table 13.5 shows chain transfer conditions (excluding combinations of the second transfer and the third transfer, and combinations of subsequent transfers).

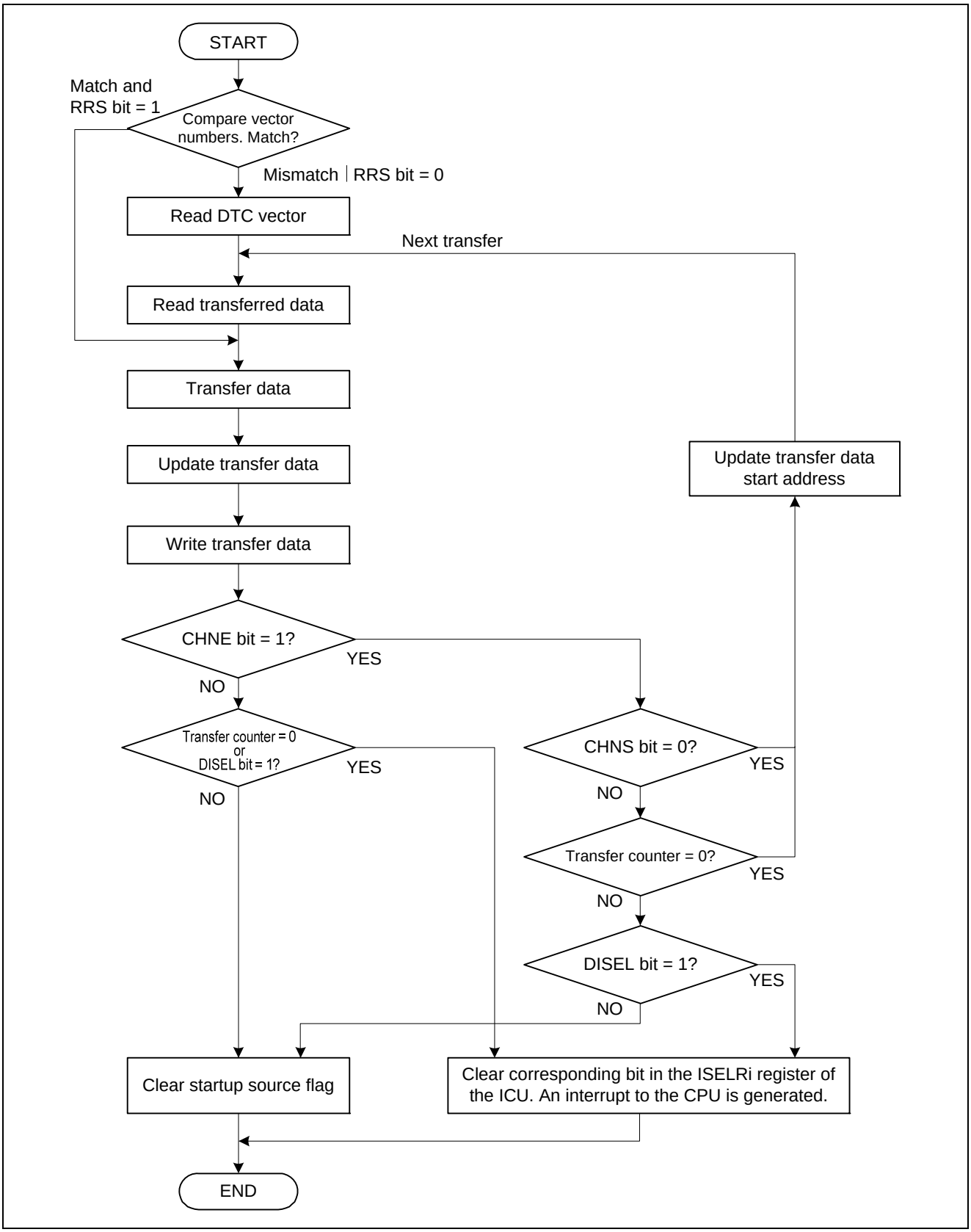


Figure 13.4 Operation Flowchart of the DTC

Table 13.5 Chain Transfer Conditions

First Transfer				Second Transfer				
CHNE Bit	CHNS Bit	DISEL Bit	Transfer Counter*1	CHNE Bit	CHNS Bit	DISEL Bit	Transfer Counter*1	DTC Transfer
0	—	0	Other than 0	—	—	—	—	Ends after the first transfer
0	—	0	0*2	—	—	—	—	Ends after the first transfer with an interrupt request to the CPU
0	—	1	—	—	—	—	—	
1	0	—	—	0	—	0	Other than 0	Ends after the second transfer
				0	—	0	0*2	Ends after the second transfer with an interrupt request to the CPU
				0	—	1	—	
1	1	0	Other than 0	—	—	—	—	Ends after the first transfer
1	1	—	0*2	0	—	0	Other than 0	Ends after the second transfer
				0	—	0	0*2	Ends after the second transfer with an interrupt request to the CPU
				0	—	1	—	
1	1	1	Other than 0	—	—	—	—	Ends after the first transfer with an interrupt request to the CPU

Notes: 1. Normal transfer mode: CRA, Repeat transfer mode: CRAL, Block transfer mode: CRB

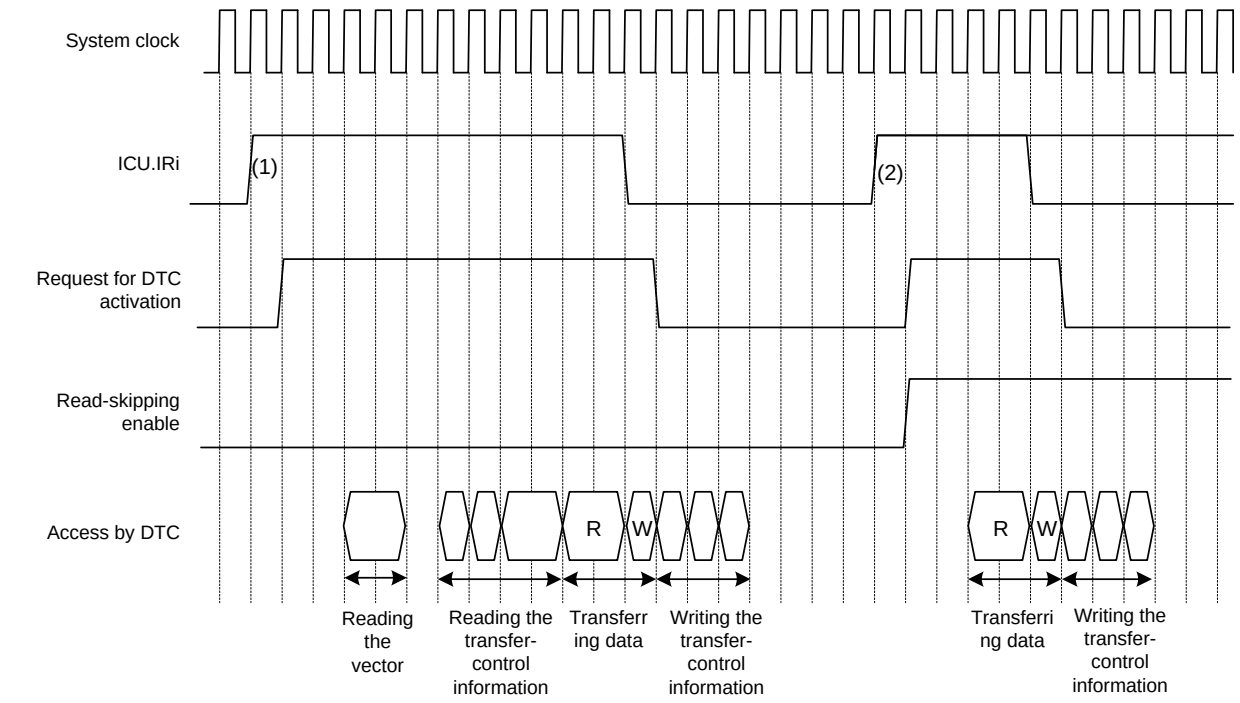
2. When the CRAL value is replaced with the CRAH value in repeat transfer mode

13.4.1 Transfer Data Read Skip Function

Vector address read and transfer data read can be skipped by the setting of the RRS bit in DTCCR.

When a DTC startup request is generated, the current DTC vector number is always compared with the DTC vector number in the previous startup process. When these vector numbers match and the RRS bit is set to 1, DTC data transfer is performed without reading the vector address and transfer data. However, when the previous transfer was chain transfer, the vector address and transfer data are always read. Furthermore, when the transfer counter (CRA register) became 0 during the previous normal transfer and when the transfer counter (CRB register) became 0 during the previous block transfer, transfer data is always read regardless of the value of RRS bit. Figure 13.5 shows an example of transfer data read skip.

To update the vector table and transfer data, set the RRS bit to 0, update the vector table and transfer data, and then set the RRS bit to 1. When the RRS bit is set to 0, the retained vector number is discarded and the vector table and transfer data that are updated in the following startup process are read.



i = DTC vector number (interrupt vector number)

Note: Since the activation request (vector number) is the same at points (1) and (2), if bit RRS = 1, reading of the transfer-control information is skipped for request (2).

Figure 13.5 Operation with Skipping of the Transfer-Control Information

13.4.2 Transfer Data Write-Back Skip Function

When the SM[1:0] bits in MRA or the DM[1:0] bits in MRB are set to "address fixed", a part of transfer data is not written back. This function is performed independently of the setting of short-address mode or full-address mode. Table 13.6 lists transfer data write-back skip conditions and applicable registers.

The CRA and CRB registers are always written back independently of the setting of short-address mode or full-address mode. Furthermore, in full-address mode, write-back of the MRA and MRB registers are always skipped.

Table 13.6 Transfer Data Write-Back Skip Conditions and Applicable Registers

SM[1:0] Bits in MRA		DM[1:0] Bits in MRB			
b3	**b2**	**b3**	**b2**	**SAR Register**	**DAR Register**
0	0	0	0	Skip	Skip
0	0	0	1		
0	1	0	0		
0	1	0	1		
0	0	1	0	Skip	Write-back
0	0	1	1		
0	1	1	0		
0	1	1	1		
1	0	0	0	Write-back	Skip
1	0	0	1		
1	1	0	0		
1	1	0	1		
1	0	1	0	Write-back	Write-back
1	0	1	1		
1	1	1	0		
1	1	1	1		

13.4.3 Normal Transfer Mode

This mode allows 1-byte, 1-word, or 1-longword data transfer on a single startup source. The transfer count can be set to 1 to 65536.

Transfer source addresses and transfer destination addresses can be set to increment, decrement, or fixed independently. This mode enables an interrupt request to the CPU to be generated at the end of specified-count transfer.

Table 13.7 lists register functions in normal transfer mode, and figure 13.6 shows the memory map of normal transfer mode.

Table 13.7 Register Functions in Normal Transfer Mode

Register	Description	Value Written Back by Writing Transfer Data
SAR	Transfer source address	Increment/decrement/fixed*
DAR	Transfer destination address	Increment/decrement/fixed*
CRA	Transfer count A	CRA - 1
CRB	Transfer count B	Not updated

Note: * Write-back operation is skipped in address-fixed mode.

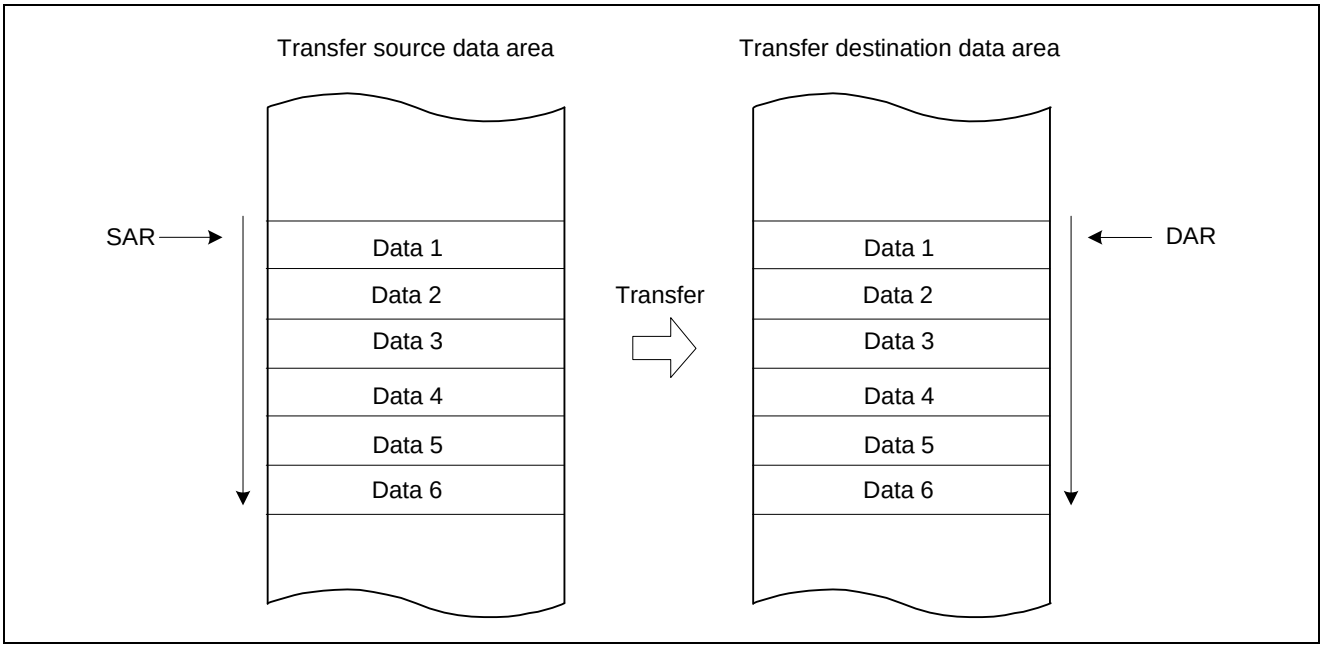


Figure 13.6 Memory Map of Normal Transfer Mode

13.4.4 Repeat Transfer Mode

This mode allows 1-byte, 1-word, or 1-longword data transfer on a single startup source.

Specify either transfer source or transfer destination for the repeat area by the DTS bit in MRB. The transfer count can be set to 1 to 256. When the specified-count transfer is completed, the initial value of the address register specified in the transfer counter and the repeat area is restored and transfer is repeated. The other address register is incremented or decremented continuously or remains unchanged.

When the transfer counter CRAL is decreased to 00h in repeat transfer mode, the CRAL value is updated to the value set in CRAH. Thus the transfer counter does not become 00h, which inhibits generation of interrupt request to the CPU when the DISEL bit in MRB is set to 0 (an interrupt request to the CPU is generated when specified data transfer is completed).

Table 13.8 lists the register functions in repeat transfer mode, and figure 13.7 shows the memory map of repeat transfer mode.

Table 13.8 Register Functions in Repeat Transfer Mode

		Value Written Back by Writing Transfer Data	
Register	**Description**	**When CRAL is not 1**	**When CRAL is 1**
SAR	Transfer source address	Increment/decrement/fixed*	(When the DTS bit in MRB is 0) Increment/decrement/fixed* (When the DTS bit in MRB is 1) SAR register initial value
DAR	Transfer destination address	Increment/decrement/fixed*	(When the DTS bit in MRB is 0) DAR register initial value (When the DTS bit in MRB is 1) Increment/decrement/fixed*
CRAH	Retains transfer count	CRAH	CRAH
CRAL	Transfer count A	CRAL - 1	CRAH
CRB	Transfer count B	Not updated	Not updated

Note: * Write-back is skipped in address-fixed mode.

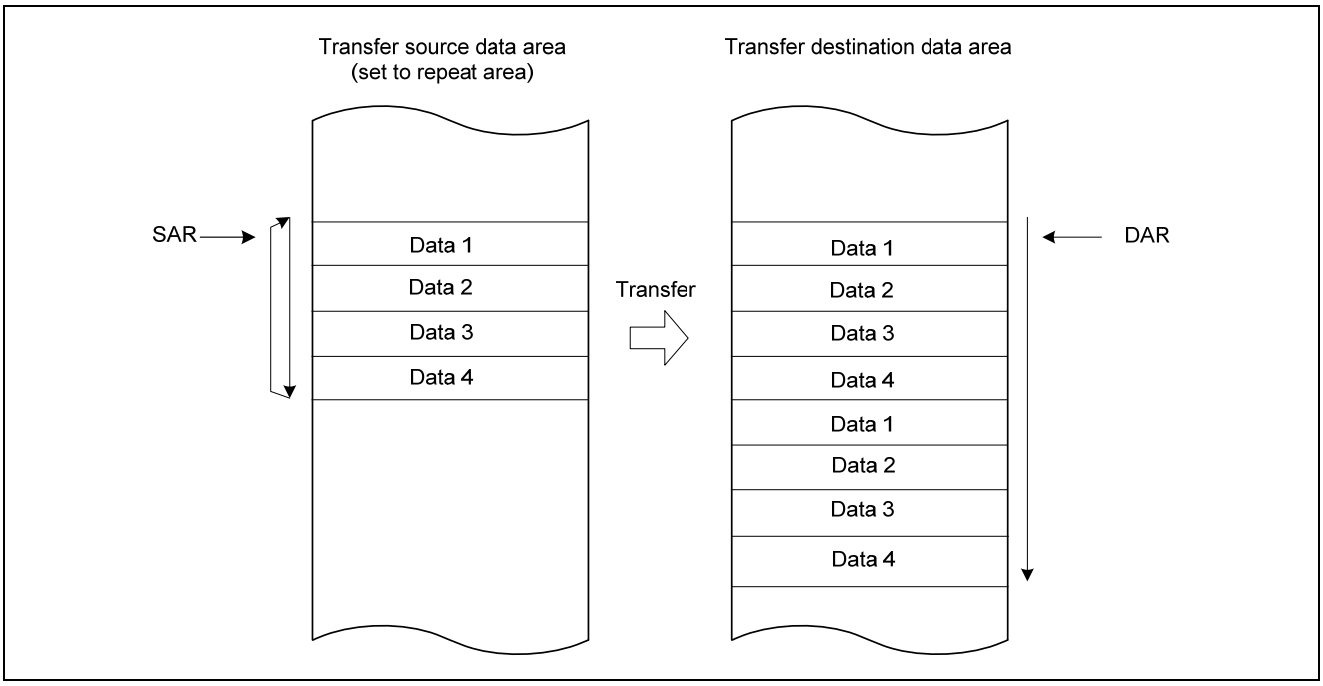


Figure 13.7 Memory Map of Repeat Transfer Mode (Transfer Source: Repeat Area)

13.4.5 Block Transfer Mode

This mode allows single-block data transfer on a single startup source.

Specify either transfer source or transfer destination for the block area by the DTS bit in MRB. The block size can be set to 1 to 256 bytes (or 1 to 256 words or 1 to 256 longwords).

When transfer of the specified one block is completed, the initial values of the block size counter CRAL and the address register (SAR when the DTS bit = 1 or DAR when the DTS bit = 0) specified in the block area are restored. The other address register is incremented or decremented continuously or remains unchanged.

The transfer count (block count) can be set to 1 to 65536. This mode enables an interrupt request to the CPU to be generated at the end of specified-count block transfer.

Table 13.9 lists register functions in block transfer mode, and figure 13.8 shows the memory map of block transfer mode.

Table 13.9 Register Functions in Block Transfer Mode

Register	Description	Value Written Back by Writing Transfer Data
SAR	Transfer source address	(When DTS bit in MRB is 0) Increment/decrement/fixed* (When DTS bit in MRB is 1) SAR register initial value
DAR	Transfer destination address	(When DTS bit in MRB is 0) DAR register initial value (When DTS bit in MRB is 1) Increment/decrement/fixed*
CRAH	Retains block size	CRAH
CRAL	Block size counter	CRAH
CRB	Block transfer counter	CRB - 1

Note: * Write-back is skipped in address-fixed mode.

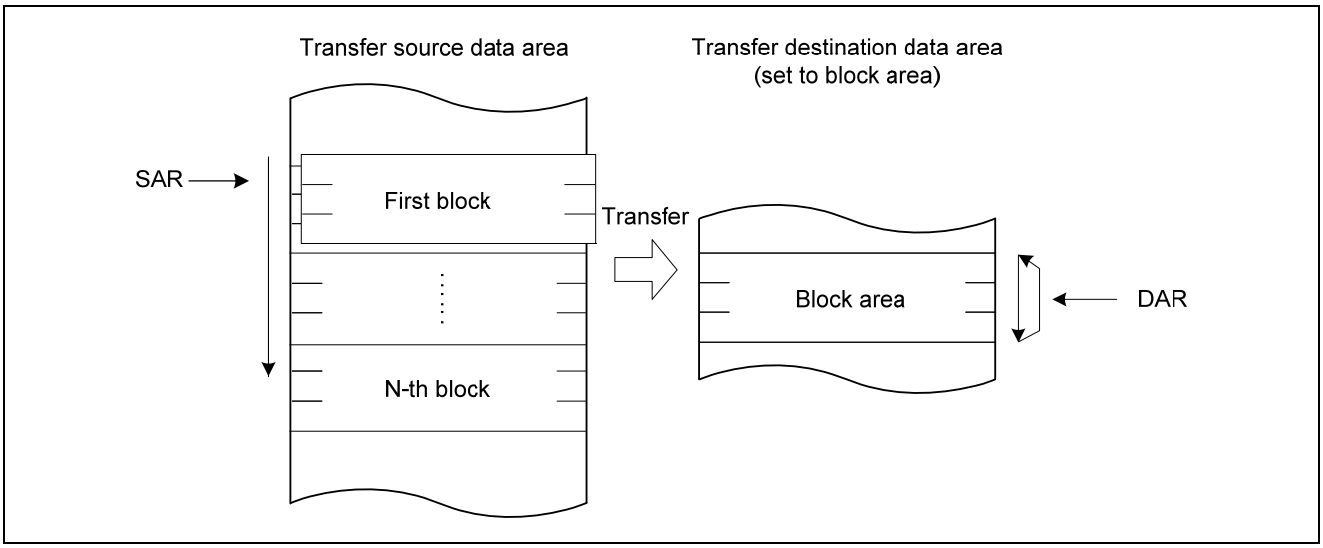


Figure 13.8 Memory Map of Block Transfer Mode (Transfer Destination: Block Area)

13.4.6 Chain Transfer

Setting the CHNE bit in MRB to 1 allows multiple data transfers continuously on a single startup source. Chain transfer can be set independently for registers SAR, DAR, CRA, and CRB that define data transfer, as well as for registers MRA and MRB. Figure 13.9 shows chain transfer operation.

When the CHNE and CHNS bits in MRB are set to 1 and 0, respectively, no interrupt is issued to the CPU and no interrupt source flag as the startup source is cleared, but chain transfer is performed instead based on the next transfer information.

When the CHNE and CHNS bits in MRB are both set to 1, no interrupt is issued to the CPU and no interrupt source flag as the startup source is cleared when the transfer counter value is 0, but chain transfer is performed instead based on the next transfer information. When the transfer counter value is not 0, the interrupt is issued to the CPU and the interrupt source flag as the startup source is cleared by setting the DISEL bit in MRB to 1.

In chain transfer, the interrupt is issued to the CPU or the interrupt source flag as the startup source is cleared upon transfer completion caused by clearing the CHNE bit in MRB to 0.

For detailed chain transfer flow, refer to figure 13.4, Operation Flowchart of the DTC, and table 13.5, Chain Transfer Conditions.

In repeat transfer mode, writing 1 to the RCHNE bit in DTCCR and the CHNE and CHNS bits in MRB enables chain transfer after data transfer of transfer counter = 1.

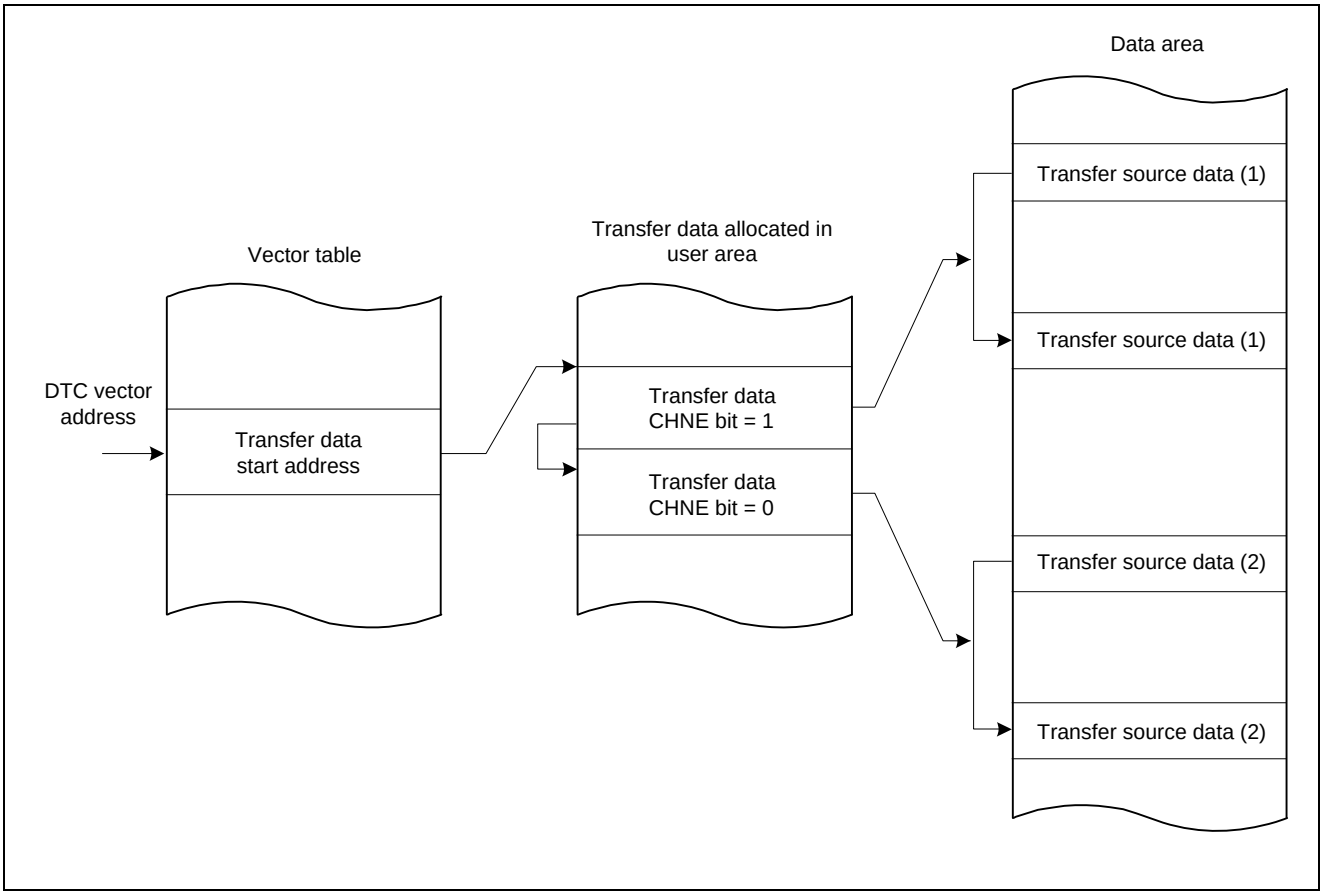


Figure 13.9 Chain Transfer Operation

13.4.7 Operation Timing

Figures 13.10 to 13.13 show examples of DTC operation timing.

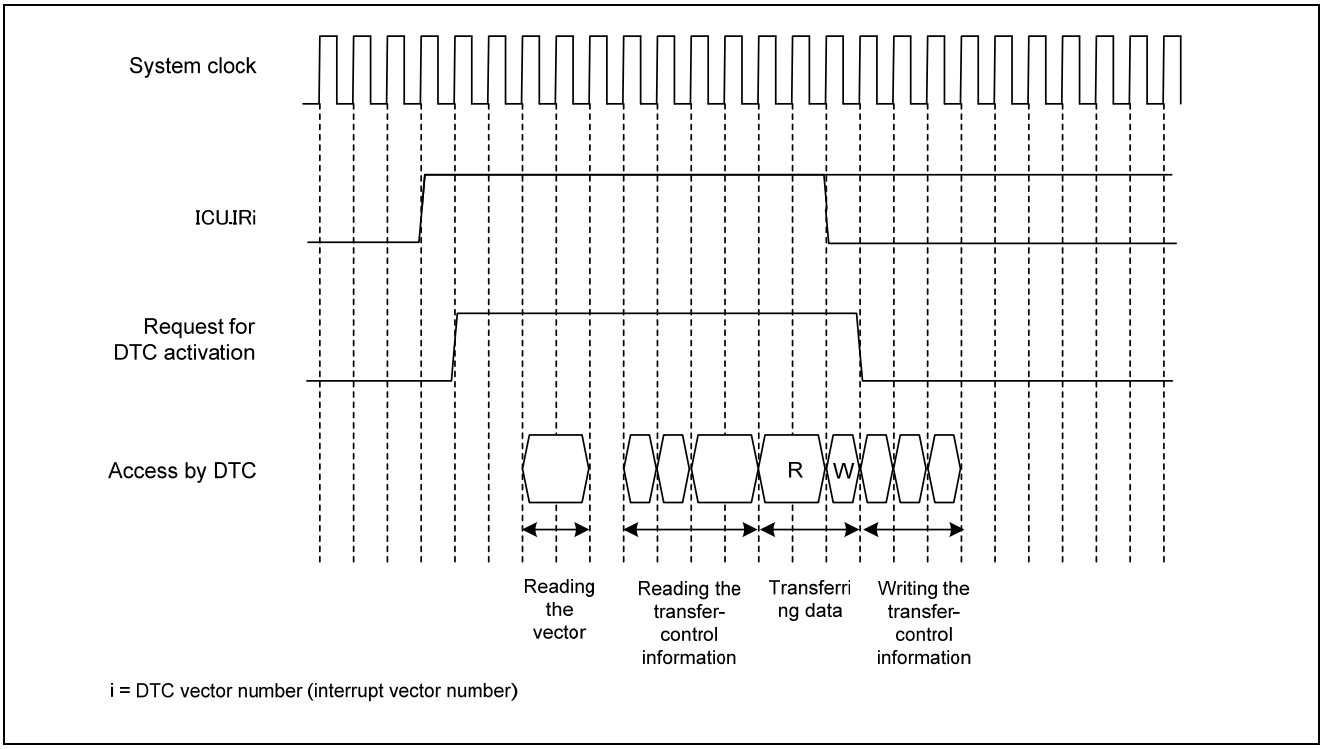


Figure 13.10 Example of DTC Operation Timing 1
(Short-Address Mode, Normal Transfer Mode, Repeat Transfer Mode)

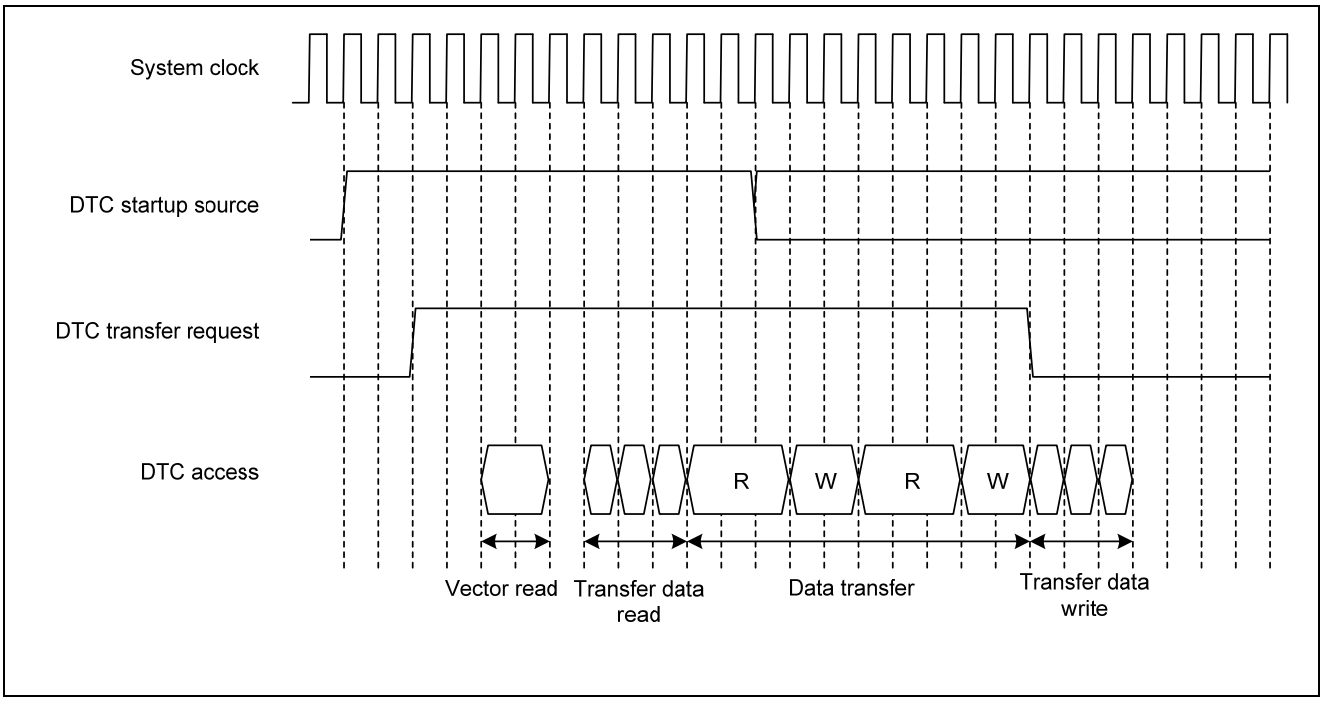


Figure 13.11 Example of DTC Operation Timing 2
(Short-Address Mode, Block Transfer Mode, Block Size = 2)

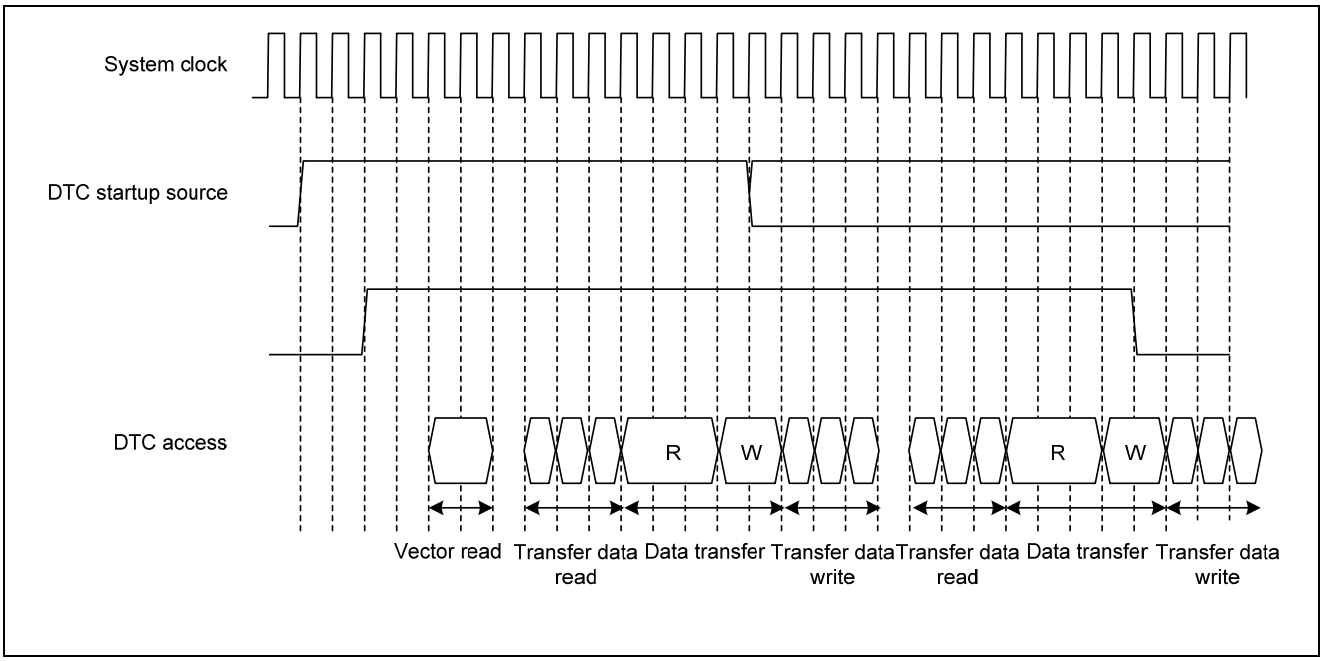


Figure 13.12 Example of DTC Operation Timing 3 (Short-Address Mode, Chain Transfer)

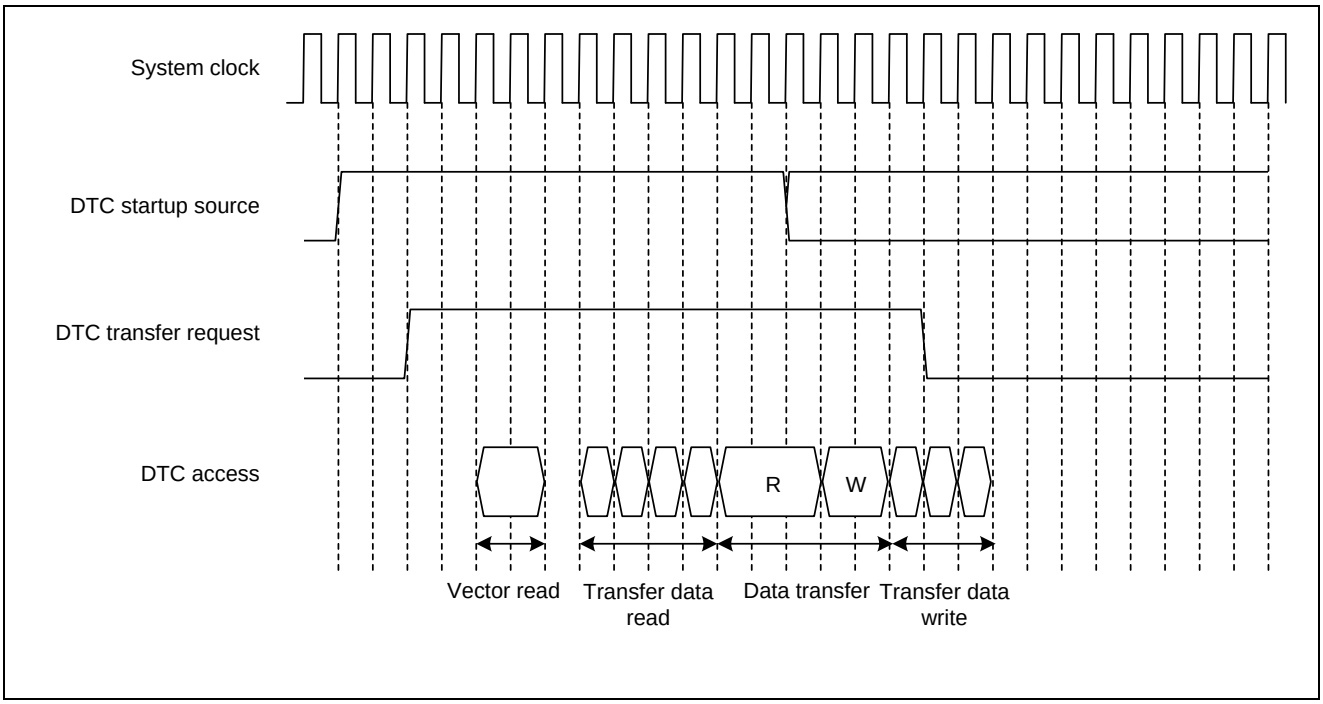


Figure 13.13 Example of DTC Operation Timing 4 (Full-Address Mode, Normal Transfer Mode, Repeat Transfer Mode)

13.4.8 Execution Cycle of the DTC

Table 13.10 lists the execution cycle of single data transfer of the DTC.

Table 13.10 Table 13.10 Execution Cycle of the DTC

Transfer Mode	Vector Read	Transfer Data Read			Transfer Data Write			Data Read	Data Write	Internal Operation	
Normal	V+1	0*1	4 × C + 1*2	3 × C + 1*3	0*1	3 × C*2, *3	2 × C*4	C*5	R+1	W	1	0*1
Repeat	V+1	0*1	4 × C + 1*2	3 × C + 1*3	0*1	3 × C*2, *3	2 × C *4	C *5	R+1	W	1	0*1
Block	V+1	0*1	4 × C + 1*2	3 × C + 1*3	0*1	3 × C*2, *3	2 × C *4	C *5	(R+1) × P	W × P	1	0*1

Notes: 1. Transfer data skip
2. Full-address mode
3. Short-address mode
4. When SAR or DAR is set to address-fixed mode
5. When SAR and DAR are set to address-fixed mode

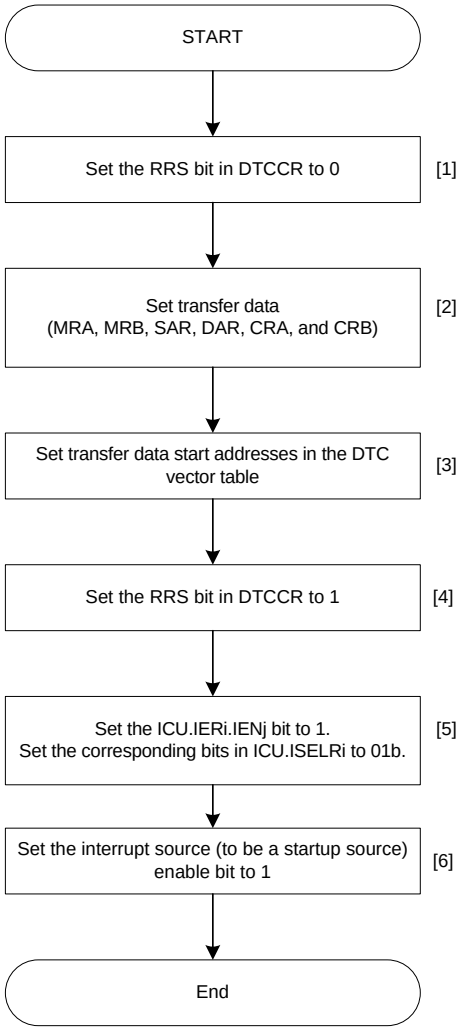
[Legend] P: Block size (set by CRAH and CRAL)
V: Access cycles for the vector information data storing destination
C: Access cycles for the transfer information data storing destination
R: Access cycles for the data read destination
W: Access cycles for the data write destination
(V, C, R, and W values depend on the access destination. For the number of cycles for the access destination, see section 25, RAM, section 26, ROM (Flash Memory for Code Storage), section 5, I/O Registers, and section 11, Buses.)

13.4.9 DTC Bus Mastership Release Timing

The DTC does not release the bus mastership during transfer data read and transfer data write. While transfer data is not read or written, bus arbitration is made according to the priority determined by the bus master arbitrator.

13.5 DTC Setting Procedure

Figure 13.14 shows the procedure to set the DTC.



[1] Setting the RRS bit in DTCCR to 0 resets he transfer data read skip flag. After that, transfer data read is not skipped while the DTC is activated.
When transfer data is updated, be sure to make this set ing.

[2] Allocate transfer data (MRA, MRB, SAR, DAR, CRA, and CRB) in the data area. For setting transfer data, see section 13.2, Register Description. For how to allocate transfer data, see section 13.3.1, Allocating Transfer Data and DTC Vector Table.

[3] Set transfer data start addresses in the DTC vector table. For how to set he DTC vector table, see section 13.3.1, Allocating Transfer Data and DTC Vector Table.

[4] Setting the RRS bit in DTCCR to 1 can skip the second and the subsequent transfer data read cycles for continuous DTC activation due to the same interrupt source. The RRS bit can always be set to 1, but this setting during DTC transfer becomes valid from the next transfer.

[5] Set the ICU.IERi.IENj bit that corresponds to the DTC startup interrupt to 1. Set the corresponding bits in ICU.ISELRi to 01b. For the correspondence between interrupt sources and ISELRi register, see table 13.3.

Note: To enable the DTC module, set the DTCST bit in DTCST to 1.

[6] Set the interrupt source enable bit to be a startup source. When a source interrupt is generated, the DTC is activated. For the setting of the interrupt source enable bit, refer to the setting of the module that is to be a startup source.

Figure 13.14 Procedure to Set the DTC

13.6 Examples of DTC Usage

13.6.1 Normal Transfer

As an example of DTC usage, its employment in the transfer of 128 bytes of data by an SCI is described below.

1. In the MRA register, make the settings to select a fixed source address (MRA.SM[1:0] = 00b), incrementation of the destination address (MRA.DM[1:0] = 10b), transfer in normal mode (MRA.MD[1:0] = 00b), and byte-sized transfer (MRA.SZ[1:0] = 00b). The MRB.DTS bit can be set to any value. For other bits of the MRB register, make the setting for one interrupt to initiate one round of transfer (MRB.CHNE = "0" and MRB.DISEL = "0"). Set the SAR to the address of the RDR for the given SCIm (m = 0 to 6), the DAR to the first address of the area in RAM where data are to be stored, and the CRA register to 128 (0080h). The CRB register can be set to any value.
2. The address where the transfer-control information for use with the RXI starts is set in the vector table for the DTC.
3. Set "01b" in the corresponding ICU.ISELRi register and "1" to the ICU.IERi.IENj bit. Set the DTCST.DTCST bit to "1".
4. Set the SCI for the prescribed reception mode. Enable reception-completed interrupts by setting the SCR.RIE bit in the given SCIm to "1". Also, so that further reception does not proceed if a reception error occurs while reception by the SCI is in progress, make the CPU able to accept reception-error interrupts.
5. Every time the reception of one byte by the SCI is completed, an RXI interrupt is generated to activate the DTC. The DTC transfers the received byte from the RDR of the SCI to RAM, after which the DAR register is incremented and the CRA register is decremented.
6. After 128 rounds of data transfer have been completed and the value in the CRA register becomes "0", an RXI interrupt request is generated for the CPU. Processing for completion is performed in the processing routine for this interrupt.

13.6.2 Chain Transfer

As an example of chained transfer by the DTC, its employment in the output of pulses by a PPG is described below.

Chained transfer is used to transfer pulse output data and vary the period of the output trigger for the PPG. The first half of the chained transfer is in repeated-transfer mode and the destinations for transfer are the PPGm.NDRH and PPGm.NDRL (where m = 0 or 1) registers. The second half of the chained transfer is in normal-transfer mode and the destinations for transfer are the TPUm.TGRA to TPUm.TGRD registers (where m = 0 to 11). This is because clearing of the activation source and generation of an interrupt on completion of the specified number of rounds of transfer are restricted to the second half of the chained transfer (transfer while MRB.CHNE = "0").

1. Settings are made for transfer to the PPGm.NDRH and PPGm.NDRL registers. In the MRA register, make the settings to select incrementation of the source address (MRA.SM[1:0] = 10b), a fixed destination address (MRA.DM[1:0] = 00b), transfer in repeated-transfer mode (MRA.MD[1:0] = 01b), and word-sized transfer (MRA.SZ[1:0] = 01b). Make the setting for a repeated area on the source side (MRB.DTS = "1"). For other bits of the MRB register, make the settings for chained transfer (MRB.CHNE = "1", MRB.CHNS = "0", and MRB.DISEL = "0"). Set the SAR to the first address of the data table, the DAR register to the address of the PPGm.NDRH register, and the CRAH and CRAL registers to the size of the data table. The CRB register can be set to any value.
2. Settings are made for transfer to the TPUm.TGRA register. In the MRA register, make the settings to select incrementation of the source address (MRA.SM[1:0] = 10b), a fixed destination address (MRA.DM[1:0] = 00b), transfer in normal mode (MRA.MD[1:0] = 00b), and word-sized transfer (MRA.SZ[1:0] = 01b). Set the SAR register to the first address of the data table, the DAR register to the address of the TPUm.TGRA register, and the CRA register to the size of the data table. The CRB register can be set to any value.
3. Place the transfer-control information for use in transfer to the TPU immediately after the transfer-control information for use in transfer to the PPGm.NDRH and PPGm.NDRL registers.
4. In the DTC vector table, set the address where the transfer-control information for use in transfer to the PPGm.NDRH and PPGm.NDRL registers starts.
5. Set "01b" in the corresponding ICU.ISELRi register and "1" to the ICU.IERi.IENj bit. Set the DTCST.DTCST bit to "1".
6. In the given TPUm, set the TIORH and TIORL registers so that the TGRA register operates as an output-compare register (with output disabled) and make the TIER setting to enable TGIA interrupt requests.
7. Set the default output values in the PPGm.NDRH and PPGm.NDRL registers and the next output values in the PPGm.NDRH and PPGm.NDRL registers. In the DDR of the corresponding port m (where m = 0 to 9 or A to E), set the appropriate bit to "1" so that output from the PPGm.NDRH and PPGm.NDRL registers proceeds. Also, select compare-match of the TPU as the output trigger in the PCR of the corresponding port m (where m = 0 to 9 or A to E).
8. Set the TSTRi.CST[5:0] (i = A, B) bits to "1" to start counting operation of the TPU.TCNT counter.
9. Every time a compare-match with the TPUm.TGRA register is generated, next output values are transferred to the PPGm.NDRH and PPGm.NDRL registers and the setting for the next output-trigger period is transferred to the TPUm.TGRA register.
10. After the specified number of rounds of data transfer has been completed (i.e. when the value in the CRA register has become "0"), a TGIA interrupt request is issued for the CPU. Processing for completion is performed in the processing routine for this interrupt.

13.6.3 Chain Transfer when Counter = 0

The second data transfer is performed only when the counter = 0. Repeat transfer of a transfer count of 256 or more is enabled by the re-setting for the first data transfer.

The following shows an example of configuring a 128-kbyte input buffer, where the input buffer is set so that its lower address starts with 0000h. Figure 13.15 shows a chain transfer when the counter = 0.

1. Set normal transfer mode for input data for the first data transfer. Set the following:
   Transfer source address: Fixed, CRA = 0000h (65,536 times), CHNE bit = 1 (chain transfer enabled) in MRB, CHNS bit = 1 (chain transfer is performed only when the transfer counter is 0) in MRB, and DISEL bit = 0 (an interrupt request to the CPU is generated when specified data transfer is completed) in MRB.
2. Prepare the upper 8-bit address of the start address at every 65,536 times of the transfer destination address for the first data transfer in another area (such as ROM). For example, when setting the input buffer to 200000h to 21FFFFh, prepare 21h and 20h.
3. For the second data transfer, set repeat transfer mode (transfer source: repeat area) for re-setting the transfer destination address of the first data transfer. Specify the upper 8 bits of DAR in the first transfer data area for the transfer destination. At this time, set CHNE bit = 0 (chain transfer disabled) in MRB and DISEL bit = 0 (an interrupt request to the CPU is generated when specified data transfer is completed) in MRB. When setting the input buffer mentioned above to 200000h to 21FFFFh, set the transfer counter to 2.
4. The first data transfer is performed by an interrupt 65,536 times. When the transfer counter of the first data transfer becomes 0, the second data transfer starts. Set the upper 8 bits of the transfer source address of the first data transfer to 21h. The transfer counter (lower 16 bits) of the transfer destination address of the first data transfer is 0000h.
5. In succession, the first data transfer is performed by an interrupt 65,536 times specified for the first data transfer. When the transfer counter of the first data transfer becomes 0, the second data transfer starts. Set the upper 8 bits of the transfer source address of the first data transfer to 20h. The transfer counter (lower 16 bits) of the transfer destination address of the first data transfer is 0000h.
6. Steps 4 and 5 above are repeated infinitely. Since the second data transfer is in repeat transfer mode, no interrupt request to the CPU is generated

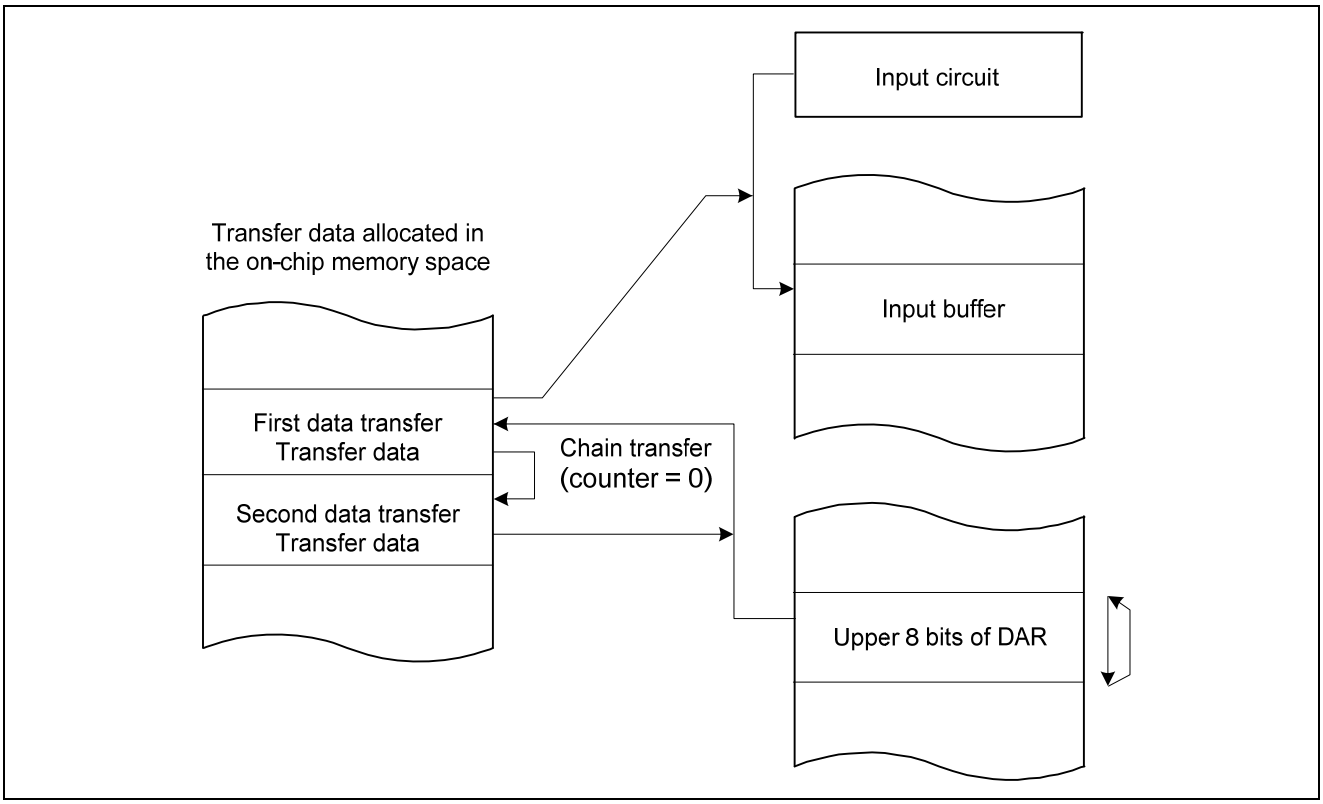


Figure 13.15 Chain Transfer when Counter = 0

13.7 Interrupt Source

When the DTC has finished data transfer of specified count or when data transfer with the DISEL bit in MRB set to 1 (an interrupt request to the CPU is generated each time DTC data transfer is performed) has been completed, an interrupt to the CPU is generated by the DTC startup source. Such interrupts to the CPU are controlled according to the CPU mask level and the priority level of the interrupt control unit.

13.8 Low-Power Consumption

13.8.1 Setting the DTC Module Start Register

To enable the DTC, the DTCST (DTC module operation) bit in DTCST must be set to 1.

Setting the DTCST (module-stop for the DTC) bit to "0" enables state transitions to module-stop mode, all-module clock-stop mode, software-standby mode, or deep software-standby mode.

(1) Module Stop

Writing 1 to the MSTPA27 bit (transition of the DTC to the module-stop state) in MSTPCRA enables the module-stop function for the DTC. If DTC operations are in progress when 1 is written to the bit, the DTC makes a transition to the module-stop state after completing DTC operations.

(2) Transition to All-Module Clock-Stop Mode

Writing 1 to the ACSE bit (permitting all-module clock-stop mode) in MSTPCRA, writing 1 to all the bits in MSTPCRA and MSTPCRB, including the MSTPA27 bit (transition of the DTC to the module-stop state), and then executing a WAIT instruction enables transition to the all-module clock-stop mode. However, if DTC operations are in progress when a WAIT instruction is executed, the DTC can make a transition to the all-module clock-stop state after completing DTC operations.

(3) Transition to Software Standby and Deep Software Standby Modes

Writing 1 to the SSBY bit (selecting a transition to software standby mode following the execution of a WAIT instruction) in SBYCR and then executing a WAIT instruction places the chip in software standby mode. If transfer by the DTC is in progress at the point of execution of the WAIT instruction, transfer continues until it is completed, after which the transition to software standby mode proceeds. Furthermore, when the setting of the DPSBY bit is "1" (selecting a transition to deep software standby mode after execution of a WAIT instruction) at the time of a transition to software standby mode, the transition will actually be to deep software standby mode.

13.9 Usage Notes

13.9.1 Transfer Data Start Address/Transfer Source Address/Transfer Destination Address

Be sure to set multiples of 4 for the transfer data start addresses in the vector table. Because, such addresses are accessed with their lowest 2 bits fixed at 00b.

13.9.2 Allocating Transfer Data

Allocate transfer data in the memory area according to the endian of the area as shown in figure 13.16.

For example, when writing CRA and CRB setting data with 16 bits in big endian, write the CRA setting data to lower address 0 and the CRB setting data to lower address 2. In little endian, write the CRB setting data to lower address 0 and the CRA setting data to lower address 2. When writing CRA and CRB setting data with 32 bits, place the CRA setting data at the MSB side and the CRB setting data at the LSB side regardless of endian, and then write the data to lower address 0.

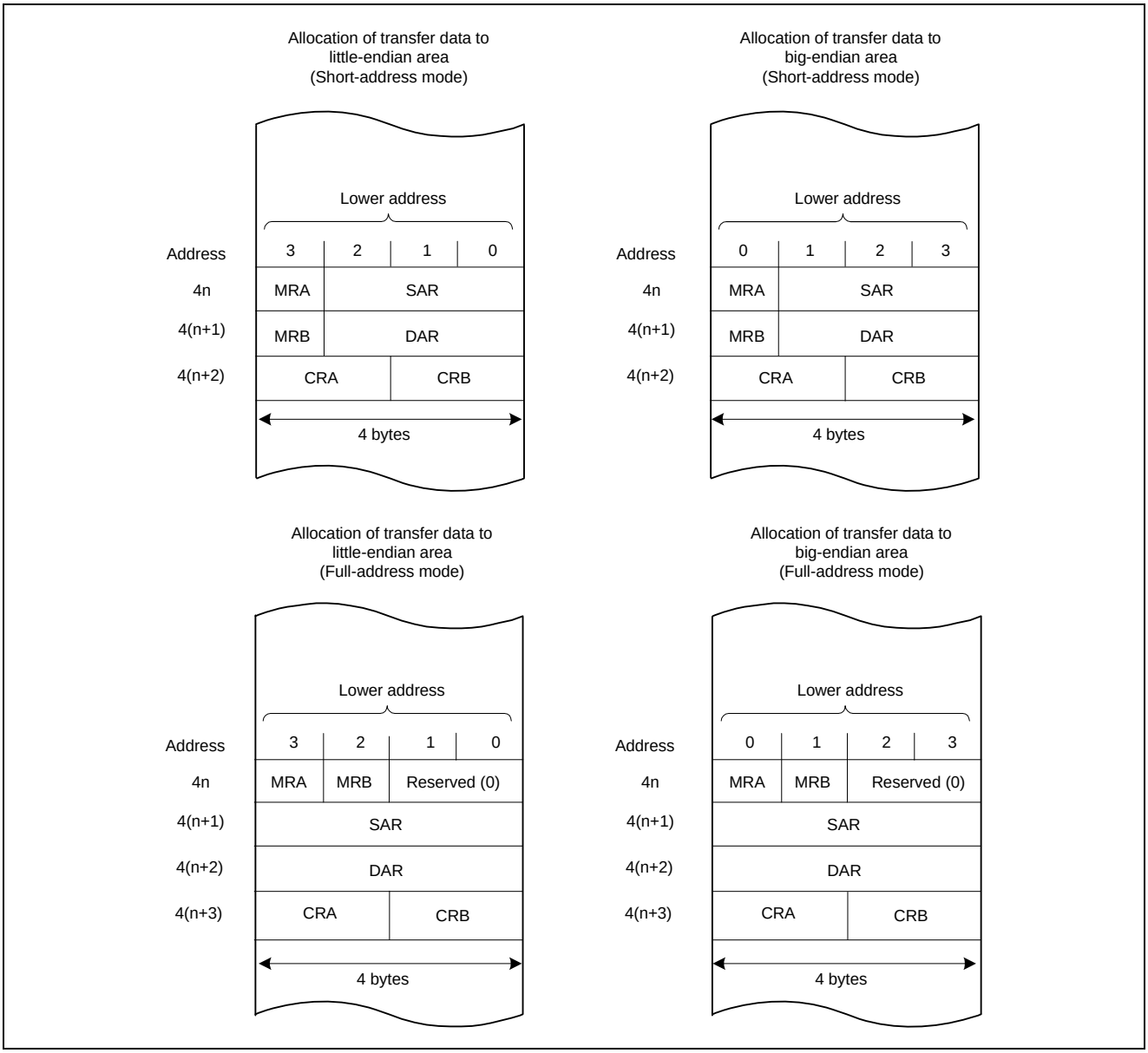


Figure 13.16 Allocation of Transfer Data

14. I/O Ports

The I/O ports of the RX610 Group function as a programmable I/O port, an I/O pin of a peripheral module, an input pin for an interrupt, or a bus control pin.

Each pin is also configurable as an I/O pin of a peripheral module or an input pin for an interrupt. All pins function as input pins immediately after a reset, and pin functions are switched by register settings. The setting of each pin is specified by the registers for the corresponding I/O port and peripheral modules.

Each port has data direction registers (DDR) that control input and output, data registers (DR) that store data for output, port registers (PORT) for reading the pin states, and input buffer control registers (ICR) that enable or disable the input buffer.

The configuration of the I/O ports differs with the package. The 144-pin LQFP version has 15 I/O ports (ports 0 to 9 and A to E), which handle 117 I/O pins. The 176-pin LFBGA version has 18 I/O ports (ports 0 to 9 and A to H), which handle 140 I/O pins.

14.1 Overview

Table 14.1 gives the specifications of the I/O ports and table 14.2 lists I/O ports and pin functions.

Table 14.1 Specifications of I/O Ports

Item		Description
I/O pins	144-pin LQFP	117
	176-pin LFBGA	140
Number of ports	144-pin LQFP	15 (0 to 9 and A to E)
	176-pin LFBGA	18 (0 to 9 and A to H)
Built-in input pull-up resistor		Ports A to E
Open drain output capability		Ports 2 and C
5-V tolerance pins		Ports 0 and 1 (P14, P15, P16, P17)
Schmitt trigger input pins		All port inputs, IRQ inputs, TPU inputs, TMR inputs, RIIC inputs, and SCI inputs
Others		Each pin is capable of driving a capacitive load of 30 pF in the case of a TTL load. When configured as an output, a pin is capable of driving a Darlington transistor

Table 14.2 Port Functions

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Input Pull-up Resistor Function	Open Drain Output Capability
			I/O	Input	Output				
Port 0	General I/O port pins, on-chip emulator inputs, interrupt inputs, TMR I/O signals, and SCI I/O signals	0	P00	TMRI2/IRQ8-A	TxD6	—	All input functions	—	—
		1	P01	TMCI2/RxD6/ IRQ9-A			All input functions		
		2	P02/SCK6	IRQ10-A/TRST#	TMO2		All input functions		
		3	P03/SCK4	TMRI3/IRQ11-A/ TMS			All input functions		
		4	P04	TMCI3/IRQ12-A/ TDI	TxD4		All input functions		
		5	P05	RxD4/IRQ13-A/ TCK	TMO3		All input functions		
Port 1	General I/O port pins, interrupt inputs, TPU inputs, SCI I/O signals, RIIC I/O signals, and A/D converter inputs	0	P10	IRQ0-B		—	All input functions	—	—
		1	P11/SCK2	IRQ1-B			All input functions		
		2	P12	RxD2/IRQ2-B			All input functions		
		3	P13	ADTRG0#/IRQ3-B	TxD2		All input functions		
		4	P14/SDA1	TCLKA-B/IRQ4-B			All input functions		
		5	P15/SCK3/ SCL1	TCLKB-B/IRQ5-B			All input functions		
		6	P16/SDA0	TCLKC-B/RxD3/ IRQ6-B			All input functions		
		7	P17/SCL0	TCLKD-B/ ADTRG1#/IRQ7-B	TxD3		All input functions		
Port 2	General I/O port pins, TPU I/O signals, PPG outputs, TMR I/O signals, and SCI I/O signals	0	P20/TIOCB3	TIOCA3/TMRI0	PO0/TxD0	—	All input functions	—	√
		1	P21/TIOCA3	TMC 0/RxD0	PO1		All input functions		
		2	P22/TIOCC3/SCK0		PO2/TMO0		All input functions		
		3	P23/TIOCD3	TIOCC3	PO3		All input functions		
		4	P24/TIOCB4	TIOCA4/TMRI1	PO4		All input functions		
		5	P25/TIOCA4	TMCI1/RxD1	PO5		All input functions		
		6	P26/TIOCA5		PO6/TMO1/ TxD1		All input functions		
		7	P27/TIOCB5/SCK1	TIOCA5	PO7		All input functions		

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Input Pull-up Resistor Function	Open Drain Output Capability
			I/O	Input	Output				
Port 3	General I/O port pins, interrupt inputs, TPU I/O signals, and PPG outputs	0	P30/TIOCA0	IRQ0-A	PO8	—	All input functions	—	—
		1	P31/TIOCB0	TIOCA0/IRQ1-A	PO9		All input functions		
		2	P32/TIOCC0	TCLKA-A/IRQ2-A	PO10		All input functions		
		3	P33/TIOCD0	TIOCC0/TCLKB-A/ IRQ3-A	PO11		All input functions		
		4	P34/TIOCA1	IRQ4-A	PO12		All input functions		
		5	P35/TIOCB1	TIOCA1/TCLKC-A	PO13		All input functions		
		6	P36/TIOCA2		PO14		All input functions		
		7	P37/TIOCB2	TIOCA2/TCLKD-A	PO15		All input functions		
Port 4	General I/O port pin, interrupt inputs, and A/D converter inputs	0	P40	AN0/IRQ8-B		—	P40, IRQ8-B	—	—
		1	P41	AN1/IRQ9-B			P41, IRQ9-B		
		2	P42	AN2/IRQ10-B			P42, IRQ10-B		
		3	P43	AN3/IRQ11-B			P43, IRQ11-B		
		4	P44	AN4/IRQ12-B			P44, IRQ12-B		
		5	P45	AN5/IRQ13-B			P45, IRQ13-B		
		6	P46	AN6/IRQ14-B			P46, IRQ14-B		
		7	P47	AN7/IRQ15-B			P47, IRQ15-B		
Port 5	General I/O port pins, system clock outputs, bus control I/O signals, and tracing I/O signals	0	P50		WR0#/WR#	—	All input functions	—	—
		1	P51		WR1#/BC1#		All input functions		
		2	P52		RD#		All input functions		
		3		P53	BCLK		All input functions		
		4	P54		TRDATA0		All input functions		
		5	P55		TRDATA1		All input functions		
		6	P56		TRDATA2		All input functions		
		7	P57	WAIT#	TRDATA3		All input functions		
Port 6	General I/O port pins, interrupt inputs, bus control outputs, and D/A converter outputs	0	P60		CS0#/ CS4#-A/ CS5#-B	—	All input functions	—	—
		1	P61		CS1#/ CS2#-B/ CS5#-A/ CS6#-B/ CS7#-B		All input functions		
		2	P62		CS2#-A/ CS6#-A		All input functions		
		3	P63		CS3#-A/ CS7#-A		All input functions		
		4	P64		CS4#-B		All input functions		
		5	P65	IRQ15-A			All input functions		
		6	P66		DA0		All input functions		
		7	P67		DA1		All input functions		

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Input Pull-up Resistor Function	Open Drain Output Capability
			I/O	Input	Output				
Port 7	General I/O port pins, interrupt inputs, bus control outputs, and A/D converter inputs	0	P70	ADTRG2#	CS3#-B	—	All input functions	—	—
		1	P71		CS4#-C/ CS5#-C/ CS6#-C/ CS7#-C		All input functions		
		2	P72				All input functions		
		3	P73				All input functions		
		4	P74	ADTRG3#			All input functions		
		5	P75				All input functions		
		6	P76	IRQ14-A			All input functions		
		7	P77				All input functions		
Port 8	General I/O port pins and tracing outputs	0	P80			—	All input functions	—	—
		1	P81		TRSYNC		All input functions		
		2	P82		TRCLK		All input functions		
		3	P83				All input functions		
		4	P84				All input functions		
		5	P85				All input functions		
		6	P86				All input functions		
Port 9	General I/O port pins and A/D converter inputs	0	P90	AN8		—	P90	—	—
		1	P91	AN9			P91		
		2	P92	AN10			P92		
		3	P93	AN11			P93		
		4	P94	AN12			P94		
		5	P95	AN13			P95		
		6	P96	AN14			P96		
		7	P97	AN15			P97		
Port A	General I/O port pins, address outputs, TPU I/O signals, and PPG outputs	0	PA0/TIOCA6		A0/PO16/ BC0#	—	All input functions	√	—
		1	PA1/TIOCB6	TIOCA6	A1/PO17		All input functions		
		2	PA2/TIOCC6	TCLKE	A2/PO18		All input functions		
		3	PA3/TIOCD6	TIOCC6/TCLKF	A3/PO19		All input functions		
		4	PA4/TIOCA7		A4/PO20		All input functions		
		5	PA5/TIOCB7	TIOCA7/TCLKG	A5/PO21		All input functions		
		6	PA6/TIOCA8		A6/PO22		All input functions		
		7	PA7/TIOCB8	TIOCA8/TCLKH	A7/PO23		All input functions		

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Input Pull-up Resistor Function	Open Drain Output Capability
			I/O	Input	Output				
Port B	General I/O port pins, address outputs, TPU I/O signals, and PPG outputs	0	PB0/TIOCA9		A8/PO24	—	All input functions	√	—
		1	PB1/TIOCB9	TIOCA9	A9/PO25		All input functions		
		2	PB2/TIOCC9		A10/PO26		All input functions		
		3	PB3/TIOCD9	TIOCC9	A11/PO27		All input functions		
		4	PB4/TIOCA10		A12/PO28		All input functions		
		5	PB5/TIOCB10	TIOCA10	A13/PO29		All input functions		
		6	PB6/TIOCA11		A14/PO30		All input functions		
		7	PB7/TIOCB11	TIOCA11	A15/PO31		All input functions		
Port C	General I/O port pins, address outputs, bus control outputs, and SCI I/O signals	0	PC0		A16	—	All input functions	√	√
		1	PC1		A17		All input functions		
		2	PC2		A18		All input functions		
		3	PC3		A19		All input functions		
		4	PC4		A20		All input functions		
		5	PC5/SCK5		A21/CS5#-D		All input functions		
		6	PC6	RxD5	A22/CS6#-D		All input functions		
		7	PC7		A23/CS4#-D/ CS7#-D/TxD5		All input functions		
Port D	General I/O port pins and bidirectional data-bus lines	0	PD0/D0			D0	PD0	√	—
		1	PD1/D1			D1	PD1		
		2	PD2/D2			D2	PD2		
		3	PD3/D3			D3	PD3		
		4	PD4/D4			D4	PD4		
		5	PD5/D5			D5	PD5		
		6	PD6/D6			D6	PD6		
		7	PD7/D7			D7	PD7		
Port E	General I/O port pins, bidirec ional data-bus lines, and interrupt inputs	0	PE0/D8			D8	PE0	√	—
		1	PE1/D9			D9	PE1		
		2	PE2/D10			D10	PE2		
		3	PE3/D11			D11	PE3		
		4	PE4/D12			D12	PE4		
		5	PE5/D13	IRQ5-A		D13	PE5, IRQ5-A		
		6	PE6/D14	IRQ6-A		D14	PE6, IRQ6-A		
		7	PE7/D15	IRQ7-A		D15	PE7, IRQ7-A		

Port	Description	Bit	Function			CMOS Input	Schmitt Trigger Input	Input Pull-up Resistor Function	Open Drain Output Capability
			I/O	Input	Output				
Port F	General I/O port pins	0	PF0			—	All input functions	—	—
		1	PF1				All input functions		
		2	PF2				All input functions		
		3	PF3				All input functions		
		4	PF4				All input functions		
		5	PF5				All input functions		
		6	PF6				All input functions		
Port G	General I/O port pins	0	PF0			—	All input functions	—	—
		1	PF1				All input functions		
		2	PF2				All input functions		
		3	PF3				All input functions		
		4	PF4				All input functions		
		5	PF5				All input functions		
		6	PF6				All input functions		
		7	PF7				All input functions		
Port H	General I/O port pins	0	PH0			—	All input functions	—	—
		1	PH1				All input functions		
		2	PH2				All input functions		
		3	PH3				All input functions		
		4	PH4				All input functions		
		5	PH5				All input functions		
		6	PH6				All input functions		
		7	PH7				All input functions		

14.2 Register Descriptions

Table 14.3 lists registers of each port.

Table 14.3 Registers for Each Port

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
P0	Data direction register	DDR	00h	0008 C000h	8
	Data register	DR	00h	0008 C020h	8
	Port register	PORT	Undefined	0008 C040h	8
	Input buffer control register	ICR	00h	0008 C060h	8
P1	Data direction register	DDR	00h	0008 C001h	8
	Data register	DR	00h	0008 C021h	8
	Port register	PORT	Undefined	0008 C041h	8
	Input buffer control register	ICR	00h	0008 C061h	8
P2	Data direction register	DDR	00h	0008 C002h	8
	Data register	DR	00h	0008 C022h	8
	Port register	PORT	Undefined	0008 C042h	8
	Input buffer control register	ICR	00h	0008 C062h	8
	Open drain control register	ODR	00h	0008 C082h	8
P3	Data direction register	DDR	00h	0008 C003h	8
	Data register	DR	00h	0008 C023h	8
	Port register	PORT	Undefined	0008 C043h	8
	Input buffer control register	ICR	00h	0008 C063h	8
P4	Data direction register	DDR	00h	0008 C004h	8
	Data register	DR	00h	0008 C024h	8
	Port register	PORT	Undefined	0008 C044h	8
	Input buffer control register	ICR	00h	0008 C064h	8
P5	Data direction register	DDR	00h	0008 C005h	8
	Data register	DR	00h	0008 C025h	8
	Port register	PORT	Undefined	0008 C045h	8
	Input buffer control register	ICR	00h	0008 C065h	8
P6	Data direction register	DDR	00h	0008 C006h	8
	Data register	DR	00h	0008 C026h	8
	Port register	PORT	Undefined	0008 C046h	8
	Input buffer control register	ICR	00h	0008 C066h	8
P7	Data direction register	DDR	00h	0008 C007h	8
	Data register	DR	00h	0008 C027h	8
	Port register	PORT	Undefined	0008 C047h	8
	Input buffer control register	ICR	00h	0008 C067h	8
P8	Data direction register	DDR	00h	0008 C008h	8
	Data register	DR	00h	0008 C028h	8
	Port register	PORT	Undefined	0008 C048h	8
	Input buffer control register	ICR	00h	0008 C068h	8

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
P9	Data direction register	DDR	00h	0008 C009h	8
	Data register	DR	00h	0008 C029h	8
	Port register	PORT	Undefined	0008 C049h	8
	Input buffer control register	ICR	00h	0008 C069h	8
PA	Data direction register	DDR	00h	0008 C00Ah	8
	Data register	DR	00h	0008 C02Ah	8
	Port register	PORT	Undefined	0008 C04Ah	8
	Input buffer control register	ICR	00h	0008 C06Ah	8
	Pull-up resistor control register	PCR	00h	0008 C0CAh	8
PB	Data direction register	DDR	00h	0008 C00Bh	8
	Data register	DR	00h	0008 C02Bh	8
	Port register	PORT	Undefined	0008 C04Bh	8
	Input buffer control register	ICR	00h	0008 C06Bh	8
	Pull-up resistor control register	PCR	00h	0008 C0CBh	8
PC	Data direction register	DDR	00h	0008 C00Ch	8
	Data register	DR	00h	0008 C02Ch	8
	Port register	PORT	Undefined	0008 C04Ch	8
	Input buffer control register	ICR	00h	0008 C06Ch	8
	Open drain control register	ODR	00h	0008 C08Ch	8
	Pull-up resistor control register	PCR	00h	0008 C0CCh	8
PD	Data direction register	DDR	00h	0008 C00Dh	8
	Data register	DR	00h	0008 C02Dh	8
	Port register	PORT	Undefined	0008 C04Dh	8
	Input buffer control register	ICR	00h	0008 C06Dh	8
	Pull-up resistor control register	PCR	00h	0008 C0CDh	8
PE	Data direction register	DDR	00h	0008 C00Eh	8
	Data register	DR	00h	0008 C02Eh	8
	Port register	PORT	Undefined	0008 C04Eh	8
	Input buffer control register	ICR	00h	0008 C06Eh	8
	Pull-up resistor control register	PCR	00h	0008 C0CEh	8
PF	Data direction register	DDR	00h	0008 C00Fh	8
	Data register	DR	00h	0008 C02Fh	8
	Port register	PORT	Undefined	0008 C04Fh	8
	Input buffer control register	ICR	00h	0008 C06Fh	8
PG	Data direction register	DDR	00h	0008 C010h	8
	Data register	DR	00h	0008 C030h	8
	Port register	PORT	Undefined	0008 C050h	8
	Input buffer control register	ICR	00h	0008 C070h	8
PH	Data direction register	DDR	00h	0008 C011h	8
	Data register	DR	00h	0008 C031h	8
	Port register	PORT	Undefined	0008 C051h	8
	Input buffer control register	ICR	00h	0008 C071h	8

Port Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
Common to two or more ports	Port function control register 0	PFCR0	00h	0008 C100h	8
	Port function control register 1	PFCR1	00h	0008 C101h	8
	Port function control register 2	PFCR2	00h	0008 C102h	8
	Port function control register 3	PFCR3	00h	0008 C103h	8
	Port function control register 4	PFCR4	00h	0008 C104h	8
	Port function control register 5	PFCR5	00h	0008 C105h	8
	Port function control register 6	PFCR6	00h	0008 C106h	8
	Port function control register 7	PFCR7	00h	0008 C107h	8
	Port function control register 8	PFCR8	00h	0008 C108h	8
	Port function control register 9	PFCR9	00h	0008 C109h	8

14.2.1 Data Direction Register (DDR)

Addresses: P0.DDR 0008 C000h、P1.DDR 0008 C001h、P2.DDR 0008 C002h、P3.DDR 0008 C003h、P4.DDR 0008 C004h、P5.DDR0008 C005h、P6.DDR 0008 C006h、P7.DDR 0008 C007h、P8.DDR 0008 C008h、P9.DDR 0008 C009h、PA.DDR 0008 C00Ah、PB.DDR 0008 C00Bh、PC.DDR 0008 C00Ch、PD.DDR 0008 C00Dh、PE.DDR 0008 C00Eh、PF.DDR 0008 C00Fh、PG.DDR 0008 C010h、PH.DDR 0008 C011h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Note: The lower six bits are valid and the upper two bits are reserved in P0.DDR.
The lower seven bits are valid and the upper one bit is reserved in P8.DDR.
The lower seven bits are valid and the upper one bit is reserved in PF.DDR.
The reserved bits are read as 0. The write value should be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pm0 I/O Select (m = 0 to 9 and A to H)	0: An input pin	R/W
b1	B1	Pm1 I/O Select	1: An output pin	R/W
b2	B2	Pm2 I/O Select		R/W
b3	B3	Pm3 I/O Select		R/W
b4	B4	Pm4 I/O Select		R/W
b5	B5	Pm5 I/O Select		R/W
b6	B6	Pm6 I/O Select		R/W
b7	B7	Pm7 I/O Select		R/W

Each DDR is used to select the input or output direction for individual pins of the corresponding port that have been configured to function as general I/O pins.

Each bit of a Pm.DDR (m = 0 to 9 or A to H) corresponds to a pin of Pm, and the settings can change from bit to bit.

14.2.2 Data Register (DR)

Addresses: P0.DR 0008 C020h、P1.DR 0008 C021h、P2.DR 0008 C022h、P3.DR 0008 C023h、
P4.DR 0008 C024h、P5.DR 0008 C025h、P6.DR 0008 C026h、P7.DR 0008 C027h、
P8.DR 0008 C028h、P9.DR 0008 C029h、PA.DR 0008 C02Ah、PB.DR 0008 C02Bh、
PC.DR 0008 C02Ch、PD.DR 0008 C02Dh、PE.DR 0008 C02Eh、PF.DR 0008 C02Fh、
PG.DR 0008 C030h、PH.DR 0008 C031h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Note: The lower six bits are valid and the upper two bits are reserved in P0.DR.
The B3 bit in P5.DR is reserved.
The lower seven bits are valid and the upper one bit is reserved in P8.DR.
The lower seven bits are valid and the upper one bit is reserved in PF.DR.
The reserved bits other than the B3 bit in P5.DR are read as 0. The write value should be 0.
The B3 bit in P5.DR is readable and writable.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pm0 Output Data Store (m = 0 to 9 and A to H)	Output data are stored.	R/W
b1	B1	Pm1 Output Data Store		R/W
b2	B2	Pm2 Output Data Store		R/W
b3	B3	Pm3 Output Data Store		R/W
b4	B4	Pm4 Output Data Store		R/W
b5	B5	Pm5 Output Data Store		R/W
b6	B6	Pm6 Output Data Store		R/W
b7	B7	Pm7 Output Data Store		R/W

Each DR stores the output data from the individual pins of the corresponding port used as a general I/O port.

In addition, the output of the P53 pin is the BCLK signal and the value of the B3 bit in P5.DR does not affect the pin.

14.2.3 Port Register (PORT)

Addresses: P0.PORT 0008 C040h、P1.PORT 0008 C041h、P2.PORT 0008 C042h、P3.PORT 0008 C043h、P4.PORT 0008 C044h、P5.PORT 0008 C045h、P6.PORT 0008 C046h、P7.PORT 0008 C047h、P8.PORT0008 C048h、P9.PORT 0008 C049h、PA.PORT 0008 C04Ah、PB.PORT 0008 C04Bh、PC.PORT 0008 C04Ch、PD.PORT 0008 C04Dh、PE.PORT 0008 C04Eh、PF.PORT 0008 C04Fh、PG.PORT 0008 C050h、PH.PORT 0008 C051h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	x	x	x	x	x	x	x	x

Note: The lower six bits are valid and the upper two bits are reserved in P0.PORT.
The lower seven bits are valid and the upper one bit is reserved in P8.PORT.
The lower seven bits are valid and the upper one bit is reserved in PF.PORT.
The reserved bits are read as 0 and cannot be modified.

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pm0 (m = 0 to 9 and A to H)	Individual pin states of the corresponding port are reflected.	R
b1	B1	Pm1		R
b2	B2	Pm2		R
b3	B3	Pm3		R
b4	B4	Pm4		R
b5	B5	Pm5		R
b6	B6	Pm6		R
b7	B7	Pm7		R

Each PORT reflects individual pin states of the corresponding port.

When a Pm.PORT (m = 0 to 9 and A to H) is read while the value in Pm.DDR is 1, the values of the corresponding bits in Pm.DR are read out. On the other hand, while the value in Pm.DDR is 0, the corresponding pin states are read out to here, regardless of the values in Pm.ICR.

14.2.4 Input Buffer Control Register (ICR)

Addresses: P0.ICR 0008 C060h、P1.ICR 0008 C061h、P2.ICR 0008 C062h、P3.ICR 0008 C063h、P4.ICR 0008 C064h、P5.ICR 0008 C065h、P6.ICR 0008 C066h、P7.ICR 0008 C067h、P8.ICR 0008 C068h、P9.ICR 0008 C069h、PA.ICR 0008 C06Ah、PB.ICR 0008 C06Bh、PC.ICR 0008 C06Ch、PD.ICR 0008 C06Dh、PE.ICR 0008 C06Eh、PF.ICR 0008 C06Fh、PG.ICR 0008 C070h、PH.ICR 0008 C071h

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Note: The lower six bits are valid and the upper two bits are reserved in P0.ICR.
The lower seven bits are valid and the upper one bit is reserved in P8.ICR.
The lower seven bits are valid and the upper one bit is reserved in PF.ICR.
The reserved bits are read as 0. The write value should be 0.

Bit	Symbol	Bit Name	Description	R/W
b0	B0*	Pm0 Input Buffer Control (m = 0 to 9 and A to E)	0: The input buffer for the corresponding pin is disabled, and the input signal is fixed to high level. 1: The input buffer for the corresponding pin is enabled.	R/W
b1	B1*	Pm1 Input Buffer Control		R/W
b2	B2*	Pm2 Input Buffer Control		R/W
b3	B3*	Pm3 Input Buffer Control		R/W
b4	B4*	Pm4 Input Buffer Control		R/W
b5	B5*	Pm5 Input Buffer Control		R/W
b6	B6*	Pm6 Input Buffer Control		R/W
b7	B7*	Pm7 Input Buffer Control		R/W

Note: * For pins being used as input pins for peripheral modules, set the corresponding bits to 1. Set the bits corresponding to pins that are not being used for their input functions or are being used as analog I/O pins to 0.

Each ICR controls the input buffers for the individual pins of the corresponding port.

Each bit of a Pm.ICR (m = 0 to 9 and A to E) corresponds to a pin of Pm, and the settings can change from bit to bit.

When a Pm.PORT register is read, the pin states of the corresponding port are read out regardless of the values in Pm.ICR. For bits where the value in Pm.ICR is 0, however, the value may not reflect the pin state on the corresponding peripheral module side.

Changes in the settings of a Pm.ICR may generate edges internally, depending on the pin state. For this reason, change the settings of Pm.ICR while the corresponding input pins are not in use. For example, in the case of IRQn (n = 0 to 15) inputs, change settings of the corresponding Pm.ICR with interrupts disabled by clearing the IR flag in IRi (i = 64 to79 ("i" shows an interrupt vector number)) of the interrupt control unit (ICU) to 0, and then enable the corresponding interrupts. If a change to a Pm.ICR setting does generate an edge, negate the edge.

14.2.5 Pull-Up Resistor Control Register (PCR)

Addresses: PA.PCR 0008 C0CAh, PB.PCR 0008 C0CBh, PC.PCR 0008 C0CCh,
PD.PCR 0008 C0CDh, PE.PCR 0008 C0CEh

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pm0 Input Pull-Up Resistor Control (m = A to E)	0: Input pull-up resistor is disabled.	R/W
b1	B1	Pm1 Input Pull-Up Resistor Control	1: Input pull-up resistor is enabled.	R/W
b2	B2	Pm2 Input Pull-Up Resistor Control		R/W
b3	B3	Pm3 Input Pull-Up Resistor Control		R/W
b4	B4	Pm4 Input Pull-Up Resistor Control		R/W
b5	B5	Pm5 Input Pull-Up Resistor Control		R/W
b6	B6	Pm6 Input Pull-Up Resistor Control		R/W
b7	B7	Pm7 Input Pull-Up Resistor Control		R/W

Each PCR controls enabling/disabling the input pull-up resistor for individual pins of the corresponding port.

When in input pin state, for the pins corresponding to bits where the value in Pm.PCR is 1, input pull-up resistor is turned on. Table 14.4 summarizes the input pull-up resistor states.

Table 14.4 Input Pull-Up Resistor States

Port	Pin State	Reset	In Other Operations
Port A	Address output	Disabled	
	Peripheral module output	Disabled	
	Port output	Disabled	
	Port input, peripheral module input	Disabled	Enabled/Disabled
Port B	Address output	Disabled	
	Peripheral module output	Disabled	
	Port output	Disabled	
	Port input, peripheral module input	Disabled	Enabled/Disabled
Port C	Address output	Disabled	
	Peripheral module output	Disabled	
	Port output	Disabled	
	Port input, peripheral module input	Disabled	Enabled/Disabled
Port D	Data I/O	Disabled	
	Port output	Disabled	
	Port input	Disabled	Enabled/Disabled
Port E	Data I/O	Disabled	
	Port output	Disabled	
	Port input, peripheral module input	Disabled	Enabled/Disabled

[Legend] Disabled: Input pull-up resistor is always disabled.

Enabled/Disabled: Input pull-up resistor is enabled when the Bj bit in Pm.PCR (m = A to E, j = 0 to 7) is set to 1, and disabled when the bit is cleared to 0.

14.2.6 Open Drain Control Register (ODR)

Addresses: P2.ODR 0008 C082h, PC.ODR 0008 C08Ch

	b7	b6	b5	b4	b3	b2	b1	b0
	B7	B6	B5	B4	B3	B2	B1	B0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	B0	Pm0 Output Type Select (m = 2 and C)	0: CMOS output pin	R/W
b1	B1	Pm1 Output Type Select	1: NMOS open-drain output pin	R/W
b2	B2	Pm2 Output Type Select		R/W
b3	B3	Pm3 Output Type Select		R/W
b4	B4	Pm4 Output Type Select		R/W
b5	B5	Pm5 Output Type Select		R/W
b6	B6	Pm6 Output Type Select		R/W
b7	B7	Pm7 Output Type Select		R/W

Each ODR is used to select an output type for the individual pins.

14.2.7 Port Function Control Register0 (PFCR0)

Address: 0008 C100h

	b7	b6	b5	b4	b3	b2	b1	b0
	CS7E	CS6E	CS5E	CS4E	CS3E	CS2E	CS1E	CS0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CS0E	CS0 Enable	0: Designated as an I/O port pin.	R/W
b1	CS1E	CS1 Enable	1: Designated as the CSn# output pin	R/W
b2	CS2E	CS2 Enable	(n = 0 to 7)	R/W
b3	CS3E	CS3 Enable		R/W
b4	CS4E	CS4 Enable		R/W
b5	CS5E	CS5 Enable		R/W
b6	CS6E	CS6 Enable		R/W
b7	CS7E	CS7 Enable		R/W

PFCR0 enables or disable CSn# output.

CSnE Bits (CSn Enable) (n = 0 to 7)

Each bit enables or disables the corresponding CSn# output.

To output a CSn signal, set the corresponding CSnE bit in PFCR0 to 1.

14.2.8 Port Function Control Register 1 (PFCR1)

Address: 0008 C101h

	b7	b6	b5	b4	b3	b2	b1	b0
	CS7S[1:0]		CS6S[1:0]		CS5S[1:0]		CS4S[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CS4S[1:0]	CS4# Output Pin Select	b1 b0	R/W
			0 0: CS4#-A is output from P60.	
			0 1: CS4#-B is output from P64.	
			1 0: CS4#-C is output from P71.	
			1 1: CS4#-D is output from PC7.	
b3, b2	CS5S[1:0]	CS5# Output Pin Select	b3 b2	R/W
			0 0: CS5#-A is output from P61.	
			0 1: CS5#-B is output from P60.	
			1 0: CS5#-C is output form P71.	
			1 1: CS5#-D is output from PC5.	
b5, b4	CS6S[1:0]	CS6# Output Pin Select	b5 b4	R/W
			0 0: CS6#-A is output from P62.	
			0 1: CS6#-B is output from P61.	
			1 0: CS6#-C is output from P71.	
			1 1: CS6#-D is output from PC6.	
b7, b6	CS7S[1:0]	CS7# Output Pin Select	b7 b6	R/W
			0 0: CS7#-A is output from P63.	
			0 1: CS7#-B is output from P61.	
			1 0: CS7#-C is output from P71.	
			1 1: CS7#-D is output from PC7.	

PFCR1 is used to select a pin for each CSn# output.

PFCR1 can designate output of the several CS signals to a single pin. When that setting is made, all of the designated CS signals are output from the single pin, where the several CS signals are designated. At the time, make the same setting to the external bus interface corresponding to each CS signal, which is output from the same single pin.

CSnS[1:0] Bits (CSn# Output Pin Select) (n = 4 to 7)

These bits select a pin for each CSn# output when a CSn# output is enabled (the corresponding CSnE bit in PFCR0 = 1).

Figure 14.1 describes the timing for output of CSn# signals for CS5 and CS6 areas to the same pin. Table 14.5 lists the relationship between CS# output pin select registers and output pins.

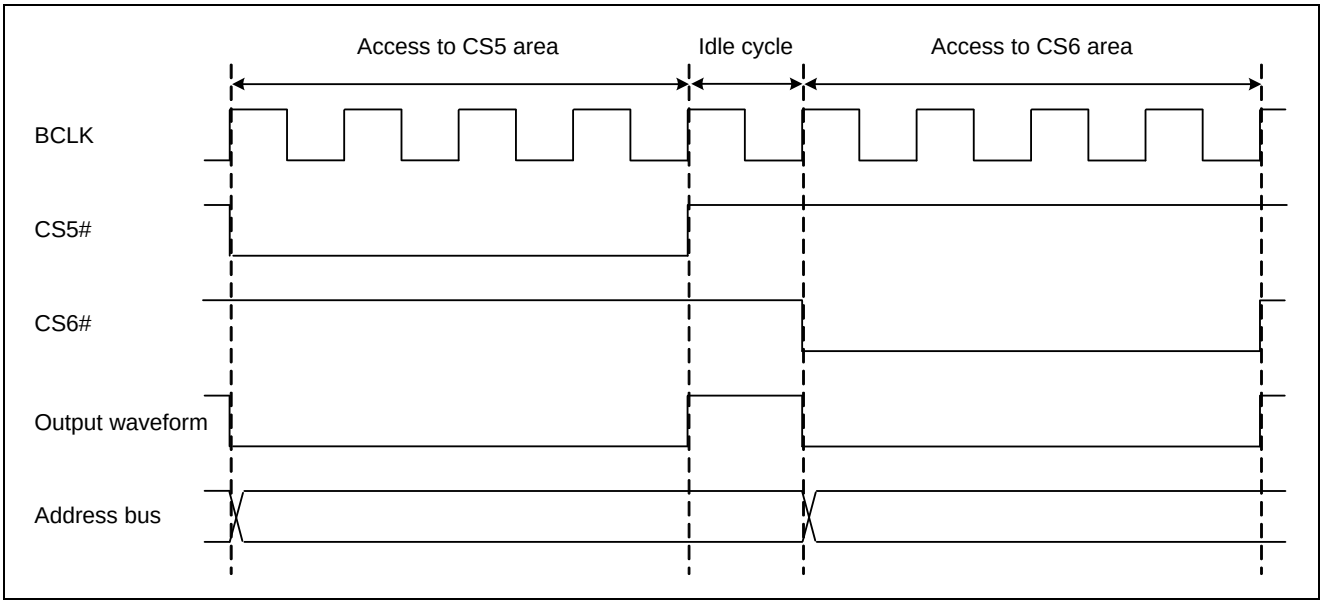


Figure 14.1 Timing for Output of CSn# Signals to the Same Pin

Table 14.5 Relationship between CS# Output Pin Select Registers and Output Pins

Output Select	CS0#	CS1#	CS2#	CS3#	CS4#	CS5#	CS6#	CS7#
	—	—	PFCR2.CS2S	PFCR2.CS3S	PFCR1.CS4S[1:0]	PFCR1.CS5S[1:0]	PFCR1.CS6S[1:0]	PFCR1.CS7S[1:0]
P60	CS0#				CS4#-A	CS5#-B		
P61		CS1#	CS2#-B			CS5#-A	CS6#-B	CS7#-B
P62			CS2#-A				CS6#-A	
P63				CS3#-A				CS7#-A
P64					CS4#-B			
P70				CS3#-B				
P71					CS4#-C	CS5#-C	CS6#-C	CS7#-C
PC5						CS5#-D		
PC6							CS6#-D	
PC7					CS4#-D			CS7#-D

14.2.9 Port Function Control Register 2 (PFCR2)

Address: 0008 C102h

	b7	b6	b5	b4	b3	b2	b1	b0
	CS3S	CS2S	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b6	CS2S	CS2# Output Pin Select	0: CS2#-A is output from P62. 1: CS2#-B is output from P61.	R/W
b7	CS3S	CS3# Output Pin Select	0: CS3#-A is output from P63. 1: CS3#-B is output from P70.	R/W

PFCR2 is used to select a pin for each CSn# output (n = 2 and 3).

CSnS Bit (CSn# Output Pin Select) (n = 2 and 3)

Each bit selects a pin for each CSn# output when a CSn# output is enabled (the corresponding CSiE bit in PFCR0 is 1).

Several CS# signals may be output from the same pin if the CS signals have been designated by CSn# output pin select bits (n = 2 and 3). For details, see section 14.2.8, Port Function Control Register 1 (PFCR1).

14.2.10 Port Function Control Register 3 (PFCR3)

Address: 0008 C103h

	b7	b6	b5	b4	b3	b2	b1	b0
	A23E	A22E	A21E	A20E	A19E	A18E	A17E	A16E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	A16E	Address A16 Enable	0: A16 output is disabled. 1: A16 output is enabled.	R/W
b1	A17E	Address A17 Enable	0: A17 output is disabled. 1: A17 output is enabled.	R/W
b2	A18E	Address A18 Enable	0: A18 output is disabled. 1: A18 output is enabled.	R/W
b3	A19E	Address A19 Enable	0: A19 output is disabled. 1: A19 output is enabled.	R/W
b4	A20E	Address A20 Enable	0: A20 output is disabled. 1: A20 output is enabled.	R/W
b5	A21E	Address A21 Enable	0: A21 output is disabled. 1: A21 output is enabled.	R/W
b6	A22E	Address A22 Enable	0: A22 output is disabled. 1: A22 output is enabled.	R/W
b7	A23E	Address A23 Enable	0: A23 output is disabled. 1: A23 output is enabled.	R/W

PFCR3 enables or disables address outputs.

AnE Bit (Address An Enable) (n = 16 to 23)

Each bit enables or disables an address output (An).

14.2.11 Port Function Control Register 4 (PFCR4)

Address: 0008 C104h

	b7	b6	b5	b4	b3	b2	b1	b0
	A15E	A14E	A13E	A12E	A11E	A10E	A9E	A8E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	A8E	Address A8 Enable	0: A8 output is disabled. 1: A8 output is enabled.	R/W
b1	A9E	Address A9 Enable	0: A9 output is disabled. 1: A9 output is enabled.	R/W
b2	A10E	Address A10 Enable	0: A10 output is disabled. 1: A10 output is enabled.	R/W
b3	A11E	Address A11 Enable	0: A11 output is disabled. 1: A11 output is enabled.	R/W
b4	A12E	Address A12 Enable	0: A12 output is disabled. 1: A12 output is enabled.	R/W
b5	A13E	Address A13 Enable	0: A13 output is disabled. 1: A13 output is enabled.	R/W
b6	A14E	Address A14 Enable	0: A14 output is disabled. 1: A14 output is enabled.	R/W
b7	A15E	Address A15 Enable	0: A15 output is disabled. 1: A15 output is enabled.	R/W

PFCR4 enables or disables address outputs.

AnE Bit (Address An Enable) (n =8 to 15)

Each bit enables or disables an address output (An).

14.2.12 Port Function Control Register 5 (PFCR5)

Address: 0008 C105h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	WR1BC1E	—	DHE	TCLKS	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b3	TCLKS	TPU External Clock Input Pin Select	0: P32, P33, P35, and P37 are designated as external clock input pins. 1: P14 to P17 are designated as external clock input pins.	R/W
b4	DHE	D15-to-D8 Enable	0: PE7 to PE0 are designated as I/O port pins. 1: PE7 to PE0 are designated as D15 to D8 pins (function as part of the external data bus)	R/W
b5	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b6	WR1BC1E	WR1#/BC1# Output Enable	0: P51 is designated as an I/O port pin. 1: P51 is designated as the WR#1 or BC1# output pin.	R/W
b7	—	Reserved	This bit is read as 0. The write value should be 0.	R/W

PFCR5 is used to select external clock input pins for the TPU.

TCLKS Bit (TPU External Clock Input Pin Select)

This bit selects the external clock input pins for the TPU.

DHE Bit (D15-to-D8 Enable)

This bit enables or disables the input and output of data signals D15 to D8 on the PE7 to PE0 pins (valid in expansion mode with on-chip ROM disabled or enabled).

Note: This setting must be in accord with the setting of the external bus width selection bits in the CSn control register (CSnCNT.BSIZE[1:0]). If the value of the DHE bit is 0 but the width of the external bus is 16 bits, operation of the port E pin functions will be disrupted. For details on the BSIZE[1:0] bits, see 11.3.1, CSn Control Register (CSnCNT).

WR1BC1E Bit (WR1#/BC1# Output Enable)

This bit enables or disables WR1#/BC1# output (valid in expansion mode with on-chip ROM disabled or enabled).

14.2.13 Port Function Control Register 6 (PFCR6)

Address: 0008 C106h

	b7	b6	b5	b4	b3	b2	b1	b0
	TPUMS5	TPUMS4	TPUMS3A	TPUMS3B	TPUMS2	TPUMS1	TPUMS0A	TPUMS0B
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TPUMS0B	Multifunction Select 0B for TPU I/O Pins	0: Output compare and input capture are allocated to P32. 1: Input capture and output compare are allocated to P33 and P32, respectively.	R/W
b1	TPUMS0A	Multifunction Select 0A for TPU I/O Pins	0: Output compare and input capture are allocated to P30. 1: Input capture and output compare are allocated to P31 and P30, respectively.	R/W
b2	TPUMS1	Multifunction Select 1 for TPU I/O Pins	0: Output compare and input capture are allocated to P34. 1: Input capture and output compare are allocated to P35 and P34, respectively.	R/W
b3	TPUMS2	Multifunction Select 2 for TPU I/O Pins	0: Output compare and input capture are allocated to P36. 1: Input capture and output compare are allocated to P37and P36, respectively.	R/W
b4	TPUMS3B	Multifunction Select 3B for TPU I/O Pins	0: Output compare and input capture are allocated to P22. 1: Input capture and output compare are allocated to P23 and P22, respectively.	R/W
b5	TPUMS3A	Multifunction Select 3A for TPU I/O Pins	0: Output compare and input capture are allocated to P21. 1: Input capture and output compare are allocated to P20 and P21, respectively.	R/W
b6	TPUMS4	Multifunction Select 4 for TPU I/O Pins	0: Output compare and input capture are allocated to P25. 1: Input capture and output compare are allocated to P24 and P25, respectively.	R/W
b7	TPUMS5	Multifunction Select 5 for TPU I/O Pins	0: Output compare and input capture are allocated to P26. 1: Input capture and output compare are allocated to P27 and P26, respectively.	R/W

PFCR6 is used to select the multiplexed function for the TPU (unit 0) I/O pins.

Setting the TPUMS0A, TPUMS1, TPUMS2, TPUMS3A, PUTMS4, and TPUMS5 bits to 1 enables the input capture inputs of TGRA and TGRB of the TPUn to be allocated to the same pin. Setting the TPUMS0B and TPUMS3B bits to 1 enables the input capture inputs of TGRC and TGRD of the TPUn to be allocated to the same pin.

By setting the timer mode register of the TPU (TPUn.TMDR), it is possible to set the input capture inputs of TRGA and TRGB or TRGC and TRGD to the same pin.

Table 14.6 shows the correspondences between the PFCR6 and TPUn.TMDR settings and the input capture inputs and external pins.

TPUMS0B Bit (Multifunction Select 0B for TPU I/O Pins)

This bit selects an input pin for TIOCC0.

TPUMS0A Bit (Multifunction Select 0A for TPU I/O Pins)

This bit selects an input pin for TIOCA0.

TPUMS1 Bit (Multifunction Select 1 for TPU I/O Pins)

This bit selects an input pin for TIOCA1.

TPUMS2 Bit (Multifunction Select 2 for TPU I/O Pins)

This bit selects an input pin for TIOCA2.

TPUMS3B Bit (Multifunction Select 3B for TPU I/O Pins)

This bit selects an input pin for TIOCC3.

TPUMS3A Bit (Multifunction Select 3A for TPU I/O Pins)

This bit selects an input pin for TIOCA3.

TPUMS4 Bit (Multifunction Select 4 for TPU I/O Pins)

This bit selects an input pin for TIOCA4.

TPUMS5 Bit (Multifunction Select 5 for TPU I/O Pins)

This bit selects a multiplexed function for TIOCA5.

Table 14.6 Correspondences between PFCR6 and TPUn.TMDR Settings, Input Capture Inputs, and External Pins

		TPU0.TGRC		TPU0.TGRD	
TPU0.TMDR. ICSELD	PFCR6. TPUMS0B	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCC0	P32	TIOCD0	P33
0	1		P33	TIOCD0	P33
1	0		P32	TIOCC0	P32
1	1		P33	TIOCC0	P33

		TPU0.TGRA		TPU0.TGRB	
TPU0.TMDR. ICSELB	PFCR6. TPUMS0A	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA0	P30	TIOCB0	P31
0	1		P31	TIOCB0	P31
1	0		P30	TIOCA0	P30
1	1		P31	TIOCA0	P31

		TPU1.TGRA		TPU1.TGRB	
TPU1.TMDR. ICSELB	PFCR6. TPUMS1	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA1	P34	TIOCB1	P35
0	1		P35	TIOCB1	P35
1	0		P34	TIOCA1	P34
1	1		P35	TIOCA1	P35

		TPU2.TGRA		TPU2.TGRB	
TPU2.TMDR. ICSELB	PFCR6. TPUMS2	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA2	P36	TIOCB2	P37
0	1		P37	TIOCB2	P37
1	0		P36	TIOCA2	P36
1	1		P37	TIOCA2	P37

		TPU3.TGRC		TPU3.TGRD	
TPU3.TMDR. ICSELD	PFCR6. TPUMS3B	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCC3	P22	TIOCD3	P23
0	1		P23	TIOCD3	P23
1	0		P22	TIOCC3	P22
1	1		P23	TIOCC3	P23

		TPU3.TGRA		TPU3.TGRB	
TPU3.TMDR. ICSELB	PFCR6. TPUMS3A	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA3	P21	TIOCB3	P20
0	1		P20	TIOCB3	P20
1	0		P21	TIOCA3	P21
1	1		P20	TIOCA3	P20

		TPU4.TGRA		TPU4.TGRB	
TPU4.TMDR. ICSELB	PFCR6. TPUMS4	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA4	P25	TIOCB4	P24
0	1		P24	TIOCB4	P24
1	0		P25	TIOCA4	P25
1	1		P24	TIOCA4	P24

		TPU5.TGRA		TPU5.TGRB	
TPU5.TMDR. ICSELB	PFCR6. TPUMS5	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA5	P26	TIOCB5	P27
0	1		P27	TIOCB5	P27
1	0		P26	TIOCA5	P26
1	1		P27	TIOCA5	P27

14.2.14 Port Function Control Register 7 (PFCR7)

Address: 0008 C107h

	b7	b6	b5	b4	b3	b2	b1	b0
	TPUMS11	TPUMS10	TPUMS9A	TPUMS9B	TPUMS8	TPUMS7	TPUMS6A	TPUMS6B
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TPUMS6B	Multifunction Select 6B for TPU I/O Pins	0: Output compare and input capture are allocated to PA2. 1: Input capture and output compare are allocated to PA3 and PA2, respectively.	R/W
b1	TPUMS6A	Multifunction Select 6A for TPU I/O Pins	0: Output compare and input capture are allocated to PA0. 1: Input capture and output compare are allocated to PA1 and PA0, respectively.	R/W
b2	TPUMS7	Multifunction Select 7 for TPU I/O Pins	0: Output compare and input capture are allocated to PA4. 1: Input capture and output compare are allocated to PA5 and PA4, respectively.	R/W
b3	TPUMS8	Multifunction Select 8 for TPU I/O Pins	0: Output compare and input capture are allocated to PA6. 1: Input capture and output compare are allocated to PA7 and PA6, respectively.	R/W
b4	TPUMS9B	Multifunction Select 9B for TPU I/O Pins	0: Output compare and input capture are allocated to PB2. 1: Input capture and output compare are allocated to PB3 and PB2, respectively.	R/W
b5	TPUMS9A	Multifunction Select 9A for TPU I/O Pins	0: Output compare and input capture are allocated to PB0. 1: Input capture and output compare are allocated to PB1 and PB0, respectively.	R/W
b6	TPUMS10	Multifunction Select 10 for TPU I/O Pins	0: Output compare and input capture are allocated to PB4. 1: Input capture and output compare are allocated to PB5 and PB4, respectively.	R/W
b7	TPUMS11	Multifunction Select 11 for TPU I/O Pins	0: Output compare and input capture are allocated to PB6. 1: Input capture and output compare are allocated to PB7 and PB6, respectively.	R/W

PFCR7 is used to select the multiplexed function for TPU (unit 1) I/O Pins.

Setting the TPUMS6A, TPUMS7, TPUMS8, TPUMS9A, PUTMS10, and TPUMS11 bits to 1 enables the input capture inputs of TGRA and TGRB of the TPUn to be allocated to the same pin. Setting the TPUMS6B and TPUMS9B bits to 1 enables the input capture inputs of TGRC and TGRD of the TPUn to be allocated to the same pin.

By setting the timer mode register of the TPU (TPUn.TMDR), it is possible to set the input capture inputs of TRGA and TRGB or TRGC and TRGD to the same pin.

Table 14.7 shows the correspondences between the PFCR7 and TPUn.TMDR settings and the input capture inputs and external pins.

TPUMS6B Bit (Multifunction Select 6B for TPU I/O Pins)

This bit selects an input pin for TIOCC6.

TPUMS6A Bit (Multifunction Select 6A for TPU I/O Pins)

This bit selects an input pin for TIOCA6.

TPUMS7 Bit (Multifunction Select 7 for TPU I/O Pins)

This bit selects an input pin for TIOCA7.

TPUMS8 Bit (Multifunction Select 8 for TPU I/O Pins)

This bit selects an input pin for TIOCA8.

TPUMS9B Bit (Multifunction Select 9B for TPU I/O Pins)

This bit selects an input pin for TIOCC9.

TPUMS9A Bit (Multifunction Select 9A for TPU I/O Pins)

This bit selects an input pin for TIOCA9.

TPUMS10 Bit (Multifunction Select 10 for TPU I/O Pins)

This bit selects an input pin for TIOCA10.

TPUMS11 Bit (Multifunction Select 11 for TPU I/O Pins TPU)

This bit selects an input pin for TIOCA11.

Table 14.7 Correspondences between PFCR7 and TPUn.TMDR Settings and Input Capture Inputs and External Pins

		TPU6.TGRC		TPU6.TGRD	
TPU6.TMDR. ICSELD	PFCR7. TPUMS6B	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCC6	PA2	TIOCD6	PA3
0	1		PA3	TIOCD6	PA3
1	0		PA2	TIOCC6	PA2
1	1		PA3	TIOCC6	PA3

		TPU6.TGRA		TPU6.TGRB	
TPU6.TMDR. ICSELB	PFCR7. TPUMS6A	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA6	PA0	TIOCB6	PA1
0	1		PA1	TIOCB6	PA1
1	0		PA0	TIOCA6	PA0
1	1		PA1	TIOCA6	PA1

		TPU7.TGRA		TPU7.TGRB	
TPU7.TMDR. ICSELB	PFCR7. TPUMS7	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA7	PA4	TIOCB7	PA5
0	1		PA5	TIOCB7	PA5
1	0		PA4	TIOCA7	PA4
1	1		PA5	TIOCA7	PA5

		TPU8.TGRA		TPU8.TGRB	
TPU8.TMDR. ICSELB	PFCR7. TPUMS8	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA8	PA6	TIOCB8	PA7
0	1		PA7	TIOCB8	PA7
1	0		PA6	TIOCA8	PA6
1	1		PA7	TIOCA8	PA7

		TPU9.TGRC		TPU9.TGRD	
TPU9.TMDR. ICSELD	PFCR7. TPUMS9B	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCC9	PB2	TIOCD9	PB3
0	1		PB3	TIOCD9	PB3
1	0		PB2	TIOCC9	PB2
1	1		PB3	TIOCC9	PB3

		TPU9.TGRA		TPU9.TGRB	
TPU9.TMDR. ICSELB	PFCR7. TPUMS9A	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA9	PB0	TIOCB9	PB1
0	1		PB1	TIOCB9	PB1
1	0		PB0	TIOCA9	PB0
1	1		PB1	TIOCA9	PB1

		TPU10.TGRA		TPU10.TGRB	
TPU10.TMDR. ICSELB	PFCR7. TPUMS10	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA10	PB4	TIOCB10	PB5
0	1		PB5	TIOCB10	PB5
1	0		PB4	TIOCA10	PB4
1	1		PB5	TIOCA10	PB5

		TPU11.TGRA		TPU11.TGRB	
TPU11.TMDR. ICSELB	PFCR7. TPUMS11	Input Capture Input	External Pin	Input Capture Input	External Pin
0	0	TIOCA11	PB6	TIOCB11	PB7
0	1		PB7	TIOCB11	PB7
1	0		PB6	TIOCA11	PB6
1	1		PB7	TIOCA11	PB7

14.2.15 Port Function Control Register 8 (PFCR8)

Address: 0008 C108h

	b7	b6	b5	b4	b3	b2	b1	b0
	ITS15	ITS14	ITS13	ITS12	ITS11	ITS10	ITS9	ITS8
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ITS8	IRQ8 Pin Select	0: P00 is designated as the IRQ8-A input pin. 1: P40 is designated as the IRQ8-B input pin.	R/W
b1	ITS9	IRQ9 Pin Select	0: P01 is designated as IRQ9-A input pin. 1: P41 is designated as IRQ9-B input pin.	R/W
b2	ITS10	IRQ10 Pin Select	0: P02 is designated as the IRQ10-A input pin. 1: P42 is designated as the IRQ10-B input pin.	R/W
b3	ITS11	IRQ11 Pin Select	0: P03 is designated as the IRQ11-A input pin. 1: P43 is designated as the IRQ11-B input pin.	R/W
b4	ITS12	IRQ12 Pin Select	0: P04 is designated as the IRQ12-A input pin. 1: P44 is designated as the IRQ12-B input pin.	R/W
b5	ITS13	IRQ13 Pin Select	0: P05 is designated as the IRQ13-A input pin. 1: P45 is designated as the IRQ13-B input pin.	R/W
b6	ITS14	IRQ14 Pin Select	0: P76 is designated as the IRQ14-A input pin. 1: P46 is designated as the IRQ14-B input pin.	R/W
b7	ITS15	IRQ15 Pin Select	0: P65 is designated as the IRQ15-A input pin. 1: P47 is designated as the IRQ15-B input pin.	R/W

PFCR8 is used to select pins for IRQ8 to IRQ15 inputs.

ITSn (IRQn Pin Select) (n = 8 to 15)

Each bit selects a pin for an IRQn input.

14.2.16 Port Function Control Register 9 (PFCR9)

Address: 0008 C109h

	b7	b6	b5	b4	b3	b2	b1	b0
	ITS7	ITS6	ITS5	ITS4	ITS3	ITS2	ITS1	ITS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ITS0	IRQ0 Pin Select	0: P30 is designated as the IRQ0-A input pin. 1: P10 is designated as the IRQ0-B input pin.	R/W
b1	ITS1	IRQ1 Pin Select	0: P31 is designated as the IRQ1-A input pin. 1: P11 is designated as the IRQ1-B input pin.	R/W
b2	ITS2	IRQ2 Pin Select	0: P32 is designated as the IRQ2-A input pin. 1: P12 is designated as the IRQ2-B input pin.	R/W
b3	ITS3	IRQ3 Pin Select	0: P33 is designated as the IRQ3-A input pin. 1: P13 is designated as the IRQ3-B input pin.	R/W
b4	ITS4	IRQ4 Pin Select	0: P34 is designated as the IRQ4-A input pin. 1: P14 is designated as the IRQ4-B input pin.	R/W
b5	ITS5	IRQ5 Pin Select	0: PE5 is designated as the IRQ5-A input pin. 1: P15 is designated as the IRQ5-B input pin.	R/W
b6	ITS6	IRQ6 Pin Select	0: PE6 is designated as the IRQ6-A input pin. 1: P16 is designated as the IRQ6-B input pin.	R/W
b7	ITS7	IRQ7 Pin Select	0: PE7 is designated as the IRQ7-A input pin. 1: P17 is designated as the IRQ7-B input pin.	R/W

PFCR9 is used to select pins for IRQ0 to IRQ7 inputs.

ITSn (IRQn Pin Select) (n= 0 to7)

Each bit selects a pin for an IRQn input.

14.3 Settings of Ports

Individual pins for peripheral modules are indicated by "_OE" appended to the end of the pin name (for example, TIOCA4_OE). In addition, the settings to enable desired outputs and the other settings are indicated as 1 and 0 in the following tables, respectively.

Table 14.8 lists the settings to enable output of the signals from the individual pins of each port. For details on the applicable output signals, see descriptions of the registers for each peripheral module.

Setting the port function control register m (PFCRm) changes the functions of peripheral-module pins with names ending in A to D. For pins functioning as inputs, the pin names are placed in parentheses: " ( ) ". "—" in the following tables means "Don't care".

Input from a pin to a peripheral module is enabled by setting the corresponding bit in the input buffer control register (Pm.ICR) to 1*. It is necessary to set the peripheral module to use the enabled input function. For the peripheral module settings to use the input function, see the section for the peripheral module.

Note: * When the input function is allocated to two or more external pins, PFCRm as well as Pm.ICR should be set to select an input pin.

14.3.1 Port 0 (P0)

(1) P00/(TMRI2)/TxD6/(IRQ8-A)

The pin function is switched as shown below according to the combination of the register setting for the SCI and the B0 bit in P0.DDR.

		Setting	
		SCI	I/O Port
Module Name	Pin Function	TxD6_OE	P0.DDR.B0
SCI	TxD6 output	1	—
I/O port	P00 output	0	1
	P00 input (initial value)	0	0

(2) P01/(TMCI2)/(RxD6)/(IRQ9-A)

The pin function is switched as shown below according to the value of the B1 bit in P0.DDR.

		Setting
		I/O Port
Module Name	Pin Function	P0.DDR.B1
I/O port	P01 output	1
	P01 input (initial value)	0

(3) P02/TMO2/SCK6/(IRQ10-A)/(TRST#)

The pin function is switched as shown below according to the combination of the register settings for the TMR and SCI and the B2 bit in P0.DDR.

		Setting		
		TMR	SCI	I/O Port
Module Name	Pin Function	TMO2_OE	SCK6_OE	P0.DDR.B2
TMR	TMO2 output	1	—	—
SCI	SCK6 output	0	1	—
I/O port	P02 output	0	0	1
	P02 input (initial value)	0	0	0

(4) P03/(TMRI3)/SCK4/(IRQ11-A)/(TMS)

The pin function is switched as shown below according to the combination of the register setting for the SCI and the B3 bit in P0.DDR.

		Setting	
		SCI	I/O Port
Module Name	Pin Function	SCK4_OE	P0.DDR.B3
SCI	SCK4 output	1	—
I/O port	P03 output	0	1
	P03 input (initial value)	0	0

(5) P04/(TMCI3)/TxD4/(IRQ12-A)/(TDI)

The pin function is switched as shown below according to the combination of the register setting for the SCI and the B4 bit in P0.DDR.

		Setting	
		SCI	I/O Port
Module Name	Pin Function	TxD4_OE	P0.DDR.B4
SCI	TxD4 output	1	—
I/O port	P04 output	0	1
	P04 input (initial value)	0	0

(6) P05/TMO3/(RxD4)/(IRQ13-A)/(TCK)

The pin function is switched as shown below according to the combination of the register setting for the TMR and the B5 bit in P0.DDR.

		Setting	
		TMR	I/O Port
Module Name	Pin Function	TMO3_OE	P0.DDR.B5
TMR	TMO3 output	1	—
I/O port	P05 output	0	1
	P05 input (initial value)	0	0

14.3.2 Port 1 (P1)

(1) P10/(IRQ0-B)

The pin function is switched as shown below according to the value of the B0 bit in P1.DDR.

		Setting
		I/O Port
Module Name	Pin Function	P1.DDR.B0
I/O port	P10 output	1
	P10 input (initial value)	0

(2) P11/SCK2/(IRQ1-B)

The pin function is switched as shown below according to the combination of the register setting for the SCI and the B1 bit in P1.DDR.

		Setting	
		SCI	I/O Port
Module Name	Pin Function	SCK2_OE	P1.DDR.B1
SCI	SCK2 output	1	—
I/O port	P11 output	0	1
	P11 input (initial value)	0	0

(3) P12/(RxD2)/(IRQ2-B)

The pin function is switched as shown below according to the value of the B2 bit in P1.DDR.

		Setting
		I/O Port
Module Name	Pin Function	P1.DDR.B2
I/O port	P12 output	1
	P12 input (initial value)	0

(4) P13/TxD2/(ADTRG0#)/(IRQ3-B)

The pin function is switched as shown below according to the combination of the register setting for the SCI and the B3 bit in P1.DDR.

		Setting	
		SCI	I/O Port
Module Name	Pin Function	TxD2_OE	P1.DDR.B3
SCI	TxD2 output	1	—
I/O port	P13 output	0	1
	P13 input (initial value)	0	0

(5) P14/(TCLKA-B)/SDA1/(IRQ4-B)

The pin function is switched as shown below according to the combination of the register setting for the RIIC and the B4 bit in P1.DDR.

		Setting	
		RIIC	I/O Port
Module Name	Pin Function	SDA1_OE	P1.DDR.B4
RIIC	SDA1 I/O	1	—
I/O port	P14 output	0	1
	P14 input (initial value)	0	0

(6) P15/(TCLKB-B)/SCK3/SCL1/(IRQ5-B)

The pin function is switched as shown below according to the combination of the register settings for the SCI and RIIC, and the B5 bit in P1.DDR.

		Setting		
		SCI	RIIC	I/O Port
Module Name	Pin Function	SCK3_OE	SCL1_OE	P1.DDR.B5
SCI	SCK3 output	1	—	—
RIIC	SCL1 I/O	0	1	—
I/O port	P15 output	0	0	1
	P15 input (initial value)	0	0	0

(7) P16/(TCLKC-B)/(RxD3)/SDA0/(IRQ6-B)

The pin function is switched as shown below according to the combination of the register setting for the RIIC and the B6 bit in P1.DDR.

		Setting	
		RIIC	I/O Port
Module Name	Pin Function	SDA0_OE	P1.DDR.B6
RIIC	SDA0 I/O	1	—
I/O port	P16 output	0	1
	P16 input (initial value)	0	0

(8) P17/(TCLKD-B)/TxD3/SCL0/(ADTRG1#)/(IRQ7-B)

The pin function is switched as shown below according to the combination of the register settings for the SCI and RIIC, and the B7 bit in P1.DDR.

		Setting		
		SCI	RIIC	I/O Port
Module Name	Pin Function	TxD3_OE	SCL0_OE	P1.DDR.B7
SCI	TxD3 output	1	—	—
RIIC	SCL0 I/O	0	1	—
I/O port	P17 output	0	0	1
	P17 input (initial value)	0	0	0

14.3.3 Port 2 (P2)

(1) P20/PO0/(TIOCA3)/TIOCB3/(TMRI0)/TxD0

The pin function is switched as shown below according to the combination of the register settings for the TPU, SCI, and PPG, and the B0 bit in P2.DDR.

		Setting			
		TPU	SCI	PPG	I/O Port
Module Name	Pin Function	TIOCB3_OE	TxD0_OE	PO0_OE	P2.DDR.B0
TPU	TIOCB3 output	1	—	—	—
SCI	TxD0 output	0	1	—	—
PPG	PO0 output	0	0	1	—
I/O port	P20 output	0	0	0	1
	P20 input (initial value)	0	0	0	0

(2) P21/PO1/TIOCA3/(TMCI0)/(RxD0)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B1 bit in P2.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCA3_OE	PO1_OE	P2.DDR.B1
TPU	TIOCA3 output	1	—	—
PPG	PO1 output	0	1	—
I/O port	P21 output	0	0	1
	P21 input (initial value)	0	0	0

(3) P22/PO2/TIOCC3/TMO0/SCK0

The pin function is switched as shown below according to the combination of the register settings for the TPU, TMR , SCI, and PPG, and the B2 bit in P2.DDR.

		Setting				
		TPU	TMR	SCI	PPG	I/O Port
Module Name	Pin Function	TIOCC3_OE	TMO0_OE	SCK0_OE	PO2_OE	P2.DDR.B2
TPU	TIOCC3 output	1	—	—	—	—
TMR	TMO0 output	0	1	—	—	—
SCI	SCK0 output	0	0	1	—	—
PPG	PO2 output	0	0	0	1	—
I/O port	P22 output	0	0	0	0	1
	P22 input (initial value)	0	0	0	0	0

(4) P23/PO3/(TIOCC3)/TIOCD3

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B3 bit in P2.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCD3_OE	PO3_OE	P2.DDR.B3
TPU	TIOCD3 output	1	—	—
PPG	PO3 output	0	1	—
I/O port	P23 output	0	0	1
	P23 input (initial value)	0	0	0

(5) P24/PO4/(TIOCA4)/TIOCB4/(TMRI1)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B4 bit in P2.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCB4_OE	PO4_OE	P2.DDR.B4
TPU	TIOCB4 output	1	—	—
PPG	PO4 output	0	1	—
I/O port	P24 output	0	0	1
	P24 input (initial value)	0	0	0

(6) P25/PO5/TIOCA4/(TMCI1)/(RxD1)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B5 bit in P2.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCA4_OE	PO5_OE	P2.DDR.B5
TPU	TIOCA4 output	1	—	—
PPG	PO5 output	0	1	—
I/O port	P25 output	0	0	1
	P25 input (initial value)	0	0	0

(7) P26/PO6/TIOCA5/TMO1/TxD1

The pin function is switched as shown below according to the combination of the register settings for the TPU, TMR , SCI, and PPG, and the B6 bit in P2.DDR.

		Setting				
		TPU	TMR	SCI	PPG	I/O Port
Module Name	Pin Function	TIOCA5_OE	TMO1_OE	TxD1_OE	PO6_OE	P2.DDR.B6
TPU	TIOCA5 output	1	—	—	—	—
TMR	TMO1 output	0	1	—	—	—
SCI	TxD1 output	0	0	1	—	—
PPG	PO6 output	0	0	0	1	—
I/O port	P26 output	0	0	0	0	1
	P26 input (initial value)	0	0	0	0	0

(8) P27/PO7/(TIOCA5)/TIOCB5/SCK1

The pin function is switched as shown below according to the combination of the register settings for the TPU, SCI, and PPG, and the B7 bit in P2.DDR.

		Setting			
		TPU	SCI	PPG	I/O Port
Module Name	Pin Function	TIOCB5_OE	SCK1_OE	PO7_OE	P2.DDR.B7
TPU	TIOCB5 output	1	—	—	—
SCI	SCK1 output	0	1	—	—
PPG	PO7 output	0	0	1	—
I/O port	P27 output	0	0	0	1
	P27 input (initial value)	0	0	0	0

14.3.4 Port 3 (P3)

(1) P30/PO8/TIOCA0/(IRQ0-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B0 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCA0_OE	PO8_OE	P3.DDR.B0
TPU	TIOCA0 output	1	—	—
PPG	PO8 output	0	1	—
I/O port	P30 output	0	0	1
	P30 input (initial value)	0	0	0

(2) P31/PO9/(TIOCA0)/TIOCB0/(IRQ1-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B1 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCB0_OE	PO9_OE	P3.DDR.B1
TPU	TIOCB0 output	1	—	—
PPG	PO9 output	0	1	—
I/O port	P31 output	0	0	1
	P31 input (initial value)	0	0	0

(3) P32/PO10/TIOCC0/(TCLKA-A)/(IRQ2-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B2 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCC0_OE	PO10_OE	P3.DDR.B2
TPU	TIOCC0 output	1	—	—
PPG	PO10 output	0	1	—
I/O port	P32 output	0	0	1
	P32 input (initial value)	0	0	0

(4) P33/PO11/(TIOCC0)/TIOCD0/(TCLKB-A)/(IRQ3-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B3 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCD0_OE	PO11_OE	P3.DDR.B3
TPU	TIOCD0 output	1	—	—
PPG	PO11 output	0	1	—
I/O port	P33 output	0	0	1
	P33 input (initial value)	0	0	0

(5) P34/PO12/TIOCA1/(IRQ4-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B4 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCA1_OE	PO12_OE	P3.DDR.B4
TPU	TIOCA1 output	1	—	—
PPG	PO12 output	0	1	—
I/O port	P34 output	0	0	1
	P34 input (initial value)	0	0	0

(6) P35/PO13/(TIOCA1)/TIOCB1/(TCLKC-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B5 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCB1_OE	PO13_OE	P3.DDR.B5
TPU	TIOCB1 output	1	—	—
PPG	PO13 output	0	1	—
I/O port	P35 output	0	0	1
	P35 input (initial value)	0	0	0

(7) P36/PO14/TIOCA2

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B6 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCA2_OE	PO14_OE	P3.DDR.B6
TPU	TIOCA2 output	1	—	—
PPG	PO14 output	0	1	—
I/O port	P36 output	0	0	1
	P36 input (initial value)	0	0	0

(8) P37/PO15/(TIOCA2)/TIOCB2/(TCLKD-A)

The pin function is switched as shown below according to the combination of the register settings for the TPU and PPG, and the B7 bit in P3.DDR.

		Setting		
		TPU	PPG	I/O Port
Module Name	Pin Function	TIOCB2_OE	PO15_OE	P3.DDR.B7
TPU	TIOCB2 output	1	—	—
PPG	PO15 output	0	1	—
I/O port	P37 output	0	0	1
	P37 input (initial value)	0	0	0

14.3.5 Port 4 (P4)

(1) P40/(AN0)/(IRQ8-B)

The pin function is switched as shown below according to the value of the B0 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B0**
I/O port	P40 output	1
	P40 input (initial value)	0

(2) P41/(AN1)/(IRQ9-B)

The pin function is switched as shown below according to the value of the B1 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B1**
I/O port	P41 output	1
	P41 input (initial value)	0

(3) P42/(AN2)/(IRQ10-B)

The pin function is switched as shown below according to the value of the B2 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B2**
I/O port	P42 output	1
	P42 input (initial value)	0

(4) P43/(AN3)/(IRQ11-B)

The pin function is switched as shown below according to the value of the B3 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B3**
I/O port	P43 output	1
	P43 input (initial value)	0

(5) P44/(AN4)/(IRQ12-B)

The pin function is switched as shown below according to the value of the B4 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B4**
I/O port	P44 output	1
	P44 input (initial value)	0

(6) P45/(AN5)/(IRQ13-B)

The pin function is switched as shown below according to the value of the B5 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B5**
I/O port	P45 output	1
	P45 input (initial value)	0

(7) P46/(AN6)/(IRQ14-B)

The pin function is switched as shown below according to the value of the B6 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B6**
I/O port	P46 output	1
	P46 input (initial value)	0

(8) P47/(AN7)/(IRQ15-B)

The pin function is switched as shown below according to the value of the B7 bit in P4.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P4.DDR.B7**
I/O port	P47 output	1
	P47 input (initial value)	0

14.3.6 Port 5 (P5)

(1) P50/WR0#/WR#

The pin function is switched as shown below according to the combination of the register setting for the bus controller and the B0 bit in P5.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	WR0#_OE/WR#_OE	P5.DDR.B0
Bus controller	WR0#/WR# output*	1	—
I/O port	P50 output	0	1
	P50 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(2) P51/WR1#/BC1#

The pin function is switched as shown below according to the combination of the port function control register (PFCRm) setting and the B1 bit in P5.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	WR1#_OE/BC1#_OE	P5.DDR.B1
Bus controller	WR1#/BC1# output*	1	—
I/O port	P51 output	0	1
	P51 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(3) P52/RD#

The pin function is switched as shown below according to the combination of the operating mode, the external bus enable bit (EXBE) in the system control register 0 (SYSCR0), and the B2 bit in P5.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	RD_OE	P5.DDR.B2
Bus controller	RD# output*	1	—
I/O port	P52 output	0	1
	P52 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(4) P53/BCLK

The pin function is switched as shown below according to the value of the B3 bit in P5.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P5.DDR.B3 (BCLK_OE)**
Clock generation circuit	BCLK output	1
I/O port	P53 input (initial value)	0

Note: If the BCLK signal is to be output, stop the BCLK clock by setting SCKCR.PSTOP1 to 1, set P5.DDR.B3 to select output for this pin, and then restore the value of SCKCR.PSTOP1 to 1 for output of the BCLK signal.

(5) P54/TRDATA0

The pin function is switched as shown below according to the combination of the register setting for the B4 bit in P5.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P5.DDR.B4**
I/O port	P54 output	1
	P54 input (initial value)	0

(6) P55/TRDATA1

The pin function is switched as shown below according to the value of the B5 bit in P5.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P5.DDR.B5**
I/O port	P55 output	1
	P55 input (initial value)	0

(7) P56/TRDATA2

The pin function is switched as shown below according to the value of the B6 bit in P5.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P5.DDR.B6**
I/O port	P56 output	1
	P56 input (initial value)	0

(8) P57/(WAIT#)/TRDATA3

The pin function is switched as shown below according to the value of the B7 bit in P5.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P5.DDR.B7**
I/O port	P57 output	1
	P57 input (initial value)	0

14.3.7 Port 6 (P6)

(1) P60/CS0#/CS4#-A/CS5#-B

The pin function is switched as shown below according to the combination of the operating mode, the external bus enable bit (EXBE) in the system control register 0 (SYSCR0), the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B0 bit in P6.DDR.

		Setting			
		Bus Controller			I/O Port
Module Name	**Pin Function**	**CS0#_OE**	**CS4#-A_OE**	**CS5#-B_OE**	**P6.DDR.B0**
Bus controller	CS0# output	1	—	—	—
	CS4#-A output	—	1	—	—
	CS5#-B output	—	—	1	—
I/O port	P60 output	0	0	0	1
	P60 input (initial value)	0	0	0	0

(2) P61/CS1#/CS2#-B/CS5#-A/CS6#-B/CS7#-B

The pin function is switched as shown below according to the combination of the operating mode, the EXBE bit in SYSCR0, the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B1 bit in P6.DDR.

		Setting					
		Bus Controller					I/O Port
Module Name	**Pin Function**	**CS1#_OE**	**CS2#-B_OE**	**CS5#-A_OE**	**CS6#-B_OE**	**CS7#-B_OE**	**P6.DDR.B1**
Bus controller	CS1# output*	1	—	—	—	—	—
	CS2#-B output*	—	1	—	—	—	—
	CS5#-A output*	—	—	1	—	—	—
	CS6#-B output*	—	—	—	1	—	—
	CS7#-B output*	—	—	—	—	1	—
I/O port	P61 output	0	0	0	0	0	1
	P61 input (initial value)	0	0	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(3) P62/CS2#-A/CS6#-A

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B2 bit in P6.DDR.

		Setting		
		Bus Controller		I/O Port
Module Name	**Pin Function**	**CS2#-A_OE**	**CS6#-A_OE**	**P6.DDR.B2**
Bus controller	CS2#-A output*	1	—	—
	CS6#-A output*	—	1	—
I/O port	P62 output	0	0	1
	P62 input (initial value)	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(4) P63/CS3#-A/CS7#-A

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B3 bit in P6.DDR.

		Setting		
		Bus Controller		I/O Port
Module Name	**Pin Function**	**CS3#-A_OE**	**CS7#-A_OE**	**P6.DDR.B3**
Bus controller	CS3#-A output*	1	—	—
	CS7#-A output*	—	1	—
I/O port	P63 output	0	0	1
	P63 input (initial value)	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(5) P64/CS4#-B

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B4 bit in P6.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	**Pin Function**	**CS4#-B_OE**	**P6.DDR.B4**
Bus controller	CS4#-B output*	1	—
I/O port	P64 output	0	1
	P64 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(6) P65/(IRQ15-A)

The pin function is switched as shown below according to the value of the B5 bit in P6.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P6.DDR.B5**
I/O port	P65 output	1
	P65 input (initial value)	0

(7) P66/DA0

The pin function is switched as shown below according to the register setting for the D/A converter and the B6 bit in P6.DDR.

		Setting	
		D/A Converter	I/O Port
Module Name	**Pin Function**	**DA0_OE**	**P6.DDR.B6**
D/A converter	DA0 output	1	—
I/O port	P66 output	0	1
	P66 input (initial value)	0	0

(8) P67/DA1

The pin function is switched as shown below according to the register setting for the D/A converter and the B7 bit in P6.DDR.

		Setting	
		D/A Converter	I/O Port
Module Name	**Pin Function**	**DA1_OE**	**P6.DDR.B7**
D/A converter	DA1 output	1	—
I/O port	P67 output	0	1
	P67 input (initial value)	0	0

14.3.8 Port 7 (P7)

(1) P70/CS3#-B/(ADTRG2#)

The pin function is switched as shown below according to the combination of the external bus enable bit (EXBE) in the system control register 0 (SYSCR0), the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B0 bit in P7.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	**Pin Function**	**CS3#-B_OE**	**P7.DDR.B0**
Bus controller	CS3#-B output*	1	—
I/O port	P70 output	0	1
	P70 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(2) P71/CS4#-C/CS5#-C/CS6#-C/CS7#-C

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B1 bit in P7.DDR.

		Setting				
		Bus Controller				I/O Port
Module Name	**Pin Function**	**CS4#-C_OE**	**CS5#-C_OE**	**CS6#-C_OE**	**CS7#-C_OE**	**P7.DDR.B1**
Bus controller	CS4#-C output*	1	—	—	—	—
	CS5#-C output*	—	1	—	—	—
	CS6#-C output*	—	—	1	—	—
	CS7#-C output*	—	—	—	1	—
I/O port	P71 output	0	0	0	0	1
	P71 input (initial value)	0	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(3) P72

The pin function is switched as shown below according to the value of the B2 bit in P7.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P7.DDR.B2**
I/O port	P72 output	1
	P72 input (initial value)	0

(4) P73

The pin function is switched as shown below according to the value of the B3 bit in P7.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P7.DDR.B3**
I/O port	P73 output	1
	P73 input (initial value)	0

(5) P74/(ADTRG3#)

The pin function is switched as shown below according to the value of the B4 bit in P7.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P7.DDR.B4**
I/O port	P74 output	1
	P74 input (initial value)	0

(6) P75

The pin function is switched as shown below according to the value of the B5 bit in P7.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P7.DDR.B5**
I/O port	P75 output	1
	P75 input (initial value)	0

(7) P76/(IRQ14-A)

The pin function is switched as shown below according to the value of the B6 bit in P7.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P7.DDR.B6**
I/O port	P76 output	1
	P76 input (initial value)	0

(8) P77

The pin function is switched as shown below according to the value of the B7 bit in P7.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P7.DDR.B7**
I/O port	P77 output	1
	P77 input (initial value)	0

14.3.9 Port 8 (P8)

(1) P80

The pin function is switched as shown below according to the value of the B0 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B0**
I/O port	P80 output	1
	P80 input (initial value)	0

(2) P81/TRSYNC#

The pin function is switched as shown below according to the value of the B1 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B1**
I/O port	P81 output	1
	P81 input (initial value)	0

(3) P82/TRCLK

The pin function is switched as shown below according to the value of the B2 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B2**
I/O port	P82 output	1
	P82 input (initial value)	0

(4) P83

The pin function is switched as shown below according to the value of the B3 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B3**
I/O port	P83 output	1
	P83 input (initial value)	0

(5) P84

The pin function is switched as shown below according to the value of the B4 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B4**
I/O port	P84 output	1
	P84 input (initial value)	0

(6) P85

The pin function is switched as shown below according to the value of the B5 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B5**
I/O port	P85 output	1
	P85 input (initial value)	0

(7) P86

The pin function is switched as shown below according to the value of the B6 bit in P8.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P8.DDR.B6**
I/O port	P86 output	1
	P86 input (initial value)	0

14.3.10 Port 9 (P9)

(1) P90/(AN8)

The pin function is switched as shown below according to the value of the B0 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B0**
I/O port	P90 output	1
	P90 input (initial value)	0

(2) P91/(AN9)

The pin function is switched as shown below according to the value of the B1 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B1**
I/O port	P91 output	1
	P91 input (initial value)	0

(3) P92/(AN10)

The pin function is switched as shown below according to the value of the B2 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B2**
I/O port	P92 output	1
	P92 input (initial value)	0

(4) P93/(AN11)

The pin function is switched as shown below according to the value of the B3 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B3**
I/O port	P93 output	1
	P93 input (initial value)	0

(5) P94/(AN12)

The pin function is switched as shown below according to the value of the B4 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B4**
I/O port	P94 output	1
	P94 input (initial value)	0

(6) P95/(AN13)

The pin function is switched as shown below according to the value of the B5 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B5**
I/O port	P95 output	1
	P95 input (initial value)	0

(7) P96/(AN14)

The pin function is switched as shown below according to the value of the B6 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B6**
I/O port	P96 output	1
	P96 input (initial value)	0

(8) P97/(AN15)

The pin function is switched as shown below according to the value of the B7 bit in P9.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**P9.DDR.B7**
I/O port	P97 output	1
	P97 input (initial value)	0

14.3.11 Port A (PA)

(1) PA0/A0/BC0#/PO16/TIOCA6

The pin function is switched as shown below according to the combination of the external bus enable bit (EXBE) in the system control register 0 (SYSCR0), the rgister settings for the PPG and TPU, and the B0 bit in PA.DDR.

		Setting				
		Bus Controller		TPU	PPG	I/O Port
Module Name	Pin Function	A0_OE	BC0#_OE	TIOCA6_OE	PO16_OE	PA.DDR.B0
Bus controller	Address output*	1	0	—	—	1
	Byte control output*	0	1	—	—	1
TPU	TIOCA6 output	0	0	1	—	—
PPG	PO16 output	0	0	0	1	—
I/O port	PA0 output*	0	0	0	0	1
	PA0 input (initial value)	0	0	0	0	0

Note: * Address output is enabled when PA.DDR.B0 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(2) PA1/A1/PO17/(TIOCA6)/TIOCB6

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B1 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A1_OE	TIOCB6_OE	PO17_OE	PA.DDR.B1
Bus controller	Address output*	1	—	—	1
TPU	TIOCB6 output	0	1	—	—
PPG	PO17 output	0	0	1	—
I/O port	PA1 output*	0	0	0	1
	PA1 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B1 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(3) PA2/A2/PO18/TIOCC6/(TCLKE)

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B2 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A2_OE	TIOCC6_OE	PO18_OE	PA.DDR.B2
Bus controller	Address output*	1	—	—	1
TPU	TIOCC6 output	0	1	—	—
PPG	PO18 output	0	0	1	—
I/O port	PA2 output*	0	0	0	1
	PA2 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B2 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(4) PA3/A3/PO19/(TIOCC6)/TIOCD6/(TCLKF)

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B3 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A3_OE	TIOCD6_OE	PO19_OE	PA.DDR.B3
Bus controller	Address output*	1	—	—	1
TPU	TIOCD6 output	0	1	—	—
PPG	PO19 output	0	0	1	—
I/O port	PA3 output*	0	0	0	1
	PA3 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B3 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(5) PA4/A4/PO20/TIOCA7

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B4 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A4_OE	TIOCA7_OE	PO20_OE	PA.DDR.B4
Bus controller	Address output*	1	—	—	1
TPU	TIOCA7 output	0	1	—	—
PPG	PO20 output	0	0	1	—
I/O port	PA4 output*	0	0	0	1
	PA4 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B4 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(6) PA5/A5/PO21/(TIOCA7)/TIOCB7/(TCLKG)

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B5 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A5_OE	TIOCB7_OE	PO21_OE	PA.DDR.B5
Bus controller	Address output*	1	—	—	1
TPU	TIOCB7 output	0	1	—	—
PPG	PO21 output	0	0	1	—
I/O port	PA5 output*	0	0	0	1
	PA5 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B5 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(7) PA6/A6/PO22/TIOCA8

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B6 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A6_OE	TIOCA8_OE	PO22_OE	PA.DDR.B6
Bus controller	Address output*	1	—	—	1
TPU	TIOCA8 output	0	1	—	—
PPG	PO22 output	0	0	1	—
I/O port	PA6 output*	0	0	0	1
	PA6 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B6 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(8) PA7/A7/PO23/(TIOCA8)/TIOCB8/(TCLKH)

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, and the B7 bit in PA.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A7_OE	TIOCB8_OE	PO23_OE	PA.DDR.B7
Bus controller	Address output*	1	—	—	1
TPU	TIOCB8 output	0	1	—	—
PPG	PO23 output	0	0	1	—
I/O port	PA7 output*	0	0	0	1
	PA7 input (initial value)	0	0	0	0

Note: * Address output is enabled when PA.DDR.B7 = 1 in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

14.3.12 Port B (PB)

(1) PB0/A8/PO24/TIOCA9

The pin function is switched as shown below according to the combination of the external bus enable bit (EXBE) in the system control register 0 (SYSCR0), the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B0 bit in PB.DDR.

		Setting			
		Bus Controller	**TPU**	**PPG**	**I/O Port**
Module Name	**Pin Function**	**A8_OE**	**TIOCA9_OE**	**PO24_OE**	**PB.DDR.B0**
Bus controller	Address output*	1	—	—	—
TPU	TIOCA9 output	0	1	—	—
PPG	PO24 output	0	0	1	—
I/O port	PB0 output*	0	0	0	1
	PB0 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(2) PB1/A9/PO25/(TIOCA9)/TIOCB9

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B1 bit in PB.DDR.

		Setting			
		Bus Controller	**TPU**	**PPG**	**I/O Port**
Module Name	**Pin Function**	**A9_OE**	**TIOCB9_OE**	**PO25_OE**	**PB.DDR.B1**
Bus controller	Address output*	1	—	—	—
TPU	TIOCB9 output	0	1	—	—
PPG	PO25 output	0	0	1	—
I/O port	PB1 output*	0	0	0	1
	PB1 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(3) PB2/A10/PO26/TIOCC9

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B2 bit in PB.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A10_OE	TIOCC9_OE	PO26_OE	PB.DDR.B2
Bus controller	Address output*	1	—	—	—
TPU	TIOCC9 output	0	1	—	—
PPG	PO26 output	0	0	1	—
I/O port	PB2 output*	0	0	0	1
	PB2 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(4) PB3/A11/PO27/(TIOCC9)/TIOCD9

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B3 bit in PB.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A11_OE	TIOCD9_OE	PO27_OE	PB.DDR.B3
Bus controller	Address output*	1	—	—	—
TPU	TIOCD9 output	0	1	—	—
PPG	PO27 output	0	0	1	—
I/O port	PB3 output*	0	0	0	1
	PB3 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(5) PB4/A12/PO28/TIOCA10

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B4 bit in PB.DDR.

		Setting			
		Bus Controller	TPU	PPG	I/O Port
Module Name	Pin Function	A12_OE	TIOCA10_OE	PO28_OE	PB.DDR.B4
Bus controller	Address output*	1	—	—	—
TPU	TIOCA10 output	0	1	—	—
PPG	PO28 output	0	0	1	—
I/O port	PB4 output*	0	0	0	1
	PB4 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(6) PB5/A13/PO29/(TIOCA10)/TIOCB10

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B5 bit in PB.DDR.

		Setting			
		Bus Controller	**TPU**	**PPG**	**I/O Port**
Module Name	**Pin Function**	**A13_OE**	**TIOCB10_OE**	**PO29_OE**	**PB.DDR.B5**
Bus controller	Address output*	1	—	—	—
TPU	TIOCB10 output	0	1	—	—
PPG	PO29 output	0	0	1	—
I/O port	PB5 output*	0	0	0	1
	PB5 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(7) PB6/A14/PO30/TIOCA11

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B6 bit in PB.DDR.

		Setting			
		Bus Controller	**TPU**	**PPG**	**I/O Port**
Module Name	**Pin Function**	**A14_OE**	**TIOCA11_OE**	**PO30_OE**	**PB.DDR.B6**
Bus controller	Address output*	1	—	—	—
TPU	TIOCA11 output	0	1	—	—
PPG	PO30 output	0	0	1	—
I/O port	PB6 output*	0	0	0	1
	PB6 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(8) PB7/A15/PO31/(TIOCA11)/TIOCB11

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the register settings for the PPG and TPU, the port function control register m (PFCRm) setting, and the B7 bit in PB.DDR.

		Setting			
		Bus Controller	**TPU**	**PPG**	**I/O Port**
Module Name	**Pin Function**	**A15_OE**	**TIOCB11_OE**	**PO31_OE**	**PB.DDR.B7**
Bus controller	Address output*	1	—	—	—
TPU	TIOCB11 output	0	1	—	—
PPG	PO31 output	0	0	1	—
I/O port	PB7 output*	0	0	0	1
	PB7 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

14.3.13 Port C (PC)

(1) PC0/A16

The pin function is switched as shown below according to the combination of the external bus enable bit (EXBE) in the system control register 0 (SYSCR0), the register setting for the bus controller, the port function control register m (PFCRm) setting, and the B0 bit in PC.DDR

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	A16_OE	PC.DDR.B0
Bus controller	A16 output*	1	—
I/O port	PC0 output	0	1
	PC0 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(2) PC1/A17

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister settings for the bus controller, the port function control register m (PFCRm) setting, and the B1 bit in PC.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	A17_OE	PC.DDR.B1
Bus controller	A17 output*	1	—
I/O port	PC1output	0	1
	PC1 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(3) PC2/A18

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B2 bit in PC.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	A18_OE	PC.DDR.B2
Bus controller	A18 output*	1	—
I/O port	PC2 output	0	1
	PC2 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(4) PC3/A19

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B3 bit in PC.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	A19_OE	PC.DDR.B3
Bus controller	A19 output*	1	—
I/O port	PC3 output	0	1
	PC3 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(5) PC4/A20

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B4 bit in PC.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	Pin Function	A20_OE	PC.DDR.B4
Bus controller	A20 output*	1	—
I/O port	PC4 output	0	1
	PC4 input (initial value)	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(6) PC5/A21/SCK5/CS5#-D

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B5 bit in PC.DDR.

		Setting			
		Bus Controller		SCI	I/O Port
Module Name	Pin Function	A21_OE	CS5#-D_OE	SCK5_OE	PC.DDR.B5
Bus controller	A21 output*	1	—	—	—
	CS5#-D output*	0	1	—	—
SCI	SCK5 output	0	0	1	—
I/O port	PC5 output	0	0	0	1
	PC5 input (initial value)	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(7) PC6/A22/(RxD5)/CS6#-D

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B6 bit in PC.DDR.

		Setting		
		Bus Controller		I/O Port
Module Name	**Pin Function**	**A22_OE**	**CS6#-D_OE**	**PC.DDR.B6**
Bus controller	A22 output*	1	—	—
	CS6#-D output*	0	1	—
I/O port	PC6 output	0	0	1
	PC6 input (initial value)	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

(8) PC7/A23/TxD5/CS4#-D/CS7#-D

The pin function is switched as shown below according to the combination of the EXBE bit in SYSCR0, the rgister setting for the bus controller, the port function control register m (PFCRm) setting, and the B7 bit in PC.DDR.

		Setting				
		Bus Controller			SCI	I/O Port
Module Name	**Pin Function**	**A23_OE**	**CS4#-D_OE**	**CS7#-D_OE**	**TxD5_OE**	**PC.DDR.B7**
Bus controller	A23 output*	1	—	—	—	—
	CS4#-D output*	0	1	—	—	—
	CS7#-D output*	0	0	1	—	—
SCI	TxD5 output	0	0	0	1	—
I/O port	PC7 output	0	0	0	0	1
	PC7 input (initial value)	0	0	0	0	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

14.3.14 Port D (PD)

(1) PD0/D0, PD1/D1, PD2/D2, PD3/D3, PD4/D4, PD5/D5, PD6/D6, PD7/D7

The pin function is switched as shown below according to the combination of the external bus enable (EXBE) bit in the system control register 0 (SYSCR0) and the Bj bit (j = 0 to 7) in PD.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PD.DDR.Bn**
Bus controller	Data I/O*	—
I/O port	PDn output	1
	PDn input (initial value)	0

Note: * Enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).

14.3.15 Port E (PE)

(1) PE0/D8, PE1/D9, PE2/D10, PE3/D11, PE4/D12, PE5/D13/(IRQ5#-A), PE6/D14/(IRQ6#-A), PE7/D15/(IRQ7#-A)

The pin function is switched as shown below according to the combination of bus mode setting, the EXBE bit in SYSCR0, the port function control register m (PFCRm) setting, and the Bj bit (j = 0 to 7) in PE.DDR.

		Setting	
		Bus Controller	I/O Port
Module Name	**Pin Function**	**Dn_E (n = 8 to 15)**	**PE.DDR.Bn**
Bus controller	Data I/O*	1	—
I/O port	PEn output	0	1
	PEn input (initial value)	0	0

Note: * The function is enabled in expansion mode with on-chip ROM disabled or disabled (SYSCR0.EXBE = 1).
These pins function as data I/O pins (D15 to D8) in 16-bit bus mode (indicated as 1 in the above table), and as general I/O pins in the other modes (indicated as 0 in the above table).

14.3.16 Port F (PF)

(1) PF0

The pin function is switched as shown below according to the value of the B0 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B0**
I/O port	PF0 output	1
	PF0 input (initial value)	0

(2) PF1

The pin function is switched as shown below according to the value of the B1 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B1**
I/O port	PF1 output	1
	PF1 input (initial value)	0

(3) PF2

The pin function is switched as shown below according to the value of the B2 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B2**
I/O port	PF2 output	1
	PF2 input (initial value)	0

(4) PF3

The pin function is switched as shown below according to the value of the B3 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B3**
I/O port	PF3 output	1
	PF3 input (initial value)	0

(5) PF4

The pin function is switched as shown below according to the value of the B4 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B4**
I/O port	PF4 output	1
	PF4 input (initial value)	0

(6) PF5

The pin function is switched as shown below according to the value of the B5 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B5**
I/O port	PF5 output	1
	PF5 input (initial value)	0

(7) PF6

The pin function is switched as shown below according to the value of the B6 bit in PF.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PF.DDR.B6**
I/O port	PF6 output	1
	PF6 input (initial value)	0

14.3.17 Port G (PG)

(1) PG0

The pin function is switched as shown below according to the value of the B0 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B0**
I/O port	PG0 output	1
	PG0 input (initial value)	0

(2) PG1

The pin function is switched as shown below according to the value of the B1 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B1**
I/O port	PG1 output	1
	PG1 input (initial value)	0

(3) PG2

The pin function is switched as shown below according to the value of the B2 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B2**
I/O port	PG2 output	1
	PG2 input (initial value)	0

(4) PG3

The pin function is switched as shown below according to the value of the B3 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B3**
I/O port	PG3 output	1
	PG3 input (initial value)	0

(5) PG4

The pin function is switched as shown below according to the value of the B4 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B4**
I/O port	PG4 output	1
	PG4 input (initial value)	0

(6) PG5

The pin function is switched as shown below according to the value of the B5 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B5**
I/O port	PG5 output	1
	PG5 input (initial value)	0

(7) PG6

The pin function is switched as shown below according to the value of the B6 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B6**
I/O port	PG6 output	1
	PG6 input (initial value)	0

(8) PG7

The pin function is switched as shown below according to the value of the B7 bit in PG.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PG.DDR.B7**
I/O port	PG7 output	1
	PG7 input (initial value)	0

14.3.18 Port H (PH)

(1) PH0

The pin function is switched as shown below according to the value of the B0 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B0**
I/O port	PH0 output	1
	PH0 input (initial value)	0

(2) PH1

The pin function is switched as shown below according to the value of the B1 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B1**
I/O port	PH1 output	1
	PH1 input (initial value)	0

(3) PH2

The pin function is switched as shown below according to the value of the B2 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B2**
I/O port	PH2 output	1
	PH2 input (initial value)	0

(4) PH3

The pin function is switched as shown below according to the value of the B3 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B3**
I/O port	PH3 output	1
	PH3 input (initial value)	0

(5) PH4

The pin function is switched as shown below according to the value of the B4 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B4**
I/O port	PH4 output	1
	PH4 input (initial value)	0

(6) PH5

The pin function is switched as shown below according to the value of the B5 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B5**
I/O port	PH5 output	1
	PH5 input (initial value)	0

(7) PH6

The pin function is switched as shown below according to the value of the B6 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B6**
I/O port	PH6 output	1
	PH6 input (initial value)	0

(8) PH7

The pin function is switched as shown below according to the value of the B7 bit in PH.DDR.

		Setting
		I/O Port
Module Name	**Pin Function**	**PH.DDR.B7**
I/O port	PH7 output	1
	PH7 input (initial value)	0

14.4 Settings to Enable Output of the Signals

Table 14.8 lists the settings to enable output from the individual pins of each port.

Table 14.8 Settings to Enable Output of the Signals from Each Port

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
P0	0	SCI6	TxD6_OE	TxD6		SCR.TE = 1
	1		—	—	—	—
	2	TMR2	TMO2_OE	TMO2		TCSR.OSA[1:0] = 01/10/11 or TCSR.OSB[1:0] = 01/10/11
		SCI6	SCK6_OE	SCK6		When SCMR.SMIF = 1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1,SCR.CKE[1] = 0
	3	SCI4	SCK4_OE	SCK4		When SCMR.SMIF = 1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0
	4	SCI4	TxD4_OE	TxD4		SCR.TE = 1
	5	TMR3	TMO3_OE	TMO3		TCSR.OSA[1:0] = 01/10/11 or TCSR.OSB[1:0] = 01/10/11
P1	0		—	—	—	—
	1	SCI2	SCK2_OE	SCK2		When SCMR.SMIF = 1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0
	2		—	—	—	—
	3	SCI2	TxD2_OE	TxD2		SCR.TE = 1
	4	RIIC1	SDA1_OE	SDA1		ICCR1.ICE = 1
	5	SCI3	SCK3_OE	SCK3		When SCMR.SMIF = 1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0
		RIIC1	SCL1_OE	SCL1		ICCR1.ICE = 1
	6	RIIC0	SDA0_OE	SDA0		ICCR1.ICE = 1
	7	SCI3	TxD3_OE	TxD3		SCR.TE = 1
		RIIC0	SCL0_OE	SCL0		ICCR1.ICE = 1

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
P2	0	TPU3	TIOCB3_OE	TIOCB3		TIORH.IOB[3] = 0, TIORH.IOB[1:0] = 01/10/11
		SCI0	TxD0_OE	TxD0		SCR.TE = 1
		PPG0	PO0_OE	PO0		NDERL.NDER0 = 1
	1	TPU3	TIOCA3_OE	TIOCA3		TIORH.IOA[3] = 0, TIORH.IOA[1:0] = 01/10/11
		PPG0	PO1_OE	PO1		NDERL.NDER1 = 1
	2	TPU3	TIOCC3_OE	TIOCC3		TMDR.BFA = 0, TIORL.IOC[3] = 0, TIORL.IOC[1:0] = 01/10/11
		TMR0	TMO0_OE	TMO0		TCSR.OSA[1:0]=01/10/11 or TCSR.OSB[1:0]=01/10/11
		SCI0	SCK0_OE	SCK0		When SCMR.SMIF = 1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0
		PPG0	PO2_OE	PO2		NDERL.NDER2 = 1
	3	TPU3	TIOCD3_OE	TIOCD3		TMDR.BFB = 0, TIORL.IOD[3] = 0, TIORL.IOD[1:0] = 01/10/11
		PPG0	PO3_OE	PO3		NDERL.NDER3 = 1
	4	TPU4	TIOCB4_OE	TIOCB4		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG0	PO4_OE	PO4		NDERL.NDER4 = 1
	5	TPU4	TIOCA4_OE	TIOCA4		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		PPG0	PO5_OE	PO5		NDERL.NDER5 = 1
	6	TPU5	TIOCA5_OE	TIOCA5		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		TMR1	TMO1_OE	TMO1		TCSR.OSA[1:0] = 01/10/11 or TCSR.OSB[1:0] = 01/10/11
		SCI1	TxD1_OE	TxD1		SCR.TE = 1
		PPG0	PO6_OE	PO6		NDERL.NDER6 = 1
	7	TPU5	TIOCB5_OE	TIOCB5		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		SCI1	SCK1_OE	SCK1		When SCMR.SMIF=1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0
		PPG0	PO7_OE	PO7		NDERL.NDER7 = 1

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
P3	0	TPU0	TIOCA0_OE	TIOCA0		TIORH.IOA[3] = 0, TIOH.IOA[1:0] = 01/10/11
		PPG0	PO8_OE	PO8		NDERH.NDER8 = 1
	1	TPU0	TIOCB0_OE	TIOCB0		TIORH.IOB[3] = 0, TIORH.IOB[1:0] = 01/10/11
		PPG0	PO9_OE	PO9		NDERH.NDER9 = 1
	2	TPU0	TIOCC0_OE	TIOCC0		TMDR.BFA = 0, TIORL.IOC[3] = 0,TIORL.IOC[1:0] = 01/10/11
		PPG0	PO10_OE	PO10		NDERH.NDER10 = 1
	3	TPU0	TIOCD0_OE	TIOCD0		TMDR.BFB = 0, TIORL.IOD[3] = 0, TIORL.IOD[1:0] = 01/10/11
		PPG0	PO11_OE	PO11		NDERH.NDER11 = 1
	4	TPU1	TIOCA1_OE	TIOCA1		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		PPG0	PO12_OE	PO12		NDERH.NDER12 = 1
	5	TPU1	TIOCB1_OE	TIOCB1		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG0	PO13_OE	PO13		NDERH.NDER13 = 1
	6	TPU2	TIOCA2_OE	TIOCA2		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		PPG0	PO14_OE	PO14		NDERH.NDER14 = 1
	7	TPU2	TIOCB2_OE	TIOCB2		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG0	PO15_OE	PO15		NDERH.NDER15 = 1
P5	0	SYSC,BSC	WR0_OE	WR0		SYSCR0.EXBE = 1, CSnMOD.WRMOD = 0
		SYSC,BSC	WR_OE	WR		SYSCR0.EXBE = 1, CSnMOD.WRMOD = 1
	1	SYSC,BSC	WR1_OE	WR1		SYSCR0.EXBE = 1, PFCR5.WR1BC1E = 1, CSnMOD.WRMOD = 0 CSnCNT.BSIZE[1:0] = 00
		SYSC,BSC	BC1_OE	BC1		SYSCR0.EXBE=1,PFCR5.WR1BC1E =1,CSnMOD.WRMOD=1 CSnCNT.BSIZE[1:0] = 00
	2	SYSC	RD_OE	RD		SYSCR0.EXBE = 1
	3	PORT	BCLK_OE	BCLK		P5.DDR.B3 = 1
	4		—	—	—	—
	5		—	—	—	—
	6		—	—	—	—
	7		—	—	—	—

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
P6	0	SYSC	CS0_OE	CS0		SYSCR0.EXBE = 1, PFCR0.CS0E = 1, CS0CNT.EXENB = 1
		SYSC	CS4A_OE	CS4	PFCR1.CS4S[1 0] = 00	SYSCR0.EXBE = 1, PFCR0.CS4E = 1, CS4CNT.EXENB = 1
		SYSC	CS5B_OE	CS5	PFCR1.CS5S[1 0] = 01	SYSCR0.EXBE = 1, PFCR0.CS5E = 1, CS5CNT.EXENB = 1
	1	SYSC	CS1_OE	CS1		SYSCR0.EXBE = 1, PFCR0.CS1E = 1, CS1CNT.EXENB = 1
		SYSC	CS2B_OE	CS2	PFCR2.CS2S = 1	SYSCR0.EXBE = 1, PFCR0.CS2E = 1, CS2CNT.EXENB = 1
		SYSC	CS5A_OE	CS5	PFCR1.CS5S[1 0] = 00	SYSCR0.EXBE = 1, PFCR0.CS5E = 1, CS5CNT.EXENB = 1
		SYSC	CS6B_OE	CS6	PFCR1.CS6S[1 0] = 01	SYSCR0.EXBE = 1, PFCR0.CS6E = 1, CS6CNT.EXENB = 1
		SYSC	CS7B_OE	CS7	PFCR1.CS7S[1 0] = 01	SYSCR0.EXBE = 1, PFCR0.CS7E = 1, CS7CNT.EXENB = 1
	2	SYSC	CS2A_OE	CS2	PFCR2.CS2S = 0	SYSCR0.EXBE = 1, PFCR0.CS2E = 1, CS2CNT.EXENB = 1
		SYSC	CS6A_OE	CS6	PFCR1.CS6S[1 0] = 00	SYSCR0.EXBE = 1, PFCR0.CS6E = 1, CS6CNT.EXENB = 1
	3	SYSC	CS3A_OE	CS3	PFCR2.CS3S = 0	SYSCR0.EXBE = 1, PFCR0.CS3E = 1, CS3CNT.EXENB = 1
		SYSC	CS7A_OE	CS7	PFCR1.CS7S[1 0] = 00	SYSCR0.EXBE = 1, PFCR0.CS7E = 1, CS7CNT.EXENB = 1
	4	SYSC	CS4B_OE	CS4	PFCR1.CS4S[1 0] = 01	SYSCR0.EXBE = 1, PFCR0.CS4E = 1, CS4CNT.EXENB = 1
	5		—	—	—	—
	6	DAC	DA0_OE	DA0		DACR.DAOE0 = 1
	7	DAC	DA1_OE	DA1		DACR.DAOE1 = 1
P7	0	SYSC	CS3B_OE	CS3	PFCR2.CS3S = 1	SYSCR0.EXBE = 1, PFCR0.CS3E = 1, CS3CNT.EXENB = 1
	1	SYSC	CS4C_OE	CS4	PFCR1.CS4S[1 0] = 10	SYSCR0.EXBE = 1, PFCR0.CS4E = 1, CS4CNT.EXENB = 1
		SYSC	CS5C_OE	CS5	PFCR1.CS5S[1 0] = 10	SYSCR0.EXBE = 1, PFCR0.CS5E = 1, CS5CNT.EXENB = 1
		SYSC	CS6C_OE	CS6	PFCR1.CS6S[1 0] = 10	SYSCR0.EXBE = 1, PFCR0.CS6E = 1, CS6CNT.EXENB = 1
		SYSC	CS7C_OE	CS7	PFCR1.CS7S[1 0] = 10	SYSCR0.EXBE = 1, PFCR0.CS7E = 1, CS7CNT.EXENB = 1
	2		—	—	—	—
	3		—	—	—	—
	4		—	—	—	—
	5		—	—	—	—
	6		—	—	—	—
	7		—	—	—	—

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
PA	0	TPU6	TIOCA6_OE	TIOCA6		TIORH.IOA[3] = 0, TIORH.IOA[1:0] = 01/10/11
		PPG1	PO 16_OE	PO16		NDERL.NDER16 = 1
		SYSC,BSC	BC0_OE	BC0		SYSCR0.EXBE = 1, CSnMOD.WRMOD = 1, PA.DDR.B0 = 1
		SYSC,BSC	A0_OE	A0		SYSCR0.EXBE = 1, CSnMOD.WRMOD = 0, PA.DDR.B0 = 1
	1	TPU6	TIOCB6_OE	TIOCB6		TIORH.IOB[3] = 0, TIORH.IOB[1:0] = 01/10/11
		PPG1	PO 17_OE	PO17		NDERL.NDER17 = 1
		SYSC	A1_OE	A1		SYSCR0.EXBE = 1, PA.DDR.B1 = 1
	2	TPU6	TIOCC6_OE	TIOCC6		TMDR.BFA = 0, TIORL.IOC[3] = 0, TIORL.IOC[1:0] = 01/10/11
		PPG1	PO 18_OE	PO18		NDERL.NDER18 = 1
		SYSC	A2_OE	A2		SYSCR0.EXBE = 1, PA.DDR.B2 = 1
	3	TPU6	TIOCD6_OE	TIOCD6		TMDR.BFB = 0, TIORL.IOD[3] = 0, TIORL.IOD[1:0] = 01/10/11
		PPG1	PO 19_OE	PO19		NDERL.NDER19 = 1
		SYSC	A3_OE	A3		SYSCR0.EXBE = 1, PA.DDR.B3 = 1
	4	TPU7	TIOCA7_OE	TIOCA7		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		PPG1	PO 20_OE	PO20		NDERL.NDER20 = 1
		SYSC	A4_OE	A4		SYSCR0.EXBE = 1, PA.DDR.B4 = 1
	5	TPU7	TIOCB7_OE	TIOCB7		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG1	PO 21_OE	PO21		NDERL.NDER21 = 1
		SYSC	A5_OE	A5		SYSCR0.EXBE = 1, PA.DDR.B5 = 1
	6	TPU8	TIOCA8_OE	TIOCA8		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		PPG1	PO 22_OE	PO22		NDERL.NDER22 = 1
		SYSC	A6_OE	A6		SYSCR0.EXBE = 1, PA.DDR.B6 = 1
	7	TPU8	TIOCB8_OE	TIOCB8		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG1	PO 23_OE	PO23		NDERL.NDER23 = 1
		SYSC	A7_OE	A7		SYSCR0.EXBE = 1, PA.DDR.B7 = 1

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
PB	0	TPU9	TIOCA9_OE	TIOCA9		TIORH.IOA[3] = 0, TIORH.IOA[1:0] = 01/10/11
		PPG1	PO24_OE	PO24		NDERH.NDER24 = 1
		SYSC	A8_OE	A8		SYSCR0.EXBE = 1, PFCR4.A08E = 1
	1	TPU9	TIOCB9_OE	TIOCB9		TIORH.IOB[3] = 0, TIORH.IOB[1:0] = 01/10/11
		PPG1	PO25_OE	PO25		NDERH.NDER25 = 1
		SYSC	A9_OE	A9		SYSCR0.EXBE = 1, PFCR4.A09E = 1
	2	TPU9	TIOCC9_OE	TIOCC9		TMDR.BFA = 0, TIORL.IOC[3] = 0, TIORL.IOC[1:0] = 01/10/11
		PPG1	PO26_OE	PO26		NDERH.NDER26 = 1
		SYSC	A10_OE	A10		SYSCR0.EXBE = 1, PFCR4.A10E = 1
	3	TPU9	TIOCD9_OE	TIOCD9		TMDR.BFB = 0, TIORL.IOD[3] = 0, TIORL.IOD[1:0] = 01/10/11
		PPG1	PO27_OE	PO27		NDERH.NDER27 = 1
		SYSC	A11_OE	A11		SYSCR0.EXBE = 1, PFCR4.A11E = 1
	4	TPU10	TIOCA10_OE	TIOCA10		TIOR.IOA[3] = 0, TIOR.IOA[1:0] = 01/10/11
		PPG1	PO28_OE	PO28		NDERH.NDER28 = 1
		SYSC	A12_OE	A12		SYSCR0.EXBE = 1, PFCR4.A12E = 1
	5	TPU10	TIOCB10_OE	TIOCB10		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG1	PO29_OE	PO29		NDERH.NDER29 = 1
		SYSC	A13_OE	A13		SYSCR0.EXBE = 1, PFCR4.A13E = 1
	6	TPU11	TIOCA11_OE	TIOCA11		TIOR.IOA[3] = 0, TIORIOA[1:0] = 01/10/11
		PPG1	PO30_OE	PO30		NDERH.NDER30 = 1
		SYSC	A14_OE	A14		SYSCR0.EXBE = 1, PFCR4.A14E = 1
	7	TPU11	TIOCB11_OE	TIOCB11		TIOR.IOB[3] = 0, TIOR.IOB[1:0] = 01/10/11
		PPG1	PO31_OE	PO31		NDERH.NDER31 = 1
		SYSC	A15_OE	A15		SYSCR0.EXBE = 1, PFCR4.A15E = 1

Port		Corresponding Peripheral Module	Signal Name for Setting Output	Output Signal Name	Register Setting for Selection of Signals	Setting for Each Internal Module
PC	0	SYSC	A16_OE	A16		SYSCR0.EXBE = 1, PFCR3.A16E = 1
	1	SYSC	A17_OE	A17		SYSCR0.EXBE = 1, PFCR3.A17E = 1
	2	SYSC	A18_OE	A18		SYSCR0.EXBE = 1, PFCR3.A18E = 1
	3	SYSC	A19_OE	A19		SYSCR0.EXBE = 1, PFCR3.A19E = 1
	4	SYSC	A20_OE	A20		SYSCR0.EXBE = 1, PFCR3.A20E = 1
	5	SYSC	A21_OE	A21		SYSCR0.EXBE = 1, PFCR3.A21E = 1
		SCI5	SCK5_OE	SCK5		When SCMR.SMIF = 1: SMR.GM = 0, SCR.CKE[1:0] = 01 or SMR.GM = 1 When SCMR.SMIF = 0: SMR.CM = 0, SCR.CKE[1:0] = 01 or SMR.CM = 1, SCR.CKE[1] = 0
		SYSC	CS5D_OE	CS5	PFCR1.CS5S[1:0] = 11	SYSCR0.EXBE = 1, PFCR0.CS5E = 1, CS5CNT.EXENB = 1
	6	SYSC	A22_OE	A22		SYSCR0.EXBE = 1, PFCR3.A22E = 1, PC.DDR.B6 = 1
		SYSC	CS6D_OE	CS6	PFCR1.CS6S[1:0] = 11	SYSCR0.EXBE = 1, PFCR0.CS6E = 1, CS6CNT.EXENB = 1
	7	SYSC	A23_OE	A23		SYSCR0.EXBE = 1, PFCR3.A23E = 1, PC.DDR.B7 = 1
		SCI5	TxD5_OE	TxD5		SCR.TE = 1
		SYSC	CS4D_OE	CS4	PFCR1.CS4S[1:0] = 11	SYSCR0.EXBE = 1, PFCR0.CS4E = 1, CS4CNT.EXENB = 1
		SYSC	CS7D_OE	CS7	PFCR1.CS7S[1:0] = 11	SYSCR0.EXBE = 1, PFCR0.CS7E = 1, CS7CNT.EXENB = 1
PD	0	SYSC	D0_E	D0		SYSCR0.EXBE = 1
	1	SYSC	D1_E	D1		SYSCR0.EXBE = 1
	2	SYSC	D2_E	D2		SYSCR0.EXBE = 1
	3	SYSC	D3_E	D3		SYSCR0.EXBE = 1
	4	SYSC	D4_E	D4		SYSCR0.EXBE = 1
	5	SYSC	D5_E	D5		SYSCR0.EXBE = 1
	6	SYSC	D6_E	D6		SYSCR0.EXBE = 1
	7	SYSC	D7_E	D7		SYSCR0.EXBE = 1
PE	0	SYSC,BSC	D8_E	D8		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	1	SYSC,BSC	D9_E	D9		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	2	SYSC,BSC	D10_E	D10		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	3	SYSC,BSC	D11_E	D11		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	4	SYSC,BSC	D12_E	D12		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	5	SYSC,BSC	D13_E	D13		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	6	SYSC,BSC	D14_E	D14		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1
	7	SYSC,BSC	D15_E	D15		SYSCR0.EXBE = 1, CSnCNT.BSIZE[1:0] = 00, PFCR5.DHE = 1

Table 14.9 Pin Functions in Each Operating Mode

		P5				P6		P7	PA	PB	PC		PD	PE	PF	PG	PH
Selection of Operating Modes	**Operating Mode**	**b7**	**b3**	**b2**	**b1, b0**	**b4 to b1**	**b0**	**b1, b0**	**b7 to b0**	**b7 to b0**	**b7 to b5**	**b4 to b0**	**b7 to b0**	**b7 to b0**	**b6 to b0**	**b7 to b0**	**b7 to b0**
Selection by he mode pins	Boot mode	P	P*/C	P	P	P	P	P	P	P	P	P	P	P	P	P	P
	User boot mode	P	P*/C	P	P	P	P	P	P	P	P	P	P	P	P	P	P
	Single-chip mode	P	P*/C	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Transition by he register	Single-chip mode	P	P/C	P	P	P	P	P	P	P	P	P	P	P	P	P	P
	Expansion mode with on-chip ROM enabled	P/C	P/C	P/C	P/C	P/C	P/C	P/C	A	P/A	P/A/C	P/A	P/D	P/D	P	P	P
	Expansion mode with on-chip ROM disabled	P/C	P/C	P/C	P/C	P/C	P/C	P/C	A	P/A	P/A/C	P/A	P/D	P/D	P	P	P

[Legend] P: I/O pin, A: Address bus output, D: Data bus output, C: Control signals, clock input/output, *: After reset

14.5 Treatment of Unused Pins

The treatment of unused pins is listed in table 14.10.

Table 14.10 Treatment of Unused Pins

Pin Name	Expansion Mode with On-Chip ROM Disabled (16-Bit Bus Width)	Expansion Mode with On-Chip ROM Disabled (8-Bit Bus Width)	Expansion Mode with On-Chip ROM Enabled	Single-Chip Mode
EMLE	Connect this pin to Vss via a pull-down resistor.			
MD1 to MD0	(Always used as mode pins)			
MDE	(Always used as mode pins)			
NMI	Connect this pin to Vcc via a pull-up resistor.			
EXTAL	(Always used as a clock pin)			
XTAL	Leave this pin open.			
WDTOVF#	Leave this pin open.			
Ports 0 to 4, P57 to P54, P67 to P61, Ports 7 to 9, PC7 to PC5	Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor, respectively. These pins can be left while Pm.ICR is in the initial state (the input buffer disabled)*.			
P53	• Connect this pin to Vcc via a pull-up resistor or to Vss via a pull-down resistor. • This pin can be left while Pm.ICR is in the initial state (the input buffer disabled)*.			• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor, respectively. • These pins can be left while Pm.ICR is in the initial state (the input buffer disabled)*
P52	This pin is left open for the RD# output.			
P51	• Connect this pin to Vcc via a pull-up resistor or to Vss via a pull-down resistor. • This pin can be left while Pm.ICR is in the initial state (the input buffer disabled)*.			
P50	This pin is left open for the WR0#/WR# output.			
P60, Ports A and B, PC4 to PC0	• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor. • These pins can be left while Pm.ICR is in the initial state (the input buffer disabled)*.			
Port D	(Used as a data bus)			• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor, respectively.
Port E	(Used as a data bus)	• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor, respectively, for the general input in the initial state. • These pins can be left while Pm.ICR is in the initial state (the input buffer disabled)*		
Port F Port G Port H	• Connect these pins to Vcc via a pull-up resistor or to Vss via a pull-down resistor. • These pins can be left while Pm.ICR is in the initial state (the input buffer disabled)*.			
VREFH	Connect this pin to AVcc			

Note: * Do not change the initial value of Pm.ICR. Changing the initial value may generate shoot-through current.

14.6 Usage Notes

14.6.1 Setting the Input Buffer Control Register (Pm.ICR)

Changes to Pm.ICR settings can lead to the generation of internal edges, depending on the setting and the pin states at the time it is made. Change the setting of a Pm.ICR while the input signal from the pins is fixed to the high level or, if a peripheral function has been assigned to a pin, while the input function is disabled.

If a Pm.ICR setting enables an input buffer, and several input functions have been allocated to the corresponding pin, the pin state is reflected in the values of all of the input signals. Thus, even for input functions that are not in use, attention must be paid to the settings of the corresponding peripheral modules.

If a pin is being used as an output pin, the output value is taken in as the pin state when the input buffer is enabled by a Pm.ICR setting. For pins being used as output pins, disable the input buffer by setting the corresponding bits in the given Pm.ICR.

14.6.2 Setting the Port Function Control Register (PFCRn)

Each PFCRn controls an I/O port. When setting input or output functions for individual pins, select a pin for the input or output and then enable or disable the input or output function.

If the levels for a pin before and after it has been switched to operate as an input differ from each other, an internal edge is generated. This may lead to operation that was not intended. To avoid this, follow the procedure below when switching a pin to input operation.

(1) Disable the input in the peripheral module settings that correspond to functions of the pin to be switched.

(2) Make the PFCRn setting to select input operation for the pin.

(3) Enable the input in the peripheral module settings that correspond to functions of the pin to be switched.

A single pin function may correspond to a pin selection bit for changing a pin for the input or output and a pin enable bit for enabling a pin function. In such cases, set the pin for the input or output and then set the enable bit to enable the pin function.

14.6.3 Port Setting when A/D Converter Input is Used

If any of a pin in ports 4 and 9 is used as an A/D converter input, use other pins in ports 4 and 9, that are not used for A/D converter input, as input pin or interrupt input by setting P4.DDR.Bj = 0 and P9.DDR.Bj = 0.

15. 16-Bit Timer Pulse Unit (TPU)

The RX610 Group has two on-chip 16-bit timer pulse units (TPU), unit 0 and unit 1, each comprising six channels. Therefore, this LSI includes twelve channels (TPU0 to TPU11).

15.1 Overview

Specifications of the TPU are shown in table 15.1. Functions of TPU (unit 0) and TPU (unit 1) are shown in table 15.2 and table 15.3, respectively.

Block diagrams of TPU (unit 0) and TPU (unit 1) are shown in figure 15.1 and figure 15.2, respectively.

Table 15.1 Specifications of TPU

Item	Description
Pulse input/output	Maximum 16
Count clock	Seven or eight types are provided for each channel.
Settable operations	• Waveform output at compare match • Input capture function • Counter clear operation • Simultaneous writing to multiple timer counters (TCNT) • Simultaneous clearing by compare match and input capture • Simultaneous input/output for registers by counter synchronous operation • Maximum of 15-phase PWM output by combination with synchronous operation • Cascaded operation
Channels 0 and 3	Buffer operation can be set.
Channels 1, 2, 4, and 5	Phase counting mode can be set independently.
Interrupt source	26 sources
Buffer operation	Automatic transfer of register data
Generation of trigger	Programmable pulse generator (PPG) output trigger can be generated. Conversion start trigger for the A/D converter can be generated.
Power-down function	Module stop state can be set for each unit.

Table 15.2 TPU (Unit 0) Functions

Item		TPU0	TPU1	TPU2	TPU3	TPU4	TPU5
Count clock		PCLK/1 PCLK/4 PCLK/16 PCLK/64 TCLKA TCLKB TCLKC TCLKD	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/256 TCLKA TCLKB	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/1024 TCLKA TCLKB TCLKC	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/256 PCLK/1024 PCLK/4096 TCLKA	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/1024 TCLKA TCLKC	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/256 TCLKA TCLKC TCLKD
Timer general registers (TGRy) (y = A to D)		TGRA TGRB TGRC*[1] TGRD*[1]	TGRA TGRB	TGRA TGRB	TGRA TGRB TGRC*[1] TGRD*[1]	TGRA TGRB	TGRA TGRB
I/O pins		TIOCA0 TIOCB0 TIOCC0 TIOCD0	TIOCA1 TIOCB1	TIOCA2 TIOCB2	TIOCA3 TIOCB3 TIOCC3 TIOCD3	TIOCA4 TIOCB4	TIOCA5 TIOCB5
Counter clear function		TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture
Compare match output	Low output	Possible	Possible	Possible	Possible	Possible	Possible
	High output	Possible	Possible	Poss ble	Possible	Possible	Possible
	Toggle output	Possible	Possible	Poss ble	Possible	Possible	Possible
Input capture function		Poss ble	Possible	Possible	Poss ble	Poss ble	Possible
Synchronous operation		Poss ble	Possible	Possible	Poss ble	Poss ble	Possible
PWM mode		Poss ble	Possible	Possible	Poss ble	Possible	Possible
Phase counting mode		Not possible	Possible	Possible	Not possible	Possible	Possible
Buffer operation		Poss ble	Not possible	Not possible	Poss ble	Not possible	Not poss ble
DTC activation		TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture

Item	TPU0	TPU1	TPU2	TPU3	TPU4	TPU5
DMAC activation	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture
A/D conversion start trigger	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture
	TGRA to TGRD compare match or input capture	Not possible	Not possible	Not poss ble	Not possible	Not possible
PPG trigger	TGRA/TGRB compare match or input capture	TGRA/TGRB compare match or input capture	TGRA/TGRB compare match or input capture	TGRA/TGRB compare match or input capture	Not poss ble	Not poss ble
Interrupt sources	5 sources • Compare match or input capture 0A • Compare match or input capture 0B • Compare match or input capture 0C • Compare match or input capture 0D • Overflow	4 sources • Compare match or input capture 1A • Compare match or input capture 1B • Overflow • Underflow	4 sources • Compare match or input capture 2A • Compare match or input capture 2B • Overflow • Underflow	5 sources • Compare match or input capture 3A • Compare match or input capture 3B • Compare match or input capture 3C • Compare match or input capture 3D • Overflow	4 sources • Compare match or input capture 4A • Compare match or input capture 4B • Overflow • Underflow	4 sources • Compare match or input capture 5A • Compare match or input capture 5B • Overflow • Underflow
Module stop setting*2	MSTPA13 bit in MSTPCRA					

Notes: 1. TGRC and TGRD can be set as a buffer register.

2. For details, see section 8, Low Power Consumption.

Table 15.3 TPU (Unit 1) Functions

Item		TPU6	TPU7	TPU8	TPU9	TPU10	TPU11
Count clock		PCLK/1 PCLK/4 PCLK/16 PCLK/64 TCLKE TCLKF TCLKG TCLKH	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/256 TCLKE TCLKF	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/1024 TCLKE TCLKF TCLKG	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/256 PCLK/1024 PCLK/4096 TCLKE	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/1024 TCLKE TCLKG	PCLK/1 PCLK/4 PCLK/16 PCLK/64 PCLK/256 TCLKE TCLKG TCLKH
Timer general registers (TGRy) (y = A to D)		TGRA TGRB TGRC*[1] TGRD*[1]	TGRA TGRB	TGRA TGRB	TGRA TGRB TGRC*[1] TGRD*[1]	TGRA TGRB	TGRA TGRB
I/O pins		TIOCA6 TIOCB6 TIOCC6 TIOCD6	TIOCA7 TIOCB7	TIOCA8 TIOCB8	TIOCA9 TIOCB9 TIOCC9 TIOCD9	TIOCA10 TIOCB10	TIOCA11 TIOCB11
Counter clear function		TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture
Compare match output	Low output	Possible	Possible	Possible	Poss ble	Possible	Possible
	High output	Possible	Possible	Possible	Poss ble	Possible	Possible
	Toggle output	Possible	Possible	Possible	Possible	Possible	Possible
Input capture function		Possible	Possible	Possible	Possible	Possible	Poss ble
Synchronous operation		Possible	Possible	Possible	Possible	Possible	Poss ble
PWM mode		Possible	Possible	Possible	Possible	Possible	Poss ble
Phase counting mode		Not possible	Possible	Possible	Not possible	Possible	Poss ble
Buffer operation		Possible	Not poss ble	Not possible	Possible	Not possible	Not possible
DTC activation		TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture	TGRy compare match or input capture

Item	TPU6	TPU7	TPU8	TPU9	TPU10	TPU11
DMAC activation	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture
A/D conversion start trigger	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture	TGRA compare match or input capture
PPG trigger	TGRA/TGRB compare match	TGRA/TGRB compare match	TGRA/TGRB compare match	TGRA/TGRB compare match	Not possible	Not possible
Interrupt sources	5 sources • Compare match or input capture 6A • Compare match or input capture 6B • Compare match or input capture 6C • Compare match or input capture 6D • Overflow	4 sources • Compare match or input capture 7A • Compare match or input capture 7B • Overflow • Underflow	4 sources • Compare match or input capture 8A • Compare match or input capture 8B • Overflow • Underflow	5 sources • Compare match or input capture 9A • Compare match or input capture 9B • Compare match or input capture 9C • Compare match or input capture 9D • Overflow	4 sources • Compare match or input capture 10A • Compare match or input capture 10B • Overflow • Underflow	4 sources • Compare match or input capture 11A • Compare match or input capture 11B • Overflow • Underflow
Module stop setting*2	MSTPA12 bit in MSTPCRA					

Notes: 1. TGRC and TGRD can be set as a buffer register.

2. For details, see section 8, Low Power Consumption.

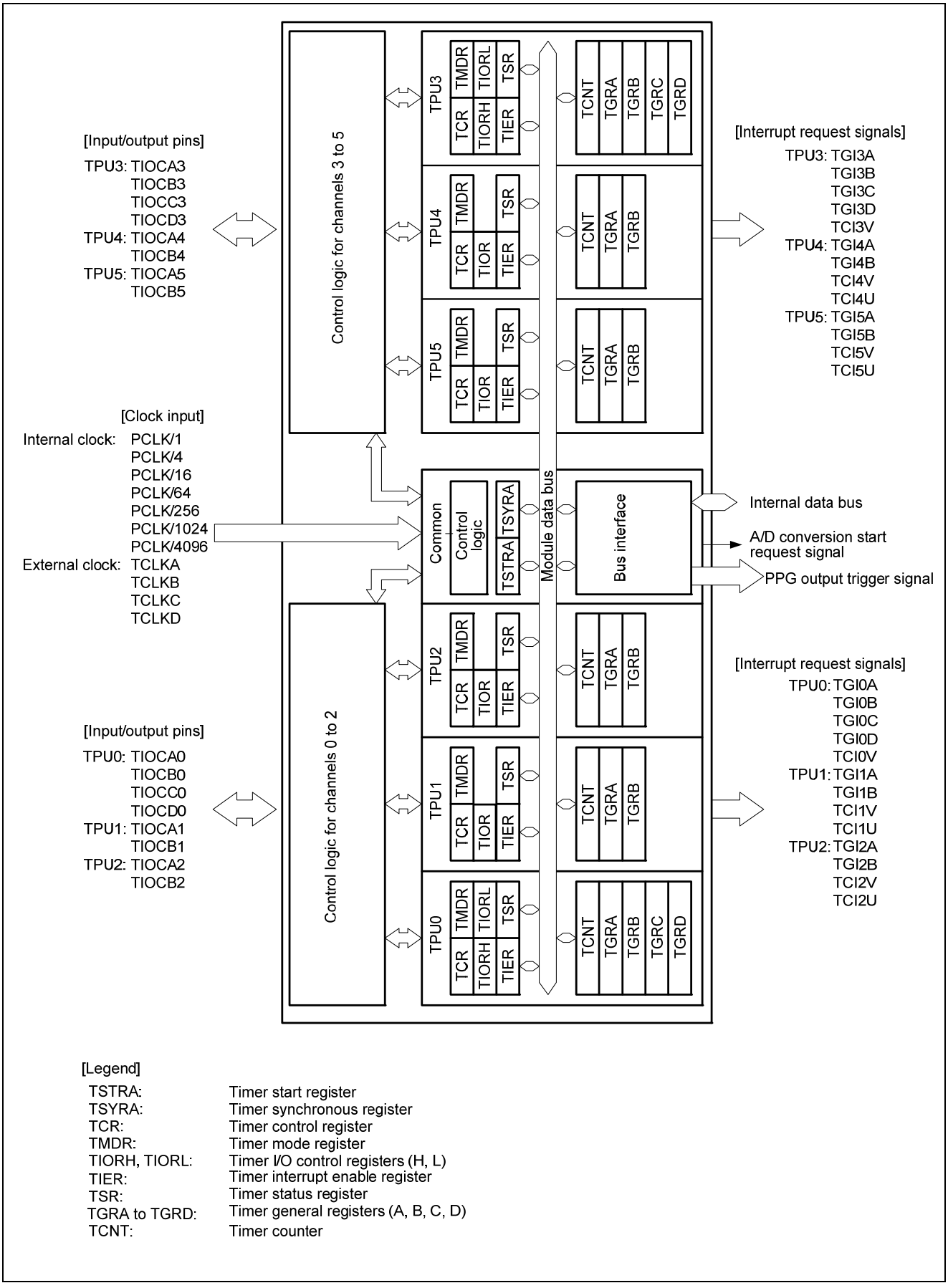


Figure 15.1 Block Diagram of TPU (Unit 0)

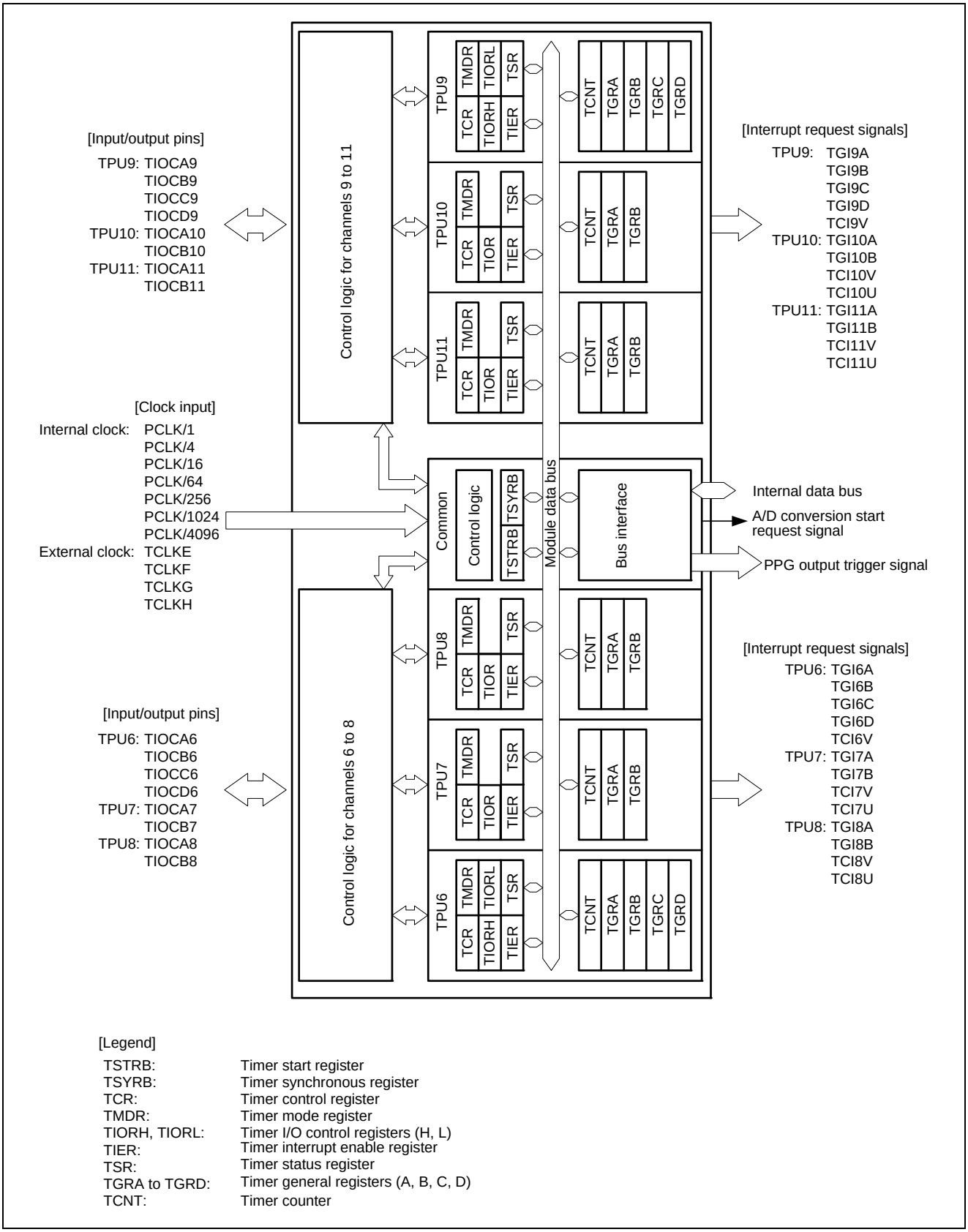


Figure 15.2 Block Diagram of TPU (Unit 1)

Table 15.4 lists the input/output pins of the TPU.

Table 15.4 Pin Configuration of TPU

Unit	Channel	Pin Name	I/O	Description
Unit 0	All	TCLKA	Input	External clock A input pin (TPU1 and TPU5 phase counting mode A phase input)
		TCLKB	Input	External clock B input pin (TPU1 and TPU5 phase counting mode B phase input)
		TCLKC	Input	External clock C input pin (TPU2 and TPU4 phase counting mode A phase input)
		TCLKD	Input	External clock D input pin (TPU2 and TPU4 phase counting mode B phase input)
	TPU0	TIOCA0	I/O	TPU0.TGRA input capture input/output compare output/PWM output pin
		TIOCB0	I/O	TPU0.TGRB input capture input/output compare output/PWM output pin
		TIOCC0	I/O	TPU0.TGRC input capture input/output compare output/PWM output pin
		TIOCD0	I/O	TPU0.TGRD input capture input/output compare output/PWM output pin
	TPU1	TIOCA1	I/O	TPU1.TGRA input capture input/output compare output/PWM output pin
		TIOCB1	I/O	TPU1.TGRB input capture input/output compare output/PWM output pin
	TPU2	TIOCA2	I/O	TPU2.TGRA input capture input/output compare output/PWM output pin
		TIOCB2	I/O	TPU2.TGRB input capture input/output compare output/PWM output pin
	TPU3	TIOCA3	I/O	TPU3.TGRA input capture input/output compare output/PWM output pin
		TIOCB3	I/O	TPU3.TGRB input capture input/output compare output/PWM output pin
		TIOCC3	I/O	TPU3.TGRC input capture input/output compare output/PWM output pin
		TIOCD3	I/O	TPU3.TGRD input capture input/output compare output/PWM output pin
	TPU4	TIOCA4	I/O	TPU4.TGRA input capture input/output compare output/PWM output pin
		TIOCB4	I/O	TPU4.TGRB input capture input/output compare output/PWM output pin
	TPU5	TIOCA5	I/O	TPU5.TGRA input capture input/output compare output/PWM output pin
		TIOCB5	I/O	TPU5.TGRB input capture input/output compare output/PWM output pin
Unit 1	All	TCLKE	Input	External clock E input pin (TPU7 and TPU11 phase counting mode A phase input)
		TCLKF	Input	External clock F input pin (TPU7 and TPU11 phase counting mode B phase input)
		TCLKG	Input	External clock G input pin (TPU8 and TPU10 phase counting mode A phase input)
		TCLKH	Input	External clock H input pin (TPU8 and TPU10 phase counting mode B phase input)
	TPU6	TIOCA6	I/O	TPU6.TGRA input capture input/output compare output/PWM output pin
		TIOCB6	I/O	TPU6.TGRB input capture input/output compare output/PWM output pin
		TIOCC6	I/O	TPU6.TGRC input capture input/output compare output/PWM output pin
		TIOCD6	I/O	TPU6.TGRD input capture input/output compare output/PWM output pin
	TPU7	TIOCA7	I/O	TPU7.TGRA input capture input/output compare output/PWM output pin
		TIOCB7	I/O	TPU7.TGRB input capture input/output compare output/PWM output pin
	TPU8	TIOCA8	I/O	TPU8.TGRA input capture input/output compare output/PWM output pin
		TIOCB8	I/O	TPU8.TGRB input capture input/output compare output/PWM output pin
	TPU9	TIOCA9	I/O	TPU9.TGRA input capture input/output compare output/PWM output pin
		TIOCB9	I/O	TPU9.TGRB input capture input/output compare output/PWM output pin
		TIOCC9	I/O	TPU9.TGRC input capture input/output compare output/PWM output pin
		TIOCD9	I/O	TPU9.TGRD input capture input/output compare output/PWM output pin
	TPU10	TIOCA10	I/O	TPU10.TGRA input capture input/output compare output/PWM output pin
		TIOCB10	I/O	TPU10.TGRB input capture input/output compare output/PWM output pin
	TPU11	TIOCA11	I/O	TPU11.TGRA input capture input/output compare output/PWM output pin
		TIOCB11	I/O	TPU11.TGRB input capture input/output compare output/PWM output pin

15.2 Register Descriptions

Table 15.5 lists the registers of the TPU.

Table 15.5 Registers of TPU

Unit	Channel	Register Name	Symbol	Value after Reset	Address	Access Size
Unit 0	TPU0	Timer control register	TCR	00h	0008 8110h	8
		Timer mode register	TMDR	00h	0008 8111h	8
		Timer I/O control register H	TIORH	00h	0008 8112h	8
		Timer I/O control register L	TIORL	00h	0008 8113h	8
		Timer interrupt enable register	TIER	40h	0008 8114h	8
		Timer status register	TSR	xxh	0008 8115h	8
		Timer counter	TCNT	0000h	0008 8116h	16
		Timer general register A	TGRA	FFFFh	0008 8118h	16
		Timer general register B	TGRB	FFFFh	0008 811Ah	16
		Timer general register C	TGRC	FFFFh	0008 811Ch	16
		Timer general register D	TGRD	FFFFh	0008 811Eh	16
	TPU1	Timer control register	TCR	00h	0008 8120h	8
		Timer mode register	TMDR	00h	0008 8121h	8
		Timer I/O control register	TIOR	00h	0008 8122h	8
		Timer interrupt enable register	TIER	40h	0008 8124h	8
		Timer status register	TSR	xxh	0008 8125h	8
		Timer counter	TCNT	0000h	0008 8126h	16
		Timer general register A	TGRA	FFFFh	0008 8128h	16
		Timer general register B	TGRB	FFFFh	0008 812Ah	16
	TPU2	Timer control register	TCR	00h	0008 8130h	8
		Timer mode register	TMDR	00h	0008 8131h	8
		Timer I/O control register	TIOR	00h	0008 8132h	8
		Timer interrupt enable register	TIER	40h	0008 8134h	8
		Timer status register	TSR	xxh	0008 8135h	8
		Timer counter	TCNT	0000h	0008 8136h	16
		Timer general register A	TGRA	FFFFh	0008 8138h	16
		Timer general register B	TGRB	FFFFh	0008 813Ah	16
	TPU3	Timer control register	TCR	00h	0008 8140h	8
		Timer mode register	TMDR	00h	0008 8141h	8
		Timer I/O control register H	TIORH	00h	0008 8142h	8
		Timer I/O control register L	TIORL	00h	0008 8143h	8
		Timer interrupt enable register	TIER	40h	0008 8144h	8
		Timer status register	TSR	xxh	0008 8145h	8
		Timer counter	TCNT	0000h	0008 8146h	16
		Timer general register A	TGRA	FFFFh	0008 8148h	16
		Timer general register B	TGRB	FFFFh	0008 814Ah	16
		Timer general register C	TGRC	FFFFh	0008 814Ch	16
		Timer general register D	TGRD	FFFFh	0008 814Eh	16

Unit	Channel	Register Name	Symbol	Value after Reset	Address	Access Size
Unit 0	TPU4	Timer control register	TCR	00h	0008 8150h	8
		Timer mode register	TMDR	00h	0008 8151h	8
		Timer I/O control register	TIOR	00h	0008 8152h	8
		Timer interrupt enable register	TIER	40h	0008 8154h	8
		Timer status register	TSR	xxh	0008 8155h	8
		Timer counter	TCNT	0000h	0008 8156h	16
		Timer general register A	TGRA	FFFFh	0008 8158h	16
		Timer general register B	TGRB	FFFFh	0008 815Ah	16
	TPU5	Timer control register	TCR	00h	0008 8160h	8
		Timer mode register	TMDR	00h	0008 8161h	8
		Timer I/O control register	TIOR	00h	0008 8162h	8
		Timer interrupt enable register	TIER	40h	0008 8164h	8
		Timer status register	TSR	xxh	0008 8165h	8
		Timer counter	TCNT	0000h	0008 8166h	16
		Timer general register A	TGRA	FFFFh	0008 8168h	16
		Timer general register B	TGRB	FFFFh	0008 816Ah	16
	All	Timer start register	TSTRA	00h	0008 8100h	8
		Timer synchronous register	TSYRA	00h	0008 8101h	8
Unit 1	TPU6	Timer control register	TCR	00h	0008 8180h	8
		Timer mode register	TMDR	00h	0008 8181h	8
		Timer I/O control register H	TIORH	00h	0008 8182h	8
		Timer I/O control register L	TIORL	00h	0008 8183h	8
		Timer interrupt enable register	TIER	40h	0008 8184h	8
		Timer status register	TSR	xxh	0008 8185h	8
		Timer counter	TCNT	0000h	0008 8186h	16
		Timer general register A	TGRA	FFFFh	0008 8188h	16
		Timer general register B	TGRB	FFFFh	0008 818Ah	16
		Timer general register C	TGRC	FFFFh	0008 818Ch	16
		Timer general register D	TGRD	FFFFh	0008 818Eh	16
	TPU7	Timer control register	TCR	00h	0008 8190h	8
		Timer mode register	TMDR	00h	0008 8191h	8
		Timer I/O control register	TIOR	00h	0008 8192h	8
		Timer interrupt enable register	TIER	40h	0008 8194h	8
		Timer status register	TSR	xxh	0008 8195h	8
		Timer counter	TCNT	0000h	0008 8196h	16
		Timer general register A	TGRA	FFFFh	0008 8198h	16
		Timer general register B	TGRB	FFFFh	0008 819Ah	16

Unit	Channel	Register Name	Symbol	Value after Reset	Address	Access Size
Unit 1	TPU8	Timer control register	TCR	00h	0008 81A0h	8
		Timer mode register	TMDR	00h	0008 81A1h	8
		Timer I/O control register	TIOR	00h	0008 81A2h	8
		Timer interrupt enable register	TIER	40h	0008 81A4h	8
		Timer status register	TSR	xxh	0008 81A5h	8
		Timer counter	TCNT	0000h	0008 81A6h	16
		Timer general register A	TGRA	FFFFh	0008 81A8h	16
		Timer general register B	TGRB	FFFFh	0008 81AAh	16
	TPU9	Timer control register	TCR	00h	0008 81B0h	8
		Timer mode register	TMDR	00h	0008 81B1h	8
		Timer I/O control register H	TIORH	00h	0008 81B2h	8
		Timer I/O control register L	TIORL	00h	0008 81B3h	8
		Timer interrupt enable register	TIER	40h	0008 81B4h	8
		Timer status register	TSR	xxh	0008 81B5h	8
		Timer counter	TCNT	0000h	0008 81B6h	16
		Timer general register A	TGRA	FFFFh	0008 81B8h	16
		Timer general register B	TGRB	FFFFh	0008 81BAh	16
		Timer general register C	TGRC	FFFFh	0008 81BCh	16
		Timer general register D	TGRD	FFFFh	0008 81BEh	16
	TPU10	Timer control register	TCR	00h	0008 81C0h	8
		Timer mode register	TMDR	00h	0008 81C1h	8
		Timer I/O control register	TIOR	00h	0008 81C2h	8
		Timer interrupt enable register	TIER	40h	0008 81C4h	8
		Timer status register	TSR	xxh	0008 81C5h	8
		Timer counter	TCNT	0000h	0008 81C6h	16
		Timer general register A	TGRA	FFFFh	0008 81C8h	16
		Timer general register B	TGRB	FFFFh	0008 81CAh	16
	TPU11	Timer control register	TCR	00h	0008 81D0h	8
		Timer mode register	TMDR	00h	0008 81D1h	8
		Timer I/O control register	TIOR	00h	0008 81D2h	8
		Timer interrupt enable register	TIER	40h	0008 81D4h	8
		Timer status register	TSR	xxh	0008 81D5h	8
		Timer counter	TCNT	0000h	0008 81D6h	16
		Timer general register A	TGRA	FFFFh	0008 81D8h	16
		Timer general register B	TGRB	FFFFh	0008 81DAh	16
	All	Timer start register	TSTRB	00h	0008 8170h	8
		Timer synchronous register	TSYRB	00h	0008 8171h	8

15.2.1 Timer Control Register (TCR)

Addresses: TPU0.TCR 0008 8110h、TPU1.TCR 0008 8120h、TPU2.TCR 0008 8130h
TPU3.TCR 0008 8140h、TPU4.TCR 0008 8150h、TPU5.TCR 0008 8160h
TPU6.TCR 0008 8180h、TPU7.TCR 0008 8190h、TPU8.TCR 0008 81A0h
TPU9.TCR 0008 81B0h、TPU10.TCR 0008 81C0h、TPU11.TCR 0008 81D0h

	b7	b6	b5	b4	b3	b2	b1	b0
	CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	TPSC[2:0]	Timer Prescaler Select	See tables 15.6 to 15.11.	R/W
b4, b3	CKEG[1:0]	Input Clock Edge Select	See table 15.12.	R/W
b7 to b5	CCLR[2:0]*	Counter Clear Source Select	See tables 15.13 and 15.14.	R/W

Note: * Bit 7 in TCR of TPU1, TPU2, TPU4, and TPU5 of unit 0 and bit 7 in TCR of TPU7, TPU8, TPU10, and TPU11 of unit 1 are reserved. These bits are read as 0. The write value should always be 0.

The TPU has twelve TCR registers, one for each channel.

TPUm.TCR controls TPUm.TCNT counter of each channel.

TPUm.TCR settings should be made while TPUm.TCNT counter operation is stopped.

TPSC[2:0] Bits (Timer Prescaler Select)

These bits select the TCNT counter clock. The clock source can be selected independently for each channel.

To select the external clock as the clock source, set the bit in the data direction register (DDR) for the corresponding pin to 0 (input port), and set the bit in the input buffer control register (ICR) to 1 (input buffer of the corresponding pin is enabled). For details, see section 14, I/O Ports.

CKEG[1:0] Bits (Input Clock Edge Select)

These bits select the input clock edge.

When the internal clock is counted using both edges, the input clock period is halved (e.g. PCLK/4 both edges = PCLK/2 rising edge).

Internal clock edge selection is valid when the input clock is PCLK/4 or slower. This setting is ignored if the input clock is PCLK/1, or when overflow/underflow of another channel is selected.

CCLR[2:0] Bits (Counter Clear Source Select)

These bits select the TCNT counter clearing source.

Table 15.6 Bits TPSC[2:0] (TPU0, TPU6)

	Bits TPSC[2:0]			
Channel	**b2**	**b1**	**b0**	**Description**
TPU0 (unit 0)	0	0	0	Internal clock: counts on PCLK/1
TPU6 (unit 1)	0	0	1	Internal clock: counts on PCLK/4
	0	1	0	Internal clock: counts on PCLK/16
	0	1	1	Internal clock: counts on PCLK/64
	1	0	0	External clock: counts on TCLKA or TCLKE pin input
	1	0	1	External clock: counts on TCLKB or TCLKF pin input
	1	1	0	External clock: counts on TCLKC or TCLKG pin input
	1	1	1	External clock: counts on TCLKD or TCLKH pin input

Table 15.7 Bits TPSC[2:0] (TPU1, TPU7)

	Bits TPSC[2:0]			
Channel	**b2**	**b1**	**b0**	**Description**
TPU1 (unit 0)	0	0	0	Internal clock: counts on PCLK/1
TPU7 (unit 1)	0	0	1	Internal clock: counts on PCLK/4
	0	1	0	Internal clock: counts on PCLK/16
	0	1	1	Internal clock: counts on PCLK/64
	1	0	0	External clock: counts on TCLKA or TCLKE pin input
	1	0	1	External clock: counts on TCLKB or TCLKF pin input
	1	1	0	Internal clock: counts on PCLK/256
	1	1	1	• TPU1 (unit 0) Counts on TPU2.TCNT counter overflow/underflow • TPU7 (unit 1) Counts on TPU8.TCNT counter overflow/underflow

Note: This setting is invalid when TPU1 or TPU7 is in phase counting mode.

Table 15.8 Bits TPSC[2:0] (TPU2, TPU8)

	Bits TPSC[2:0]			
Channel	**b2**	**b1**	**b0**	**Description**
TPU2 (unit 0)	0	0	0	Internal clock: counts on PCLK/1
TPU8 (unit 1)	0	0	1	Internal clock: counts on PCLK/4
	0	1	0	Internal clock: counts on PCLK/16
	0	1	1	Internal clock: counts on PCLK/64
	1	0	0	External clock: counts on TCLKA or TCLKE pin input
	1	0	1	External clock: counts on TCLKB or TCLKF pin input
	1	1	0	External clock: counts on TCLKC or TCLKG pin input
	1	1	1	Internal clock: counts on PCLK/1024

Note: This setting is invalid when TPU2 or TPU8 is in phase counting mode.

Table 15.9 Bits TPSC[2:0] (TPU3, TPU9)

	Bits TPSC[2:0]			
Channel	**b2**	**b1**	**b0**	**Description**
TPU3 (unit 0)	0	0	0	Internal clock: counts on PCLK/1
TPU9 (unit 1)	0	0	1	Internal clock: counts on PCLK/4
	0	1	0	Internal clock: counts on PCLK/16
	0	1	1	Internal clock: counts on PCLK/64
	1	0	0	External clock: counts on TCLKA or TCLKE pin input
	1	0	1	Internal clock: counts on PCLK/1024
	1	1	0	Internal clock: counts on PCLK/256
	1	1	1	Internal clock: counts on PCLK/4096

Table 15.10 Bits TPSC[2:0] (TPU4, TPU10)

	Bits TPSC[2:0]			
Channel	**b2**	**b1**	**b0**	**Description**
TPU4 (unit 0)	0	0	0	Internal clock: counts on PCLK/1
TPU10 (unit 1)	0	0	1	Internal clock: counts on PCLK/4
	0	1	0	Internal clock: counts on PCLK/16
	0	1	1	Internal clock: counts on PCLK/64
	1	0	0	External clock: counts on TCLKA or TCLKE pin input
	1	0	1	External clock: counts on TCLKC or TCLKG pin input
	1	1	0	Internal clock: counts on PCLK/1024
	1	1	1	• TPU4 (unit 0) Counts on TPU5.TCNT counter overflow/underflow • TPU10 (unit 1) Counts on TPU11.TCNT counter overflow/underflow

Note: This setting is invalid when TPU4 or TPU10 is in phase counting mode.

Table 15.11 Bits TPSC[2:0] (TPU5, TPU11)

	Bits TPSC[2:0]			
Channel	**b2**	**b1**	**b0**	**Description**
TPU5 (unit 0)	0	0	0	Internal clock: counts on PCLK/1
TPU11 (unit 1)	0	0	1	Internal clock: counts on PCLK/4
	0	1	0	Internal clock: counts on PCLK/16
	0	1	1	Internal clock: counts on PCLK/64
	1	0	0	External clock: counts on TCLKA or TCLKE pin input
	1	0	1	External clock: counts on TCLKC or TCLKG pin input
	1	1	0	Internal clock: counts on PCLK/256
	1	1	1	External clock: counts on TCLKD pin input

Note: This setting is invalid when TPU5 or TPU11 is in phase counting mode.

Table 15.12 Bits CKEG[1:0]

Bits CKEG[1:0]		Input Clock	
b4	**b3**	**Internal Clock**	**External clock**
0	0	Counted at falling edge	Counted at rising edge
0	1	Counted at rising edge	Counted at falling edge
1	0	Counted at both edges	Counted at both edges
1	1	Counted at both edges	Counted at both edges

Table 15.13 Bits CCLR[2:0] (TPU0, TPU3, TPU6, TPU9)

	Bits CCLR[2:0]			
Channel	**b7**	**b6**	**b5**	**Description**
(Unit 0) TPU0, TPU3	0	0	0	TCNT counter clearing disabled
	0	0	1	TCNT counter cleared by TGRA compare match/input capture
	0	1	0	TCNT counter cleared by TGRB compare match/input capture
(Unit 1) TPU6, TPU9	0	1	1	TCNT counter cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*1
	1	0	0	TCNT counter clearing disabled
	1	0	1	TCNT counter cleared by TGRC compare match/input capture*1
	1	1	0	TCNT counter cleared by TGRD compare match/input capture*1
	1	1	1	TCNT counter cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*2

Notes: 1. When TGRC or TGRD is used as a buffer register, TCNT counter is not cleared because the buffer register setting has priority, and compare match/input capture does not occur.

2. Synchronous operation is selected by setting the SYNCi bit (i = 0, 3) bit in TSYRm (m = A, B) to 1.

Table 15.14 Bits CCLR[2:0] (TPU1, TPU2, TPU4, TPU5, TPU7, TPU8, TPU10, TPU11)

	Bits CCLR[2:0]*1			
Channel	**b7**	**b6**	**b5**	**Description**
(Unit 0) TPU1, TPU2, TPU4, TPU5	0	0	0	TCNT counter clearing disabled
	0	0	1	TCNT counter cleared by TGRA compare match/input capture
	0	1	0	TCNT counter cleared by TGRB compare match/input capture
(Unit 1) TPU7, TPU8, TPU10, TPU11	0	1	1	TCNT counter cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*2
	1	0	0	Setting proh bited
	1	0	1	Setting proh bited
	1	1	0	Setting proh bited
	1	1	1	Setting proh bited

Notes: 1. Bit 7 in TCR of TPU1, TPU2, TPU4, and TPU5 of unit 0 and bit 7 in TCR of TPU7, TPU8, TPU10, and TPU11 of unit 1 are reserved. These bits are read as 0. The write value should always be 0.

2. Synchronous operation is selected by setting the SYNCi bit (i = 1, 2, 4, 5) bit in TSYRm (m = A, B) to 1.

15.2.2 Timer Mode Register (TMDR)

Addresses: TPU0.TMDR 0008 8111h, TPU1.TMDR 0008 8121h, TPU2.TMDR 0008 8131h
TPU3.TMDR 0008 8141h, PU4.TMDR 0008 8151h, TPU5.TMDR 0008 8161h
TPU6.TMDR 0008 8181h, TPU7.TMDR 0008 8191h, TPU8.TMDR 0008 81A1h
TPU9.TMDR 0008 81B1h, TPU10.TMDR 0008 81C1h, TPU11.TMDR 0008 81D1h

	b7	b6	b5	b4	b3	b2	b1	b0
	ICSELD	ICSELB	BFB	BFA	MD[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	MD[3:0]	Mode Select	b3*[1] b0 0 0 0 0: Normal operation 0 0 0 1: Setting prohibited 0 0 1 0: PWM mode 1 0 0 1 1: PWM mode 2 0 1 0 0: Phase counting mode 1*[2] 0 1 0 1: Phase counting mode 2*[2] 0 1 1 0: Phase counting mode 3*[2] 0 1 1 1: Phase counting mode 4*[2] (Settings other than above are prohibited.)	R/W
b4	BFA*[3]	Buffer Operation A	0: TPUm.TGRA operates normally 1: TPUm.TGRA and TPUm.TGRC used together for buffer operation (n = 0, 3, 6, 9)	R/W
b5	BFB*[4]	Buffer Operation B	0: TPUm.TGRB operates normally 1: TPUm.TGRB and TPUm.TGRD used together for buffer operation (n = 0, 3, 6, 9)	R/W
b6	ICSELB	TGRB Input Capture Input Select	0: Input capture input source is TIOCBn pin 1: Input capture input source is TIOCAn pin (n = 0 to 11)	R/W
b7	ICSELD*[4]	TGRD Input Capture Input Select	0: Input capture input source is TIOCDn pin 1: Input capture input source is TIOCCn pin (n = 0, 3, 6, 9)	R/W

Notes: 1. Bit 3 is reserved. This bit is always read as 0. The write value should always be 0.

2. Phase counting mode cannot be set for TPU0, TPU3 (unit 0), TPU6, and TPU9 (unit 1). A 0 should always be written to bit 2 for them.

3. Bit 4 of TPU1, TPU2, TPU4, TPU5 (unit 0), TPU7, TPU8, TPU10, and TPU11 (unit 1) that do not have TGRC is reserved. This bit is always read as 0. The write value should always be 0.

4. Bits 5 and 7 of TPU1, TPU2, TPU4, TPU5 (unit 0), TPU7, TPU8, TPU10, and TPU11 (unit 1) that do not have TGRD are reserved. These bits are always read as 0. The write value should always be 0.

The TPU has twelve TMDR registers, one for each channel.

TPUm.TMDR sets the operating mode for each channel.

TPUm.TMDR settings should be made while TPUm.TCNT counter operation is stopped.

MD[3:0] Bits (Mode Select)

Set the timer operating mode.

BFA Bit (Buffer Operation A)

Specifies whether TPUm.TGRA (m = 0, 3, 6, 9) is to normally operate, or TPUm.TGRA and TPUm.TGRC (m = 0, 3, 6, 9) are to be used together for buffer operation.

When TGRC is used as a buffer register, TGRC input capture/output compare is not generated.

BFB Bit (Buffer Operation B)

Specifies whether TPUm.TGRB (m = 0, 3, 6, 9) is to normally operate, or TPUm.TGRB and TPUm.TGRD (m = 0, 3, 6, 9) are to be used together for buffer operation.

When TGRD is used as a buffer register, TGRD input capture/output compare is not generated.

ICSELB Bit (TGRB Input Capture Input Select)

Selects the input capture input for TPUm.TGRB (m = 0 to 11).

This function allows measurement of high-level width and period of the input pulse on a TIOCAn input pin.

ICSELD (TGRD Input Capture Input Select)

Selects the input capture input for TPUm.TGRD (m = 0, 3, 6, 9).

This function allows measurement of high-level width and period of the input pulse on a TIOCCn input pin.

15.2.3 Timer I/O Control Register (TIORH, TIORL, TIOR)

- Unit 0 (TPU0.TIORH, TPU1.TIOR, TPU2.TIOR, TPU3.TIORH, TPU4.TIOR, TPU5.TIOR)
  Unit 1 (TPU6.TIORH, TPU7.TIOR, TPU8.TIOR, TPU9.TIORH, TPU10.TIOR, TPU11.TIOR)

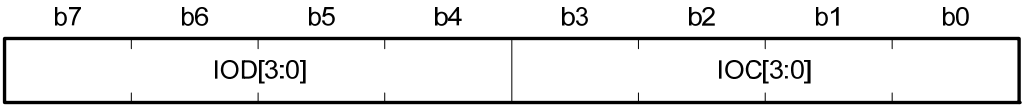
Addresses: TPU0.TIORH 0008 8112h, TPU1.TIOR 0008 8122h, TPU2.TIOR 0008 8132h
TPU3.TIORH 0008 8142h, TPU4.TIOR 0008 8152h, TPU5.TIOR 0008 8162h
TPU6.TIORH 0008 8182h, TPU7.TIOR 0008 8192h, TPU8.TIOR 0008 81A2h
TPU9.TIORH 0008 81B2h, TPU10.TIOR 0008 81C2h, TPU11.TIOR 0008 81D2h

Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	IOA[3:0]	TGRA Control	See tables 15.15 to 15.20.	R/W
b7 to b4	IOB[3:0]	TGRB Control	See tables 15.15 to 15.20.	R/W

- Unit 0 (TPU0.TIORL, TPU3.TIORL)
  Unit 1 (TPU6.TIORL, TPU9.TIORL)

Addresses: TPU0.TIORL 0008 8113h, TPU3.TIORL 0008 8143h
TPU6.TIORL 0008 8183h, TPU9.TIORL 0008 81B3h



Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	IOC[3:0]	TGRC Control	See tables 15.21 and 15.22.	R/W
b7 to b4	IOD[3:0]	TGRD Control	See tables 15.21 and 15.22.	R/W

The TPU has four TIORH registers, one for TPU0, TPU3, TPU6, and TPU9, and four TIORL registers, one for TPU0, TPU3, TPU6, and TPU9, and also has eight TIOR registers, one for TPU1, TPU2, TPU4, TPU5, TPU7, TPU8, TPU10, and TPU11. Thus the TPU has sixteen timer I/O control registers in total.

TIORH, TIORL, and TIOR control registers TGRA, TGRB, TGRC, and TGRD.

Note that TIORH, TIORL, and TIOR are affected by the TMDR setting.

The initial output specified by TIORH, TIORL, and TIOR is valid when the counter is stopped (the CSTj bit (j = 0 to 5) in TSTRm (m = A, B) is cleared to 0). In PWM mode 2, the output at the time when the TCNT counter is cleared to 0 is specified.

When TGRC or TGRD is specified for buffer operation, this setting is invalid and the register operates as a buffer register.

To specify the input capture pin in TIORH, TIORL, or TIOR, set the bit in the data direction register (DDR) for the corresponding pin to 0 (input port), and set the bit in the input buffer control register (ICR) to 1 (input buffer of the corresponding pin is enabled). For details, see section 14, I/O Ports.

IOA[3:0] Bits (TGRA Control)

Select the function of TPUm.TGRA (m = 0 to 11).

IOB[3:0] Bits (TGRB Control)

Select the function of TPUm.TGRB (m = 0 to 11).

IOC[3:0] Bits (TGRC Control)

Select the function of TPUm.TGRC (m = 0, 3, 6, 9).

IOD[3:0] Bits (TGRD Control)

Select the function of TPUm.TGRD (m = 0, 3, 6, 9).

Table 15.15 TPU0.TIORH, TPU6.TIORH

Bits IOA[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRA (m = 0, 6) Function**	**TIOCAn Pin (n = 0, 6) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCAn pin; input capture at rising edge
1	0	0	1		Capture input source is TIOCAn pin; input capture at falling edge
1	0	1	x		Capture input source is TIOCAn pin; input capture at both edges
1	1	x	x		• TPU0 Capture input source is TPU1 count clock Input capture at TPU1.TCNT count-up/count-down*1 • TPU6 Capture input source is TPU7 count clock Input capture at TPU7.TCNT count-up/count-down*1

Bits IOB[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRB (m = 0, 6) Function**	**TIOCBn Pin (n = 0, 6) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCBn or TIOCAn pin*2; input capture at rising edge
1	0	0	1		Capture input source is TIOCBn or TIOCAn pin*2; input capture at falling edge
1	0	1	x		Capture input source is TIOCBn or TIOCAn pin*2; input capture at both edges
1	1	x	x		• TPU0 Capture input source is TPU1 count clock Input capture at TPU1.TCNT count-up/count-down*1 • TPU6 Capture input source is TPU7 count clock Input capture at TPU7.TCNT count-up/count-down*1

Notes: 1. When the TPSC[2:0] bits in TPUm.TCR are set to 000b and PCLK/1 is used as the TPUm.TCNT count clock, this setting is invalid and input capture is not generated (m = 1, 7).

2. Selected by the ICSELB bit in TPUm.TMDR (m = 0, 6).

[Legend] x: Don't care

Table 15.16 TPU1.TIOR, TPU7.TIOR

Bits IOA[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRA (m = 1, 7) Function**	**TIOCAn Pin (n = 1, 7) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is lowoutput; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCAn pin; input capture at rising edge
1	0	0	1		Capture input source is TIOCAn pin; input capture at falling edge
1	0	1	x		Capture input source is TIOCAn pin; input capture at both edges
1	1	x	x		• TPU1 Capture input source is TPU0.TGRA compare match/input capture Input capture at generation of TPU0.TGRA compare match/input capture • TPU7 Capture input source is TPU6.TGRA compare match/input capture Input capture at generation of TPU6.TGRA compare match/input capture

Bits IOB[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRB (m = 1, 7) Function**	**TIOCBn Pin (n = 1, 7) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCBn or TIOCAn pin*; input capture at rising edge
1	0	0	1		Capture input source is TIOCBn or TIOCAn pin*; input capture at falling edge
1	0	1	x		Capture input source is TIOCBn or TIOCAn pin*; input capture at both edges
1	1	x	x		• TPU1 Capture input source is TPU0.TGRC compare match/input capture Input capture at generation of TPU0.TGRC compare match/input capture • TPU7 Capture input source is TPU6.TGRC compare match/input capture Input capture at generation of TPU6.TGRC compare match/input capture

Note: * Selected by the ICSELB bit in TPUm.TMDR (m = 1, 7).

[Legend] x: Don't care

Table 15.17 TPU2.TIOR, TPU8.TIOR

Bits IOA[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRA (m = 2, 8) Function**	**TIOCAn Pin (n = 2, 8) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	x	0	0	Input capture register	Capture input source is TIOCAn pin; input capture at rising edge
1	x	0	1		Capture input source is TIOCAn pin; input capture at falling edge
1	x	1	x		Capture input source is TIOCAn pin; input capture at both edges

Bits IOB[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRB (m = 2, 8) Function**	**TIOCBn Pin (n = 2, 8) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	x	0	0	Input capture register	Capture input source is TIOCBn or TIOCAn pin*; input capture at rising edge
1	x	0	1		Capture input source is TIOCBn or TIOCAn pin*; input capture at falling edge
1	x	1	x		Capture input source is TIOCBn or TIOCAn pin*; input capture at both edges

Note: * Selected by the ICSELB bit in TPUm.TMDR (m = 2, 8).

[Legend] x: Don't care

Table 15.18 TPU3.TIORH, TPU9.TIORH

Bits IOA[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRA (m = 3, 9) Function**	**TIOCAn Pin (n = 3, 9) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCAn pin; input capture at rising edge
1	0	0	1		Capture input source is TIOCAn pin; input capture at falling edge
1	0	1	x		Capture input source is TIOCAn pin; input capture at both edges
1	1	x	x		• TPU3 Capture input source is TPU4 count clock Input capture at TPU4.TCNT count-up/count-down*1 • TPU9 Capture input source is TPU10 count clock Input capture at TPU10.TCNT count-up/count-down*1

Bits IOB[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRB (m = 3, 9) Function**	**TIOCBn Pin (n = 3, 9) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCBn or TIOCAn pin*2; input capture at rising edge
1	0	0	1		Capture input source is TIOCBn or TIOCAn pin*2; input capture at falling edge
1	0	1	x		Capture input source is TIOCBn or TIOCAn pin*2; input capture at both edges
1	1	x	x		• TPU3 Capture input source is TPU4 count clock Input capture at TPU4.TCNT count-up/count-down*1 • TPU9 Capture input source is TPU10 count clock Input capture at TPU10.TCNT count-up/count-down*1

Notes: 1. When the TPSC[2:0] bits in TPUm.TCR are set to 000b and PCLK/1 is used as the TPUm.TCNT count clock, this setting is invalid and input capture is not generated (m = 4, 10).

2. Selected by the ICSELB bit in TPUm.TMDR (m = 3, 9).

[Legend] x: Don't care

Table 15.19 TPU4.TIOR, TPU10.TIOR

Bits IOA[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRA (m = 4, 10) Function**	**TIOCAn Pin (n = 4, 10) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCAn pin; input capture at rising edge
1	0	0	1		Capture input source is TIOCAn pin; input capture at falling edge
1	0	1	x		Capture input source is TIOCAn pin; input capture at both edges
1	1	x	x		• TPU4 Capture input source is TPU3.TGRA compare match/input capture Input capture at generation of TPU3.TGRA compare match/input capture • TPU10 Capture input source is TPU9.TGRA compare match/input capture Input capture at generation of TPU9.TGRA compare match/input capture

Bits IOB[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRB (m = 4, 10) Function**	**TIOCBn Pin (n = 4, 10) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCBn or TIOCAn pin*; input capture at rising edge
1	0	0	1		Capture input source is TIOCBn or TIOCAn pin*; input capture at falling edge
1	0	1	x		Capture input source is TIOCBn or TIOCAn pin*; input capture at both edges
1	1	x	x		• TPU4 Capture input source is TPU3.TGRC compare match/input capture Input capture at generation of TPU3.TGRC compare match/input capture • TPU10 Capture input source is TPU9.TGRC compare match/input capture Input capture at generation of TPU9.TGRC compare match/input capture

Note: * Selected by the ICSELB bit in TPUm.TMDR (m = 4, 10).

[Legend] x: Don't care

Table 15.20 TPU5.TIOR, TPU11.TIOR

Bits IOA[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRA (m = 5, 11) Function**	**TIOCAn Pin (n = 5, 11) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	x	0	0	Input capture register	Capture input source is TIOCAn pin; input capture at rising edge
1	x	0	1		Capture input source is TIOCAn pin; input capture at falling edge
1	x	1	x		Capture input source is TIOCAn pin; input capture at both edges

Bits IOB[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRB (m = 5, 11) Function**	**TIOCBn Pin (n = 5, 11) Function**
0	0	0	0	Output compare register	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	x	0	0	Input capture register	Capture input source is TIOCBn or TIOCAn pin*; input capture at rising edge
1	x	0	1		Capture input source is TIOCBn or TIOCAn pin*; input capture at falling edge
1	x	1	x		Capture input source is TIOCBn or TIOCAn pin*; input capture at both edges

Note: * Selected by the ICSELB bit in TPUm.TMDR (m = 5, 11).

[Legend] x: Don't care

Table 15.21 TPU0.TIORL, TPU6.TIORL

Bits IOC[3:0]				Description	
b3	**b2**	**b1**	**b0**	**TPUm.TGRC (m = 0, 6) Function**	**TIOCCn Pin (n = 0, 6) Function**
0	0	0	0	Output compare register*1	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register*1	Capture input source is TIOCCn pin; input capture at rising edge
1	0	0	1		Capture input source is TIOCCn pin; input capture at falling edge
1	0	1	x		Capture input source is TIOCCn pin; input capture at both edges
1	1	x	x		• TPU0 Capture input source is TPU1 count clock Input capture at TPU1.TCNT count-up/count-down*3 • TPU6 Capture input source is TPU7 count clock Input capture at TPU7.TCNT count-up/count-down*3

Bits IOD[3:0]				Description	
b7	**b6**	**b5**	**b4**	**TPUm.TGRD (m = 0, 6) Function**	**TIOCDn Pin (n = 0, 6) Function**
0	0	0	0	Output compare register*2	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register*2	Capture input source is TIOCDn or TIOCCn pin*4; input capture at rising edge
1	0	0	1		Capture input source is TIOCDn or TIOCCn pin*4; input capture at falling edge
1	0	1	x		Capture input source is TIOCDn or TIOCCn pin*4; input capture at both edges
1	1	x	x		• TPU0 Capture input source is TPU1 count clock Input capture at TPU1.TCNT count-up/count-down*3 • TPU6 Capture input source is TPU7 count clock Input capture at TPU7.TCNT count-up/count-down*3

Notes: 1. When the BFA bit in TPUm.TMDR is set to 1 (TPUm.TGRA and TPUm.TGRC are used for buffer operation) and TPUm.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated (m = 0, 6).

2. When the BFB bit in TPUm.TMDR is set to 1 (TPUm.TGRB and TPUm.TGRD are used for buffer operation) and TPUmn.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated (m = 0, 6).

3. When the TPSC[2:0] bits in TPUm.TCR are set to 000b and PCLK/1 is used as the TPUm.TCNT count clock, this setting is invalid and input capture is not generated (m = 1, 7).

4. Selected by the ICSELD bit in TPUm.TMDR (m = 0, 6).

[Legend] x: Don't care

Table 15.22 TPU3.TIORL, TPU9.TIORL

Bits IOC[3:0]				Description	
b3	**B2**	**b1**	**b0**	**TPUm.TGRC (m = 3, 9) Function**	**TIOCCn Pin (n = 3, 9) Function**
0	0	0	0	Output compare register*1	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input capture register*1	Capture input source is TIOCCn pin; input capture at rising edge
1	0	0	1		Capture input source is TIOCCn pin; input capture at falling edge
1	0	1	x		Capture input source is TIOCCn pin; input capture at both edges
1	1	x	x		• TPU3 Capture input source is TPU4 count clock Input capture at TPU4.TCNT count-up/count-down*3 • TPU9 Capture input source is TPU10 count clock Input capture at TPU10.TCNT count-up/count-down*3

Bits IOD[3:0]				Description	
b7	**B6**	**b5**	**b4**	**TPUm.TGRD (m = 3, 9) Function**	**TIOCDn Pin (n = 3, 9) Function**
0	0	0	0	Output compare register*2	Output disabled
0	0	0	1		Initial output is low output; low output at compare match
0	0	1	0		Initial output is low output; high output at compare match
0	0	1	1		Initial output is low output; toggle output at compare match
0	1	0	0		Output disabled
0	1	0	1		Initial output is high output; low output at compare match
0	1	1	0		Initial output is high output; high output at compare match
0	1	1	1		Initial output is high output; toggle output at compare match
1	0	0	0	Input Capture register*2	Capture input source is TIOCDn or TIOCCn pin*4; input capture at rising edge
1	0	0	1		Capture input source is TIOCDn or TIOCCn pin*4; input capture at falling edge
1	0	1	x		Capture input source is TIOCDn or TIOCCn pin*4; input capture at both edges
1	1	x	x		• TPU3 Capture input source is TPU4 count clock Input capture at TPU4.TCNT count-up/count-down*3 • TPU9 Capture input source is TPU10 count clock Input capture at TPU10.TCNT count-up/count-down*3

Notes: 1. When the BFA bit in TPUm.TMDR is set to 1 (TPUm.TGRA and TPUm.TGRC are used for buffer operation) and TPUm.TGRC is used as a buffer register, this setting is invalid and input capture/output compare is not generated (m = 0, 6).

2. When the BFB bit in TPUm.TMDR is set to 1 (TPUm.TGRB and TPUm.TGRD are used for buffer operation) and TPUm.TGRD is used as a buffer register, this setting is invalid and input capture/output compare is not generated (m = 0, 6).

3. When the TPSC[2:0] bits in TPUm.TCR are set to 000b and PCLK/1 is used as the TPUm.TCNT count clock, this setting is invalid and input capture is not generated (m = 1, 7).

4. Selected by the ICSELD bit in TPUm.TMDR (m = 0, 6).

[Legend] x: Don't care

15.2.4 Timer Interrupt Enable Register (TIER)

Addresses: TPU0.TIER 0008 8114h, TPU1.TIER 0008 8124h, TPU2.TIER 0008 8134h
TPU3.TIER 0008 8144h, TPU4.TIER 0008 8154h, TPU5.TIER 0008 8164h
TPU6.TIER 0008 8184h, TPU7.TIER 0008 8194h, TPU8.TIER 0008 81A4h
TPU9.TIER 0008 81B4h, TPU10.TIER 0008 81C4h, TPU11.TIER 0008 81D4h

	b7	b6	b5	b4	b3	b2	b1	b0
	TTEG	—	TCIEU	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
Value after reset:	0	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TGIEA	TGRA Interrupt Enable	0: Interrupt requests (TGImA) disabled 1: Interrupt requests (TGImA) enabled (m = 0 to 11)	R/W
b1	TGIEB	TGRB Interrupt Enable	0: Interrupt requests (TGImB) disabled 1: Interrupt requests (TGImB) enabled (m = 0 to 11)	R/W
b2	TGIEC*1	TGRC Interrupt Enable	0: Interrupt requests (TGImC) disabled 1: Interrupt requests (TGImC) enabled (m = 0, 3, 6, 9)	R/W
b3	TGIED*1	TGRD Interrupt Enable	0: Interrupt requests (TGImD) disabled 1: Interrupt requests (TGImD) enabled (m = 0, 3, 6, 9)	R/W
b4	TCIEV	Overflow Interrupt Enable	0: Interrupt requests (TCImV) disabled 1: Interrupt requests (TCImV) enabled (m = 0 to 11)	R/W
b5	TCIEU*2	Underflow Interrupt Enable	0: Interrupt requests (TCImU) disabled 1: Interrupt requests (TCImU) enabled (m = 1, 2, 4, 5, 7, 8, 10, 11)	R/W
b6	—	Reserved	This bit is read as 1. The write value should always be 1.	R/W
b7	TTGE	A/D Conversion Start Request Enable	0: A/D conversion start request generation disabled 1: A/D conversion start request generation enabled	R/W

Notes: 1. Bits 3 and 2 in TIER of TPU1, TPU2, TPU4, TPU5 (unit 0), TPU7, TPU8, TPU10, and TPU11 (unit 1) are reserved. These bits are read as 0. The write value should always be 0.

2. Bits 5 in TIER of TPU0, TPU3 (unit 0), TPU6, and TPU9 (unit 1) is reserved. This bit is read as 0. The write value should always be 0.

The TPU has twelve TIER registers, one for each channel.

TPUm.TIER controls enabling or disabling of interrupt requests for each channel.

TGIEA Bit (TGRA Interrupt Enable)

Enables/disables interrupt requests (TGImA) (m = 0 to 11).

TGIEB Bit (TGRB Interrupt Enable)

Enables/disables interrupt requests (TGImB) (m = 0 to 11).

TGIEC Bit (TGRC Interrupt Enable)

Enables/disables interrupt requests (TGImC) (m = 0, 3, 6, 9).

TGIED Bit (TGRD Interrupt Enable)

Enables/disables interrupt requests (TGImD) (m = 0, 3, 6, 9).

TCIEV Bit (Overflow Interrupt Enable)

Enables/disables interrupt requests (TCImV) (m = 0 to 11).

TCIEU Bit (Underflow Interrupt Enable)

Enables/disables interrupt requests (TCImU) (m = 1, 2, 4, 5, 7, 8, 10, 11).

TTGE Bit (A/D Conversion Start Request Enable)

Enables/disables generation of A/D conversion start requests by TPUm.TGRA (m = 0 to 11) input capture/compare match.

15.2.5 Timer Status Register (TSR)

Addresses: TPU0.TSR 0008 8115h, TPU1.TSR 0008 8125h, TPU2.TSR 0008 8135h
TPU3.TSR 0008 8145h, TPU4.TSR 0008 8155h, TPU5.TSR 0008 8165h
TPU6.TSR 0008 8185h, TPU7.TSR 0008 8195h, TPU8.TSR 0008 81A5h
TPU9.TSR 0008 81B5h, TPU10.TSR 0008 81C5h, TPU11.TSR 0008 81D5h

	b7	b6	b5	b4	b3	b2	b1	b0
	TCFD	—	—	—	—	—	—	—
Value after reset:	1	1	x	x	x	x	x	x

[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b5 to b0	—	Reserved	The read value is undefined. The write value should always be 0.	R/W
b6	—	Reserved	This bit is read as 1 and cannot be modified.	R
b7	TCFD*	Count Direction Flag	0: TPUm.TCNT counts down 1: TPUm.TCNT counts up (m = 1, 2, 4, 5, 7, 8, 10, 11)	R

Note: * Bit 7 in TSR of TPU0, TPU3 (unit 0), TPU6, and TPU9 (unit 1) is reserved. This bit is read as 1. The write value should always be 1.

The TPU has twelve TSR registers, one for each channel.

TPUm.TSR indicates the count direction of the TPUm.TCNT counter.

TCFD Flag (Count Direction Flag)

Status flag that shows that TPUm.TCNT (m = 1, 2, 4, 5, 7, 8, 10, 11) counts up or down.

15.2.6 Timer Counter (TCNT)

Addresses: TPU0.TCNT 0008 8116h, TPU1.TCNT 0008 8126h, TPU2.TCNT 0008 8136h
TPU3.TCNT 0008 8146h, TPU4.TCNT 0008 8156h, TPU5.TCNT 0008 8166h
TPU6.TCNT 0008 8186h, TPU7.TCNT 0008 8196h, TPU8.TCNT 0008 81A6h
TPU9.TCNT 0008 81B6h, TPU10.TCNT 0008 81C6h, TPU11.TCNT 0008 81D6h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The TPU has twelve TCNT counters, one for each channel.

TPUm.TCNT is a 16-bit counter that counts the internal clock or external events.

This counter can be read/written in 16-bit units.

This counter is initialized to 0000h by a reset.

15.2.7 Timer General Register A (TGRA)
Timer General Register B (TGRB)
Timer General Register C (TGRC)
Timer General Register D (TGRD)

Addresses: TPU0.TGRA 0008 8118h, TPU0.TGRB 0008 811Ah, TPU0.TGRC 0008 811Ch, TPU0.TGRD 0008 811Eh
TPU1.TGRA 0008 8128h, TPU1.TGRB 0008 812Ah
TPU2.TGRA 0008 8138h, TPU2.TGRB 0008 813Ah
TPU3.TGRA 0008 8148h, TPU3.TGRB 0008 814Ah, TPU3.TGRC 0008 814Ch, TPU3.TGRD 0008 814Eh
TPU4.TGRA 0008 8158h, TPU4.TGRB 0008 815Ah
TPU5.TGRA 0008 8168h, TPU5.TGRB 0008 816Ah
TPU6.TGRA 0008 8188h, TPU6.TGRB 0008 818Ah, TPU6.TGRC 0008 818Ch, TPU6.TGRD 0008 818Eh
TPU7.TGRA 0008 8198h, TPU7.TGRB 0008 819Ah
TPU8.TGRA 0008 81A8h, TPU8.TGRB 0008 81AAh
TPU9.TGRA 0008 81B8h, TPU9.TGRB 0008 81BAh, TPU9.TGRC 0008 81BCh, TPU9.TGRD 0008 81BEh
TPU10.TGRA 0008 81C8h, TPU10.TGRB 0008 81CAh
TPU11.TGRA 0008 81D8h, TPU11.TGRB 0008 81DAh

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The TPU has 32 TGR registers in total, four each for TPU0, TPU3, TPU6, and TPU9 and two each for TPU1, TPU2, TPU4, TPU5, TPU7, TPU8, TPU10, and TPU11.

TPUm.TGRA (m = 0 to 11), TPUm.TGRB (m = 0 to 11), TPUm.TGRC (m = 0, 3, 6, 9), and TPUm.TGRD (m = 0, 3, 6, 9) are 16-bit registers with a dual function as output compare and input capture registers.

These registers can be read/written in 16-bit units.

TPUm.TGRC and TPUm.TGRD can also be specified for operation as buffer registers. Register combinations during buffer operations are TPUm.TGRA–TPUm.TGRC and TPUm.TGRB–TPUm.TGRD.

15.2.8 Timer Start Register (TSTRA, TSTRB)

Addresses: TSTRA 0008 8100h, TSTRB 0008 8170h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CST5	CST4	CST3	CST2	CST1	CST0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	CST0	Counter Start 0	0: TCNT count operation is stopped	R/W
b1	CST1	Counter Start 1	1: TCNT performs count operation	R/W
b2	CST2	Counter Start 2		R/W
b3	CST3	Counter Start 3		R/W
b4	CST4	Counter Start 4		R/W
b5	CST5	Counter Start 5		R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

TSTRA starts or stops TCNT count operation for TPU0 to TPU5.

TSTRB starts or stops TCNT count operation for TPU6 to TPU11.

Before setting the operating mode in TPUm.TMDR or setting the TPUm.TCNT count clock in TPUm.TCR, stop the TPUm.TCNT counter.

CSTj Bits (Counter Start) (j = 0 to 5)

These bits start or stop the TCNT counter.

When the CSTj bit is cleared to 0 with CSTj = 1 and the corresponding TIOCyn pin (y = A to D, n = 0 to 11) specified for output, the counter stops but the output compare output level of the corresponding TIOCyn pin is retained.

If TIORH, TIORL, or TIOR is written to when the CSTj bit is 0, the pin output level will be changed to the set initial output value.

15.2.9 Timer Synchronous Register (TSYRA, TSYRB)

Addresses: TSYRA 0008 8101h, TSYRB 0008 8171h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	SYNC5	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SYNC0	Timer Synchronization 0	0: TCNT operates independently	R/W
b1	SYNC1	Timer Synchronization 1	(TCNT presetting/clearing is unrelated to other channels)	R/W
b2	SYNC2	Timer Synchronization 2	1: TCNT performs synchronous operation*	R/W
b3	SYNC3	Timer Synchronization 3	(TCNT synchronous presetting/synchronous clearing is possible)	R/W
b4	SYNC4	Timer Synchronization 4		R/W
b5	SYNC5	Timer Synchronization 5		R/W
b7, b6	—	Reserved	These bits are read as 0. The write value should always be 0.	R/W

Note: * To set synchronous operation, the SYNCj bit (j = 0 to 5) for at least two channels must be set to 1. To set synchronous clearing, the TCNT clearing source must also be set by the CCLR[2:0] bits in TCR in addition to the SYNCj bit.

TSYRA selects independent operation or synchronous operation for the TCNT counters of TPU0 to TPU5.

TSYRB selects independent operation or synchronous operation for the TCNT counters of TPU6 to TPU11.

SYNCj Bits (Timer Synchronization) (j = 0 to 5)

These bits select whether the TCNT operation is independent of or synchronized with TCNT of other channels.

When synchronous operation is selected, synchronous presetting of multiple TCNT counters and synchronous clearing through counter clearing on another channel are possible.

15.3 Operation

15.3.1 Basic Functions

Each channel has a TPUm.TCNT counter and a TPUm.TGRy register (y = A to D).

TCNT is a 16-bit up-counter, and is also capable of free-running operation, periodic counting, and external event counting.

TGRy can be used as an input capture register or output compare register.

(1) Counter Operation

When the CSTj bit (j = 0 to 5) in TSTRA or the CSTj bit (j = 0 to 5) in TSTRB is set to 1, the TCNT counter for the corresponding channel starts counting. TCNT can operate as a free-running counter, periodic counter, and so on.

(a) Example of count operation setting procedure

Figure 15.3 shows an example of the count operation setting procedure.

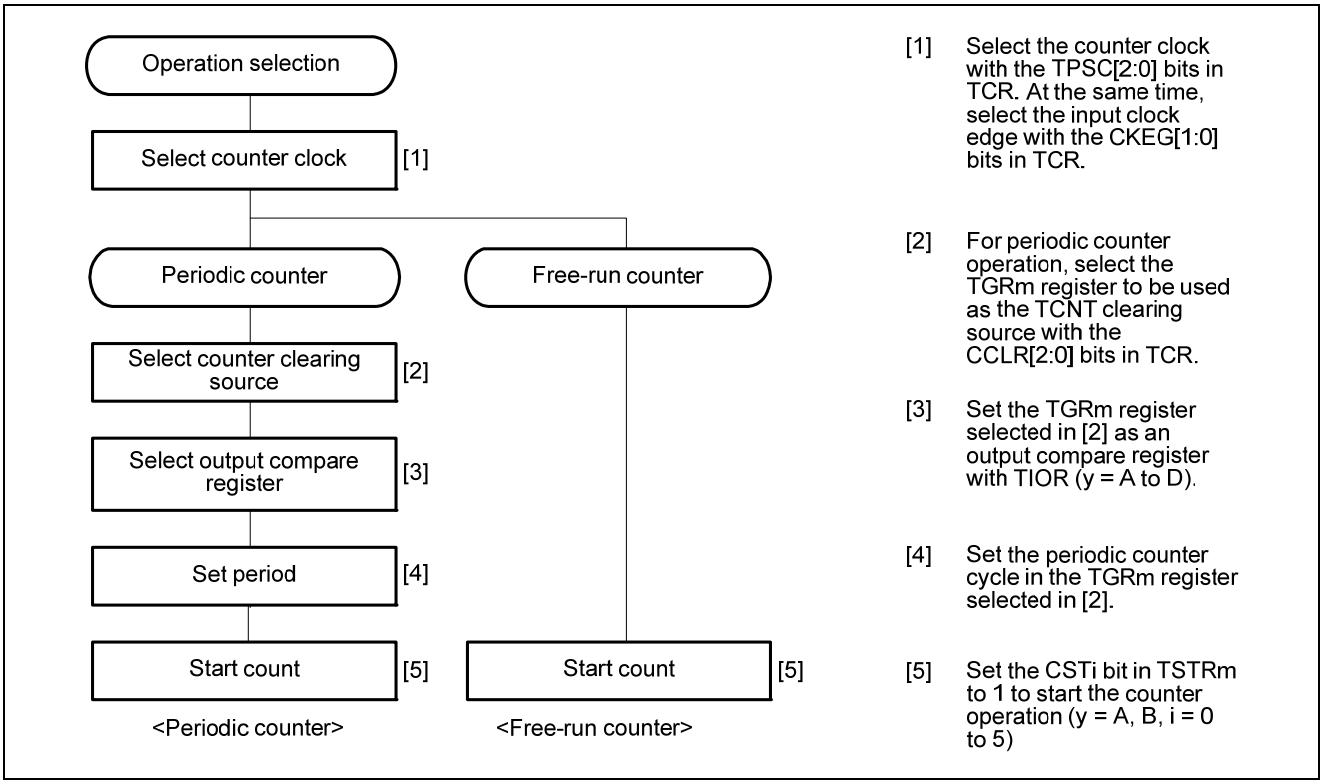


Figure 15.3 Example of Counter Operation Setting Procedure

(b) Free-running count operation and periodic count operation

Immediately after a reset, the TPUm.TCNT counters are all set as free-running counters. When the relevant bit in TSTRA or TSTRB is set to 1, the corresponding TCNT counter starts up-count operation as a free-running counter. When TCNT overflows (changes from FFFFh to 0000h), the TPU requests an interrupt. After an overflow, TCNT restarts counting up from 0000h.

Figure 15.4 shows free-running counter operation.

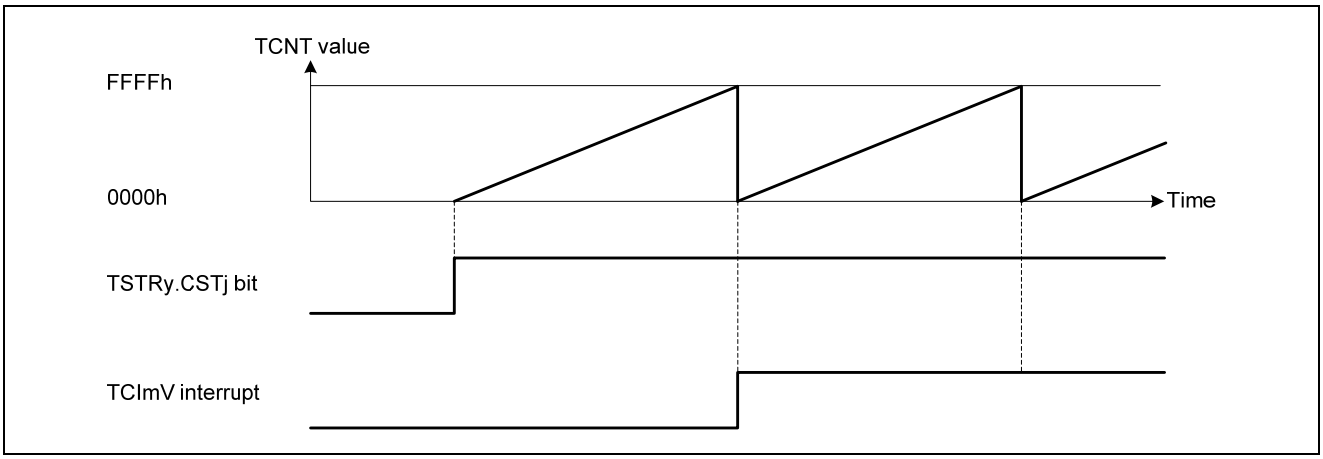


Figure 15.4 Free-Running Counter Operation

When compare match is selected as the TCNT clearing source, the TCNT counter for the relevant channel performs periodic count operation. The TPUm.TGRy for setting the period is set as an output compare register, and counter clearing by compare match is selected by the CCLR[2:0] bits in TPUm.TCR. After the settings have been made, TCNT starts count-up operation as a periodic counter when the corresponding bit in TSTRA or TSTRB is set to 1. When the count value matches the TGRy value, TCNT is cleared to 0000h.

At this time, the TPU requests an interrupt. After a compare match, TCNT restarts counting up from 0000h.

Figure 15.5 shows periodic counter operation.

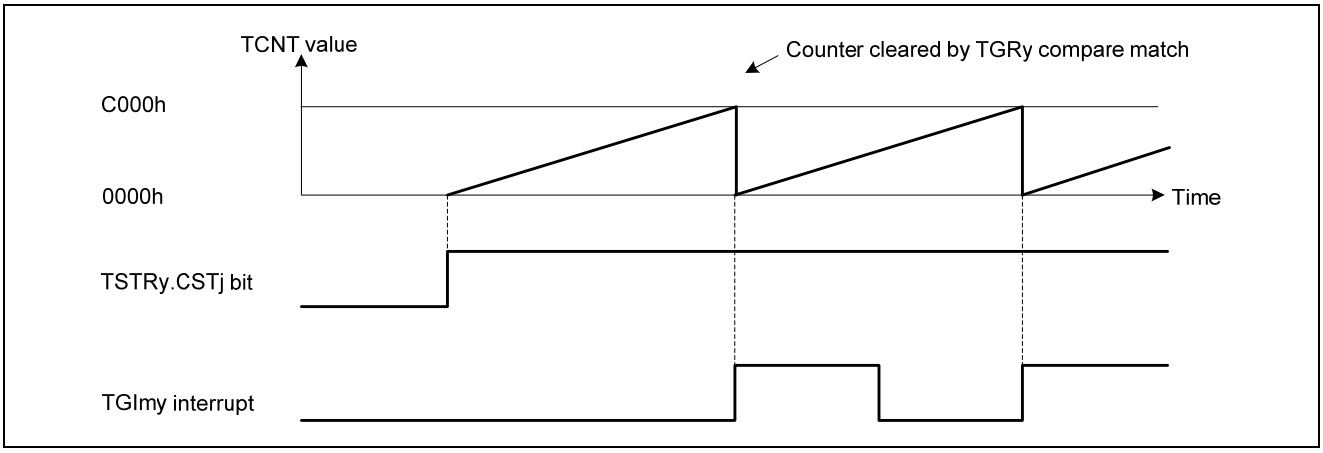


Figure 15.5 Periodic Counter Operation

(2) Waveform Output by Compare Match

The TPU can perform low, high, or toggle output from the corresponding output pin using a compare match.

(a) Example of setting procedure for waveform output by compare match

Figure 15.6 shows an example of the setting procedure for waveform output by a compare match.

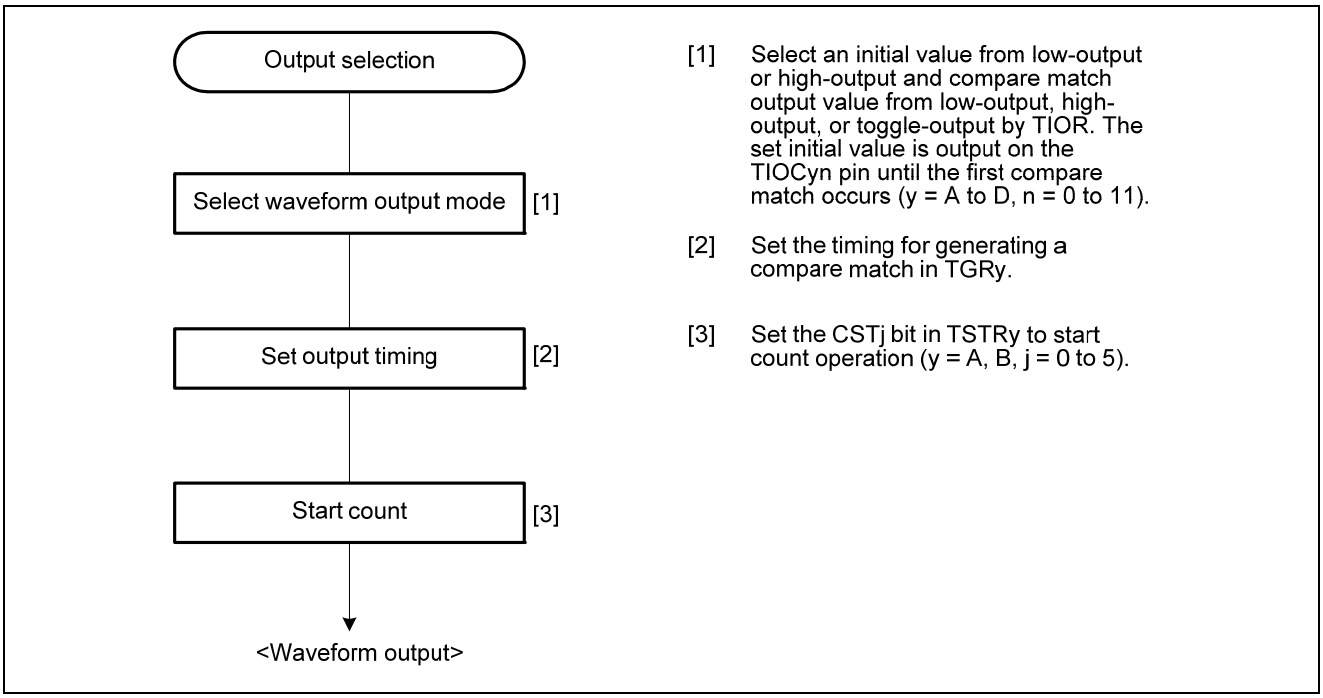


Figure 15.6 Example of Setting Procedure for Waveform Output by Compare Match

(b) Examples of waveform output operation

Figure 15.7 shows an example of low output/high output.

In this example, TPUm.TCNT has been set as a free-running counter, and settings have been made so that high is output by compare match A and low is output by compare match B. When the set level and the pin level match, the pin level does not change.

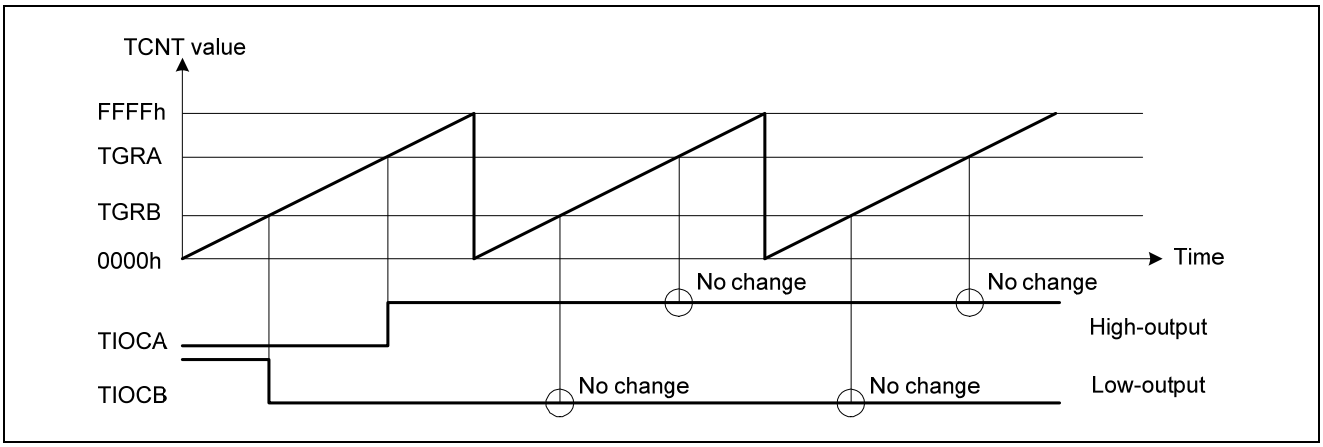


Figure 15.7 Example of Low-Output/High-Output Operation

Figure 15.8 shows an example of toggle output.

In this example, TPUm.TCNT has been set as a periodic counter (with counter clearing performed by compare match B), and settings have been made so that output is toggled by both compare match A and compare match B.

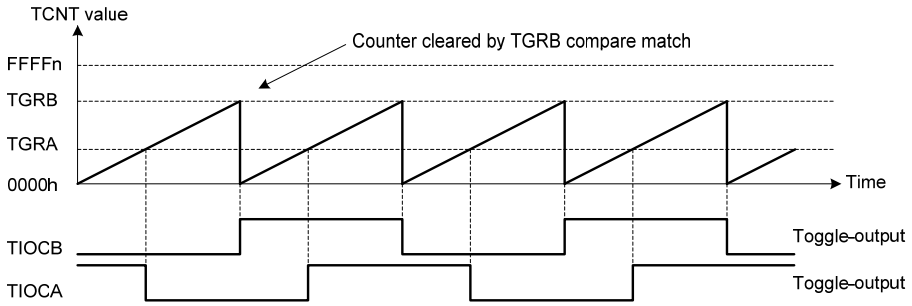


Figure 15.8 Example of Toggle Output Operation

(3) Input Capture Function

The TPUm.TCNT value can be transferred to TPUm.TGRy on detection of the TIOCyn pin (y = A to D, n = 0 to 11) input edge.

The rising edge, the falling edge, or both edges can be selected as the detection edge. It is also possible to specify the counter input clock or compare match signal of TPU0, TPU1, TPU3, and TPU4 (TPU6, TPU7, TPU9, and TPU10) as the input capture source.

Note: When another channel's counter input clock is used as the input capture input for TPU0 and TPU3 (TPU6 and TPU9), PCLK/1 should not be selected as the counter input clock used for input capture input. Input capture will not be generated if PCLK/1 is selected.

(a) Example of setting procedure for input capture operation

Figure 15.9 shows an example of the setting procedure for input capture operation.

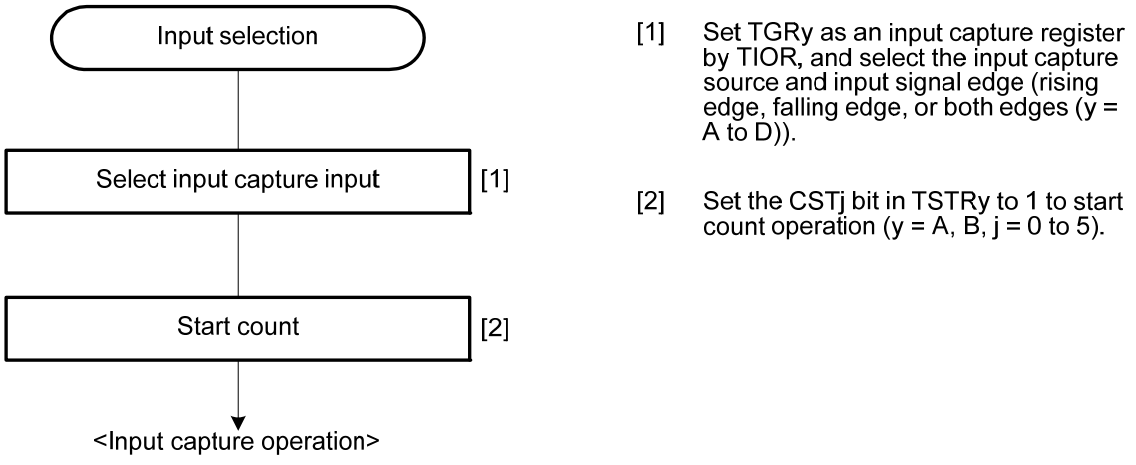


Figure 15.9 Example of Setting Procedure for Input Capture Operation

(b) Example of input capture operation

Figure 15.10 shows an example of input capture operation.

In this example, both rising and falling edges have been selected as the TIOCAn pin input capture input edge, the falling edge has been selected as the TIOCBn pin input capture input edge, and counter clearing by TPUm.TGRB input capture has been set for TPUm.TCNT.

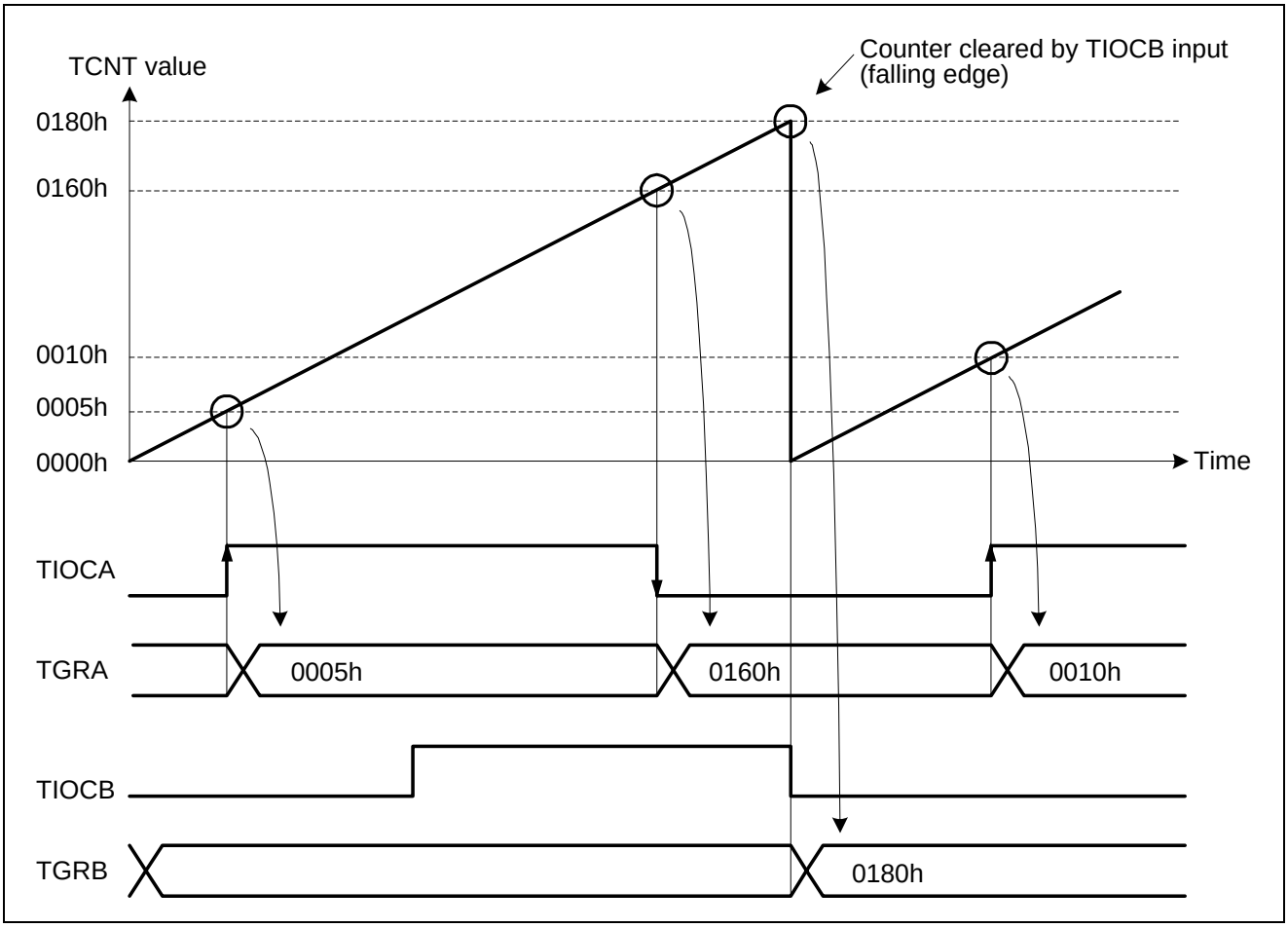


Figure 15.10 Example of Input Capture Operation

15.3.2 Synchronous Operation

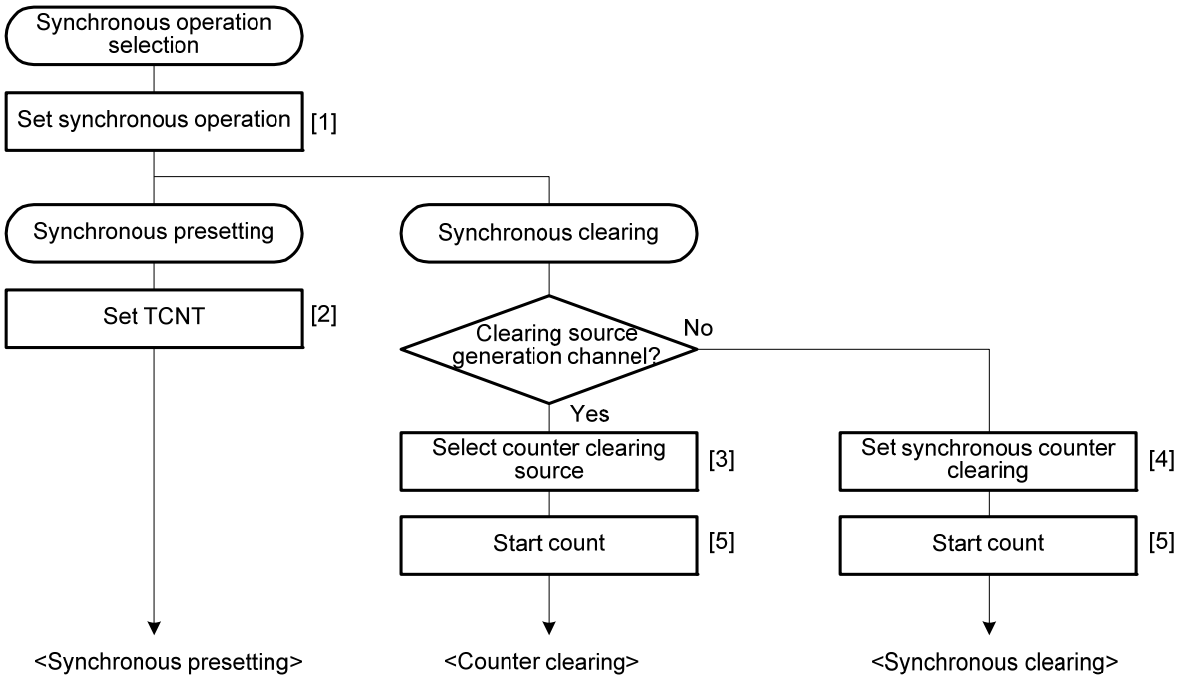
In synchronous operation, the values in multiple TPUm.TCNT counters can be rewritten simultaneously (synchronous presetting). Also, multiple TCNT counters can be cleared simultaneously (synchronous clearing) by making the appropriate setting in TPUm.TCR.

Synchronous operation enables TPUm.TGRy to be incremented with respect to a single time base.

TPU0 to TPU5 (TPU6 to TPU11) can all be set for synchronous operation.

(1) Example of Synchronous Operation Setting Procedure

Figure 15.11 shows an example of the synchronous operation setting procedure.



[1] Set the SYNCj bit in TSYRy corresponding to the channels to be set for synchronous operation to 1 (y = A, B, j = 0 to 5).

[2] When any of TCNT of the channels set for synchronous operation is written to, the same value is simultaneously written to the other TCNT counters.

[3] Use the CCLR[2:0] bits in TCR to specify TCNT clearing by input capture/output compare, etc.

[4] Use the CCLR[2:0] bits in TCR to specify synchronous clearing for the counter clearing source.

[5] Set the CSTj bit in TSTRy for the relevant channels to 1 to start count operation (y = A, B, j = 0 to 5).

Figure 15.11 Example of Synchronous Operation Setting Procedure

(2) Example of Synchronous Operation

Figure 15.12 shows an example of synchronous operation.

In this example, synchronous operation and PWM mode 1 have been set for TPU0 to TPU2, TPU0.TGRB compare match has been set as the TPU0 counter clearing source, and synchronous clearing has been set for the TPU1 and TPU2 counter clearing source.

Three-phase PWM waveforms are output from pins TIOCA0, TIOCA1, and TIOCA2. At this time, synchronous presetting and synchronous clearing by TPU0.TGRB compare match are performed for TPUm.TCNT of TPU0 to TPU2, and the data set in TPU0.TGRB is used as the PWM cycle.

For details on PWM modes, see section 15.3.5, PWM Modes.

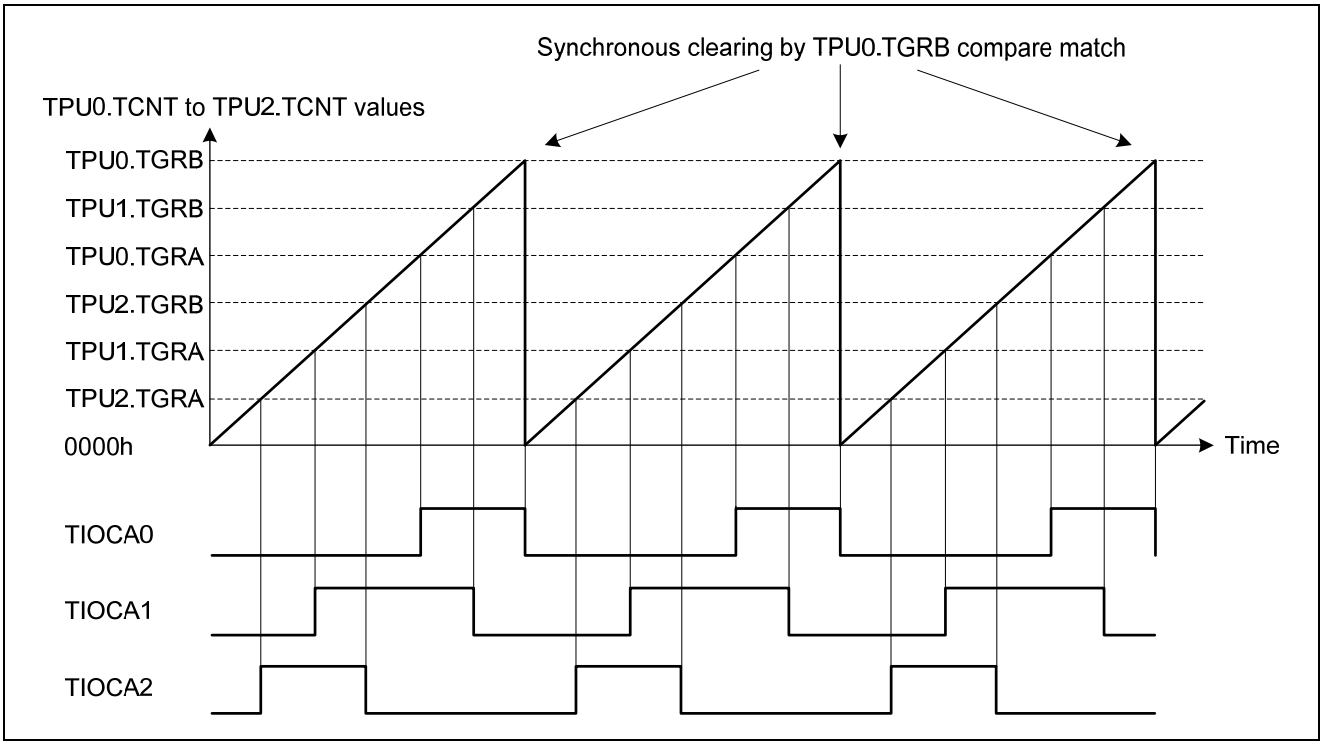


Figure 15.12 Example of Synchronous Operation

15.3.3 Buffer Operation

Buffer operation, provided for TPU0 and TPU3 (TPU6 and TPU9), enables TPUm.TGRC and TPUm.TGRD to be used as buffer registers.

Buffer operation differs depending on whether TPUm.TGRy has been set as an input capture register or a compare match register.

Table 15.23 lists the register combinations used in buffer operation.

Table 15.23 Register Combinations in Buffer Operation

Unit	Channel	Timer General Register	Buffer Register
0	TPU0	TPU0.TGRA	TPU0.TGRC
		TPU0.TGRB	TPU0.TGRD
	TPU3	TPU3.TGRA	TPU3.TGRC
		TPU3.TGRB	TPU3.TGRD
1	TPU6	TPU6.TGRA	TPU6.TGRC
		TPU6.TGRB	TPU6.TGRD
	TPU9	TPU9.TGRA	TPU9.TGRC
		TPU9.TGRB	TPU9.TGRD

- When TPUm.TGRy is an output compare register
  When a compare match occurs, the value in the buffer register for the corresponding channel is transferred to the timer general register.

  This operation is shown in figure 15.13.

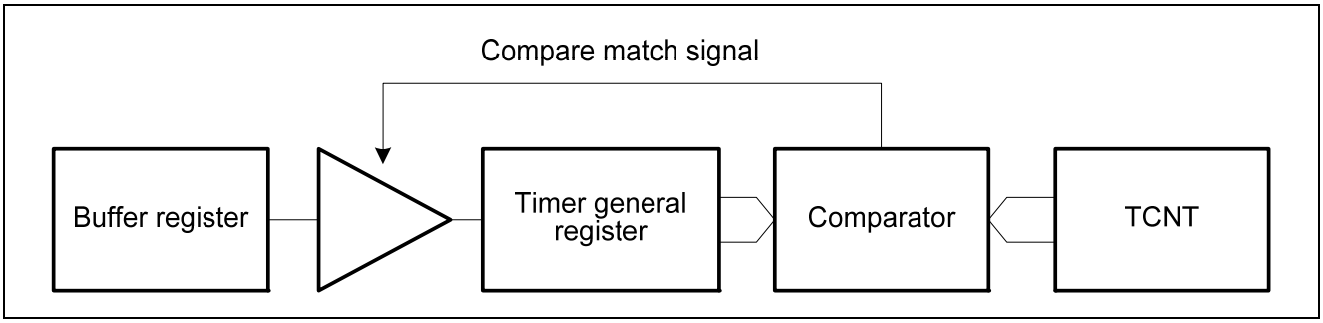


Figure 15.13 Compare Match Buffer Operation

- When TPUm.TGRy is an input capture register
  When input capture occurs, the value in TPUm.TCNT is transferred to TGRy and the value previously held in TGRy is transferred to the buffer register.

  This operation is shown in figure 15.14.

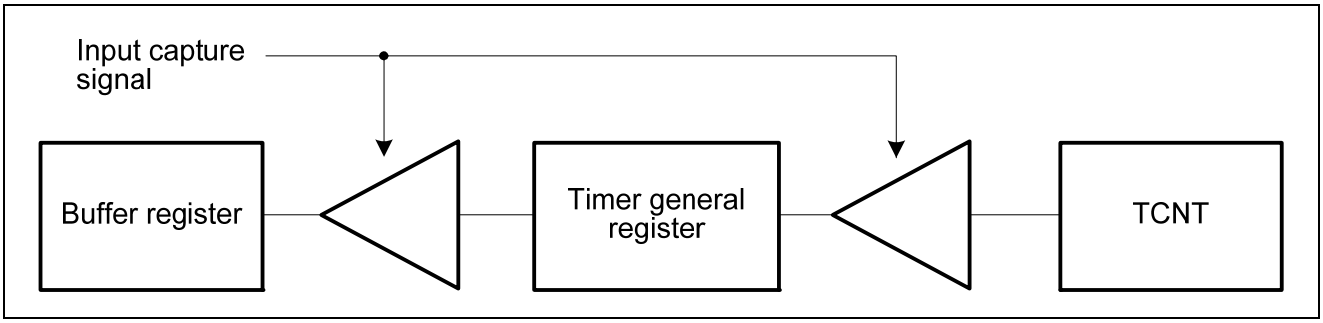


Figure 15.14 Input Capture Buffer Operation

(1) Example of Buffer Operation Setting Procedure

Figure 15.15 shows an example of the buffer operation setting procedure.

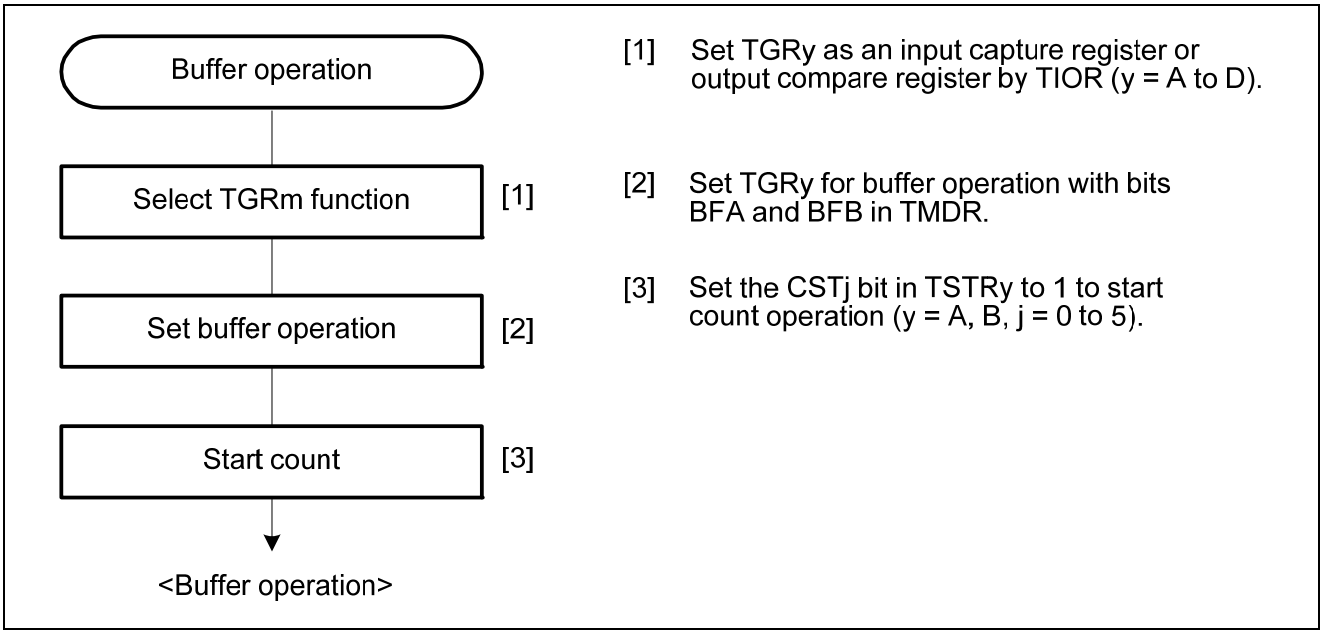


Figure 15.15 Example of Buffer Operation Setting Procedure

(2) Examples of Buffer Operation

(a) When TPUm.TGRy is an output compare register

Figure 15.16 shows an operation example in which PWM mode 1 has been set for TPU0, and buffer operation has been set for TPU0.TGRA and TPU0.TGRC. The settings used in this example are TPU0.TCNT clearing by compare match B, high output at compare match A, and low output at compare match B.

As buffer operation has been set, when compare match A occurs, the output changes and the TPU0.TGRC value is simultaneously transferred to TPU0.TGRA. This operation is repeated each time compare match A occurs.

For details on PWM modes, see section 15.3.5, PWM Modes.

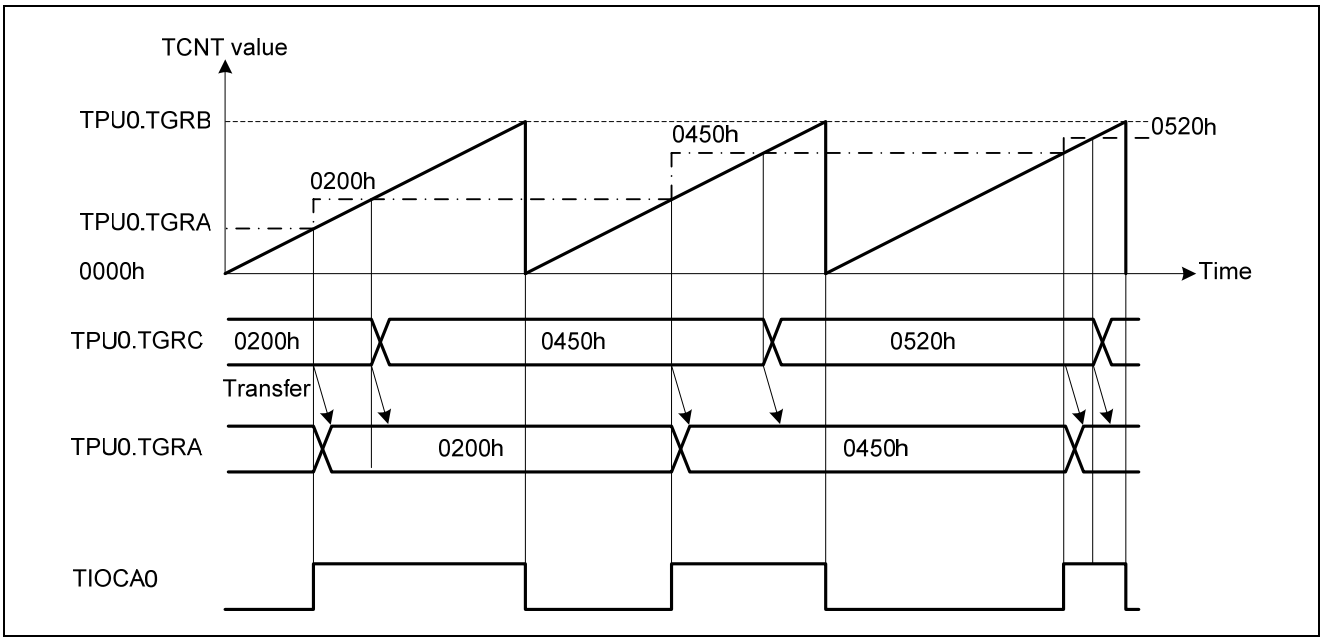


Figure 15.16 Example of Buffer Operation (1)

(b) When TPUm.TGRy is an input capture register

Figure 15.17 shows an operation example in which TPUm.TGRA has been set as an input capture register, and buffer operation has been set for the TGRA register and TPUm.TGRC.

Counter clearing by TGRA input capture has been set for TPUm.TCNT, and both rising and falling edges have been selected as the TIOCAn pin input capture input edge.

As buffer operation has been set, when the TCNT value is stored in TGRA upon occurrence of input capture A, the value previously stored in TGRA is simultaneously transferred to TGRC.

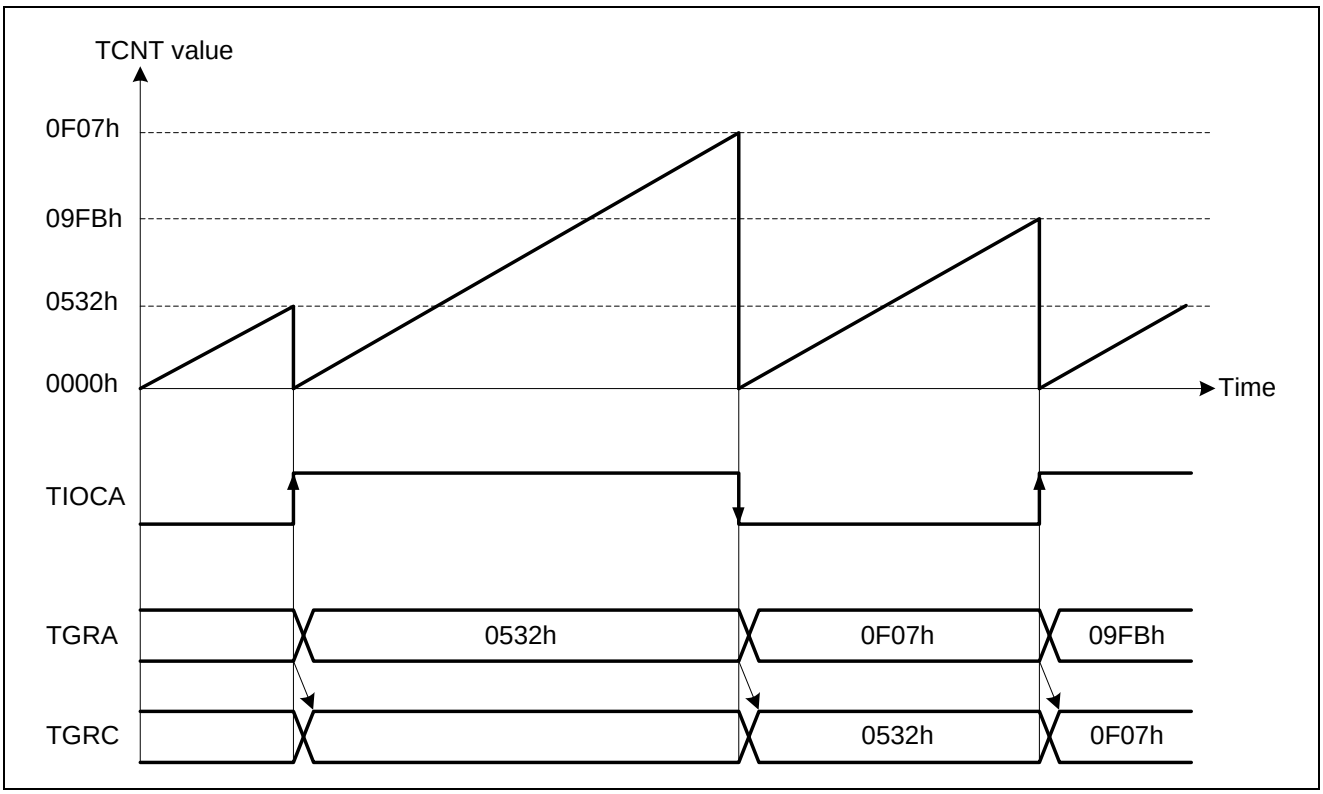


Figure 15.17 Example of Buffer Operation (2)

15.3.4 Cascaded Operation

In cascaded operation, two 16-bit counters for different channels are used together as a 32-bit counter.

In the case of unit 0, this function works by counting the TPU1 (TPU4) counter clock at overflow/underflow of TPU2.TCNT (TPU5.TCNT) as set by the TPSC[2:0] bits in TPU1.TCR (TPSC[2:0] bits in TPU4.TCR).

In the case of unit 1, this function works by counting the TPU7 (TPU10) counter clock at overflow/underflow of TPU8.TCNT (TPU11.TCNT) as set by the TPSC[2:0] bits in TPU7.TCR (TPSC[2:0] bits in TPU10.TCR).

Underflow occurs only when the lower 16-bit TPUm.TCNT is in phase counting mode.

Table 15.24 lists the register combinations used in cascaded operation.

Note: When phase counting mode is set for TPU1 or TPU4 (TPU7 or TPU10), the counter clock setting is invalid and the counter operates independently in phase counting mode.

Table 15.24 Cascaded Combinations

Unit	Combination	Upper 16 Bits	Lower 16 Bits
0	TPU1 and TPU 2	TPU1.TCNT	TPU2.TCNT
	TPU 4 and TPU 5	TPU4.TCNT	TPU5.TCNT
1	TPU 7 and TPU 8	TPU7.TCNT	TPU8.TCNT
	TPU 10 and TPU 11	TPU10.TCNT	TPU11.TCNT

(1) Example of Cascaded Operation Setting Procedure

Figure 15.18 shows an example of the setting procedure for cascaded operation.

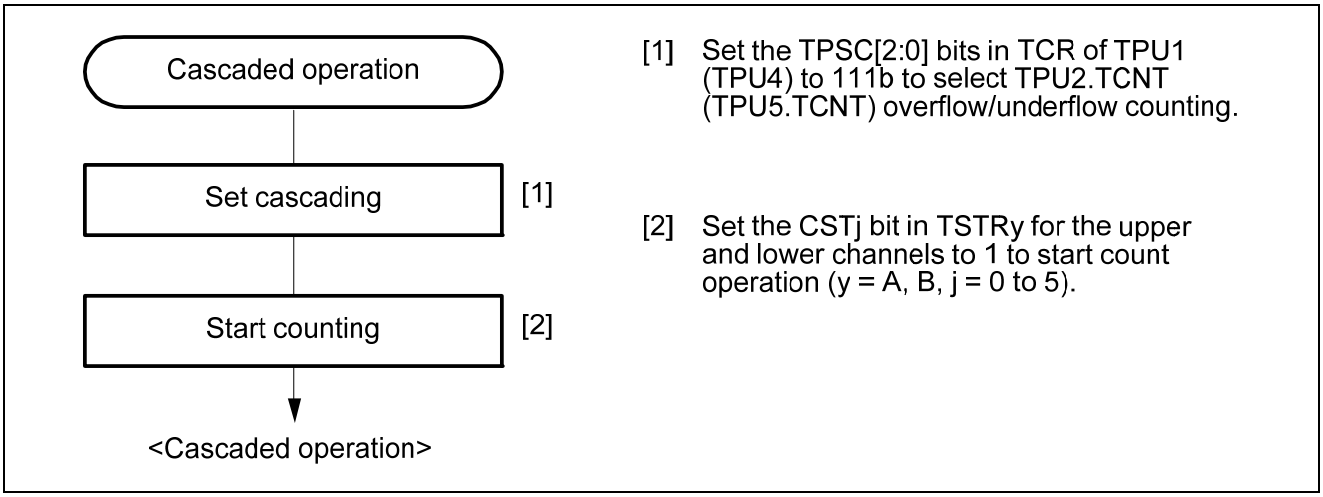


Figure 15.18 Cascaded Operation Setting Procedure

(2) Examples of Cascaded Operation

Figure 15.19 shows the operation when counting upon TPU2.TCNT overflow/underflow has been set for TPU1.TCNT, TPU1.TGRA and TPU2.TGRA have been set as input capture registers, and the rising edge of the TIOCA1 and TIOCA2 pins has been selected.

When a rising edge is input to the TIOCA1 and TIOCA2 pins simultaneously, the upper 16 bits of the 32-bit data are transferred to TPU1.TGRA, and the lower 16 bits to TPU2.TGRA.

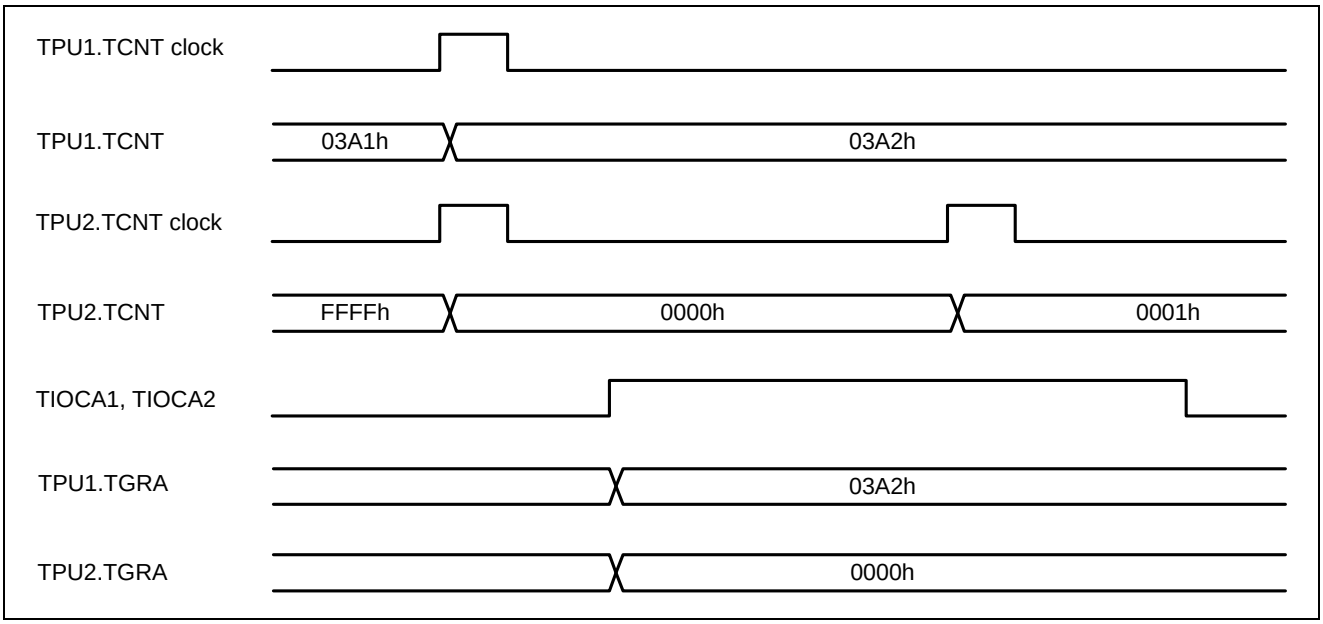


Figure 15.19 Example of Cascaded Operation (1)

Figure 15.20 shows the operation when counting upon TPU2.TCNT overflow/underflow has been set for TPU1.TCNT, and phase counting mode has been specified for TPU2.

TPU1.TCNT is incremented by TPU2.TCNT overflow and decremented by TPU2.TCNT underflow.

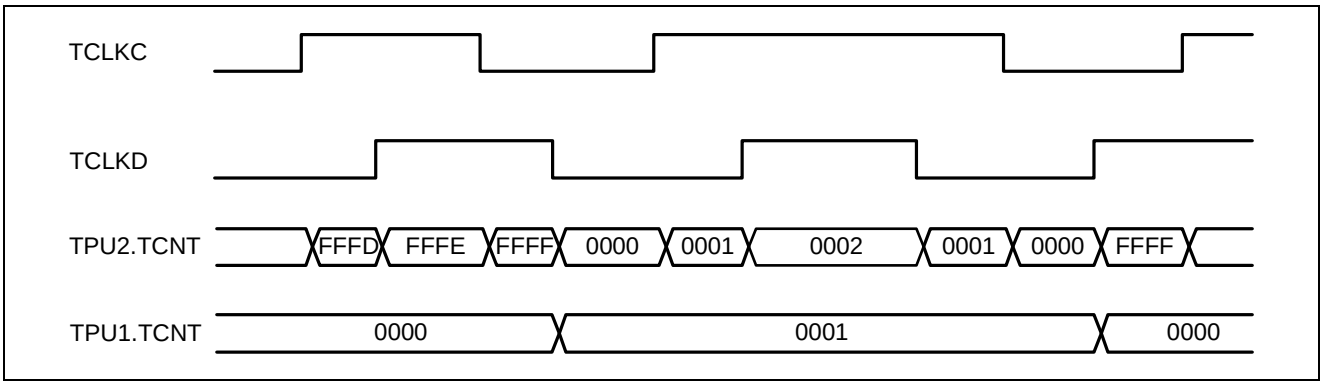


Figure 15.20 Example of Cascaded Operation (2)

15.3.5 PWM Modes

In PWM mode, PWM waveforms are output from the output pins. low-, high-, or toggle-output can be selected as the output level in response to compare match of each TPUm.TGRy.

Settings of TGRy registers can output a PWM waveform in the range of 0% to 100% duty cycle.

Specifying TGRy compare match as the counter clearing source enables the cycle to be set in that register. All channels can be set for PWM mode independently. Synchronous operation is also possible.

There are two PWM modes, as described below.

1. PWM mode 1
   PWM waveform is generated from the TIOCAn and TIOCCn pins by pairing TPUm.TGRA with TPUm.TGRB and TPUm.TGRC with TPUm.TGRD. The outputs specified by the IOA[3:0] bits in TPUm.TIOR(H) and IOC[3:0] bits in TPUm.TIORL are output from the TIOCAn and TIOCCn pins at compare matches A and C, respectively. The outputs specified by the IOB[3:0] bits in TPUm.TIOR(H) and IOD[3:0] bits in TPUm.TIORL are output from the TIOCAn and TIOCCn pins at compare matches B and D, respectively. The initial output value is the value set in TGRA or TGRC. If the set values of paired TGRy registers are identical, the output value does not change even when a compare match occurs.
   In PWM mode 1, a maximum 8-phase PWM output is possible.
2. PWM mode 2
   PWM waveform is generated by using one TPUm.TGRy as the cycle register and the others as duty cycle registers. The output specified in TPUm.TIORH, TPUm.TIORL, or TPUm.TIOR is performed by compare matches. Upon counter clearing by a synchronous register compare match, the output value of each pin is the initial value set in TIORH, TIORL, or TIOR. If the set values of the cycle register and duty cycle register are identical, the output value does not change even when a compare match occurs.
   In PWM mode 2, a maximum 15-phase PWM waveform is possible by combined use with synchronous operation.

The correspondence between PWM output pins and registers is listed in table 15.25.

Table 15.25 PWM Output Registers and Output Pins

			Output Pin	
Unit	**Channel**	**Register**	**PWM Mode 1**	**PWM Mode 2**
0	TPU 0	TPU0.TGRA	TIOCA0	TIOCA0
		TPU0.TGRB		TIOCB0
		TPU0.TGRC	TIOCC0	TIOCC0
		TPU0.TGRD		TIOCD0
	TPU 1	TPU1.TGRA	TIOCA1	TIOCA1
		TPU1.TGRB		TIOCB1
	TPU 2	TPU2.TGRA	TIOCA2	TIOCA2
		TPU2.TGRB		TIOCB2
	TPU 3	TPU3.TGRA	TIOCA3	TIOCA3
		TPU3.TGRB		TIOCB3
		TPU3.TGRC	TIOCC3	TIOCC3
		TPU3.TGRD		TIOCD3
	TPU 4	TPU4.TGRA	TIOCA4	TIOCA4
		TPU4.TGRB		TIOCB4
	TPU 5	TPU5.TGRA	TIOCA5	TIOCA5
		TPU5.TGRB		TIOCB5
1	TPU 6	TPU6.TGRA	TIOCA6	TIOCA6
		TPU6.TGRB		TIOCB6
		TPU6.TGRC	TIOCC6	TIOCC6
		TPU6.TGRD		TIOCD6
	TPU 7	TPU7.TGRA	TIOCA7	TIOCA7
		TPU7.TGRB		TIOCB7
	TPU 8	TPU8.TGRA	TIOCA8	TIOCA8
		TPU8.TGRB		TIOCB8
	TPU 9	TPU9.TGRA	TIOCA9	TIOCA9
		TPU9.TGRB		TIOCB9
		TPU9.TGRC	TIOCC9	TIOCC9
		TPU9.TGRD		TIOCD9
	TPU 10	TPU10.TGRA	TIOCA10	TIOCA10
		TPU10.TGRB		TIOCB10
	TPU 11	TPU11.TGRA	TIOCA11	TIOCA11
		TPU11.TGRB		TIOCB11

Note: In PWM mode 2, PWM waveform is not possible for the TPUm.TGRy register in which the cycle is set.

(1) Example of PWM Mode Setting Procedure

Figure 15.21 shows an example of the PWM mode setting procedure.

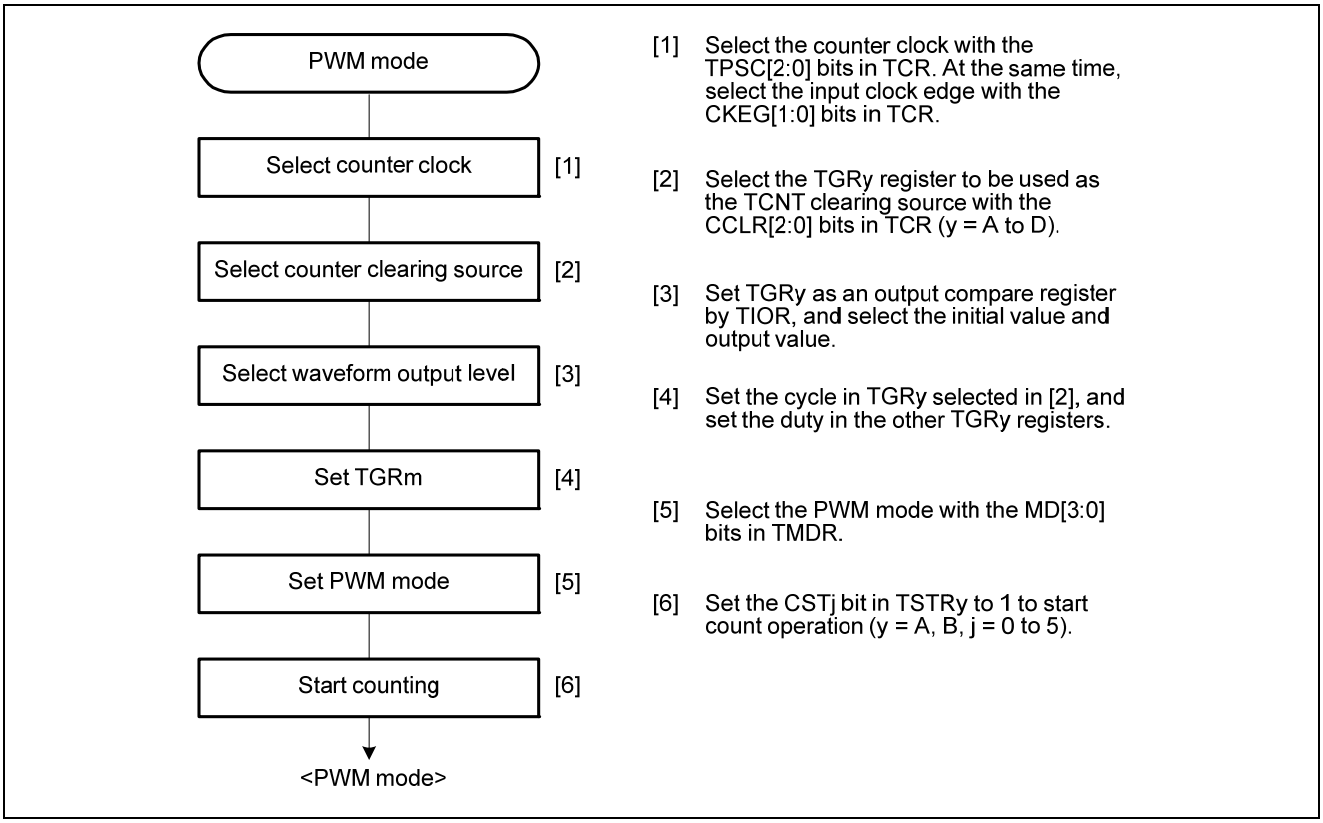


Figure 15.21 Example of PWM Mode Setting Procedure

(2) Examples of PWM Mode Operation

Figure 15.22 shows an example of PWM mode 1 operation.

In this example, TPUm.TGRA compare match is set as the TPUm.TCNT clearing source, 0 is set for the TGRA initial output value and output value, and 1 is set as the TPUm.TGRB output value.

In this case, the value set in TGRA is used as the cycle, and the value set in TGRB is used as the duty cycle.

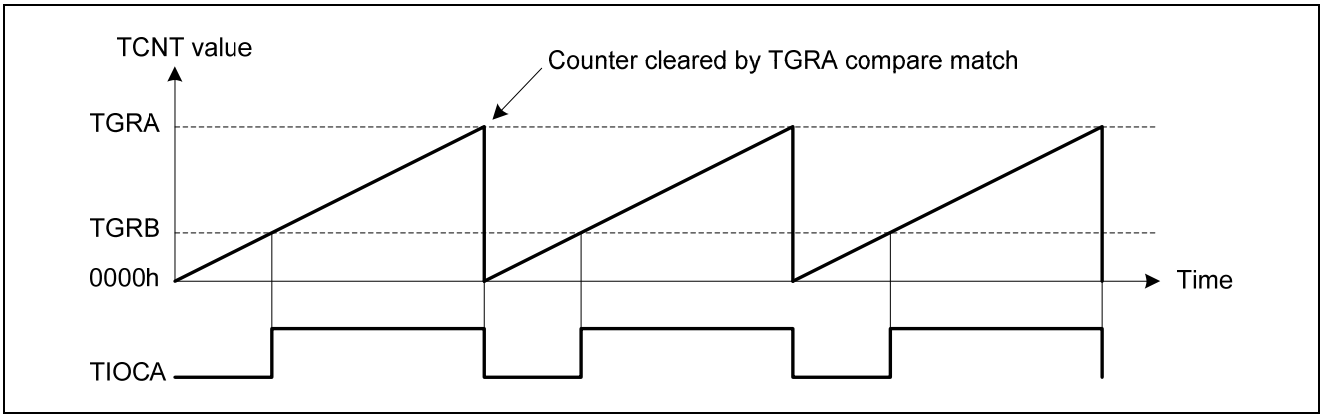


Figure 15.22 Example of PWM Mode Operation (1)

Figure 15.23 shows an example of PWM mode 2 operation.

In this example, synchronous operation is specified for TPU0 and TPU1, TPU1.TGRB compare match is set as the TPUm.TCNT clearing source, and 0 is set for the initial output value and 1 for the output value of the other TPUm.TGRy registers (TPU0.TGRA to TPU0.TGRD and TPU1.TGRA), to output a 5-phase PWM waveform.

In this case, the value set in TPU1.TGRB is used as the cycle, and the values set in the other TGRy registers are used as the duty cycle.

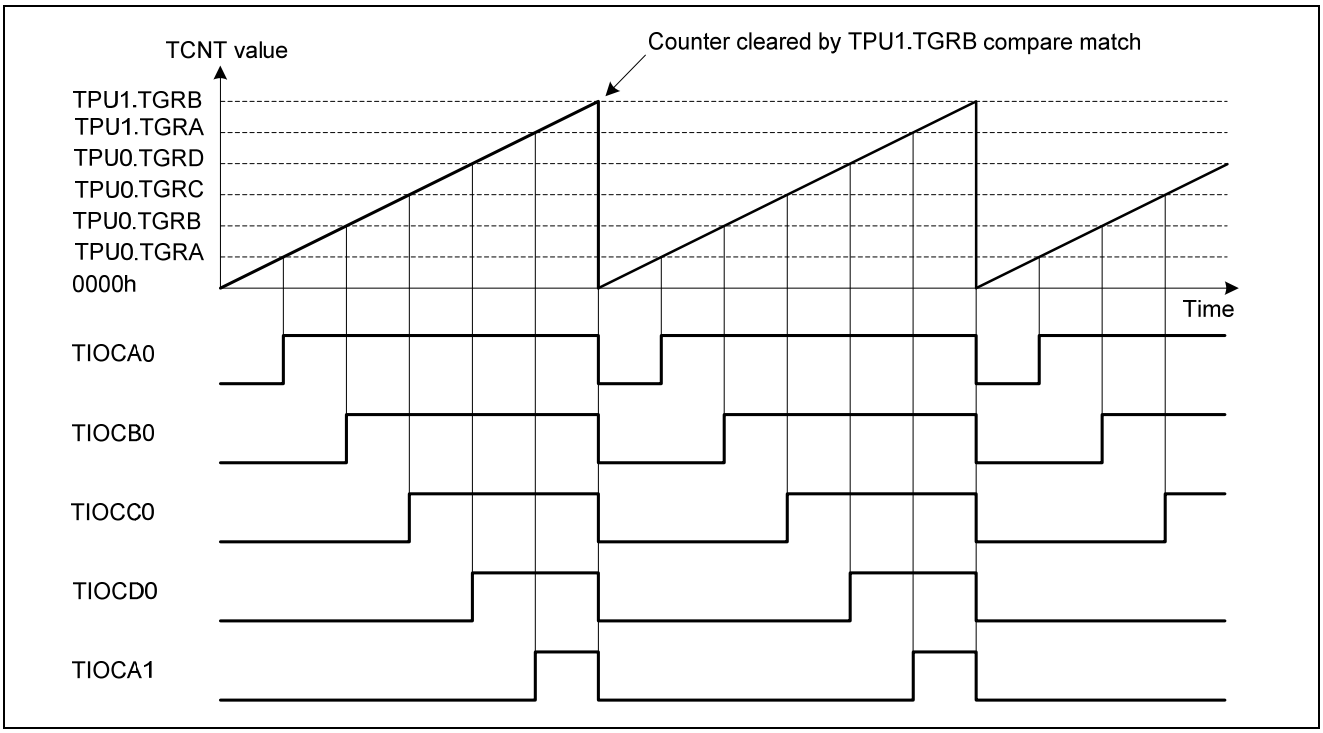


Figure 15.23 Example of PWM Mode Operation (2)

Figure 15.24 shows examples of PWM waveform output with 0% duty cycle and 100% duty cycle in PWM mode.

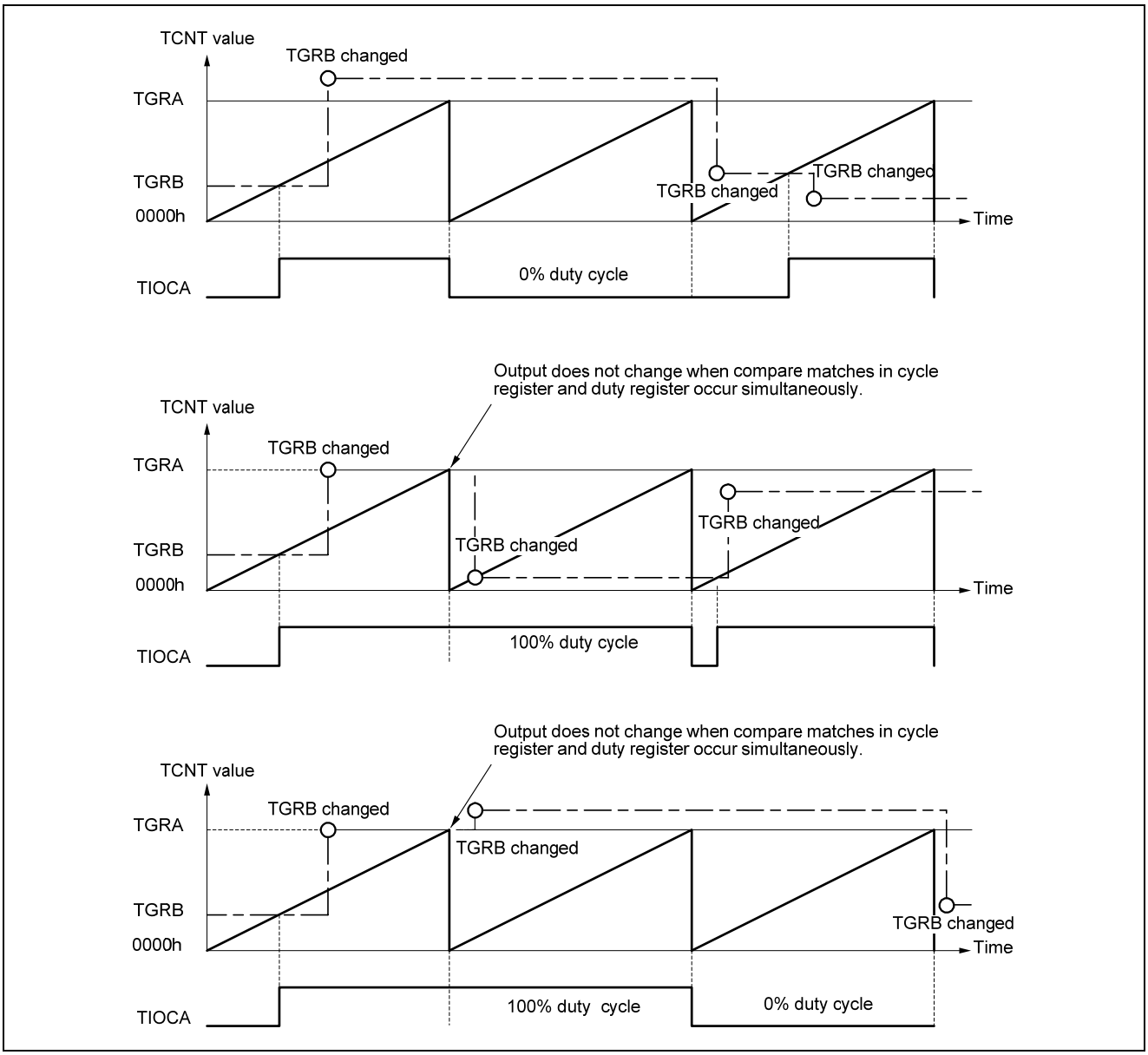


Figure 15.24 Example of PWM Mode Operation (3)

15.3.6 Phase Counting Mode

In phase counting mode, the phase difference between two external clock inputs is detected by the settings for channels 1, 2, 4, and 5 (unit 0) and channels 7, 8, 10, and 11 (unit 1), and TPUm.TCNT is incremented/decremented accordingly.

When phase counting mode is set, an external clock is selected as the counter input clock and TCNT operates as an up-/down-counter regardless of the setting of the TPSC[2:0] bits and CKEG[1:0] bits in TPUm.TCR. However, the lower 2 bits of the CCLR[2:0] bits in TPUm.TCR and the functions of TPUm.TIORH, TPUm.TIORL, TPUm.TIOR, TPUm.TIER, and TPUm.TGRy are valid, and therefore input capture/compare match and interrupt functions are available.

This can be used for two-phase encoder pulse input.

When an overflow occurs while TCNT is counting up, a TCIV interrupt request is generated; when an underflow occurs while TCNT is counting down, a TCIU interrupt request is generated. The TCFD bit in TPUm.TSR is the count direction flag. Reading the TCFD flag provides an indication of whether TCNT is counting up or down.

Table 15.26 shows the correspondence between external clock pins and channels.

Table 15.26 Clock Input Pins in Phase Counting Mode

		External Clock Pins	
Unit	**Channel**	**A-Phase**	**B-Phase**
0	When TPU1 or TPU5 is set to phase counting mode	TCLKA	TCLKB
	When TPU2 or TPU4 is set to phase counting mode	TCLKC	TCLKD
1	When TPU7 or TPU11 is set to phase counting mode	TCLKE	TCLKF
	When TPU8 or TPU10 is set to phase counting mode	TCLKG	TCLKH

(1) Example of Phase Counting Mode Setting Procedure

Figure 15.25 shows an example of the phase counting mode setting procedure.

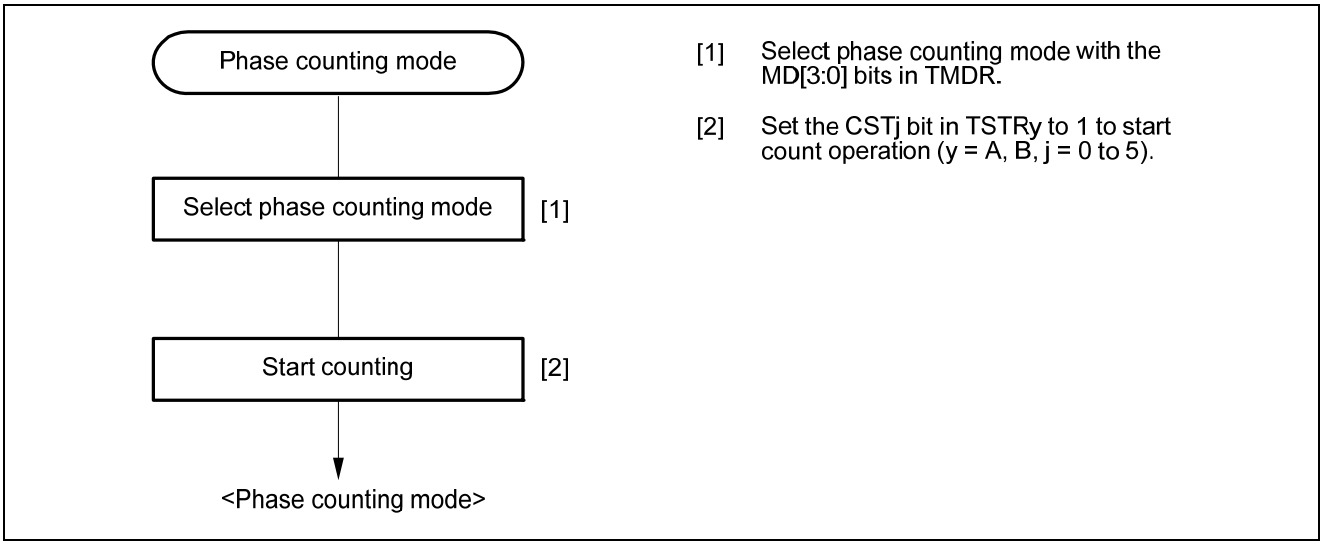


Figure 15.25 Example of Phase Counting Mode Setting Procedure

(2) Examples of Phase Counting Mode Operation

In phase counting mode, TPUm.TCNT counts up or down according to the phase difference between two external clocks. There are four modes, according to the count conditions.

(a) Phase counting mode 1

Figure 15.26 shows an example of phase counting mode 1 operation, and table 15.27 lists the TCNTn up-/down-count conditions.

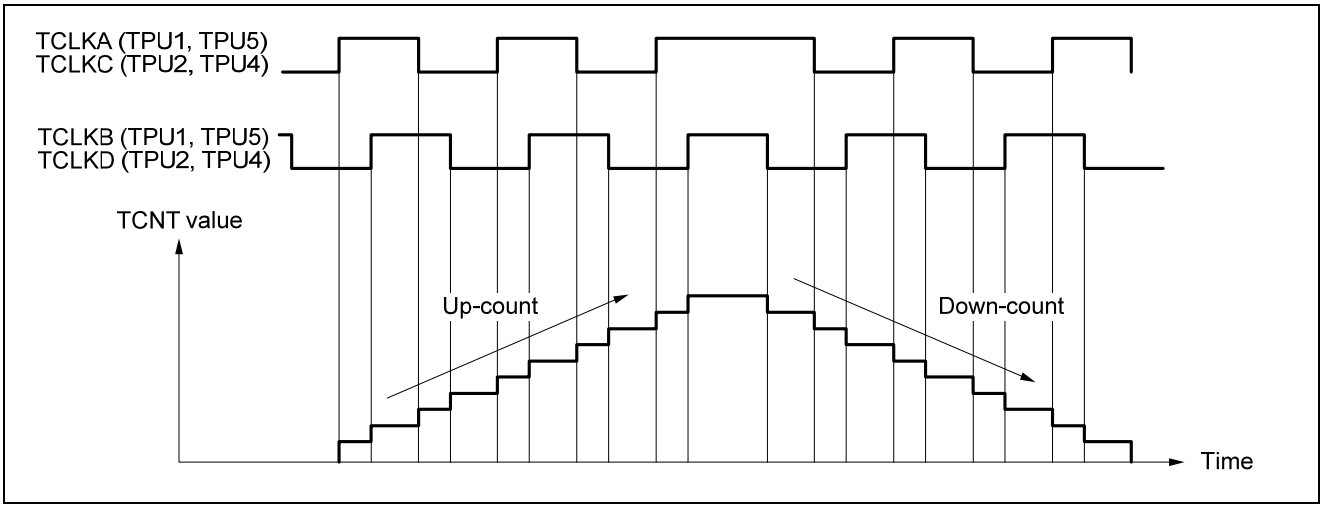


Figure 15.26 Example of Phase Counting Mode 1 Operation

Table 15.27 Up-/Down-Count Conditions in Phase Counting Mode 1

TCLKA (TPU1, TPU5) TCLKC (TPU2, TPU4)	TCLKB (TPU1, TPU5) TCLKD (TPU2, TPU4)	Operation
High level	↑	Up-count
Low level	↓	
↑	Low level	
↓	High level	
High level	↓	Down-count
Low level	↑	
↑	High level	
↓	Low level	

[Legend]
↑: Rising edge
↓: Falling edge

(b) Phase counting mode 2

Figure 15.27 shows an example of phase counting mode 2 operation, and table 15.28 lists the TPUm.TCNT up-/down-count conditions.

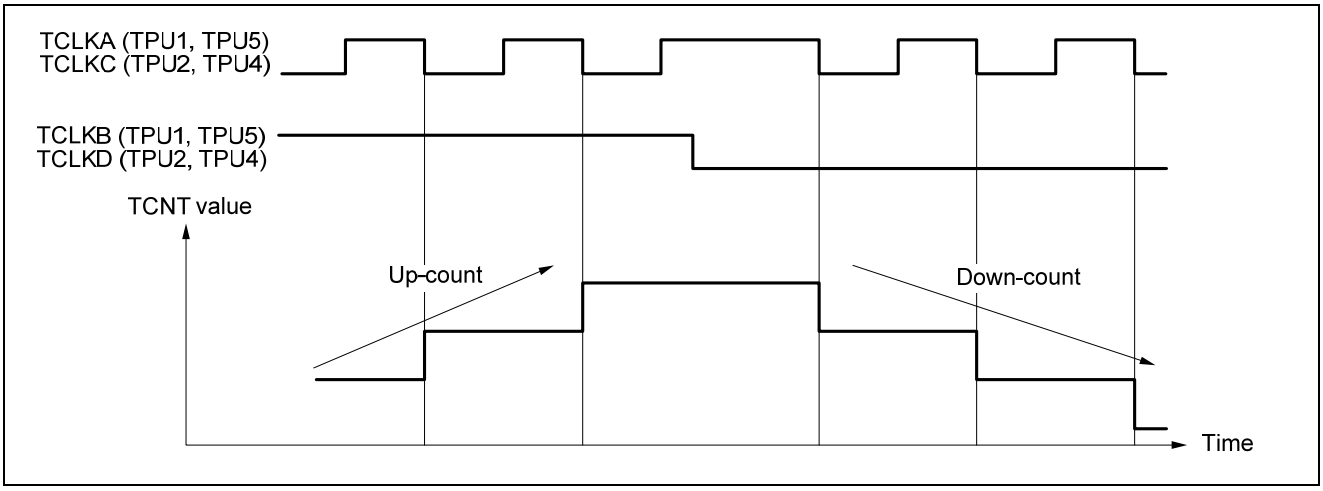


Figure 15.27 Example of Phase Counting Mode 2 Operation

Table 15.28 Up-/Down-Count Conditions in Phase Counting Mode 2

TCLKA (TPU1, TPU5) TCLKC (TPU2, TPU4)	TCLKB (TPU1, TPU5) TCLKD (TPU2, TPU4)	Operation
High level	↑	Don't care
Low level	↓	Don't care
↑	Low level	Don't care
↓	High level	Up-count
High level	↓	Don't care
Low level	↑	Don't care
↑	High level	Don't care
↓	Low level	Down-count

[Legend]
↑ : Rising edge
↓ : Falling edge

(c) Phase counting mode 3

Figure 15.28 shows an example of phase counting mode 3 operation, and table 15.29 lists the TPUm.TCNT up-/down-count conditions.

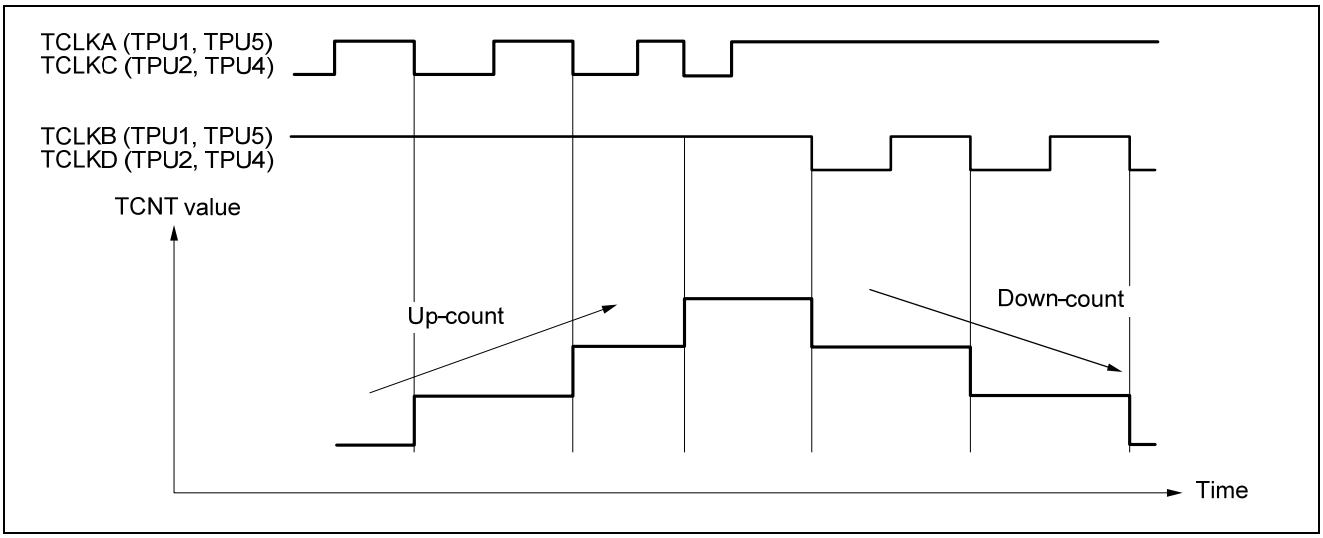


Figure 15.28 Example of Phase Counting Mode 3 Operation

Table 15.29 Up-/Down-Count Conditions in Phase Counting Mode 3

TCLKA (TPU1, TPU5) TCLKC (TPU2, TPU4)	TCLKB (TPU1, TPU5) TCLKD (TPU2, TPU4)	Operation
High level	↑	Don't care
Low level	↓	Don't care
↑	Low level	Don't care
↓	High level	Up-count
High level	↓	Down-count
Low level	↑	Don't care
↑	High level	Don't care
↓	Low level	Don't care

[Legend]
↑: Rising edge
↓: Falling edge

(d) Phase counting mode 4

Figure 15.29 shows an example of phase counting mode 4 operation, and table 15.30 lists the TPUm.TCNT up-/down-count conditions.

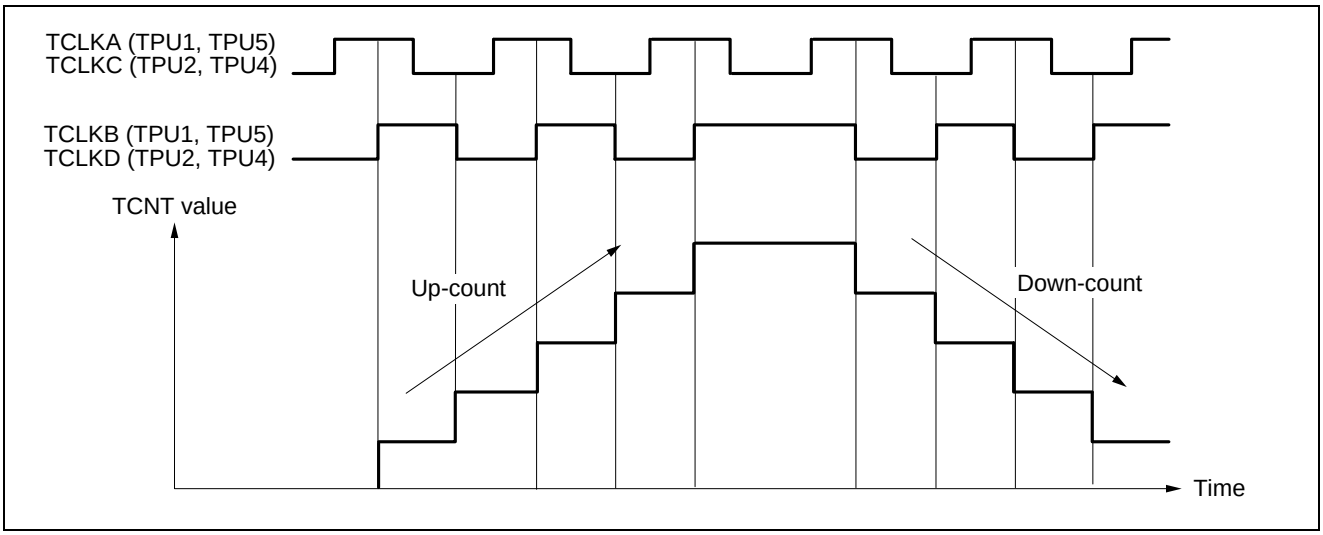


Figure 15.29 Example of Phase Counting Mode 4 Operation

Table 15.30 Up-/Down-Count Conditions in Phase Counting Mode 4

TCLKA (TPU1, TPU5) / TCLKC (TPU2, TPU4)	TCLKB (TPU1, TPU5) / TCLKD (TPU2, TPU4)	Operation
High level	↑	Up-count
Low level	↓	
↑	Low level	Don't care
↓	High level	
High level	↓	Down-count
Low level	↑	
↑	High level	Don't care
↓	Low level	

[Legend]
↑: Rising edge
↓: Falling edge

15.3.6.1 Phase Counting Mode Application Example

Figure 15.30 shows an example in which phase counting mode is set for TPU1, and TPU1 is coupled with TPU0 to input servo motor 2-phase encoder pulses in order to detect the position or speed.

TPU1 is set to phase counting mode 1, and the encoder pulse A-phase and B-phase are input to the TCLKA and TCLKB pins.

TPU0 operates with TPU0.TCNT counter clearing by TPU0.TGRC compare match; TPU0.TGRA and TPU0.TGRC are used for the compare match function and are set with the speed control cycle and position control cycle. TPU0.TGRB is used for input capture, with TPU0.TGRB and TPU0.TGRD operating in buffer mode. The TPU1 counter input clock is specified as the TPU0.TGRB input capture source, and the pulse width of 2-phase encoder 4-multiplication pulses is detected.

TPU1.TGRA and TPU1.TGRB for TPU1 are specified for input capture, TPU0.TGRA and TPU0.TGRC compare matches are selected as the input capture source, and the up-/down-counter values for the control cycles are stored.

This procedure enables accurate position/speed detection to be achieved.

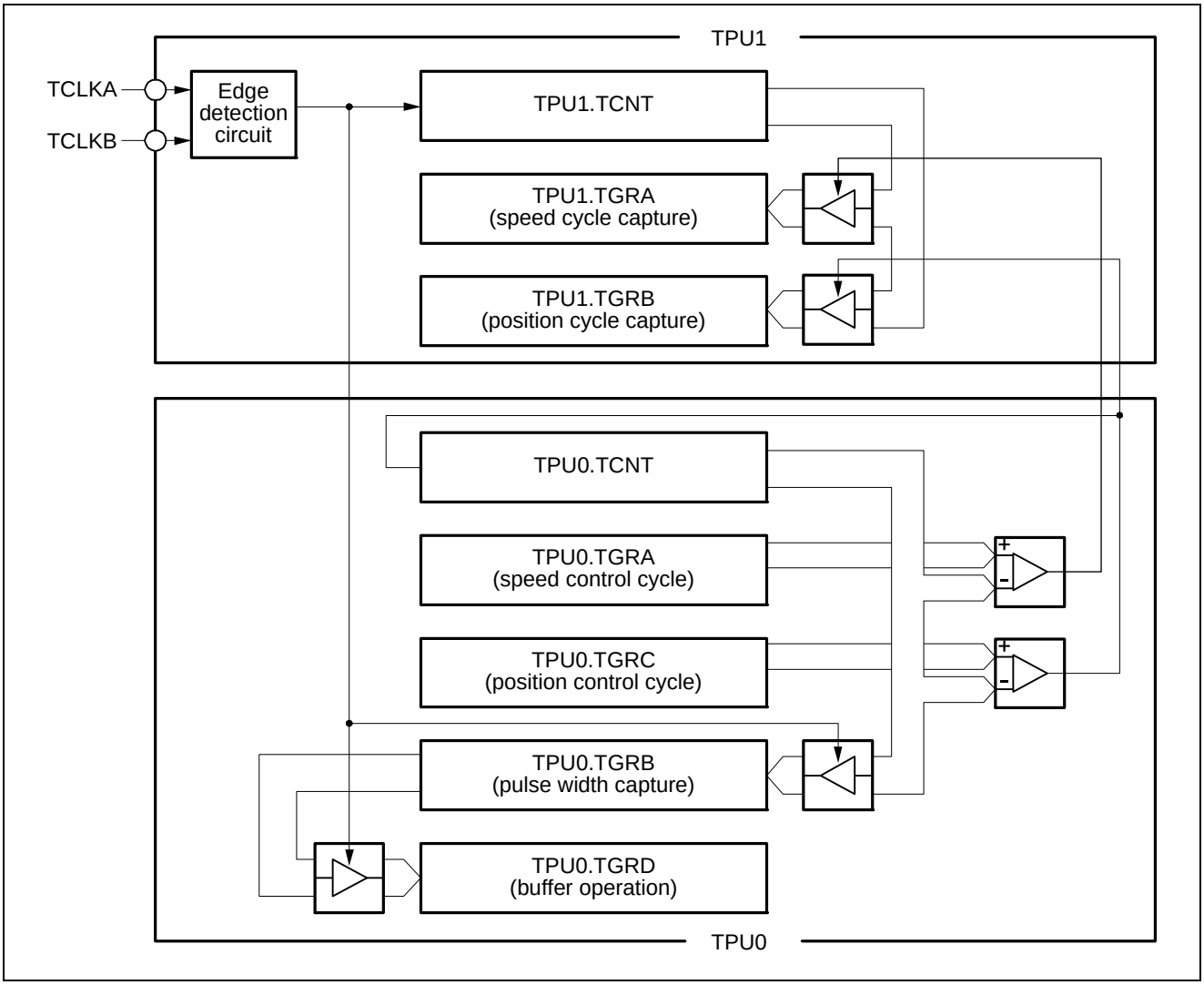


Figure 15.30 Phase Counting Mode Application Example

15.4 Interrupt Sources

There are three kinds of TPU interrupt sources: TPUm.TGRy input capture/compare match, TPUm.TCNT overflow, and TPUm.TCNT underflow.

Relative channel priority levels can be changed by the interrupt controller, but the priority within a channel is fixed. For details, see section 10, Interrupt Control Unit (ICU).

Table 15.31 lists the TPU interrupt sources.

Table 15.31 TPU Interrupts

Unit	Channel	Name	Interrupt Source	DTC Activation	DMAC Activation
0	TPU0	TGI0A	TPU0.TGRA input capture/compare match	Possible	Poss ble
		TGI0B	TPU0.TGRB input capture/compare match	Possible	Not possible
		TGI0C	TPU0.TGRC input capture/compare match	Possible	Not possible
		TGI0D	TPU0.TGRD input capture/compare match	Possible	Not possible
		TCI0V	TPU0.TCNT overflow	Not possible	Not possible
	TPU1	TGI1A	TPU1.TGRA input capture/compare match	Possible	Poss ble
		TGI1B	TPU1.TGRB input capture/compare match	Possible	Not possible
		TCI1V	TPU1.TCNT overflow	Not possible	Not possible
		TCI1U	TPU1.TCNT underflow	Not possible	Not possible
	TPU2	TGI2A	TPU2.TGRA input capture/compare match	Possible	Poss ble
		TGI2B	TPU2.TGRB input capture/compare match	Possible	Not possible
		TCI2V	TPU2.TCNT overflow	Not possible	Not possible
		TCI2U	TPU2.TCNT underflow	Not possible	Not possible
	TPU3	TGI3A	TPU3.TGRA input capture/compare match	Possible	Poss ble
		TGI3B	TPU3.TGRB input capture/compare match	Possible	Not possible
		TGI3C	TPU3.TGRC input capture/compare match	Possible	Not possible
		TGI3D	TPU3.TGRD input capture/compare match	Possible	Not possible
		TCI3V	TPU3.TCNT overflow	Not possible	Not possible
	TPU4	TGI4A	TPU4.TGRA input capture/compare match	Possible	Poss ble
		TGI4B	TPU4.TGRB input capture/compare match	Possible	Not possible
		TCI4V	TPU4.TCNT overflow	Not possible	Not possible
		TCI4U	TPU4.TCNT underflow	Not possible	Not possible
	TPU5	TGI5A	TPU5.TGRA input capture/compare match	Possible	Poss ble
		TGI5B	TPU5.TGRB input capture/compare match	Possible	Not possible
		TCI5V	TPU5.TCNT overflow	Not possible	Not possible
		TCI5U	TPU5.TCNT underflow	Not possible	Not possible
1	TPU6	TGI6A	TPU6.TGRA input capture/compare match	Possible	Poss ble
		TGI6B	TPU6.TGRB input capture/compare match	Possible	Not possible
		TGI6C	TPU6.TGRC input capture/compare match	Possible	Not possible
		TGI6D	TPU6.TGRD input capture/compare match	Possible	Not possible
		TCI6V	TPU6.TCNT overflow	Not possible	Not possible
	TPU7	TGI7A	TPU7.TGRA input capture/compare match	Possible	Poss ble
		TGI7B	TPU7.TGRB input capture/compare match	Possible	Not possible
		TCI7V	TPU7.TCNT overflow	Not possible	Not possible
		TCI7U	TPU7.TCNT underflow	Not possible	Not possible
	TPU8	TGI8A	TPU8.TGRA input capture/compare match	Possible	Poss ble
		TGI8B	TPU8.TGRB input capture/compare match	Possible	Not possible
		TCI8V	TPU8.TCNT overflow	Not possible	Not possible
		TCI8U	TPU8.TCNT underflow	Not possible	Not possible

Unit	Channel	Name	Interrupt Source	DTC Activation	DMAC Activation
1	TPU9	TGI9A	TPU9.TGRA input capture/compare match	Possible	Poss ble
		TGI9B	TPU9.TGRB input capture/compare match	Possible	Not possible
		TGI9C	TPU9.TGRC input capture/compare match	Possible	Not possible
		TGI9D	TPU9.TGRD input capture/compare match	Possible	Not possible
		TCI9V	TPU9.TCNT overflow	Not possible	Not possible
	TPU10	TGI10A	TPU10.TGRA input capture/compare match	Possible	Poss ble
		TGI10B	TPU10.TGRB input capture/compare match	Possible	Not possible
		TCI10V	TPU10.TCNT overflow	Not possible	Not possible
		TCI10U	TPU10.TCNT underflow	Not possible	Not possible
	TPU11	TGI11A	TPU11.TGRA input capture/compare match	Possible	Poss ble
		TGI11B	TPU11.TGRB input capture/compare match	Possible	Not possible
		TCI11V	TPU11.TCNT overflow	Not possible	Not possible
		TCI11U	TPU11.TCNT underflow	Not possible	Not possible

Note: This table shows the initial state immediately after a reset. The relative channel priority levels can be changed by the interrupt controller.

(1) Input Capture/Compare Match Interrupt

An interrupt is requested when the TGIEy bit (y = A, B, C, D) in TPUm.TIER is set to 1 by the occurrence of a TPUm.TGRy input capture/compare match on a channel. The TPU has 32 input capture/compare match interrupts, four each for TPU0 and TPU3 (TPU6 and TPU9), and two each for TPU1, TPU2, TPU4, and TPU5 (TPU7, TPU8, TPU10, and TPU11).

(2) Overflow Interrupt

An interrupt is requested when the TCIEV bit in TPUm.TIER is set to 1 by the occurrence of a TPUm.TCNT overflow on a channel. The TPU has twelve overflow interrupts, one for each channel.

(3) Underflow Interrupt

An interrupt is requested when the TCIEU bit in TPUm.TIER is set to 1 by the occurrence of a TPUm.TCNT underflow on a channel. The TPU has eight underflow interrupts, one each for TPU1, TPU2, TPU4, and TPU5 (TPU7, TPU8, TPU10, and TPU11).

15.5 DTC Activation

The DTC can be activated by the TPUm.TGRy input capture/compare match interrupt of each channel. For details, see section 13, Data Transfer Controller (DTC).

A total of 32 input capture/compare match interrupts can be used as DTC activation sources, four each for TPU0 and TPU3 (TPU6 and TPU9), and two each for TPU1, TPU2, TPU4, and TPU5 (TPU7, TPU8, TPU10, and TPU11).

15.6 DMAC Activation

The DMAC can be activated by the TPUm.TGRA input capture/compare match interrupt of each channel. For details, see section 12, DMA controller (DMAC).

A total of twelve TPUm.TGRA input capture/compare match interrupts can be used as DMAC activation sources, one for each channel.

15.7 A/D Converter Activation

The TPU can activate the A/D converter by the TPUm.TGRA input capture/compare match for each channel. Moreover, the A/D converter is activated by the TGRA to TGRD input capture/compare match from TPU0.*

When the TTGE bit in TPUm.TIER is set to 1, the TPU requests the A/D converter to start A/D conversion by the occurrence of a TPUm.TGRA input capture/compare match on a particular channel. If the TPU conversion start trigger has been selected on the A/D converter side at this time, A/D conversion is started. Moreover, the TPU requests the A/D converter to start A/D conversion by the occurrence of a TGRA to TGRD input capture/compare match from TPU0 . If the TPU conversion start trigger has been selected on the A/D converter side at this time, A/D conversion is started.

Note: * For the corresponding unit of A/D converter, see section 23, A/D Converter.

15.8 Operation Timing

15.8.1 Input/Output Timing

(1) TPUm.TCNT Count Timing

Figure 15.31 shows TPUm.TCNT count timing in internal clock operation, and figure 15.32 shows TCNT count timing in external clock operation.

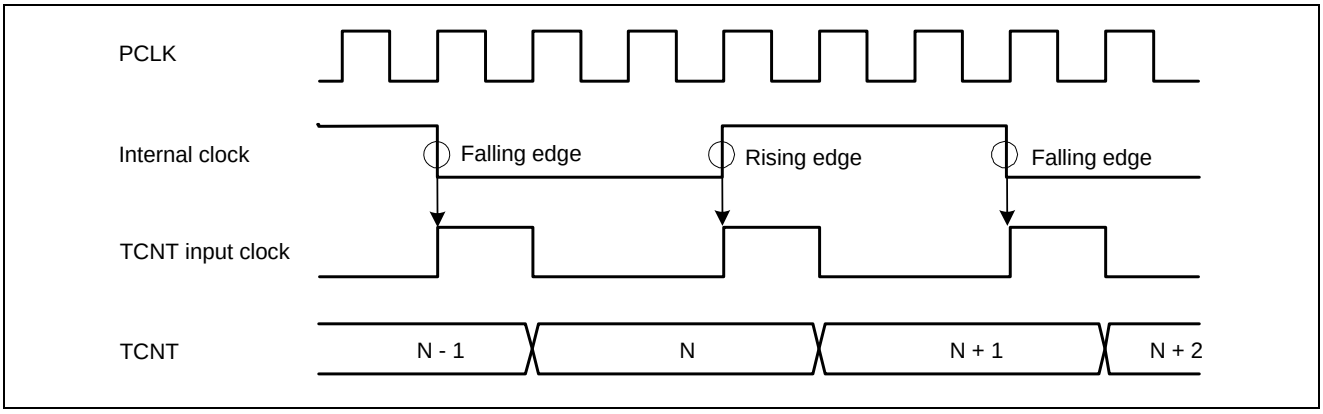


Figure 15.31 Count Timing in Internal Clock Operation

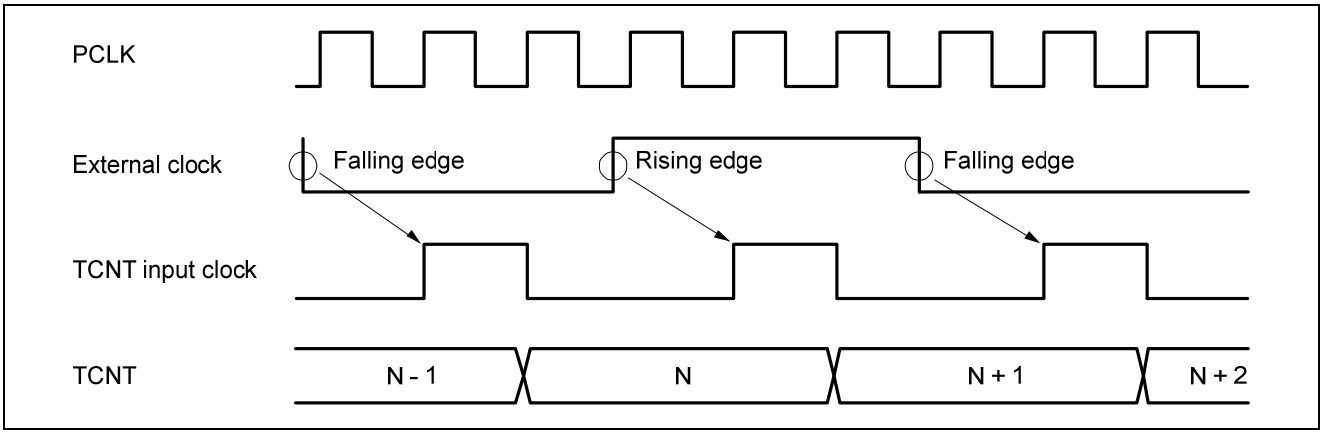


Figure 15.32 Count Timing in External Clock Operation

(2) Output Compare Output Timing

A compare match signal is generated in the final state in which TPUm.TCNT and TPUm.TGRy match (the point at which the count value matched by TCNT is updated). When a compare match signal is generated, the output value set in TPUm.TIORH, TPUm.TIORL, or TPUm.TIOR is output to the output compare output pin TIOCyn (y = A to D, n = 0 to 11). After a match between TCNT and TGRy, the compare match signal is not generated until the TCNT input clock is generated.

Figure 15.33 shows output compare output timing.

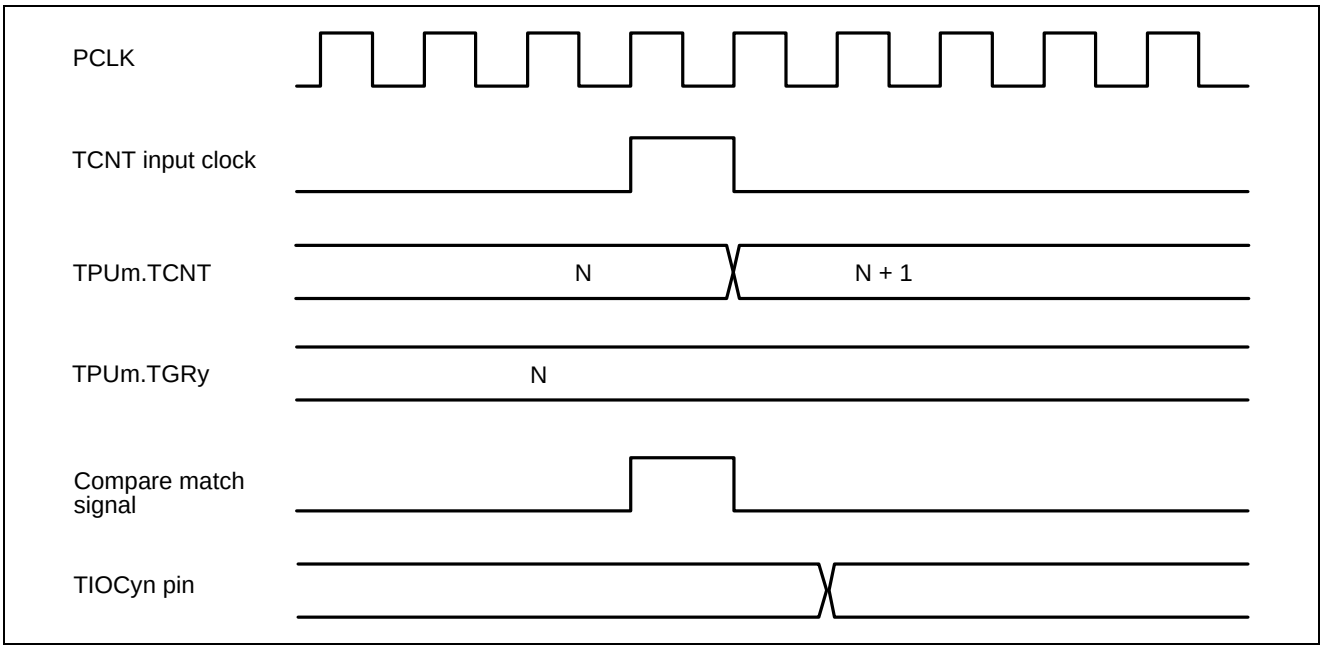


Figure 15.33 Output Compare Output Timing

(3) Input Capture Signal Timing

Figure 15.34 shows input capture signal timing.

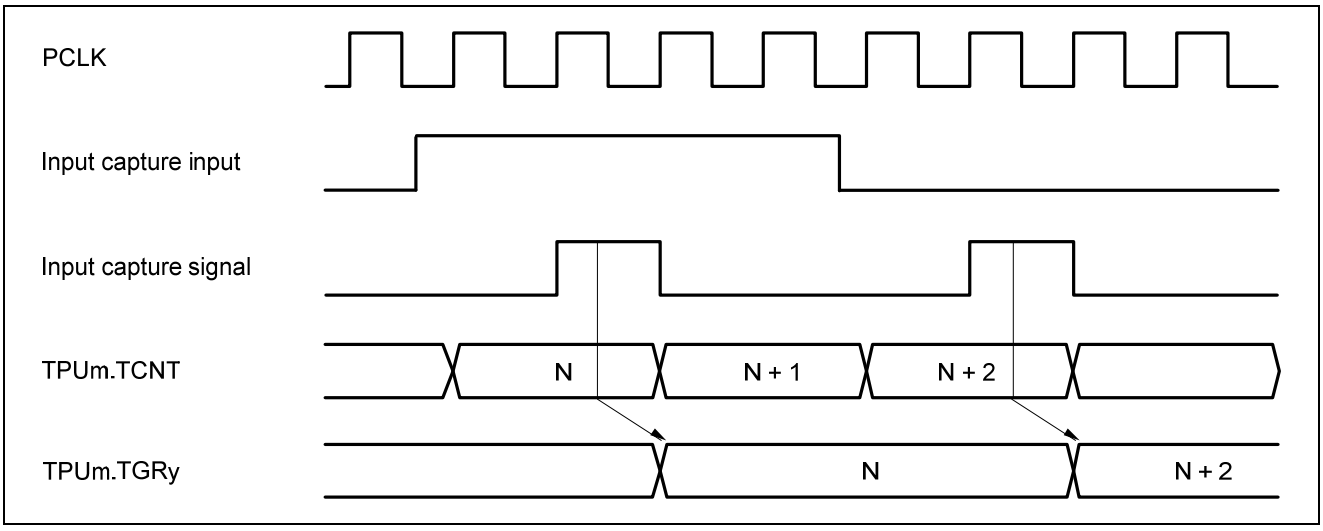


Figure 15.34 Input Capture Signal Timing

(4) Timing for Counter Clearing by Compare Match/Input Capture

Figure 15.35 shows the timing when counter clearing by compare match occurrence is specified, and figure 15.36 shows the timing when counter clearing by input capture occurrence is specified.

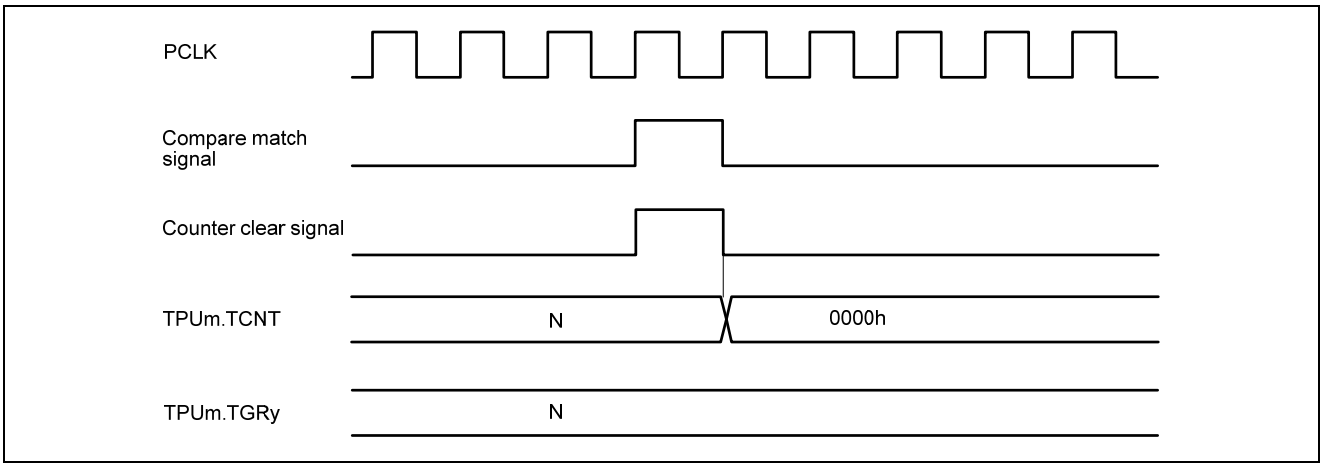


Figure 15.35 Counter Clear Timing (Compare Match)

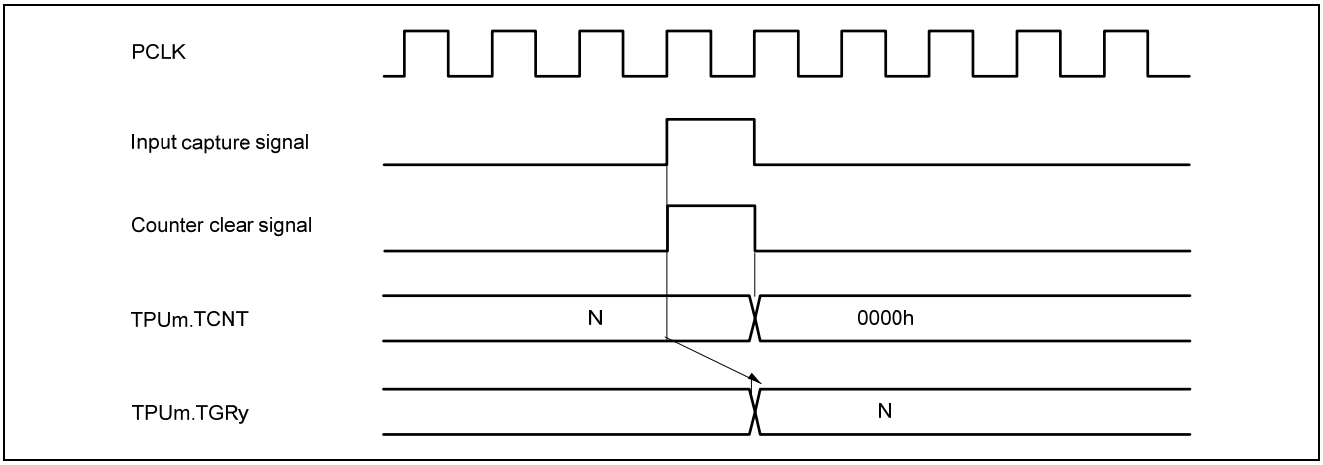


Figure 15.36 Counter Clear Timing (Input Capture)

(5) Buffer Operation Timing

Figures 15.37 and 15.38 show the timings in buffer operation.

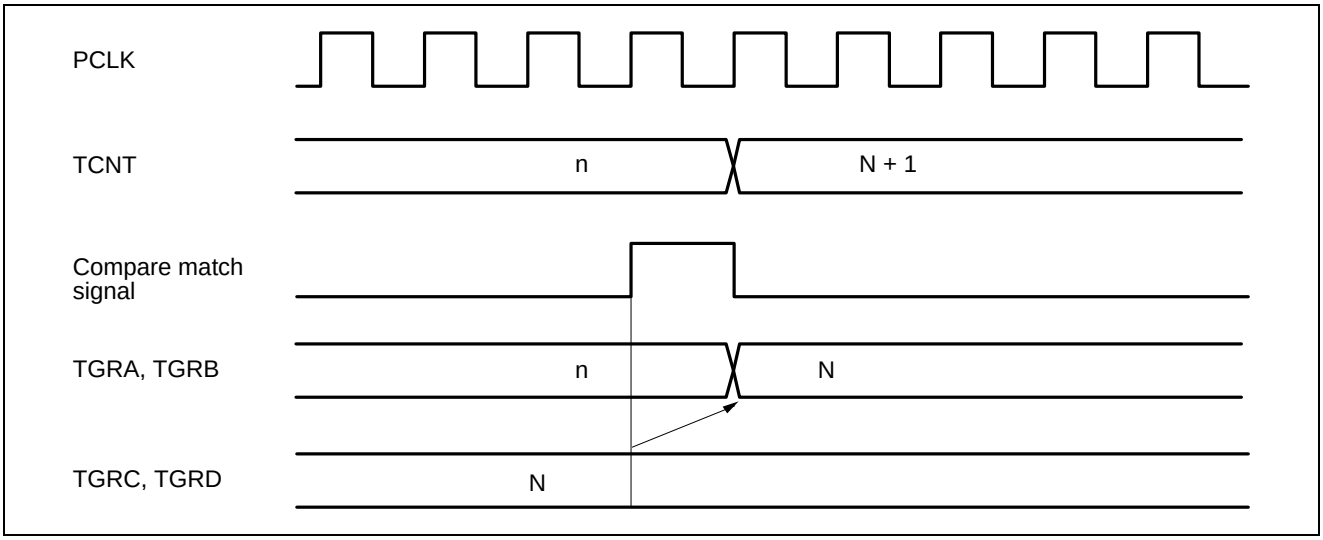


Figure 15.37 Buffer Operation Timing (Compare Match)

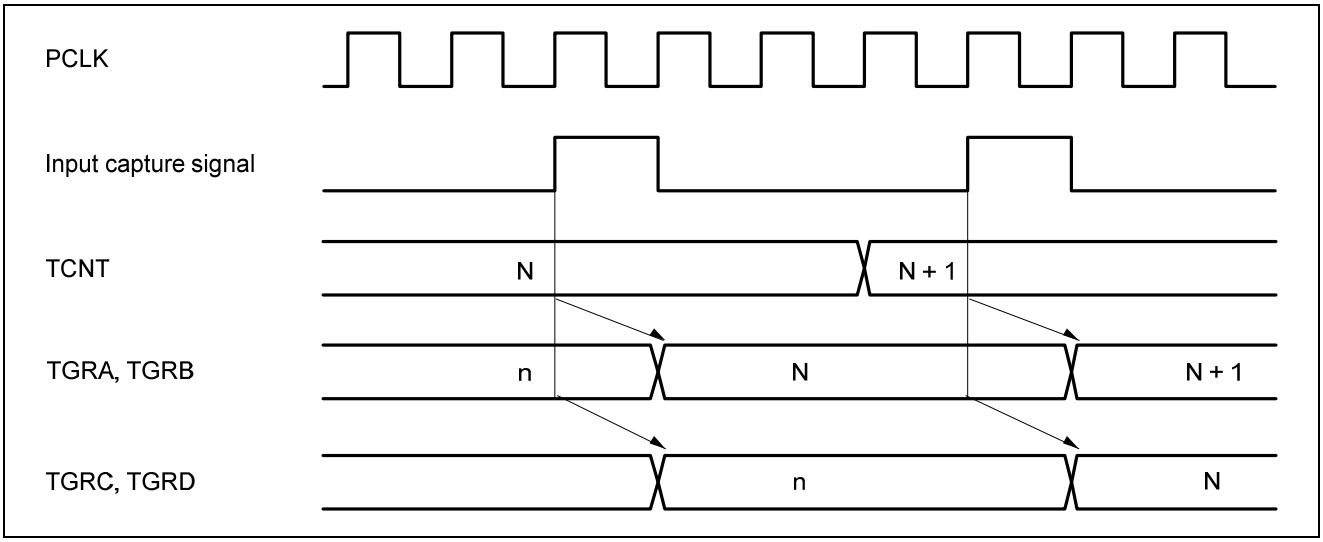


Figure 15.38 Buffer Operation Timing (Input Capture)

15.8.2 Interrupt Signal Timing

(1) Interrupt Flag Setting to 1 in Case of Compare Match

Figure 15.39 shows the timing for setting the interrupt flag by compare match occurrence.

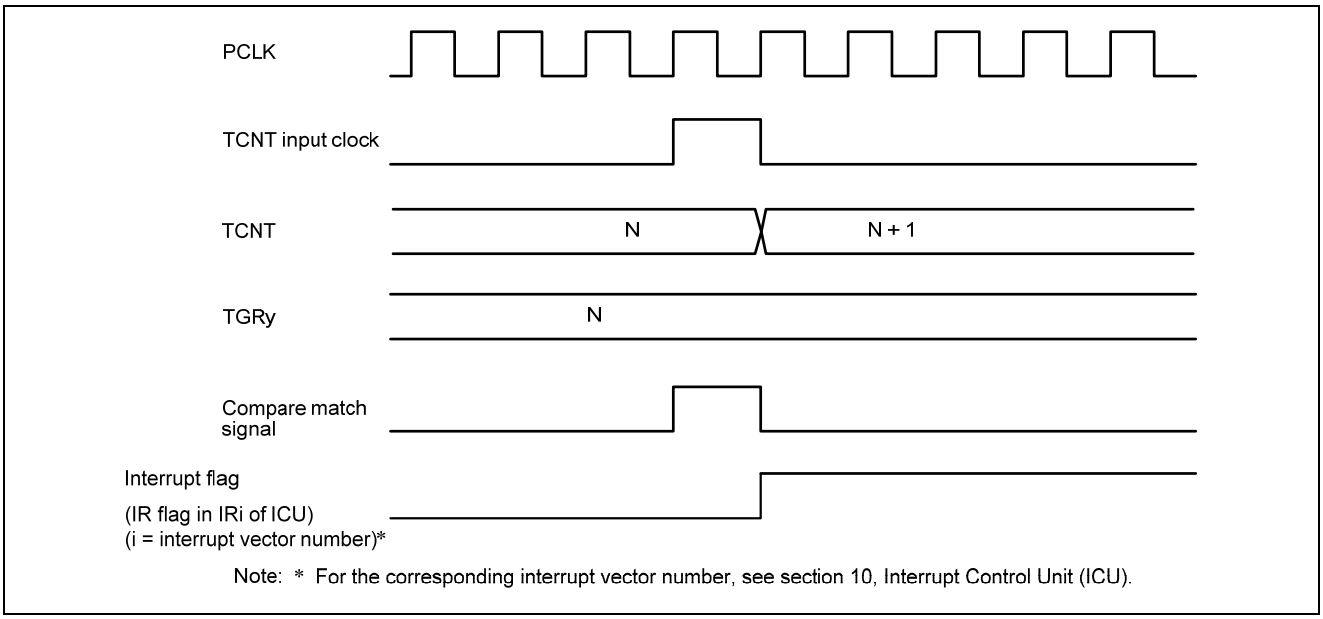


Figure 15.39 TGImy Interrupt Timing (Compare Match)

(2) Interrupt Flag Setting to 1 in Case of Input Capture

Figure 15.40 shows the timing for setting the interrupt flag by input capture occurrence.

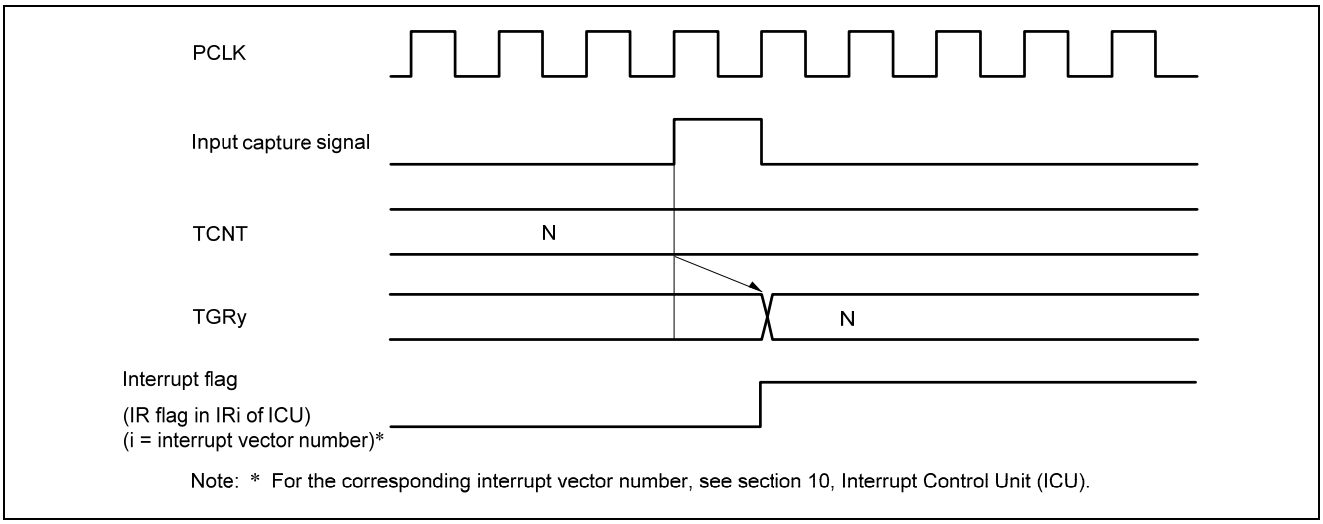


Figure 15.40 TGImy Interrupt Timing (Input Capture)

(3) TCImV/TCImU Interrupt Flag Setting to 1

Figure 15.41 shows the timing for generating the TCImV interrupt request signal by overflow occurrence.

Figure 15.42 shows the timing for generating the TCImU interrupt request signal by underflow occurrence.

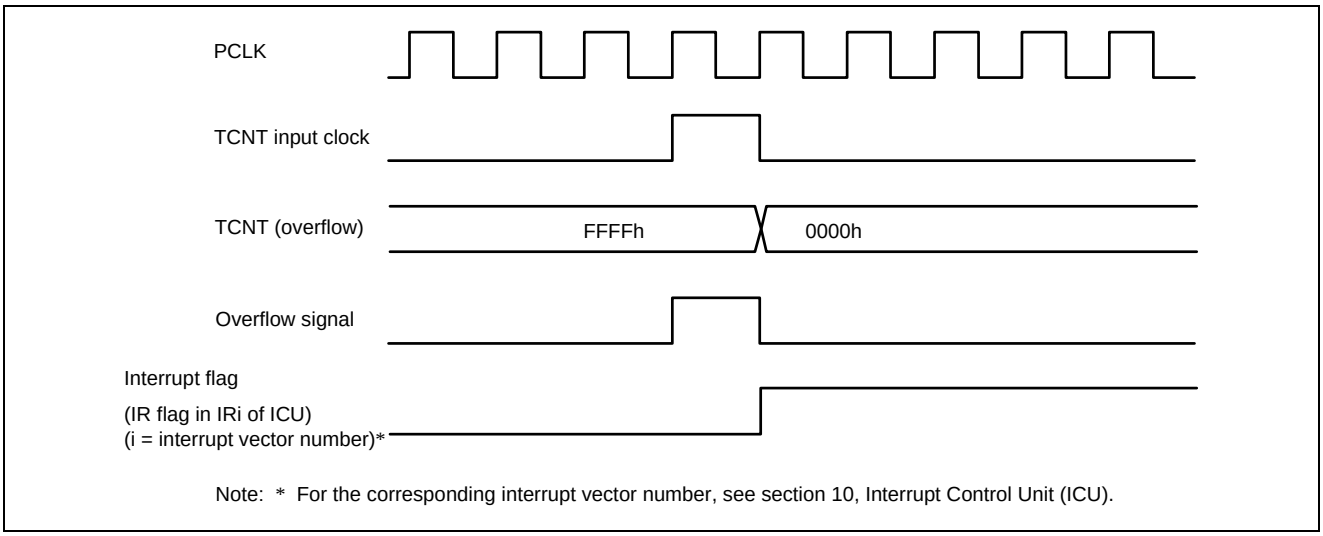


Figure 15.41 TCImV Interrupt Setting Timing

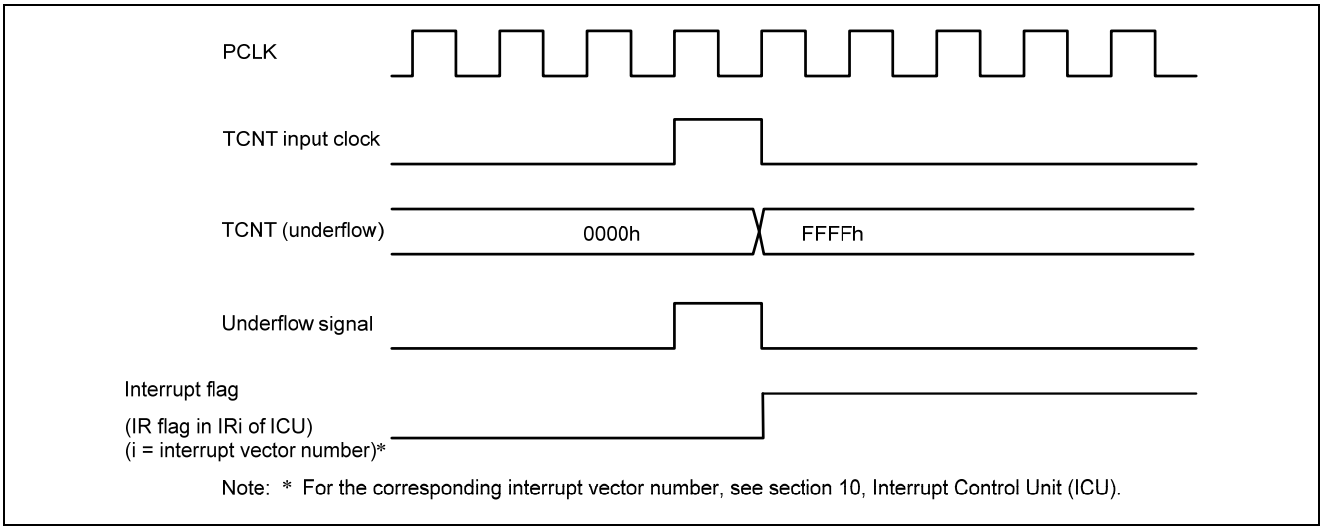


Figure 15.42 TCImU Interrupt Setting Timing

15.9 Usage Notes

15.9.1 Module Stop Function Setting

Operation of the TPU can be disabled or enabled using the module stop control register. The TPU does not operate with the initial setting. Register access is enabled by clearing module stop state. For details, see section 8, Low Power Consumption.

15.9.2 Input Clock Restrictions

The input clock pulse width must be at least 1.5 states in the case of single-edge detection, and at least 2.5 states in the case of both-edge detection. The TPU will not operate properly with a narrower pulse width.

In phase counting mode, the phase difference and overlap between the two input clocks must be at least 1.5 states, and the pulse width must be at least 2.5 states. Figure 15.43 shows the input clock conditions in phase counting mode.

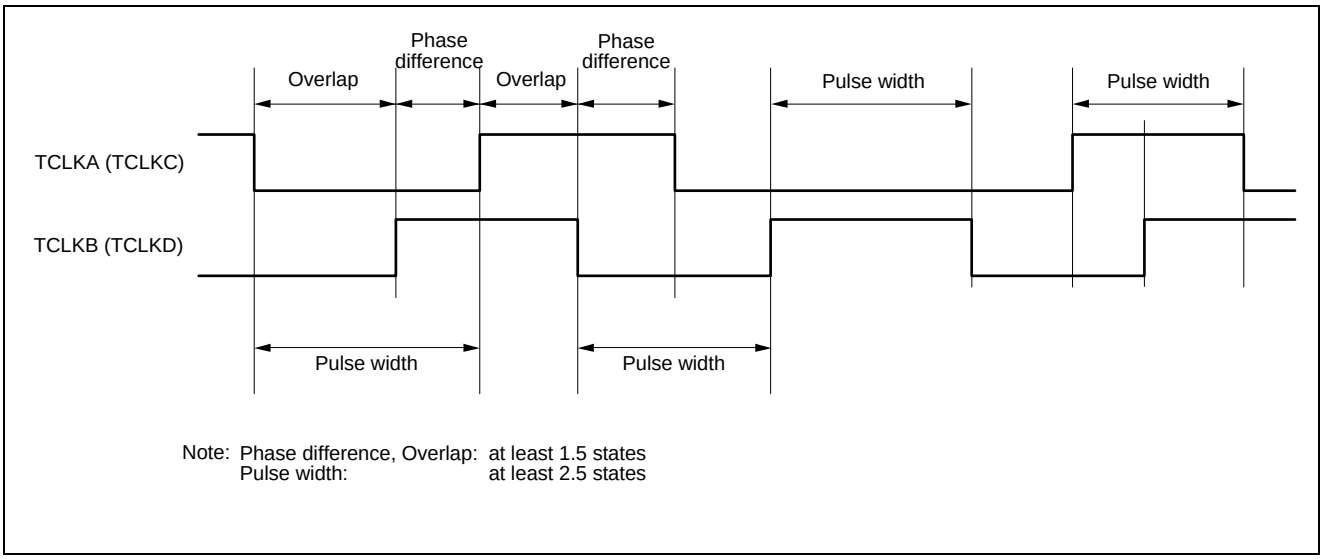


Figure 15.43 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode

15.9.3 Caution on Cycle Setting

When counter clearing by compare match is set, TPUm.TCNT is cleared in the final state in which it matches the TPUm.TGRy value (the point at which the count value matched by TCNT is updated). Consequently, the actual counter frequency is given by the following formula:

$$f = \frac{PCLK}{(N + 1)}$$

f: Counter frequency
PCLK: Operating frequency
N: TGRy set value

15.9.4 Conflict between TPUm.TCNT Write and Clear Operations

If the counter clearing signal is generated in a TCNT write cycle, TCNT clearing takes precedence and the TCNT write is not performed. Figure 15.44 shows the timing in this case.

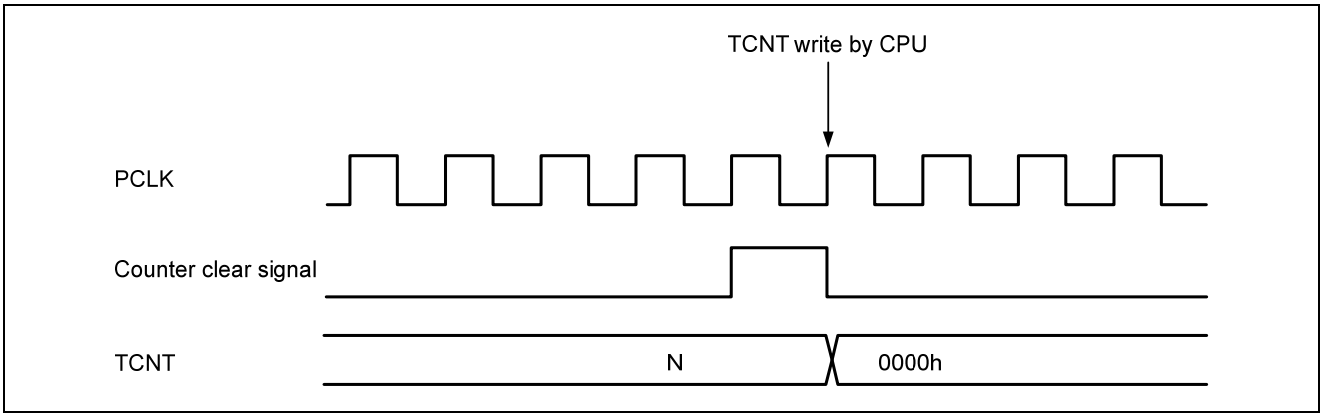


Figure 15.44 Conflict between TPUm.TCNT Write and Clear Operations

15.9.5 Conflict between TPUm.TCNT Write and Increment Operations

If incrementing occurs in a TCNT write cycle, the TCNT write takes precedence and TCNT is not incremented. Figure 15.45 shows the timing in this case.

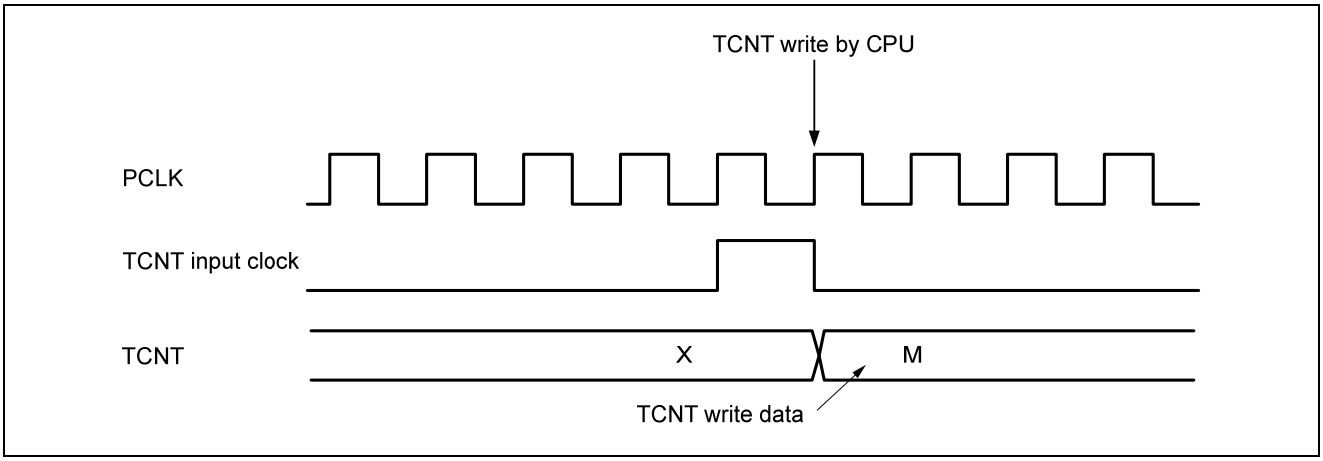


Figure 15.45 Conflict between TPUm.TCNT Write and Increment Operations

15.9.6 Conflict between TPUm.TGRy Write and Compare Match

If a compare match occurs in a TGRy write cycle, the TGRy write takes precedence and the compare match signal is disabled. A compare match also does not occur when the same value as before is written.

Figure 15.46 shows the timing in this case.

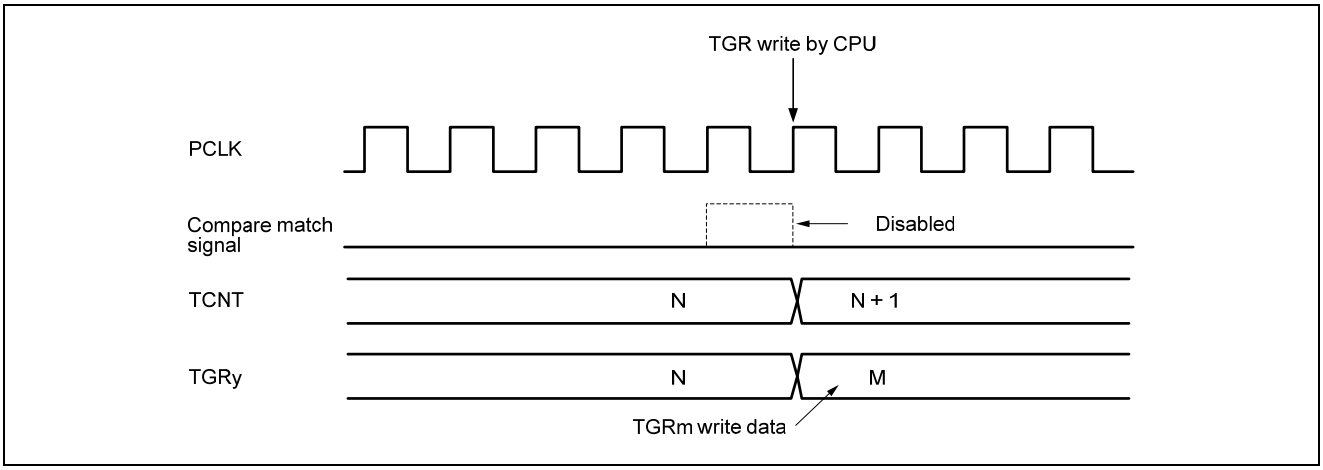


Figure 15.46 Conflict between TPUm.TGRy Write and Compare Match

15.9.7 Conflict between Buffer Register Write and Compare Match

If a compare match occurs in a TPUm.TGRy write cycle, the data transferred to TGRy by the buffer operation will be the data before writing.

Figure 15.47 shows the timing in this case.

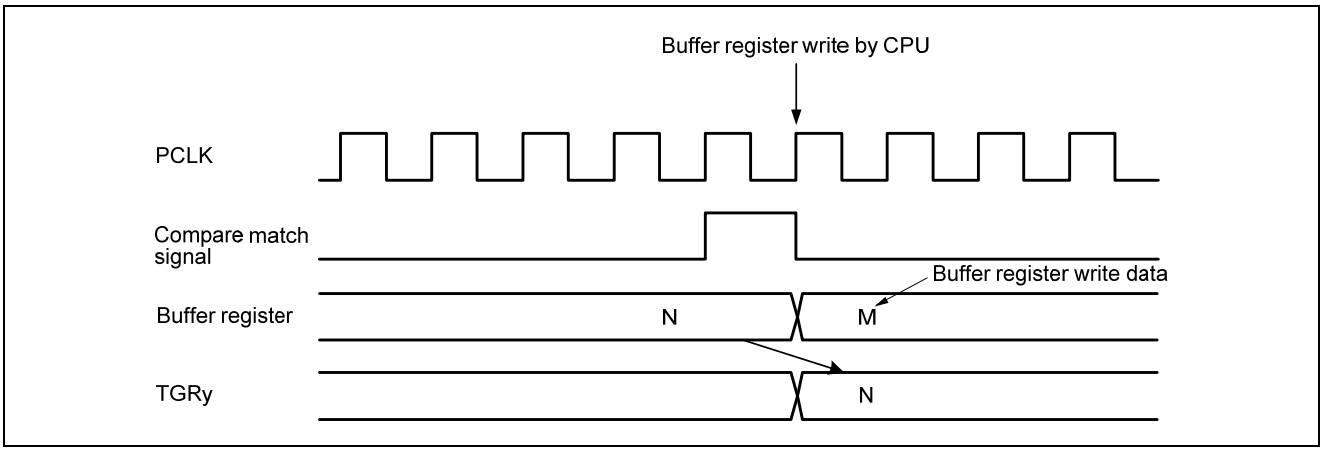


Figure 15.47 Conflict between Buffer Register Write and Compare Match

15.9.8 Conflict between TPUm.TGRy Read and Input Capture

If the input capture signal is generated in a TGRy read cycle, the data that is read will be the data before input capture transfer.

Figure 15.48 shows the timing in this case.

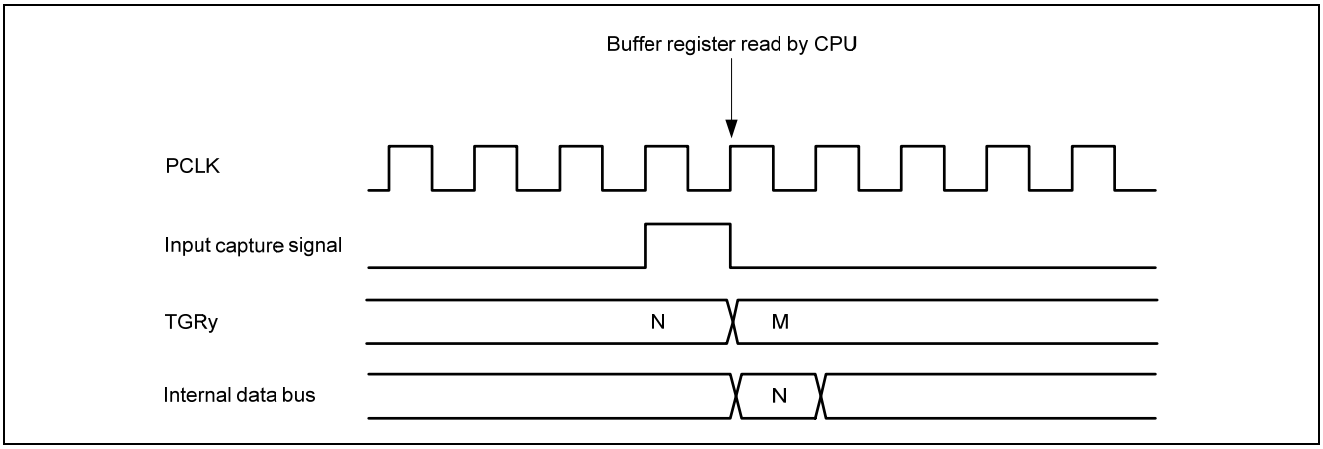


Figure 15.48 Conflict between TPUm.TGRy Read and Input Capture

15.9.9 Conflict between TPUm.TGRy Write and Input Capture

If the input capture signal is generated in a TGRy write cycle, the input capture operation takes precedence and the write to TGRy is not performed. Figure 15.49 shows the timing in this case.

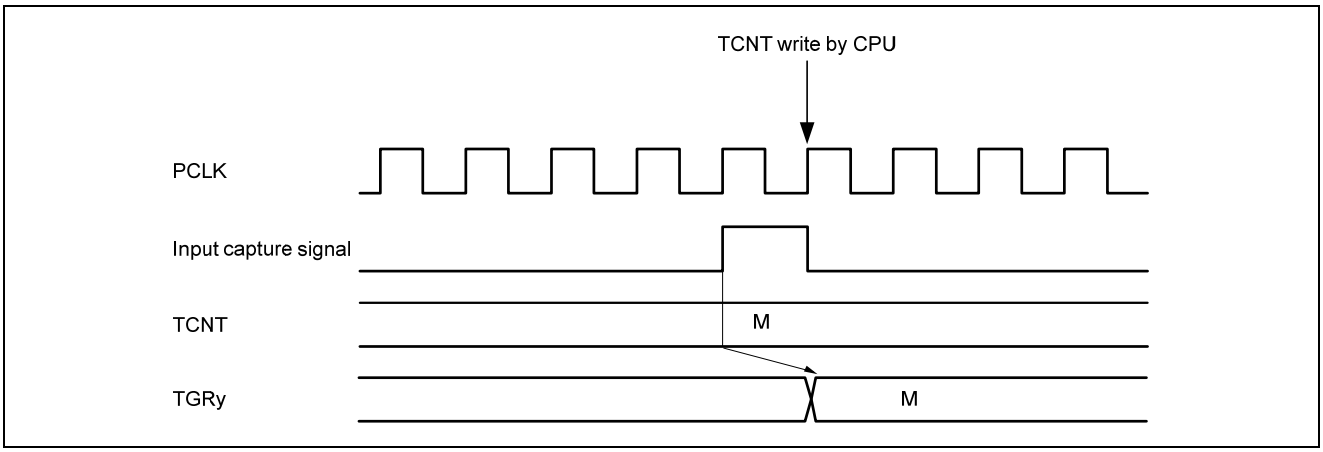


Figure 15.49 Conflict between TPUm.TGRy Write and Input Capture

15.9.10 Conflict between Buffer Register Write and Input Capture

If the input capture signal is generated in a buffer register write cycle, the buffer operation takes precedence and the write to the buffer register is not performed. Figure 15.50 shows the timing in this case.

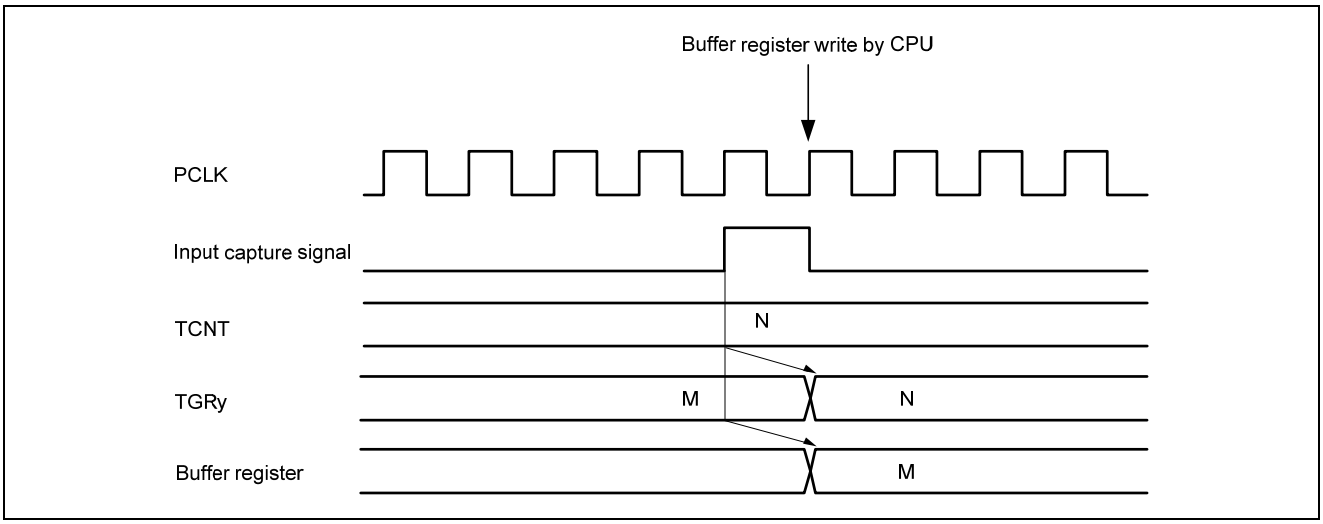


Figure 15.50 Conflict between Buffer Register Write and Input Capture

15.9.11 Conflict between Overflow/Underflow and Counter Clearing

If overflow/underflow and counter clearing occur simultaneously, TPUm.TCNT counter is cleared with the generation of the compare match interrupt and an overflow interrupt is generated.

Figure 15.51 shows the operation timing when a TPUm.TGRy compare match is specified as the clearing source and FFFFh is set in TGRy.

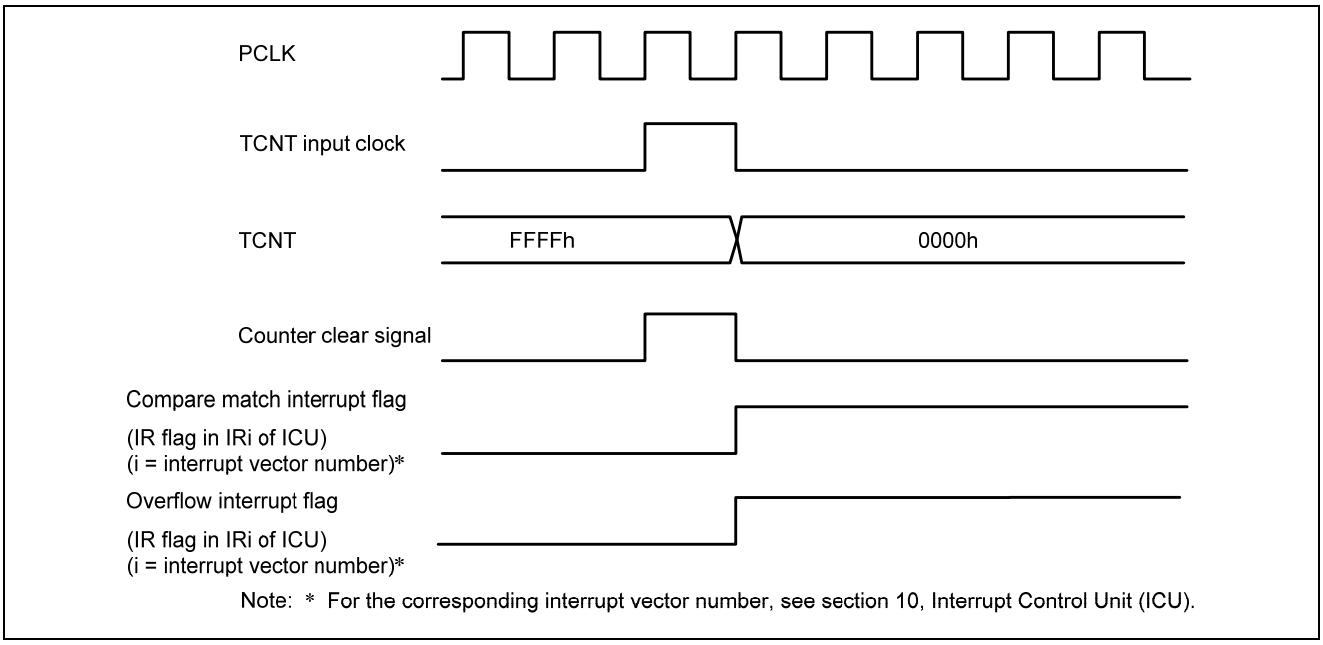


Figure 15.51 Conflict between Overflow and Counter Clearing

15.9.12 Conflict between TPUm.TCNT Write and Overflow/Underflow

If an overflow/underflow occurs due to increment/decrement in a TCNT write cycle, the TCNT write takes precedence.

Figure 15.52 shows the operation timing when there is conflict between TCNT write and overflow.

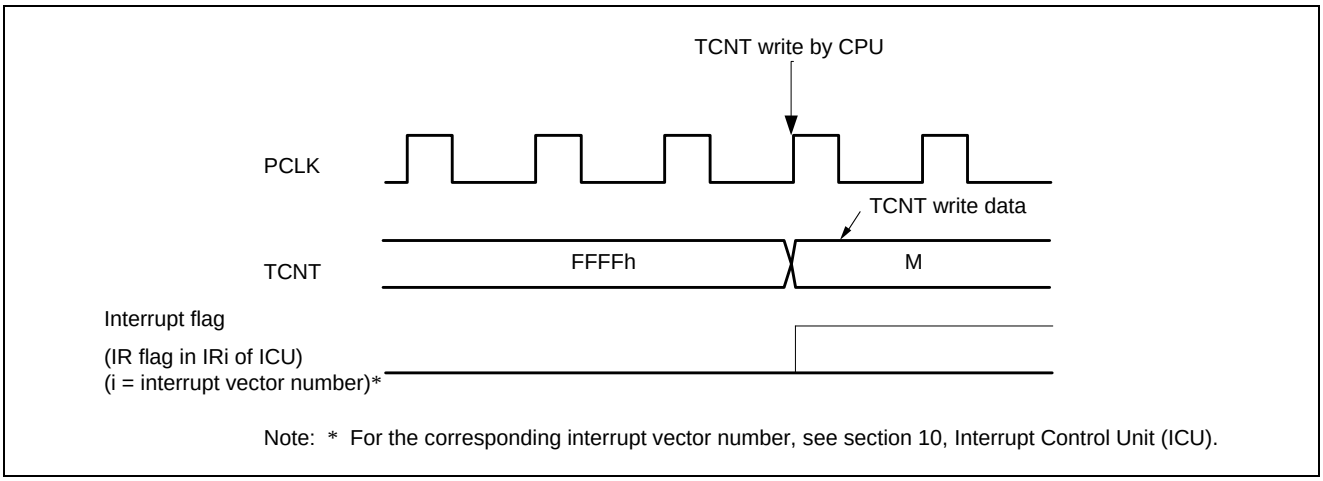


Figure 15.52 Conflict between TPUm.TCNT Write and Overflow

15.9.13 Multiplexing of I/O Pins

In the RX610 Group, the TCLKA-A input pin is multiplexed with the TIOCC0 I/O pin, the TCLKB-A input pin with the TIOCD0 I/O pin, the TCLKC-A input pin with the TIOCB1 I/O pin, and the TCLKD-A input pin with the TIOCB2 I/O pin. When an external clock is input, compare match output should not be performed from a multiplexed pin.

16. Programmable Pulse Generator (PPG)

The programmable pulse generator (PPG) generates pulse outputs by using the 16-bit timer pulse unit (TPU) as a time base.

The RX610 Group has two PPG units, each of which controls up to 16 pulse output pins. The pulse outputs from the PPGs are divided into 4-bit groups that can operate all simultaneously and independently.

16.1 Overview

Table 16.1 lists the specifications of the PPG and table 16.2 lists PPG functions.

Figures 16.1 and 16.2 show block diagrams of the PPGs.

Table 16.1 Specifications of PPG

Item	Specifications
Number of output bits	Up to 32 bits
Pulse output	• Two units, each capable of output through four pin groups • Output trigger signals are selectable. • Non-overlapping operation is possible. • Inverted output is selectable.
Output data transfer	Can operate together with the DTC and DMAC (When TPU interrupt is in use)
Power-down function	Module stop state can be set for each unit.

Table 16.2 List of PPG Functions

Item			PPG0	PPG1
PPG output trigger	TPU (unit 0) channels 0 to 3 (TPU0 to TPU3)	Compare match	√	√
		Input capture	√	√
	TPU (unit 1) channels 6 to 9 (TPU6 to TPU9)	Compare match	—	√
		Input capture	—	√
Non-overlapping operation			√	√
Output data transfer	DTC		√	√
	DMAC		√	√
Selecting inverted output			√	√
Setting the module stop state*			The MSTPA11 bit in MSTPCRA	The MSTPA10 bit in MSTPCRA

[Legend] √: Possible
—: Not possible

Note: * For details, see section 8, Low Power Consumption.

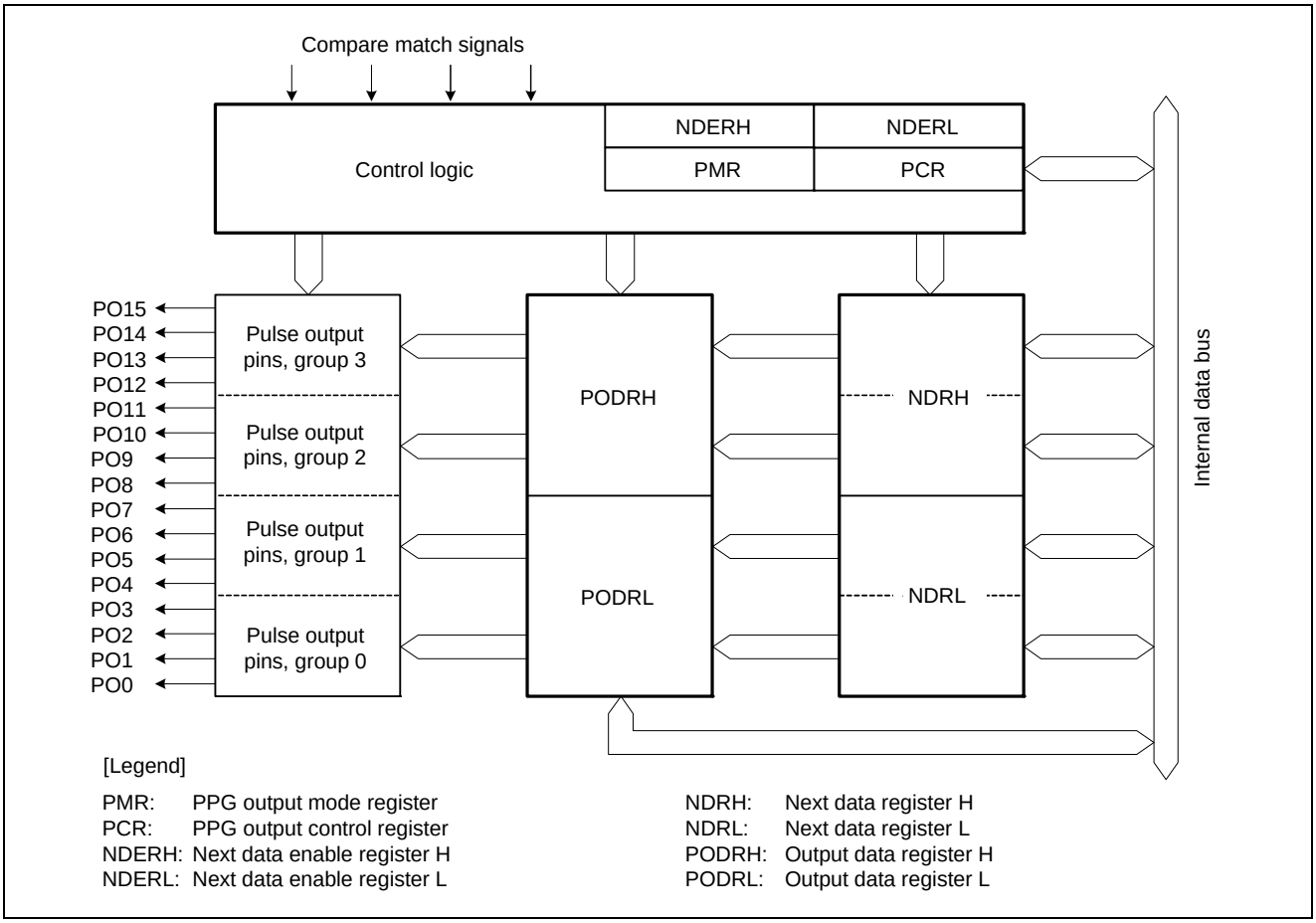


Figure 16.1 Block Diagram of PPG (Unit 0)

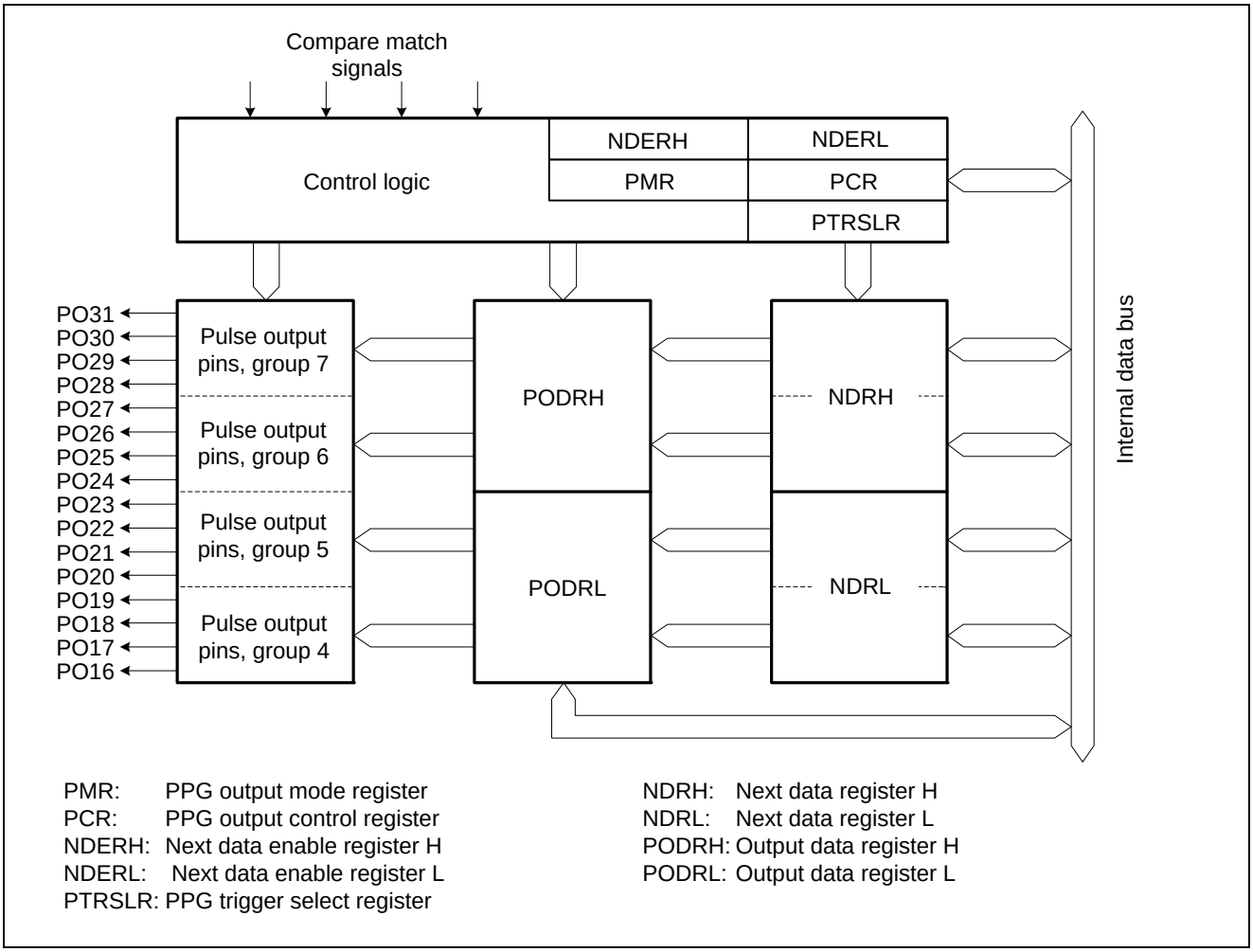


Figure 16.2 Block Diagram of PPG (Unit 1)

Table 16.3 lists the pin configuration of the PPG.

Table 16.3 Pin Configuration of PPG

Unit	Pin Name	I/O	Function
PPG0	PO0	Output	Group 0 pulse output
	PO1	Output	
	PO2	Output	
	PO3	Output	
	PO4	Output	Group 1 pulse output
	PO5	Output	
	PO6	Output	
	PO7	Output	
	PO8	Output	Group 2 pulse output
	PO9	Output	
	PO10	Output	
	PO11	Output	
	PO12	Output	Group 3 pulse output
	PO13	Output	
	PO14	Output	
	PO15	Output	
PPG1	PO16	Output	Group 4 pulse output
	PO17	Output	
	PO18	Output	
	PO19	Output	
	PO20	Output	Group 5 pulse output
	PO21	Output	
	PO22	Output	
	PO23	Output	
	PO24	Output	Group 6 pulse output
	PO25	Output	
	PO26	Output	
	PO27	Output	
	PO28	Output	Group 7 pulse output
	PO29	Output	
	PO30	Output	
	PO31	Output	

16.2 Register Descriptions

Table 16.4 lists the registers of the PPG.

Table 16.4 Registers of PPG

Unit	Register Name	Symbol	Value after Reset	Address	Access Size
PPG0	PPG output control register	PCR	FFh	0008 81E6h	8
	PPG output mode register	PMR	F0h	0008 81E7h	8
	Next data enable register H	NDERH	00h	0008 81E8h	8
	Next data enable register L	NDERL	00h	0008 81E9h	8
	Output data register H	PODRH	00h	0008 81EAh	8
	Output data register L	PODRL	00h	0008 81EBh	8
	Next data register H	NDRH	00h	0008 81ECh*1	8
	Next data register L	NDRL	00h	0008 81EDh*2	8
	Next data register H	NDRH	00h	0008 81EEh*1	8
	Next data register L	NDRL	00h	0008 81EFh*2	8
PPG1	PPG trigger select register	PTRSLR	01h	0008 81F0h	8
	PPG output control register	PCR	FFh	0008 81F6h	8
	PPG output mode register	PMR	F0h	0008 81F7h	8
	Next data enable register H	NDERH	00h	0008 81F8h	8
	Next data enable register L	NDERL	00h	0008 81F9h	8
	Output data register H	PODRH	00h	0008 81FAh	8
	Output data register L	PODRL	00h	0008 81FBh	8
	Next data register H	NDRH	00h	0008 81FCh*3	8
	Next data register L	NDRL	00h	0008 81FDh*4	8
	Next data register H	NDRH	00h	0008 81FEh*3	8
	Next data register L	NDRL	00h	0008 81FFh*4	8

Notes:
1. When pulse output groups 2 and 3 have the same output trigger by PPG0.PCR settings, the PPG0.NDRH address is 0008 81ECh. When they have different output triggers, the PPG0.NDRH addresses corresponding to groups 2 and 3 are 0008 81EEh and 0008 81ECh, respectively.
2. When pulse output groups 0 and 1 have the same output trigger by PPG0.PCR settings, the PPG0.NDRL address is 0008 81EDh. When they have different output triggers, the PPG0.NDRL addresses corresponding to groups 0 and 1 are 0008 81EFh and 0008 81EDh, respectively.
3. When pulse output groups 6 and 7 have the same output trigger by PPG1.PCR settings, the PPG1.NDRH address is 0008 81FCh. When they have different output triggers, the PPG1.NDRH addresses corresponding to groups 6 and 7 are 0008 81FEh and 0008 81FCh, respectively.
4. When pulse output groups 4 and 5 have the same output trigger by PPG1.PCR settings, the PPG1.NDRL address is 0008 81FDh. When they have different output triggers, the PPG1.NDRL addresses corresponding to groups 4 and 5 are 0008 81FFh and 0008 81FDh, respectively.

16.2.1 PPG Trigger Select Register (PTRSLR)

Address: 0008 81F0h

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	PTRSL
Value after reset:	0	0	0	0	0	0	0	1

- PPG1.PTRSLR

Bit	Symbol	Bit Name	Description	R/W
b0	PTRSL	PPG Trigger Select	0: Selects the set of TPU0 toTPU3 as the trigger channels for PPG1. 1: Selects the set of TPU6 to TPU9 as the trigger channels for PPG1.	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PPG1.PTRSLR selects a set of trigger channels.

PTRSL Bit (PPG Trigger Select)

This bit selects either TPU0 to TPU3 or TPU6 to TPU9 as a set of trigger channels for PPG1.

When this bit is set to 0, TPU0 to TPU3 are selected as a set of trigger channels for PPG1.When it is set to 1, TPU6 to TPU9 are selected as a set of trigger channels for PPG1.

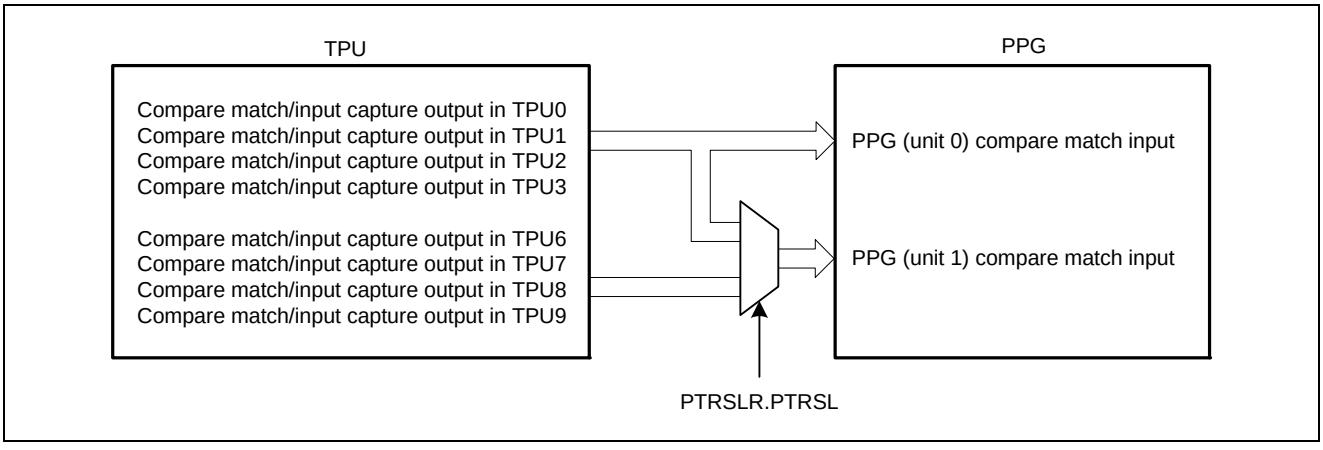


Figure 16.3 Block Diagram of PPG Trigger Selection

16.2.2 Next Data Enable Registers H and L (NDERH, NDERL)

Address: 0008 81E8h

	b7	b6	b5	b4	b3	b2	b1	b0
PPG0.NDERH	NDER15	NDER14	NDER13	NDER12	NDER11	NDER10	NDER9	NDER8
Value after reset:	0	0	0	0	0	0	0	0

Address: 0008 81E9h

	b7	b6	b5	b4	b3	b2	b1	b0
PPG0.NDERL	NDER7	NDER6	NDER5	NDER4	NDER3	NDER2	NDER1	NDER0
Value after reset:	0	0	0	0	0	0	0	0

- PPG0.NDERH

Bit	Symbol	Bit Name	Description	R/W
b0	NDER8	Next Data Transfer Enable	0: Data transfer is disabled.	R/W
b1	NDER9	Next Data Transfer Enable	1: Data transfer is enabled.	R/W
b2	NDER10	Next Data Transfer Enable		R/W
b3	NDER11	Next Data Transfer Enable		R/W
b4	NDER12	Next Data Transfer Enable		R/W
b5	NDER13	Next Data Transfer Enable		R/W
b6	NDER14	Next Data Transfer Enable		R/W
b7	NDER15	Next Data Transfer Enable		R/W

PPG0.NDERH selects the pins (PO8 to PO15) for outputs of pulse from the PPG on a bit-by-bit basis.

NDERj Bits (Next Data Transfer Enable) (j = 8 to 15)

When these bits are set to 1, the output trigger specified by PTRSLR transfers data from the corresponding bit in PPG0.NDRH to the bit in PPG0.PODRH. When these bits are set to 0, the data are not transferred from PPG0.NDRH to PPG0.PODRH.

- PPG0.NDERL

Bit	Symbol	Bit Name	Description	R/W
b0	NDER0	Next Data Transfer Enable	0: Data transfer is disabled.	R/W
b1	NDER1	Next Data Transfer Enable	1: Data transfer is enabled.	R/W
b2	NDER2	Next Data Transfer Enable		R/W
b3	NDER3	Next Data Transfer Enable		R/W
b4	NDER4	Next Data Transfer Enable		R/W
b5	NDER5	Next Data Transfer Enable		R/W
b6	NDER6	Next Data Transfer Enable		R/W
b7	NDER7	Next Data Transfer Enable		R/W

PPG0.NDERL selects the pins (PO0 to PO7) for outputs of pulse from the PPG on a bit-by-bit basis.

NDERj Bits (Next Data Transfer Enable) (j = 0 to 7)

When these bits are set to 1, the output trigger specified by PTRSLR transfers data from the corresponding bit in PPG0.NDRL to the bit in PPG0.PODRL. When these bits are set to 0, the data are not transferred from PPG0.NDRL to PPG0.PODRL.

Address: 0008 81F8h

	b7	b6	b5	b4	b3	b2	b1	b0
PPG1.NDERH	NDER31	NDER30	NDER29	NDER28	NDER27	NDER26	NDER25	NDER24
Value after reset:	0	0	0	0	0	0	0	0

Address: 0008 81F9h

	b7	b6	b5	b4	b3	b2	b1	b0
PPG1.NDERL	NDER23	NDER22	NDER21	NDER20	NDER19	NDER18	NDER17	NDER16
Value after reset:	0	0	0	0	0	0	0	0

- PPG1.NDERH

Bit	Symbol	Bit Name	Description	R/W
b0	NDER24	Next Data Transfer Enable	0: Data transfer is disabled.	R/W
b1	NDER25	Next Data Transfer Enable	1: Data transfer is enabled.	R/W
b2	NDER26	Next Data Transfer Enable		R/W
b3	NDER27	Next Data Transfer Enable		R/W
b4	NDER28	Next Data Transfer Enable		R/W
b5	NDER29	Next Data Transfer Enable		R/W
b6	NDER30	Next Data Transfer Enable		R/W
b7	NDER31	Next Data Transfer Enable		R/W

PPG1.NDERH selects the pins (PO24 to PO31) for outputs of pulse from the PPG on a bit-by-bit basis.

NDERj Bits (Next Data Transfer Enable) (j = 24 to 31)

When these bits are set to 1, the output trigger specified by PTRSLR transfers data from the corresponding bit in PPG1.NDRH to the bit in PPG1.PODRH. When these bits are set to 0, the data are not transferred from PPG1.NDRH to PPG1.PODRH.

- PPG1.NDERL

Bit	Symbol	Bit Name	Description	R/W
b0	NDER16	Next Data Transfer Enable	0: Data transfer is disabled.	R/W
b1	NDER17	Next Data Transfer Enable	1: Data transfer is enabled.	R/W
b2	NDER18	Next Data Transfer Enable		R/W
b3	NDER19	Next Data Transfer Enable		R/W
b4	NDER20	Next Data Transfer Enable		R/W
b5	NDER21	Next Data Transfer Enable		R/W
b6	NDER22	Next Data Transfer Enable		R/W
b7	NDER23	Next Data Transfer Enable		R/W

PPG1.NDERL selects the pins (PO16 to PO23) for outputs of pulse from the PPG on a bit-by-bit basis.

NDERj Bits (Next Data Transfer Enable) (j = 16 to 23)

When these bits are set to 1, the output trigger specified by PTRSLR transfers data from the corresponding bit in PPG1.NDRL to the bit in PPG1.PODRL. When these bits are set to 0, the data are not transferred from PPG1.NDRL to PPG1.PODRL.

16.2.3 Output Data Registers H and L (PODRH, PODRL)

Address: 0008 81EAh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG0.PODRH	POD15	POD14	POD13	POD12	POD11	POD10	POD9	POD8
Value after reset:	0	0	0	0	0	0	0	0

Address: 0008 81EBh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG0.PODRL	POD7	POD6	POD5	POD4	POD3	POD2	POD1	POD0
Value after reset:	0	0	0	0	0	0	0	0

- PPG0.PODRH

Bit	Symbol	Bit Name	Description	R/W
b0	POD8	Output Data Register	For bits corresponding to pins that have been set for pulse output by PPG0.NDERH, the output trigger transfers the values in PPG0.NDRH to this register during PPG operation. If any of the NDERj (j = 8 to 15) bits in PPG0.NDERH is set to 1, the CPU cannot write to this register. Initial output values for the pins can be set while PPG0.NDERH is clear (00h).	R/W
b1	POD9	Output Data Register		R/W
b2	POD10	Output Data Register		R/W
b3	POD11	Output Data Register		R/W
b4	POD12	Output Data Register		R/W
b5	POD13	Output Data Register		R/W
b6	POD14	Output Data Register		R/W
b7	POD15	Output Data Register		R/W

PPG0.PODRH stores pulse output values. For bits corresponding to pins that have been set for pulse output by PPG0.NDERH, the output trigger transfers the values in PPG0.NDRH to this register.

- PPG0.PODRL

Bit	Symbol	Bit Name	Description	R/W
b0	POD0	Output Data Register	For bits corresponding to pins that have been set for pulse output by PPG0.NDERL, the output trigger transfers the values in PPG0.NDRL to this register during PPG operation. If any of the NDERj (j = 0 to 7) bits in PPG0.NDERL is set to 1, the CPU cannot write to this register. Initial output values for the pins can be set while PPG0.NDERL is clear (00h).	R/W
b1	POD1	Output Data Register		R/W
b2	POD2	Output Data Register		R/W
b3	POD3	Output Data Register		R/W
b4	POD4	Output Data Register		R/W
b5	POD5	Output Data Register		R/W
b6	POD6	Output Data Register		R/W
b7	POD7	Output Data Register		R/W

PPG0.PODRL stores pulse output values. For bits corresponding to pins that have been set for pulse output by PPG0.NDERL, the output trigger transfers the values in PPG0.NDRL to this register.

Address: 0008 81FAh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG1.PODRH	POD31	POD30	POD29	POD28	POD27	POD26	POD25	POD24
Value after reset:	0	0	0	0	0	0	0	0

Address: 0008 81FBh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG1.PODRL	POD23	POD22	POD21	POD20	POD19	POD18	POD17	POD16
Value after reset:	0	0	0	0	0	0	0	0

- PPG1.PODRH

Bit	Symbol	Bit Name	Description	R/W
b0	POD24	Output Data Register	For bits corresponding to pins that have been set for pulse output by PPG1.NDERH, the output trigger transfers the values in PPG1.NDRH to this register during PPG operation. If any of the NDERj (j = 24 to 31) bits in PPG1.NDERH is set to 1, the CPU cannot write to this register. Initial output values for the pins can be set while PPG1.NDERH is clear (00h).	R/W
b1	POD25	Output Data Register		R/W
b2	POD26	Output Data Register		R/W
b3	POD27	Output Data Register		R/W
b4	POD28	Output Data Register		R/W
b5	POD29	Output Data Register		R/W
b6	POD30	Output Data Register		R/W
b7	POD31	Output Data Register		R/W

PPG1.PODRH stores pulse output values. For bits corresponding to pins that have been set for pulse output by PPG1.NDERH, the output trigger transfers the values in PPG1.NDRH to this register.

- PPG1.PODRL

Bit	Symbol	Bit Name	Description	R/W
b0	POD16	Output Data Register	For bits corresponding to pins that have been set for pulse output by PPG1.NDERL, the output trigger transfers the values in PPG1.NDRL to this register during PPG operation. If any of the NDERj (j = 16 to 23) bits in PPG1.NDERL is set to 1, the CPU cannot write to this register. Initial output values for the pins can be set while PPG1.NDERL is clear (00h).	R/W
b1	POD17	Output Data Register		R/W
b2	POD18	Output Data Register		R/W
b3	POD19	Output Data Register		R/W
b4	POD20	Output Data Register		R/W
b5	POD21	Output Data Register		R/W
b6	POD22	Output Data Register		R/W
b7	POD23	Output Data Register		R/W

PPG1.PODRL stores pulse output values. For bits corresponding to pins that have been set for pulse output by PPG1.NDERL, the output trigger transfers the values in PPG1.NDRL to this register.

16.2.4 Next Data Registers H and L (NDRH, NDRL)

Addresses: 0008 81ECh, 0008 81EEh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG0.NDRH	NDR15	NDR14	NDR13	NDR12	NDR11	NDR10	NDR9	NDR8
Value after reset:	0	0	0	0	0	0	0	0

Addresses: 0008 81EDh, 0008 81EFh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG0.NDRL	NDR7	NDR6	NDR5	NDR4	NDR3	NDR2	NDR1	NDR0
Value after reset:	0	0	0	0	0	0	0	0

- PPG0.NDRH

PPG0.NDRH stores the next data for pulse output. The PPG0.NDRH address differs depending on whether pulse output groups have the same output trigger or different output triggers.

(1) When pulse output groups 2 and 3 have the same output trigger

If pulse output groups 2 and 3 have the same output trigger, all eight bits are mapped to the same address and can be accessed at one time.

(0008 81ECh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR8	Next Data Register	The output trigger specified by PPG0.PCR transfers the values in this register to the corresponding bits in PPG0.PODRH.	R/W
b1	NDR9	Next Data Register		R/W
b2	NDR10	Next Data Register		R/W
b3	NDR11	Next Data Register		R/W
b4	NDR12	Next Data Register		R/W
b5	NDR13	Next Data Register		R/W
b6	NDR14	Next Data Register		R/W
b7	NDR15	Next Data Register		R/W

(2) When pulse output groups 2 and 3 have different output triggers

If pulse output groups 2 and 3 have different output triggers, upper 4 bits and lower 4 bits are mapped to the different addresses.

(Pulse output group 3: 0008 81ECh)

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b4	NDR12	Next Data Register	The output trigger specified by PPG0.PCR transfers the values in this register to the corresponding bits in PPG0.PODRH.	R/W
b5	NDR13	Next Data Register		R/W
b6	NDR14	Next Data Register		R/W
b7	NDR15	Next Data Register		R/W

(Pulse output group 2: 0008 81EEh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR8	Next Data Register	The output trigger specified by PPG0.PCR transfers the values in this register to the corresponding bits in PPG0.PODRH.	R/W
b1	NDR9	Next Data Register		R/W
b2	NDR10	Next Data Register		R/W
b3	NDR11	Next Data Register		R/W
b7 to b4	—	Reserved	These bits are always read as 1 and cannot be modified.	R

- PPG0.NDRL

PPG0.NDRL stores the next data for pulse output. The PPG0.NDRL address differs depending on whether pulse output groups have the same output trigger or different output triggers.

(1) When pulse output groups 0 and 1 have the same output trigger

If pulse output groups 0 and 1 have the same output trigger, all eight bits are mapped to the same address and can be accessed at one time.

(0008 81EDh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR0	Next Data Register	The output trigger specified by PPG0.PCR transfers the values in this register to the corresponding bits in PPG0.PODRL.	R/W
b1	NDR1	Next Data Register		R/W
b2	NDR2	Next Data Register		R/W
b3	NDR3	Next Data Register		R/W
b4	NDR4	Next Data Register		R/W
b5	NDR5	Next Data Register		R/W
b6	NDR6	Next Data Register		R/W
b7	NDR7	Next Data Register		R/W

(2) When pulse output groups 0 and 1 have different output triggers

If pulse output groups 0 and 1 have different output triggers, upper 4 bits and lower 4 bits are mapped to the different addresses.

(Pulse output group 1: 0008 81EDh)

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b4	NDR4	Next Data Register	The output trigger specified by PPG0.PCR transfers the values in this register to the corresponding bits in PPG0.PODRL.	R/W
b5	NDR5	Next Data Register		R/W
b6	NDR6	Next Data Register		R/W
b7	NDR7	Next Data Register		R/W

(Pulse output group 0: 0008 81EFh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR0	Next Data Register	The output trigger specified by PPG0.PCR transfers the values in this register to the corresponding bits in PPG0.PODRL.	R/W
b1	NDR1	Next Data Register		R/W
b2	NDR2	Next Data Register		R/W
b3	NDR3	Next Data Register		R/W
b7 to b4	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

Addresses: 0008 81FCh, 0008 81FEh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG1.NDRH	NDR31	NDR30	NDR29	NDR28	NDR27	NDR26	NDR25	NDR24
Value after reset:	0	0	0	0	0	0	0	0

Addresses: 0008 81FDh, 0008 81FFh

	b7	b6	b5	b4	b3	b2	b1	b0
PPG1.NDRL	NDR23	NDR22	NDR21	NDR20	NDR19	NDR18	NDR17	NDR16
Value after reset:	0	0	0	0	0	0	0	0

- PPG1.NDRH

PPG1.NDRH stores the next data for pulse output. The PPG1.NDRH address differs depending on whether pulse output groups have the same output trigger or different output triggers.

(1) When pulse output groups 6 and 7 have the same output trigger

If pulse output groups 6 and 7 have the same output trigger, all eight bits are mapped to the same address and can be accessed at one time.

(0008 81FCh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR24	Next Data Register	The output trigger specified by PPG1.PCR transfers the values in this register to the corresponding bits in PPG1.PODRH.	R/W
b1	NDR25	Next Data Register		R/W
b2	NDR26	Next Data Register		R/W
b3	NDR27	Next Data Register		R/W
b4	NDR28	Next Data Register		R/W
b5	NDR29	Next Data Register		R/W
b6	NDR30	Next Data Register		R/W
b7	NDR31	Next Data Register		R/W

(2) When pulse output groups 6 and 7 have different output triggers

If pulse output groups 6 and 7 have different output triggers, upper 4 bits and lower 4 bits are mapped to the different addresses.

(Pulse output group 7: 0008 81FCh)

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b4	NDR28	Next Data Register	The output trigger specified by PPG1.PCR transfers the values in this register to the corresponding bits in PPG1.PODRH.	R/W
b5	NDR29	Next Data Register		R/W
b6	NDR30	Next Data Register		R/W
b7	NDR31	Next Data Register		R/W

(Pulse output group 6: 0008 81FEh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR24	Next Data Register	The output trigger specified by PPG1.PCR transfers the values in this register to the corresponding bits in PPG1.PODRH.	R/W
b1	NDR25	Next Data Register		R/W
b2	NDR26	Next Data Register		R/W
b3	NDR27	Next Data Register		R/W
b7 to b4	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

- PPG1.NDRL

PPG1.NDRL stores the next data for pulse output. The PPG1.NDRL address differs depending on whether pulse output groups have the same output trigger or different output triggers.

(1) When pulse output groups 4 and 5 have the same output trigger

If pulse output groups 4 and 5 have the same output trigger, all eight bits are mapped to the same address and can be accessed at one time.

(0008 81FDh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR16	Next Data Register	The output trigger specified by PPG1.PCR transfers the values in this register to the corresponding bits in PPG1.PODRL.	R/W
b1	NDR17	Next Data Register		R/W
b2	NDR18	Next Data Register		R/W
b3	NDR19	Next Data Register		R/W
b4	NDR20	Next Data Register		R/W
b5	NDR21	Next Data Register		R/W
b6	NDR22	Next Data Register		R/W
b7	NDR23	Next Data Register		R/W

(2) When pulse output groups 4 and 5 have different output triggers

If pulse output groups 4 and 5 have different output triggers, upper 4 bits and lower 4 bits are mapped to the different addresses.

(Pulse output group 5: 0008 81FDh)

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b4	NDR20	Next Data Register	The output trigger specified by PPG1.PCR transfers the values in this register to the corresponding bits in PPG1.PODRL.	R/W
b5	NDR21	Next Data Register		R/W
b6	NDR22	Next Data Register		R/W
b7	NDR23	Next Data Register		R/W

(Pulse output group 4: 0008 81FFh)

Bit	Symbol	Bit Name	Description	R/W
b0	NDR16	Next Data Register	The output trigger specified by PPG1.PCR transfers the values in this register to the corresponding bits in PPG1.PODRL.	R/W
b1	NDR17	Next Data Register		R/W
b2	NDR18	Next Data Register		R/W
b3	NDR19	Next Data Register		R/W
b7 to b4	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

16.2.5 PPG Output Control Register (PCR)

Addresses: PPG0.PCR 0008 81E6h, PPG1.PCR 0008 81F6h

	b7	b6	b5	b4	b3	b2	b1	b0
	G3CMS[1:0]		G2CMS[1:0]		G1CMS[1:0]		G0CMS[1:0]	
Value after reset:	1	1	1	1	1	1	1	1

- PPG0.PCR

Bit	Symbol	Bit Name	Description	R/W
b1, b0	G0CMS[1:0]	Group 0 Compare Match Select	b1 b0 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3	R/W
b3, b2	G1CMS[1:0]	Group 1 Compare Match Select	b3 b2 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3	R/W
b5, b4	G2CMS[1:0]	Group 2 Compare Match Select	b5 b4 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3	R/W
b7, b6	G3CMS[1:0]	Group 3 Compare Match Select	b7 b6 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3	R/W

- PPG1.PCR

Bit	Symbol	Bit Name	Description	R/W
b1, b0	G0CMS[1:0]	Group 4 Compare Match Select	• When the PTRSL bit in PPG1.PTRSLR is set to 0. b1 b0 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3 • When the PTRSL bit in PPG1.PTRSLR is set to 1. b1 b0 0 0: Compare match in TPU6 0 1: Compare match in TPU7 1 0: Compare match in TPU8 1 1: Compare match in TPU9	R/W

Bit	Symbol	Bit Name	Description	R/W
b3, b2	G1CMS[1:0]	Group 5 Compare Match Select	• When the PTRSL bit in PPG1.PTRSLR is set to 0. b3 b2 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3 • When the PTRSL bit in PPG1.PTRSLR is set to 1. b3 b2 0 0: Compare match in TPU6 0 1: Compare match in TPU7 1 0: Compare match in TPU8 1 1: Compare match in TPU9	R/W
b5, b4	G2CMS[1:0]	Group 6 Compare Match Select	• When the PTRSL bit in PPG1.PTRSLR is set to 0. b5 b4 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3 • When the PTRSL bit in PPG1.PTRSLR is set to 1. b5 b4 0 0: Compare match in TPU6 0 1: Compare match in TPU7 1 0: Compare match in TPU8 1 1: Compare match in TPU9	R/W
b7, b6	G3CMS[1:0]	Group 7 Compare Match Select	• When the PTRSL bit in PPG1.PTRSLR is set to 0. b7 b6 0 0: Compare match in TPU0 0 1: Compare match in TPU1 1 0: Compare match in TPU2 1 1: Compare match in TPU3 • When the PTRSL bit in PPG1.PTRSLR is set to 1. b7 b6 0 0: Compare match in TPU6 0 1: Compare match in TPU7 1 0: Compare match in TPU8 1 1: Compare match in TPU9	R/W

PPGm.PCR (m = 0, 1) selects pulse output trigger signals on a group-by-group basis. For details on output trigger selection, see section 16.2.6, PPG Output Mode Register (PMR).

GjCMS[1:0] Bits (Group k Compare Match Select) (j = 0 to 3, k = 0 to 7)

Each bit selects an output trigger of pulse output group k.

16.2.6 PPG Output Mode Register (PMR)

Addresses: PPG0.PMR 0008 81E7h, PPG1.PMR 0008 81F7h

	b7	b6	b5	b4	b3	b2	b1	b0
	G3INV	G2INV	G1INV	G0INV	G3NOV	G2NOV	G1NOV	G0NOV
Value after reset:	1	1	1	1	0	0	0	0

- PPG0.PMR

Bit	Symbol	Bit Name	Description	R/W
b0	G0NOV	Group 0 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3)	R/W
b1	G1NOV	Group 1 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3)	R/W
b2	G2NOV	Group 2 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3)	R/W
b3	G3NOV	Group 3 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3)	R/W
b4	G0INV	Group 0 Output Polarity Invert	0: Inverted output 1: Direct output	R/W
b5	G1INV	Group 1 Output Polarity Invert	0: Inverted output 1: Direct output	R/W
b6	G2INV	Group 2 Output Polarity Invert	0: Inverted output 1: Direct output	R/W
b7	G3INV	Group 3 Output Polarity Invert	0: Inverted output 1: Direct output	R/W

- PPG1.PMR

Bit	Symbol	Bit Name	Description	R/W
b0	G0NOV	Group 4 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3, 6 to 9)	R/W
b1	G1NOV	Group 5 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3, 6 to 9)	R/W
b2	G2NOV	Group 6 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3, 6 to 9)	R/W
b3	G3NOV	Group 7 Non-Overlap	0: Normal operation (Output values updated on compare match A in the selected TPUm) 1: Non-overlapping operation (Output values updated on compare match A or B in the selected TPUm) (m = 0 to 3, 6 to 9)	R/W
b4	G0INV	Group 4 Output Polarity Invert	0: Inverted output 1: Direct output	R/W
b5	G1INV	Group 5 Output Polarity Invert	0: Inverted output 1: Direct output	R/W
b6	G2INV	Group 6 Output Polarity Invert	0: Inverted output 1: Direct output	R/W
b7	G3INV	Group 7 Output Polarity Invert	0: Inverted output 1: Direct output	R/W

PPGm.PCR (m = 0, 1) selects the pulse output mode of the PPG on a group-by-group basis.

While inverted output is selected, a low-level pulse is output when the values in PPGm.PODRH and PPGm.PODRL are 1, and a high-level pulse is output when the values in PPGm.PODRH and PPGm.PODRL are 0.

In addition, when non-overlapping operation is selected, the PPG updates its output values on compare match A or B in a TPU channel that functions as an output trigger.

For details, see section 16.3.4, Non-Overlapping Pulse Output.

GjNOV Bits (Group k Non-Overlap) (j = 0 to 3, k = 0 to 7)

Each bit selects normal operation or non-overlapping operation for pulse output group j.

GjINV Bits (Group k Invert) (j = 0 to 3, k = 0 to 7)

Each bit selects direct output or inverted output for pulse output group k.

16.3 Operation

Figure 16.4 shows a schematic diagram of the PPG.

PPG pulse output is enabled when the corresponding bits in PPGm.NDERH and PPGm.NDERL (m = 0, 1) are set to 1 (data transfer is enabled).

An initial output value is determined by the initial settings in the corresponding PPGm.PODRH and PPGm.PODRL. When the compare match event selected in PPGm.PCR occurs, the output values are updated by transfer of the values in the corresponding PPGm.NDRH and PPGm.NDRL to PPGm.PODRH and PPGm.PODRL, respectively.

Consecutive output of up to 16 bits of data is possible by writing new output data to PPGm.NDRH and PPGm.NDRL before the next compare match.

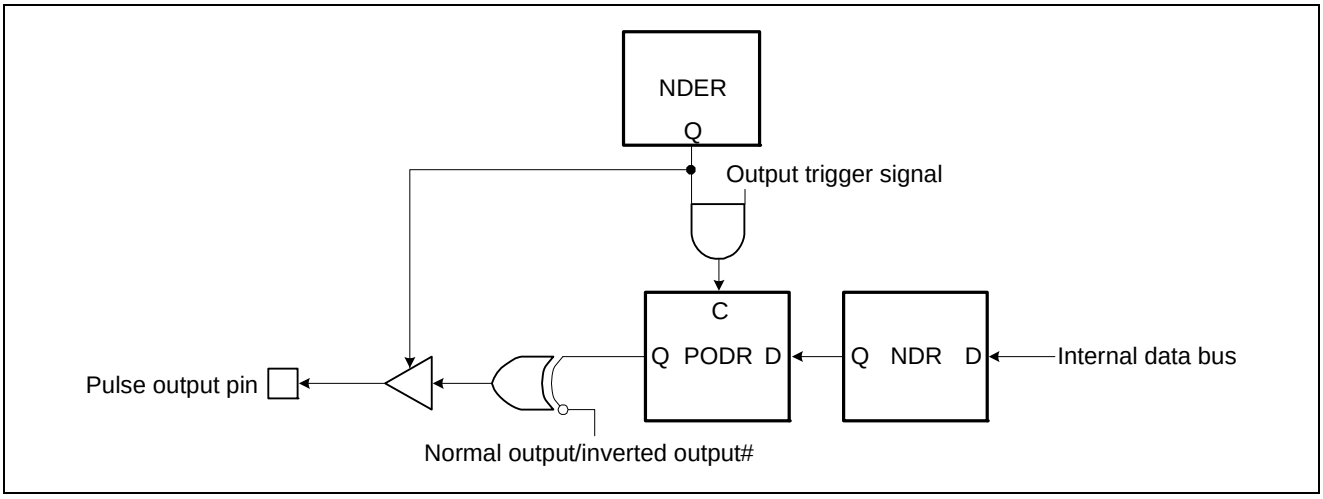


Figure 16.4 Schematic Diagram of PPG

16.3.1 Output Timing

When the selected compare match event occurs while pulse output is enabled, the values in PPGm.NDRH and PPGm.NDRL (m = 0, 1) are transferred to PPGm.PODRH and PPGm.PODRL, respectively, and then output on the corresponding pins.

Figure 16.5 shows the timing of the above operation. In this case, the timing when compare match A triggers normal output from groups 2 and 3 is shown.

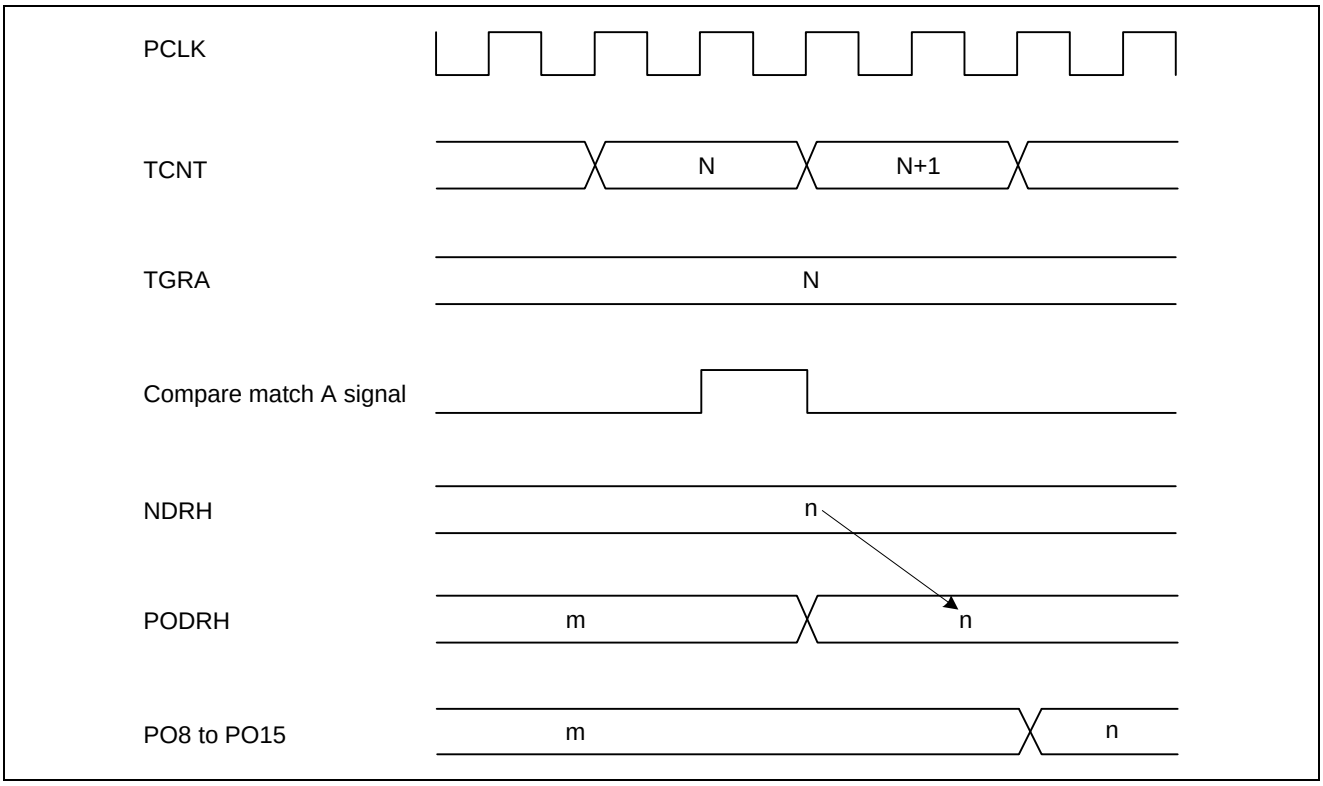


Figure 16.5 Timing of Transfer and Output of the Values in NDR (Example)

16.3.2 Sample Setup Procedure for Normal Pulse Output

Figures 16.6 and 16.7 show sample procedures for setting normal pulse output.

(1) PPG0 Setting

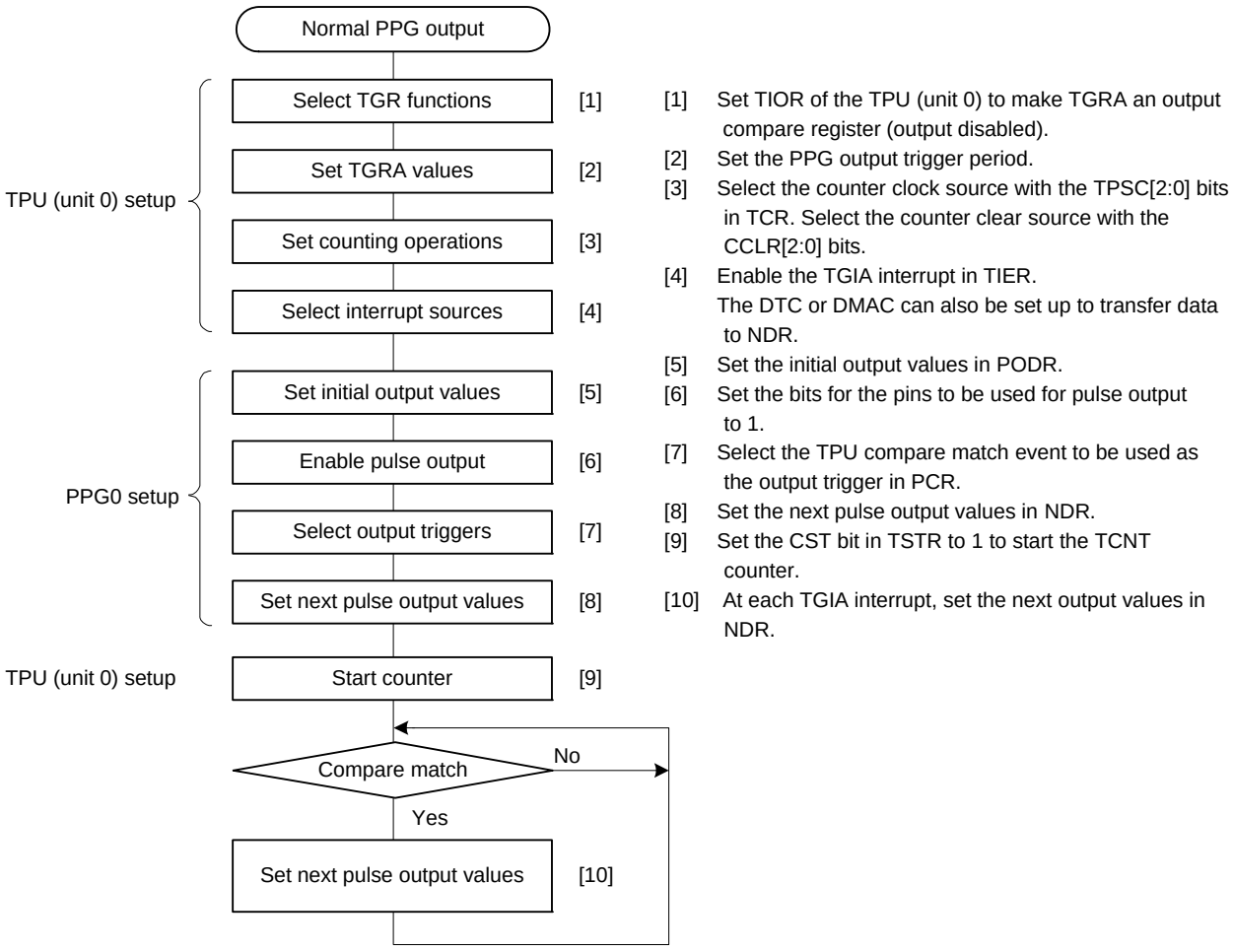


Figure 16.6 Sample Setup Procedure for Normal Pulse Output (PPG0 Setting)

(2) PPG1 Setting

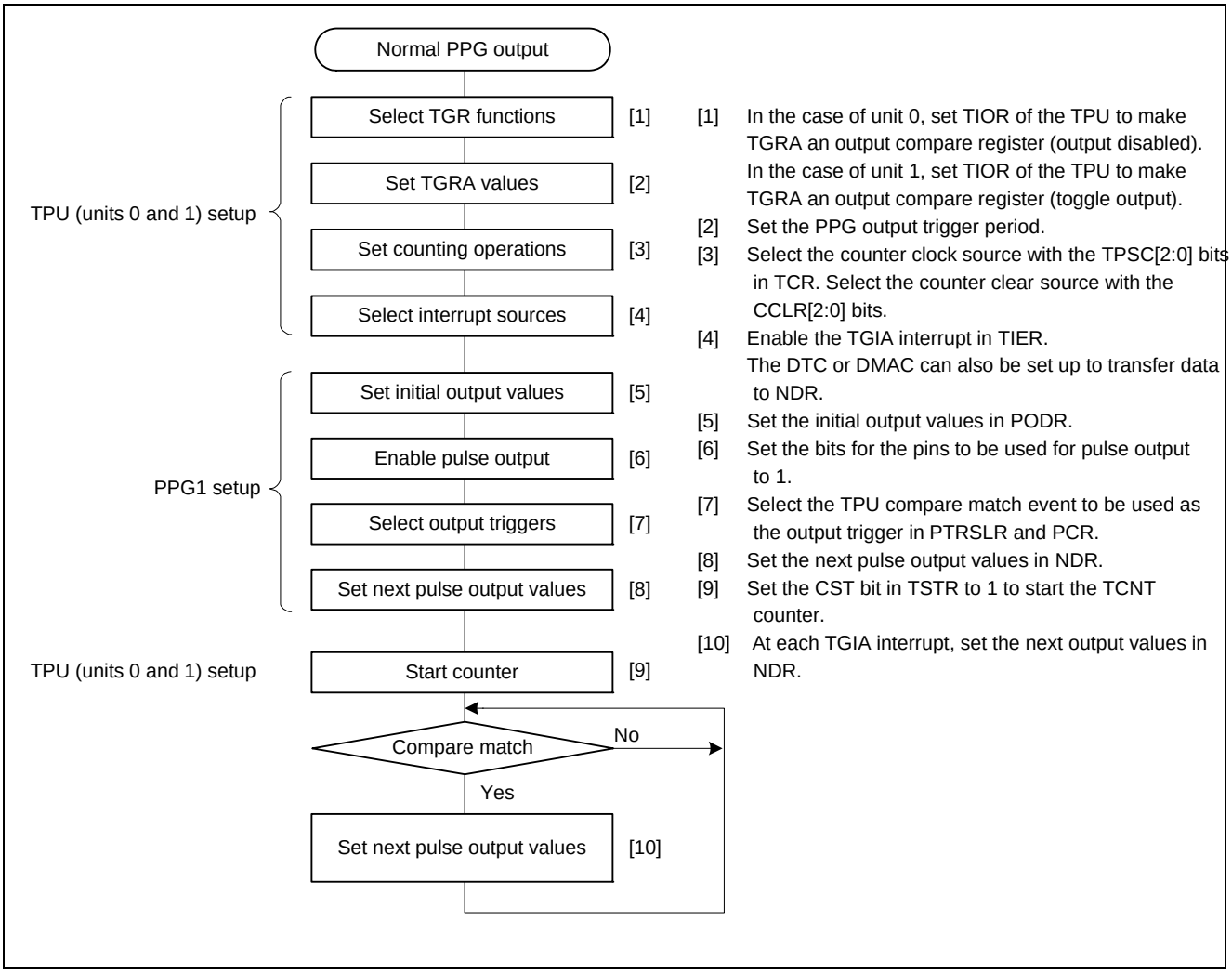


Figure 16.7 Sample Setup Procedure for Normal Pulse Output (PPG1 Setting)

16.3.3 Example of Normal Pulse Output (Example of Five-Phase Pulse Output)

Figure 16.8 shows an example in which pulse output from the PPG0 is used for cyclic five-phase pulse output.

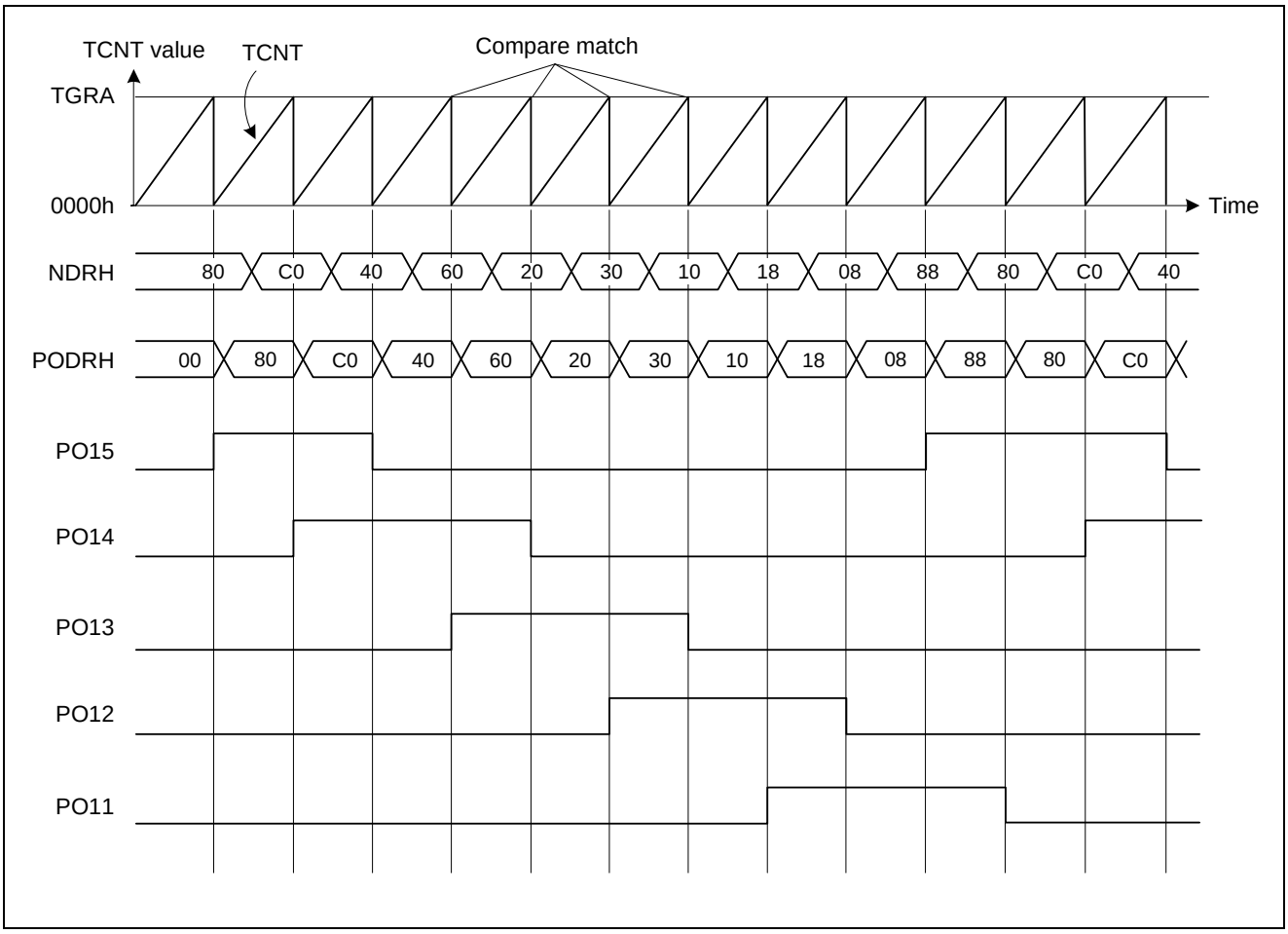


Figure 16.8 Example of Normal Pulse Output (Example of Five-Phase Pulse Output)

1. Set an output compare register of the TPU, i.e. TPUm.TGRA (m = 0 to 3) so that the corresponding compare match signal is the output trigger. Set a cycle in TGRA so that the counter will be cleared by compare match A. Set the TGIEA bit in TPUm.TIER to 1 to enable the compare match/input capture A (TGImA) interrupt.
2. Write F8h to PPG0.NDERH, and set the G3CMS[1:0] and G2CMS[1:0] bits in PPG0.PCR to select the respective compare matches in the TPUm selected in the previous step to be the output triggers. Write output data 80h to PPG0.NDRH.
3. The timer counter in the TPUm starts. When compare match A occurs, the values in PPG0.NDRH are transferred to PPG0.PODRH and output. The TGImA interrupt handling routine writes the next output data C0h to PPG0.NDRH.
4. Five-phase pulse output (one or two phases active at a time) can be obtained subsequently by writing 40h, 60h, 20h, 30h, 10h, 18h, 08h, 88h... at successive TGImA interrupts.
   If the DTC or DMAC is set for activation by the TGImA interrupt, pulse output can be obtained without imposing a load on the CPU.

16.3.4 Non-Overlapping Pulse Output

During non-overlapping operation, data transfer from PPGm.NDRH and PPGm.NDRL (m = 0, 1) to PPGm.PODRH and PPGm. PODRL is performed as follows.

- On compare match A, the values in PPGm.NDRH and PPGm.NDRL are always transferred to PPGm.PODRH and PPGm. PODRL.
- On compare match B, data transfer proceeds for bits in PPGm.NDRH and PPGm.NDRL that have the value 0. It does not proceed for bits having the value 1.

Figure 16.9 shows the non-overlapping pulse output operation.

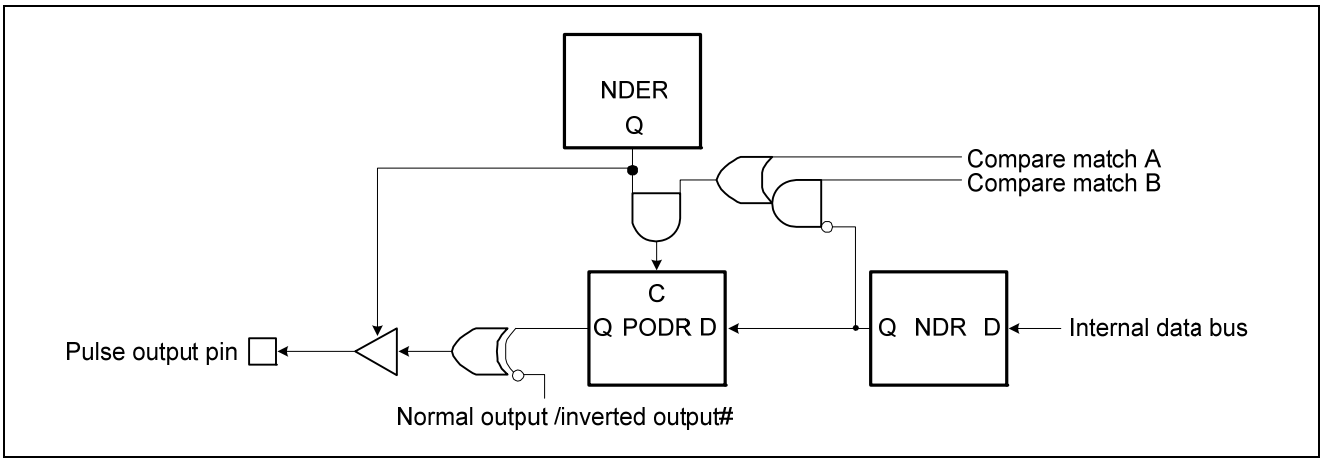


Figure 16.9 Non-Overlapping Pulse Output

Therefore, compare match B before compare match A allows 0-valued data to be transferred in advance of 1-valued data.

Do not change the values in PPGm.NDRH and PPGm.NDRL during the interval from compare match B to compare match A (the non-overlap margin).

To transfer 0-valued data in advance of 1-valued data, write the next data to PPGm.NDRH and PPGm.NDRL from within the TGIA interrupt handling routine or by using a TGIA interrupt to activate transfer by the DTC or DMAC. In any case, the next data must be written before the next compare match B occurs.

Figure 16.10 shows the timing of the above procedure.

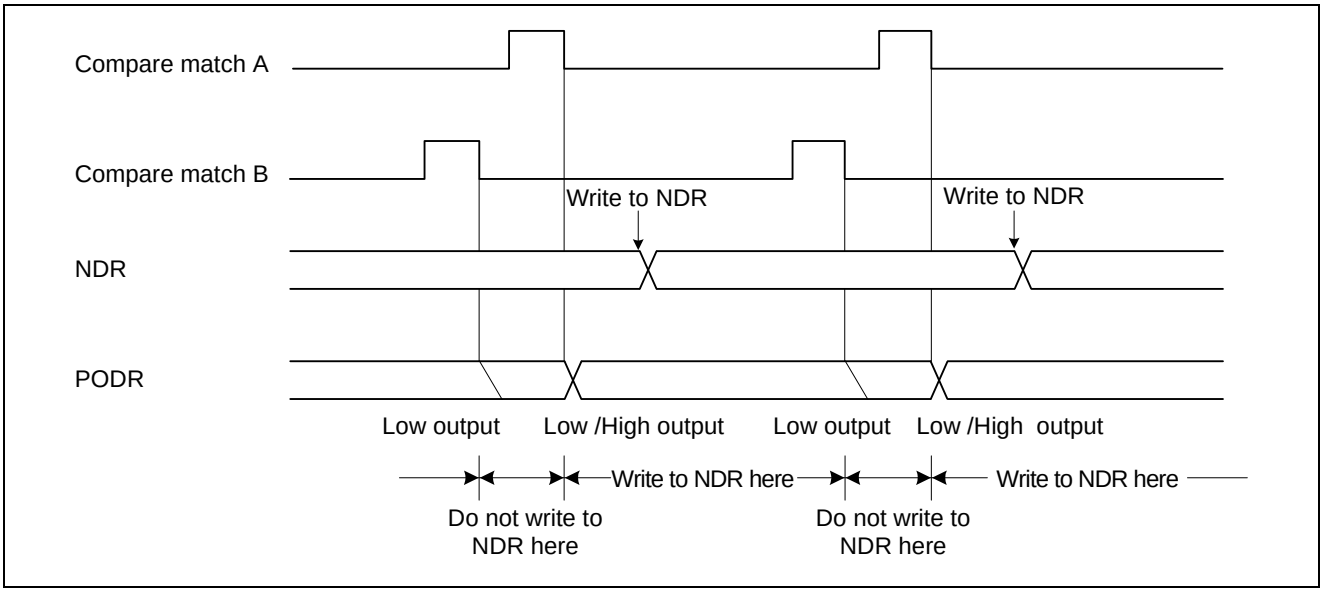


Figure 16.10 Non-Overlapping Operation and Write Timing to PPGm.NDRH and PPGm.NDRL

16.3.5 Sample Setup Procedure for Non-Overlapping Pulse Output

Figures 16.11 and 16.12 show sample procedures for setting up non-overlapping pulse outputs.

(1) PPG0 Setting

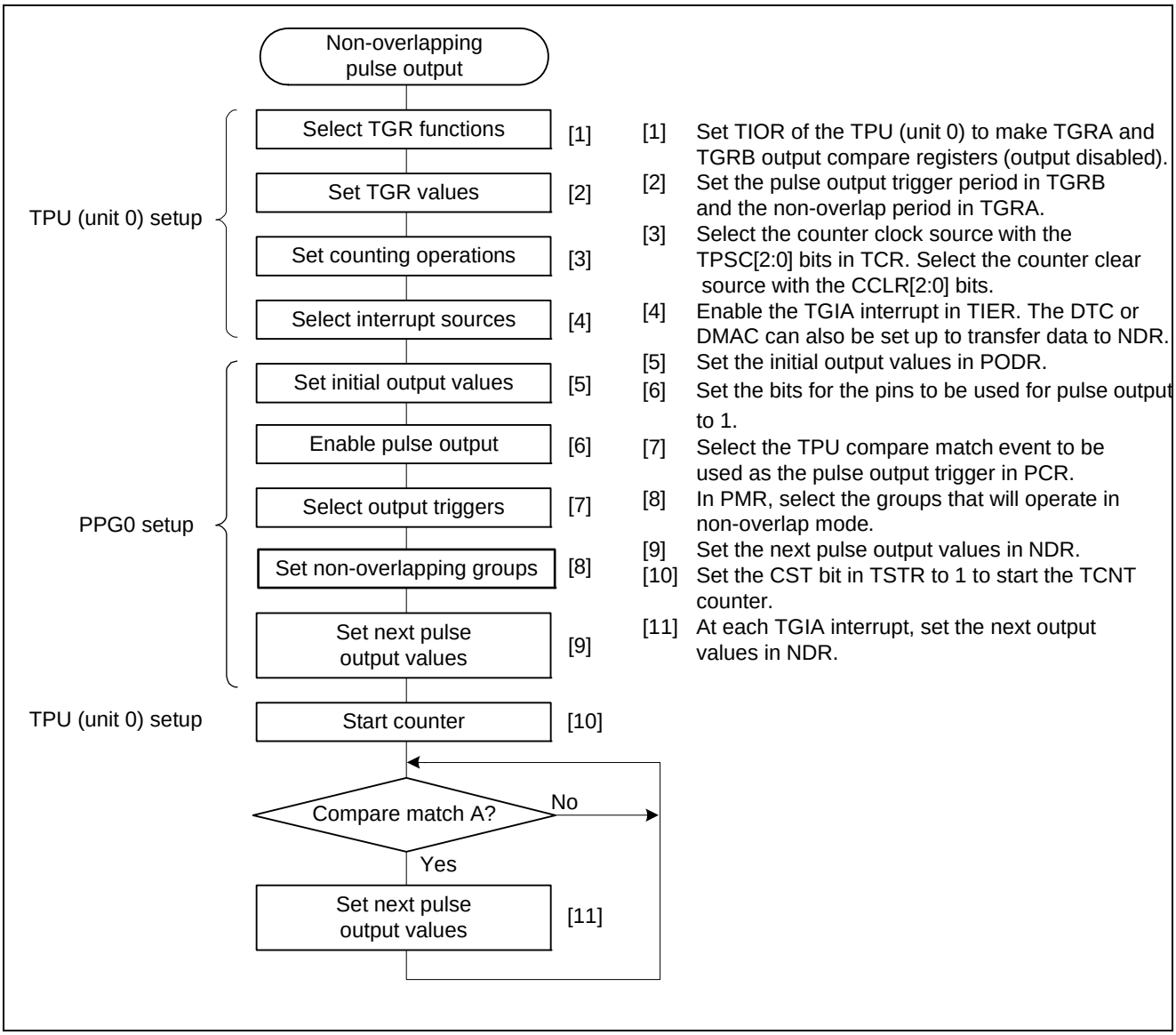
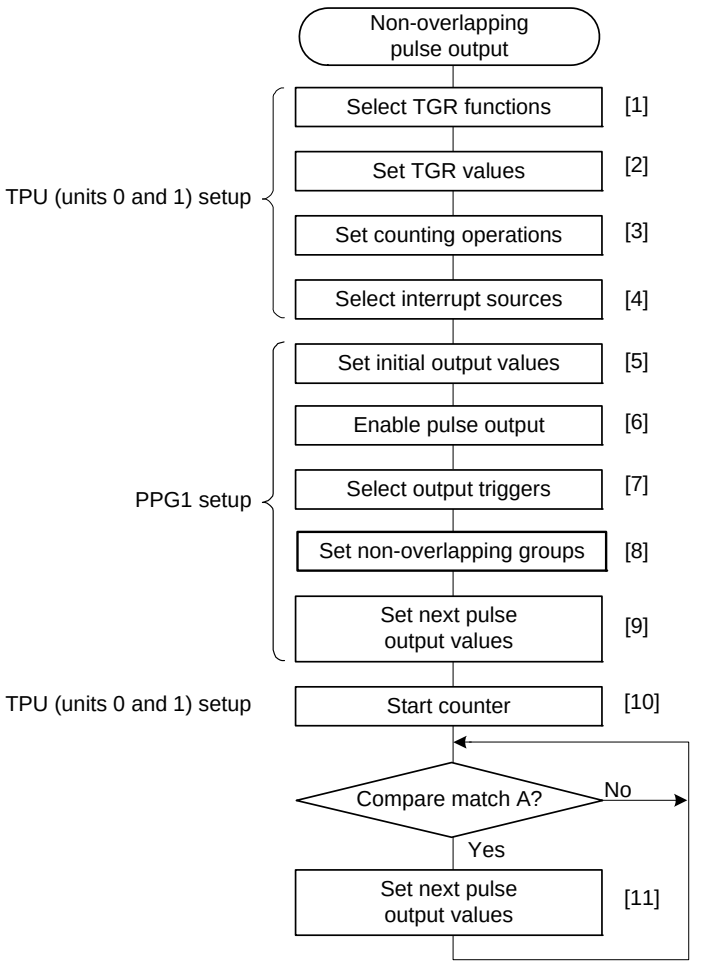


Figure 16.11 Sample Setup Procedure for Non-Overlapping Pulse Output (PPG0 Setting)

(2) PPG1 Setting



[1] In the case of unit 0, set TIOR of the TPU to make TGRA and TGRB output compare registers (output disabled).
In the case of unit 1, set TIOR of the TPU to make TGRA and TGRB output compare registers (toggle output).
[2] Set the pulse output trigger period in TGRB and the non-overlap period in TGRA.
[3] Select the counter clock source with the TPSC[2:0] bits in TCR.
Select the counter clear source with the CCLR[2:0] bits.
[4] Enable the TGIA interrupt in TIER. The DTC or DMAC can also be set up to transfer data to NDR.
[5] Set the initial output values in PODR.
[6] Set the bits for the pins to be used for pulse output to 1.
[7] Select the TPU compare match event to be used as the pulse output trigger in PTRSLR and PCR.
[8] In PMR, select the groups that will operate in non-overlap mode.
[9] Set the next pulse output values in NDR.
[10] Set the CST bit in TSTR to 1 to start the TCNT counter.
[11] At each TGIA interrupt, set the next output values in NDR.

Figure 16.12 Sample Setup Procedure for Non-Overlapping Pulse Output (PPG1 Setting)

16.3.6 Example of Non-Overlapping Pulse Output (Example of Four-Phase Complementary Non-Overlapping Output)

Figure 16.13 shows an example in which pulse output from the PPG0 is used for four-phase complementary non-overlapping pulse output.

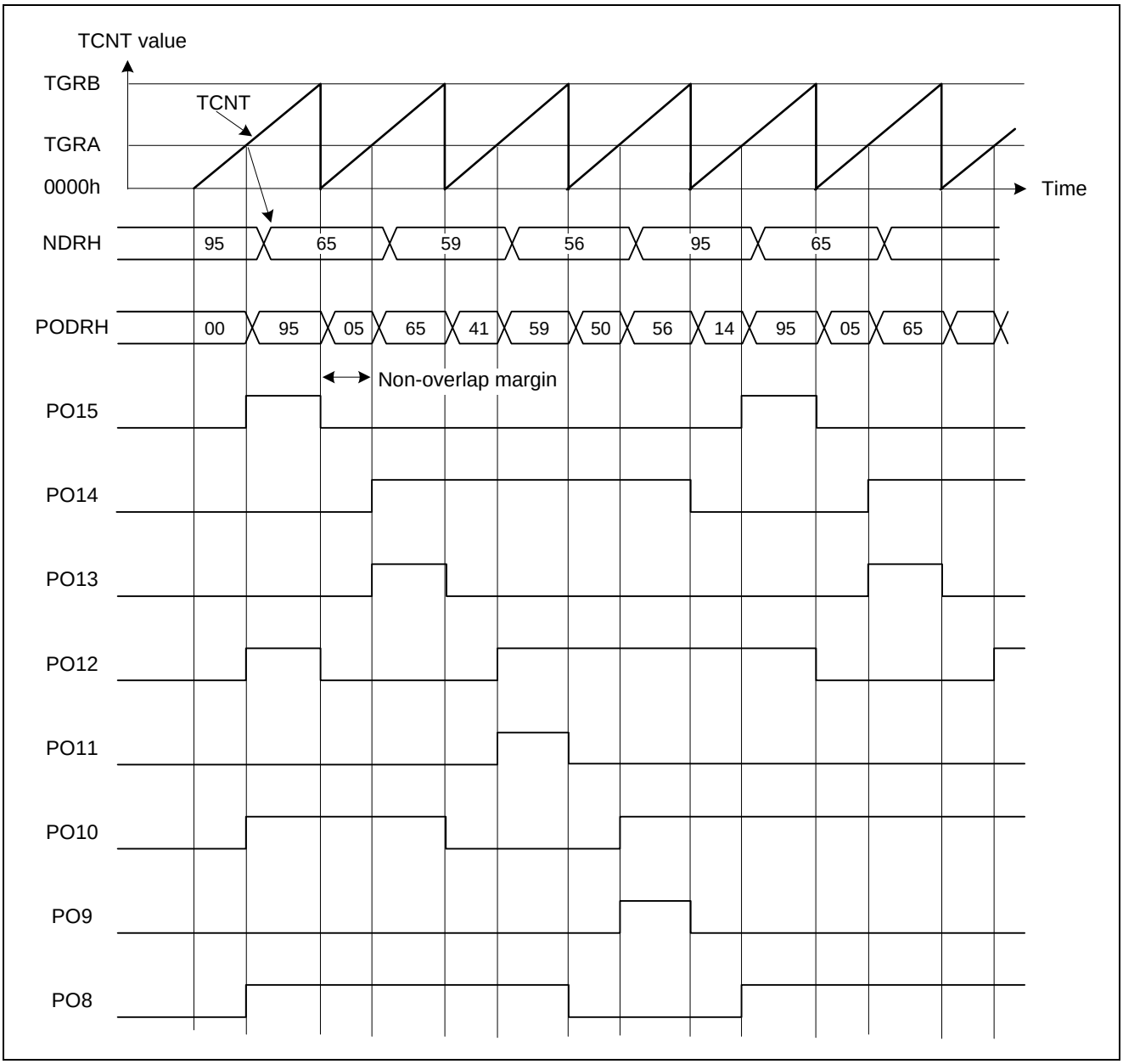


Figure 16.13 Example of Non-Overlapping Pulse Output (Example of Four-Phase Complementary Non-Overlapping Output)

1. Set output compare registers of the TPU, i.e. TPUm.TGRA and TPUm.TGRB (m = 0 to 3) so that the corresponding compare match signals are the output triggers. Set the trigger period in TGRB and the non-overlap margin in TGRA, and set the counter to be cleared by compare match B. Set the TGIEA bit in TPUm.TIER to 1 to enable the compare match/input capture A (TGImA) interrupt.
2. Write FFh in PPG0.NDERH, and set the G3CMS[1:0] and G2CMS[1:0] bits in PPG0.PCR to select the respective compare matches in the TPUm selected in the previous step to be the output triggers.
   Set the G3NOV and G2NOV bits in PPG0.PMR to 1 to select non-overlapping outputs. Write output data 95h in PPG0.NDRH.
3. The timer counter in the TPUm starts. When a compare match with TGRB occurs, outputs change from high to low. When a compare match with TGRA occurs, outputs change from low to high (the change from low to high is delayed by the value set in TGRA).
   The TGImA interrupt handling routine writes the next output data 65h in PPG0.NDRH.
4. Four-phase complementary non-overlapping pulse output can be obtained subsequently by writing 59h, 56h, 95h... at successive TGImA interrupts.
   If the DTC or DMAC is set for activation by the TGImA interrupt, pulse output can be obtained without imposing a load on the CPU.

16.3.7 Inverted Pulse Output

When the G3INV, G2INV, G1INV, and G0INV bits in PPG0.PMR are cleared to 0, the values that are the inverse of the respective values in PPG0.PODRH and PPG0.PODRL can be output.

Figure 16.14 shows the outputs when the G3INV and G2INV bits are cleared to 0 in addition to the settings in figure 16.13.

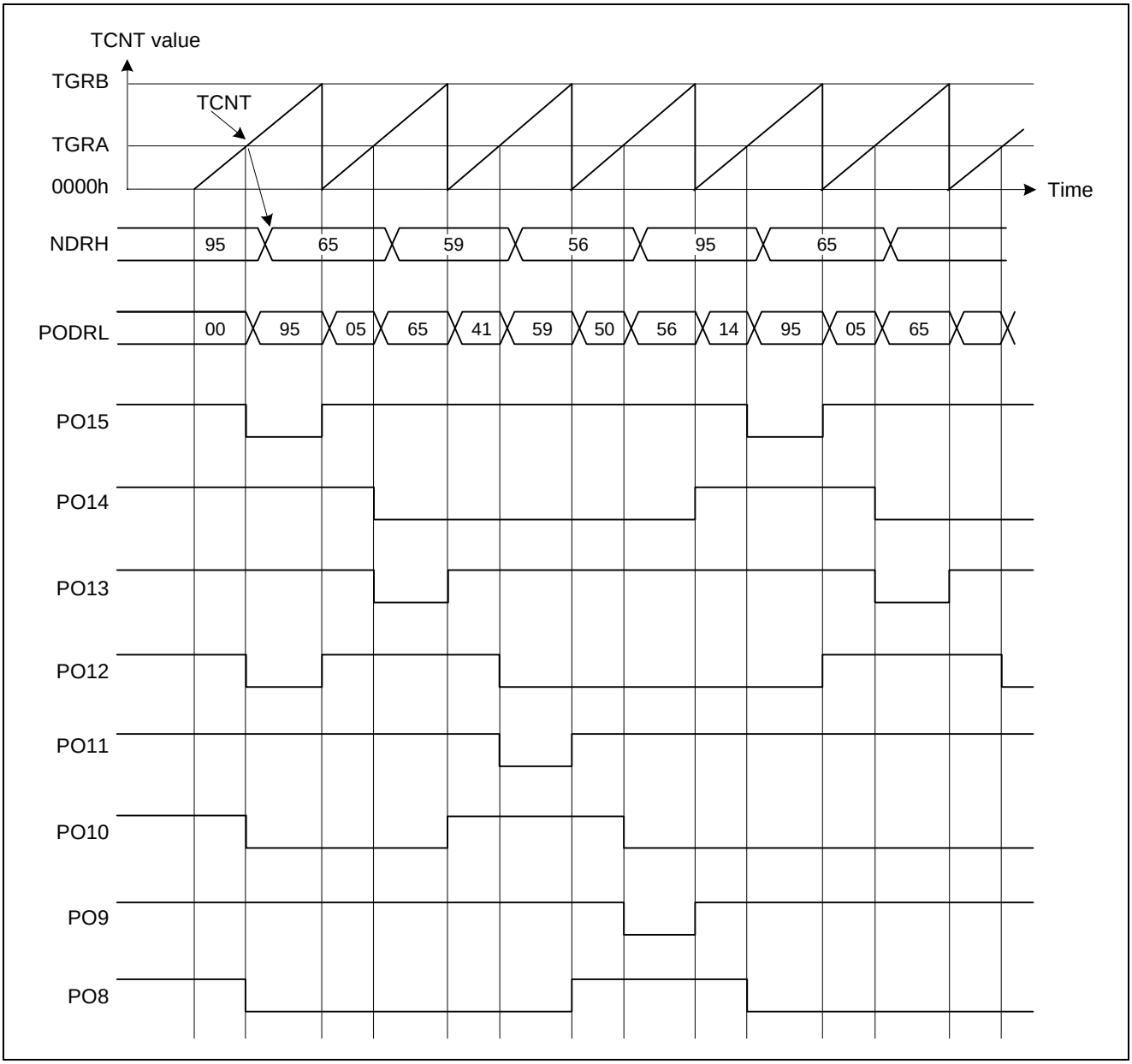


Figure 16.14 Inverted Pulse Output (Example)

16.3.8 Pulse Output Triggered by Input Capture

Pulse output from the PPG0 can be triggered by the TPU (unit 0) input capture as well as by compare match. When a TPUm.TGRA (m = 0 to 3) functions as an input capture register in the TPU (unit 0) channel selected by PPG0.PCR, pulse output is triggered by the input capture signal.

Figure 16.15 shows the timing of pulse output triggered by input capture.

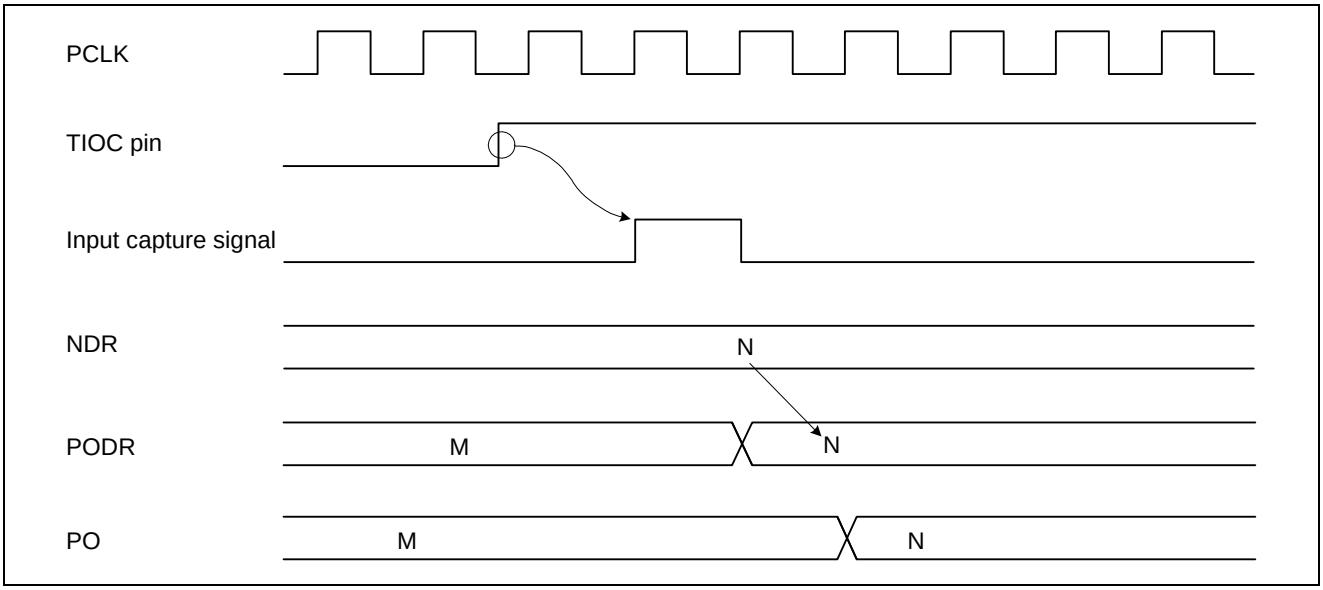


Figure 16.15 Timing of Pulse Output Triggered by Input Capture (Example)

16.4 Usage Note

16.4.1 Module Stop Function Setting

Operation of the PPG can be disabled or enabled by the module stop control register. The initial setting is for operation of the PPG to be halted. Register access is enabled by clearing module stop state. For details, see section 8, Low Power Consumption.

17. 8-Bit Timer (TMR)

The RX610 Group has two units (unit 0, unit 1) of an on-chip 8-bit timer (TMR) module that comprise two 8-bit counter channels, totaling four channels. The 8-bit timer module can be used to count external events and also be used as a multifunction timer in a variety of applications, such as generation of counter reset, interrupt requests, and pulse output with a desired duty cycle using a compare-match signal with two registers.

Unit 0 and unit 1 can generate a baud rate clock signal for the SCI and have the same functions.

17.1 Overview

Table 17.1 shows the specifications of the TMR.

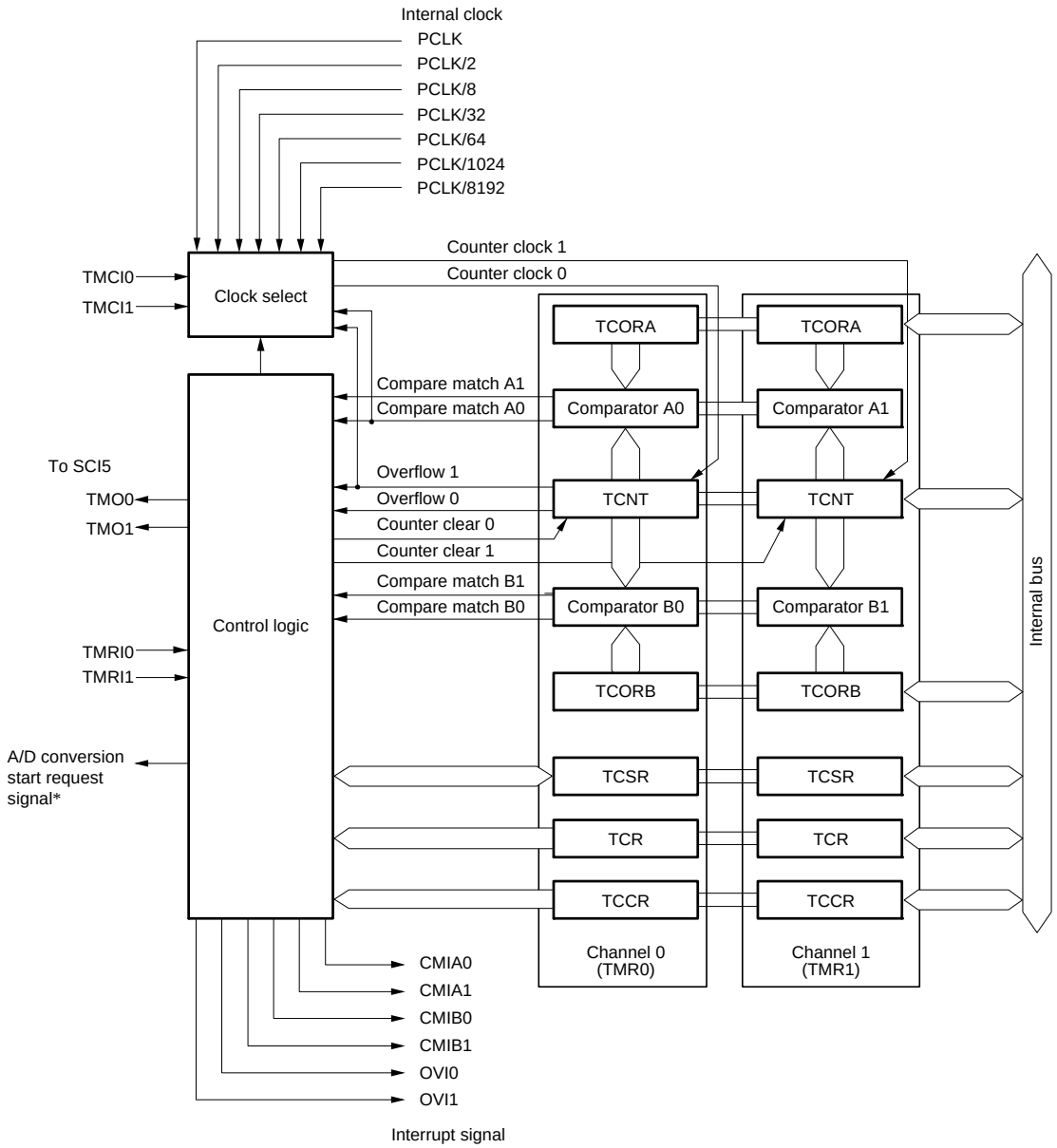
Figure 17.1 shows a block diagram of the 8-bit timer module (unit 0), and figure 17.2 shows that of the 8-bit timer module (unit 1).

Table 17.1 Specifications of TMR

Item	Description
Count clock	• Internal clock: PCLK, PCLK/2, PCLK/8, PCLK/32, PCLK/64, PCLK/1024, PCLK/8192 • External clock
Number of channels	(8 bits x 2 channels) x 2 units
Compare match	• 8-bit mode (compare match A, compare match B) • 16-bit mode (compare match A, compare match B)
Counter clear	Selected by compare match A or B, or an external reset signal.
Timer output	Output pulses with a desired duty cycle or PWM output
Cascading of two channels	• 16-bit count mode 16-bit timer using TMR0 for the upper 8 bits and TMR1 for the lower 8 bits (TMR2 for the upper 8 bits and TMR3 for the lower 8 bits) • Compare match count mode TMR1 can be used to count TMR0 compare matches (TMR3 can be used to count TMR2 compare matches).
Interrupt sources	Compare match A, compare match B, and overflow
DTC activation	DTC can be activated by compare match A interrupts or compare match B interrupts.
Generation of trigger to start A/D converter conversion	Compare match A of TMR0 and TMR2*[1]
Capable of generating baud rate clock for SCI	Generates baud rate clock for SCI5 and SCI6.*[2]
Power-down function	Each unit can be placed in a module stop state.

Notes: 1. For details, see section 23, A/D Converter.

2. For details, see section 20, Serial Communication Interface (SCI).

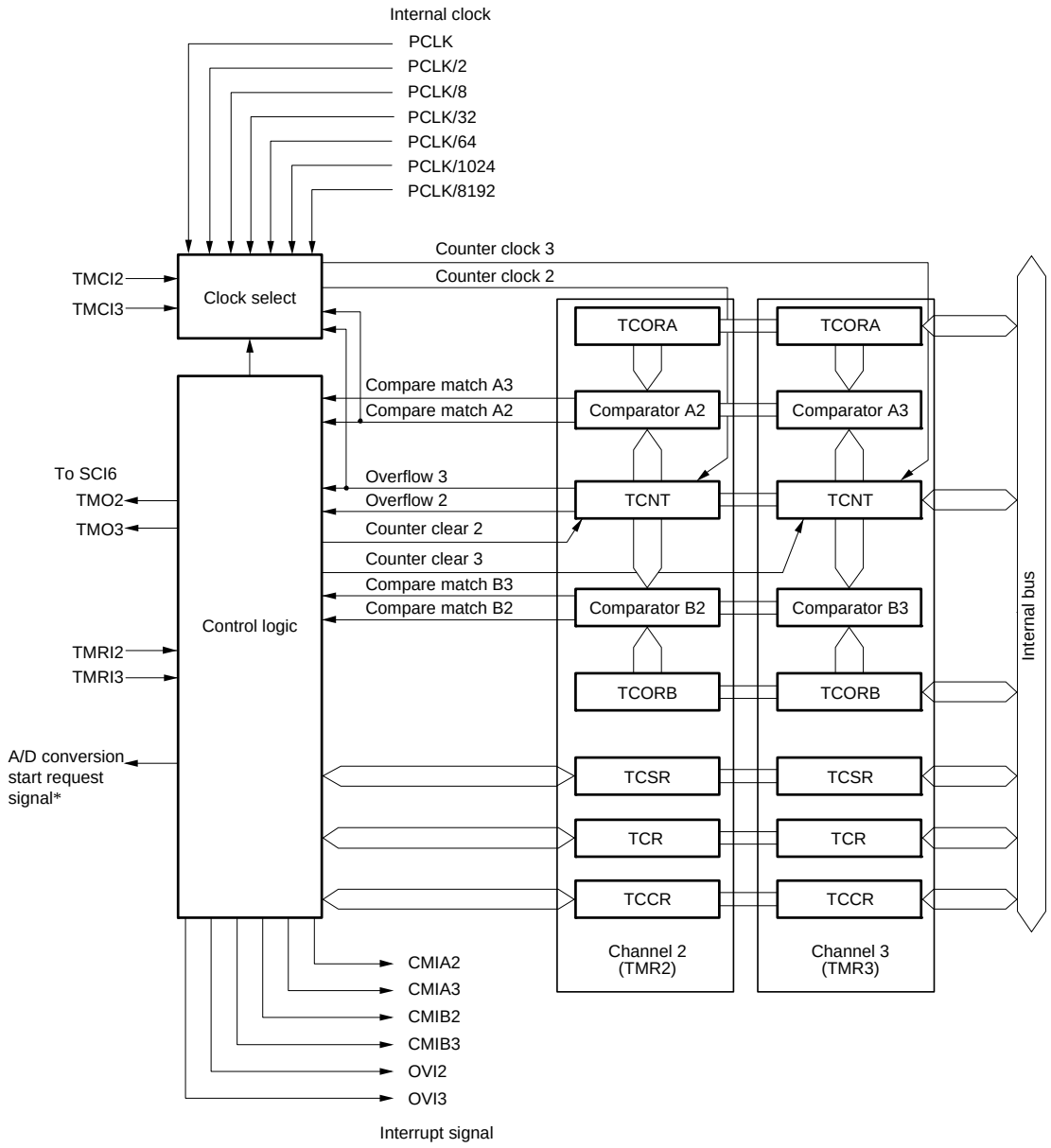


[Legend]

TCORA:	Time constant register A
TCNT:	Timer counter
TCORB:	Time constant register B
TCSR:	Timer control/status register
TCR:	Timer control register
TCCR:	Timer counter control register

Note: * For the corresponding A/D converter channels, see section 23, A/D Converter.

Figure 17.1 Block Diagram of TMR (Unit 0)



[Legend]

TCORA:	Time constant register A
TCNT:	Timer counter
TCORB:	Time constant register B
TCSR:	Timer control/status register
TCR:	Timer control register
TCCR:	Timer counter control register

Note: * For he corresponding A/D converter channels, see section 23, A/D Converter.

Figure 17.2 Block Diagram of TMR (Unit 1)

Table 17.2 lists the input/output pins of the TMR.

Table 17.2 Pin Configuration of TMR

Unit	Channel	Pin Name	I/O	Description
0	TMR0	TMO0	Output	Outputs compare match
		TMCI0	Input	Inputs external clock for counter
		TMRI0	Input	Inputs external reset to counter
	TMR1	TMO1	Output	Outputs compare match
		TMCI1	Input	Inputs external clock for counter
		TMRI1	Input	Inputs external reset to counter
1	TMR2	TMO2	Output	Outputs compare match
		TMCI2	Input	Inputs external clock for counter
		TMRI2	Input	Inputs external reset to counter
	TMR3	TMO3	Output	Outputs compare match
		TMCI3	Input	Inputs external clock for counter
		TMRI3	Input	Inputs external reset to counter

17.2 Register Descriptions

Table 17.3 shows the registers of the TMR.

Table 17.3 Registers of TMR

Unit	Channel	Register Name	Symbol	Value after Reset	Address*	Access Size
0	TMR0	Timer counter	TCNT	00h	0008 8208h	8 or 16
		Time constant register A	TCORA	FFh	0008 8204h	8 or 16
		Time constant register B	TCORB	FFh	0008 8206h	8 or 16
		Timer control register	TCR	00h	0008 8200h	8
		Timer counter control register	TCCR	00h	0008 820Ah	8 or 16
		Timer control/status register	TCSR	x0h	0008 8202h	8
	TMR1	Timer counter	TCNT	00h	0008 8209h	8 or 16*
		Time constant register A	TCORA	FFh	0008 8205h	8 or 16*
		Time constant register B	TCORB	FFh	0008 8207h	8 or 16*
		Timer control register	TCR	00h	0008 8201h	8
		Timer counter control register	TCCR	00h	0008 820Bh	8 or 16*
		Timer control/status register	TCSR	x0h	0008 8203h	8
1	TMR2	Timer counter	TCNT	00h	0008 8218h	8 or 16
		Time constant register A	TCORA	FFh	0008 8214h	8 or 16
		Time constant register B	TCORB	FFh	0008 8216h	8 or 16
		Timer control register	TCR	00h	0008 8210h	8
		Timer counter control register	TCCR	00h	0008 821Ah	8 or 16
		Timer control/status register	TCSR	x0h	0008 8212h	8
	TMR3	Timer counter	TCNT	00h	0008 8219h	8 or 16*
		Time constant register A	TCORA	FFh	0008 8215h	8 or 16*
		Time constant register B	TCORB	FFh	0008 8217h	8 or 16*
		Timer control register	TCR	00h	0008 8211h	8
		Timer counter control register	TCCR	00h	0008 821Bh	8 or 16*
		Timer control/status register	TCSR	x0h	0008 8213h	8

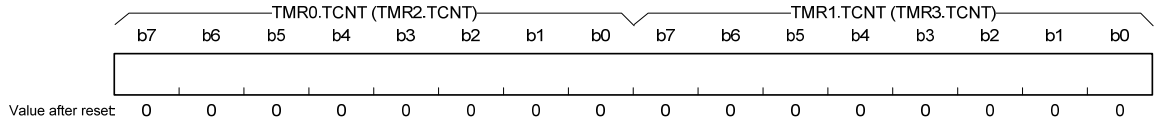
Note: * Odd addresses should not be accessed in 16-bit units. When accessing a register in 16-bit units, access the address of the TMR0 or TMR2 register. Table 17.4 lists register allocation for 16-bit access.

Table 17.4 Register Allocation for 16-Bit Access

Address	Upper 8 Bits	Lower 8 Bits
0008 8208h	TMR0.TCNT	TMR1.TCNT
0008 8204h	TMR0.TCORA	TMR1.TCORA
0008 8206h	TMR0.TCORB	TMR1.TCORB
0008 820Ah	TMR0.TCCR	TMR1.TCCR
0008 8218h	TMR2.TCNT	TMR3.TCNT
0008 8214h	TMR2.TCORA	TMR3.TCORA
0008 8216h	TMR2.TCORB	TMR3.TCORB
0008 821Ah	TMR2.TCCR	TMR3.TCCR

17.2.1 Timer Counter (TCNT)

Addresses: TMR0.TCNT 0008 8208h, TMR1.TCNT 0008 8209h
TMR2.TCNT 0008 8218h, TMR3.TCNT 0008 8219h



TCNT is an 8-bit readable/writable up-counter.

TMR0.TCNT and TMR1.TCNT (TMR2.TCNT and TMR3.TCNT) comprise a single 16-bit counter so they can be accessed together by a word transfer instruction.

The TCCR.CSS[1:0] and CKS[2:0] bits are used to select a clock.

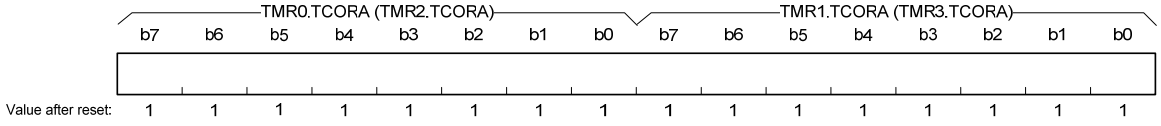
TCNT can be cleared by an external reset input signal, compare match A signal, or compare match B signal. Which signal to be used for clearing is selected by the TCR.CCLR[1:0] bits.

When TCNT overflows from FFh to 00h, the interrupt flag is set to 1.

For details on the corresponding interrupt vector number, see section 10, Interrupt Control Unit (ICU), and table 17.6, TMR Interrupt Sources.

17.2.2 Time Constant Register A (TCORA)

Addresses: TMR0.TCORA: 0008 8204h, TMR1.TCORA: 0008 8205h
TMR2.TCORA: 0008 8214h, TMR3.TCORA: 0008 8215h



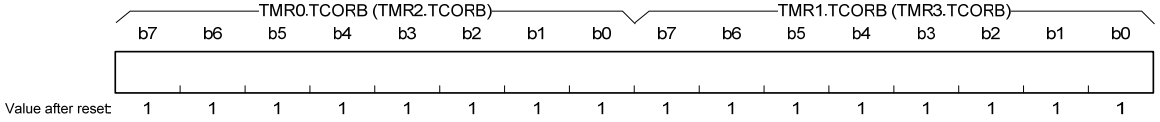
TCORA is an 8-bit readable/writable register.

TMR0.TCORA and TMR1.TCORA (TMR2.TCORA and TMR3.TCORA) comprise a single 16-bit register so they can be accessed together by a word transfer instruction.

The value in TCORA is continually compared with the value in TCNT. When a match is detected, the corresponding compare match A signal is set to high. Note however that comparison is not performed during writing to TCORA. The timer output from the TMOn pin can be freely controlled by this compare match A signal and the settings of the TCSR.OSA[1:0] bits.

17.2.3 Time Constant Register B (TCORB)

Addresses: TMR0.TCORB 0008 8206h, TMR1.TCORB 0008 8207h
TMR2.TCORB 0008 8216h, TMR3.TCORB 0008 8217h



TCORB is an 8-bit readable/writable register.

TMR0.TCORB and TMR1.TCORB (TMR2.TCORB and TMR3.TCORB) comprise a single 16-bit register so they can be accessed together by a word transfer instruction.

The value in TCORB is continually compared with the value in TCNT. When a match is detected, the corresponding compare match B signal is set to high. Note however that comparison is not performed during writing to TCORB. The timer output from the TMOn pin can be freely controlled by this compare match B signal and the settings of the TCSR.OSB[1:0] bits.

17.2.4 Timer Control Register (TCR)

Addresses: TMR0.TCR 0008 8200h, TMR1.TCR 0008 8201h
TMR2.TCR 0008 8210h, TMR3.TCR 0008 8211h

	b7	b6	b5	b4	b3	b2	b1	b0
	CMIEB	CMIEA	OVIE	CCLR[1:0]		—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4, b3	CCLR[1:0]	Counter Clear*	b4 b3 0 0: Clearing is disabled 0 1: Cleared by compare match A 1 0: Cleared by compare match B 1 1: Cleared by the external reset input (Select edge or level by the TMRIS bit in TCCR.)	R/W
b5	OVIE	Timer Overflow Interrupt Enable	0: Overflow interrupt requests (OVIm) are disabled 1: Overflow interrupt requests (OVIm) are enabled	R/W
b6	CMIEA	Compare Match Interrupt Enable A	0: Compare match A interrupt requests (CMIAm) are disabled 1: Compare match A interrupt requests (CMIAm) are enabled	R/W
b7	CMIEB	Compare Match Interrupt Enable B	0: Compare match B interrupt requests (CMIBm) are disabled 1: Compare match B interrupt requests (CMIBm) are enabled	R/W

Note: * To use an external reset, set the Pn.DDR.Bi bit for the corresponding pin to "0" and the Pn.ICR.Bi bit to "1".

TCR specifies the condition for clearing TCNT.

CCLR[1:0] Bits (Counter Clear)

Select the method by which TCNT is cleared.

OVIE Bit (Timer Overflow Interrupt Enable)

Selects whether overflow interrupt requests (OVIm) issued by TCNT are enabled or disabled.

CMIEA Bit (Compare Match Interrupt Enable A)

Selects whether compare match A interrupt requests (CMIAm) that are issued when the value of TCORA corresponds to that of TCNT are enabled or disabled.

CMIEB Bit (Compare Match Interrupt Enable B)

Selects whether compare match B interrupt requests (CMIBm) that are issued when the value of TCORB corresponds to that of TCNT are enabled or disabled.

17.2.5 Timer Counter Control Register (TCCR)

Addresses: TMR0.TCCR 0008 820Ah, TMR1.TCCR 0008 820Bh
TMR2.TCCR 0008 821Ah, TMR3.TCCR 0008 821Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	TMRIS	—	—	CSS[1:0]		CKS[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	CKS[2:0]	Clock Select*	See table 17.5.	R/W
b4, b3	CSS[1:0]	Clock Source Select	See table 17.5.	R/W
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	TMRIS	Timer Reset Detection Condition Select	0: Cleared at rising edge of the external reset 1: Cleared when the external reset is high	R/W

Note * To use an external clock, set the Pn.DDR.Bi bit for the corresponding pin to "0" and the PnICR.Bi bit to "1". For details, see section 14, I/O Ports.

TCCR selects an internal clock source for TCNT and the condition for detecting external reset.

CKS[2:0] Bits (Clock Select)
CSS[1:0] Bits (Clock Source Select)

The CKS[2:0] and CSS[1:0] bits select a clock. For details, see table 17.5.

TMRIS Bit (Timer Reset Detection Condition Select)

This bit is enabled when the TCR.CCLR[1:0] bits are 11b (cleared by external reset input) and selects the condition for detecting external reset (level or edge).

Table 17.5 Clock Input to TCNT and Count Condition

	TCCR Register					
	CSS[1:0]			CKS[2:0]		
Channel	b4	b3	b2	b1	b0	Description
TMR0 (TMR2)	0	0	—	0	0	Clock input prohibited
					1	Uses external clock. Counts at rising edge*1.
				1	0	Uses external clock. Counts at falling edge*1.
					1	Uses external clock. Counts at both rising and falling edges*1.
	0	1	0	0	0	Uses internal clock. Counts at PCLK.
					1	Uses internal clock. Counts at PCLK/2.
				1	0	Uses internal clock. Counts at PCLK/8.
					1	Uses internal clock. Counts at PCLK/32.
			1	0	0	Uses internal clock. Counts at PCLK/64.
					1	Uses internal clock. Counts at PCLK/1024.
				1	0	Uses internal clock. Counts at PCLK/8192.
					1	Clock input prohibited
	1	0	—	—	—	Setting prohibited
	1	1	—	—	—	Counts at TMR1.TCNT (TMR3.TCNT) overflow signal*2.
TMR1 (TMR3)	0	0	—	0	0	Clock input prohibited
					1	Uses external clock. Counts at rising edge*1.
				1	0	Uses external clock. Counts at falling edge*1.
					1	Uses external clock. Counts at both rising and falling edges*1.
	0	1	0	0	0	Uses internal clock. Counts at PCLK.
					1	Uses internal clock. Counts at PCLK/2.
				1	0	Uses internal clock. Counts at PCLK/8.
					1	Uses internal clock. Counts at PCLK/32.
			1	0	0	Uses internal clock. Counts at PCLK/64.
					1	Uses internal clock. Counts at PCLK/1024.
				1	0	Uses internal clock. Counts at PCLK/8192.
					1	Clock input prohibited
	1	0	—	—	—	Setting prohibited
	1	1	—	—	—	Counts at TMR0.TCNT (TMR2.TCNT) compare match A*2.

Notes: 1. To use an external clock, set the Pn.DDR.Bi bit for the corresponding pin to "0" and the Pn.ICR.Bi bit to "1". For details, see section 14, I/O Ports.

2. If the clock input of TMR0 (TMR2) is the overflow signal of the TMR1.TCNT (TMR3.TCNT) counter and that of TMR1 (TMR3) is the compare match signal of the TMR0.TCNT (TMR2.TCNT) counter, no incrementing clock is generated. Do not use this setting.

17.2.6 Timer Control/Status Register (TCSR)

Addresses: TMR0.TCSR 0008 8202h, TMR2.TCSR 0008 8212h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	ADTE	OSB[1:0]		OSA[1:0]	
Value after reset:	x	x	x	0	0	0	0	0

Addresses: TMR1.TCSR 0008 8203h, TMR3.TCSR 0008 8213h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	OSB[1:0]		OSA[1:0]	
Value after reset:	x	x	x	1	0	0	0	0

[Legend] x: Undefined

- TMR0.TCSR, TMR2.TCSR

Bit	Symbol	Bit Name	Description	R/W
b1, b0	OSA[1:0]	Output Select A*[1]	b1 b0 0 0: No change when compare match A occurs 0 1: Low is output when compare match A occurs 1 0: High is output when compare match A occurs 1 1: Output is inverted when compare match A occurs (toggle output)	R/W
b3, b2	OSB[1:0]	Output Select B*[1]	b3 b2 0 0: No change when compare match B occurs 0 1: Low is output when compare match B occurs 1 0: High is output when compare match B occurs 1 1: Output is inverted when compare match B occurs (toggle output)	R/W
b4	ADTE	A/D Trigger Enable*[2]	0: A/D converter start requests by compare match A are disabled 1: A/D converter start requests by compare match A are enabled	R/W
b7 to b5	—	Reserved	These bits are always read as an undefined value. The write value should always be 1.	R/W

Notes: 1. Timer output is disabled when the OSB[1:0] and OSA[1:0] bits are all 0. Timer output is 0 until the first compare match occurs after a reset.

2. For the corresponding A/D converter channels, see section 23, A/D Converter.

- TMR1.TCSR, TMR3.TCSR

Bit	Symbol	Bit Name	Description	R/W
b1, b0	OSA[1:0]	Output Select A*	b1 b0 0 0: No change when compare match A occurs 0 1: Low is output when compare match A occurs 1 0: High is output when compare match A occurs 1 1: Output is inverted when compare match A occurs (toggle output)	R/W
b3, b2	OSB[1:0]	Output Select B*	b3 b2 0 0: No change when compare match B occurs 0 1: Low is output when compare match B occurs 1 0: High is output when compare match B occurs 1 1: Output is inverted when compare match B occurs (toggle output)	R/W
b4	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b7 to b5	—	Reserved	These bits are always read as an undefined value. The write value should always be 1.	R/W

Note: * Timer output is disabled when the OSB[1:0] and OSA[1:0] bits are all 0. Timer output is 0 until the first compare match occurs after a reset.

TCSR controls compare match output.

OSA[1:0] Bits (Output Select A)

These bits select a method of TMOn pin output when compare match A of TCORA and TCNT occurs.

OSB[1:0] Bits (Output Select B)

These bits select a method of TMOn pin output when compare match B of TCORB and TCNT occurs.

ADTE Bit (A/D Trigger Enable)

Selects enabling or disabling of A/D converter start requests by compare match A.

This bit is reserved for TMR1.TCSR and TMR3.TCSR.

17.3 Operation

17.3.1 Pulse Output

Figure 17.3 shows an example of the 8-bit timer being used to generate a pulse output with a desired duty cycle.

1. Set the TCR.CCLR[1:0] bits to 01b (cleared by compare match A) so that TCNT is cleared at a compare match of TCORA.
2. Set the TCSR.OSA[1:0] bits to 10b (high-output) and TCSR.OSB[1:0] bits to 01b (low-output), causing the output to change to high at a compare match of TCORA and to low at a compare match of TCORB.

With these settings, the 8-bit timer provides pulses output at a cycle determined by TCORA with a pulse width determined by TCORB. No software intervention is required.

The timer output is low until the first compare match occurs after a reset.

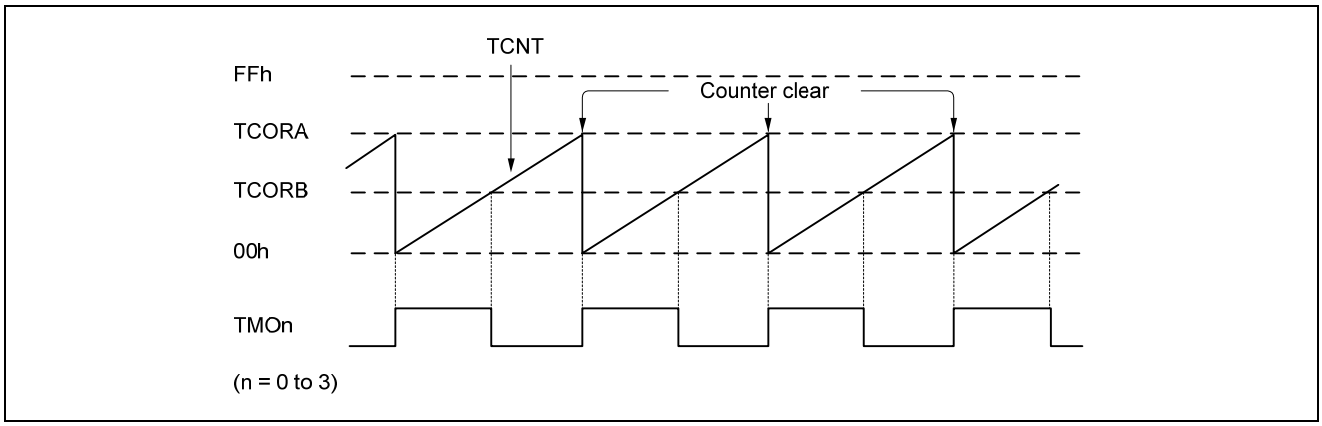


Figure 17.3 Example of Pulse Output

17.3.2 Reset Input

Figure 17.4 shows an example of the 8-bit timer being used to generate a pulse which is output after a desired delay time from a TMRIn input.

1. Set the TCR.CCLR[1:0] bits to 11b (cleared by external reset input) and set the TMRIS bit in TCCR to high (cleared when the external reset is high) so that TCNT is cleared at the high level input of the TMRIn signal.
2. Set the TCSR.OSA[1:0] bits to 10b (high-output) and the TCSR.OSB[1:0] bits to 01b (low-output), causing the output to change to high at a compare match of TCORA and to low at a compare match of TCORB.

With these settings, the 8-bit timer provides pulses output at a desired delay time from a TMRIn input determined by TCORA and with a pulse width determined by TCORB and TCORA.

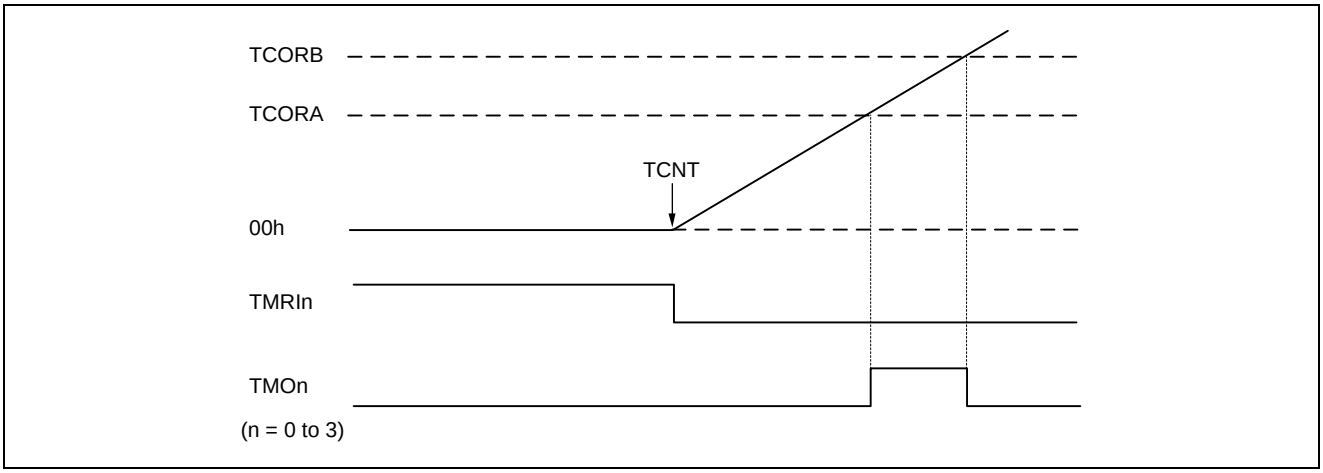


Figure 17.4 Example of Reset Input

17.4 Operation Timing

17.4.1 TCNT Count Timing

Figure 17.5 shows the count timing of TCNT for internal clock input. Figure 17.6 shows the count timing of TCNT for external clock input.

Note that the external clock pulse width must be at least 1.5 states for increment at a single edge, and at least 2.5 states for increment at both edges. The counter will not increment correctly if the pulse width is less than these values.

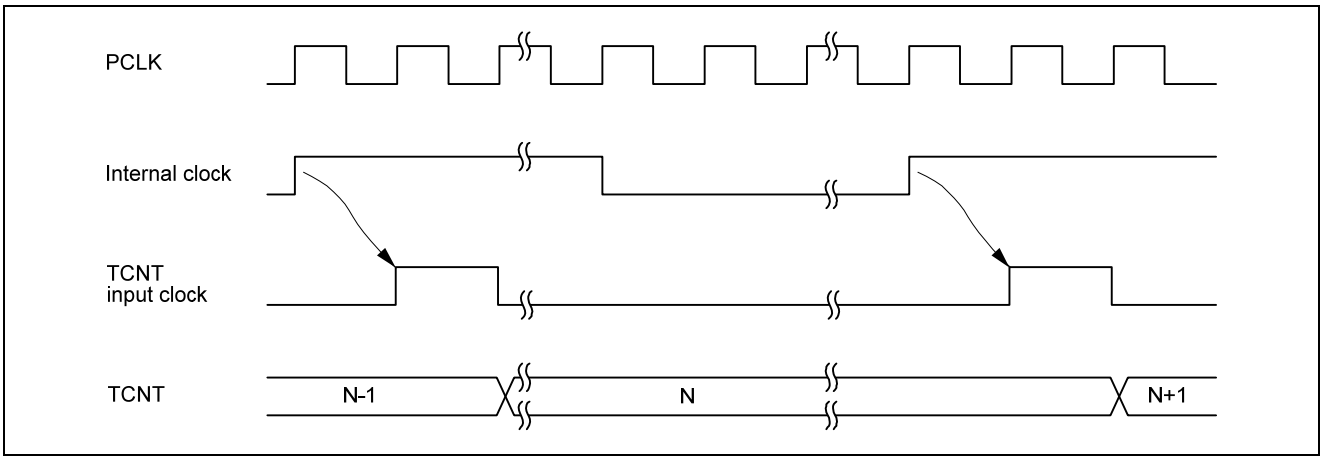


Figure 17.5 Count Timing for Internal Clock Input

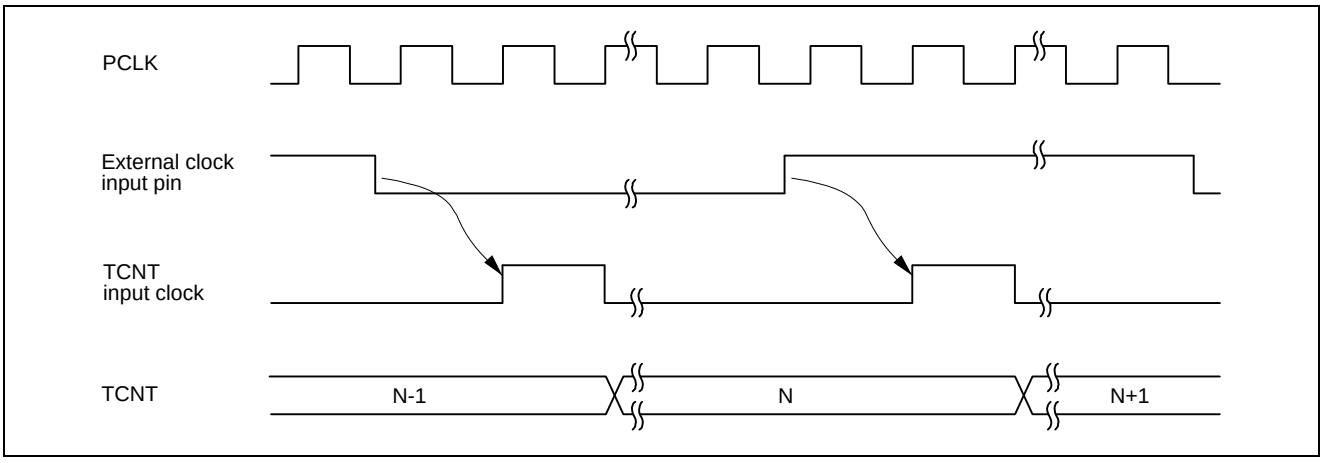


Figure 17.6 Count Timing for External Clock Input

17.4.2 Timing of Interrupt Flag Setting to 1 at Compare Match

The interrupt flag is set to 1 by a compare match signal generated when values of TCORA and TCORB and that of TCNT match.

The compare match signal is generated at the last state in which the match is true, just before the timer counter is updated. Therefore, when values of TCORA and TCORB and that of TCNT match, the compare match signal is not generated until the next TCNT clock input.

Figure 17.7 shows this timing. For details on the corresponding interrupt vector number, see section 10, Interrupt Control Unit (ICU) and table 17.6, TMR Interrupt Sources.

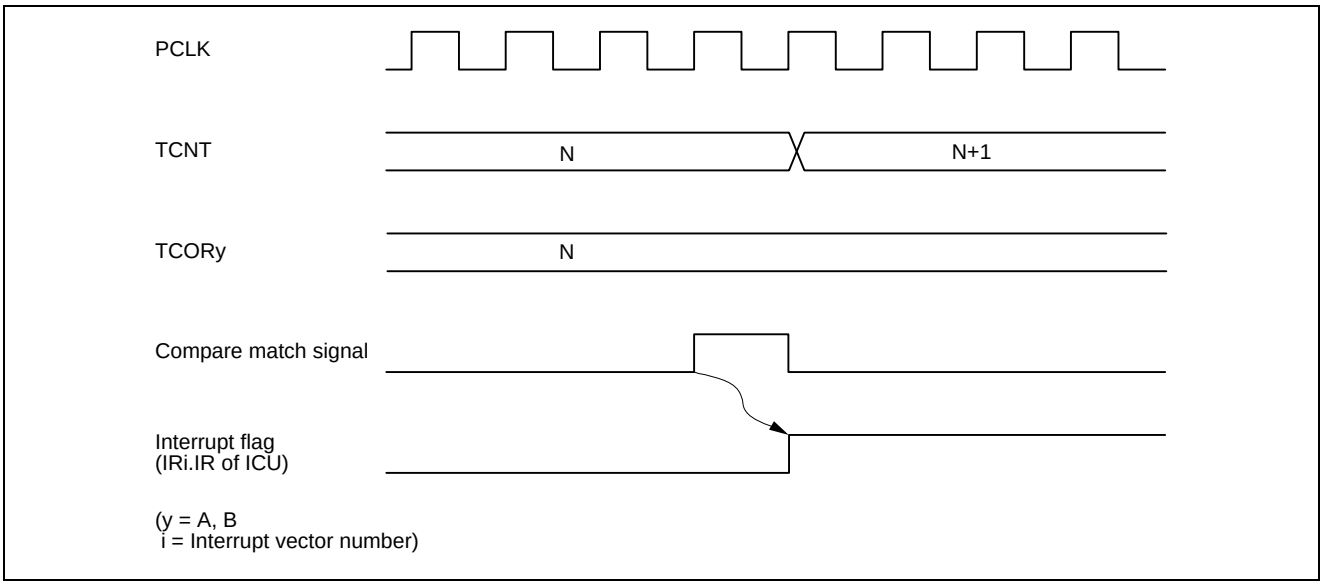


Figure 17.7 Timing of Interrupt Flag Setting at Compare Match

17.4.3 Timing of Timer Output at Compare Match

When a compare match signal is generated, the timer output changes as specified by the TCSR.OSA[1:0] and OSB[1:0] bits.

Figure 17.8 shows the timing when the timer output is toggled by the compare match A signal.

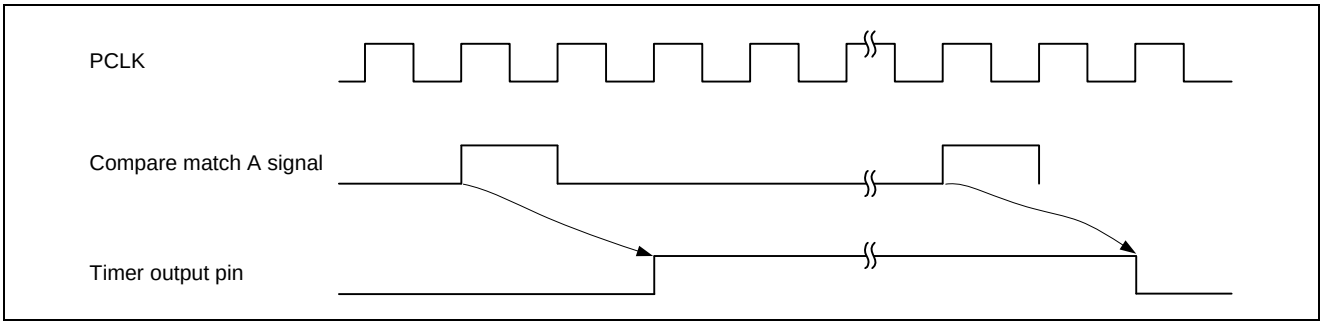


Figure 17.8 Timing of Timer Output at Compare Match A

17.4.4 Timing of Counter Clear by Compare Match

TCNT is cleared when compare match A or B occurs, depending on the settings of the TCR.CCLR[1:0] bits.

Figure 17.9 shows the timing of this operation.

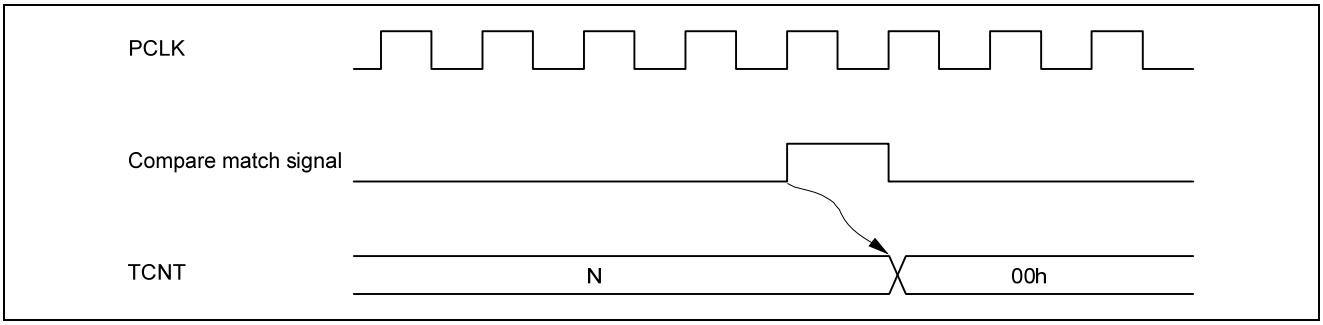


Figure 17.9 Timing of Counter Clear by Compare Match

17.4.5 Timing of the External Reset for TCNT

TCNT is cleared at the rising edge or high level of an external reset input, depending on the settings of the TCR.CCLR[1:0] bits. At least 2 states are required from an external reset input to clearing of TCNT.

Figures 17.10 and 17.11 show the timing of this operation.

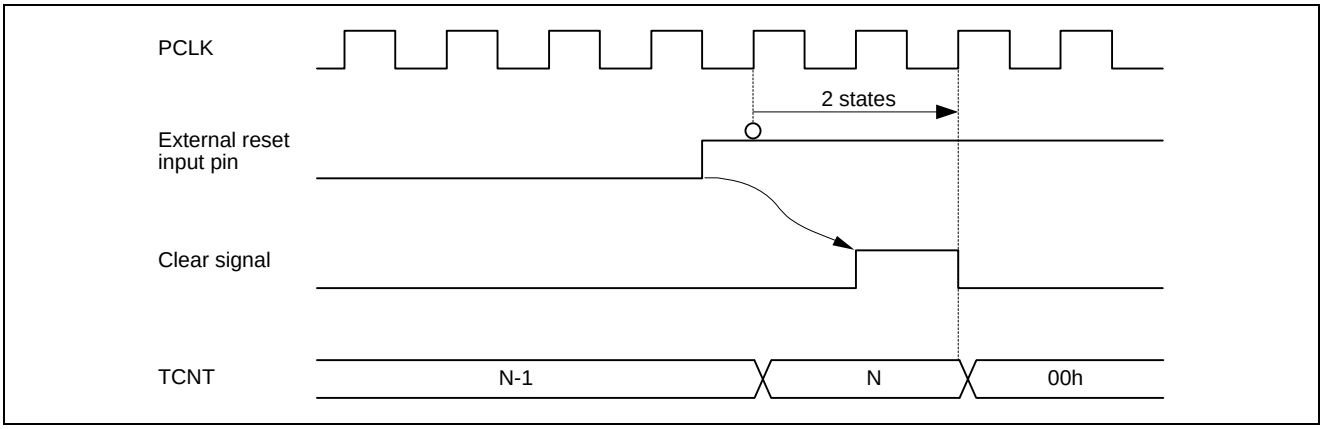


Figure 17.10 Timing of Clearance by External Reset (Rising Edge)

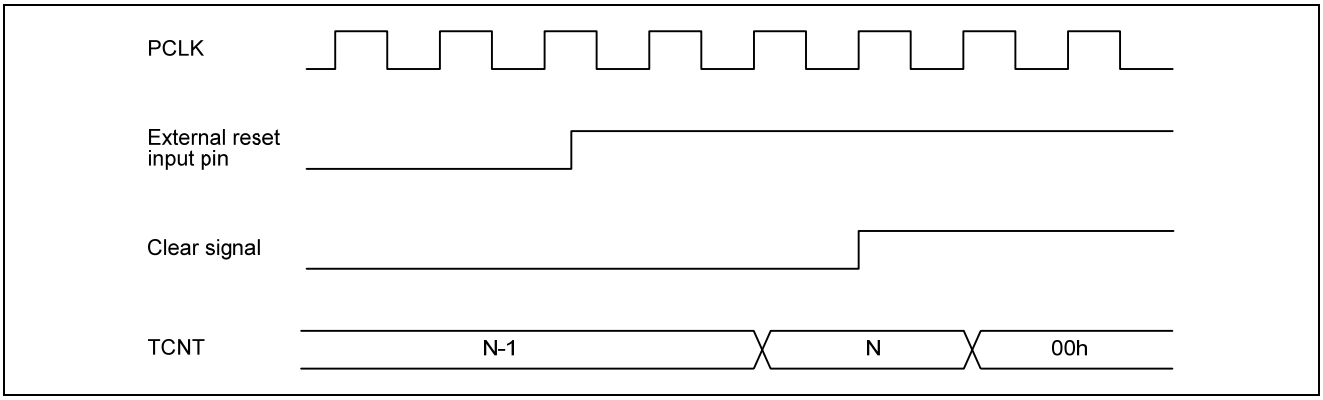


Figure 17.11 Timing of Clearance by External Reset (High Level)

17.4.6 Timing of Overflow Interrupt Flag Setting to 1

The interrupt flag is set to 1 by an overflow signal outputted when TCNT overflows (changes from FFh to 00h).

Figure 17.12 shows the timing of this operation.

For details on the corresponding interrupt vector number, see section 10, Interrupt Control Unit (ICU) and table 17.6, TMR Interrupt Sources.

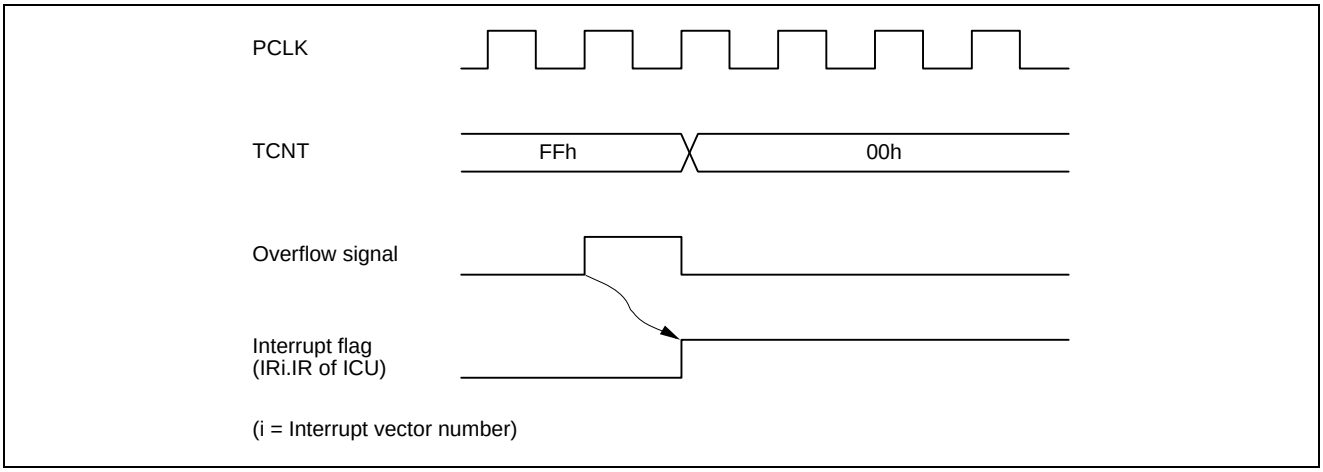


Figure 17.12 Timing of Overflow Interrupt Flag Setting

17.5 Operation with Cascaded Connection

If the CSS[1:0] bits in either TMR0.TCCR or TMR1.TCCR are set to 11b, the TMR of the two channels are cascaded. With this configuration, a single 16-bit timer could be used (16-bit count mode) or compare matches of TMR0 could be counted by TMR1 (compare match count mode).

This section describes unit 0. The operation of unit 1 with cascaded connection is the same as unit 0.

17.5.1 16-Bit Count Mode

When the TMR0.TCCR.CSS[1:0] bits are set to 11b, the timer functions as a single 16-bit timer with TMR0 occupying the upper 8 bits and TMR1 occupying the lower 8 bits. Only in this mode, registers whose Access Size column in table 17.3 is 8 or 16 can be accessed in 16-bit units.

(1) Counter Clear Specification

- The settings of the TMR0.TCR.CCLR[1:0] bits become effective for the 16-bit counter. If the TMR0.TCR.CCLR[1:0] bits have been set for counter clear at compare match, the 16-bit counter (TMR0.TCNT and TMR1.TCNT together) is cleared when a 16-bit compare match event occurs. The 16-bit counter (TMR0.TCNT and TMR1.TCNT together) is cleared even if counter clear by the TMRI0 pin has been set.
- The settings of the TMR1.TCR.CCLR[1:0] bits are ignored.

(2) Pin Output

- Control of output from the TMO0 pin by the TMR0.TCSR.OSA[1:0] and OSB[1:0] bits is in accordance with the 16-bit compare match conditions.
- Control of output from the TMO1 pin by the TMR1.TCSR.OSA[1:0] and OSB[1:0] bits is in accordance with the lower 8-bit compare match conditions.

17.5.2 Compare Match Count Mode

When the TMR1.TCCR.CSS[1:0] bits are set to 11b, TMR1.TCNT counts the number of occurrences of compare match A for TMR0. TMR0 and TMR1 are controlled independently. Conditions such as generation of interrupts, output from the TMOn (n = 0, 1) pin, and counter clear are in accordance with the settings for each channel.

17.6 Interrupt Sources

17.6.1 Interrupt Sources and DTC Activation

There are three interrupt sources for TMRn: CMIAm, CMIBm, and OVIm. Their interrupt sources and priorities are listed in table 17.6.

It is also possible to activate the DTC by means of CMIAm and CMIBm interrupts. The DMAC cannot be activated by the interrupt sources for TMRn.

Table 17.6 TMR Interrupt Sources

Name	Interrupt Sources	Interrupt Status Flag*	DTC Activation	Priority
CMIA0	TMR0.TCORA compare match	IR174.IR	Possible	High
CMIB0	TMR0.TCORB compare match	IR175.IR	Possible	
OVI0	TMR0.TCNT overflow	IR176.IR	Not possible	
CMIA1	TMR1.TCORA compare match	IR177.IR	Possible	
CMIB1	TMR1.TCORB compare match	IR178.IR	Possible	
OVI1	TMR1.TCNT overflow	IR179.IR	Not possible	
CMIA2	TMR2.TCORA compare match	IR180.IR	Possible	
CMIB2	TMR2.TCORB compare match	IR181.IR	Possible	
OVI2	TMR2.TCNT overflow	IR182.IR	Not possible	
CMIA3	TMR3.TCORA compare match	IR183.IR	Possible	
CMIB3	TMR3.TCORB compare match	IR184.IR	Possible	
OVI3	TMR3.TCNT overflow	IR185.IR	Not possible	Low

Note: * For details on the interrupt status flag, see section 10, Interrupt Control Unit (ICU).

17.6.2 A/D Converter Activation

The A/D converter can be activated by a compare match A for TMR0 or TMR2.

If the TMRn.TCSR.ADTE bit (n = 0, 2) is set to 1 (A/D converter start requests by compare match A are enabled), a request to start A/D conversion is sent to the A/D converter by the occurrence of a compare match A. If the 8-bit timer conversion start trigger has been selected on the A/D converter side at this time, A/D conversion is started.

For the corresponding A/D converter units, see section 23, A/D Converter.

17.7 Usage Notes

17.7.1 Module Stop State Setting

Operation of the TMR can be disabled or enabled by using the module-stop control registers. The initial setting is for halting of TMR operation. Register access becomes possible after release from the module-stop state. For details, see section 8, Power-Down Modes.

17.7.2 Notes on Setting Cycle

If the compare match is selected for counter clear, TCNT is cleared at the last state in the cycle in which the value of TCNT matches with that of TCORA or TCORB. TCNT updates the counter value at this last state. Therefore, the counter frequency is obtained by the following formula (f: Counter frequency, ϕ: Operating frequency, N: TCORA and TCORB register setting value).

$$f = \phi / (N + 1)$$

17.7.3 Conflict between TCNT Write and Counter Clear

If a counter clear signal is generated concurrently with CPU write to TCNT, the clear takes priority and the write is not performed as shown in figure 17.13.

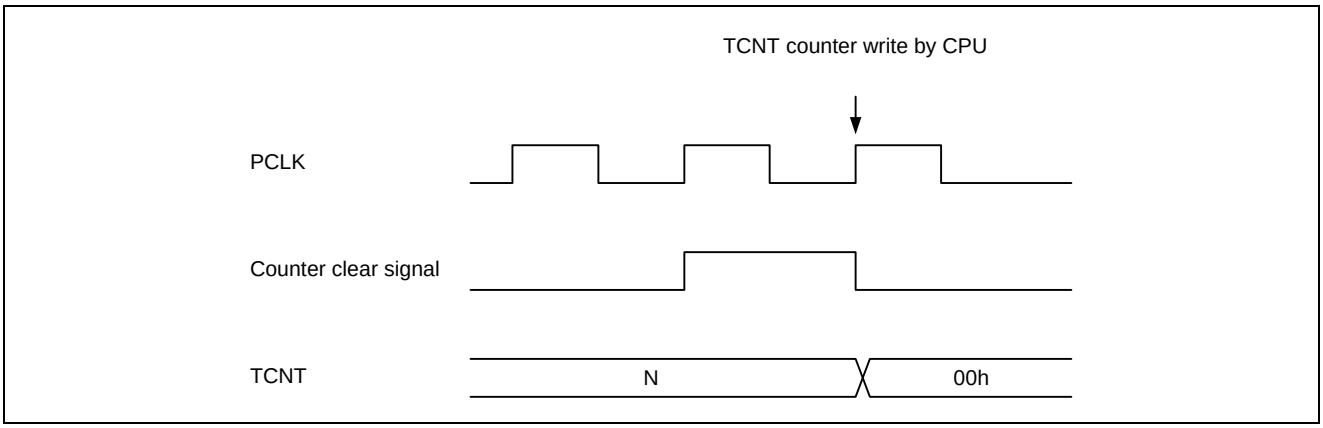


Figure 17.13 Conflict between TCNT Write and Counter Clear

17.7.4 Conflict between TCNT Write and Increment

Even if a counting-up signal is generated concurrently with CPU write to TCNT, the counting-up is not performed and the write takes priority as shown in figure 17.14.

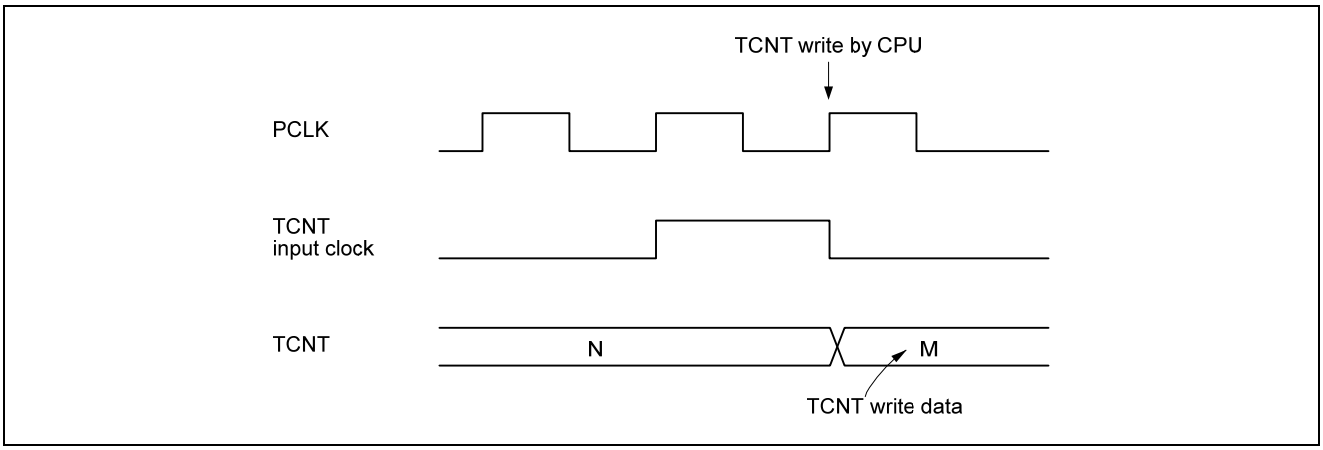


Figure 17.14 Conflict between TCNT Write and Increment

17.7.5 Conflict between TCORA or TCORB Write and Compare Match

Even if a compare match signal is generated simultaneously with CPU write to TCORA or TCORB, the write takes priority and the compare match signal is not set as shown in figure 17.15.

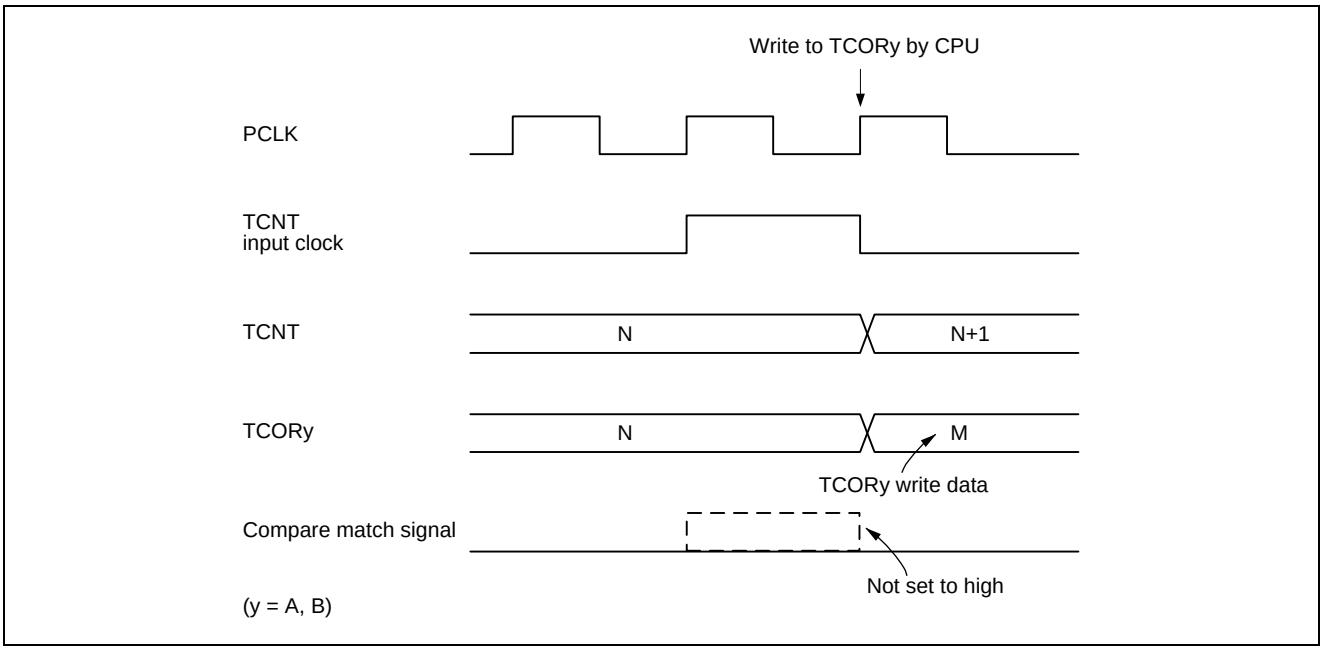


Figure 17.15 Conflict between TCORA or TCORB Write and Compare Match

17.7.6 Conflict between Compare Matches A and B

If compare match events A and B occur at the same time, the 8-bit timer operates in accordance with the priorities for the output statuses set for compare match A and compare match B, as shown in table 17.7.

Table 17.7 Timer Output Priorities

Output Setting	Priority
Toggle output	High
High-output	↑
Low-output	
No change	Low

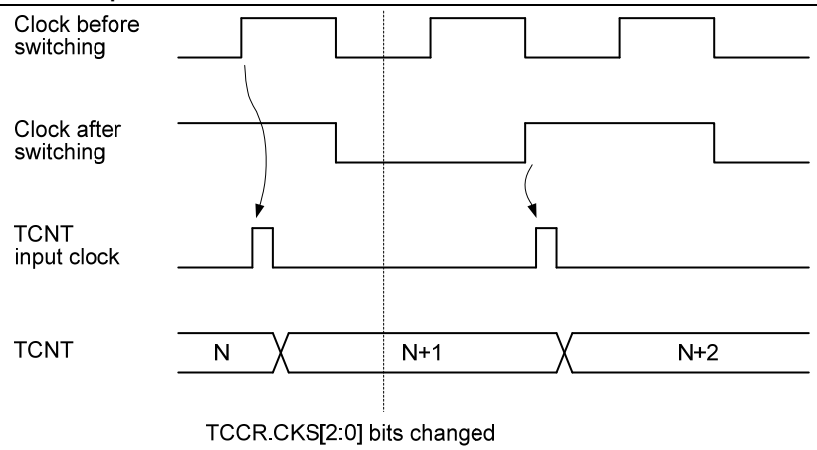
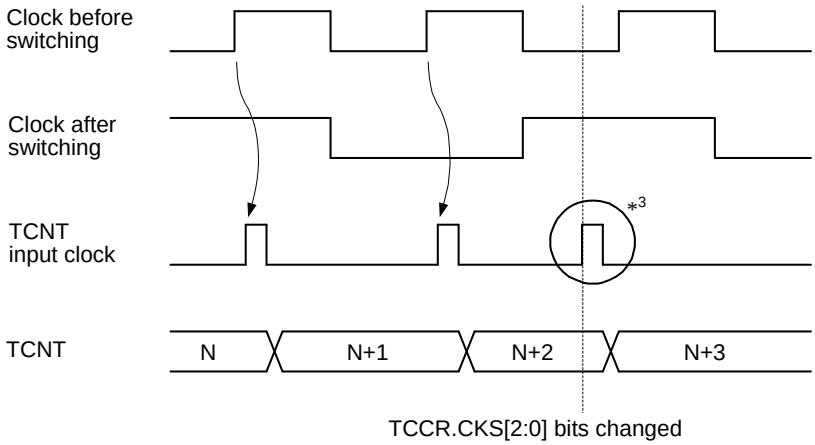
17.7.7 Switching of Internal Clocks and TCNT Operation

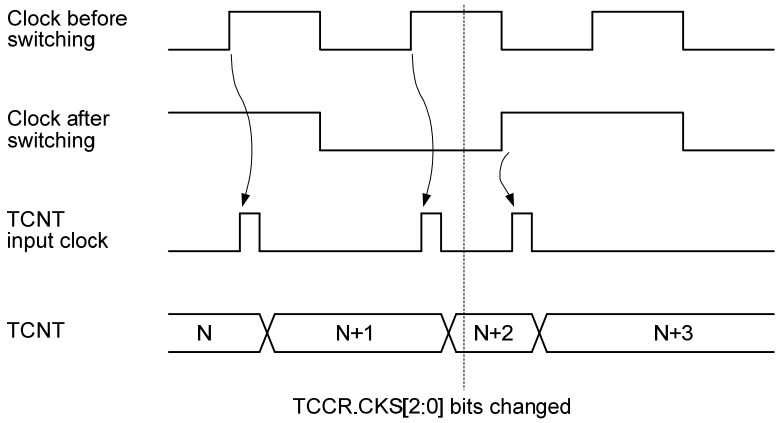
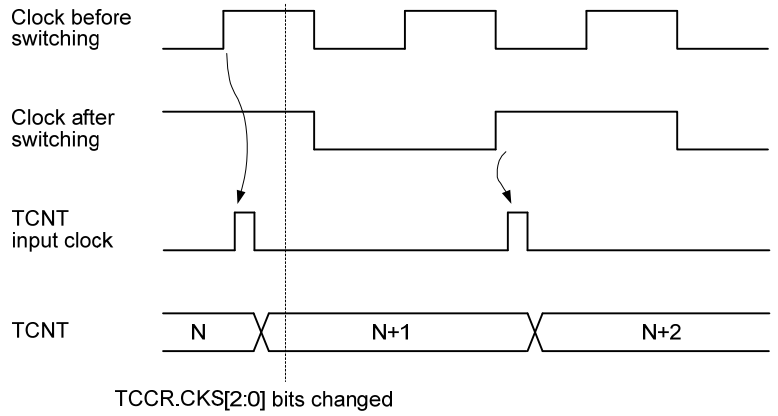
TCNT may be incremented erroneously depending on when the internal clock is switched. Table 17.8 shows the relationship between the timing at which the internal clock is switched (by writing to the TCCR.CKS[2:0] bits) and the operation of TCNT.

When TCNT clock is generated from an internal clock, the rising edge of the internal clock pulse are always monitored. If the signal levels of the clocks before and after switching change from low to high as shown in No. 2 in table 17.8, the change is considered as an edge. Therefore, a TCNT clock pulse is generated and TCNT is incremented.

The erroneous increment of TCNT can also happen when switching between internal and external clocks.

Table 17.8 Switching of Internal Clocks and TCNT Operation

Timing to Change the TCCR.CKS[2:0] Bits	TCNT Clock Operation
Switching from low to low*1	
Switching from low to high*2	

Timing to Change the TCCR.CKS[2:0] Bits	TCNT Clock Operation
Switching from high to low*4	
Switching from high to high	

Notes: 1. Includes switching from low to stop, and from stop to low.

2. Includes switching from stop to high.

3. Generated because the change of the signal levels is considered as an edge; TCNT is incremented.

4. Includes switching from high to stop.

17.7.8 Clock Source Setting with Cascaded Connection

If 16-bit count mode and compare match count mode are specified at the same time, input clocks for TMR0.TCNT and TMR1.TCNT (TMR2.TCNT and TMR3.TCNT) are not generated, and the counter stops. Do not specify 16-bit count mode and compare match count mode simultaneously.

18. Compare Match Timer (CMT)

The RX610 Group has two on-chip compare match timer (CMT) units (unit 0 and unit 1) each consisting of a two-channel 16-bit timer (i.e., a total of four channels). The CMT has a 16-bit counter, and can generate interrupts at set intervals.

18.1 Overview

Table 18.1 lists the specifications for the CMT.

Figure 18.1 shows a block diagram of the CMT (unit 0). A two-channel CMT constitutes a unit. Unit 0 and unit 1 are the same in terms of specifications.

Table 18.1 Specifications of CMT

Item	Description
Count clock	• Four internal clocks One clock from PCLK/8, PCLK/32, PCLK/128, and PCLK/512 can be selected individually for each channel.
Interrupt	A compare match interrupt can be requested individually for each channel.
Power-down function	Each unit can be placed in a module stop state.

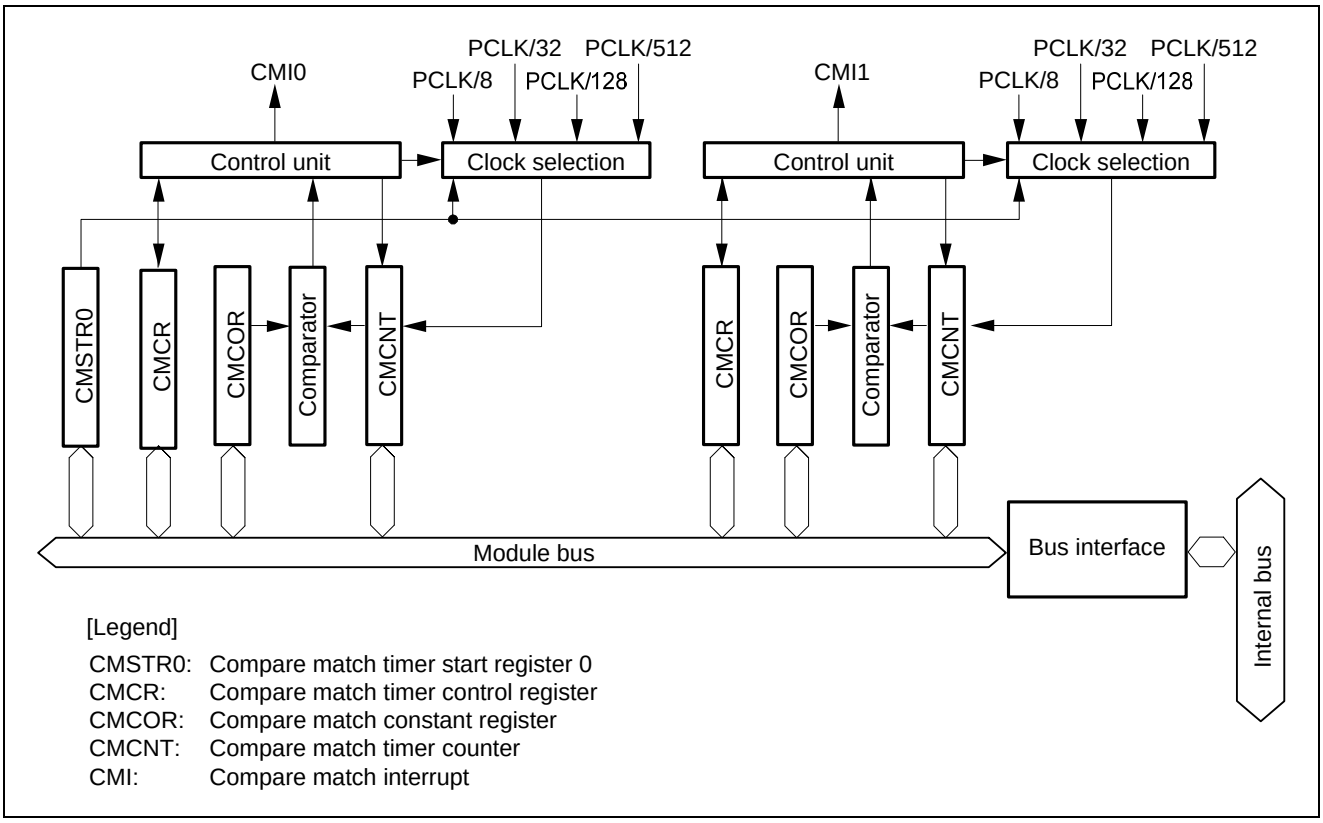


Figure 18.1 Block Diagram of CMT (Unit 0)

18.2 Register Descriptions

Table 18.2 lists the registers of the CMT.

Table 18.2 List of CMT Registers

Unit	Channel	Register Name	Symbol	Value after Reset	Address	Access Size
Unit 0	Common	Compare match timer start register 0	CMSTR0	0000h	0008 8000h	16
	CMT0	Compare match timer control register	CMCR	00x0h	0008 8002h	16
		Compare match timer counter	CMCNT	0000h	0008 8004h	16
		Compare match timer constant register	CMCOR	FFFFh	0008 8006h	16
	CMT1	Compare match timer control register	CMCR	00x0h	0008 8008h	16
		Compare match timer counter	CMCNT	0000h	0008 800Ah	16
		Compare match timer constant register	CMCOR	FFFFh	0008 800Ch	16
Unit 1	Common	Compare match timer start register 1	CMSTR1	0000h	0008 8010h	16
	CMT2	Compare match timer control register	CMCR	00x0h	0008 8012h	16
		Compare match timer counter	CMCNT	0000h	0008 8014h	16
		Compare match timer constant register	CMCOR	FFFFh	0008 8016h	16
	CMT3	Compare match timer control register	CMCR	00x0h	0008 8018h	16
		Compare match timer counter	CMCNT	0000h	0008 801Ah	16
		Compare match timer constant register	CMCOR	FFFFh	0008 801Ch	16

18.2.1 Compare Match Timer Start Register 0 (CMSTR0)

Address: 0008 8000h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	STR1	STR0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	STR0	Count Start 0	0: CMT0.CMCNT count is stopped 1: CMT0.CMCNT count is started	R/W
b1	STR1	Count Start 1	0: CMT1.CMCNT count is stopped 1: CMT1.CMCNT count is started	R/W
b15 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CMSTR0 selects whether the CMT0.CMCNT or CMT1.CMCNT counter operates or is stopped.

STR0 Bit (Count Start 0)

The STR0 bit specifies whether CMT0.CMCNT operates or is stopped.

STR1 Bit (Count Start 1)

The STR1 bit specifies whether CMT1.CMCNT operates or is stopped.

18.2.2 Compare Match Timer Start Register 1 (CMSTR1)

Address: 0008 8010h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	STR3	STR2
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	STR2	Count Start 2	0: CMT2.CMCNT count is stopped 1: CMT2.CMCNT count is started	R/W
b1	STR3	Count Start 3	0: CMT3.CMCNT count is stopped 1: CMT3.CMCNT count is started	R/W
b15 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CMSTR1 selects whether the CMT2.CMCNT or CMT3.CMCNT counter operates or is stopped.

STR2 Bit (Count Start 2)

The STR2 bit specifies whether CMT2.CMCNT operates or is stopped.

STR3 Bit (Count Start 3)

The STR3 bit specifies whether CMT3.CMCNT operates or is stopped.

18.2.3 Compare Match Timer Control Register (CMCR)

Addresses: CMT0.CMCR 0008 8002h, CMT1.CMCR 0008 8008h,
CMT2.CMCR 0008 8012h, CMT3.CMCR 0008 8018h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	CMIE	—	—	—	—	CKS[1:0]	
Value after reset:	x	0	0	0	0	0	0	0

[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	CKS[1:0]	Clock Select	b1 b0 0 0: PCLK/8 0 1: PCLK/32 1 0: PCLK/128 1 1: PCLK/512	R/W
b5 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b6	CMIE	Compare Match Interrupt Enable	0: Compare match interrupt (CMIm) disabled 1: Compare match interrupt (CMIm) enabled	R/W
b7	—	Reserved	This bit is always read as an undefined value. The write value should always be 1.	R/W
b15 to b8	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

CMCR sets the clock used for counting up.

CKS[1:0] Bits (Clock Select)

These bits select the clock to be input to CMCNT from four internal clocks obtained by dividing the peripheral clock (PCLK).

When the STRj (j = 0 to 3) bit in CMSTRy (y = 0 or 1) is set to 1, CMCNT starts counting up on the clock selected with bits CKS[1:0].

CMIE Bit (Compare Match Interrupt Enable)

The CMIE bit enables or disables compare match interrupt (CMIm) (m = 0 to 3) generation when CMCNT and CMCOR values match.

18.2.4 Compare Match Counter (CMCNT)

Addresses: CMT0.CMCNT 0008 8004h, CMT1.CMCNT 0008 800Ah,
CMT2.CMCNT 0008 8014h, CMT3.CMCNT 0008 801Ah

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CMCNT is a readable/writable up-counter to generate interrupt requests.

When an internal clock is selected by bits CKS[1:0] in CMCR and the STRj (j = 0 to 3) bit in CMSTRy (y = 0 or 1) is set to 1, CMCNT starts counting up using the selected clock.

When the value in CMCNT and the value in CMCOR match, CMCNT is cleared to 0000h. At the same time, a compare match interrupt (CMIm) (m = 0 to 3) is generated.

18.2.5 Compare Match Constant Register (CMCOR)

Addresses: CMT0.CMCOR 0008 8006h, CMT1.CMCOR 0008 800Ch,
CMT2.CMCOR 0008 8016h, CMT3.CMCOR 0008 801Ch

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

CMCOR sets the interval up to a compare match with CMCNT.

18.3 Operation

18.3.1 Periodic Count Operation

When an internal clock is selected by bits CKS[1:0] in CMCR and the STRj (j = 0 to 3) bit in CMSTRy (y = 0 or 1) is set to 1, CMCNT starts counting up using the selected clock.

When the value in CMCNT and the value in CMCOR match, CMCNT is cleared to 0000h. At the same time, a compare match interrupt (CMIm) (m = 0 to 3) is generated. CMCNT then starts counting up again from 0000h. Figure 18.2 shows the operation of the CMCNT counter.

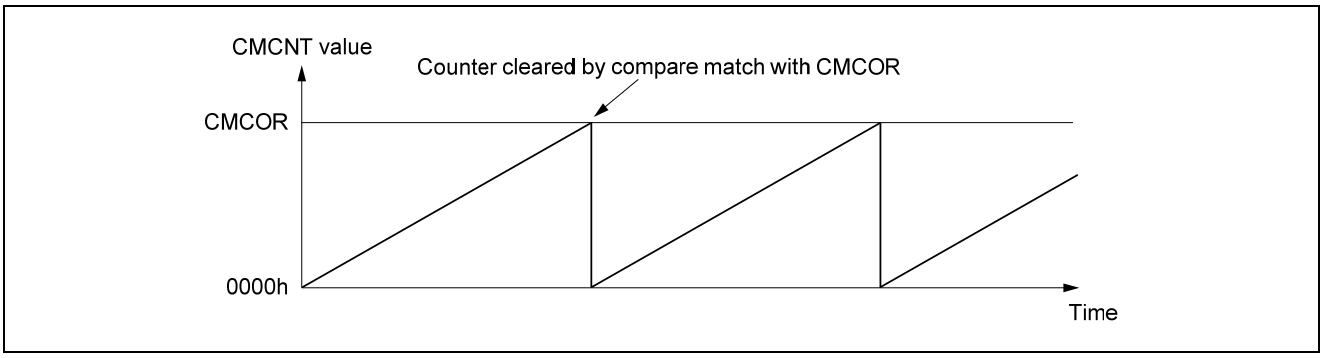


Figure 18.2 CMCNT Counter Operation

18.3.2 CMCNT Count Timing

One of four internal clocks (PCLK/8, PCLK/32, PCLK/128, and PCLK/512) obtained by dividing the peripheral clock (PCLK) can be selected with the CKS[1:0] bits in CMCSR. Figure 18.3 shows the timing of CMCNT.

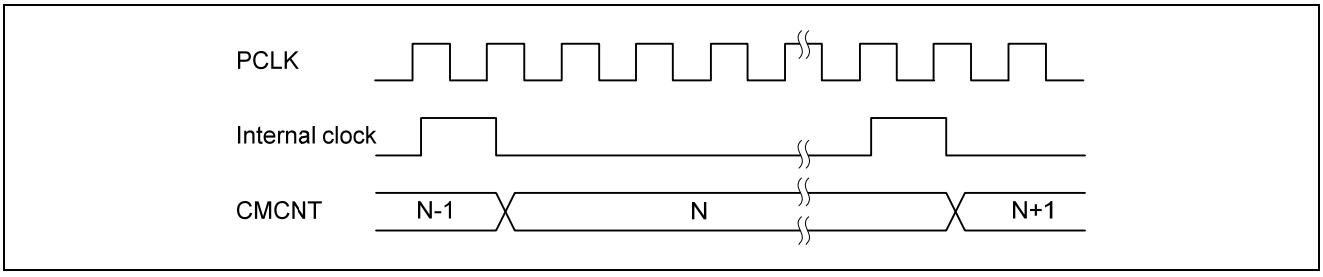


Figure 18.3 CMCNT Count Timing

18.4 Interrupts

18.4.1 Interrupt Sources

The CMT has channels and each of them to which a different vector address is allocated has a compare match interrupt (CMIm) (m = 0 to 3). When a compare match interrupt occurs, the corresponding interrupt request is output.

When the interrupt is used to activate a CPU interrupt, the priority of channels can be changed by the interrupt control unit settings. For details, see section 10, Interrupt Control Unit (ICU).

Table 18.3 CMT Interrupt Sources

Name	Interrupt Sources	Interrupt Status Flag	DTC Activation	DMAC Activation
CMI0	Compare match between CMT0.CMCNT and CMT0.CMCOR	IR028.IR	Possible	Possible
CMI1	Compare match between CMT1.CMCNT and CMT1.CMCOR	IR029.IR	Possible	Possible
CMI2	Compare match between CMT2.CMCNT and CMT2.CMCOR	IR030.IR	Possible	Possible
CMI3	Compare match between CMT3.CMCNT and CMT3.CMCOR	IR031.IR	Possible	Possible

18.4.2 Timing of Compare Match Interrupt Generation

When CMCNT and CMCOR match, a compare match interrupt (CMIm) (m = 0 to 3) is generated.

A compare match signal is generated at the last state in which the values match (the timing when the CMCNT counter updates the matched count value). That is, after a match between CMCOR and CMCNT, the compare match signal is not generated until the next CMCNT counter clock input.

Figure 18.4 shows the timing of interrupt flag setting to 1.

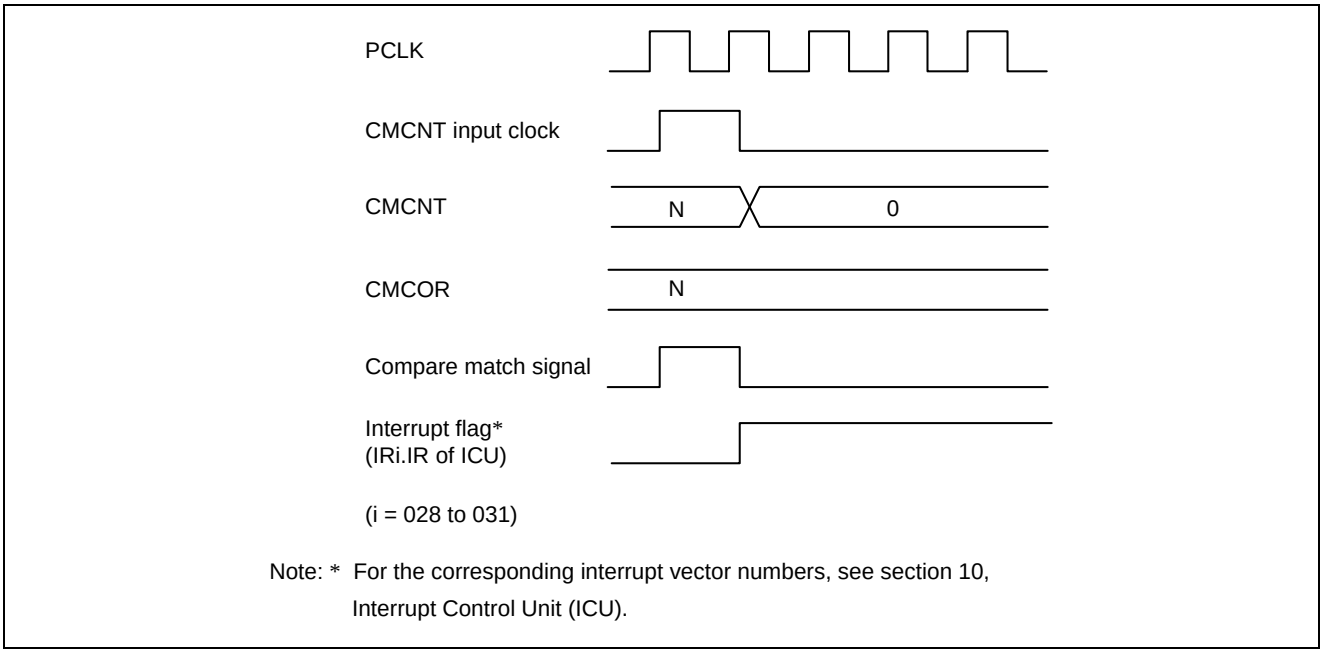


Figure 18.4 Timing of Compare Match Interrupt Flag Setting to 1

18.5 Usage Notes

18.5.1 Setting the Module Stop Function

The CMT can be enabled or disabled using the module stop control register. The CMT is disabled by default. The registers can be accessed by canceling the module stop state. For details, see section 8, Low Power Consumption.

18.5.2 Conflict between Write and Compare-Match Processes of CMCNT

When the compare match signal is generated while writing to CMCNT, clearing CMCNT has priority over writing to it. In this case, CMCNT is not written to. Figure 18.5 shows the timing to clear the CMCNT counter.

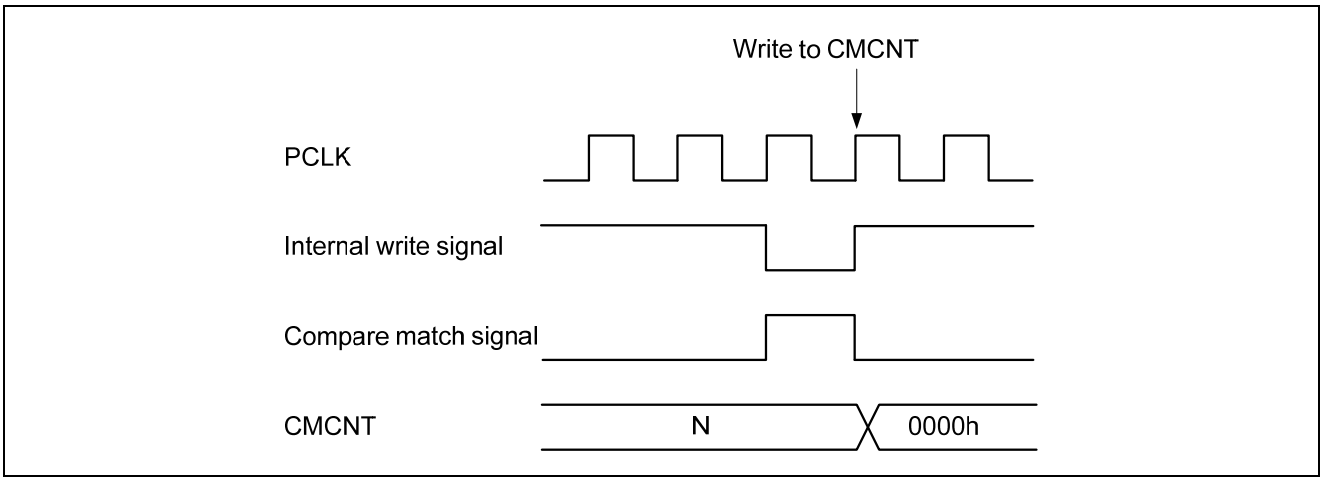


Figure 18.5 Conflict between Write and Compare Match Processes of CMCNT

18.5.3 Conflict between Write and Count-Up Processes of CMCNT

Even when the count-up occurs while writing to CMCNT, the writing has priority over the count-up. In this case, the count-up is not performed. Figure 18.6 shows the timing to write the CMCNT counter.

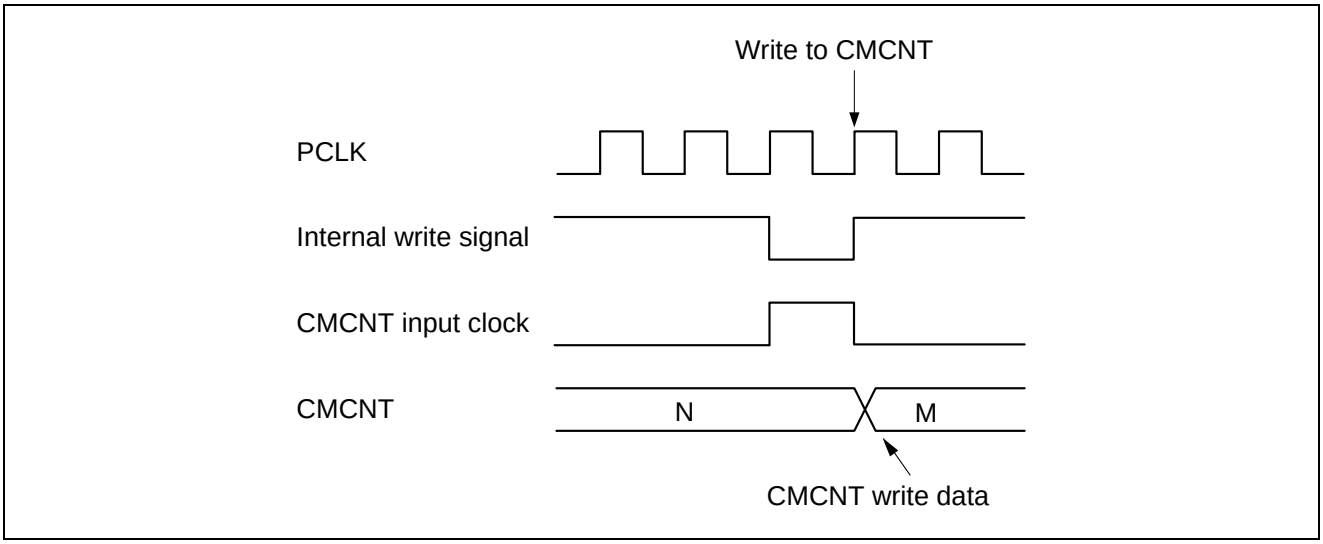


Figure 18.6 Conflict between Write and Count-Up Processes of CMCNT

18.5.4 Notes on Rewriting Compare Match Timer Control Register (CMCR)

When rewriting to the CMCR competes with generation of the compare match, writing to the CMCR is ignored. Therefore, it is necessary to check if data is written correctly by reading the CMCR after writing to the CMCR. If the data is not written correctly, once again the writing should be carried out to the CMCR. Because the read value of bit 7 in CMCR is not defined, care should to be taken while comparing it with the written data.

18.5.5 Notes on Compare Match Timer Counter (CMCNT) and Compare Match Constant Register (CMCOR)

Do not set the CMCNT and the CMCOR to the same value while the count operation of the CMCNT is stopped. If the CMCNT and the CMCOR are set to the same value with the CMCNT count operation halted, the compare match occurs irrespective of halted count operation. At this time, when the compare match interrupt enable bit (the CMIE bit in CMCR) has been enabled (set to 1), the compare match interrupt occurs. Despite of disabling/enabling of the compare match interrupt, if the compare match occurs due to matching of the value with the value of the CMCOR, the CMCNT is automatically cleared to 0000h.

19. Watchdog Timer (WDT)

The watchdog timer (WDT) is an 8-bit timer that outputs an overflow signal (WDTOVF#) if a system crash prevents the CPU from writing to the timer counter, thus allowing it to overflow. At the same time, the WDT can also generate an internal reset signal.

When this watchdog function is not needed, the WDT can be used as an interval timer. In interval timer operation, an interval timer interrupt is generated each time the counter overflows.

19.1 Overview

Table 19.1 lists the specifications of the WDT.

Figure 19.1 shows a block diagram of the WDT.

Table 19.1 Specifications of WDT

Item	Specifications
Count clocks	PCLK/4, PCLK/64, PCLK/128, PCLK/512, PCLK/2048, PCLK/8192, PCLK/32768, and PCLK/131072
Number of channels	8 bits x 1 channel
Count clear	Write to TCNT
Operating modes	Switchable between watchdog timer mode and interval timer mode
Watchdog timer mode	Outputs a WDTOVF# signal when the counter overflows. Selectable whether or not to internally reset the LSI at the same time.
Interval timer mode	Generates an interval timer interrupt (WOVI) when the counter overflows.

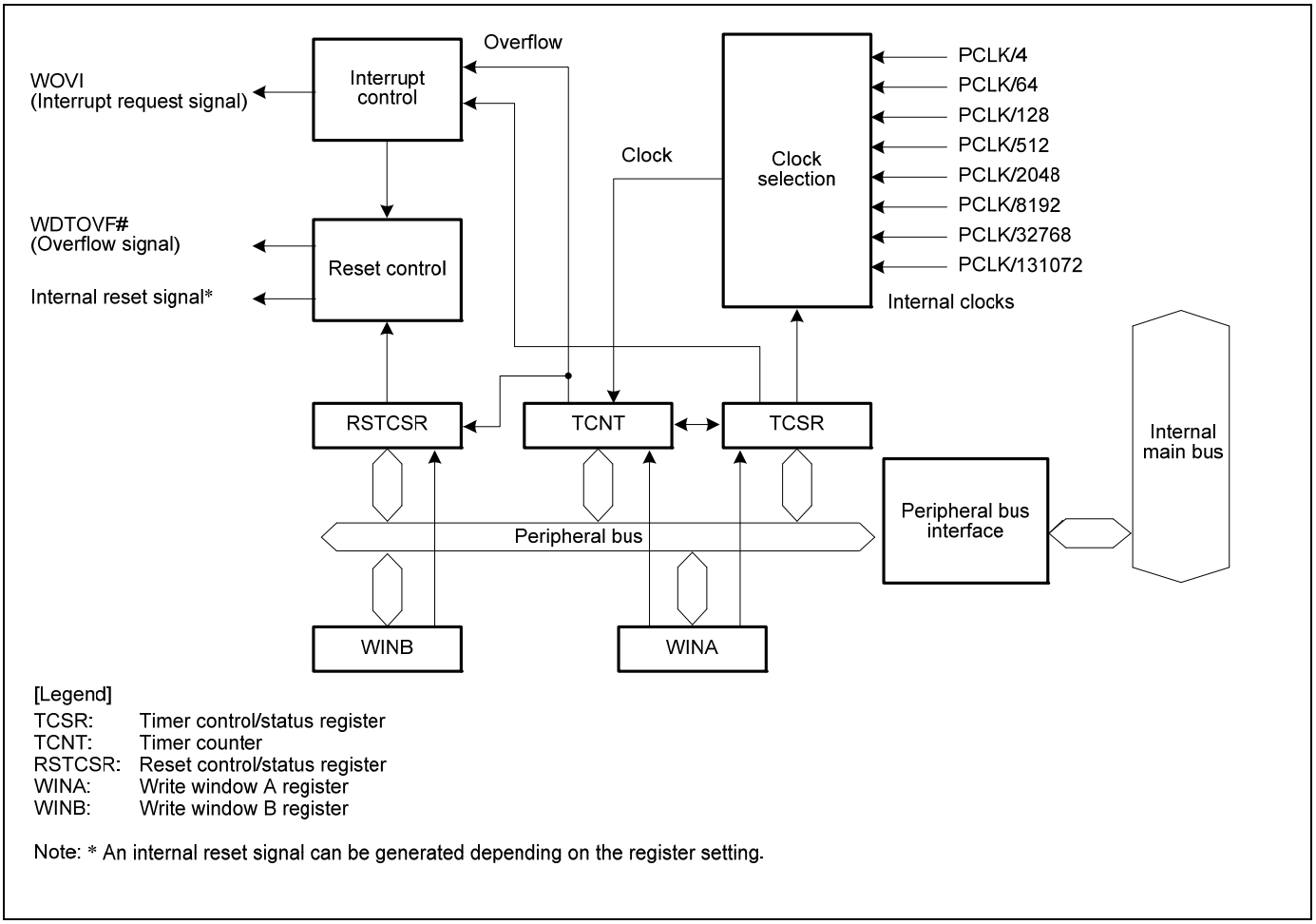


Figure 19.1 Block Diagram of WDT

Table 19.2 shows the input/output pin used for the WDT.

Table 19.2 Pin Configuration

Pin Name	I/O	Description
WDTOVF#	Output	Outputs a counter overflow signal in watchdog timer mode.

19.2 Register Descriptions

Table 19.3 lists the registers of the WDT.

Table 19.3 WDT Registers

Register Name	Symbol	Value after Reset	Address	Access Size
Timer control/status register	TCSR	x8h	0008 8028h*1	8
Timer counter	TCNT	00h	0008 8029h*1	8
Reset control/status register	RSTCSR	1Fh	0008 802Bh*1	8
Write window A register	WINA	—	0008 8028h*2	16
Write window B register	WINB	—	0008 802Ah*2	16

Notes: 1. Read-only register
2. Write-only register

19.2.1 Timer Counter (TCNT)

Address: 0008 8029h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

TCNT is an 8-bit up-counter for the internal clock.

TCNT is initialized to 00h when the TME bit in TCSR is set to 0.

To read this counter, use 8-bit access.

To write to this counter, write data to WINA in 16 bits.

For details, see section 19.5.1, Notes on Register Access.

19.2.2 Timer Control/Status Register (TCSR)

Address: 0008 8028h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	TMS	TME	—	—	CKS[2:0]		
Value after reset:	x	0	0	1	1	0	0	0

[Legend] x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	CKS[2:0]	Clock Select	b2 b0 0 0 0: PCLK/4 (cycle: 20.4 μs) 0 0 1: PCLK/64 (cycle: 326.4 μs) 0 1 0: PCLK/128 (cycle: 652.8 μs) 0 1 1: PCLK/512 (cycle: 2.6 ms) 1 0 0: PCLK/2048 (cycle: 10.4 ms) 1 0 1: PCLK/8192 (cycle: 41.8 ms) 1 1 0: PCLK/32768 (cycle: 167.1 ms) 1 1 1: PCLK/131072 (cycle: 668.5 ms) Note: The overflow cycle for PCLK = 50 MHz is indicated in parentheses.	R/W
b4, b3	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b5	TME	Timer Enable	0: TCNT stops counting and is initialized to 00h. 1: TCNT starts counting.	R/W
b6	TMS	Timer Mode Select	0: Interval timer mode When TCNT overflows, an interval timer interrupt (WOVI) is requested. 1: Watchdog timer mode When TCNT overflows, WDTOVF# is output.	R/W
b7	—	Reserved	This bit is always read as an undefined value. The write value should always be 1.	R/W

TCSR selects the clock source to be input to TCNT, and the timer mode.

To read this register, use 8-bit access.

To write to this register, write data to WINA in 16 bits.

For details, see section 19.5.1, Notes on Register Access.

CKS[2:0] Bits (Clock Select)

These bits select the clock source to be input to TCNT.

TME Bit (Timer Enable)

Selects whether TCNT starts or stops counting. When this bit is set to 1, TCNT starts counting. When this bit is cleared to 0, TCNT stops counting and is initialized to 00h.

TMS Bit (Timer Select)

Selects whether the WDT is used as a watchdog timer or interval timer.

19.2.3 Reset Control/Status Register (RSTCSR)

Address: 0008 802Bh

	b7	b6	b5	b4	b3	b2	b1	b0
	WOVF	RSTE	–	–	–	–	–	–
Value after reset:	0	0	0	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W
b5	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6	RSTE	Reset Enable	0: The LSI is not reset internally when TCNT overflows in watchdog timer mode. (TCNT and TCSR of the WDT are reset.) 1: The LSI is internally reset when TCNT overflows in watchdog timer mode.	R/W
b7	WOVF	Watchdog Timer Overflow Flag	0: TCNT has not overflowed in watchdog timer mode. 1: TCNT has overflowed in watchdog timer mode.	R/(W)*

Note: * Only 0 can be written to this bit.

RSTCSR controls the generation of the internal reset signal when TCNT overflows, and selects the type of internal reset signal.

RSTCSR is initialized to 1Fh by a reset signal from the RES# pin or a deep software standby reset, but not by the WDT internal reset signal caused by a WDT overflow.

To read this register, use 8-bit access.

To write to this register, write data to WINB in 16 bits.

For details, see section 19.5.1, Notes on Register Access.

RSTE Bit (Reset Enable)

Selects whether or not this LSI is internally reset when TCNT overflows in watchdog timer mode.

WOVF Flag (Watchdog Timer Overflow Flag)

Indicates that TCNT overflows in watchdog timer mode. This bit cannot be set to 1 in interval timer mode.

[Setting condition]

- When TCNT overflows (changed form FFh to 00h) in watchdog timer mode

[Clearing condition]

- Reading RSTCSR when WOVF = 1, and then writing 0 to WOVF

19.2.4 Write Window A Register (WINA)

Address: 0008 8028h

b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

WINA is a write-only register for writing to TCNT and TCSR.

The writing method varies between TCNT and TCSR. For details, see section 19.5.1, Notes on Register Access.

To write to this register, use 16-bit access.

19.2.5 Write Window B Register (WINB)

Address: 0008 802Ah

b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

WINB is a write-only register for writing to RSTCSR.

The writing method varies between writing 0 to the WOVF flag in RSTCSR and writing the RSTE bit in RSTCSR. For details, see section 19.5.1, Notes on Register Access. To write to this register, use 16-bit access.

19.3 Operation

19.3.1 Watchdog Timer Mode

To use the WDT in watchdog timer mode, set both the TMS bit and TME bit in TCSR to 1.

During watchdog timer operation, if TCNT overflows without being rewritten because of a system crash or another error, the WDTOVF# signal is output. This ensures that TCNT does not overflow while the system is operating normally. Software must prevent TCNT overflows by rewriting the TCNT value (normally 00h is written) before overflow occurs. This WDTOVF# signal can be used to reset the LSI internally in watchdog timer mode.

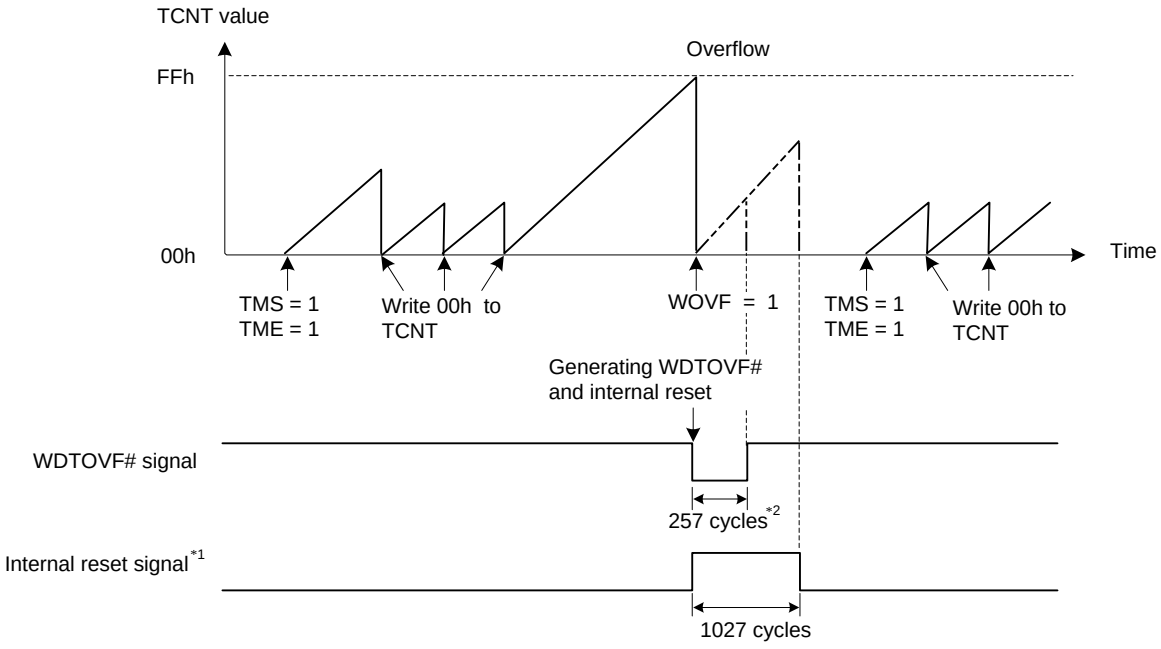
If TCNT overflows when the RSTE bit in RSTCSR is set to 1, a signal that resets this LSI internally is generated as the same time as the WDTOVF# signal. If a reset caused by a signal input to the RES# pin occurs at the same time as a reset caused by a WDT overflow, the RES# pin reset has priority and the WOVF flag in RSTCSR is cleared to 0.

The WDTOVF# signal is output for 257 cycles of PCLK when RSTE = 1, and for 256 cycles of PCLK when RSTE = 0. The internal reset signal is output for 1027 cycles of PCLK.

When RSTE = 1, an internal reset signal is generated. Since the system clock control register (SCKCR) is initialized, the multiplication ratio of PCLK becomes the initial value.

When RSTE = 0, an internal reset signal is not generated. Neither SCKCR nor the multiplication ratio of PCLK is changed.

When TCNT overflows in watchdog timer mode, the WOVF flag is set to 1.



Notes: 1. An internal reset signal is generated if TCNT overflows when the RSTE bit in RSTCSR is set to 1.
2. The WDTOVF# signal is output for 256 cycles when RSTE bit in RSTCSR is set to 0.

Figure 19.2 Operation in Watchdog Timer Mode

19.3.2 Interval Timer Mode

To use the WDT as an interval timer, set the TMS bit to 0 and the TME bit to 1 in TCSR.

When the WDT is used as an interval timer, an interval timer interrupt (WOVI) is generated each time TCNT overflows. Therefore, an interrupt can be generated at intervals.

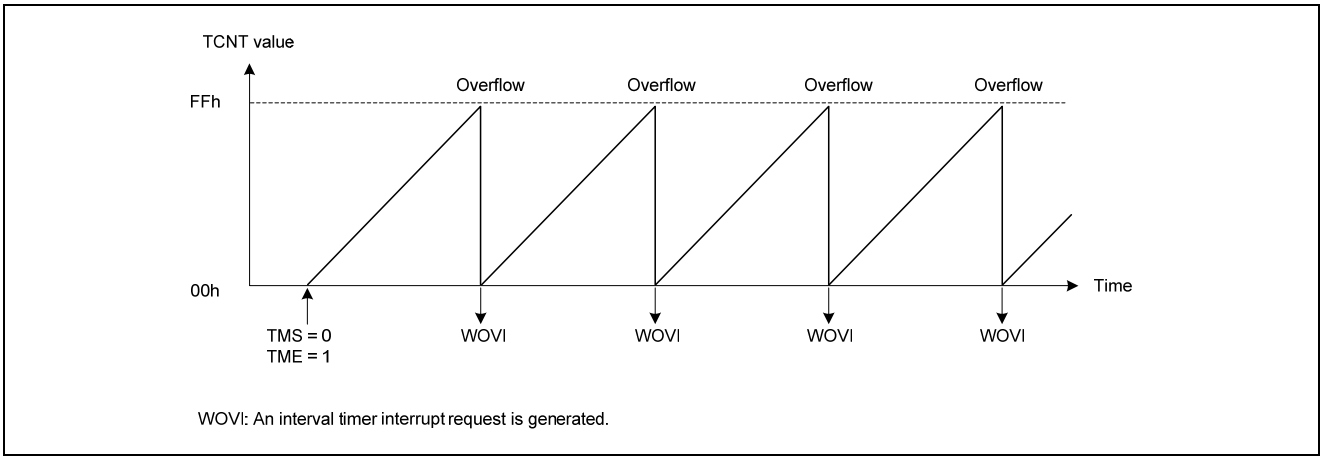


Figure 19.3 Operation in Interval Timer Mode

19.4 Interrupt Source

During interval timer mode operation, a TCNT overflow generates an interval timer interrupt (WOVI). For details, see section 10, Interrupt Control Unit (ICU).

Table 19.4 WDT Interrupt Source

Name	Interrupt Source	Interrupt Status Flag	DTC Activation	DMAC Activation
WOVI	TCNT overflow	IR096.IR	Not possible	Not possible

19.5 Usage Notes

19.5.1 Notes on Register Access

The watchdog timer's TCNT, TCSR, and RSTCSR differ from other registers in being more difficult to write to.

(1) Writing to TCNT Counter, TCSR Register, and RSTCSR Register

When writing to TCNT and TCSR, be sure to use a word transfer instruction to the write window A register (WINA) (00088028h). For writing, TCNT and TCSR are assigned to the same address. Accordingly, perform data transfer as shown in figure 19.4.

To write to TCNT, set 5Ah in the upper byte and data in the lower byte, and perform data transfer to TCNT.

To write to TCSR, set A5h in the upper byte and data in the lower byte, and perform data transfer to TCSR.

When writing to RSTCSR, use a word transfer instruction to the write window B register (WINB) (0008802Ah).

The method of writing 0 to the WOVF flag in RSTCSR differs from that of writing to the RSTE bit in RSTCSR.

To write 0 to the WOVF flag, set A5h in the upper byte and 00h in the lower byte and use 16-bit access, as shown in figure 19.4. This has no effect on the RSTE bit.

To write to the RSTE bit, set A5h in the upper byte and data to be written to RSTCSR in the lower byte and use 16-bit access, as shown in figure 19.4. This has no effect on the WOVF flag.

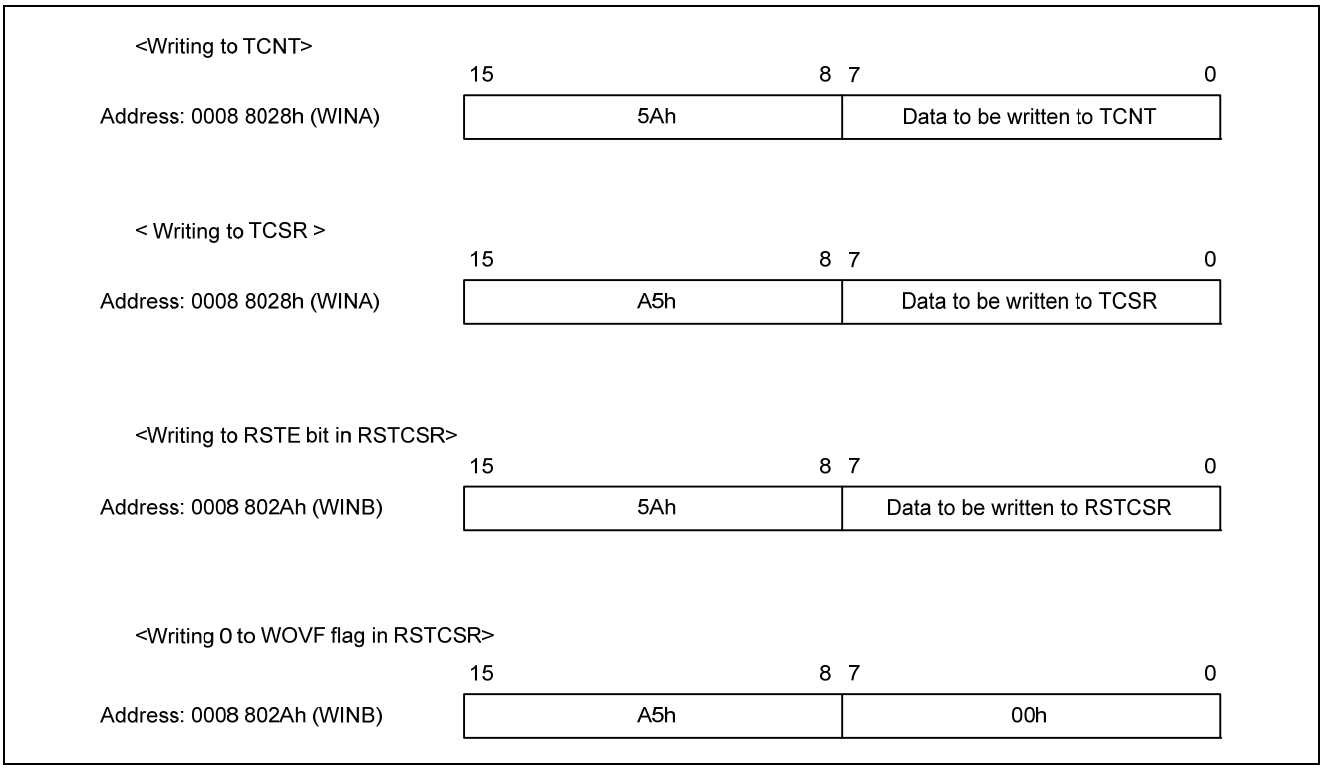


Figure 19.4 Writing to TCNT, TCSR, and RSTCSR

(2) Reading from TCNT Counter, TCSR Register, and RSTCSR Register

These counter and registers can be read from in the same way as other registers.

TCSR is assigned to address 00088028h, TCNT to address 00088029h, and RSTCSR to address 0008802Ah. For reading, use 8-bit access.

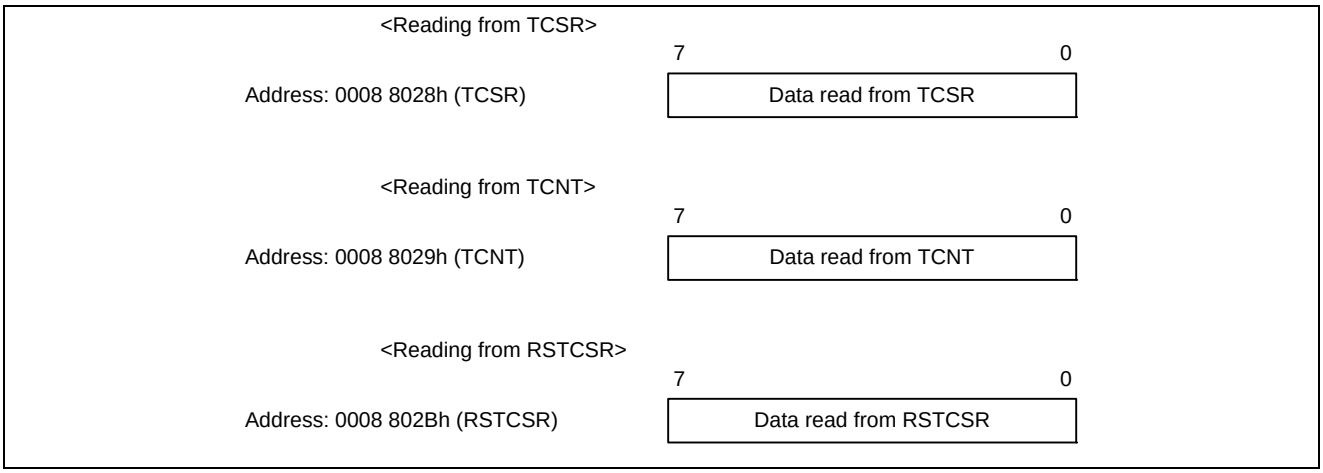


Figure 19.5 Reading from TCNT, TCSR, and RSTCSR

19.5.2 Conflict between Timer Counter (TCNT) Write and Increment

If a TCNT clock pulse is generated during a TCNT write cycle, the write takes priority and the timer counter is not incremented. Figure 19.6 shows this operation.

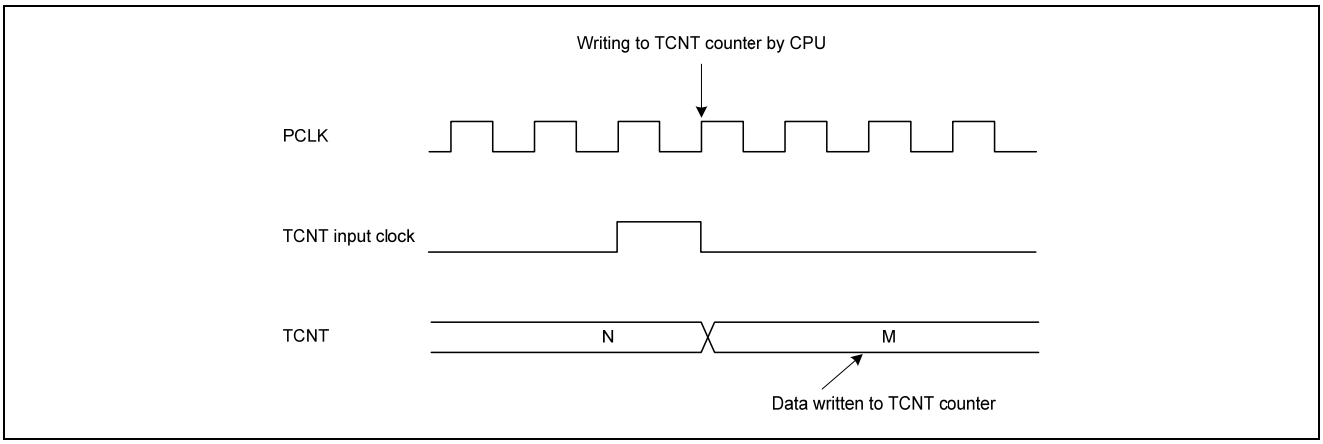


Figure 19.6 Conflict between TCNT Write and Increment

19.5.3 Changing Values of Bits CKS[2:0]

If bits CKS[2:0] bits in TCSR are written to while the watchdog timer is operating, errors could occur in the incrementation. The watchdog timer must be stopped (by clearing the TME bit in TCSR to 0) before the values of CKS[2:0] bits in TCSR are changed.

19.5.4 Switching between Watchdog Timer Mode and Interval Timer Mode

If the timer mode is switched from watchdog timer mode to interval timer mode while the watchdog timer is operating, errors could occur in the operation. The watchdog timer must be stopped (by clearing the TME bit in TCSR to 0) before switching the timer mode.

19.5.5 Internal Reset in Watchdog Timer Mode

This LSI is not reset internally if TCNT overflows while the RSTE bit in RSTCSR is cleared to 0 during watchdog time mode operation, but TCNT and the TCSR of the watchdog timer are reset.

TCNT, TCSR, and RSTCSR cannot be written to while the WDTOVF# signal is low. Also note that a read of the WOVF flag in RSTCSR is not recognized during this period. To clear the WOVF flag, therefore, read RSTCSR after the WDTOVF# signal goes high, then write 0 to the WOVF flag.

19.5.6 System Reset by WDTOVF# Signal

If the WDTOVF# signal is input to the RES# pin, this LSI will not be initialized correctly. Make sure that the WDTOVF# signal is not input logically to the RES# pin. To reset the entire system by means of the WDTOVF# signal, use a circuit like that shown in figure 19.7.

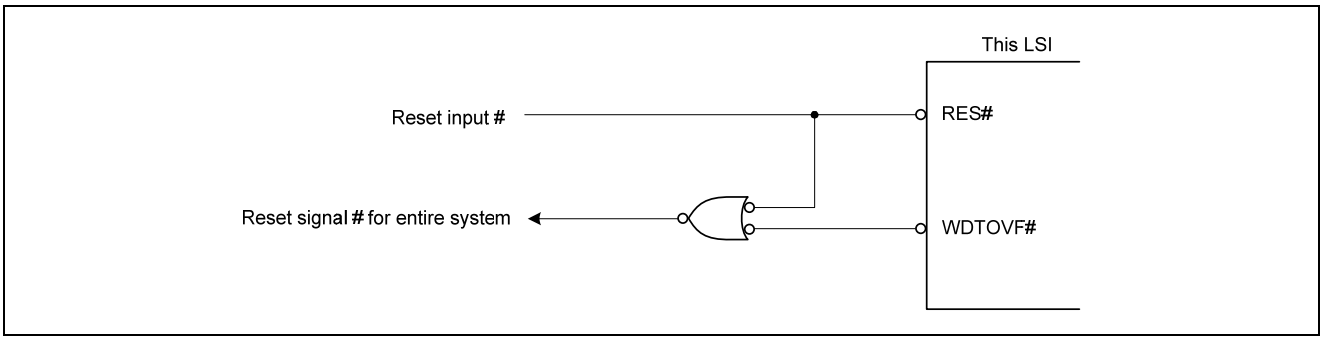


Figure 19.7 Circuit for System Reset by WDTOVF# Signal (Example)

19.5.7 Transition to Watchdog Timer Mode or Software Standby Mode

When the WDT operates in watchdog timer mode, a transition to software standby mode is not made even when the WAIT instruction is executed when the software standby bit (SSBY in SBYCR) in the standby control register is set to 1. Instead, a transition to sleep mode or all-module clock-stop mode is made.

To transit to software standby mode, the WAIT instruction must be executed after halting the watchdog timer (clearing the TME bit in TCSR to 0).

When the WDT operates in interval timer mode, a transition to software standby mode is made through execution of the WAIT instruction when the SSBY bit is set to 1. For details, see section 8, Low Power Consumption.

20. Serial Communications Interface (SCI)

The RX610 Group has seven independent serial communications interface (SCI) units.

The SCI can handle both asynchronous and clock synchronous serial communications.

Asynchronous serial data communications can be carried out with standard asynchronous communications chips such as a Universal Asynchronous Receiver/Transmitter (UART) or Asynchronous Communications Interface Adapter (ACIA).

The SCI also supports the smart card (IC card) interface supporting ISO/IEC 7816-3 (Identification Card) as an extended asynchronous communications mode.

20.1 Overview

Table 20.1 lists the specifications of the SCI and table 20.2 lists the functions of each SCI channel.

Figure 20.1 shows a block diagram of the SCI0 to SCI4. Figure 20.2 shows a block diagram of the SCI5 and SCI6.

Table 20.1 Specifications of SCI

Item		Specifications
Serial communications mode		• Asynchronous • Clock synchronous • Smart card interface
Transfer speed		Bit rate specifiable with on-chip baud rate generator.
Full-duplex communications		Transmitter: Enables continuous transmission by double-buffering. Receiver: Enables continuous reception by double-buffering.
Input/output pins		See table 20.3.
Data transfer		Selectable from LSB-first or MSB-first transfer
Interrupt sources		Transmit-end, transmit-data-empty, receive-data-full, and receive error
Power-down function		Module stop state can be set for each unit.
Asynchronous mode	Data length	7 or 8 bits
	Transmission stop bit	1 or 2 bits
	Parity	Even, odd, or none
	Receive error detection	Parity, overrun, and framing errors
	Break detection	Break can be detected by reading RxDn (n = 0 to 6) pin level directly in case of a framing error
	Clock source	Selectable from internal or external clock Enables transfer rate clock input from TMR (SCI5 and SCI6)
Clock synchronous mode	Data length	8 bits
	Receive error detection	Overrun errors
Smart card interface mode	Error processing	An error signal can be automatically transmitted on detection of a parity error during reception
		Data can be automatically re-transmitted on receiving an error signal during transmission
	Data type	Both direct convention and inverse convention are supported.

Table 20.2 Function List of SCI Channels

Item	SCI0 to SCI4	SCI5 and SCI6
Asynchronous mode	Possible	Possible
Clock synchronous mode	Possible	Possible
Smart card interface mode	Possible	Possible
TMR clock input	Not possible	Possible

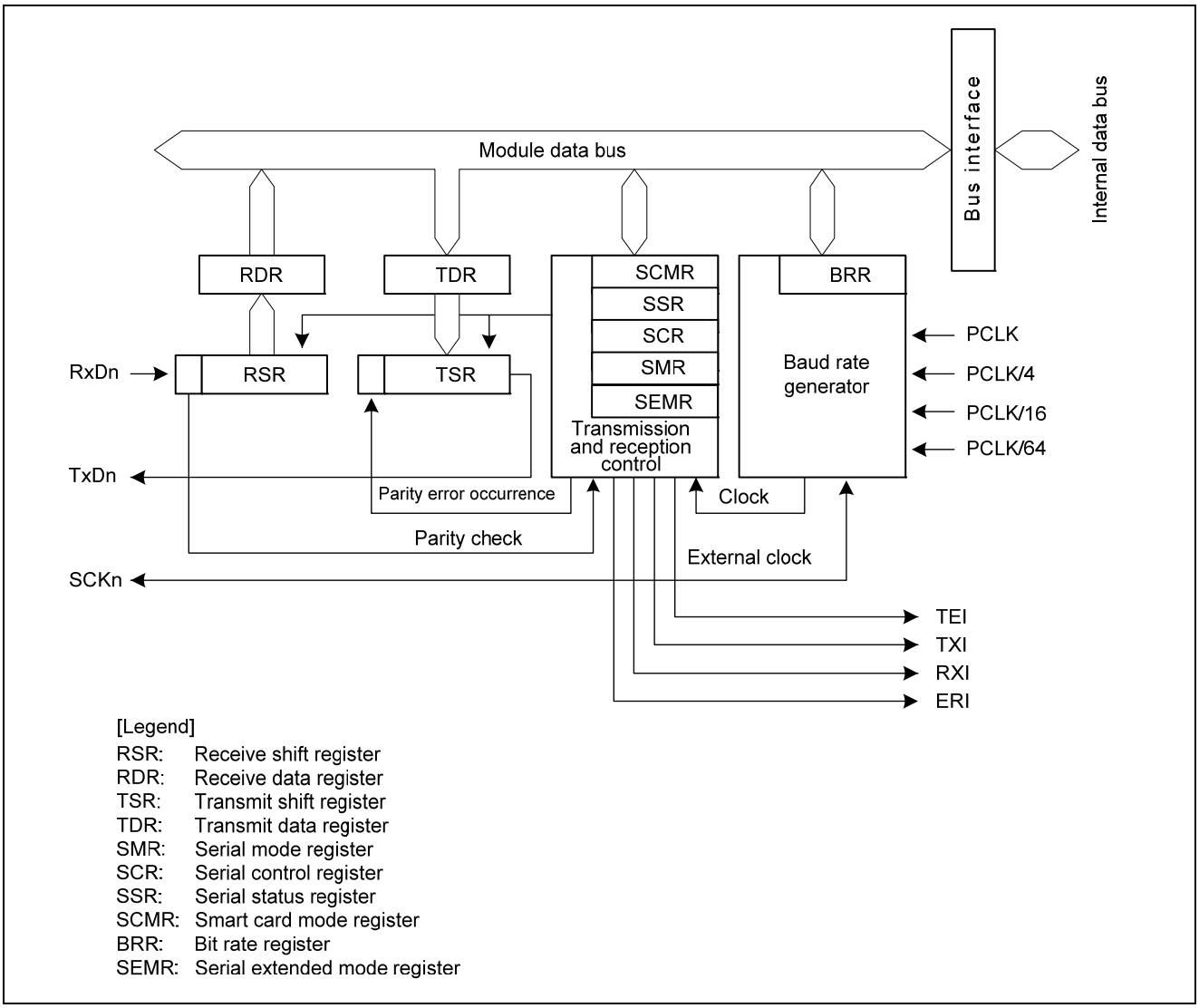


Figure 20.1 Block Diagram of SCI0 to SCI4

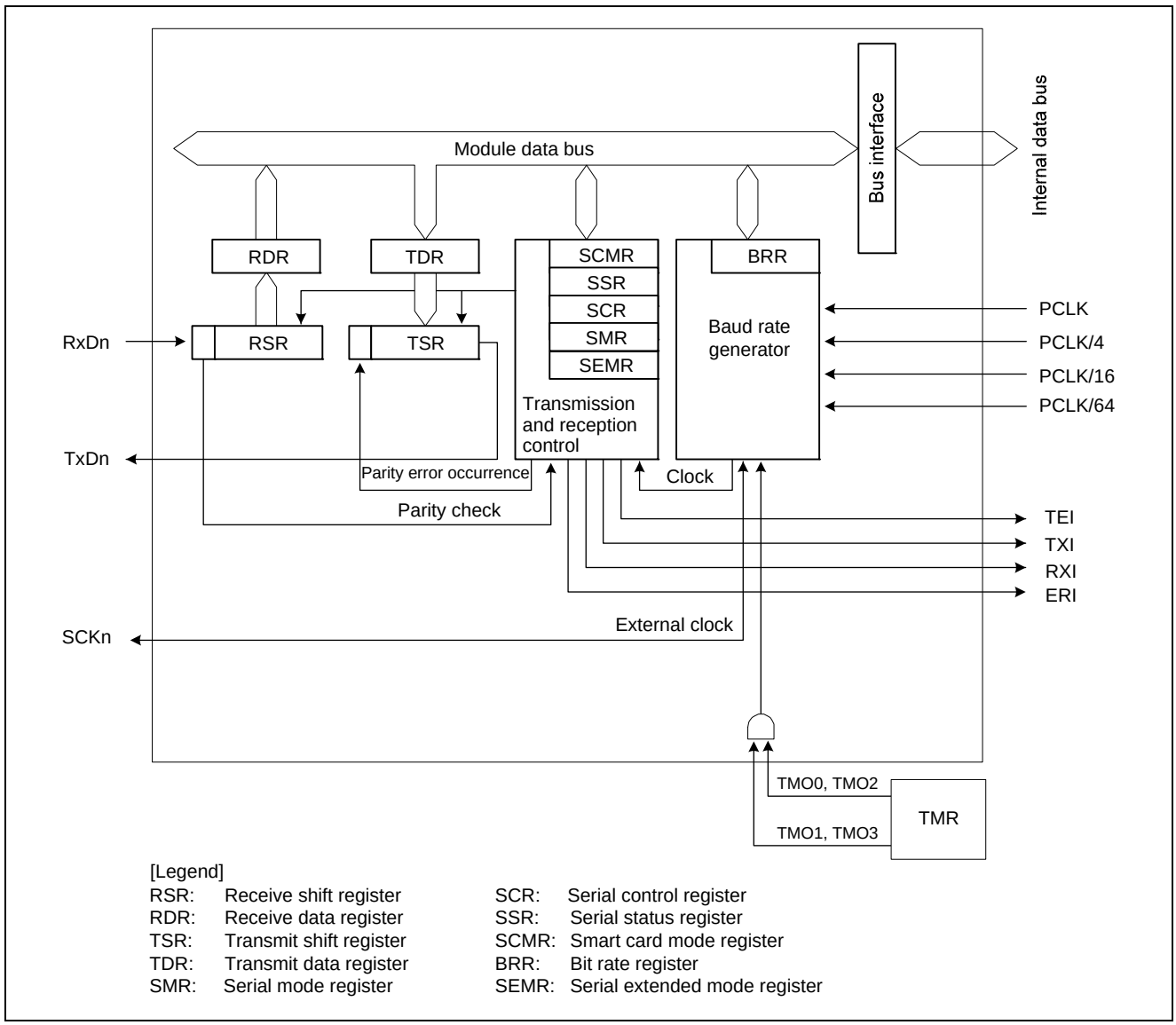


Figure 20.2 Block Diagram of SCI5 and SCI6

Table 20.3 lists the pin configuration of the SCI.

Table 20.3 Pin Configuration of SCI

Channel	Pin Name	I/O	Function
SCI0	SCK0	I/O	SCI0 clock input/output
	RxD0	Input	SCI0 receive data input
	TxD0	Output	SCI0 transmit data output
SCI1	SCK1	I/O	SCI1 clock input/output
	RxD1	Input	SCI1 receive data input
	TxD1	Output	SCI transmit data output
SCI2	SCK2	I/O	SCI2 clock input/output
	RxD2	Input	SCI2 receive data input
	TxD2	Output	SCI2 transmit data output
SCI3	SCK3	I/O	SCI3 clock input/output
	RxD3	Input	SCI3 receive data input
	TxD3	Output	SCI3 transmit data output
SCI4	SCK4	I/O	SCI4 clock input/output
	RxD4	Input	SCI receive data input
	TxD4	Output	SCI4 transmit data output
SCI5	SCK5	I/O	SCI5 clock input/output
	RxD5	Input	SCI5 receive data input
	TxD5	Output	SCI5 transmit data output
SCI6	SCK6	I/O	SCI6 clock input/output
	RxD6	Input	SCI6 receive data input
	TxD6	Output	SCI6 transmit data output

20.2 Register Descriptions

Table 20.4 lists the registers of the SCI.

Table 20.4 Registers of SCI

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
SCI0	Serial mode register	SMR	00h	0008 8240h	8
	Bit rate register	BRR	FFh	0008 8241h	8
	Serial control register	SCR	0xh	0008 8242h	8
	Transmit data register	TDR	FFh	0008 8243h	8
	Serial status register	SSR	84h	0008 8244h	8
	Receive data register	RDR	00h	0008 8245h	8
	Smart card mode register	SCMR	F2h	0008 8246h	8
	Serial extended mode register	SEMR	00h	0008 8247h	8
SCI1	Serial mode register	SMR	00h	0008 8248h	8
	Bit rate register	BRR	FFh	0008 8249h	8
	Serial control register	SCR	0xh	0008 824Ah	8
	Transmit data register	TDR	FFh	0008 824Bh	8
	Serial status register	SSR	84h	0008 824Ch	8
	Receive data register	RDR	00h	0008 824Dh	8
	Smart card mode register	SCMR	F2h	0008 824Eh	8
	Serial extended mode register	SEMR	00h	0008 824Fh	8
SCI2	Serial mode register	SMR	00h	0008 8250h	8
	Bit rate register	BRR	FFh	0008 8251h	8
	Serial control register	SCR	0xh	0008 8252h	8
	Transmit data register	TDR	FFh	0008 8253h	8
	Serial status register	SSR	84h	0008 8254h	8
	Receive data register	RDR	00h	0008 8255h	8
	Smart card mode register	SCMR	F2h	0008 8256h	8
	Serial extended mode register	SEMR	00h	0008 8257h	8
SCI3	Serial mode register	SMR	00h	0008 8258h	8
	Bit rate register	BRR	FFh	0008 8259h	8
	Serial control register	SCR	0xh	0008 825Ah	8
	Transmit data register	TDR	FFh	0008 825Bh	8
	Serial status register	SSR	84h	0008 825Ch	8
	Receive data register	RDR	00h	0008 825Dh	8
	Smart card mode register	SCMR	F2h	0008 825Eh	8
	Serial extended mode register	SEMR	00h	0008 825Fh	8
SCI4	Serial mode register	SMR	00h	0008 8260h	8
	Bit rate register	BRR	FFh	0008 8261h	8
	Serial control register	SCR	0xh	0008 8262h	8
	Transmit data register	TDR	FFh	0008 8263h	8
	Serial status register	SSR	84h	0008 8264h	8
	Receive data register	RDR	00h	0008 8265h	8
	Smart card mode register	SCMR	F2h	0008 8266h	8
	Serial extended mode register	SEMR	00h	0008 8267h	8
Channel	**Register Name**	**Symbol**	**Value after Reset**	**Address**	**Access Size**
SCI5	Serial mode register	SMR	00h	0008 8268h	8

	Bit rate register	BRR	FFh	0008 8269h	8
	Serial control register	SCR	0xh	0008 826Ah	8
	Transmit data register	TDR	FFh	0008 826Bh	8
	Serial status register	SSR	84h	0008 826Ch	8
	Receive data register	RDR	00h	0008 826Dh	8
	Smart card mode register	SCMR	F2h	0008 826Eh	8
	Serial extended mode register	SEMR	00h	0008 826Fh	8
SCI6	Serial mode register	SMR	00h	0008 8270h	8
	Bit rate register	BRR	FFh	0008 8271h	8
	Serial control register	SCR	0xh	0008 8272h	8
	Transmit data register	TDR	FFh	0008 8273h	8
	Serial status register	SSR	84h	0008 8274h	8
	Receive data register	RDR	00h	0008 8275h	8
	Smart card mode register	SCMR	F2h	0008 8276h	8
	Serial extended mode register	SEMR	00h	0008 8277h	8

20.2.1 Receive Shift Register (RSR)

RSR is a shift register which is used to receive serial data input from the RxDn pin and converts it into parallel data.

When one frame of data has been received, it is transferred to RDR automatically.

RSR cannot be directly accessed by the CPU.

20.2.2 Receive Data Register (RDR)

Addresses: SCI0.RDR 0008 8245h, SCI1.RDR 0008 824Dh, SCI2.RDR 0008 8255h, SCI3.RDR 0008 25Dh
SCI4.RDR 0008 8265h, SCI5.RDR 0008 826Dh, SCI6.RDR 0008 8275h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

RDR is an 8-bit register that stores receive data.

When the SCI has received one frame of serial data, it transfers the received serial data from RSR to RDR where it is stored. This allows RSR to receive the next data.

Since RSR and RDR function as a double buffer in this way, continuous receive operations can be performed.

Read RDR only once after a receive data full interrupt (RXI) has occurred. Note that if next one frame of data is received before reading receive data from RDR, an overrun error occurs.

RDR cannot be written to by the CPU.

20.2.3 Transmit Data Register (TDR)

Addresses: SCI0.TDR 0008 8243h, SCI1.TDR 0008 824Bh, SCI2.TDR 0008 8253h, SCI3.TDR 0008 25Bh
SCI4.TDR 0008 8263h, SCI5.TDR 0008 826Bh, SCI6.TDR 0008 8273h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

TDR is an 8-bit register that stores transmit data.

When the SCI detects that TSR is empty, it transfers the transmit data written in TDR to TSR and starts transmission.

The double-buffered structures of TDR and TSR enable continuous serial transmission. If the next transmit data has already been written to TDR when one frame of data is transmitted, the SCI transfers the written data to TSR to continue transmission.

The CPU is able to read from or write to TDR at any time. Only write data for transmission to TDR once after each instance of the transmit data empty interrupt (TXI).

20.2.4 Transmit Shift Register (TSR)

TSR is a shift register that transmits serial data.

To perform serial data transmission, the SCI first automatically transfers transmit data from TDR to TSR, and then sends the data to the TxDn pin.

TSR cannot be directly accessed by the CPU.

20.2.5 Serial Mode Register (SMR)

Note: Some bits in SMR have different functions in serial communications interface mode and smart card interface mode.

(1) Serial Communications Interface Mode (SMIF in SCMR = 0)

Addresses: SCI0.SMR 0008 8240h, SCI1.SMR 0008 8248h, SCI2.SMR 0008 8250h, SCI3.SMR 0008 8258h
SCI4.SMR 0008 8260h, SCI5.SMR 0008 8268h, SCI6.SMR 0008 8270h

	b7	b6	b5	b4	b3	b2	b1	b0
	CM	CHR	PE	PM	STOP	—	CKS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKS[1:0]	Clock Select	b1 b0 00: PCLK clock (n = 0)*1 01: PCLK/4 clock (n = 1)*1 10: PCLK/16 clock (n = 2)*1 11: PCLK/64 clock (n = 3)*1	R/W*4
b2	—	Reserved	This bit is read as 0. The write value should be 0.	R/W*4
b3	STOP	Stop Bit Length	(Valid only in asynchronous mode) 0: 1 stop bit 1: 2 stop bits	R/W*4
b4	PM	Parity Mode	(Valid only when the PE bit is 1 in asynchronous mode) 0: Selects even parity 1: Selects odd parity	R/W*4
b5	PE	Parity Enable	(Valid only in asynchronous mode) • When transmitting 0: Parity bit addition is not performed 1: The parity bit is added • When receiving 0: Parity bit checking is not performed 1: The parity bit is checked	R/W*4
b6	CHR	Character Length	(Valid only in asynchronous mode) 0: Selects 8 bits as the data length*2 1: Selects 7 bits as the data length*3	R/W*4
b7	CM	Communications Mode	0: Asynchronous mode 1: Clock synchronous mode	R/W*4

Notes: 1. n is the decimal notation of the value of n in BRR (see section 20.2.9, Bit Rate Register (BRR)).
2. In clock synchronous mode, this bit setting is invalid and a fixed data length of 8 bits is used.
3. LSB-first is fixed and the MSB (bit 7) in TDR is not transmitted in transmission.
4. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).

SMR is used to set the SCI's serial transfer format and select the baud rate generator clock source.

CKS[1:0] Bits (Clock Select)

These bits select the clock source for the baud rate generator.

For the relation between the settings of these bits and the baud rate, see section 20.2.9, Bit Rate Register (BRR).

STOP Bit (Stop Bit Length)

Selects the stop bit length in transmission.

In reception, only the first stop bit is checked. If the second stop bit is 0, it is treated as the start bit of the next transmit frame.

PM Bit (Parity Mode)

Selects the parity mode (even or odd) for transmission and reception.

PE Bit (Parity Enable)

When this bit is set to 1, the parity bit is added to transmit data, and the parity bit is checked in reception.

CHR Bit (Character Length)

Selects the data length for transmission and reception.

In clock synchronous mode, a fixed data length of 8 bits is used.

CM Bit (Communications Mode)

Selects asynchronous or clock synchronous mode.

(2) Smart Card Interface Mode (SMIF in SCMR = 1)

Addresses: SCI0.SMR 0008 8240h, SCI1.SMR 0008 8248h, SCI2.SMR 0008 8250h, SCI3.SMR 0008 8258h
SCI4.SMR 0008 8260h, SCI5.SMR 0008 8268h, SCI6.SMR 0008 8270h

	b7	b6	b5	b4	b3	b2	b1	b0
	GM	BLK	PE	PM	BCP[1:0]		CKS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKS[1:0]	Clock Select	b1 b0 00: PCLK clock (n = 0)*1 01: PCLK/4 clock (n = 1)*1 10: PCLK/16 clock (n = 2)*1 11: PCLK/64 clock (n = 3)*1	R/W*3
b3, b2	BCP[1:0]	Base Clock Pulse	Selects the number of base clock cycles in combination with the BCP2 bit in SCMR. Setting values in BCP2 bit in SCMR and BCP[1:0] bits in SMR: BCP2 b3 b2 0 0 0: 93 clock cycles (S = 93)*2 0 0 1: 128 clock cycles (S = 128)*2 0 1 0: 186 clock cycles (S = 186)*2 0 1 1: 512 clock cycles (S = 512)*2 1 0 0: 32 clock cycles (S = 32)*2 (Initial value) 1 0 1: 64 clock cycles (S = 64)*2 1 1 0: 372 clock cycles (S = 372)*2 1 1 1: 256 clock cycles (S = 256)*2	R/W*3
b4	PM	Parity Mode	(Valid only when the PE bit is 1 in asynchronous mode) 0: Selects even parity 1: Selects odd parity	R/W*3
b5	PE	Parity Enable	(Valid only in asynchronous mode) When this bit is set to 1, the parity bit is added to transmit data before transmission, and the parity bit is checked in reception. Set this bit to 1 in smart card interface mode.	R/W*3
b6	BLK	Block Transfer Mode	0: Normal mode operation 1: Block transfer mode operation	R/W*3
b7	GM	GSM Mode	0: Normal mode operation 1: GSM mode operation	R/W*3

Notes: 1. n is the decimal notation of the value of n in BRR (see section 20.2.9, Bit Rate Register (BRR)).
2. S is the value of S in BRR (see section 20.2.9, Bit Rate Register (BRR)).
3. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).

SMR is used to set the SCI's serial transfer format and select the baud rate generator clock source.

CKS[1:0] Bits (Clock Select)

These bits select the clock source for the on-chip baud rate generator.

For the relationship between the settings of these bits and the baud rate, see section 20.2.9, Bit Rate Register (BRR).

BCP[1:0] Bits (Base Clock Pulse)

These bits select the number of base clock cycles in a 1-bit data transfer time in smart card interface mode.

Set these bits in combination with the BCP2 bit in SCMR.

For details, see section 20.5.4, Receive Data Sampling Timing and Reception Margin.

PM Bit (Parity Mode)

Selects the parity mode for transmission and reception (even or odd).

For details on the usage of this bit in smart card interface mode, see section 20.5.2, Data Format (Except in Block Transfer Mode).

PE Bit (Parity Enable)

Set the PE bit to 1.

The parity bit is added to transmit data before transmission, and the parity bit is checked in reception.

BLK Bit (Block Transfer Mode)

Setting this bit to 1 allows block transfer mode operation.

For details, see section 20.5.3, Block Transfer Mode.

GM Bit (GSM Mode)

Setting this bit to 1 allows GSM mode operation.

In GSM mode, the SSR.TEND flag set timing is put forward to 11.0 etu (elementary time unit = 1-bit transfer time) from the start and the clock output control function is appended. For details, see 20.5.6, Serial Data Transmission (Except in Block Transfer Mode) and section 20.5.8, Clock Output Control.

20.2.6 Serial Control Register (SCR)

Note: Some bits in SCR have different functions in serial communications interface mode and smart card interface mode.

(1) Serial Communications Interface Mode (SMIF in SCMR = 0)

Address: SCI0.SCR 0008 8242h, SCI1.SCR 0008 824Ah, SCI2.SCR 0008 8252h, SCI3.SCR 0008 825Ah
SCI4.SCR 0008 8262h, SCI5.SCR 0008 826Ah, SCI6.SCR 0008 8272h

	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKE[1:0]	Clock Enable	• For SCI0 to SCI4 Asynchronous mode b1 b0 0 0: On-chip baud rate generator The SCKn pin functions as I/O port. 0 1: On-chip baud rate generator The clock with the same frequency as the bit rate is output from the SCKn pin. 1 0: External clock The clock with a frequency 16 times the bit rate should be input from the SCKn pin. (When the SEMR.ABCS bit is 1, the clock with a frequency 8 times the bit rate should be input.) 1 1: External clock The clock with a frequency 16 times the bit rate should be input from the SCKn pin. (When the SEMR.ABCS bit is 1, the clock with a frequency 8 times the bit rate should be input.) Clock synchronous mode b1 b0 0 0: Internal clock The SCKn pin functions as the clock output pin. 0 1: Internal clock The SCKn pin functions as the clock output pin. 1 0: External clock The SCKn pin functions as the clock input pin. 1 1: External clock The SCKn pin functions as the clock input pin.	R/W*1

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKE[1:0]	Clock Enable	• For SCI5 and SCI6 Asynchronous mode b1 b0 0 0: On-chip baud rate generator The SCKn pin functions as I/O port. 0 1: On-chip baud rate generator The clock with the same frequency as the bit rate is output from the SCKn pin. 1 0: External clock or TMR clock • When an external clock is used, the clock with a frequency 16 times the bit rate should be input from the SCKn pin. (When the SEMR.ABCS bit is 1, the clock with a frequency 8 times the bit rate should be input.) • The TMR clock can be used. 1 1: External clock or TMR clock • When an external clock is used, the clock with a frequency 16 times the bit rate should be input from the SCKn pin. (When the SEMR.ABCS bit is 1, the clock with a frequency 8 times the bit rate should be input.) • The TMR clock can be used. Clock synchronous mode b1 b0 0 0: Internal clock The SCKn pin functions as the clock output pin. 0 1: Internal clock The SCKn pin functions as the clock output pin. 1 0: External clock The SCKn pin functions as the clock input pin. 1 1: External clock The SCKn pin functions as the clock input pin.	R/W*1
b2	TEIE	Transmit End Interrupt Enable	0: A TEI interrupt request is disabled 1: A TEI interrupt request is enabled	R/W
b3	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b4	RE	Receive Enable	0: Serial reception is disabled 1: Serial reception is enabled	R/W*2
b5	TE	Transmit Enable	0: Serial transmission is disabled 1: Serial transmission is enabled	R/W*2
b6	RIE	Receive Interrupt Enable	0: RXI and ERI interrupt requests are disabled 1: RXI and ERI interrupt requests are enabled	R/W
b7	TIE	Transmit Interrupt Enable	0: A TXI interrupt request is disabled 1: A TXI interrupt request is enabled	R/W

Notes: 1. Writable only when TE = 0 and RE = 0.
2. A 1 can be written only when TE = 0 and RE = 0. After setting TE or RE to 1, only 0 can be written in TE and RE.

SCR is a register that enables or disables the SCI transfer operations and selects the transfer clock source.

CKE[1:0] Bits (Clock Enable)

These bits select the clock source and SCKn pin function.

TEIE Bit (Transmit End Interrupt Enable)

Enables or disables a TEI interrupt request.

A TEI interrupt request is disabled by clearing the TEIE bit to 0.

RE Bit (Receive Enable)

Enables or disables serial reception.

When this bit is set to 1, serial reception is started by detecting the start bit in asynchronous mode or the synchronous clock input in clock synchronous mode. Note that SMR should be set prior to setting the RE bit to 1 in order to designate the reception format.

Even if reception is halted by clearing the RE bit to 0, the ORER, FER, and PER flags in SSR are not affected and the previous value is retained.

TE Bit (Transmit Enable)

Enables or disables serial transmission.

When this bit is set to 1, serial transmission is started by writing transmit data to TDR. Note that SMR should be set prior to setting the TE bit to 1 in order to designate the transmission format.

RIE Bit (Receive Interrupt Enable)

Enables or disables RXI and ERI interrupt requests.

An RXI interrupt request is disabled by clearing the RIE bit to 0.

An ERI interrupt request can be cancelled by reading 1 from the ORER, FER, or PER flag in SSR and then clearing the flag to 0, or clearing the RIE bit to 0.

TIE Bit (Transmit Interrupt Enable)

Enables or disables notification of a TXI interrupt request.

Notification of a TXI interrupt request is disabled by clearing the TIE bit to 0.

(2) Smart Card Interface Mode (SMIF in SCMR = 1)

Addresses: SCI0.SCR 0008 8242h, SCI1.SCR 0008 824Ah, SCI2.SCR 0008 8295h, SCI3.SCR 0008 25Ah
SCI4.SCR 0008 8262h, SCI5.SCR 0008 826Ah, SCI6.SCR 0008 8272h

	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	RIE	TE	RE	—	TEIE	CKE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b1, b0	CKE[1:0]	Clock Enable	• When GM in SMR = 0 b1 b0 0 0: Output disabled (SCKn pin functions as I/O port.) 0 1: Clock output 1 0: Setting prohibited 1 1: Setting prohibited • When GM in SMR = 1 0 0: Output fixed low 0 1: Clock output 1 0: Output fixed high 1 1: Clock output	R/W*1
b2	TEIE	Transmit End Interrupt Enable	This bit should be 0 in smart card interface mode.	R/W
b3	—	Reserved	This bit is read as 0. The write value should be 0.	R/W
b4	RE	Receive Enable	0: Serial reception is disabled 1: Serial reception is enabled	R/W*2
b5	TE	Transmit Enable	0: Serial transmission is disabled 1: Serial transmission is enabled	R/W*2
b6	RIE	Receive Interrupt Enable	0: RXI and ERI interrupt requests are disabled 1: RXI and ERI interrupt requests are enabled	R/W
b7	TIE	Transmit Interrupt Enable	0: A TXI interrupt request is disabled 1: A TXI interrupt request is enabled	R/W

Notes: 1. Writable only when TE = 0 and RE = 0.
2. A 1 can be written only when TE = 0 and RE = 0. After setting TE or RE to 1, only 0 can be written in TE and RE.

SCR is a register that enables/disables the SCI transfer operations and selects the transfer clock source. For details on interrupt requests, see 20.6, Interrupt Sources.

CKE[1:0] Bits (Clock Enable)

These bits control the clock output from the SCKn pin.

In GSM mode, clock output can be dynamically switched. For details, see section 20.5.8, Clock Output Control.

TEIE Bit (Transmit End Interrupt Enable)

This bit should be 0 in smart card interface mode.

RE Bit (Receive Enable)

Enables or disables serial reception.

When this bit is set to 1, serial reception is started by detecting the start bit. Note that SMR should be set prior to setting the RE bit to 1 in order to designate the reception format.

Even if reception is halted by clearing the RE bit to 0, the ORER, FER, and PER flags in SSR are not affected and the previous value is retained.

TE Bit (Transmit Enable)

Enables or disables serial transmission.

When this bit is set to 1, serial transmission is started by writing transmit data to TDR. Note that SMR should be set prior to setting the TE bit to 1 in order to designate the transmission format.

RIE Bit (Receive Interrupt Enable)

Enables or disables RXI and ERI interrupt requests.

An RXI interrupt request is disabled by clearing the RIE bit to 0.

An ERI interrupt request can be cancelled by reading 1 from the ORER, FER, or PER flag in SSR and then clearing the flag to 0, or clearing the RIE bit to 0.

TIE Bit (Transmit Interrupt Enable)

Enables or disables notification of a TXI interrupt request.

Notification of a TXI interrupt request is disabled by clearing the TIE bit to 0.

20.2.7 Serial Status Register (SSR)

Note: Some bits in SSR have different functions in serial communications interface mode and smart card interface mode.

(1) Serial Communications Interface Mode (SMIF in SCMR = 0)

Addresses: SCI0.SSR 0008 8244h, SCI1.SSR 0008 824Ch, SCI2.SSR 0008 8254h, SCI3.SSR 0008 25Ch, SCI4.SSR 0008 8264h, SCI5.SSR 0008 826Ch, SCI6.SSR 0008 8274h

	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	TDRF	ORER	FER	PER	TEND	—	—
Value after reset:	1	0	0	0	0	1	0	0

x: Undefined

Bit	Symbol	Bit Name	Function	R/W
b0, b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b2	TEND	Transmit End Flag	0: A character is being transmitted. 1: Character transfer has been completed.	R
b3	PER	Parity Error Flag	0: No parity error occurred 1: A parity error has occurred	R/(W)*1
b4	FER	Framing Error Flag	0: No framing error occurred 1: A framing error has occurred	R/(W)*1
b5	ORER	Overrun Error Flag	0: No overrun error occurred 1: An overrun error has occurred	R/(W)*1
b6	RDRF	Receive Data Full Flag	0: When data is transferred from RDR 1: When data has been received normally, and transferred from RSR to RDR	R/W*2
b7	TDRE	Transmit Data Empty Flag	0: When data is transferred to TDR 1: When data is transferred from TDR to TSR	R/W*2

Notes: 1. Only 0 can be written to this bit, to clear the flag.
2. Write 1 when writing is necessary.

SSR is a register containing status flags of the SCI.

TEND Flag (Transmission End Flag)

Indicates completion of transmission.

[Setting conditions]

- Clearing of the SCR.TE bit to 0 (disabling serial transmission operations)
- The TDR is not updated at the time of transmission of the tail-end bit of a character being transmitted

[Clearing condition]

- Writing of further data for transmission to the TDR

When the TEND flag is cleared by writing the data for transmission to the TDR, read the TEND flag and check that it has actually been cleared to 0.

PER Bit (Parity Error Flag)

Indicates that a parity error has occurred during reception in asynchronous mode and the reception ends abnormally.

[Setting condition]

- When a parity error is detected during reception
  Although receive data when the parity error occurs is transferred to RDR, no RXI interrupt request occurs. Note that when the PER flag is being set to 1, the subsequent serial reception cannot be performed. In clock synchronous mode, serial transmission also cannot continue.

[Clearing condition]

- When a 0 is written to PER after reading PER = 1 (After writing a 0 to it, read the PER bit and check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0 (which indicates that serial reception is disabled), the PER flag is not affected and retains its previous value.

FER Bit (Framing Error Flag)

Indicates that a framing error has occurred during reception in asynchronous mode and the reception ends abnormally.

[Setting condition]

- When the stop bit is 0
  In 2-stop-bit mode, only the first stop bit is checked whether it is 1 but the second stop bit is not checked. Note that although receive data when the framing error occurs is transferred to RDR, no RXI interrupt request occurs. In addition, when the FER flag is being set to 1, the subsequent serial reception cannot be performed. In clock synchronous mode, serial transmission also cannot continue.

[Clearing condition]

- When a 0 is written to FER after reading FER = 1 (After writing a 0 to it, read the FER bit and check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0, the FER flag is not affected and retains its previous value.

ORER Bit (Overrun Error Flag)

Indicates that an overrun error has occurred during reception and the reception ends abnormally.

[Setting condition]

- When the next data is received before receive data is read from RDR
  In RDR, receive data prior to an overrun error occurrence is retained, but data received after the overrun error occurrence is lost. When the ORER flag is set to 1, subsequent serial reception cannot be performed. Note that, in clock synchronous mode, serial transmission also cannot continue.

[Clearing condition]

- When a 0 is written to ORER after reading ORER = 1 (After writing a 0 to it, read the ORER bit and check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0, the ORER flag is not affected and retains its previous value.

RDRF Bit (Receive Data Full Flag)

Indicates whether RDR has received data.

[Setting condition]

- When data has been received normally, and transferred from RSR to RDR

[Clearing condition]

- When data is transferred from RDR.

TDRE Bit (Transmit Data Empty Flag)

Indicates whether TDR has data to be transmitted.

[Setting condition]

- When data is transferred from TDR to TSR

[Clearing condition]

- When data is transferred to TDR

(2) Smart Card Interface Mode (SMIF in SCMR = 1)

Addresses: SCI0.SSR 0008 8244h, SCI1.SSR 0008 824Ch, SCI2.SSR 0008 8254h, SCI3.SSR 0008 25Ch, SCI4.SSR 0008 8264h, SCI5.SSR 0008 826Ch, SCI6.SSR 0008 8274h

	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	RDRF	ORER	ERS	PER	TEND	—	—
Value after reset:	1	0	0	0	0	1	0	0

x: Undefined

Bit	Symbol	Bit Name	Function	R/W
b0, b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b2	TEND	Transmit End Flag	0: A character is being transmitted. 1: Character transfer has been completed.	R
b3	PER	Parity Error Flag	0: No parity error occurred 1: A parity error has occurred	R/(W)*1
b4	ERS	Error Signal Status Flag	0: Low error signal not responded 1: Low error signal responded	R/(W)*1
b5	ORER	Overrun Error Flag	0: No overrun error occurred 1: An overrun error has occurred	R/(W)*1
b6	RDRF	Receive Data Full Flag	0: When data is transferred from RDR 1: When data has been received normally, and transferred from RSR to RDR	R/W*2
b7	TDRE	Transmit Data Empty Flag	0: When data is transferred to TDR 1: When data is transferred from TDR to TSR	R/W*2

Notes: 1. Only 0 can be written to this bit, to clear the flag.
2. Write 1 when writing is necessary.

SSR is a register containing status flags of the SCI.

TEND Flag (Transmission End Flag)

With no error signal from the receiving side, this bit is set to 1 when further data for transfer is ready to be transferred to the TDR register.

[Setting conditions]

- When SCR.TE bit = 0 (disabling serial transmission operations) and ERS flag = 0
- When a specified period has elapsed after the latest transmission of one byte, the ERS flag is 0, and the TDR register is not updated
  The set timing is determined by register settings as listed below.
  When SMR.GM = 0 and SMR.BLK = 0, 12.5 etu after the start of transmission
  When SMR.GM = 0 and SMR.BLK = 1, 11.5 etu after the start of transmission
  When SMR.GM = 1 and SMR.BLK = 0, 11.0 etu after the start of transmission
  When SMR.GM = 1 and SMR.BLK = 1, 11.0 etu after the start of transmission

[Clearing condition]

- Writing further data for transmission to the TDR register

PER Flag (Parity Error Flag)

Indicates that a parity error has occurred during reception in asynchronous mode and the reception ends abnormally.

[Setting condition]

- When a parity error is detected during reception
  Although receive data when the parity error occurs is transferred to RDR, no RXI interrupt request occurs. Note that when the PER flag is being set to 1, the subsequent serial reception cannot be performed. In clock synchronous mode, serial transmission also cannot continue.

[Clearing condition]

- When a 0 is written to PER after reading PER = 1 (After writing a 0 to it, read the PER bit and check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0 (which indicates that serial reception is disabled), the PER flag is not affected and retains its previous value.

ERS Flag (Error Signal Status Flag)

[Setting condition]

- When a low error signal is sampled

[Clearing condition]

- When a 0 is written to ERS after reading ERS = 1

ORER Flag (Overrun Error Flag)

Indicates that an overrun error has occurred during reception and the reception ends abnormally.

[Setting condition]

- When the next data is received before receive data is read from RDR
  In RDR, the receive data prior to an overrun error occurrence is retained, but data received following the overrun error occurrence is lost. When the ORER flag is set to 1, subsequent serial reception cannot be performed.

[Clearing condition]

- When a 0 is written to ORER after reading ORER = 1 (After writing a 0 to it, read the ORER bit and check that it has actually been cleared to 0.)
  Even when the RE bit in SCR is cleared to 0, the ORER flag is not affected and retains its previous value.

RDRF Bit (Receive Data Full Flag)

Indicates whether RDR has received data.

[Setting condition]

- When data has been received normally, and transferred from RSR to RDR
  [Clearing condition]
- When data is transferred from RDR.

TDRE Bit (Transmit Data Empty Flag)

Indicates whether TDR has data to be transmitted.

[Setting condition]

- When data is transferred from TDR to TSR

[Clearing condition]

- When data is transferred to TDR

20.2.8 Smart Card Mode Register (SCMR)

Addresses: SCI0.SCMR 0008 8246h, SCI1.SCMR 0008 824Eh, SCI2.SCMR 0008 8256h, SCI3.SCMR 0008 25Eh
SCI4.SCMR 0008 8266h, SCI5.SCMR 0008 826Eh, SCI6.SCMR 0008 8276h

	b7	b6	b5	b4	b3	b2	b1	b0
	BCP2	—	—	—	SDIR	SINV	—	SMIF
Value after reset:	1	1	1	1	0	0	1	0

Bit	Symbol	Bit Name	Function	R/W
b0	SMIF	Smart Card Interface Mode Select	0: Serial communications interface mode 1: Smart card interface mode	R/W*1
b1	—	Reserved	This bit is read as 1. The write value should be 1.	R/W
b2	SINV	Smart Card Data Invert	0: TDR contents are transmitted as they are. Receive data is stored as it is in RDR. 1: TDR contents are inverted before being transmitted. Receive data is stored in inverted form in RDR.	R/W*1
b3	SDIR	Bit Order Select	0: Transfer with LSB-first 1: Transfer with MSB-first	R/W*1
b6 to b4	—	Reserved	These bits are read as 1. The write value should be 1.	R/W
b7	BCP2	Base Clock Pulse 2	Selects the number of base clock cycles in combination with the BCP1 and BCP0 bits in SMR. Setting values in BCP2 bit in SCMR and BCP1 and BCP0 bits in SMR BCP2 BCP1 BCP0 0 0 0: 93 clock cycles (S = 93)*2 0 0 1: 128 clock cycles (S = 128)*2 0 1 0: 186 clock cycles (S = 186)*2 0 1 1: 512 clock cycles (S = 512)*2 1 0 0: 32 clock cycles (S = 32)*2 (Initial Value) 1 0 1: 64 clock cycles (S = 64)*2 1 1 0: 372 clock cycles (S = 372)*2 1 1 1: 256 clock cycles (S = 256)*2	R/W*1

Notes: 1. Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).
2. S is the value of S in BRR (see section 20.2.9, Bit Rate Register (BRR)).

SCMR selects smart card interface mode and its format.

SMIF Bit (Smart Card Interface Mode Select)

When this bit is set to 1, smart card interface mode is selected.

When this bit is set to 0, asynchronous or clock synchronous mode is selected.

SINV Bit (Smart Card Data Invert)

Inverts the transmit/receive data logic level. This bit does not affect the logic level of the parity bit. To invert the parity bit, invert the PM bit in SMR.

SDIR Bit (Bit Order Select)

Selects the serial/parallel conversion format.

BCP2 Bit (Base Clock Pulse 2)

Selects the number of base clock cycles in a 1-bit data transfer time in smart card interface mode. Set this bit in combination with the BCP1 and BCP2 bits in SMR.

20.2.9 Bit Rate Register (BRR)

Addresses: SCI0.BRR 0008 8241h, SCI1.BRR 0008 8249h, SCI2.BRR 0008 8251h, SCI3.BRR 0008 8259h
SCI4.BRR 0008 8261h, SCI5.BRR 0008 8269h, SCI6.BRR 0008 8271h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

BRR is an 8-bit register that adjusts the bit rate.

As the SCI performs baud rate generator control independently for each channel, different bit rates can be set for each channel. Table 20.5 shows the relationships between the N setting in BRR and bit rate B for normal asynchronous mode and clock synchronous mode, and smart card interface mode.

The initial value of BRR is FFh.

BRR can be read from by the CPU at all times, but it can be written to only when the TE and RE bits in SCR are 0.

Table 20.5 Relationships between N Setting in BRR and Bit Rate B

Mode	ABCS Bit in SEMR	BRR Setting	Error
Asynchronous	0	$N = \frac{PCLK \times 10^6}{64 \times 2^{2n-1} \times B} - 1$	$Error\ (\%) = \{ \frac{PCLK \times 10^6}{B \times 64 \times 2^{2n-1} \times (N+1)} - 1 \} \times 100$
	1	$N = \frac{PCLK \times 10^6}{32 \times 2^{2n-1} \times B} - 1$	$Error\ (\%) = \{ \frac{PCLK \times 10^6}{B \times 32 \times 2^{2n-1} \times (N+1)} - 1 \} \times 100$
Clock synchronous		$N = \frac{PCLK \times 10^6}{8 \times 2^{2n-1} \times B} - 1$	
Smart card interface		$N = \frac{PCLK \times 10^6}{S \times 2^{2n+1} \times B} - 1$	$Error\ (\%) = \{ \frac{PCLK \times 10^6}{B \times S \times 2^{2n+1} \times (N+1)} - 1 \} \times 100$

[Legend]
B: Bit rate (bps)
N: BRR setting for baud rate generator ($0 \leq N \leq 255$)
PCLK: Operating frequency (MHz)
n and S: Determined by the SMR setting shown in the following table.

SMR Setting			
CKS[1:0] bps		**Clock Source**	**n**
0	0	PCLK clock	0
0	1	PCLK/4 clock	1
1	0	PCLK/16 clock	2
1	1	PCLK/64 clock	3

SCMR Setting	SMR Setting		
BCP2 Bit	BCP[1:0] bps	Base Clock	S
0	0 0	93 clock cycles	93
0	0 1	128 clock cycles	128
0	1 0	186 clock cycles	186
0	1 1	512 clock cycles	512
1	0 0	32 clock cycles	32
1	0 1	64 clock cycles	64
1	1 0	372 clock cycles	372
1	1 1	256 clock cycles	256

Tables 20.6 shows sample N settings in BRR in normal asynchronous mode. Table 20.7 shows the maximum bit rate settable for each operating frequency. Tables 20.9 and 20.11 show sample N settings in BRR in clock synchronous mode and smart card interface mode, respectively. In smart card interface mode, the number of base clock cycles S in a 1-bit data transfer time can be selected. For details, see section 20.5.4, Receive Data Sampling Timing and Reception Margin. Tables 20.8 and 20.10 show the maximum bit rates with external clock input.

When the ABCS bit in the serial extended mode register (SEMR) is set to 1 in asynchronous mode, the bit rate is two times that of shown in table 20.6.

Table 20.6 Examples of BRR Settings for Various Bit Rates (Asynchronous Mode) (1)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	8			9.8304			10			12		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	141	0.03	2	174	-0.26	2	177	-0.25	2	212	0.03
150	2	103	0.16	2	127	0.00	2	129	0.16	2	155	0.16
300	1	207	0.16	1	255	0.00	2	64	0.16	2	77	0.16
600	1	103	0.16	1	127	0.00	1	129	0.16	1	155	0.16
1200	0	207	0.16	0	255	0.00	1	64	0.16	1	77	0.16
2400	0	103	0.16	0	127	0.00	0	129	0.16	0	155	0.16
4800	0	51	0.16	0	63	0.00	0	64	0.16	0	77	0.16
9600	0	25	0.16	0	31	0.00	0	32	-1.36	0	38	0.16
19200	0	12	0.16	0	15	0.00	0	15	1.73	0	19	-2.34
31250	0	7	0.00	0	9	-1.70	0	9	0.00	0	11	0.00
38400	-	-	-	0	7	0.00	0	7	1.73	0	9	-2.34

Bit Rate (bps)	Operating Frequency PCLK (MHz)								
	12.288			14			16		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	217	0.08	2	248	-0.17	3	70	0.03
150	2	159	0.00	2	181	0.16	2	207	0.16
300	2	79	0.00	2	90	0.16	2	103	0.16
600	1	159	0.00	1	181	0.16	1	207	0.16
1200	1	79	0.00	1	90	0.16	1	103	0.16
2400	0	159	0.00	0	181	0.16	0	207	0.16
4800	0	79	0.00	0	90	0.16	0	103	0.16
9600	0	39	0.00	0	45	-0.93	0	51	0.16
19200	0	19	0.00	0	22	-0.93	0	25	0.16
31250	0	11	2.40	0	13	0.00	0	15	0.00
38400	0	9	0.00	—	—	—	0	12	0.16

Notes: This is an example when the ABCS bit in SEMR is 0.
When the ABCS bit is set to 1, the bit rate is two times.

Table 20.6 Examples of BRR Settings for Various Bit Rates (Asynchronous Mode) (2)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	17.2032			18			19.6608			20		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	75	0.48	3	79	-0.12	3	86	0.31	3	88	-0.25
150	2	223	0.00	2	233	0.16	2	255	0.00	3	64	0.16
300	2	111	0.00	2	116	0.16	2	127	0.00	2	129	0.16
600	1	223	0.00	1	233	0.16	1	255	0.00	2	64	0.16
1200	1	111	0.00	1	116	0.16	1	127	0.00	1	129	0.16
2400	0	223	0.00	0	233	0.16	0	255	0.00	1	64	0.16
4800	0	111	0.00	0	116	0.16	0	127	0.00	0	129	0.16
9600	0	55	0.00	0	58	-0.69	0	63	0.00	0	64	0.16
19200	0	27	0.00	0	28	1.02	0	31	0.00	0	32	-1.36
31250	0	16	1.20	0	17	0.00	0	19	-1.70	0	19	0.00
38400	0	13	0.00	0	14	-2.34	0	15	0.00	0	15	1.73

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	25			30			33			50		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	110	-0.02	3	132	0.13	3	145	0.33	3	221	-0.02
150	3	80	0.47	3	97	-0.35	3	106	0.39	3	162	-0.15
300	2	162	-0.15	2	194	0.16	2	214	-0.07	3	80	0.47
600	2	80	0.47	2	97	-0.35	2	106	0.39	2	162	-0.15
1200	1	162	-0.15	1	194	0.16	1	214	-0.07	2	80	0.47
2400	1	80	0.47	1	97	-0.35	1	106	0.39	1	162	-0.15
4800	0	162	-0.15	0	194	0.16	0	214	-0.07	1	80	0.47
9600	0	80	0.47	0	97	-0.35	0	106	0.39	1	40	-0.77
19200	0	40	-0.76	0	48	-0.35	0	53	-0.54	0	80	0.47
31250	0	24	0.00	0	29	0	0	32	0	0	49	0.00
38400	0	19	1.73	0	23	1.73	0	26	-0.54	0	40	-0.77

Notes: This is an example when the ABCS bit in SEMR is 0.
When the ABCS bit is set to 1, the bit rate is two times.

Table 20.7 Maximum Bit Rate for Each Operating Frequency (Asynchronous Mode)

PCLK (MHz)	Maximum Bit Rate (bps)	n	N	PCLK (MHz)	Maximum Bit Rate (bps)	n	N
8	250000	0	0	17.2032	537600	0	0
9.8304	307200	0	0	18	562500	0	0
10	312500	0	0	19.6608	614400	0	0
12	375000	0	0	20	625000	0	0
12.288	384000	0	0	25	781250	0	0
14	437500	0	0	30	937500	0	0
16	500000	0	0	33	1031250	0	0
				50	1562500	0	0

Note: When the ABCS bit in SEMR is set to 1, the bit rate is two times.

Table 20.8 Maximum Bit Rate with External Clock Input (Asynchronous Mode) (1)

PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
8	2.0000	125000	17.2032	4.3008	268800
9.8304	2.4576	153600	18	4.5000	281250
10	2.5000	156250	19.6608	4.9152	307200
12	3.0000	187500	20	5.0000	312500
12.288	3.0720	192000	25	6.2500	390625
14	3.5000	218750	30	7.5000	468750
16	4.0000	250000	33	8.2500	515625
			50	12.500	781250

Note: This is an example when the ABCS bit in SEMR is 0.

Table 20.8 Maximum Bit Rate with External Clock Input (Asynchronous Mode) (2)

PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
8	2.0000	250000	17.2032	4.3008	537600
9.8304	2.4576	307200	18	4.5000	562500
10	2.5000	312500	19.6608	4.9152	614400
12	3.0000	375000	20	5.0000	625000
12.288	3.0720	384000	25	6.2500	781250
14	3.5000	437500	30	7.5000	937500
16	4.0000	500000	33	8.2500	1031250
			50	12.500	1562500

Note: This is an example when the ABCS bit in SEMR is 1.

Table 20.9 BRR Settings for Various Bit Rates (Clock Synchronous Mode)

Bit Rate (bps)	Operating Frequency PCLK (MHz)															
	8		10		16		20		25		30		33		50	
	n	N	n	N	n	N	n	N	n	N	n	N	n	N	n	N
110																
250	3	124	-	-	3	249										
500	2	249	-	-	3	124	-	-			3	233				
1k	2	124	-	-	2	249	-	-	3	97	3	116	3	128	3	194
2.5k	1	199	1	249	2	99	2	124	2	155	2	187	2	205	3	77
5k	1	99	1	124	1	199	1	249	2	77	2	93	2	102	2	155
10k	0	199	0	249	1	99	1	124	1	155	1	187	1	205	2	77
25k	0	79	0	99	0	159	0	199	0	249	1	74	1	82	1	124
50k	0	39	0	49	0	79	0	99	0	124	0	149	0	164	1	61
100k	0	19	0	24	0	39	0	49	0	62	0	74	0	82	0	124
250k	0	7	0	9	0	15	0	19	0	24	0	29	0	32	0	49
500k	0	3	0	4	0	7	0	9	-	-	0	14	-	-	0	24
1M	0	1			0	3	0	4	-	-	-	-	-	-	-	-
2.5M			0	0*			0	1	-	-	0	2	-	-	0	4
5M							0	0*	-	-	-	-	-	-	-	-

[Legend]

Space: Setting proh bited.

-: Can be set, but there will be error.

Note: * Continuous transmission or reception is not possible.

Table 20.10 Maximum Bit Rate with External Clock Input (Clock Synchronous Mode)

PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	PCLK (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
8	1.3333	1333333.3	20	3.3333	3333333.3
10	1.6667	1666666.7	25	4.1667	4166666.7
12	2.0000	2000000.0	30	5.0000	5000000.0
14	2.3333	2333333.3	33	5.5000	5500000.0
16	2.6667	2666666.7	50	8.3333	8333333.3
18	3.0000	3000000.0			

Table 20.11 BRR Settings for Various Bit Rates (Smart Card Interface Mode, n = 0, S = 372)

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	7.1424			10.00			10.7136			13.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	0	0.00	0	1	30	0	1	25	0	1	8.99

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	14.2848			16.00			18.00			20.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	1	0.00	0	1	12.01	0	2	15.99	0	2	6.66

Bit Rate (bps)	Operating Frequency PCLK (MHz)											
	25.00			30.00			33.00			50.00		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
9600	0	3	12.49	0	3	5.01	0	4	7.59	0	6	0.00

Table 20.12 Maximum Bit Rate for Each Operating Frequency (Smart Card Interface Mode, S = 372)

PCLK (MHz)	Maximum Bit Rate (bps)	n	N	PCLK (MHz)	Maximum Bit Rate (bps)	n	N
10.00	13441	0	0	18.00	24194	0	0
10.7136	14400	0	0	20.00	26882	0	0
13.00	17473	0	0	25.00	33602	0	0
16.00	21505	0	0	30.00	40323	0	0
				33.00	44355	0	0
				50.00	67205	0	0

20.2.10 Serial Extended Mode Register (SEMR)

Addresses: SCI0.SEMR 0008 8247h, SCI1.SEMR 0008 824Fh, SCI2.SEMR 0008 8257h, SCI3.SEMR 0008 825Fh
SCI4.SEMR 0008 8267h, SCI5.SEMR 0008 826Fh, SCI6.SEMR 0008 8277h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	ABCS	—	—	—	ACS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Function	R/W
b0	ACS0	Asynchronous Mode Clock Source Select	(Valid only in asynchronous mode) 0: External clock input (SCI0 to SCI6) 1: TMR clock input (valid only for SCI5 and SCI6) The following table shows the correspondence between SCI channels and compare match outputs.	R/W*
b3 to b1	—	Reserved	These bits are read as 0. The write value should be 0.	R/W
b4	ABCS	Asynchronous Mode Base Clock Select	(Valid only in asynchronous mode) 0: Selects 16 base clock cycles for 1-bit period 1: Selects 8 base clock cycles for 1-bit period	R/W*
b7 to b5	—	Reserved	These bits are read as 0. The write value should be 0..	R/W

SCI	TMR	Compare Match Output
SCI5	Unit 0	TMO0, TMO1
SCI6	Unit 1	TMO2, TMO3

Note: * Writable only when TE in SCR = 0 and RE in SCR = 0 (both serial transmission and reception are disabled).

SEMR selects the clock source for 1-bit period in asynchronous mode.

For SCI5 and SCI6, the TMOn output (n = 0 to 3) of TMR units 0 and 1 can be set as the serial transfer base clock.

Figure 20.3 shows a setting example when the TMOn output of TMRn (n = 0 to 3) is selected.

ACS0 Bit (Asynchronous Mode Clock Source Select)

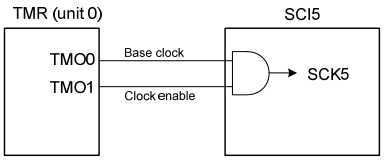
Selects the clock source in the asynchronous mode.

The ACS0 bit is valid in asynchronous mode (CM bit in SMR = 0) and when an external clock input is selected (CKE[1:0] bits in SCR = 10b or 11b). An external clock input or internal TMR clock input can be selected.

These bits for the other SCI channels than SCI5 and SCI6 are reserved. The write values to these bits for other than SCI5 and SCI6 should always be 0.

ABCS Bit (Asynchronous Mode Base Clock Select)

Selects the number of base clock pulses for 1-bit period.



This figure shows an example when TMR clock is input to SCI5.
When generating 187.5 kbps of TMR average transfer rate for PCLK = 32 MHz:

(1) Generate a frequency of 4 MHz using TMO0 as the base clock.
(2) Set TMO1 in the compare match count of TCNT in TMR0 and generate 3/4 clock enable to set an average transfer rate of 3 MHz/16 = 187.5 kbps.

Setting examples of TMR and SCI
TMR0.TCR = 08h (TMR0.TCNT is cleared at compare match in TMR0.TCORA, the count is incremented at rising edge of PCLK/2)
TMR0.TCCR = 09h
TMR1.TCR = 08h (TMR1.TCNT is cleared at compare match in TMR1.TCORA, the count is incremented at compare match A in TMR0.TCNT)
TMR1.TCCR = 18h
TMR0.TCSR = 09h (Low is output at compare match in TMR0.TCORA, High is output at compare match in TMR0.TCORB)
TMR1.TCSR = 09h (Low is output at compare match in TMR1.TCORA, High is output at compare match in TMR1.TCORB)
TMR0.TCNT = TMR1.TCNT = 0
TMR0.TCORA = 03h, TMR0.TCORB = 01h
TMR1.TCORA = 03h, TMR1.TCORB = 00h
SCI5.SEMR = 10h

When using SCI6, set TM02 as the base clock and TMO3 as clock enable.

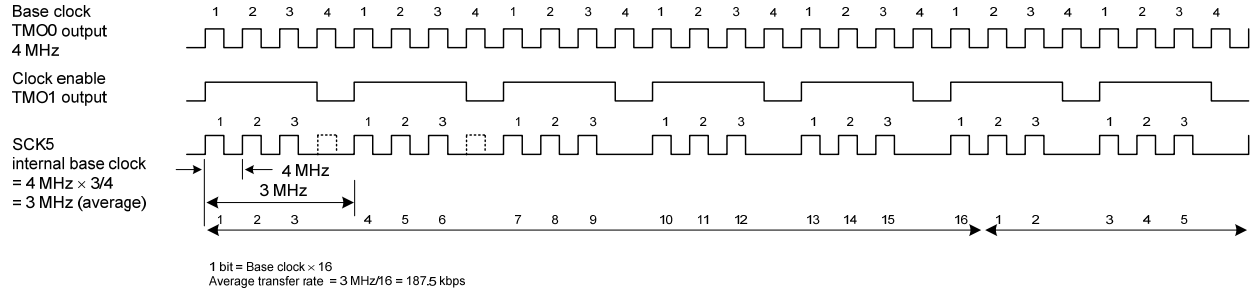


Figure 20.3 Example of Average Transfer Rate Setting when TMR Clock is Input

20.3 Operation in Asynchronous Mode

Figure 20.4 shows the general format for asynchronous serial communications.

One frame consists of a start bit (low level), transmit/receive data, a parity bit, and stop bits (high level).

In asynchronous serial communications, the communications line is usually held in the mark state (high level).

The SCI monitors the communications line, and when it goes to the space state (low level), recognizes a start bit and starts serial communications.

Inside the SCI, the transmitter and receiver are independent units, enabling full-duplex communications. Both the transmitter and the receiver also have a double-buffered structure, so that data can be read or written during transmission or reception, enabling continuous data transmission and reception.

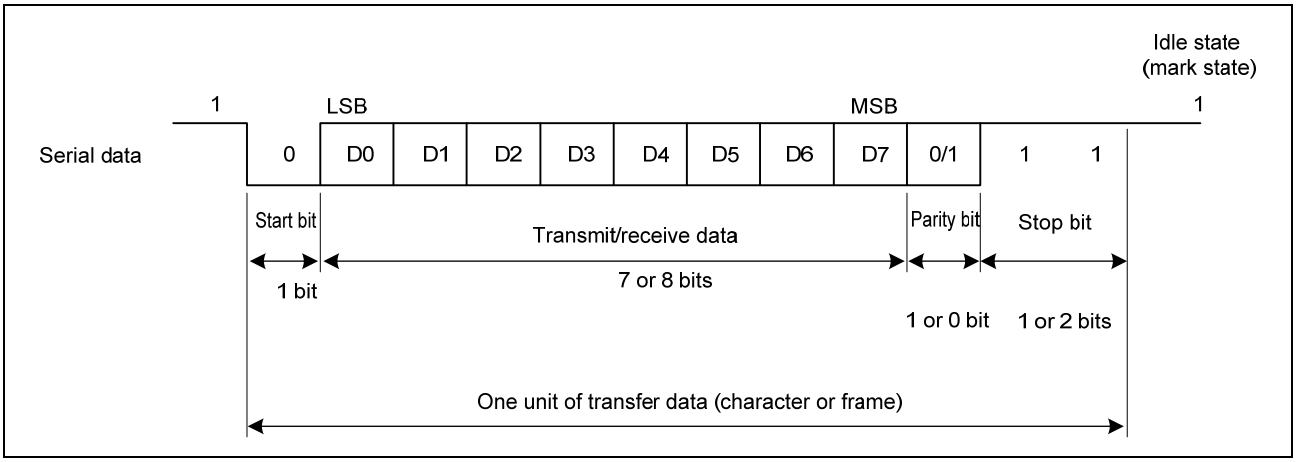


Figure 20.4 Data Format in Asynchronous Serial Communications (Example with 8-Bit Data, Parity, Two Stop Bits)

20.3.1 Serial Data Transfer Format

Table 20.13 shows the serial data transfer formats that can be used in asynchronous mode.

Any of 8 transfer formats can be selected according to the SMR setting.

Table 20.13 Serial Transfer Formats (Asynchronous Mode)

SMR Setting			Serial Transfer Format and Frame Length
CHR	PE	STOP	1 2 3 4 5 6 7 8 9 10 11 12
0	0	0	S 8-bit data STOP
0	0	1	S 8-bit data STOP STOP
0	1	0	S 8-bit data P STOP
0	1	1	S 8-bit data P STOP STOP
1	0	0	S 7-bit data STOP
1	0	1	S 7-bit data STOP STOP
1	1	0	S 7-bit data P STOP
1	1	1	S 7-bit data P STOP STOP

[Legend] S: Start bit
STOP: Stop bit
P: Parity bit

20.3.2 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI operates on a base clock with a frequency of 16 times* the bit rate.

In reception, the SCI samples the falling edge of the start bit using the base clock, and performs internal synchronization. Since receive data is sampled at the rising edge of the 8th pulse* of the base clock, data is latched at the middle of each bit, as shown in figure 20.5. Thus the reception margin in asynchronous mode is determined by formula (1) below.

$$M = \left| (0.5 - \frac{1}{2N}) - (L - 0.5) F - \frac{D - 0.5}{N} (1+F) \right| \times 100\ [\%] \quad \cdots \text{Formula (1)}$$

[Legend]
M: Reception margin
N: Ratio of bit rate to clock (N = 16 when ABCS in SEMR = 0, N = 8 when ABCS in SEMR = 1)
D: Duty cycle of clock (D = 0.5 to 1.0)
L: Frame length (L = 9 to 12)
F: Absolute value of clock frequency deviation

Assuming values of F = 0 and D = 0.5 in formula (1), the reception margin is determined by the formula below.

$$M = \{0.5 - 1/(2 \times 16)\} \times 100\ (\%) = 46.875\%$$

However, this is only the computed value, and a margin of 20% to 30% should be allowed in system design.

Note: * This is an example when the ABCS bit in SEMR is 0. When the ABCS bit is 1, a frequency of 8 times the bit rate is used as a base clock and receive data is sampled at the rising edge of the 4th pulse of the base clock.

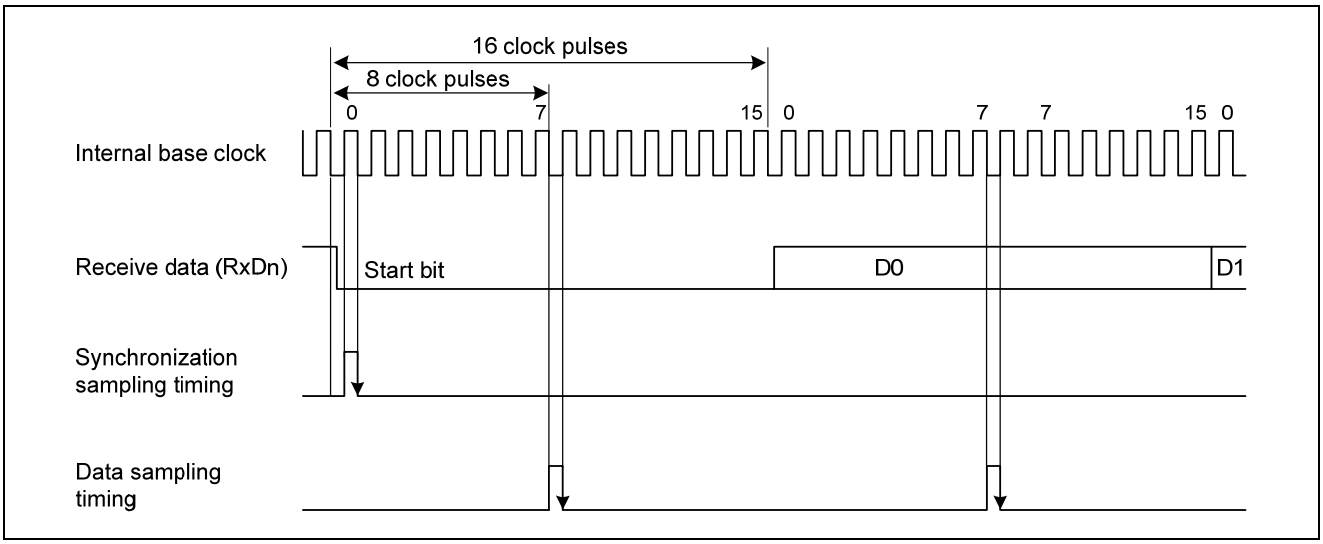


Figure 20.5 Receive Data Sampling Timing in Asynchronous Mode

20.3.3 Clock

Either an internal clock generated by the on-chip baud rate generator or an external clock input to the SCKn pin can be selected as the SCI's transfer clock, according to the setting of the CA bit in SMR and the CKE[1:0] bits in SCR.

When an external clock is input to the SCKn pin, the clock frequency should be 16 times the bit rate (when ABCS in SEMR = 0) and 8 times the bit rate (when ABCS in SEMR = 1). In addition, when an external clock is specified, the base clock of TMR0 and TMR1 can be selected by the ACS0 bit in SEMR of SCIn (n = 5, 6).

When the SCI is operated on an internal clock, the clock can be output from the SCKn pin. The frequency of the clock output in this case is equal to the bit rate, and the phase is such that the rising edge of the clock is in the middle of the transmit data, as shown in figure 20.6.

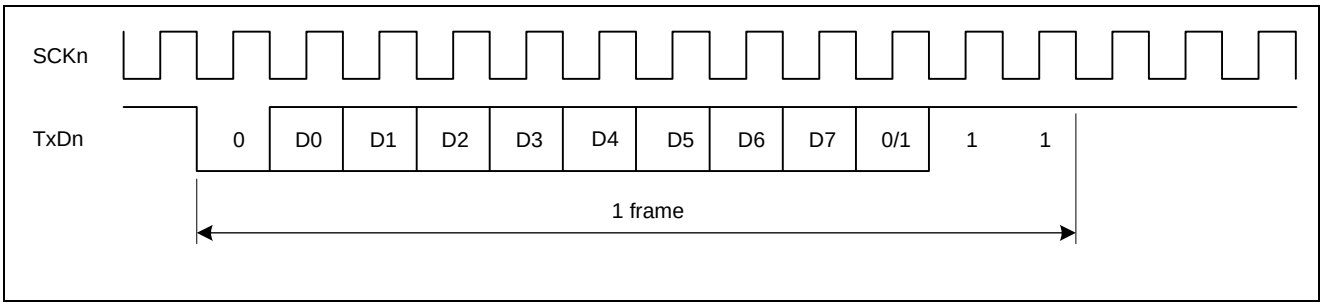


Figure 20.6 Phase Relationship between Output Clock and Transmit Data (Asynchronous Mode)

20.3.4 SCI Initialization (Asynchronous Mode)

Before transmitting and receiving data, start by writing the initial value "00h" to the SCR and then continue through the procedure for SCI given in the sample flowchart (figure 20.7). Whenever the operating mode or transfer format is changed, the SCR must be initialized before the change is made.

When the external clock is used in asynchronous mode, ensure that the clock signal is supplied even during initialization.

Note that clearing the SCR.RE bit to 0 initializes neither the ORER, FER, and PER flags in SSR nor RDR.

Moreover, note that switching the value of the SCR.TE bit from 1 to 0 or 0 to 1 while the SCR.TIE bit is 1 leads to the generation of a TXI interrupt request.

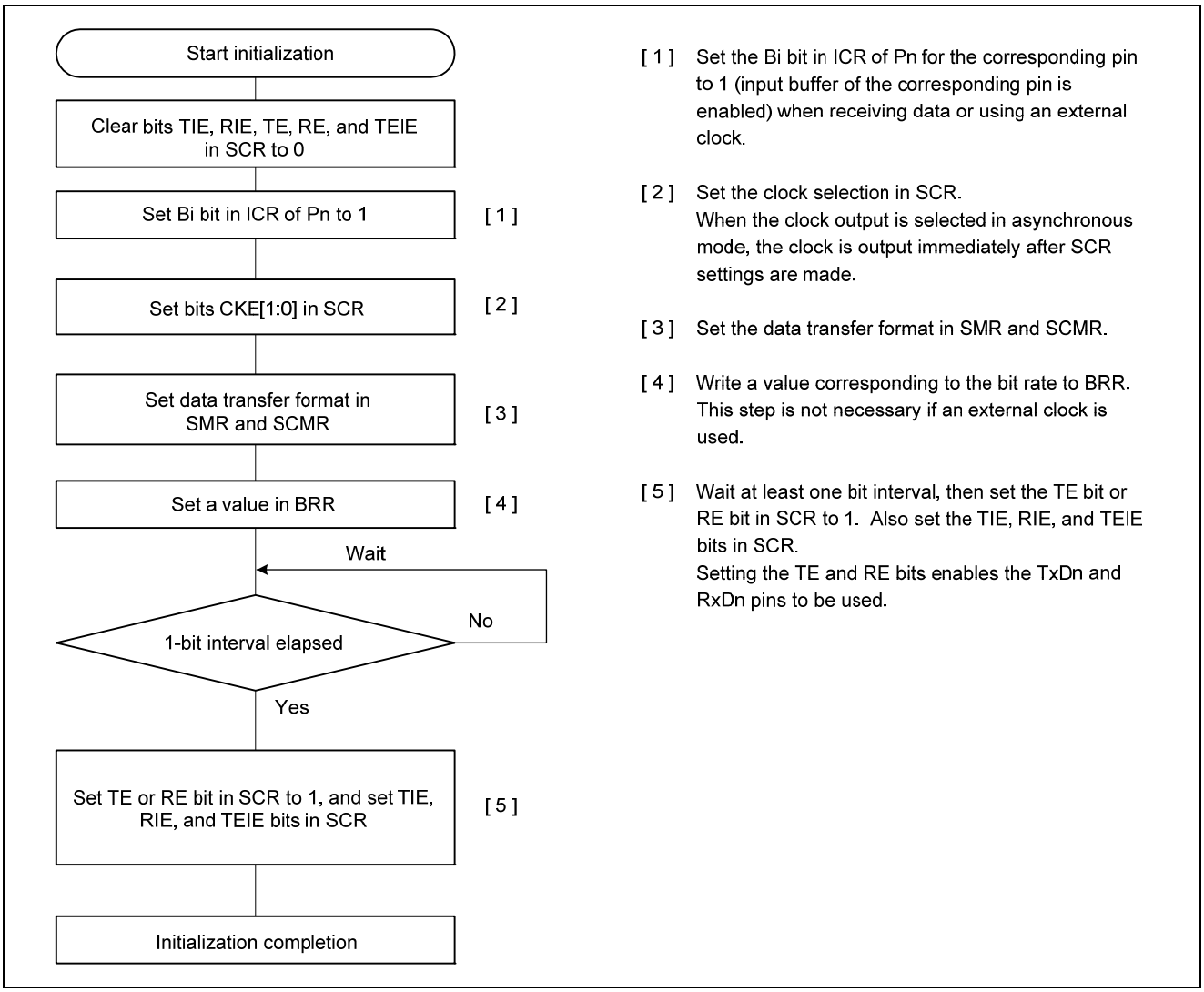


Figure 20.7 Sample SCI Initialization Flowchart (Asynchronous Mode)

20.3.5 Serial Data Transmission (Asynchronous Mode)

Figure 20.8 shows an example of the operation for serial transmission in asynchronous mode.

In serial transmission, the SCI operates as described below.

1. The SCI transfers data from TDR to TSR when data is written to TDR in the TXI interrupt processing routine. The TXI interrupt request at the beginning of transmission is generated when the TE bit in SCR is set to 1 after the TIE bit in SCR is set to 1 or when these two bits are set to 1 simultaneously by a single instruction.
2. After transferring data from TDR to TSR, the SCI starts transmission. If the TIE bit is set to 1 at this time, an SCR.TXI interrupt request is generated. Continuous transmission is enabled by writing the next transmit data to TDR in the TXI interrupt processing routine before transmission of the current transmit data is completed.
3. Data is sent from the TxDn pin in the following order: start bit, transmit data, parity bit (may be omitted depending on the format), and stop bit.
4. The SCI checks for updating of (writing to) the TDR at the time of stop bit output.
5. When TDR is updated, the next transmit data is transferred from TDR to TSR, the stop bit is sent, and then serial transmission of the next frame is started.
6. If TDR is not updated, the TEND flag in SSR is set to 1, the stop bit is sent, and then the mark state is entered in which high is output. If the TEND flag in SSR is set to 1 at this time, a TEI interrupt request is generated.

Figure 20.9 shows a sample flowchart for serial transmission in asynchronous mode.

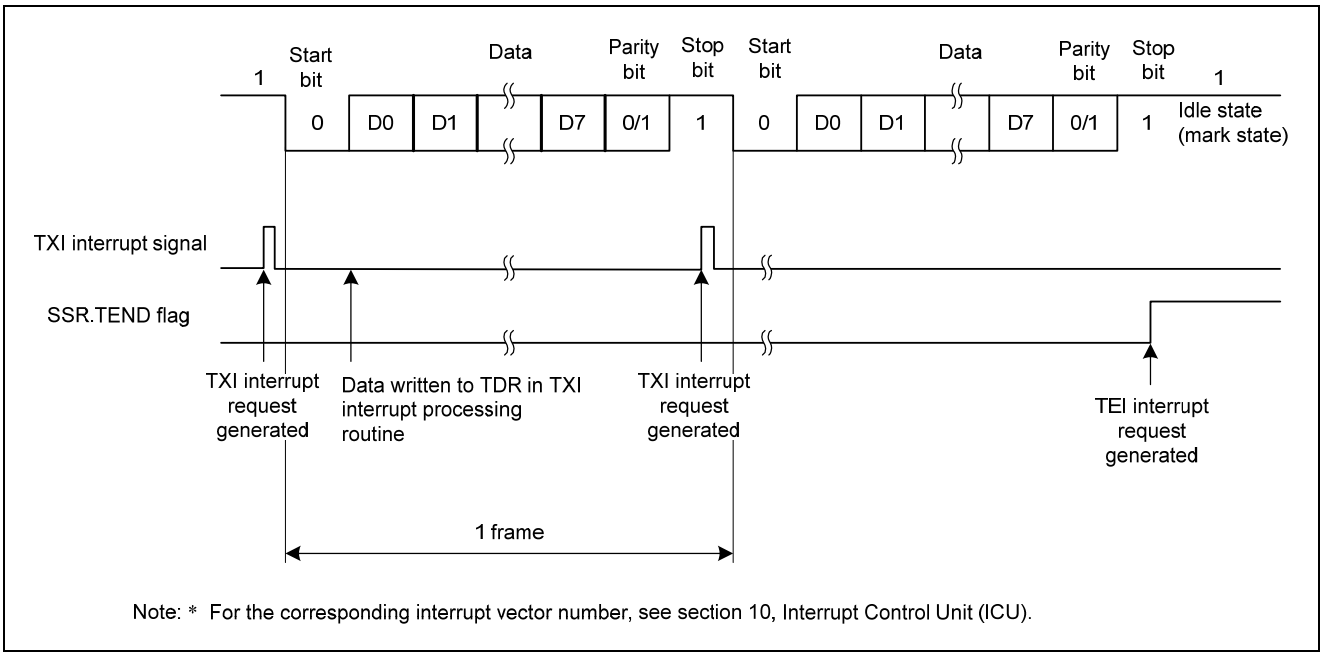
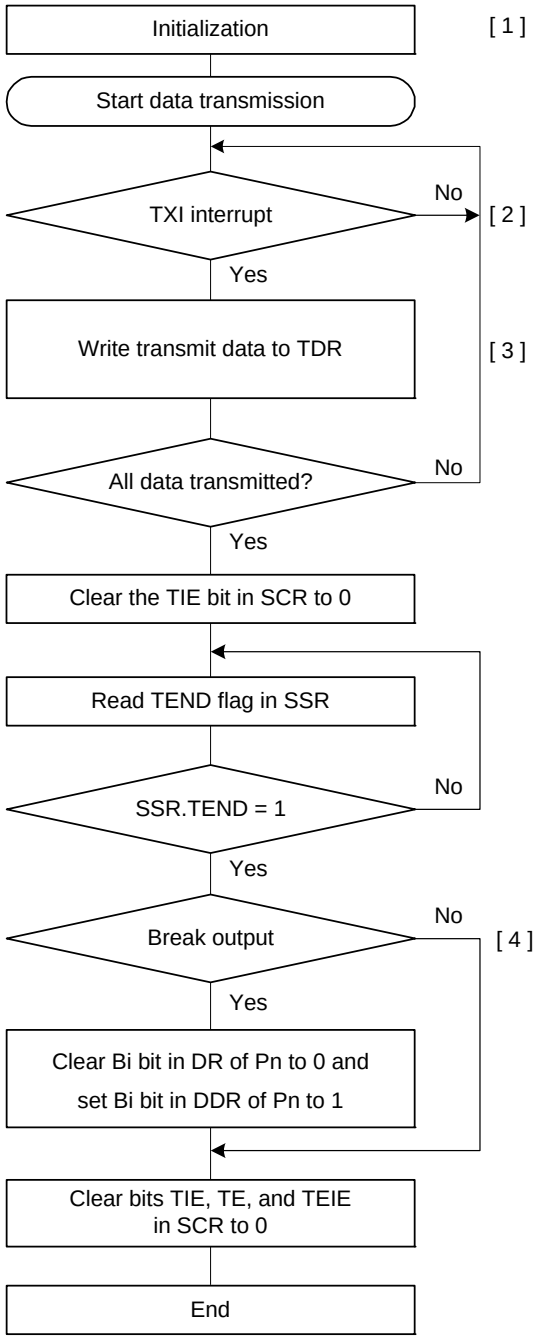


Figure 20.8 Example of Operation for Serial Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)



[1] SCIn initialization:
The TxDn pin is automatically designated as the transmit data output pin. After the TE bit in SCR is set to 1, a 1 is output for a frame, and transmission is enabled.

[2] Transmit data write to TDR upon accepting a TXI interrupt request:
When transmit data is transferred from TDR to TSR, a transmit data empty interrupt (TXI) request is generated. Write transmit data to TDR once in the TXI interrupt processing routine.

[3] Serial transmission continuation procedure:
To continue serial transmission, write transmit data to TDR once upon accepting a TXI interrupt request. Transmit data can also be written to TDR by initiating the DMAC or DTC.

[4] Break output at the end of serial transmission:
To output a break in serial transmission, set the Bi bit in DDR of Pn for the port corresponding to the TxDn pin to 1 (output port), clear the Bi bit in DR of Pn to 0 (low level output), then clear the TE bit in SCR to 0.

Figure 20.9 Example of Serial Transmission Flowchart in Asynchronous Mode

20.3.6 Serial Data Reception (Asynchronous Mode)

Figure 20.10 shows an example of the operation for serial data reception in asynchronous mode.

In serial data reception, the SCI operates as described below.

1. When the SCI monitors the communications line and detects a start bit, it performs internal synchronization, stores receive data in RSR, and checks the parity bit and stop bit.
2. If an overrun error occurs, the ORER flag in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR.
3. If a parity error is detected, the PER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated.
4. If a framing error (when the stop bit is 0) is detected, the FER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated.
5. When reception finishes successfully, receive data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an RXI interrupt request is generated. Continuous reception is enabled by reading the receive data transferred to RDR in this RXI interrupt processing routine before reception of the next receive data is completed.

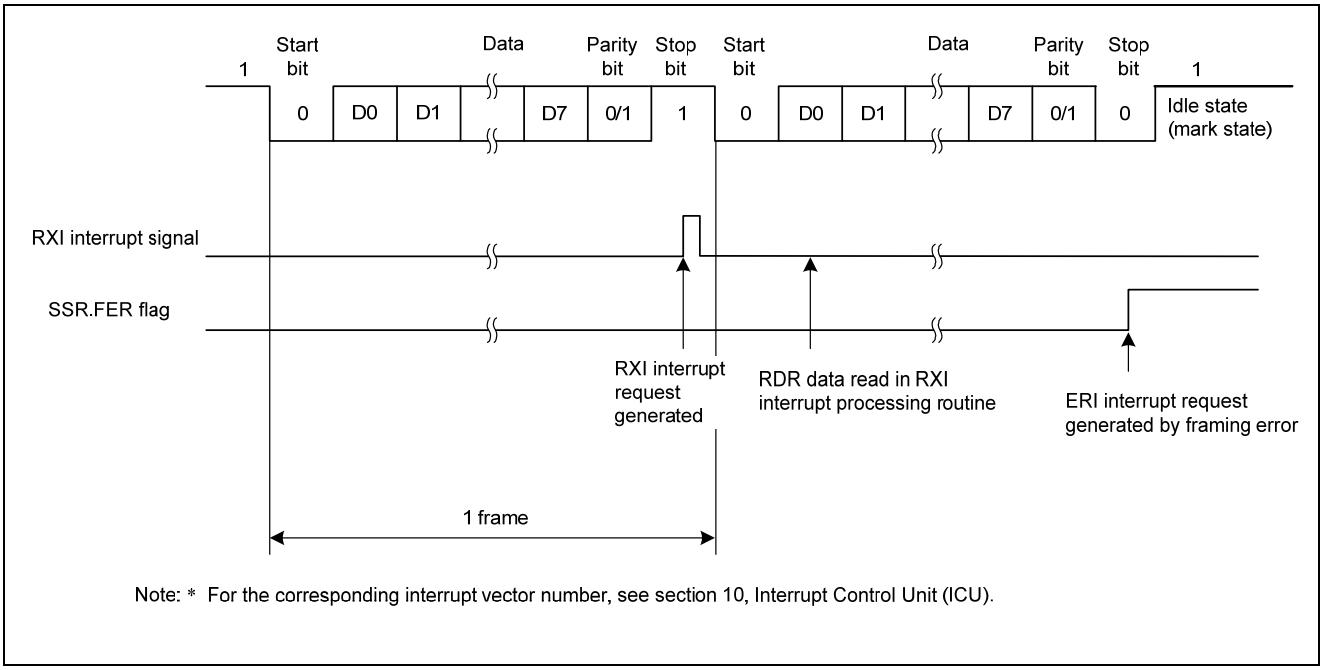


Figure 20.10 Example of SCI Operation for Serial Reception in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)

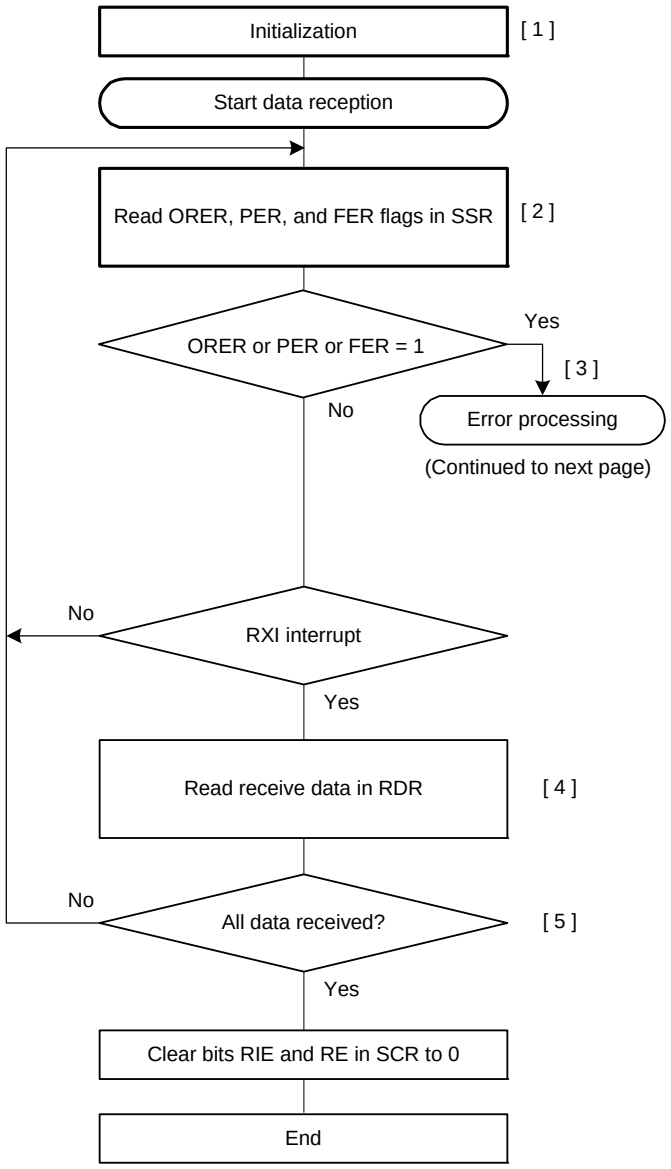
Table 20.14 shows the states of the SSR status flags and receive data handling when a receive error is detected.

If a receive error is detected, an ERI interrupt request is generated but an RXI interrupt request is not generated. Data reception cannot be resumed while the receive error flag is set to 1. Accordingly, clear the ORER, FER, and PER bits to 0 before resuming reception. Moreover, be sure to read the RDR during overrun error processing.

Figure 20.11 shows samples of flowcharts for serial data reception.

Table 20.14 SSR Status Flags and Receive Data Handling

SSR Status Flag				
ORER	**FER**	**PER**	**Receive Data**	**Receive Error Type**
1	0	0	Lost	Overrun error
0	1	0	Transferred to RDR	Framing error
0	0	1	Transferred to RDR	Parity error
1	1	0	Lost	Overrun error + framing error
1	0	1	Lost	Overrun error + parity error
0	1	1	Transferred to RDR	Framing error + parity error
1	1	1	Lost	Overrun error + framing error + parity error



[1] SCIn initialization:
The RxDn pin is automatically designated as the receive data input pin.

[2] [3] Receive error processing and break detection:
If a receive error occurs, an ERI interrupt is generated. After performing the appropriate error processing, be sure to clear the ORER, PER, and FER flags to 0. Reception cannot be resumed if any of these flags is set to 1. In the case of a framing error, a break can be detected by reading the value of the input port corresponding to the RxDn pin.

[4] Read the receive data in RDR once in the RXI interrupt processing routine.

[5] Serial reception continuation procedure:
To continue serial reception, before the stop bit of the current frame is received, read data from RDR in the RXI interrupt processing routine. The RDR data can also be read by initiating the DMAC or DTC.

Figure 20.11 Example of Serial Reception Flowchart (1) (Asynchronous Mode)

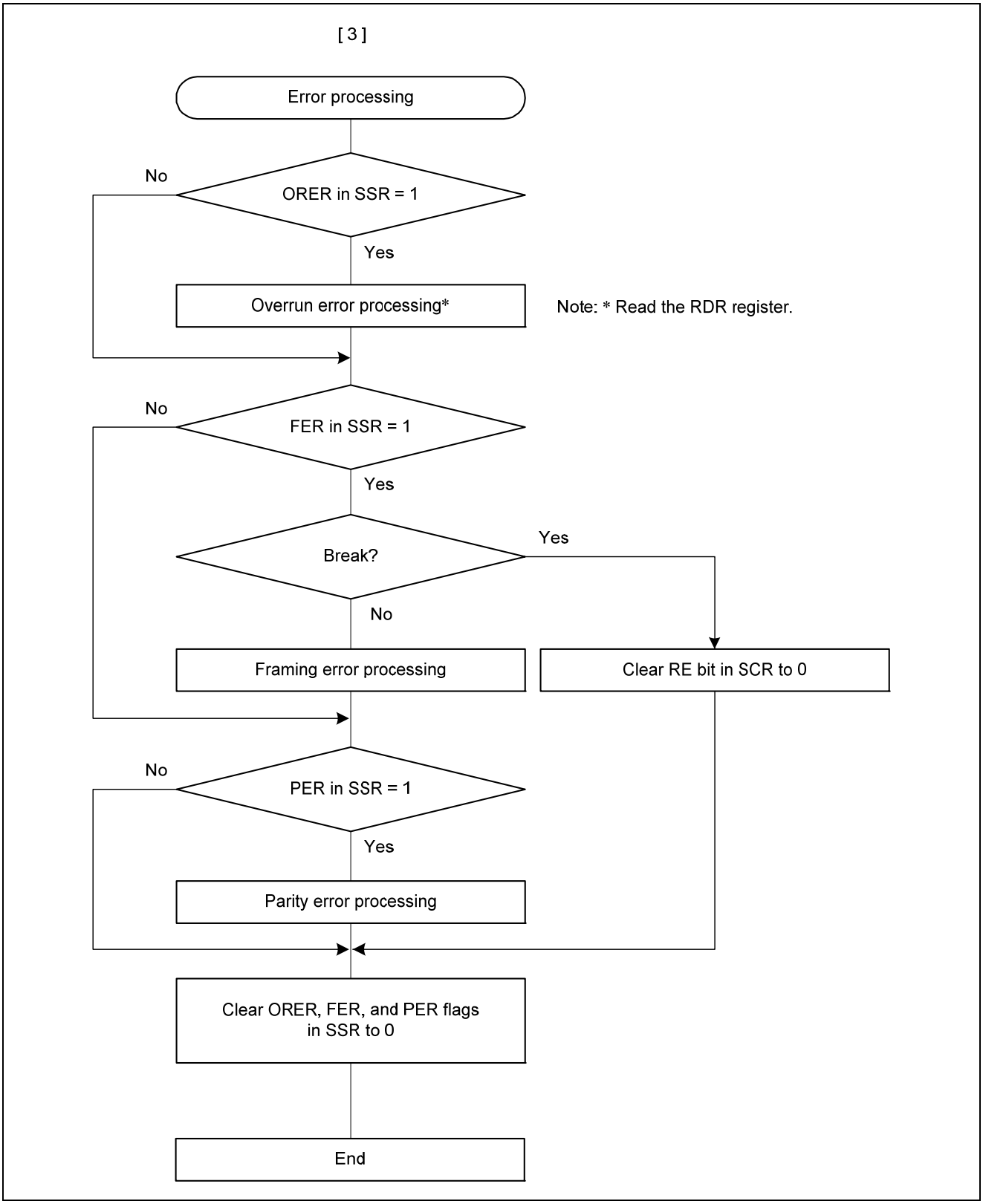


Figure 20.11 Example of Serial Reception Flowchart (2) (Asynchronous Mode)

20.4 Operation in Clock Synchronous Mode

Figure 20.12 shows the data format for clock synchronous serial data communications.

In clock synchronous mode, data is transmitted or received in synchronization with clock pulses. One character in transfer data consists of 8-bit data. In clock synchronous mode, no parity bit can be added.

In data transmission, the SCI outputs data from one falling edge of the synchronization clock to the next. In data reception, the SCI receives data in synchronization with the rising edge of the synchronization clock. After 8-bit data is output, the transmission line holds the MSB output state.

Inside the SCI, the transmitter and receiver are independent units, enabling full-duplex communications by use of a common clock. Both the transmitter and the receiver also have a double-buffered structure, so that the next transmit data can be written during transmission or the previous receive data can be read during reception, enabling continuous data transfer.

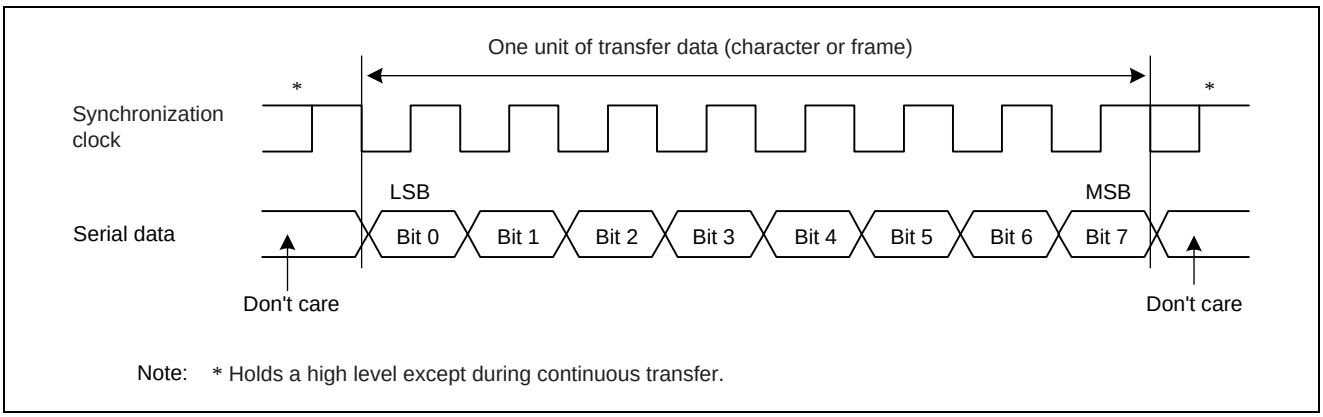


Figure 20.12 Data Format in Clock Synchronous Serial Communications (LSB-First)

20.4.1 Clock

Either an internal clock generated by the on-chip baud rate generator or an external synchronization clock input at the SCKn pin can be selected, according to the setting of the CKE[1:0] bits in SCR.

When the SCI is operated on an internal clock, the synchronization clock is output from the SCKn pin. Eight synchronization clock pulses are output in the transfer of one character, and when no transfer is performed the clock is held high. However, the synchronization clock is continuously output only during data reception until an overrun error occurs or the RE bit in SCR is cleared to 0.

20.4.2 SCI Initialization (Clock Synchronous Mode)

Before transmitting and receiving data, start by writing the initial value "00h" to the SCR and then continue through the procedure for SCI given in the sample flowchart (figure 20.13). Whenever the operating mode or transfer format is changed, the SCR must be initialized before the change is made.

Note that clearing the SCR.RE bit to 0 initializes neither the ORER, FER, and PER flags in SSR nor RDR.

Moreover, note that switching the value of the SCR.TE bit from 1 to 0 or 0 to 1 while the SCR.TIE bit is 1 leads to the generation of a TXI interrupt request.

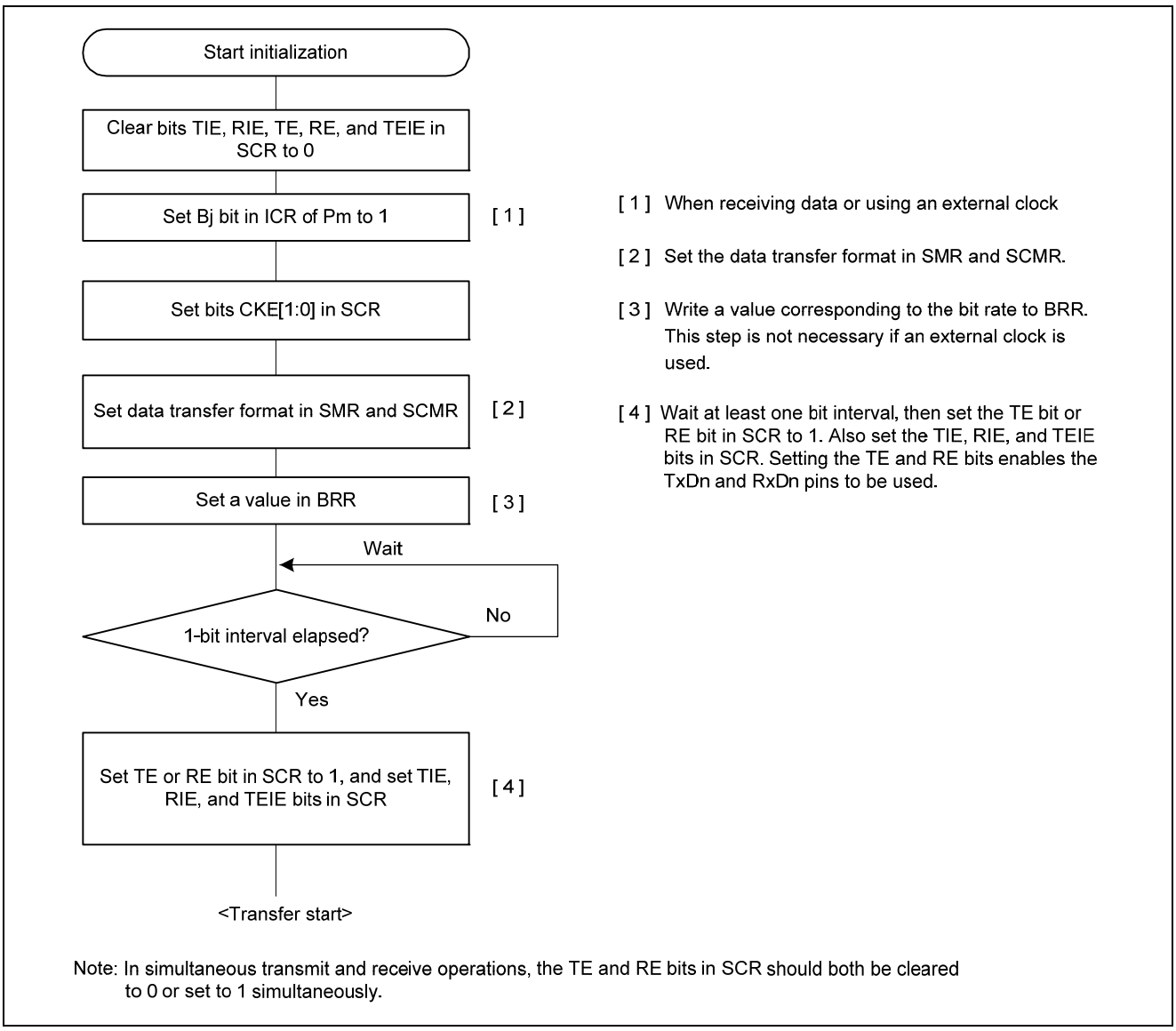


Figure 20.13 Example of SCI Initialization Flowchart (Clock Synchronous Mode)

20.4.3 Serial Data Transmission (Clock Synchronous Mode)

Figure 20.14 shows an example of the operation for serial transmission in clock synchronous mode.

In serial data transmission, the SCI operates as described below.

1. The SCI transfers data from TDR to TSR when data is written to TDR in the TXI interrupt processing routine. The TXI interrupt request at the beginning of transmission is generated when the TE bit in SCR is set to 1 after the TIE bit in SCR is set to 1 or when these two bits are set to 1 simultaneously by a single instruction.
2. After transferring data from TDR to TSR, the SCI starts transmission. When the TIE bit is set to 1 at this time, a TXI interrupt request is generated. Continuous transmission is enabled by writing the next transmit data to TDR in this TXI interrupt processing routine before transmission of the current transmit data has finished.
3. 8-bit data is sent from the TxDn pin in synchronization with the output clock when clock output mode has been specified and in synchronization with the input clock when use of an external clock has been specified.
4. The SCI checks for updating of (writing to) the TDR at the time of stop bit output.
5. When TDR is updated, the next transmit data is transferred from TDR to TSR, and serial transmission of the next frame is started.
6. If TDR is not updated, set the SSR flag in TEND to 1 and the TxDn pin retains the output state of the last bit. If the TEIE bit in SCR is set to 1 at this time, a TEI interrupt request is generated. The SCKn pin is held high.

Figure 20.15 shows a sample flowchart of serial data transmission.

Transmission will not start while a receive error flag (ORER, FER, or PER in SSR) is set to 1. Be sure to clear the receive error flags to 0 before starting transmission. Note that clearing the RE bit in SCR to 0 does not clear the receive error flags.

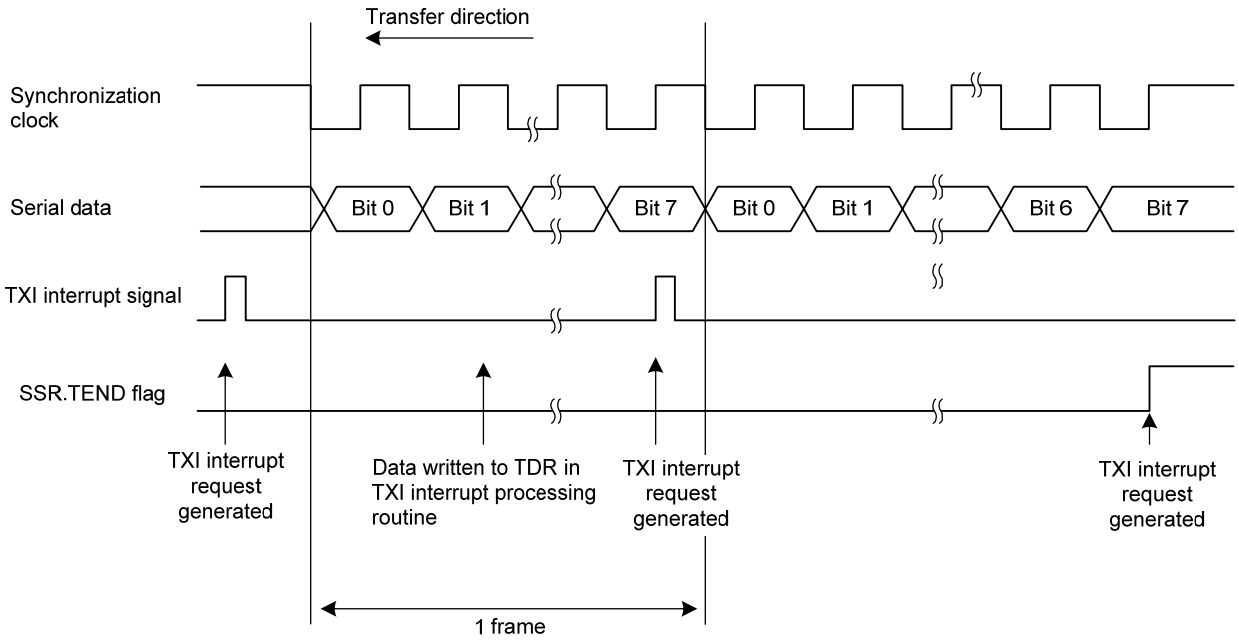
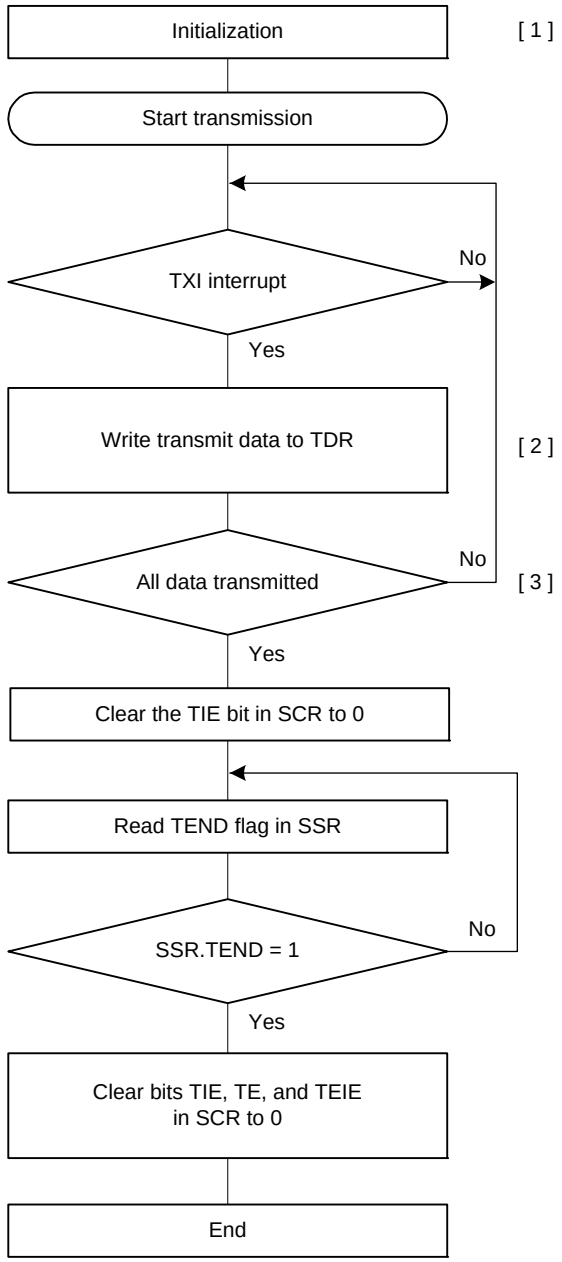


Figure 20.14 Example of Operation for Serial Transmission in Clock Synchronous Mode



[1] SCIn initialization:
The TxDn pin is automatically designated as the transmit data output pin.

[2] Transmit data write to TDR upon accepting a TXI interrupt request:
When transmit data is transferred from TDR to TSR, a transmit data empty interrupt (TXI) request is generated.
Write transmit data to TDR once upon accepting a transmit data empty interrupt (TXI) request.

[3] Serial transmission continuation procedure:
To continue serial transmission, write transmit data to TDR upon accepting a TXI interrupt request. Transmit data can also be written to TDR by initiating the DMAC or DTC when a TXI interrupt request is accepted.

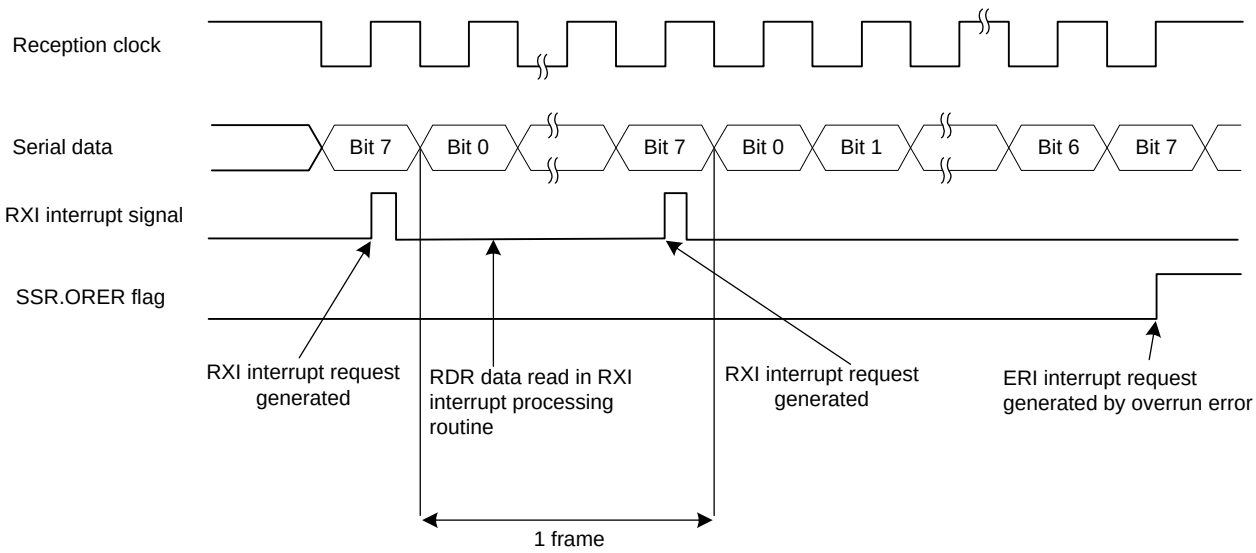
Figure 20.15 Example of Serial Transmission Flowchart (Clock Synchronous Mode)

20.4.4 Serial Data Reception (Clock Synchronous Mode)

Figure 20.16 shows an example of SCI operation for serial reception in clock synchronous mode.

In serial data reception, the SCI operates as described below.

1. The SCI performs internal initialization and starts receiving data in synchronization with a synchronization clock input or output, and stores the receive data in RSR.
   If an overrun error occurs, the ORER bit in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR.
2. When reception finishes successfully, receive data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an RXI interrupt request is generated. Continuous reception is enabled by reading the receive data transferred to RDR in this RXI interrupt processing routine before reception of the next receive data is completed.

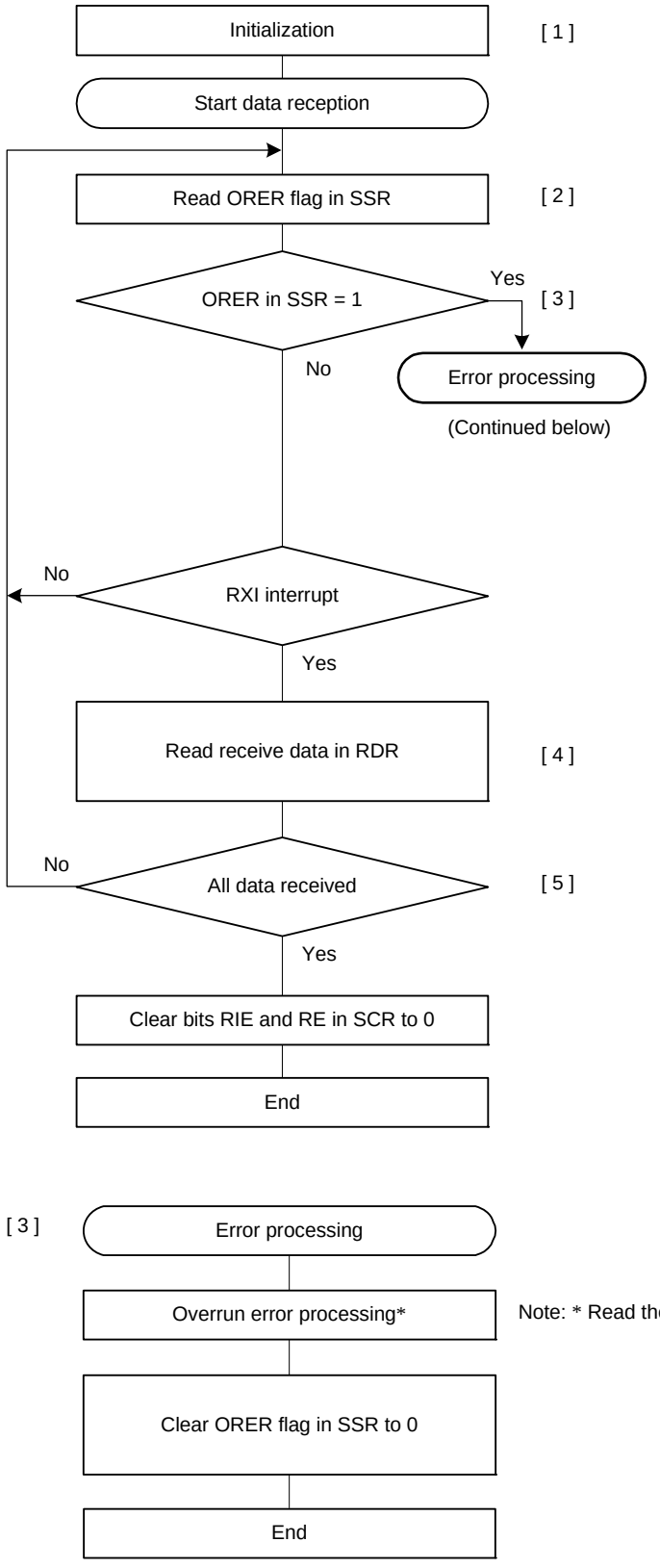


Note: * For the corresponding interrupt vector number, see section 10, Interrupt Control Unit (ICU).

Figure 20.16 Example of Operation for Serial Reception in Clock Synchronous Mode

Data transfer cannot be resumed while a receive error flag is set to 1. Accordingly, clear the ORER, FER, and PER bits in SSR to 0 before resuming reception. Moreover, be sure to read the RDR during overrun error processing.

Figure 20.17 shows a sample flowchart for serial data reception.



[1] SCIn initialization:
Set the port to be used as the RxDn pin to an input port.

[2] [3] Receive error processing:
If a receive error occurs, read the ORER flag in SSR, perform the relevant error processing, and then clear the ORER flag to 0. Data reception cannot be resumed while the ORER flag is set to 1.

[4] Read the receive data in RDR once upon accepting an RXI interrupt request.

[5] Serial reception continuation procedure:
To continue serial reception, before the MSB (bit 7) of the current frame is received, finish reading the receive data in RDR. The RDR data can also be read by initiating the DMAC or DTC when an RXI interrupt request is accepted.

Note: * Read the RDR register.

Figure 20.17 Example of Serial Reception Flowchart (Clock Synchronous Mode)

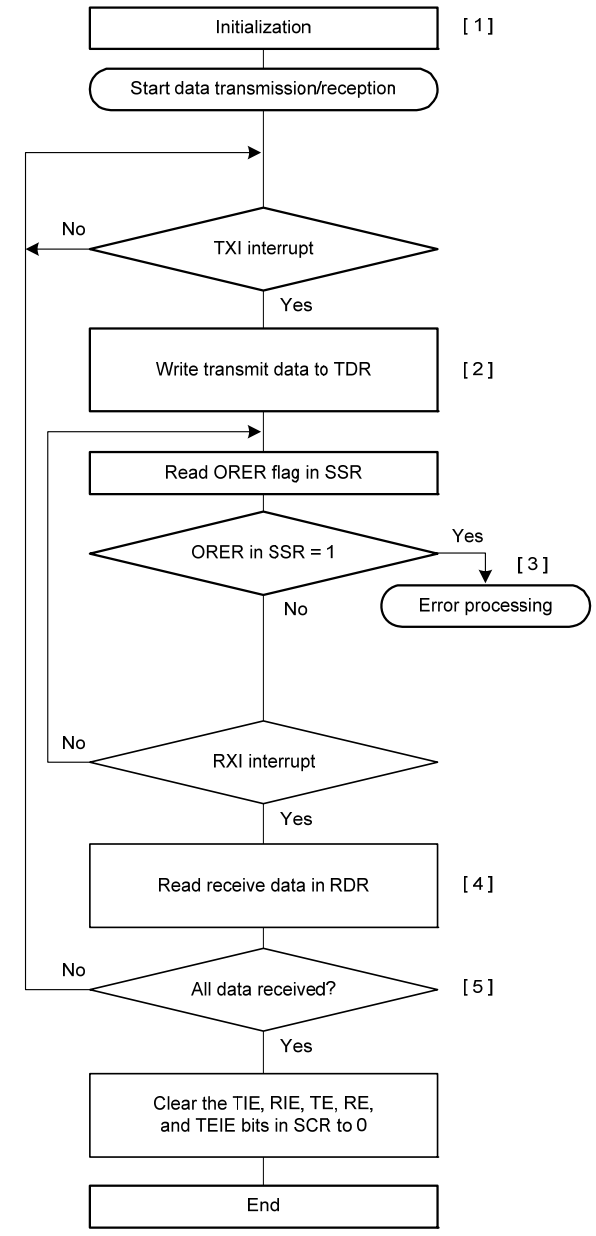
20.4.5 Simultaneous Serial Data (Clock Synchronous Mode)

Figure 20.18 shows a sample flowchart for simultaneous serial transmit and receive operations in clock synchronous mode.

After initializing the SCI, the following procedure should be used for simultaneous serial data transmit and receive operations.

To switch from transmit mode to simultaneous transmit and receive mode, check that the SCI has finished by reading that the TEND flag in SSR in SSR is set to 1, and then initialize the SCR register. Then set the TIE, RIE, TE, RE, and TEIE bits in SCR to 1 simultaneously by a single instruction.

To switch from receive mode to simultaneous transmit and receive mode, check that the SCI has finished reception, and then clear the RIE and RE bits to 0. Then check that the receive error flags (ORER, FER, and PER in SSR) are cleared to 0, and then the TIE, RIE, TE, RE, and TEIE bits in SCR to 1 simultaneously by a single instruction.



[1] SCI initialization:
The TxDn pin is designated as the transmit data output pin, and the RxDn pin is designated as the receive data input pin, enabling simultaneous transmit/receive operations.

[2] Transmit data write:
Write transmit data to TDR once upon accepting a TXI interrupt request.

[3] Receive error processing:
If a receive error occurs, read the ORER flag in SSR, perform the relevant error processing, and then clear the ORER flag to 0. Data reception cannot be resumed while the ORER flag is set to 1.

[4] Receive data read:
Read the receive data in RDR once upon accepting an RXI interrupt request.

[5] Serial transmission/reception continuation procedure:
To continue serial transmission/reception, before the MSB (bit 7) of the current frame is received, finish reading the receive data in RDR by the RXI interrupt. Also, before the MSB (bit 7) of the current frame is transmitted, write data to TDR by the TX interrupt.
Transmit data can also be written to TDR by initiating the DMAC or DTC when a transmit data empty interrupt (TXI) request is accepted. Similarly, the RDR data can also be read by initiating the DMAC or DTC when a receive data full interrupt (RXI) request is accepted.

Note: When switching from transmit or receive operation to simultaneous transmit and receive operations, first clear the TIE, RIE, TE, RE, and TEIE bits in SCR to 0, and then set these bits to 1 simultaneously.

Figure 20.18 Example of Simultaneous Serial Transmission/Reception Flowchart (Clock Synchronous Mode)

20.5 Operation in Smart Card Interface Mode

The SCI supports the smart card (IC card) interface conforming to the ISO/IEC 7816-3 (Identification Card) standard, as an extended function of the SCI.

Smart card interface mode can be selected using the appropriate register.

20.5.1 Sample Connection

Figure 20.19 shows a sample connection between the smart card (IC card) and this LSI.

As in the figure, since this LSI communicates with the IC card using a single transmission line, interconnect the TxDn and RxDn pins and pull up the data transmission line to Vcc using a resistor.

Setting the TE and RE bits in SCR to 1 with the IC card disconnected enables closed transmission/reception allowing self diagnosis.

To supply the IC card with the clock pulses generated by the SCI, input the SCKn pin output to the CLK pin of the IC card.

The output port of this LSI can be used to output a reset signal.

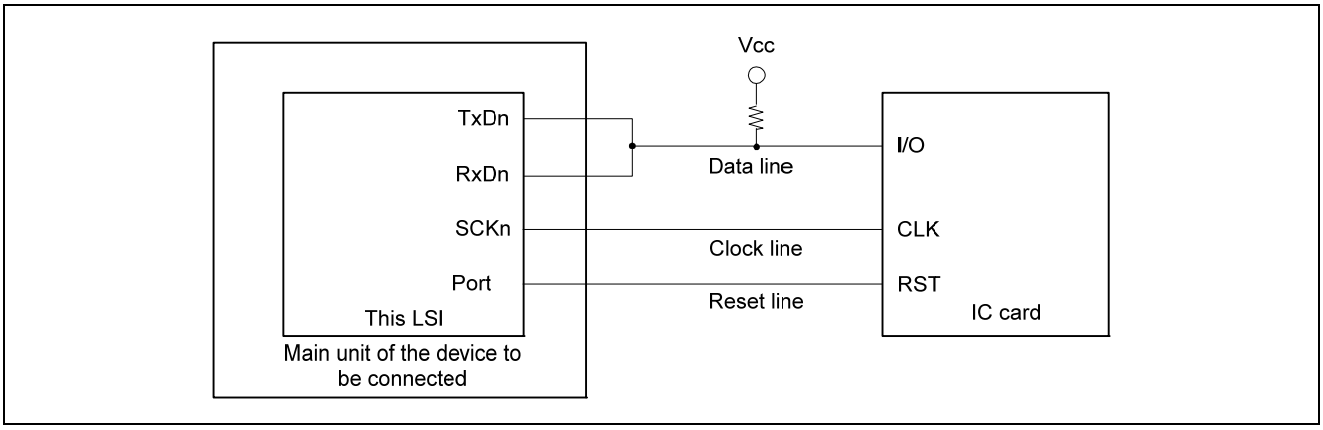


Figure 20.19 Sample Connection with a Smart Card (IC Card)

20.5.2 Data Format (Except in Block Transfer Mode)

Figure 20.20 shows the data transfer formats in smart card interface mode.

- One frame consists of 8-bit data and a parity bit in asynchronous mode.
- During transmission, at least 2 etu (elementary time unit: time required for transferring one bit) is secured as a guard time from the end of the parity bit until the start of the next frame.
- If a parity error is detected during reception, a low-level error signal is output for 1 etu after 10.5 etu has passed from the start bit.
- If an error signal is sampled during transmission, the same data is automatically re-transmitted after at least 2 etu.

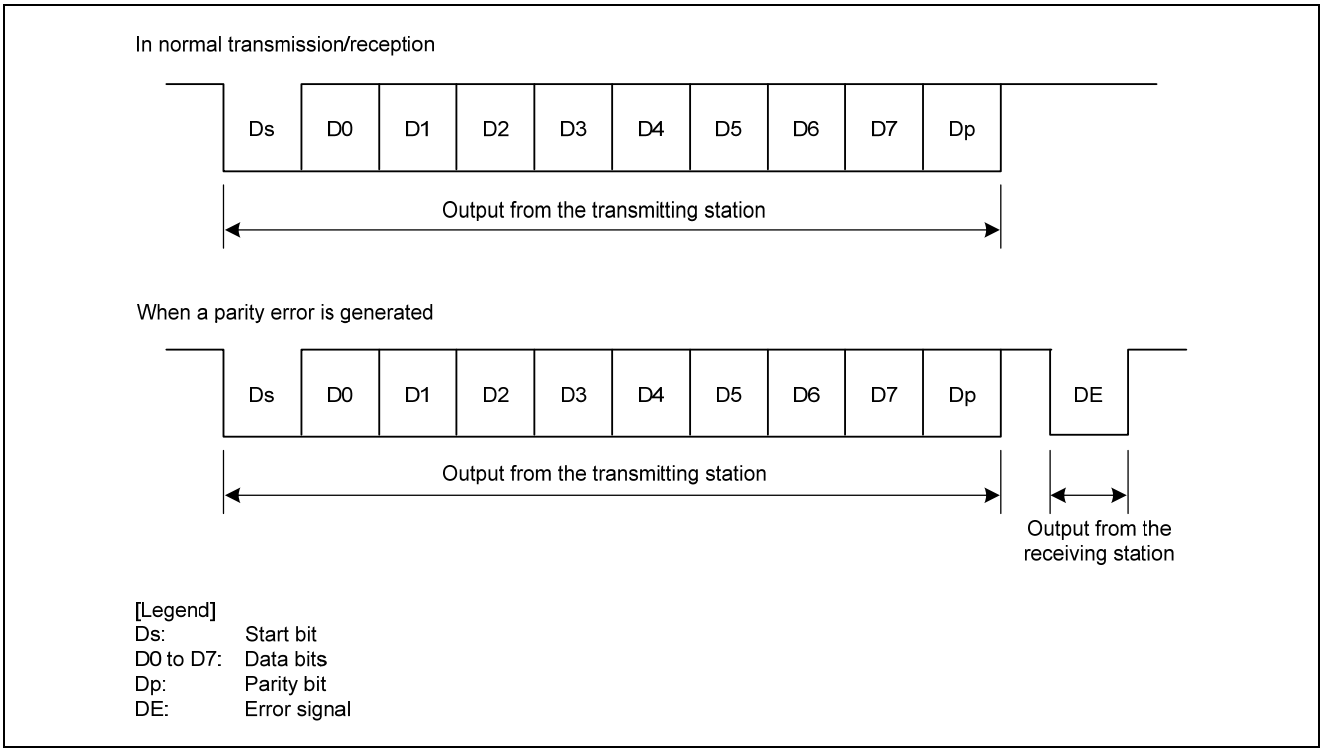


Figure 20.20 Data Formats in Smart Card Interface Mode

For communications with IC cards of the direct convention type and inverse convention type, follow the procedure below.

(1) Direct Convention Type

For the direct convention type, logic levels 1 and 0 correspond to states Z and A, respectively, and data is transferred with LSB-first as the start character, as shown in figure 20.21. Therefore, data in the start character in the figure is 3Bh.

When using the direct convention type, write 0 to both the SDIR and SINV bits in SCMR. Write 0 to the PM bit in SMR in order to use even parity, which is prescribed by the smart card standard.

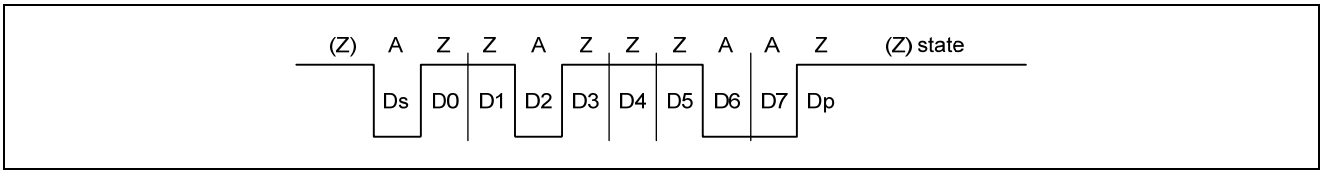


Figure 20.21 Direct Convention (SDIR in SCMR = 0, SINV in SCMR =0, PM in SMR = 0)

(2) Inverse Convention Type

For the inverse convention type, logic levels 1 and 0 correspond to states A and Z, respectively and data is transferred with MSB-first as the start character, as shown in figure 20.22. Therefore, data in the start character in the figure is 3Fh.

When using the inverse convention type, write 1 to both the SDIR and SINV bits in SCMR. The parity bit is logic level 0 to produce even parity, which is prescribed by the smart card standard, and corresponds to state Z. Since the SNIV bit of this LSI only inverts data bits D7 to D0, write 1 to the PM bit in SMR to invert the parity bit for both transmission and reception.

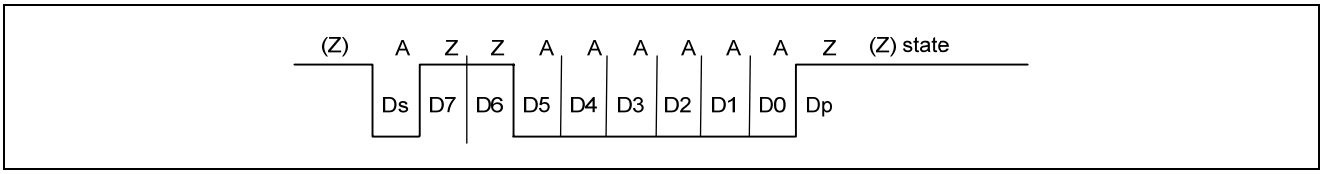


Figure 20.22 Inverse Convention (SDIR in SCMR = 1, SINV in SCMR =1, PM in SMR = 1)

20.5.3 Block Transfer Mode

Block transfer mode is different from normal smart card interface mode in the following respects.

- Even if a parity error is detected during reception, no error signal is output. Since the PER bit in SSR is set by error detection, clear the PER bit before receiving the parity bit of the next frame.
- During transmission, at least 1 etu is secured as a guard time from the end of the parity bit until the start of the next frame.
- Since the same data is not re-transmitted during transmission, the SSR.TEND flag is set 11.5 etu after transmission start.
- In block transfer mode, the ERS flag in SSR indicates the error signal status as in normal smart card interface mode, but the flag is always read as 0 because no error signal is transferred.

20.5.4 Receive Data Sampling Timing and Reception Margin

Only the internal clock generated by the on-chip baud rate generator can be used as a transfer clock in smart card interface mode.

In this mode, the SCI can operate on a base clock with a frequency of 32, 64, 372, 256, 93, 128, 186, or 512 times the bit rate according to the settings of the BCP2 bit in SCMR and BCP[1:0] bits in SMR (the frequency is always 16 times the bit rate in normal asynchronous mode).

For data reception, the falling edge of the start bit is sampled with the base clock to perform internal synchronization. For data reception, the falling edge of the start bit is sampled with the base clock to perform internal synchronization. Receive data is sampled on the 16th, 32nd, 186th, 128th, 46th, 64th, 93rd, and 256th rising edges of the base clock so that it can be latched at the middle of each bit as shown in figure 20.23. The reception margin here is determined by the following formula.

$$M = \left| (0.5 - \frac{1}{2N}) - (L - 0.5)\ F - \frac{\left| D - 0.5 \right|}{N}\ (1+F) \right| \times 100\ [\%]$$

[Legend]
M: Reception margin (%)
N: Ratio of bit rate to clock (N = 32, 64, 372, 256)
D: Duty cycle of clock (D = 0 to 1.0)
L: Frame length (L = 10)
F Absolute value of clock frequency deviation

Assuming values of F = 0, D = 0.5, and N = 372 in the above formula, the reception margin is determined by the formula below.

$$M = \{0.5 - 1/(2 \times 372)\} \times 100\ (\%) = 49.866\%$$

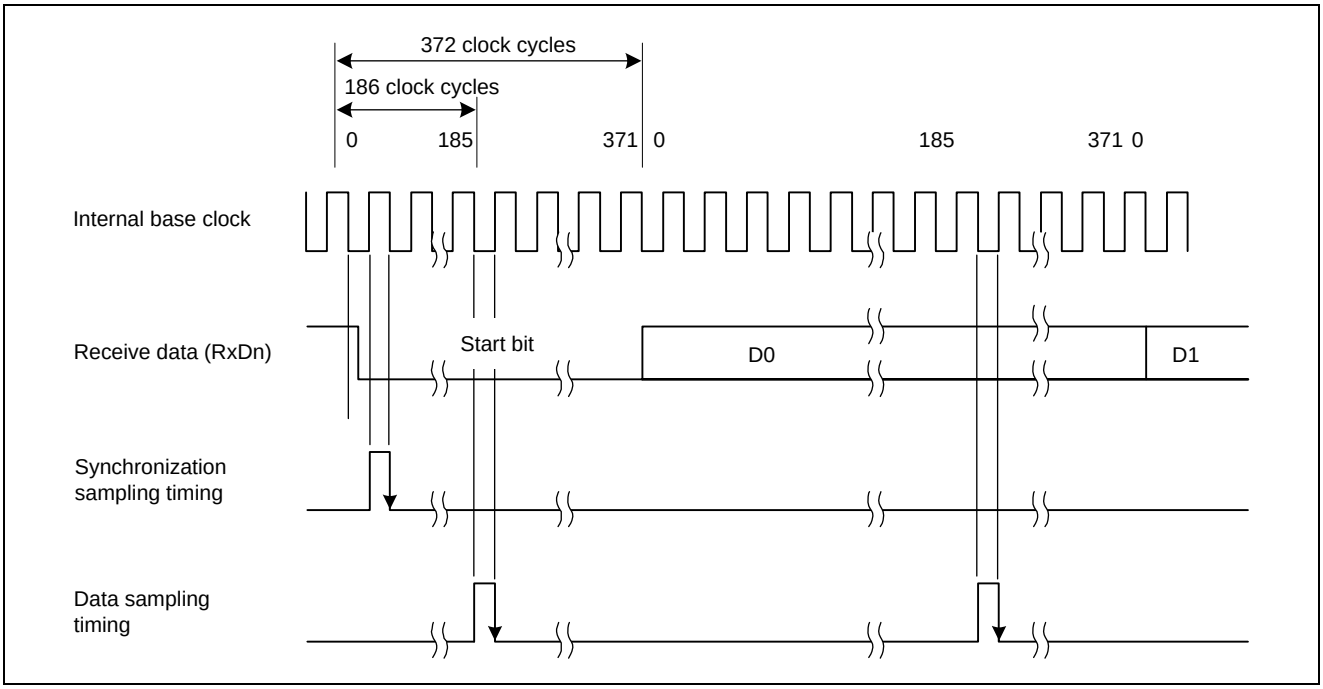


Figure 20.23 Receive Data Sampling Timing in Smart Card Interface Mode (When Clock Frequency is 372 Times the Bit Rate)

20.5.5 Initialization of the SCI

Before transmitting and receiving data, initialize the SCI using the following procedure. Initialization is also necessary before switching from transmission to reception and vice versa.

1. Write the initial value "00h" to the SCR.
2. Set the Bj bit (j = 0 to 7) in ICR of Pm (m = 0 to 9, A to E) of the corresponding pin to 1.
3. Set the error flags ORER, ERS, and PER in SSR to 0.
4. Set bits GM, BLK, OE, BCP[1:0], and CKS[1:0] in SMR and the BCP2 bit in SCMR appropriately. Also set the PE bit in SMR to 1.
5. Set bits SDIR, SINV, and SMIF in SCMR appropriately. Also set the Bj bit in DDR of Pm corresponding to the TxDn pin to 0. Then the TxDn and RxDn pins are changed from port pins to SCI pins, placing the pins into high impedance state.
6. Set the value corresponding to the bit rate in BRR.
7. Set the CKE[1:0] bits in SCR appropriately, and set bits TIE, RIE, TE, RE, and TEIE in SCR to 0 at the same time. When the CKE0 bit is set to 1, the SCKn pin is allowed to output clock pulses.
8. Wait for at least a 1-bit interval, and then set the TIE, RIE, TE, and RE bits in SCR. Setting the TE and RE bits to 1 simultaneously is prohibited except for self diagnosis.

To change reception mode to transmission mode, first check that reception has completed, and then initialize the SCI. At the end of initialization, set TE = 1 and RE = 0. Reception completion can be verified by reading the RXI request, ORER, or PER flag in SSR.

To change transmission mode to reception mode, first check that transmission has completed, and then initialize the SCI. At the end of initialization, set TE = 0 and RE = 1. Transmission completion can be verified by reading the SSR.TEND flag.

20.5.6 Serial Data Transmission (Except in Block Transfer Mode)

Serial data transmission in smart card interface mode (except in block transfer mode) is different from that in normal serial communications interface mode in that an error signal is sampled and data can be re-transmitted. Figure 20.24 shows the data re-transfer operation during transmission.

1. When an error signal from the receiving end is sampled after one-frame data has been transmitted, the ERS flag in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Clear the ERS flag to 0 before the next parity bit is sampled.
2. For a frame in which an error signal is received, the SSR.TEND flag is not set. Data is re-transferred from TDR to TSR allowing automatic data retransmission.
3. If no error signal is returned from the receiving end, the ERS flag in SSR is not set to 1.
4. In this case, the SCI judges that transmission of one-frame data (including retransfer) has been completed, and the SSR.TEND flag is set. If the TIE bit in SCR is set to 1 at this time, a TXI interrupt request is generated. Writing transmit data to TDR starts transmission of the next data.

Figure 20.26 shows a sample flowchart of serial transmission. All the processing steps are automatically performed using a TXI interrupt request to activate the DTC or DMAC.

When the SSR.TEND flag is set to 1 in transmission, if the TIE bit in SCR is set to 1, a TXI interrupt request is generated. The DTC or DMAC is activated by a TXI interrupt request if the TXI interrupt request is specified as a source of DTC or DMAC activation beforehand, allowing transfer of transmit data. The TEND flag is automatically cleared to 0 when the DTC or DMAC transfers the data.

If an error occurs, the SCI automatically re-transmits the same data. During this retransmission, the TEND flag is kept to 0 and the DTC or DMAC is not activated. Therefore, the SCI and DTC or DMAC automatically transmit the specified number of bytes, including retransmission in the case of error occurrence. However, since the ERS flag is not automatically cleared; set the RIE bit to 1 beforehand to enable an ERI interrupt request to be generated at error occurrence, and clear the ERS flag to 0.

When transmitting/receiving data using the DTC or DMAC, be sure to make settings to enable the DTC or DMAC before making SCI settings.

For DTC or DMAC settings, see section 12, DMA Controller (DMAC) and section 13, Data Transfer Controller (DTC).

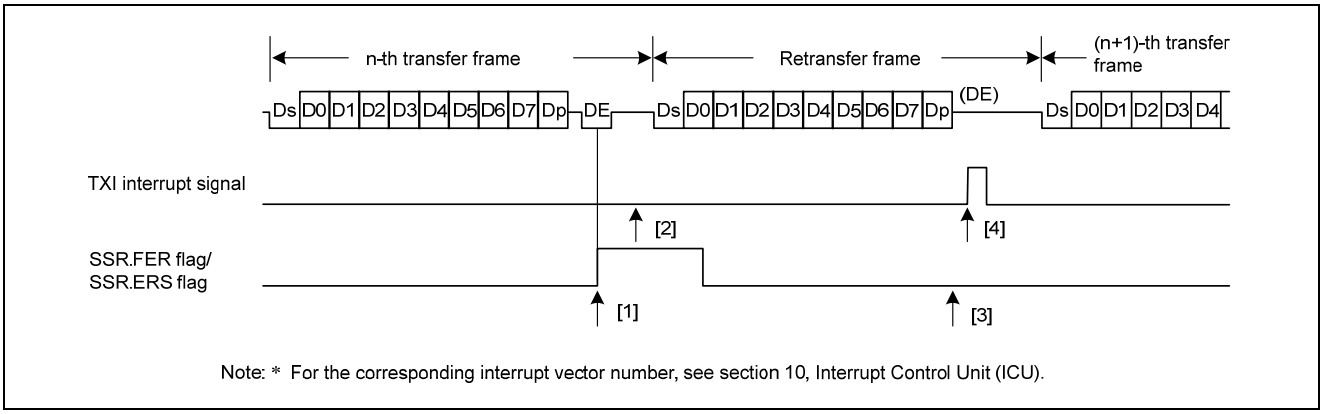


Figure 20.24 Data Retransfer Operation in SCI Transmission Mode

Note that the SSR.TEND flag is set in different timings depending on the GM bit setting in SMR. Figure 20.25 shows the

TEND flag generation timing.

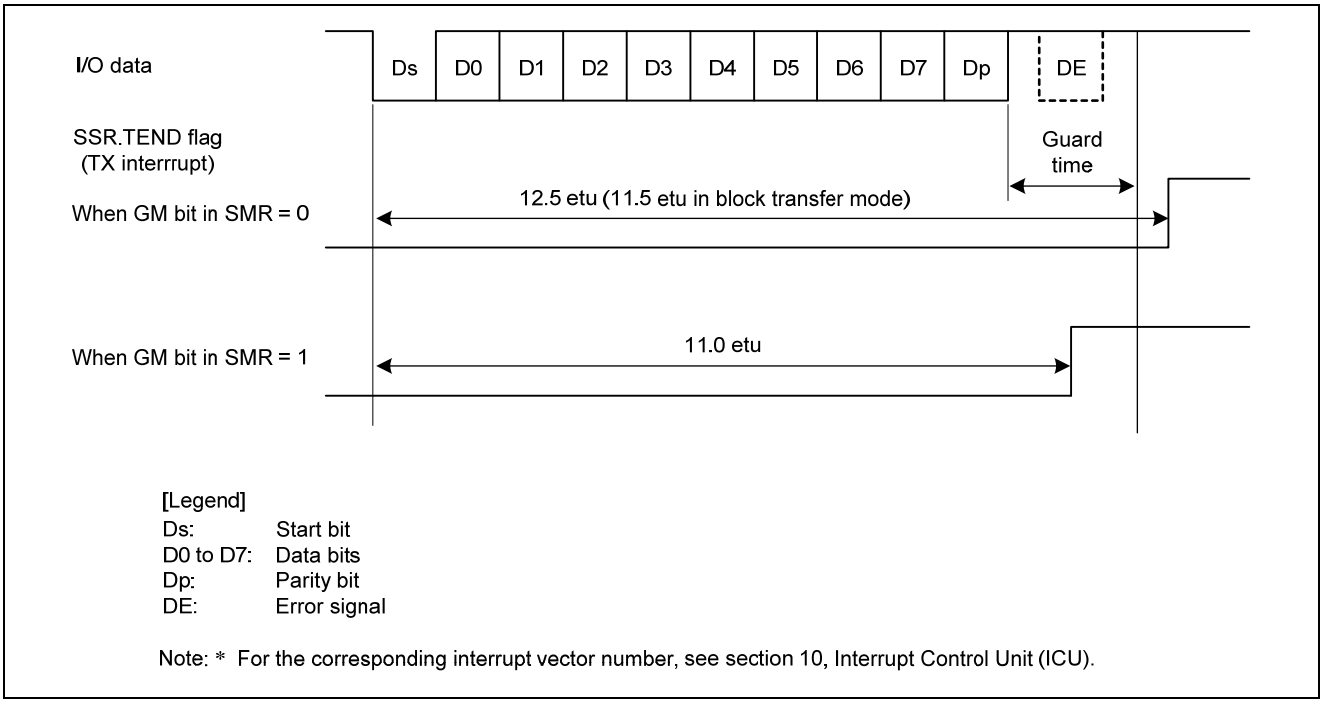


Figure 20.25 SSR.TEND Flag Generation Timing during Transmission

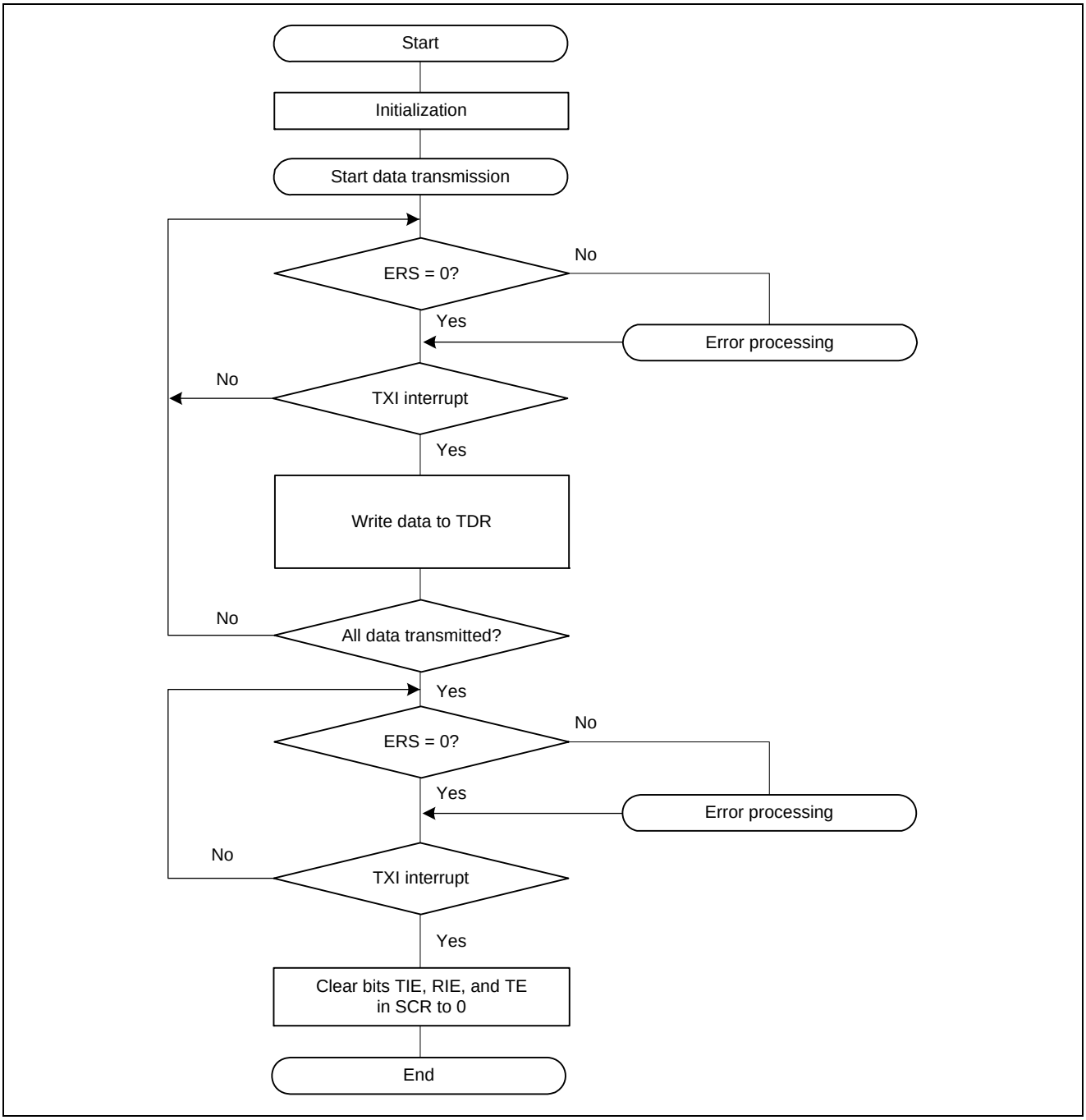


Figure 20.26 Sample Serial Transmission Flowchart

20.5.7 Serial Data Reception (Except in Block Transfer Mode)

Serial data reception in smart card interface mode is similar to that in serial communications interface mode. Figure 20.27 shows the data retransfer operation in reception mode.

1. If a parity error is detected in receive data, the PER flag in SSR is set to 1. When the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Clear the PER flag to 0 before the next parity bit is sampled.
2. For a frame in which a parity error is detected, no RXI interrupt is generated.
3. When no parity error is detected, the PER flag in SSR is not set to 1.
4. In this case, data is determined to have been received successfully. When the RIE bit in SCR is set to 1, an RXI interrupt request is generated.

Figure 20.28 shows a sample flowchart for serial data reception. All the processing steps are automatically performed using an RXI interrupt request to activate the DTC or DMAC.

In reception, setting the RIE bit to 1 allows an RXI interrupt request to be generated. The DTC or DMAC is activated by an RXI interrupt request if the RXI interrupt request is specified as a source of DTC or DMAC activation beforehand, allowing transfer of receive data.

If an error occurs during reception and either the ORER or PER flag in SSR is set to 1, a receive error interrupt (ERI) request is generated. Clear the error flag. If an error occurs, the DTC or DMAC is not activated and receive data is skipped. Therefore, the number of bytes of receive data specified in the DTC or DMAC is transferred.

Even if a parity error occurs and the PER flag is set to 1 during reception, receive data is transferred to RDR, thus allowing the data to be read.

Note: For operations in block transfer mode, see section 20.3, Operation in Asynchronous Mode.

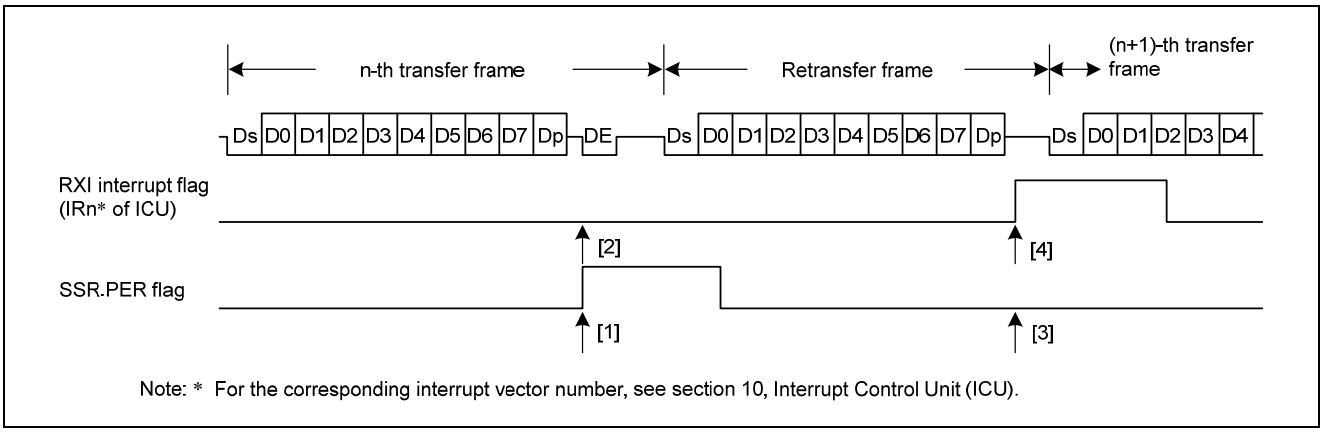


Figure 20.27 Data Retransfer Operation in SCI Reception Mode

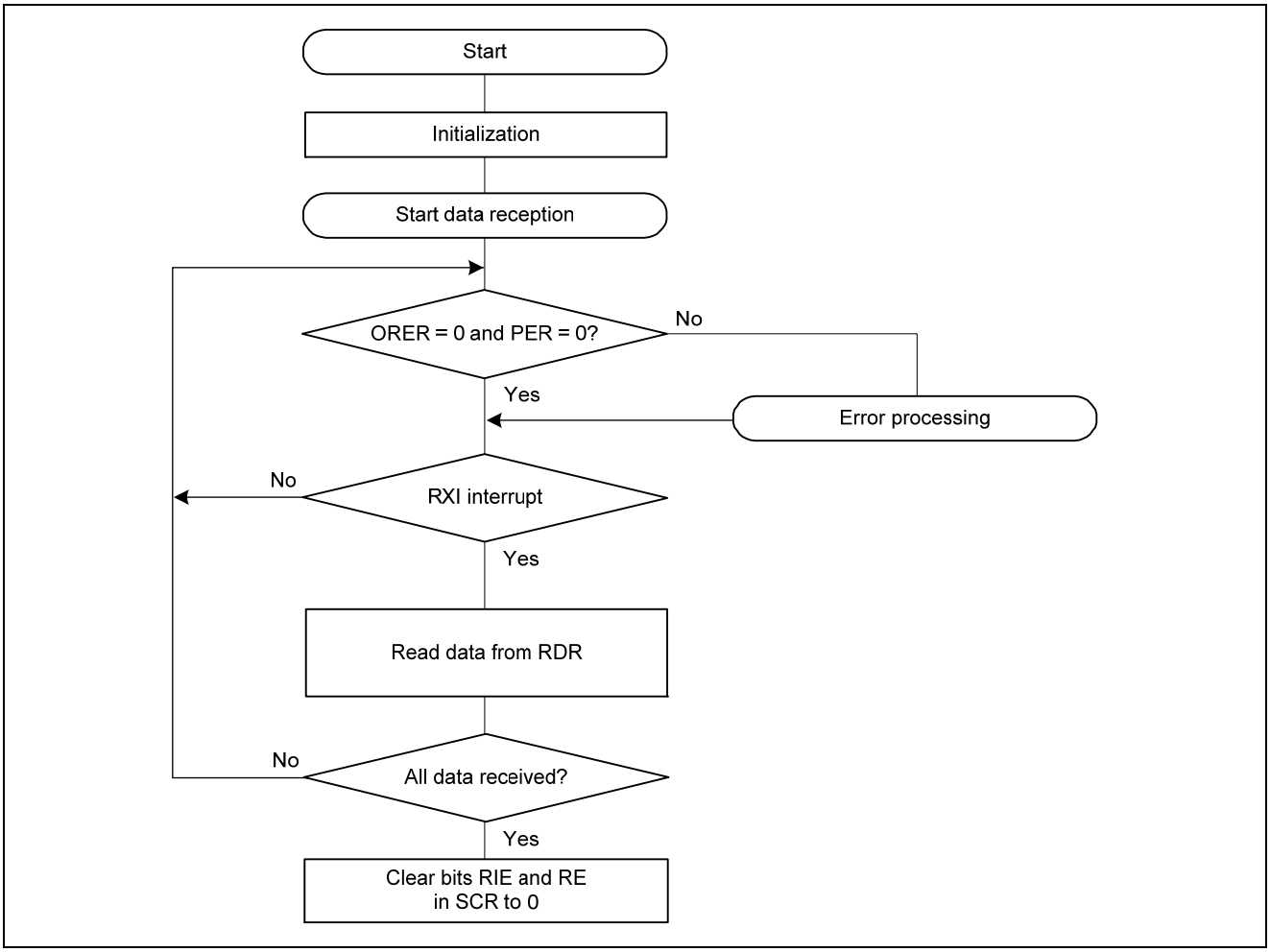


Figure 20.28 Sample Serial Reception Flowchart

20.5.8 Clock Output Control

Clock output can be fixed using the CKE[1:0] bits in SCR when the GM bit in SMR is set to 1. Specifically, the minimum width of a clock pulse can be specified.

Figure 20.29 shows an example of clock output stop timing when the CKE0 bit is controlled with GM = 1 and CKE1 = 0.

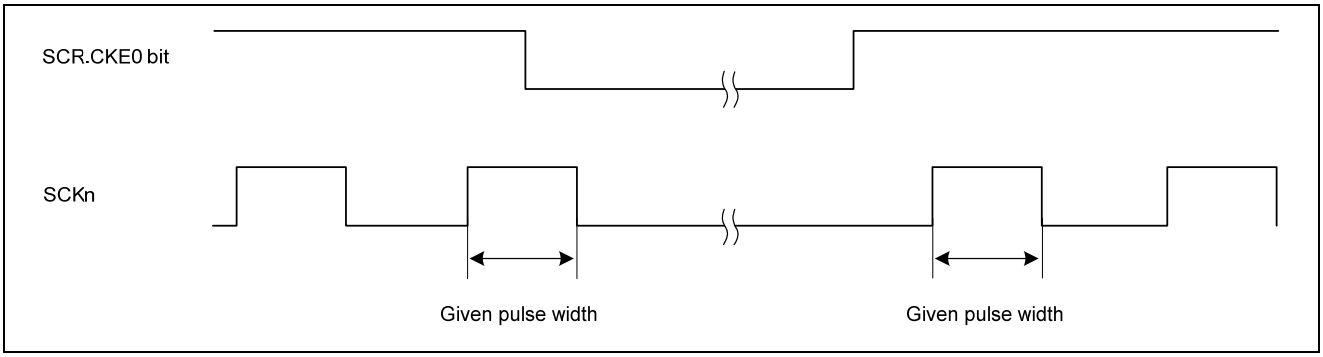


Figure 20.29 Clock Output Stop Timing

At power-on and transitions to/from software standby mode, use the following procedure to secure the appropriate clock

duty cycle.

(1) At Power-On

To secure the appropriate clock duty cycle simultaneously with power-on, use the following procedure.

1. Initially, port input is enabled in the high-impedance state. To fix the potential level, use a pull-up or pull-down resistor.
2. Fix the SCKn pin to the specified output using the CKE1 bit in SCR.
3. Set SMR and SCMR to enable smart card interface mode. Set the CKE0 bit in SCR to 1 to start clock output.

(2) At Mode Switching

(a) At transition from smart card interface mode to software standby mode

1. Set the data register (DR of Pm) and data direction register (DDR of Pm) corresponding to the SCKn pin to the values for the output fixed state in software standby mode.
2. Write 0 to the TE and RE bits in SCR to stop transmission/reception.
   Simultaneously, set the CKE1 bit in SCR to the value for the output fixed state in software standby mode.
3. Write 0 to the CKE0 bit in SCR to stop the clock.
4. Wait for one cycle of the serial clock. In the mean time, the clock output stops and is fixed low level after the specified high-level period is output.
5. Make a transition to software standby mode.

(b) At transition from software standby mode to smart card interface mode

1. Cancel software standby mode.
2. Set the CKE0 bit in SCR to 1. The clock output with the specified frequency is then re-started.

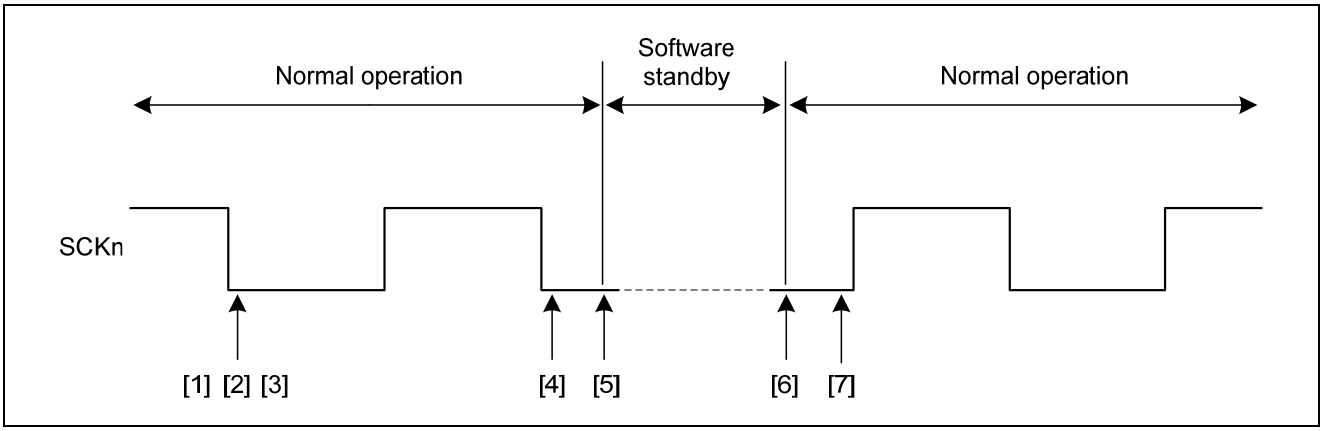


Figure 20.30 Clock Stop and Restart Procedure

20.6 Interrupt Sources

20.6.1 Interrupts in Serial Communications Interface Mode

Table 20.15 lists interrupt sources in normal serial communications interface mode. A different interrupt vector is assigned to each interrupt source, and individual interrupt sources can be enabled or disabled with the enable bits in SCR.

Transfer of data from the transmit data register (TDR) to the TSR while the SCR.TIE bit is 1 leads to the generation of a TXI interrupt request. Moreover, setting the TIE bit in SCR to 1 and then setting the TE bit to 1, or setting the TIE and TE bits in SCR to 1 simultaneously using one instruction, leads to the generation of a TXI interrupt request. A TXI interrupt request can activate the DTC or DMAC for data transfer.

Setting of received data in the RDR while the SCR.RIE bit is 1 leads to the generation of an RXI interrupt request. An RXI interrupt can activate the DTC or DMAC for data transfer.

Setting the ORER, FER, or PER flag in the SSR to 1 while the SCR.RIE bit is 1 leads to generation of an ERI interrupt request.

If the TDR has not been updated by the time of transmission of the tail-end bit of data being transmitted, the SSR.TEND flag is set to 1 and, if the value of the SCR.TEIE bit is 1, a TEI interrupt request is generated. Writing of data to the TDR during TXI interrupt processing leads to clearing of the SSR.TEND flag and clearing of the TEI interrupt at its source.

The TXI interrupt request is generated by setting the TIE bit in SCR to 1 and then setting the TE bit to 1 or by setting the TIE and TE bits in SCR to 1 simultaneously using one instruction. The TXI interrupt is not generated if the TE bit is set while the TIE bit is 0 or the TIE bit is set to 1 after the TE bit is set to 1. Therefore, to disable the TXI interrupt, perform the transmit end interrupt processing, and then start data transfer again, for example, in the final data transmission, the TXI interrupt should be enabled/disabled using the corresponding ICU.IERm.IENj bit.

Table 20.15 SCI Interrupt Sources

Name	Interrupt Source	Interrupt Flag	DTC Activation	DMAC Activation	Priority
ERI	Receive error	ORER, FER, or PER	Not possible	Not possible	High
RXI	Receive data full	—	Possible	Possible	↑
TXI	Transmit data empty	—	Possible	Possible	
TEI	Transmit end	TEND	Not possible	Not possible	Low

20.6.2 Interrupts in Smart Card Interface Mode

Table 20.16 lists interrupt sources in smart card interface mode. A transmit end interrupt (TEI) request cannot be used in this mode.

Table 20.16 SCI Interrupt Sources

Name	Interrupt Source	Interrupt Flag	DTC Activation	DMAC Activation	Priority
ERI	Receive error or error signal detection	ORER, PER, or ERS	Not possible	Not possible	High
RXI	Receive data full	—	Possible	Possible	↑
TXI	Transmit data empty	TEND	Possible	Possible	Low

Data transmission/reception using the DTC or DMAC is also possible in smart card interface mode, similar to in the normal SCI mode. In transmission, when the SSR.TEND flag is set to 1, a TXI interrupt request is generated. This TXI interrupt request activates the DTC or DMAC allowing transfer of transmit data if the TXI request is specified beforehand as a source of DTC or DMAC activation. The TEND flag is automatically cleared to 0 when the DTC or DMAC transfers the data.

If an error occurs, the SCI automatically re-transmits the same data. During the retransmission, the TEND flag is kept to 0 and the DTC or DMAC is not activated. Therefore, the SCI and DTC or DMAC automatically transmit the specified number of bytes, including retransmission in the case of error occurrence. However, the ERS flag in SSR is not automatically cleared to 0 at error occurrence. Therefore, the ERS flag must be cleared by previously setting the RIE bit in SCR to 1 to enable an ERI interrupt request to be generated at error occurrence.

When transmitting/receiving data using the DTC or DMAC, be sure to make settings to enable the DTC or DMAC before making SCI settings. For DTC or DMAC settings, see section 12, DMA Controller (DMAC) and section 13, Data Transfer Controller (DTC).

In reception, an RXI interrupt request is generated when receive data is set to RDR. This RXI interrupt request activates the DTC or DMAC allowing transfer of receive data if the RXI request is specified beforehand as a source of DTC or DMAC activation. If an error occurs, the error flag is set. Therefore, the DTC or DMAC is not activated and an ERI interrupt request is issued to the CPU instead; the error flag must be cleared.

20.7 Usage Notes

20.7.1 Setting the Module Stop Function

Operation of the SCI can be disabled or enabled using the module stop control register B (MSTPCRB). The initial setting is for operation of the SCI to be halted. Register access is enabled by clearing the module stop state. For details, see section 8, Low Power Consumption.

20.7.2 Break Detection and Processing

When a framing error is detected, a break can be detected by reading the RxDn pin value directly. In a break, the input from the RxDn pin becomes all 0s, and so the FER flag in SSR is set to 1 (framing error), and the PER flag in SSR may also be set to 1 (parity error). The SCI continues the receive operation even after a break is received. Therefore, note that even if the FER flag is cleared to 0 (no framing error), it will be set to 1 again.

20.7.3 Mark State and Break Detection

When the TE bit in SCR is 0 (serial transmission disabled), the TxDn pin is used as an I/O port. This can be used to set the TxDn pin to mark state or send a break during serial data transmission.

To maintain the communications line in mark state (the state of 1) until the TE bit is set to 1 (to enable serial transmission), set both Bj bit in DR of Pm and Bj bit in DDR of Pm to 1. Since the TE bit is cleared to 0 at this time, the TxDn pin becomes an I/O port, and 1 is output from the TxDn pin.

To send a break during serial data transmission, first set Bj bit in DDR of Pm = 1 and Bj bit in DR of Pm = 0, and then clear the TE bit to 0. When the TE bit is cleared to 0, the transmitter is initialized regardless of the current transmission state, the TxDn pin becomes an I/O port, and a 0 is output from the TxDn pin.

20.7.4 Receive Error Flags and Transmit Operations (Clock Synchronous Mode Only)

Transmission cannot be started when a receive error flag (ORER, FER, or RER) in SSR is set to 1, even if data is written to TDR. Be sure to clear the receive error flags to 0 before starting transmission. Note also that the receive error flags cannot be cleared to 0 even if the RE bit in SCR is cleared to 0 (serial reception disabled).

20.7.5 Writing Data to TDR

Data can always be written to TDR. However, if new data is written to TDR when transmit data is remaining in TDR, the previous data in TDR is lost because it has not been transferred to TSR yet. Be sure to write transmit data to TDR in the TXI interrupt request processing routine.

20.7.6 Restrictions on Clock Synchronous Transmission

When the external clock source is used as a synchronization clock, update TDR by the DMAC or DTC and wait for at least five clock cycles before allowing the transmit clock to be input. If the transmit clock is input within four clock cycles after TDR is updated, the SCI may malfunction.

20.7.7 Restrictions on Using DTC or DMAC

When using the DMAC or DTC to read RDR, be sure to set the receive end interrupt (RXI) as the activation source of the relevant SCI.

20.7.8 SCI Operations during Power-Down State

(1) Transmission

Before specifying the module stop state or making a transition to software standby mode, stop the transmit operations (TIE = TE = TEIE = 0 in SCR). TSR, TDR, and SSR are reset. The states of the output pins in the module stop state or in software standby mode depend on the port settings, and the output pins are held high after cancellation. If the transition is made during data transmission, the data being transmitted will be undefined.

To transmit data in the same transmission mode after cancellation of the power-down state, set the TE bit to 1, read SSR, and write data to TDR sequentially to start data transmission. To transmit data with a different transmission mode, initialize the SCI first.

Figure 20.31 shows a sample flowchart for transition to software standby mode during transmission. Figures 20.32 and 20.33 show the port pin states during transition to software standby mode.

Before specifying the module stop state or making a transition to software standby mode from the transmission mode using DTC transfer, stop the transmit operations (TE = 0). To start transmission after cancellation using the DTC, set the TE bit to 1. The TXI interrupt flag is set to 1 and transmission starts using the DTC.

(2) Reception

Before specifying the module stop state or making a transition to software standby mode, stop the receive operations (RE = 0 in SCR). RSR, RDR, and SSR are reset. If transition is made during data reception, the data being received will be invalid.

To receive data in the same reception mode after cancellation of the power-down state, set the RE bit to 1, and then start reception. To receive data in a different reception mode, initialize the SCI first.

Figure 20.34 shows a sample flowchart for mode transition during reception.

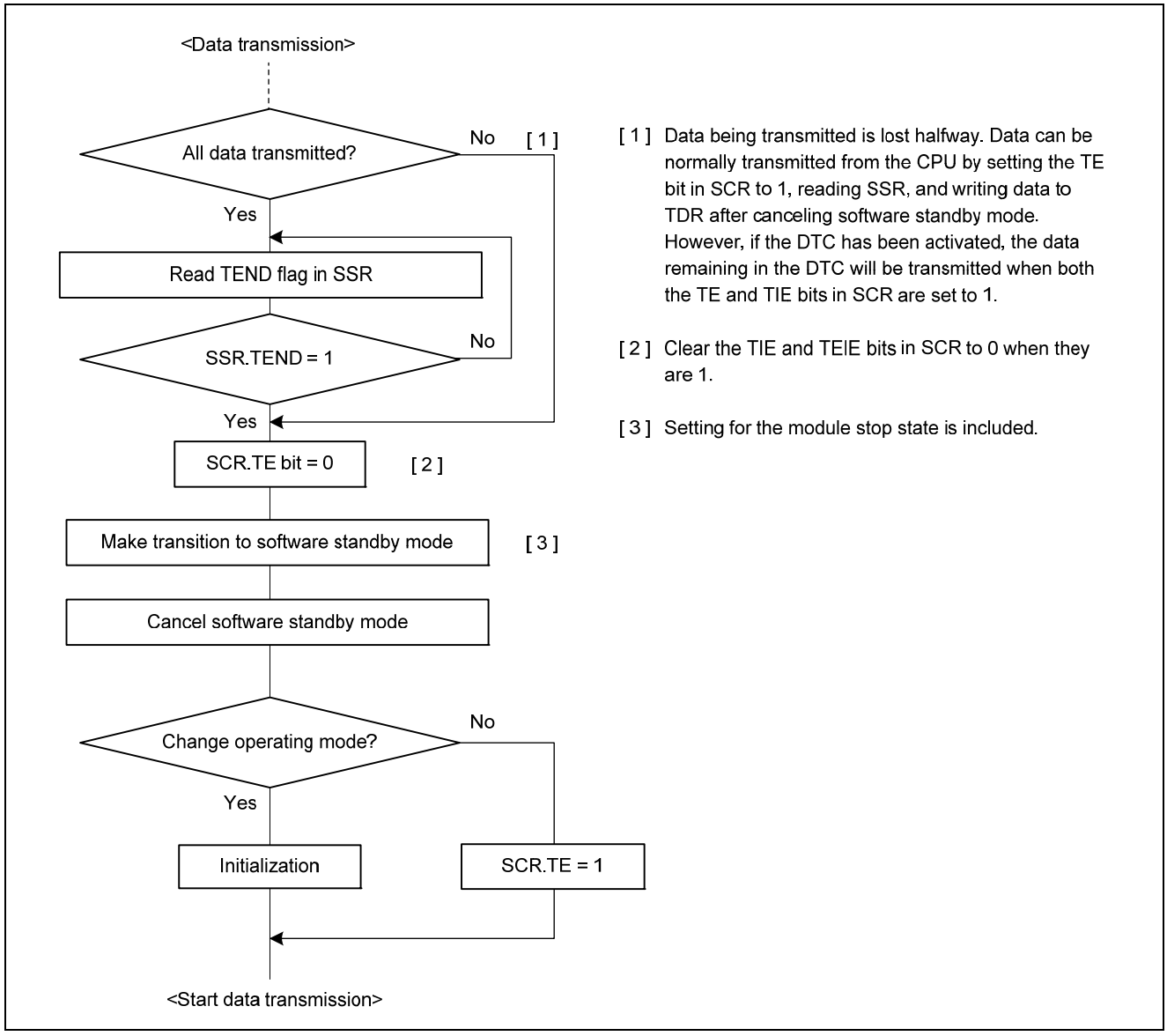


Figure 20.31 Example of Flowchart for Transition to Software Standby Mode during Transmission

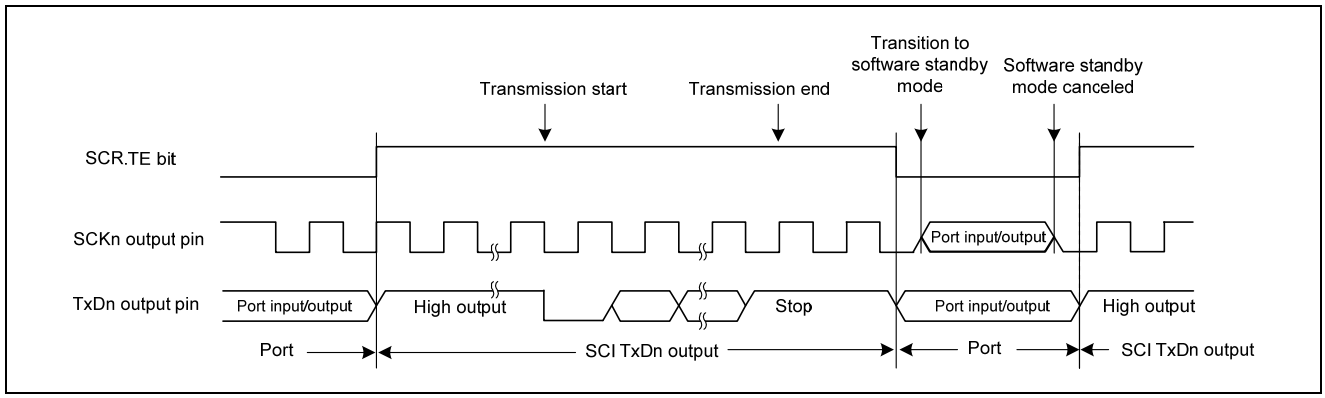


Figure 20.32 Port Pin States during Transition to Software Standby Mode (Internal Clock, Asynchronous Transmission)

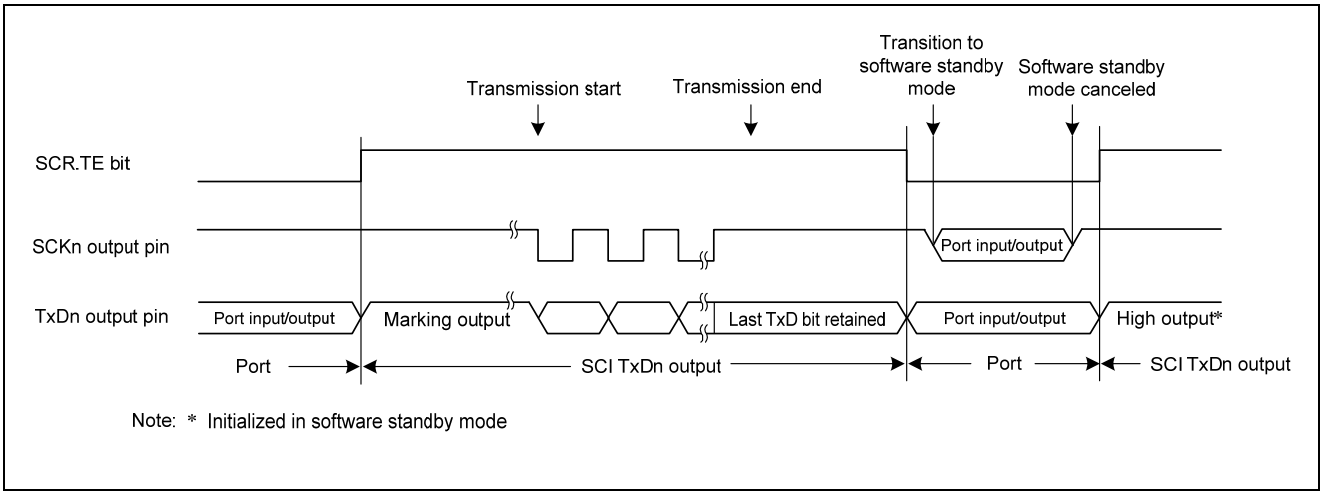


Figure 20.33 Port Pin States during Transition to Software Standby Mode (Internal Clock, Clock Synchronous Transmission)

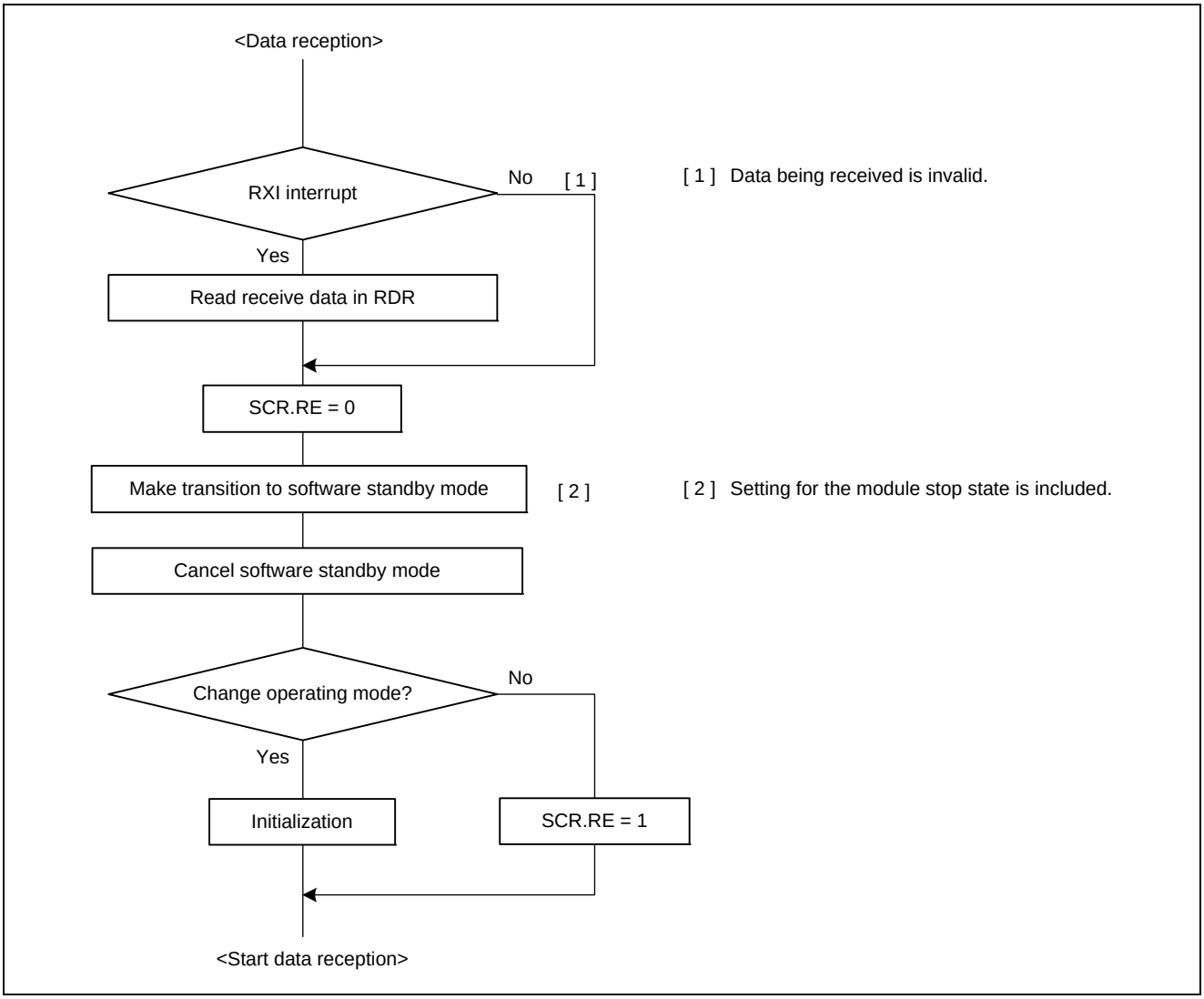


Figure 20.34 Example of Flowchart for Transition to Software Standby Mode during Reception

20.7.9 External Clock Input in Clock Synchronous Mode

In clock synchronous mode, the external clock SCKn must be input as follows:

High-pulse period, low-pulse period = 2 clock cycles or more, period = 6 clock cycles or more

21. CRC Calculator (CRC)

The CRC (Cyclic Redundancy Check) calculator generates CRC codes of data blocks.

21.1 Overview

Table 21.1 lists the specifications of the CRC calculator, and figure 21.1 shows a block diagram of the CRC calculator.

Table 21.1 Specifications of CRC

Item	Description
Data for CRC calculation*	CRC code generated for any desired data in 8n-bit units (where n is a whole number)
Data block size	8 bits
CRC processor unit	Operation executed on eight bits in parallel
CRC generating polynomial	One of three generating polynomials selectable • 8-bit CRC $X^8 + X^2 + X + 1$ • 16-bit CRC $X^{16} + X^{15} + X^2 + 1$ $X^{16} + X^{12} + X^5 + 1$
CRC calculation switching	CRC code generation for LSB-first or MSB-first communication selectable
Power-down function	Module stop state can be set

Note: * The circuit does not have functionality to divide data for calculation into a data-block size. Write data in 8-bit units.

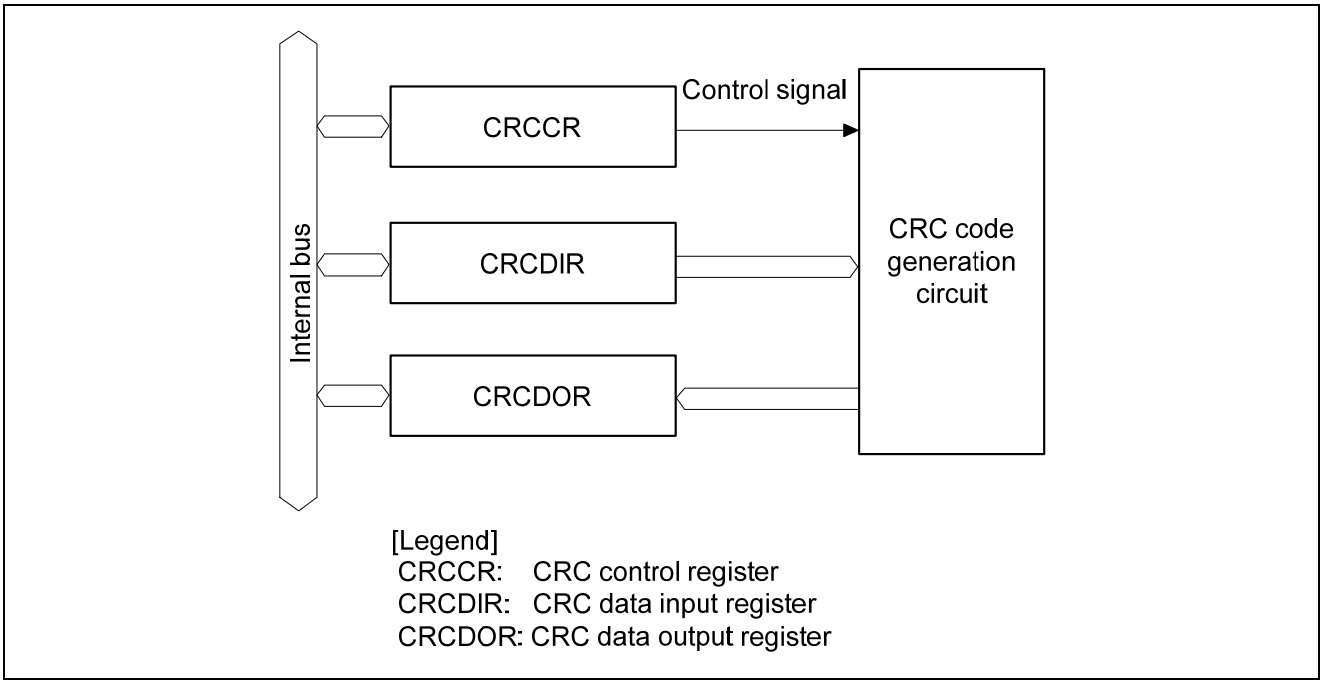


Figure 21.1 Block Diagram of CRC Calculator

21.2 Register Descriptions

Table 21.2 lists the registers of the CRC calculator.

Table 21.2 Registers of CRC Calculator

Register Name	Symbol	Value after Reset	Address	Access Size
CRC control register	CRCCR	00h	0008 8280h	8
CRC data input register	CRCDIR	00h	0008 8281h	8
CRC data output register	CRCDOR	0000h	0008 8282h	16

21.2.1 CRC Control Register (CRCCR)

Address: 0008 8280h

	b7	b6	b5	b4	b3	b2	b1	b0
	DORCLR	—	—	—	—	LMS	GPS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	GPS[1:0]	CRC Generating Polynomial Switching	b0 b1 0 0: No calculation is executed.* 0 1: $X^8 + X^2 + X + 1$ 1 0: $X^{16} + X^{15} + X^2 + 1$ 1 1: $X^{16} + X^{12} + X^5 + 1$	R/W
b2	LMS	CRC Calculation Switching	0: Performs CRC operation for LSB-first communication. The lower-order byte (bits 7 to 0) is the first to be transmitted when the value of the CRCDOR (CRC code) are divided into bytes. 1: Performs CRC operation for MSB-first communication. The higher-order byte (bits 15 to 8) is first to be transmitted when the value of the CRCDOR (CRC code) are divided into bytes.	R/W
b6 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DORCLR	CRCDOR Register Clear	0: No effect on the operation 1: Clear the CRCDOR register This bit is always read as 0.	R/W

Note: * The CRC data output register (CRCDOR) is always 0000h.

CRCCR initializes the CRC calculator, switches the operation mode, and selects the generating polynomial.

GPS[1:0] Bits (CRC Generating Polynomial Switching)

These bits select the CRC code generating polynomial.

LMS Bit (CRC Calculation Switching)

Selects LSB-first or MSB-first communication for the CRC code generation.

DORCLR Bit (CRCDOR Register Clear)

Write 1 to this bit so that the CRCDOR register is cleared to 0000h.

This bit is always read as 0.

21.2.2 CRC Data Input Register (CRCDIR)

Address: 0008 8281h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

CRCDIR is an 8-bit readable/writable register, to which the bytes to be CRC-operated are written.

21.2.3 CRC Data Output Register (CRCDOR)

Address: 0008 8282h

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CRCDOR is a 16-bit readable/writable register that contains the result of CRC calculation.

In general, the value will be 0 if there is no CRC error when the calculated CRC code matches the CRC code that continues on, for verification, from the transferred data.

When an 8-bit CRC ($X^8 + X^2 + X + 1$ polynomial) is in use, the valid CRC code is obtained in the lower-order byte (b7 to b0). The higher-order byte (b15 to b8) is read as 00h.

21.3 Operation

The CRC calculator generates CRC codes for use in LSB-first or MSB-first transfer.

The following figures show examples in which the CRCCR.GPS[1:0] bits are set to 11b so the CRC code is calculated by using a 16-bit CRC (with the polynomial $X^{16} + X^{12} + X^5 + 1$), and the CRC code is calculated for the value "F0h".

When an 8-bit CRC (with the polynomial $X^8 + X^2 + X + 1$) is in use, the valid bits of the CRC code are obtained in the lower-order byte of CRCDOR.

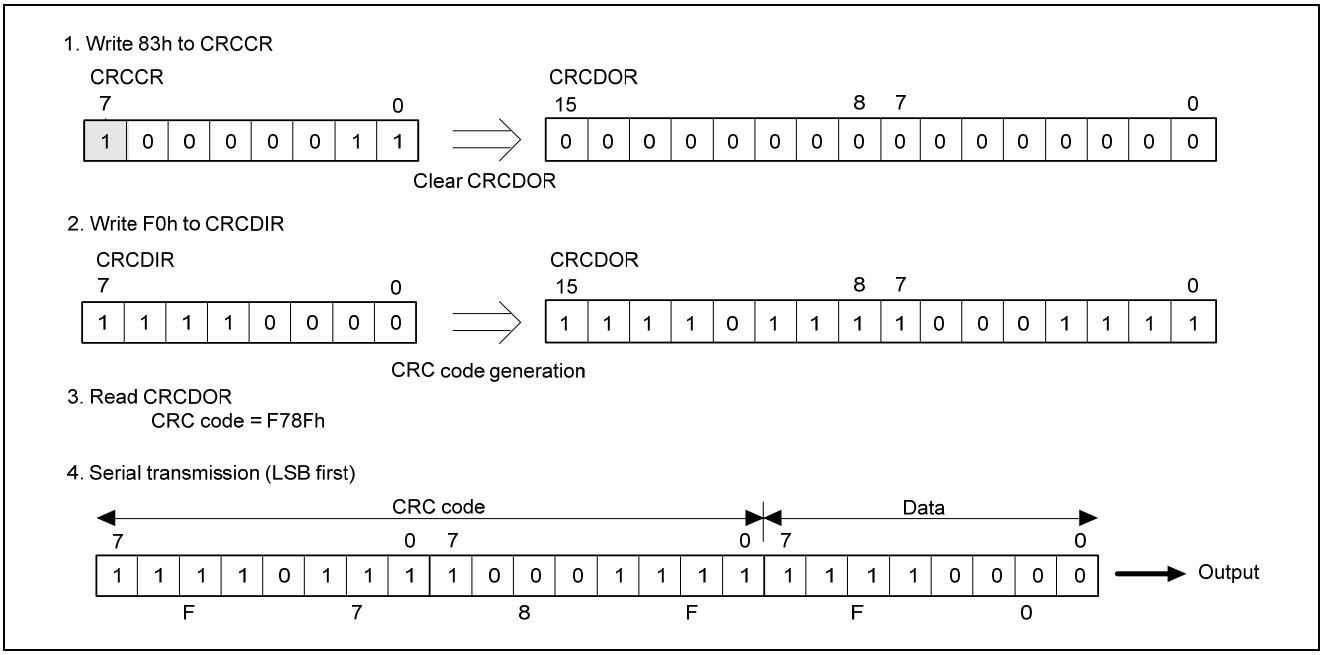


Figure 21.2 LSB-First Data Transmission

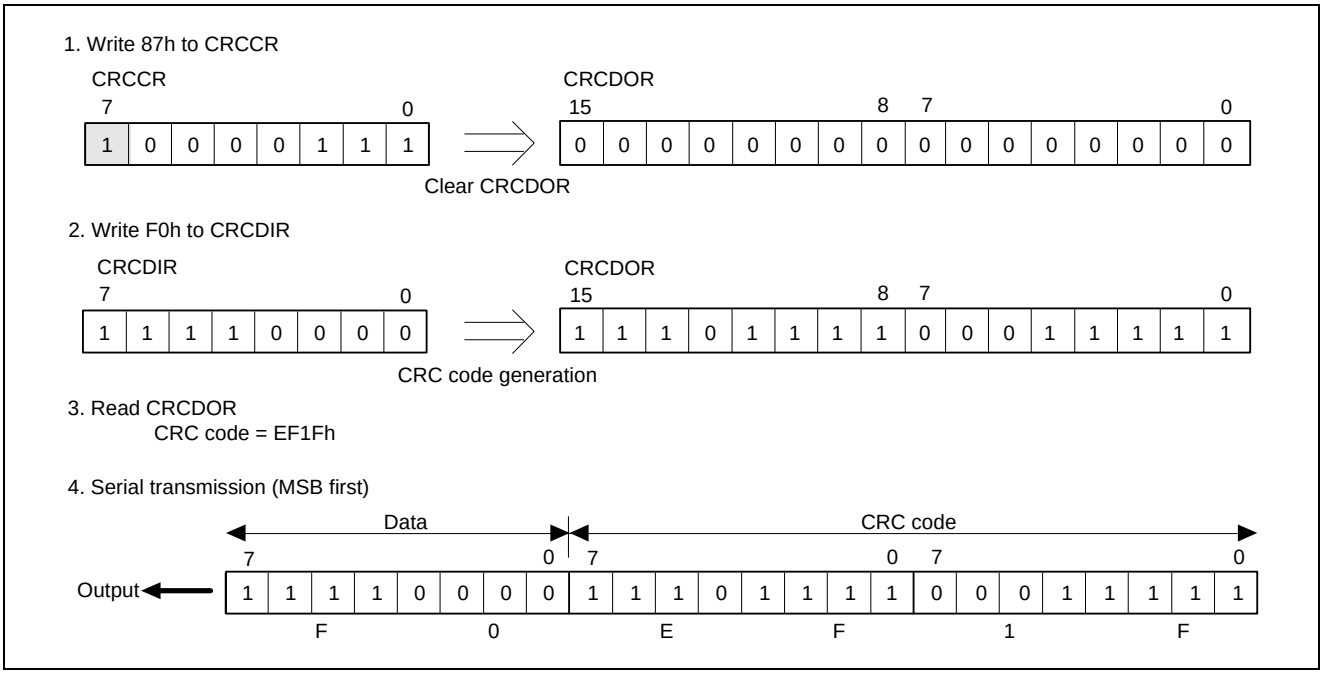


Figure 21.3 MSB-First Data Transmission

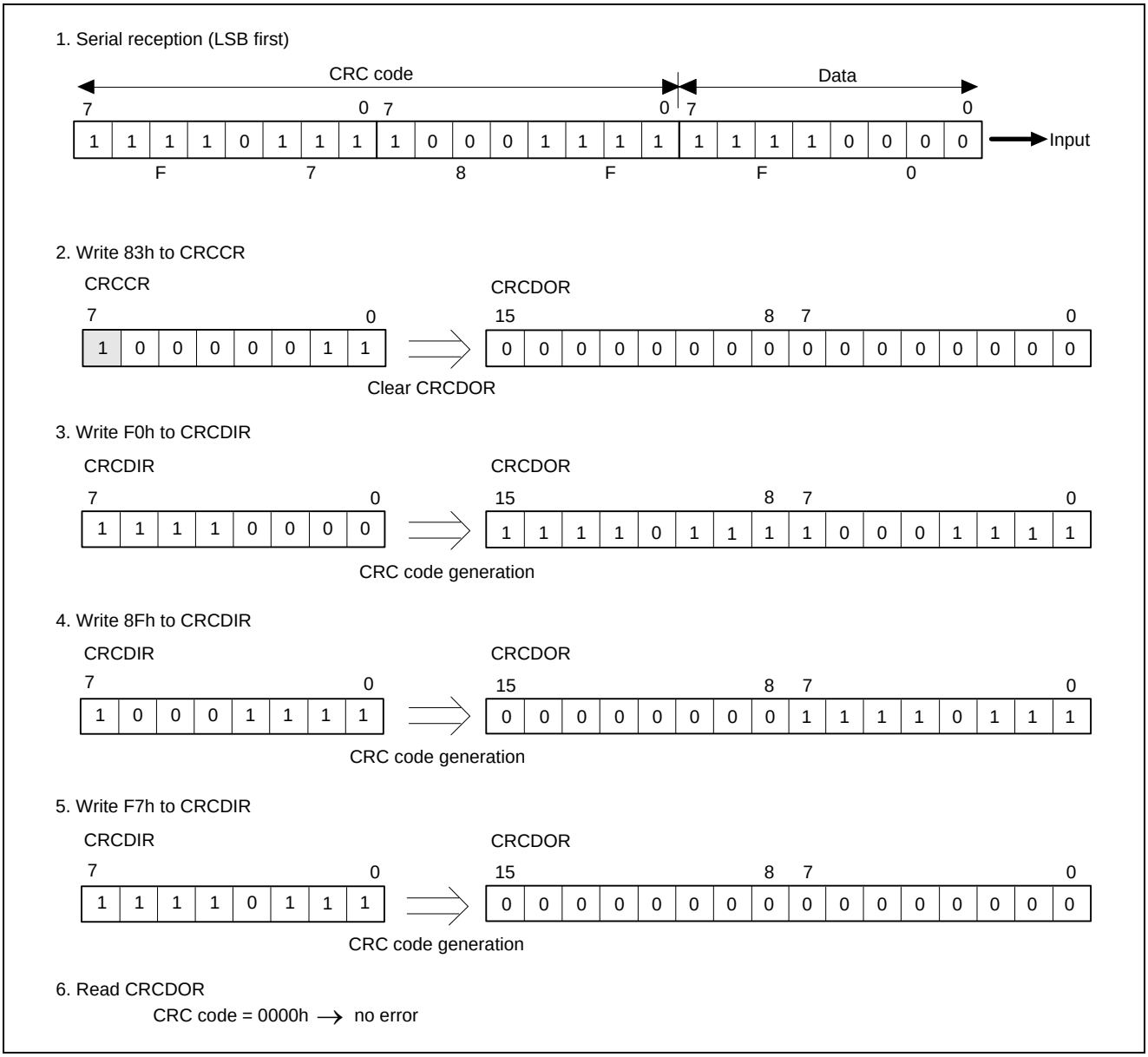


Figure 21.4 LSB-First Data Reception

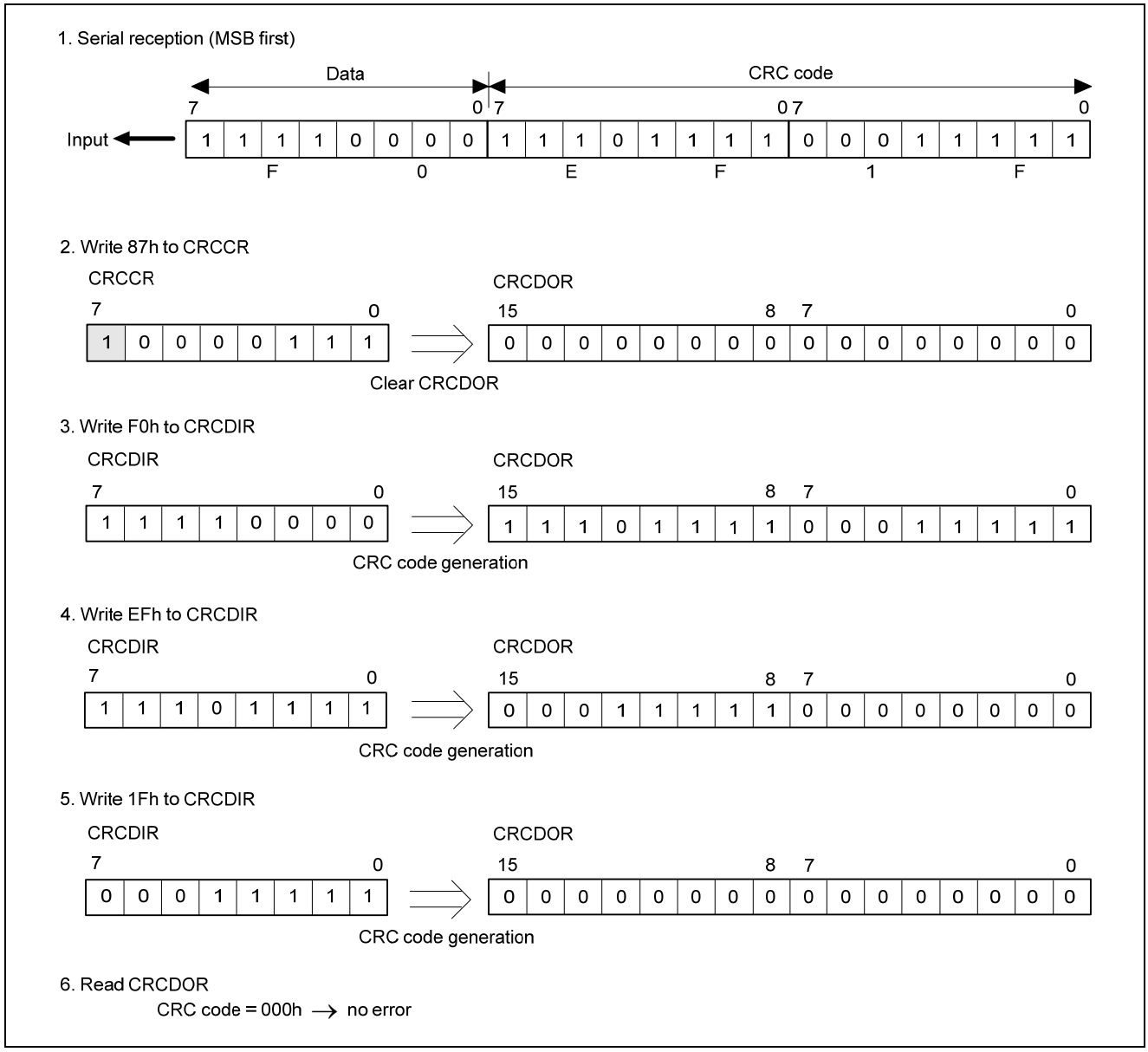


Figure 21.5 MSB-First Data Reception

21.4 Usage Notes

21.4.1 Module Stop Function Setting

Operation of the CRC calculator can be disabled or enabled using the module stop control register B (MSTPCRB). The initial setting is for operation of the CRC calculator to be halted. Register access is enabled by clearing the module stop state. For details, see section 8, Low Power Consumption.

21.5 Note on Transmission

Note that the sequence of transmission for the CRC code differs according to whether transmission is LSB-first or MSB-first.

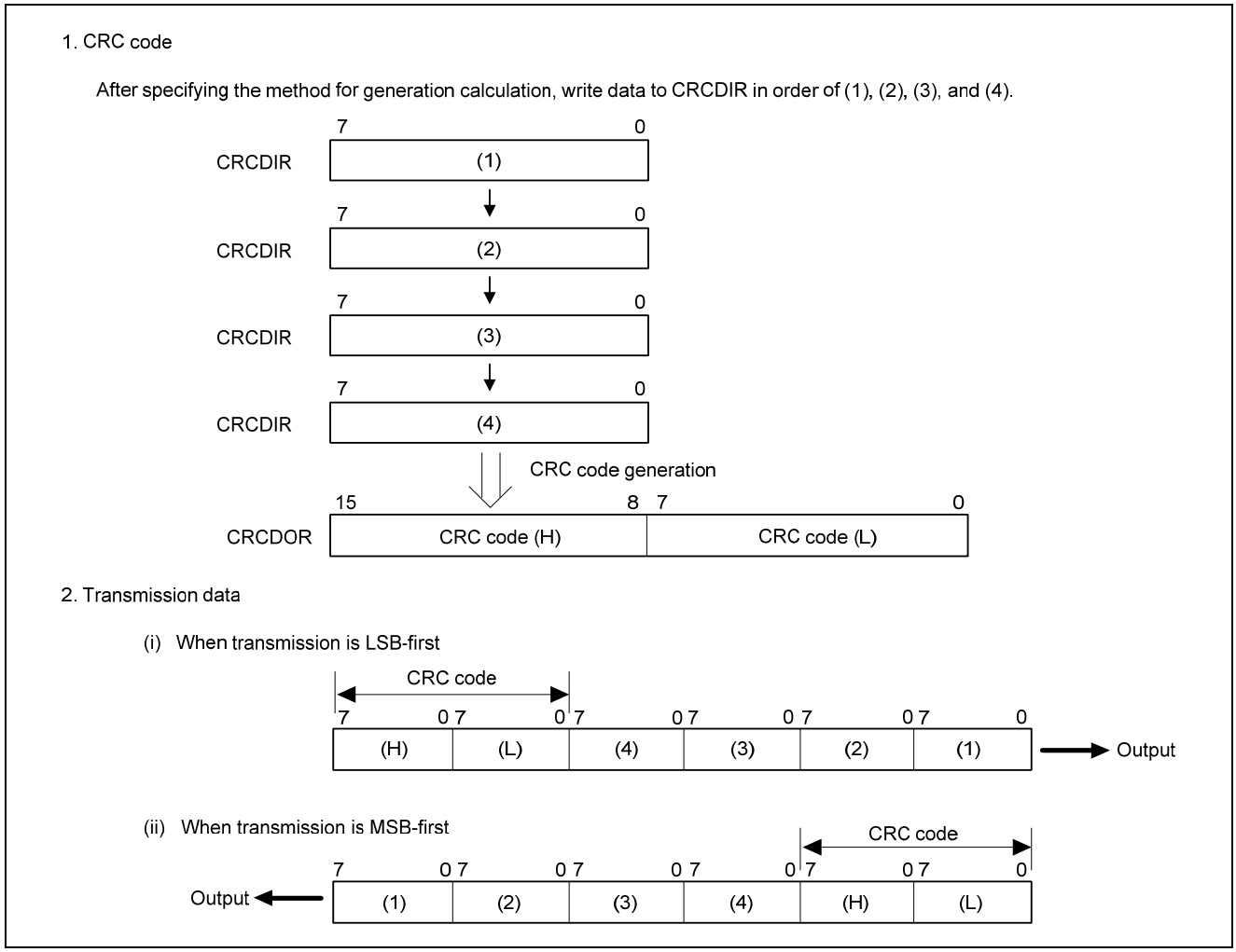


Figure 21.6 LSB-First and MSB-First Data Transmission

22. I²C Bus Interface (RIIC)

The RX610 Group has two I²C bus interfaces (RIIC modules).

The RIIC module conforms with and provides a subset of the NXP I²C bus (inter-IC bus) interface functions.

22.1 Overview

Table 22.1 lists the specifications of the RIIC, figure 22.1 shows a block diagram of the RIIC, and figure 22.2 shows an example of I/O pin connections to external circuits (I²C bus configuration example). Table 22.2 shows the input/output pins of the RIIC.

Table 22.1 RIIC Specifications

Item	Specifications
Communications format	• I²C bus format or SMBus format • Master mode or slave mode selectable • Automatic securing of the various set-up times, hold times, and bus-free times for the transfer rate
Transfer rate	Up to 1M bps
SCL clock	For master operation, the duty cycle of the SCL clock is selectable in the range from 4% to 96%.
Issuing and detecting conditions	Start, restart, and stop conditions are automatically generated. Start conditions (including restart conditions) and stop conditions are detectable.
Slave address	• Up to three slave-address settings can be made. • Seven- and ten-bit address formats are supported (along with the use of both at once). • General call addresses, device ID addresses, and SMBus host addresses are detectable.
Acknowledgement	• For transmission, the acknowledge bit is automatically loaded. Transfer of the next data for transmission can be automatically suspended on detection of a not-acknowledge bit. • For reception, the acknowledge bit is automatically transmitted. If a wait between the eighth and ninth clock cycles has been selected, software control of the value in the acknowledge field in response to the received value is possible (i.e. the return of ACK or NACK is selectable).
Wait function	• In reception, the following periods of waiting can be obtained by holding the clock signal (SCL) at the low level: waiting between the eighth and ninth clock cycles; and waiting between the ninth clock cycle and the first clock cycle of the next transfer (WAIT function)
SDA output delay function	Timing of the output of transmitted data, including the acknowledge bit, can be delayed.
Arbitration	• For multi-master operation Operation to synchronize the SCL (clock) signal in cases of conflict with the SCL signal from another master is possible. When issuing the start condition would create conflict on the bus, loss of arbitration is detected by testing for non-matching between the internal signal for the SDA line and the level on the SDA line. In master operation, loss of arbitration is detected by testing for non-matching between the signal on the SDA line and the internal signal for the SDA line. • Loss of arbitration due to detection of the start condition while the bus is busy is detectable (to prevent the issuing of double start conditions). • Loss of arbitration in transfer of a not-acknowledge bit due to the internal signal for the SDA line and the level on the SDA line not matching is detectable. • Loss of arbitration due to non-matching of internal and line levels for data is detectable in slave transmission.

Item	Specifications
Timeout detection function	• The internal timeout detection function is capable of detecting long-interval stoppages of the SCL (clock signal).
Noise removal	• The interface incorporates digital noise filters for both the SCL and SDA signals, and the width for noise cancellation by the filters is adjustable.
Interrupt sources	• Four sources: Error in transfer or occurrence of events (detection of AL, NACK, timeout, a start condition including a restart condition, or a stop condition) Receive-data-full (including matching with a slave address) Transmit-data-empty (including matching with a slave address) Transmission complete

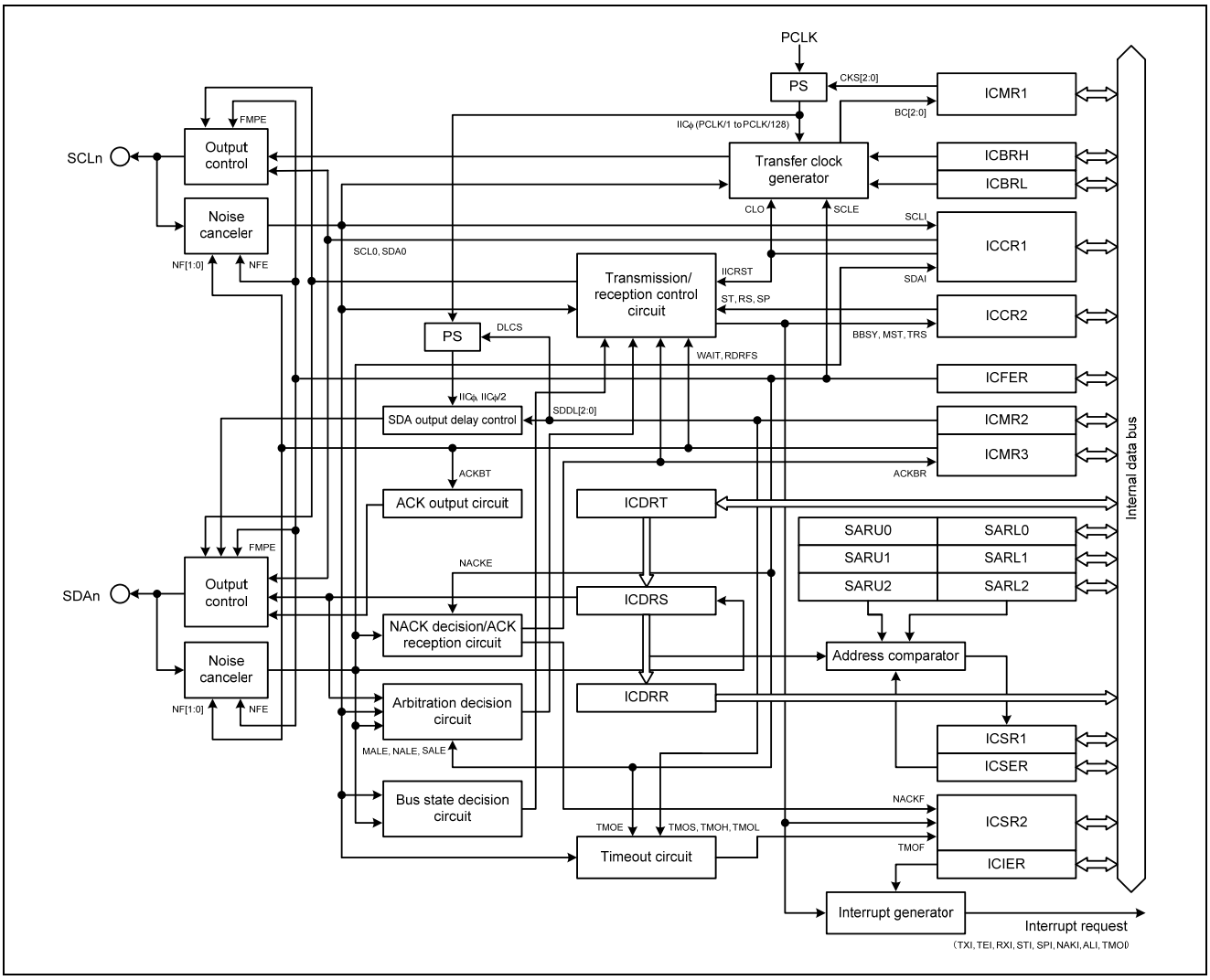


Figure 22.1 Block Diagram of RIIC

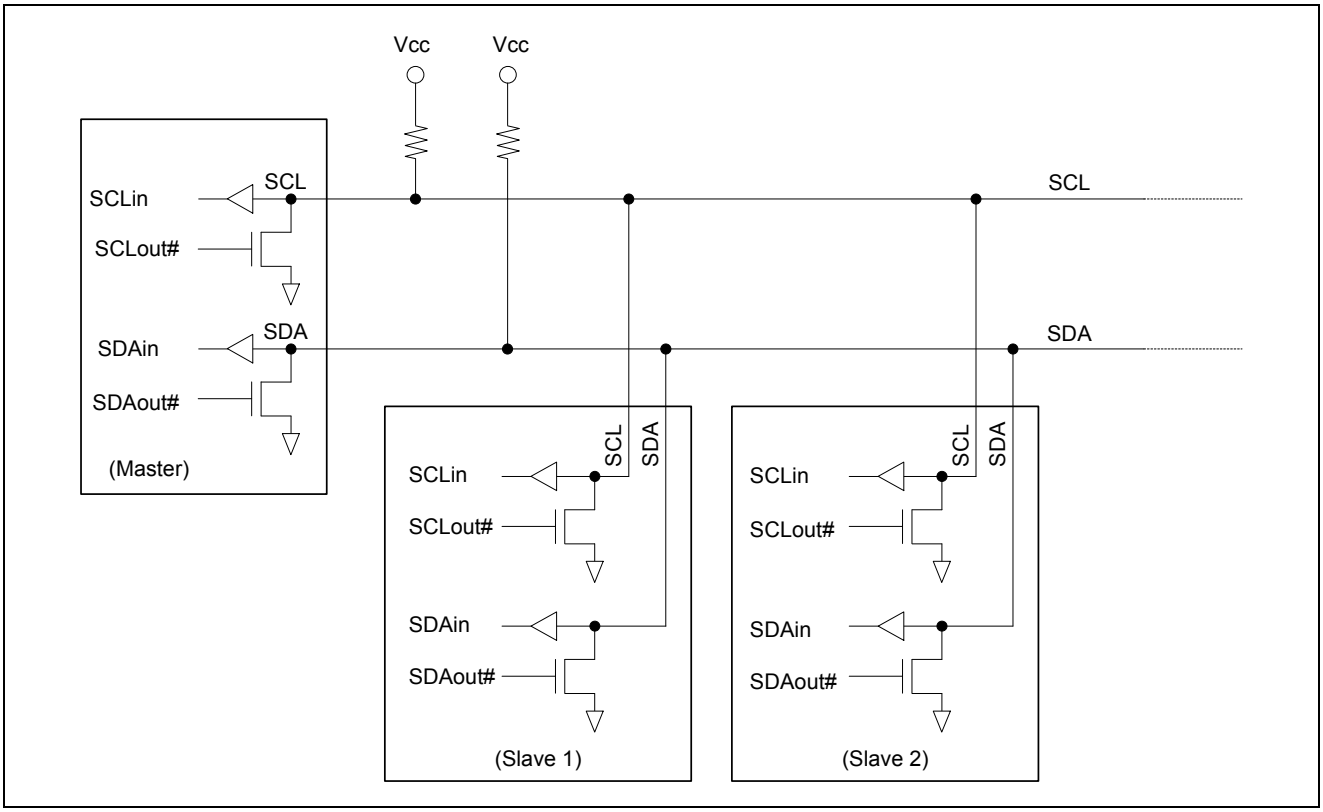


Figure 22.2 Connections to the External Circuit by the I/O Pins (I²C Bus Configuration Example)

Table 22.2 Pin Configuration

Channel	Pin Name	I/O	Function
RIIC0	SCL0	I/O	RIIC0 serial clock I/O pin
	SDA0	I/O	RIIC0 serial data I/O pin
RIIC1	SCL1	I/O	RIIC1 serial clock I/O pin
	SDA1	I/O	RIIC1 serial data I/O pin

22.2 Register Descriptions

Table 22.3 lists the registers of the RIIC.

Table 22.3 Registers of the RIIC

Channel	Register Name	Symbol	Value after Reset	Address	Access Size
RIIC0	I²C bus control register 1	ICCR1	1Fh	0008 8300h	8
	I²C bus control register 2	ICCR2	00h	0008 8301h	8
	I²C bus mode register 1	ICMR1	08h	0008 8302h	8
	I²C bus mode register 2	ICMR2	06h	0008 8303h	8
	I²C bus mode register 3	ICMR3	00h	0008 8304h	8
	I²C bus function enable register	ICFER	72h	0008 8305h	8
	I²C bus status enable register	ICSER	09h	0008 8306h	8
	I²C bus interrupt enable register	ICIER	00h	0008 8307h	8
	I²C bus status register 1	ICSR1	00h	0008 8308h	8
	I²C bus status register 2	ICSR2	00h	0008 8309h	8
	Slave address register L0	SARL0	00h	0008 830Ah	8
	Slave address register U0	SARU0	F0h	0008 830Bh	8
	Slave address register L1	SARL1	00h	0008 830Ch	8
	Slave address register U1	SARU1	F0h	0008 830Dh	8
	Slave address register L2	SARL2	00h	0008 830Eh	8
	Slave address register U2	SARU2	F0h	0008 830Fh	8
	I²C bus bit rate low-level register	ICBRL	FFh	0008 8310h	8
	I²C bus bit rate high-level register	ICBRH	FFh	0008 8311h	8
	I²C bus transmit data register	ICDRT	FFh	0008 8312h	8
	I²C bus receive data register	ICDRR	00h	0008 8313h	8
	I²C bus shift register	ICDRS	—	—	8
RIIC1	I²C bus control register 1	ICCR1	1Fh	0008 8320h	8
	I²C bus control register 2	ICCR2	00h	0008 8321h	8
	I²C bus mode register 1	ICMR1	08h	0008 8322h	8
	I²C bus mode register 2	ICMR2	06h	0008 8323h	8
	I²C bus mode register 3	ICMR3	00h	0008 8324h	8
	I²C bus function enable register	ICFER	72h	0008 8325h	8
	I²C bus status enable register	ICSER	09h	0008 8326h	8
	I²C bus interrupt enable register	ICIER	00h	0008 8327h	8
	I²C bus status register 1	ICSR1	00h	0008 8328h	8
	I²C bus status register 2	ICSR2	00h	0008 8329h	8
	Slave address register L0	SARL0	00h	0008 832Ah	8
	Slave address register U0	SARU0	F0h	0008 832Bh	8
	Slave address register L1	SARL1	00h	0008 832Ch	8
	Slave address register U1	SARU1	F0h	0008 832Dh	8
	Slave address register L2	SARL2	00h	0008 832Eh	8
	Slave address register U2	SARU2	F0h	0008 832Fh	8
	I²C bus bit rate low-level register	ICBRL	FFh	0008 8330h	8
	I²C bus bit rate high-level register	ICBRH	FFh	0008 8331h	8
	I²C bus transmit data register	ICDRT	FFh	0008 8332h	8
	I²C bus receive data register	ICDRR	00h	0008 8333h	8
	I²C bus shift register	ICDRS	—	—	8

22.2.1 I²C Bus Control Register 1 (ICCR1)

Addresses: RIIC0.ICCR1 0008 8300h, RIIC1.ICCR1 0008 8320h

	b7	b6	b5	b4	b3	b2	b1	b0
	ICE	IICRST	CLO	SOWP	SCLO	SDAO	SCLI	SDAI
Value after reset:	0	0	0	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	SDAI	SDA Bus Input Monitor	0: SDAn pin input is at a low level 1: SDAn pin input is at a high level	R
b1	SCLI	SCL Bus Input Monitor	0: SCLn pin input is at a low level 1: SCLn pin input is at a high level	R
b2	SDAO	SDA Output Control*1*2	Read: 0: SDAn pin output is at a low level 1: SDAn pin is in a high-impedance state Write: 0: Changes the SDAn pin output to a low level 1: Changes the SDAn pin in a high-impedance state (High level output is achieved through an external pull-up resistor.)	R/W *1, *2
b3	SCLO	SCL Output Control*1*2	Read: 0: SCLn pin output is at a low level 1: SCLn pin is in a high-impedance state Write: 0: Changes the SCLn pin output to a low level 1: Changes the SCLn pin in a high-impedance state (High level output is achieved through an external pull-up resistor.)	R/W *1, *2
b4	SOWP	SCLO/SDAO Write Protect*2	0: Allows the SCLO and SDAO bits to be rewritten (This bit is always read as 1.)	R/W *2
b5	CLO	Extra SCL Clock Cycle Output	0: Does not output an extra SCL clock cycle (default) 1: Outputs an extra SCL clock cycle (The CLO bit is cleared automatically after one clock cycle is output.)	R/W
b6	IICRST	I²C Bus Interface Internal Reset	0: Clears the RIIC reset or internal reset 1: Initiates the RIIC reset or internal reset (Clears the bit counter and the SCLn/SDAn output latch)	R/W
b7	ICE	I²C Bus Interface Enable	0: Disables the RIIC (the SCLn pin and SDAn pin function as ports) 1: Enables the RIIC transfer function (the SCLn pin and SDAn pin drive the bus)	R/W

Notes: 1. Do not write to these bits during communication. Changing a value during communication may cause a transmission or reception failure or an AL error.

2. To change the SDAO and SCLO bits, set the SOWP bit to 0 at the same timing to set the SDAO and SCLO bits to 0.

ICCR1 enables or disables the RIIC, resets the internal state of the RIIC, outputs an extra SCL clock cycle, and manipulates and monitors the SCLn pin and SDAn pin.

SDAI Bit (SDA Bus Input Monitor)

This bit indicates the input level of the SDAn pin.

SCLI Bit (SCL Bus Input Monitor)

This bit indicates the input level of the SCLn pin.

SDAO Bit (SDA Output Control)

This bit controls the output level of the SDAn pin. This bit also indicates the output state of the SDAn pin.

SCLO Bit (SCL Output Control)

This bit controls the output level of the SCLn pin. This bit also indicates the output state of the SCLn pin.

SOWP Bit (SCLO/SDAO Write Protect)

This bit controls the modification of the SCLO and SDAO bits.

CLO Bit (Extra SCL Clock Cycle Output)

This bit is used to output an extra SCL clock cycle for debugging or error processing.

Normally, set the bit to 0. Setting the bit to 1 in a normal communication state causes a communication error.

For details on this function, see section 22.11.2, Extra SCL Clock Cycle Output Function.

IICRST Bit (I²C Bus Interface Internal Reset)

This bit is used to reset the internal states of the RIIC.

Setting this bit to 1 initiates an RIIC reset or internal reset.

Whether an RIIC reset or internal reset is initiated is determined according to the combination with the ICE bit. Table 22.4 lists the resets of the RIIC.

The RIIC reset resets all registers including the BBSY flag in ICCR2 and internal states of the RIIC, and the internal reset resets the bit counter (BC[2:0] bits in ICMR1), the I²C bus shift register (ICDRS), and the I²C bus status registers (ICSR1 and ICSR2) as well as the internal states of the RIIC. For the reset conditions for each register, see section 22.14, Reset States.

An internal reset initiated with the IICRST bit set to 1 during operation (with the ICE bit set to 1) resets the internal states of the RIIC without initializing the port settings and the control and setting registers of the RIIC when the bus or RIIC hangs up due to a communication error.

If the RIIC hangs up in a low level output state, resetting the internal states cancels the low level output state and releases the bus with the SCLn pin and SDAn pin at a high impedance.

Note: If an internal reset is initiated using the IICRST bit for a bus hang-up occurred during communication with the master device in slave mode, the states may become different between the slave device and the master device (due to the difference in the bit counter information). For this reason, do not initiate an internal reset in slave mode, but initiate restoration processing from the master device. If an internal reset is necessary because the RIIC hangs up with the SCLn line in a low level output state in slave mode, initiate an internal reset and then issue a restart condition from the master device or resume communication from the start condition issuance after issuing a stop condition. If communication is restarted by initiating a reset solely in the slave device without issuing a start condition or restart condition from the master device, synchronization will be lost because the master and slave devices operate asynchronously.

Table 22.4 RIIC Resets

IICRST	ICE	State	Specifications
1	0	RIIC reset	Resets all registers and internal states of the RIIC.
	1	Internal reset	Reset the BC[2:0] bits in ICMR1, and the ICSR1, ICSR2, ICDRS registers and the internal states of the RIIC.

ICE Bit (I²C Bus Interface Enable)

This bit is used to enable or disable the transfer operation of the RIIC.

When this bit is set to 0 to disable the RIIC, the SCLn pin and SDAn pin function as ports. An RIIC reset is initiated by setting the IICRST bit to 1 with the ICE bit set to 0, and an internal reset is initiated by setting the IICRST bit to 1 with the ICE bit set to 1.

To prevent unexpected communications, set the RIIC registers with the ICE bit set to 0 (to disable the RIIC), and set the ICE bit to 1 (to enable the transfer operation) after finishing all register settings.

Note: In addition to the I²C bus pin functions, other functions are also multiplexed onto the pins of the RX610 Group. To use the pins as I²C bus pins (SCLn pin and SDAn pin), disable the other multiplexed functions. Since both of the SCLn pin and SDAn pin of the I²C bus pins are I/O pins, set the corresponding Pn.DDR register to 0 (input) and set the Pn.ICR register to 1 (input buffer enabled).

22.2.2 I²C Bus Control Register 2 (ICCR2)

Addresses: RIIC0.ICCR2 0008 8301h, RIIC1.ICCR2 0008 8321h

	b7	b6	b5	b4	b3	b2	b1	b0
	BBSY	MST	TRS	—	SP	RS	ST	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b1	ST	Start Condition Issuance Request	0: Does not request to issue a start condition 1: Requests to issue a start condition	R/W
b2	RS	Restart Condition Issuance Request	0: Does not request to issue a restart condition 1: Requests to issue a restart condition	R/W
b3	SP	Stop Condition Issuance Request	0: Does not request to issue a stop condition 1: Requests to issue a stop condition	R/W
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b5	TRS	Transmit/Receive Mode	0: Receive mode 1: Transmit mode	R/W*
b6	MST	Master/Slave Mode	0: Slave mode 1: Transmit mode	R/W*
b7	BBSY	Bus Busy Detection Flag	0: The I²C bus is released (bus free state) 1: The I²C bus is occupied (bus busy state or in the bus free state)	R

Note: * When the MTWP bit in ICMR1 is set to 1, the MST and TRS bits can be written to.

ICCR2 has a flag function that indicates whether or not the I²C bus is occupied and whether the RIIC is in transmit/receive or master/slave mode as well as a function to issue a start or stop condition.

ST Bit (Start Condition Issuance Request)

This bit is used to request transition to master mode and issuance of a start condition.

When this bit is set to 1 to request to issue a start condition, a start condition is issued when the BBSY flag is set to 0 (bus free).

For details on the start condition issuance, see section 22.10, Start Condition/Restart Condition/Stop Condition Issuing Function.

[Setting condition]

- When 1 is written to the ST bit

[Clearing conditions]

- When 0 is written to the ST bit
- When a start condition has been issued
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note: Set the ST bit to 1 (start condition issuance request) when the BBSY flag is set to 0 (bus free).

Note that arbitration may be lost if the ST bit is set to 1 (start condition issuance request) when the BBSY flag is set to 1 (bus busy).

RS Bit (Restart Condition Issuance Request)

This bit is used to request that a restart condition be issued in master mode.

When this bit is set to 1 to request to issue a restart condition, a restart condition is issued when the BBSY flag is set to 1 (bus busy) and the MST bit is set to 1 (master mode).

For details on the restart condition issuance, see section 22.10, Start Condition/Restart Condition/Stop Condition Issuing Function.

[Setting condition]

- When 1 is written to the RS bit with the BBSY flag in ICCR2 set to 1

[Clearing conditions]

- When 0 is written to the RS bit
- When a restart condition has been issued or a start condition is detected
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Notes: 1. Do not set the RS bit to 1 while issuing a stop condition.

2. If the RS bit is set to 1 (restart condition issuance request) in mode other than master mode, the restart condition is not issued in this mode but the restart condition issuance request bit remains set. If the operating mode changes to master mode with the bit not being cleared, the restart condition may be issued: this may hinder communications or cause an unexpected action.

SP Bit (Stop Condition Issuance Request)

This bit is used to request that a stop condition be issued in master mode.

When this bit is set to 1 to request to issue a stop condition, a stop condition is issued when the BBSY flag is set to 1 (bus busy) and the MST bit is set to 1 (master mode).

For details on the stop condition issuance, see section 22.10, Start Condition/Restart Condition/Stop Condition Issuing Function.

[Setting condition]

- When 1 is written to the SP bit with both the BBSY flag and the MST bit in ICCR2 set to 1

[Clearing conditions]

- When 0 is written to the SP bit after reading SP = 1
- When a stop condition has been issued or a stop condition is detected
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When a start condition and a restart condition are detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Notes: 1. Writing to the SP bit is not possible while the setting of the BBSY flag is 0 (bus free).

2. Do not set the SP bit to 1 while a restart condition is being issued.

TRS Bit (Transmit/Receive Mode)

This bit indicates transmit or receive mode.

The RIIC is in receive mode when the TRS bit is set to 0 and is in transmit mode when the bit is set to 1. Combination of this bit and the MST bit indicates the operating mode of the RIIC.

The value of the TRS bit is automatically changed to the value for transmission mode or reception mode by detection or issuing of a start condition, setting or clearing of the R/W# bit, etc. Although writing to the TRS bit is possible when the MTWP bit in ICMR1 is set to 1, writing to this bit is not necessary during normal usage.

[Setting conditions]

- When a start condition is issued normally according to the start condition issuance request (when a start condition is detected with the ST bit set to 1)
- When the R/W# bit added to the slave address is set to 0 in master mode
- When the address received in slave mode matches the address enabled in ICSER, with the R/W# bit set to 1
- When 1 is written to the TRS bit with the MTWP bit in ICMR1 set to 1

[Clearing conditions]

- When a stop condition is detected
- The AL (arbitration lost) flag in ICSR2 being set to 1
- In master mode, reception of a slave address to which an R/W# bit with the value 1 is appended
- In slave mode, a match between the received address and the address enabled in ICSER when the value of the received R/W# bit is 0 (including cases where the received address is the general call address)
- In slave mode, a restart condition is detected (a start condition is detected with ICCR2.BBSY = 1 and ICCR2.MST = 0)
- When 0 is written to the TRS bit with the MTWP bit in ICMR1 set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

MST Bit (Master/Salve Mode)

This bit indicates master or slave mode.

The RIIC is in slave mode when the MST bit is set to 0 and is in master mode when the bit is set to 1. Combination of this bit and the TRS bit indicates the operating mode of the RIIC.

The value of the MST bit is automatically changed to the value for master mode or slave mode by detection or issuing of a start condition, etc. Although writing to the MST bit is possible when the MTWP bit in ICMR1 is set to 1, writing to this bit is not necessary during normal usage.

[Setting conditions]

- When a start condition is issued normally according to the start condition issuance request (when a start condition is detected with the ST bit set to 1)
- When 1 is written to the MST bit with the MTWP bit in ICMR1 set to 1

[Clearing conditions]

- When a stop condition is detected
- When the AL (arbitration lost) flag in ICSR2 is set to 1
- When 0 is written to the MST bit with the MTWP bit in ICMR1 set to 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

BBSY Flag (Bus Busy Detection)

The BBSY flag indicates whether the I²C bus is occupied (bus busy) or released (bus free).

This bit is set to 1 when the SDAn line changes from high to low under the condition of SCLn = high, assuming that a start condition has been issued.

When the SDAn line changes from low to high under the condition of SCLn = high, this bit is cleared to 0 after the bus free time (specified in ICBRL) start condition is not detected, assuming that a stop condition has been issued.

[Setting condition]

- When a start condition is detected

[Clearing conditions]

- When the bus free time (specified in ICBRL) start condition is not detected after detecting a stop condition
- When 1 is written to the IICRST bit in ICCR1 with the ICE bit in ICCR1 set to 0 (RIIC reset)

22.2.3 I²C Bus Mode Register 1 (ICMR1)

Addresses: RIIC0.ICMR1 0008 8302h, RIIC1.ICMR1 0008 8322h

	b7	b6	b5	b4	b3	b2	b1	b0
	MTWP	CKS[2:0]			BCWP	BC[2:0]		
Value after reset:	0	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b2 to b0	BC[2:0]	Bit Counter*	b2 b1 b0	R/W*
			0 0 0: 9 bits	
			0 0 1: 2 bits	
			0 1 0: 3 bits	
			0 1 1: 4 bits	
			1 0 0: 5 bits	
			1 0 1: 6 bits	
			1 1 0: 7 bits	
			1 1 1: 8 bits	
b3	BCWP	BC Write Protect*	0: Enables a value to be written in the BC[2:0] bits	R/W*
			(This bit is always read as 1.)	
b6 to b4	CKS[2:0]	Internal Reference Clock Selection	b6 b5 b4	R/W
			0 0 0: PCLK/1 clock	
			0 0 1: PCLK/2 clock	
			0 1 0: PCLK/4 clock	
			0 1 1: PCLK/8 clock	
			1 0 0: PCLK/16 clock	
			1 0 1: PCLK/32 clock	
			1 1 0: PCLK/64 clock	
			1 1 1: PCLK/128 clock	
b7	MTWP	MST/TRS Write Protect	0: Disables writing to the MST and TRS bits in ICCR2	R/W
			1: Enables writing to the MST and TRS bits in ICCR2	

Note: * Set the BCWP bit to 0 to rewrite the BC[2:0] bits. The BC[2:0] bits must be rewritten by using the MOV instruction.

ICMR1 specifies the internal reference clock source within the RIIC, indicates the number of bits to be transferred, and protects the MST and TRS bits in ICCR2 from being written.

BC[2:0] Bits (Bit Counter)

These bits function as a counter that indicates the number of bits remaining to be transferred at the detection of a rising edge on the SCLn line. Although these bits are writable and readable, it is not necessary to access these bits under normal conditions.

To write to these bits, specify the number of bits to be transferred plus one (data is transferred with an additional acknowledge bit) between transferred frames when the SCLn line is at a low level.

The values of the BC[2:0] bits return to 000b at the end of a data transfer including the acknowledge bit or when a start condition including a restart condition is detected.

BCWP Bit (BC Write Protect)

This bit enables a value to be written in the BC[2:0] bits.

CKS[2:0] Bits (Internal Reference Clock Selection)

These bits select a reference clock source (IICϕ) inside the RIIC.

MTWP Bit (MST/TRS Write Protect)

This bit controls the modification of the MST and TRS bits in ICCR2.

22.2.4 I²C Bus Mode Register 2 (ICMR2)

Addresses: RIIC0.ICMR2 0008 8303h, RIIC1.ICMR2 0008 8323h

	b7	b6	b5	b4	b3	b2	b1	b0
	DLCS	SDDL[2:0]			—	TMOH	TMOL	TMOS
Value after reset:	0	0	0	0	0	1	1	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOS	Timeout Detection Time Selection	0: Long mode is selected 1: Short mode is selected	R/W
b1	TMOL	Timeout L Count Control	0: Count is disabled while the SCLn line is at a low level 1: Count is enabled while the SCLn line is at a low level	R/W
b2	TMOH	Timeout H Count Control	0: Count is disabled while the SCLn line is at a high level 1: Count is enabled while the SCLn line is at a high level	R/W
b3	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b6 to b4	SDDL[2:0]	SDA Output Delay Counter	• When ICMR2.DLCS = 0 (IICϕ) b6 b4 0 0 0: No output delay 0 0 1: 1 IICϕ cycle 0 1 0: 2 IICϕ cycles 0 1 1: 3 IICϕ cycles 1 0 0: 4 IICϕ cycles 1 0 1: 5 IICϕ cycles 1 1 0: 6 IICϕ cycles 1 1 1: 7 IICϕ cycles • When ICMR2.DLCS = 1 (IICϕ/2) b6 b4 0 0 0: No output delay 0 0 1: 1 or 2 IICϕ cycles 0 1 0: 3 or 4 IICϕ cycles 0 1 1: 5 or 6 IICϕ cycles 1 0 0: 7 or 8 IICϕ cycles 1 0 1: 9 or 10 IICϕ cycles 1 1 0: 11 or 12 IICϕ cycles 1 1 1: 13 or 14 IICϕ cycles	R/W
b7	DLCS	SDA Output Delay Clock Source Selection	0: The internal reference clock (IICϕ) is selected as the clock source of the SDA output delay counter 1: The internal reference clock divided by 2 (IICϕ/2) is selected as the clock source of the SDA output delay counter	R/W

ICMR2 has a timeout detection function and an SDA output delay function.

TMOS Bit (Timeout Detection Time Selection)

This bit is used to select long mode or short mode for the timeout detection time when the timeout detection function is enabled (TMOE bit = 1 in ICFER). When this bit is set to 0, long mode is selected. When this bit is set to 1, short mode is selected. In long mode, the timeout detection internal counter functions as a 16 bit-counter. In short mode, the counter functions as a 14 bit-counter. While the SCLn line is in the state that enables this counter as specified by bits TMOH and TMOL, the counter counts up in synchronization with the internal reference clock (IICϕ) as a count source.

For details on the timeout detection function, see section 22.11.1, Timeout Detection Function.

TMOL Bit (Timeout L Count Control)

This bit is used to enable or disable the internal counter of the timeout detection function to count up while the SCLn line is held low when the timeout detection function is enabled (TMOE bit = 1 in ICFER).

TMOH Bit (Timeout H Count Control)

This bit is used to enable or disable the internal counter of the timeout detection function to count up while the SCLn line is held high when the timeout detection function is enabled (TMOE bit = 1 in ICFER).

SDDL[2:0] Bits (SDA Output Delay Setup Counter)

The SDA output can be delayed by the SDDL[2:0] setting. This counter works with the clock source selected by the DLCS bit. The setting of this function can be used for all types of SDA output, including the transmission of the acknowledge bit.
For details on this function , see section 22.5, Facility for Delaying SDA Output.

Notes: 1. Set the SDA output delay time to meet the I²C bus standard (within the data enable time/acknowledge enable time*²) or the SMBus standard (within the data hold time: 300 ns or more, and SCL-clock low-level period – the data setup time: 250 ns). Note that, if a value outside the standard is set, communication with communication devices may malfunction or it may seemingly become a start condition or stop condition depending on the bus state.

2. Data enable time/acknowledge enable time
   3,450 ns (up to 100 kbps: standard mode [Sm])
   900 ns (up to 400 kbps: fast mode [fm])
   450 ns (up to 1 Mbps: fast mode plus [fm+])

DLCS bit (SDA Output Delay Clock Source Selection)

This bit is used to select the internal reference clock (IICϕ) or the internal reference clock divided by 2 (IICϕ/2) as the clock source of the SDA output delay time.

22.2.5 I²C Bus Mode Register 3 (ICMR3)

Addresses: RIIC0.ICMR3 0008 8304h, RIIC1.ICMR3 0008 8324h

	b7	b6	b5	b4	b3	b2	b1	b0
	SMBS	WAIT	RDRFS	ACKWP	ACKBT	ACKBR	NF[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	NF[1:0]	Noise Filter Stage Selection	b1 b0 0 0: Noise of up to 1-PCLK range is filtered out (single-stage filter) 0 1: Noise of up to 2-PCLK range is filtered out (2-stage filter) 1 0: Noise of up to 3-PCLK range is filtered out (3-stage filter) 1 1: Noise of up to 4-PCLK range is filtered out (4-stage filter)	R/W
b2	ACKBR	Receive Acknowledge	0: A 0 is received as the acknowledge bit (ACK reception) 1: A 1 is received as the acknowledge bit (NACK reception)	R
b3	ACKBT	Transmit Acknowledge	0: A 0 is sent as the acknowledge bit (ACK transmission) 1: A 1 is sent as the acknowledge bit (NACK transmission)	R/W *1
b4	ACKWP	ACKBT Write Protect	0: Modification of the ACKBT bit is disabled 1: Modification of the ACKBT bit is enabled*1	W*1
b5	RDRFS	RDRF Flag Set Timing Selection*2	0: The RDRF flag is set at the rising edge of the ninth SCL clock cycle (The SCLn line is not held low at the falling edge of the eighth clock cycle.) 1: The RDRF flag is set at the rising edge of the eighth SCL clock cycle (The SCLn line is held low at the falling edge of the eighth clock cycle.) • Low-hold is released by writing a value to the ACKBT bit	R/W *2
b6	WAIT	WAIT	0: No WAIT (The period between ninth clock cycle and first clock cycle is not held low.) 1: WAIT (The period between ninth clock cycle and first clock cycle is held low.) • Low-hold is released by reading ICDRR	R/W *2
b7	SMBS	SMBus/I²C Bus Selection	0: The I²C bus is selected 1: The SMBus is selected	R/W

Notes: 1. If it is attempted to write 1 to both ACKWP and ACKBT bits, the ACKBT bit cannot be set to 1.

2. The WAIT and RDRFS bits are valid only in receive mode (invalid in transmit mode).

ICMR3 has functions to send/receive acknowledge and to select the RDRF set timing in RIIC receive operation, WAIT operation, and the SCLn pin and SDAn pin input level of the RIIC.

NF[1:0] Bits (Noise Filter Stage Selection)

These bits are used to select the number of stages of the digital noise filter.

Note: Set the noise range to be filtered out by the noise filter within a range less than the SCLn line high-level period or low-level period. If the noise range is set to a value of (SCL clock width: high-level period or low-level period, whichever is shorter) – [1.5 internal reference clock (IICϕ) cycles + analog noise filter: 120 ns (reference value)] or more, the SCL clock is regarded as noise by the noise filter function of the RIIC, which may prevent the RIIC from operating normally.

ACKBR Bit (Receive Acknowledge)

This bit is used to store the acknowledge bit information received from the receive device in transmit mode.

[Setting condition]

- When a 1 is received as the acknowledge bit with the TRS bit in ICCR2 set to 1

[Clearing conditions]

- When a 0 is received as the acknowledge bit with the TRS bit in ICCR2 set to 1
- When 1 is written to the IICRST bit in ICCR1 while the ICE bit in ICCR1 is 0 (RIIC reset)

ACKBT Bit (Transmit Acknowledge)

This bit is used to set the bit to be sent at the acknowledge timing in receive mode.

[Setting condition]

- When 1 is written to this bit with the ACKWP bit set to 1

[Clearing conditions]

- When 0 is written to this bit with the ACKWP bit set to 1
- When stop condition issuance is detected (when a stop condition is detected with the SP bit in ICCR2 set to 1)
- When 1 is written to the IICRST bit in ICCR1 while the ICE bit in ICCR1 is 0 (RIIC reset)

Note: The ACKBT bit must be modified while the ACKWP bit is 1. If the ACKBT bit is modified with the ACKWP bit cleared to 0, writing to the ACKBT bit is disabled.

ACKWP Bit (ACKBT Write Protect)

This bit is used to control the modification of the ACKBT bit.

RDRFS Bit (RDRF Flag Set Timing Selection)

This bit is used to select the RDRF flag set timing in receive mode and also to select whether to hold the SCLn line low at the falling edge of the eighth SCL clock cycle.

When the RDRFS bit is 0, the SCLn line is not held low at the falling edge of the eighth SCL clock cycle, and the RDRF flag is set to 1 at the rising edge of the ninth SCL clock cycle.

When the RDRFS bit is 1, the RDRF flag is set to 1 at the rising edge of the eighth SCL clock cycle and the SCLn line is held low at the falling edge of the eighth SCL clock cycle. The low-hold of the SCLn line is released by writing a value to the ACKBT bit.

After data is received with this setting, the SCLn line is automatically held low before the acknowledge bit is sent. This enables processing to send ACK (ACKBT = 0) or NACK (ACKBT = 1) according to receive data.

WAIT Bit (WAIT)

This bit is used to control whether to hold the period between the ninth SCL clock cycle and the first SCL clock cycle low until the receive data buffer (ICDRR) is completely read each time single-byte data is received in receive mode.

When the WAIT bit is 0, the receive operation is continued without holding the period between the ninth and the first SCL clock cycle low. When both the RDRFS and WAIT bits are 0, continuous receive operation is enabled with the double buffer.

When the WAIT bit is 1, the SCLn line is held low from the falling edge of the ninth clock cycle until the ICDRR value is read each time single-byte data is received. This enables receive operation in byte units.

Note: When the value of the WAIT bit is to be read, be sure to read the ICDRR beforehand.

SMBS Bit (SMBus/I²C Bus Selection)

Setting this bit to 1 selects the SMBus and enables the HOAE bit in ICSER.

22.2.6 I²C Bus Function Enable Register (ICFER)

Addresses: RIIC0.ICFER 0008 8305h, RIIC1.ICFER 0008 8325h

	b7	b6	b5	b4	b3	b2	b1	b0
	FMPE	SCLE	NFE	NACKE	SALE	NALE	MALE	TMOE
Value after reset:	0	1	1	1	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOE	Timeout Detection Function Enable	0: The timeout detection function is disabled 1: The timeout detection function is enabled	R/W
b1	MALE	Master Arbitration Lost Detection Enable	0: Master arbitration lost detection is disabled (Disables the arbitration lost detection function and does not clear the MST and TRS bits in ICCR2 automatically when arbitration is lost.) 1: Master arbitration lost detection is enabled (Enables the arbitration lost detection function and clears the MST and TRS bits in ICCR2 automatically when arbitration is lost.)	R/W
b2	NALE	NACK Transmission Arbitration Lost Detection Enable	0: NACK transmission arbitration lost detection is disabled 1: NACK transmission arbitration lost detection is enabled	R/W
b3	SALE	Slave Arbitration Lost Detection Enable	0: Slave arbitration lost detection is disabled 1: Slave arbitration lost detection is enabled	R/W
b4	NACKE	NACK Reception Transfer Suspension Enable	0: Transfer operation is not suspended during NACK reception (transfer suspension disabled) 1: Transfer operation is suspended during NACK reception (transfer suspension enabled)	R/W
b5	NFE	Digital Noise Filter Circuit Enable	0: No digital noise filter circuit is used 1: A digital noise filter circuit is used	R/W
b6	SCLE	SCL Synchronous Circuit Enable	0: No SCL synchronous circuit is enabled 1: An SCL synchronous circuit is enabled	R/W
b7	FMPE	Fast-mode Plus Enable	0: No fm+ slope control circuit is used for the SCLn pin and SDAn pin 1: An fm+ slope control circuit is used for the SCLn pin and SDAn pin	R/W

ICFER enables or disables the timeout detection function, the arbitration lost detection function, and the receive operation suspension function during NACK reception, and selects the use of a digital noise filter circuit and SCL synchronous circuit.

TMOE Bit (Timeout Detection Function Enable)

This bit is used to enable or disable the timeout detection function.

For details on the timeout detection function, see section 22.11.1, Timeout Detection Function.

MALE Bit (Master Arbitration Lost Detection Enable)

This bit is used to specify whether to use the arbitration lost detection function in master mode. Normally, set this bit to 1.

NALE Bit (NACK Transmission Arbitration Lost Detection Enable)

This bit is used to specify whether to cause arbitration to be lost when ACK is detected during transmission of NACK in receive mode (such as when slaves with the same address exist on the bus or when two or more masters select the same slave device simultaneously with different number of receive bytes).

SALE Bit (Slave Arbitration Lost Detection Enable)

This bit is used to specify whether to cause arbitration to be lost when a value different from the value being transmitted is detected on the bus in slave transmit mode (such as when slaves with the same address exist on the bus or when a mismatch with the transmit data occurs due to noise).

NACKE Bit (NACK Reception Transfer Suspension Enable)

This bit is used to specify whether to continue or discontinue the transfer operation when NACK is received from the slave device in transmit mode. Normally, set this bit to 1.

When NACK is received with the NACKE bit set to 1, the next transfer operation is suspended.

When the NACKE bit is 0, the next transfer operation is continued regardless of the received acknowledge content.

For details on the NACK reception transfer suspension function, see section 22.8.2, NACK Reception Transfer Suspension Function.

NFE Bit (Digital Noise Filter Circuit Enable)

This bit is used to specify whether to use a digital noise filter circuit.

SCLE Bit (SCL Synchronous Circuit Enable)

This bit is used to specify whether to synchronize the SCL clock with the SCL input clock. Normally, set this bit to 1.

When the SCLE bit is cleared to 0 (SCL synchronous circuit is invalid), the RIIC does not synchronize the SCL clock with the SCL input clock (by detecting the SCLn line level) for the SCL clock output operation in master mode, and the RIIC outputs the SCL clock with the transfer rate set in ICBRH and ICBRL regardless of the SCLn line state. For this reason, if the bus load of the I²C bus line is much larger than the specification value or if the SCL clock output overlaps in multiple masters, the short-cycle SCL clock that does not meet the specification may be output. When SCL synchronous circuit is invalid, it also affects the issuance of a start condition, restart condition, and stop condition, and the continuous output of extra SCL clock cycles.

This bit must not be cleared to 0 except for checking the output of the transfer rate that was set during debugging.

FMPE Bit (Fast-mode Plus Enable)

This bit is used to specify whether to use a slope control circuit for Fast-mode Plus[fm+].

When this bit is set to 1, a slope control circuit conforming to the Fast-mode Plus[fm+] slope control standard (tof) of the I²C bus is selected. When this bit is cleared to 0, a slope control circuit conforming to the Standard-mode[Sm] and Fast-mode[fm] slope control standard (tof) of the I²C bus is selected.

Set this bit to 1 when using the transmission rate within a range up to 1 Mbps (Fast-mode Plus[fm+]) of the I²C bus standard. Clear this bit to 0 when using the transmission rate at other rates (up to 100 kbps[Sm], up to 400 kbps[fm]) or for SMBus (10 to 100 kbps).

22.2.7 I²C Bus Status Enable Register (ICSER)

Addresses: RIIC0.ICSER 0008 8306h, RIIC1.ICSER 0008 8326h

	b7	b6	b5	b4	b3	b2	b1	b0
	HOAE	—	DIDE	—	GCAE	SAR2E	SAR1E	SAR0E
Value after reset:	0	0	0	0	1	0	0	1

Bit	Symbol	Bit Name	Description	R/W
b0	SAR0E	Slave Address Register 0 Enable	0: Slave address in SARL0 and SARU0 is disabled 1: Slave address in SARL0 and SARU0 is enabled	R/W
b1	SAR1E	Slave Address Register 1 Enable	0: Slave address in SARL1 and SARU1 is disabled 1: Slave address in SARL1 and SARU1 is enabled	R/W
b2	SAR2E	Slave Address Register 2 Enable	0: Slave address in SARL2 and SARU2 is disabled 1: Slave address in SARL2 and SARU2 is enabled	R/W
b3	GCAE	General Call Address Enable	0: General call address detection is disabled 1: General call address detection is enabled	R/W
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b5	DIDE	Device-ID Address Detection Enable	0: Device-ID address detection is disabled 1: Device-ID address detection is enabled	R/W
b6	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b7	HOAE	Host Address Enable	0: Host address detection is disabled 1: Host address detection is enabled	R/W

ICSER enables or disables comparison of slave addresses, general call address detection, device-ID command detection, and host address detection.

SARyE Bit (Slave Address Register y Enable) (y = 0 to 2)

This bit is used to enable or disable the received slave address and the slave address set in SARLy and SARUy.

When this bit is set to 1, the slave address set in SARLy and SARUy is enabled and is compared with the received slave address.

When this bit is cleared to 0, the slave address set in SARLy and SARUy is disabled and is ignored even if it matches the received slave address.

GCAE Bit (General Call Address Enable)

This bit is used to specify whether to ignore the general call address (0000 000b + 0 [W]: All 0) when it is received.

When this bit is set to 1, if the received slave address matches the general call address, the RIIC recognizes the received slave address as the general call address independently of the slave addresses set in SARLy and SARUy (y = 0 to 2) and performs data receive operation.

When this bit is cleared to 0, the received slave address is ignored even if it matches the general call address.

DIDE Bit (Device-ID Address Detection Enable)

This bit is used to specify whether to recognize and execute the Device-ID address when a device ID (1111 100b) is received in the first frame after a start condition or restart condition is detected.

When this bit is set to 1, if the received first frame matches the device ID, the RIIC recognizes that the Device-ID address has been received. When the following R/W# bit is 0 [W], the RIIC recognizes the second and the following frames as slave addresses and continues the receive operation.

When this bit is cleared to 0, the RIIC ignores the received first frame even if it matches the device ID address and recognizes the first frame as a normal slave address.

For details on the device-ID address detection, see section 22.7.3, Device-ID Address Detection.

HOAE Bit (Host Address Enable)

This bit is used to specify whether to ignore received host address (0001 000b) when the SMBS bit in ICMR3 is 1.

When this bit is set to 1 while the SMBS bit in ICMR3 is 1, if the received slave address matches the host address, the RIIC recognizes the received slave address as the host address independently of the slave addresses set in SARLy and SARUy (y = 0 to 2) and performs the receive operation.

When the SMBS bit in ICMR3 or the HOAE bit is cleared to 0, the received slave address is ignored even if it matches the host address.

22.2.8 I²C Bus Interrupt Enable Register (ICIER)

Addresses: RIIC0.ICIER 0008 8307h, RIIC1.ICIER 0008 8327h

	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	TEIE	RIE	NAKIE	SPIE	STIE	ALIE	TMOIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOIE	Timeout Interrupt Enable	0: Timeout interrupt request (TMOI) is disabled 1: Timeout interrupt request (TMOI) is enabled	R/W
b1	ALIE	Arbitration Lost Interrupt Enable	0: Arbitration lost interrupt request (ALI) is disabled 1: Arbitration lost interrupt request (ALI) is enabled	R/W
b2	STIE	Start Condition Detection Interrupt Enable	0: Start condition detection interrupt request (STI) is disabled 1: Start condition detection interrupt request (STI) is enabled	R/W
b3	SPIE	Stop Condition Detection Interrupt Enable	0: Stop condition detection interrupt request (SPI) is disabled 1: Stop condition detection interrupt request (SPI) is enabled	R/W
b4	NAKIE	NACK Reception Interrupt Enable	0: NACK reception interrupt request (NAKI) is disabled 1: NACK reception interrupt request (NAKI) is enabled	R/W
b5	RIE	Receive Data Full Interrupt Enable	0: Receive data full interrupt request (ICRXI) is disabled 1: Receive data full interrupt request (ICRXI) is enabled	R/W
b6	TEIE	Transmit End Interrupt Enable	0: Transmit end interrupt request (ICTEI) is disabled 1: Transmit end interrupt request (ICTEI) is enabled	R/W
b7	TIE	Transmit Data Empty Interrupt Enable	0: Transmit data empty interrupt request (ICTXI) is disabled 1: Transmit data empty interrupt request (ICTXI) is enabled	R/W

ICIER enables or disables various interrupt sources.

TMOIE Bit (Timeout Interrupt Enable)

This bit is used to enable or disable timeout interrupt requests (TMOI) when the TMOF flag in ICSR2 is set to 1. A TMOI interrupt request is canceled by clearing the TMOF flag or the TMOIE bit to 0.

ALIE Bit (Arbitration Lost Interrupt Enable)

This bit is used to enable or disable arbitration lost interrupt requests (ALI) when the AL flag in ICSR2 is set to 1. An ALI interrupt request is canceled by clearing the AL flag or the ALIE bit to 0.

STIE Bit (Start Condition Detection Interrupt Enable)

This bit is used to enable or disable start condition detection interrupt requests (STI) when the START flag in ICSR2 is set to 1. An STI interrupt request is canceled by clearing the START flag or the STIE bit to 0.

SPIE Bit (Stop Condition Detection Interrupt Enable)

This bit is used to enable or disable stop condition detection interrupt requests (SPI) when the STOP flag in ICSR2 is set to 1. An SPI interrupt request is canceled by clearing the STOP flag or the SPIE bit to 0.

NAKIE Bit (NACK Reception Interrupt Enable)

This bit is used to enable or disable NACK reception interrupt requests (NAKI) when the NACKF flag in ICSR2 is set to 1. An NAKI interrupt request is canceled by clearing the NACKF flag or the NAKIE bit to 0.

RIE Bit (Receive Data Full Interrupt Enable)

This bit is used to enable or disable receive data full interrupt requests (ICRXI) when the RDRF flag in ICSR2 is set to 1.

TEIE Bit (Transmit End Interrupt Enable)

This bit is used to enable or disable transmit end interrupts (ICTEI) when the TDRE flag in ICSR2 is set to 1. An ICTEI interrupt request is canceled by clearing the TEND flag or the TEIE bit to 0.

TIE Bit (Transmit Data Empty Interrupt Enable)

This bit is used to enable or disable transmit data empty interrupts (ICTXI) when the TDRE flag in ICSR2 is set to 1.

22.2.9 I²C Bus Status Register 1 (ICSR1)

Addresses: RIIC0.ICSR1 0008 8308h, RIIC1.ICSR1 0008 8328h

	b7	b6	b5	b4	b3	b2	b1	b0
	HOA	—	DID	—	GCA	AAS2	AAS1	AAS0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	AAS0	Slave Address 0 Detection Flag	0: Slave address 0 is not detected 1: Slave address 0 is detected • This bit is set to 1 when the received slave address matches the SVA[7:1] value in SARL0 while the FS bit in SARU0 is 0 (7-bit address format selected). • This bit is set to 1 when the received slave address matches a value of (1111 0b + SVA [9:8] in SARU0) and the following address matches the SARL0 value while the FS bit in SARU0 is 1 (10-bit address format selected). (This bit is set at the rising edge of the ninth SCL clock cycle in the SARL0 match determination frame.)	R/(W) *
b1	AAS1	Slave Address 1 Detection Flag	0: Slave address 1 is not detected 1: Slave address 1 is detected • This bit is set to 1 when the received slave address matches the SVA[7:1] value in SARL1 while the FS bit in SARU1 is 0 (7-bit address format selected). • This bit is set to 1 when the received slave address matches a value of (1111 0b + SVA [9:8] in SARU1) and the following address matches the SARL1 value while the FS bit in SARU1 is 1 (10-bit address format selected). (This bit is set at the rising edge of the ninth SCL clock cycle in the SARL1 match determination frame.)	R/(W) *
b2	AAS2	Slave Address 2 Detection Flag	0: Slave address 2 is not detected 1: Slave address 2 is detected • This bit is set to 1 when the received slave address matches the SVA[7:1] value in SARL2 while the FS bit in SARU2 is 0 (7-bit address format selected). • This bit is set to 1 when the received slave address matches a value of (1111 0b + SVA [9:8] in SARU2) and the following address matches the SARL2 value while the FS bit in SARU2 is 1 (10-bit address format selected). (This bit is set at the rising edge of the ninth SCL clock cycle in the SARL2 match determination frame.)	R/(W) *
b3	GCA	General Call Address Detection Flag	0: General call address is not detected 1: General call address is detected • This bit is set to 1 when the received slave address matches the general call address (all 0).	R/(W) *
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
b5	DID	Device-ID Command Detection Flag	0: Device-ID command is not detected 1: Device-ID command is detected • This bit is set to 1 when the first frame received immediately after a start condition is detected matches a value of (device ID (1111 100b) + 0 [W]).	R/(W) *
b6	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b7	HOA	Host Address Detection Flag	0: Host address is not detected 1: Host address is detected • This bit is set to 1 when the received slave address matches the host address (0001 000b).	R/(W) *

Note: * Only 0 can be written to clear the flag.

ICSR1 indicates various address detection statuses.

AASy Flag (Slave Address y Detection) (ym = 0 to 2)

[Setting conditions]

<For 7-bit address format: SARUy.FS = 0>

- When the received slave address matches the SVA[7:1] value in SARLy with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

<For 10-bit address format: SARUy.FS = 1>

- When the received slave address matches a value of (1111 0b + SVA [9:8] in SARUy) and the following address matches the SARLy value with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the AASy bit after reading AASy = 1
- When a stop condition is detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

<For 7-bit address format: SARUy.FS = 0>

- When the received slave address does not match the SVA[7:1] value in SARLy with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.

<For 10-bit address format: SARUy.FS = 1>

- When the received slave address does not match a value of (1111 0b + SVA [9:8] in SARUy) with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When the received slave address matches a value of (1111 0b + SVA [9:8] in SARUy) and the following address does not match the SARLy value with the SARyE bit in ICSER set to 1 (slave address m detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.

GCA Flag (General Call Address Detection)

[Setting condition]

- When the received slave address matches the general call address (0000 000b + 0 [W]) with the GCAE bit in ICSER set to 1 (general call address detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the GCA bit after reading GCA = 1
- When a stop condition is detected
- When the received slave address does not match the general call address (0000 000b + 0 [W]) with the GCAE bit in ICSER set to 1 (general call address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

DID Flag (Device-ID Address Detection)

[Setting condition]

- When the first frame received immediately after a start condition or restart condition is detected matches a value of (device ID (1111 100b) + 0 [W]) with the DIDE bit in ICSER set to 1 (Device-ID address detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the DID bit after reading DID = 1
- When a stop condition is detected
- When the first frame received immediately after a start condition or restart condition is detected does not match a value of (device ID (1111 100b)) with the DIDE bit in ICSER set to 1 (Device-ID address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When the first frame received immediately after a start condition or restart condition is detected matches a value of (device ID (1111 100b) + 0 [W]) and the second frame does not match any of slave addresses 0 to 2 with the DIDE bit in ICSER set to 1 (Device-ID address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

HOA Flag (Host Address Detection)

[Setting condition]

- When the received slave address matches the host address (0001 000b) with the HOAE bit in ICSER set to 1 (host address detection enabled)
  This flag is set to 1 at the rising edge of the ninth SCL clock cycle in the frame.

[Clearing conditions]

- When 0 is written to the HOA bit after reading HOA = 1
- When a stop condition is detected
- When 0 is written to the SMBS bit in ICMR3 or the HOAE bit in ICSER
- When the received slave address does not match the host address (0001 000b) with the HOAE bit in ICSER set to 1 (host address detection enabled)
  This flag is cleared to 0 at the rising edge of the ninth SCL clock cycle in the frame.
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

22.2.10 I²C Bus Status Register 2 (ICSR2)

Addresses: RIIC0.ICSR2 0008 8309h, RIIC1.ICSR2 0008 8329h

	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	TEND	RDRF	NACKF	STOP	START	AL	TMOF
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	TMOF	Timeout Detection Flag	0: Timeout is not detected	R/(W)
			1: Timeout is detected	*
b1	AL	Arbitration Lost Flag	0: Arbitration is not lost	R/(W)
			1: Arbitration is lost	*
b2	START	Start Condition Detection Flag	0: Start condition is not detected	R/(W)
			1: Start condition is detected	*
b3	STOP	Stop Condition Detection Flag	0: Stop condition is not detected	R/(W)
			1: Stop condition is detected	*
b4	NACKF	NACK Detection Flag	0: NACK is not detected	R/(W)
			1: NACK is detected	*
b5	RDRF	Receive Data Full Flag	0: ICDRR contains no receive data	R/(W)
			1: ICDRR contains receive data	*
b6	TEND	Transmit End Flag	0: Data is being transmitted	R/(W)
			1: Data has been transmitted	*
b7	TDRE	Transmit Data Empty Flag	0: ICDRT contains transmit data	R
			1: ICDRT contains no transmit data	

Note: * Only 0 can be written to clear the flag.

ICSR2 indicates various interrupt request flags and statuses.

TMOF Flag (Timeout Detection)

This flag is set to 1 when the RIIC recognizes timeout after the SCLn line state remains unchanged for a certain period.

[Setting condition]

- When the SCLn line state remains unchanged for the period specified by bits TMOH, TMOL, and TMOS in ICMR2 with the TMOE bit in ICFER set to 1 (timeout detection function enabled) in master mode or in the slave specification state.

[Clearing conditions]

- When 0 is written to the TMOF bit after reading TMOF = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

AL Flag (Arbitration Lost Flag)

This flag shows that bus mastership has been lost (loss in arbitration) due to a bus conflict or some other reason when a start condition is issued or an address and data are transmitted. The RIIC monitors the level on the SDAn line during transmission and, if the level on the line does not match the value of the bit being output, sets the value of the AL bit to 1 to indicate that the bus is occupied by another device.

The RIIC can also set the flag to indicate the detection of loss of arbitration during NACK transmission in master mode or during data transmission in slave mode.

[Setting conditions]

<When master arbitration lost detection is enabled: ICFER.MALE = 1>

- When the internal SDA output state does not match the SDAn line level at the rising edge of SCL clock except for the ACK period during data (including slave address) transmission in master transmit mode (when the SDAn line is driven low while the internal SDA output is 1 (the SDAn pin is in the high-impedance state))
- When a start condition is detected while the ST bit in ICCR2 is 1 (start condition issuance request) or the internal SDA output state does not match the SDAn line level
- When the ST bit in ICCR2 is set to 1 (start condition issuance request) with the BBSY flag in ICCR2 set to 1.

<When NACK arbitration lost detection is enabled: ICFER.MALE = 1>

- When the internal SDA output state does not match the SDAn line level at the rising edge of SCL clock in the ACK period during NACK transmission in receive mode

<When slave arbitration lost detection is enabled>

- When the internal SDA output state does not match the SDAn line level at the rising edge of SCL clock except for the ACK period during data transmission in slave transmit mode

[Clearing conditions]

- When 0 is written to the AL bit after reading AL = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Table 22.5 Relationship between Arbitration Lost Generation Sources and Arbitration Lost Enable Functions

ICFER			ICSR2		
MALE	NALE	SALE	AL	Error	Arbitration Lost Generation Source
1	*	*	1	Start condition issuance error	When internal SDA output state does not match SDAn line level when a start condition is detected while the ST bit in ICCR2 is 1
					When ST in ICCR2 is set to 1 with BBSY in ICCR2 set to 1
			1	Transmit data mismatch	When transmit data (including slave address) does not match the bus state in master transmit mode
*	1	*	1	NACK transmission mismatch	When ACK is detected during transmission of NACK in master receive mode or slave receive mode
*	*	1	1	Transmit data mismatch	When transmit data does not match the bus state in slave transmit mode

[Legend] *: Don't care

START Flag (Start Condition Detection)

[Setting condition]

- When a start condition (or a restart condition) is detected

[Clearing conditions]

- When 0 is written to the START bit after reading START = 1
- When a stop condition is detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

STOP Flag (Stop Condition Detection)

[Setting condition]

- When a stop condition is detected

[Clearing conditions]

- When 0 is written to the STOP bit after reading STOP = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

NACKF Flag (NACK Detection)

[Setting condition]

- When acknowledge is not received (NACK is received) from the receive device in transmit mode with the NACKE bit in ICFER set to 1 (transfer suspension enabled)

[Clearing conditions]

- When 0 is written to the NACKF bit after reading NACKF = 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note: When the NACKF flag is set to 1, the RIIC suspends data transmission/reception. Writing to ICDRT in transmit mode or reading from ICDRR in receive mode with the NACKF flag set to 1 does not enable data transmit/receive operation. To restart data transmission/reception, clear the NACKF flag to 0.

RDRF Flag (Receive Data Full)

[Setting conditions]

- When receive data has been transferred from ICDRS to ICDRR
  This flag is set to 1 at the rising edge of the eighth or ninth SCL clock cycle (selected by the RDRFS bit in ICMR3)
- When the received slave address matches after a start condition (or a restart condition) is detected with the TRS bit in ICCR2 cleared to 0

[Clearing conditions]

- When 0 is written to the RDRF bit after reading RDRF = 1
- When data is read from ICDRR
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

TEND Flag (Transmit End)

[Setting condition]

- At the rising edge of the ninth SCL clock cycle while the TDRE flag is 1

[Clearing conditions]

- When 0 is written to the TEND bit after reading TEND = 1
- When data is written to ICDRT
- When a stop condition is detected
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

TDRE Flag (Transmit Data Empty)

[Setting conditions]

- When data has been transferred from ICDRT to ICDRS and ICDRT becomes empty
- When the TRS bit in ICCR2 is set to 1
  a. When the MST bit in ICCR2 is set to 1 after a start condition (or a restart condition) is detected
  b. When the RIIC enters transmit mode from receive mode
  c. When 1 is written to while the ICMR1.MTWP bit is 1
- When the received slave address matches while the TRS bit is 1

[Clearing conditions]

- When data is written to ICDRT
- When the TRS bit in ICCR2 is cleared to 0
  a. When a stop condition is detected
  b. When the RIIC enters receive mode from transmit mode
  c. When 0 is written to while the ICMR1.MTWP bit is 1
- When 1 is written to the IICRST bit in ICCR1 to apply an RIIC reset or an internal reset

Note: When the NACKF flag is set to 1 while the NACKE bit in ICFER is 1, the RIIC suspends data transmission/reception. Here, if the TDRE flag is 0 (next transmit data has been written), data is transferred to the ICDRS register and the ICDRT register becomes empty at the rising edge of the ninth clock cycle, but the TDRE flag is not set to 1.

22.2.11 Slave Address Register Ly (SARLy) (y = 0 to 2)

Addresses: RIIC0.SARL0 0008 830Ah, RIIC1.SARL0 0008 832Ah
RIIC0.SARL1 0008 830Ch, RIIC1.SARL1 0008 832Ch
RIIC0.SARL2 0008 830Eh, RIIC1.SARL2 0008 832Eh

	b7	b6	b5	b4	b3	b2	b1	b0
	SVA[7:1]							SVA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	SVA0	10-Bit Address LSB	The least significant bit (LSB) of a 10-bit slave address is set • When the FS bit in SARUy is 0 (7-bit address format), this bit is invalid • When the FS bit in SARUy is 1 (10-bit address format), this bit is the LSB of the lower 8-bit address (combined with the SVA[7:1] bits) of a 10-bit slave address	R/W
b7 to b1	SVA[7:1]	7-Bit Address/10-Bit Address Lower Bits	A slave address is set • When the FS bit in SARUy is 0 (7-bit address format), these bits form a 7-bit slave address • When the FS bit in SARUy is 1 (10-bit address format), these bits form the lower 8-bit address (combined with the SVA0 bit) of a 10-bit slave address	R/W

SARLy sets slave address y (7-bit address or lower eight bits of 10-bit address).

SVA0 Bit (10-Bit Address LSB)

When the 10-bit address format is selected (SARUy.FS = 1), this bit functions as the LSB of a 10-bit address and forms the lower eight bits of a 10-bit address in combination with the SVA[7:1] bits.

When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 1, this bit is valid. While the SARUy.FS bit or SARyE bit is 0, the setting of this bit is ignored.

SVA[7:1] Bits (7-Bit Address/10-Bit Address Lower Bits)

When the 7-bit address format is selected (SARUy.FS = 0), these bits function as a 7-bit address. When the 10-bit address format is selected (SARUy.FS = 1), these bits function as the lower eight bits of a 10-bit address in combination with the SVA0 bit.

While the SARyE bit in ICSER is 0, the setting of these bits is ignored.

22.2.12 Slave Address Register Uy (SARUy) (y = 0 to 2)

Addresses: RIIC0.SARU0 0008 830Bh, RIIC1.SARU0 0008 832Bh
RIIC0.SARU1 0008 830Dh, RIIC1.SARU1 0008 832Dh
RIIC0.SARU2 0008 830Fh, RIIC1.SARU2 0008 832Fh

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	SVA[9:8]		FS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FS	7-Bit/10-Bit Address Format Selection	0: The 7-bit address format is selected 1: The 10-bit address format is selected	R/W
b2, b1	SVA[9:8]	10-Bit Address Upper Bits	A slave address is set • When the SARUy.FS bit is 0 (7-bit address format), these bits are invalid • When the SARUy.FS bit is 1 (10-bit address format), these bits form the upper two bits of a 10-bit slave address	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

SARUy selects 7-bit address format or 10-bit address format and sets the upper bits of a 10-bit slave address.

FS Bit (7-Bit/10-Bit Address Format Selection)

This bit is used to select 7-bit address or 10-bit address for slave address m (in SARLy and SARUy).

When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 0, the 7-bit address format is selected for slave address m, the SVA[7:1] setting in SARLy is valid, and the settings of the SVA[9:8] bits and the SVA0 bit in SARLy are ignored.

When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 1, the 10-bit address format is selected for slave address m and the settings of the SVA[9:8] bits and SARLy are valid.

While the SARyE bit in ICSER is 0 (SARLy and SARUy disabled), the setting of the SARUy.FS bit is invalid.

SVA[9:8] Bits (10-Bit Address Upper Bits)

When the 10-bit address format is selected (FS = 1), these bits function as the upper two bits of a 10-bit address.

When the SARyE bit in ICSER is set to 1 (SARLy and SARUy enabled) and the SARUy.FS bit is 1, these bits are valid. While the SARUy.FS bit or SARyE bit is 0, the setting of these bits is ignored.

22.2.13 I²C Bus Bit Rate Low-Level Register (ICBRL)

Addresses: RIIC0.ICBRH 0008 8310h, RIIC1.ICBRH 0008 8330h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	BRL[4:0]				
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	BRL[4:0]	Bit Rate Low-Level Period	Low-level period of SCL clock	R/W
b7 to b5	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

ICBRL is a 5-bit register to set the low-level period of SCL clock. It also works to generate the data setup time for automatic SCL low-hold operation (see section 22.8, Function to Automatically Hold SCLn Clock Low); when the RIIC is used only in slave mode, this register needs to be set to a value longer than the data setup time*.

ICBRL counts the low-level period with the internal reference clock source (IICϕ) specified by the CKS[2:0] bits in ICMR1.

Note: Data setup time (tSU: DAT)
250 ns (up to 100 kbps: standard mode [Sm])
100 ns (up to 400 kbps: fast mode [fm])
50 ns (up to 1 Mbps: fast mode plus [fm+])

22.2.14 I²C Bus Bit Rate High-Level Register (ICBRH)

Addresses: RIIC0.ICBRL 0008 8311h, RIIC1.ICBRL 0008 8331h

Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	BRH[4:0]	Bit Rate High-Level Period	High-level period of SCL clock	R/W
b7 to b5	—	Reserved	These bits are always read as 1. The write value should always be 1.	R/W

ICBRH is a 5-bit register to set the high-level period of SCL clock. ICBRH is valid in master mode. If the RIIC is used only in slave mode, this register need not to set the high-level period.

ICBRH counts the high-level period with the internal reference clock source (IICϕ) specified by the CKS[2:0] bits in ICMR1.

The I²C transfer rate and the SCL clock duty ratio are calculated using the following expression.

Transfer rate = 1 / { [(ICBRH + 1) + (ICBRL + 1)] / IICϕ*1 + SCLn line rising time [tr] + SCLn line falling time [tf]}

Duty cycle = { SCLn line rising time [tr]*2 + (ICBRH + 1) / IICϕ} / {SCLn line falling time [tf]*2 + (ICBRL + 1) / IICϕ}

Notes: 1. IICϕ = PCLK × 106 × Division ratio

2. The SCLn line rising time [tr] and SCLn line falling time [tf] depend on the total bus line capacitance [Cb] and the pull-up resistor [Rp]. For details, see the I²C bus standard from NXP Semiconductors.

Table 22.6 shows examples of ICBRH/ICBRL settings.

Table 22.6 Examples of ICBRH/ICBRL Settings for Transfer Rate

Transfer Rate (kbps)	Operating Frequency PCLK (MHz)								
	8			10			12.5		
	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL
10	100b	22 (F6h)	25 (F9h)	101b	13 (EDh)	15 (EFh)	101b	16 (F0h)	20 (F4h)
50	010b	16 (F0h)	19 (F3h)	010b	21 (F5h)	24 (F8h)	011b	12 (ECh)	15 (EFh)
100	001b	15 (EFh)	18 (F2h)	001b	19 (F3h)	23 (F7h)	001b	24 (F8h)	29 (FDh)
400	000b	4 (E4h)	10 (EAh)	000b	5 (E5h)	12 (ECh)	000b	7 (E7h)	16 (F0h)
1000	000b	2 (E2h)	3 (E3h)	000b	2 (E2h)	4 (E4h)	000b	3 (E3h)	6 (E6h)

Transfer Rate (kbps)	Operating Frequency PCLK (MHz)								
	16			20			25		
	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL
10	101b	22 (F6h)	25 (F9h)	110b	13 (EDh)	15 (EFh)	110b	16 (F0h)	20 (F4h)
50	011b	16 (F0h)	19 (F3h)	011b	21 (F5h)	24 (F8h)	100b	12 (ECh)	15 (EFh)
100	010b	15 (EFh)	18 (F2h)	010b	19 (F3h)	23 (F7h)	010b	24 (F8h)	29 (FDh)
400	000b	9 (E9h)	20 (F4h)	000b	11 (EBh)	25 (F9h)	001b	7 (E7h)	16 (F0h)
1000	000b	4 (E4h)	7 (E7h)	000b	5 (E5h)	9 (E9h)	000b	6 (E6h)	12 (ECh)

Transfer Rate (kbps)	Operating Frequency PCLK (MHz)								
	30			33			50		
	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL	CKS [2:0]	ICBRH	ICBRL
10	110b	20 (F4h)	24 (F8h)	110b	22 (F6h)	26 (FAh)	111b	16 (F0h)	20 (F4h)
50	100b	15 (EFh)	18 (F2h)	100b	17 (F1h)	20 (F4h)	100b	26 (FAh)	31 (FFh)
100	010b	2 (E2h)	3 (E3h)	011b	16 (F0h)	19 (F3h)	011b	24 (F8h)	29 (FDh)
400	001b	8 (E8h)	19 (F3h)	001b	9 (E9h)	21 (F5h)	010b	7 (E7h)	16 (F0h)
1000	000b	7 (E7h)	14 (EEh)	000b	8 (E8h)	16 (F0h)	000b	12 (ECh)	24 (F8h)

Note: ICBRH/ICBRL settings in these tables are calculated using the following values:

SCLn line rising time (tr): 100 kbps or less, [Sm]: 1000 ns, 400 kbps or less, [Fm]: 300 ns, 1 Mbps or less, [Fm+]: 120 ns

SCLn line falling time (tf): 400 kbps or less, [Sm/Fm]: 300 ns, 1 Mbps or less, [Fm+]: 120 ns

For the specified values of SCLn line rising time (tr) and SCLn line falling time (tf), see the I²C bus standard from NXP Semiconductors.

22.2.15 I²C Bus Transmit Data Register (ICDRT)

Addresses: RIIC0.ICDRT 0008 8312h, RIIC1.ICDRT 0008 8332h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	1	1	1	1	1	1	1	1

ICDRT is an 8-bit readable/writable register that stores transmit data. When ICDRT detects a space in the I²C bus shift register (ICDRS), it transfers the transmit data that has been written to ICDRT to ICDRS and starts transmitting data in transmit mode.

The double-buffer structure of ICDRT and ICDRS allows continuous transmit operation if the next transmit data has been written to ICDRT while the ICDRS data is being transmitted.

ICDRT can always be read and written. Write transmit data to ICDRT once when a transmit data empty interrupt (ICTXI) request is generated.

22.2.16 I²C Bus Receive Data Register (ICDRR)

Addresses: RIIC0.ICDRR 0008 8313h, RIIC1.ICDRR 0008 8333h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	0	0	0	0	0

ICDRR is an 8-bit read-only register that stores receive data. When one byte of data has been received, the received data is transferred from the I²C bus shift register (ICDRS) to ICDRR to enable the next data to be received.

The double-buffer structure of ICDRS and ICDRR allows continuous receive operation if the received data has been read from ICDRR while ICDRS is receiving data.

ICDRR cannot be written. Read data from ICDRR once when a receive data full interrupt (ICRXI) request is generated.

If ICDRR receives the next receive data before the current data is read from ICDRR (while the RDRF flag in ICSR2 is 1), the RIIC automatically holds the SCL clock low one cycle before the RDRF flag is set to 1 next.

22.2.17 I²C Bus Shift Register (ICDRS)

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	?	?	?	?	?	?	?	?

ICDRS is an 8-bit shift register to transmit and receive data.

During transmission, transmit data is transferred from ICDRT to ICDRS and is sent from the SDAn pin. During reception, data is transferred from ICDRS to ICDRR after one byte of data has been received.

ICDRS cannot be accessed directly.

22.3 Operation

22.3.1 Communication Data Format

The I²C bus format consists of 8-bit data and 1-bit acknowledge. The frame following a start condition or restart condition is an address frame used to specify a slave device with which the master device communicates. The specified slave is valid until a new slave is specified or a stop condition is issued.

Figure 22.3 shows the I²C bus format, and figure 22.4 shows the I²C bus timing.

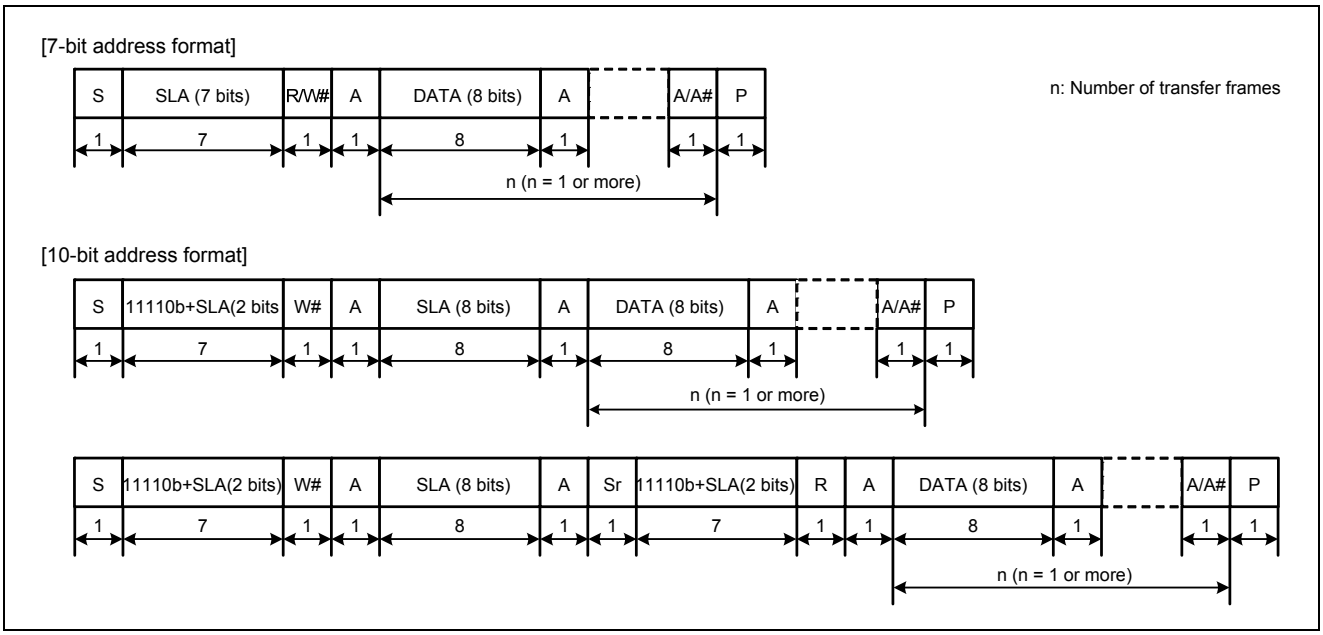


Figure 22.3 I²C Bus Format

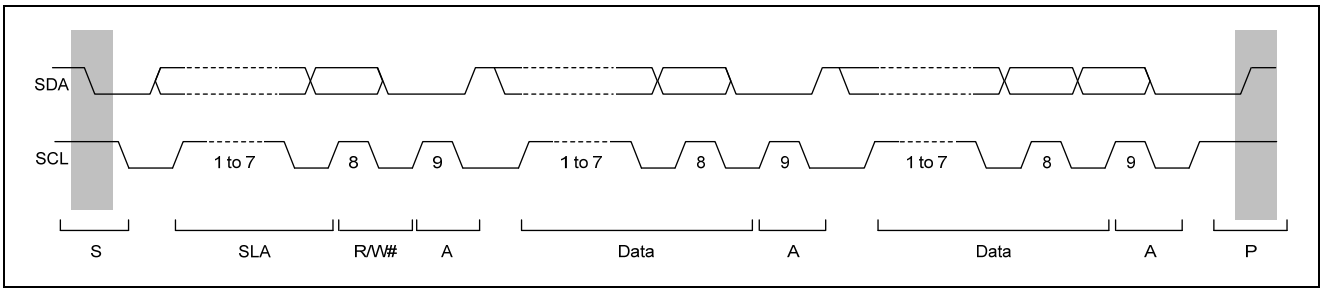


Figure 22.4 I²C Bus Timing (SLA = 7 Bits)

[Legend]

S:	Start condition. The master device drives the SDAn line low from high level while the SCLn line is at a high level.
SLA:	Slave address, by which the master device selects a slave device.
R/W#:	Indicates the direction of data transfer: from the slave device to the master device when R/W is 1, or from the master device to the slave device when R/W is 0.
A:	Acknowledge. The receive device drives the SDAn line low. (In master transmit mode, the slave device returns acknowledge. In master receive mode, the master device returns acknowledge.)
Sr:	Restart condition. The master device drives the SDAn line low from the high level after the setup time has elapsed with the SCLn line at the high level.
DATA:	Transmitted or received data
P:	Stop condition. The master device drives the SDAn line high from low level while the SCLn line is at a high level.

22.3.2 Initial Settings

Before starting data transmission and reception, initialize the RIIC according to the procedure in figure 22.5.

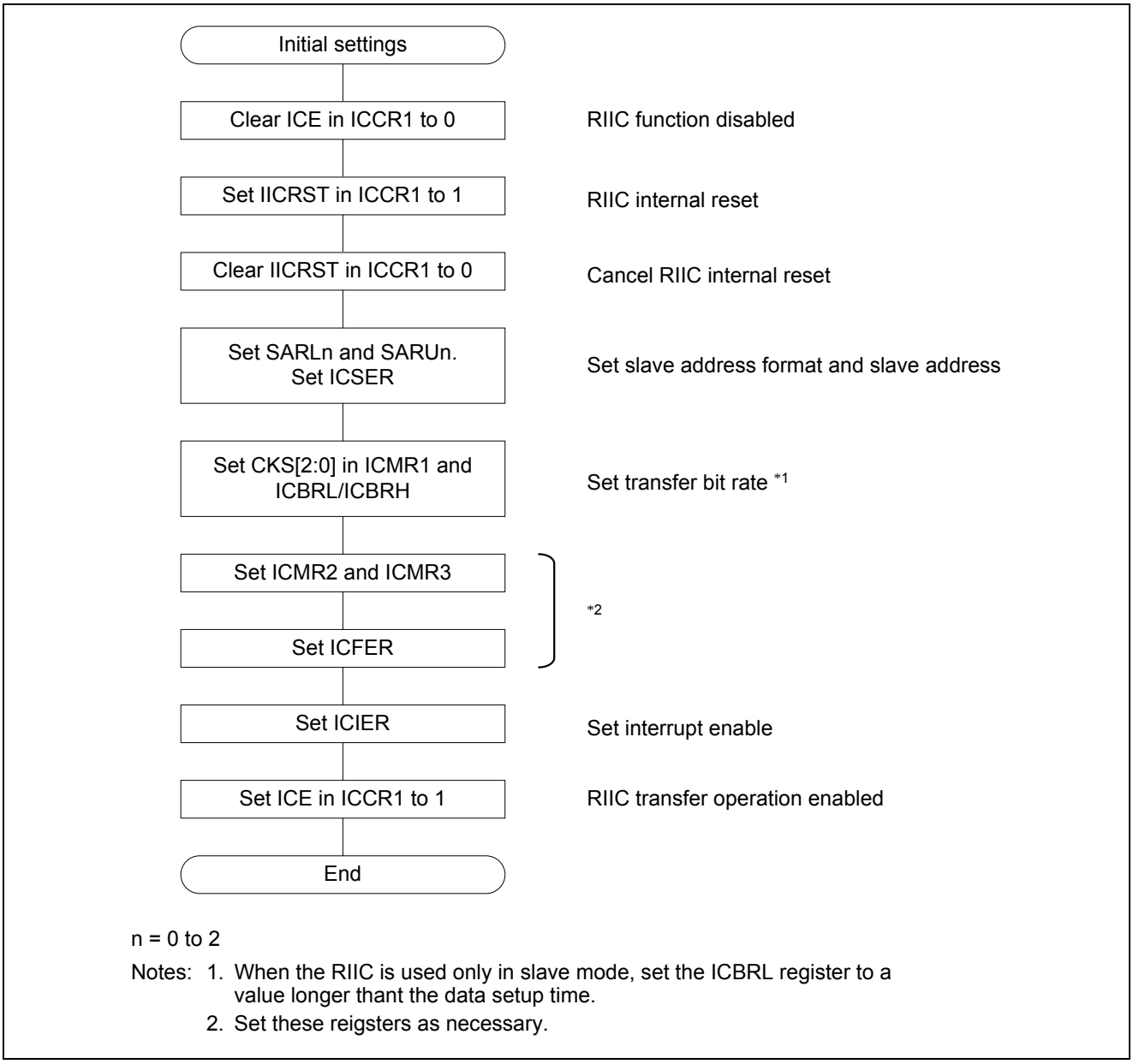


Figure 22.5 Example of RIIC Initialization Flow

22.3.3 Master Transmitter Operation

In master transmitter operation, the RIIC outputs the SCL (clock) and transmitted data signals as the master device, and the slave device returns acknowledgements. Figure 22.6 shows an example of usage of master transmission and figures 22.7 to 22.9 show the timing of operations in master transmission.

The following describes the procedure and operations for master transmission.

1. Set the IICRST bit in ICCR1 to 1 (internal reset) and then clear the IICRST bit to 0 (canceling reset) with the ICE bit in ICCR1 cleared to 0 (disabling the interface). This initializes the internal state and the various flags of ICSR1. After that, set registers SARLy, SARUy, ICSER, ICMR1, ICBRH, and ICBRL (y = 0 to 2), and set the other registers as necessary (for initial settings of the RIIC, see figure 22.5). When the necessary register settings have been completed, set the ICE bit to 1 (to enable transfer). This step is not necessary if initialization of the RIIC has already been completed.

2. Read the BBSY flag in ICCR2 to check that the bus is open, and then set the ST bit in ICCR2 to 1 (start condition issuance request). Upon receiving the request, the RIIC issues a start condition. At the same time, the BBSY flag and the START flag in ICSR2 are automatically set to 1 and the ST bit is automatically cleared to 0. At this time, if the start condition is detected and the internal levels for the SDA output state and the levels on the SDAn line have matched while the ST bit is 1, the RIIC recognizes that issuing of the start condition as requested by the ST bit has been successfully completed, and the MST and TRS bits in ICCR2 are automatically set to 1, placing the RIIC in master transmitter mode. The TDRE flag in ICSR2 is also automatically set to 1 in response to setting of the TRS bit to 1.

3. Check that the TDRE flag in ICSR2 is 1, and then write the value for transmission (the slave address and the R/W# bit) to ICDRT. Once the data for transmission are written to ICDRT, the TDRE flag is automatically cleared to 0, the data are transferred from ICDRT to ICDRS, and the TDRE flag is again set to 1. After the byte containing the slave address and R/W# bit has been transmitted, the value of the TRS bit is automatically updated to select master transmitter or master receiver mode in accord with the value of the transmitted R/W# bit. If the value of the R/W# bit was 0, the RIIC continues in master transmitter mode.
   Since the ICSR2.NACKF flag being 1 at this time indicates that no slave device recognized the address or there was an error in communications, write 1 to the ICCR2.SP bit to issue a stop condition.
   For data transmission with an address in the 10-bit format, start by writing 1111 0b, the two higher-order bits of the slave address, and W to ICDRT as the first address transmission. Then, as the second address transmission, write the eight lower-order bits of the slave address to ICDRT.

4. After confirming that the TDRE flag in ICSR2 is 1, write the data for transmission to the ICDRT register. The RIIC automatically holds the SCLn line low until the data for transmission are ready or a stop condition is issued.

5. After all bytes of data for transmission have been written to the ICDRT register, wait until the value of the TEND flag in ICSR2 returns to 1, and then set the SP bit in ICCR2 to 1 (stop condition issuance request). Upon receiving a stop condition issuance request, the RIIC issues the stop condition.

6. Upon detecting the stop condition, the RIIC automatically clears the MST and TRS bits in ICCR2 to 00b and enters slave receiver mode. Furthermore, it automatically clears the TDRE and TEND flags to 0, and sets the STOP flag in ICSR2 to 1.

7. After checking that the ICSR2.STOP flag is 1, clear the ICSR2.NACKF and STOP flags to 0 for the next transfer operation.

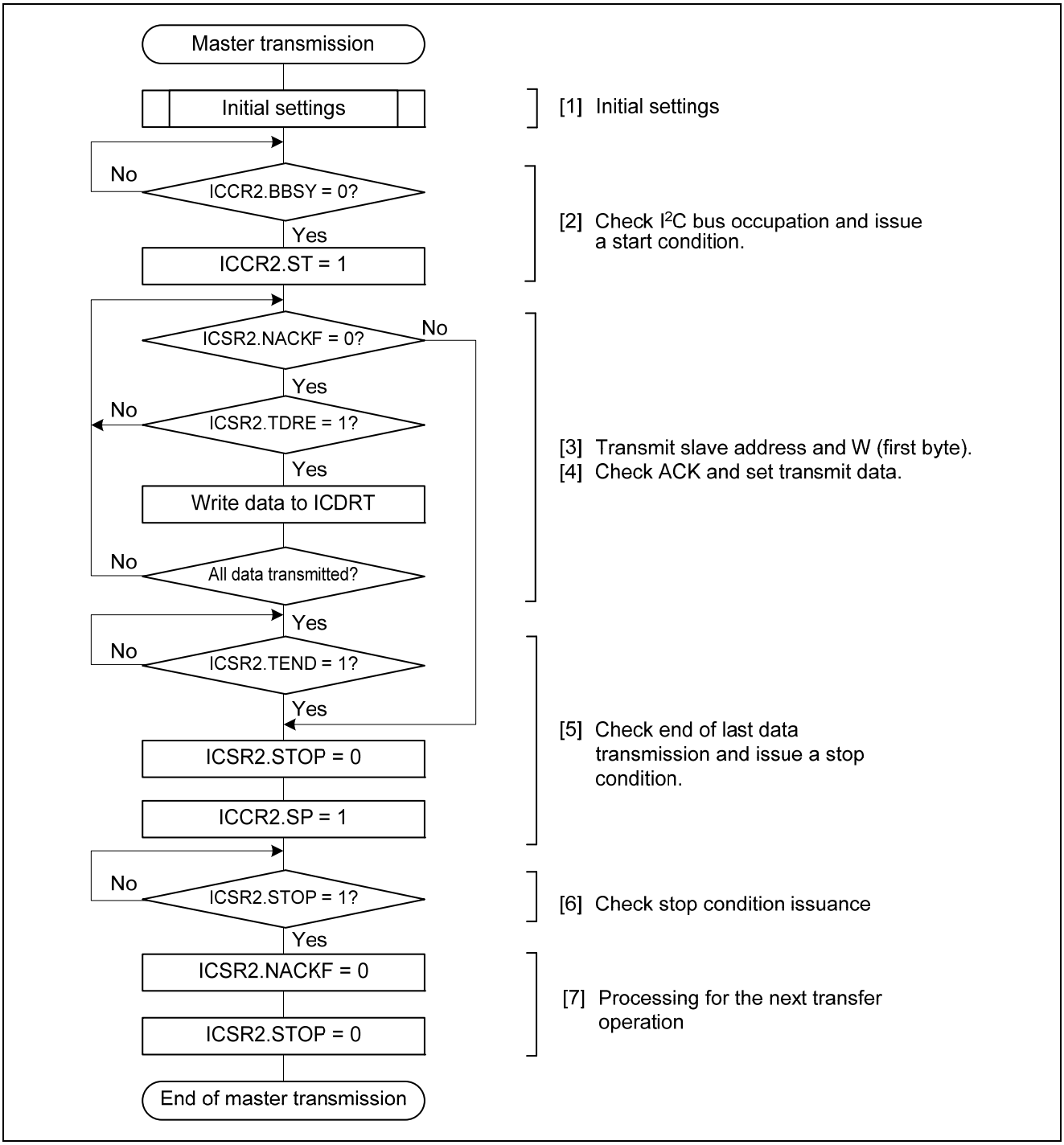


Figure 22.6 Example of Master Transmission Flowchart

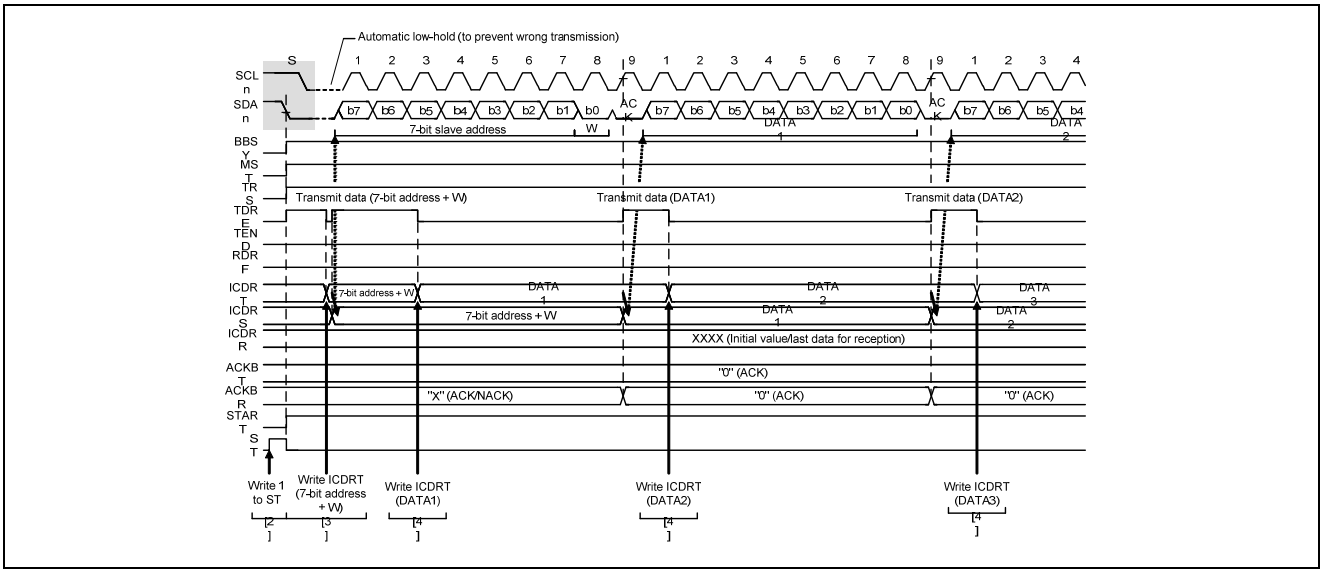


Figure 22.7 Master Transmit Operation Timing (1) (7-Bit Address Format)

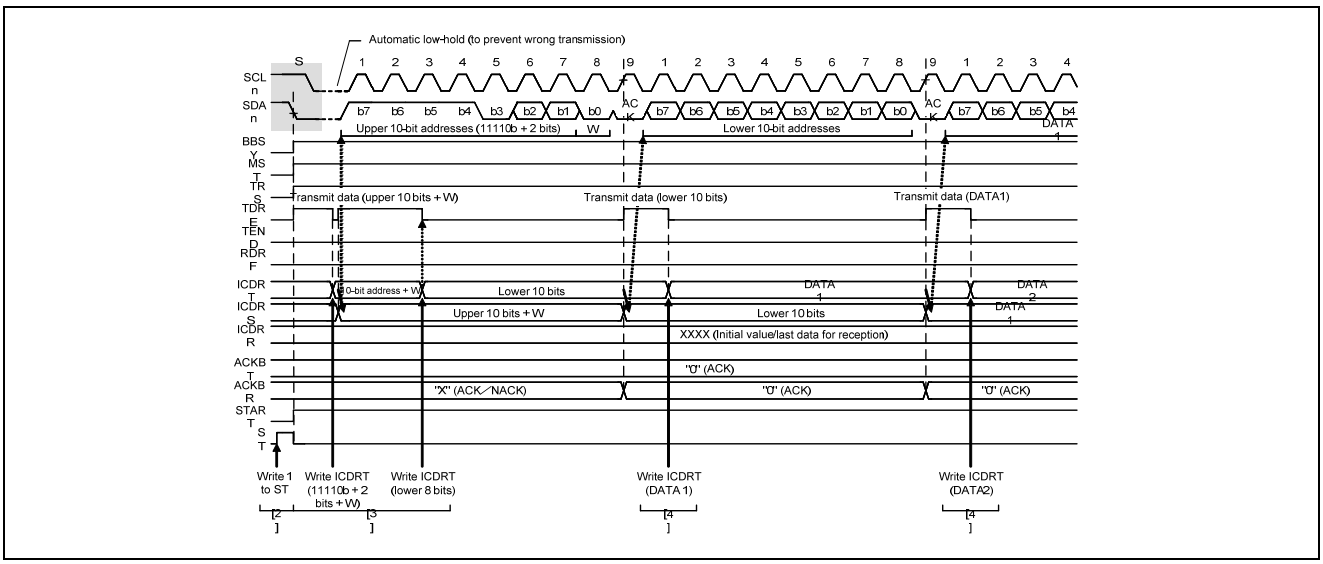


Figure 22.8 Master Transmit Operation Timing (2) (10-Bit Address Format)

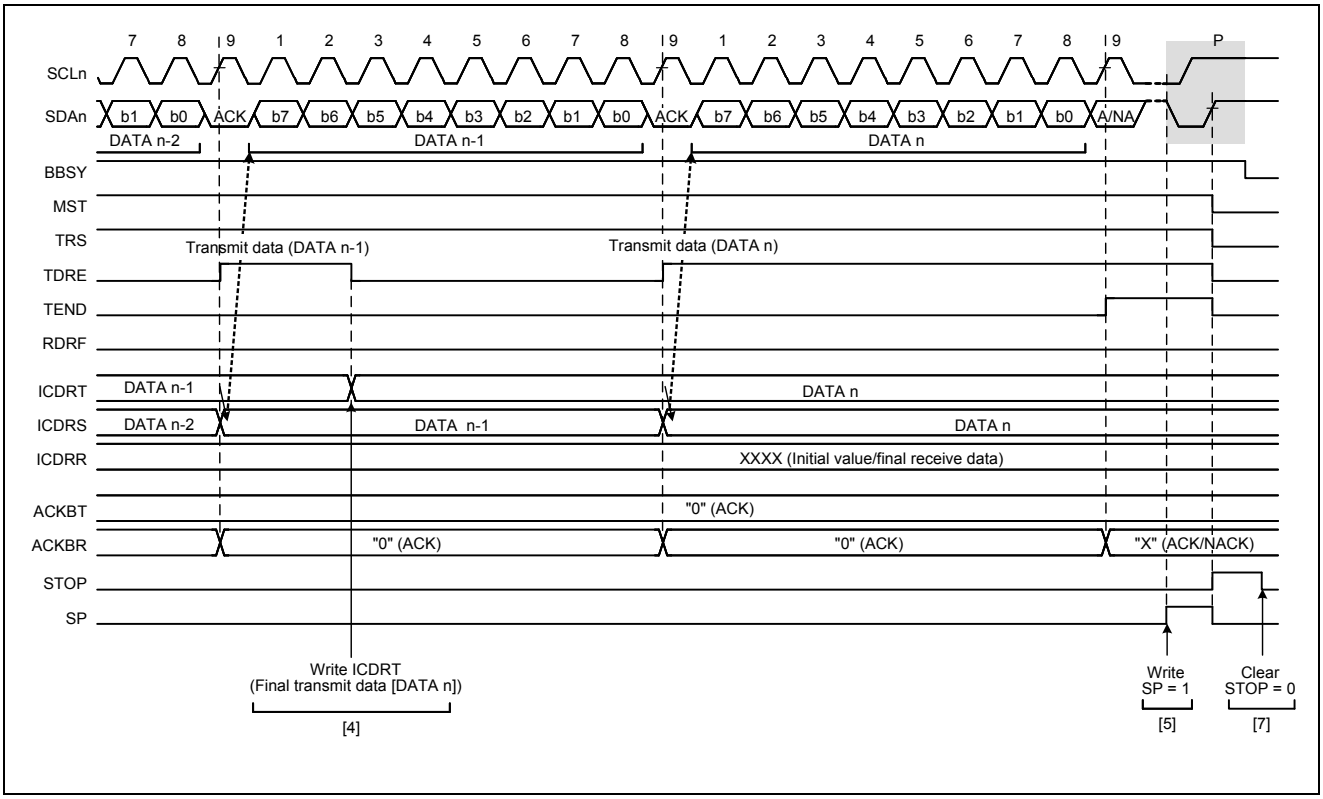


Figure 22.9 Master Transmit Operation Timing (3)

22.3.4 Master Receiver Operation

In master receiver operation, the RIIC as a master device outputs the SCL (clock) signal, receives data from the slave device, and returns acknowledgements. Since the RIIC must start by sending a slave address to the corresponding slave device, this part of the procedure is performed in master transmitter mode, but the subsequent steps are in master receiver mode.

Figure 22.10 shows an example of usage of master reception and figures 22.11 and 22.13 show the timing of operations in master reception.

The following describes the procedure and operations for master reception.

1. Set the IICRST bit in ICCR1 to 1 (internal reset) and then clear the IICRST bit to 0 (canceling reset) with the ICE bit in ICCR1 cleared to 0 (disabling the interface). This initializes the internal state and the various flags of ICSR1. After that, set registers SARLy, SARUy, ICSER, ICMR1, ICBRH, and ICBRL (y = 0 to 2), and set the other registers as necessary (for initial settings of the RIIC, see figure 22.5). When the necessary register settings have been completed, set the ICE bit to 1 (to enable transfer). This step is not necessary if initialization of the RIIC has already been completed.
2. Read the BBSY flag in ICCR2 to check that the bus is open, and then set the ST bit in ICCR2 to 1 (start condition issuance request). Upon receiving the request, the RIIC issues a start condition. When the RIIC detects the start condition, the BBSY flag and the START flag in ICSR2 are automatically set to 1 and the ST bit is automatically cleared to 0. At this time, if the start condition is detected and the levels for the SDA output and the levels on the SDAn line have matched while the ST bit is 1, the RIIC recognizes that issuing of the start condition as requested by the ST bit has been successfully completed, and the MST and TRS bits in ICCR2 are automatically set to 1, placing the RIIC in master transmitter mode. The TDRE flag in ICSR2 is also automatically set to 1 in response to setting of the TRS bit to 1.
3. Check that the TDRE flag in ICSR2 is 1, and then write the value for transmission (the first byte indicates the slave address and value of the R/W# bit) to ICDRT. Once the data for transmission are written to ICDRT, the TDRE flag is automatically cleared to 0, the data are transferred from ICDRT to ICDRS, and the TDRE flag is again set to 1. Once the byte containing the slave address and R/W# bit has been transmitted, the value of the ICCR2.TRS bit is automatically updated to select master transmitter or master receiver mode in accord with the value of the transmitted R/W# bit. If the value of the R/W# bit was 1, the TRS bit is cleared to 0 on the rising edge of the ninth cycle of SCLn (the clock signal), placing the RIIC in master receiver mode. At this time, the TDRE flag is automatically cleared to 0 and the ICSR2.RDRF flag is automatically set to 1.
   Since the ICSR2.NACKF flag being 1 at this time indicates that no slave device recognized the address or there was an error in communications, write 1 to the ICCR2.SP bit to issue a stop condition.
   For master reception from a device with a 10-bit address, start by using master transmission to issue the 10-bit address, and then issue a restart condition. After that, transmitting 1111 0b, the two higher-order bits of the slave address, and the R bit places the RIIC in master receiver mode.
4. Dummy read ICDRR after confirming that the RDRF flag in ICSR2 is 1; this makes the RIIC start output of the SCL (clock) signal and start data reception.

5. After one byte of data has been received, the RDRF flag in ICSR2 is set to 1 on the rising edge of the eighth or ninth cycle of SCL clock (the clock signal) as selected by the RDRFS bit in ICMR3. Reading out ICDRR at this time will produce the received data, and the RDRF flag is automatically cleared to 0 at the same time. Furthermore, the value of the acknowledgement field received during the ninth cycle of SCL clock is returned as the value set in the ACKBT bit of ICMR3.Furthermore, if the next byte to be received is the next to last byte, set the ICMR3.WAIT bit to 1 (for wait insertion) before reading the ICDRR (containing the second byte from last). As well as enabling NACK output even in the case of delays in processing to set the ICMR3.ACKBT bit to 1 (NACK) in step (6), due to other interrupts etc., this fixes the SCLn line to the low level on the rising edge of the ninth clock cycle in reception of the last byte, so the state is such that issuing a stop condition is possible.
6. When the ICMR3.RDRFS bit is 0 and the slave device must be notified that it is to end transfer for data reception after transfer of the next (final) byte, set the ACKBT bit in ICMR3 to 1 (NACK).
7. After reading out the byte before last from the ICDRR register, if the value of the ICSR2.RDRF flag is confirmed to be 1, write 1 to the SP bit in ICCR2 (stop condition issuance request) and then read the last byte from ICDRR. When ICDRR is read, the RIIC is released from the wait state and issues the stop condition after low-level output in the ninth clock cycle is completed or the SCL line is released from the low-hold state.
8. Upon detecting the stop condition, the RIIC automatically clears the MST and TRS bits in ICCR2 to "00b" and enters slave receiver mode. Furthermore, detection of the stop condition leads to setting of the STOP flag in ICSR2 to 1.
9. After checking that the ICSR2.STOP flag is 1, clear the ICSR2.NACKF and STOP flags to 0 for the next transfer operation.

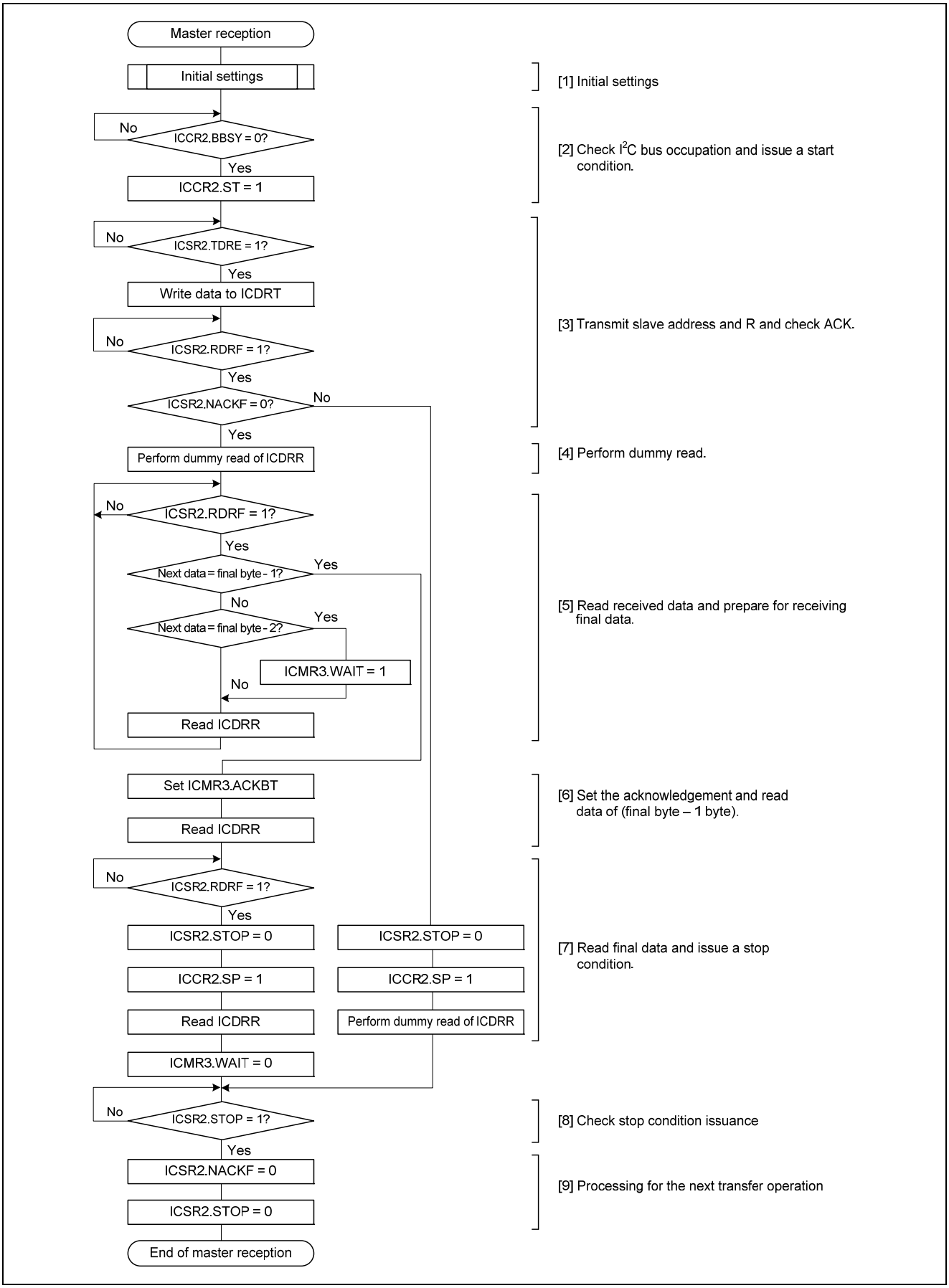


Figure 22.10 Example of Master Reception Flowchart (7-Bit Address Format)

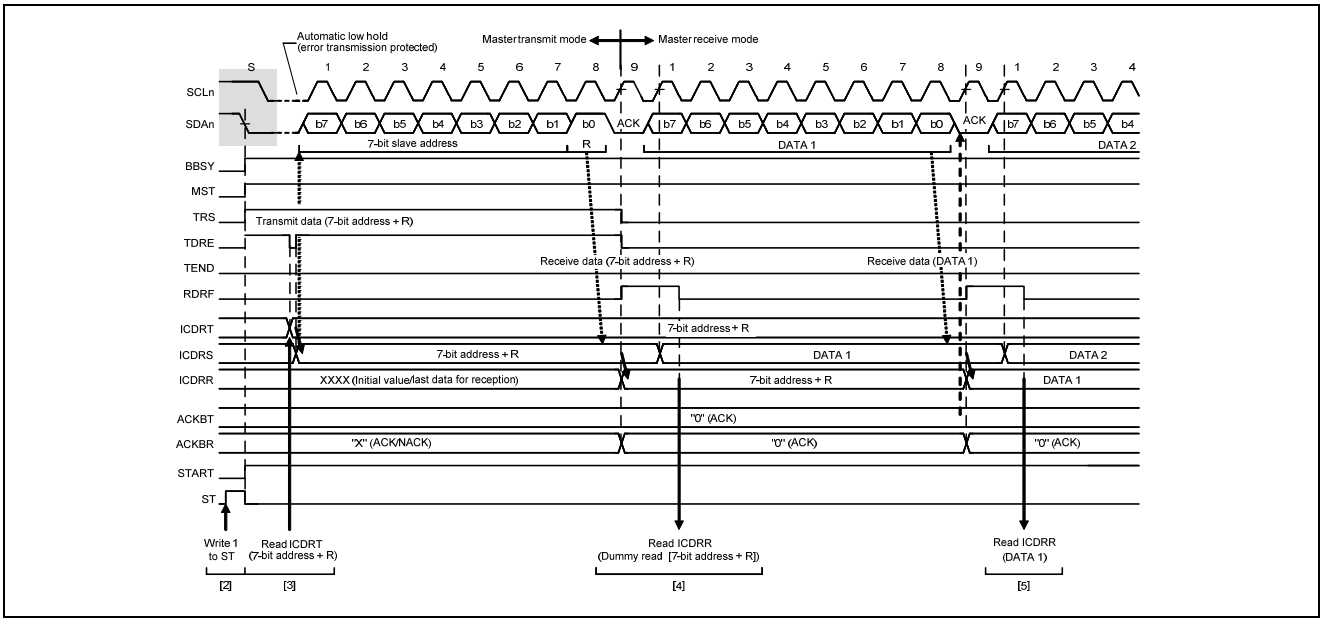


Figure 22.11 Master Receive Operation Timing (1) (7-Bit Address Format, when RDRFS=0)

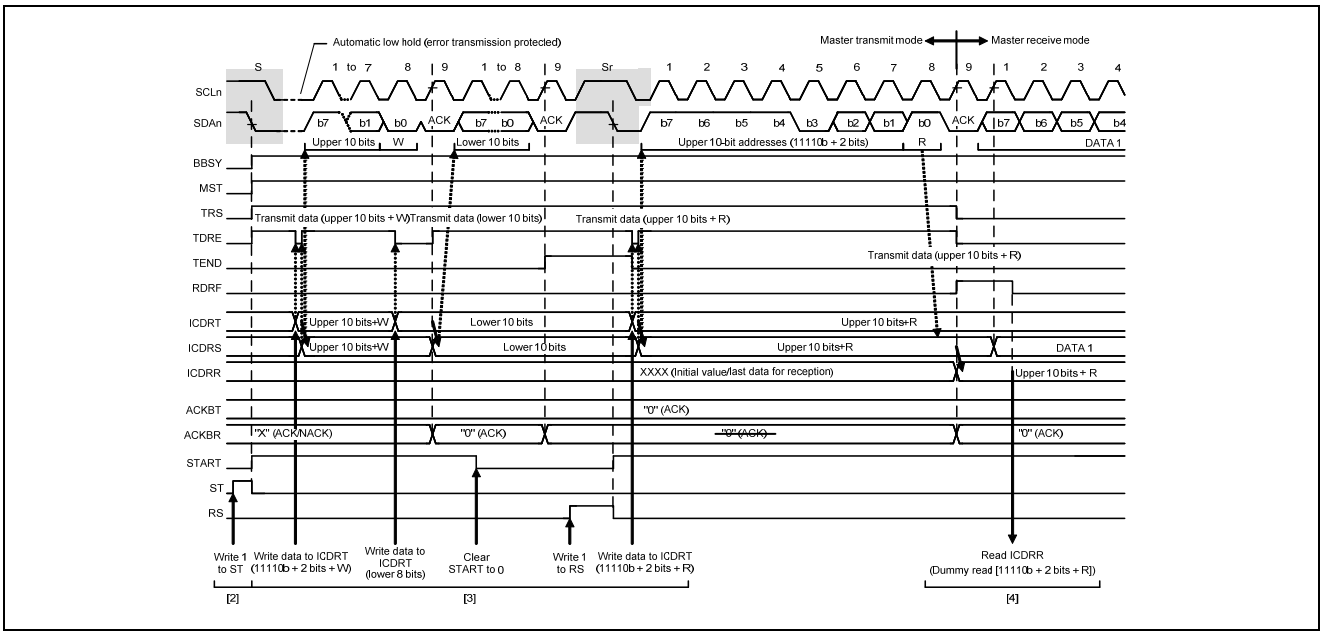


Figure 22.12 Master Receive Operation Timing (2) (10-Bit Address Format, when RDRFS=0)

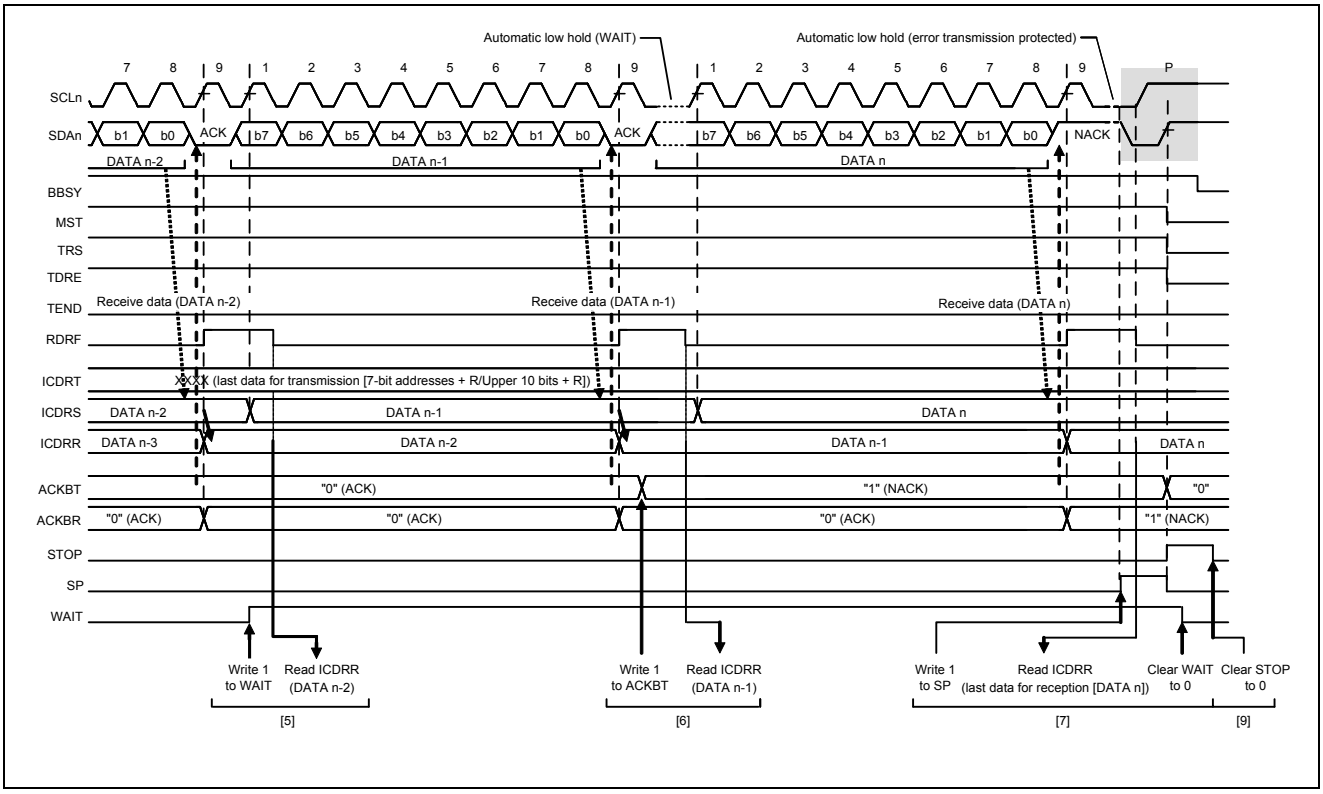


Figure 22.13 Master Receive Operation Timing (3) (when RDRFS=0)

22.3.5 Slave Transmitter Operation

In slave transmitter operation, the master device outputs the SCL (clock) signal, the RIIC transmits data as a slave device, and the master device returns acknowledgements.

Figure 22.14 shows an example of usage of slave transmission and figures 22.15 and 22.16 show the timing of operations in slave transmission.

The following describes the procedure and operations for slave transmission.

1. Follow the procedure in figure 22.5 to make initial settings for the RIIC. This step is not necessary if initialization of the RIIC has already been completed. After initial settings, the RIIC will stay in the standby state until it receives a slave address that it matches.
2. After receiving a matching slave address, the RIIC sets one of the corresponding bits ICSR1.HOA, GCA, and AASy (y = 0 to 2) to 1 on the rising edge of the ninth cycle of SCL clock (the clock signal) and outputs the value set in the ICMR3.ACKBT bit to the acknowledge bit on the ninth cycle of SCL clock. If the value of the R/W# bit that was also received at this time is 1, the RIIC automatically places itself in slave transmitter mode by setting both the TRS bit and the TDRE flag in ICSR2 to 1.
3. After the ICSR2.TEND flag is confirmed to be 1, write the data for transmission to the ICDRT register. At this time, if the RIIC receives no acknowledge from the master device (receives an NACK signal) while the ICFER.NACKE bit is 1, the RIIC suspends transfer of the next data.
4. Wait unit the ICSR2.TEND flag is set to 1 while the ICSR2.TDRE flag is 1, after the ICSR2.NACKF flag is set to 1or the last byte for transmission is written to the ICDRT register. When the ICSR2.NACKF flag or the TEND flag is 1, the RIIC drives the SCLn line low on the ninth falling edge of SCL clock.
5. When the ICSR2.NACKF flag or the ICSR2.TEND flag is 1, dummy read ICDRR to complete the processing. This releases the SCLn line.
6. Upon detecting the stop condition, the RIIC automatically clears bits ICSR1.HOA, GCA, and AASy (y = 0 to 2), flags ICSR2.TDRE and TEND, and the ICCR2.TRS bit to 0, and enters slave receiver mode.
7. After checking that the ICSR2.STOP flag is 1, clear the ICSR2.NACKF and STOP flags to 0 for the next transfer operation.

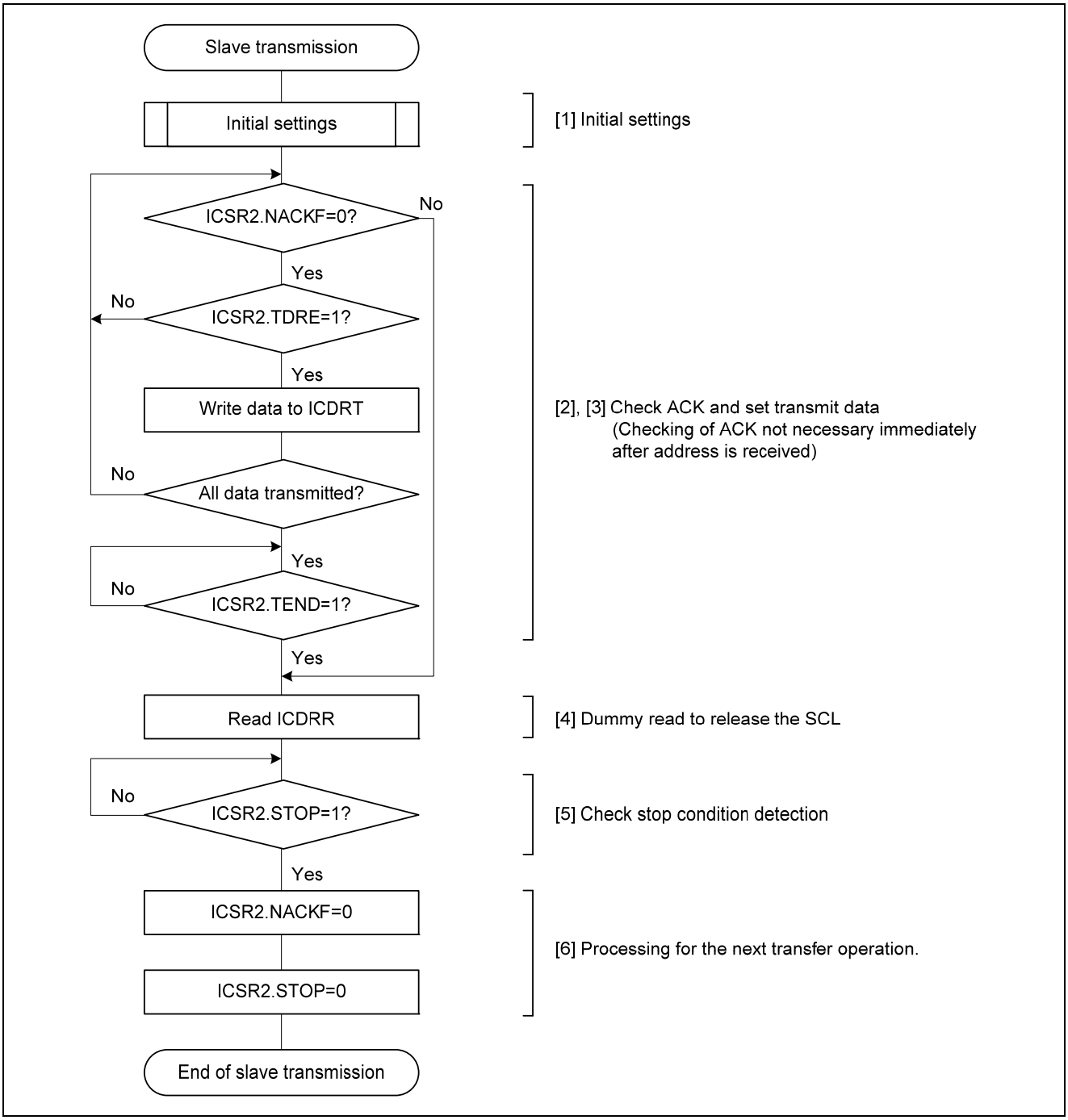


Figure 22.14 Example of Slave Transmission Flowchart

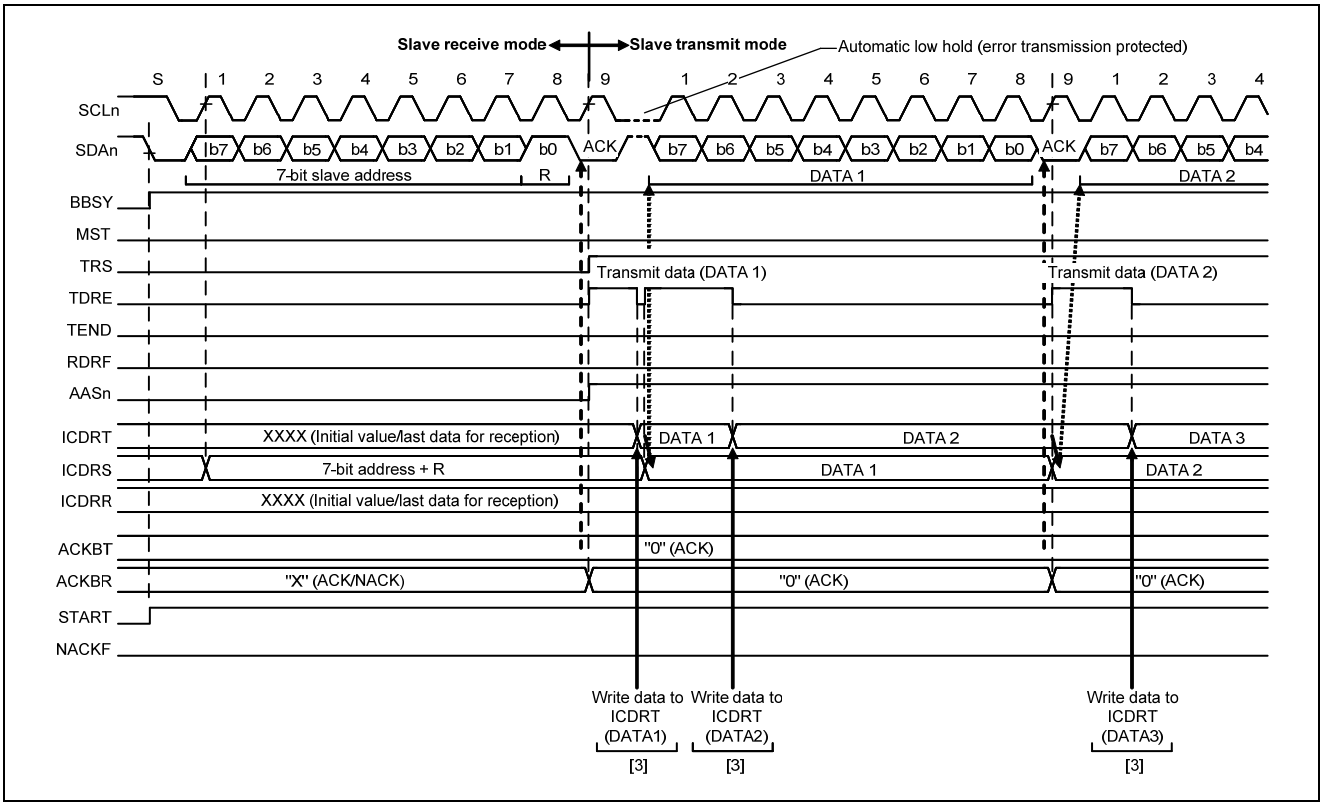


Figure 22.15 Slave Transmit Operation Timing (1) (7-Bit Address Format)

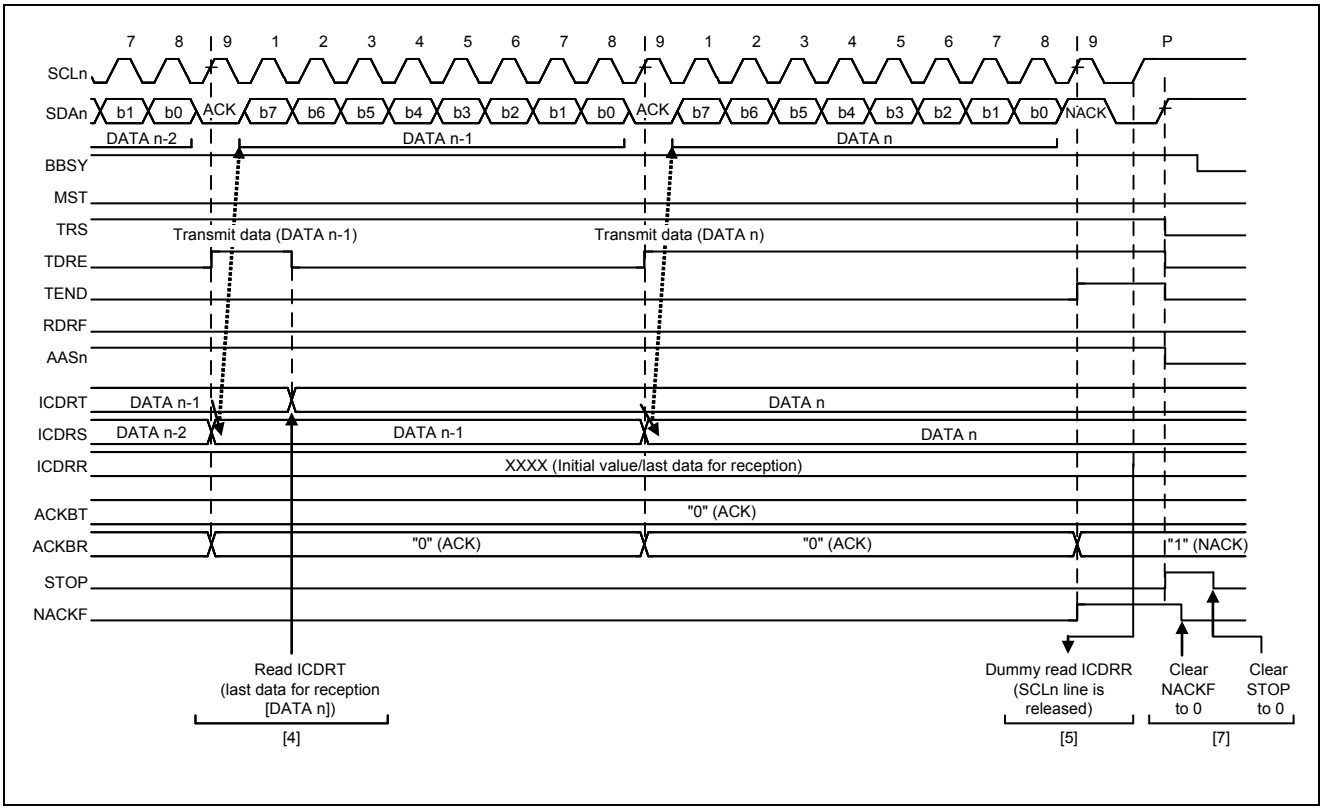


Figure 22.16 Slave Transmit Operation Timing (2)

22.3.6 Slave Receiver Operation

In slave receiver operation, the master device outputs the SCL clock and data, and the RIIC returns acknowledgements as a slave device.

Figure 22.17 shows an example of usage of slave reception and figures 22.18 and 22.19 show the timing of operations in slave reception.

The following describes the procedure and operations for slave reception.

1. Follow the procedure in figure 22.5 to make initial settings for the RIIC. This step is not necessary if initialization of the RIIC has already been completed. After initial settings, the RIIC will stay in the standby state until it receives a slave address that it matches.
2. After receiving a matching slave address, the RIIC sets one of the corresponding bits ICSR1.HOA, GCA, and AASy (y = 0 to 2) to 1 on the rising edge of the ninth cycle of SCL clock (the clock signal) and outputs the value set in the ICMR3.ACKBT bit to the acknowledge bit on the ninth cycle of SCL clock. If the value of the R/W# bit that was also received at this time is 1, the RIIC continues to place itself in slave receiver mode and sets the RDRF flag in ICSR2 to 1.
3. After the ICSR2.STOP flag is confirmed to be 0 and the ICSR2.RDRF flag to be 1, dummy read ICDRR (the dummy value consists of the slave address and R/W# bit when the 7-bit address format is selected, or the lower eight bits when the 10-bit address format is selected).
4. When ICDRR is read, the RIIC automatically clears the ICSR2.RDRF flag to 0. If reading of ICDRR is delayed and a next byte is received while the RDRF flag is still set to 1, the RIIC holds the SCLn line low from one SCL cycle before the timing with which RDRF should be set. In this case, reading ICDRR releases the SCLn line from being held at the low level.
   When the ICSR2.STOP flag is 1 and the ICSR2.RDRF flag is also 1, read ICDRR until all the data is completely received.
5. Upon detecting the stop condition, the RIIC automatically clears bits ICSR1.HOA, GCA, and AASy (y = 0 to 2) to 0.
6. After checking that the ICSR2.STOP flag is 1, clear the ICSR2. STOP flag to 0 for the next transfer operation.

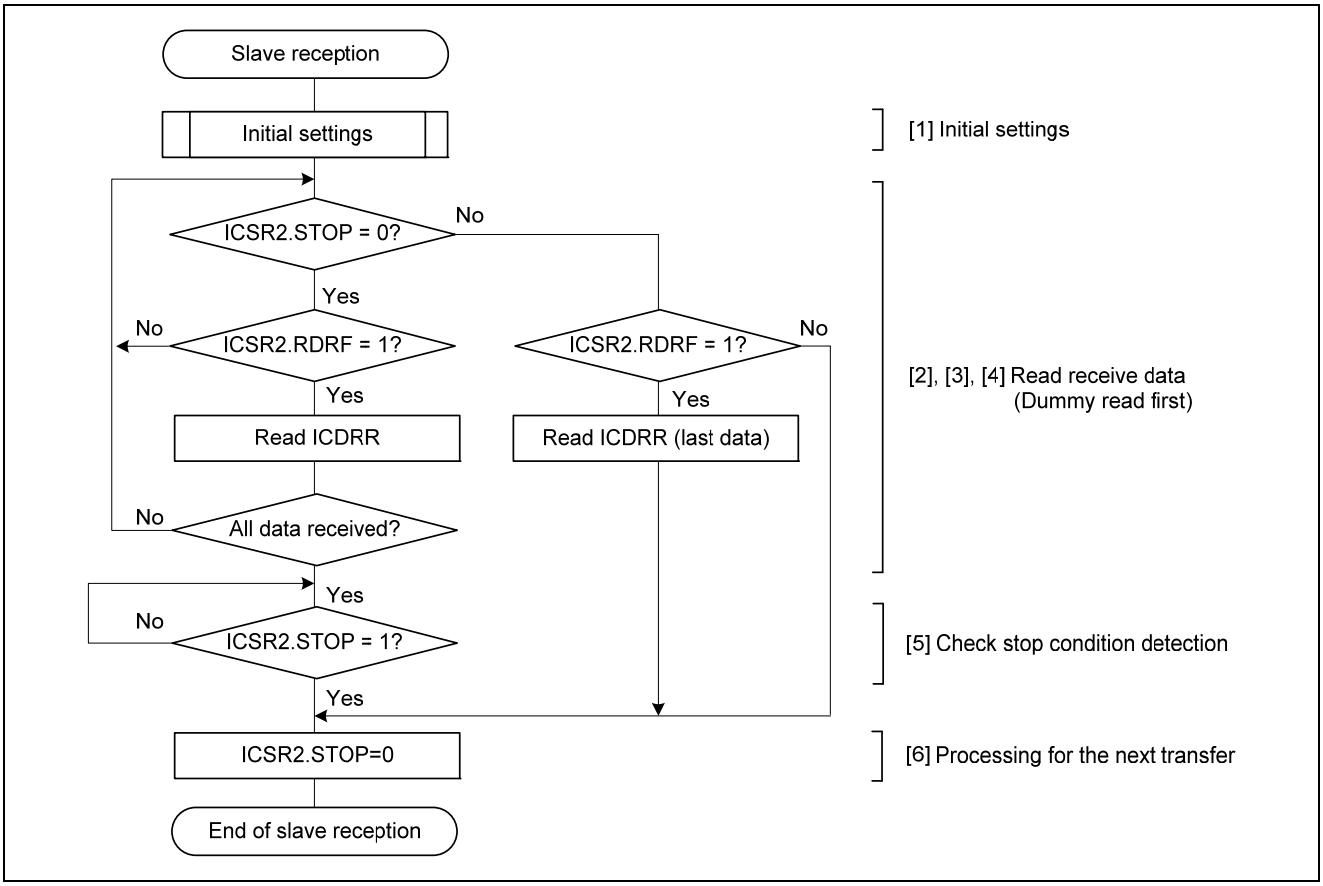


Figure 22.17 Example of Slave Reception Flowchart

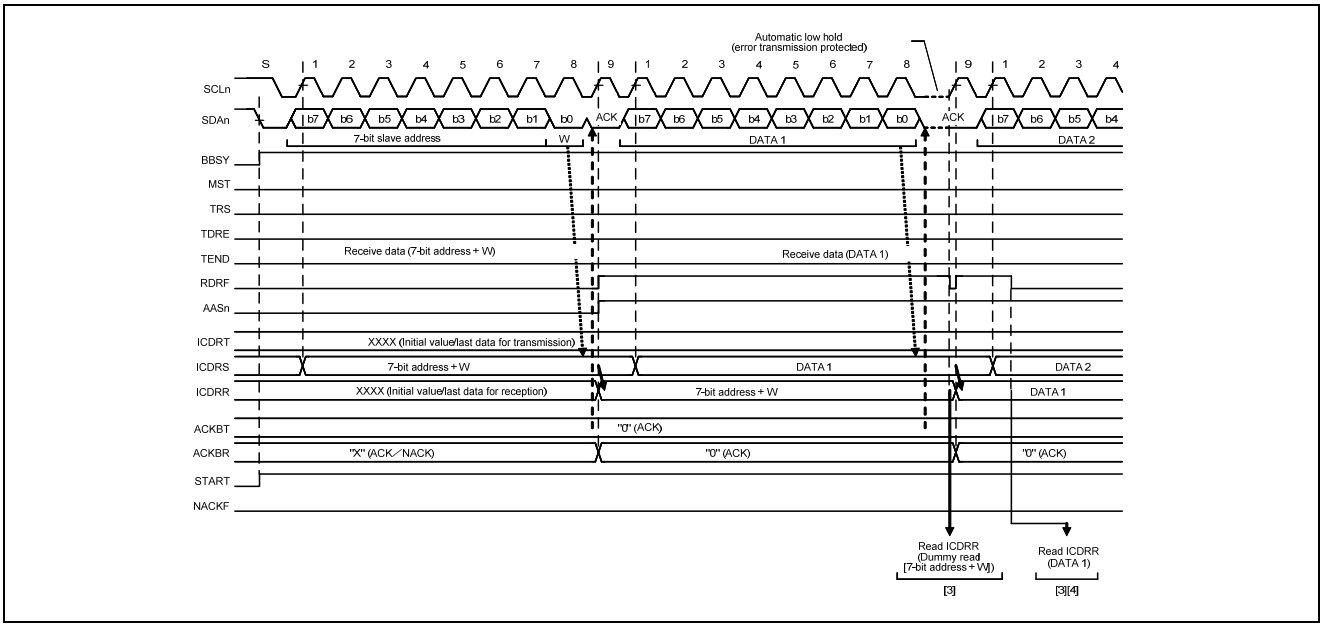


Figure 22.18 Slave Receive Operation Timing (1) (7-Bit Address Format, when RDRFS=0)

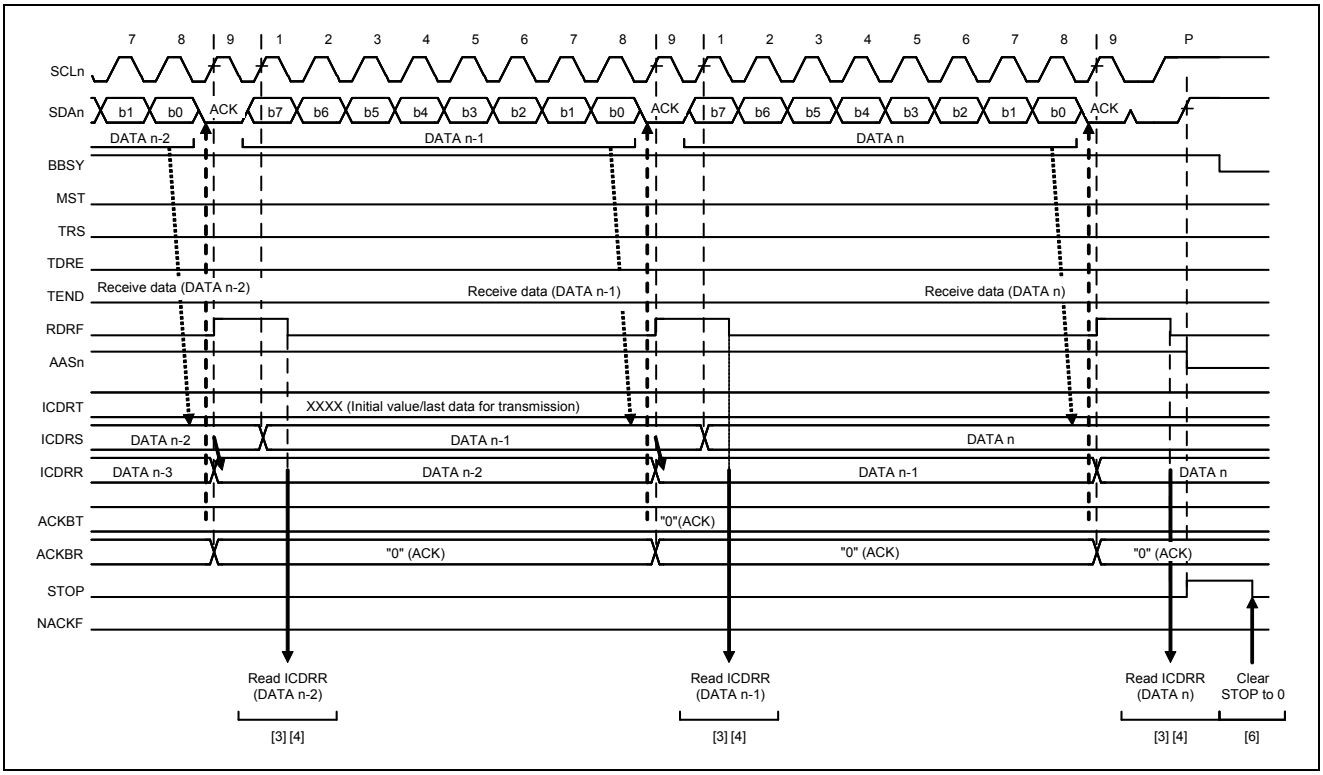


Figure 22.19 Slave Receive Operation Timing (2) (when RDRFS=0)

22.4 SCL Synchronization Circuit

In generation of the SCL (clock) signal, the RIIC starts counting out the value for width at high level specified in ICBRH when it detects a rising edge on the SCLn line and drives the SCLn line low once counting of the width at high level is complete. When the RIIC detects the falling edge of the SCLn line, it starts counting out the width at low level period specified in ICBRL, and then stops driving the SCLn line (releases the line) once counting of the width at low level is complete. The SCL (clock) signal is thus generated.

If multiple master devices are connected to the I²C bus, a collision of SCL signals may arise due to contention with another master device. In such cases, the master devices have to synchronize their SCL signals. Since this synchronization of SCL signals must be bit by bit, the RIIC is equipped with a facility (the SCL synchronization circuit) to obtain bit-by-bit synchronization of the SCL clock signals by monitoring the SCLn line while in master mode.

When the RIIC has detected a rising edge on the SCLn line and thus started counting out the width at high level specified in ICBRH, and the level on the SCL line falls because an SCL signal is being generated by another master device, the RIIC stops counting when it detects the falling edge, drives the level on the SCL line low, and starts counting out the width at low level specified in ICBRL. When the RIIC finishes counting out the width at low level, it stops driving the SCLn line to the low level (i.e. releases the line). At this time, if the width at low level of the SCL clock signal from the other master device is longer than the width at low level set in the RIIC, the width at low level of the SCL signal will be extended. Once the width at low level for the other master device has ended, the SCL signal rises because the SCL line has been released. When the RIIC finishes outputting the low-level period of the SCL clock of, the SCLn line is released and the SCL clock rises. That is, in cases of contention of SCL signals from more than one master, the width at high level of the SCL signal is synchronized with that of the clock having the narrower width, and the width at low level of the SCL signal is synchronized with that of the clock having the broader width. However, such synchronization of the SCL signal is only enabled when the SCLE bit in ICFER is set to 1.

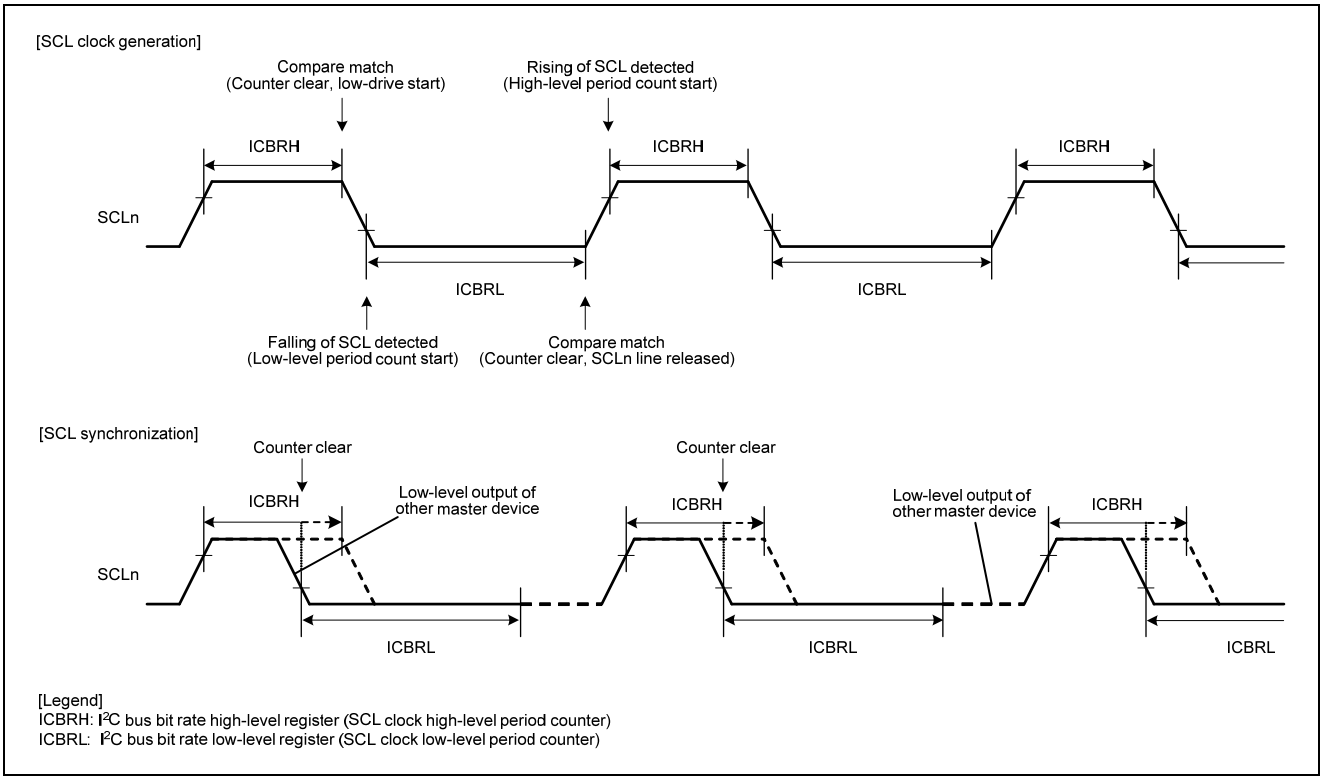


Figure 22.20 Generation and Synchronization of the SCL Signal from the RIIC

22.5 Facility for Delaying SDA Output

The RIIC module incorporates a facility for delaying output on the SDA line. The delay can be applied to all output (issuing of the start, restart, and stop conditions, data, and the ACK and NACK signals) on the SDA line.

With the SDA output delay facility, SDA output is delayed from detection of a falling edge of the SCL signal to ensure that the SDA signal is output within the interval over which the SCL (clock) signal is at the low level. Doing this leads to usage with the aim of preventing erroneous operation of communications devices, with the aim of satisfying the 300-ns (min.) data-hold time requirement of the SMBus specification.

The output delay facility is enabled by setting the SDDL[2:0] bits in IMCR2 to any value other than 000b, and disabled by setting the same bits to 000b.

While the SDA output delay facility is enabled (i.e. while the SDDL[2:0] bits in IMCR2 are set to any value other than 000b), the DLCS bit in IMCR2 selects the clock source for counting by the SDA output delay counter as the internal base clock (IICϕ) for the IIC module or as a clock signal derived by dividing the frequency of the internal base clock by two (IICϕ/2). The counter counts the number of cycles set in the SDDL[2:0] bits in IMCR2. After counting of the set number of cycles of delay is completed, the RIIC module places the required output (start, restart, or stop condition, data, or an ACK or NACK signal) on the SDA line.

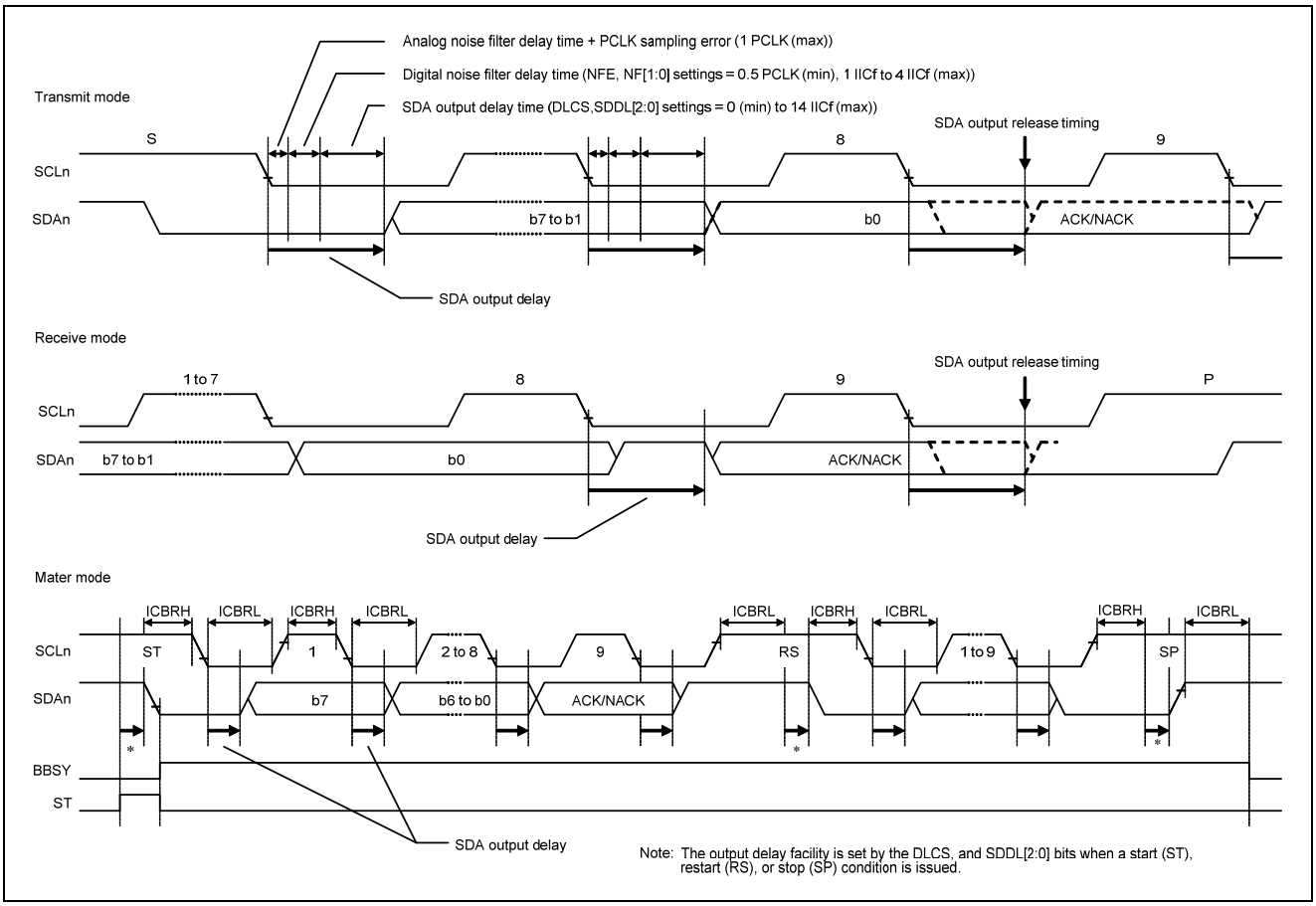


Figure 22.21 SDA Output Delay Facility

22.6 Digital Noise-Filter Circuits

The states of the SCLn and SDAn pins are conveyed to the internal circuitry through analog noise-filter and digital noise-filter circuits. Figure 22.22 is a block diagram of the digital noise-filter circuit.

The on-chip digital noise-filter circuit of the RIIC consists of four flip-flop circuit stages connected in series and a match-detection circuit.

The number of effective stages in the digital noise filter is selected by the NF[1:0] bits in ICMR3. The selected number of effective stages determines the noise-filtering capability as a period from one to four PCLK cycles.

The input signal to the SCLn pin (or SDAn pin) is sampled on falling edges of the PCLK signal. When the input signal level matches the output level of the number of effective flip-flop circuit stages as selected by the NF[1:0] bits in ICMR3, the signal level is conveyed to the subsequent stage. If the signal levels do not match, the previous value is retained.

If the ratio between the frequency of the internal operating clock (PCLK) and the transfer rate is small (e.g. data transfer at 400 kbps with PCLK = 4 MHz), the characteristics of the digital noise filter may lead to the elimination of needed signals as noise. In such cases, it is possible to disable the digital noise-filter circuit (by clearing the NFE bit in ICFER) and use only the analog noise-filter circuit.

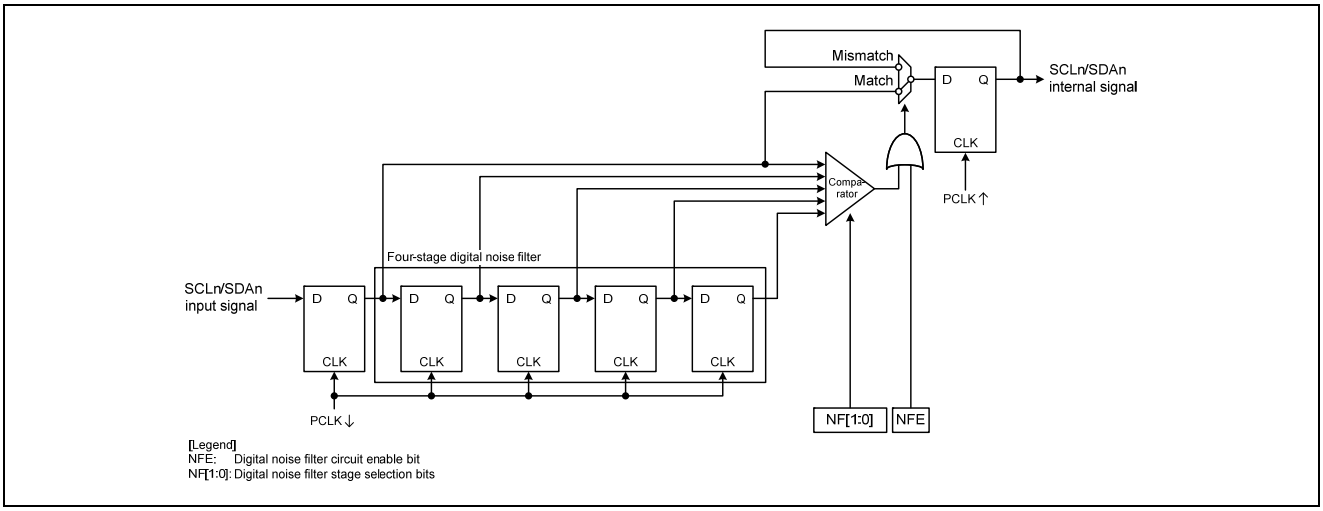


Figure 22.22 Block Diagram of Digital Noise Filter Circuit

22.7 Address Match Detection

The RIIC can set three unique slave addresses in addition to the general call address and host address, and also can set 7-bit or 10-bit slave addresses.

22.7.1 Slave-Address Match Detection

The RIIC can set three unique slave addresses, and has a slave address detection function for each unique slave address. When the SARyE bit (y = 0 to 2) in ICSER is set to 1, the slave addresses set in SARUy and SARLy (y = 0 to 2) can be detected.

When the RIIC detects a match of the set slave address, the corresponding AASy flag (y = 0 to 2) in ICSR1 is set to 1 at the falling edge of the ninth SCL clock cycle, and the RDRF flag in ICSR2 or the TDRE flag in ICSR2 is set to 1 by the following R/W# bit. This causes a receive data full interrupt (ICRXI) or transmit data empty interrupt (ICTXI) to be generated. The AASy flag is used to identify which slave address has been specified.

Figures 22.23 to 22.25 show the AASy flag set timing in three cases.

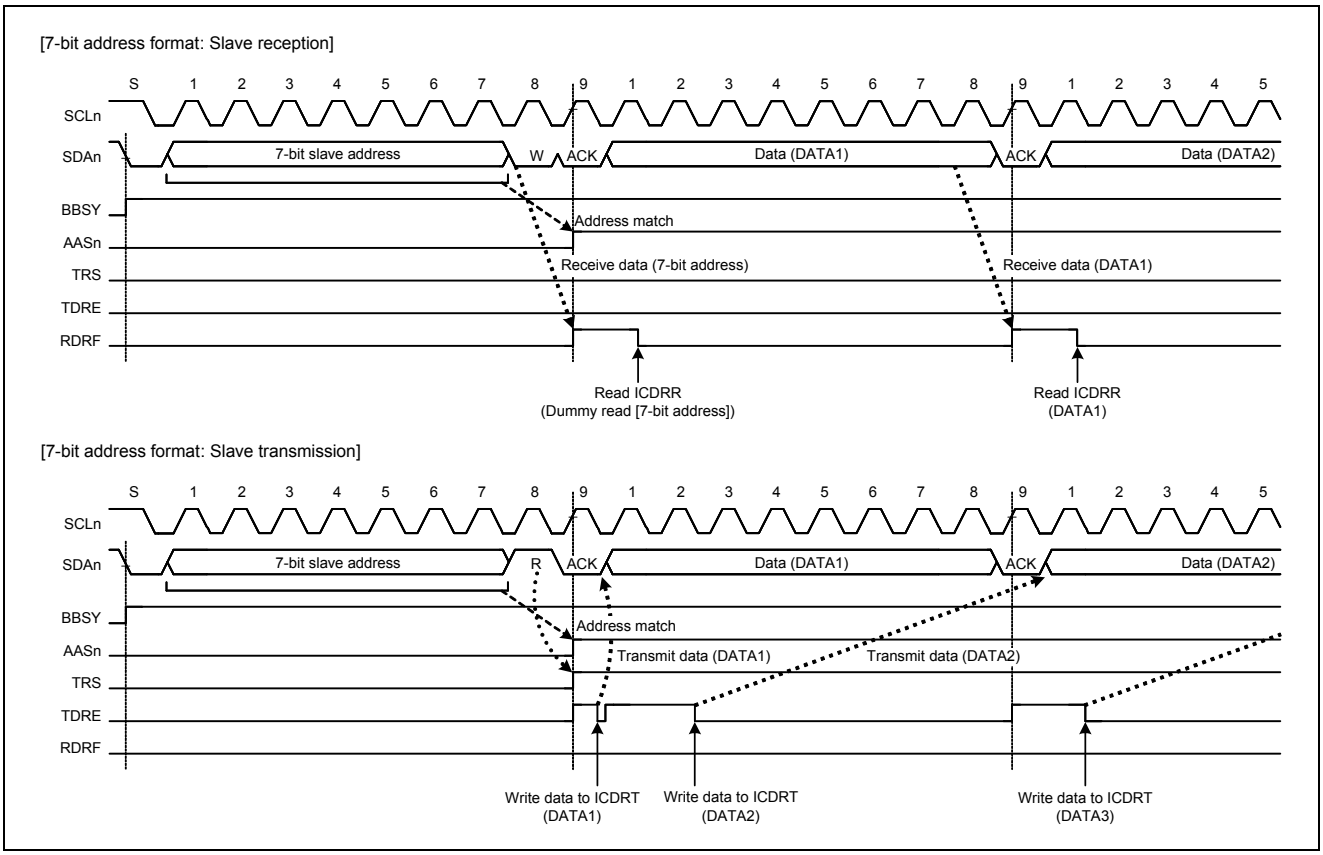


Figure 22.23 Timing of AASy Flag Setting to 1 with 7-Bit Address Format Selected

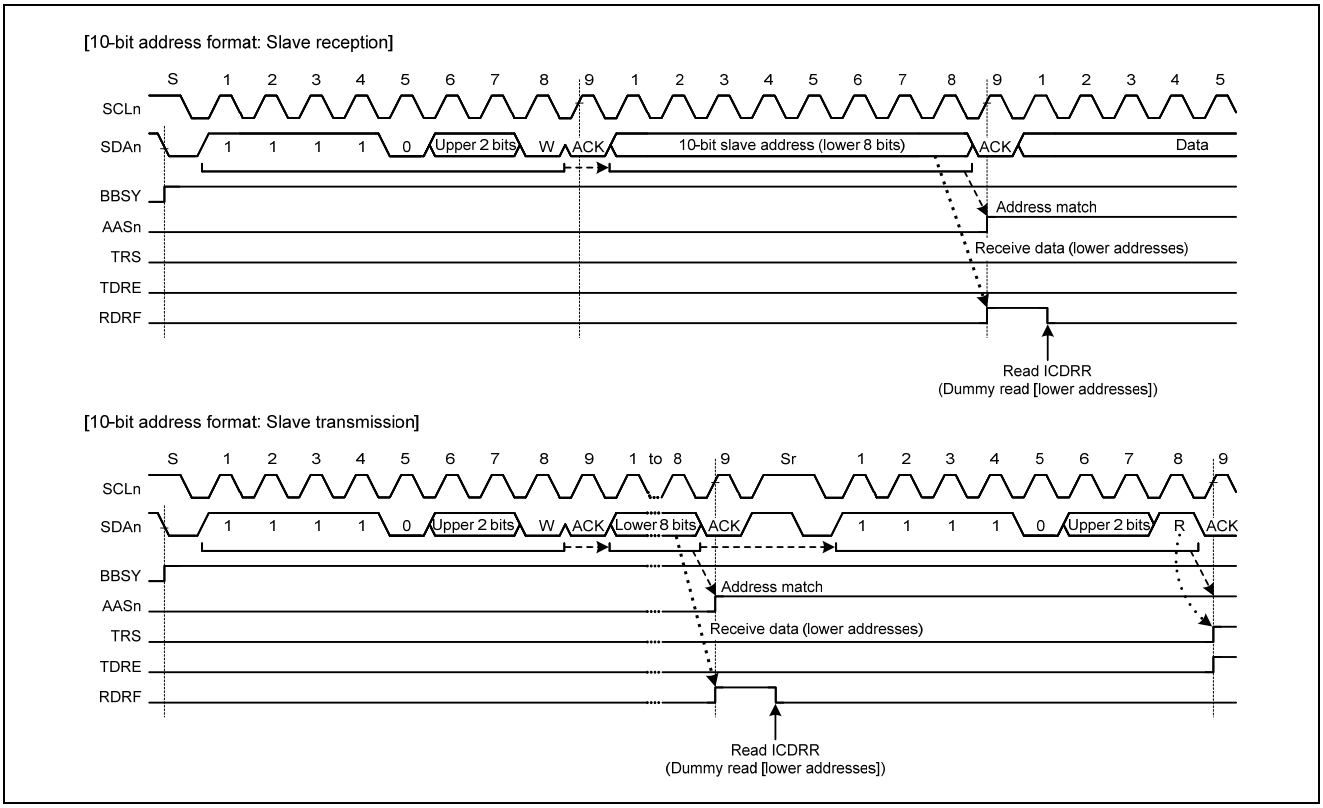


Figure 22.24 Timing of AASy Flag Setting to 1 with 10-Bit Address Format Selected

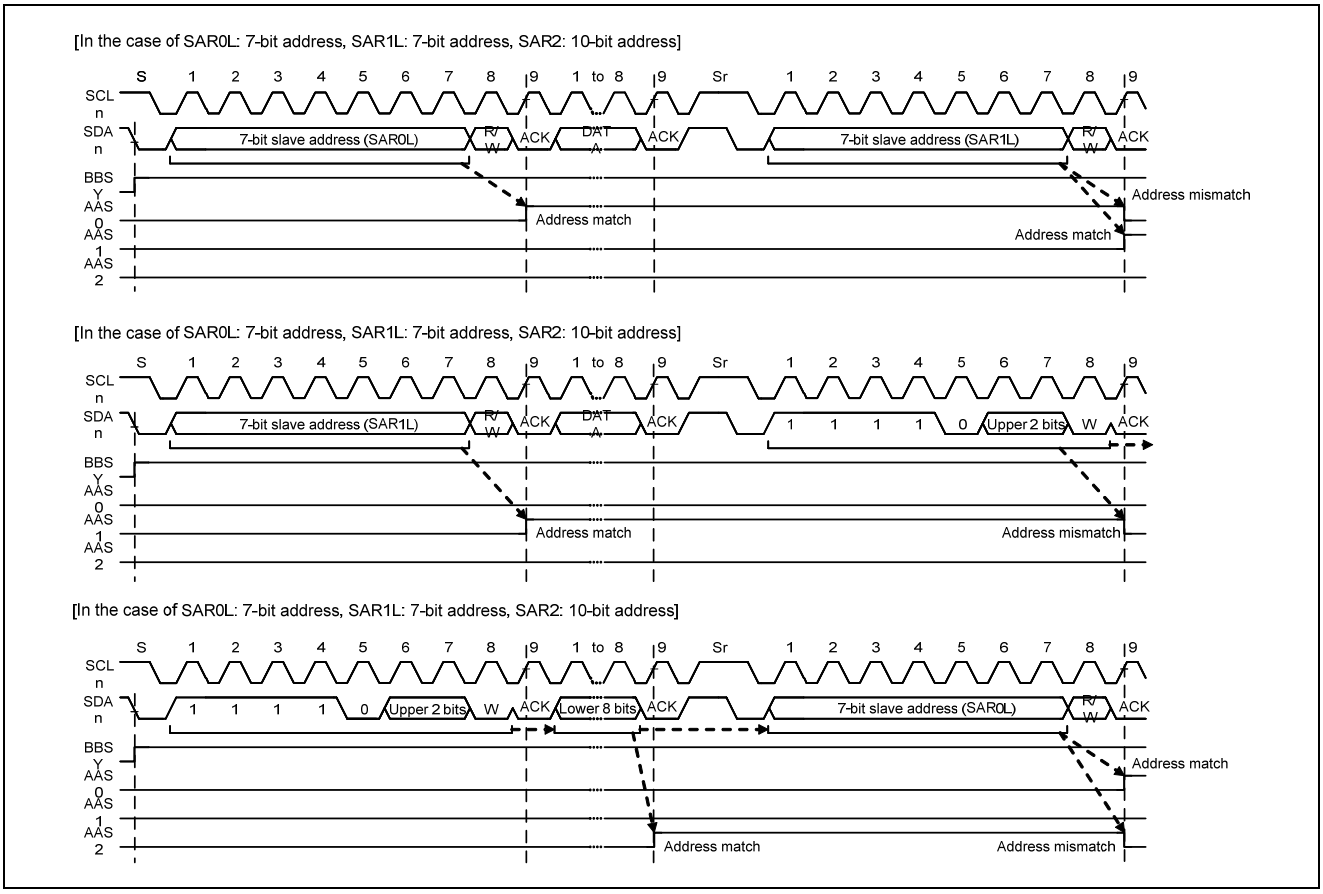


Figure 22.25 Timing of AASy Flag Setting to 1/0 with 7-Bit/10-Bit Address Formats Mixed

22.7.2 Detection of the General Call Address

The RIIC has a facility for detecting the general call address (0000 000b + 0 [W]). This is enabled by setting the GCAE bit in ICSER to 1.

If the address received after a start or restart condition is issued is 0000 000b + 1[R] (start byte), the RIIC recognizes this as the address of a slave device with an "all-zero" address but not as the general call address.

When the RIIC detects the general call address, both the GCA flag in ICSR1 and the RDRF flag in ICSR2 are set to 1 on the falling edge of the ninth cycle of SCL clock. This leads to the generation of a receive data full interrupt (ICRXI). The value of the GCA flag can be confirmed to recognize that the general call address has been transmitted.

Operation after detection of the general call address is the same as normal slave receive operation.

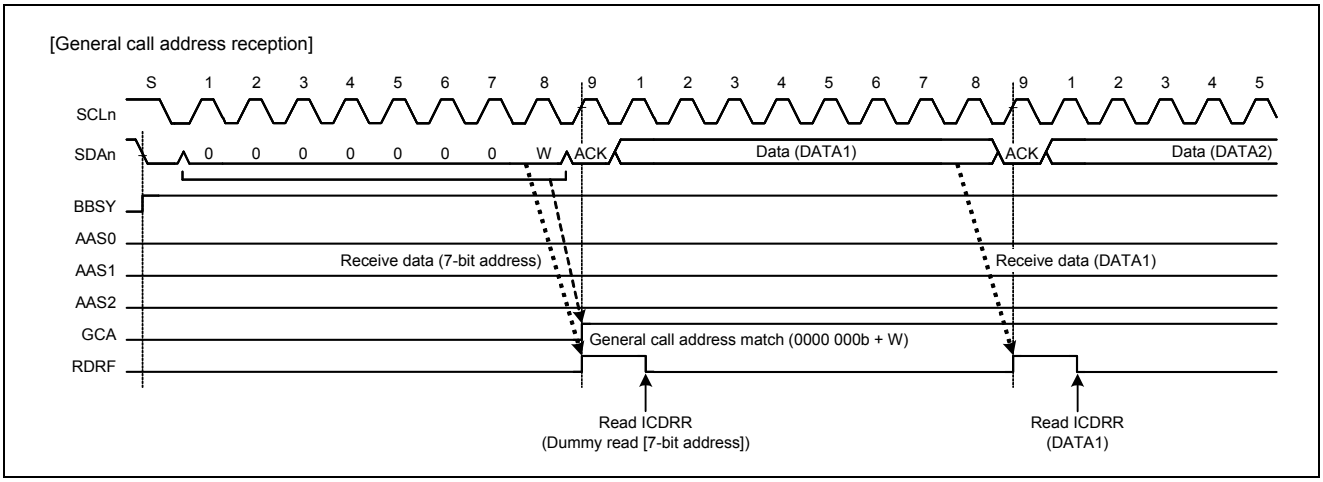


Figure 22.26 Timing of GCA Flag Setting to 1 during Reception of General Call Address

22.7.3 Device-ID Address Detection

The RIIC module has a facility for detecting device-ID addresses conformant with the I²C bus specification (Rev. 03). When the RIIC receives 1111 100b as the first byte after a start condition or restart condition was issued with the DIDE bit in ICSER set to 1, the RIIC recognizes the address as a device ID, sets the DID flag in ICSR1 to 1 on the rising edge of the ninth SCL clock cycle when the following R/W# bit is 0, and then compares the second and subsequent bytes with its own slave address. If the address matches the value in the slave address register, the RIIC sets the corresponding AASy flag (y = 0 to 2) in ICSR1 to 1.

After that, when the first byte received after a restart condition is issued matches the device ID address (1111 100b) again and the following R/W# bit is 1, the RIIC does not compare the second and subsequent bytes and sets the ICSR2.TDRE flag to 1.

In the device-ID address detection function, the RIIC clears the DID flag to 0 if a match with the RIIC's own slave address is not obtained or a match with the device ID address is not obtained after a match with the RIIC's own slave address and the detection of a restart condition. If the first byte after detection of a start or restart condition matches the device ID address (1111 100b) and the R/W# bit is 0, the RIIC sets the DID flag to 1 and compares the second and subsequent bytes with the RIIC's slave address. If the R/W# bit is 1, the DID flag holds the previous value and the RIIC does not compare the second and subsequent bytes. Therefore, the reception of a device-ID address can be checked by reading the DID flag after confirming that TDRE = 1.

Furthermore, prepare the device-ID fields (three bytes: 12 bits indicating the manufacturer + 9 bits identifying the part + 3 bits indicating the revision) that must be sent to the host after reception of a continuous device-ID field as normal data for transmission. For details of the information that must be included in device-ID fields, contact NXP Semiconductors.

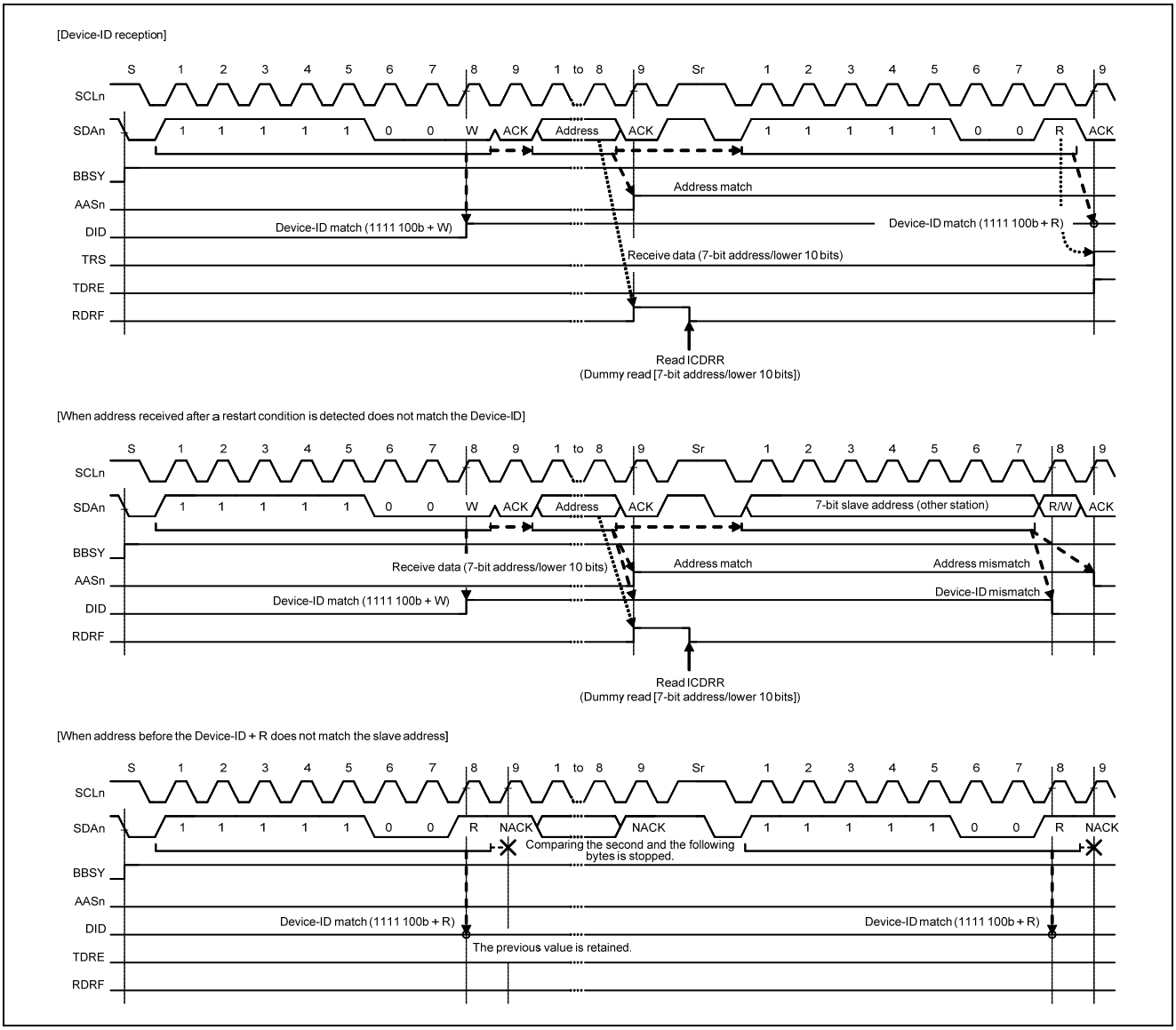


Figure 22.27 AASy/DID Flag Set/Clear Timing during Reception of Device-ID

22.7.4 Host Address Detection

The RIIC has a function to detect the host address while the SMBus is operating. When the HOAE bit in ICSER is set to 1 while the SMBS bit in ICMR3 is 1, the RIIC can detect the host address (0001 000b) in slave receive mode (MST and TRS bits = 00b in ICCR2).

When the RIIC detects the host address, the HOA flag in ICSR1 is set to 1 at the falling edge of the ninth SCL clock cycle, and at the same time, the TDRE flag in ICSR2 is set to 1 when the R/W# bit is 0 (Wr bit). This causes a transmit data empty interrupt (ICTXI) to be generated. The HOA flag is used to recognize that the host address was sent from the smart battery or other devices.

If the bit following the host address (0001 000b) is an Rd bit (R/W# bit = 1), the RIIC can also detect the host address. After the host address is detected, the RIIC operates in the same manner as normal slave operation.

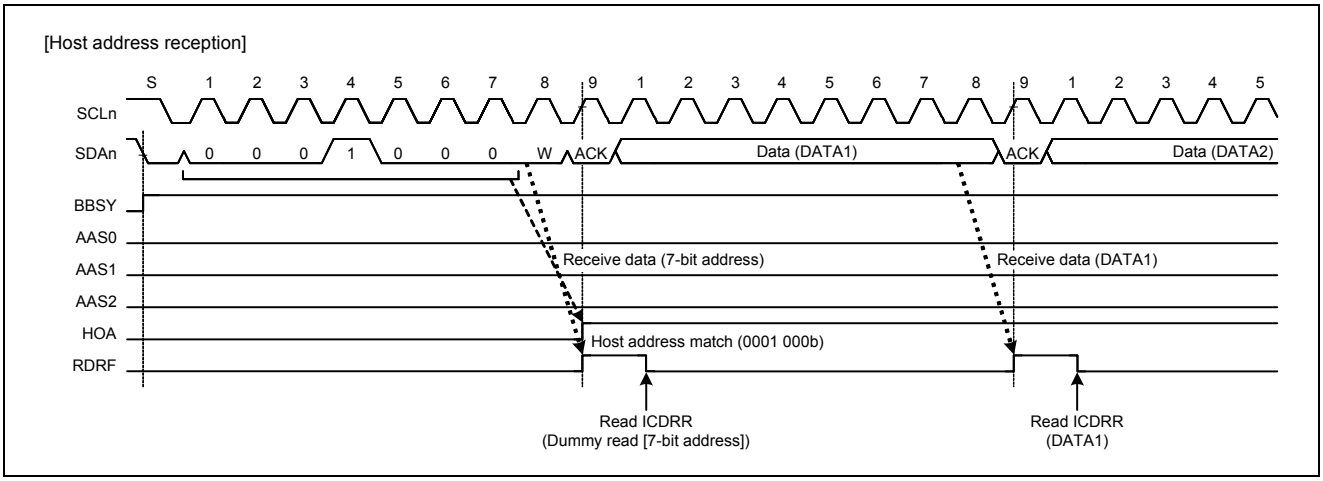


Figure 22.28 HOA Flag Set Timing during Reception of Host Address

22.8 Function to Automatically Hold SCLn Clock Low

22.8.1 Function to Prevent Wrong Transmission of Transmit Data

If the shift register (ICDRS) is empty when data have not been written to the transmit data register (ICDRT) with the RIIC in transmission mode (TRS bit = 1 in ICCR2), the SCLn signal is automatically held at the low level over the intervals shown below. This low-hold period is extended until data for transmission have been written, which prevents the unintended transmission of erroneous data.

<Master transmitter mode>

- Low-level interval after a start condition or restart condition is issued
- Low-level interval of one clock cycle between the ninth clock cycle of one transfer and the first clock cycle of the next

<Slave transmitter mode>

- Low-level interval between the ninth clock cycle of one transfer and the first clock cycle of the next

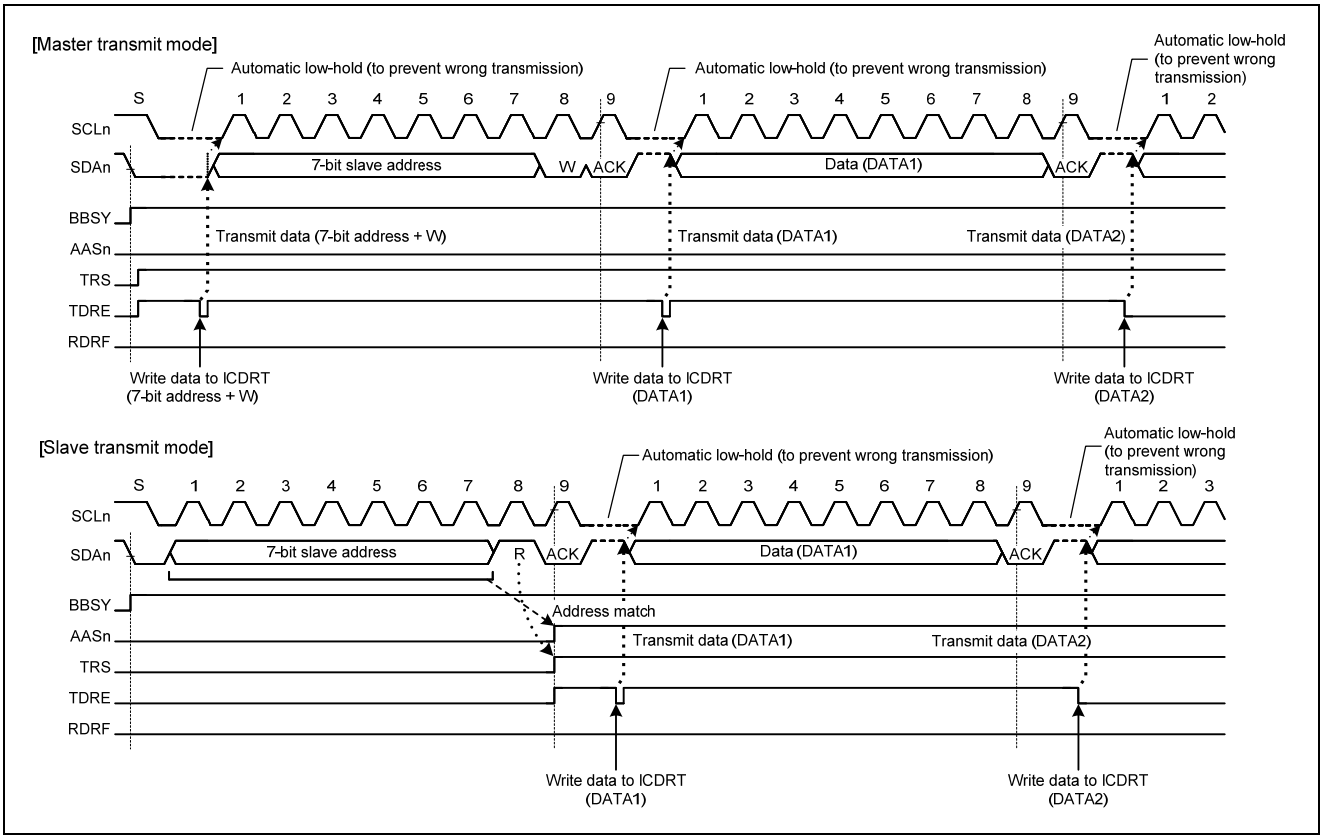


Figure 22.29 Automatic Low-Hold Operation in Transmit Mode

22.8.2 NACK Reception Transfer Suspension Function

The RIIC has a function to suspend transfer operation when NACK is received in transmit mode (TRS bit = 1 in ICCR2). This function is enabled when the NACKE bit in ICFER is set to 1 (transfer suspension enabled). If the next transmit data has already been written (TDRE flag = 0 in ICSR2) when NACK is received, next data transmission at the falling edge of the ninth SCL clock cycle is automatically suspended. This prevents the SDAn line output level from being held low when the MSB of the next transmit data is 0.

If the transfer operation is suspended by this function (NACKF flag = 1 in ICSR2), transmit operation and receive operation are discontinued. To restore transmit/receive operation, be sure to clear the NACKF flag to 0. In master transmit mode, clear the NACKF flag to 0, issue a restart or stop condition, and then issue a start condition again.

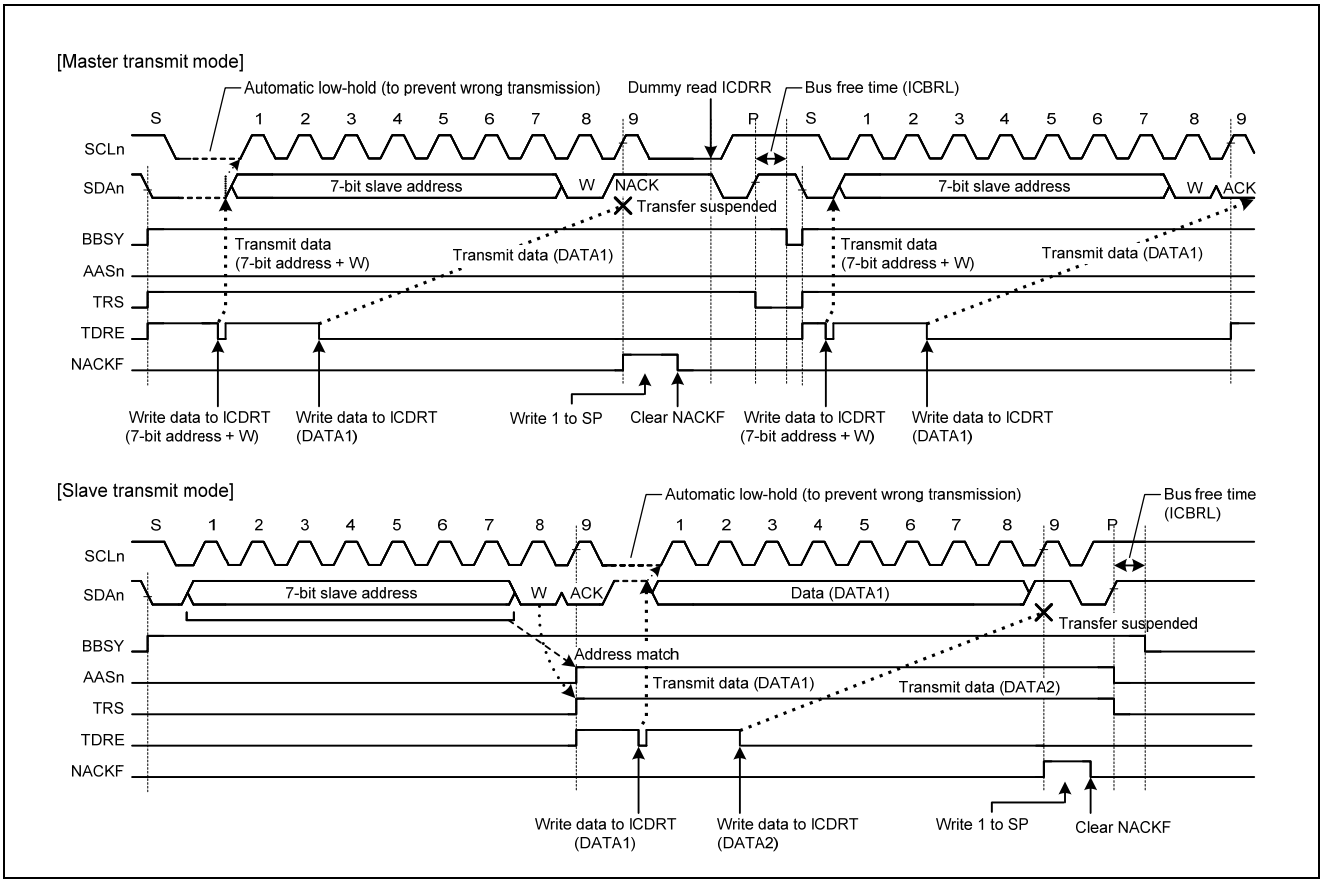


Figure 22.30 Suspension of Data Transfer when NACK is Received (NACKE = 1)

22.8.3 Function to Prevent Failure to Receive Data

If response processing is delayed when receive data (ICDRR) read is delayed for a period of one transfer frame or more with receive data full (RDRF flag = 1 in ICSR2) in receive mode (TRS = 0 in ICCR2), the RIIC holds the SCLn line low automatically immediately before the next data is received to prevent failure to receive data.

This function to prevent failure to receive data using the automatic low-hold function is also enabled even if the read processing of the final receive data is delayed and, in the meantime, the RIIC's own slave address is designated after a stop condition is issued. This function does not disturb other communication because the RIIC does not hold the SCLn line low when a mismatch with its own slave address occurs after a stop condition is issued.

Sections in which the SCLn line is held low can be selected with a combination of the WAIT and RDRFS bits in ICMR3.

(1) One-Byte Receive Operation and Automatic Low-Hold Function Using the WAIT Bit

When the WAIT bit in ICMR3 is set to 1, the RIIC performs one-byte receive operation using the WAIT bit function. Furthermore, when the ICMR3.RDRFS bit is 0, the RIIC automatically sends the ACKBT bit value in ICMR3 for the acknowledge bit in the period from the falling edge of the eighth SCL clock cycle to the falling edge of the ninth SCL clock cycle, and automatically holds the SCLn line low at the falling edge of the ninth SCL clock cycle using the WAIT bit function. This low-hold is released by reading data from ICDRR, which enables bytewise receive operation.

The WAIT bit function is enabled for receive frames after a match with the RIIC's own slave address (including the general call address and host address) is obtained in master receive mode or slave receive mode.

(2) One-Byte Receive Operation (ACK/NACK Transmission Control) and Automatic Low-Hold Function Using the RDRFS Bit

When the RDRFS bit in ICMR3 is set to 1, the RIIC performs one-byte receive operation using the RDRFS bit function. When the RDRFS bit is set to 1, the RDRF flag (receive data full) in ICSR2 is set to 1 at the rising edge of the eighth SCL clock cycle, and the SCLn line is automatically held low at the falling edge of the eighth SCL clock cycle. This low-hold is released by writing a value to the ACKBT bit in ICMR3, but cannot be released by reading data from ICDRR, which enables receive operation by the ACK/NACK transmission control according to the data received in byte units.

The RDRFS bit function is enabled for receive frames after a match with the RIIC’s own slave address (including the general call address and host address) is obtained in master receive mode or slave receive mode.

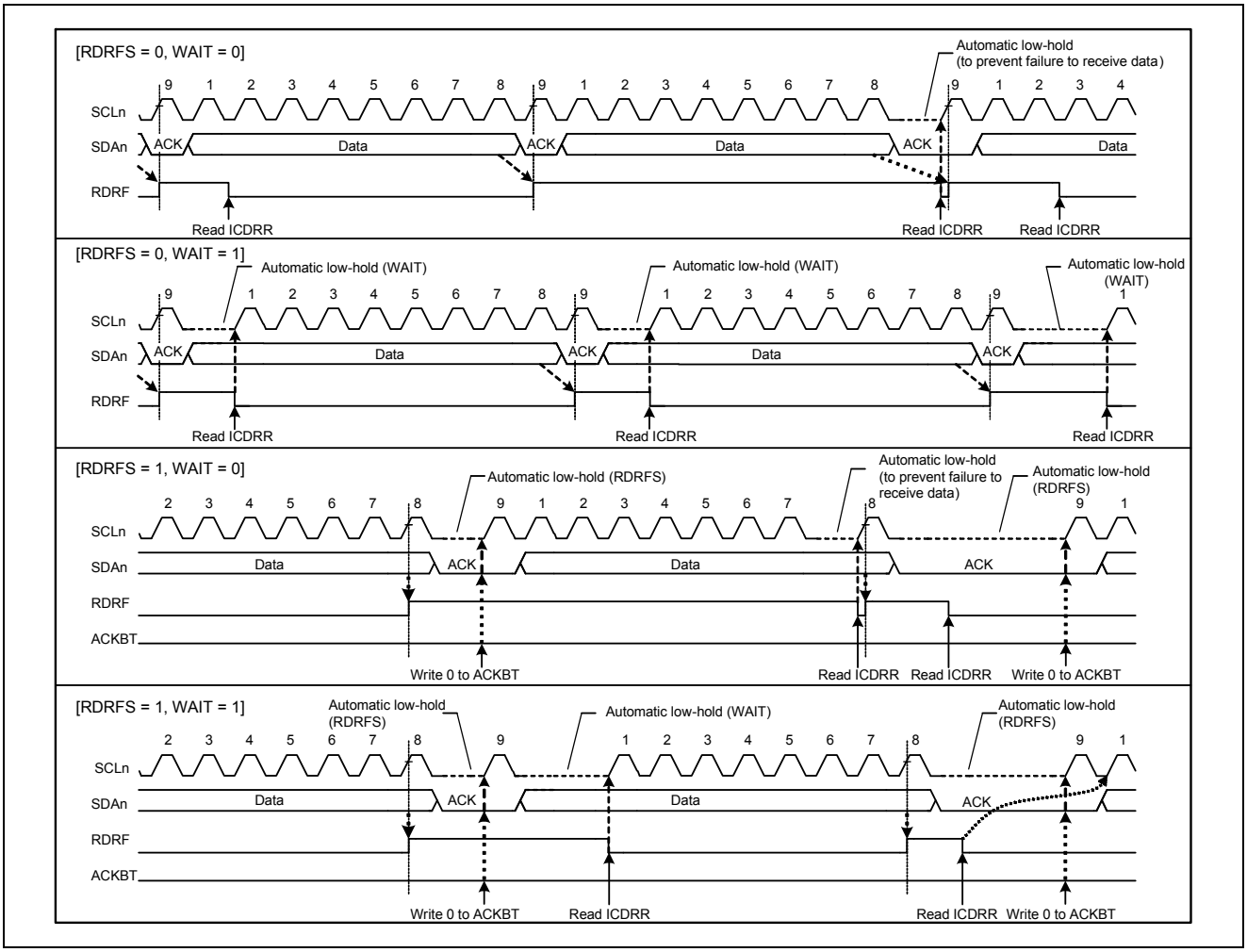


Figure 22.31 Automatic Low-Hold Operation in Receive Mode (Using RDRFS and WAIT Bits)

22.9 Arbitration-Lost Detection Functions

In addition to the normal arbitration-lost detection function defined by the I²C bus standard, the RIIC has functions to prevent double-issue of a start condition, to detect arbitration during transmission of NACK, and to detect arbitration in slave transmit mode.

22.9.1 Master Arbitration Lost Detection (MALE Bit)

The RIIC drives the SDAn line low to issue a start condition. However, if the SDAn line has already been driven low by another master device issuing a start condition, the RIIC regards its own issuing of a start condition as an error and considers this a loss in arbitration, so priority is given to transfer by the other master device. Similarly, if a request to issue a start condition is made by setting the ST bit in ICCR2 to 1 while the bus is busy (BBSY flag = 1 in ICCR2), the RIIC regards this as a double-issuing-of-start-condition error and considers itself to have lost in arbitration, thus preventing a failure of transfer due to issuing of a start condition while transfer is in progress.

When a start condition is issued successfully, if the data for transmission including the address bits (i.e. the internal SDA output level) and the level on the SDAn line do not match (the high output as the internal SDA output; i.e. the SDAn pin is in the high-impedance state) and the low level is detected on the SDAn line, the RIIC loses in arbitration.

After a loss in arbitration of mastership, the RIIC immediately enters slave receiver mode. If a slave address (including the general call address) matches its own address at this time, the RIIC continues in slave operation.

A loss in arbitration of mastership is detected when the following conditions are met while the MALE bit in ICFER is 1 (master arbitration lost detection enabled).

[Master arbitration lost conditions]

- Non-matching of the internal level for output on SDA and the level on the SDAn line after a start condition was issued by setting the ST bit in ICCR2 to 1 while the BBSY flag in ICCR2 was cleared to 0 (erroneous issuing of a start condition)
- Setting of the ST bit in ICCR2 to 1 (start condition double-issue error) while the BBSY flag is set to 1
- When the transmit data excluding acknowledge (internal SDA output level) does not match the level on the SDAn line in master transmit mode (MST and TRS bits = 11b in ICCR2)

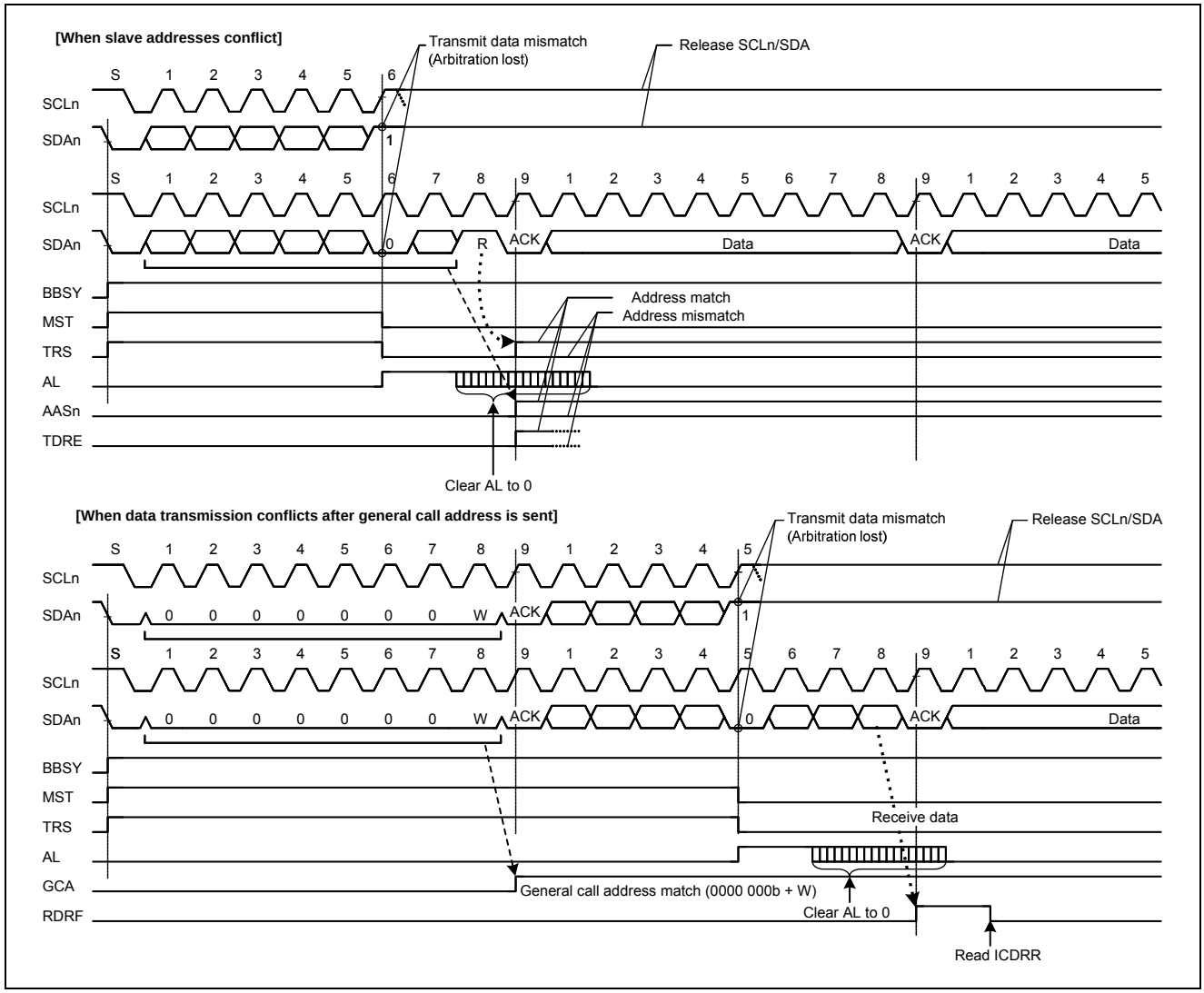


Figure 22.32 Examples of Master Arbitration Lost Detection (MALE = 1)

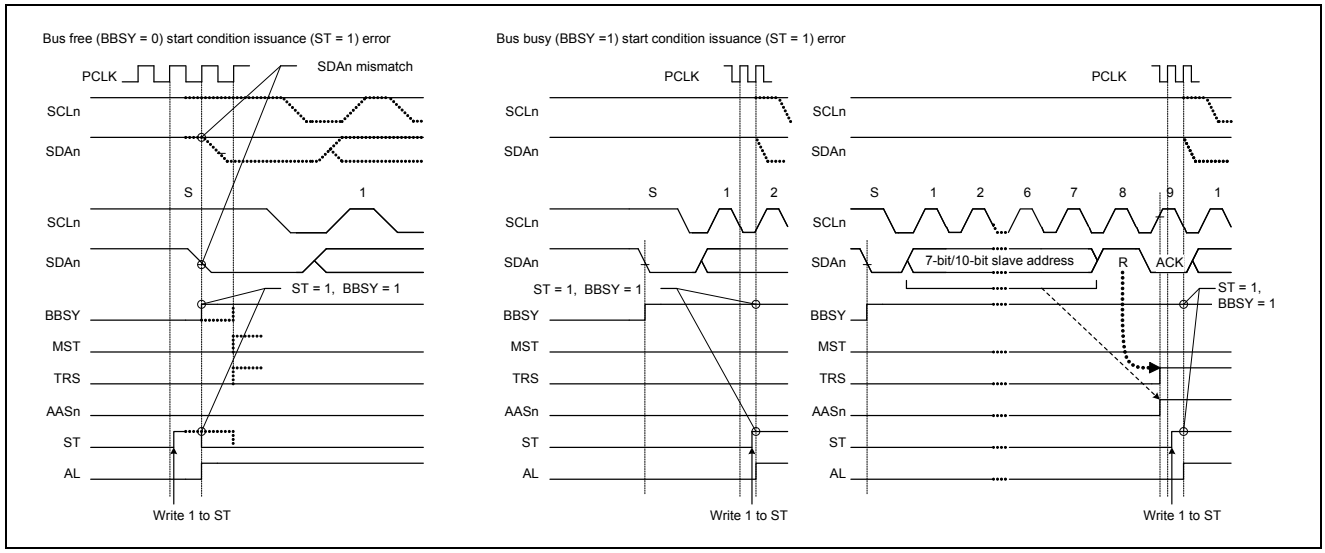


Figure 22.33 Arbitration Lost when a Start Condition is Issued (MALE = 1)

22.9.2 Function to Detect Loss of Arbitration during NACK Transmission (NALE Bit)

The RIIC has a function to cause arbitration to be lost if the internal SDA output level does not match the level on the SDAn line (the high output as the internal SDA output; i.e. the SDAn pin is in the high-impedance state) and the low level is detected on the SDA line during transmission of NACK in receive mode. Arbitration is lost due to a conflict of NACK transmission and ACK transmission when two or more master devices receive data from the same slave device simultaneously in a multi-master system. Such conflict occurs when multiple master devices send/receive the same information through a single slave device. Figure 22.34 shows an example of arbitration lost detection during transmission of NACK.

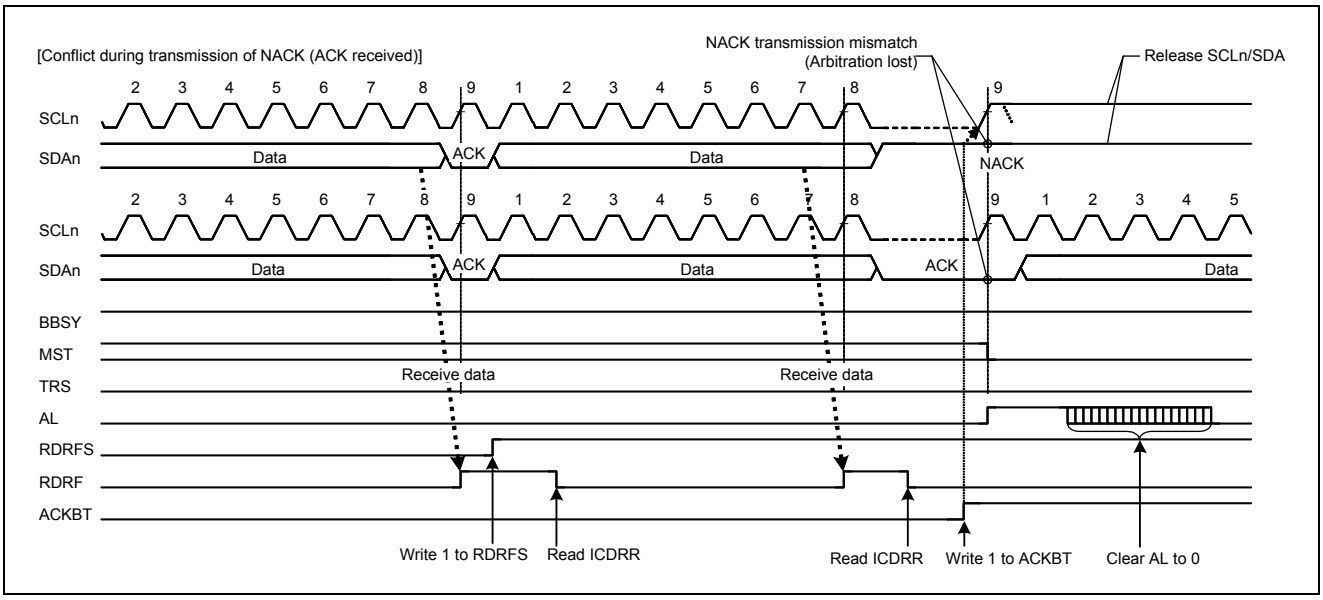


Figure 22.34 Example of Arbitration Lost Detection during Transmission of NACK (NALE = 1)

The following explains arbitration lost detection using an example where two master devices (master A and master B) and a single slave device are connected through the bus. In this example, master A receives two bytes of data from the slave device, and master B receives four bytes of data from the slave device.

If master A and master B access the slave device simultaneously, because the slave address is identical, arbitration is not lost in both master A and master B during access to the slave device. Therefore, both master A and master B recognize that they have obtained the bus mastership and operate as such. Here, master A sends NACK when it has received two final bytes of data from the slave device. Meanwhile, master B sends ACK because it has not received necessary four bytes of data. At this time, the NACK transmission from master A and the ACK transmission from master B conflict. In general, if a conflict like this occurs, master A cannot detect ACK transmitted by master B and issues a stop condition. Therefore, the issuance of the stop condition conflicts with the SCL clock output of master B, which disturbs communication.

When the RIIC receives ACK during transmission of NACK, it detects a defeat in conflict with other master devices and causes arbitration to be lost.

If arbitration is lost during transmission of NACK, the RIIC immediately cancels the slave match condition and enters slave receive mode. This prevents a stop condition from being issued, preventing a communication failure on the bus.

Similarly, in the ARP command processing of SMBus, the function to detect loss of arbitration during transmission of NACK is also available for eliminating the extra clock cycle processing (such as FFh transmission processing) necessary if no response is received in the Get UDID (general) processing after the Assign address command.

The RIIC detects arbitration lost during transmission of NACK when the following condition is met with the NALE bit in ICFER set to 1 (arbitration lost detection during NACK transmission enabled).

[Condition for arbitration lost during NACK transmission]

- When the internal SDA output level does not match the SDAn line (ACK is received) during transmission of NACK (ACKBT bit = 1 in ICMR3)

22.9.3 Slave Arbitration Lost Detection (SALE Bit)

The RIIC has a function to cause arbitration to be lost if the data for transmission (i.e. the internal SDA output level) and the level on the SDAn line do not match (the high output as the internal SDA output; i.e. the SDAn pin is in the high-impedance state) and the low level is detected on the SDA line in slave transmitter mode. This arbitration lost detection function is mainly used when transmitting a UDID (Unique Device Identifier) over an SMBus.

When it loses slave arbitration, the RIIC is immediately released from the slave-matched state and enters slave receiver mode. This function can detect conflicts of data during transmission of UDIDs over an SMBus and eliminates subsequent redundant processing (processing for the transmission of FFh).

The RIIC detects slave arbitration lost when the following condition is met with the SALE bit in ICFER set to 1 (slave arbitration lost detection enabled).

[Condition for slave arbitration lost]

- When transmit data excluding acknowledge (internal SDA output level) does not match the SDAn line in slave transmit mode (MST and TRS bits = 01b in ICCR2)

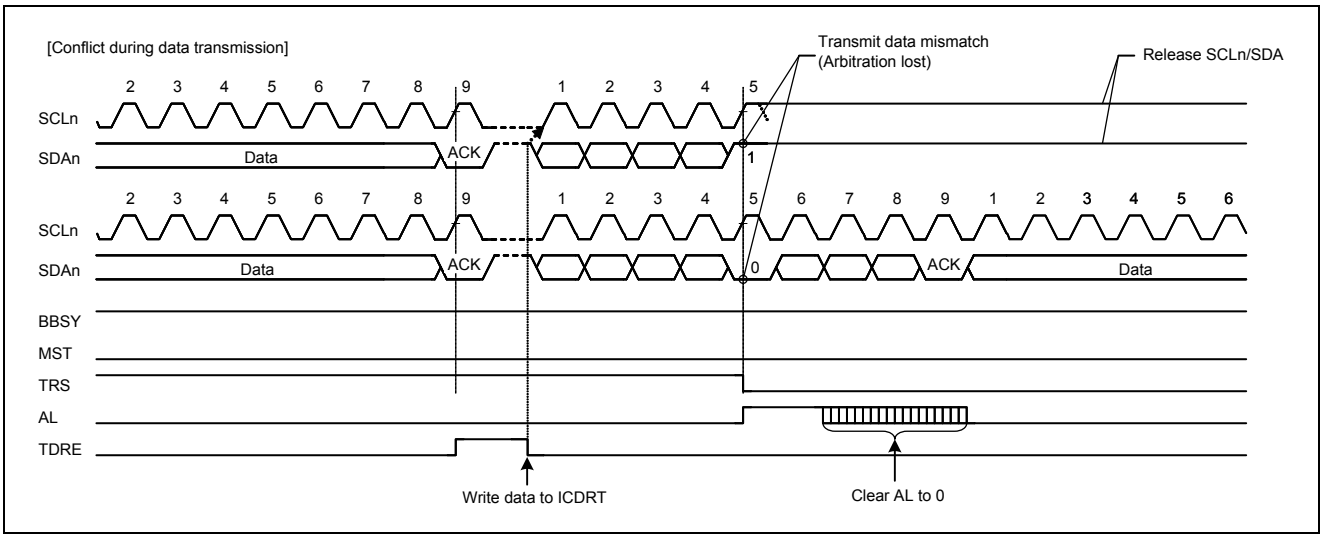


Figure 22.35 Example of Slave Arbitration Lost Detection (SALE = 1)

22.10 Start Condition/Restart Condition/Stop Condition Issuing Function

22.10.1 Issuing a Start Condition

The RIIC issues a start condition when the ST bit in ICCR2 is set to 1.

When the ST bit is set to 1, a start condition issuance request is made and the RIIC issues a start condition when the BBSY flag in ICCR2 is 0 (bus free). When a start condition is issued normally, the RIIC automatically shifts to the master transmit mode.

A start condition is issued in the following sequence.

[Start condition issuance]

- Drive the SDAn line low (high level to low level).
- Ensure the time set in ICBRH and the start condition hold time.
- Drive the SCLn line low (high level to low level).
- Detect low level of the SCLn line and ensure the low-level period of SCLn set in ICBRL.

22.10.2 Issuing a Restart Condition

The RIIC issues a restart condition when the RS bit in ICCR2 is set to 1.

When the RS bit is set to 1, a restart condition issuance request is made and the RIIC issues a restart condition when the BBSY flag in ICCR2 is 1 (bus busy) and the MST bit in ICCR2 is 1 (master mode).

A restart condition is issued in the following sequence.

[Restart condition issuance]

- Release the SDAn line.
- Ensure the low-level period of SCLn line set in ICBRL.
- Release the SCLn line (low level to high level).
- Detect a high level of the SCLn line and ensure the time set in ICBRL and the restart condition setup time.
- Drive the SDAn line low (high level to low level).
- Ensure the time set in ICBRH and the restart condition hold time.
- Drive the SCLn line low (high level to low level).
- Detect a low level of the SCLn line and ensure the low-level period of SCLn line set in ICBRL.

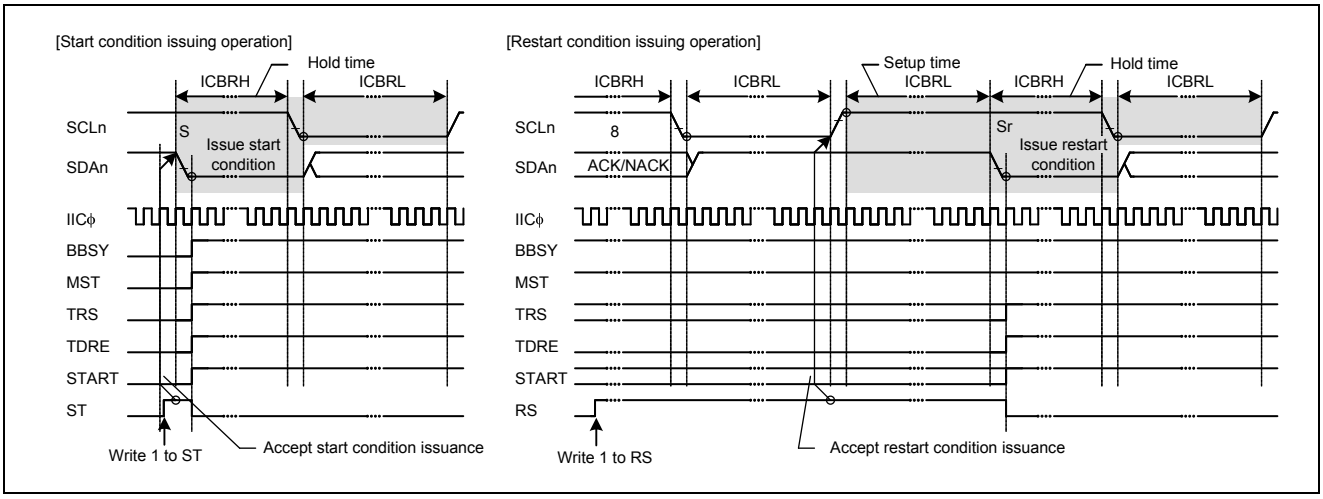


Figure 22.36 Start Condition/Restart Condition Issue Timing (ST and RS Bits)

22.10.3 Issuing a Stop Condition

The RIIC issues a stop condition when the SP bit in ICCR2 is set to 1.

When the SP bit is set to 1, a stop condition issuance request is made and the RIIC issues a stop condition when the BBSY flag in ICCR2 is 1 (bus busy) and the MST bit in ICCR2 is 1 (master mode).

A stop condition is issued in the following sequence.

[Stop condition issuance]

- Drive the SDAn line low (high level to low level).
- Ensure the low-level period of SCLn line set in ICBRL.
- Release the SCLn line (low level to high level).
- Detect a high level of the SCLn line and ensure the time set in ICBRH and the stop condition setup time.
- Release the SDAn line (low level to high level).
- Ensure the time set in ICBRL and the bus free time.
- Clear the BBSY flag to 0 (to release the bus mastership).

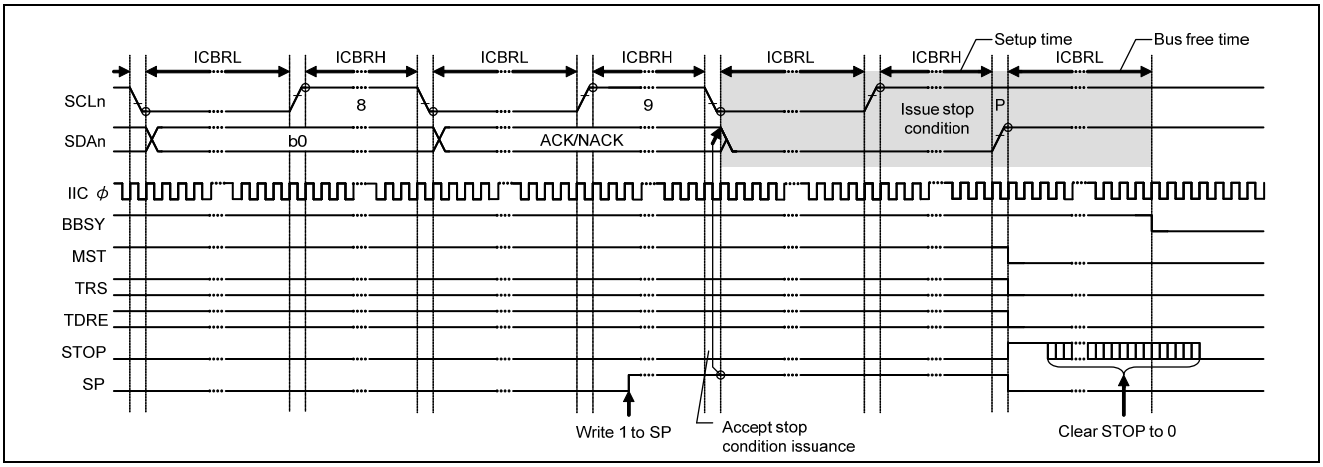


Figure 22.37 Stop Condition Issue Timing (SP Bit)

22.11 Bus Hanging

If the clock signals from the master and slave devices go out of synchronization due to noise or other factors, the I²C bus might hang with a fixed level on the SCLn line and/or SDAn line.

As measures against the bus hanging, the RIIC has a timeout detection function to detect hanging by monitoring the SCLn line, a function for the output of an extra SCL clock cycle to release the bus from a hung state due to clock signals being out of synchronization, and the RIIC/internal reset function.

By checking the SCLO, SDAO, SCLI, and SDAI bits in ICCR1, it is possible to see whether the RIIC or its partner in communications is placing the low level on the SCLn or SDAn lines.

22.11.1 Timeout Detection Function

The RIIC has the timeout detection function to detect an abnormality that the SCLn line is held for a certain period of time. In the bus busy state, the RIIC can detect an abnormal bus state by monitoring that the SCLn line is held low or high for a predetermined time.

The timeout detection function monitors the SCLn line state and counts the low-level period or high-level period using the internal counter. The timeout detection function resets the internal counter each time the SCLn line changes (rising or falling), but continues to count unless the SCLn line changes. If the internal counter overflows due to no SCLn line change, the RIIC can detect the timeout and report the bus abnormality.

This timeout detection function is enabled when the TMOE bit in ICFER is 1. It detects an abnormal bus state that the SCLn line is held low or high when the bus is busy (BBSY flag = 1 in ICCR2) in master mode or when the BBSY flag is 1 and the RIIC's own slave address matches (ICSR1 is not 00h) in slave mode.

The internal counter of the timeout detection function works using the internal reference clock (IICϕ) set by the CKS[2:0] bits in ICMR1 as a count source. It functions as a 16-bit counter when long mode is selected (TMOS bit = 0 in ICMR2) or a 14-bit counter when short mode is selected (TMOS bit = 1).

The SCLn line level (low/high or both levels) during which this counter is activated can be selected by the setting of the TMOH and TMOL bits in ICMR2. If both TMOL and TMOH bits are cleared to 0, the internal counter does not work.

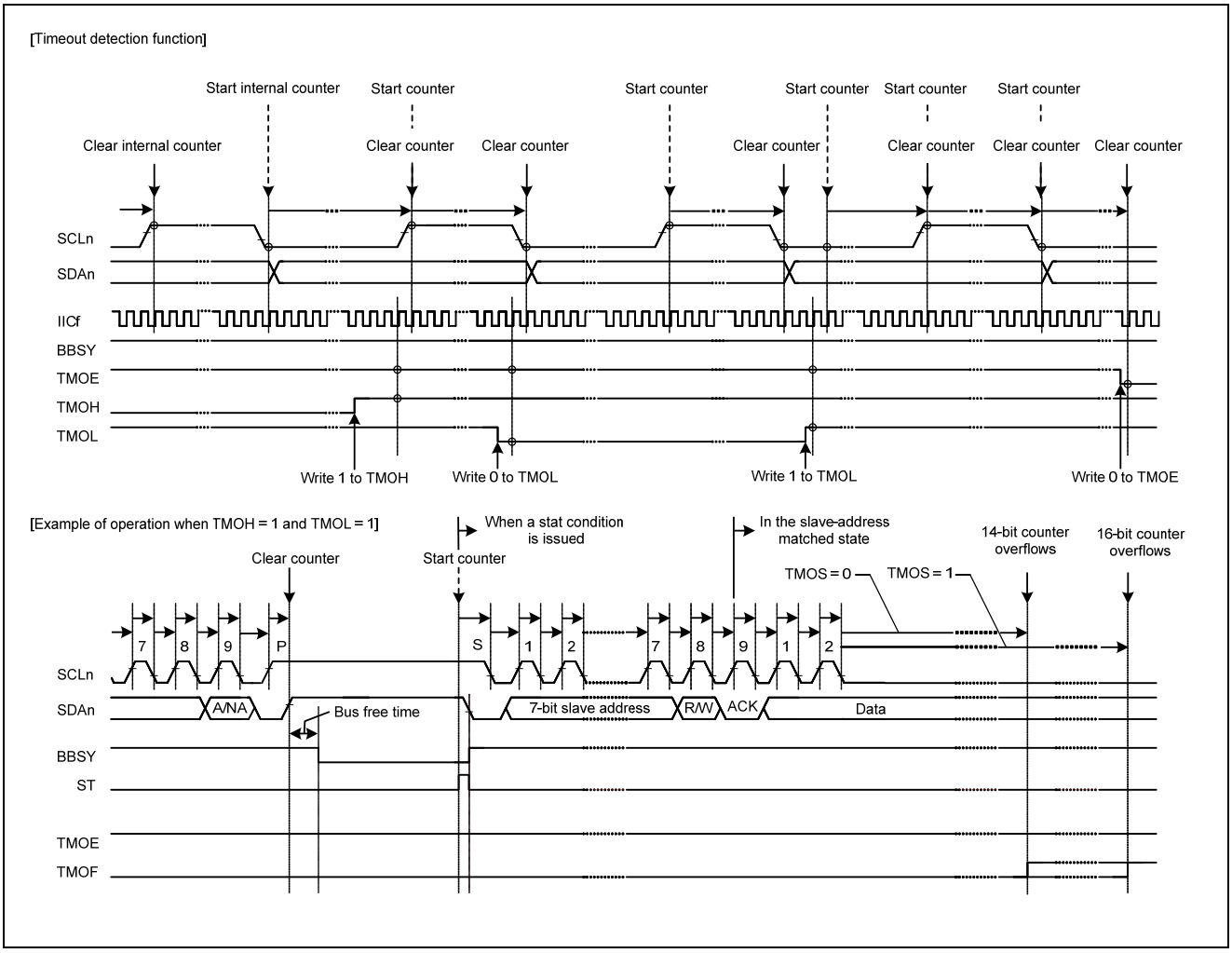


Figure 22.38 Timeout Detection Function (TMOE, TMOS, TMOH, and TMOL Bits)

22.11.2 Extra SCL Clock Cycle Output Function

In master mode, the RIIC module has a facility for the output of extra SCL (clock) cycles to release the SDAn line of the slave device from being held at the low level due to the master being out of synchronization with the slave device.

This function is mainly used in master mode to release the SDAn line of the slave device from the state of being fixed to the low level by including extra cycles of SCLn output from the RIIC with single cycles of the SCL (clock) signal as the unit in the case of a bus error where the RIIC cannot issue a stop condition because the slave device is holding the SDAn line at the low level. Do not use this facility in normal situations. Using it when communications are proceeding correctly will lead to malfunctions.

When the CLO bit in ICCR1 is set to 1 in master mode, a single cycle of the SCL clock at the frequency corresponding to the transfer rate settings (settings of the CKS[2:0] bits in ICMR1, and of the ICBRH and ICBRL registers) is output as an extra clock cycle. After output of this single cycle of the SCL clock, the CLO bit is automatically cleared to 0. Therefore, further extra clock cycles can be output consecutively by the software program writing 1 to the CLO bit after having read CLO = 0.

When the RIIC module is in master mode and the slave device is holding the SDAn line at the low level because synchronization with the slave device has been lost due to the effects of noise etc., the output of a stop condition is not possible. The facility for output of an extra cycle of the SCL (clock) signal can be used to output extra cycles of SCL one by one to make the slave device release the SDAn line from being held at the low level, thus recovering the bus from an unusable state. Release of the SDAn line by the slave device can be monitored by reading the SDAI bit in ICCR1. After confirming release of the SDAn line by the slave device, complete communications by reissuing the stop condition.

Use this facility with the MALE bit (master arbitration lost detection disabled) in ICFER cleared to 0. If the MALE bit is set to 1 (master arbitration lost detection enabled), arbitration is lost when the value of the SDAO bit in ICCR1does not match the state of the SDAn line, so take care on this point.

[Conditions for using the CLO bit in ICCR1]

- When the bus is free (BBSY flag in ICCR2 = 0) or in master mode (MST bit = 1 and BBSY flag = 1 in ICCR2)
- When the communication device does not hold the SCL line low

Figure 22.39 shows the operation timing of the extra SCL clock cycle output function.

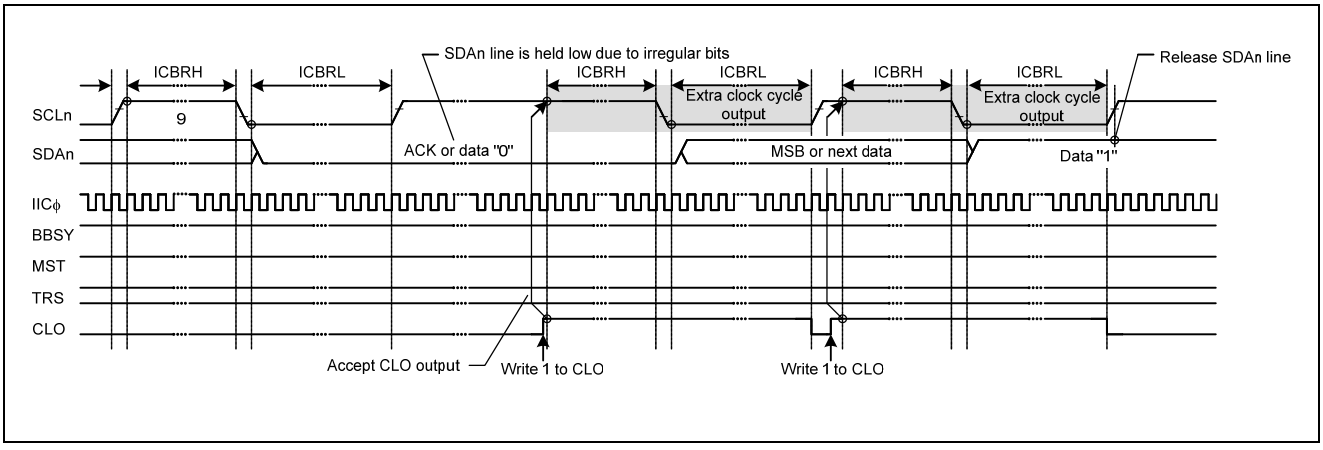


Figure 22.39 Extra SCL Clock Cycle Output Function (CLO Bit)

22.11.3 RIIC Reset and Internal Reset

The RIIC module incorporates a function for resetting itself. There are two types of reset. One is referred to as an RIIC reset; this initializes all registers including the BBSY flag in ICCR2. The other is referred to as an internal reset; this releases the RIIC from the slave-address matched state and initializes the internal counter while retaining other settings. After issuing a reset, be sure to clear the IICRST bit in ICCR1 to 0.

Both types of reset are effective for release from bus-hung states since both restore the output state of the SCLn and SDAn pins to the high impedance state.

Issuing a reset during slave operation may lead to a loss of synchronization between the master device clock and the slave device clock, so avoided this where possible. Note that monitoring of the bus state, such as for the presence of a start condition, is not possible during an RIIC reset (ICE and IICRST bits = 01b in ICCR1).

For a detailed description of the RIIC and internal resets, see section 22.14, Reset States.

22.12 SMBus Operation

The RIIC is available for data communication conforming to the SMBus (Version 2.0). To perform SMBus communication, set the SMBS bit in ICMR3 to 1 to select input level conforming to the SMBus for the SCLn pin/SDAn pin function. To use the transfer rate within a range of 10 kbps to 100 kbps of the SMBus standard, set the CKS[2:0] bits in ICMR1, ICBRH, and ICBRL. In addition, determine the values of the DLCS bit in ICMR2 and the SDDL[2:0] bits in ICMR2 to meet the data hold time specification of 300 ns or more. When the RIIC is used only as a slave device, the transfer rate setting is not necessary, whereas the ICBRL needs to be set to a value longer than the data setup time (250 ns).

For the SMBus device default address (1100 001b), use one of the slave address registers L0 to L2 (SARL0, SARL1, and SARL2), and set the corresponding FS bit (7-bit/10-bit address format select) in SARUy (y = 0 to 2) to 0 (7-bit address format).

When transmitting the UDID (Unique Device Identifier), set the SALE bit in ICFER to 1 to enable the slave arbitration lost detection function.

22.12.1 SMBus Timeout Measurement

(1) Measuring timeout of slave device

The following period (timeout interval: $T_{LOW:SEXT}$) must be measured for slave devices in SMBus communication.

- From start condition to stop condition

To measure timeout for slave devices, measure the period from start condition detection to stop condition detection with the TPU or TMR timer using a start condition detection interrupt (STI) and stop condition detection interrupt (SPI) of the RIIC. The measured timeout period must be within the total clock low-level period [slave device] $T_{LOW:SEXT}$: 25 ms (max.) of the SMBus standard.

If the time measured with the TPU or TMR exceeds the clock low-level detection timeout $T_{TIMEOUT}$: 25 ms (min.) of the SMBus standard, the slave device must release the bus by writing 1 to the IICRST bit in ICCR1 to issue an internal reset of the RIIC. When an internal reset is issued, the RIIC stops driving the bus for the SCLn pin and SDAn pin and make the SCLn/SDAn pin outputs high impedance, which releases the bus.

(2) Measuring timeout of master device

The following periods (timeout interval: $T_{LOW:MEXT}$) must be measured for master devices in SMBus communication.

- From start condition to acknowledge bit
- Between acknowledge bits
- From acknowledge bit to stop condition

To measure timeout for master devices, measure these periods with the TPU or TMR timer using a start condition detection interrupt (STI), stop condition detection interrupt (SPI), and transmit end interrupt (ICTEI) or receive data full interrupt (ICRXI) of the RIIC. The measured timeout period must be within the total clock low-level extended period [master device] $T_{LOW:MEXT}$: 10 ms (max.) of the SMBus standard, and the total of all $T_{LOW:MEXT}$ from start condition to stop condition must be within $T_{LOW:SEXT}$: 25 ms (max.).

For the ACK receive timing (rising edge of the ninth SMBCLK clock cycle), monitor the TEND flag in ICSR2 in master transmit mode (master transmitter) and the RDRF flag in ICSR2 in master receive mode (master receiver). For this reason, perform bytewise transmit operation in master transmit mode, and hold the RDRFS bit in ICMR3 0 until the byte just before reception of the final byte in master receive mode. While the RDRFS bit is 0, the RDRF flag is set to 1 at the rising edge of the ninth SMBCLK clock cycle.

If the period measured with the TPU or TMR exceeds the total clock low-level extended period [master device] $T_{LOW:MEXT}$: 10 ms (max.) of the SMBus standard or the total of measured periods exceeds the clock low-level detection timeout $T_{TIMEOUT}$: 25 ms (min.) of the SMBus standard, the master device must stop the transaction by issuing a stop condition. In master transmit mode, immediately stop the transmit operation (writing data to ICDRT).

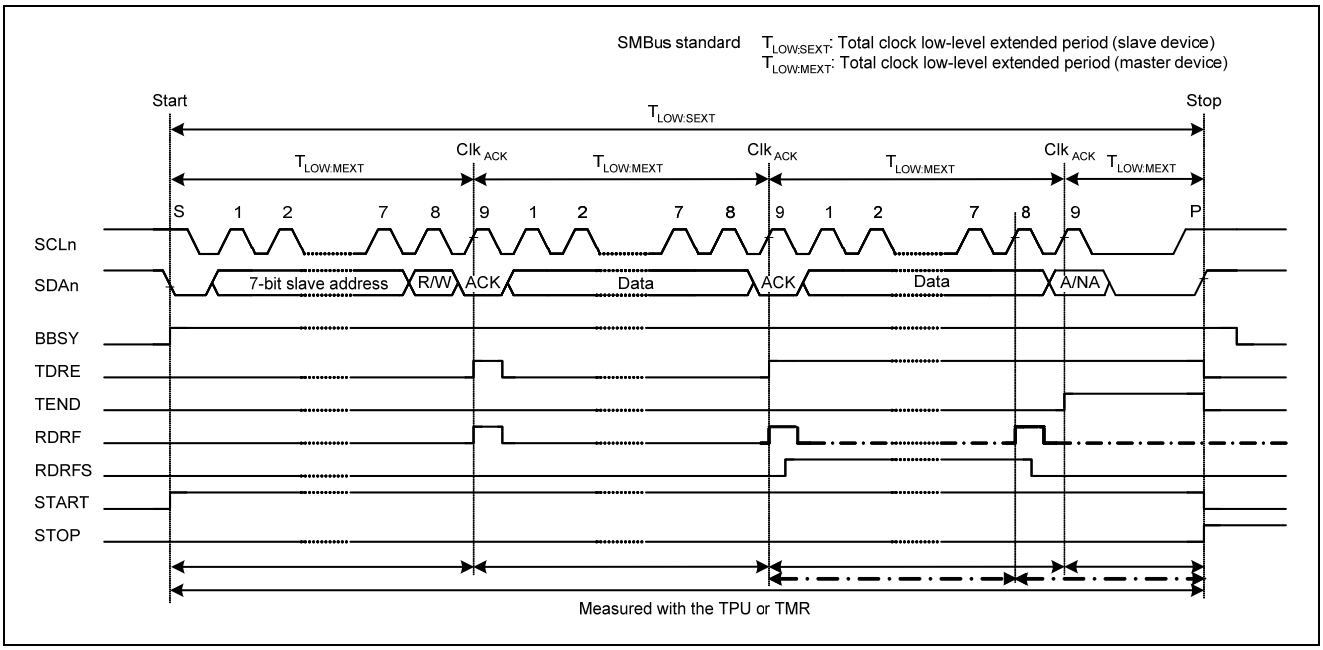


Figure 22.40 SMBus Timeout Measurement

22.12.2 Packet Error Code (PEC)

The RX610 Group incorporates a CRC operation circuit. The CRC operation circuit enables transmission of a packet error code (PEC) or checking the received data of the SMBus in data communication of the RIIC. For the CRC generating polynomials of the CRC operation circuit, see section 21, CRC Operation Circuit (CRC).

The PEC data in master transmit mode (master transmitter) can be generated by writing all transmit data to the CRC data input register (CRCDIR) in the CRC operation circuit.

The REC data in master receive mode (master receiver) can be checked by writing all receive data to CRCDIR in the CRC operation circuit and comparing the obtained value in the CRC data output register (CRCDOR) with the received PEC data.

To send ACK or NACK according to the match or mismatch result when the final byte is received as a result of the PEC code check, set the RDRFS bit in ICMR3 to 1 before the rising edge of the eighth SMBCLK clock cycle during reception of the final byte, and hold the SCLn line low at the falling edge of the eighth clock cycle.

22.12.3 SMBus Host Notification Protocol/Notify ARP Master

In communications over an SMBus, a slave device can temporarily act as a master device to notify the SMBus host (or ARP master) of (or request the SMBus host for) its own slave address or to request its own slave address from the SMBus host.

For a product of the RX610 Group to operate as an SMBus host (or ARP master), the host address (0001 000b) sent from the slave device must be detected as a slave address, so the RIIC has a function for detecting the host address. To detect the host address as a slave address, set the SMBS bit in ICMR3 and the HOAE bit in ICSER to 1. Operation after the host address has been detected is the same as normal slave operation.

22.13 Interrupt Request

The RIIC issues four types of interrupt request: transfer error or event generation (arbitration lost, NACK detection, timeout detection, start condition detection, and stop condition detection), receive data full, transmit data empty, and transmit end.

Table 22.7 shows details of the several interrupt requests. The receive data full and transmit data empty are both capable of launching data transfer by the DTC or DMAC.

Table 22.7 Interrupt Sources

Abbreviation	Interrupt Request	Interrupt Flag	DTC Launching	DMAC Launching	Priority	Interrupt Condition
ICEEI	Transfer Error/ Event Generation	AL, NACKF, TMOF, START, STOP	Not possible	Not possible	High ↑	AL=1 and ALIE=1 NACKF=1 and NAKIE=1 TMOF=1 and TMO E=1 START=1 and STIE=1 STOP=1 and SPIE=1
ICRXI	Receive Data Full	—	Possible	Poss ble		RDRF=1 and RIE=1
ICTXI	Transmit Data Empty	—	Possible	Poss ble		TDRE=1 and TIE=1
ICTEI	Transmit End	TEND	Not possible	Not possible	↓ Low	TEND=1 and TEIE=1

Clear or mask the various interrupt sources during interrupt handling.

Notes on interrupt processing:

1. There is a latency (delay) between the execution of a write instruction for a peripheral module by the CPU and actual writing to the module. Thus, when an interrupt flag has been cleared or masked, read the relevant flag again to check whether clearing or masking has been completed, and then return from interrupt processing. Returning from interrupt processing without checking that writing to the module has been completed creates a possibility of repeated processing of the same interrupt.
2. Since ICTXI is an edge-detected interrupted, it does not require clearing. Furthermore, the TDRE flag in ICSR2 (a condition for ICTXI) is automatically cleared to 0 when data for transmission are written to ICDRT or a stop condition is detected (STOP flag = 1 in ICSR2).
3. Since ICRXI is an edge-detected interrupted, it does not require clearing. Furthermore, the RDRF flag in ICSR2 (a condition for ICRXI) is automatically cleared to 0 when data are read out from ICDRR.
4. When using the ICTEI interrupt, clear the TEND flag in ICSR2 in the ICTEI interrupt processing, Note that the TEND flag in ICSR2 is automatically cleared to 0 when data for transmission are written to ICDRT or a stop condition is detected (STOP flag = 1 in ICSR2).

22.14 Reset States

The RIIC has chip reset, RIIC reset, and internal reset functions. Table 22.8 shows the scope of each reset and reset conditions.

Table 22.8 Reset Conditions

		Chip Reset	RIIC Reset (ICE = 0, IICRST = 1)	Internal Reset (ICE = 1, IICRST = 1)	Start Condition/ Restart Condition Detection	Stop Condition Detection
ICCR1	ICE, IICRST	At a reset	Retained	Retained	Operation (retained)	Operation (retained)
	SCLO, SDAO		At a reset	At a reset		
	Others			Retained		
ICCR2	BBSY	At a reset	At a reset	Operation	Operation	Operation
	ST			At a reset	At a reset	Operation (retained)
	Others					At a reset
ICMR1	BC[2:0]	At a reset	At a reset	At a reset	At a reset	Operation (retained)
	Others			Retained	Operation (retained)	
ICMR2		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICMR3		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICFER		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICSER		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICIER		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICSR1		At a reset	At a reset	At a reset	Operation (retained)	At a reset
ICSR2	TDRE, TEND	At a reset	At a reset	At a reset	Operation (retained)	At a reset
	START				Operation	
	STOP				Operation (retained)	Operation
	Others					Operation (retained)
SARL0 to SARL2 SARU0 to SARU2		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICBRH, ICBRL		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICDRT		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICDRR		At a reset	At a reset	Retained	Operation (retained)	Operation (retained)
ICDRS		At a reset	At a reset	At a reset	Operation (retained)	Operation (retained)
Timeout detection function		At a reset	At a reset	Operation	Operation	Operation
Bus free time measurement		At a reset	At a reset	Operation	Operation	Operation

22.15 Usage Notes

22.15.1 Setting Module Stop Function

Module stop state can be entered or canceled using module stop control register B (MSTPCRB). The initial setting is for operation of the RIIC to be halted. RIIC register access is enabled by clearing module stop state.
For details of module stop control register B, see section 8, Low Power Consumption.

22.15.2 Setting Input Buffer Control Register

Input to peripheral modules can be enabled or disabled using the input buffer control register (Pn.ICR). The initial setting is for input to the RIIC to be disabled.
As the SCL and SDA lines on the I²C bus are bidirectional, the SCLn and SDAn pins of the RIIC are input/output pins. Make appropriate settings in the input buffer control bits in the P1.ICR corresponding to the SCLn and SDAn pins of the RIIC to enable input to the RIIC. If the required input is disabled, the RIIC cannot detect start conditions (including restart conditions) or stop conditions, or count the SCL clock cycles.
For details of the input buffer control register, see section 14, I/O Ports.

22.15.3 Timings for Writing and Outputting of Transmit Acknowledge Bit

The transmit acknowledge (ICMR3.ACKBT) bit value at the falling edge of the eighth SCL clock cycle is always output regardless of the setting in the RDRF flag set timing selection (ICMR3.RDRFS) bit. The ACKBT value written after the falling edge of the eighth SCL clock cycle is output at the falling edge of the eighth clock cycle of the next frame.

22.15.4 Restrictions on Timings for Stop Condition Issuance Request and Transmit Data Writing in Master Transmitter Mode

In master transmitter mode, when the low-level output in the ninth clock cycle ends at the same time as the stop condition issuance request (writing 1 to the ICCR2.SP bit) while the transmit end (ICSR2.TEND) flag is 1, if a sharp rise occurs on the SCL line due to the external pull-up resistance, the generated waveforms may look the same as the start condition waveforms depending on the timing relationship between the SCL sharp rise and the fall on the SDA line by the stop condition issuance. In this case, reexamine the external pull-up resistance or send a stop condition issuance request after waiting for the end of the low-level output in the ninth clock cycle.
Likewise, in maser transmitter mode, when the low-level output in the ninth clock cycle ends at the same time as writing of transmit data (ICDRT) while the transmit end (ICSR2.TEND) flag is 1, a momentary low signal may be output on the SDA line and the generated waveforms may look the same as the stop condition waveforms. In master transmitter mode, be sure to write transmit data while the transmit end flag is 0; if the transmit end flag is 1, write transmit data after waiting for the end of the low-level output in the ninth clock cycle.

22.15.5 Notes when Communication is Restarted with the NACK Reception in Master Mode

When NACK is received from the slave device in master transmission mode (ICMR3.ACKBR = 1), be sure to end the communication once by issuing the stop condition, and then restart the communication by issuing the start condition.

As the RIIC transmission is a buffer operation, if the communication continues without issuing the stop condition to end the communication but with issuing the restart condition, the transmission data in ICDRT that has not been transmitted might be output. To restart the communication after the NACK is received, make sure to end the communication once by issuing the stop condition, and then restart the communication by issuing the start condition.

22.15.6 Notes on the RDRF Flag Set Timing Selection Bit (RDRFS)

In slave mode, slave addresses are matched while the RDRF flag set timing selection bit (RDRFS bit) is 1 (the receive data full flag (RDRF flag) is set to 1 at the eighth rising cycle of the SCL clock). In such a case, if the communication is not ended by the stop condition and the restart condition specifies the slave addresses (SAR0 to SAR2) of the RIIC again, the RDRF flag is set to 1 at the ninth rising cycle of the SCL soon after the flag is set to 1 at the eighth rising cycle of the SCL.

23. A/D Converter

23.1 Overview

The RX610 Group includes four successive approximation type 10-bit A/D converters (units 0 to 3). Each unit allows up to four analog input channels to be selected.

The A/D converter has two kinds of operating modes, that are single mode which converts the analog input of the specified single channel for only once and scan mode which continuously converts the analog inputs of the specified channels up to four.

Table 23.1 lists the specifications of the A/D converter and the table 23.2 indicates the comparison of functions by each unit. Figures 23.1 to 23.4 show block diagrams of the A/D converter units 0 to 4, respectively.

Table 23.1 Specifications of A/D Converter

Item	Specifications
Number of units	Four units
Input channels	Each unit: 4 channels (total 16 channels)
A/D conversion method	Successive approximation method
Resolution	10 bits
Conversion time	1.0 μs per 1 channel (when operating peripheral module clock PCLK = 50 MHz)
A/D conversion clock	4 types: PCLK, PCLK/2, PCLK/4, PCLK/8
Operating modes	• Single mode: A/D conversion is to be performed for only once on the analog input of the specified single channel. • Scan mode Continuous scan mode: A/D conversion is to be performed sequentially on the analog inputs of the specified channels up to four. Single scan mode: A/D conversion is to be performed for one cycle on the analog inputs of the specified channels up to four.
Conditions of A/D conversion start	• Software trigger • Conversion start trigger by the 16-bit timer pulse unit (TPU) or 8-bit timer (TMR). • External trigger A/D conversion for each unit can be externally triggered from the ADTRGn# pin. For units 0 and 1, an external trigger can be simultaneously started from the ADTRG0# pin. For units 2 and 3, an external trigger can be simultaneously started from the ADTRG2# pin.
Function	• Sample-and-hold function • Number of sampling state is adjustable.
Interrupt source	• A/D conversion end interrupt (ADI) request can be generated by each unit. • An ADI interrupt can activate data transfer controller (DTC) or DMA controller (DMAC).
Power-down function	Module stop state can be set for each unit.

Table 23.2 Comparison of Functions by Each Unit

Item			Unit 0 (AD0)	Unit 1 (AD1)	Unit 2 (AD2)	Unit 3 (AD3)
Analog input channel			AN0 AN1 AN2 AN3	AN4 AN5 AN6 AN7	AN8 AN9 AN10 AN11	AN12 AN13 AN14 AN15
A/D conversion start conditions*1	Software	Software trigger	√	√	√	√
	External trigger	ADTRG0#	√	√	—	—
		ADTRG1#	—	√	—	—
		ADTRG2#	—	—	√	√
		ADTRG3#	—	—	—	√
	Timer trigger	Compare match/ input capture from TPU0	TGRA	TGRB	TGRC	TGRD
		Compare match/ input capture from TPU0 to TPU5	TGRA	TGRA	TGRA	TGRA
		Compare match/ input capture from TPU6 to TPU11	TGRA	TGRA	TGRA	TGRA
		Compare match from TMR0	Compare match A	Compare match A	—	—
		Compare match from TMR2	—	—	Compare match A	Compare match A
Interrupt			ADI0	ADI1	ADI2	ADI3
Module stop function setting*2			MSTPCRA. MSTPA23 bit	MSTPCRA. MSTPA22 bit	MSTPCRA. MSTPA21 bit	MSTPCRA. MSTPA20 bit

[Legend]

√: Enabled

—: Disabled

Notes: 1. A/D conversion start conditions can be selected by each unit.

2. For details, see section 8, Low Power Consumption.

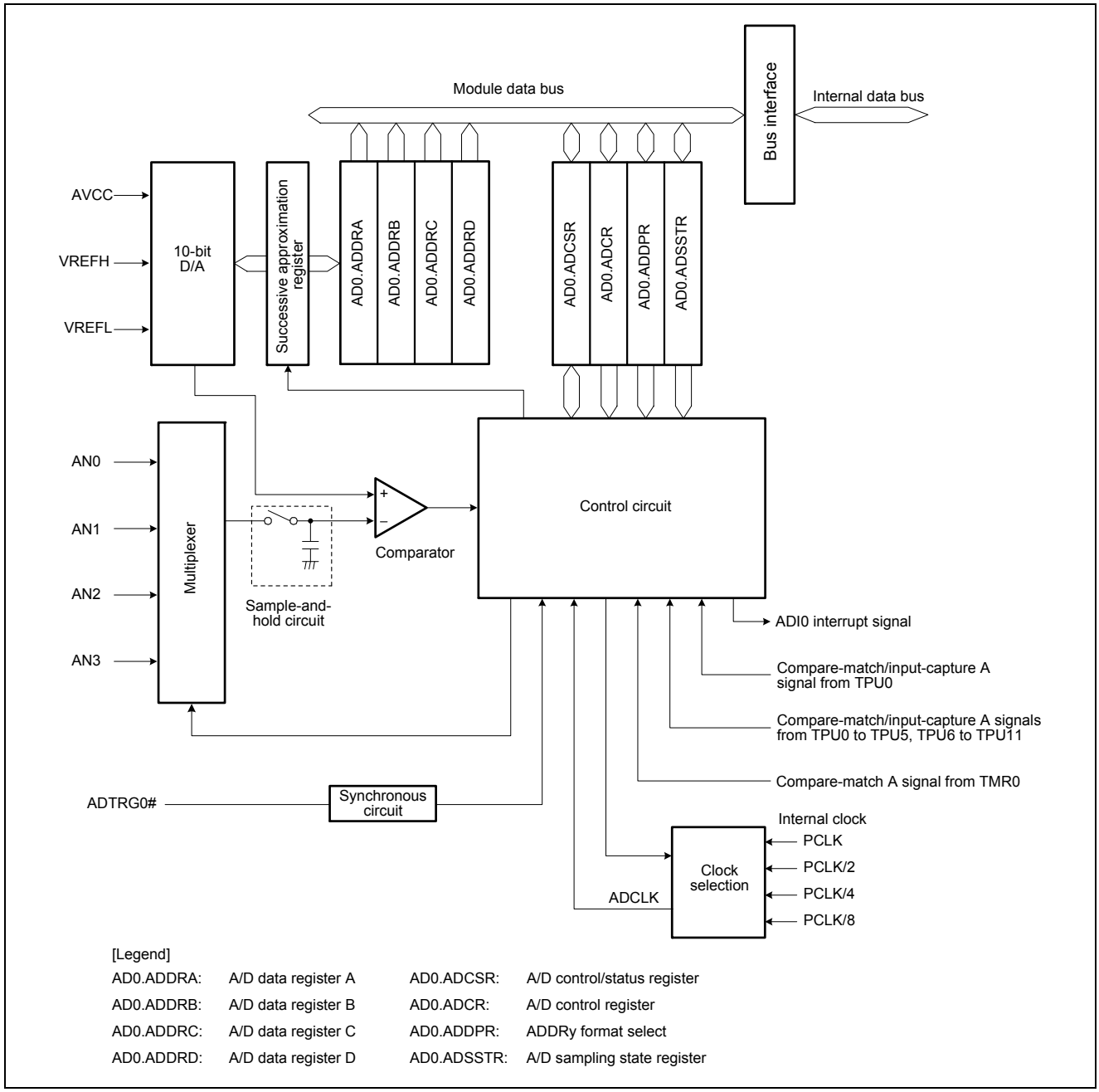


Figure 23.1 Block Diagram of A/D Converter Unit 0 (AD0)

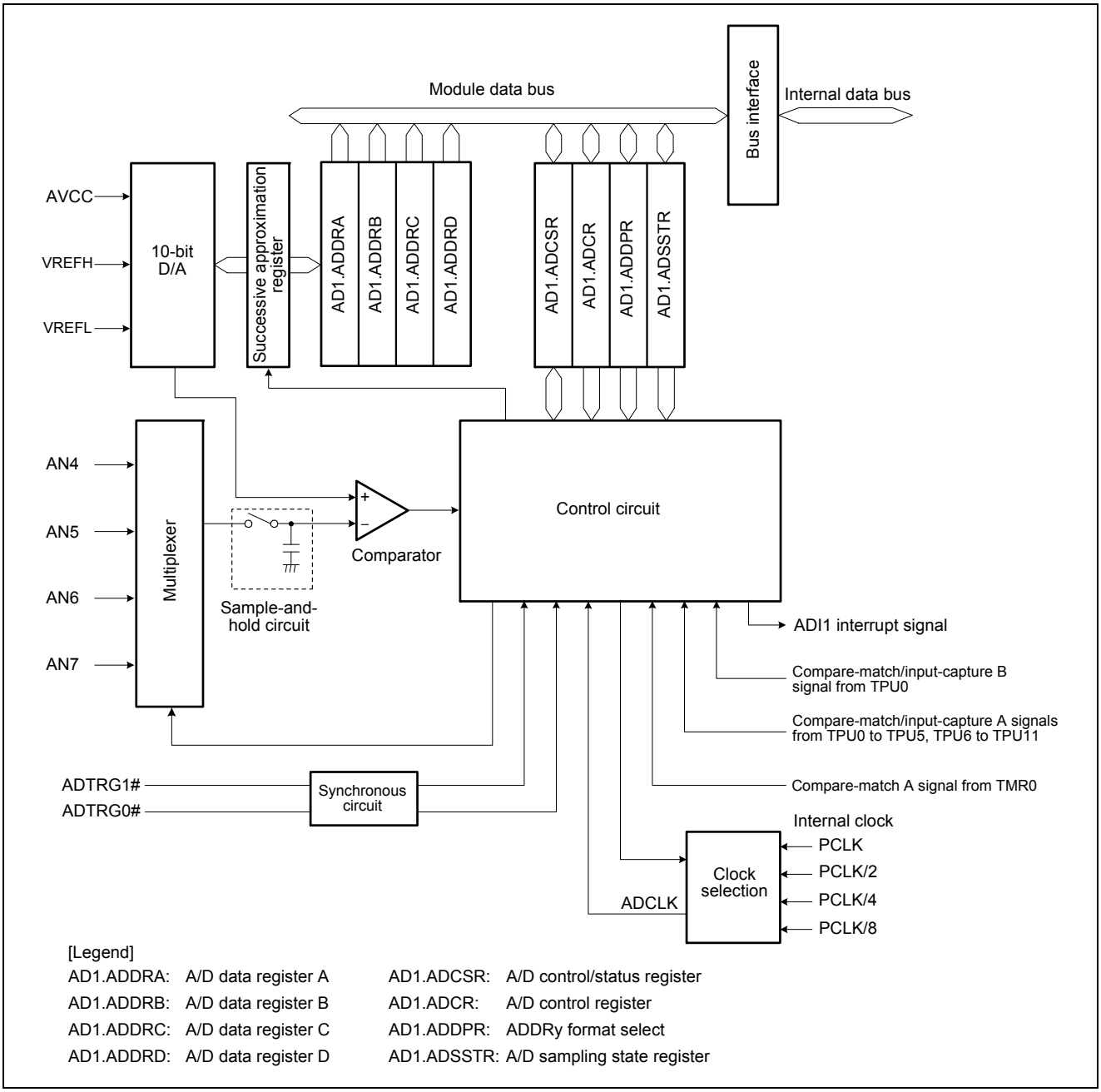


Figure 23.2 Block Diagram of A/D Converter Unit 1 (AD1)

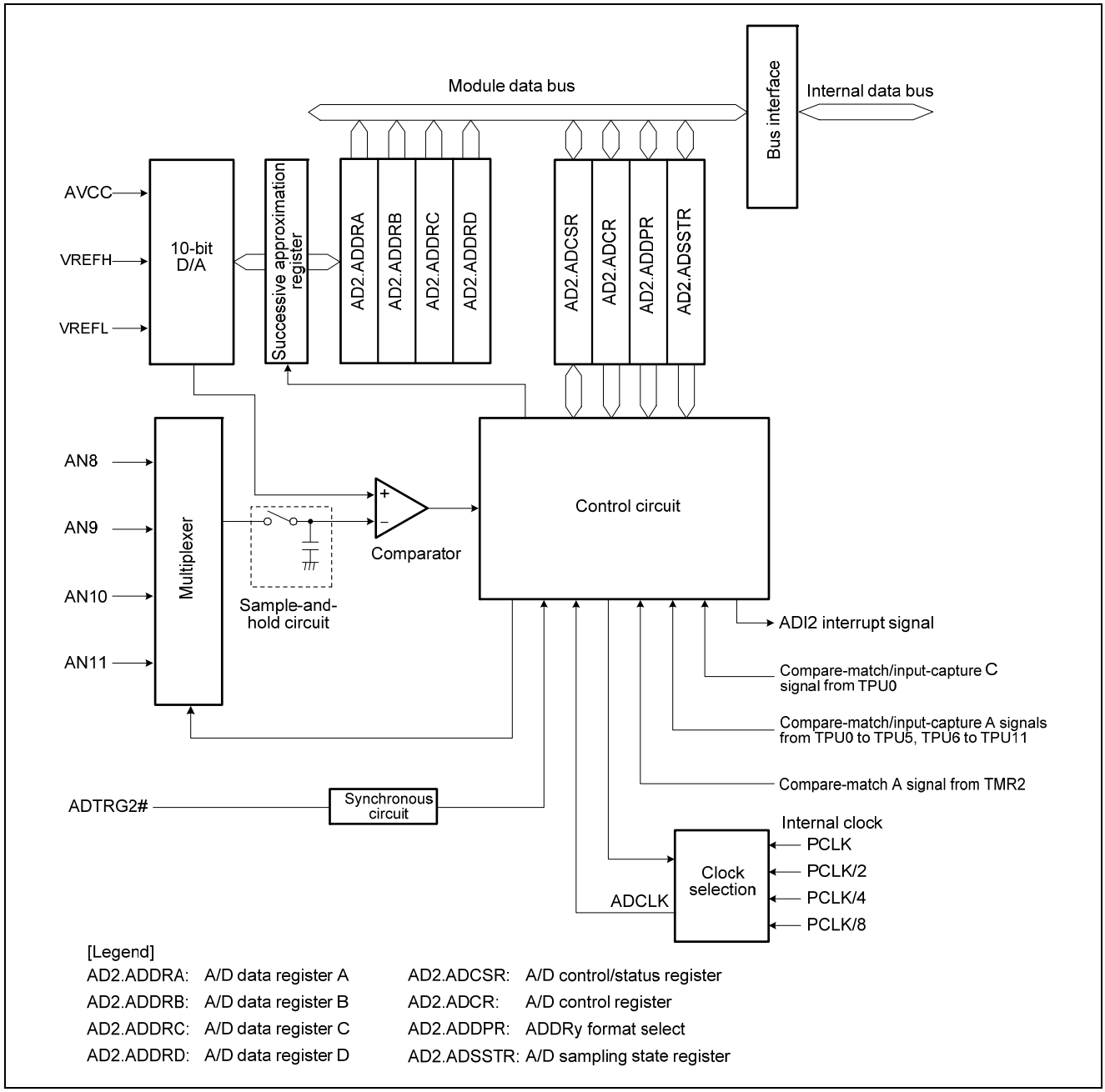


Figure 23.3 Block Diagram of A/D Converter Unit 2 (AD2)

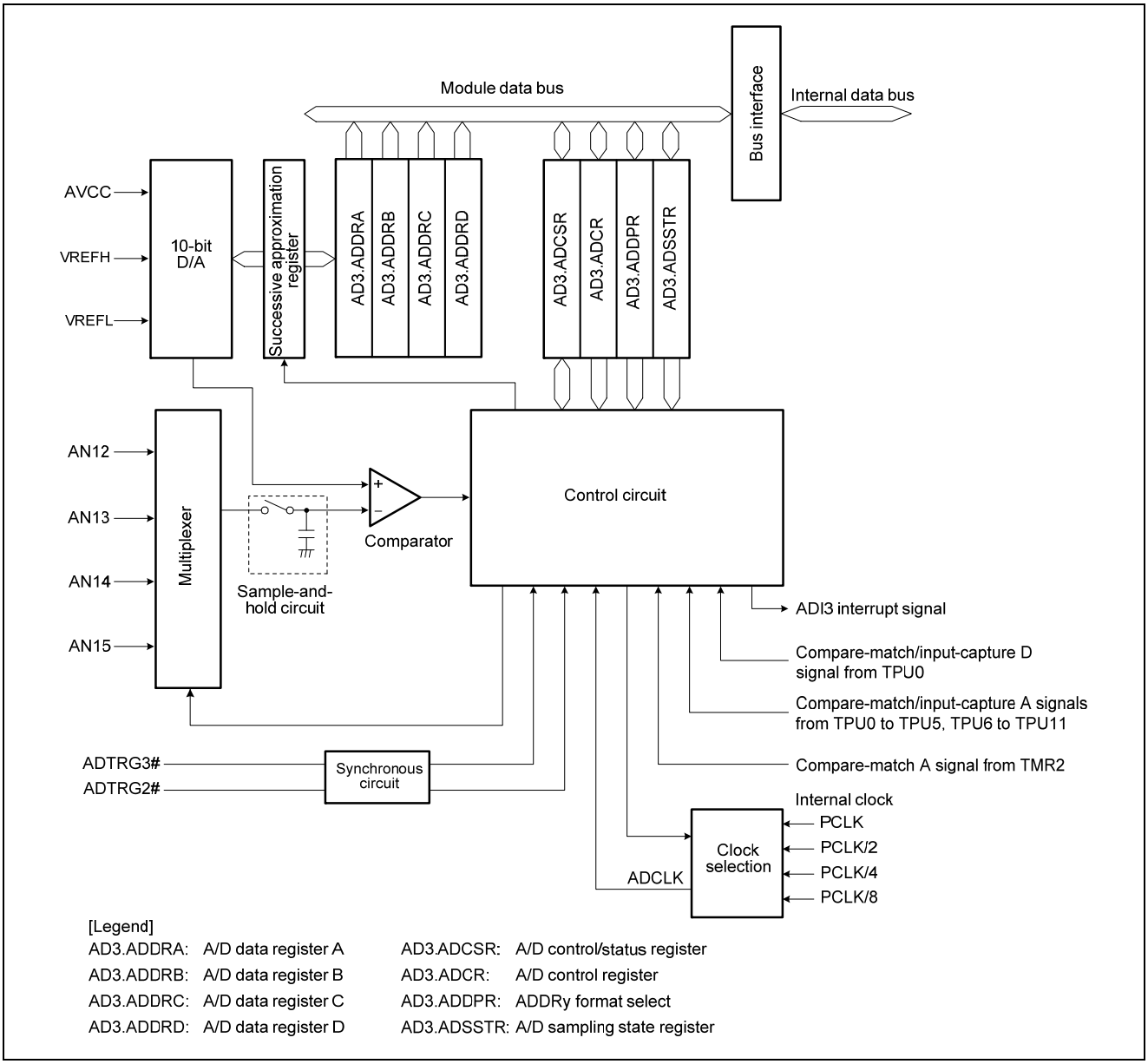


Figure 23.4 Block Diagram of A/D Converter Unit 3 (AD3)

Table 23.3 indicates the input pins of the A/D converter.

Table 23.3 Input Pins of A/D Converter

Unit	Module Symbol	Pin Name	Input	Function
0	AD0	AN0 to AN3	Input	Analog input pins
		ADTRG0#	Input	External trigger input pin for starting A/D conversion
1	AD1	AN4 to AN7	Input	Analog input pins
		ADTRG0#	Input	External trigger input pin for starting A/D conversion
		ADTRG1#	Input	External trigger input pin for starting A/D conversion
2	AD2	AN8 to AN11	Input	Analog input pins
		ADTRG2#	Input	External trigger input pin for starting A/D conversion
3	AD3	AN12 to AN15	Input	Analog input pins
		ADTRG2#	Input	External trigger input pin for starting A/D conversion
		ADTRG3#	Input	External trigger input pin for starting A/D conversion
Common		AV_{CC}	Input	Analog circuit power supply pin
		AV_{SS}	Input	Analog circuit ground pin
		V_{REFH}	Input	A/D converter reference power supply pin
		V_{REFL}	Input	A/D converter reference ground pin Connect this pin to the analog reference power supply (0 V).

23.2 Register Descriptions

Table 23.4 lists the registers of the A/D converter.

Table 23.4 Registers of A/D Converter

Unit	Module Symbol	Register Name	Register Symbol	Value after Reset	Address	Access Size
0	AD0	A/D data register A	ADDRA	0000h	0008 8040h	16
		A/D data register B	ADDRB	0000h	0008 8042h	16
		A/D data register C	ADDRC	0000h	0008 8044h	16
		A/D data register D	ADDRD	0000h	0008 8046h	16
		A/D control/status register	ADCSR	x0h	0008 8050h	8
		A/D control register	ADCR	00h	0008 8051h	8
		ADDRy format select register	ADDPR	00h	0008 8052h	8
		A/D sampling state register	ADSSTR	19h	0008 8053h	8
1	AD1	A/D data register A	ADDRA	0000h	0008 8060h	16
		A/D data register B	ADDRB	0000h	0008 8062h	16
		A/D data register C	ADDRC	0000h	0008 8064h	16
		A/D data register D	ADDRD	0000h	0008 8066h	16
		A/D control/status register	ADCSR	x0h	0008 8070h	8
		A/D control register	ADCR	00h	0008 8071h	8
		ADDRy format select register	ADDPR	00h	0008 8072h	8
		A/D sampling state register	ADSSTR	19h	0008 8073h	8
2	AD2	A/D data register A	ADDRA	0000h	0008 8080h	16
		A/D data register B	ADDRB	0000h	0008 8082h	16
		A/D data register C	ADDRC	0000h	0008 8084h	16
		A/D data register D	ADDRD	0000h	0008 8086h	16
		A/D control/status register	ADCSR	x0h	0008 8090h	8
		A/D control register	ADCR	00h	0008 8091h	8
		ADDRy format select register	ADDPR	00h	0008 8092h	8
		A/D sampling state register	ADSSTR	19h	0008 8093h	8
3	AD3	A/D data register A	ADDRA	0000h	0008 80A0h	16
		A/D data register B	ADDRB	0000h	0008 80A2h	16
		A/D data register C	ADDRC	0000h	0008 80A4h	16
		A/D data register D	ADDRD	0000h	0008 80A6h	16
		A/D control/status register	ADCSR	x0h	0008 80B0h	8
		A/D control register	ADCR	00h	0008 80B1h	8
		ADDRy format select register	ADDPR	00h	0008 80B2h	8
		A/D sampling state register	ADSSTR	19h	0008 80B3h	8

23.2.1 A/D Data Register y (ADDRy) (y = A to D)

Addresses: AD0.ADDRA 0008 8040h, AD0.ADDRB 0008 8042h, AD0.ADDRC 0008 8044h, AD0.ADDRD 0008 8046h
AD1.ADDRA 0008 8060h, AD1.ADDRB 0008 8062h, AD1.ADDRC 0008 8064h, AD1.ADDRD 0008 8066h
AD2.ADDRA 0008 8080h, AD2.ADDRB 0008 8082h, AD2.ADDRC 0008 8084h, AD2.ADDRD 0008 8086h
AD3.ADDRA 0008 80A0h, AD3.ADDRB 0008 80A2h, AD3.ADDRC 0008 80A4h, AD3.ADDRD 0008 80A6h

ADDPR.DPSEL bit = 0 (Data padded at the LSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–										
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ADDPR.DPSEL bit = 1 (Data padded at the MSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
											–	–	–	–	–	–
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ADDRy registers are 16-bit read-only registers, which store an A/D conversion result for each channel.

Table 23.5 lists the analog input channels and corresponding ADDRy registers.

10-bit data can be relocated by setting the DPSEL bit in ADDPR.

Bits "—" are always read as 0. The write value should always be 0.

Table 23.5 Analog Input Channels and Corresponding ADDRy Registers

Analog Input Channel	ADDRy Register
AN0	AD0.ADDRA
AN1	AD0.ADDRB
AN2	AD0.ADDRC
AN3	AD0.ADDRD
AN4	AD1.ADDRA
AN5	AD1.ADDRB
AN6	AD1.ADDRC
AN7	AD1.ADDRD
AN8	AD2.ADDRA
AN9	AD2.ADDRB
AN10	AD2.ADDRC
AN11	AD2.ADDRD
AN12	AD3.ADDRA
AN13	AD3.ADDRB
AN14	AD3.ADDRC
AN15	AD3.ADDRD

23.2.2 A/D Control/Status Register (ADCSR)

Addresses: AD0.ADCSR 0008 8050h, AD1.ADCSR 0008 8070h
AD2.ADCSR 0008 8090h, AD3.ADCSR 0008 80B0h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	ADIE	ADST	—	CH[3:0]			
Value after reset:	x	0	0	0	0	0	0	0

[Legend] x: Undefined

Bit	Symbol	Bit Name	Description			R/W
b3 to b0	CH[3:0]	Channel Select*	Unit	Single mode (ADCR.MODE[1:0] = 00b)	Scan mode (ADCR.MODE[1:0] = 10b or 11b)	R/W
			Unit 0	b3 b0 0 0 0 0: AN0 0 0 0 1: AN1 0 0 1 0: AN2 0 0 1 1: AN3 Settings other than above are prohibited.	b3 b0 0 0 0 0: AN0 0 0 0 1: AN0 and AN1 0 0 1 0: AN0 to AN2 0 0 1 1: AN0 to AN3 Settings other than above are proh bited.	
			Unit 1	b3 b0 0 0 0 0: AN4 0 0 0 1: AN5 0 0 1 0: AN6 0 0 1 1: AN7 Settings other than above are prohibited.	b3 b0 0 0 0 0: AN4 0 0 0 1: AN4 and AN5 0 0 1 0: AN4 to AN6 0 0 1 1: AN4 to AN7 Settings other than above are proh bited.	
			Unit 2	b3 b0 0 0 0 0: AN8 0 0 0 1: AN9 0 0 1 0: AN10 0 0 1 1: AN11 Settings other than above are prohibited.	b3 b0 0 0 0 0: AN8 0 0 0 1: AN8 and AN9 0 0 1 0: AN8 to AN10 0 0 1 1: AN8 to AN11 Settings other than above are proh bited.	
			Unit 3	b3 b0 0 0 0 0: AN12 0 0 0 1: AN13 0 0 1 0: AN14 0 0 1 1: AN15 Settings other than above are prohibited.	b3 b0 0 0 0 0: AN12 0 0 0 1: AN12 and AN13 0 0 1 0: AN12 to AN14 0 0 1 1: AN12 to AN15 Settings other than above are proh bited.	
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.			R/W
b5	ADST	A/D Start	0: Stops A/D conversion 1: Starts A/D conversion			R/W

Bit	Symbol	Bit Name	Description	R/W
b6	ADIE	A/D Interrupt Enable	0: ADI interrupt is disabled by completing A/D conversion 1: ADI interrupt is enabled by completing A/D conversion	R/W
b7	—	Reserved	This bit is always read as an undefined value. The write value should always be 1.	R/W

Note: * The Pm.DDR.Bj bit for the analog input should be set to 0 (input port) and the Pm.ICR.Bj (m = 4 or 9, j = 0 to 7) bit should be set to 0 (disabling the input buffer and fixing the input signal to the high level). For details, see section 14, I/O Ports.

ADCSR controls the A/D conversion operations.

CH[3:0] Bits (Channel Select)

These bits select analog input channels that allow A/D conversion.

- Single mode (ADCR.MODE[1:0] bits = 00b)
  Select the single analog input channel that allows A/D.
- Scan mode (ADCR.MODE[1:0] bits = 10b or 11b)
  Select analog input channels up to 4 that allow A/D conversion.

ADST Bit (A/D Start)

The ADST bit starts/stops A/D conversion.

Before setting the ADST bit to 1, complete the setting for A/D conversion clock and the operation mode.

[Setting conditions]

- When 1 is written by software
- Detection of the trigger selected by the ADCR.TRGS [2:0] bits

[Clearing conditions]

- When 0 is written by software
- The A/D conversion is completed in single mode
- The A/D conversion is completed on every selected channel in single scan mode.

ADIE Bit (A/D Interrupt Enable)

The ADIE bit enables/disables the A/D conversion end interrupt (ADI).

23.2.3 A/D Control Register (ADCR)

Addresses: AD0.ADCR 0008 8051h, AD1.ADCR 0008 8071h
AD2.ADCR 0008 8091h, AD3.ADCR 0008 80B1h

	b7	b6	b5	b4	b3	b2	b1	b0
	TRGS[2:0]			—	CKS[1:0]		MODE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description		R/W
b1, b0	MODE[1:0]	Operation Mode Select	b1 b0 0 0: Single mode 0 1: Setting prohibited 1 0: Continuous scan mode 1 1: Single scan mode		R/W
b3, b2	CKS[1:0]	Clock Select	b3 b2 0 0: PCLK/8 0 1: PCLK/4 1 0: PCLK/2 1 1: PCLK		R/W
b4	—	Reserved	This bit is always read as 0. The write value should always be 0.		R/W
b7 to b5	TRGS[2:0]	Trigger Select	Unit	Trigger signal	R/W
			Unit 0	b7 b6 b5 0 0 0: Software trigger 0 0 1: Compare-match/input-capture A signals from TPU0 to TPU5 0 1 0: Compare-match A signal from TMR0 0 1 1: Trigger from ADTRG0#* 1 0 0: Compare-match/input-capture A signal from TPU0 1 0 1: Compare-match/input-capture A signals from TPU6 to TPU11 1 1 0: Setting prohibited 1 1 1: Setting prohibited	
			Unit 1	b7 b6 b5 0 0 0: Software trigger 0 0 1: Compare-match/input-capture A signals from TPU0 to TPU5 0 1 0: Compare-match A signal from TMR0 0 1 1: Trigger from ADTRG1#* 1 0 0: Compare-match/input-capture B signal from TPU0 1 0 1: Compare-match/input-capture A signals from TPU6 to TPU11 1 1 0: Setting prohibited 1 1 1: Trigger from ADTRG0#*	

Bit	Symbol	Bit Name	Description		R/W
b7 to b5	TRGS[2:0]	Trigger Select	Unit	Trigger signal	R/W
			Unit 2	b7 b6 b5	
				0 0 0: Software trigger	
				0 0 1: Compare-match/input-capture A signals from TPU0 to TPU5	
				0 1 0: Compare-match A signal from TMR2	
				0 1 1: Trigger from ADTRG2#*	
				1 0 0: Compare-match/input-capture C signal from TPU0	
				1 0 1: Compare-match/input-capture A signals from TPU6 to TPU11	
				1 1 0: Setting prohibited	
				1 1 1: Setting prohibited	
			Unit 3	b7 b6 b5	
				0 0 0: Software trigger	
				0 0 1: Compare-match/input-capture A signals from TPU0 to TPU5	
				0 1 0: Compare-match A signal from TMR2	
				0 1 1: Trigger from ADTRG3#*	
				1 0 0: Compare-match/input-capture D signal from TPU0	
				1 0 1: Compare-match/input-capture A signals from TPU6 to TPU11	
				1 1 0: Setting prohibited	
				1 1 1: Trigger from ADTRG2#*	

Note: * To start the A/D conversion by the ADTRGn# (n = 0 to 3) pin, the Pm.DDR.Bj bit should be set to 0 (input port) and the Pm.ICR.Bj (m = 1 or 7, j = 0, 3, 4, or 7) bit should be set to 1 (input buffer for the corresponding pin is valid). For details, see section 14, I/O Ports.

ADCR enables setting for an A/D conversion start trigger, an operating mode, and A/D conversion clock mode.
Set ADCR while the ADST bit in ADCSR is 0.

MODE[1:0] Bits (Operating Mode Select)

These bits select the A/D conversion operation mode.

CKS[1:0] Bits (Clock Select)

These bits set the frequency of the A/D conversion clock (ADCLK) and thus select the A/D conversion time.

Set the frequency of ADCLK to 4 MHz or higher.

For details, see section 23.3.3, Input Sampling and A/D Conversion Time.

TRGS[2:0] Bits (Trigger Select)

These bits select the A/D conversion start trigger.

23.2.4 ADDRy Format Select Register (ADDPR)

Addresses: AD0.ADDPR 0008 8052h, AD1.ADDPR 0008 8072h
AD2.ADDRR 0008 8092h, AD3.ADDPR 0008 80B2h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSEL	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DPSEL	ADDRy Format Select	0: A/D data is padded at the LSB end. 1: A/D data is padded at the MSB end.	R/W

ADDPR selects the placement of data in the A/D data registers.

DPSEL Bit (ADDRy Format Select)

The DPSEL bit selects whether data in the A/D data registers is padded at the LSB or MSB end.

23.2.5 A/D Sampling State Register (ADSSTR)

Addresses: AD0.ADSSTR 0008 8053h, AD1.ADSSTR 0008 8073h
AD2.ADSSTR 0008 8093h, AD3.ADSSTR 0008 80B3h

	b7	b6	b5	b4	b3	b2	b1	b0
Value after reset:	0	0	0	1	1	0	0	1

ADSSTR is an 8-bit readable/writable register that is used to set the sampling time for analog inputs.

Sampling time is adjustable when the signal source impedance of analog input is high and the sampling time is insufficient or the speed of peripheral module clock (PCLK) is low.

Set the value of 02h or larger.

Ensure to rewrite this register while the A/D conversion is stopped (the ADST bit in ADCSR = 0) in order to prevent incorrect operation.

For details, see section 23.3.3, Input Sampling and A/D Conversion Time.

23.3 Operation

The RX610 Group includes four units of A/D converter and the each unit has a same feature.

Definitions of a single unit are given below.

The A/D converter has two operating modes: single mode and scan mode.

In single mode, A/D conversion is to be performed for only once on the analog input of the specified single channel.

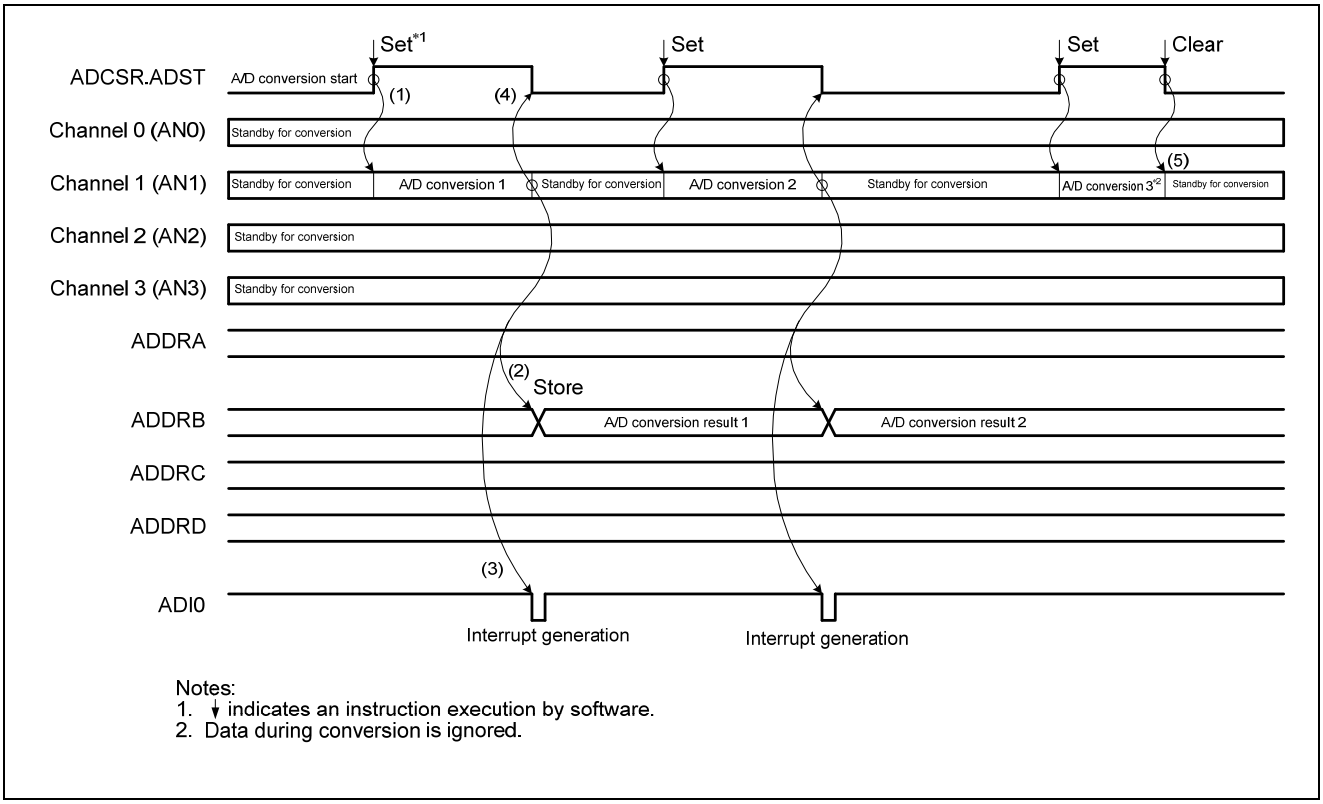
In scan mode, A/D conversion is to be performed sequentially on the analog inputs of the specified channels up to four. Two types of scan mode are provided, that is, continuous san mode where A/D conversion is repeatedly performed and single scan mode where A/D conversion is performed for the specified channels for one cycle.

23.3.1 Single Mode

In single mode, A/D conversion is to be performed for only once on the analog input of the specified single channel as below.

1. A/D conversion for the selected channel is started when the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, TPU, TMR, or an external trigger input.
2. When A/D conversion is completed, the A/D conversion result is stored into the corresponding A/D data register (ADDRn) of the channel.
3. When A/D conversion is completed, if the ADIE bit in ADCSR is set to 1 (A/D interrupt enable by completing A/D conversion), an ADI interrupt request is generated.
4. The ADST bit remains at 1 during A/D conversion, and is automatically cleared to 0 when A/D conversion ends. Then the A/D converter enters a wait state.
5. If the ADST bit is cleared to 0 during A/D conversion (A/D conversion stop), A/D conversion stops and the A/D converter enters a wait state.

Figure 23.5 shows an example of operation when AN1 is selected as an analog input.



Notes:
1. ↓ indicates an instruction execution by software.
2. Data during conversion is ignored.

Figure 23.5 Example of A/D Converter Operation (Single Mode)

23.3.2 Scan Mode

In scan mode, A/D conversion is to be performed sequentially on the analog inputs of the specified channels up to four. Two types of scan mode are provided, that is, continuous scan mode where A/D conversion is repeatedly performed and single scan mode where A/D conversion is performed for the specified channels for one cycle.

23.3.2.1 Continuous Scan Mode

In continuous scan mode, A/D conversion is to be performed sequentially on the analog inputs of the specified channels as below.

1. When the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, TPU, TMR, or an external trigger input, A/D conversion starts on the first channel in the specified channel group.
2. When A/D conversion for each channel is completed, the A/D conversion result is stored into the corresponding A/D data registers (ADDRy).
3. When A/D conversion of all selected channels is completed, if the ADIE bit in ADCSR is set to 1 (A/D interrupt enable by completing A/D conversion), an ADI interrupt request is generated. A/D converter starts A/D conversion from the first channel.
4. The ADST bit is not cleared automatically, and steps 2 to 3 are repeated as long as the ADST bit remains set to 1 (A/D conversion start). When the ADST bit is cleared to 0 (A/D conversion stop), A/D conversion stops and the A/D converter enters a wait state.
5. If the ADST bit is later set to 1 (A/D conversion start), A/D conversion starts again from the first channel in the group.

Figure 23.6 shows an example of A/D conversion when three channels (AN0 to AN2) are selected for analog input.

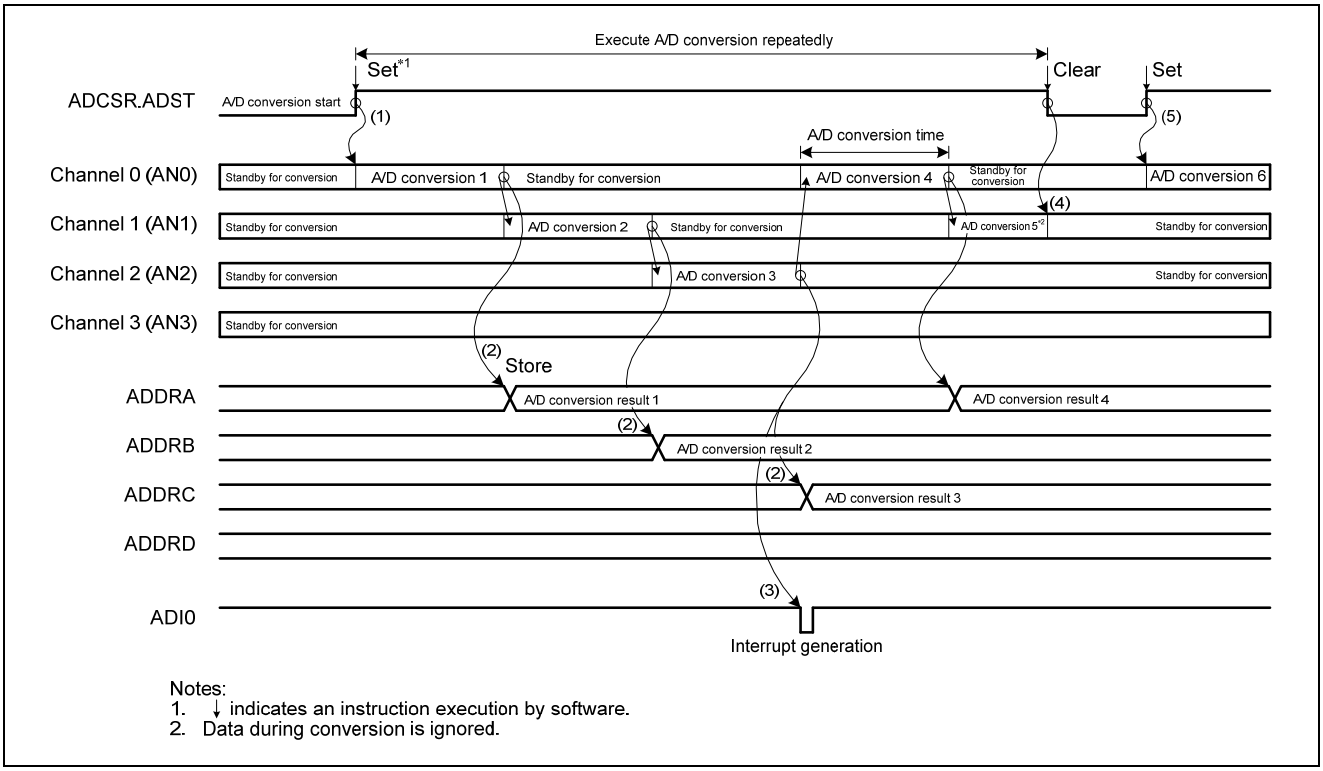


Figure 23.6 Example of A/D Converter Operation (Continuous Scan Mode)

23.3.2.2 Single Scan Mode

In single scan mode, A/D conversion is to be performed for one cycle on the analog inputs of the specified channels as below.

1. When the ADST bit in ADCSR is set to 1 (A/D conversion start) by software, TPU, TMR, or an external trigger input, A/D conversion starts on the first channel in the specified channel group.
2. When A/D conversion for each channel is completed, the A/D conversion result is stored into the corresponding A/D data registers (ADDRy).
3. When A/D conversion of all selected channels is completed, if the ADIE bit in ADCSR is set to 1 (A/D interrupt enable by completing A/D conversion), an ADI interrupt request is generated.
4. The ADST bit remains at 1 (A/D conversion start) during A/D conversion, and is automatically cleared to 0 when A/D conversion of all selected channels end. The A/D converter enters a wait state.

Figure 23.7 shows an example of A/D conversion when three channels (AN4 to AN6) are selected for analog input.

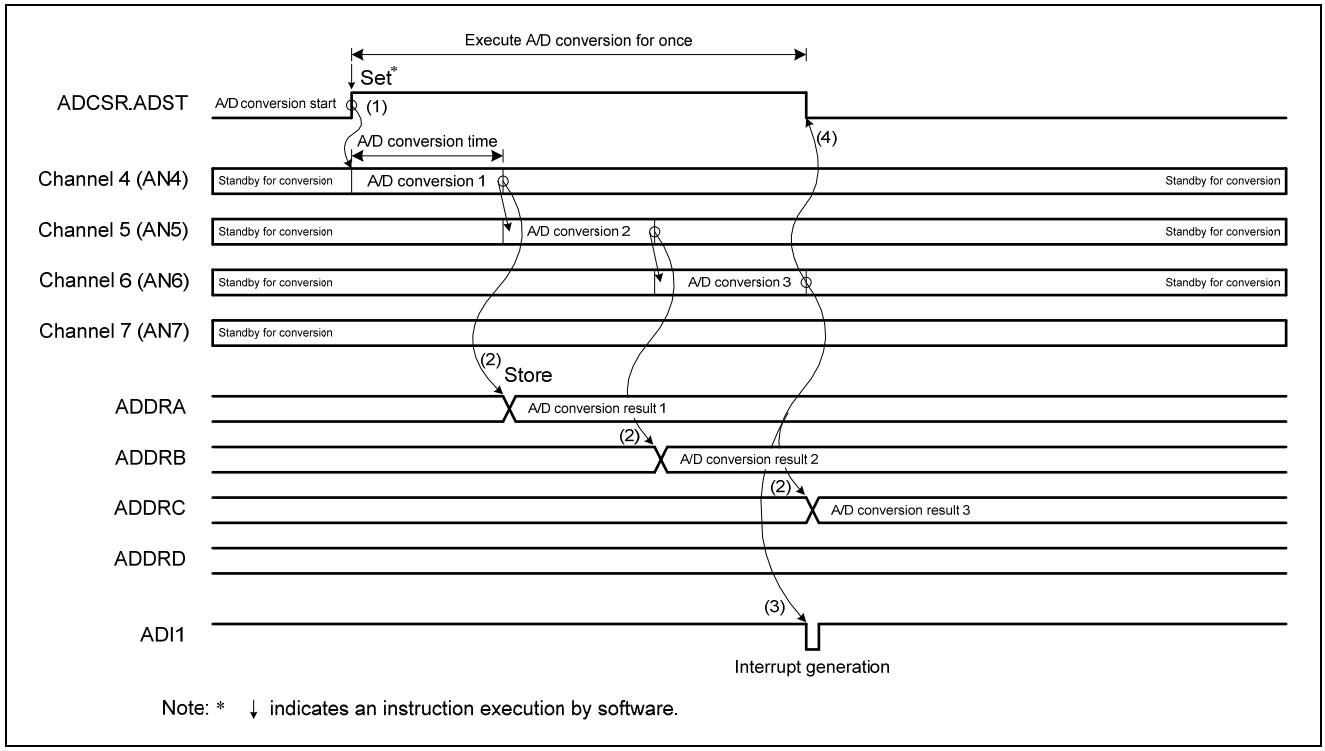


Figure 23.7 Example of A/D Converter Operation (Single Scan Mode)

23.3.3 Input Sampling and A/D Conversion Time

The A/D converter samples the analog input when the A/D conversion start delay time (tD) passes after the conditions of A/D conversion start are generated by software, TPU, TMR, or an external trigger, then starts A/D conversion.

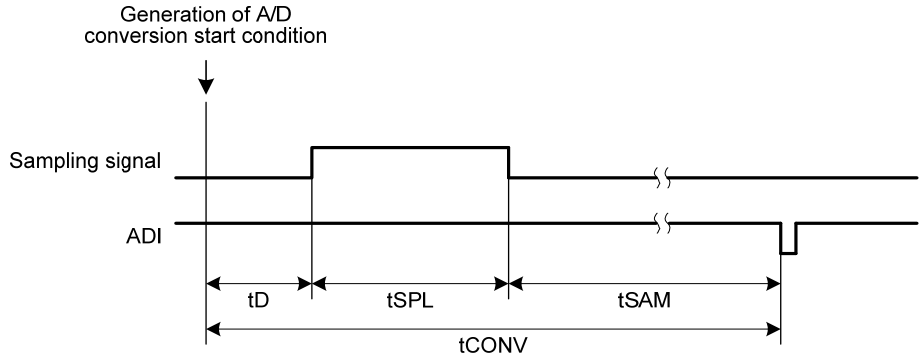
Figure 23.8 shows the A/D conversion timing.

The A/D conversion time (tCONV) directly after the generation of the A/D conversion start condition includes the A/D conversion start delay time (tD), the input sampling time (tSPL), and the successive conversion time (tSAM). The subsequent A/D conversion time (tCONV) includes tSPL and tSAM.

The input sampling time (tSPL) is the time charging of the input capacitance of the A/D converter's sample-and-hold circuit takes. If the impedance of the signal source is high and the sampling time is insufficient or the peripheral module clock (PCLK) is running at low speed, the sampling time can be adjusted by using the ADSSTR.

The successive conversion time (tSAM) is fixed at 25 states of ADCLK.

Table 23.6 lists the sample of ADSSTR settings and table 23.7 lists the A/D conversion time.



[Legend]
tD: A/D conversion start delay time
tSPL: Sampling time
tSAM: Successive conversion time
tCONV: A/D conversion time

Figure 23.8 A/D Conversion Timing

Table 23.6 Example of ADSSTR Settings

Example of Setting	Setting Range	Sampling Time*
Standard (initial value)	19h	0.5 μs (When PCLK = ADCLK = 50 MHz)
Analog input signal impedance is high and the sampling time may be insufficient	1Ah to FFh	Example: FFh 5.1 μs (When PCLK = ADCLK = 50 MHz)
Input sampling time is less than the initial value when ADCLK is below 50 MHz	02h to 18h	Example: 14h 0.5 μs (When PCLK = ADCLK = 40 MHz)

Note: * Set the sampling time ≥ 0.5 μs. Sampling time is shown as the formula below.

$$\text{Sampling time (μs)} = \frac{\text{Setting value of ADSSTR}}{\text{ADCLK (MHz)}}$$

Table 23.7 A/D Conversion Time

Item	Symbol	Formula	
		min	max
A/D conversion start delay time (1)	tD	$\frac{3}{\text{PCLK (MHz)}}$	$\frac{1}{\text{ADCLK (MHz)}} + \frac{4}{\text{PCLK (MHz)}}$
Input sampling time (2)	tSPL	$\frac{\text{Setting value of ADSSTR}}{\text{ADCLK (MHz)}}$	
Successive conversion time (3)	tSAM	$\frac{25}{\text{ADCLK (MHz)}}$	
A/D conversion time*1	tCONV	(1) + (2) + (3)	
A/D conversion time*2	tCONV	(2) + (3)	

Notes: 1. A/D conversion time in single mode and scan mode (first round)
2. A/D conversion time in scan mode (after the second round)

The examples of the calculation of A/D conversion times are listed below.

When PCLK = ADCLK = 50 MHz, ADSSTR = 19h, and the conversion is the second round in scan mode,
A/D conversion time (tCONV) = ADSSTR/ADCLK + 25/ADCLK
= 25/50 MHz + 25/50 MHz
= 0.5 µs + 0.5 µs
= 1.0 µs

When PCLK = ADCLK = 40 MHz, ADSSTR = 14h, and conversion is the first (min.) round in scan mode,
A/D conversion time (tCONV) = 3/PCLK + ADSSTR/ADCLK + 25/ADCLK
= 3/40 MHz + 20/40 MHz + 25/40 MHz
= 0.075 µs + 0.5 µs + 0.625 µs
= 1.2 µs

23.3.4 Activation by External Triggers

External trigger signals (ADTRG0# to ADTRG3#) are capable of starting A/D conversion by each of the units.

For unit 0, when the setting of the AD0.ADCR.TRGS[2:0] bits is 011b (specifying ADTRG0# as a trigger), a falling edge on the ADTRG0# pin leads to setting of the ADST (A/D conversion start) bit in AD0.ADCR to 1 and thus starts A/D conversion. Figure 23.9 shows the timing.

An external trigger input is capable of simultaneously starting A/D conversion by two units (synchronized unit activation). Simultaneous activation of units 0 and 1 by a falling edge of the ADTRG0# signal is specified by setting the AD0.ADCR.TRGS[2:0] bits to 011b (specifying ADTRG0# as the trigger for unit 0) and the AD1.ADCR.TRGS[2:0] bits to 111b (specifying ADTRG0# as the trigger for unit 1). Simultaneous activation of units 2 and 3 by a falling edge of the ADTRG2# signal can be set up in the same way.

Take note that if the external trigger input is already at the low-level, selecting the external trigger may generate a falling edge in the internal signal and thus start A/D conversion.

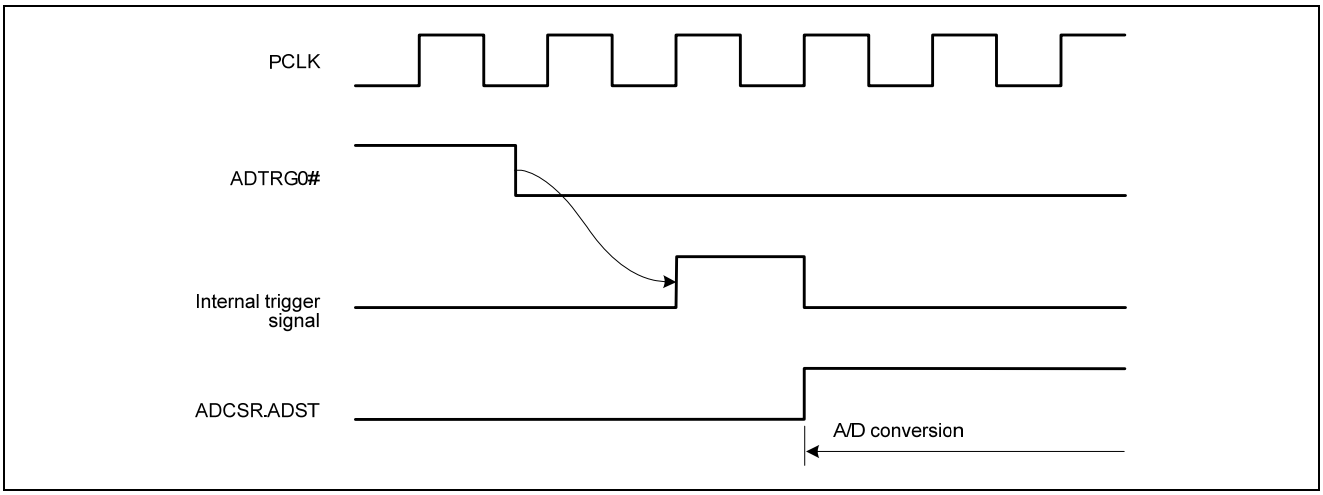


Figure 23.9 Timing of Activation by an External Trigger

23.3.5 Activation by the Compare-Match/Input-Capture A to D Signals from TPU0

The compare-match/input-capture A to D signals from TPU0 are capable of starting A/D conversion by units 0 to 3.

The connections between the units of the converter and the compare-match/input-capture A to D signals from TPU0 are shown in figure 23.10.

The compare-match/input-capture A to D signals from TPU0 are capable of starting A/D conversion by all four converter units. Setting the AD0.ADCR.TRGS[2:0] bits to 100b (specifying the compare-match/input-capture A signal from TPU0), setting the AD1.ADCR.TRGS[2:0] bits to 100b (specifying the compare-match/input-capture B signal from TPU0), setting the AD2.ADCR.TRGS[2:0] bits to 100b (specifying the compare-match/input-capture C signal from TPU0), and setting the AD3.ADCR.TRGS[2:0] bits to 100b (specifying the compare-match/input-capture D signal from TPU0) set up the compare-match/input-capture A to D signals from TPU0 as the triggers that start conversion by units 0 to 3.

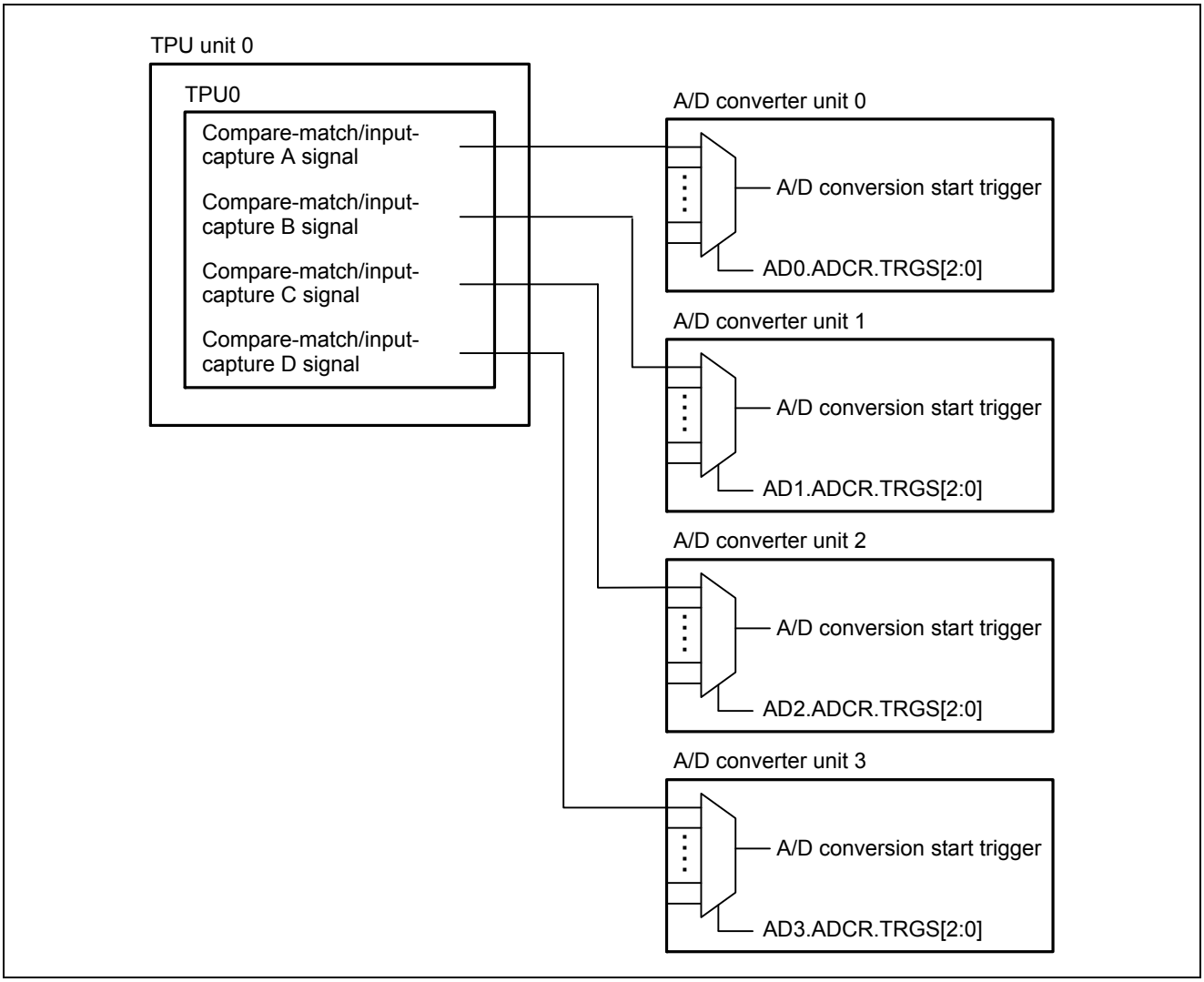


Figure 23.10 Connections between Compare-Match/Input-Capture A to D Signals from TPU0 and the Respective Converter Units

23.3.6 Activation by the Compare-Match/Input-Capture A Signals from TPU0 to TPU5

The compare-match/input-capture A signals from TPU0 to TPU5 are capable of starting A/D conversion by units 0 to 3. The compare-match/input-capture A signals from TPU6 to TPU11 are also capable of starting A/D conversion by units 0 to 3.

The connections between the units of the converter and the compare-match/input-capture A signals are shown in figure 23.11.

The compare-match/input-capture A signals from TPU0 to TPU5 are capable of simultaneously starting A/D conversion by a maximum of all four converter units. Setting the ADn.ADCR.TRGS[2:0] bits (n = 0 to 3) to 001b (specifying the compare-match/input-capture A signals from TPU0 to TPU5) and setting the TTGE bits in the TIERs of TPU0 and TPU2 to 1 set up the compare-match/input-capture A signals from TPU0 and TPU2 as the triggers that start simultaneous conversion by units 0 to 3.

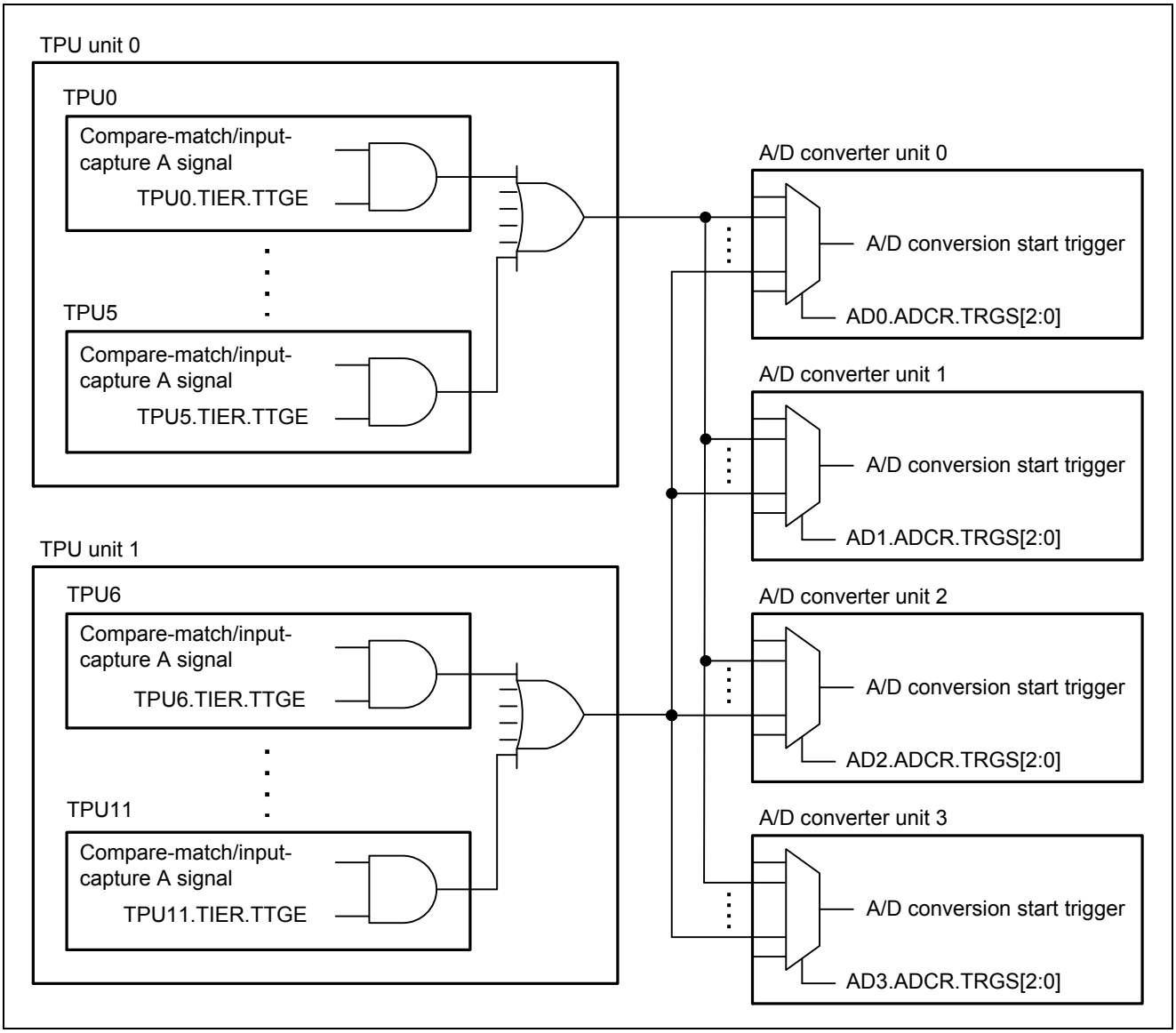


Figure 23.11 Connections between Compare-Match/Input-Capture A Signals and the Respective Converter Units

23.3.7 Activation on Compare-Match of TMR Units

The compare-match A signal from TMR0 is capable of starting A/D conversion by units 0 and 1. In the same way, the compare-match A signal from TMR2 is capable of starting A/D conversion by units 2 and 3.

The connections between the units of the converter and the compare-match A signals from TMR0 and TMR2 are shown in figure 23.12.

The compare-match A signal from TMR0 is capable of simultaneously starting A/D conversion by no more than two converter units. Setting the ADn.ADCR.TRGS[2:0] bits (n = 0, 1) to 010b (specifying the compare-match A signal from TMR0) and setting the ADTE bit in TCSR of TMR0 to 1 set up the compare-match A signal from TMR0 as the trigger that starts simultaneous conversion by units 0 and 1.

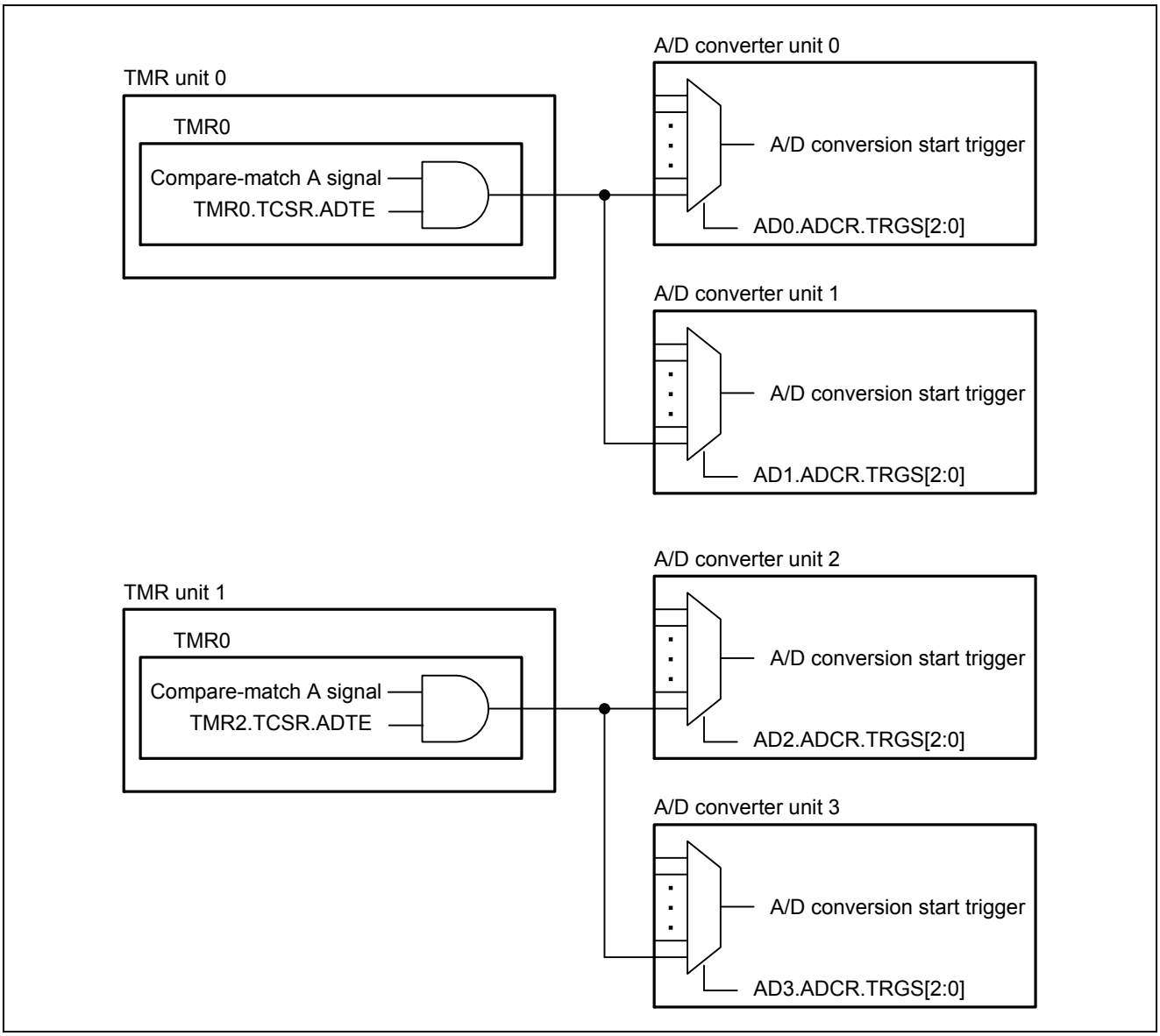


Figure 23.12 Connections between Compare-Match A Signals from TMR0 and TMR2 and the Respective Converter Units

23.4 Interrupt Source

The A/D converter generates an A/D conversion end interrupt (ADI) at the end of A/D conversion while the ADIE bit in ADCSR is set to 1 (after ADI interrupt is enabled by completing A/D conversion).

The data transfer controller (DTC) and DMA controller (DMAC) can be activated by an ADI interrupt. Having the converted data read by the DTC or DMAC in response to an ADI interrupt enables continuous conversion to be achieved without imposing a load on software.

Table 23.8 A/D Converter Interrupt Source

Name	Interrupt Source	Interrupt Status Flag	DTC Activation	DMAC Activation
ADI0	A/D conversion end	ICU.IR98.IR	Possible	Possible
ADI1	A/D conversion end	ICU.IR99.IR	Possible	Possible
ADI2	A/D conversion end	ICU.IR100.IR	Possible	Possible
ADI3	A/D conversion end	ICU.IR101.IR	Possible	Possible

23.5 A/D Conversion Accuracy Definitions

This LSI's A/D conversion accuracy definitions are given below.

- Resolution

  The number of A/D converter digital output codes
- Quantization error

  The deviation inherent in the A/D converter, given by 1/2 LSB (see figure 23.13)
- Offset error

  The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from the minimum voltage value 0000000000b (000h) to 0000000001b (001h) (see figure 23.14)
- Full-scale error

  The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from 1111111110b (3FEh) to 1111111111b (3FFh) (see figure 23.14)
- Nonlinearity error

  The error with respect to the ideal A/D conversion characteristic between the zero voltage and the full-scale voltage. Does not include the offset error, full-scale error, or quantization error (see figure 23.14).
- Absolute accuracy

  The deviation between the digital value and the analog input value. Includes the offset error, full-scale error, quantization error, and nonlinearity error.

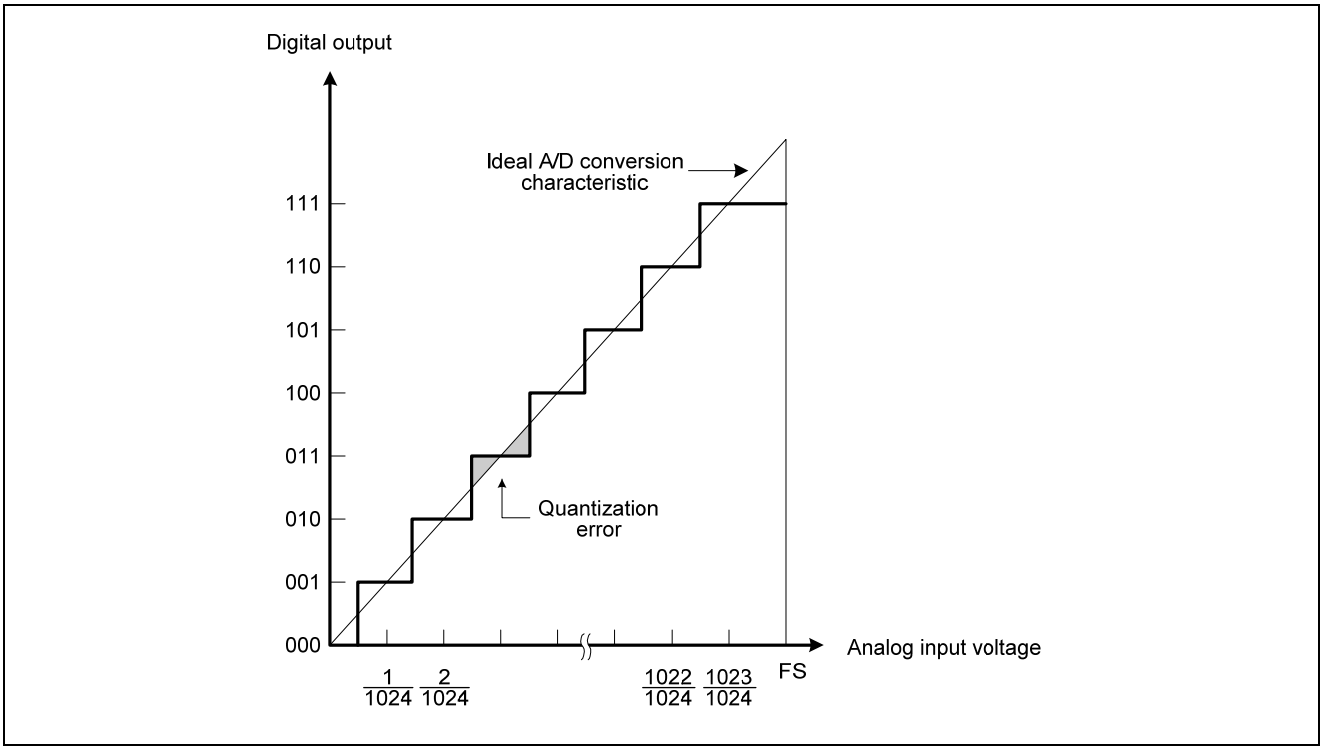


Figure 23.13 A/D Conversion Accuracy Definitions (1)

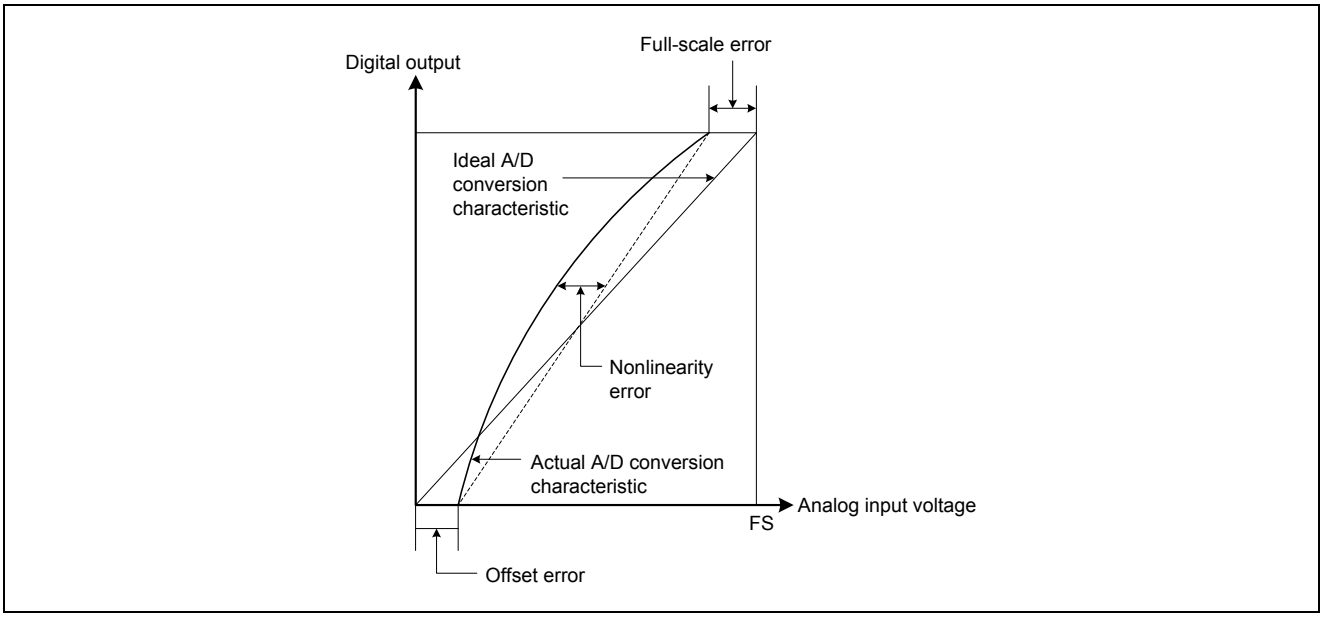


Figure 23.14 A/D Conversion Accuracy Definitions (2)

23.6 Usage Notes

23.6.1 Module Stop Function Setting

Operation of the A/D converter can be disabled or enabled for each unit using the module stop control register. The initial setting is for operation of the A/D converter to be halted. Register access is enabled by clearing the module stop state. For details, see section 8, Low Power Consumption.

23.6.2 Notes on Disabling A/D Conversion

To disable A/D conversion when an external trigger or timer has been selected as the condition for starting A/D conversion, set the ADCR.TRGS[2:0] bits to 000b to select the software trigger as the trigger to start A/D conversion, and then set the ADST bit in ADCSR to 0 (to stop A/D conversion).

23.6.3 Notes on Restarting A/D Conversion

Stopping analog input to the A/D converter by clearing the ADST bit in ADCSR to 0, requires one cycle of the ADCLK.

If A/D conversion is to be restarted right after the ADST bit was set to 0, set the ADST bit to 1 allow A/D conversion to restart after one clock cycle has elapsed.

23.6.4 Notes on Entering Power-Down States

When this LSI enters the module stop state or software standby mode with A/D conversion enabled, the analog power supply current is the same as it is during A/D conversion. If the analog power supply current needs to be reduced in the module stop state or software standby mode, disable A/D conversion. To do so, set the ADST bit in ADCSR to 0, and allow time for disabling of the analog input to the A/D converter.

Follow the procedure given below to ensure that this time is secured.

(1) Set the ADCR.TRGS[2:0] bits to 000b (software trigger).

(2) Clear the ADCSR.ADST bit to 0.

(3) Set the ADCR.CKS[1:0] bits to 11b (PCLK).

(4) After confirming that the A/D converter has been disabled, place the LSI in the module stop state or software standby mode.

23.6.5 Permissible Impedance of Signal Sources

To realize high-speed conversion 1.0 µs, the A/D conversion accuracy is guaranteed only when the impedance of the signal sources for analog input signals of this LSI circuit is less than or equal to 1.0 kΩ. If a large external capacitance is provided in the case of conversion in single mode, the input load becomes only the actual internal input resistance (6.5 kΩ), so the impedance of the signal source becomes insufficient. However, since the circuit has become a low-pass filter, the rapid and large fluctuations in the analog signal produced by differentiation (for example, greater than 5 mV/µs) become impossible to track (figure 23.15). Include a low-impedance buffer if high-rate analog signals are to be converted or conversion is to be in scan mode.

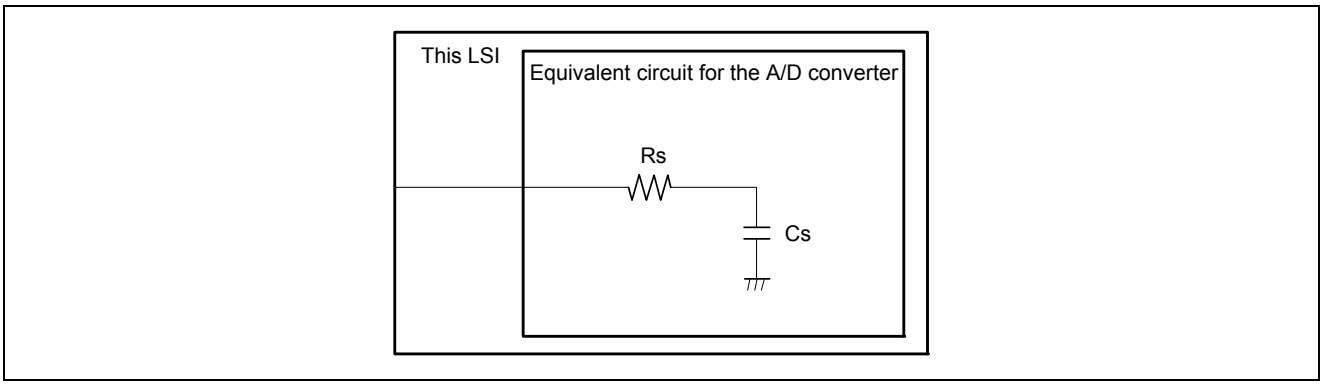


Figure 23.15 Equivalent Circuit for the Internal Circuit of Analog Input Pins

Table 23.9 Specifications of Analog Pins

Item		Min.	Max.	Unit
Permissible signal-source impedance		—	1.0	kΩ
Values in the equivalent circuits for the internal circuits of pins	Rs	—	6.5	kΩ
	Cs	—	6.0	pF

23.6.6 Factors Affecting Absolute Accuracy

Including a capacitor introduces ground coupling. A noisy ground can have a bad effect on absolute accuracy, so be sure to connect the V_{REFL} pins and so on to an electrically stable ground.

Furthermore, a mounted filter circuit can interfere with digital-signal lines on the board, so take care to ensure that the design does not set up an antenna.

23.6.7 Ranges of Settings for Analog Power Supply and Other Pins

Using this LSI circuit with voltages beyond the ranges given below can have a bad effect on LSI reliability.

- Range for the setting of analog input voltages
  Keep voltages applied to analog input pins (ANn pins) within the range defined by $V_{REFL} \leq V_{AN} \leq V_{REFH}$.
- Relations between AVcc and AVss, V_{REFH} and V_{REFL}, and Vcc and Vss
  Ensure that the relations between AVcc and AVss and between Vcc and Vss are AVcc = Vcc and AVss = Vss.
  To realize AVcc = Vcc and AVss = Vss at the points where the power-supply lines originate, set up closed loops with wiring runs between power-supply pins that are as short as possible and connect 0.1-µF capacitors as shown in figure 23.16. Even if the A/D converters are not in use, ensure that V_{REFH} = AVcc = Vcc and V_{REFL} = AVss = Vss by making the same connections.
- Range for the setting of V_{REFH}
  Keep the reference voltage on the V_{REFH} pin within the range defined by $V_{REFH} \leq$ AVcc.

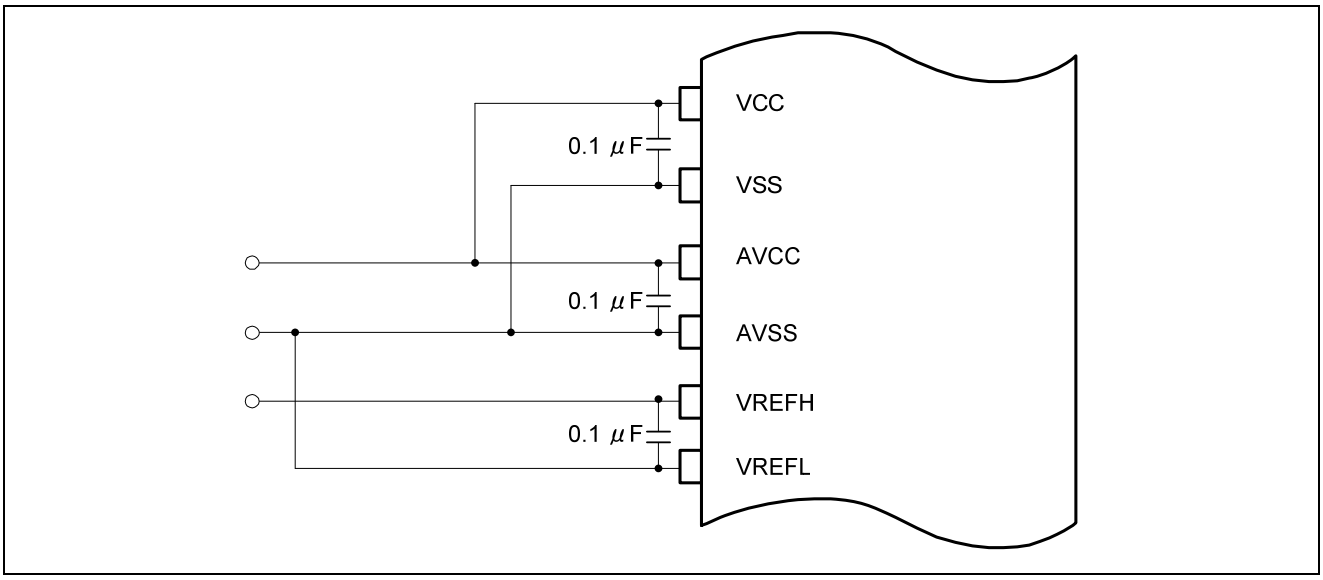


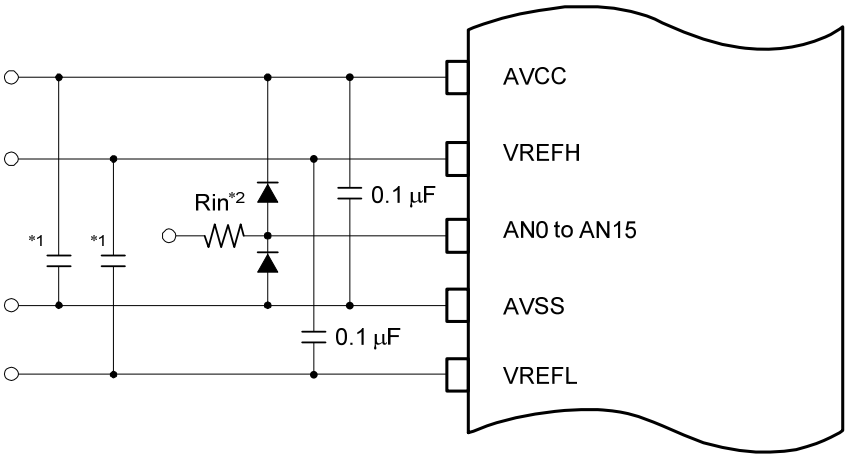
Figure 23.16 Example of Connection for Power-Supply Pins

23.6.8 Point for Caution Regarding Board Design

As far as possible, separate the analog circuits from the digital circuits in board design. Furthermore, do not allow the wiring runs for a signal of a digital circuit and a signal of an analog circuit to cross or be in each other's vicinity. Inductive coupling leads to analog circuits operating incorrectly and has a bad effect on the results of analog conversion. Keep the signal lines for analog input pins (AN0 to AN15), the analog reference power supply pin (V_{REFH}), the analog power-supply voltage (AVcc), and analog ground (AVSS) away from digital circuitry. Furthermore, connect the analog ground (V_{REFL}) to the stabilized ground (Vss) on the board at a single point.

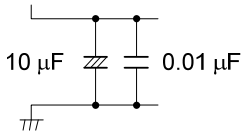
23.6.9 Point for Caution Regarding Countermeasures for Noise

To prevent destruction of the circuits for the analog input pins by abnormal voltages such as excessively large surges, connect capacitors as shown in figure 23.17 between AVcc and AVss, and between V_{REFH} and V_{REFL}; also connect suitable protective circuits to the analog input pins (AN0 to AN15).



Notes: The value in parentheses indicates the pin number.

1. The value is for reference.



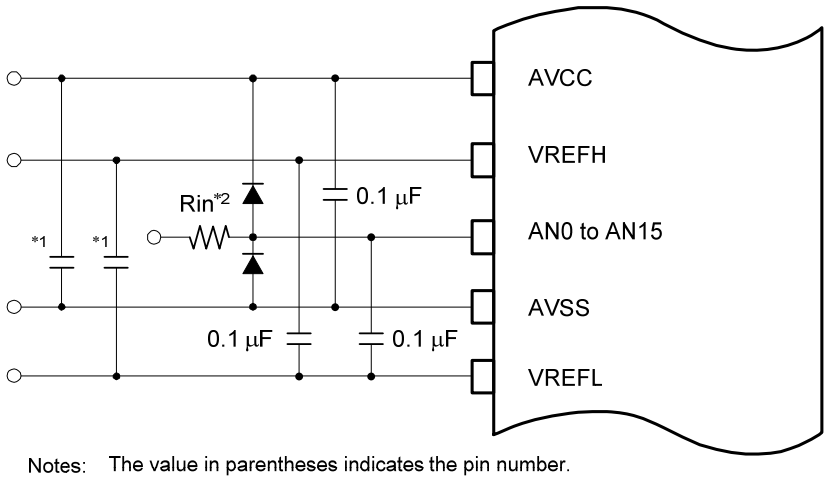
2. Rin: Input impedance

Figure 23.17 Example of a Protective Circuit for Analog Inputs

23.6.10 Realizing High-Speed Conversion

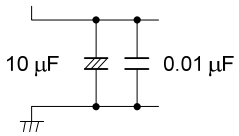
To realize high-speed conversion, connect external 0.1-μF capacitors between the analog input pins (AN0 to AN15) and V_{REFL}. This is shown in figure 23.18. However, to prevent the impedance of the signal source due to the input capacitance of the sample-and-hold circuit of the A/D converter from affecting the conversion time, the externally connected capacitors must be fully charged before the start of conversion.

Furthermore, when the voltages on the analog input pins fluctuate due to scanning and so on, so describing renewal of the charge of the externally connected capacitors, high-speed conversion is not realized.



Notes: The value in parentheses indicates the pin number.

1. The value is for reference.



2. Rin: Input impedance

Figure 23.18 Example of an Externally Connected Capacitor for High-Speed Conversion

23.6.11 Notes when Using Multiple Units of A/D Converter

Since the same power supply is used between the units of the A/D converter contained in the RX610 Group, when multiple units are used and conversion start timing between each unit is different, conversion accuracy may get affected. When the conversion accuracy is affected, adopt the following methods and perform an adequate evaluation.

(1) Example of recommended operation of simultaneous conversion of each unit at the time of multiple unit operation

When multiple units of A/D converter are used, select the activation method of the trigger select bit as either activation by compare match from TPU or activation by compare match from TMR, and match the conversion start timing and end timing of each unit.

Figure 23.19 shows timing example (1) when the conversion timings of four units are simultaneous.

Figure 23.20 shows timing example (2) when the conversion timings of four units are simultaneous.

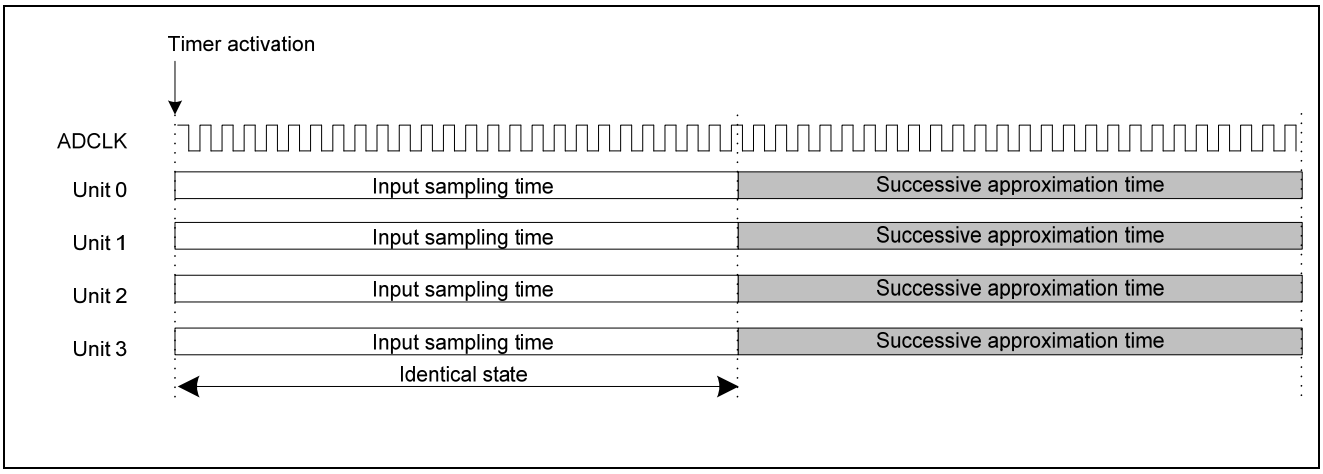


Figure 23.19 Example (1) of Simultaneous Conversion Timings of Four Units

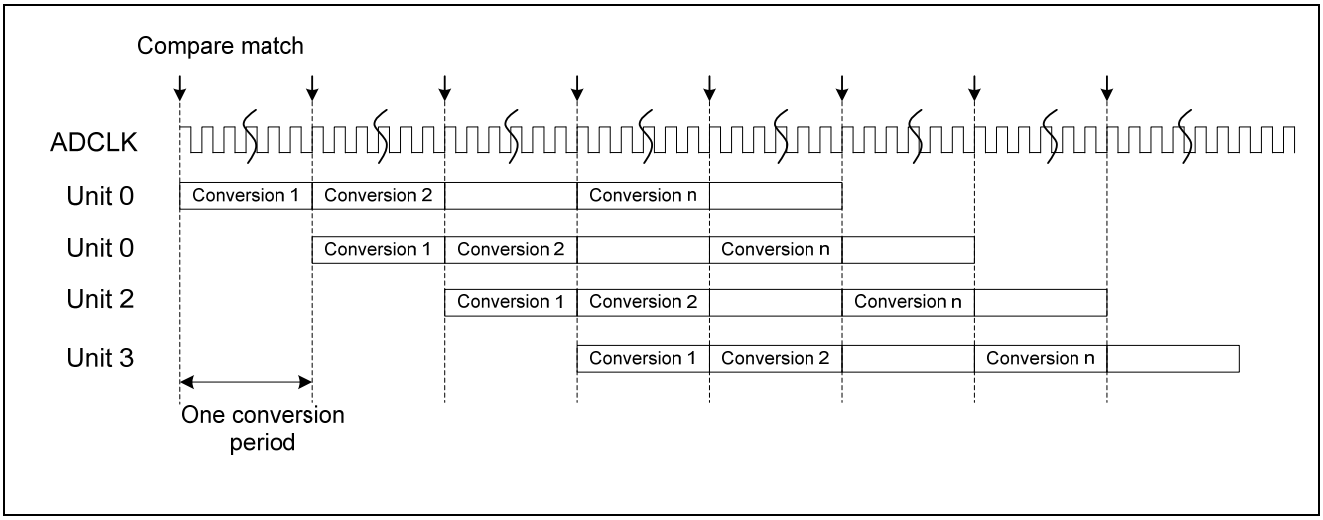


Figure 23.20 Example (2) of Simultaneous Conversion Timings of Four Units

(2) Register settings of recommended operation

The following registers and bits should be set to the same value between all of the units.

- A/D sampling state register (ADSSTR)
- Clock select bits (ADCR.CKS[1:0])
- Trigger select bits (ADCR.TRGS[2:0])

(3) Trigger selection corresponding to number of units

The number of units that can be activated depends on the selected trigger. See the following table.

Table 23.10 Trigger Activation and Number of Corresponding Units

No.	Trigger Selection	ADCR.TRGS[2:0]	Number of Multiple Units		
			4	3	2
1	Activation by compare match A to D[*1] of TPU0	100b	Possible	Possible	Possible
2	Activation by compare match A of TPU0 to TPU5[*2]	001b	Possible	Possible	Possible
3	Activation by compare match A of TPU6 to TPU11[*2]	101b	Possible	Possible	Possible
4	Activation by compare match A of TMR0[*3]	010b	Impossible	Impossible	Possible
5	Activation by compare match A of TMR2[*3]	010b	Impossible	Impossible	Possible

Notes: 1. Set the same value to TGRA to TGRD.

2. The compare match A that is to be input to each unit of A/D converter should be set for the same TPU channel.

3. Units 0 and 1 of A/D converter become compare match A of TMR0, and units 2 and 3 of that become compare match A of TMR2.

For details on activation method of each unit, see section 23.3.5, Activation by the Compare-Match/Input-Capture A to D Signals from TPU0, section 23.3.6, Activation by the Compare-Match/Input-Capture A Signals from TPU0 to TPU5, and section 23.3.7, Activation on Compare-Match of TMR Units.

(4) Other procedures

- Perform an averaging procedure using a program.

  Averaging procedure example: Perform A/D conversion of the analog input to identical pins successively for four times. Calculate an average of two values of the A/D conversion result excluding the maximum value and the minimum value.

- When the A/D converter is operated asynchronously, ensure that the conversion of one unit is complete and then operation of another single unit is started.

24. D/A Converter

24.1 Overview

The RX610 Group includes a two-channel of 10-bit D/A converter.

Table 24.1 lists the specifications of the D/A converter and figure 24.1 shows a block diagram of the D/A converter.

Table 24.1 Specifications of D/A Converter

Item	Specifications
Resolution	10 bits
Output channels	Two channels
Power-down function	Module stop state can be set for each unit.

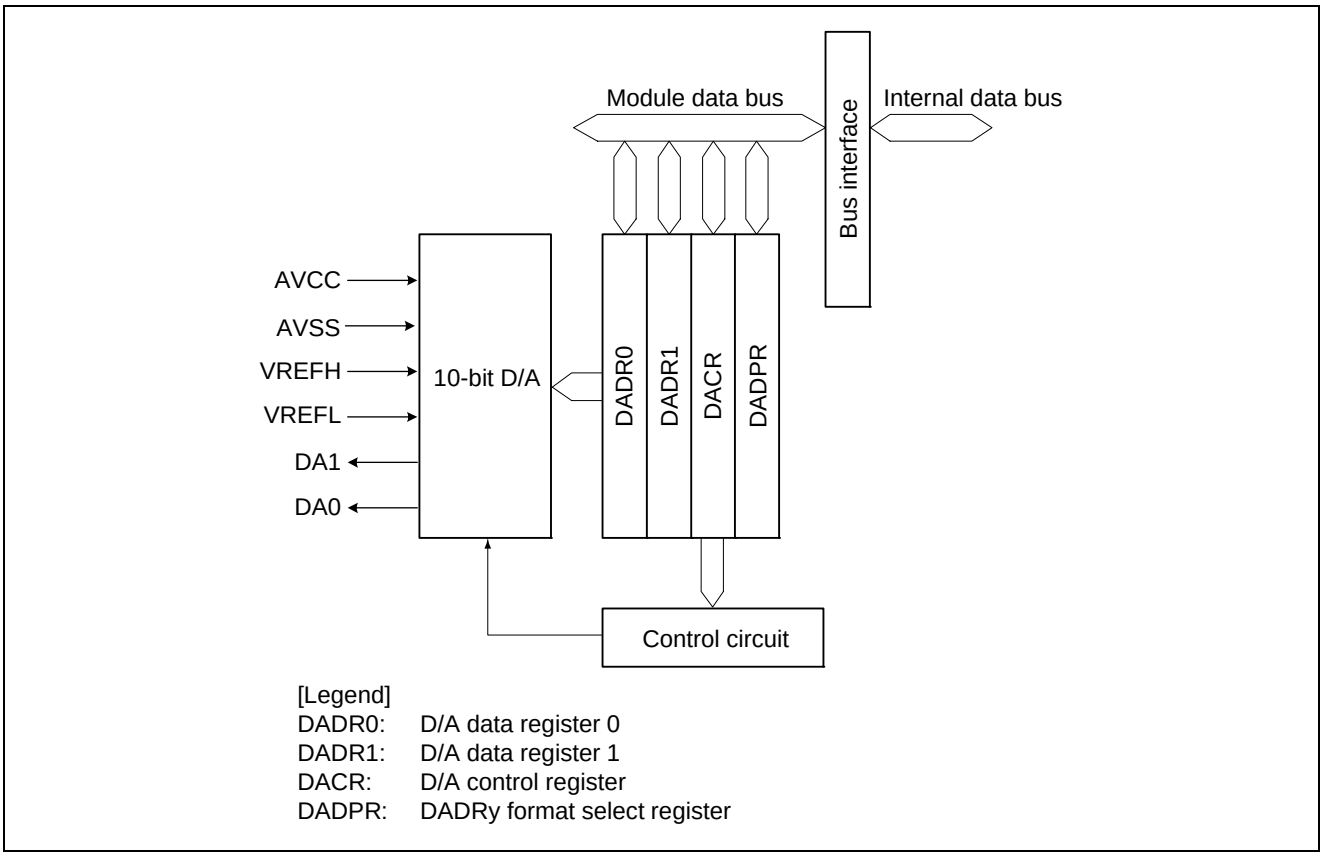


Figure 24.1 Block Diagram of D/A Converter

Table 24.2 lists the pin configuration of the D/A converter.

Table 24.2 Pin Configuration of D/A Converter

Pin Name	I/O	Function
AV_{CC}	Input	Analog circuit power supply pin
AV_{SS}	Input	Analog circuit ground pin
VREFH	Input	D/A converter reference power supply pin
VREFL	Input	D/A converter reference ground pin Connect this pin to the analog reference power supply (0 V).
DA0	Output	Channel 0 analog output pin
DA1	Output	Channel 1 analog output pin

24.2 Register Descriptions

Table 24.3 lists the registers of the D/A converter.

Table 24.3 Registers of D/A Converter

Register Name	Symbol	Value after Reset	Address	Access Size
D/A data register 0	DADR0	0000h	0008 80C0h	16
D/A data register 1	DADR1	0000h	0008 80C2h	16
D/A control register	DACR	1Fh	0008 80C4h	8
DADRy format select register	DADPR	00h	0008 80C5h	8

24.2.1 D/A Data Register y (DADRy) (y = 0, 1)

Addresses: 0008 80C0h, DADR1 0008 80C2h

DADPR.DPSEL bit = 0 (Data padded at the LSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—										
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DADPR.DPSEL bit = 1 (Data padded at the MSB end)

	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
											—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DADRy registers are 16-bit readable/writable registers, which store data to which D/A conversion is to be performed. Whenever an analog output is enabled, the values in DADRy are converted and output to the analog output pins.

10-bit data can be relocated by setting the DPSEL bit in DADPR.

Bits "—" are always read as 0. The write value should always be 0.

24.2.2 D/A Control Register (DACR)

Address: 0008 80C4h

	b7	b6	b5	b4	b3	b2	b1	b0
	DAOE1	DAOE0	DAE	—	—	—	—	—
Value after reset:	0	0	0	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
b4 to b0	—	Reserved	These bits are read as 1. The write value should always be 1.	R/W
b5	DAE*1	D/A Enable	0: D/A conversion is independently controlled on channels 0 and 1. 1: D/A conversion on channels 0 and 1 is controlled as a single whole.	R/W
b6	DAOE0	D/A Output Enable 0	0: Analog output of channel 0 (DA0) is disabled. 1: D/A conversion of channel 0 is enabled. Analog output of channel 0 (DA0) is enabled.*2	R/W
b7	DAOE1	D/A Output Enable 1	0: Analog output of channel 1 (DA1) is disabled. 1: D/A conversion of channel 1 is enabled. Analog output of channel 1 (DA1) is enabled.*2	R/W

Notes: 1. This bit controls D/A conversion in combination with the DAOEj bit (j = 0, 1). The DAOEj bit controls output of the results of conversion. For details, see table 24.4.

2. Set the P6.DDR.Bj bits (j = 7, 6) for pins used as analog outputs and the corresponding P6.ICR.Bj bits (j = 7, 6) to 0. For details, see section 14, I/O ports.

Table 24.4 Controls of D/A Conversion

b5	b7	b6	
DAE	**DAOE1**	**DAOE0**	**Description**
0	0	0	D/A conversion is disabled.
		1	D/A conversion of channel 0 is enabled. D/A conversion of channel 1 is disabled. Analog output of channel 0 (DA0) is enabled. Analog output of channel 1 (DA1) is disabled.
	1	0	D/A conversion of channel 0 is disabled. D/A conversion of channel 1 is enabled. Analog output of channel 0 (DA0) is disabled. Analog output of channel 1 (DA1) is enabled.
		1	D/A conversion of channels 0 and 1 is enabled. Analog output of channels 0 and 1 (DA0 and DA1) is enabled.
1	0	0	D/A conversion of channels 0 and 1 is enabled. Analog output of channels 0 and 1 (DA0 and DA1) is disabled.
		1	D/A conversion of channels 0 and 1 is enabled. Analog output of channel 0 (DA0) is enabled. Analog output of channel 1 (DA1) is disabled.
	1	0	D/A conversion of channels 0 and 1 is enabled. Analog output of channel 0 (DA0) is disabled. Analog output of channel 1 (DA1) is enabled.
		1	D/A conversion of channels 0 and 1 is enabled. Analog output of channels 0 and 1 (DA0 and DA1) is enabled.

DACR controls the operation of the D/A converter.

DAE Bit (D/A Enable)

The DAE bit controls D/A conversion in combination with the DAOE0 and DAOE1 bits.

When the DAE bit is 0, D/A conversion is independently controlled on channels 0 and 1. When the DAE bit is 1, D/A conversion on channels 0 and 1 is controlled as a single whole. The DAOE0 and DAOE1 bits control output of the results of conversion.

DAOE0 Bit (D/A Output Enable 0)

The DAOE0 bit controls the D/A conversion and analog output.

DAOE1 Bit (D/A Output Enable 1)

The DAOE1 bit controls the D/A conversion and analog output.

24.2.3 DADRy Format Select Register (DADPR)

Address: 0008 80C5h

	b7	b6	b5	b4	b3	b2	b1	b0
	DPSEL	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b6 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	DPSEL	DADRy Format Select	0: D/A data register is padded at the LSB end. 1: D/A data register is padded at the MSB end.	R/W

DADPR selects the placement of data in the D/A data registers.

DPSEL Bit (DADRy Format Select)

The DPSEL bit selects whether data in the D/A data registers is padded at the LSB or MSB end.

24.3 Operation

The D/A converter includes D/A conversion circuits for two channels, each of which can operate independently. When the DAOEn bit (n = 0, 1) in DACR is set to 1, D/A converter is enabled and the conversion result is output.

An operation example of D/A conversion on channel 0 is shown below. Figure 24.2 shows the timing of this operation.

1. Write the data for conversion to DADR0.
2. Set the DAOE0 bit in DACR to 1 to start D/A conversion. The conversion result is output from the analog output pin DA0 after the conversion time tDCCONV has elapsed. The conversion result continues to be output until DADR0 is written to again or the DAOE0 bit is cleared to 0. The output value is expressed by the following formula:

$$\frac{\text{Setting value of DADR0}}{1024} \times \text{VREFH}$$

3. If DADR0 is written to again, the conversion is immediately started. The conversion result is output after the conversion time tDCONV has elapsed.
4. If the DAOE0 bit is cleared to 0, analog output is disabled.

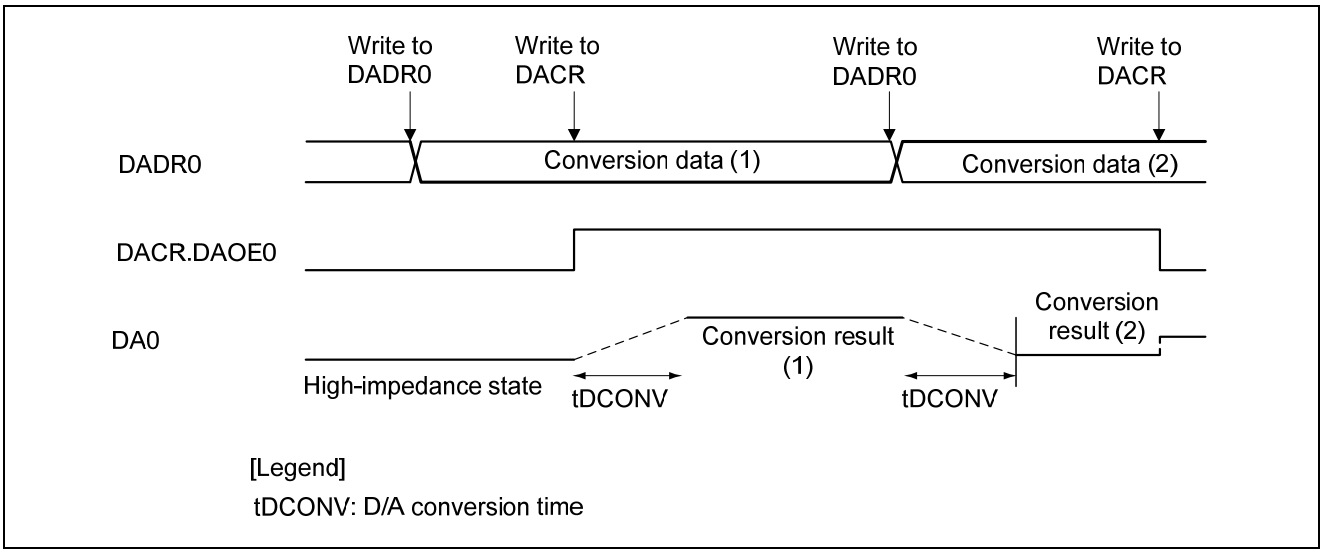


Figure 24.2 Example of D/A Converter Operation

24.4 Usage Notes

24.4.1 Module Stop Function Setting

Operation of the D/A converter can be disabled or enabled by using the module stop control register. The initial setting is for operation of the D/A converter to be halted. Register access is enabled by clearing the module stop state. For details, refer to section 8, Low Power Consumption.

24.4.2 Operation of the D/A Converter in Module Stop State

When this LSI enters the module stop state with D/A conversion enabled, the D/A outputs are retained, and the analog power supply current is the same as during D/A conversion. If the analog power supply current has to be reduced in the module stop state, disable D/A conversion by clearing the DAOE1, DAOE0, and DAE bits to 0.

24.4.3 Operation of the D/A Converter in Software Standby Mode

When this LSI enters software standby mode with D/A conversion enabled, the D/A outputs are retained, and the analog power supply current is the same as during D/A conversion. If the analog power supply current has to be reduced in software standby mode, disable D/A conversion by clearing the DAOE1, DAOE0, and DAE bits to 0.

24.4.4 Note on Entering Deep Software Standby Mode

When this LSI enters deep software standby mode with D/A conversion enabled, the outputs of the D/A converter are placed in a high impedance state.

24.4.5 Note when Using the A/D Converter and D/A Converter Simultaneously

Because the A/D converter and the D/A converter of the RX610 Group use the same power supply, conversion accuracy of A/D conversion result may get affected depending on the usage. The conversion accuracy is likely to be affected in the following cases.

- If the D/A data register (DADR) of D/A converter is rewritten while the A/D converter is being operated
- If the D/A control register (DACR) is rewritten by setting a value other than 000h to the DADR

When conversion accuracy is affected, implement the following measures.

(1) Method of rewriting DADR with AD converter operated

When rewriting the DADR while the AD converter is being operated, implement any one of the following methods.

1 When the DADR register is rewritten, discard the result of the A/D converter that is undergoing conversion.

2 When the DADR register is written, perform an averaging procedure for the A/D conversion result using a program.
Averaging procedure example: Perform A/D conversion of the analog input to identical pins successively for four times.

3 Calculate an average of two values of the A/D conversion result excluding the maximum and minimum values.

4 Set the rewriting procedure for DADR register as follows.

5 When the DADR register is written, keep the difference before changing and after changing at less than 100h, and when the next data is written, keep an interval of more than one conversion period of A/D converter. However, when rewriting is performed by maintaining the difference before and after changing at less than 080h, it is not necessary to maintain an interval of more than one conversion period of A/D converter.

Further, when multiple units of A/D converter are operated, implement the method described in section 23.6.11, Notes when Using Multiple Units of A/D Converter, and match one conversion period between each of the units.

Figure 24.3 shows an example of procedure of rewriting the DADR register from 000h to 3FFh.

- Before changing 000h (00 0000 0000b)
- First period of rewriting 100h (01 0000 0000b) => Difference before and after rewriting 100h
- Second period of rewriting 200h (10 0000 0000b) => Difference before and after rewriting 100h
- Third period of rewriting 300h (11 0000 0000b) => Difference before and after rewriting 100h
- Fourth period of rewriting 3FFh (11 1111 1111b) => Difference before and after rewriting 0FFh
- After changing 3FFh (11 1111 1111b)

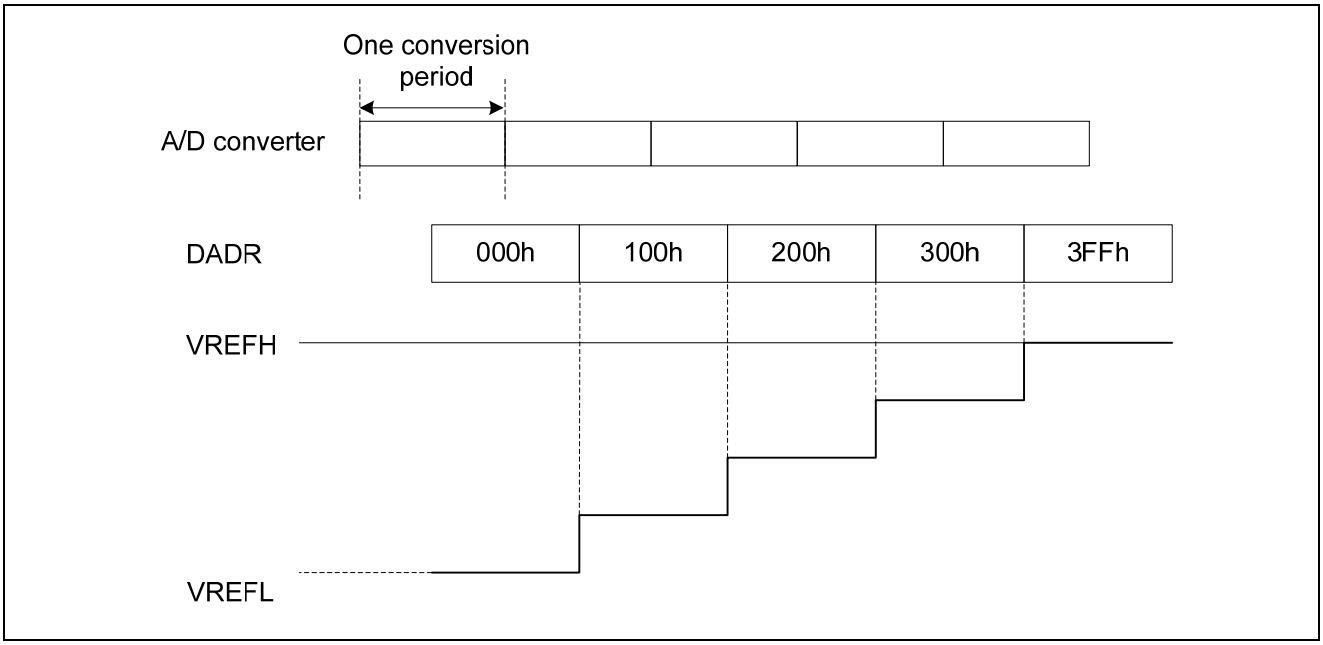


Figure 24.3 Example of Procedure of Rewriting the DADR Register from 000h to 3FFh

(2) Rewriting DACR with AD converter operated

When the value of DACR is changed, rewrite the DACR with the DADR register value set to 000h. If the DACR register is rewritten under other conditions, the accuracy of the AD converter may not be guaranteed.

25. RAM

The RX610 Group has a high-speed static RAM.

25.1 Overview

Table 25.1 lists the specifications of the RAM.

Table 25.1 Specifications of the RAM

Item	Description
RAM capacity	128 Kbytes (RAM0: 64 Kbytes, RAM1: 64 Kbytes)
RAM address	RAM0: 0000 0000h to 0000 FFFFh RAM1: 0001 0000h to 0001 FFFFh
Access	• Single-cycle access is possible for both reading and writing. • Enabling or disabling of on-chip RAM is selectable.*
Data retention function	Data in RAM0 can be retained during periods in deep standby mode.
Power-down function	The module stop state is independently selectable for RAM0 and RAM1.

Note: * Selectable by the RAME bit in SYSCR1. For details on SYSCR1, see section 3.2.4, System Control Register 1 (SYSCR1).

25.2 Operation

25.2.1 Data Retention

The address space for on-chip RAM is divided into the RAM0 and RAM1 areas. The difference between the two is whether internal power can be supplied in deep software standby mode.

Whether or not the supply of internal power to RAM0 continues in deep software standby mode is selectable by the RAMCUTn bit (n = 2 to 0) in DPSBYCR.

If continuation of the supply of internal power is selected, data in RAM0 are retained during periods in deep software standby mode. The supply of internal power supply to RAM1 is halted at this time, so data are not retained in RAM 1.

See section 8, Low Power Consumption, for details on the DPSBYCR.RAMCUTn (n = 0 to 2) bits.

25.2.2 Power-Down Function

Power consumption can be reduced by setting the module stop control register C (MSTPCRC) to stop supply of the clock signal to the on-chip RAM.

If the MSTPC0 bit in MSTPCRC is set to 1, supply of the clock signal to RAM0 is stopped. If the MSTPC1 bit in MSTPCRC is set to 1, supply of the clock signal to RAM1 is stopped.

The respective modules (RAM0 and RAM1) are thus placed in the module stop state by stopping supply of the clock signals. The initial value after a reset is for the RAM to be operational.

RAM is not accessible if it is in the module stop state. A transition to the module stop state should not be made while access to RAM is in progress.

For details on the MSTPCRC registers, see section 8, Low Power Consumption.

26. ROM (Flash Memory for Code Storage)

The RX610 has two flash-memory modules: a maximum 2-Mbyte ROM for storing code and a 32-Kbyte data flash block for storing data.

This section covers the flash memory for code storage. For the data flash, see section 27, Data Flash (Flash Memory for Data Storage).

26.1 Overview

Table 26.1 lists the specifications of the ROM, and figure 26.1 show a block diagram of the ROM, data-flash memory (data flash), and related modules.

Table 26.1 Specifications of the ROM

Item		Specifications
Two types of memory mats		• User mat: 2 Mbytes, 1.5 Mbytes, 1 Mbyte, or 768 Kbytes*1 • User boot mat: 16 Kbytes
High-speed reading		A read operation takes one cycle of ICLK
Programming/erasing method		• The chip incorporates a dedicated sequencer (FCU) for programming of the ROM and data flash. • Programming and erasing the ROM and data flash are handled by issuing commands to the FCU.
BGO (background operation)		• The CPU is able to execute program code from areas other than the ROM or data flash while the ROM is being programmed or erased. • Execution of program code from the ROM is possible while the data flash memory is being programmed or erased.
Suspension and resumption		• The CPU is able to execute program code from the ROM during suspension of programming or erasure. • Programming and erasure of the ROM can be restarted (resumed) after suspension.
Units of programming and erasure		• Unit of programming for the user mat and user boot mat: 256 bytes • Units of erasure for the user mat: 8 Kbytes (8 blocks), 64 Kbytes (9 blocks), 128 Kbytes (11 blocks) • Unit of erasure for the user boot mat: 16 Kbytes
On-board programming (three types)	Boot mode	• The user mat and user boot mat are programmable via the SCI. • The bit rate for SCI transfer between the host and RX610 is automatically adjusted.
	User boot mode	Booting up from the user boot mat and programming of the user mat
	User program	Programming of the user mat under program control
Off-board programming		A PROM programmer can be used to program the user mat and user boot mat.
Protection	Software-controlled protection	The FENTRYR.FENTRY1*2, FENTRYR.FENTRY0, FWEPROR.FLWE[1:0], and lock bits can be used to prevent unintentional programming.
	Error protection	Prevention of further programming or erasure after the detection of abnormal operations during programming or erasure
Times for programming and erasure, durability (number of times reprogramming is possible)		See section 28, Electrical Characteristics.

Notes: 1. Each product has different ROM sizes.

Product Code	ROM Size	ROM Addresses
R5F56108	2 Mbytes	FFE0 0000h to FFFF FFFFh
R5F56107	1.5 Mbytes	FFE8 0000h to FFFF FFFFh
R5F56106	1 Mbyte	FFF0 0000h to FFFF FFFFh
R5F56104	768 Kbytes	FFF4 0000h to FFFF FFFFh

2. Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

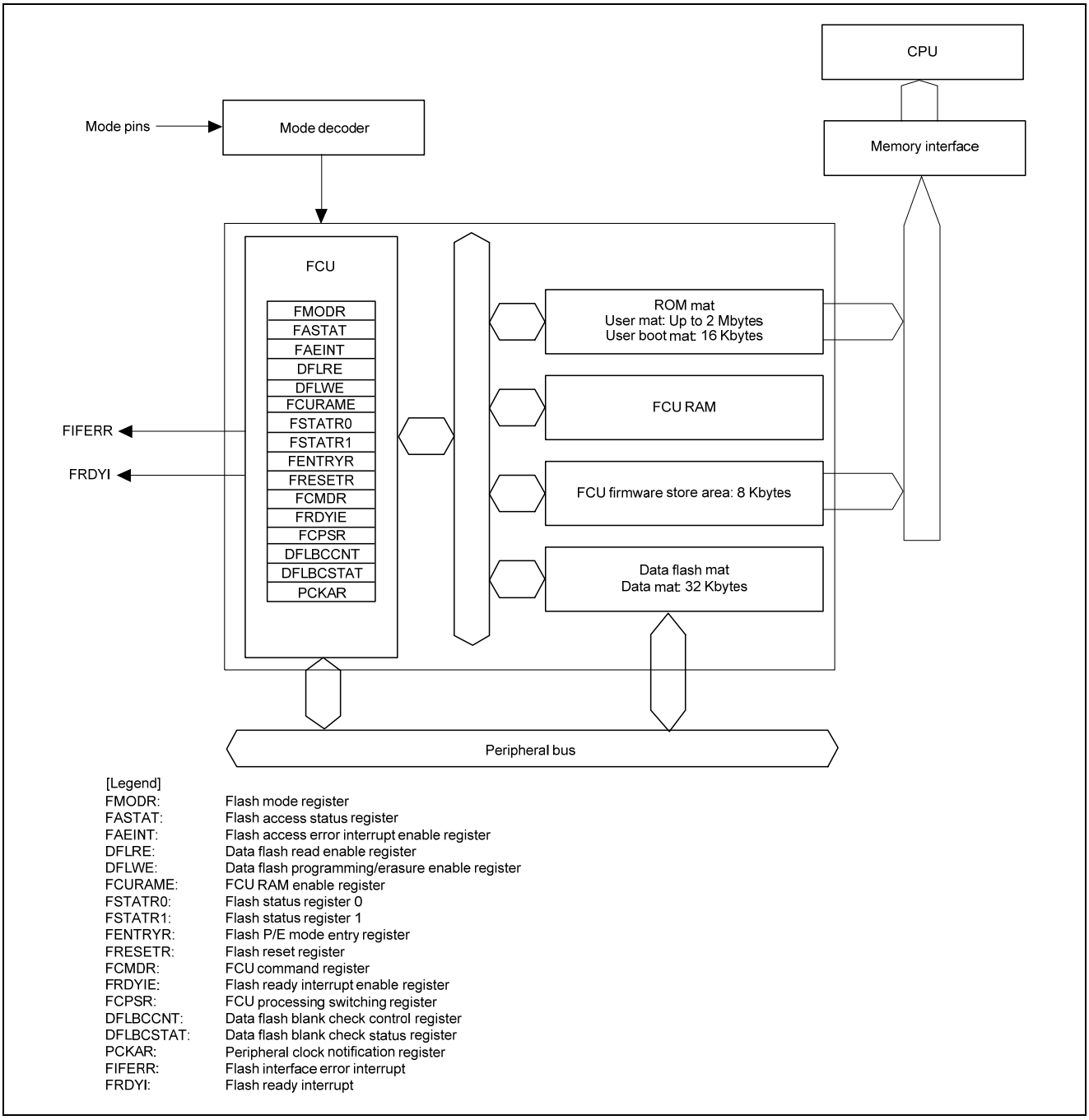


Figure 26.1 Block Diagram of ROM

Input and output pins associated with the ROM are listed in table 26.2.

Table 26.2 Input and Output Pins Associated with the ROM

Pin Name	I/O	Description
P05/RxD4	Input	Used in boot mode to receive data via SCI4 (for host communications)
P04/TxD4	Output	Used in boot mode to transmit data from SCI4 (for host communications)

26.2 Register Descriptions

Table 26.3 lists the registers related to ROM. Although some registers have bits related to data flash, this section deals only with the bits related to ROM. For details on the bits related to the data flash, see section 27.2, Register Descriptions in the data flash section.

The registers related to the ROM are initialized by a reset.

Table 26.3 Registers Related to ROM

Register Name	Symbol	Value after Reset	Address	Access Size
Flash mode register	FMODR	00h	007F C402h	8
Flash access status register	FASTAT	00h	007F C410h	8
Flash access error interrupt enable register	FAEINT	9Bh	007F C411h	8
Flash ready interrupt enable register	FRDYIE	00h	007F C412h	8
FCU RAM enable register	FCURAME	0000h	007F C454h	16
Flash status register 0	FSTATR0	80h	007F FFB0h	8
Flash status register 1	FSTATR1	0xh	007F FFB1h	8
Flash P/E mode entry register	FENTRYR	0000h	007F FFB2h	16
Flash protection register	FPROTR	0000h	007F FFB4h	16
Flash reset register	FRESETR	0000h	007F FFB6h	16
FCU command register	FCMDR	FFFFh	007F FFBAh	16
FCU processing switching register	FCPSR	0000h	007F FFC8h	16
Flash P/E status register	FPESTAT	0000h	007F FFCCh	16
Peripheral clock notification register	PCKAR	0000h	007F FFE8h	16
Flash write erase protection register	FWEPROR	02h	0008 C289h	8

26.2.1 Flash Mode Register (FMODR)

Address: 007F C402h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	FRDMD	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	FRDMD	FCU Read Mode Select	0: Memory Area Read Method Memory area read mode is set to read a lock bit of ROM in ROM lock bit read mode. 1: Register Read Method Register read mode is set to read a lock bit of ROM using the lock bit read 2 command.	R/W
b7 to b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FMODR is a register to specify the method for the reading of lock bits.

When on-chip ROM is disabled, the data read from FMODR is 00h and writing is disabled.

FMODR is initialized by a reset.

FRDMD Bit (FCU Read Mode Select)

This bit is used to specify the method for the reading of lock bits.

If the blank checking command for the data flash is to be used, this bit has to be set for the register read mode (see section 27, Data Flash (Flash Memory for Data Storage)).

26.2.2 Flash Access Status Register (FASTAT)

Address: 007F C410h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAE	—	—	CMDLK	DFLAE	—	DFLRPE	DFLWPE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPE	Data Flash Programming/Erasure Protection Violation	See section 27, Data Flash (Flash Memory for Data Storage).	R/(W)*
b1	DFLRPE	Data Flash Read Protection Violation	See section 27, Data Flash (Flash Memory for Data Storage).	R/(W)*
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAE	Data Flash Access Violation	See section 27, Data Flash (Flash Memory for Data Storage).	R/(W)*
b4	CMDLK	FCU Command Lock	0: FCU is not in the command-locked state 1: FCU is in the command-locked state	R
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAE	ROM Access Violation	0: No ROM access error 1: ROM access error	R/(W)*

Note: * Only 0 can be written after reading 1 to clear the flag.

FASTAT is a register to check if the access to the ROM/data flash is allowed.

When on-chip ROM is disabled, the data read from FASTAT is 00h and writing is disabled. When one of the bits in FASTAT is set to 1, the FCU is placed in the command-locked state (see section 26.8.2, Error Protection). To clear the command-locked state, a status clear command must be issued to the FCU after setting FASTAT to 10h.

FASTAT is initialized by a reset.

CMDLK Bit (FCU Command Lock)

This bit indicates that the FCU is in the command-locked state (see section 26.8.2, Error Protection).

[Setting condition]

- After the FCU detects an error and enters the command-locked state

[Clearing condition]

- After the FCU processes a status clear command under conditions where FASTAT is set to 10h

ROMAE Bit (ROM Access Violation)

This bit indicates whether a ROM access violation occurred.

When the ROMAE bit is set to 1, the ILGLERR bit in FSTATR0 is set to 1, placing the FCU in the command-locked state.

[Setting conditions]

- A read command is issued for ROM programming/erasure addresses 00E0 0000h to 00EF FFFFh when the FCU is in ROM P/E normal mode and the FENTRYR.FENTRY1 bit* is set to 1.
- A read command is issued for ROM programming/erasure addresses 00F0 0000h to 00FF FFFFh when the FCU is in ROM P/E normal mode and the FENTRYR.FENTRY0 bit is set to 1.
- A command is issued for ROM programming/erasure addresses 00E0 0000h to 00EF FFFFh when the FENTRY1 bit is set to 0.
- A command is issued for ROM programming/erasure addresses 00F0 0000h to 00FF FFFFh when the FENTRY0 bit is set to 0.
- A read command is issued for ROM read addresses FFE0 0000h to FFFF FFFFh when FENTRYR is set to other than 0000h.

[Clearing condition]

- When 0 is written after reading 1

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

26.2.3 Flash Access Error Interrupt Enable Register (FAEINT)

Address: 007F C411h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAEIE	—	—	CMDLKIE	DFLAEIE	—	DFLRPEIE	DFLWPEIE
Value after reset:	1	0	0	1	1	0	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPEIE	Data Flash Programming/Erasure Protection Violation Interrupt Enable	See section 27, Data Flash (Flash Memory for Data Storage).	R/W
b1	DFLRPEIE	Data Flash Read Protection Violation Interrupt Enable	See section 27, Data Flash (Flash Memory for Data Storage).	R/W
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAEIE	Data Flash Access Violation Interrupt Enable	See section 27, Data Flash (Flash Memory for Data Storage).	R/W
b4	CMDLKIE	FCU Command Lock Interrupt Enable	0: FIFERR interrupt requests disabled when the CMDLK bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the CMDLK bit in FASTAT is set to 1	R/W
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAEIE	ROM Access Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the ROMAE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the ROMAE bit in FASTAT is set to 1	R/W

FAEINT is a register to enable and disable the flash interface error interrupt (FIFERR).

When on-chip ROM is disabled, the data read from FAEINT is 00h and writing is disabled.

FAEINT is initialized by a reset.

CMDLKIE Bit (FCU Command Lock Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when an FCU command lock occurs and the CMDLK bit in FASTAT is set to 1.

ROMAEIE Bit (ROM Access Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a ROM access violation occurs and the ROMAE bit in FASTAT is set to 1.

26.2.4 FCU RAM Enable Register (FCURAME)

Address: 007F C454h

	b15	b14	b13	b12	b11	b10	b9	b8
	KEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	FCRME
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FCRME	FCU RAM Enable	0: Access to the FCU RAM disabled 1: Access to the FCU RAM enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	KEY[7:0]	Key Code	This bit is used to enable or disable rewriting of the FCRME bit.	R/(W)*

Note: * Write data is not retained.

FCURAME is a register to enable and disable an access to the FCU RAM area.

Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from FCURAME is 00h and writing is disabled.

FCURAME is initialized by a reset.

FCRME Bit (FCU RAM Enable)

This bit is used to enable and disable an access to the FCU RAM.

Data written to the FCRME bit is valid only when it is written in word access and the KEY[7:0] bits are C4h. When programming data to the FCU RAM, set FENTRYR to 0000h and stop the FCU.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the FCRME bit.

Data written to the KEY[7:0] bits is not retained.

26.2.5 Flash Status Register 0 (FSTATR0)

Address: 007F FFB0h

	b7	b6	b5	b4	b3	b2	b1	b0
	FRDY	ILGLERR	ERSERR	PRGERR	SUSRDY	—	ERSSPD	PRGSPD
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	PRGSPD	Programming Suspend Status	0: Other than the status described below 1: During programming suspend processing or programming suspended	R
b1	ERSSPD	Erasure Suspend Status	0: Other than the status described below 1: When erasure suspend processing or erasure suspended	R
b2	—	Reserved	These bits are always read as 0 and cannot be modified.	R
b3	SUSRDY	Suspend Ready	0: P/E suspend commands cannot be received 1: P/E suspend commands can be received	R
b4	PRGERR	Programming Error	0: Programming terminates normally 1: An error occurs during programming	R
b5	ERSERR	Erasure Error	0: Erasure terminates normally 1: An error occurs during erasure	R
b6	ILGLERR	Illegal Command Error	0: FCU detects no illegal command or ROM/data flash access 1: FCU detects an illegal command or ROM/data flash access	R
b7	FRDY	Flash Ready	0: During programming/erasure, During suspending programming/erasure, During the lock bit read 2 command processing, During the blank check processing of data flash (See section 27, Data Flash (Flash Memory for Data Storage)). 1: Processing described above is not performed	R

FSTATR0 is a register to check the FCU status.

When on-chip ROM is disabled, the data read from FSTATR0 is 00h.

FSTATR0 is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

PRGSPD Bit (Programming Suspend Status)

This bit is used to indicate that the FCU enters the programming suspend processing state or programming suspended state (see section 26.7, Suspending Operation).

[Setting condition]

- The FCU has initiated a write suspend command.

[Clearing condition]

- The FCU has accepted a resume command.

ERSSPD Bit (Erasure Suspend Status)

This bit is used to indicate that the FCU enters the erasure suspend processing state or erasure suspended state (see section 26.7, Suspending Operation).

[Setting condition]

- The FCU has initiated an erasure suspend command.

[Clearing condition]

- The FCU has accepted a resume command.

SUSRDY Bit (Suspend Ready Status)

This bit is used to indicate whether the FCU can receive a P/E suspend command.

[Setting condition]

- After starting programming/erasure process, the FCU enters a state in which P/E suspend commands can be received.

[Clearing conditions]

- The FCU has accepted a P/E suspend command.
- During programming/erasure process, the FCU enters the command-locked state.

PRGERR Bit (Programming Error)

This bit is used to indicate the result of the ROM/data flash programming process by the FCU.

When the PRGERR bit is set to 1, the FCU is placed in the command-locked state (see section 26.8.2, Error Protection).

[Setting condition]

- An error occurs during programming.
- A programming command is issued to areas protected by a lock bit.

[Clearing condition]

- After the FCU processes a status clear command

ERSERR Bit (Erasure Error)

This bit is used to indicate the result of the ROM/data flash erasure process by the FCU.

When the ERSERR bit is set to 1, the FCU is placed in the command-locked state (see section 26.8.2, Error Protection).

[Setting condition]

- An error occurs during erasure.
- A block erase command is issued to areas protected by a lock bit.

[Clearing condition]

- After the FCU processes a status clear command

ILGLERR Bit (Illegal Command Error)

This bit is used to indicate that the FCU detects any illegal command or ROM/data flash access.

When the ILGLERR bit is set to 1, the FCU is placed in the command-locked state (see section 26.8.2, Error Protection).

[Setting conditions]

- The FCU detects an illegal command.
- The FCU detects an illegal ROM/data flash access
  (one of the ROMAE, DFLAE, DFLRPE, and DFLWPE bits in FASTAT is 1).
- The setting of FENTRYR is invalid.

[Clearing condition]

- After the FCU processes a status clear command under conditions where FASTAT is set to 10h

FRDY Bit (Flash Ready)

This bit is used to check the processing status of the FCU.

26.2.6 Flash Status Register 1 (FSTATR1)

Address: 007F FFB1h

	b7	b6	b5	b4	b3	b2	b1	b0
	FCUERR	—	—	FLOCKST	—	—	—	—
Value after reset:	0	0	0	0	0	0	x	x

x: Undefined

Bit	Symbol	Bit Name	Description	R/W
b1, b0	—	Reserved	The read value is undefined and these bits cannot be modified.	R
b3, b2	—	Reserved	These bits are always read as 0 and cannot be modified.	R
b4	FLOCKST	Lock Bit Status	0: Protected 1: Not protected	R
b6, b5	—	Reserved	These bits are always read as 0 and cannot be modified.	R
b7	FCUERR	FCU Error	0: No error occurs in the FCU processing 1: An error occurs in the FCU processing	R

FSTATR1 is a register to check the FCU status.

When on-chip ROM is disabled, the data read from FSTATR1 is 00h.

FSTATR1 is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

FLOCKST Bit (Lock Bit Status)

This bit is to reflect the read data of a lock bit when using the lock bit read 2 command.

When the FRDY bit in FSTATR0 is set to 1 after a lock bit read 2 command is issued, valid data is stored in the FLOCKST bit. The value of the FLOCKST bit is retained until the completion of the next lock bit read 2 command.

FCUERR Bit (FCU Error)

This bit is used to indicate that an error occurs in the FCU internal processing.

When the FCUERR bit is set to 1, set the FRESET bit in FRESETR to 1 to initialize the FCU. Additionally, recopy the FCU firmware from the FCU firmware area to the FCU RAM area.

26.2.7 Flash Ready Interrupt Enable Register (FRDYIE)

Address: 007F C412h

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	FRDYIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FRDYIE	Flash Ready Interrupt Enable	0: FRDYI interrupt requests disabled 1: FRDYI interrupt requests enabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FRDYIE is a register to enable and disable the flash ready interrupt (FRDYI) output.

When on-chip ROM is disabled, the data read from FRDYIE is 00h and writing is disabled.

FRDYIE is initialized by a reset.

FRDYIE Bit (Flash Ready Interrupt Enable)

This bit is to enable/disable a FRDYI interrupt request when programming/erasure is completed.

If the FRDYIE bit is set to 1, a flash ready interrupt request (FRDYI) is generated when execution of the FCU command has completed (FSTATR0.FRDY bit changes from 0 to 1).

26.2.8 Flash P/E Mode Entry Register (FENTRYR)

Address: 007F FFB2h

	b15	b14	b13	b12	b11	b10	b9	b8
	FEKEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	FENTRYD	—	—	—	—	—	FENTRY1	FENTRY0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FENTRY0	ROM P/E Mode Entry 0	0: ROM within 1 Mbyte*1 is in ROM read mode 1: ROM within 1 Mbyte*1 is in ROM P/E mode	R/W
b1	FENTRY1*1	ROM P/E Mode Entry 1	0: ROM more than 1 Mbyte is in ROM read mode 1: ROM more than 1 Mbyte is in ROM P/E mode	R/W
b6 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	FENTRYD	Data Flash P/E Mode Entry	See section 27, Data Flash (Flash Memory for Data Storage).	R/W
b15 to b8	FEKEY[7:0]	Key Code	These bits enable or disable rewriting of the FENTRYD, FENTRY1*2 and FENTRY0 bits.	R/(W)*3

Notes: 1. ROM within 1 Mbyte: Address for reading, FFF0 0000h to FFFF FFFFh
Address for writing/erasing, 00F0 0000h to 00FF FFFFh
ROM more than 1 Mbyte: Address for reading, FFE0 0000h to FFEF FFFFh
Address for writing/erasing, 00E0 0000h to 00EF FFFFh

2. Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

3. Write data is not retained.

FENTRYR is a register to place the ROM/data flash in P/E mode.

To place the ROM/data flash in P/E mode so that the FCU can accept commands, one of the FENTRYD, FENTRY1*, and FENTRY0 bits must be set to 1. Note that if more than one of these bits is set to 1, the ILGLERR bit in FSTATR0 is set and the FCU enters the command-locked state.

Only specific values written to the upper byte in word access are valid. Any other writing causes the register to be initialized. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from FENTRYR is 0000h and writing is disabled.

FENTRYR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

FENTRY0 Bit (ROM P/E Mode Entry 0)

This bit is used to place 1 Mbyte of ROM (read addresses: FFF0 0000h to FFFF FFFFh, programming/erasure addresses 00F0 0000h to 00FF FFFFh) in P/E mode.

[Writing-enable conditions (when all of the following conditions are met)]

- On-chip ROM is enabled.
- The FRDY bit in FSTATR0 is set to 1.
- AAh is written to the FEKEY[7:0] bits in word access.

[Setting condition]

- When the writing-enable conditions are met, FENTRYR is set to 0000h, and 1 is written to the FENTRY0 bit

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FEKEY[7:0] bits are other than AAh.
- When the writing-enable conditions are met, 0 is written to the FENTRY0 bit.
- When the writing-enable conditions are met and FENTRYR is other than 0000h, data is written to FENTRYR.

FENTRY1 Bit* (ROM P/E Mode Entry 1)

This bit is used to place 1 Mbyte of ROM (read addresses: FFE0 0000h to FFEF FFFFh, programming/erasure addresses 00E0 0000h to 00EF FFFFh) in P/E mode.

[Writing-enable conditions (when all of the following conditions are met)]

- On-chip ROM is enabled.
- The FRDY bit in FSTATR0 is set to 1.
- AAh is written to the FEKEY[7:0] bits in word access.

[Setting condition]

- When the writing-enable conditions are met, FENTRYR is set to 0000h, and 1 is written to the FENTRY1 bit*

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FEKEY[7:0] bits are other than AAh.
- When the writing-enable conditions are met, 0 is written to the FENTRY1 bit*.
- When the writing-enable conditions are met and FENTRYR is other than 0000h, data is written to FENTRYR.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

FEKEY[7:0] Bits (Key Code)

These bits enable or disable rewriting of the FENTRYD, FENTRY1*, and FENTRY0 bits.

Data written to the FEKEY[7:0] bits is not retained.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

Table 26.4 Correspondence of FENTRY1 and FENTRY0 Bits in Each Product

Product Code	ROM Size	FENTRY1 Bit*[1]	FENTRY0 Bit	FCU Mode	Target Addresses
R5F56108	2 Mbytes	0	0	ROM read mode	Read addresses: FFE0 0000h to FFFF FFFFh
		0	1	ROM P/E mode	Programming/erasure addresses: 00F0 0000h to 00FF FFFFh
					Access disabled addresses: FFE0 0000h to FFFF FFFFh
		1	0		Programming/erasure addresses: 00E0 0000h to 00EF FFFFh
					Access disabled addresses: FFE0 0000h to FFFF FFFFh
		1	1	Do not set.	—
R5F56107	1.5 Mbytes	0	0	ROM read mode	Read addresses: FFE8 0000h to FFFF FFFFh
		0	1	ROM P/E mode	Programming/erasure addresses: 00F0 0000h to 00FF FFFFh
					Access disabled addresses: FFE8 0000h to FFFF FFFFh
		1	0		Programming/erasure addresses: 00E8 0000h to 00EF FFFFh
					Access disabled addresses: FFE8 0000h to FFFF FFFFh
		1	1	Do not set.	—
R5F56106	1 Mbyte	Unusable*[2]	0	ROM read mode	Read addresses: FFF0 0000h to FFFF FFFFh
		Unusable*[2]	1	ROM P/E mode	Programming/erasure addresses: 00F0 0000h to 00FF FFFFh
					Access disabled addresses: FFF0 0000h to FFFF FFFFh
R5F56104	768 Kbytes	Unusable*[2]	0	ROM read mode	Read addresses: FFF4 0000h to FFFF FFFFh
		Unusable*[2]	1	ROM P/E mode	Programming/erasure addresses: 00F4 0000h to 00FF FFFFh
					Access disabled addresses: FFF4 0000h to FFFF FFFFh

Notes: 1. Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

2. This is a reserved bit in the R5F56106 and R5F56104. The write value should always be 0.

26.2.9 Flash Protection Register (FPROTR)

Address: 007F FFB4h

	b15	b14	b13	b12	b11	b10	b9	b8
	FPKEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	FPROTCN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FPROTCN	Lock Bit Protection Cancel	0: Protection with a lock bit enabled 1: Protection with a lock bit disabled	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	FPKEY[7:0]	Key Code	These bits are used to enable or disable rewriting of the FPROTCN bit.	R/(W)*

Note: * Write data is not retained.

FPROTR is a register used to enable/disable the programming/erasure protection function with a lock bit.

Only specific values written to the upper byte in word access are valid. Any other writing causes the register to be initialized. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from FPROTR is 0000h and writing is disabled.

FPROTR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

FPROTCN Bit (Lock Bit Protection Cancel)

This bit is used to enable/disable the programming/erasure protection with a lock bit.

[Setting condition]

- The FPKEY[7:0] bits are set to 55h, and the FPROTCN bit is set to 1 in word access when the value of FENTRYR is other than 0000h.

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FPKEY[7:0] bits are other than 55h.
- The FPKEY[7:0] bits are set to 55h, and the FPROTCN bit is set to 0 in word access.
- The value of FENTRYR is 0000h.

FPKEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the FPROTCN bit.

Data written to the FPKEY[7:0] bits is not retained.

26.2.10 Flash Reset Register (FRESETR)

Address: 007F FFB6h

	b15	b14	b13	b12	b11	b10	b9	b8
	FRKEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	–	FRESET
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FRESET	Flash Reset	0: FCU is not reset 1: FCU is reset	R/W
b7 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	FRKEY[7:0]	Key Code	These bits are used to enable or disable rewriting of the FRESET bit.	R/(W)*

Note: * Write data is not retained.

FRESETR is a register to initialize the FCU.

Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from FRESETR is 0000h and writing is disabled.

FRESETR is initialized by a reset.

FRESET Bit (Flash Reset)

When the FRESET bit is set to 1, programming/erasure operations for the ROM/data flash are forcibly terminated, and the FCU is initialized.

High voltage is applied to the memory of the ROM/data flash during programming/erasure. To ensure time required for dropping the voltage applied to the memory, keep the FRESET bit set to 1 for tRESW2 (see section 28, Electrical Characteristics) when initializing the FCU. While the FRESET bit is kept 1, prohibit the ROM/data flash from being read. Additionally, when the FRESET bit is set to 1, the FCU commands cannot be used because FENTRYR is initialized.

Writing of the FRESET bit is enabled only in word access and when the FRKEY[7:0] bits are CCh.

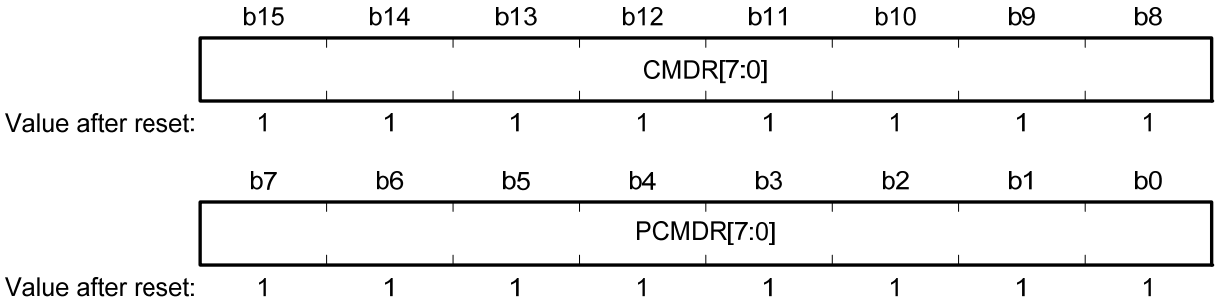
FRKEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the FRESET bit.

Data written to the FRKEY[7:0] bits is not retained.

26.2.11 FCU Command Register (FCMDR)

Address: 007F FFBAh



Bit	Symbol	Bit Name	Description	R/W
b7 to b0	PCMDR[7:0]	Precommand	Store the command immediately before the last command received by the FCU.	R
b15 to b8	CMDR[7:0]	Command	Store the last command received by the FCU.	R

FCMDR is a register to store commands received by the FCU.

When on-chip ROM is disabled, the data read from FCMDR is 0000h and writing is disabled.

FCMDR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

Table 26.5 lists the states of FCMDR after receiving each command. For details on the blank check processing, see section 27.6, Programming and Erasing the Data Flash Memory.

Table 26.5 States of FCMDR after Receiving Each Command

Command	CMDR	PCMDR
Normal mode transition	FFh	Previous command
Status read mode transition	70h	Previous command
Lock bit read mode transition (lock bit read 1)	71h	Previous command
Peripheral clock notification command	E9h	Previous command
Programming	E8h	Previous command
Block erase	D0h	20h
P/E suspend	B0h	Previous command
P/E resume	D0h	Previous command
Status register clear	50h	Previous command
Lock bit read 2 blank check	D0h	71h
Lock bit programming	D0h	77h

26.2.12 FCU Processing Switching Register (FCPSR)

Address: 007F FFC8h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	ESUSPMD
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	ESUSPMD	Erasure Suspend Mode	0: suspension priority mode 1: Erasure priority mode	R/W
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FCPSR is a register to select the method of suspending the FCU erasure processing.

When on-chip ROM is disabled, the data read from FCPSR is 0000h and writing is disabled.

FCPSR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

ESUSPMD Bit (Erasure Suspend Mode)

This bit is to select the erasure suspend mode for when a P/E suspend command is issued while the FCU executes the erasure processing for the ROM/data flash (see section 26.7, Suspending Operation).

26.2.13 Flash P/E Status Register (FPESTAT)

Address: 007F FFCCh

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	PEERRST[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	PEERRST[7:0]	P/E Error Status	01h: Programming error against areas protected by a lock bit 02h: Programming error due to sources other than the lock bit protection 11h: Erasure error against areas protected by a lock bit 12h: Erasure error due to sources other than the lock bit protection (Values other than above are reserved)	R
b15 to b8	—	Reserved	These bits are always read as 0 and cannot be modified.	R

FPESTAT is a register to indicate the result of the programming/erasure processing for the ROM/data flash.

When on-chip ROM is disabled, the data read from FPESTAT is 0000h and writing is disabled.

FPESTAT is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

PEERRST[7:0] Bits (P/E Error Status)

These bits are used to indicate the reason of an error that occurs during the programming/erasure processing for the ROM/data flash.

The value of the PEERRST[7:0] bits is valid only when the ERSERR bit or PRGERR bit in FSTATR0 is 1. The value of the reason of the past error is retained in the PEERRST[7:0] bits when the ERSERR bit and PRGERR bit is 0.

26.2.14 Peripheral Clock Notification Register (PCKAR)

Address: 007F FFE8h

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	PCKA[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b7 to b0	PCKA[7:0]	Peripheral Clock Notification	These bits are used to set the peripheral clock (PCLK) at the programming/erasure for the ROM/data flash.	R/W
b15 to b8	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

PCKAR is a register to notify the sequencer of the frequency setting data of the peripheral clock (PCLK) at the programming/erasure for the ROM/data flash. This setting is used to control programming and erasure times.

When on-chip ROM is disabled, the data read from PCKAR is 0000h and writing is disabled.

PCKAR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

PCKA[7:0] Bits (Peripheral Clock Notification)

These bits are used to set the peripheral clock (PCLK) at the programming/erasure for the ROM/data flash.

Set the PCKA[7:0] bits to the PCLK frequency and issue a peripheral clock notification command before programming/erasure. Do not change the frequency during the programming/erasure processing for the ROM/data flash.

Calculate the setting value as follows:

- Convert an operating frequency represented in MHz units to binary and write it to the PCKA[7:0] bits.

  For example, when the operating frequency of the peripheral clock is 35.9 MHz, the setting value is calculated as follows:

- Round up 35.9
- Convert 36 to binary and set the upper bits and lower bits of the PCKA[7:0] bits to 00h and 24h (0010 0100b).

Notes: 1. When the PCKA[7:0] bits are set to values outside the range from 8 to 50 MHz, do not issue a programming command to the ROM/data flash.

2. When the PCKA[7:0] bits are set to a frequency that is different from the FCLK, the data of the ROM/E2 data flash may be damaged.

3. Please note that programming time depends on the frequency to some extent even if the PCKA[7:0] bits are used.

26.2.15 Flash Write Erase Protection Register (FWEPROR)

Address: 0008 C289h

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	–	–	–	FLWE[1:0]	
Value after reset:	0	0	0	0	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
b1, b0	FLWE[1:0]	Flash Write/Erase	b1 and b0 0 0: Write/erase disabled 0 1: Write/erase enabled 1 0: Write/erase disabled (initial value) 1 1: Write/erase disabled	R/W
b7 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

FWEPROR is a readable/writable register to protect the execution of the flash write/erase with software.

FWEPROR is initialized in software standby mode or deep software standby.

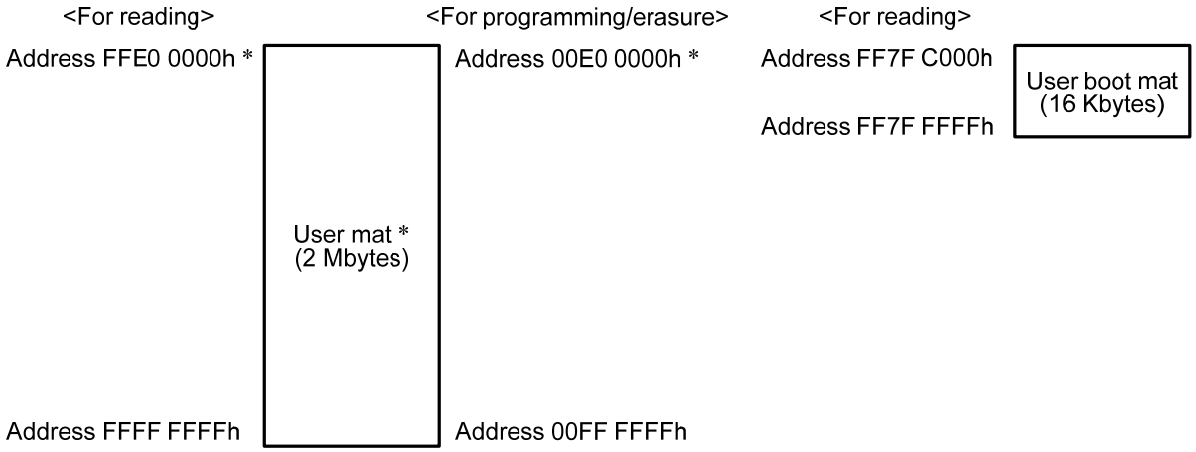
FLWE[1:0] Bits (Flash Write/Erase)

These bits protect the execution of the flash write/erase with software.

26.3 Configuration of Memory Mats for the ROM

The ROM of products in the RX610 Group is configured of a maximum 2-Mbyte user mat and a 16-Kbyte user boot mat. The address ranges occupied by these mats are shown in figure 26.2.

Note that for the user mat, the address range for reading differs from the address range for programming and erasure.



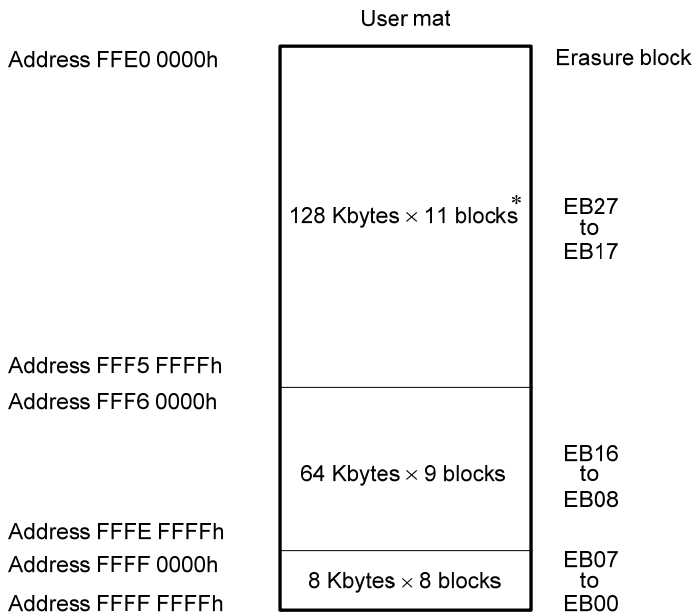
Note: * The read addresses and programming/erasure addresses differ in each product.

Product Code	Read Address	Programming/Erasure Address	Memory Space
R5F56108	FFE0 0000h	00E0 0000h	2 Mbytes
R5F56107	FFE8 0000h	00E8 0000h	1.5 Mbytes
R5F56106	FFF0 0000h	00F0 0000h	1 Mbyte
R5F56104	FFF4 0000h	00F4 0000h	768 Kbytes

Figure 26.2 Memory Mat Configuration of ROM

26.4 Block Configuration

The configuration of erasure blocks for the user mat is shown in figure 26.3. As units of erasure, the user mat is divided into 8 blocks of 8 Kbytes each, 9 blocks of 64 Kbytes each, and 11 blocks of 128 Kbytes each. For programming, the user mat consists of the 256-byte units starting from 00h as the lower-order byte of the address.



Note: * The erasure blocks differ in each product.

Product Code	Address	Number of 128-Kbyte Erasure Blocks	Erasure Blocks
R5F56108	FFE0 0000h	11	EB17 to EB27
R5F56107	FFE8 0000h	7	EB17 to EB23
R5F56106	FFF0 0000h	3	EB17 to EB19
R5F56104	FFF4 0000h	1	EB17

Figure 26.3 Configuration of Erasure Blocks for the User Mat

26.5 Operating Modes Associated with the ROM

Figure 26.4 is a diagram of the operating-mode transitions for the RX610 Group.

On release from the reset state, transitions are in accord with the levels on the MD0 and MD1 pins, as shown in figure 26.4.

For more information on the connections between the settings of the levels on the MD0 and MD1 pins and the operating mode for the RX610 Group, refer to section 3, Operating Modes.

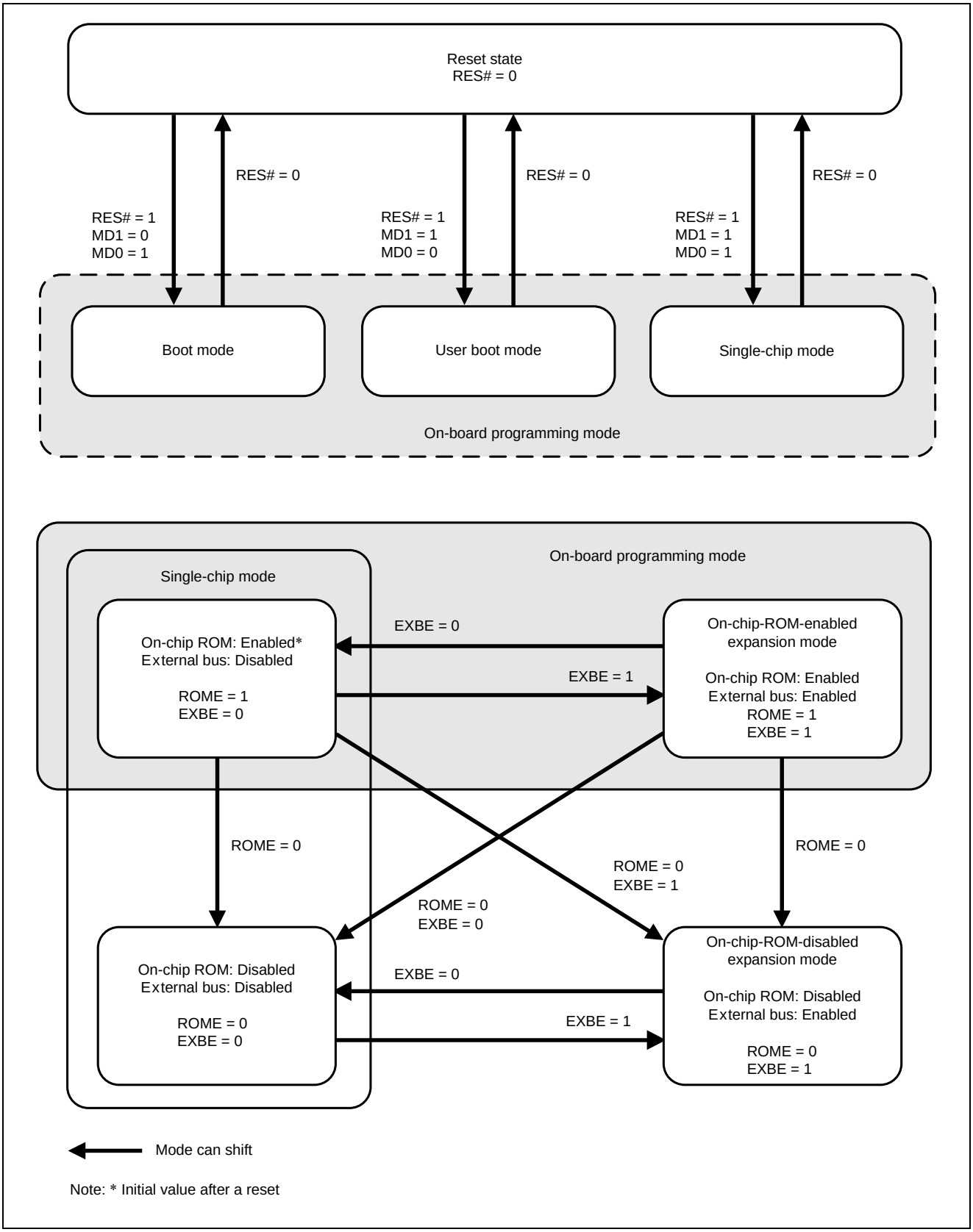


Figure 26.4 Transitions between Operating Modes in Terms of the ROM

Reading, programming, and erasing of the ROM in an on-board device can proceed if the device is in boot, user-boot, or single-chip mode (with on-chip ROM enabled), or in on-chip-ROM-enabled expansion mode.

Which mats are programmable and erasable, the mat from which booting up proceeds after a reset, etc., differs with the mode. The differences between modes are indicated in table 26.6.

Table 26.6 Differences between Modes

Item	Boot Mode	User Boot Mode	Single-Chip Mode (with On-chip ROM Enabled) or On-chip-ROM-Enabled Expansion Mode
Environment for programming and erasure	On-board programming	On-board programming	On-board programming
Programmable and erasable mat	User mat User boot mat	User mat	User mat
Division into erasure blocks	Possible*1	Possible	Possible
Target mat for booting after a reset	Mat containing the embedded program*2	User boot mat	User mat

Notes: 1. The entire ROM may be erased at the time of booting up. Specified blocks can subsequently be erased. For details, refer to section 26.10.2, ID Code Protection.

2. Not available to users.

- Programming and erasure of the user boot mat are only possible in boot mode.
- In boot mode, a host is able to program or read out the user mat, user boot mat, or data mat via an SCI.
- After booting up from the user boot mat in user boot mode, programming and erasure of the user mat or data mat via the desired interface is possible.
- In boot mode, on-chip RAM is employed for the embedded program for use in boot mode. For this reason, preserving the contents of on-chip RAM is not possible in this case.

26.6 Programming and Erasing the ROM

The ROM is programmed and erased by issuing commands to a dedicated sequencer (FCU) for programming and erasure. The FCU has five modes. For programming and erasure, the mode is changed and then commands for programming and erasure are issued.

The mode transitions required to program or erase the ROM and the system of commands are described below. The descriptions apply in common to boot, user-boot, and single-chip mode (with on-chip ROM enabled), and to on-chip-ROM-enabled expansion mode.

26.6.1 FCU Modes

The FCU has five modes or sets of modes. Transitions between modes are caused by modifying FENTRYR or issuing FCU commands. Figure 26.5 is a diagram of the FCU mode transitions.

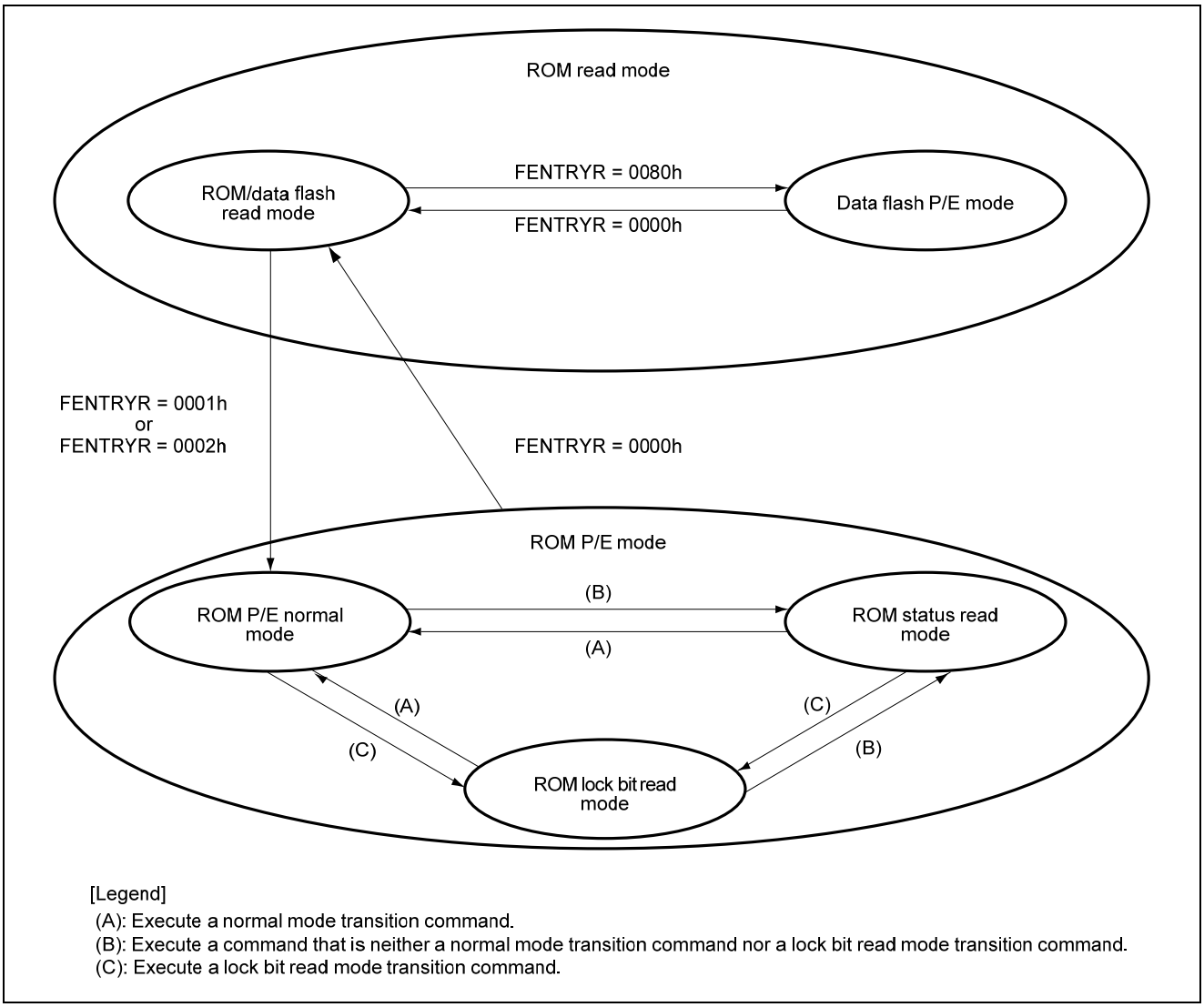


Figure 26.5 Mode Transitions of the FCU (Associated with the ROM)

26.6.1.1 ROM Read Modes

The ROM read modes are for high-speed reading of the ROM. Access to an address for reading can be accomplished in one cycle of ICLK.

ROM/data-flash read mode and data-flash P/E mode are the two kinds of ROM reading mode.

(1) ROM/Data Flash Read Mode

This mode is for reading the ROM and data-flash memory. The FCU does not accept commands.

The FCU enters this mode when the FENTRY1* and FENTRY0 bits in FENTRYR are set to 0, and the FENTRYD bit in FENTRYR is set to 0.

(2) Data Flash P/E Modes

These modes are for programming and erasure of the data-flash memory. High-speed reading of the ROM is also possible. Although the FCU accepts FCU commands related to the data-flash memory in this mode, it does not accept FCU commands related to the ROM. The FCU enters these modes when the FENTRY1* and FENTRY0 bits in FENTRYR are set to 0, or the FENTRYD bit in FENTRYR is set to 1.

For details on the data flash P/E modes, see section 27.6.1, FCU Modes

26.6.1.2 ROM P/E Modes

The ROM P/E modes are for programming and erasure of the ROM. High-speed reading of the ROM is not possible in these modes. Read access to an address within the range for reading causes a ROM-access violation, and the FCU enters the command-locked state (see section 26.8.2, Error Protection).

ROM P/E normal mode, ROM status read mode, and ROM lock-bit read mode are the three ROM P/E modes.

(1) ROM P/E Normal Mode

The transition to ROM P/E normal mode is the first transition in the process of programming or erasing the ROM. The FCU enters this mode when the FENTRYD bit in FENTRYR is set to 0, and either the FENTRY1* or FENTRY0 bit in FENTRYR is set to 1 in ROM read mode, or when the normal mode transition command is received in ROM P/E modes. Table 26.9 lists the acceptable commands in this mode.

Read access to an address within the range for programming and erasure while the FENTRY1* and FENTRY0 bits in FENTRYR are set to 1 causes a ROM-access violation, and the FCU enters the command-locked state (see section 26.8.2, Error Protection).

(2) ROM Status Read Mode

The ROM status read mode is for reading information on the state of the ROM. The FCU enters this mode when a command other than the normal mode transition and lock bit read mode transition command is received in ROM P/E modes.

ROM status read mode encompasses the states where the FRDY bit in FSTATR0 is 0 and the command-locked state after an error has occurred. Table 26.9 lists the acceptable commands in this mode.

Read access to an address within the range for programming and erasure while the FENTRY1* and FENTRY0 bits in FENTRYR are 1 will actually read out the value of FSTATR0.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

(3) ROM Lock-Bit Read Mode

The ROM lock-bit read mode is for reading the values of the lock bits of the ROM. The FCU enters this mode when a lock-bit read mode transition command is received in ROM P/E modes. Table 26.9 lists the acceptable commands in this mode.

In read access to an address within the range for programming and erasure while the FENTRY1* and FENTRY0 bits in FENTRYR are 1, all bits of the value read out have the value of the lock bit of the erasure block that includes the accessed address.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

26.6.2 FCU Commands

FCU commands consist of commands for mode transitions of the FCU and commands for programming and erasure. Table 26.7 lists the FCU commands for use with the ROM.

Table 26.7 FCU Commands for Use with the ROM

Command	Description
P/E normal mode transition	Changes the mode to normal mode (see section 26.6.3, Connections between FCU Modes and Commands)
Status read mode transition	Changes the mode to status read mode (see section 26.6.3, Connections between FCU Modes and Commands)
Lock bit read mode transition (lock bit read 1)	Changes the mode to lock bit read mode (see section 26.6.3, Connections between FCU Modes and Commands)
Peripheral clock notification	Sets the frequency of the peripheral clock
Programming	ROM programming (in 256-byte units)
Block erasure	ROM erasure (in block units, with the lock bit being erased simultaneously)
P/E suspension	Suspends programming/erasure
P/E resumption	Resumes programming/erasure
Status register clearing	Clears the ILGLERR, ERSERR and PRGERR bits in FSTATR0 and releases the FCU from the command locked state
Lock bit read 2/blank checking	Reads the lock bit of a specified erasure block (the value of the lock bit is reflected in the FLOCKST bit of FSTATR1)/blank checking of the data-flash memory
Lock bit programming	Programs the lock bit of a specified erasure block

The lock bit read 2 command is also used as the blank-checking command for the data-flash memory. That is, when a lock bit read 2 command is issued for the data flash, blank checking is executed for the data-flash memory (see section 27, Data Flash (Flash Memory for Data Storage)).

Commands for the FCU are issued by write access to addresses within the range for programming and erasure. Table 26.8 shows the formats of the FCU commands. Write access as listed in table 26.8 and in accord with certain conditions causes the FCU to execute processing for the corresponding command. For details on the conditions for the acceptance of the individual FCU commands, see section 26.6.3, Connections between FCU Modes and Commands. For how to use the FCU commands, see section 26.6.4, FCU Command Usage.

Table 26.8 FCU Command Formats

Command	Number of bus cycles	First Cycle		Second Cycle		Third Cycle		4th to 5th Cycles		6th Cycle		7th to 130th Cycles		131st Cycle	
		Address	Data	Address	Data	Address	Data	Address	Data	Address	Data	Address	Data	Address	Data
P/E normal mode transition	1	RA	FFh	—	—	—	—	—	—	—	—	—	—	—	—
Status read mode transition	1	RA	70h	—	—	—	—	—	—	—	—	—	—	—	—
Lock bit read mode transition (lock bit read 1)	1	RA	71h	—	—	—	—	—	—	—	—	—	—	—	—
Peripheral clock notification	6	RA	E9h	RA	03h	RA	0F0Fh	RA	0F0Fh	RA	D0h	—	—	—	—
Programming	131	RA	E8h	RA	80h	WA	WDn	RA	WDn	RA	WDn	RA	WDn	RA	D0h
Block erasure	2	RA	20h	BA	D0h	—	—	—	—	—	—	—	—	—	—
P/E suspension	1	RA	B0h	—	—	—	—	—	—	—	—	—	—	—	—
P/E resumption	1	RA	D0h	—	—	—	—	—	—	—	—	—	—	—	—
Status register clearing	1	RA	50h	—	—	—	—	—	—	—	—	—	—	—	—
Lock bit read 2	2	RA	71h	BA	D0h	—	—	—	—	—	—	—	—	—	—
Lock bit programming	2	RA	77h	BA	D0h	—	—	—	—	—	—	—	—	—	—

[Legend] Address column RA: ROM programming/erasure address
When the FENTRY0 bit in FENTRYR is 1: An address from 00F0 0000h to 00FF FFFFh
When the FENTRY1* bit in FENTRYR is 1: An address from 00E0 0000h to 00EF FFFFh
WA: ROM programming-destination address
Start address for programming of 256 bytes of data
BA: ROM erasure block address
An address within the target erasure block (specified as an address in the range for programming and erasure)
Data column WDn: nth word of data for programming (n = 1 to 128)

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

26.6.3 Connections between FCU Modes and Commands

The sets of FCU commands that can be accepted in each of the FCU modes are fixed. Furthermore, which commands are acceptable in a given FCU mode also depends on the state of the FCU.

Issuing of an FCU command must follow checking of the FCU's state after transitions of the FCU mode.

Commands that are acceptable in the various FCU modes and states are listed in table 26.9. Issuing a command that is not currently acceptable leads to the FCU being placed in the command-locked state (see section 26.8.2, Error Protection).

Issuing of an FCU command must follow checking of the values of the FRDY, ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and of the FCUERR bit in FSTATR1 after transitions of the FCU mode. Furthermore, the CMDLK bit in FASTAT can be checked to see if an error has occurred. The value of the CMDLK bit in FASTAT is the logical OR of the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the FCUERR bit in FSTATR1.

Table 26.9 Acceptable Commands and the State and Mode (ROM P/E Mode) of the FCU

	P/E Normal Mode			Status Read Mode						Lock-Bit Read Mode		
	Programming suspended	Erasure suspended	Other state	Programming or erasure	Processing to suspend programming or erasure	Lock bit read 2 processing	Programming suspended	Erasure suspended	Command-locked state	Other state	Programming suspended	Erasure suspended	Other state
FSTATR0.FRDY bit	1	1	1	0	0	0	1	1	0/1	1	1	1	1
FSTATR0.SUSRDY bit	0	0	0	1	0	0	0	0	0	0	0	0	0
FSTATR0.ERSSPD bit	0	1	0	0	0/1	0	0	1	0	0	0	1	0
FSTATR0.PRGSPD bit	1	0	0	0	0/1	0	1	0	0	0	1	0	0
FASTAT.CMDLK bit	0	0	0	0	0	0	0	0	1	0	0	0	0
Normal mode transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Status read transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Lock-bit read transition (lock bit read 1)	A	A	A	X	X	X	A	A	X	A	A	A	A
Peripheral clock setting	X	X	A	X	X	X	X	X	X	A	X	X	A
Programming	X	*	A	X	X	X	X	*	X	A	X	*	A
Block erasure	X	X	A	X	X	X	X	X	X	A	X	X	A
P/E suspension	X	X	X	A	X	X	X	X	X	X	X	X	X
P/E resumption	A	A	X	X	X	X	A	A	X	X	A	A	X
Status register clearing	A	A	A	X	X	X	A	A	A	A	A	A	A
Lock bit read 2	A	A	A	X	X	X	A	A	X	A	A	A	A
Lock bit programming	X	*	A	X	X	X	X	*	X	A	X	*	A

[Legend]

A: Acceptable

*: Only programming is acceptable for blocks other than the block where erasure was suspended

X: Not acceptable

26.6.4 FCU Command Usage

The set of FCU commands consists of commands for FCU mode transitions, actually programming or erasing the ROM, error processing, and suspension and resumption. The following passages describe the various commands. For a description of the modes and states where the respective commands are acceptable, see section 26.6.3, Connections between FCU Modes and Commands.

26.6.4.1 Mode Transitions

This subsection covers the commands for mode transitions. For an illustration of the various transitions between modes, see figure 26.5.

(1) Switching to ROM P/E Mode

A transition to ROM P/E mode is required before executing an FCU command for the ROM becomes possible.

Setting the FENTRY0 or FENTRY1* bit in FENTRYR to 1 causes a transition to ROM P/E mode for programming and erasure of the corresponding address range.

Before actually proceeding to program or erase the ROM, enable programming and erasure by writing 01h as a byte to FWEPROR (see section 26.2.15, Flash Write Erase Protection Register (FWEPROR)).

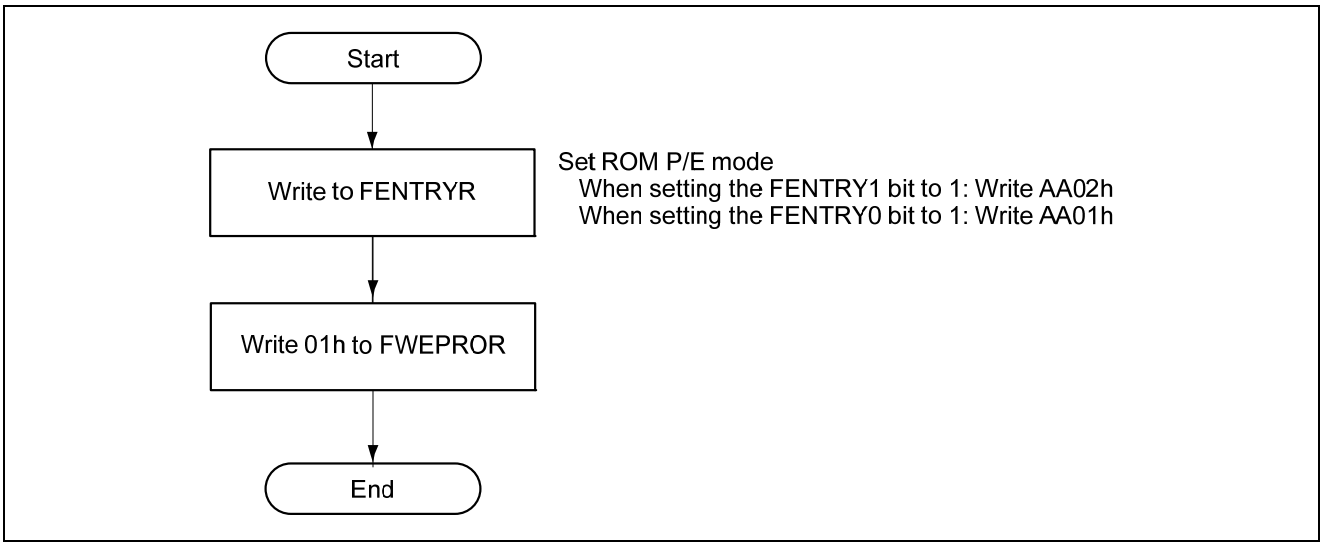


Figure 26.6 Procedure for Transition to ROM P/E Mode

(2) Switching to ROM Read Mode

High-speed reading of the ROM requires clearing of the FENTRY0 or FENTRY1* bit in FENTRYR, which places the FCU in ROM read mode.

Writing of 02h to FWEPROR is also required to disable programming and erasure (see section 26.2.15, Flash Write Erase Protection Register (FWEPROR).

Before switching the FCU from P/E mode to read mode, ensure that all processing of FCU commands has been completed and that the FCU has not detected an error.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

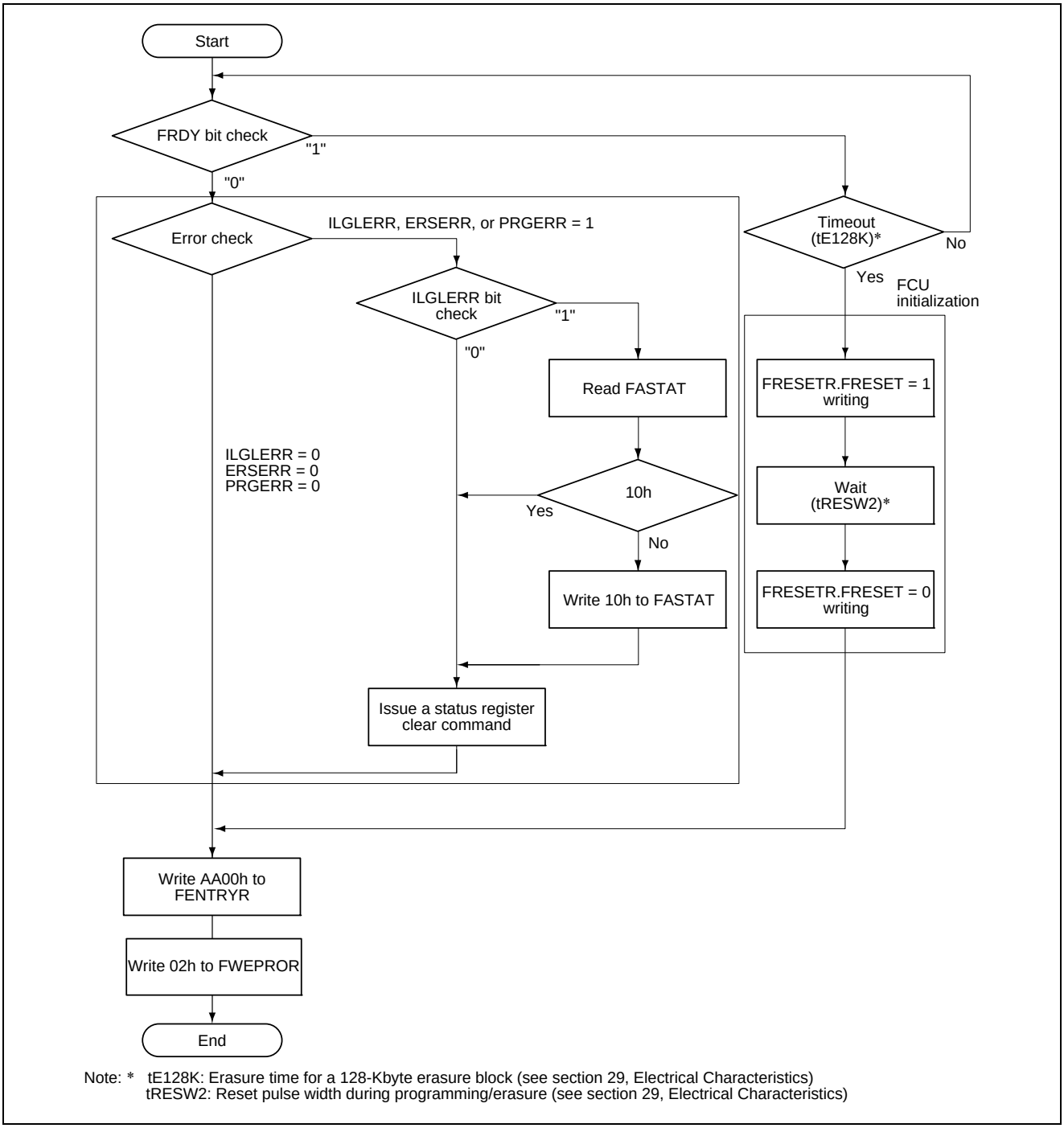


Figure 26.7 Procedure for Transition to ROM Read Mode

(3) Switching to ROM P/E Normal Mode

Two methods are available for the transition to ROM P/E normal mode: setting the FENTRYR register while the FCU is in ROM read mode (see section 26.6.1, FCU Modes), or issuing the normal mode transition command while the FCU is in ROM P/E mode (see figure 26.8). The normal mode transition command is issued by writing FFh as a byte to an address in the range for programming and erasure of the ROM.

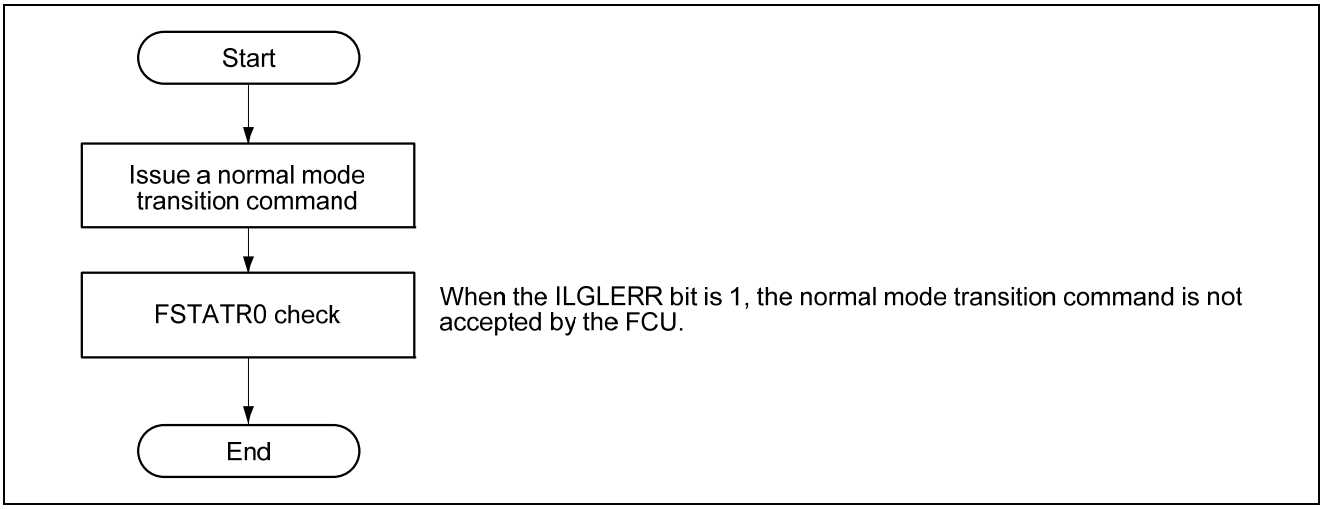


Figure 26.8 Procedure for Transition to ROM P/E Normal Mode

(4) Switching to ROM Status Read Mode

Issuing an FCU command other than a normal mode transition or lock bit read mode transition command places the FCU in ROM status read mode. The same transition can be obtained by issuing the status read mode transition command. Figure 26.9 shows the procedure for checking the register FSTATR0 as an example. In the example, the status read mode transition command is issued to place the FCU in ROM status read mode, and the value of FSTATR0 is obtained by read access to the area for programming and erasure and then checked.

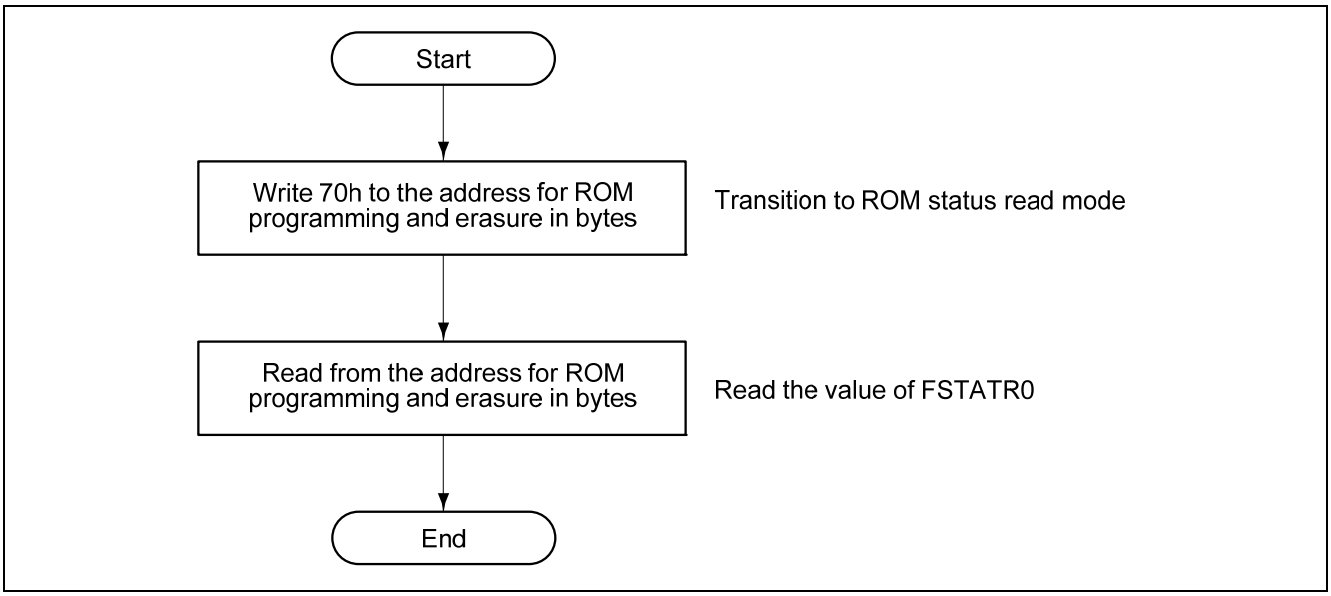


Figure 26.9 Procedure for Transition to ROM Status Read Mode and the Status Checking

(5) Switching to ROM Lock-Bit Read Mode

Clearing the FRDMD bit in FMODR (memory area method) issues a lock bit read mode transition (lock bit read 1) command. After the transition to ROM lock bit read mode, lock bit value are obtained by read access to the area for ROM programming and erasure. All bits of a value thus read out have the value of the lock bit of the erasure block that contains the accessed address (figure 26.10).

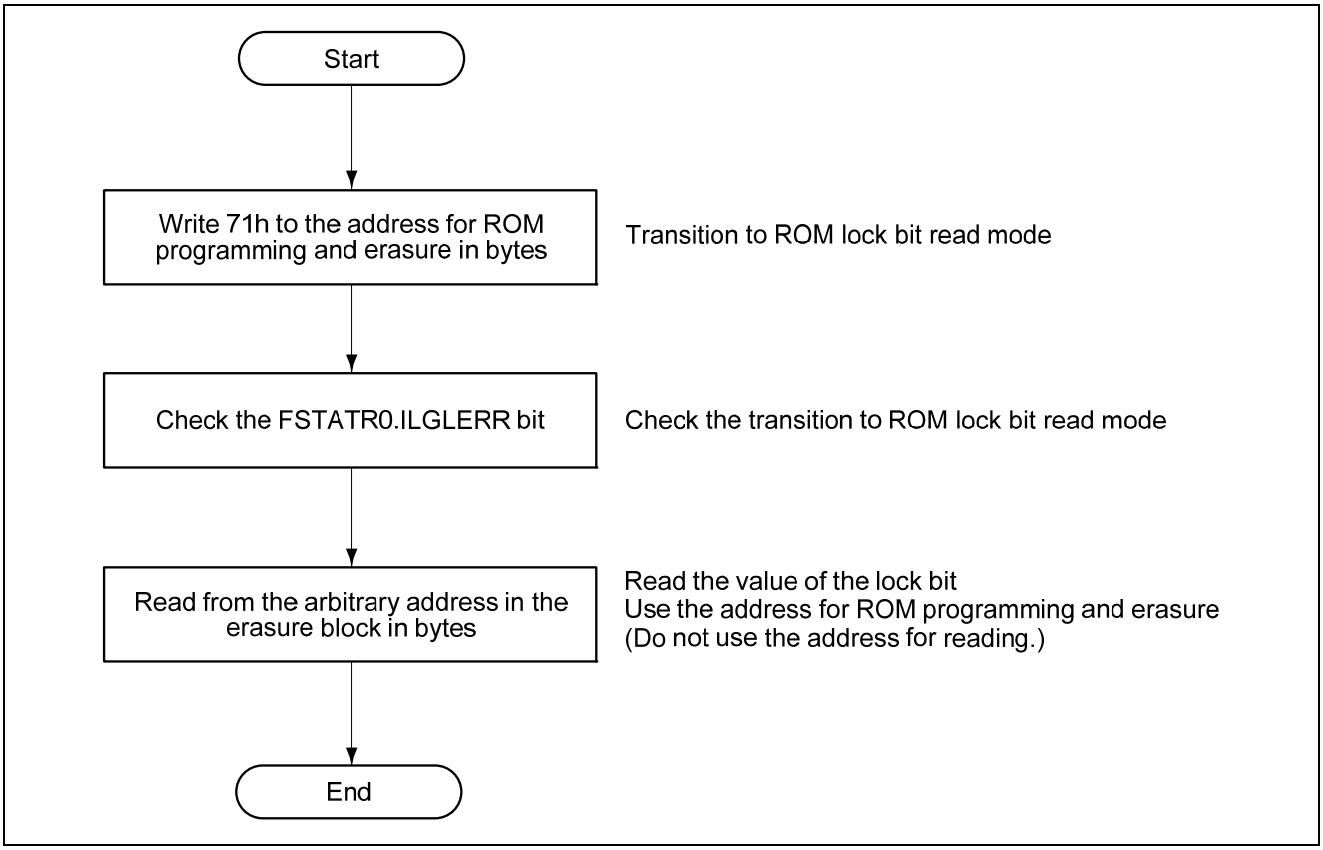
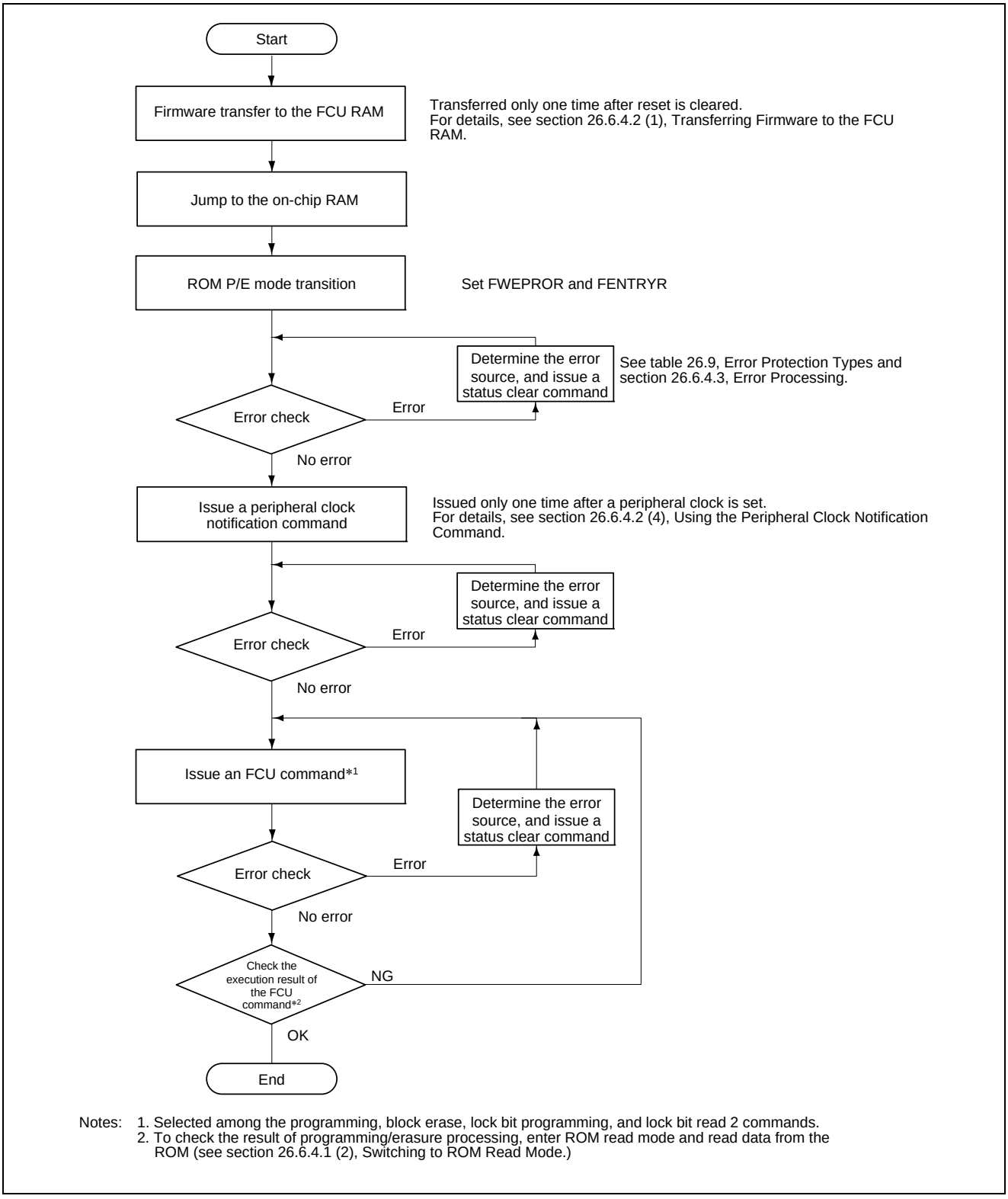


Figure 26.10 Procedure for Transition to ROM Lock-Bit Read Mode and the Lock-Bit Read Method

26.6.4.2 Programming and Erasure Procedures

The following passages describe the flow of procedures for programming or erasing the ROM. For details on the acceptance of commands by the FCU, see section 26.6.3, Connections between FCU Modes and Commands.

Figure 26.11 is a simple flowchart of the procedure for executing FCU commands.



Notes: 1. Selected among the programming, block erase, lock bit programming, and lock bit read 2 commands.
2. To check the result of programming/erasure processing, enter ROM read mode and read data from the ROM (see section 26.6.4.1 (2), Switching to ROM Read Mode.)

Figure 26.11 Simple Flowchart of the Procedure for Programming and Erasure

(1) Transferring Firmware to the FCU RAM

FCU commands can only be used if the FCU RAM holds the firmware for the FCU. The FCU RAM does not hold the FCU firmware immediately after the chip has been booted up, so the firmware must be copied from the FCU firmware area to the FCU RAM. Furthermore, when the FCUERR bit in FSTATR1 is set to 1, the FCU must be reset and the firmware recopied because the firmware stored in the FCU RAM may have been corrupted.

Figure 26.12 shows the flow of the procedure for transferring firmware to the FCU RAM. Before writing data to the FCU RAM, set FENTRYR to 0000h and stop the FCU. See section 12, DMA Controller (DMAC), for information on setting up the DMAC to handle data transfer.

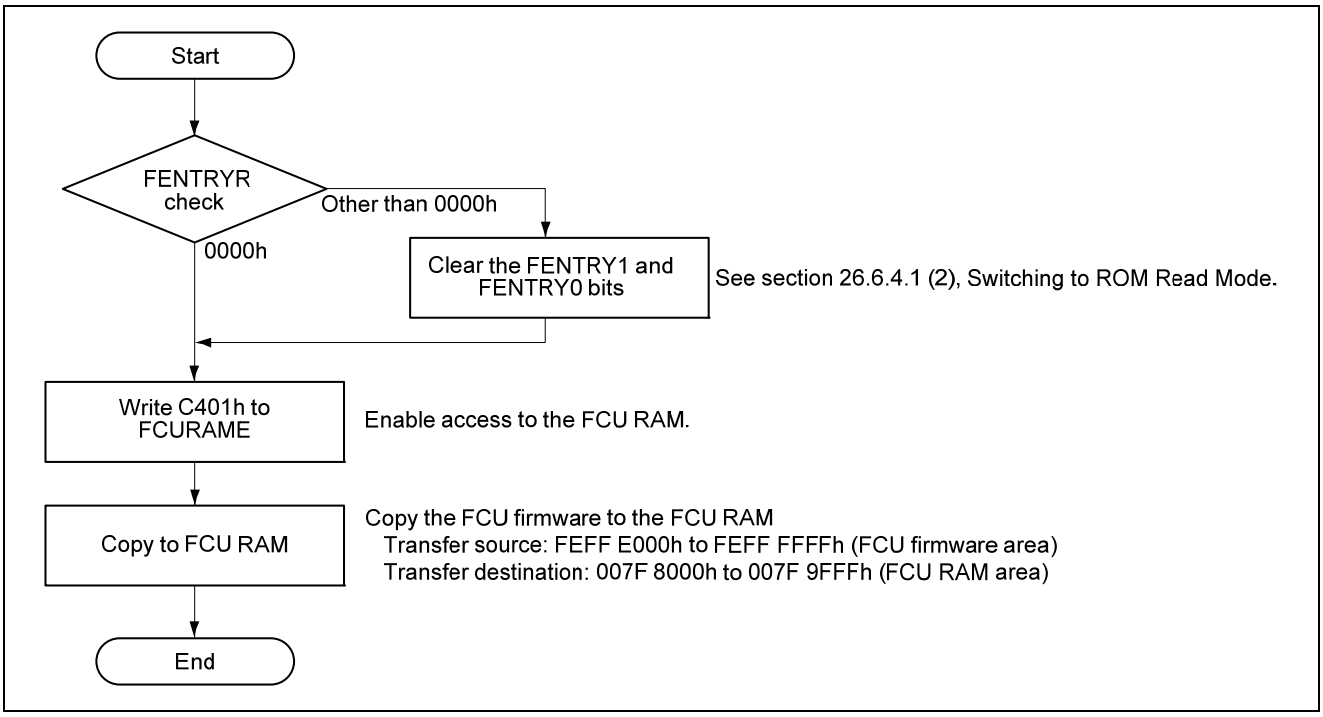


Figure 26.12 Procedure for Firmware Transfer to FCU RAM

(2) Jumping to Locations in On-chip RAM

Since fetching instructions from the ROM is not possible while the ROM is being programmed or erased, code has to be executed from an area other than the ROM. Copy the required program code to on-chip RAM and then make execution jump to the address where the code starts in on-chip RAM.

(3) Transition to ROM P/E Mode

The FCU is placed in ROM P/E mode by the settings of the FENTRY1* or FENTRY0 bit in FENTRYR and of FWEPROR. Details are given in section 26.6.4.1 (3)Switching to ROM P/E Normal Mode.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

(4) Using the Peripheral Clock Notification Command

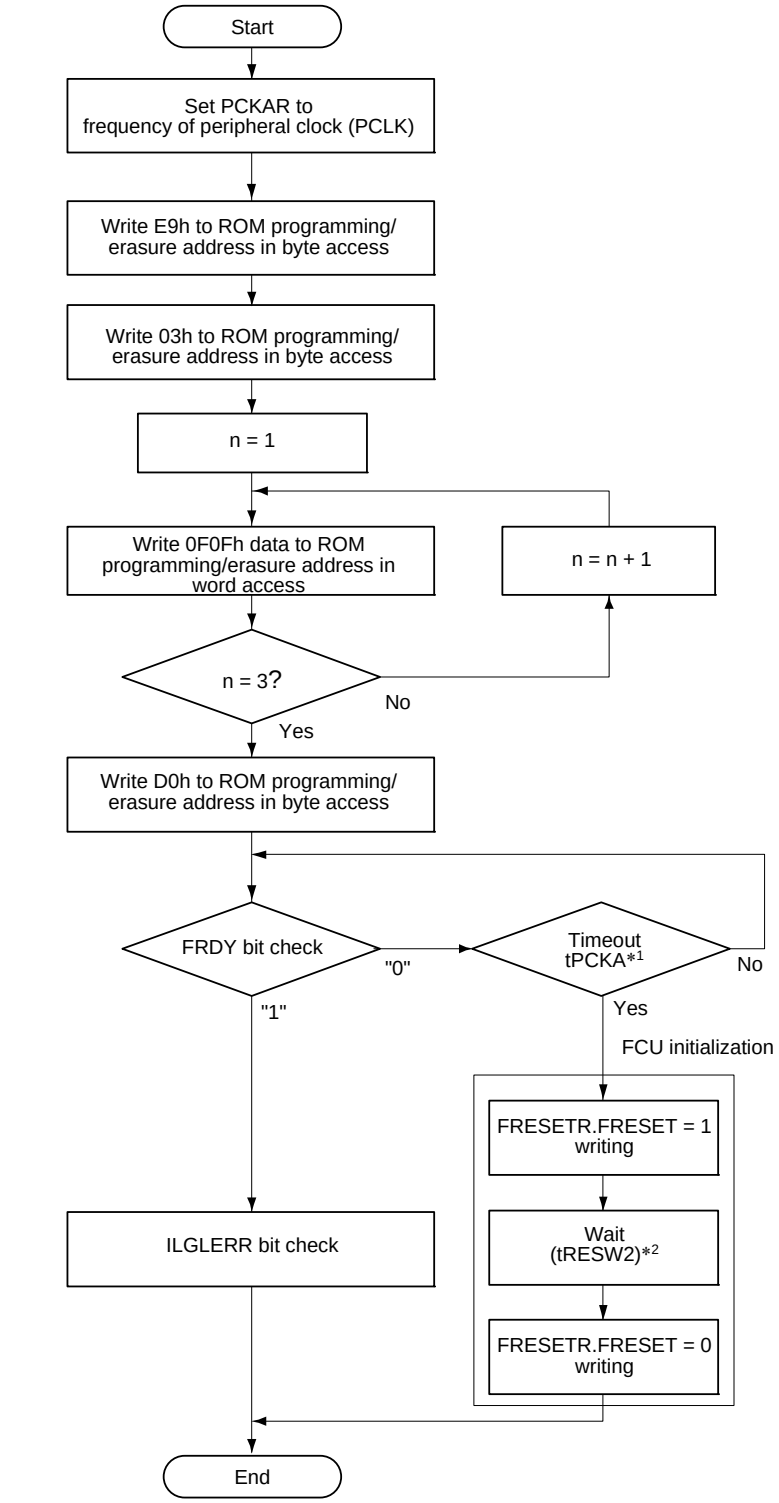
The peripheral clock is used in programming and erasing the ROM, so the frequency of this clock has to be set in the PCKAR. Frequencies in the range from 8 to 50 MHz are selectable. Do not set frequencies out of this range.

The peripheral clock notification command is used after the PCKAR setting has been made. In the first and second cycles for the peripheral clock notification command, respectively, the values E9h and 03h are written to the address range for programming and erasure of the ROM. Word-unit writing is used in the third to fifth cycles of the command. Accordingly, make sure that the addresses used are aligned with four-byte boundaries. After 0F0Fh has been written three times (as a word) to the address range for programming and erasure of the ROM, the process of the FCU setting the frequency of the peripheral clock starts once the value D0h has been written as a byte in the sixth cycle. The FRDY bit in FSTATR0 can be used to check whether or not the settings have been completed.

Addresses that can be used in the first to sixth cycles differ according to the settings of the FENTRY0 and FENTRY1* bits in FENTRYR. Ensure that the addresses suit the settings of these bits. If issuing of the command is attempted with an erroneous combination of the setting of the bits and specified addresses, the FCU will detect the error and enter the command-blocked state (see section 26.8.2, Error Protection).

Furthermore, if the setting for the peripheral clock in use will not be changed from this setting after release from the reset state, this setting is also valid for the next FCU command.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.



Notes: 1. tPCKA: 60 μs when PCLK = 50 MHz, 120 μs when PCLK = 25 MHz
2. tRESW2: Reset pulse width during programming/erasure (see section 29, Electrical Characteristics)

Figure 26.13 Using the Peripheral Clock Notification Command

(5) Programming

The programming command is used to write data to the ROM.

In the first and second cycles for the peripheral clock notification command, respectively, the values E8h and 80h are written to the address range for programming and erasure of the ROM. In the third cycle, write the actual data to be programmed, as a word unit, to the target address for programming. For this first address, always use an address that is on a 256-byte boundary. In the fourth to the 130th cycles, write the data for programming in 127 word-unit rounds to the address range for programming and erasure of the ROM. Once the value D0h has been written as a byte to the address range for programming and erasure of the ROM in the 131st cycle, the FCU begins the actual process of programming the ROM. The FRDY bit in FSTATR0 can be used to check whether or not the programming has been completed.

Addresses that can be used in the first to 131st cycles differ according to the settings of the FENTRY0 and FENTRY1* bits in FENTRYR. Ensure that the addresses suit the settings of these bits. If issuing of the command is attempted with an erroneous combination of the setting of the bits and specified addresses, the FCU will detect the error and enter the command-blocked state (see section 26.8.2, Error Protection).

In cases where the target range in the third to 130th cycles includes addresses that do not require programming, use FFFFh as the data for programming to those addresses. To execute a programming with lock bit protection disabled, proceed with programming after setting the FPROTCN bit in FPROTR.

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

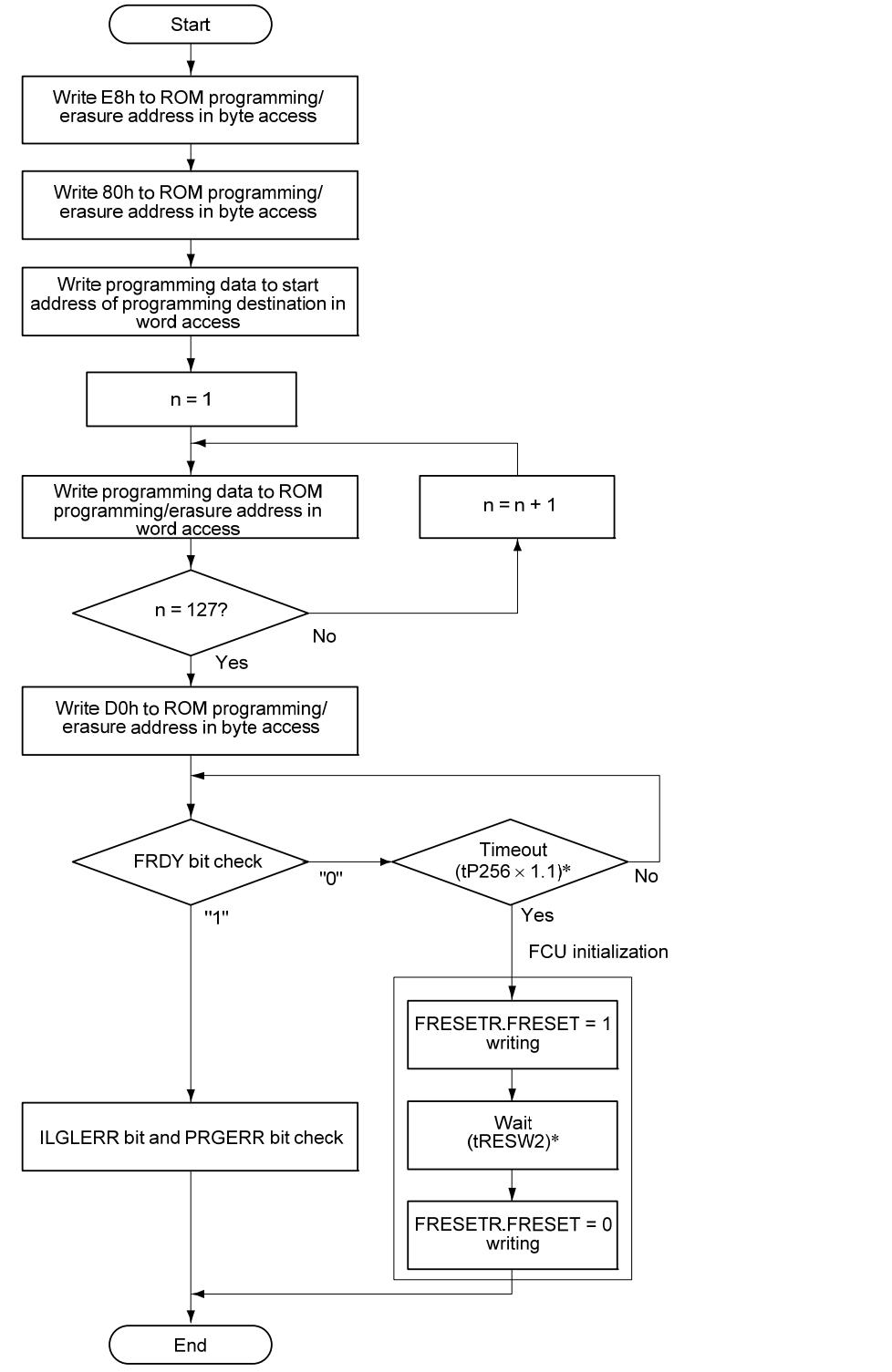


Figure 26.14 Procedure for ROM Programming

(6) Erasure

To erase data from the ROM, use the block erase command.

Write 20h to the ROM programming/erasure address in byte access in the first cycle of the block erase command. When D0h is written to an arbitrary address in an erasure target block in byte access in the second cycle, the FCU start the erasure processing for the ROM. Whether erasure is completed can be checked with the FRDY bit in FSTATR0.

To execute an erasure with lock bit protection disabled, set the FPROTCN bit in FPROTR before erasure.

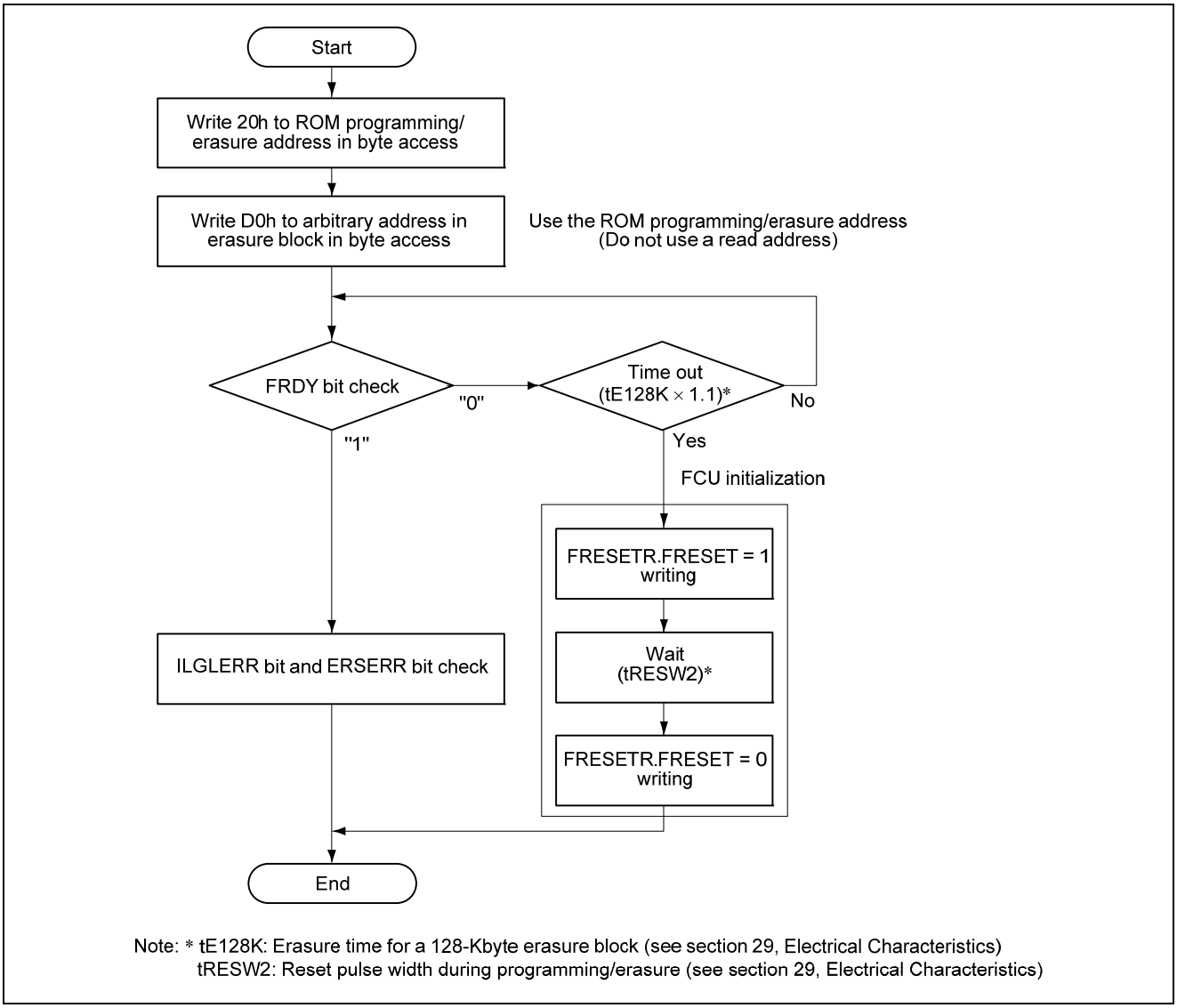


Figure 26.15 Procedure for ROM Erasure

(7) Writing to/Erasing Lock Bit

Each erasure block in the user mat includes a lock bit. To write to a lock bit, use the lock bit programming command. In the first cycle of the lock bit programming command, 77h is programmed to the ROM programming/erasure address in byte access. When D0h is programmed to an arbitrary address in an erasure block whose lock bit is to be programmed in the second cycle in byte access, the FCU start the programming processing of the lock bit. Whether programming is completed can be checked with the FRDY bit in FSTATR0.

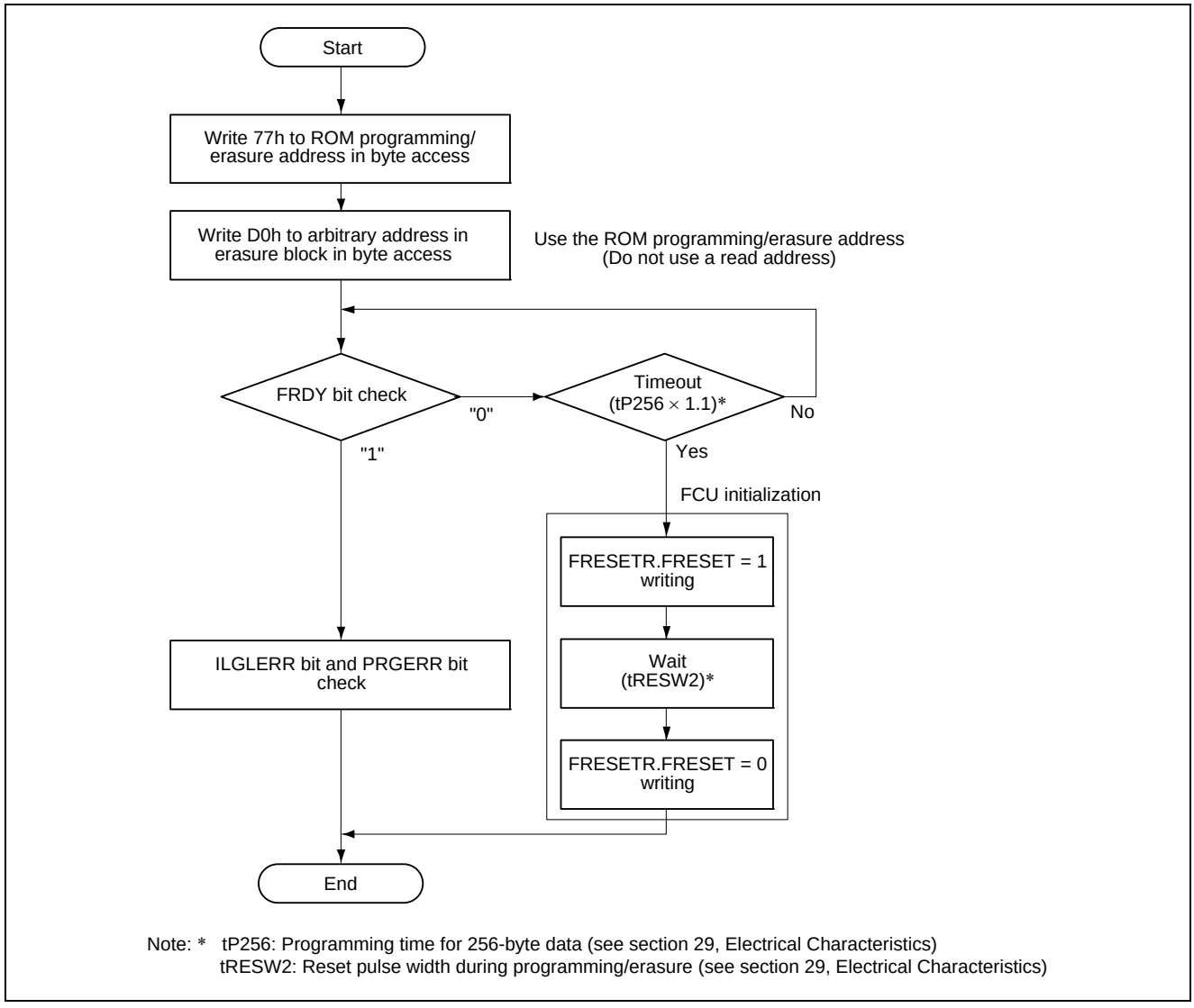


Figure 26.16 Program Setting of the Lock Bit

To erase a lock bit, use the block erase command.

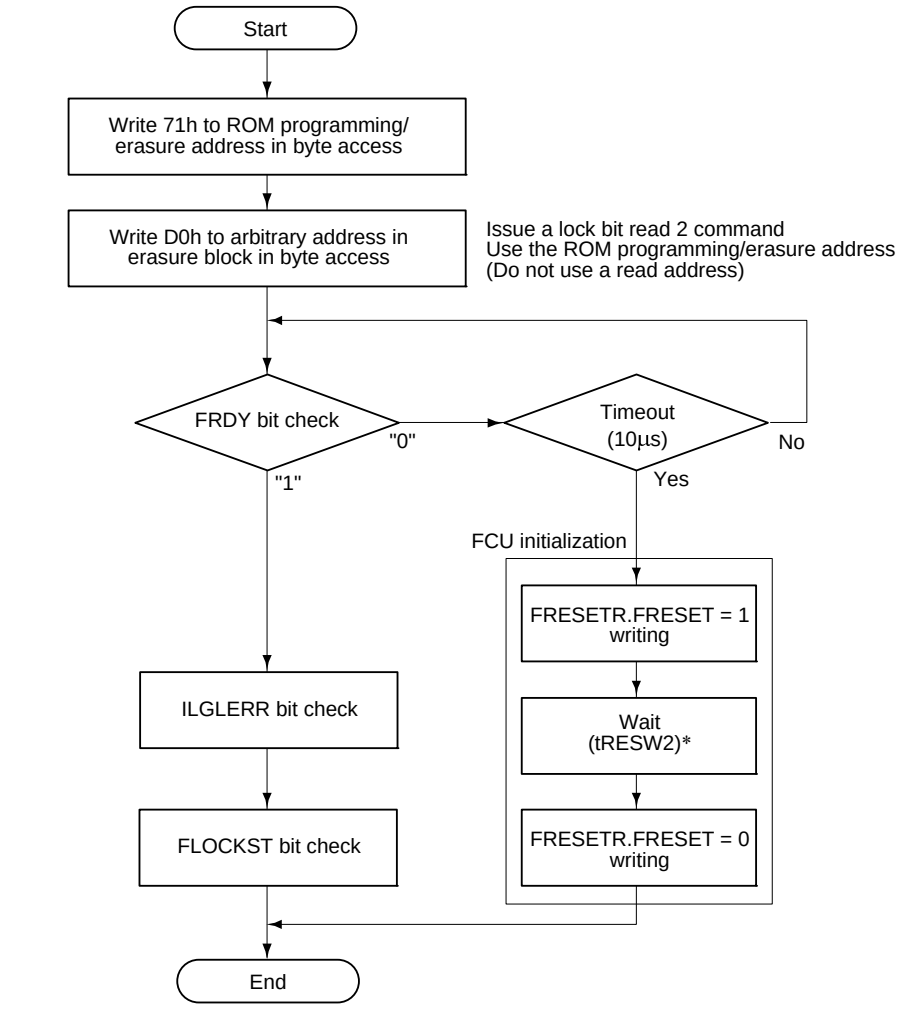
When the FPROTCN bit in FPROTR is 0, erasure blocks whose lock bit is set to 0 cannot be erased. When erasing a lock bit, issue a block erase command with the FPROTCN bit set to 1. Using the block erase command erases all data in the erasure block. It is impossible to erase only a lock bit.

(8) Reading Lock Bits

Lock bits can be read out by either reading from a memory area or reading from a register.

The lock bit read 2 command is issued in the case of the register-reading method (i.e. when the FRDMD bit in FMODR is 1). This command is issued to an address within the block for which the lock bit is to be read out; the address range is that for programming and erasing the ROM. In the first and second cycles of the lock bit read 2 command, the values 71h and D0h are written as bytes; once these values have been written, the value of the lock bit for the specified erasure block is copied to the FLOCKST bit in FSTATR1.

In the case of the memory area reading method (i.e. when the FRDMD bit in FMODR is 0), the FCU is placed in lock-bit reading mode, and the lock bit is obtained by reading from an address within the address range for programming and erasure of the ROM. Details are given in section 26.6.4.1 (5)Switching to ROM Lock-Bit Read Mode.



Note: * tRESW2: Reset pulse width during programming/erasure (see section 29, Electrical Characteristics)

Figure 26.17 Procedure for Reading Lock Bit in Register Read Mode

26.6.4.3 Error Processing

The following passages describe the flow of error processing. For details on errors, see section 26.8, Protection.

(1) Checking Flash Status Register 0 (FSTATR0)

To check FSTATR0, read FSTATR0 directly or read the ROM programming/erasure address in ROM status read mode.

For the reading in ROM status read mode, see section 26.6.4.1 (4)Switching to ROM Status Read Mode.

(2) Clearing Flash Status Register 0 (FSTATR0)

To clear the ILGLERR, ERSERR and PRGERR bits in FSTATR0, use the status register clear command.

When one of the ILGLERR, ERSERR and PRGERR bits in FSTATR0 is 1, the FCU is placed in the command-locked state and receives no FCU commands other than the status register clear command. If the ILGLERR is 1, also check the values of the ROMAE, DFLAE, DFLRPE, and DFLWPE bits in FASTAT. Even if issuing a status register clear command without clearing these bits, the ILGLERR bit is not cleared.

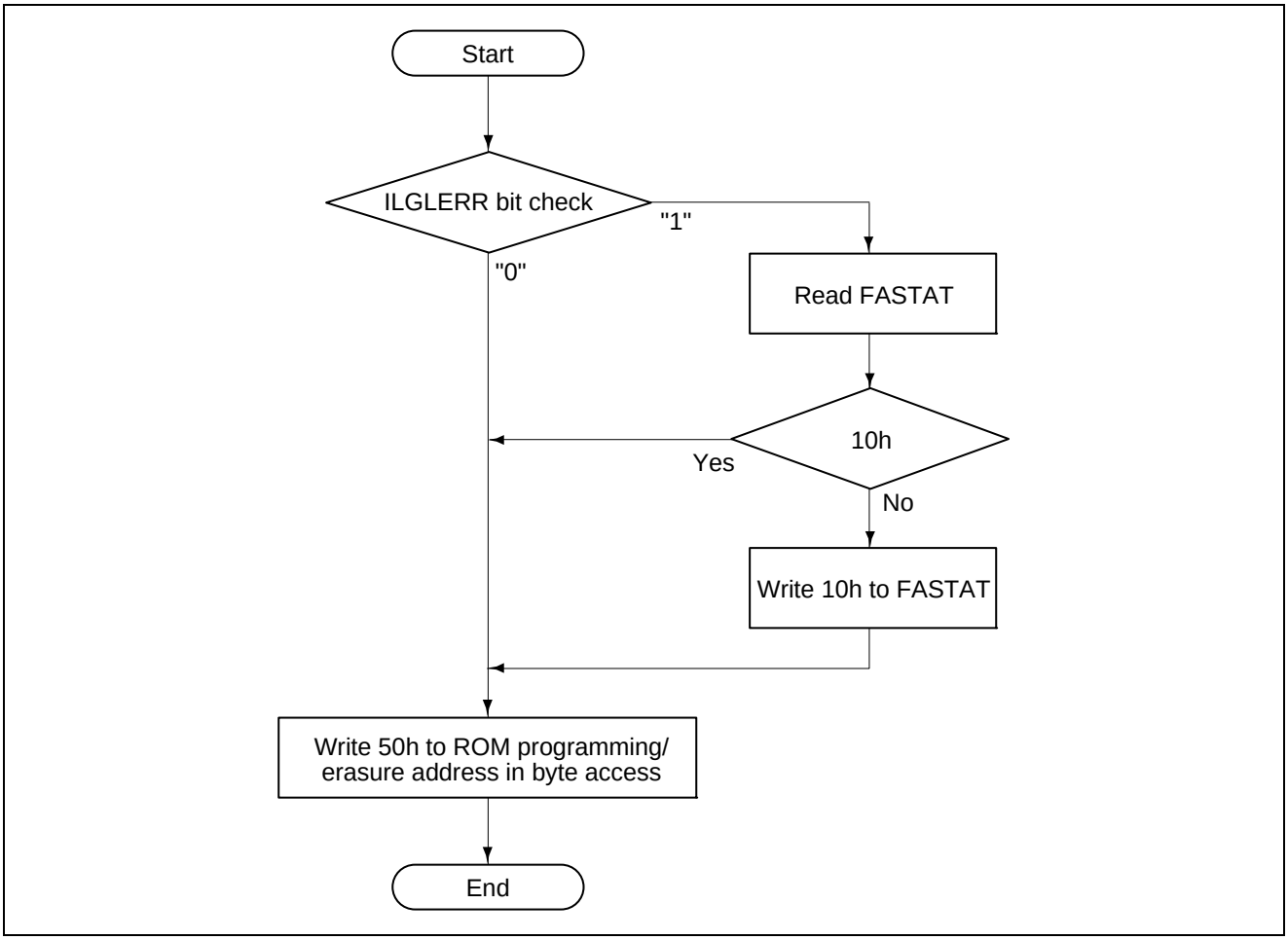


Figure 26.18 Procedure for Clearing FSTATR0

(3) Initializing the FPU

When a timeout leads to the FRDY bit in FSTATR0 not being set to 1 after an FCU command has been issued, FRESETR must be used to initialize the FCU. This is also necessary when the FCUERR bit in FSTATR1 has been set. In either case, maintain the FRESET bit in FRESETR at logical one over a period of at least tRESW2 (see section 28, Electrical Characteristics). Disable reading from the ROM and data-flash memory over this period. In addition, while the FRESET bit is 1, FCU commands are disabled because the FENTRYR register is initialized. Restart the processing from the start, as shown in figure 26.11.

26.6.4.4 Suspension and Resumption

(1) Suspending Programming or Erasure

To suspend programming/erasure for the ROM, use the P/E suspend command.

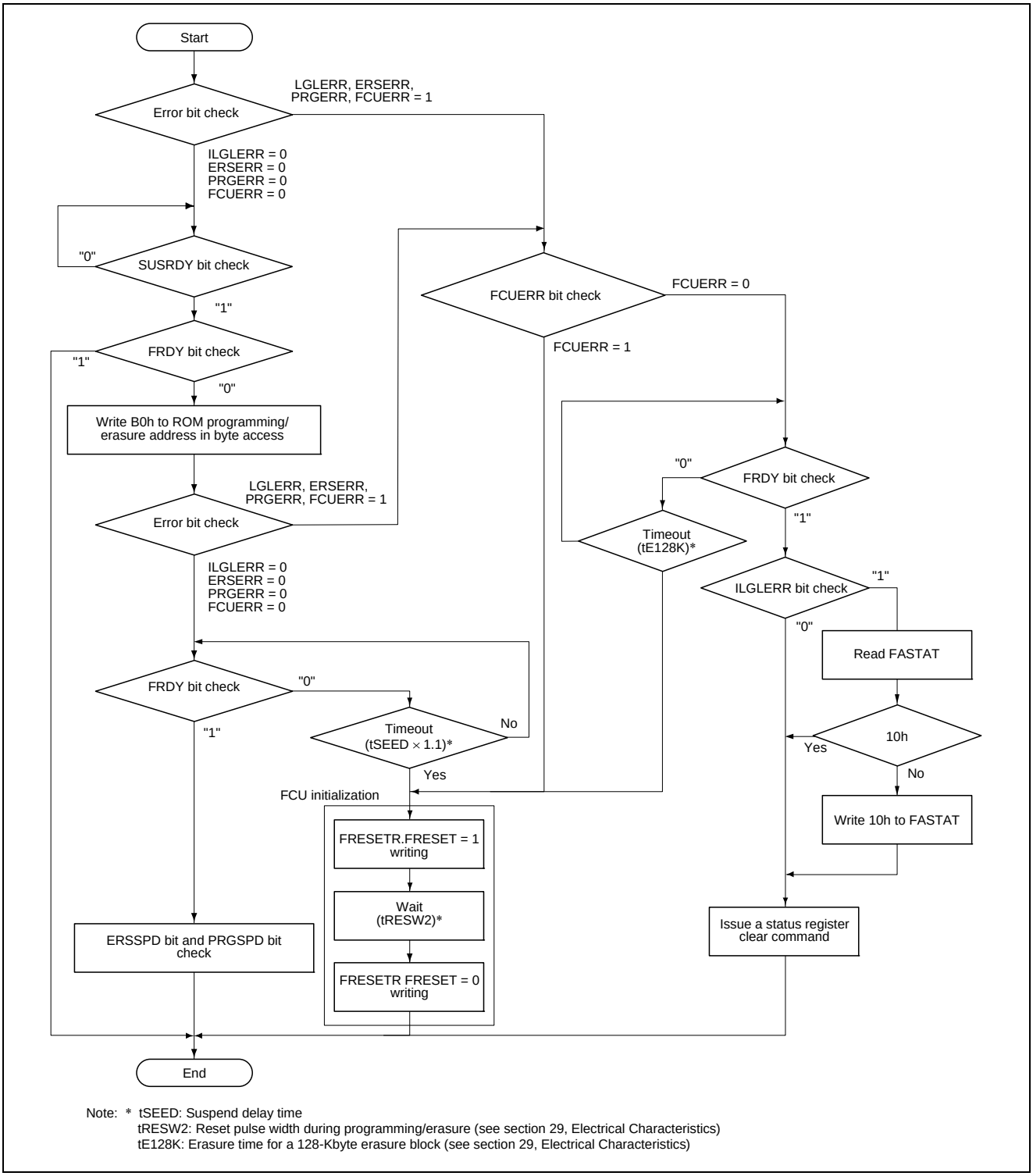
When issuing a P/E suspend command, check that the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the FCUERR bit in FSTATR1 are 0, and the execution of programming/erasure is normally performed. To confirm that the suspend command can be received, also check that the SUSRDY bit in FSTATR0 is 1. After issuing a P/E suspend command, read FSTATR0 and FSTATR1 to confirm that no error occurs.

If an error occurs during programming/erasure, at least one of the ILGLERR, PRGERR, ERSERR, and FCUERR bits is set to 1. When programming/erasure processing has finished during the interval from when it is checked that the SUSRDY bit is 1 to when a P/E suspend command is received, the ILGLERR bit is set to 1 because the issued P/E suspend command is detected as an illegal command.

When programming/erasure processing has finished simultaneously with the reception of a P/E suspend command, no error occurs and the suspended state is not entered (the FRDY bit in FSTATR0 is 1 and the ERSSPD and PRGSPD bits in FSTATR0 are 0). When a P/E suspend command is received and then the programming/erasure suspend processing finishes normally, the FCU enters the suspended state, the FRDY bit is set to 1, and the ERSSPD or PRGSPD bit is set to 1. After issuing a P/E suspend command, check that the ERSSPD or PRGSPD bit is 1 and the FCU enters the suspended state, and then decide the subsequent flow. When issuing a P/E resume command in the subsequent flow although the FCU does not enter the suspended state, an illegal command error occurs and the FCU is placed in the command-locked state (see section 26.8.2, Error Protection).

If the erasure suspended state is entered, programming to blocks other than an erasure target can be performed. Additionally, the programming and erasure suspended states can change to ROM read mode by clearing FENTRYR.

For details on FCU operations at the reception of a P/E suspend command, see section 26.7, Suspending Operation.



Note: * tSEED: Suspend delay time
tRESW2: Reset pulse width during programming/erasure (see section 29, Electrical Characteristics)
tE128K: Erasure time for a 128-Kbyte erasure block (see section 29, Electrical Characteristics)

Figure 26.19 Procedure for Programming/Erasure Suspension

(2) Resuming Programming or Erasure

To resume a suspended programming/erasure processing, use the P/E resume command. When the settings of FENTRYR are changed during suspension, reset FENTRYR to the value immediately before a P/E suspend command is issued, and then issue a P/E resume command.

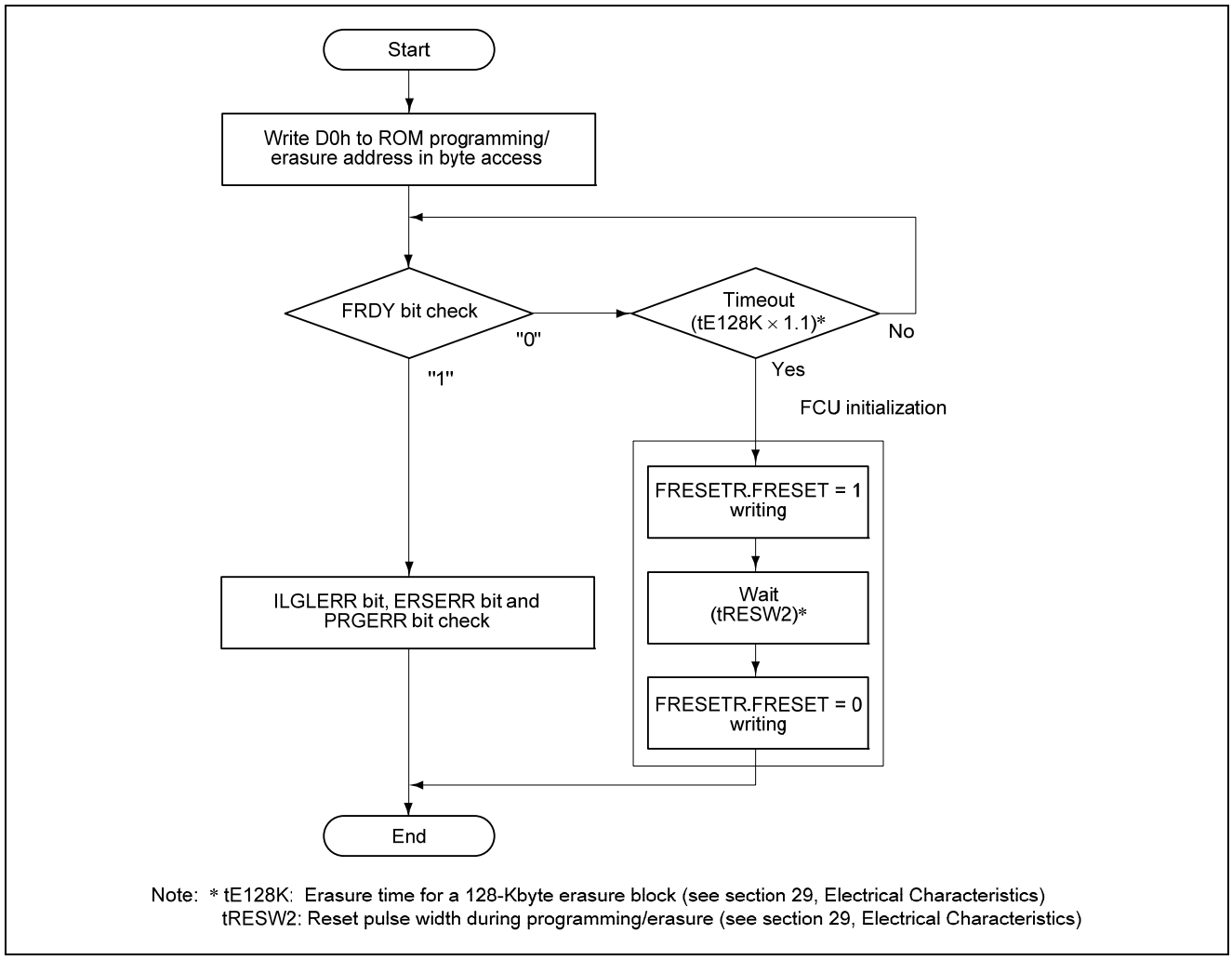


Figure 26.20 Procedure for Resuming Programming or Erasure

26.7 Suspending Operation

The ROM cannot be read out during programming/erasure. The ROM can be read out by suspending the ROM programming/erasure with the P/E suspend command. The P/E suspend command includes one programming mode and two erasure modes (suspension priority mode and erasure priority mode). The P/E resume command that resumes suspended programming/erasure processing is also provided.

26.7.1 Suspension during Programming

When issuing a P/E suspend command during the ROM programming/erasure, the FCU suspends programming processing. Figure 26.21 shows the suspend operation of programming.

When receiving a programming-related command, the FCU clears the FRDY bit in FSTATR0 to 0 to start programming. If the FCU enters the state in which the P/E suspend command can be received after starting programming, the SUSRDY bit in FSTATR0 is set to 1. When a P/E suspend command is issued, the FCU receives the command and clears the SUSRDY bit to 0. If the FCU receives a P/E suspend command while a programming pulse is being applied, the FCU continues applying the pulse. After specified pulse application time, the FCU finishes pulse application, and starts the programming suspend processing and sets the PRGSPD bit in FSTATR0 to 1. When the suspend processing finishes, the FCU sets the FRDY bit to 1 to enter the programming suspended state. If receiving a P/E resume command in the programming suspended state, the FCU clears the FRDY and PRGSPD bits to 0 and resumes programming.

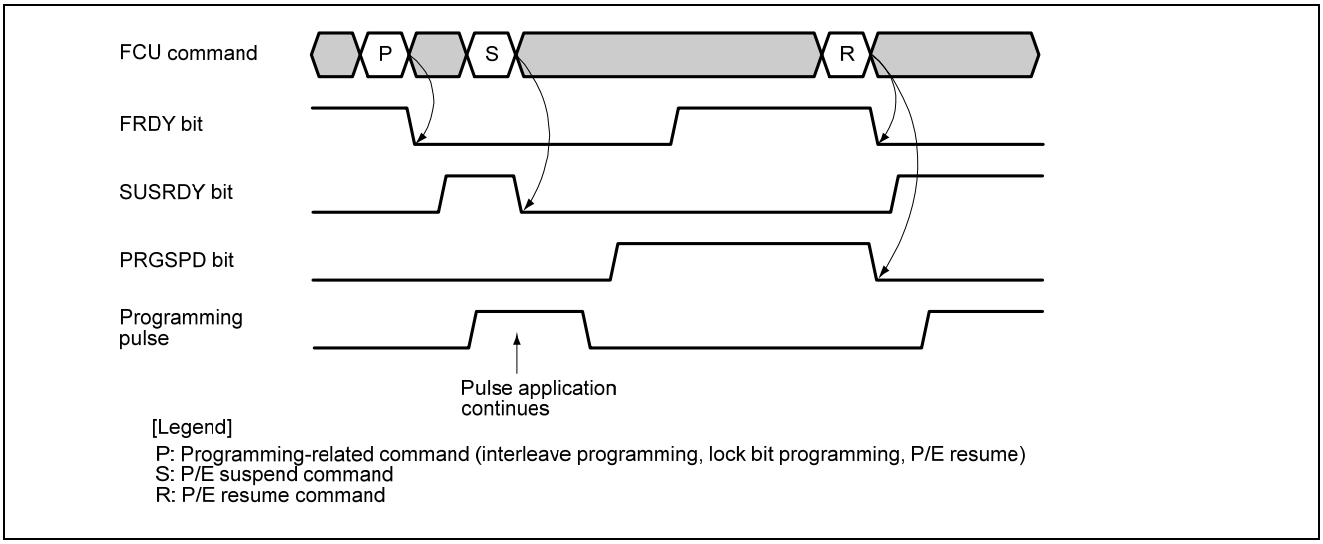


Figure 26.21 Suspension during Programming

26.7.2 Suspension during Erasure (Suspension Priority Mode)

Figure 26.22 shows the suspend operation of erasure when the erasure suspend mode is set to the suspension priority mode (ESUSPMD bit in FCPSR is 0).

When receiving an erasure-related command, the FCU clears the FSTATR0.FRDY bit to 0 to start erasure. If the FCU enters the state in which the P/E suspend command can be received after starting erasure, the FSTATR0.SUSRDY bit is set to 1. When a P/E suspend command is issued, the FCU receives the command and clears the SUSRDY bit to 0. When receiving a suspend command during erasure, the FCU starts the suspend processing and sets the ERSSPD bit in FSTATR0 to 1 even if it is applying an erasure pulse. When the suspend processing finishes, the FCU sets the FRDY bit to 1 to enter the erasure suspended state. If receiving a P/E resume command in the erasure suspended state, the FCU clears the FRDY and ERSSPD bits to 0 and resumes erasure.

The setting of the erasure suspend mode affects the control method of erasure pulses. In suspension priority mode, when receiving a P/E suspend command while erasure pulse A that has never been suspended in the past is being applied, the FCU suspends the application of erasure pulse A and enters the erasure suspended state. When receiving a P/E suspend command while reapplying erasure pulse A after erasure is resumed by a P/E resume command, the FCU continues applying erasure pulse A. After specified pulse application time, the FCU finishes erasure pulse application and enters the erasure suspended state. When the FCU receives a P/E resume command next and erasure pulse B starts to be newly applied, and then the FCU receives a P/E suspend command again, the application of erasure pulse B is suspended. In suspension priority mode, delay due to suspend can be minimized because the application of an erasure pulse is suspended one time per pulse and priority is given to the suspension processing.

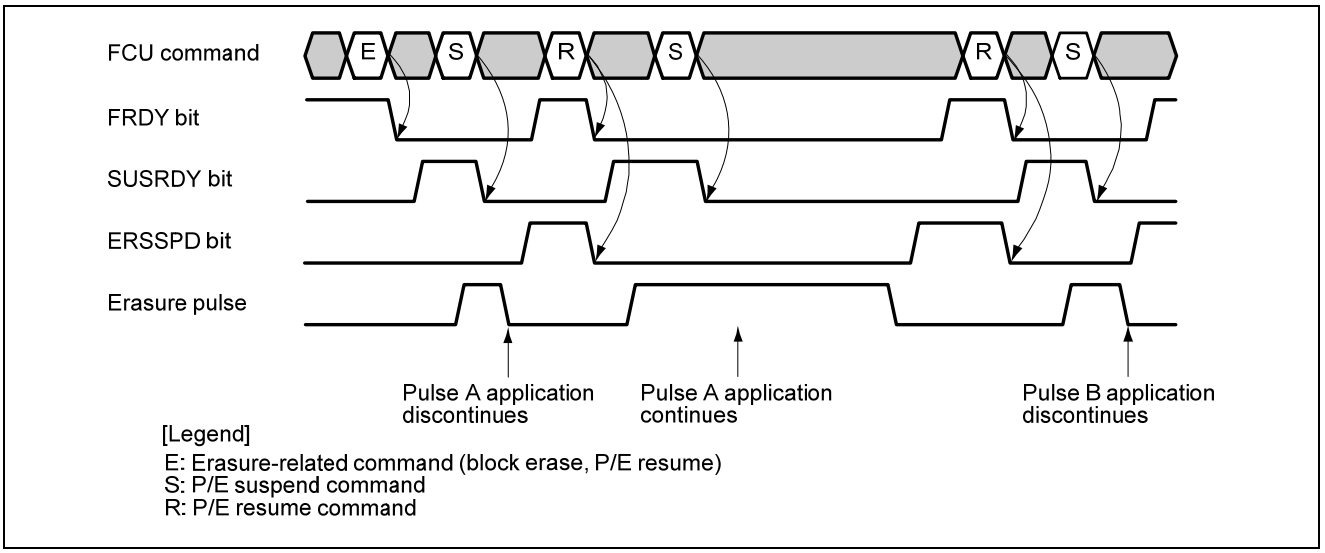


Figure 26.22 Suspension during Erasure (Suspension Priority Mode)

26.7.3 Suspension during Erasure (Erasure Priority Mode)

Figure 26.23 shows the suspend operation of erasure when the erasure suspend mode is set to the erasure priority mode (ESUSPMD bit in FCPSR is 1). The control method of erasure pulses in erasure priority mode is the same as that of programming pulses for the programming suspend processing.

If the FCU receives a P/E suspend command while an erasure pulse is being applied, the FCU definitely continues applying the pulse. In this mode, required time for the whole erasure processing can be reduced as compared with the suspension priority mode because the reapplication of erasure pulses does not occur when a P/E resume command issued.

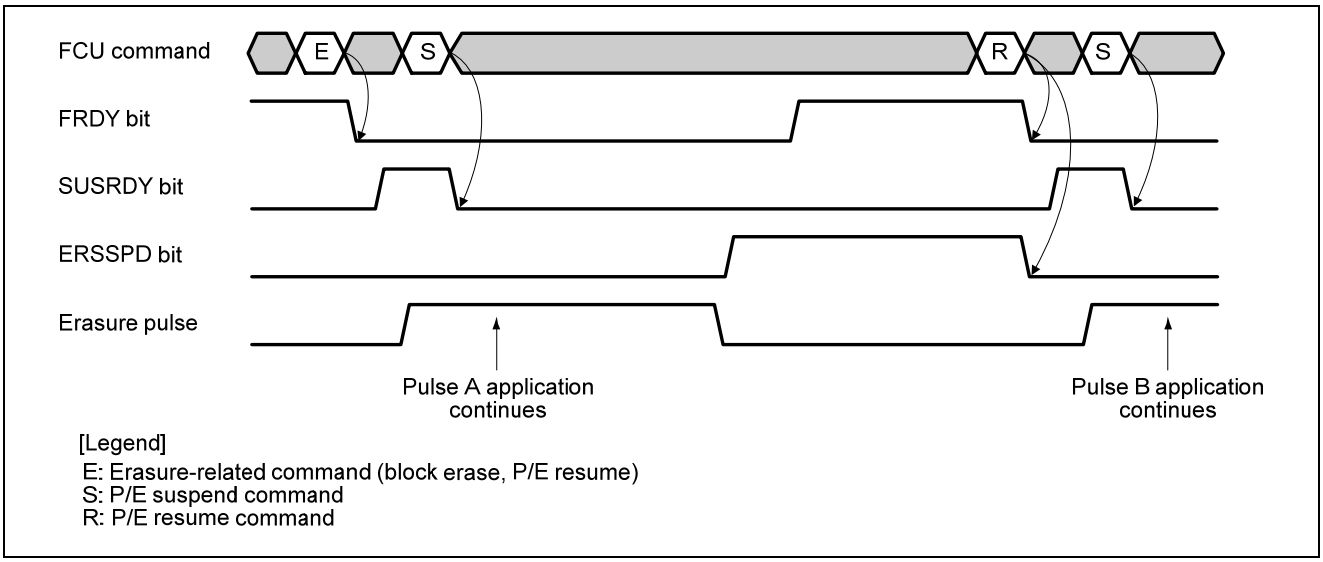


Figure 26.23 Suspension during Erasure (Erasure Priority Mode)

26.8 Protection

Protection against programming/erasure for the ROM includes software protection and error protection.

26.8.1 Software Protection

With the software protection, the ROM programming/erasure is prohibited by the settings of the control register or user mat lock bit. When the software protection is violated and a ROM programming/erasure-related command is issued, the FCU detects an error and enters the command-locked state.

(1) Protection through FWEPROR

If the FLWE[1:0] bits in FWEPROR are not set to 01b, programming cannot be performed in any of the modes.

(2) Protection through FENTRYR

When the FENTRY1* and FENTRY0 bits in FENTRYR are 0, ROM read mode is selected. Because the FCU command cannot be received in ROM read mode, ROM programming/erasure is prohibited. When an FCU command is issued in ROM read mode, the FCU detects an illegal command error and is placed in the command-locked state (see section 26.8.2, Error Protection).

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

(3) Protection through Lock Bit

Each erasure block in the user mat includes a lock bit. When the FPROTCN bit in FPROTR is 0, erasure blocks whose lock bit is set to 0 are prohibited from being programmed/erased. To program or erase erasure blocks whose lock bit is set to 0, set the FPROTCN bit to 1. When the lock bit protection is violated and a ROM programming/erasure-related command is issued, the FCU detects a programming/erasure error and enters the command-locked state (see section 26.8.2, Error Protection).

26.8.2 Error Protection

With the error protection, FCU command issuance errors, prohibited access occurrences, and FCU malfunctions are detected, and an FCU command is prohibited from being received (command-locked state). When the FCU enters the command-locked state (FASTAT.CMDLK bit is 1), one or several of the status bits (FSTATR0.ILGLERR, ERSERR, and PRGERR bits, FSTATR1.FCUERR bit, and FASTST.ROMAE bit) are set to 1 and programming and erasure of the ROM are prohibited. To clear the command-locked state, a status register clear command must be issued with FASTAT set to 10h.

While the CMDLKIE bit in FAEINT is set to 1, if the FCU is placed in the command-locked state (CMDLK bit in FASTAT is set to 1), a flash interface error (FIFERR) interrupt occurs. While the ROMAEIE bit in FAEINT is set to 1, if the ROMAE bit in FASTAT is set to 1, an FIFERR interrupt occurs.

Table 26.10 lists the relationship between the contents of the ROM-related error protection and status bit values (ILGLERR, ERSERR, PRGERR bits in FSTATR0, FCUERR bit in FSTATR1, ROMAE bit in FASTAT) at error detection. If a command other than the suspend command is issued during programming/erasure and the FCU enters the command-locked state, it continues the programming/erasure. In this state, it is impossible to issue a P/E suspend command and suspend programming/erasure. When a command is issued in the command-locked state, the ILGLERR bit is set to 1.

Table 26.10 Error Protection Types (Types Dedicated to ROM and Types Common to ROM and Data Flash)

Type	Description	ILGLERR	ERSERR	PRGERR	FCUERR	ROMAE	CMDLK
FENTRYR setting error	More than one bit is set to 1 among the FENTRYD, FENTRY1*, and FENTRY0 bits in FENTRYR	1	0	0	0	0	1
	The FENTRYR setting at suspension disagrees with that at resume	1	0	0	0	0	1
Illegal command error	Undefined code is specified in the first cycle of an FCU command	1	0	0	0	0	1
	Other than D0h is specified in the last cycle of a multi-cycle FCU command	1	0	0	0	0	1
	A command other than the suspend command is issued during programming/erasure	1	0	0	0	0	1
	A suspend command is issued during processing other than programming/erasure	1	0	0	0	0	1
	A suspend command is issued in the suspended state	1	0	0	0	0	1
	A resume command is issued in other than the suspended state	1	0	0	0	0	1
	A programming/erasure-related (programming/lock bit programming/block erase) command is issued in the programming suspended state	1	0	0	0	0	1
	A block erase command is issued in the erasure suspended state	1	0	0	0	0	1
	A programming or lock bit programming command is issued to an erasure suspend target area in the erasure suspended state	1	0	0	0	0	1
	Other than 80h is specified in the second cycle of the programming command	1	0	0	0	0	1
	A command is issued in the command-locked state	1	0/1	0/1	0/1	0/1	1
Erasure error	An error occurs during erasure	0	1	0	0	0	1
	When the FPROTCN bit in FPROTR is 0, a block erase command is issued to a erasure block whose lock bit is set to 0	0	1	0	0	0	1
Programming error	An error occurs during programming	0	0	1	0	0	1
	When the FPROTCN bit in FPROTR is 0, a programming or lock bit programming command is issued to a erasure block whose lock bit is set to 0	0	0	1	0	0	1
FCU error	An error occurs during FCU internal processing	0	0	0	1	0	1
ROM access violation	When the FENTRY1* bit in FENTRYR is 1 and the FCU is in P/E normal mode, a read command is issued for addresses 00E0 0000h to 00EF FFFFh	1	0	0	0	1	1
	When the FENTRY0 bit in FENTRYR is 1 and the FCU is in P/E normal mode, a read command is issued for addresses 00F0 0000h to 00FF FFFFh	1	0	0	0	1	1
	When the FENTRY1* bit in FENTRYR is 0, a command is issued for addresses 00E0 0000h to 00EF FFFFh	1	0	0	0	1	1
	When the FENTRY0 bit in FENTRYR is 0, a command is issued for addresses 00F0 0000h to 00FF FFFFh	1	0	0	0	1	1
	A read command is issued for addresses FFE0 0000h to FFFF FFFFh when FENTRYR is set to other than 0000h	1	0	0	0	1	1

Note: * Cannot be used in a product whose ROM size is equal to or smaller than 1 Mbyte.

26.9 User Boot Mode

When the reset clearing is executed with the MD1 and MD0 pins set to user boot mode, the FCU enters user boot mode. The reset vector at this time is address FF7F FFFCh in the user boot mat. For other vector tables, see the normal vector table (see section 10, Interrupt Control Unit (ICU)).

In user boot mode, software for programming with an arbitrary interface can be prepared, and the user mat or data mat can be programmed/erased by issuing an FCU command. Programming for the user boot mat should be performed only in boot mode.

26.10 Boot Mode

26.10.1 System Configuration

In boot mode, the host sends control commands and data for programming, and the user mat, user boot mat, and data mat are programmed or erased accordingly. An on-chip SCI handles transfer between the host and RX610 in asynchronous mode. Tools for the transmission of control commands and the data for programming must be prepared in the host.

When the RX610 is activated in boot mode, the program on the mat that holds the embedded program is executed. This program automatically adjusts the bit rate of the SCI and controls programming/erasure by receiving control commands from the host.

Figure 26.24 shows the system configuration for operations in boot mode.

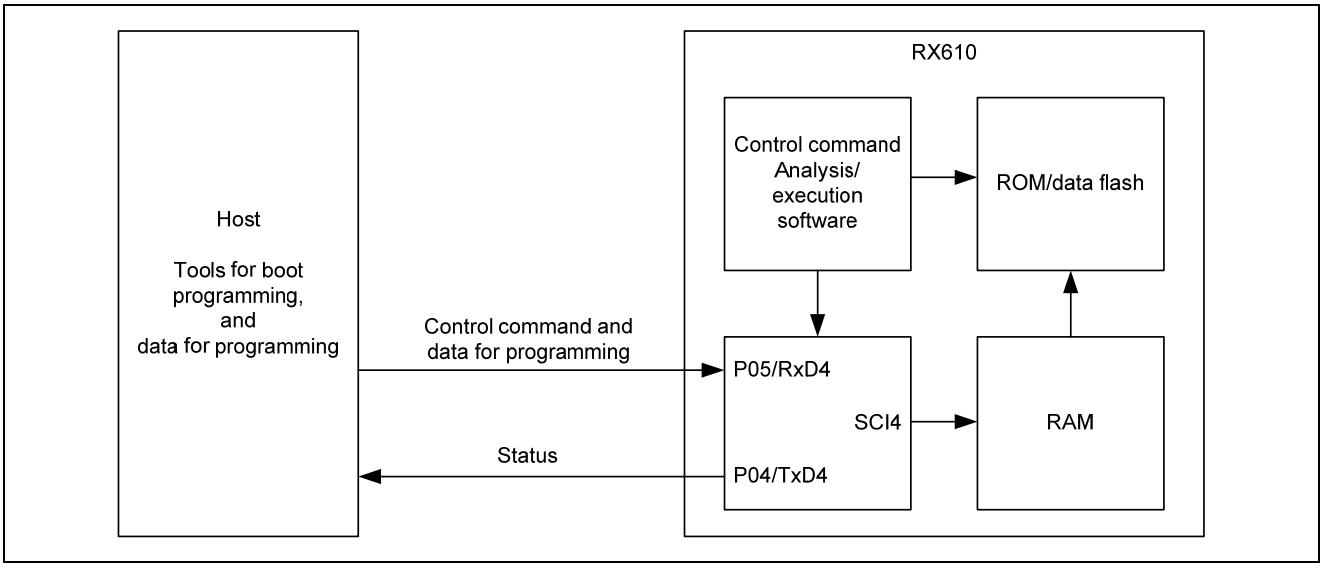


Figure 26.24 System Configuration for Operations in Boot Mode

26.10.2 ID Code Protection

This function is used to prohibit reading/programming/erasure from the host.

Using the control code and ID code written in the ROM, ID code protection is enabled or disabled and ID code protection is judged. When ID code protection is enabled, the code sent from the host is compared with the control code and ID code in the ROM to determine whether they match, and reading/programming/erasure will be enabled only when the two match.

The control code and ID code in the ROM consists of four 32-bit words. Figure 26.25 shows the configuration of the control code and ID code. The ID code should be set in 32-bit units.

	31 24	23 16	15 8	7 0
FFFF FFA0h	Control code	ID code 1	ID code 2	ID code 3
FFFF FFA4h	ID code 4	ID code 5	ID code 6	ID code 7
FFFF FFA8h	ID code 8	ID code 9	ID code 10	ID code 11
FFFF FFACh	ID code 12	ID code 13	ID code 14	ID code 15

Figure 26.25 Configuration of Control Code and ID Code in ROM

(1) Control Code

The control code determines whether ID code protection is or is not enabled and the method of authentication to use with the host. Table 26.11 shows how the control code determines the method of authentication

Table 26.11 Specifications for ID Code Protection

Control Code	ID Code	State of Protection	Operations at the Time of SCI Connection
45h	As desired	Protection enabled (authentication method 1)	Matching ID code: ID code protection is lifted, and this is followed by a transition to the state of waiting for a host command. Non-matching ID code: Up to two more transitions to the ID code protection waiting state; complete erasure if a non-matching ID code is received for a third time.
52h	Sequences other than 50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh	Protection enabled (authentication method 2)	Matching ID code: ID code protection is lifted, and this is followed by a transition to the state of waiting for a host command. Non-matching ID code: Further transition to the ID code protection waiting state
	50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh	Protection enabled (authentication method 3)	Always judged to be a non-matching ID code.
Other than the above	—	Protection disabled	Erasure of all blocks

(2) ID Code

The ID code can be set to any desired value. However, if the control code is 52h and the ID code is 50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh (from the ID code 1 field), there is no determination of matching and the ID code is always considered to be non-matching. Accordingly, reading, programming, and erasure from the host are prohibited.

(3) Example of Assembler Directives for Setting an ID Code

The following assembler directives set up a control code of 45h and an ID code of 01h, 02h, 03h, 04h, 05h, 06h, 07h, 08h, 0Ah, 0Bh, 0Ch, 0Dh, 0Eh, 0Fh (from the ID code 1 field).

```
.SECTION    ID_CODE,CODE
.ORG        0FFFFFFA0h
.LWORD      45010203h
.LWORD      04050607h
.LWORD      08090A0Bh
.LWORD      0C0D0E0Fh
```

26.10.3 State Transitions in Boot Mode

Figure 26.26 is a diagram of the state transitions in boot mode.

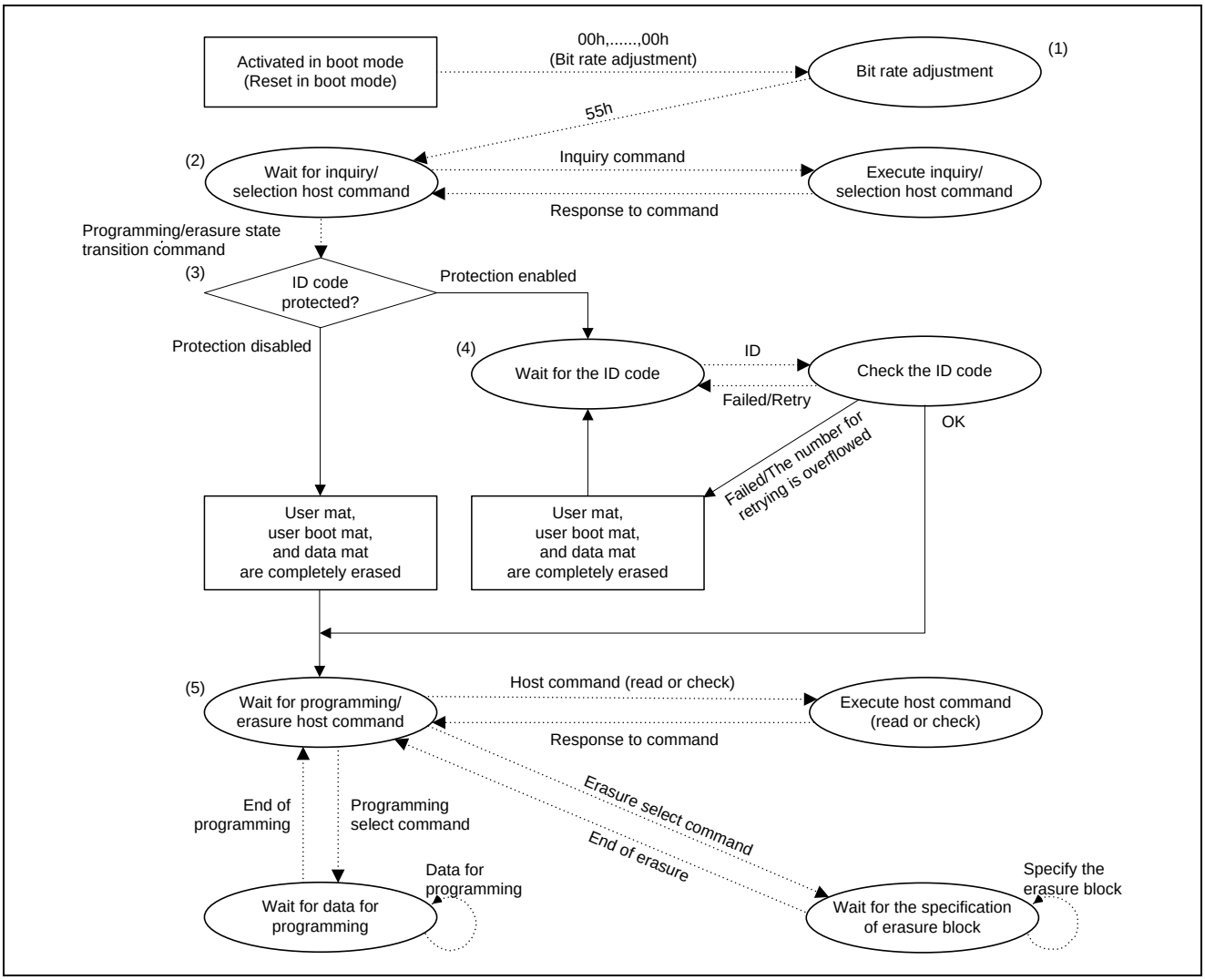


Figure 26.26 State Transitions in Boot Mode

(1) Matching the Bit Rates

When the RX610 is activated in boot mode, the bit rate of the SCI is automatically adjusted to match that of the host. On completion of this adjustment, the RX610 transmits the value 00h to the host. On subsequent correct reception of the value 55h sent from the host, the RX610 enters the state of waiting for a host command for inquiry or selection. For details on matching of the bit rates, see section 26.10.4, Automatic Adjustment of the Bit Rate.

(2) Waiting for a Host Command for Inquiry or Selection

This state is for inquiries on mat size, mat configuration, the addresses where mats start, the state of support etc., and for selection of the device, clock mode, and bit rate. The RX610 receives a programming/erasure state transition command issued by the host and then enters the state to determine whether ID code protection is enabled or disabled. For the inquiry/selection host commands, see section 26.10.5, Inquiry/Selection Host Command Wait State.

(3) Judging ID Code Protection

This state is for determining whether ID code protection is enabled or disabled. The control code and ID code written in the ROM are used to determine whether ID code protection is enabled or disabled. When enabled, the state of waiting for the ID code is entered. When disabled, the user mat, user boot mat, and data mat are all completely erased, and the state of waiting for programming and erasure commands from the host is entered. For details on the control code and ID code, see section 26.10.2, ID Code Protection.

(4) Waiting for an ID Code

This state is for waiting for the control code and ID code to be sent from the host. The control code and ID code sent by the host are compared with the code stored in the ROM, and the state of waiting for programming and erasure commands from the host is entered if the two match. If they do not match, the next transition is back to the state of waiting for an ID code. However, if the ID codes fail to match three times in a row and also the state of protection is authentication method 1, the ROM is completely erased, and the state of waiting for an ID code is entered again. A reset is required to release the system from this state due to non-matching ID codes. For details on the control code and ID code, see section 26.10.2, ID Code Protection.

(5) Waiting for a Host Command for Programming or Erasure

In this state, programming and erasure proceed in accordance with commands from the host. In response to the reception of a command, the RX610 enters the state of waiting for the data to use in programming, waiting for specification of the erasure block to be erased, or executing the processing of commands for reading, fetching and so on.

When the RX610 receives a programming selection command, it enters the state of waiting for the data to use in programming. After the host has issued the programming selection command, the process continues with the address where programming is to start and then the data for programming. Setting of FFFF FFFFh as the address where programming is to start indicates the completion of programming, and the next transition is from the state of waiting for the data to use in programming to the state of waiting for programming and erasure commands.

When the RX610 receives a programming selection command, it enters the state of waiting for specification of the erasure block to be erased. After the host has issued the programming selection command, the process continues with the number of the erasure block to be erased. Setting of FFh as the number of the erasure block indicates the completion of erasure, and the next transition is from the state of waiting for specification of the erasure block to the state of waiting for programming and erasure commands. Since the user mat, user boot mat, and data mat are all completely erased during the interval between booting up in boot mode and transition to the state of waiting for programming and erasure

commands, explicit execution of erasure is not necessary unless newly programmed data are to be erased without a further reset.

Other than the programming and erasure commands, commands from the host for execution in this state include those for sum checking of the user mat and user boot mat, blank checking (to confirm erasure), reading from memory, and acquiring state information.

26.10.4 Automatic Adjustment of the Bit Rate

When the RX610 is booted up in boot mode, asynchronous transfer by the SCI is used to measure the periods at low level of consecutive bytes with value 00h that are sent from the host. While the period at low level is being measured, set the host's SCI parameters to eight-bit data, one stop bit, no parity, and a transfer rate of 9,600 bps or 19,200 bps. The RX610 calculates the host's SCI bit rate from the measured periods at low level, adjusts its own bit rate accordingly, and then sends a 00h byte to the host. If reception of the value 00h by the host is normal, the host responds by sending the value 55h to the RX610. If normal reception of 00h by the host is not possible, the RX610 is re-booted in boot mode, and then repeats the process of automatically adjusting the bit rate. If reception of the value 55h by the RX610 is normal, it responds by sending E6h to the host, and if normal reception of 55h by the RX610 is not possible, it responds by sending FFh to the host.

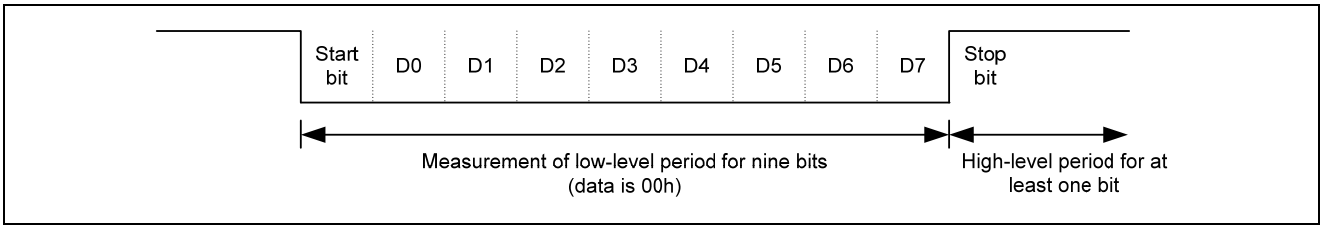


Figure 26.27 Transfer Format Used by the SCI in Automatic Adjustment of the Bit Rate

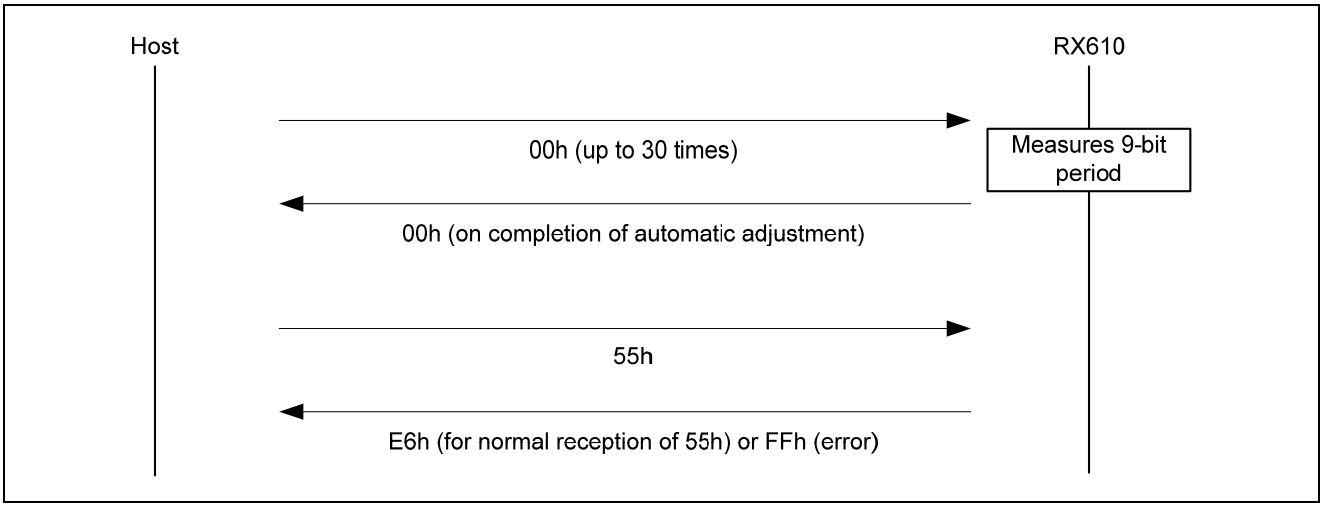


Figure 26.28 Sequence of Transfer between the Host and RX610

Since the bit rate of the RX610's SCI module depends on the frequency of the peripheral clock, adjustment to match the bit rate of the host will not be possible under some conditions. Accordingly, ensure that SCI transfer is under the conditions given in table 26.12.

Table 26.12 Conditions for Automatic Bit-Rate Adjustment to be Possible

Bit Rate of the SCI in the Host	Range of Frequency for the EXTAL Signal
9,600 bps	8 to 14 MHz
19,200 bps	8 to 14 MHz

26.10.5 Inquiry/Selection Host Command Wait State

Table 26.13 shows the host commands available in the inquiry/selection host command wait state. The embedded program status inquiry command can also be used in the programming/erasure host command wait state. The other commands can only be used in the inquiry/selection host command wait state.

Table 26.13 Inquiry/Selection Host Commands

Host Command Name	Function
Supported device inquiry	Inquires regarding the device codes and the product codes for the embedded programs
Device selection	Selects a device code
Clock mode inquiry	Inquires regarding the clock mode
Clock mode selection	Notifies the selected clock mode
Multiplication ratio inquiry	Inquires regarding the number of clock types, the number of multiplication/division ratios, and the multiplication /division ratios
Operating frequency inquiry	Inquires regarding the number of clock types and the maximum and minimum operating frequencies
User boot mat information inquiry	Inquires regarding the number of user boot mats and the start and end addresses
User mat information inquiry	Inquires regarding the number of user mats and the start and end addresses
Erasure block information inquiry	Inquires regarding the number of blocks and the start and end addresses
Programming size inquiry	Inquires regarding the size of programming data
New bit rate selection	Modifies the bit rate of SCI communications between the host and RX610
Programming/erasure state transition	Enters the state for determining ID code protection
Embedded program status inquiry	Inquires regarding the processing state

If the host has sent an undefined command, the RX610 returns a response indicating a command error in the format shown below. The command field holds the first byte of the undefined command sent from the host.

Error response	80h	Command

In the inquiry/selection host command wait state, send selection commands from the host in the order of device selection, clock mode selection, and new bit rate selection to set up the RX610 according to the responses to inquiry commands. Note that the supported device inquiry and clock mode inquiry commands are the only inquiry commands that can be sent before the clock mode selection command; other inquiry commands must not be issued before the clock mode selection command. If commands are issued in an incorrect order, the RX610 returns a response indicating a command error. Figure 26.29 shows an example of the procedure to use inquiry/selection host commands.

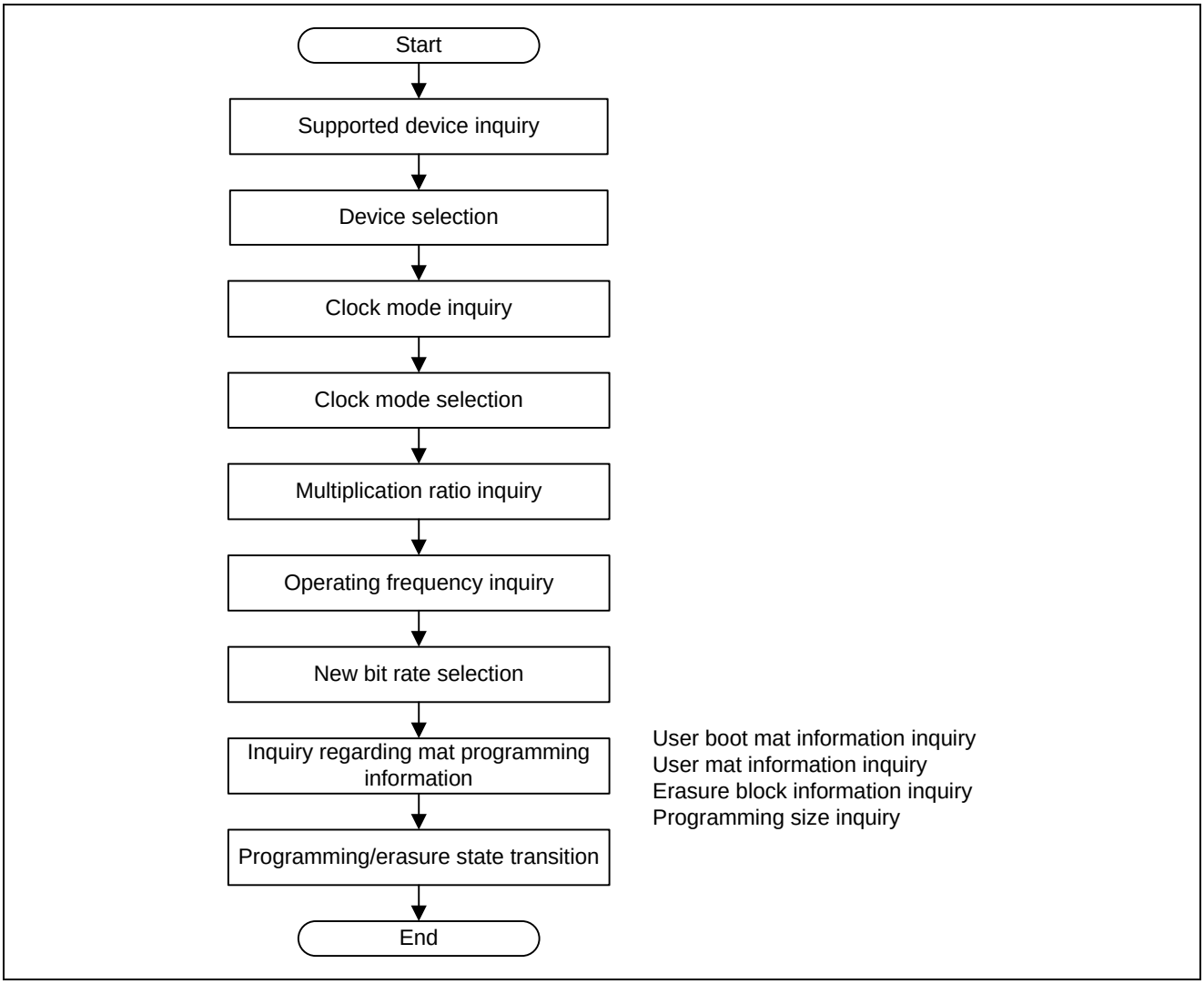


Figure 26.29 Example of Procedure to Use Inquiry/Selection Host Commands for User Mat/User Boot Mat

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX610 and the "response" indicates a response sent from the RX610 to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX610 becomes 00h.

(1) Supported Device Inquiry

In response to a supported device inquiry command sent from the host, the RX610 returns the information concerning the devices supported by the embedded program for boot mode. If the supported device inquiry command comes after the host has selected a device, the RX610 only returns the information concerning the selected device.

Command

20h

Response

30h	Size	Device count
Character count	Device code	Product code
Character count	Device code	Product code
:	:	:
Character count	Device code	Product code
SUM		

[Legend]

Size (1 byte): Total number of bytes in the device count, character count, device code, and product code fields

Device count (1 byte): Number of device types supported by the embedded program for boot mode

Character count (1 byte): Number of characters included in the device code and product code fields

Device code (4 bytes): ASCII code for the product name of the chip

Product code (n bytes): ASCII code for the supported device

SUM (1 byte): Checksum (in response)

(2) Device Selection

In response to a device selection command sent from the host, the RX610 checks if the selected device is supported. When the selected device is supported, the RX610 specifies this device as the device for use and returns a response (06h). If the selected device is not supported or the sent command is illegal, the RX610 returns an error response (90h).

Even when 01h has been returned as the number of supported devices in response to a supported device inquiry command, issue a device selection command to specify the device code that has been returned as the result of the inquiry.

Command	10h	Size	Device code	SUM
Response	06h			
Error response	90h	Error		

[Legend]

Size (1 byte): Number of characters in the device code field (fixed at four)

Device code (4 bytes): ASCII code for the product name of the chip (one of the device codes returned in response to the supported device inquiry command)

SUM (1 byte): Checksum

Error (1 byte): Error code
11h: Checksum error (illegal command)
21h: Incorrect device code error

(3) Clock Mode Inquiry

In response to a clock mode inquiry command sent from the host, the RX610 returns the supported clock modes. If the clock mode inquiry command comes after the host has selected a clock mode, the RX610 only returns the information concerning the selected clock mode.

Command	21h			
Response	31h	Size		
	Mode	Mode	. . .	Mode
	SUM			

[Legend]

Size (1 byte): Total number of bytes in the mode count and mode fields

Mode (1 byte): Supported clock mode (for example, 01h indicates clock mode 1)

SUM (1 byte): Checksum

(4) Clock Mode Selection

In response to a clock mode selection command sent from the host, the RX610 checks if the selected clock mode is supported. When the selected mode is supported, the RX610 specifies this clock mode for use and returns a response (06h). If the selected mode is not supported or the sent command is illegal, the RX610 returns an error response (91h).

Be sure to issue a clock mode selection command only after issuing a device selection command. Even when 00h or 01h has been returned as the number of supported clock modes in response to a clock mode inquiry command, issue a clock mode selection command to specify the clock mode that has been returned as the result of the inquiry.

Command	11h	Size	Mode	SUM
Response	06h			
Error response	91h	Error		

[Legend]

Size (1 byte): Number of characters in the mode field (fixed at 1)

Mode (1 byte): Clock mode (same mode as the response to the clock mode inquiry command)

SUM (1 byte): Checksum

Error (1 byte): Error code
11h: Checksum error (illegal command)
21h: Incorrect clock mode error

(5) Multiplication Ratio Inquiry

In response to a multiplication ratio inquiry command sent from the host, the RX610 returns the clock types, the number of multiplication/division ratios, and the multiplication division ratios supported.

Command

22h

Response

32h	Size	Clock type count		
Multiplication ratio count	Multiplication ratio	Multiplication ratio	. . .	Multiplication ratio
Multiplication ratio count	Multiplication ratio	Multiplication ratio	. . .	Multiplication ratio
:	:	:	. . .	:
Multiplication ratio count	Multiplication ratio	Multiplication ratio	. . .	Multiplication ratio
SUM				

[Legend]

Size (1 byte): Total number of bytes in the clock type count, multiplication ratio type, and multiplication ratio fields

Clock type count (1 byte): Number of clock types (for example, 02h indicates two clock types; that is, a system clock and a peripheral clock)

Multiplication ratio count (1 byte): Number of supported multiplication/division ratios (for example, 04h indicates that four multiplication ratios are supported for the system clock (x1, x2, x4, and x8))

Multiplication ratio (1 byte): A positive value indicates a multiplication ratio (for example, 04h = 4 = multiplication by 4)
A negative value indicates a division ratio (for example, FEh = -2 = division by 2)

SUM (1 byte): Checksum

(6) Operating Clock Frequency Inquiry

In response to an operating clock frequency inquiry command sent from the host, the RX610 returns the minimum and maximum frequencies for each clock.

Command	23h

Response	33h	Size	Clock type count
	Minimum frequency		Maximum frequency
	Minimum frequency		Maximum frequency
	:		:
	Minimum frequency		Maximum frequency
	SUM		

[Legend]

Size (1 byte): Total number of bytes in the clock type count, minimum frequency, and maximum frequency fields

Clock type count (1 byte): Number of clock types (for example, 02h indicates two clock types; that is, a system clock and a peripheral clock)

Minimum frequency (2 bytes): Minimum value of the operating frequency (for example, 07D0h indicates 20.00 MHz).
This value should be calculated by multiplying the frequency value (MHz) to two decimal places by 100.

Maximum frequency (2 bytes): Maximum value of the operating frequency represented in the same format as the minimum frequency

SUM (1 byte): Checksum

(7) User Boot Mat Information Inquiry

In response to a user boot mat information inquiry command sent from the host, the RX610 returns the number of user boot mat areas and their addresses.

Command	24h		
Response	34h	Size	Area count
	Area start address		
	Area end address		
	Area start address		
	Area end address		
	:		
	Area start address		
	Area end address		
	SUM		

[Legend]

Size (1 byte): Total number of bytes in the area count, area start address, and area end address fields

Area count (1 byte): Number of user boot mat areas (consecutive areas are counted as one area)

Area start address (4 bytes): Start address of a user boot mat area

Area end address (4 bytes): End address of a user boot mat area

SUM (1 byte): Checksum

(8) User Mat Information Inquiry

In response to a user mat information inquiry command sent from the host, the RX610 returns the number of user mat areas and their addresses.

Command	25h		
Response	35h	Size	Area count
	Area start address		
	Area end address		
	Area start address		
	Area end address		
	:		
	Area start address		
	Area end address		
	SUM		

[Legend]

Size (1 byte): Total number of bytes in the area count, area start address, and area end address fields

Area count (1 byte): Number of user mat areas (consecutive areas are counted as one area)

Area start address (4 bytes): Start address of a user mat area

Area end address (4 bytes): End address of a user mat area

SUM (1 byte): Checksum

(9) Erasure Block Information Inquiry

In response to an erasure block information inquiry command sent from the host, the RX610 returns the number of erasure blocks in the user mat and their addresses.

Command	26h		
Response	36h	Size	Block count
	Block start address		
	Block end address		
	Block start address		
	Block end address		
	:		
	Block start address		
	Block end address		
	SUM		

[Legend]

Size (1 byte): Total number of bytes in the block count, block start address, and block end address fields

Block count (1 byte): Number of erasure blocks in the user mat

Block start address (4 bytes): Start address of an erasure block

Block end address (4 bytes): End address of an erasure block

SUM (1 byte): Checksum

(10) Programming Size Inquiry

In response to a programming size inquiry command sent from the host, the RX610 returns the programming size.

Command	27h			
Response	37h	Size	Programming size	SUM

[Legend]

Size (1 byte): Number of characters included in the programming size field (fixed at two)

Programming size (2 bytes): Programming unit (bytes)

SUM (1 byte): Checksum

(11) New Bit Rate Selection

In response to a new bit rate selection command sent from the host, the RX610 checks if the on-chip SCI can be set to the selected new bit rate. When the SCI can be set to the new bit rate, the RX610 returns a response (06h) and sets the SCI to the new bit rate. If the SCI cannot be set to the new bit rate or the sent command is illegal, the RX610 returns an error response (BFh). Upon reception of response 06h, the host waits for a one-bit period in the previous bit rate with which the new bit rate selection command has been sent, and then sets the host's bit rate to the new one. After that, the host sends confirmation data (06h) in the new bit rate, and the RX610 returns a response (06h) to the confirmation data.

Be sure to issue a new bit rate selection command only after a clock mode selection command.

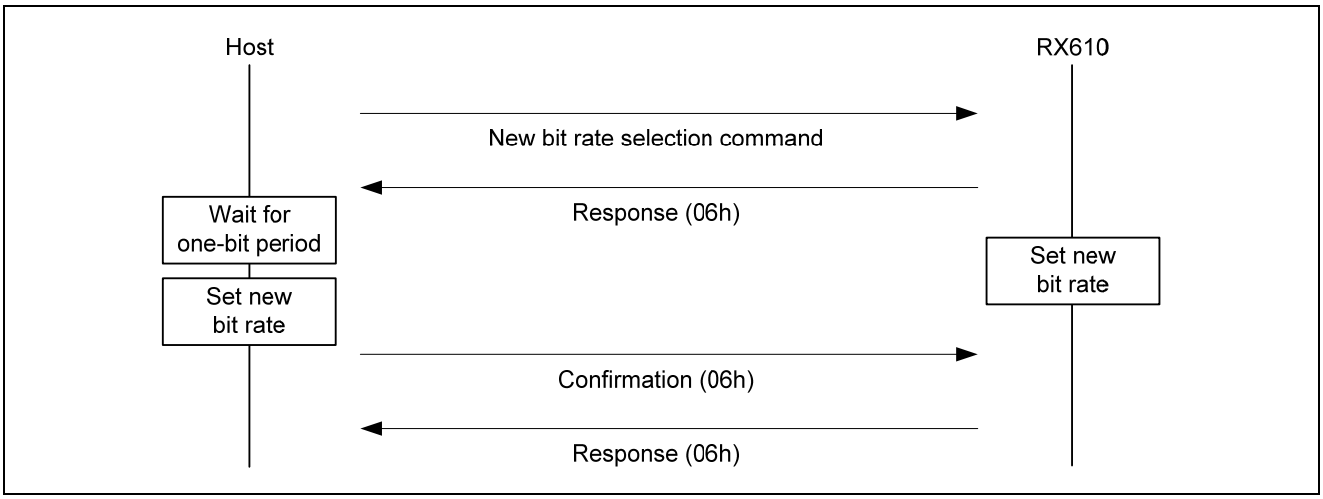


Figure 26.30 New Bit Rate Selection Sequence

Command	3Fh	Size	Bit rate	Input frequency
	Clock type count	Multiplication ratio 1	Multiplication ratio 2	
	SUM			
Response	06h			
Error response	BFh	Error		
Confirmation	06h			
Response	06h			

[Legend]

Size (1 byte):	Total number of bytes in the bit rate, input frequency, clock type count, and multiplication ratio fields
Bit rate (2 bytes):	New bit rate (for example, 00C0h indicates 19200 bps) 1/100 of the new bit rate value should be specified.
Input frequency (2 bytes):	Clock frequency input to the RX610 (for example, 04E2h indicates 12.50 MHz) This value should be calculated by multiplying the input frequency value to two decimal places by 100.
Clock type count (1 byte):	Number of clock types (for example, 02h indicates two clock types; that is, a system clock and a peripheral clock)
Multiplication ratio 1 (1 byte):	Multiplication/division ratio of the input frequency to obtain the system clock (ICLK) A positive value indicates a multiplication ratio (for example, 04h = 4 = multiplication by 4) A negative value indicates a division ratio (for example, FEh = -2 = division by 2)
Multiplication ratio 2 (1 byte):	Multiplication/division ratio of the input frequency to obtain the peripheral clock (PCLK) This value is represented in the same format as multiplication ratio 1
SUM (1 byte):	Checksum
Error:	Error code 11h: Checksum error 24h: Bit rate selection error 25h: Input frequency error 26h: Multiplication ratio error 27h: Operating frequency error

- Bit rate selection error

  A bit rate selection error occurs when the bit rate selected through a new bit rate selection command cannot be set for the SCI of the RX610 within an error of 4%. The bit rate error can be obtained by the following equation from the bit rate (B) selected through a new bit rate selection command, the input frequency (f_{EX}), multiplication ratio 2 ($M_{P\phi}$), the bit rate register (BRR) setting (N) in the SCI, and the CKS[1:0] bit value (n) in the serial mode register (SMR).

$$\text{Error (\%)} = \frac{f_{EX} \times M_{P\phi} \times 10^6}{(N+1) \times B \times 32 \times 2^{2n-1}} - 1$$

- Input frequency error

  An input frequency error occurs when the input frequency specified through a new bit rate selection command is outside the range from the minimum to maximum input frequencies for the clock mode selected through a clock mode selection command.

- Multiplication ratio error

  A multiplication ratio error occurs when the multiplication ratio specified through a new bit rate selection command does not match the clock mode selected through a clock mode selection command. To check the selectable multiplication ratios, issue a multiplication ratio inquiry command.

- Operating frequency error

  An operating frequency error occurs when the RX610 cannot operate at the operating frequencies selected through a new bit rate selection command. The RX610 calculates the operating frequencies from the input frequency and multiplication ratios specified through a new bit rate selection command and checks if each calculated frequency is within the range from the minimum to maximum frequencies for the respective clock. To check the minimum and maximum operating frequencies for each clock, issue an operating clock frequency inquiry command.

(12) Programming/Erasure State Transition

In response to a programming/erasure state transition command sent from the host, the RX610 determines whether ID code protection is enabled or disabled using the control code and ID code written in the ROM. When ID code protection is enabled, the RX610 returns a response (16h) and waits for the ID code. When ID code protection is disabled, the RX610 erases the entire area of each of the user mat, user boot mat, and data mat. After completing erasure, the RX610 returns a response (06h) and waits for a programming/erasure host command. If the RX610 has failed to complete erasure due to an error, it returns an error response (sends C0h and 51h in that order).

Do not issue a programming/erasure state transition command before device selection, clock mode selection, and new bit rate selection commands.

Command	40h	
Response	ACK	
Error response	C0h	51h

[Legend]

ACK (1 byte): ACK code
06h: ID code protection is disabled
16h: ID code protection is enabled

(13) Embedded Program Status Inquiry

In response to an embedded program status inquiry command sent from the host, the RX610 returns its current status. The embedded program status inquiry command can be issued in both the inquiry/selection host command wait state and programming/erasure host command wait state.

Command	4Fh			
Response	5Fh	Size	Status	Error

[Legend]

Size (1 byte): Total number of bytes in the status and error fields (fixed at two)

Status (1 byte): Current status in the RX610 (see table 26.14)

Error (1 byte): Error status in the RX610 (see table 26.15)

Table 26.14 Status Code

Code	Description
11h	Waiting for device selection
12h	Waiting for clock mode selection
13h	Waiting for bit rate selection
1Fh	Waiting for transition to programming/erasure host command wait state (bit rate has been selected)
31h	Erasing the user mat and user boot mat
3Fh	Waiting for a programming/erasure host command
4Fh	Waiting for reception of programming data
5Fh	Waiting for erasure block selection

Table 26.15 Error Code

Code	Description
00h	No error
11h	Checksum error
21h	Incorrect device code error
22h	Incorrect clock mode error
24h	Bit rate selection error
25h	Input frequency error
26h	Multiplication ratio error
27h	Operating frequency error
29h	Block number error
2Ah	Address error
2Bh	Data size error
51h	Erasure error
52h	Incomplete erasure error
53h	Programming error
54h	Selection error
80h	Command error
FFh	Bit rate adjustment verification error

26.10.6 ID Code Wait State

Table 26.16 shows the host command available in the ID code wait state.

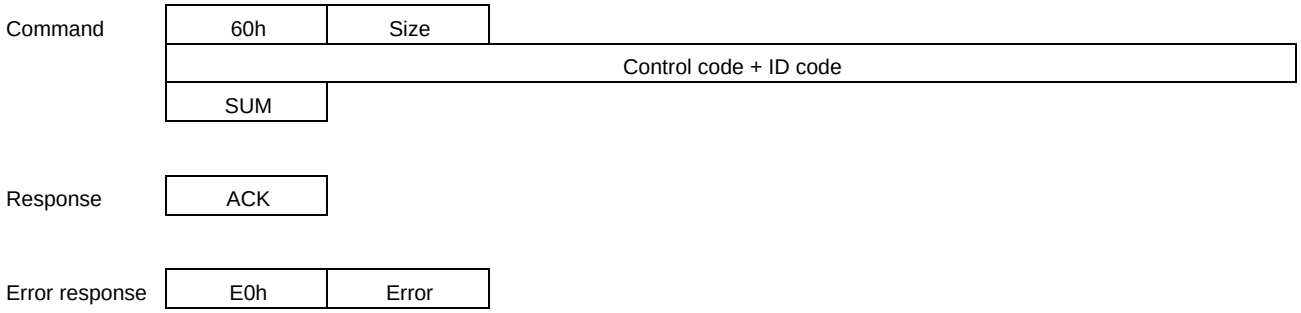
Table 26.16 ID Code Check Host Command

Host Command Name	Function
ID code check	Performs the ID code check

If the host has sent an undefined command, the RX610 returns a response indicating a command error. For the format of this response, see section 26.10.5, Inquiry/Selection Host Command Wait State.

(1) ID Code Check

In response to an ID code check command sent from the host, the RX610 compares the code sent from the host with the control code and ID code in the ROM and returns the result.



[Legend]

Size (1 byte): Number of bytes in the ID code field (fixed at 16)

ID code (16 bytes): Control code (1 byte) + ID code (15 bytes)

SUM (1 byte): Checksum

ACK (1 byte): ACK code
26h: Returns the response for a programming/erasure state transition command

Error (1 byte): Error code
11h: Checksum error
61h: ID code mismatch
63h: ID code mismatch (erasure error)
An error has occurred during erasure triggered by an ID code mismatch.

26.10.7 Programming/Erasure Host Command Wait State

Table 26.17 shows the host commands available in the programming/erasure host command wait state.

Table 26.17 Programming/Erasure Host Commands

Host Command Name	Function
User boot mat programming selection	Selects the program for user boot mat programming
User mat programming selection	Selects the program for user mat programming
256-byte programming	Programs 256 bytes of data
Erasure selection	Selects the erasure program
Block erasure	Erases block data
Memory read	Reads data from memory
User boot mat checksum	Performs checksum verification for the user boot mat
User mat checksum	Performs checksum verification for the user mat
User boot mat blank check	Checks whether the user boot mat is blank
User mat blank check	Checks whether the user mat is blank
Read lock bit status	Reads from the lock bit
Lock bit program	Writes to the lock bit
Lock bit enable	Enables the lock bit protection
Lock bit disable	Disables the lock bit protection
Embedded program status inquiry	Inquires regarding the state of the RX610

If the host has sent an undefined command, the RX610 returns a response indicating a command error. For the format of this response, see section 26.10.5, Inquiry/Selection Host Command Wait State.

To program the ROM, issue a programming selection command (user boot mat programming selection or user mat programming selection command) and then a 256-byte programming command from the host. Upon reception of a programming selection command, the RX610 enters the programming data wait state (see section 26.10.3, State Transitions in Boot Mode). In response to a 256-byte programming command sent from the host in this state, the RX610 starts programming the ROM. When the host sends a 256-byte programming command specifying FFFF FFFFh as the programming start address, the RX610 detects it as the end of programming and enters the programming/erasure host command wait state.

To erase the ROM, issue an erasure selection command and then a block erasure command from the host. Upon reception of an erasure selection command, the RX610 enters the erasure block selection wait state (see section 26.10.3, State Transitions in Boot Mode). In response to a block erasure command sent from the host in this state, the RX610 erases the specified block in the ROM. When the host sends a block erasure command specifying FFh as the block number, the RX610 detects it as the end of erasure and enters the programming/erasure host command wait state.

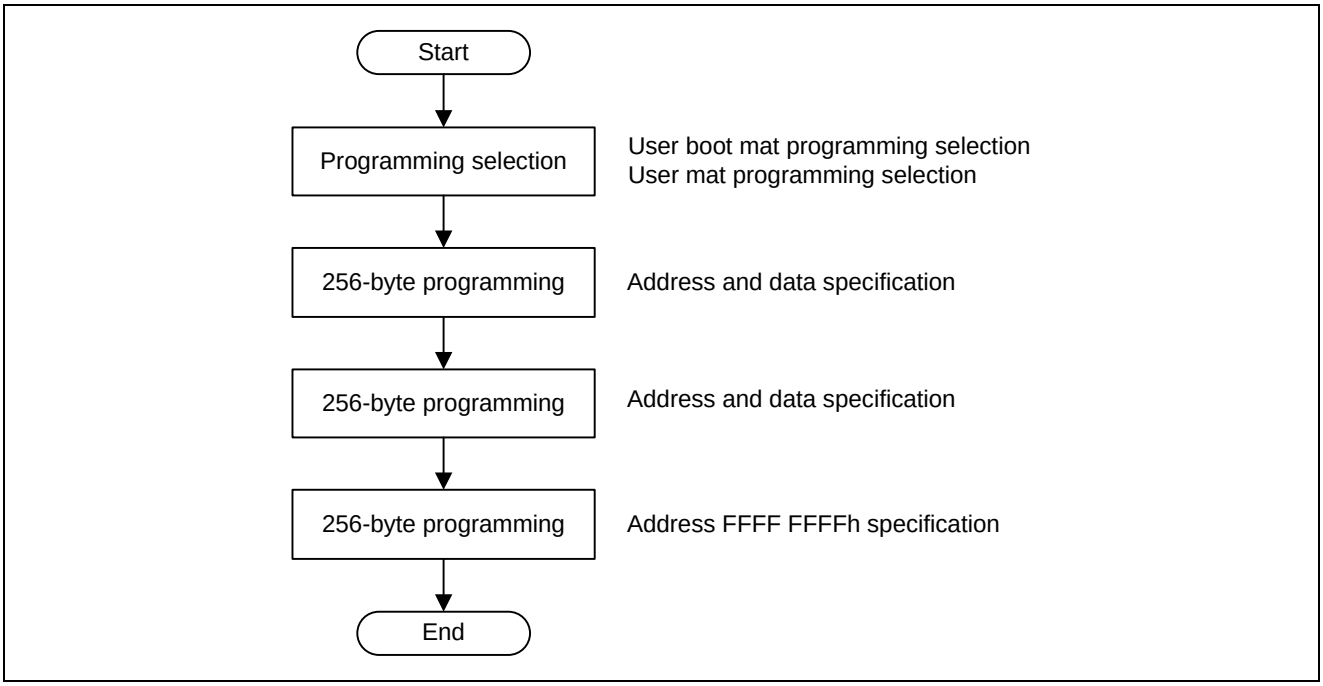


Figure 26.31 Procedure for ROM Programming in Boot Mode

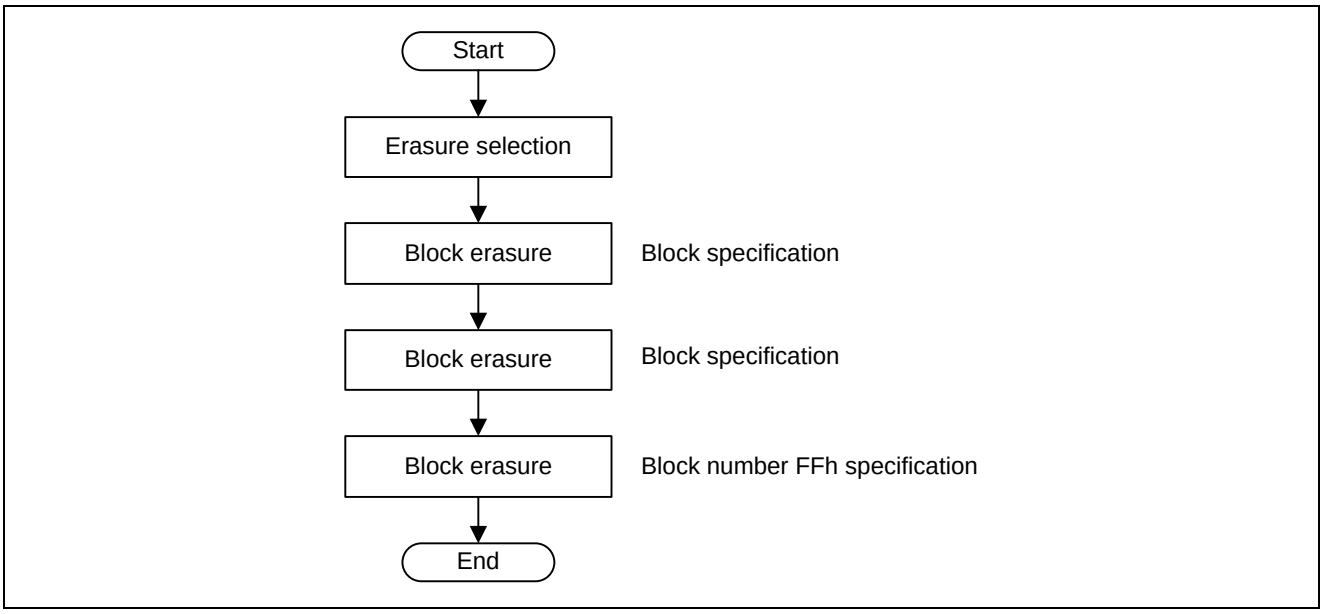


Figure 26.32 Procedure for ROM Erasure in Boot Mode

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX610 and the "response" indicates a response sent from the RX610 to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX610 becomes 00h.

(1) User Boot Mat Programming Selection

In response to a user boot mat programming selection command sent from the host, the RX610 selects the program for user boot mat programming and waits for programming data.

Command	42h
Response	06h

(2) User Mat Programming Selection

In response to a user mat programming selection command sent from the host, the RX610 selects the program for user mat programming and waits for programming data.

Command	43h
Response	06h

(3) 256-Byte Programming

In response to a 256-byte programming command sent from the host, the RX610 programs the ROM. After completing ROM programming successfully, the RX610 returns a response (06h). If an error has occurred during ROM programming, the RX610 returns an error response (D0h).

Command	50h	Programming address		
	Data	Data	. . .	Data
	SUM			
Response	06h			
Error response	D0h	Error		

[Legend]

Programming address (4 bytes): Target address of programming
To program the ROM, a 256-byte boundary address should be specified.
To terminate programming, FFFF FFFFh should be specified.

Data (256 bytes): Programming data
FFh should be specified for the bytes that do not need to be programmed.
When terminating programming, no data needs to be sent (only the programming address and SUM should be sent in that order).

SUM (1 byte): Checksum

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error (the specified address is not in the target mat)
53h: Programming cannot be done due to a programming error

(4) Erasure Selection

In response to an erasure selection command sent from the host, the RX610 selects the erasure program and waits for erasure block specification.

Command	48h
Response	06h

(5) Block Erasure

In response to a block erasure command sent from the host, the RX610 erases the ROM. After completing ROM erasure successfully, the RX610 returns a response (06h). If an error has occurred during ROM erasure, the RX610 returns an error response (D8h).

Command	58h	Size	Block	SUM
Response	06h			
Error response	D8h	Error		

[Legend]

Size (1 byte):	Number of bytes in the block specification field (fixed at 1)
Block (1 byte):	Block number whose data is to be erased To terminate erasure, FFh should be specified.
SUM (1 byte):	Checksum
Error (1 byte):	Error code 11h: Checksum error 29h: Block number error (an incorrect block number is specified) 51h: Erasure cannot be done due to an erasure error

(6) Memory Read

In response to a memory read command sent from the host, the RX610 reads data from the ROM. After completing ROM reading successfully, the RX610 returns the data stored in the address specified by the memory read command. If the RX610 has failed to read the ROM, the RX610 returns an error response (D2h).

Command	52h	Size	Area	Read start address
	Reading size			SUM

Response	52h	Reading size		
	Data	Data	. . .	Data
	SUM			

Error response	D2h	Error

[Legend]

Size (1 byte): Total number of bytes in the area, read start address, and reading size fields

Area (1 byte): Target mat to be read
00h: User boot mat
01h: User mat

Read start address (4 bytes): Start address of the area to be read

Reading size (4 bytes): Size of data to be read (bytes)

SUM (1 byte): Checksum

Data (1 byte): Data read from the ROM

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error
- The value specified for area selection is neither 00h nor 01h.
- The specified read start address is outside the selected mat.

2Bh: Data size error
- 00h is specified for the reading size.
- The reading size is larger than the mat.
- The end address calculated from the read start address and the reading size is outside the selected mat.

(7) User Boot Mat Checksum

In response to a user boot mat checksum command sent from the host, the RX610 sums the user boot mat data in byte units and returns the result (checksum).

Command	4Ah			
Response	5Ah	Size	Mat checksum	SUM

[Legend]

Size (1 byte): Number of bytes in the mat checksum field (fixed at 4)

Mat checksum (4 bytes): Checksum of the user boot mat data

SUM (1 byte): Checksum (for the response data)

(8) User Mat Checksum

In response to a user mat checksum command sent from the host, the RX610 sums the user mat data in byte units and returns the result (checksum).

Command	4Bh			
Response	5Bh	Size	Mat checksum	SUM

[Legend]

Size (1 byte): Number of bytes in the mat checksum field (fixed at 4)

Mat checksum (4 bytes): Checksum of the user mat data
The user mat also stores the key code for debugging function authentication. Note that the checksum includes this key code value.

SUM (1 byte): Checksum (for the response data)

(9) User Boot Mat Blank Check

In response to a user boot mat blank check command sent from the host, the RX610 checks whether the user boot mat is completely erased. When the user boot mat is completely erased, the RX610 returns a response (06h). If the user boot mat has an unerased area, the RX610 returns an error response (sends CCh and 52h in that order).

Command	4Ch	
Response	06h	
Error response	CCh	52h

(10) User Mat Blank Check

In response to a user mat blank check command sent from the host, the RX610 checks whether the user mat is completely erased. When the user mat is completely erased, the RX610 returns a response (06h). If the user mat has an unerased area, the RX610 returns an error response (sends CDh and 52h in that order).

Command	4Dh	
Response	06h	
Error response	CDh	52h

(11) Read Lock Bit Status

In response to a read lock bit status command sent from the host, the RX610 reads data from the lock bit. After completing the lock bit reading successfully, the RX610 returns the data stored in the address specified by the read lock bit status command. If the RX610 has failed to read the lock bit, the RX610 returns an error response (F1h).

Command	71h	Size	Area	Third highest order address	Second highest order address	Highest order address	SUM
Response	Status						
Error response	F1h	Error					

[Legend]

Size (1 byte): Total number of bytes in the area, third highest order address, second highest order address, and highest order address fields (fixed at 4 in the RX610)

Area (1 byte): Target mat to be read
01h: User mat

Third highest order address (1 byte): Third highest order address at the specified block's end address (8 to 15 bits)

Second highest order address (1 byte): Second highest order address at the specified block's end address (16 to 23 bits)

Highest order address (1 byte): Highest order address at the specified block's end address (24 to 31 bits)

SUM (1 byte): Checksum

Status (1 byte): Bit 6 locked at "0"
Bit 6 unlocked at "1"

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error (the specified address is not in the target mat)

(12) Lock Bit Program

In response to a lock bit program command sent from the host, the RX610 writes to a lock bit and locks the specified block. After completing the lock bit blocking successfully, the RX610 returns a response (06h). If the RX610 has failed to lock, the RX610 returns an error response (F7h).

Command	77h	Size	Area	Third highest order address	Second highest order address	Highest order address	SUM
Response	06h						
Error response	F7h	Error					

[Legend]

Size (1 byte): Total number of bytes in the area, third highest order address, second highest order address, and highest order address fields (fixed at 4 in the RX610)

Area (1 byte): Target mat to be locked
01h: User mat

Third highest order address (1 byte): Third highest order address at the specified block's end address (8 to 15 bits)

Second highest order address (1 byte): Second highest order address at the specified block's end address (16 to 23 bits)

Highest order address (1 byte): Highest order address at the specified block's end address (24 to 31 bits)

SUM (1 byte): Checksum

Error (1 byte): Error code
11h: Checksum error
2Ah: Address error (the specified address is not in the target mat)
53h: Locking cannot be done due to a programming error

(13) Lock Bit Enable

In response to a lock bit enable command sent from the host, the RX610 enables a lock bit.

Command	7Ah
Response	06h

(14) Lock Bit Disable

In response to a lock bit disable command sent from the host, the RX610 disables a lock bit.

Command	75h
Response	06h

(15) Embedded Program Status Inquiry

For details, refer to section 26.10.5, Inquiry/Selection Host Command Wait State.

26.11 ID Code Protection on Connection of the On-Chip Debugger

This function is used to prohibit connection with the on-chip debugger. When connecting an on-chip debugger, the control code and ID code that have been written to the ROM are used to determine whether ID code protection on connection of the on-chip debugger is enabled or disabled and to judge ID code protection on connection of the on-chip debugger. When the ID code protection is enabled, the code sent from the on-chip debugger is compared with the control code and ID code in the ROM to determine whether they match. If they match, connection with the on-chip debugger is allowed. If they do not match, the on-chip debugger cannot be connected. However, if the control code is 52h and the ID code is 50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh (from the ID code 1 field), there is no determination of matching and the ID code is always considered to be non-matching. Furthermore, if all bytes of the control code and ID code have the value FFh, there is no determination of matching, the ID code is always considered to match, and connection of the on-chip debugger is allowed. See figure 26.25 for the configuration of ID codes in flash memory.

Table 26.18 Specifications for ID Code Protection on Connection of the On-Chip Debugger

Control Code	ID Code	State of Protection	Operations at the Time of Connection with the On-Chip Debugger
FFh	FFh, …, FFh (all bytes FFh)	Protection disabled	The control code and ID code are not judged, the ID code always matches, and connection to the on-chip debugger is permitted.
52h	50h, 72h, 6Fh, 74h, 65h, 63h, 74h, FFh, ..., FFh	Protection enabled	The control code and ID code are not judged, the ID code is always non-matching, and connection to the on-chip debugger is proh bited.
Other than the above	Other than the above	Protection enabled	Matching ID code: Authentication of the on-chip debugger is ended and connection with the on-chip debugger is permitted. Non-matching ID code: Further transition to the ID code protection waiting state

26.12 ROM Code Protection

ROM code protection is a facility for prohibiting a PROM programmer from reading from or writing to flash memory. The ROM code in flash memory is a 32-bit code. Figure 26.33 shows the configuration of ROM codes. Set ROM codes as 32-bit units.

For release from ROM code protection, erase block EB00 (erasure block 00) in boot mode or by user programming.

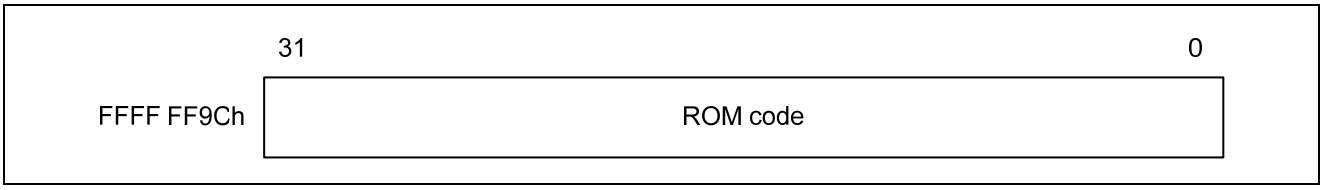


Figure 26.33 Configuration of a ROM Code

Table 26.19 Specifications for ROM Code Protection

ROM Code	State of Protection	Operations at the Time of Connection with the PROM Programmer
0000 0000h	Protection enabled (ROM code protection 1)	Access (both reading and writing) to the user mat and user boot mat is prohibited.
0000 0001h	Protection enabled (ROM code protection 2)	Reading from the user mat and user boot mat is prohibited.
Other than the above	Protection disabled	Access (both reading and writing) to the user mat and user boot mat is permitted.

26.13 Usage Notes

(1) Areas where Programming or Erasure is Suspended

Data in areas where programming or erasure is suspended are undefined. To avoid malfunctions due to the reading of undefined data, prevent the reading of data and execution of code from areas where programming or erasure is currently suspended.

(2) Suspending Programming or Erasure

If you use the programming/erasure suspension command to suspend the processing of programming or erasure, be sure to use the resumption command so that the processing is completed. 20µs (when PCLK = 50 MHz) after issuance of the resumption command, the programming/erasure command should not be issued again.

(3) Prohibition of Reprogramming

Two or more programming operations cannot be performed for the same address range. If an address range that has already been programmed is to be programmed again, be sure to erase the area in advance of the programming.

(4) Reset during Programming or Erasure

Do not apply a reset by asserting the signal on the RES# pin during programming or erasure, since doing so can permanently damage the flash memory. In the case of erroneous input of the reset signal, only de-assert the signal after assertion of the signal has continued for at least 100 µs.

If programming or erasure is proceeding and the FRESET bit in FRESETR is used to reset the FCU or an internal reset is performed because the watchdog timer has overflowed, make sure that the reset state is maintained over the period tRESW2 (see section 28, Electrical Characteristics). Do not attempt to read the ROM during the period of a reset of this type.

(5) Prohibition of NMI Interrupts during Programming or Erasure

If an NMI interrupt occurs during programming or erasure, as this will lead to fetching of the vector from the ROM, and the data read out will be undefined. Ensure that NMI interrupts are not generated during programming or erasure.

(6) Interrupt Vector Assignment During Programming or Erasure

The generation of interrupts during programming or erasure may lead to the fetching of vectors from the ROM. To prevent access to the ROM area due to the generation of interrupts, set the interrupt table register (INTB) of the CPU so that the destination for the fetching of interrupt vector is an area outside the ROM.

(7) Actions Prohibited during Programming and Erasure

Programming and erasure lead to the application of high voltages within flash memory. Prevent damage to the device by observing the prohibitions described below.

- Do not make a transition to all-module-clock-stopped mode, software standby mode, or deep software standby mode.
- Do not cut off power to the RX610.
- Do not change the values of the FLWE[1:0] bits in the FWEPROR.
- Do not change the operating mode by changing the setting of the SYSCR0.ROME bit.

27. Data Flash (Flash Memory for Data Storage)

The RX610 has a maximum 2-Mbyte flash memory for storing program code (ROM) and a 32-Kbyte flash memory for storing data (data flash).

This section covers the flash memory for data storage. For the ROM, see section 26, ROM (Flash Memory for Code Storage).

27.1 Overview

Table 27.1 lists the specifications of the data flash memory, and figure 27.1 is a block diagram of the ROM, data-flash memory, and related modules.

Table 27.1 Specifications of Data Flash Memory

Item		Specifications
Memory space		32 Kbytes
Reading via the peripheral bus		A read operation takes three cycles of PCLK in words or bytes
Programming/erasing method		• The chip incorporates a dedicated sequencer (FCU) for programming of the ROM and data flash. • Programming and erasing the ROM and data flash are handled by issuing commands to the FCU.
BGO (background operation)		• The CPU is able to execute program code from areas other than the ROM or data flash while the ROM is being programmed or erased. • Execution of program code from the ROM is possible while the data flash memory is being programmed or erased.
Suspension and resumption		• The CPU is able to execute program code from the ROM during suspension of programming or erasure. • Programming and erasure of the ROM can be restarted (resumed) after suspension.
Units of programming and erasure		• Unit of programming for the data mat: 8 or 128 bytes • Unit of erasure for the data mat: 8 Kbytes (4 blocks)
Blank checking function		• The blank checking command can be executed to check the erasure state of data flash. • The size of the area to be blank-checked is 8 bytes or 8Kbytes.
On-board programming (three types)	Boot mode	• The data mat is programmable via the SCI. • The bit rate for SCI transfer between the host and RX610 is automatically adjusted.
	User boot mode	Booting up from the user boot mat and programming of the data mat
	User program	Programming of the data mat under program control
Protection	Software-controlled protection	The FENTRYR.FENTRYD and FWEPROR.FLWE[1:0] bits, and the DFLRE and DFLWE registers, can be used to prevent unintentional programming.
	Error protection	Prevention of further programming or erasure after the detection of abnormal operations during programming or erasure
Times for programming and erasure, durability (number of times reprogramming is possible)		See section 29, Electrical Characteristics.

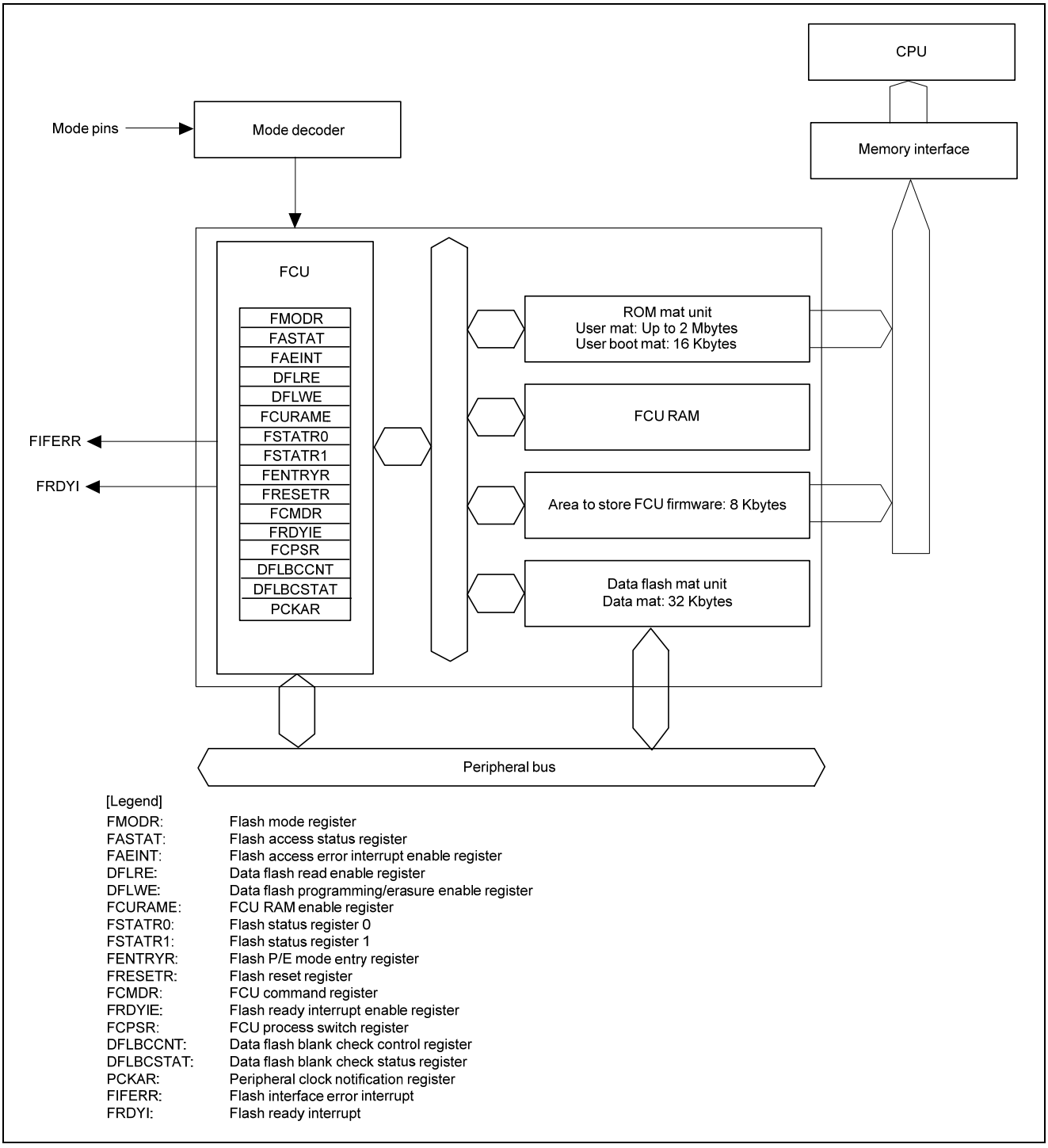


Figure 27.1 Block Diagram of Data Flash Memory

Input and output pins associated with the data flash are listed in table 27.2.

Table 27.2 Input and Output Pins Associated with the Data Flash

Pin Name	I/O	Description
P05/RxD4	Input	Used in boot mode to receive data via SCI4 (for host communications)
P04/TxD4	Output	Used in boot mode to transmit data from SCI4 (for host communications)

27.2 Register Descriptions

Table 27.3 lists the registers related to the data flash memory. Some registers also have bits related to the ROM, but this section deals only with the bits that are relevant to the data flash. For registers containing bits with common functions for the ROM and data flash (FRDYIE, FCURAME, FSTATR0, FSTATR1, FRESETR, FCMDR, FCPSR, PCKAR, and FWEPROR) and details on the functions of bits dedicated to the ROM, see section 26.2, Register Descriptions.

The registers related to the data flash are initialized by a reset.

Table 27.3 Registers Related to the Data Flash

Register Name	Symbol	Value after Reset	Address	Access Size
Flash mode register	FMODR	00h	007F C402h	8
Flash access status register	FASTAT	00h	007F C410h	8
Flash access error interrupt enable register	FAEINT	9Bh	007F C411h	8
Flash ready interrupt enable register	FRDYIE	00h	007F C412h	8
Data flash read enable register	DFLRE	0000h	007F C440h	16
Data flash programming/erasure enable register	DFLWE	0000h	007F C450h	16
FCU RAM enable register	FCURAME	0000h	007F C454h	16
Flash status register 0	FSTATR0	80h	007F FFB0h	8
Flash status register 1	FSTATR1	00h	007F FFB1h	8
Flash P/E mode entry register	FENTRYR	0000h	007F FFB2h	16
Flash reset register	FRESETR	0000h	007F FFB6h	16
FCU command register	FCMDR	FFFFh	007F FFBAh	16
FCU processing switching register	FCPSR	0000h	007F FFC8h	16
Data flash blank check control register	DFLBCCNT	0000h	007F FFCAh	16
Data flash blank check status register	DFLBCSTAT	0000h	007F FFCEh	16
Peripheral clock notification register	PCKAR	0000h	007F FFE8h	16
Flash write erase protection register	FWEPROR	02h	0008 C289h	8

27.2.1 Flash Mode Register (FMODR)

Address: 007F C402h

	b7	b6	b5	b4	b3	b2	b1	b0
	–	–	–	FRDMD	–	–	–	–
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b3 to b0	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b4	FRDMD	FCU Read Mode Select	0: Memory Area Reading Method The method of lock bit reading is set. Since there are no lock bits for the data flash, undefined data are read from the data flash area after the FCU has been placed in lock bit read mode. 1: Register Reading Method This is the setting when the blank checking command is to be used.	R/W
b7 to b5	—	Reserved	These bits are always read as 0.The write value should always be 0.	R/W

FMODR is used to specify the method for the reading of lock bits. Set the FRDMD bit to 1 if blank checking is to be used.

In modes in which the on-chip ROM is disabled, the value read from FMODR is 00h and writing is disabled.

FMODR is initialized by a reset.

FRDMD Bit (FCU Read Mode Select)

Processing for a transition of the lock bit reading mode is used in processing for blank checking of the data flash.

The FRDMD bit is used to select the method of reading when lock bit values for the ROM are read out (see section 26, ROM (Flash Memory for Code Storage)).

27.2.2 Flash Access Status Register (FASTAT)

Address: 007F C410h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAE	–	–	CMDLK	DFLAE	–	DFLRPE	DFLWPE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPE	Data Flash Programming/Erasure Protection Violation	0: No data flash programming/erasure command is issued which conflicts with the DFLWE settings 1: A data flash programming/erasure command is issued which conflicts with the DFLWE settings	R/(W)*
b1	DFLRPE	Data Flash Read Protection Violation	0: There is no such data flash read that conflicts with the DFLRE settings 1: There is such data flash read that conflicts with the DFLRE setting	R/(W)*
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAE	Data Flash Access Violation	0: No data flash access violation 1: Data flash access violation	R/(W)*
b4	CMDLK	FCU Command Lock	0: FCU is not in the command-locked state 1: FCU is in the command-locked state	R
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAE	ROM Access Violation	See section 26, ROM (Flash Memory for Code Storage).	R/(W)*

Note: * Only 0 can be written after reading 1 to clear the flag.

FASTAT is a register to check if the access to the ROM/data flash is allowed.

When on-chip ROM is disabled, the data read from FASTAT is 00h and writing is disabled. When one of the bits in FASTAT is set to 1, the FCU is placed in the command-locked state (see section 27.7.2, Error Protection). To clear the command-locked state, a status clear command must be issued to the FCU after setting FASTAT to 10h.

FASTAT is initialized by a reset.

EEPWPE Bit (Data Flash Programming/Erasure Protection Violation)

This bit is used to indicate whether or not the programming/erasure protection set by DFLWE is violated.

[Setting condition]

- A programming/erasure command is issued for a data flash area for which programming or erasure is disabled by DFLWE.

[Clearing condition]

- When 0 is written after reading 1

DFLRPE Bit (Data Flash Read Protection Violation)

This bit is used to indicate whether or not the reading protection set by DFLRE is violated.

[Setting condition]

- A read command is issued for a data flash area for which reading is disabled by DFLRE.

[Clearing condition]

- When 0 is written after reading 1

DFLAE Bit (Data Flash Read Protection Violation)

This bit indicates whether a data flash access violation occurred.

When the DFLAE bit is set to 1, the ILGLERR bit in FSTATR0 is set to 1, placing the FCU in the command-locked state.

For FSTATR0, see section 26.2.5, Flash Status Register 0 (FSTATR0).

[Setting conditions]

- A read command is issued for a data flash area in data flash P/E normal mode and when the FENTRYD bit in FENTRYR is set to 1.
- A write command is issued for a data flash area when the FENTRYD bit is set to 0.
- A command is issued for a data flash area when the FENTRY1 or FENTRY0 bit in FENTRYR is set to 1.

[Clearing condition]

- When 0 is written after reading 1

CMDLK Bit (FCU Command-Locked)

This command indicates that the FCU is in the command-locked state (see section 27.7.2, Error Protection).

[Setting condition]

- After the FCU detects an error and enters the command-locked state

[Clearing condition]

- After the FCU has processed a status clear command

27.2.3 Flash Access Error Interrupt Enable Register (FAEINT)

Address: 007F C411h

	b7	b6	b5	b4	b3	b2	b1	b0
	ROMAEIE	—	—	CMDLKIE	DFLAEIE	—	DFLRPEIE	DFLWPEIE
Value after reset:	1	0	0	1	1	0	1	1

Bit	Symbol	Bit Name	Description	R/W
b0	DFLWPEIE	Data Flash Programming/Erasure Protection Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the DFLWPE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the DFLWPE bit in FASTAT is set to 1	R/W
b1	DFLRPEIE	Data Flash Read Protection Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the DFLRPE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the DFLRPE bit in FASTAT is set to 1	R/W
b2	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b3	DFLAEIE	Data Flash Read Access Violation Interrupt Enable	0: FIFERR interrupt requests disabled when the DFLAE bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the DFLAE bit in FASTAT is set to 1	R/W
b4	CMDLKIE	FCU Command Lock Interrupt Enable	0: FIFERR interrupt requests disabled when the CMDLK bit in FASTAT is set to 1 1: FIFERR interrupt requests enabled when the CMDLK bit in FASTAT is set to 1	R/W
b6, b5	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	ROMAEIE	ROM Access Violation Interrupt Enable	See section 26, ROM (Flash Memory for Code Storage).	R/W

FAEINT is a register to enable and disable a flash interface error interrupt (FIFERR).

When on-chip ROM is disabled, the data read from FAEINT is 00h and writing is disabled.

FAEINT is initialized by a reset.

DFLWPEIE Bit (Data Flash Programming/Erasure Protection Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a data flash programming/erasure protection violation occurs and the DFLWPE bit in FASTAT is set to 1.

DFLRPEIE Bit (Data Flash Read Protection Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a data flash read protection violation occurs and the DFLRPE bit in FASTAT is set to 1.

DFLAEIE Bit (Data Flash Read Protection Violation Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a data flash access violation occurs and the DFLAE bit in FASTAT is set to 1.

CMDLKIE Bit (FCU Command Lock Interrupt Enable)

This bit is used to enable or disable FIFERR interrupt requests when a FCU command-locked state occurs and the CMDLK bit in FASTAT is set to 1.

27.2.4 Data Flash Read Enable Register (DFLRE)

Address: 007F C440h

	b15	b14	b13	b12	b11	b10	b9	b8
	KEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	DBRE3	DBRE2	DBRE1	DBRE0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DBRE0	DB0 Block Read Enable	0: Read disabled	R/W
b1	DBRE1	DB1 Block Read Enable	1: Read enabled	R/W
b2	DBRE2	DB2 Block Read Enable		R/W
b3	DBRE3	DB3 Block Read Enable		R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	KEY[7:0]	Key Code	Enable or disable rewriting of the DBREj bit (j = 3 to 0).	R/(W)*

Note: * Write data is not retained.

DFLRE is a register to enable or disable the DB0 to DB3 blocks (see figure 27.3) to be read.

Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from DFLRE is 0000h and writing is disabled.

DFLRE is initialized by a reset.

DBREj Bit (DBj Block Read Enable) (j = 3 to 0)

This bit is used to enable or disable the DB3 to DB0 blocks of the data mat to be read.

The DBREj bit is used to control reading of the DBj blocks.

Writing to the DBREj is enabled only in word access when the KEY[7:0] bits are 2Dh.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the DBREj bit.

Data written to the KEY[7:0] bits is not retained.

27.2.5 Data Flash Programming/Erasure Enable Register (DFLWE)

Address: 007F C450h

	b15	b14	b13	b12	b11	b10	b9	b8
	KEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	DBWE3	DBWE2	DBWE1	DBWE0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	DBWE0	DB0 Block Programming/Erasure Enable	0: Programming/erasure disabled	R/W
b1	DBWE1	DB1 Block Programming/Erasure Enable	1: Programming/erasure enabled	R/W
b2	DBWE2	DB2 Block Programming/Erasure Enable		R/W
b3	DBWE3	DB3 Block Programming/Erasure Enable		R/W
b7 to b4	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b15 to b8	KEY[7:0]	Key Code	Enable or disable rewriting of the DBWEj bit (j = 3 to 0).	R/(W)*

Note: * Write data is not retained.

DFLWE is a register to enable or disable the DB0 to DB3 blocks (see figure 27.3) to be programmed or erased.

Only specific values written to the upper byte in word access are valid. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from DFLWE is 0000h and writing is disabled.

DFLWE is initialized by a reset.

DBWEj Bit (DBj Block Programming/Erasure Enable) (j = 0 to 3)

This bit is used to enable or disable the DB3 to DB0 blocks of the data mat to be programmed or erased.

The DBWEj bit is used to control programming/erasure of the DBj blocks.

Programming of the DBWEj bit is enabled only in word access when the KEY[7:0] bits are 1Eh.

KEY[7:0] Bits (Key Code)

These bits are used to enable or disable rewriting of the DBWEj bit.

Data written to the KEY[7:0] bits is not retained.

27.2.6 Flash P/E Mode Entry Register (FENTRYR)

Address: 007F FFB2h

	b15	b14	b13	b12	b11	b10	b9	b8
	FEKEY[7:0]							
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	FENTRYD	—	—	—	—	—	FENTRY1	FENTRY0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	FENTRY0	ROM P/E Mode Entry 0	See section 26, ROM (Flash Memory for Code Storage).	R/W
b1	FENTRY1	ROM P/E Mode Entry 1	See section 26, ROM (Flash Memory for Code Storage).	R/W
b6 to b2	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b7	FENTRYD	Data Flash P/E Mode Entry	0: Data flash is in read mode 1: Data flash is in P/E mode	R/W
b15 to b8	FEKEY[7:0]	Key Code	Enable or disable rewriting of the FENTRYD, FENTRY1 and FENTRY0 bits.	R/(W)*

Note: * Write data is not retained.

FENTRYR is a register to place the ROM/data flash in P/E mode.

To place ROM/data flash in P/E mode and accept commands from the FCU, one of the FENTRYD, FENTRY1 and FENTRY0 bits must be set to 1. If more than one bit is set to 1, the ILGLERR bit is set in FSTATR0 and the FCU enters the command-locked state.

Only specific values written to the upper byte in word access are valid. Any other writing causes the register to be initialized. Data written to the upper byte is not retained.

When on-chip ROM is disabled, the data read from FENTRYR is 0000h and writing is disabled.

FENTRYR is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

For FSTATR0, see section 26.2.5, Flash Status Register 0 (FSTATR0).

For FRESETR, see section 26.2.10, Flash Reset Register (FRESETR).

FENTRYD Bit (Data Flash P/E Mode Entry)

The FENTRYD bit is used to place the data flash in P/E mode.

[Writing-enable conditions (when all of the following conditions are met)]

- On-chip ROM is enabled.
- The FRDY bit in FSTATR0 is set to 1
- AAh is written to the FEKEY[7:0] bits in word access.

[Setting condition]

- When the writing-enable conditions are met, FENTRYR is set to 0000h, and 1 is written to the FENTRYD bit

[Clearing conditions]

- Data is written in byte access.
- Data is written in word access when the FEKEY[7:0] bits are other than AAh.
- When the writing-enable conditions are met, 0 is written to the FENTRYD bit.
- When the writing-enable conditions are met and FENTRYR is other than 0000h, data is written to FENTRYR.

FEKEY[7:0] Bits (Key Code)

These bits enable or disable rewriting of the FENTRYD, FENTRY1 and FENTRY0 bits.

Data written to the FEKEY[7:0] bits is not retained.

27.2.7 Data Flash Blank Check Control Register (DFLBCCNT)

Address: 007F FFCAh

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	BCADR[9:0]				
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	BCADR[9:0]					—	—	BCSIZE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BCSIZE	Blank Check Size Setting	0: The size of the area to be blank-checked is 8 bytes. 1: The size of the area to be blank-checked is 8 Kbytes.	R/W
b2, b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b12 to b3	BCADR[9:0]	Blank Check Address Setting	Set the address of the area to be checked	R/W
b15 to b13	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DFLBCCNT is a register for specifying the address and size of the area to be checked by a blank check command.

When on-chip ROM is disabled, the data read from DFLBCCNT is 0000h and writing is disabled.

DFLBCCNT is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

For FRESETR, see section 26.2.10, Flash Reset Register (FRESETR).

BCSIZE Bit (Blank Check Size Setting)

The BCSIZE bit is used to set the size of the area to be checked by a blank check command.

BCADR[9:0] Bits (Blank Check Address Setting)

When the size of the area to be checked by a blank check command is 8 bytes (the BCSIZE bit is set to 0), this bit is used to set the address of the area to be checked.

When the BCSIZE bit is set to 0, the setting of DFLBCCNT (the setting of the BCADR bit shifted three bits in the MSB direction) added with the erased block start address specified when issuing a blank check command is the start address of the area to be checked.

27.2.8 Data Flash Blank Check Status Register (DFLBCSTAT)

Address: 007F FFCEh

	b15	b14	b13	b12	b11	b10	b9	b8
	—	—	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	—	BCST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	BCST	Blank Check Status	0: The area to be blank-checked is erased (blank) 1: 0 or 1 is written in the area to be blank-checked	R
b15 to b1	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

DFLBCSTAT is a register which stores the results of a blank check command.

When on-chip ROM is disabled, the data read from DFLBCSTAT is 0000h and writing is disabled.

DFLBCSTAT is initialized by a reset, or when the FRESET bit in FRESETR is set to 1.

For FRESETR, see section 26.2.10, Flash Reset Register (FRESETR).

BCST Bit (Blank Check Status)

This bit is used to indicate the results of blank checking.

27.3 Configuration of Memory Mat for the Data Flash Memory

The data flash memory of products in the RX610 Group is configured as a 32-Kbyte data mat. The address range occupied by this mat is shown in figure 27.2.

Note that for the data mat, the address range for reading is the same as the address range for programming and erasure.

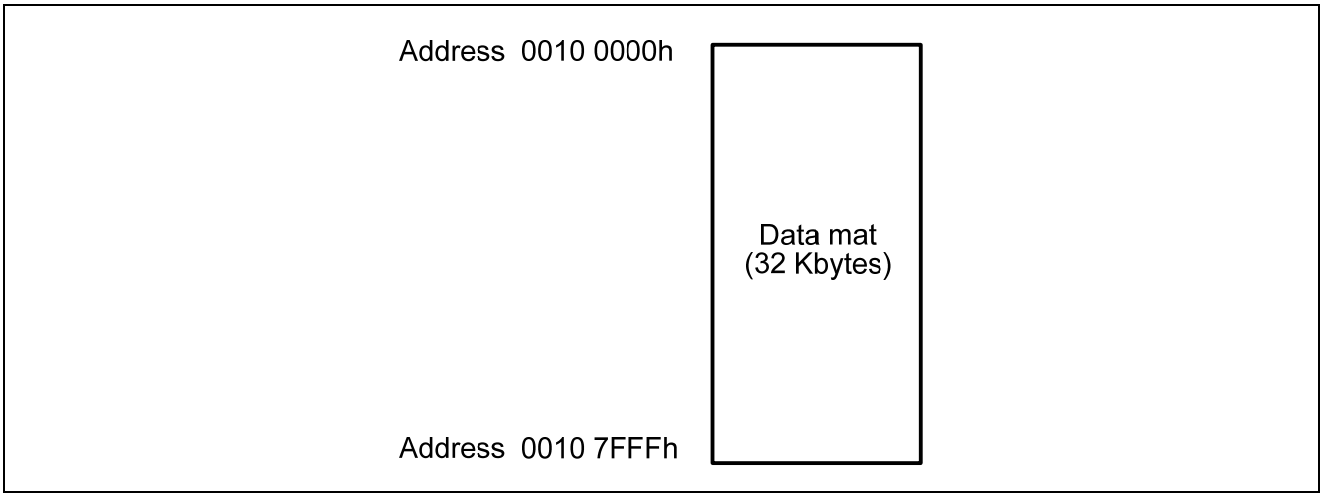


Figure 27.2 Configuration of the Data Mat

27.4 Block Configuration

The configuration of erasure blocks for the data mat is shown in figure 27.3. As units of erasure, the data mat is divided into 4 blocks of 8 Kbytes. Programming is in 8- or 128-byte units. Programming in eight-byte units proceeds for the eight bytes from an address for which the three lower-order bits are zero. Programming in 128-byte units proceeds for the 128 bytes from an address for which the lower-order byte is 00h or 80h.

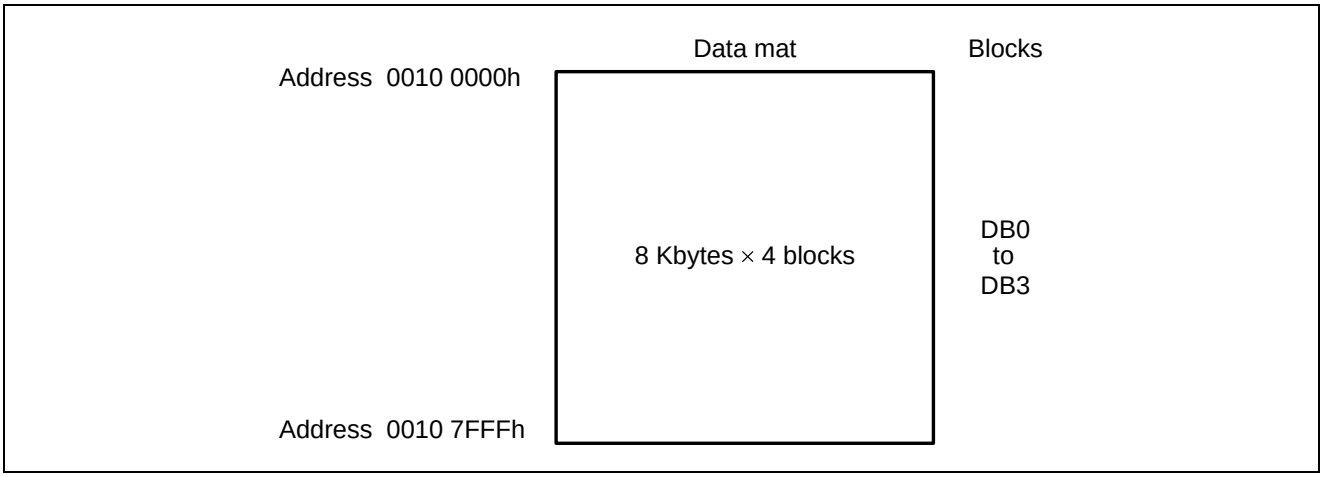


Figure 27.3 Division of the Data Mat into Erasure Blocks

27.5 Operating Modes Associated with the Data Flash

For the transitions between operating modes, see section 26.5, Operating Modes Associated with the ROM.

Reading, programming, and erasing of the data flash memory in an on-board device can proceed if the device is in boot, user-boot, or single-chip mode (with on-chip ROM enabled), or in on-chip-ROM-enabled expansion mode.

The differences between modes are indicated in table 27.4.

Table 27.4 Differences between Modes

Item	Boot Mode	User Boot Mode	Single-Chip Mode (with On-chip ROM Enabled) or On-chip-ROM-Enabled Expansion Mode
Environment for programming and erasure	On-board programming	On-board programming	On-board programming
Programmable and erasable mat	Data mat	Data mat	Data mat
Division into erasure blocks	Poss ble*1	Possible	Possible
Target mat for booting after a reset	Mat containing the embedded program*2	User boot mat	User mat

Notes: 1. All flash memory areas may be erased at the time of booting up. Specified blocks can subsequently be erased. For details, refer to section 26.10.4, ID Code Protection in Boot Mode.

2. Not available to users.

- In boot mode, a host is able to program or read out the data mat via an SCI.
- After booting up from the user boot mat in user boot mode, programming and erasure of the user mat or data mat via the desired interface is possible.
- In boot mode, on-chip RAM is employed for the embedded program for use in boot mode. For this reason, preserving the contents of on-chip RAM is not possible in this case.

27.6 Programming and Erasing the Data Flash Memory

The data flash memory is programmed and erased by issuing commands to a dedicated sequencer (FCU) for programming and erasure. The FCU has five modes. For programming and erasure, the mode is changed and then commands for programming and erasure are issued.

The mode transitions required to program or erase the data flash and the system of commands are described below. The descriptions apply in common to boot, user-boot, and single-chip mode (with on-chip ROM enabled), and to on-chip-ROM-enabled expansion mode.

27.6.1 FCU Modes

The FCU has five modes or sets of modes. Transitions between modes are caused by writing to FENTRYR or issuing FCU commands. Figure 27.4 is a diagram of the FCU mode transitions.

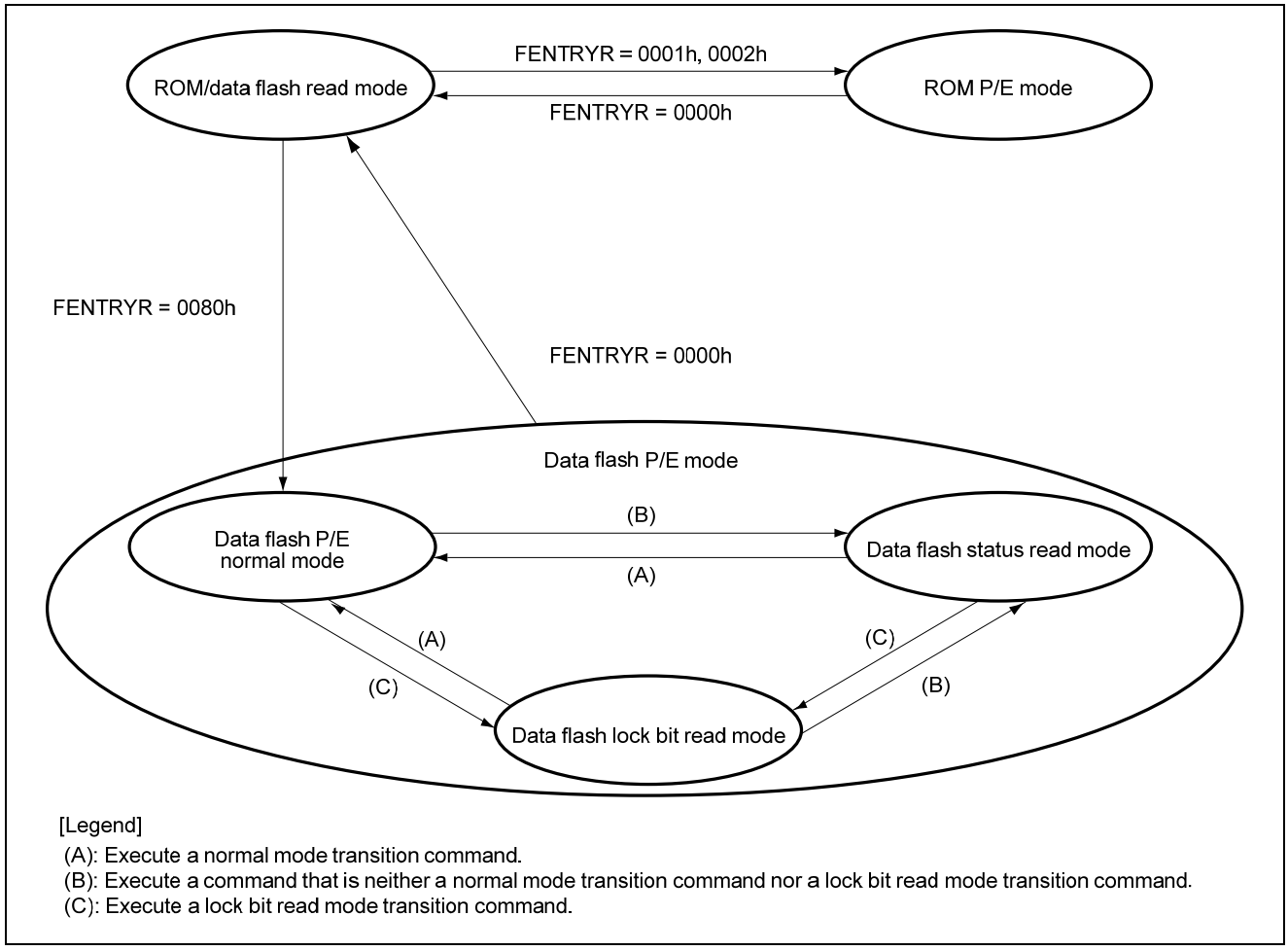


Figure 27.4 Mode Transitions of the FCU (Associated with the Data Flash)

27.6.1.1 ROM P/E Modes

The ROM P/E modes are for programming and erasure of the ROM.

For details on the ROM P/E modes, see section 26.6.1.2, ROM P/E Modes.

27.6.1.2 ROM/Data Flash Read Mode

This mode is for reading the ROM or data-flash memory. The FCU does not accept commands.
The FCU enters this mode when the FENTRYD bit in FENTRYR is set to 0 and the FENTRY1 and FENTRY0 bits in FENTRYR are set to 0.

27.6.1.3 Data Flash P/E Modes

These modes are for programming and erasure of the data-flash memory. Reading out the data flash is not possible.

Data flash P/E normal mode, data flash status read mode, and data flash lock-bit read mode are the three data flash P/E modes.

(1) Data Flash P/E Normal Mode

The transition to data flash P/E normal mode is the first transition in the process of programming or erasing the data flash. The FCU enters this mode when the FENTRYD bit in FENTRYR is set to 1 and the FENTRY1 and FENTRY0 bits in FENTRYR are set to 0 in ROM/data flash read mode, or when the normal mode transition command is received in data flash P/E modes. Table 27.7 lists the acceptable commands in this mode.

Read access to an address within the data flash area causes a data-flash-access violation, and the FCU enters the command-locked state. High-speed reading of the ROM is possible.

(2) Data Flash Status Read Mode

The data flash status read mode is for reading information on the state of the data flash.

The FCU enters this mode when a command other than the normal mode transition and lock bit read mode transition command is received in data flash P/E modes. Data flash status read mode encompasses the states where the FRDY bit in FSTATR0 is 0 and the command-locked state after an error has occurred. Table 27.7 lists the acceptable commands in this mode.

Read access to an address within the data flash area will actually read out the value of FSTATR0. High-speed reading of the ROM is possible.

(3) Data Flash Lock-Bit Read Mode

The data flash lock-bit read mode is for reading the values of the lock bits of the data flash. However, this is not possible because the data flash does not have lock bits.

The FCU enters this mode when a lock-bit read mode transition command is received in data flash P/E modes. Table 27.7 lists the acceptable commands in this mode.

Since the data flash does not have lock bits, data read out in read access to addresses within the data flash area are undefined. However, the access does not lead to a data-flash-access violation. High-speed reading of the ROM is possible.

27.6.2 FCU Commands

FCU commands consist of commands for mode transitions of the FCU and of commands for programming and erasure.

Table 27.5 lists the FCU commands for use with the data flash.

Table 27.5 FCU Commands for Use with Data Flash Memory

Command	Description
Normal mode transition	Changes the mode to normal mode (see section 27.6.3, Connections between FCU Modes and Commands)
Status read mode transition	Changes the mode to status read mode (see section 27.6.3, Connections between FCU Modes and Commands)
Lock bit read mode transition (lock bit read 1)	Changes the mode to lock bit read mode (see section 27.6.3, Connections between FCU Modes and Commands)
Peripheral clock notification	Sets the frequency of the peripheral clock
Programming	Data flash programming (in 8-byte or 128-byte units)
Block erasure	Data flash erasure (in block units, with the lock bit being erased simultaneously)
P/E suspension	Suspends programming/erasure
P/E resumption	Resumes programming/erasure
Status register clearing	Clears the ILGLERR, ERSERR and PRGERR bits in FSTATR0 and releases the FCU from the command-locked state
Lock bit read 2/blank checking	Checks whether the specified block of data-flash memory has been erased (is blank)

Commands other than the blank-checking command are also for use with the ROM.

The blank-checking command for the data-flash memory is also used as the lock bit read 2 command for the ROM. That is, when the same command is issued for the ROM, a lock bit of the ROM is read out.

Commands for the FCU are issued by write access to addresses within the data flash area.

Table 27.6 shows the formats of the programming commands and the blank checking command. Write access as listed in table 27.6 and in accord with certain conditions causes the FCU to execute processing for the corresponding command. For details on the conditions for acceptance of the individual FCU commands, see section 27.6.3, Connections between FCU Modes and Commands. For how to use the FCU commands, see section 27.6.4, FCU Command Usage.

Table 27.6 FCU Command Formats

Command	Number of bus cycles	First Cycle		Second Cycle		Third Cycle		4th to (N+2)th Cycles		(N+3)th Cycles	
		Address	Data	Address	Data	Address	Data	Address	Data	Address	Data
Programming (8-byte programming; n = 4)	7	EA	E8h	EA	04h	WA	WDn	EA	WDn	EA	D0h
Programming (128-byte programming; n = 64)	67	EA	E8h	EA	40h	WA	WDn	EA	WDn	EA	D0h
Blank checking	2	EA	71h	BA	D0h	—	—	—	—	—	—

[Legend] Address column EA: Address within the data flash area: Any address in the range from 0010 0000h to 0010 7FFFh
WA: Start address of 8 bytes or 128 bytes
BA: Address in an erasure block of the data flash
Any address within the target erasure block
Data columns WDn: nth word of data for programming (n = 1 to N)

27.6.3 Connections between FCU Modes and Commands

The sets of FCU commands that can be accepted in each of the FCU modes are fixed. Furthermore, which commands are acceptable in a given FCU mode varies according to the state of the FCU.

Issuing of an FCU command must follow checking of the FCU's state after transitions of the FCU mode.

Commands that are acceptable in the various FCU modes and states are listed in table 27.7. Issuing a command that is not currently acceptable leads to the FCU being placed in the command-locked state (see section 27.7.2, Error Protection).

Issuing of an FCU command must follow checking of the values of the FRDY, ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and of the FCUERR bit in FSTATR1 after transitions of the FCU mode. Furthermore, the CMDLK bit in FASTAT can be checked to see if an error has occurred. The value of the CMDLK bit in FASTAT is the logical OR of the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the FCUERR bit in FSTATR1.

Table 27.7 Acceptable Commands and the State and Mode (Data Flash P/E Mode) of the FCU

	P/E Normal Mode			Status read mode							Lock-bit read mode		
	Programming suspended	Erasure suspended	Other state	Programming or erasure	Processing to suspend programming or erasure	Blank checking	Programming suspended	Erasure suspended	Command-locked state	Other state	Programming suspended	Erasure suspended	Other state
FSTATR0.FRDY bit	1	1	1	0	0	0	1	1	0/1	1	1	1	1
FSTATR0.SUSRDY bit	0	0	0	1	0	0	0	0	0	0	0	0	0
FSTATR0.ERSSPD bit	0	1	0	0	0/1	0	0	1	0	0	0	1	0
FSTATR0.PRGSPD bit	1	0	0	0	0/1	0	1	0	0	0	1	0	0
FASTAT.CMDLK bit	0	0	0	0	0	0	0	0	1	0	0	0	0
Normal mode transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Status read transition	A	A	A	X	X	X	A	A	X	A	A	A	A
Lock-bit read transition (lock bit read 1)	A	A	A	X	X	X	A	A	X	A	A	A	A
Peripheral clock notification	X	X	A	X	X	X	X	X	X	A	X	X	A
Programming	X	*	A	X	X	X	X	*	X	A	X	*	A
Block erasure	X	X	A	X	X	X	X	X	X	A	X	X	A
P/E suspension	X	X	X	A	X	X	X	X	X	X	X	X	X
P/E resumption	A	A	X	X	X	X	A	A	X	X	A	A	X
Status register clearing	A	A	A	X	X	X	A	A	A	A	A	A	A
Blank checking	A	A	A	X	X	X	A	A	X	A	A	A	A

[Legend]

A: Acceptable

*: Only programming is acceptable for blocks other than the block where erasure was suspended

X: Not acceptable

27.6.4 FCU Command Usage

This section shows how to program and erase the data flash memory by using programming and block erasure commands, respectively, and how to check the state of erasure of the data flash by using the blank check command. For the method for transferring the firmware to the FCU RAM and the ways to use other FCU commands, see section 26.6.4, FCU Command Usage.

(1) Using the Peripheral Clock Notification Command

This command handles notification of the frequency of the peripheral clock. For details, see section 26.6.4, FCU Command Usage. Set the FENTRYD bit in FENTRYR to 1 and make settings to indicate an address within the data flash area.

(2) Programming

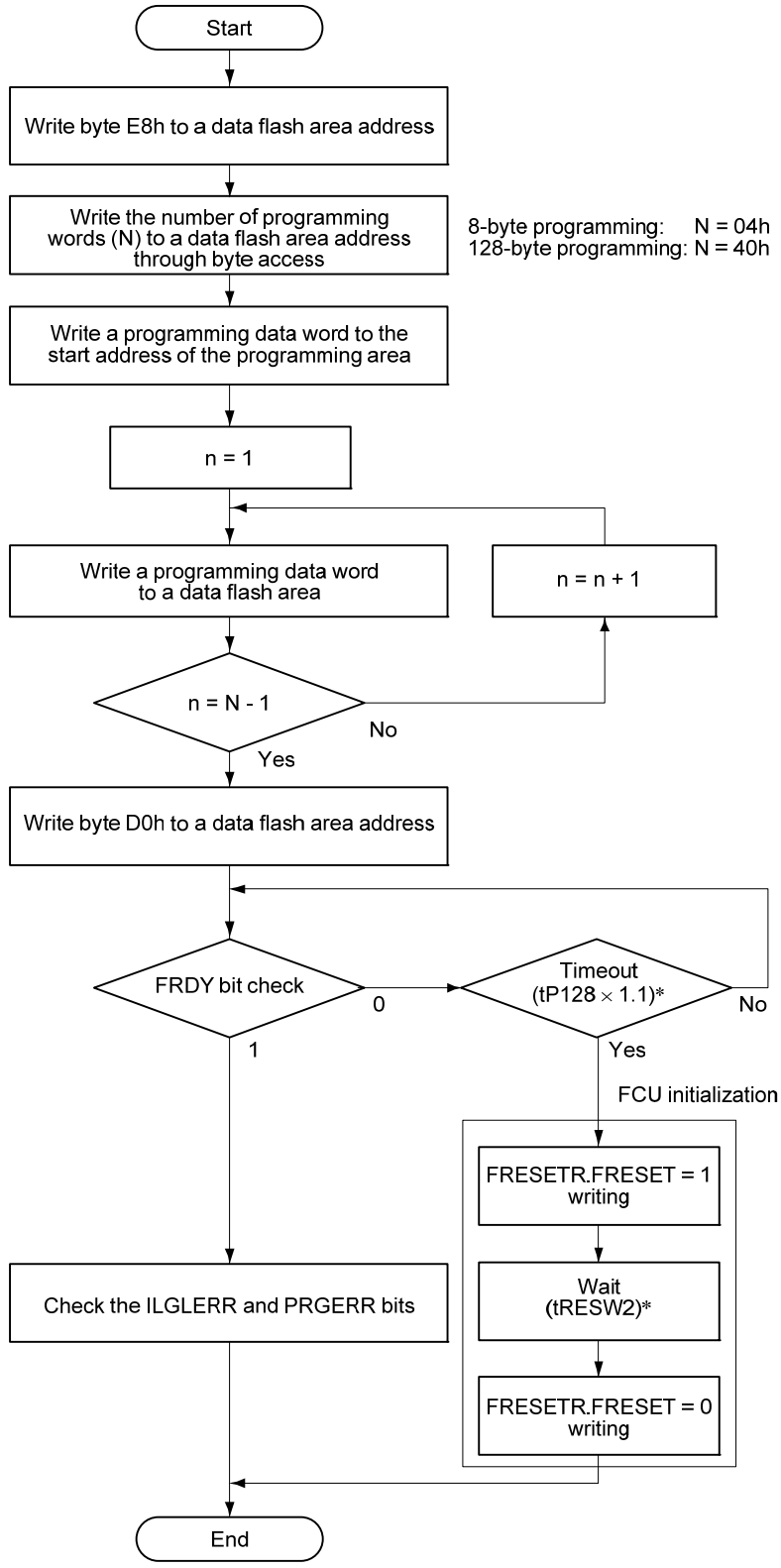
To program the data flash, use one of the programming commands.

Use byte access to write E8h to an address within the data flash area in the first cycle of the programming command, and the number of words (N)* to be programmed in the second cycle. Access the peripheral bus in words from the third cycle to cycle N + 2 of the command. In the third cycle, write the first word of data for programming to the address where the target area for programming starts. This address must be on an 8-byte boundary for 8-byte programming or on a 128-byte boundary address for 128-byte programming. After writing words to addresses in the data flash area N times, write byte D0h to an address within the data flash area in cycle N + 3; the FCU will then start actual programming of the data flash. Read the FRDY bit in FSTATR0 to confirm the completion of data flash programming.

If the area accessed in the third cycle to cycle N + 2 includes addresses that do not require programming, write FFFFh as the programming data for those addresses. To ignore the programming and erasure protection provided by the DFLWE settings, set the program/erase enable bit for the target block to 1 before programming starts.

Figure 27.5 shows the procedure for data flash programming.

Note: * N = 04h for 8-byte programming or N = 40h for 128-byte programming.



Note: * tP128: Time required for programming 128-byte data (see section 29, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 29, Electrical Characteristics)

Figure 27.5 Procedure for Data Flash Programming

(3) Erasure

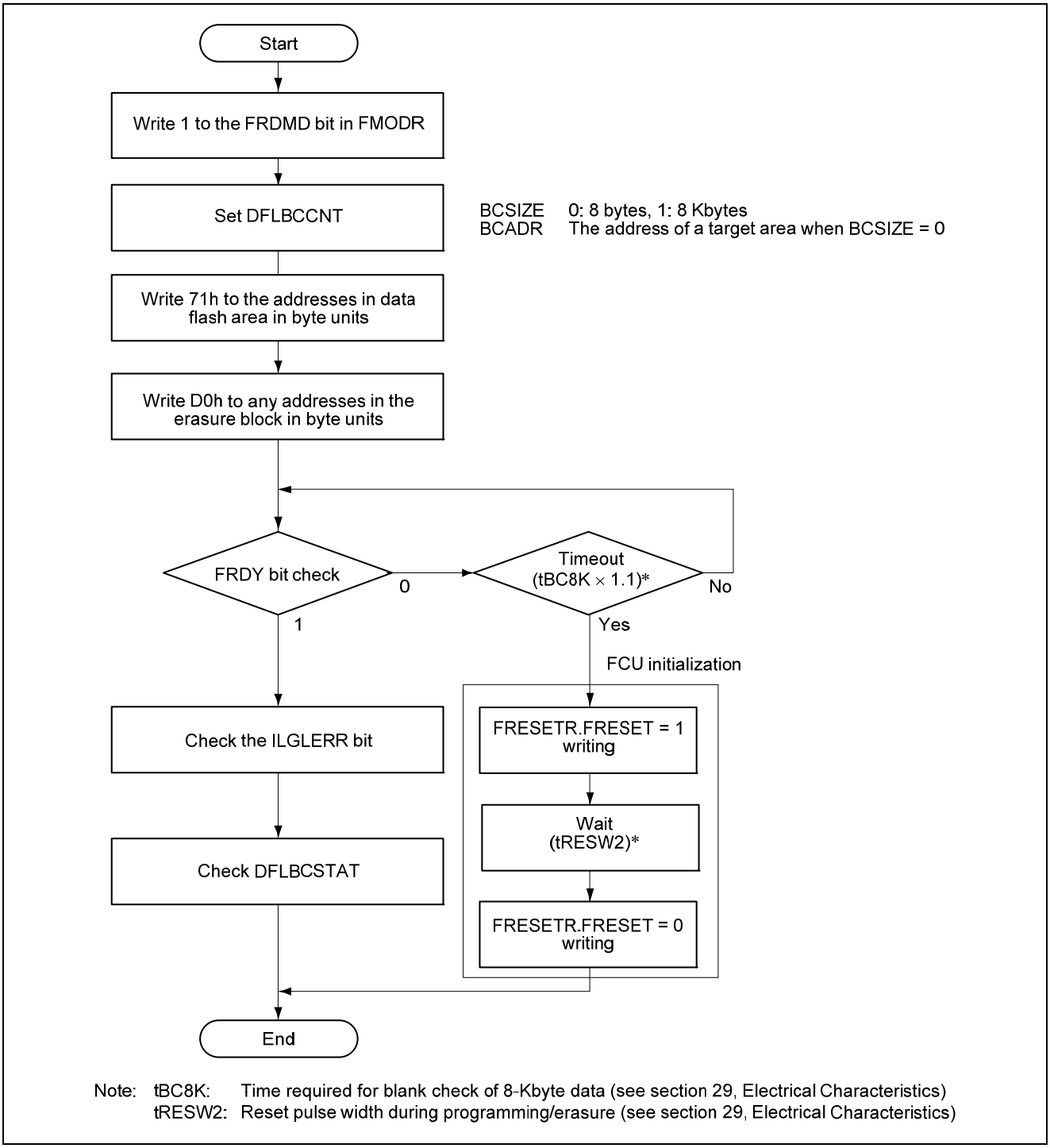
To erase the data flash, use the block erasure command. The data flash is erased in the same way as the ROM (see section 26, ROM (Flash Memory for Code Storage)).

Note that the data flash has a programming and erasure protection function that is controlled by DFLWE. Erasure can only be performed with protection provided by the DFLWE setting disabled, so set the programming/erasure enable bit for the target erasure block to 1 before issuing the erasure command.

(4) Blank Checking

Since using the CPU to read erased areas of the data flash produces undefined values, the blank checking command should be used to check whether the data flash has actually been erased. To make the blank checking command available for use, start by setting the FRDMD bit in FMODR to 1 to enable the command, and then specify the size and start address of the target area in DFLBCCNT. If the BCSIZE bit of DFLBCCNT is set to 1, checking will be performed for the entire erasure block (8 Kbytes) specified in the second cycle of the command. If the BCSIZE bit is set to 0, checking will be performed on the 8-byte range starting from the address obtained by adding the start address of the erased area as specified in the second cycle of the command and the value held by DFLBCCNT. In the first cycle of the command sequence, the value 71h is written as a byte unit to an address in the data flash. In the second cycle, when the value D0h is written to an address within the target area, the FCU starts blank checking of the data flash. Test the FRDY bit in FSTATR0 to check whether or not the check is complete. On completion of blank checking, check the BCST bit of DFLBCSTAT to see whether the target area has been erased or is filled with 0s and/or 1s via.

Figure 27.6 shows the procedure for blank checking of the data flash.



Note: tBC8K: Time required for blank check of 8-Kbyte data (see section 29, Electrical Characteristics)
tRESW2: Reset pulse width during programming/erasure (see section 29, Electrical Characteristics)

Figure 27.6 Procedure for Blank Checking of the Data Flash

27.7 Protection

There are two types of data flash programming/erasure protection: software protection and error protection.

27.7.1 Software Protection

In the software protection function, control register settings are used to disable data flash programming and erasure. If an attempt is made to issue a programming or erasure command for the data flash and the command violates current software protection, the FCU detects the error and enters the command-locked state.

(1) Protection through FWEPROR

If the FLWE[1:0] bits in FWEPROR are not set to 01b, programming cannot be performed in any mode.

(2) Protection through FENTRYR

When the FENTRYD bit in FENTRYR is 0, the ROM/data flash read mode is selected. Since the FCU does not accept commands in ROM/data flash read mode, data flash programming and erasure are disabled. If an attempt is made to issue an FCU command for the data flash in ROM/data flash read mode, the FCU detects an illegal command error and enters the command-locked state (see section 27.7.2, Error Protection).

(3) Protection through DFLWE

When the DBWEj (j = 3 to 0) bit in DFLWE is 0, programming and erasure of block DBj in the data mat is disabled. If an attempt is made to program or erase block DBj while the DBWEj bit is 0, the FCU detects a programming/erasure protection error and enters the command-locked state (see section 27.7.2, Error Protection).

(4) Protection through DFLRE

When the DBREj (j = 3 to 0) bit in DFLRE is 0, reading of block DBj in the data mat is disabled. If an attempt is made to read block DBj while the DBREj bit is 0, the FCU detects a read protection error and enters the command-locked state (see section 27.7.2, Error Protection).

27.7.2 Error Protection

Error protection is the detection of errors in the issuing of FCU commands and of prohibited access, and response in the form of notification of the FCU malfunction and prohibition of the reception of further commands by the FCU (the FCU enters the command-locked state). When the FCU enters the command-locked state (FASTAT.CMDLK bit is 1), one or several of the status bits (FSTATR0.ILGLERR, ERSERR, and PRGERR bits, FSTATR1.FCUERR bit, and FASTST.DFLAE, DFLRPE, and DFLWPE bits) are set to 1 and programming and erasure of the data-flash are prohibited. To release the FCU from the command-locked state, a status register clearing command must be issued with FASTAT set to 10h.

While the CMDLKIE bit in FAEINT is 1, a flash interface error (FIFERR) interrupt will be generated if the FCU enters the command-locked state (the CMDLK bit in FASTAT becomes 1). While a data flash-related interrupt enable bit (DFLAEIE, DFLRPEIE, or DFLWPEIE) in FAEINT is 1, an FIFERR interrupt will also be generated if the corresponding status bit (DFLAE, DFLRPE, or DFLWPE) in FASTAT becomes 1.

Table 27.8 shows the error protection types for the data flash and the values of the status bits (the ILGLERR, ERSERR, and PRGERR bits in FSTATR0 and the DFLAE, DFLRPE, and DFLWPE bits in FASTAT) after the detection of each type of error. For the error protection types used in common by the ROM and data flash (FENTRYR setting error, most illegal command errors, erasing errors, programming errors, and FCU errors, see section 26.8.2, Error Protection.

If the FCU enters the command-locked state due to a command other than a suspension command issued during programming or erasure processing, the FCU continues programming or erasing the data flash. In this state, the P/E suspension command cannot suspend programming or erasure. If a command is issued in the command-locked state, the ILGLERR bit becomes 1.

Table 27.8 Error Protection Types (for Data Flash Only)

Error	Description	ILGLERR	ERSERR	PRGERR	DFLAE	DFLRPE	DFLWPE	CMDLK
Illegal command error	The value specified in the second cycle of a programming command was neither 04h nor 40h.	1	0	0	0	0	0	1
	A lock bit programming command was issued for an area in the data flash while the FENTRYD bit of FENTRYR register was set to 1.	1	0	0	0	0	0	1
Data flash access error	A read access command was issued for the data flash area while FENTRYD = 1 in FENTRYR in data flash P/E normal mode.	1	0	0	1	0	0	1
	A write access command was issued for the data flash area while FENTRYD = 0.	1	0	0	1	0	0	1
	An access command was issued for the data flash area while the FENTRY1 or FENTRY0 bit in FENTRYR was 1.	1	0	0	1	0	0	1
Data flash read protect error	A read access command was issued for the data flash area while it was protected against reading by the DFLRE setting.	1	0	0	0	1	0	1
Data flash programming protect error	A program/block erase command was issued for the data flash area while it was protected against programming and erasure by the DFLWE setting.	1	0	0	0	0	1	1

27.8 Boot Mode

To program or erase the data mat in boot mode, send control commands and programming data from the host. For the system configuration and settings in boot mode, see section 26.10, Boot Mode. This section describes only the commands dedicated for the data flash.

27.8.1 Inquiry/Selection Host Commands

Table 27.9 shows the inquiry/selection host commands dedicated to the data flash. The data mat inquiry and data mat information inquiry commands are used in the step of "Inquiry regarding mat programming information" in the flowchart shown in figure 26.29 (Example of Procedure to Use Inquiry/Selection Host Commands for User Mat/User Boot Mat) in section 26.10.5, Inquiry/Selection Host Command Wait State.

Table 27.9 Inquiry/Selection Host Commands (only for Data Flash)

Host Command Name	Function
Data mat inquiry	Inquires regarding the availability of data mat
Data mat information inquiry	Inquires regarding the number of data mats and the start and end addresses

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX610 and the "response" indicates a response sent from the RX610 to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX610 becomes 00h.

(1) Data Mat Inquiry

In response to a data mat inquiry command sent from the host, the RX610 returns the information concerning the availability of data mats.

Command	2Ah			
Response	3Ah	Size	Mat availability	SUM

[Legend]

Size (1 byte): Number of characters in the mat availability field (fixed at 1)

Mat availability (1 byte): Availability of data mats (fixed at 21h)

21h: Data mat is available

SUM (1 byte): Checksum

(2) Data Mat Information Inquiry

In response to a data mat information inquiry command sent from the host, the RX610 returns the number of data mat areas and their addresses.

Command	2Bh		
Response	3Bh	Size	Area count
	Area start address		
	Area end address		
	Area start address		
	Area end address		
	:		
	Area start address		
	Area end address		
	SUM		

[Legend]

Size (1 byte): Total number of bytes in the area count, area start address, and area end address fields

Area count (1 byte): Number of data mat areas (consecutive areas are counted as one area)

Area start address (4 bytes): Start address of a data mat area

Area end address (4 bytes): End address of a data mat area

SUM (1 byte): Checksum

The information concerning the block configuration in the data mat is included in the response to the erasure block information inquiry command (see section 26.10.5, Inquiry/Selection Host Command Wait State).

27.8.2 Programming/Erasing Host Commands

Table 27.10 shows the programming/erasing host commands dedicated to the data flash. Data flash-dedicated host commands are provided only for checksum and blank check of the data flash; the programming, erasing, and reading commands are used in common for the ROM and data flash.

To program the data mat, issue from the host a user mat programming selection command and then a 256-byte programming command specifying a data mat address as the programming address. To erase the data mat, issue an erasure selection command and then a block erasure command specifying an erasure block in the data mat. The information concerning the erasure block in the data mat is included in the response to the erasure block information inquiry command. To read data from the data mat, select the user mat through a memory read command specifying a data mat address as the read address.

For the user mat programming selection, user boot mat programming selection, 256-byte programming, erasure selection, block erasure, and memory read commands, refer to section 26.10.7, Programming/Erasing Host Command Wait State. For the erasure block information inquiry command, refer to section 26.10.5, Inquiry/Selection Host Command Wait State.

Table 27.10 Programming/Erasure Host Commands (only for Data Flash)

Host Command Name	Function
Data mat checksum	Performs checksum verification for the data mat
Data mat blank check	Checks whether the data mat is blank

Each host command is described in detail below. The "command" in the description indicates a command sent from the host to the RX610 and the "response" indicates a response sent from the RX610 to the host. The "checksum" is byte-size data calculated so that the sum of all bytes to be sent by the RX610 becomes 00h.

(1) Data Mat Checksum

In response to a data mat checksum command sent from the host, the RX610 sums the data mat data in byte units and returns the result (checksum).

Command	61h			
Response	71h	Size	Mat checksum	SUM

[Legend]

Size (1 byte): Number of bytes in the mat checksum field (fixed at 4)

Mat checksum (4 bytes): Checksum of the data mat data

SUM (4 bytes): Checksum (for the response data)

(2) Data Mat Blank Check

In response to a data mat blank check command sent from the host, the RX610 checks whether the data mat is completely erased. When the data mat is completely erased, the RX610 returns a response (06h). If the data mat has an unerased area, the RX610 returns an error response (sends E2h and 52h in that order).

Command	62h	
Response	06h	
Error response	E2h	52h

27.9 Usage Notes

(1) Protection of the Data Mat Immediately after a Reset

As the initial values of DFLRE and DFLWE are 0000h, programming, erasure, and reading of the data mat are disabled immediately after a reset. To read data from the data mat, set DFLRE appropriately before accessing the data mat. To program or erase the data mat, set DFLWE appropriately before issuing an FCU command for programming or erasure. If an attempt is made to read, program, or erase the data mat without setting the registers, the FCU detects the error and enters the command-locked state.

(2) Other Points to Note

The other points to note are the same as for the ROM. See section 26.13, Usage Notes.

28. Boundary Scan

The RX610 Group has boundary scan function, and this function is supported only in the 176-pin LFBGA version.

The boundary scan is a serial I/O interface based on the JTAG (Joint Test Action Group, IEEE Std.1149.1 and IEEE Standard Test Access Port and Boundary-Scan Architecture).

28.1 Features

Table 28.1 lists the specifications of boundary scan.

Figure 28.1 shows the block diagram of the boundary scan function.

Table 28.1 Specifications of Boundary Scan

Item	Description
Boundary scan enabled/disabled	Boundary can is enabled when the EMLE pin is driven low and the BSCANP pin is driven high.
Dedicated boundary scan pins	Pins P02, P03, P04, P05, and WDTOVF# are dedicated for JTAG, when boundary scan function is enabled.
Six test modes	• BYPASS mode • EXTEST mode • SAMPLE/PRELOAD mode • CLAMP mode • HIGHZ mode • IDCODE mode

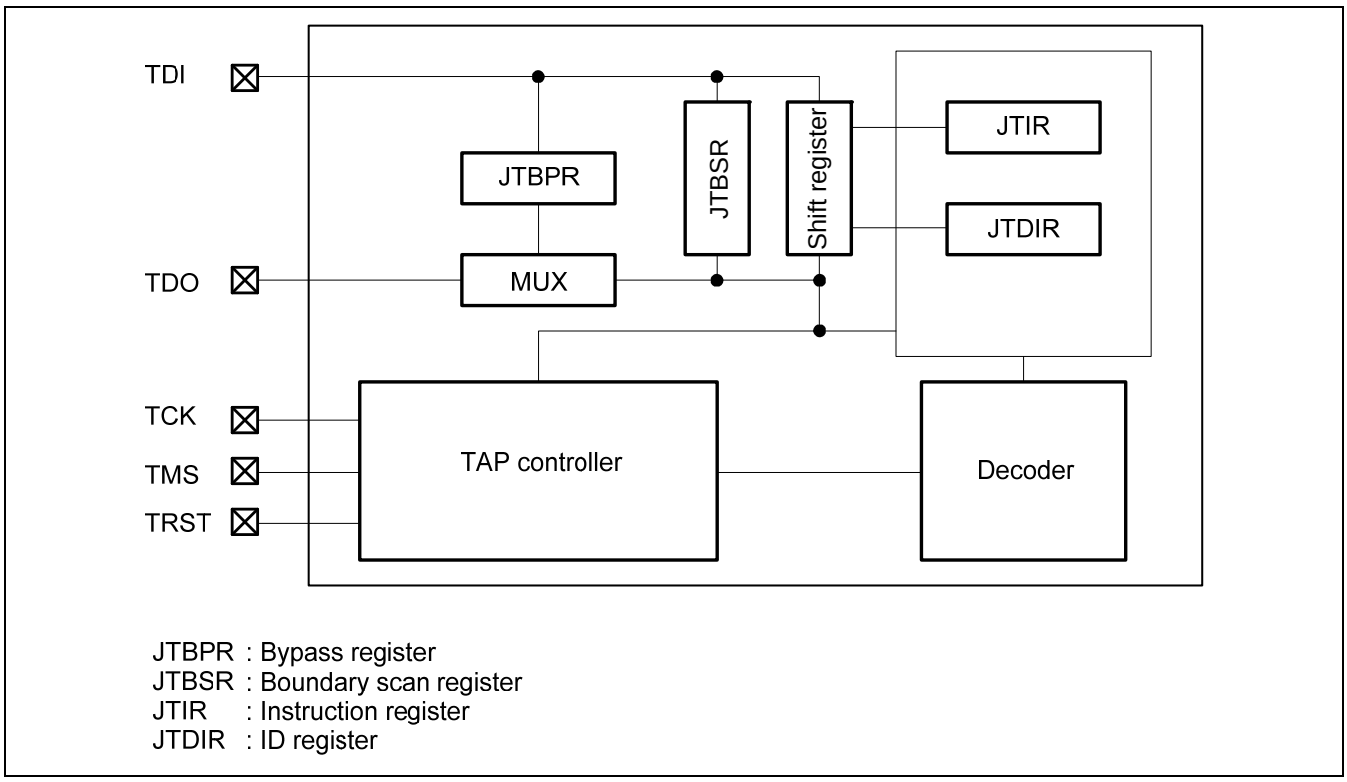


Figure 28.1 Block Diagram of Boundary Scan Function

Table 28.2 shows the I/O pins used in the boundary scan function.

Table 28.2 Pin Configuration

Pin Name	I/O	Description
TCK	Input	Test clock input pin Clock signal for boundary scan. Input the clock the duty cycle of which is 50 percent when boundary scan function is used.
TMS	Input	Test mode select pin
TDI	Input	Test data input pin
TDO	Output	Test data output pin
TRST	Input	Test reset input pin

28.2 Register Descriptions

Table 28.3 lists the boundary scan registers.

Register Name	Symbol	Value after Reset	Address	Access Size
Instruction register	JTIR	4h	—	4
Bypass register	JTBPR	Undefinded	—	1
Boundary scan register	JTBSR	Undefinded	—	—
IDCODE register	JTIDR	0809 9447h	—	32

Instructions can be input to the instruction register (JTIR) via the test data input pin (TDI) by serial transfer.

The bypass register (JTBPR), which is a 1-bit register, is connected between the TDI and TDO pins in BYPASS mode.

The boundary scan register (JTBSR), which is a JTBSR-bit register (see table 28.6), is connected between the TDI and TDO pins when test data are being shifted in.

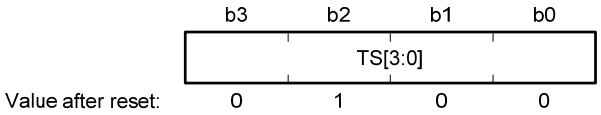
None of the registers is accessible from the CPU.

Table 28.4 shows the availability of serial transfer for the registers.

Table 28.4 Serial Transfers for Registers

Register Abbreviation	Serial Input	Serial Output
JTIR	Available	Available
JTBPR	Available	Available
JTBSR	Available	Available
JTID	Available	Available

28.2.1 Instruction Register (JTIR)



Bit	Symbol	Bit Name	Description	R/W
b3 to b0	TS[3:0]	Test Bit Set	The command configuration is as shown in table 28.5.	—

Table 28.5 Command Configuration

TS3	TS2	TS1	TS0	Instruction
0	0	0	0	EXTEST
0	0	0	1	SAMPLE/PRELOAD
0	1	0	0	IDCODE (initial value)
0	1	1	0	CLAMP
0	1	1	1	HIGHZ
1	1	1	1	BYPASS
Other than above				Reserved

JTIR is a 4-bit register.

JTAG instructions can be transferred to JTIR by serial input from the TDI pin.

JTIR is initialized when the TRST signal is low level, when the TAP controller is in the Test-Logic-Reset state.

28.2.2 Bypass Register (JTBPR)

JTBPR is a 1-bit register and is connected between the TDI and TDO pins when JTIR is set to BYPASS mode.

JTBPR cannot be read from or written to by the CPU.

28.2.3 Boundary Scan Register (JTBSR)

JTBSR is a shift register to control the external input and output pins of this LSI and is distributed across the pads.

The EXTEST, SAMPLE/PRELOAD, CLAMP, and HIGHZ instructions are issued to apply JTBSR in boundary-scan testing conformant to the JTAG standard.

Table 28.6 shows the correspondence between the JTBSR bits and the pins of this LSI.

The value after reset is undefined.

Table 28.6 Relationship between Pins and JTBSR Bits

		From TDI	
176-Pin LFBGA	**Pin Name**	**Input/Output**	**Bit Name**
B1	P67	Input	411
		Output enable	410
		Output	409
C2	P66	Input	408
		Output enable	407
		Output	406
D2	P01	Input	405
		Output enable	404
		Output	403
E4	P00	Input	402
		Output enable	401
		Output	400
D1	P65	Input	399
		Output enable	398
		Output	397
F4	MDE	Input	396
F1	MD1	Input	395
F2	MD0	Input	394
G4	P86	Input	393
		Output enable	392
		Output	391
G3	P85	Input	390
		Output enable	389
		Output	388
H2	NMI	Input	387
J4	P34	Input	386
		Output enable	385
		Output	384
J3	PF6	Input	383
		Output enable	382
		Output	381
J1	PF5	Input	380
		Output enable	379
		Output	378
J2	PF4	Input	377
		Output enable	376
		Output	375
K4	P33	Input	374
		Output enable	373
		Output	372
K3	P32	Input	371
		Output enable	370
		Output	369
K1	P31	Input	368
		Output enable	367
		Output	366
K2	P30	Input	365
		Output enable	364
		Output	363
L3	PF3	Input	362
		Output enable	361
		Output	360

From TDI

176-Pin LFBGA	Pin Name	Input/Output	Bit Name
L1	PF2	Input	359
		Output enable	358
		Output	357
L2	PF1	Input	356
		Output enable	355
		Output	354
L4	PF0	Input	353
		Output enable	352
		Output	351
M1	P27	Input	350
		Output enable	349
		Output	348
M2	P26	Input	347
		Output enable	346
		Output	345
N1	P25	Input	344
		Output enable	343
		Output	342
N2	P24	Input	341
		Output enable	340
		Output	339
P1	P23	Input	338
		Output enable	337
		Output	336
P2	P22	Input	335
		Output enable	334
		Output	333
R1	P21	Input	332
		Output enable	331
		Output	330
N3	P20	Input	329
		Output enable	328
		Output	327
R2	P17	Input	326
		Output enable	325
		Output	324
N4	P16	Input	323
		Output enable	322
		Output	321
P4	P15	Input	320
		Output enable	319
		Output	318
M5	P14	Input	317
		Output enable	316
		Output	315
R4	P13	Input	314
		Output enable	313
		Output	312
N5	P12	Input	311
		Output enable	310
		Output	309
P5	P11	Input	308
		Output enable	307
		Output	306

From TDI

176-Pin LFBGA	Pin Name	Input/Output	Bit Name
R5	P10	Input	305
		Output enable	304
		Output	303
M6	P37	Input	302
		Output enable	301
		Output	300
N6	P36	Input	299
		Output enable	298
		Output	297
R6	P35	Input	296
		Output enable	295
		Output	294
P6	P84	Input	293
		Output enable	292
		Output	291
M7	P57	Input	290
		Output enable	289
		Output	288
N7	P56	Input	287
		Output enable	286
		Output	285
R7	P55	Input	284
		Output enable	283
		Output	282
P7	P54	Input	281
		Output enable	280
		Output	279
M8	P83	Input	278
		Output enable	277
		Output	276
R8	P82	Input	275
		Output enable	274
		Output	273
M9	P81	Input	272
		Output enable	271
		Output	270
N9	P80	Input	269
		Output enable	268
		Output	267
R9	P53	Input	266
		Output enable	265
		Output	264
P9	P52	Input	263
		Output enable	262
		Output	261
M10	P51	Input	260
		Output enable	259
		Output	258
N10	P50	Input	257
		Output enable	256
		Output	255
R10	PH7	Input	254
		Output enable	253
		Output	252

From TDI

176-Pin LFBGA	Pin Name	Input/Output	Bit Name
P10	PH6	Input	251
		Output enable	250
		Output	249
R11	PH5	Input	248
		Output enable	247
		Output	246
M11	PH4	Input	245
		Output enable	244
		Output	243
R12	PH3	Input	242
		Output enable	241
		Output	240
P12	P77	Input	239
		Output enable	238
		Output	237
N12	P76	Input	236
		Output enable	235
		Output	234
R13	P75	Input	233
		Output enable	232
		Output	231
M12	PC7	Input	230
		Output enable	229
		Output	228
P13	PC6	Input	227
		Output enable	226
		Output	225
R14	PC5	Input	224
		Output enable	223
		Output	222
P14	PC4	Input	221
		Output enable	220
		Output	219
R15	PC3	Input	218
		Output enable	217
		Output	216
N13	PH2	Input	215
		Output enable	214
		Output	213
N14	PC2	Input	212
		Output enable	211
		Output	210
N15	PC1	Input	209
		Output enable	208
		Output	207
M14	PC0	Input	206
		Output enable	205
		Output	204
L12	PB7	Input	203
		Output enable	202
		Output	201
M15	PB6	Input	200
		Output enable	199
		Output	198

From TDI

176-Pin LFBGA	Pin Name	Input/Output	Bit Name
L13	PB5	Input	197
		Output enable	196
		Output	195
L14	PB4	Input	194
		Output enable	193
		Output	192
L15	PB3	Input	191
		Output enable	190
		Output	189
K12	PB2	Input	188
		Output enable	187
		Output	186
K13	PB1	Input	185
		Output enable	184
		Output	183
K15	P74	Input	182
		Output enable	181
		Output	180
K14	P73	Input	179
		Output enable	178
		Output	177
J12	P72	Input	176
		Output enable	175
		Output	174
J13	P71	Input	173
		Output enable	172
		Output	171
J15	P70	Input	170
		Output enable	169
		Output	168
H12	PB0	Input	167
		Output enable	166
		Output	165
H15	PH1	Input	164
		Output enable	163
		Output	162
H14	PH0	Input	161
		Output enable	160
		Output	159
G12	PA7	Input	158
		Output enable	157
		Output	156
G13	PA6	Input	155
		Output enable	154
		Output	153
G15	PA5	Input	152
		Output enable	151
		Output	150
G14	PA4	Input	149
		Output enable	148
		Output	147
F12	PA3	Input	146
		Output enable	145
		Output	144

From TDI

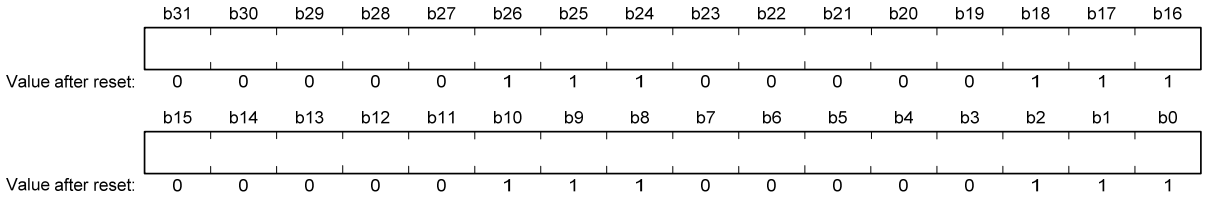
176-Pin LFBGA	Pin Name	Input/Output	Bit Name
F13	PA2	Input	143
		Output enable	142
		Output	141
F15	PA1	Input	140
		Output enable	139
		Output	138
F14	PA0	Input	137
		Output enable	136
		Output	135
E13	PG7	Input	134
		Output enable	133
		Output	132
E14	PG6	Input	131
		Output enable	130
		Output	129
D15	PG5	Input	128
		Output enable	127
		Output	126
D14	PE7	Input	125
		Output enable	124
		Output	123
D13	PE6	Input	122
		Output enable	121
		Output	120
C15	PE5	Input	119
		Output enable	118
		Output	117
D12	PE4	Input	116
		Output enable	115
		Output	114
C14	PE3	Input	113
		Output enable	112
		Output	111
B15	PE2	Input	110
		Output enable	109
		Output	108
B14	PE1	Input	107
		Output enable	106
		Output	105
A15	PE0	Input	104
		Output enable	103
		Output	102
C13	PD7	Input	101
		Output enable	100
		Output	99
A14	PD6	Input	98
		Output enable	97
		Output	96
B13	PD5	Input	95
		Output enable	94
		Output	93
A13	PD4	Input	92
		Output enable	91
		Output	90

From TDI

176-Pin LFBGA	Pin Name	Input/Output	Bit Name
D11	P64	Input	89
		Output enable	88
		Output	87
A12	P63	Input	86
		Output enable	85
		Output	84
C11	P62	Input	83
		Output enable	82
		Output	81
B11	P61	Input	80
		Output enable	79
		Output	78
A11	P60	Input	77
		Output enable	76
		Output	75
D10	PD3	Input	74
		Output enable	73
		Output	72
C10	PD2	Input	71
		Output enable	70
		Output	69
A10	PD1	Input	68
		Output enable	67
		Output	66
B10	PD0	Input	65
		Output enable	64
		Output	63
D9	PG4	Input	62
		Output enable	61
		Output	60
C9	PG3	Input	59
		Output enable	58
		Output	57
A9	PG2	Input	56
		Output enable	55
		Output	54
B9	PG1	Input	53
		Output enable	52
		Output	51
D8	PG0	Input	50
		Output enable	49
		Output	48
A8	P97	Input	47
		Output enable	46
		Output	45
B8	P96	Input	44
		Output enable	43
		Output	42
D7	P95	Input	41
		Output enable	40
		Output	39
C7	P94	Input	38
		Output enable	37
		Output	36

From TDI			
176-Pin LFBGA	**Pin Name**	**Input/Output**	**Bit Name**
A7	P93	Input	35
		Output enable	34
		Output	33
B7	P92	Input	32
		Output enable	31
		Output	30
D6	P91	Input	29
		Output enable	28
		Output	27
A6	P90	Input	26
		Output enable	25
		Output	24
C5	P47	Input	23
		Output enable	22
		Output	21
A5	P46	Input	20
		Output enable	19
		Output	18
B5	P45	Input	17
		Output enable	16
		Output	15
D5	P44	Input	14
		Output enable	13
		Output	12
A4	P43	Input	11
		Output enable	10
		Output	9
B4	P42	Input	8
		Output enable	7
		Output	6
C4	P41	Input	5
		Output enable	4
		Output	3
D4	P40	Input	2
		Output enable	1
		Output	0

28.2.4 IDCODE Register (JTID)



Bit	Description	R/W
b31 to b0	JTID is a register with the fixed value that indicates the device IDCODE.	—

JTID is a 32-bit register.

JTID data is output from the TDO pin when the IDCODE instruction has been executed.

28.3 Operations

The boundary scan functionality is valid when the EMLE pin is driven low and the BSCANP pin is driven high.

28.3.1 TAP Controller

Figure 28.2 shows the state transition diagram of the TAP controller.

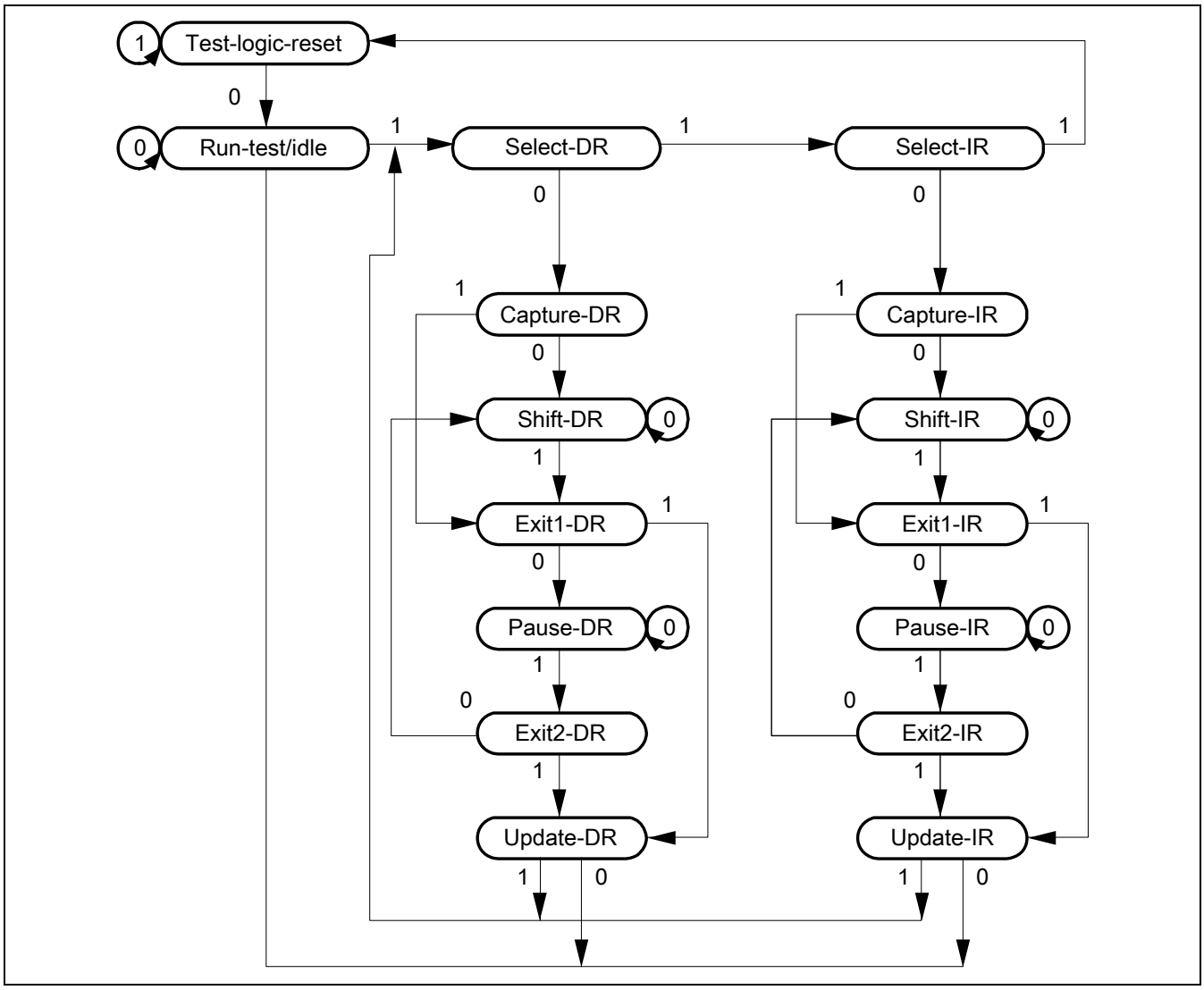


Figure 28.2 State Transition of TAP Controller

28.3.2 List of Commands

(1) BYPASS [Instruction Code: 1111b]

The BYPASS instruction is an instruction that drives the bypass register (JTBPR). This instruction shortens the shift path, facilitating the transfer of serial data to other LSIs on a printed-circuit board at higher speeds. While this instruction is being executed, the test circuit has no effect on the system circuits.

The bypass register (JTBPR) is connected between the TDI and TDO pins. Bypass operation is initiated from shift-DR operation. The TDO is low in the first clock cycle in the shift-DR state; in the subsequent clock cycles, the TDI signal is output on the TDO pin.

(2) EXTEST [Instruction Code: 0000b]

The EXTEST instruction is used to test external circuits when this LSI is installed on the printed circuit board. If this instruction is executed, output pins are used to output test data (specified by the SAMPLE/PRELOAD instruction) from the boundary scan register to the print circuit board, and input pins are used to input test result.

(3) SAMPLE/PRELOAD [Instruction Code: 0001b]

The SAMPLE/PRELOAD instruction is used to input data from the LSI internal circuits to the boundary scan register, output data from scan path, and reload the data to the scan path. While this instruction is executed, input signals are directly input to the LSI and output signals are also directly output to the external circuits. The LSI system circuit is not affected by this instruction.

In SAMPLE operation, the boundary scan register latches the snap shot of data transferred from input pins to internal circuit or data transferred from internal circuit to output pins. The latched data is read from the scan path. The scan register latches the snap data at the rising edge of the TCK in Capture-DR state. The scan register latches snap shot without affecting the LSI normal operation.

In PRELOAD operation, initial value is written from the scan path to the parallel output latch of the boundary scan register prior to the EXTEST instruction execution. If the EXTEST is executed without executing this PRELOAD operation, undefined values are output from the beginning to the end (transfer to the output latch) of the EXTEST sequence. (In EXTEST instruction, output parallel latches are always output to the output pins.)

(4) IDCODE [Instruction Code: 0100b]

When the IDCODE instruction is selected, IDCODE register value is output to the TDO in Shift-DR state of the TAP controller. In this case, IDCODE register value is output from the LSB. During this instruction execution, test circuit does not affect the system circuit. INSTR is initialized by the IDCODE instruction in Test-Logic-Reset state of the TAP controller.

(5) CLAMP [Instruction Code: 0110b]

When the CLAMP instruction is selected, output pins output the boundary scan register value which was specified by the SAMPLE/PRELOAD instruction in advance. While the CLAMP instruction is selected, the status of boundary scan register is maintained regardless of the TAP controller state.

BYPASS is connected between TDI and TDO, the same operation as BYPASS instruction can be achieved.

(6) HIGHZ [Instruction Code: 0111b]

When the HIGHZ instruction is selected, all output pins enter high-impedance state. While the HIGHZ instruction is selected, the status of boundary scan register is maintained regardless of the state of the TAP controller.

BYPASS is connected between TDI and TDO pins, leading to the same operation as when the BYPASS instruction has been selected.

28.4 Usage Notes

1. In serial transfer, data are input or output in LSB order (see figure 28.3).

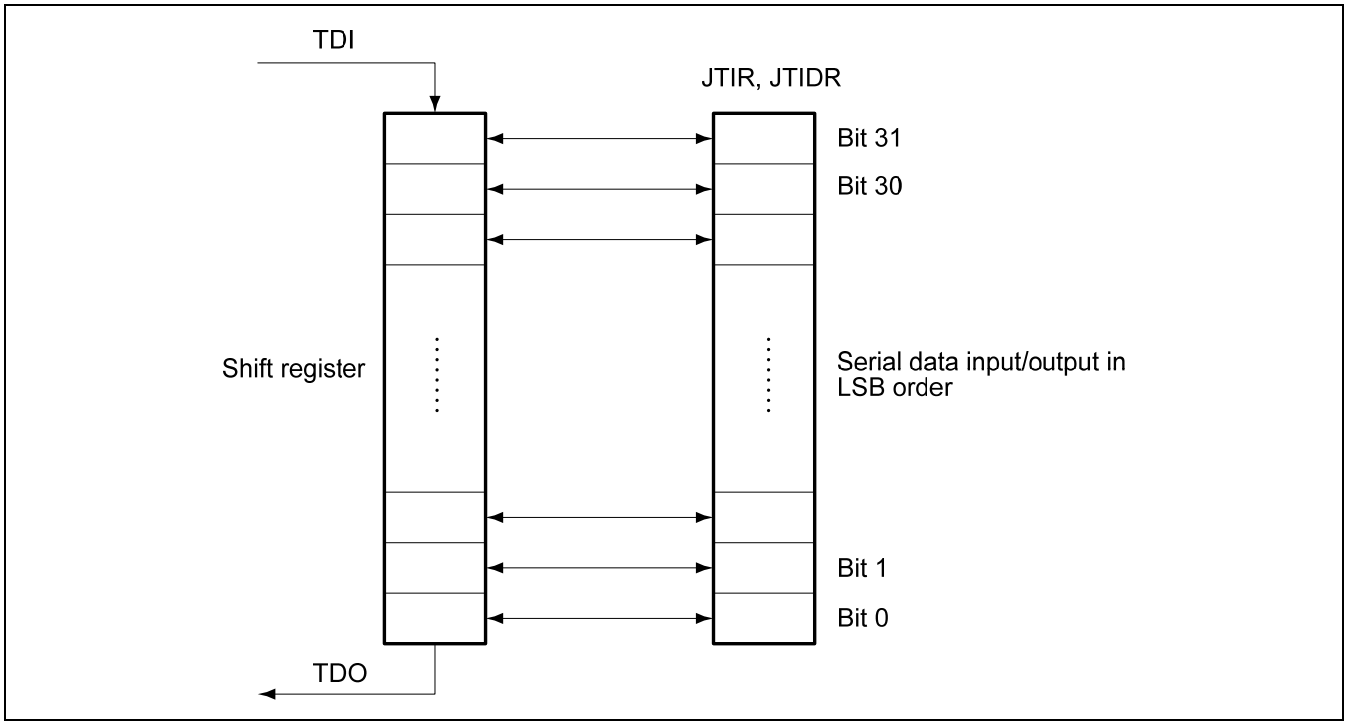


Figure 28.3 Serial Data Input/Output

2. Pins of the boundary scan (TCK, TDI, TMS, and TRST#) have to be pulled up by pull-up resistors.
3. Power supply pins (VCC, VCL, VSS, AVCC, AVSS, VREFH, VREF, PLLVCC, and PLLVSS) cannot be boundary-scanned.
4. Clock pins (EXTAL and XTAL) cannot be boundary-scanned.
5. Reset signal (RES#) cannot be boundary-scanned.
6. Boundary scan pins (TCK, TMS, TRST#, TDI, and TDO) cannot be boundary-scanned.
7. The boundary scan function is not available when this LSI are in the following states.
   (1) Reset state
   (2) Hardware standby mode, software standby mode, and deep software standby mode
8. While the pin with the open-drain function is enabled, set the output scan register to 1 and the output enable register to 1 by the boundary scan function. In this case, executing any of EXTEST, CLAMP, and SAMPLE/PRELOAD instructions makes the pin high-output instead of high-impedance.
9. Figure 28.4 (1) shows the pin configuration of pins P14 to P17. When the boundary scan function is used with pins P14 to P17 to be used as RIIC pins (SDA0, SDA1, SCL0, SCL1), the conflict with the open-drain output or sneak current might be generated.
10. Figure 28.4 (2) shows the pin configuration of pins P40 to P47, and P90 to P97. When the boundary scan function is used with pins P40 to P47, and P90 to P97 to be used as AD input pins (AN0 to AN7, and AN8 to AN15), the conflict with the AD input or sneak current might be generated.

11. Figure 28.4 (3) shows the pin configuration of pins P66 and P67. When the boundary scan function is used with pins P66 and P67 to be used as DA output pins (DA0 and DA1), the conflict with the DA output or sneak current might be generated.

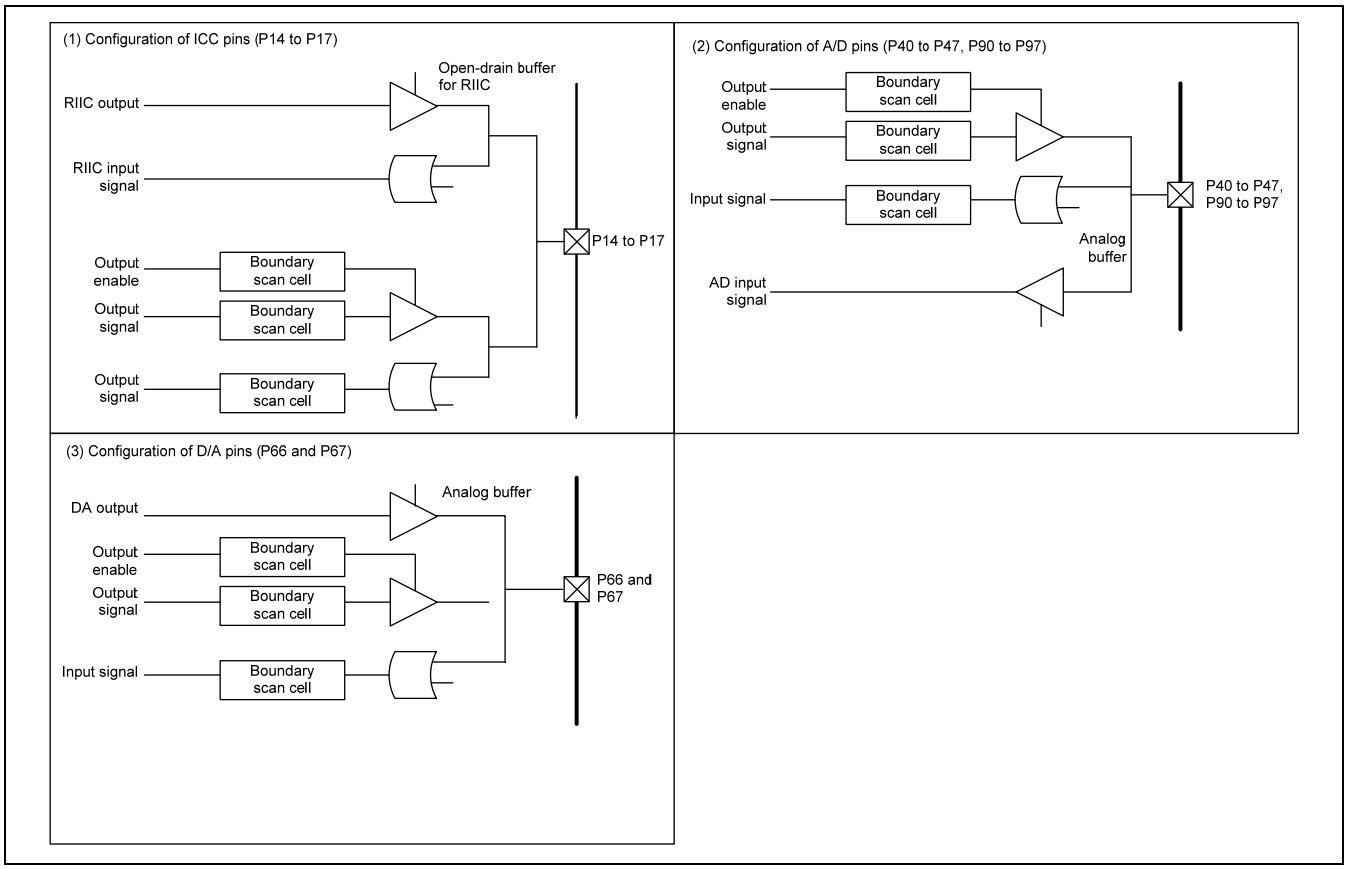


Figure 28.4 Pin Configuration

29. Electrical Characteristics

29.1 Absolute Maximum Ratings

Table 29.1 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}, $PLLV_{CC}$	-0.3 to +4.6	V
Input voltage (except for ports 0, 14 to 17)	V_{in}	-0.3 to V_{CC} +0.3	V
Input voltage (ports 0, 14 to 17*1)	V_{in}	-0.3 to +6.5	V
Reference power supply voltage	V_{REFH}	-0.3 to V_{CC} +0.3	V
Analog power supply voltage	AV_{CC}*2	-0.3 to +4.6	V
Analog input voltage	V_{AN}	-0.3 to V_{CC} +0.3	V
Operating temperature	T_{opr}	Regular specifications: -20 to +85	C
		Wide-range specifications: -40 to +85	
Storage temperature	T_{stg}	-55 to +125	C

Caution: Permanent damage to the LSI may result if absolute maximum ratings are exceeded.

Notes: 1. Ports 0, and 14 to 17 are 5 V tolerant.

2. Connect AV_{CC} to V_{CC}. When neither the A/D converter nor the D/A converter is in use, do not leave the AV_{SS}, V_{REFH}, and V_{REFL} pins open. Connect the AV_{CC} and V_{REFH} pins to V_{CC}, and the AV_{SS} and V_{REFL} pins to V_{SS}, respectively.

29.2 DC Characteristics

Table 29.2 DC Characteristics

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	IRQ input pin*1 TPU input pin*1 TMR input pin*1 SCI input pin*1 ADTRG# input pin*1 RES#, NMI	V_{IH}	V_{CC} x 0.8	—	V_{CC} + 0.3	V	
		V_{IL}	-0.3	—	V_{CC} x 0.2		
		ΔV_T	V_{CC} x 0.06	—	—		
	RIIC input pin	V_{IH}	V_{CC} x 0.7	—	5.8		
		V_{IL}	-0.3	—	V_{CC} x 0.3		
		ΔV_T	V_{CC} x 0.05	—	—		
	Ports 0, 14 to 17*2	V_{IH}	V_{CC} x 0.8	—	5.8		
		V_{IL}	-0.3	—	V_{CC} x 0.2		
	Ports 10 to 13, ports 2 to E (144-pin LQFP) ports 2 to H (176-pin LFBGA) Other input pins	V_{IH}	V_{CC} x 0.8	—	V_{CC} + 0.3		
		V_{IL}	-0.3	—	V_{CC} x 0.2		
Input high voltage (except Schmitt trigger input pin)	MD pin, EMLE	V_{IH}	V_{CC} x 0.9	—	V_{CC} + 0.3	V	
	EXTAL		V_{CC} x 0.8	—	V_{CC} + 0.3		
	D0 to D15		V_{CC} x 0.7	—	V_{CC} + 0.3		
Input low voltage (except Schmitt trigger input pin)	MD pin, EMLE	V_{IL}	-0.3	—	V_{CC} x 0.1	V	
	EXTAL		-0.3	—	V_{CC} x 0.2		
	D0 to D15		-0.3	—	V_{CC} x 0.3		
Output high voltage	All output pins	V_{OH}	V_{CC}-0.5	—	—	V	I_{OH} = -1 mA
Output low voltage	All output pins (except for RIIC pins)	V_{OL}	—	—	0.5	V	I_{OL} = 1.0 mA
	RIIC pins		—	—	0.4		I_{OL} = 3.0 mA
			—	—	0.6		I_{OL} = 6.0 mA
	RIIC pins (only P14 and P15 in channel 1)		—	—	0.4		I_{OL} = 15 mA (ICFER.FMPE = 1)
			—	0.4	—		I_{OL} = 20 mA (ICFER.FMPE = 1)
Input leakage current	RES#, MD pin, EMLE, NMI	$\lvert I_{in} \rvert$	—	—	1.0	µA	V_{in} = 0 V, V_{CC}
Three-state leakage current (off state)	Ports 10 to 13, ports 2 to E (144-pin LQFP) ports 2 to H (176-pin LFBGA)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0 V, V_{CC}
	Port 0, ports 14 to 17		—	—	5.0		

Item				Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input pull-up resistor current	Ports A to E			$-I_p$	10	—	300	µA	V_{CC} = 3.0 to 3.6 V, V_{in} = 0 V
Input capacitance	All input pins (except port 0, ports 14 to 17)			C_{in}	—	—	15	pF	V_{in} = 0 V, f = 1 MHz, T_a= 25 C
	Port 0, ports 14 to 17				—	—	30		
Supply current*3	In operation	Max.*4		I_{CC}*5	—	—	100	mA	ICLK = 100 MHz PCLK = 50 MHz BCLK = 25 MHz
		Normal*6			—	35	—		
		Increased by BGO operation*7			—	15	—		
	Sleep				—	18	52		
	All-module-clock-stop mode*8				—	14	28		
	Standby mode	Software standby mode			—	0.08	3.0		
		Deep software standby mode	RAM retained		—	15	200	µA	
			RAM power supply halted		—	0.9	26		
Analog power supply current	During A/D conversion (per unit)			AI_{CC}	—	0.8	1.2	mA	
	During D/A conversion (per unit)				—	0.3	1.0	µA	
	Idle (all units)				—	0.3	1.0		
Reference power supply current	During A/D conversion (per unit)				—	0.06	0.1	mA	
	During D/A conversion (per unit)				—	0.4	0.6		
	Idle (all units)				—	0.3	1.0	µA	
RAM standby voltage				V_{RAM}	2.5	—	—	V	
V_{CC} start voltage*9				$V_{CCSTART}$	—	—	0.8	V	
V_{CC} rising gradient*9				SV_{CC}	—	—	20	ms/V	

Notes:
1. This does not include the pins, which are multiplexed as ports 0, and 14 to 17 for 5 V tolerant.
2. This includes the multiplexed pins, but RIIC input pins for ports 14 to 17 are excluded.
3. Supply current values are with all output pins unloaded, all input pins for V_{IH} = V_{CC} and V_{IL}= 0 V, and all input pull-up resistors in the off state.
4. Measured with clocks supplied to the peripheral functions. This does not include the BGO operation.
5. I_{CC} depends on f (ICLK) as follows. (ICLK : PCLK : BCLK = 8 : 4: 2)

   I_{CC} max. = 0.89 x f + 11 (max.)
   I_{CC} typ. = 0.30 x f + 5 (normal operation)
   I_{CC} max. = 0.41 x f + 11 (sleep mode)
6. Measured with clocks not supplied to the peripheral functions. This does not include the BGO operation.
7. Incremented if data is written to or erased from the ROM or data flash for data storage during the program execution.
8. The values are for reference.
9. This can be applied when the RES# pin is held low at power-on.

Table 29.3 Permissible Output Currents

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item		Symbol	Min.	Typ.	Max.	Unit
Permissible output low current (average value per pin)	All output pins except for RIIC pins	I_{OL}	—	—	2.0	mA
	RIIC pins (ICFER.FMPE = 0)	I_{OL}	—	—	6.0	mA
	RIIC pins (ICFER.FMPE = 1)	I_{OL}	—	—	20.0	mA
Permissible output low current (max. value per pin)	All output pins except for RIIC pins	I_{OL}	—	—	4.0	mA
	RIIC pins (ICFER.FMPE = 0)	I_{OL}	—	—	6.0	mA
	RIIC pins (ICFER.FMPE = 1)	I_{OL}	—	—	20.0	mA
Permissible output low current (total)	Total of all output pins	ΣI_{OL}	—	—	80	mA
Permissible output high current (average value per pin)	All output pins	$-I_{OH}$	—	—	2.0	mA
Permissible output high current (max. value per pin)	All output pins	$-I_{OH}$	—	—	4.0	mA
Permissible output high current (total)	Total of all output pins	$\Sigma-I_{OH}$	—	—	80	mA

Caution: To protect the LSI's reliability, do not exceed the output current values in table 29.3.

29.3 AC Characteristics

Table 29.4 Operation Frequency Value

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

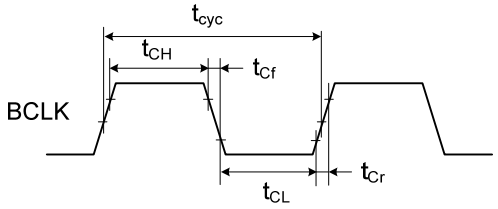
Item		Symbol	Min.	Typ.	Max.	Unit
Operation frequency	System clock (ICLK)	f	8	—	100	MHz
	Peripheral module clock (PCLK)		8	—	50	
	External bus clock (BCLK)		8	—	25	

29.3.1 Clock Timing

Table 29.5 Clock Timing

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
ICLK = 8 to 100 MHz, BCLK = 8 to 25 MHz, PCLK = 8 to 50 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item	Symbol	Min.	Max.	Unit	Test Conditions
Clock cycle time	t_{cyc}	40	125	ns	Figure 29.1
Clock high pulse width	t_{CH}	15	—	ns	
Clock low pulse width	t_{CL}	15	—	ns	
Clock rising time	t_{Cr}	—	5	ns	
Clock falling time	t_{Cf}	—	5	ns	
Oscillation settling time after reset (crystal)	t_{OSC1}	10	—	ms	Figure 29.4
Oscillation settling time after leaving software standby mode (crystal)	t_{OSC2}	10	—	ms	Figure 29.2
Oscillation settling time after leaving deep software standby mode (crystal)	t_{OSC3}	10	—	ms	Figure 29.3
External clock output delay settling time	t_{DEXT}	1	—	ms	Figure 29.4
External clock input low pulse width	t_{EXL}	30.71	—	ns	Figure 29.5
External clock input high pulse width	t_{EXH}	30.71	—	ns	
External clock rising time	t_{EXr}	—	5	ns	
External clock falling time	t_{EXf}	—	5	ns	



Test conditions V_{OH} = V_{CC} × 0.7、V_{OL} = V_{CC} × 0.3、I_{OH} = - 1.0mA、I_{OL} = 1.0mA、C = 30pF

Figure 29.1 External Bus Clock Timing

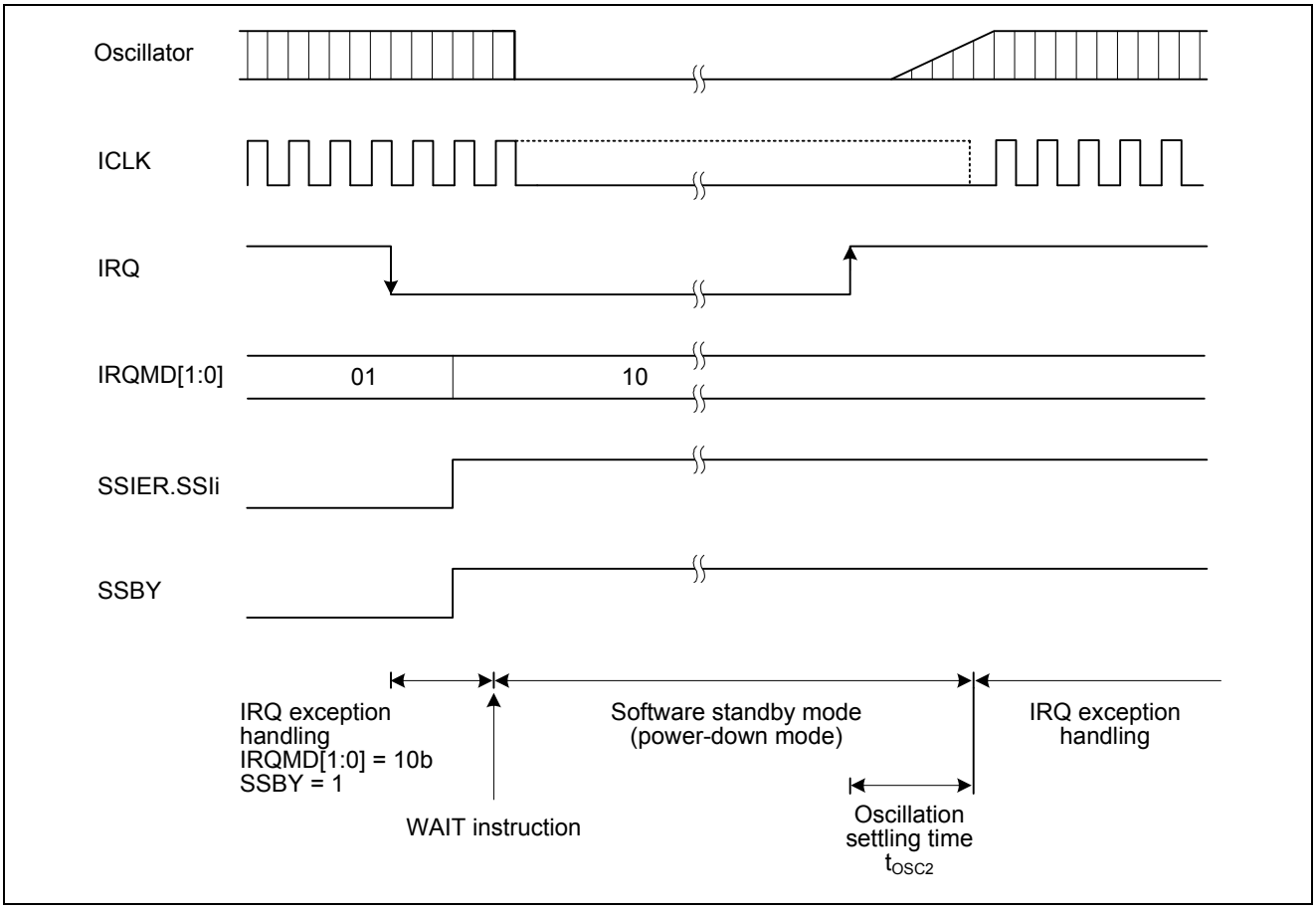


Figure 29.2 Oscillation Settling Timing after Software Standby Mode

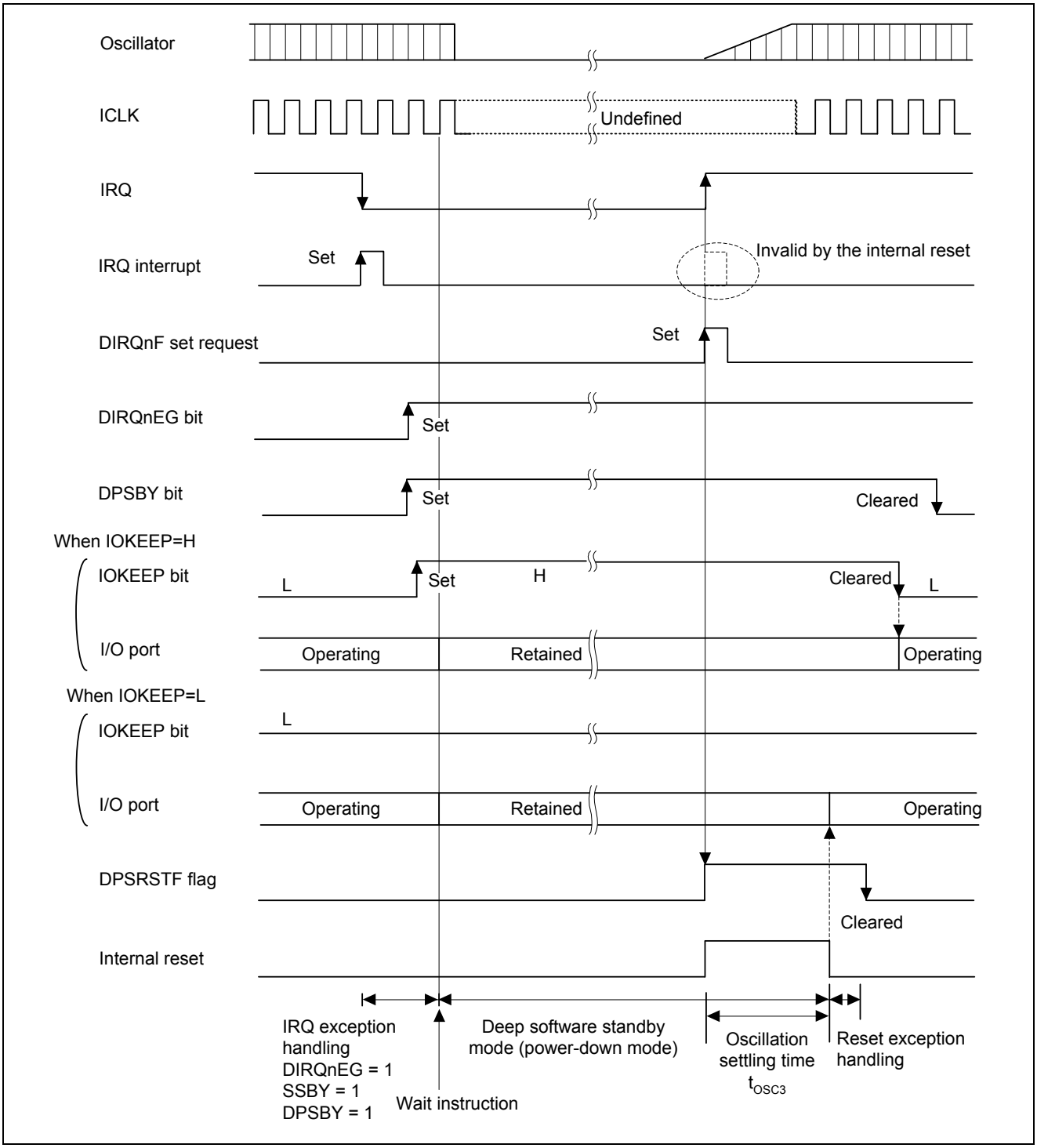


Figure 29.3 Oscillation Settling Timing after Deep Software Standby Mode

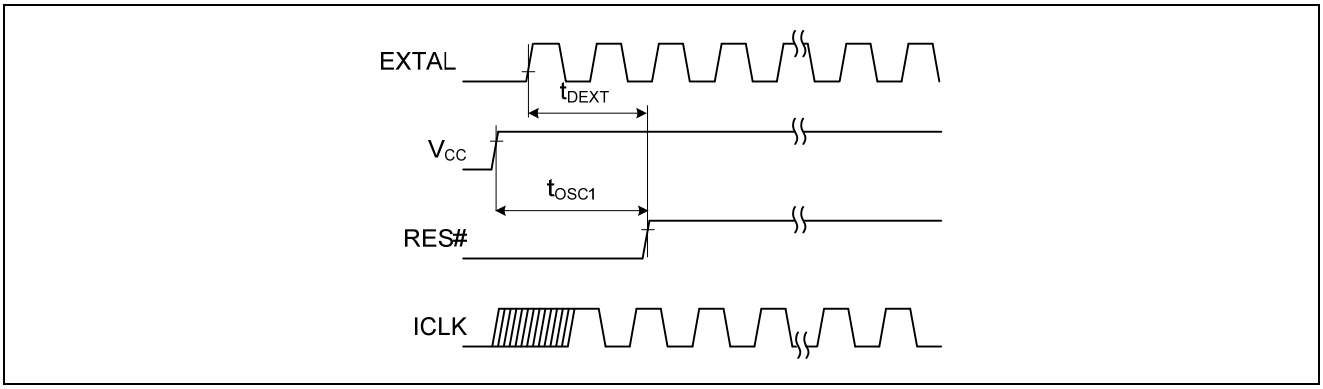


Figure 29.4 Oscillation Settling Timing

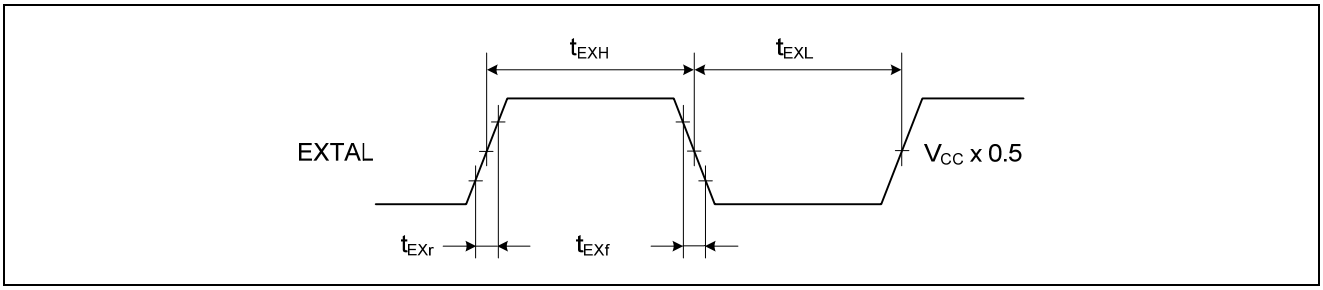


Figure 29.5 External Input Clock Timing

29.3.2 Control Signal Timing

Table 29.6 Control Signal Timing

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
ICLK = 8 to 100 MHz, BCLK = 8 to 25 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item	Symbol	Min.	Max.	Unit	Test Conditions
RES# pulse width (except for ROM, data flash programming/erasure)	t_{RESW}*1	20	—	t_{cyc}	Figure 29.6
		1.5	—	μs	
Internal reset time (during ROM, data flash programming/erasure)	t_{RESW2}*2	35	—	μs	
NMI pulse width	t_{NMIW}	200	—	ns	Figure 29.7
IRQ pulse width	t_{IRQW}	200	—	ns	Figure 29.8

Notes: 1. Both the time and the number of cycles should satisfy the specifications.
2. This is to specify the FCU reset and the WDT reset.

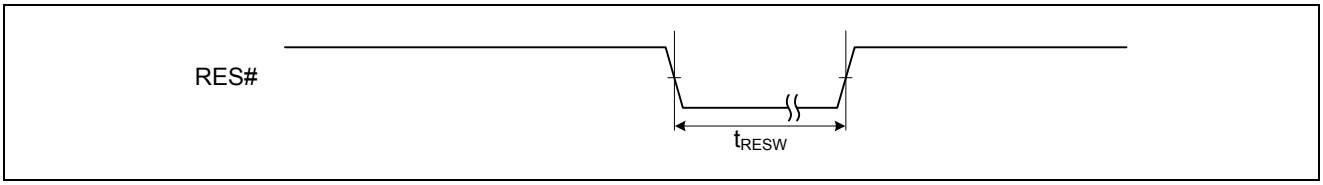


Figure 29.6 Reset Input Timing

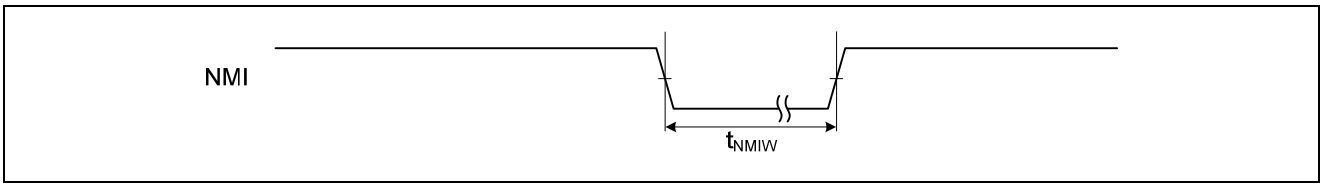


Figure 29.7 NMI Interrupt Input Timing

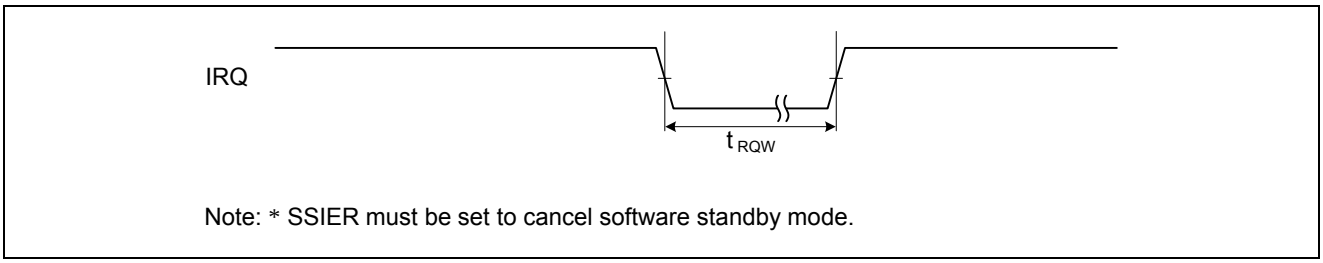


Figure 29.8 IRQ Interrupt Input Timing

29.3.3 Bus Timing

Table 29.7 Bus Timing

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V, BCLK = 8 to 25 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)
Output load conditions: V_{OH} = V_{CC} x 0.5, V_{OL} = V_{CC} x 0.5, I_{OH} = -1.0 mA, I_{OL} = 1.0 mA, C = 30 pF

Item	Symbol	Min.	Max.	Unit	Test Conditions
Address delay time	t_{AD}	—	30	ns	Figures 29.9 to 29.12
Byte control delay time	t_{BCD}	—	30	ns	
CS# delay time	t_{CSD}	—	30	ns	
RD# delay time	t_{RSD}	—	20	ns	
RD# setup time	t_{RSS}	0.5 × (1/BCLK) - 20	—	ns	
Read data setup time	t_{RDS}	15	—	ns	
Read data hold time	t_{RDH}	0	—	ns	
WR# delay time	t_{WRD}	—	20	ns	
WR# setup time	t_{WRS}	0.5 × (1/BCLK) - 20	—	ns	
Write data delay time	t_{WDD}	—	35	ns	
Write data hold time	t_{WDH}	0	—	ns	
WAIT# setup time	t_{WTS}	15	—	ns	Figure 29.13
WAIT# hold time	t_{WTH}	0	—	ns	

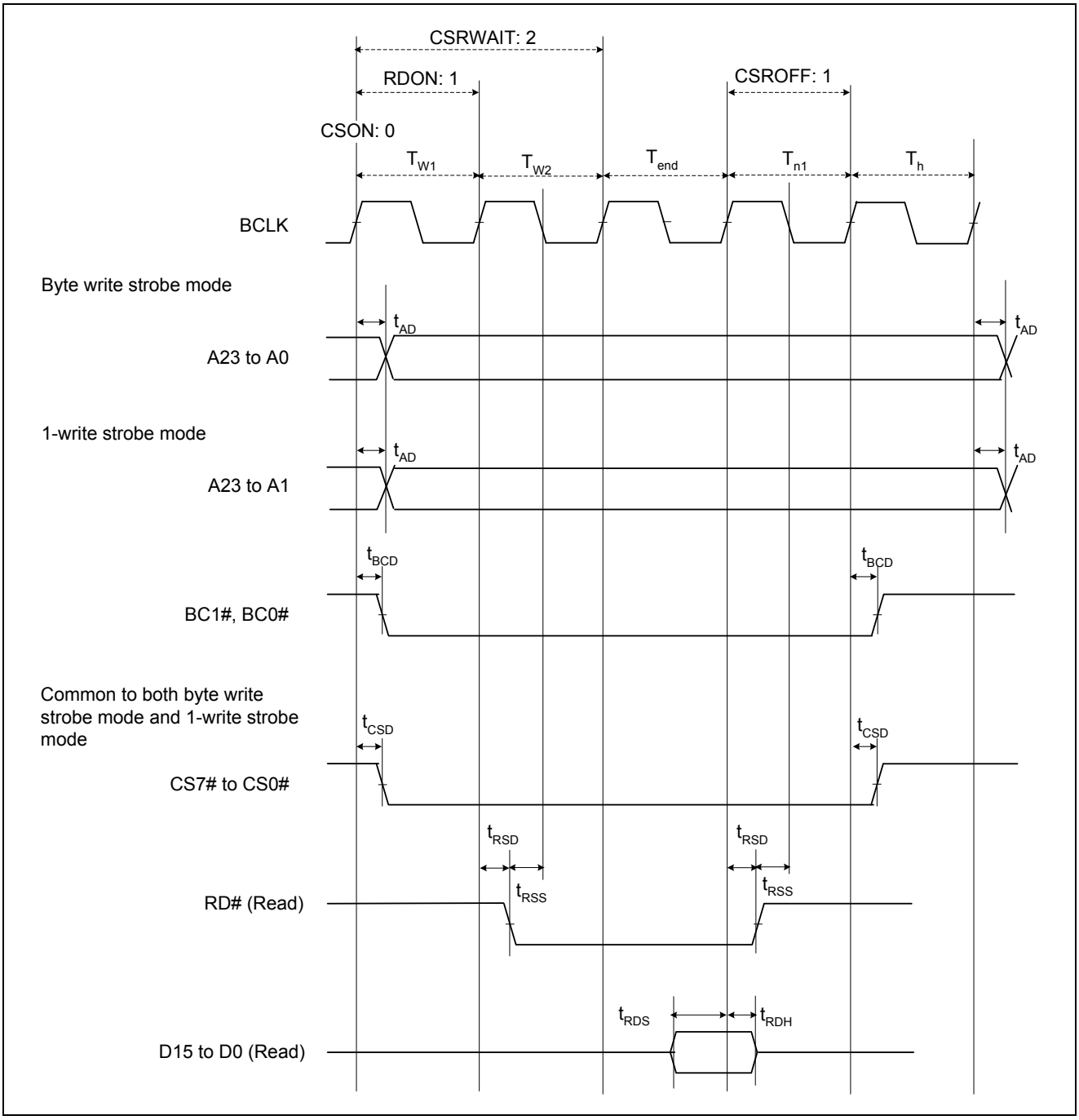


Figure 29.9 External Bus Timing/Normal Read Cycle (Bus Clock Synchronized)

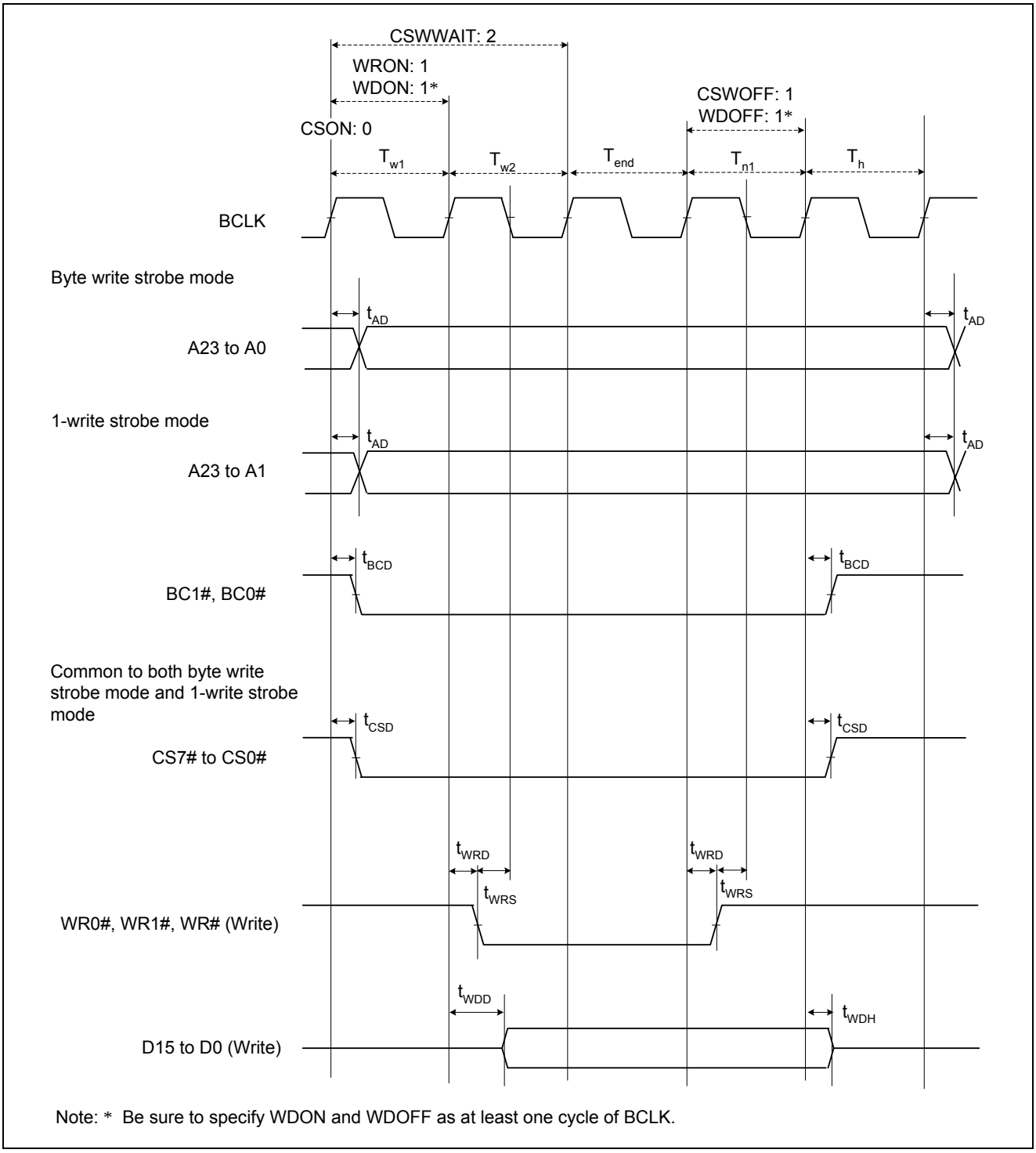


Figure 29.10 External Bus Timing/Normal Write Cycle (Bus Clock Synchronized)

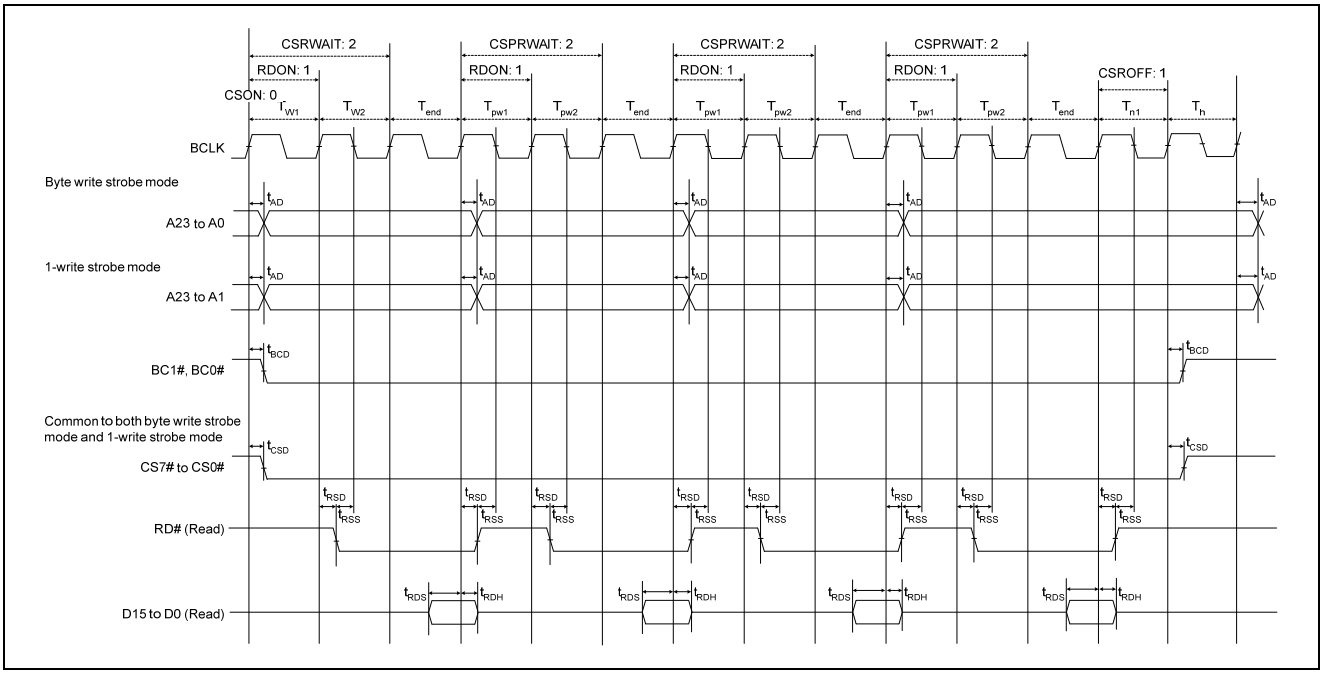


Figure 29.11 External Bus Timing/Page Read Cycle (Bus Clock Synchronized)

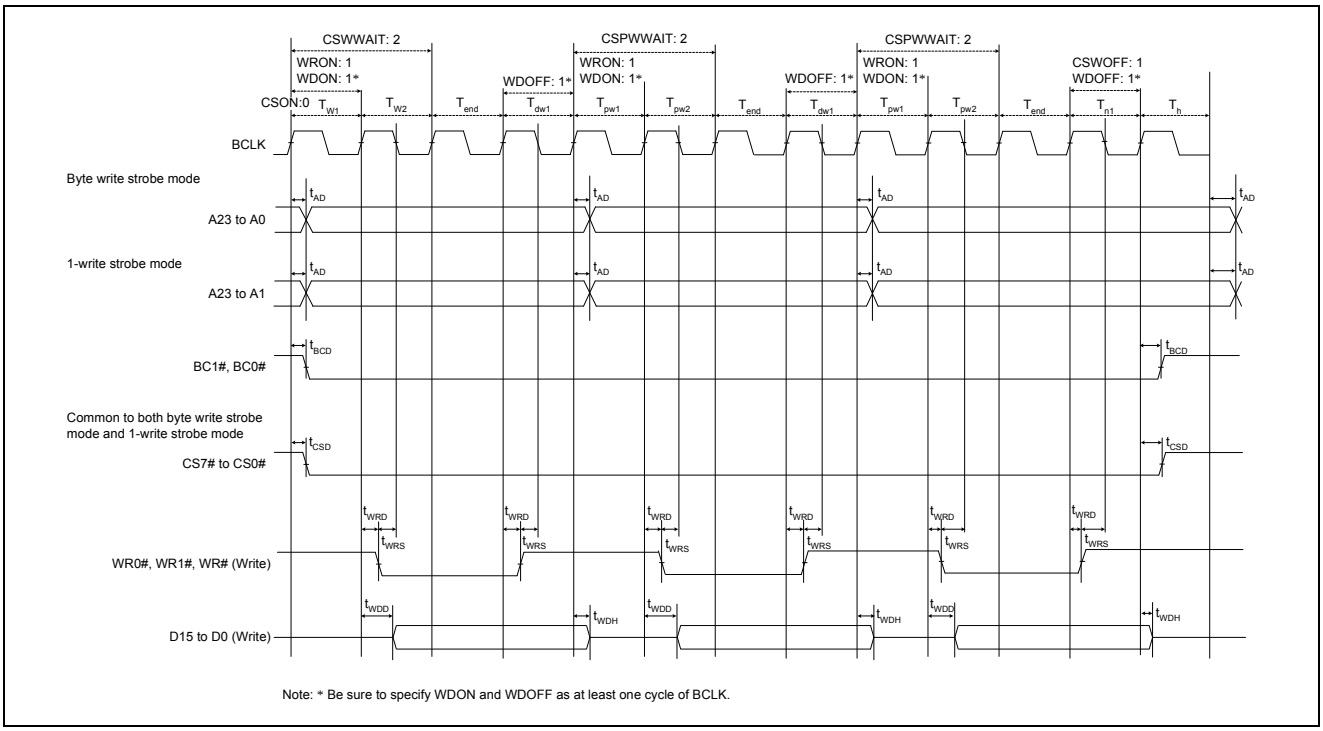


Figure 29.12 External Bus Timing/Page Write Cycle (Bus Clock Synchronized)

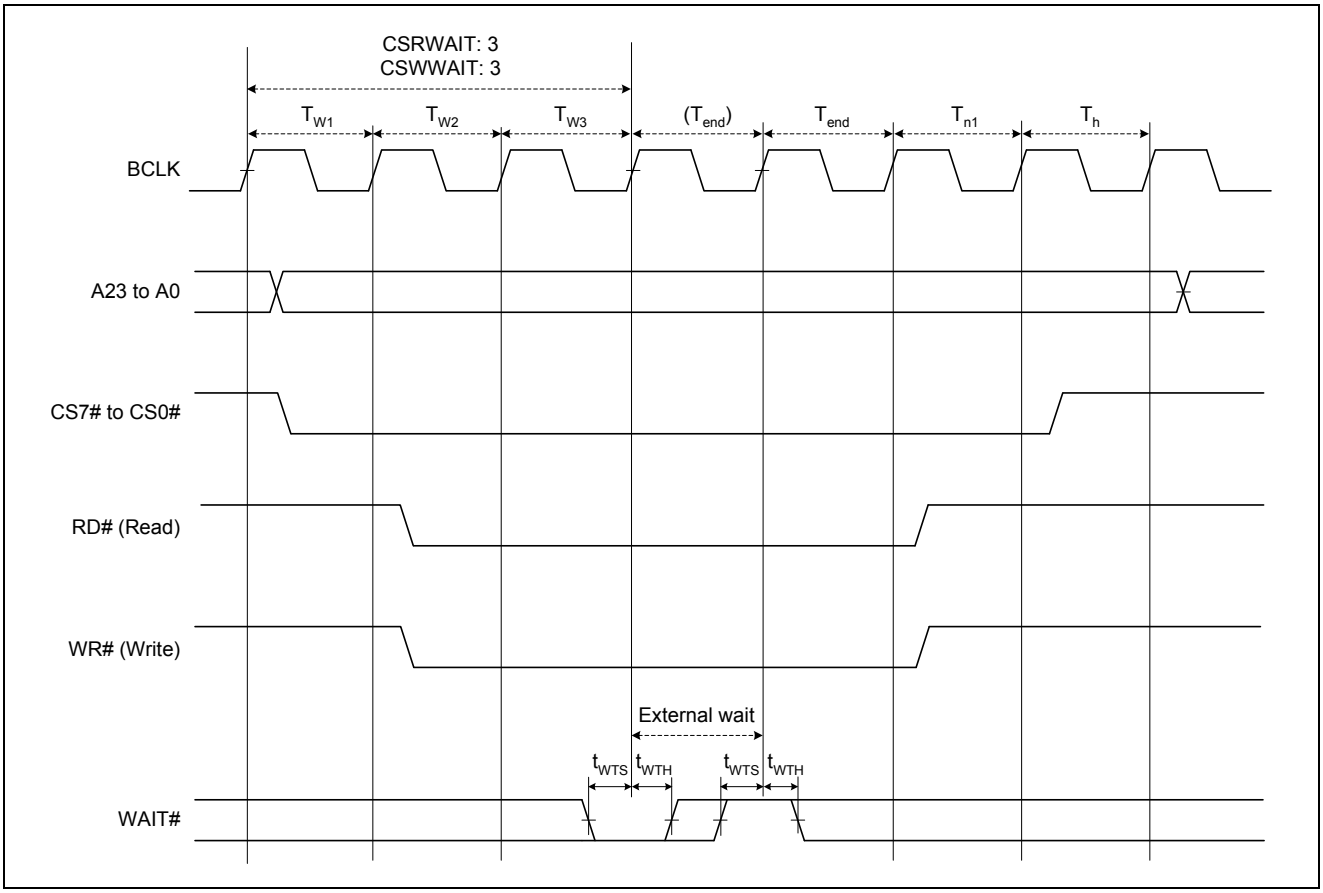


Figure 29.13 External Bus Timing/External Wait Control

29.3.4 Timing of On-Chip Peripheral Modules

Table 29.8 Timing of On-Chip Peripheral Modules (1)

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V, PCLK = 8 to 50 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)
Output load conditions: V_{OH} = V_{CC} x 0.5, V_{OL} = V_{CC} x 0.5, I_{OH} = -1.0 mA, I_{OL} = 1.0 mA, C = 30 pF

Item			Symbol	Min.	Max.	Unit	Test Conditions
I/O ports	Output data delay time		t_{PWD}	—	40	ns	Figure 29.14
	Input data setup time		t_{PRS}	25	—	ns	
	Input data hold time		t_{PRH}	25	—	ns	
TPU	Timer output delay time		t_{TOCD}	—	40	ns	Figure 29.15
	Timer input setup time		t_{TICS}	25	—	ns	
	Timer clock input setup time		t_{TCKS}	25	—	ns	Figure 29.16
	Timer clock pulse width	Single-edge setting	t_{TCKWH}	1.5 x (1/PCLK)	—	t_{cyc}	
		Both-edge setting	t_{TCKWL}	2.5 x (1/PCLK)	—	t_{cyc}	
PPG	Pulse output delay time		t_{POD}	—	40	ns	Figure 29.17
8-bit timer	Timer output delay time		t_{TMOD}	—	40	ns	Figure 29.18
	Timer reset input setup time		t_{TMRS}	25	—	ns	Figure 29.19
	Timer clock input setup time		t_{TMCS}	25	—	ns	Figure 29.20
	Timer clock pulse width	Single-edge setting	t_{TMCWH}	1.5 x (1/PCLK)	—	t_{cyc}	
		Both-edge setting	t_{TMCWL}	2.5 x (1/PCLK)	—	t_{cyc}	
WDT	Overflow output delay time		t_{WOVD}	—	40	ns	Figure 29.21
SCI	Input clock cycle	Asynchronous	t_{Scyc}	4 x (1/PCLK)	—	t_{cyc}	Figure 29.22
		Clock synchronous		6 x (1/PCLK)	—		
	Input clock pulse width		t_{SCKW}	0.4 x t_{Scyc}	0.6 x t_{Scyc}	t_{Scyc}	
	Input clock rise time		t_{SCKr}	—	20	ns	
	Input clock fall time		t_{SCKf}	—	20	ns	
	Output clock cycle	Asynchronous	t_{Scyc}	4 x (1/PCLK)	—	t_{cyc}	
		Clock synchronous		6 x (1/PCLK)	—		
	Output clock pulse width		t_{SCKW}	0.4 x t_{Scyc}	0.6 x t_{Scyc}	t_{Scyc}	
	Output clock rise time		t_{SCKr}	—	20	ns	
	Output clock fall time		t_{SCKf}	—	20	ns	
	Transmit data delay time		t_{TXD}	—	40	ns	Figure 29.23
	Receive data setup time (clock synchronous)		t_{RXS}	40	—	ns	
	Receive data hold time (clock synchronous)		t_{RXH}	40	—	ns	
A/D converter	Trigger input setup time		t_{TRGS}	25	—	ns	Figure 29.24

Table 29.8 Timing of On-Chip Peripheral Modules (2)

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V, PCLK = 8 to 50 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item		Symbol	Min. *1*2	Max.	Unit	Test Conditions
RIIC (Standard-mode) ICFER.FMPE = 0	SCL input cycle time	t_{SCL}	8(10) x (1/PCLK) + 1300	—	ns	Figure 29.25
	SCL input high pulse width	t_{SCLH}	3(5) x (1/PCLK) + 300	—	ns	
	SCL input low pulse width	t_{SCLL}	5x (1/PCLK) + 1000	—	ns	
	SCL, SDA input rising time	t_{Sr}	—	1000	ns	
	SCL, SDA input falling time	t_{Sf}	—	300	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	4 x (1/PCLK)	ns	
	SDA input bus free time	t_{BUF}	5x (1/PCLK) + 1000	—	ns	
	Start condition input hold time	t_{STAH}	3(5) x (1/PCLK) + 300	—	ns	
	Re-start condition input setup time	t_{STAS}	5x (1/PCLK) + 1000	—	ns	
	Stop condition input setup time	t_{STOS}	3(5) x (1/PCLK) + 300	—	ns	
	Data input setup time	t_{SDAS}	250	—	ns	
	Data input hold time	t_{SDAH}	0	—	ns	
	SCL, SDA capacitive load	C_b	—	400	pF	
RIIC (Fast-mode) ICFER.FMPE = 0	SCL input cycle time	t_{SCL}	8(10) x (1/PCLK) + 600	—	ns	
	SCL input high pulse width	t_{SCLH}	3(5) x (1/PCLK) + 300	—	ns	
	SCL input low pulse width	t_{SCLL}	5 x (1/PCLK) + 300	—	ns	
	SCL, SDA input rising time	t_{Sr}	20 + 0.1C_b	300	ns	
	SCL, SDA input falling time	t_{Sf}	20 + 0.1C_b	300	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	4 x (1/PCLK)	ns	
	SDA input bus free time	t_{BUF}	5 x (1/PCLK) + 300	—	ns	
	Start condition input hold time	t_{STAH}	3(5) x (1/PCLK) + 300	—	ns	
	Re-start condition input setup time	t_{STAS}	5 x (1/PCLK) + 300	—	ns	
	Stop condition input setup time	t_{STOS}	3(5) x (1/PCLK) + 300	—	ns	
	Data input setup time	t_{SDAS}	100	—	ns	
	Data input hold time	t_{SDAH}	0	—	ns	
	SCL, SDA capacitive load	C_b	—	400	pF	

Table 29.8 Timing of On-Chip Peripheral Modules (3)

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V,
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item		Symbol	Min. *1*2	Max.	Unit	Test Conditions
RIIC (Fast-mode+) ICFER.FMPE = 1	SCL input cycle time	t_{SCL}	8(10) x (1/PCLK) + 240	—	ns	Figure 29.25
	SCL input high pulse width	t_{SCLH}	3(5) x (1/PCLK) + 120	—	ns	
	SCL input low pulse width	t_{SCLL}	5 x (1/PCLK) + 120	—	ns	
	SCL, SDA input rising time	t_{Sr}	—	120	ns	
	SCL, SDA input falling time	t_{Sf}	—	120	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	4 x (1/PCLK)	ns	
	SDA input bus free time	t_{BUF}	5 x (1/PCLK) + 120	—	ns	
	Start condition input hold time	t_{STAH}	3(5) x (1/PCLK) + 120	—	ns	
	Re-start condition input setup time	t_{STAS}	5 x (1/PCLK) + 120	—	ns	
	Stop condition input setup time	t_{STOS}	3(5) x (1/PCLK) + 120	—	ns	
	Data input setup time	t_{SDAS}	50	—	ns	
	Data input hold time	t_{SDAH}	0	—	ns	
	SCL, SDA capacitive load	C_b	—	550	pF	
Boundary scan (176-pin LFBGA)	TCK clock cycle time	tTCKcyc	100	—	ns	Figure 29.26
	TCK clock high level pulse width	tTCKH	45	—	ns	
	TCK clock low level pulse width	tTCKL	45	—	ns	
	TCK clock rising time	tTCKr	—	5	ns	
	TCK clock falling time	tTCKf	—	5	ns	
	TRST# pulse width	tTRSTW	20	—	Tcyc	Figure 29.27
	TMS setup time	tTMSS	20	—	ns	Figure 29.28
	TMS hold time	tTMSH	20	—	ns	
	TDI setup time	tTDIS	20	—	ns	
	TDI hold time	tTDIH	20	—	ns	
	TDO data delay time	tTDOD	—	40	ns	

Notes:1. The value in parentheses is used when ICMR3.NF[1:0] are set to 11b while a digital filter is enabled with ICFER.NFE = 1.

2. Cb indicates the total capacity of the bus line.

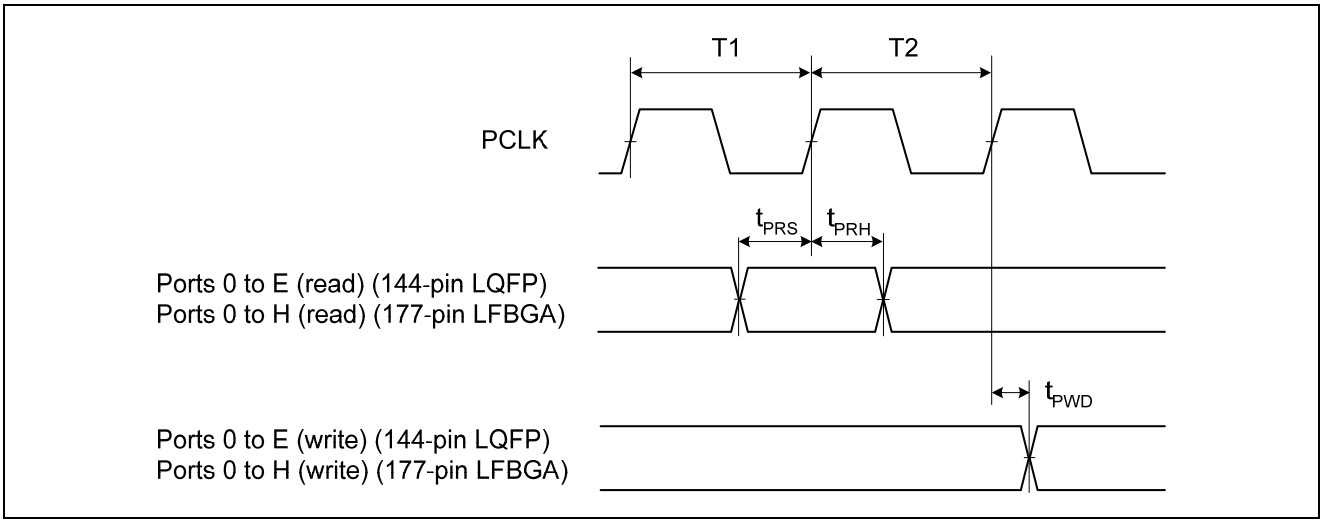


Figure 29.14 I/O Port Input/Output Timing

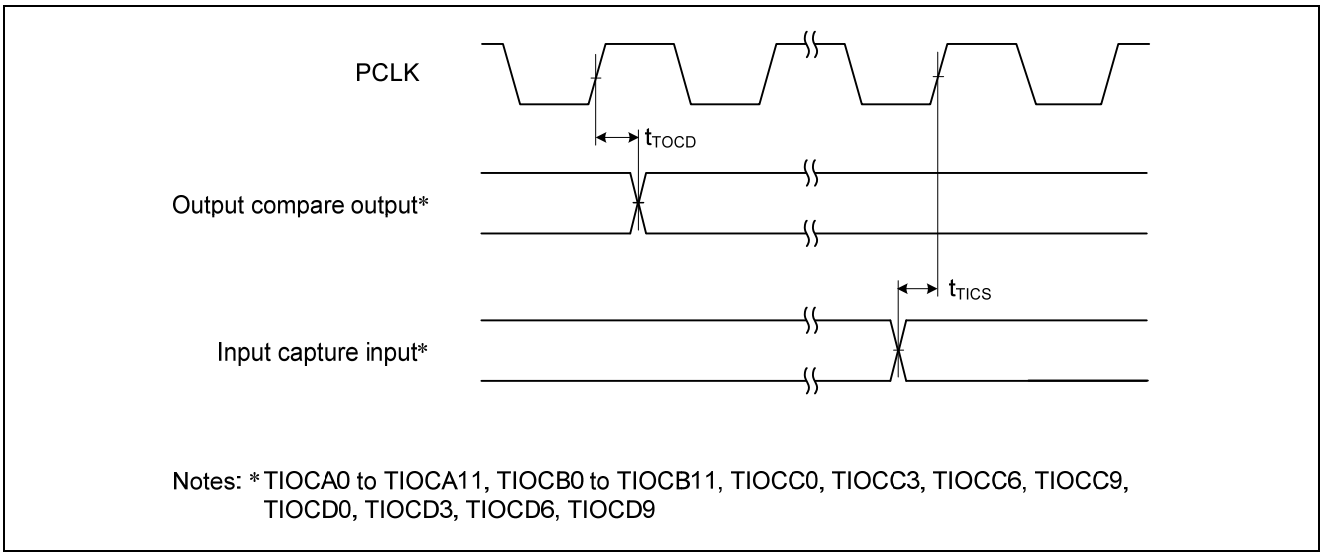


Figure 29.15 TPU Input/Output Timing

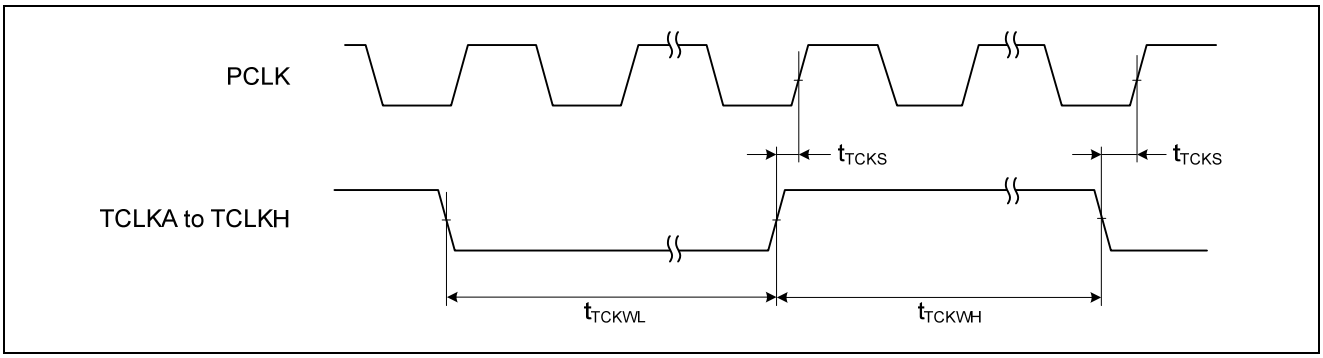


Figure 29.16 TPU Clock Input Timing

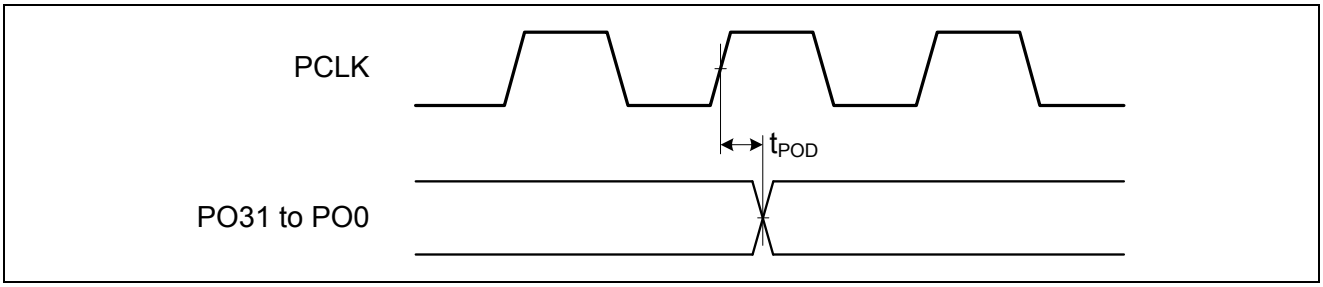


Figure 29.17 PPG Output Timing

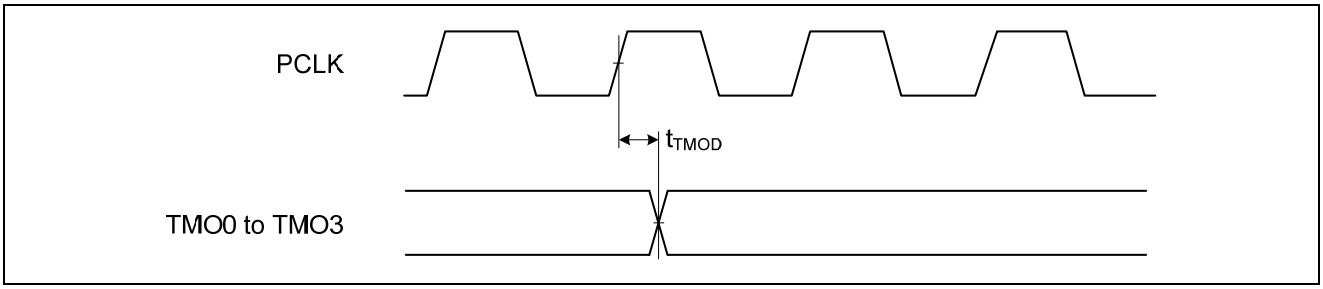


Figure 29.18 8-Bit Timer Output Timing

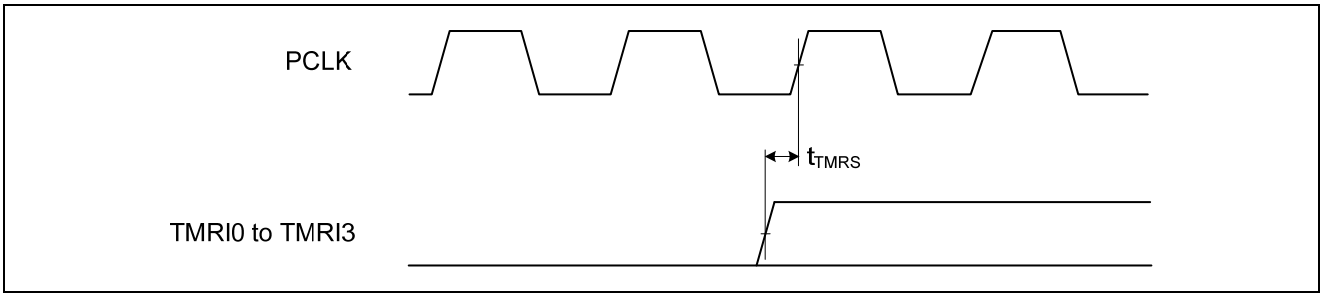


Figure 29.19 8-Bit Timer Reset Input Timing

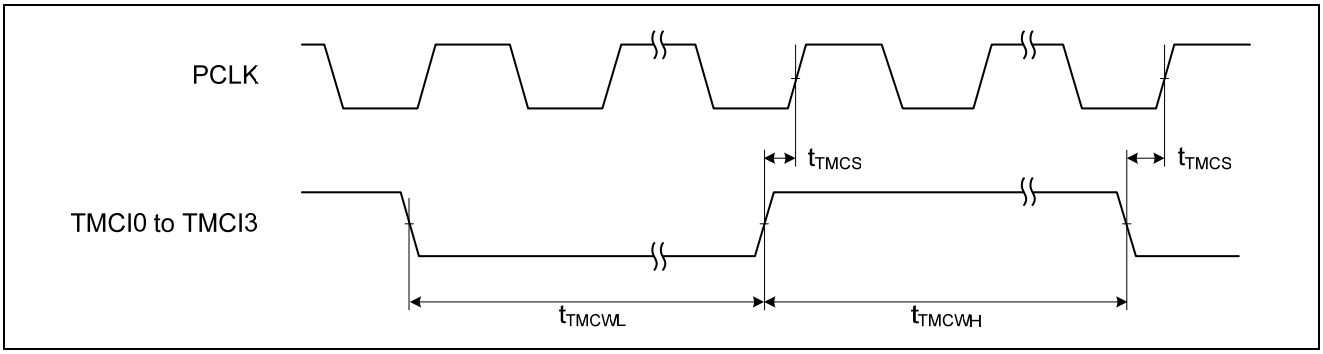


Figure 29.20 8-Bit Timer Clock Input Timing

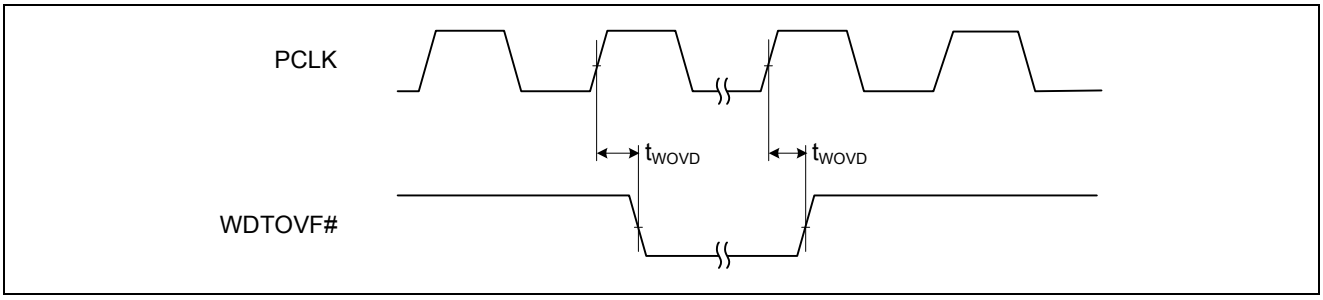


Figure 29.21 WDT Output Timing

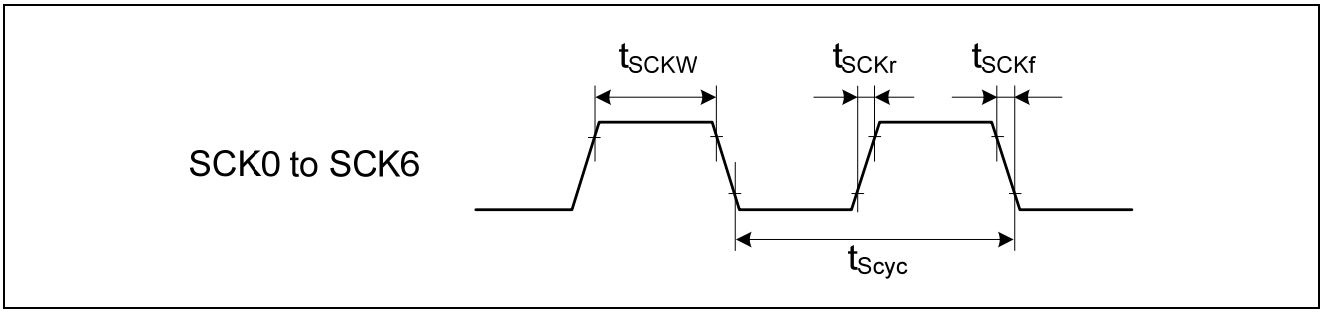


Figure 29.22 SCK Clock Input Timing

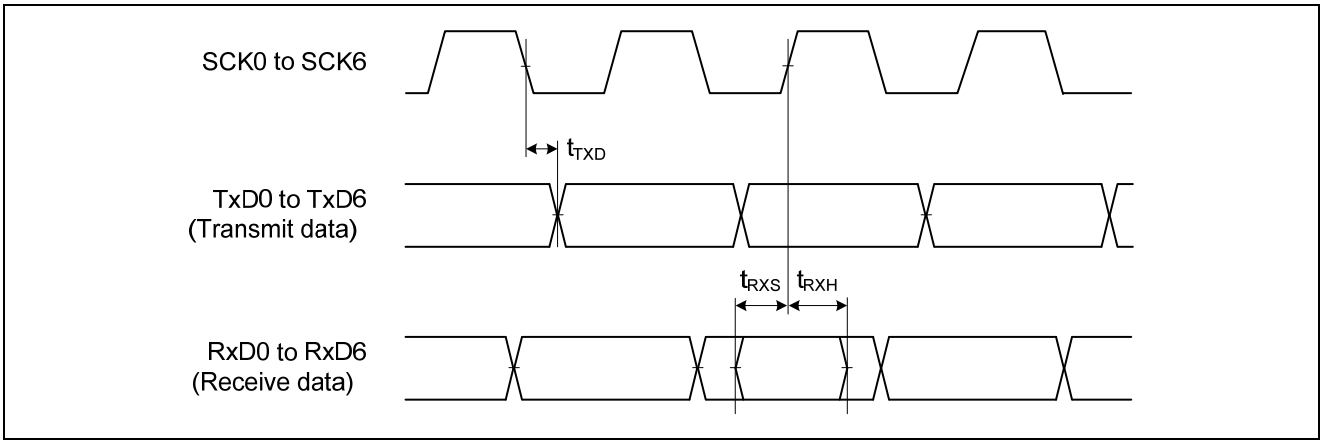


Figure 29.23 SCI Input/Output Timing: Clock Synchronous Mode

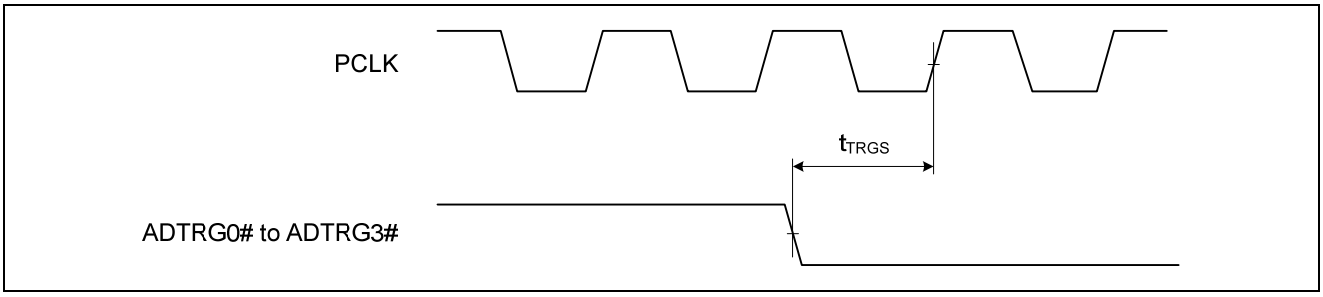


Figure 29.24 A/D Converter External Trigger Input Timing

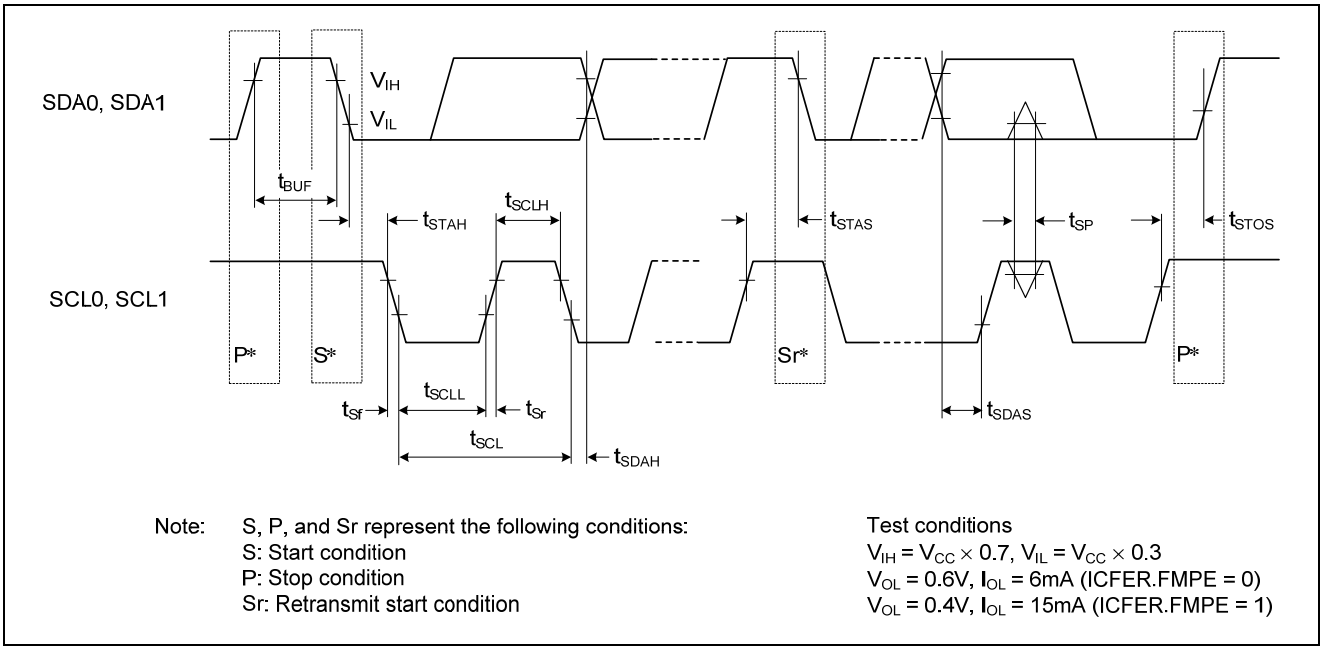


Figure 29.25 I²C Bus Interface Input/Output Timing

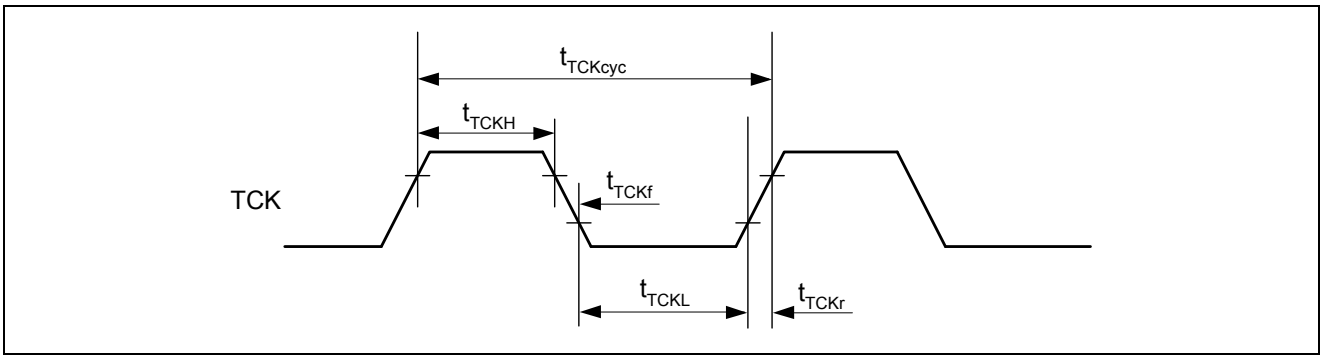


Figure 29.26 Boundary Scan TCK Timing

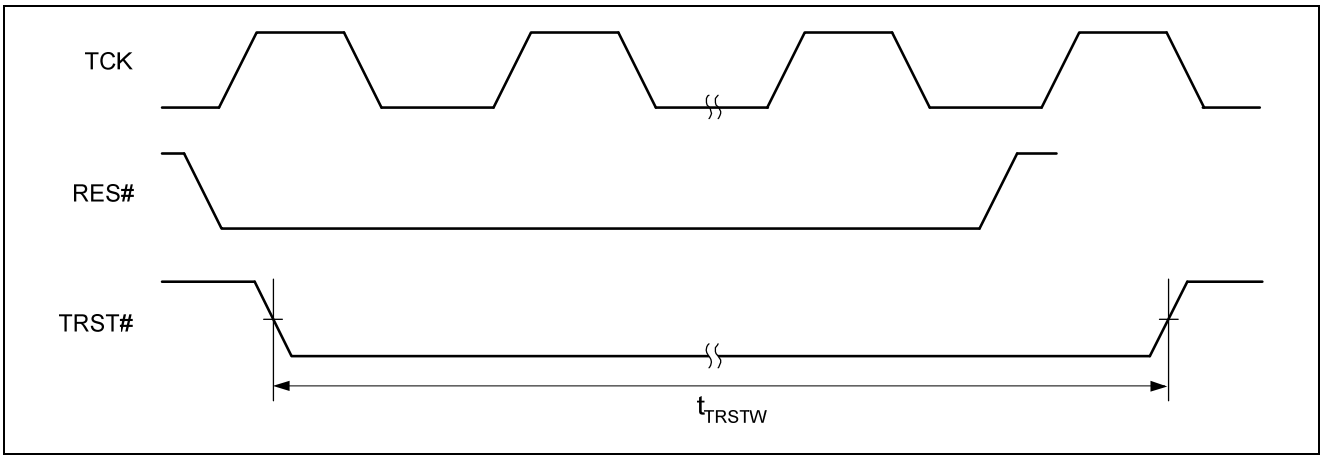


Figure 29.27 Boundary Scan TRST# Timing

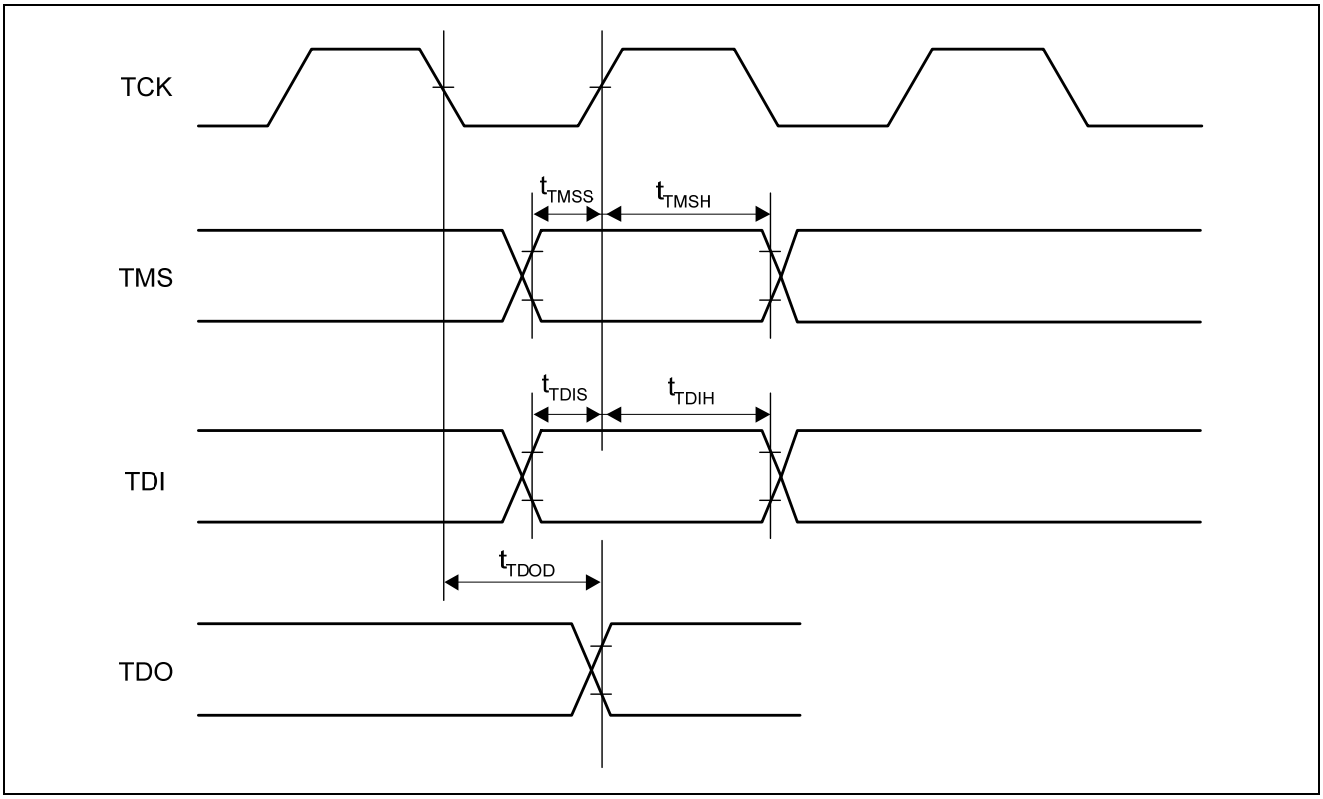


Figure 29.28 Boundary Scan Input/Output Timing

29.4 A/D Conversion Characteristics

Table 29.9 A/D Conversion Characteristics

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V, PCLK = 8 to 50 MHz, ADCLK = 4 to 50 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item			Min.	Typ.	Max.	Unit	Test Conditions
Resolution			10	10	10	Bit	
Conversion time*1 (ADCLK = 50-MHz operation)	With 0.1-µF external capacitor	When the capacitor is charged enough*2	0.8 (0.3)*3	—	—	µs	Sampling 15 states
	Without external capacitor	Permiss ble signal source impedance (max.) = 1.0 kΩ	1.0 (0.5)*3	—	—		Sampling 25 states
		Permiss ble signal source impedance (max.) = 5.0 kΩ	2.6 (2.1)*3	—	—		Sampling 105 states
Analog input capacitance			—	—	6.0	pF	
INL integral nonlinearity error (INL)			—	±1.5	±3.0	LSB	
Offset error			—	±1.5	±3.0	LSB	
Full-scale error			—	±1.5	±3.0	LSB	
Quantization error			—	±0.5	—	LSB	
Absolute accuracy			—	±1.5	±3.0	LSB	
DNL differential nonlinearity error (DNL)			—	±0.5	±1.0	LSB	

Notes: 1. The conversion time includes the sampling time and the comparison time. As the test conditions, the number of sampling states is indicated.

2. The scanning is not supported.

3. The value in parentheses indicates the sampling time.

29.5 D/A Conversion Characteristics

Table 29.10 D/A Conversion Characteristics

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V, PCLK = 8 to 50 MHz
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item	Min.	Typ.	Max.	Unit	Test Conditions
Resolution	10	10	10	Bit	
Conversion time	—	—	3	µs	20-pF capacitive load
Absolute accuracy	—	±2.0	±4.0	LSB	2-MΩ resistive load
	—	—	±3.0	LSB	4-MΩ resistive load
	—	—	±2.0	LSB	10-MΩ resistive load
RO output resistance	—	3.6	—	kΩ	

29.6 ROM (Flash Memory for Code Storage) Characteristics

Table 29.11 ROM (Flash Memory for Code Storage) Characteristics

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
Operating temperature range during programming/erasing:
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Programming time	256 bytes	t_{P256}	—	2	12	ms	PCLK = 50 MHz
	8 Kbytes	t_{P8K}	—	45	100	ms	$N_{PEC} \leq 100$
	256 bytes	t_{P256}	—	2.4	14.4	ms	PCLK = 50 MHz
	8 Kbytes	t_{P8K}	—	54	120	ms	$N_{PEC} > 100$
Erasure time	8 Kbytes	t_{E8K}	—	50	120	ms	PCLK = 50 MHz
	64 Kbytes	t_{E64K}	—	400	875	ms	$N_{PEC} \leq 100$
	128 Kbytes	t_{E128K}	—	800	1750	ms	
	8 Kbytes	t_{E8K}	—	60	144	ms	PCLK = 50 MHz
	64 Kbytes	t_{E64K}	—	480	1050	ms	$N_{PEC} > 100$
	128 Kbytes	t_{E128K}	—	960	2100	ms	
Rewrite/erase cycle*[1]		N_{PEC}	1000*[2]	—	—	Times	
Suspend delay time during writing		t_{SPD}	—	—	120	µs	Figure 29.29
First suspend delay time during erasing (in suspend priority mode)		t_{SESD1}	—	—	120	µs	PCLK = 50 MHz
Second suspend delay time during erasing (in suspend priority mode)		t_{SESD2}	—	—	1.7	ms	
Suspend delay time during erasing (in erasure priority mode)		t_{SEED}	—	—	1.7	ms	
Data hold time*[3]		T_{DRP}	10	—	—	Year	

Notes: 1. Definition of rewrite/erase cycle:
The rewrite/erase cycle is the number of erasing for each block. When the rewrite/erase cycle is n times (n = 1000), erasing can be performed n times for each block. For instance, when 256-byte writing is performed 32 times for different addresses in 8-Kbyte block and then the entire block is erased, the rewrite/erase cycle is counted as one. However, writing to the same address for several times as one erasing is not enabled (over writing is prohibited).
2. This indicates the minimum number that guarantees the characteristics after rewriting. (The guaranteed value is in the range from one to the minimum number.)
3. This indicates the characteristic when rewrite is performed within the specification range including the minimum number.

29.7 Data Flash (Flash Memory for Data Storage) Characteristics

Table 29.12 Data Flash (Flash Memory for Data Storage) Characteristics

Conditions: V_{CC} = $PLLV_{CC}$ = AV_{CC} = 3.0 to 3.6 V, V_{REFH} = 3.0 V to AV_{CC}, V_{SS} = $PLLV_{SS}$ = V_{REFL} = 0 V
Operating temperature range during programming/erasing:
T_a = -20 to +85°C (regular specifications), T_a = -40 to +85°C (wide-range specifications)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Programming time	8 bytes	t_{DP8}	—	0.4	2	ms	PCLK = 50-MHz operation
	128 bytes	t_{DP128}	—	1	5	ms	
Erasure time	8 Kbytes	t_{DE8K}	—	300	900	ms	PCLK = 50-MHz operation
Blank check time	8 bytes	t_{DBC8}	—	—	30	µs	PCLK = 50-MHz operation
	8 Kbytes	t_{DBC8K}	—	—	2.5	ms	
Rewrite/erase cycle*1		N_{DPEC}	30000*2	—	—	Times	
Suspend delay time during writing		t_{DSPD}	—	—	120	µs	Figure 29.29 PCLK = 50-MHz operation
First suspend delay time during erasing (in suspend priority mode)		t_{DSESD1}	—	—	120	µs	
Second suspend delay time during erasing (in suspend priority mode)		t_{DSESD2}	—	—	1.7	ms	
Suspend delay time during erasing (in erasure priority mode)		t_{DSEED}	—	—	1.7	ms	
Data hold time*3		T_{DDRP}	10	—	—	Year	

Notes: 1. Definition of rewrite/erase cycle:
The rewrite/erase cycle is the number of erasing for each block. When the rewrite/erase cycle is n times (n = 30000), erasing can be performed n times for each block. For instance, when 128-byte writing is performed 64 times for different addresses in 8-Kbyte block and then the entire block is erased, the rewrite/erase cycle is counted as one. However, writing to the same address for several times as one erasing is not enabled (over writing is prohibited).
2. This indicates the minimum number that guarantees the characteristics after rewriting. (The guaranteed value is in the range from one to the minimum number.)
3. This indicates the characteristic when rewrite is performed within the specification range including the minimum number.

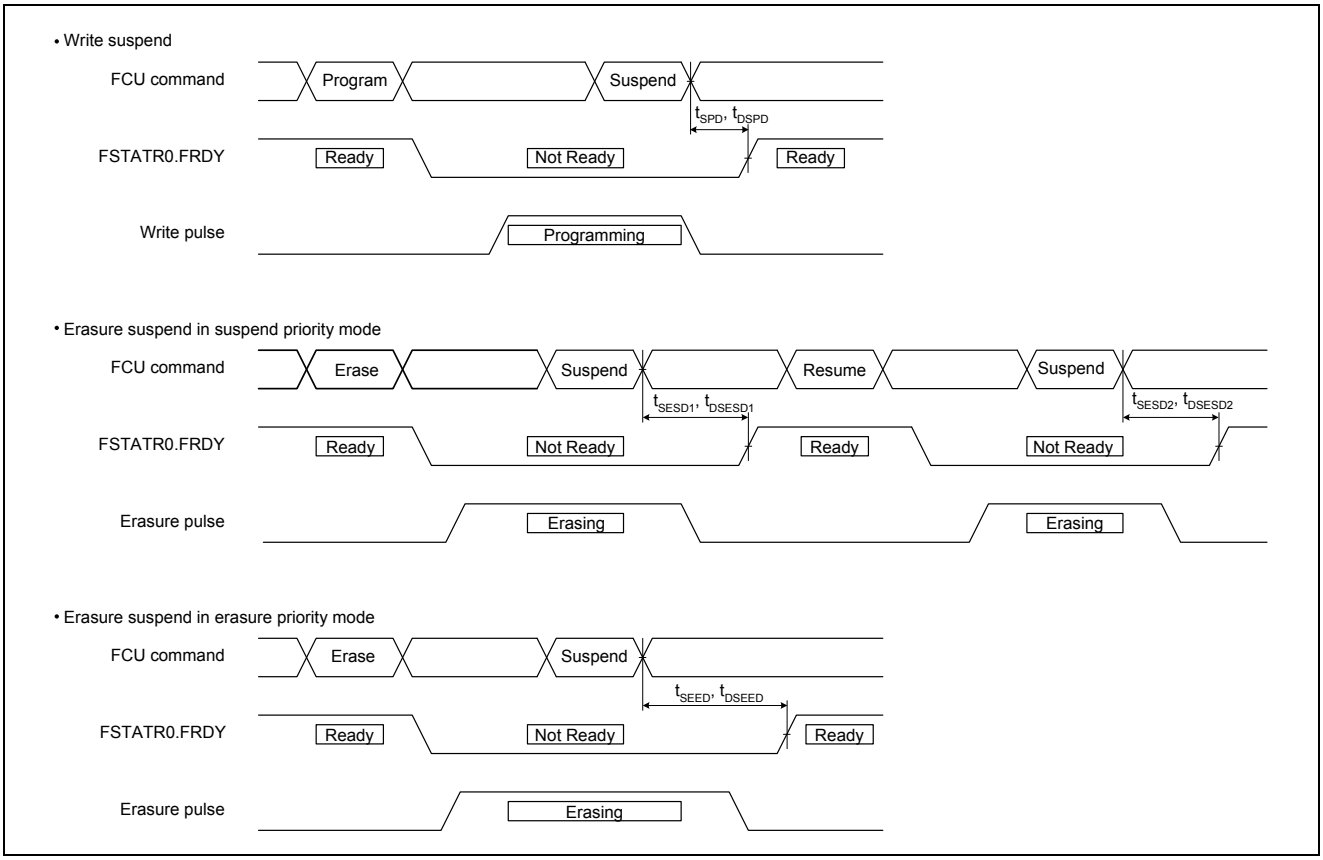


Figure 29.29 ROM, Data Flash Write/Erase Suspend Timing

Appendix 1. Port States in Each Processing Mode

Table 1.1 Port States in Each Processing State

Port Name / Pin Name	Operating Mode According to Registers Setting	Reset	Software Standby Mode		Deep Software Standby Mode	After Deep Software Standby Mode is Canceled (Return of Start-up Mode)	
			OPE = 1	OPE = 0	IOKEE P = 1/0	IOKEEP = 1*	IOKEEP = 0
Port 0	All	HiZ	Keep-O*1		Keep	Keep	HiZ
Port 1	All	HiZ	Keep-O*1		Keep	Keep	HiZ
Port 2	All	HiZ	Keep-O		Keep	Keep	HiZ
P30 to P33	All	HiZ	Keep-O*1		Keep-O*2	Keep	HiZ
P34/PO12/TIOCA1/IRQ4-A	All	HiZ	Keep-O*1		Keep	Keep	HiZ
P35 to P37	All	HiZ	Keep-O		Keep	Keep	HiZ
Port 4	All	HiZ	Keep-O*1		Keep	Keep	HiZ
P50/WR0/WR	Single-chip mode (EXBE = 0)	HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)		[WR0/WR output] H	[WR0/WR output] HiZ			
P51/WR1/BC1	Single-chip mode (EXBE = 0)	HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)		[WR1/WR output] H	[WR1/WR output] HiZ			
			[Other than the above] Keep-O				
P52/RD	Single-chip mode (EXBE = 0)	HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)		[RD output] H	[RD output] HiZ			
P53/BCLK	All	HiZ	[Clock output] H [Other than the above] Hi-Z		Keep	Keep	HiZ
P54/TRDATA0	All	HiZ	Keep-O		Keep	Keep	HiZ
P55/TRDATA1	All	HiZ	Keep-O		Keep	Keep	HiZ
P56/TRDATA2	All	HiZ	Keep-O		Keep	Keep	HiZ
P57/TRDATA3/WAIT	All	HiZ	Keep-O		Keep	Keep	HiZ

Port Name Pin Name	Operating Mode According to Registers Setting	Reset	Software Standby Mode		Deep Software Standby Mode IOKEE P = 1/0	After Deep Software Standby Mode is Canceled (Return of Start-up Mode)	
			OPE = 1	OPE = 0		IOKEEP = 1*	IOKEEP = 0
P60/CS0/ CS4-A/CS5-B	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ
P61/CS1/ CS2-B/CS5-A/ CS6-B/CS7-B	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ
P62/CS2-A/ CS6-A	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ
P63/CS3-A/ CS7-A	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ
P64/CS4-B	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ
P65/ RQ15-A	All	HiZ	Keep-O*1		Keep	Keep	HiZ
P66/DA0	All	HiZ	[DAOE0=1] DA output retained [DAOE0=0] Keep-O		[DAOE0=1] HiZ [DAOE0=0] Keep	Keep	HiZ
P67/DA1	All	HiZ	[DAOE1=1] DA output retained [DAOE1=0] Keep-O		[DAOE1=1] HiZ [DAOE1=0] Keep-O	Keep	HiZ
P70/CS3-B/ ADTRG2	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ

Port Name Pin Name	Operating Mode According to Registers Setting	Reset	Software Standby Mode		Deep Software Standby Mode IOKEE P = 1/0	After Deep Software Standby Mode is Canceled (Return of Start-up Mode)	
			OPE = 1	OPE = 0		IOKEEP = 1*	IOKEEP = 0
P71/CS4-C/ CS5-C/CS6-C/ CS7-C	All	HiZ	[CS output] H [Other than the above] Keep-O	[CS output] HiZ [Other than the above] Keep-O	Keep	Keep	HiZ
P72 to P75	All	HiZ	Keep-O		Keep	Keep	HiZ
P76/ RQ14-A	All	HiZ	Keep-O*1		Keep	Keep	HiZ
P77	All	HiZ	Keep-O		Keep	Keep	HiZ
Port 8	All	HiZ	Keep-O		Keep	Keep	HiZ
Port 9	All	HiZ	Keep-O		Keep	Keep	HiZ
Port A	Single-chip mode (EXBE = 0)	HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)		[Address output] Address output retained [Other than the above] HiZ	[Address output] HiZ [Other than the above] HiZ			
Port B	Single-chip mode (EXBE = 0)	HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled extended mode		[Address output] Address output retained [Other than the above] Keep-O	[Address output] HiZ [Other than the above] Keep-O			

Port Name / Pin Name	Operating Mode According to Registers Setting		Reset	Software Standby Mode		Deep Software Standby Mode IOKEE P = 1/0	After Deep Software Standby Mode is Canceled (Return of Start-up Mode)	
				OPE = 1	OPE = 0		IOKEEP = 1*	IOKEEP = 0
PC0 to PC4	Single-chip mode (EXBE = 0)		HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)			[Address output] Address output retained [Other than the above] Keep-O	[Address output] HiZ [Other than the above] Keep-O			
PC5 to PC7	Single-chip mode (EXBE = 0)		HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)			[Address output] Address output retained [CS output] H [Other than the above] Keep-O	[Address output] HiZ [CS output] HiZ [Other than the above] Keep-O			
Port D	Single-chip mode (EXBE = 0))		HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/disabled extended mode (EXBE = 1)			HiZ				
PE0 to PE4	Single-chip mode (EXBE = 0)		HiZ	Keep-O		Keep	Keep	HiZ
	On-chip ROM enabled/ disabled extended mode (EXBE=1)	8-bit bus		Keep-O				
		16-bit bus		HiZ				

Port Name / Pin Name	Operating Mode According to Registers Setting		Reset	Software Standby Mode		Deep Software Standby Mode IOKEE P = 1/0	After Deep Software Standby Mode is Canceled (Return of Start-up Mode)	
				OPE = 1	OPE = 0		IOKEEP = 1*	IOKEEP = 0
PE5 to PE7	Single-chip mode (EXBE = 0)		HiZ	Keep-O*1		Keep	Keep	HiZ
	On-chip ROM enabled/ disabled extended mode (EXBE=1)	8-bit bus		Keep-O*1				
		16-bit bus		HiZ				
Port F	All		HiZ	Keep-O		Keep	Keep	HiZ
Port G	All		HiZ	Keep-O		Keep	Keep	HiZ
Port H	All		HiZ	Keep-O		Keep	Keep	HiZ
WDTOVF	All		WDTOVF output	H		H	H	

[Legend]

H: High-level

L: Low-level

Keep-O: Output pins retain their previous values, and input pins become high-impedance.

*1. Input to pins in use as external interrupt pins and set up as triggers for release from software standby mode is possible.

*2. Input to pins set up as triggers for release from deep software standby mode is possible.

Keep: Pin states are retained during periods on software standby.

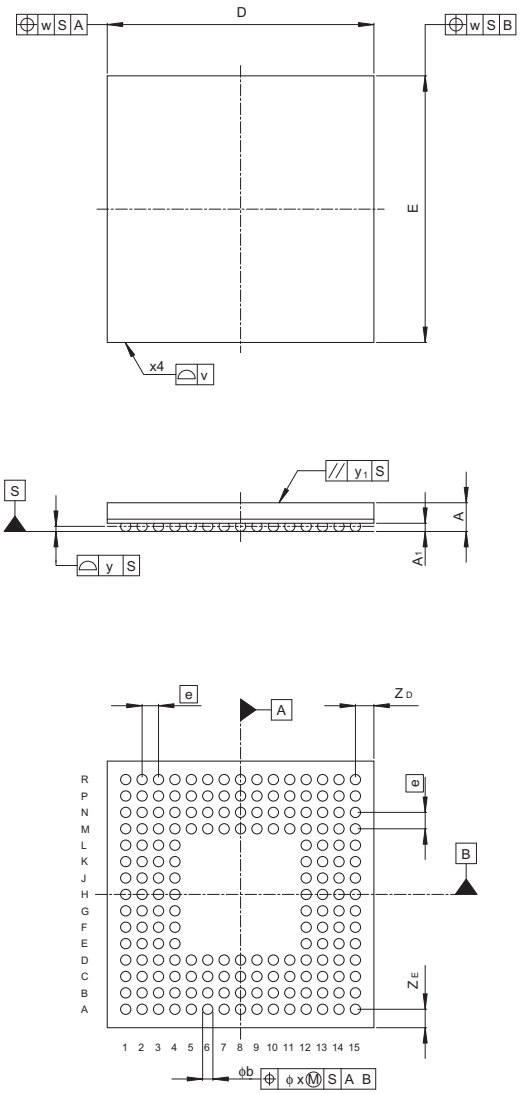
HiZ: High-impedance

IOKEEP = 1*: I/O pins retain their states until the IOKEEP bit in DPSBYCR is cleared to 0.

Appendix 2. Package Dimensions

Information on the latest version of the package dimensions or mountings has been displayed in "Packages" on Renesas Technology Corp. website.

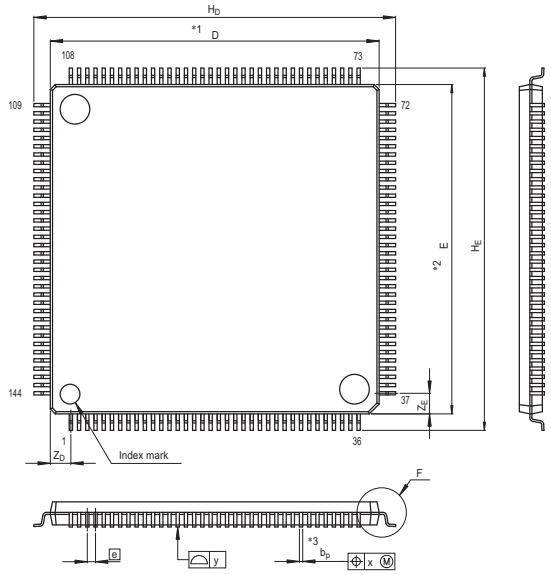
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LFBGA176-13x13.0-0.80	PLBG0176GA-A	BP-176/BP-176V	0.45g

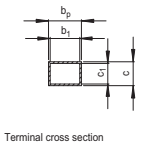


Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	—	13.0	—
E	—	13.0	—
v	—	—	0.15
w	—	—	0.20
A	—	—	1.40
A_1	0.35	0.40	0.45
e	—	0.80	—
b	0.45	0.50	0.55
x	—	—	0.08
y	—	—	0.10
y_1	—	—	0.2
S_D	—	—	—
S_E	—	—	—
Z_D	—	0.90	—
Z_E	—	0.90	—

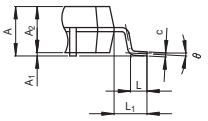
176-pin LFBGA (PLBG0176GA-A)

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP144-20x20-0.50	PLQP0144KA-A	144P6Q-A / FP-144L / FP-144LV	1.2g





Terminal cross section



Detail F

NOTE)
1 DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH
2 DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	19.9	20.0	20.1
E	19.9	20.0	20.1
A_2	—	1.4	—
H_D	21.8	22.0	22.2
H_E	21.8	22.0	22.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.17	0.22	0.27
b_1	—	0.20	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.10
Z_D	—	1.25	—
Z_E	—	1.25	—
L	0.35	0.5	0.65
L_1	—	1.0	—

144-pin LQFP (PLQP0144KA-A)

REVISION HISTORY RX610 Group Hardware Manual

Rev.	Data	Description	
		Page	Summary
0.11	Apr 15, 2009	–	First edition issued
0.12	Aug 07, 2009		1.Overview
		24	Table 1.1 Outline of Specifications: Interrupt control unit, changed
		24	Table 1.1 Outline of Specifications: Programmable I/O ports, changed
		27	Figure 1.2 Block Diagram changed
			2.CPU
		44	2.2.2.4 Processor Status Word (PSW): Note 1. changed
		50	2.3.3 Privileged Instruction: MVTIPL Instruction deleted
		64	Table 2.13 Instructions that are Converted into a Single Micro-Operation: System manipulation instructions, "MVTIPL#IMM" deleted
			5. I/O Registers
		83 to 103	Table 5.1 List of I/O Registers (Address Order) changed
		104 to 131	Table 5.2 List of I/O Registers (bit Order) changed
			7. Clock Generation Circuit
		142	Figure 7.2 Example of Crystal Resonator Connection changed
		142	Table 7.4 Damping Resistance: Reference values added
		142	Table 7.5 Crystal Resonator Characteristics: Reference values added
		143	7.3.2 External Clock Input: Parasitic capacitance added
			8. Power-Down Modes
		163	8.2.8 Deep Standby Interrupt Flag Register (DPSIFR): Description added
		168	8.5.2.1 Transitions to All-Module Clock Stop Mode: Note 5. added
		170	8.5.3.1 Transition to Software Standby Mode: Note 3. added
		178	Figure 8.4 Example of Flowchart to Use Deep Software Standby Mode changed
		180	8.7.5 Input Buffer Control by DIRQiE Bit (i = 3 to 0) changed
			10. Interrupt Control Unit (ICU)
		193	10.1 Overview changed
		193	Table 10.1 Specifications of the Interrupt Control Unit changed
		197 to 199	Table 10.3 Registers of the Interrupt Control Unit changed
		203	10.2.1 Interrupt Request Register n (IRn) changed
		205	10.2.2 Interrupt Destination Setting Register n (ISELRn) changed
		206	10.2.3 Interrupt Request Enable Register m (IERm) changed
		207	10.2.4 Interrupt Priority Register m (IPRm) changed
		208	10.2.5 Fast Interrupt Register (FIR) changed
		209	10.2.6 IRQ Detection Enable Register i (IRQERi) changed
		210	10.2.7 IRQ Control Register i (IRQCRi) changed
		212	10.2.9 NMI Pin Interrupt Control Register (NMICR) changed
		215	10.2.12 Software Standby Release IRQ Enable Register (SSIER) changed
		216	10.3 Vector Table changed
		216	10.3.1 Interrupt Vector Table changed
		216	Table 10.4 Interrupt Vector Table: In the Interrupt Source column, FCUIF is changed to FCU
		221	10.3.2 Fast Interrupt Vector Address changed
		221	10.3.3 Non-maskable Interrupt Vector Address changed
		222	10.4 Operation changed

Rev.	Data	Description Page	Summary
0.12	Aug 07, 2009	222	10.4.1 Enabling and Disabling Interrupts changed
		223	10.4.2 Interrupt Status Flag changed
		223	10.4.2.1 Interrupt Status Flag in Edge Detection changed
		224	10.4.2.2 Interrupt Status Flag in Level Detection changed
		225	10.4.3 Selecting Interrupt Request Destinations changed
		228	10.4.4 Determining Priority changed
		228	10.4.5 Fast Interrupt changed
		229	10.4.6 External Interrupts changed
		230	10.5 Non-maskable Interrupt changed
		231	Table 10.5 List of Interrupt Sources changed
		231	10.6.1 Returning from Sleep Mode and All-Module Clock Stop Mode changed
		232	10.6.2 Returning from Software Standby Mode changed
			11. Buses
			11.3.5 CSi Wait Control Register 2 (CSiWCNT2) (i = 0 to 7):
		252	Description on the WDOFF[2:0] bit and the WDON[2:0] bit changed
		265	Figure 11.10 Example of Normal-Read Operation (when Two Rounds of Bus Access are Generated in Response to a Single Request for Transfer) changed
		265	Figure 11.11 Example of Normal-Write Operation (when Two Rounds of Bus Access are Generated in Response to a Single Request for Transfer) changed
		275	11.5.5.4 Point for Caution Regarding Register Settings added
			12. DMA Controller (DMAC)
		285	Table 12.4 Setting of DCTG[5:0] Bits: DMA Request Source changed for 100111b, 101000b, 101001b, and 101010b on the DCTG[5:0] bit
			13. Data Transfer Controller (DTC)
		338	Figure 13.14 Procedure to Activate the DTC by an Interrupt changed
			14. I/O Ports
		345	Table 14.1 Specifications of I/O Ports changed
		353	14.2.2 Data Register (DR) Bit layout: Bit order changed Table of bits: Note changed
			16. Programmable Pulse Generator (PPG)
		516	Figure 16.11 Sample Setup Procedure for Non-Overlapping Pulse Output (PPG0 Setting) changed
		517	Figure 16.12 Sample Setup Procedure for Non-Overlapping Pulse Output (PPG1 Setting) changed
		521	16.3.8 Pulse Output Triggered by Input Capture changed
			20. Serial Communications Interface (SCI)
			20.2.6 Serial Control Register (SCR)
		582	(1) Serial Communications Interface Mode (SMIF in SCMR = 0) Description on the TEIE, RIE, and TIE bits changed
		584	(2) Smart Card Interface Mode (SMIF in SCMR = 1) Description on the RIE and TIE bits change

Rev.	Data	Description Page	Summary
0.12	Aug 07, 2009		20.2.7 Serial Status Register (SSR)
			(1) Serial Communications Interface Mode (SMIF in SCMR = 0)
		585 to 586	Description on the TEND, PER, FER, and ORER flags changed
			(2) Smart Card Interface Mode (SMIF in SCMR = 1)
		587 to 588	Description on the TEND, PER, and ORER flags changed
		604	20.3.4 SCI Initialization (Asynchronous Mode) changed
		604	Figure 20.7 Sample SCI Initialization Flowchart (Asynchronous Mode) changed
		605	20.3.5 Serial Data Transmission (Asynchronous Mode) changed
		606	Figure 20.9 Example of Serial Transmission Flowchart in Asynchronous Mode changed
		608	20.3.6 Serial Data Reception (Asynchronous Mode) changed
		609	Figure 20.11 Example of Serial Reception Flowchart (1) (Asynchronous Mode) changed
		610	Figure 20.11 Example of Serial Reception Flowchart (2) (Asynchronous Mode) changed
		612	20.4.2 SCI Initialization (Clock Synchronous Mode) changed
		612	Figure 20.13 Example of SCI Initialization Flowchart (Clock Synchronous Mode) changed
		613	20.4.3 Serial Data Transmission (Clock Synchronous Mode) changed
		614	Figure 20.15 Example of Serial Transmission Flowchart (Clock Synchronous Mode) changed
		615	20.4.4 Serial Data Reception (Clock Synchronous Mode) Changed
		616	Figure 20.17 Example of Serial Reception Flowchart (Clock Synchronous Mode) changed
		617	20.4.5 Simultaneous Serial Data Transmission and Reception (Clock Synchronous Mode) changed
		618	Figure 20.18 Example of Simultaneous Serial Transmission/Reception Flowchart (Clock Synchronous Mode) changed
		623	20.5.5 Initialization of the SCI changed
		627	Figure 20.26 Sample Serial Transmission Flowchart changed
		629	Figure 20.28 Sample Serial Reception Flowchart changed
		631	20.6.1 Interrupts in Serial Communications Interface Mode changed
		634	20.7.6 Restrictions on Clock Synchronous Transmission changed
			22. I2C Bus Interface (RIIC)
			(Configuration in this section changed)
		647	Figure 22.1 Block Diagram of RIIC changed
		649	Table 22.3 Registers of the RII changed
		650	22.2.1 I2C Bus Control Register 1 (ICCR1) changed
		653	22.2.2 I2C Bus Control Register 2 (ICCR2) changed
		657	22.2.3 I2C Bus Mode Register 1 (ICMR1) changed
		659	22.2.4 I2C Bus Mode Register 2 (ICMR2) changed
		661	22.2.5 I2C Bus Mode Register 3 (ICMR3) changed
		664	22.2.6 I2C Bus Function Enable Register (ICFER) changed
		670	22.2.9 I2C Bus Status Register 1 (ICSR1) changed
		675	22.2.10 I2C Bus Status Register 2 (ICSR2) changed
		679	22.2.11 Slave Address Register L0 (SARL0) changed
		680	22.2.12 Slave Address Register U0 (SARU0) changed
		681	22.2.13 Slave Address Register L1 (SARL1) changed
		682	22.2.14 Slave Address Register U1 (SARU1) changed
		683	22.2.15 Slave Address Register L2 (SARL2) changed
		684	22.2.16 Slave Address Register U2 (SARU2) changed

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0.12	Aug 07, 2009	685	22.2.17 I2C Bus Bit Rate Low-Level Register (ICBRL) changed
		685	22.2.18 I2C Bus Bit Rate High-Level Register (ICBRH) changed
		686	Table 22.6 Examples of ICBRH/ICBRL Settings for Transfer Rate changed
		687	22.2.20 I2C Bus Receive Data Register (ICDRR) changed
		687	22.2.21 I2C Bus Shift Register (ICDRS) changed
		688 to 704	22.3 Operation changed
		706	22.5 Facility for Delaying SDA Output added changed
		711	22.7.3 Device-ID Address Detection changed
		718	22.9.1 Master Arbitration Lost Detection (MALE Bit) changed
		720	22.9.2 Function to Detect Loss of Arbitration during NACK Transmission (NALE Bit) changed
		721	22.9.3 Slave Arbitration Lost Detection (SALE Bit) changed
		724	22.11.1 Timeout Function changed
		725	Figure 22.38 Timeout Function (TMOE, TMOS, TMOH, and TMOL Bits) changed
		726	22.11.2 Extra SCL Clock Cycle Output Function changed
		727	22.11.3 RIIC Reset and Internal Reset changed
		728	22.12 SMBus Operation changed
		731	22.13 Interrupt Request changed
			23. A/D Converter
		761	23.6.5 Permissible Impedance of Signal Sources changed
		762	23.6.7 Ranges of Settings for Analog Power Supply and Other Pins changed
		762	Figure 23.16 Example of Connections for AVcc = Vcc and AVss = Vss changed
		762	23.6.9 Point for Caution Regarding Countermeasures for Noise changed
		763	Figure 23.17 Example of a Protective Circuit for Analog Inputs changed
		763	23.6.10 Realizing High-Speed Conversion changed
		763	Figure 23.18 Example of an Externally Connected Capacitor for High-Speed Conversion changed
			26. ROM (Flash Memory for Code Storage) (Configuration in this section changed)
		772	Table 26.1 Specifications of the ROM changed
		773	Figure 26.1 Block Diagram of ROM changed
		773	Table 26.2 Input and Output Pins Associated with the ROM changed
		775	26.2.1 Flash Mode Register (FMODR) Table of bits: Function on the FRDMD bit changed Description on the FRDMD bit changed
		792	26.2.14 Peripheral Clock Notification Register (PCKAR) changed
		793	26.2.15 Flash Write Erase Protection Register (FWEPROR) changed
		794	26.3 Configuration of Memory Mats for the ROM added
		794	26.4 Block Configuration added
		795	26.5 Operating Modes Associated with the ROM changed
		795	Figure 26.4 Transitions between Operating Modes in Terms of the ROM added
		796	Table 26.5 Differences between Modes changed
		797	26.6 Programming and Erasing the ROM added
		797	26.6.1 FCU Modes added
		798	26.6.1.1 ROM Read Modes changed
		798	26.6.1.2 ROM P/E Modes added

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0.12	Aug 07, 2009	799	26.6.2 FCU Commands changed
		799	Table 26.6 FCU Commands for Use with the ROM changed
		800	Table 26.7 FCU Command Formats changed
		801	26.6.3 Connections between FCU Modes and Commands added
		802	26.6.4 FCU Command Usage changed
		802	26.6.4.1 Mode Transitions changed
		806	26.6.4.2 Programming and Erasure changed
		815	26.6.4.3 Error Processing added
		816	26.6.4.4 Suspension and Resumption added
		824	26.10 Boot Mode added
		824	26.10.1 System Configuration added
		825	26.10.2 State Transitions in Boot Mode added
		827	26.10.3 Automatic Adjustment of the Bit Rate added
		828	26.10.4 ID Code Protection in Boot Mode added
		829	26.11 ID Code Protection on Connection of the On-Chip Debugger added
		830	26.12 ROM Code Protection added
		831	26.13 Usage Notes changed
			27. Data Flash Memory (Flash Memory for Data Storage) (Configuration in this section changed)
		832	Table 27.1 Specifications of Data Flash Memory added
		833	Figure 27.1 Block Diagram of Data Flash Memory changed
		833	Table 27.2 Input and Output Pins Associated with the Data Flash changed
		835	27.2.1 Flash Mode Register (FMODR) Table of bits: Function on the FRDMD bit changed Description on the FRDMD bit changed
		846	27.3 Configuration of Memory Mat for the Data Flash Memory added
		846	27.4 Block Configuration added
		847	27.5 Operating Modes Associated with the Data Flash added
		847	Table 27.4 Differences between Modes changed
		848	27.6 Programming and Erasing the Data Flash Memory added
		848	27.6.1 FCU Modes added
		849	27.6.1.1 ROM P/E Modes changed
		849	27.6.1.2 ROM/Data Flash Read Mode changed
		849	27.6.1.3 Data Flash P/E Modes changed
		850	27.6.2 FCU Commands changed
		850	Table 27.5 FCU Commands for Use with Data Flash Memory changed
		850	Table 27.6 FCU Command Formats changed
		851	27.6.3 Connections between FCU Modes and Commands changed
		851	Table 27.7 Acceptable Commands and the State and Mode (Data Flash P/E Mode) of the FCU
		852	27.6.4 FCU Command Usage changed
		856	27.7.1 Software Protection changed
		857	27.7.2 Error Protection changed
		858	27.8 Usage Notes changed

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0.12	Aug 07, 2009		28. Electrical Characteristics
		861	Table 28.2 DC Characteristics (1): Note 4 added
		868	Table 28.9 Timing of On-Chip Peripheral Modules (1) changed
		869	Table 28.9 Timing of On-Chip Peripheral Modules (2) changed
		870	Table 28.9 Timing of On-Chip Peripheral Modules (3) changed
			Appendix 1.Port States in Each Processing Mode
		878 to 881	Table 1.1Port States in Each Processing State (by Activation Mode) changed
0.40	Dec. 16, 2009	All	Register description (reserved bit) reviewed
			"General Precautions in the Handling of MPU/MCU Products" added
			"How to Use This Manual" added
			Section 1 Overview
		27 to 29	Table 1.1 Outline of Specifications, changed
			Reference power supply pin for the A/D and D/A converters: Vref (pin no. 142) → VREFH,
			Reference ground pin: AVSS (pin no. 140) → VREFL, Pin name changed
		32	Figure 1.3 Pin Assignment of the 144-Pin LQFP, changed
		33	Figure 1.4 Pin Assignment (Assistance Diagram) of the 144-Pin LQFP, changed
		38	Table 1.3 List of Pins and Pin Functions, changed
		43	Table 1.4 Pin Functions, changed
			Section 2 CPU
		44	2.1 Features: Register set of the CPU, Accumulator, changed
		45	Figure 2.1 Register Set of the CPU, changed
			2.2.2.8 Floating-Point Status Word (FPSW)
		51 to 54	RM[1:0], Floating-Point Rounding-Mode Setting: Bit name changed
			Bit description added
		55	2.2.3 Accumulator (ACC), changed
		59	2.5.1 Switching the Endian, changed
		65	Figure 2.8 Fixed Vector Table, changed
		68	2.8 Pipeline, 2.8.1 Overview (4), changed
		74	Figure 2.15 MOV Instruction (Memory-Memory), Bit Manipulation Instruction (Memory
			Source Operand), changed
		78	2.8.4 Interrupt Response Cycles, added
			Section 3 Operating Modes
		82, 83	3.2.3 System Control Register 0 (SYSCR0), bits ROME and KEY[7:0]: Bit description
			changed
		84	3.2.4 System Control Register 1 (SYSCR1), bit RAME: Bit description changed
			Section 4 Address Space
		88	Figure 4.1 Memory Map of the R5F56108, added
		89	Figure 4.2 Memory Map of the R5F56107, added
		90	Figure 4.3 Memory Map of the R5F56106, added
		91	Figure 4.4 Memory Map of the R5F56105, added
			Section 5 I/O Registers
		93, 94	3. Notes on writing to I/O registers, added
		116 to 143	Table 5.2 List of I/O Registers (Bit Order), changed

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0.40	Dec 16, 2009		Section 8 Low Power Consumption (section title changed)
		160	Table 8.1 States of Operation, Note 7. added
		164, 165	8.2.1 Standby Control Register (SBYCR), bit SSBY: Bit description changed
		172	8.2.5 Deep Standby Control Register (DPSBYCR), bit DPSBY: Bit description changed
		175	8.2.8 Deep Standby Interrupt Flag Register (DPSIFR), Register description changed
		181	8.5.2.1 Transitions to All-Module Clock Stop Mode, changed
		184	8.5.3.2 Canceling Software Standby Mode, added
		187	8.5.4.1 Transition to Deep Software Standby Mode, Note 2. added
		190	8.5.4.5 Example of Deep Software Standby Mode Application, changed
		191	Figure 8.4 Example of Flowchart to Use Deep Software Standby Mode, changed
		193	8.7.7 Timing of Wait Instructions, changed
			Section 9 Exceptions
		199	Table 9.2 Vector and Site for Saving the Values in the PC and PSW Registers, changed
		200	9.4 Hardware Processing for Accepting and Returning from Exceptions, added
		200	(b) Updating of the PM, U, and I bits in the PSW register, changed
		203	9.6 Return from Exception Processing Routines, changed
			Section 10 Interrupt Control Unit (ICU)
		217	10.2.2 Interrupt Request Destination Setting Register n (ISELRn), Bit description list: Notes 1. and 2. added
		219	10.2.4 Interrupt Priority Register m (IPRm), bits IPR[2:0]: Bit name changed
		228 to 233	Table 10.4 Interrupt Vector Table, changed
		244	10.6.2 Returning from Software Standby Mode, added
			Section 11 Buses
		251	Table 11.6 Registers of the External Bus Controller, changed
			11.3.1 CSi Control Register (CSiCNT):
		253	Bit allocation: Value of CS0CNT after a reset, changed, Note deleted, Bit description list: Note 2. changed
		254	Bits BSIZE[1:0]: Bit description changed
		257	11.3.3 CSi Mode Register (CSiMOD), bit PRMOD: Bit description changed
			11.3.4 CSi Wait Control Register 1 (CSiWCNT1):
		259 to 262	Bits CSPWWAIT[2:0] , CSPRWAIT[2:0] , CSWWAIT[4:0] , and CSRWAIT[4:0] : Note added
			11.3.5 CSi Wait Control Register 2 (CSiWCNT2) :
		263 to 266	Bits CSWOFF[2:0] , WDOFF[2:0] , RDON[2:0] , and WRON[2:0] : Note added
		287	11.5.3 Insertion of Recovery Cycles, changed
		287	Figure 11.21 Example of Recovery Timing, changed
		290	11.6.2 Operations When a Bus Error Occurs, added
			Section 12 DMA Controller (DMAC)
		299	Table 12.4 Setting of DCTG[5:0] Bits, changed
		313	12.2.16 DMA Transfer End Detect Register (DMEDET), flag DEDETn: Bit description added
		314	12.3.1 Bus Mastership Release Timing, corrected
		317	Figure 12.4 Register Setting Procedure, changed
		322	12.4 Interrupts, changed, Figure 12.8 Schematic Logic Diagram of Interrupt Outputs, added
		324	12.6.1 Register Settings, (7) added

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0.40	Dec 16, 2009		Section 13 Data Transfer Controller (DTC)
		338	Table 13.3 Correspondence between Interrupt Sources, DTC Vector Addresses, and the ISELRn Register of the ICU, changed
		349	13.4.6 Chain Transfer, changed
		349	Figure 13.9 Chain Transfer Operation, changed
		353	13.5 DTC Setting Procedure, changed
		353	Figure 13.14 Procedure to Set the DTC, changed
		358	13.8.1 Setting the DTC Module Start Register, Description on (1) and (2), changed
			Section 14 I/O Ports
		379 to 381	14.2.13 Port Function Control Register 6 (PFCR6), changed
			Table 14.6 Correspondences between PFCR6 and TPUn.TMDR Settings, Input Capture Inputs, and External Pins, added
		382 to 384	14.2.14 Port Function Control Register 7 (PFCR7), changed
			Table 14.7 Correspondences between PFCR7 and TPUn.TMDR Settings and Input Capture Inputs and External Pins, added
		387	14.3 Settings of Ports, changed
		429	Table 14.10 Treatment of Unused Pins, changed
			Section 15 16-Bit Timer Pulse Unit (TPU)
		439 to 441	Table 15.5 Registers of TPU, changed
		460	15.2.5 Timer Status Register (TSR), Bit allocation: Value after a reset, changed
		462	15.2.8 Timer Start Register (TSTRA, TSTRB), Bit allocation: TSTRB address, changed
		463	15.2.9 Timer Synchronous Register (TSYRA, TSYRB), Bit allocation: TSYRB address, changed
			Section 17 8-Bit Timer (TMR)
		543	Table 17.3 Registers of TMR, changed
		549	17.2.6 Timer Control/Status Register (TCSR), Bit allocation: Value after a reset, changed
			Section 18 Compare Match Timer (CMT)
		566	Table 18.2 List of CMT Registers, changed
		569	18.2.3 Compare Match Timer Control Register (CMCR), Bit allocation: Value after a reset, changed
			Section 19 Watchdog Timer (WDT)
		576	Table 19.3 WDT Registers, changed
		577	19.2.2 Timer Control/Status Register (TCSR), Bit allocation: Value after a reset, changed
			Section 20 Serial Communications Interface (SCI)
		589 to 590	Table 20.4 Registers of SCI, changed
		601, 603	20.2.7 Serial Status Register (SSR), Bit allocation: Value after a reset, changed
		602	Flag PER, corrected
		647	20.6.1 Interrupts in Serial Communications Interface Mode, changed
			Section 22 I^2C Bus Interface (RIIC)
		661 to 745	RIIC interrupt names changed (EEI → ICEEI, RXI → ICRXI, TXI → ICTXI, TEI → ICTEI)
		663	Figure 22.1 Block Diagram of RIIC, changed
		664	Figure 22.2 Connections to the External Circuit by the I/O Pins (I^2C Bus Configuration Example), changed
		665	Table 22.3 Registers of the RIIC, changed

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0.40	Dec 16, 2009		22.2.2 I²C Bus Control Register 2 (ICCR2):
		669	Bit allocation: Value after a reset, changed
		669 to 672	Bit description changed
		673	22.2.3 I²C Bus Mode Register 1 (ICMR1), bits BC[2:0]: Bit description changed
		678	22.2.5 I²C Bus Mode Register 3 (ICMR3), bits ACKBR and ACKBT: Bit description changed
			22.2.7 I²C Bus Status Enable Register (ICSER):
		682	Bits SAR0E, SAR1E, and SAR2E → Bits SARmE (m = 0 to 2), Bit description changed
		687	22.2.9 I²C Bus Status Register 1 (ICSR1), Bit description list: Note added
		687	Flags AAS0, AAS1, and AAS2 → Flag AASm (m = 0 to 2), Bit description changed
		687 to 688	Bit description changed
		690	22.2.10 I²C Bus Status Register 2 (ICSR2), Bit description list: Note added
		690 to 693	Bit description changed
		694	(Registers SARL0, SARL1, and SARL2 → Register SARLm (m = 0 to 2), Register description changed)
			22.2.11 Slave Address Register Lm (SARLm) (m = 0 to 2)
		695	(Registers SARU0, SARU1, and SARU2 → Register SARUm (m = 0 to 2), Register description changed)
			22.2.12 Slave Address Register Um (SARUm) (m = 0 to 2)
		696	22.2.13 I²C Bus Bit Rate Low-Level Register (ICBRL), Register description changed
			22.2.14 I²C Bus Bit Rate High-Level Register (ICBRH)
		697	Transfer rate expression, changed
		698	Table 22.6 Examples of ICBRH/ICBRL Settings for Transfer Rate, changed
		701	Figure 22.5 Example of RIIC Initialization Flow, changed
		702	22.3.3 Master Transmitter Operation, changed
		703	Figure 22.6 Example of Master Transmission Flowchart, changed
		706 to 707	22.3.4 Master Receiver Operation, changed
		708	Figure 22.10 Example of Master Reception Flowchart (7-Bit Address Format), changed
		711	22.3.5 Slave Transmitter Operation, changed
		712	Figure 22.14 Example of Slave Transmission Flowchart, changed
		714	22.3.6 Slave Receiver Operation, changed
		723	22.7.3 Device-ID Address Detection, changed
		727	Figure 22.30 Suspension of Data Transfer when NACK is Received (NACKE = 1), changed
		736	22.11.1 Timeout Function, changed
		743	22.13 Interrupt Request, Notes on interrupt processing 4., changed
		743	Table 22.7 Interrupt Sources, changed
		745	22.15 Usage Notes, changed
			Section 23 A/D Converter
			Reference power supply pin: Vref → VREFH, Reference ground pin: AVSS → VREFL, Pin name changed
		748 to 751	Figures 23.1 to 23.4, Block Diagram of A/D Converter, changed
		752	Table 23.3 Input Pins of A/D Converter, changed
		753	Table 23.4 Registers of A/D Converter, changed
		755	23.2.2 A/D Control/Status Register (ADCSR), Bit allocation: Value after a reset, changed
		768	Figure 23.10 Connections between Compare-Match/Input-Capture A to D Signals from TPU0 and the Respective Converter Units, changed
		769	Figure 23.11 Connections between Compare-Match/Input-Capture A Signals and the Respective Converter Units, changed

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0.40	Dec 16, 2009	770	Figure 23.12 Connections between Compare-Match A Signals from TMR0 and TMR2 and the Respective Converter Units, changed
		775	23.6.7 Ranges of Settings for Analog Power Supply and Other Pins, changed
		775	Figure 23.16 Example of Connections for AVcc = Vcc and AVss = Vss = VREFL, changed
		775	23.6.8 Point for Caution Regarding Board Design, changed
		776	23.6.9 Point for Caution Regarding Countermeasures for Noise, changed
		776	Figure 23.17 Example of a Protective Circuit for Analog Inputs, changed
		777	23.6.10 Realizing High-Speed Conversion, changed
		777	Figure 23.18 Example of an Externally Connected Capacitor for High-Speed Conversion, changed
			Section 24 D/A Converter Reference power supply pin: Vref → VREFH, Reference ground pin: AVSS → VREFL, Pin name changed
		778	Figure 24.1 Block Diagram of D/A Converter, changed
		779	Table 24.2 Pin Configuration of D/A Converter, changed
		781	24.2.2 D/A Control Register (DACR), Bit description list: Note 2. changed
			Section 26 ROM (Flash Memory for Code Storage) User mat: 2 Mbytes → 2 Mbytes, 1.5 Mbytes, 1 Mbyte, or 768 Kbytes, changed Flash interface error name: FCUERR → FIFERR, changed
		787, 788	Table 26.1 Specifications of the ROM, changed and Note added
		789	Figure 26.1 Block Diagram of ROM, changed
		790	Table 26.3 Registers Related to ROM, changed
		793	26.2.2 Flash Access Status Register (FASTAT), bit ROMAE: Bit description (Note) added
		799	26.2.6 Flash Status Register 1 (FSTATR1), Bit allocation: Value after a reset
		800	26.2.7 Flash Ready Interrupt Enable Register (FRDYIE), Bit FRDYIE, Bit description added
			26.2.8 Flash P/E Mode Entry Register (FENTRYR):
		801	Bit description list (FENTRY1, FENTRY0), changed
		801	Register description, changed
		802	Bit FENTRY1: Bit description (Note) added
		803	Table 26.4 Correspondence of FENTRY1 and FENTRY0 Bits in Each Product, added
		811	Figure 26.2 Memory Mat Configuration of ROM, changed
		812	Figure 26.3 Configuration of Erasure Blocks for the User Mat, changed
			26.6.1.2 ROM P/E Modes
		816	(1) ROM P/E Normal Mode, Note added
		816	(2) ROM Status Read Mode, Note added
		817	(3) ROM Lock-Bit Read Mode, Note added
		818	Table 26.8 FCU Command Formats, changed
			26.6.4.2 Programming and Erasure Procedures
		825	(2) Jumping to Locations in On-chip RAM, Note added
		826	(4) Using the Peripheral Clock Notification Command, Note added
		828	(5) Programming, Note added
			26.8.1 Software Protection
		840	(2) Protection through FENTRYR, Note added
		840	26.8.2 Error Protection, changed
		841	Table 26.10 Error Protection Types (Types Dedicated to ROM and Types Common to ROM and Data Flash), changed
		842	26.9 User Boot Mode, changed

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0.40	Dec 16, 2009	842	26.10 Boot Mode, 26.10.1 System Configuration, changed
		842	Figure 26.24 System Configuration for Operations in Boot Mode, changed
		843 to 844	26.10.2 ID Code Protection, changed
			26.10.3 State Transitions in Boot Mode
		845	Figure 26.26 State Transitions in Boot Mode, changed
		846	(2) Waiting for a Host Command for Inquiry or Selection, (3) Judging ID Code Protection,
		846	(4) Waiting for an ID Code, changed
		848 to 861	26.10.5 Inquiry/Selection Host Command Wait State, added
		862	26.10.6 ID Code Wait State, added
		863 to 871	26.10.7 Programming/Erasure Host Command Wait State, added
		872	26.11 ID Code Protection on Connection of the On-Chip Debugger, changed
			Section 27 Data Flash (Flash Memory for Data Storage)
			Flash interface error name: FCUERR → FIFERR, changed
		876	Figure 27.1 Block Diagram of Data Flash Memory, changed
		885	27.2.6 Flash P/E Mode Entry Register (FENTRYR), Register description, changed
		900	27.7.2 Error Protection, changed
		900	Table 27.8 Error Protection Types (for Data Flash Only), changed
		901 to 904	27.8 Boot Mode, added
			Section 28 Electrical Characteristics
		905 to 925	Vref → VREFH, AVSS → VREFL, changed
		909	Table 28.5 Clock Timing, (tcyc, tCH, tCL) changed
1.00	Mar. 16, 2010		1. Overview
		31	Figure 1.2 Block Diagram: Ports F to H added
		32	Figure 1.3 Pin Assignment of the 176-pin LFBGA, added
		35 to 40	Table 1.3 List of Pins and Pin Functions (176-Pin LFBGA), added
			Table 1.5 Pin Functions:
		46, 50	Description on the BSCANP, PF0 to PF6, PG0 to PG7, and PH0 to PH7 pins added
			2. CPU
		55	2.2.2.4 Processor Status Word (PSW): Note 4 added to the IPL[2:0] bits
		78	Table 2.14 Instructions that are Converted into Multiple Micro-Operations: Instructions DIV and DIVU added
		84	2.8.4 Numbers of Cycles for Response to Interrupts, changed
			5. I/O Registers
		100	4.Number of Access Cycles to I/O Registers, added
			Table 5.1 List of I/O Registers (Address Order):
		101 to 121	Column for number of access cycles, and notes 7 and 8, added
			6. Resets
		156	6.5 Usage Notes, added
			7. Clock Generation Circuit
		165	7.7.3 Notes on Board Design, changed
			8. Low Power Consumption
		189	8.5.3.1 Transition to Software Standby Mode: Note 3 changed
		190	8.5.3.2 Canceling Software Standby Mode:
		192	Description on 1. Canceling by an interrupt, added
		196	Figure 8.2 Example of Software Standby Mode Application, changed
			Figure 8.3 Example of Deep Software Standby Mode Application, changed

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1.00	Mar 16, 2010		10. Interrupt Control Unit (ICU)
		249	10.6.2 Returning from Software Standby Mode, changed
		250	10.7 Usage Notes, added
			14. I/O Ports
		362	Table 14.1 Specifications of I/O Ports: 176-pin LFBGA added
		367	Table 14.2 Port Functions: Description on ports F to H, added
			Table 14.3 Registers for Each Port:
		369	Registers DDR, DR, PORT, and ICR for PF, PG, and PH, added
		371	14.2.1 Data Direction Register (DDR):
			Description on PF.DDR, PG.DDR, and PH.DDR added
		372	14.2.2 Data Register (DR): Description on PF.DR, PG.DR, and PH.DR, added
		373	14.2.3 Port Register (PORT): Description on PF.PORT, PG.PORT, and PH.PORT, added
		374	14.2.4 Input Buffer Control Register (ICR):
			Description on PF.ICR, PG.ICR, and PH.ICR, added
		425 to 426	14.3.16 Port F (PF), added
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