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16

H8S/20103, H8S/20203, H8S/20223 Group

Hardware Manual

Hardware Manual

Renesas 16-Bit Single-Chip Microcomputer
H8S Family / H8S/Tiny Series

H8S/20103	R4F20103
H8S/20203	R4F20203
H8S/20223	R4F20223

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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 type number, confirm that the change will not lead to problems.
   — The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type 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 H8S/20103 Group, H8S/20203 Group, H8S/20223 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.
Data Sheet	Overview of hardware and electrical characteristics	—	—
Hardware Manual	Hardware specifications (pin assignments, memory maps, peripheral specifications, electrical characteristics, and timing charts) and descriptions of operation	H8S/20103 Group H8S/20203 Group H8S/20223 Group Hardware Manual	This manual
Software Manual	Detailed descriptions of the CPU and instruction set	H8S/2600 Series H8S/2000 Series Software Manual	REJ09B0143
Application Note	Examples of applications and sample programs	The latest versions are available from our web site.	
Renesas Technical Update	Preliminary report on the specifications of a product, document, etc.		

2. Description of Numbers and Symbols

Aspects of the notations for register names, bit names, numbers, and symbolic names in this manual are explained below.

(1) Overall notation

In descriptions involving the names of bits and bit fields within this manual, the modules and registers to which the bits belong may be clarified by giving the names in the forms "module name"."register name"."bit name" or "register name"."bit name".

(2) Register notation

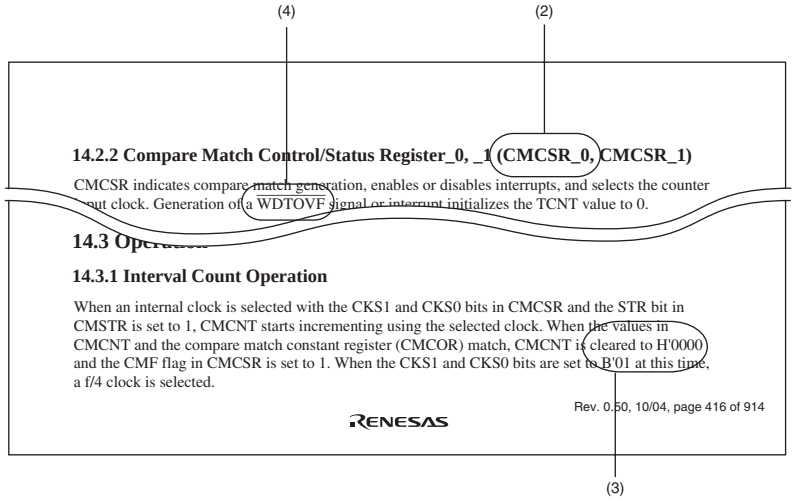
The style "register name"_"instance number" is used in cases where there is more than one instance of the same function or similar functions.
[Example] CMCSR_0: Indicates the CMCSR register for the compare-match timer of channel 0.

(3) Number notation

Binary numbers are given as B'nnnn (B' may be omitted if the number is obviously binary), hexadecimal numbers are given as H'nnnn or 0xnnnn, and decimal numbers are given as nnnn.
[Examples] Binary: B'11 or 11
Hexadecimal: H'EFA0 or 0xEFA0
Decimal: 1234

(4) Notation for active-low

An overbar on the name indicates that a signal or pin is active-low.
[Example] $\overline{\text{WDTOVF}}$

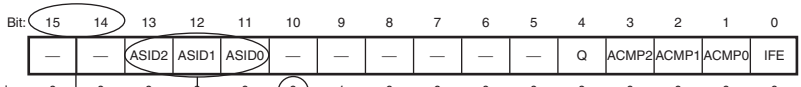


Note: The bit names and sentences in the above figure are examples and have nothing to do with the contents of this manual.

3. 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.

[Bit Chart]



[Table of Bits]

(1) (2) (3) (4) (5)

Bit	Bit Name	Initial Value	R/W	Description
15	–	0	R	Reserved
14	–	0	R	These bits are always read as 0.
13 to 11	ASID2 to ASID0	All 0	R/W	Address Identifier These bits enable or disable the pin function.
10	–	0	R	Reserved This bit is always read as 0.
9	–	1	R	Reserved This bit is always read as 1.
	–	0		

Note: The bit names and sentences in the above figure are examples, and have nothing to do with the contents of this manual.

(1) Bit
Indicates the bit number or numbers.
In the case of a 32-bit register, the bits are arranged in order from 31 to 0. In the case of a 16-bit register, the bits are arranged in order from 15 to 0.

(2) Bit name
Indicates the name of the bit or bit field.
When the number of bits has to be clearly indicated in the field, appropriate notation is included (e.g., ASID[3:0]).
A reserved bit is indicated by "–".
Certain kinds of bits, such as those of timer counters, are not assigned bit names. In such cases, the entry under Bit Name is blank.

(3) Initial value
Indicates the value of each bit immediately after a power-on reset, i.e., the initial value.
0: The initial value is 0
1: The initial value is 1
–: The initial value is undefined

(4) R/W
For each bit and bit field, this entry indicates whether the bit or field is readable or writable, or both writing to and reading from the bit or field are impossible.
The notation is as follows:

R/W: The bit or field is readable and writable.
R/(W): The bit or field is readable and writable.
However, writing is only performed to flag clearing.
R: The bit or field is readable.
"R" is indicated for all reserved bits. When writing to the register, write the value under Initial Value in the bit chart to reserved bits or fields.
W: The bit or field is writable.

(5) Description
Describes the function of the bit or field and specifies the values for writing.

4. Description of Abbreviations

The abbreviations used in this manual are listed below.

- Abbreviations specific to this product

Abbreviation	Description
BSC	Bus controller
CPG	Clock pulse generator
INT	Interrupt controller
SCI	Serial communications interface
TPU	16-bit timer pulse unit
WDT	Watchdog timer

- Abbreviations other than those listed above

Abbreviation	Description
ACIA	Asynchronous communications 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 (IEBus is a trademark of NEC Electronics Corporation.)
I/O	Input/output
IrDA	Infrared Data Association
LSB	Least significant bit
MSB	Most significant bit
NC	No connection
PLL	Phase-locked loop
PWM	Pulse width modulation
SFR	Special function register
SIM	Subscriber Identity Module
UART	Universal asynchronous receiver/transmitter
VCO	Voltage-controlled oscillator

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Section 1 Overview

1.1 Features

The H8S/Tiny series is a 16-bit CISC (complex instruction set computer) microcontroller, each member of the H8S/Tiny series has the powerful H8S/2000 CPU with an internal 32-bit architecture as its core. The H8S/2000 CPU provides upwards-compatibility with the other members of the Renesas Technology H8 Family: H8/300, H8/300H Tiny and H8/300H.

The on-chip peripheral function modules include a data transfer controller, event link controller, serial communication interface, I^2C bus interface 2, synchronous serial communication unit, hardware LIN communication interface, A/D and D/A converters, low-voltage detection circuit, and versatile timers. These modules realize low-cost systems. The power consumption of these modules can be controlled dynamically using power-down modes.

1.1.1 Applications

Examples of the applications include home appliances, office automation equipment, consumer equipment, and industrial equipment.

1.1.2 Overview of Functions

Table 1.1 lists the specifications of the products of this series.

Table 1.1 Overview of Functions

Classification	Module/ Function	Description
Memory	ROM	• Flash memory version Program memory: 128 kbytes or 96 kbytes Number of program/erase times: 1000 times Data flash: 4 kbytes × two blocks Number of program/erase times: 10000 times
	RAM	• Capacity: 8 kbytes

Classification	Module/ Function	Description
CPU	CPU	• 16-bit high-speed H8S/2000 CPU (CISC type) Upwardly compatible with H8/300 and H8/300H CPUs at object level • General-register architecture (sixteen 16-bit general registers) • Eight addressing modes • 16-Mbyte address space — Program: 16 Mbytes available — Data: 16 Mbytes available • 65 basic instructions including bit operation instructions, multiply and divide instructions, bit manipulation instructions, and others • Minimum instruction execution time: 50 ns (for an ADD instruction) while system clock ϕ = 20 MHz and V_{cc} = 2.7 to 5.5 V
	Operating mode	Advanced single-chip mode
Interrupt (source)	Interrupt controller (INTC)	• Nine external interrupt pins (NMI, and $\overline{IRQ7}$ to $\overline{IRQ0}$) • Internal interrupt sources — 55 (H8S/20103 group) — 61 (H8S/20203 group) — 63 (H8S/20223 group) • Two interrupt control modes (specified by the interrupt control register) • Four interrupt priority orders specifiable (by setting the interrupt priority register) • Independent vector addresses
Clock	Clock pulse generator (CPG)	• Two clock generation circuits: main and sub-clock oscillators • Two on-chip oscillators — High speed: 40 MHz — Low speed: 125 kHz • Three power-down modes: sleep mode, software standby mode, and module standby mode

Classification	Module/ Function	Description
Voltage detection	Voltage detection circuit (LVD)	Voltage drop detected
DMA	Data transfer controller (DTC)	• Transfer via any number of channels possible • Three transfer modes
A/D converter	A/D converter (ADC)	• 10-bit resolution × eight to sixteen input channels • Sample and hold function included • Conversion time: 2 μs per channel • Two operating modes: single mode and scan mode • Three ways to start A/D conversion: software, timer trigger, and external pin trigger.
D/A converter	D/A converter (DAC)	• 8-bit resolution × two input channels
Timers	Timer RA	8 bits × one channel (with 8-bit prescaler)
	Timer RB	8 bits × one channel (with 8-bit prescaler)
	Timer RC	16 bits × one channel (only available with H8S/20103 group)
	Timer RD	16 bits × two channels (× two units in H8S/20203 and H8S/20223 groups)
	Timer RE	8 bits × one channel with real-time clock function
	Timer RG	16 bits × one channel with phase-counting mode
	Watchdog timer (WDT)	8 bit × one channel
Serial interfaces	Serial communi-cation interface (SCI3)	• Three channels (either for asynchronous or clock-synchronous communication) • Full-duplex communication capability • Any desired bit rate selectable
		IrDA (only available with channel 2)
	Synchro-nous serial communi-cation unit (SSU)	• One channel (IIC2 and selection format) • Clock-synchronous communication with chip-select function

Classification	Module/ Function	Description
Serial interfaces	I^2C bus interface 2 (IIC2)	• One channel (SSU and selection format) • Continuous transmission and reception possible • Two transmission/reception formats — I^2C bus format: generates start and stop conditions in master mode automatically, acknowledge bit, master or slave operation — Clock-synchronous serial format: no acknowledge bit, master operation only
	Hardware LIN interface	One channel (timer RA and SCI3 used)
Event link controller (ELC)		Events (interrupts) generated by peripheral modules can be interconnected between modules, enabling cooperation between the modules without CPU intervention.
I/O ports		• I/O pins — 55 (H8S/20103 group) — 69 (H8S/20203 and H8S/20223 groups) • Pull-up resistors settable for all ports • LED driving capability

Classification	Module/ Function	Description
Packages		• 64-pin QFP package (PLQP0064KB-A) — Former code: 64P6Q-A — Body size: 10 × 10 mm — Pin pitch: 0.50 mm • 64-pin QFP package (PLQP0064GA-A) — Former code: 64P6U-A — Body size: 14 × 14 mm — Pin pitch: 0.80 mm • 80-pin QFP package (PLQP0080JA-A) — Former code: FP-80W — Body size: 14 × 14 mm — Pin pitch: 0.65 mm • 80-pin QFP package (PLQP0080KB-A) — Former code: 80P6Q-A — Body size: 12 × 12 mm — Pin pitch: 0.50 mm
Operating frequency/ Power supply voltage		• Operating frequency: 4 to 20 MHz • Power supply voltage: Vcc = 2.7 to 5.5 V, Avcc = 2.7 to 5.5 V
Operating ambient temperature (°C)		• –20 to +85°C (version N) • –40 to +85°C (version D)

1.2 List of Products

Table 1.2 lists products of this series, and figure 1.1 shows how to read the part number.

Table 1.2 List of Products

Group	Part No.	ROM Capacity	RAM Capacity	Package	Remarks
H8S/20103	R4F20103NFA	128 kbytes	8 kbytes	PLQP0064KB-A	Version N
	R4F20102NFA	96 kbytes	8 kbytes	(LQFP1010-64)	
	R4F20103NFB	128 kbytes	8 kbytes	PLQP0064GA-A	
	R4F20102NFB	96 kbytes	8 kbytes	(LQFP1414-64)	
	R4F20103DFA	128 kbytes	8 kbytes	PLQP0064KB-A	Version D
	R4F20102DFA	96 kbytes	8 kbytes	(LQFP1010-64)	
	R4F20103DFB	128 kbytes	8 kbytes	PLQP0064GA-A	
	R4F20102DFB	96 kbytes	8 kbytes	(LQFP1414-64)	
H8S/20203	R4F20203NFC	128 kbytes	8 kbytes	PLQP0080KB-A	Version N
	R4F20202NFC	96 kbytes	8 kbytes	(LQFP1212-80)	
	R4F20203NFD	128 kbytes	8 kbytes	PLQP0080JA-A	
	R4F20202NFD	96 kbytes	8 kbytes	(LQFP1414-80)	
	R4F20203DFC	128 kbytes	8 kbytes	PLQP0080KB-A	Version D
	R4F20202DFC	96 kbytes	8 kbytes	(LQFP1212-80)	
	R4F20203DFD	128 kbytes	8 kbytes	PLQP0080JA-A	
	R4F20202DFD	96 kbytes	8 kbytes	(LQFP1414-80)	
H8S/20223	R4F20223NFC	128 kbytes	8 kbytes	PLQP0080KB-A	Version N
	R4F20222NFC	96 kbytes	8 kbytes	(LQFP1212-80)	
	R4F20223NFD	128 kbytes	8 kbytes	PLQP0080JA-A	
	R4F20222NFD	96 kbytes	8 kbytes	(LQFP1414-80)	
	R4F20223DFC	128 kbytes	8 kbytes	PLQP0080KB-A	Version D
	R4F20222DFC	96 kbytes	8 kbytes	(LQFP1212-80)	
	R4F20223DFD	128 kbytes	8 kbytes	PLQP0080JA-A	
	R4F20222DFD	96 kbytes	8 kbytes	(LQFP1414-80)	

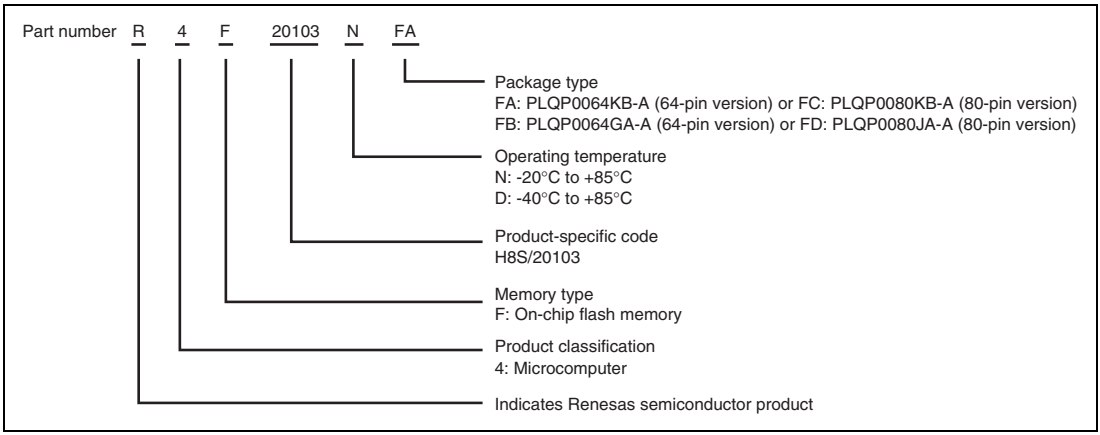


Figure 1.1 How to Read the Part Number

1.3 Block Diagram

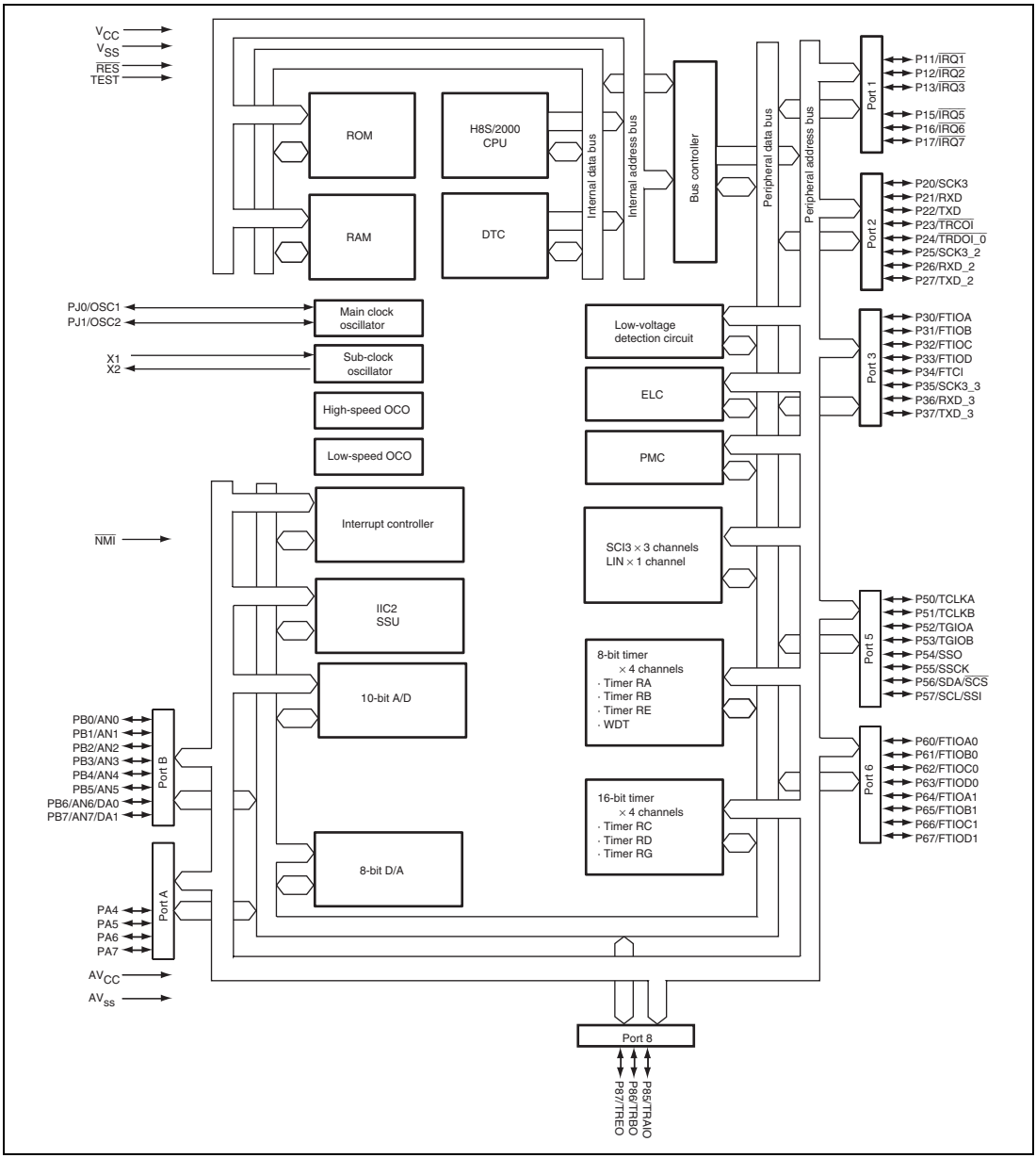


Figure 1.2 Block Diagram of H8S/20103 Group

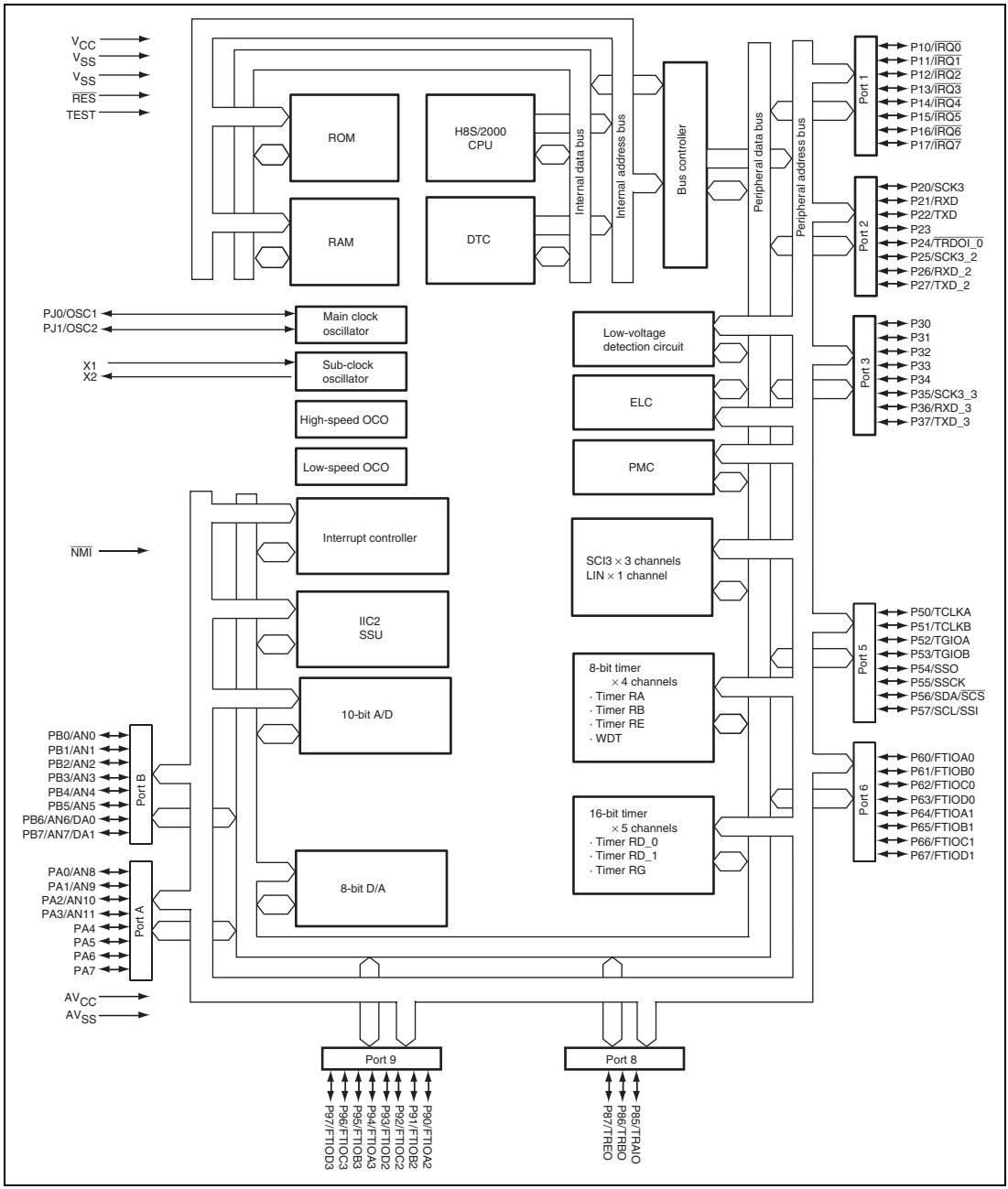


Figure 1.3 Block Diagram of H8S/20203 Group

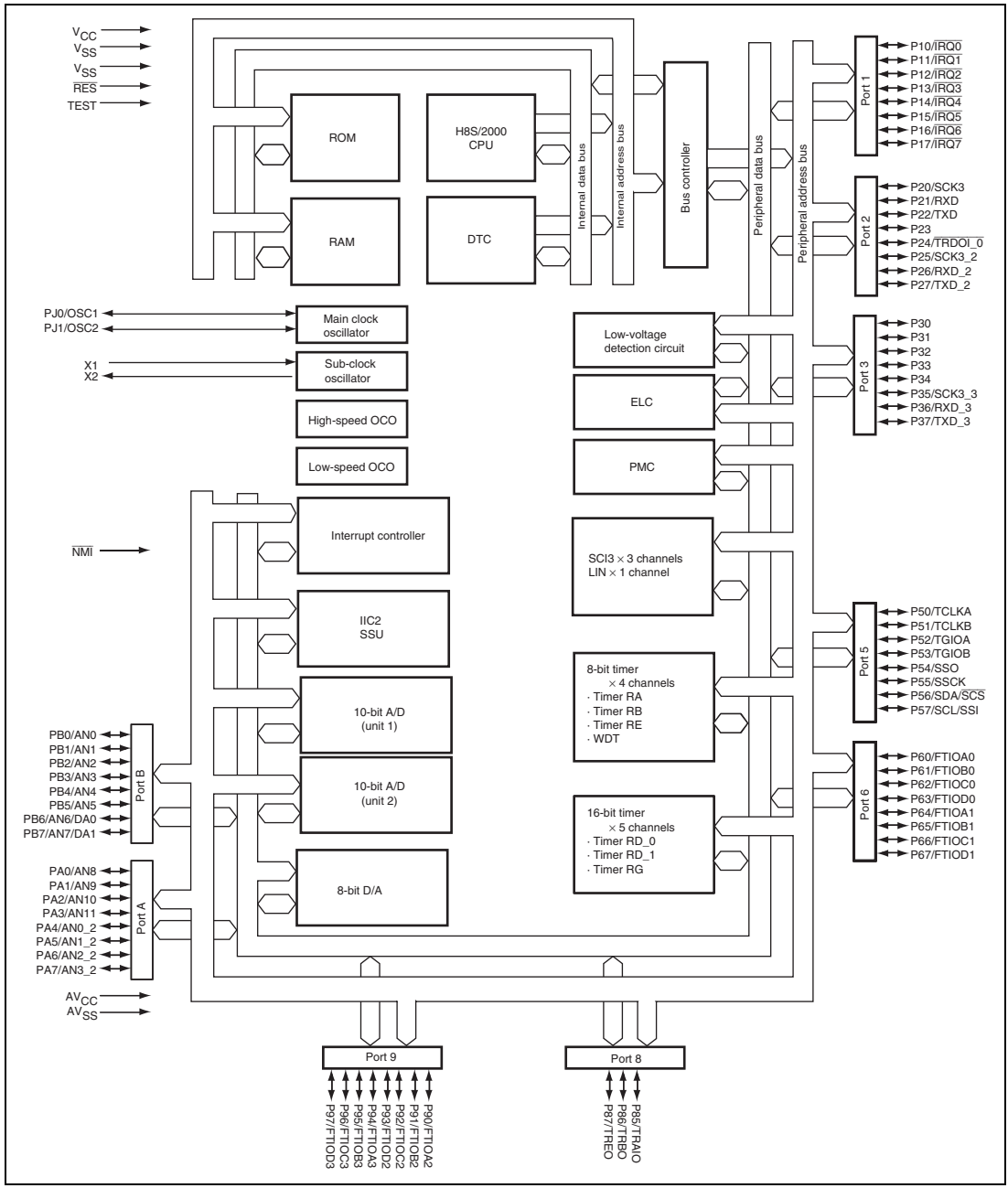


Figure 1.4 Block Diagram of H8S/20223 Group

1.4 Pin Assignments

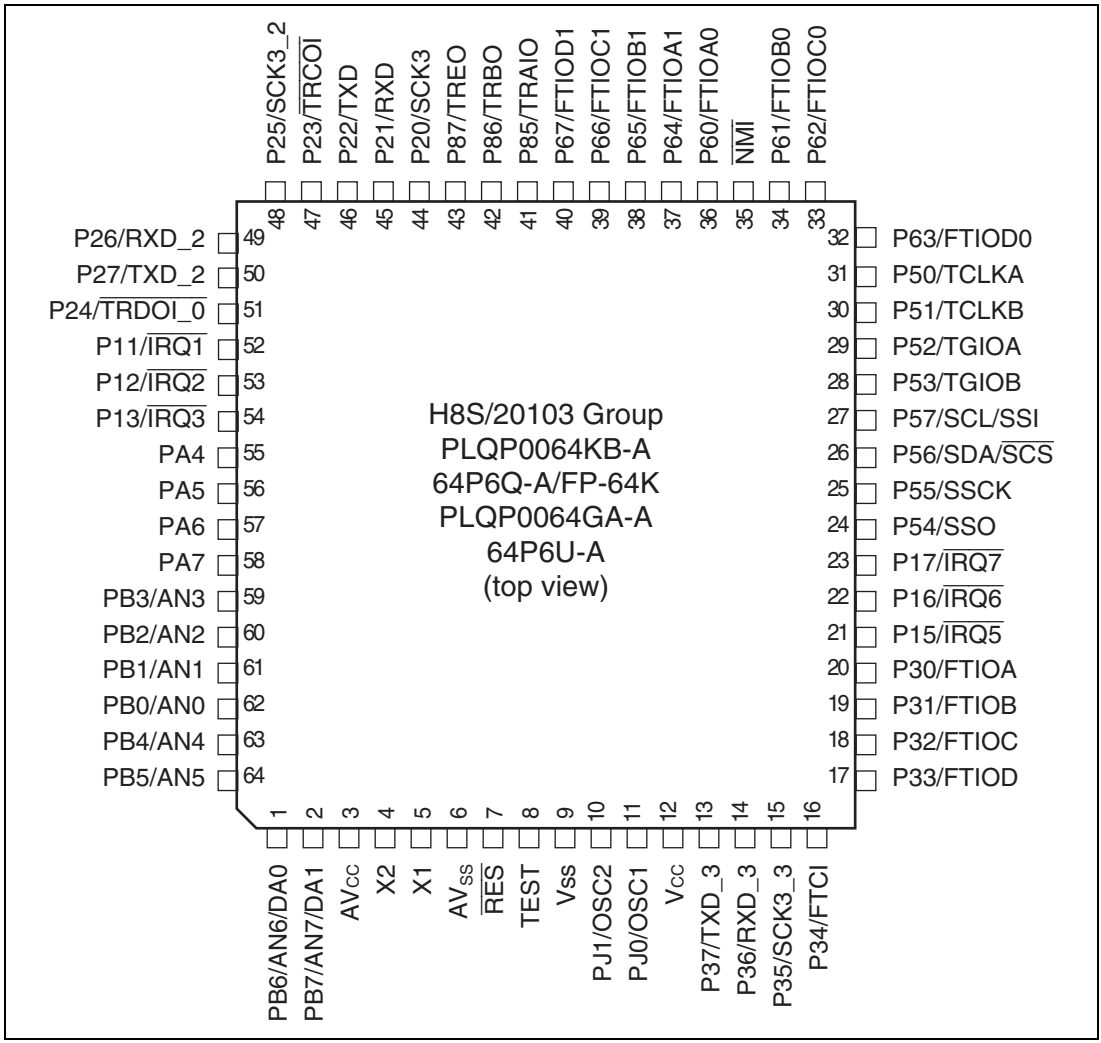
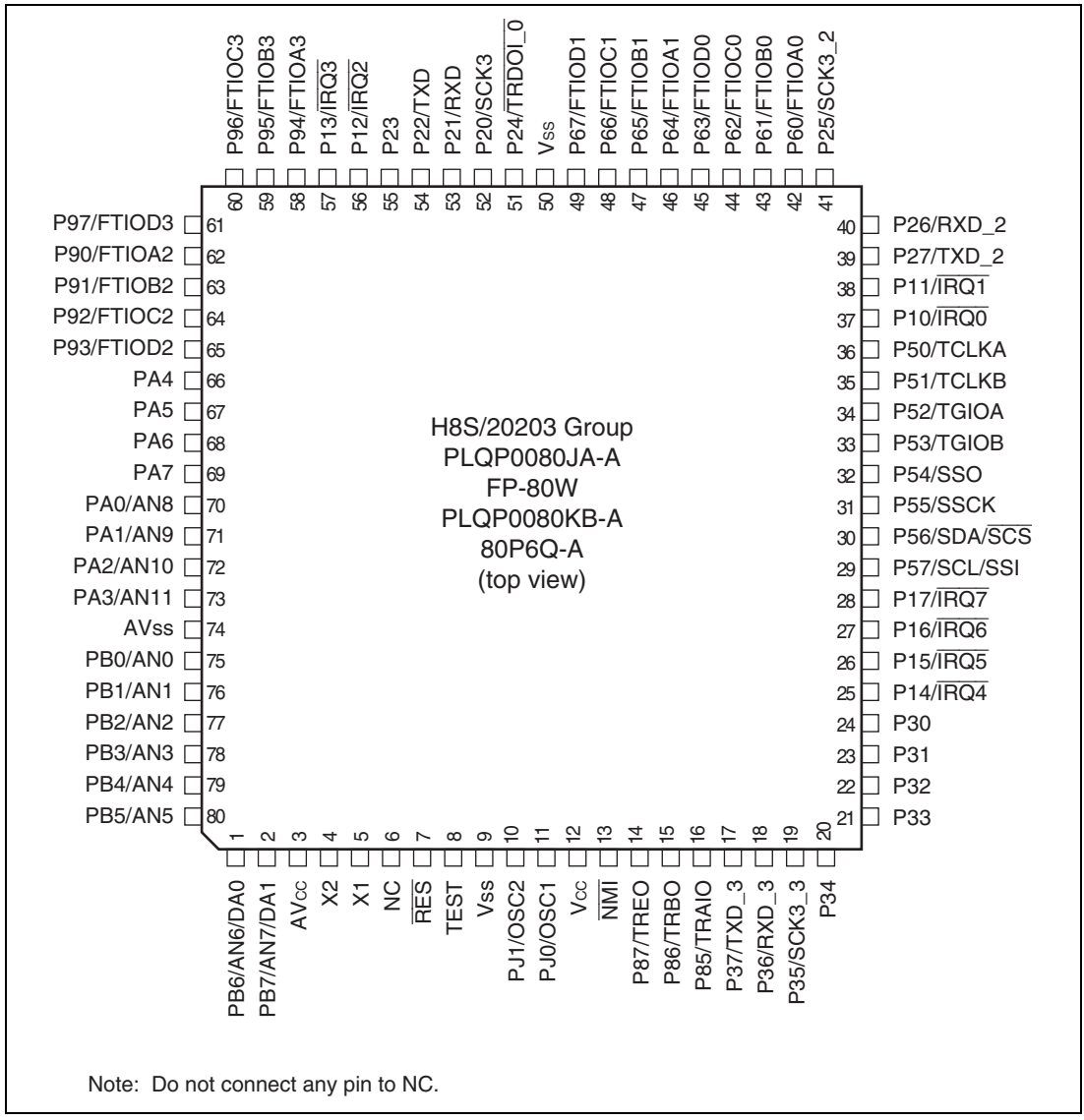
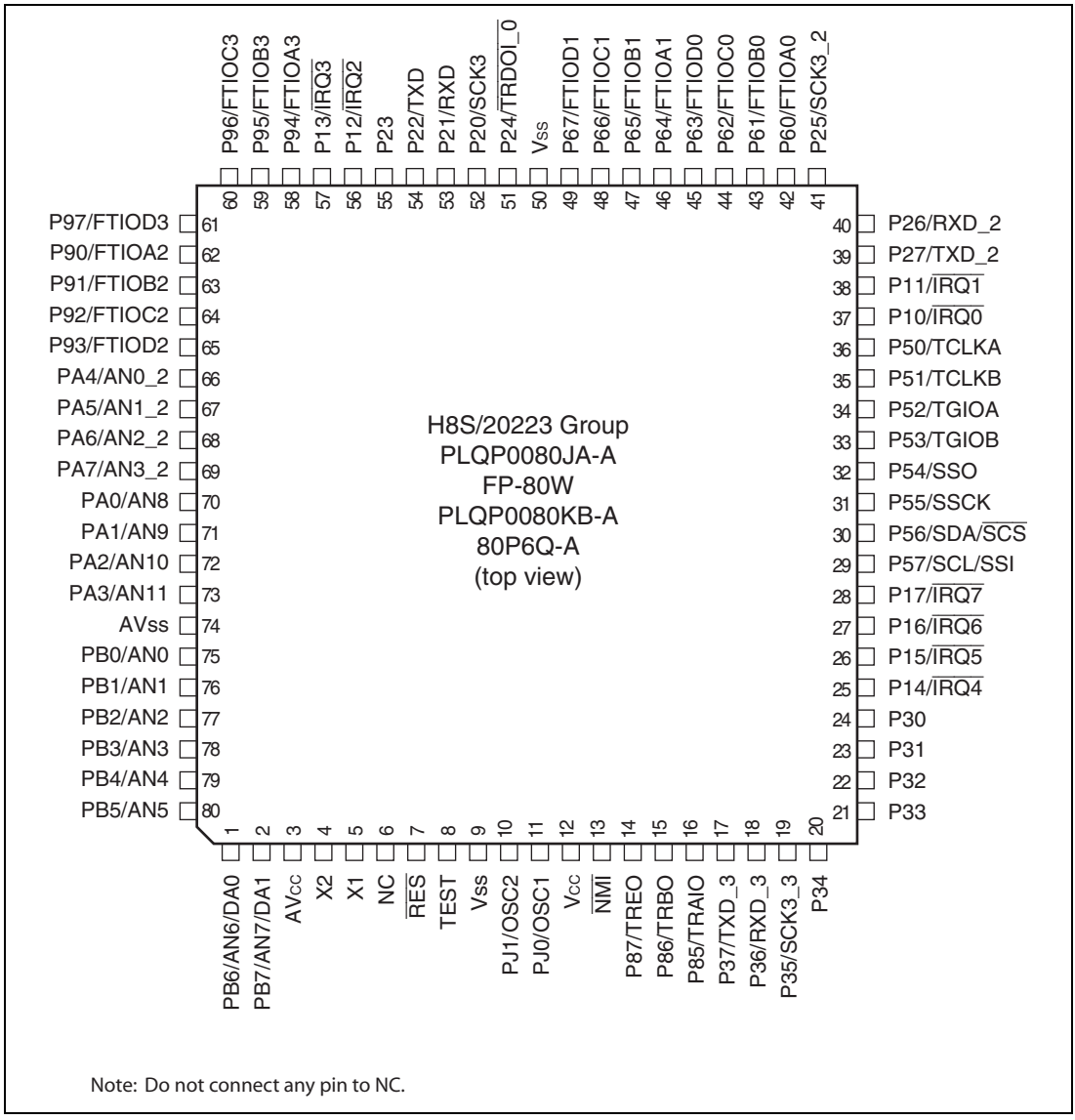


Figure 1.5 Pin Assignment of H8S/20103 Group



Note: Do not connect any pin to NC.

Figure 1.6 Pin Assignment of H8S/20203 Group



Note: Do not connect any pin to NC.

Figure 1.7 Pin Assignment of H8S/20223 Group

1.4.1 Pin Functions

Table 1.3 Pin Functions

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
Power supply	V_{CC}	12	12	Input	Power supply pin. Connect this pin to the system power supply.
	V_{SS}	9	9, 50	Input	Ground pin. Connect this pin to the system power supply (0 V).
	AV_{CC}	3	3	Input	Analog power supply pin for A/D and D/A converters. When A/D and D/A converters are not used, connect this pin to the system power supply.
	AV_{SS}	6	74	Input	Analog ground pin for A/D and D/A converters. Connect this pin to the system power supply (0 V).
Clock	OSC1	11	11	Input	Pins to be connected to a crystal or ceramic resonator for the system clock. An external clock can also be input to OSC1. When the on-chip oscillator is not used, the system clock signal can be output from OSC2. For connection examples, see section 5, Clock Pulse Generator.
	OSC2/CLKOUT	10	10	Output	

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
Clock	X1	5	5	Input	Pins to be connected to a crystal resonator for the 32.768-kHz sub-clock. For connection examples, see section 5, Clock Pulse Generator.
	X2	4	4	Output	
System control	$\overline{RES}$	7	7	Input	Reset pin. Applying a low level signal to this pin resets this LSI.
	TEST	8	8	Input	Test pin. Connect this pin to V_{SS}.
External interrupt	$\overline{NMI}$	35	13	Input	Non-maskable interrupt request input pin. Be sure to pull up this pin with a resistor.
	$\overline{IRQ0}$ to $\overline{IRQ7}$	52 to 54*1 21 to 23	37, 38 56, 57 25 to 28	Input	External interrupt request input pins. Either rising, falling, or rising/falling edge of these pins can be detected.
Timer RA	TRAIO	41	16	I/O	Pin for pulse output, count source input, and input of pulses to be measured.
	TRAO	*2	*2	Output	Pin for inverted pulse output.
Timer RB	TRGB	*2	*2	Input	Pin for trigger input.
	TRBO	42	15	Output	Pin for pulse output and PWM output.
Timer RC*3	FTCI	16	—	Input	Pin for external event input.
	FTIOA to FTIOD	20 to 17	—	I/O	Pins for output-compare output, input-capture input, and PWM output.

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
Timer RC*3	TRGC	20	—	Input	Pin for external trigger input.
	$\overline{\text{TRCOI}}$	47	—	Input	Pin for inputting the timer-output enable or disable signal.
Timer RD_0	FTIOA0	36	42	I/O	Pin for output-compare output, input-capture input, and external clock input.
	FTIOB0	34	43	I/O	Pin for output-compare output, input-capture input, and PWM output.
	FTIOC0	33	44	I/O	Pin for output-compare output, input-capture input, and PWM synchronous output (at reset or in complementary PWM mode).
	FTIOD0	32	45	I/O	Pin for output-compare output, input-capture input, and PWM output.
	FTIOA1	37	46	I/O	Pin for output-compare output, input-capture input, and PWM output (at reset or in complementary PWM mode).
	FTIOB1 to FTIOD1	38 to 40	47 to 49	I/O	Pins for output-compare output, input-capture input, and PWM output.
	$\overline{\text{TRDOI_0}}$	51	51	Input	Pin for inputting the timer-output enable or disable signal.

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
Timer RD_1*[5]	FTIOA2	—	62	I/O	Pin for output-compare output, input-capture input, and external clock input.
	FTIOB2	—	63	I/O	Pin for output-compare output, input-capture input, and PWM output.
	FTIOC2	—	64	I/O	Pin for output-compare output, input-capture input, and PWM synchronous output (at reset or in complementary PWM mode).
	FTIOD2	—	65	I/O	Pin for output-compare output, input-capture input, and PWM output.
	FTIOA3	—	58	I/O	Pin for output-compare output, input-capture input, and PWM output (at reset or in complementary PWM mode).
	FTIOB3 to FTIOD3	—	59 to 61	I/O	Pins for output-compare output, input-capture input, and PWM output.
	$\overline{\text{TRDOI_1}}$	—	*[4]	Input	Pin for inputting the timer-output enable or disable signal.
Timer RE	TREO	43	14	Output	Pin for clock signal output.
Timer RG	TCLKA	31	36	Input	Pins for external clock input.
	TCLKB	30	35		
	TGIOA	29	34	I/O	Pins for output-compare output, input-capture input, and PWM output.
	TGIOB	28	33		

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
Serial communication interface 3 (SCI3)	TXD	46	54	Output	Output pins for data transmission.
	TXD_2	50	39		
	TXD_3	13	17		
	RXD	45	53	Input	Input pins for data reception.
	RXD_2	49	40		
	RXD_3	14	18		
	SCK3	44	52	I/O	Input/output pins for clock signals.
	SCK3_2	48	41		
	SCK3_3	15	19		
I^2C bus interface 2 (IIC2)	SDA	26	30	I/O	Input/output pin for I^2C data. Bus can be directly driven by the NMOS open-drain output. When this pin is used, an external pull-up resistor is required.
	SCL	27	29	I/O	Input/output pin for I^2C clock signal. Bus can be directly driven by the NMOS open-drain output. When this pin is used, an external pull-up resistor is required.
Synchronous serial communication unit (SSU)	$\overline{SCS}$	26	30	I/O	Input/output pin for the chip select signal.
	SSCK	25	31	I/O	Input/output pin for the clock signal.
	SSI	27	29	I/O	Input/output pin for data transmission/reception.
	SSO	24	32	I/O	Input/output pin for data transmission/reception.

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
AD converter_1	AN11 to AN0*6	2, 1, 64, 63, 59 to 62	73 to 70, 2, 1 80 to 75	Input	Analog input pins.
	$\overline{\text{ADTRG1}}$	*7	*7	Input	Input pin for the conversion-start trigger signal.
AD converter_2*8	AN3_2 to AN0_2	—	69 to 66	Input	Analog input pins.
	$\overline{\text{ADTRG2}}$	—	*7	Input	Input pin for the conversion-start trigger signal.
DA converter	DA1	2	2	Output	Analog output pins.
	DA0	1	1		
I/O ports	P17 to P10*9	23 to 21, 54 to 52	28 to 25, 57, 56, 38, 37	I/O	8-bit input/output port pins.
	P27 to P20	50, 49, 51, 48 to 44	39 to 41, 51, 55 to 52	I/O	8-bit input/output port pins.
	P37 to P30	20 to 13	17 to 24	I/O	8-bit input/output port pins.
	P57 to P50	31 to 28 24 to 27	29 to 36	I/O	8-bit input/output port pins.
	P67 to P60	36, 34 to 32, 37 to 40	49 to 42	I/O	8-bit input/output port pins.
	P87 to P85	41 to 43	14 to 16	I/O	3-bit input/output port pins.
	P97 to P90*10	—	61 to 58 65 to 62	I/O	8-bit input/output port pins.
	PA7 to PA0*11	58 to 55	69 to 66 73 to 70	I/O	8-bit input/output port pins.

Classification	Symbol	Pin No. H8S/20103 Group	Pin No. H8S/20203 and H8S/20223 Groups	I/O	Description
I/O ports	PB7 to PB0	62 to 59, 63, 64, 1, 2	2, 1, 80 to 75	I/O	8-bit input/output port pins.
	PJ1 and PJ0	10, 11	10, 11	I/O	2-bit input/output port pins.

Notes: 1. In the H8S/20103 group, the $\overline{\text{IRQ0}}$ and $\overline{\text{IRQ4}}$ pins are not available with the initial setting of the PMC.
2. The TRAO and TRGB pins are not available with the initial setting of the PMC.
3. The H8S/20203 and H8S/20223 groups do not incorporate timer RC.
4. The $\overline{\text{TRDOI_1}}$ pin is not available with the initial setting of the PMC.
5. The H8S/20103 group does not incorporate timer RD_1.
6. In the H8S/20103 group, AN8 to AN11 are not available.
7. The $\overline{\text{ADTRG1}}$ and $\overline{\text{ADTRG2}}$ functions are not available due to the initial setting of the PMC.
8. The H8S/20103 and H8S/20203 group do not incorporate A/D converter_2.
9. The H8S/20103 group does not provide P14 or P10.
10. The H8S/20103 group does not provide P97 to P90.
11. The H8S/20103 group does not provide PA3 to PA0.

Section 2 CPU

The H8S/2000 CPU is a high-speed central processing unit with an internal 32-bit architecture that is upward-compatible with the H8/300 and H8/300H CPUs. The H8S/2000 CPU has sixteen 16-bit general registers, can address a 16-Mbyte linear address space, and is ideal for realtime control.

This section describes the H8S/2000 CPU.

2.1 Features

- Upward-compatibility with H8/300 and H8/300H CPUs
  Can execute H8/300 and H8/300H CPU object programs
- General-register architecture
  Sixteen 16-bit general registers also usable as sixteen 8-bit registers or eight 32-bit registers
- Sixty-five basic instructions
  - 8/16/32-bit arithmetic and logic instructions
  - Multiply and divide instructions
  - Powerful bit-manipulation instructions
- Eight addressing modes
  - Register direct [Rn]
  - Register indirect [@ERn]
  - Register indirect with displacement [@(d:16,ERn) or @(d:32,ERn)]
  - Register indirect with post-increment or pre-decrement [@ERn+ or @–ERn]
  - Absolute address [@aa:8, @aa:16, @aa:24, or @aa:32]
  - Immediate [#xx:8, #xx:16, or #xx:32]
  - Program-counter relative [@(d:8,PC) or @(d:16,PC)]
  - Memory indirect [@@aa:8]
- 16-Mbyte address space
  - Program: 16 Mbytes
  - Data: 16 Mbytes

- High-speed operation
  All frequently-used instructions are executed in one or two states
  — 8/16/32-bit register-register add/subtract: 1 state
  — 8 × 8-bit register-register multiply: 12 states (MULXU.B), 13 states (MULXS.B)
  — 16 ÷ 8-bit register-register divide: 12 states (DIVXU.B)
  — 16 × 16-bit register-register multiply: 20 states (MULXU.W), 21 states (MULXS.W)
  — 32 ÷ 16-bit register-register divide: 20 states (DIVXU.W)
- Two CPU operating modes
  — Normal mode
  — Advanced mode
- Power-down state
  Transition to power-down state by SLEEP instruction
  Selectable CPU clock speed

2.1.1 Differences between H8S/2600 CPU and H8S/2000 CPU

The differences between the H8S/2600 CPU and the H8S/2000 CPU are as shown below.

- Register configuration
  The MAC register is supported only by the H8S/2600 CPU.
- Basic instructions
  The four instructions MAC, CLRMAC, LDMAC, and STMAC are supported only by the H8S/2600 CPU.
- The number of execution states of the MULXU and MULXS instructions

		Execution States	
Instruction	**Mnemonic**	**H8S/2600**	**H8S/2000**
MULXU	MULXU.B Rs, Rd	3	12
	MULXU.W Rs, ERd	4	20
MULXS	MULXS.B Rs, Rd	4	13
	MULXS.W Rs, ERd	5	21

In addition, there are differences in address space, CCR and EXR register functions, power-down modes, etc., depending on the model.

2.1.2 Differences from H8/300 CPU

In comparison to the H8/300 CPU, the H8S/2000 CPU has the following enhancements.

- More general registers and control registers
  Eight 16-bit extended registers, and one 8-bit and two 32-bit control registers, have been added.
- Expanded address space
  Normal mode supports the same 64-kbyte address space as the H8/300 CPU.
  Advanced mode supports a maximum 16-Mbyte address space.
- Enhanced addressing
  The addressing modes have been enhanced to make effective use of the 16-Mbyte address space.
- Enhanced instructions
  Addressing modes of bit-manipulation instructions have been enhanced.
  Signed multiply and divide instructions have been added.
  Two-bit shift and two-bit rotate instructions have been added.
  Instructions for saving and restoring multiple registers have been added.
  A test and set instruction has been added.
- Higher speed
  Basic instructions are executed twice as fast.

2.1.3 Differences from H8/300H CPU

In comparison to the H8/300H CPU, the H8S/2000 CPU has the following enhancements.

- Additional control register
  One 8-bit control register has been added.
- Enhanced instructions
  Addressing modes of bit-manipulation instructions have been enhanced.
  Two-bit shift and two-bit rotate instructions have been added.
  Instructions for saving and restoring multiple registers have been added.
  A test and set instruction has been added.
- Higher speed
  Basic instructions are executed twice as fast.

2.2 CPU Operating Modes

The H8S/2000 CPU has two operating modes: normal and advanced. Note that this LSI supports only advanced mode. Advanced mode supports a maximum 16-Mbyte address space.

2.2.1 Advanced Mode

- Address space

  Linear access to a maximum address space of 16 Mbytes is possible.
- Extended registers (En)

  The extended registers (E0 to E7) can be used as 16-bit registers. They can also be used as the upper 16-bit segments of 32-bit registers or address registers.
- Instruction set

  All instructions and addressing modes can be used.
- Exception vector table and memory indirect branch addresses

  In advanced mode, the top area starting at H'00000000 is allocated to the exception vector table in 32-bit units. In each 32 bits, the upper 8 bits are ignored and a branch address is stored in the lower 24 bits (see figure 2.1). For details of the exception vector table, see section 3, Exception Handling.

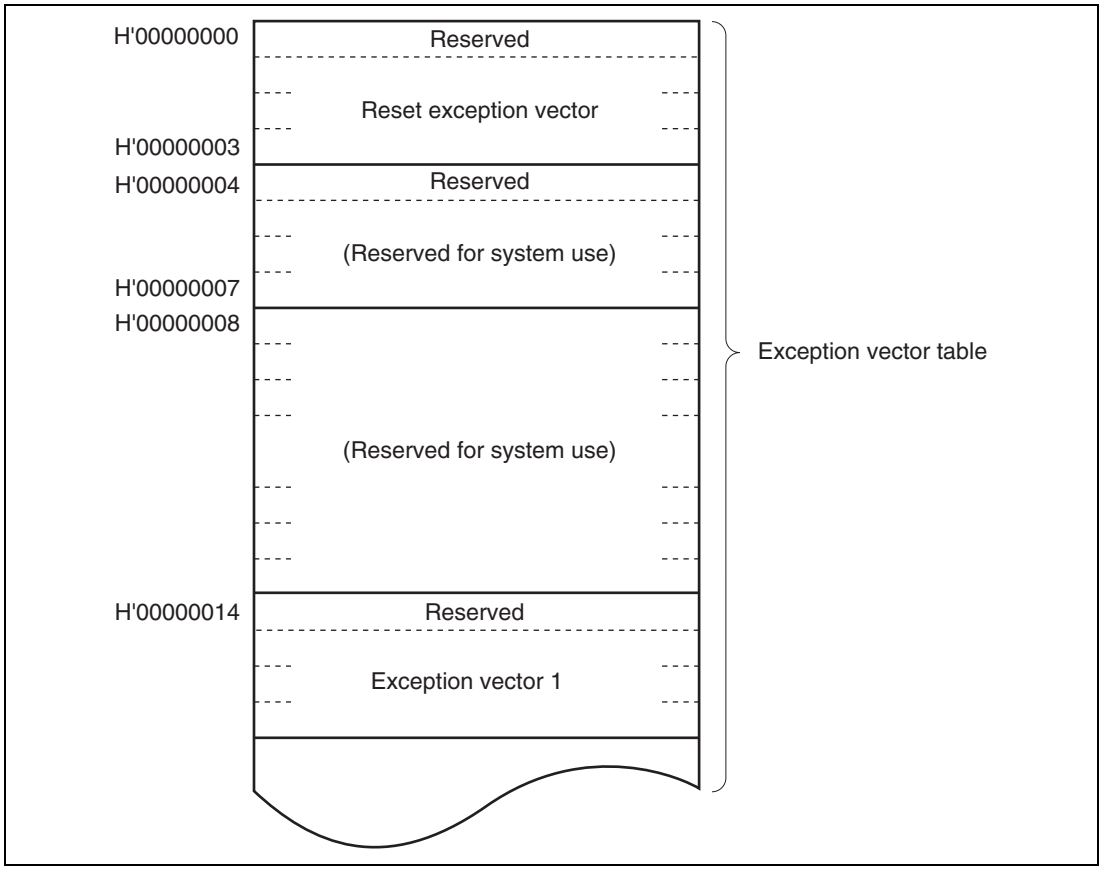
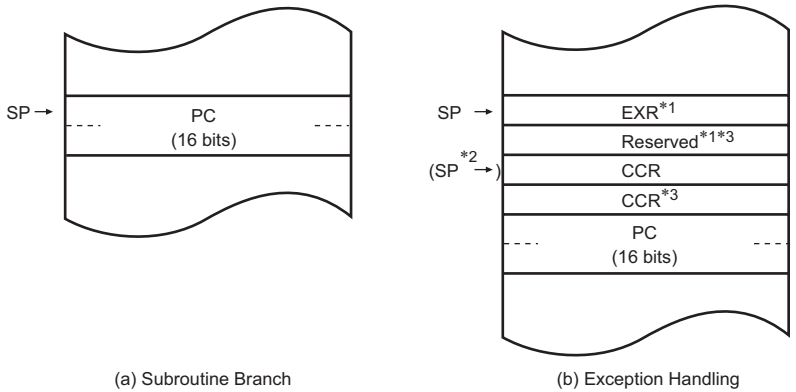


Figure 2.1 Exception Vector Table (Advanced Mode)

The memory indirect addressing mode (@@aa:8) employed in the JMP and JSR instructions uses an 8-bit absolute address included in the instruction code to specify a memory operand that contains a branch address. In advanced mode, the operand is a 32-bit longword operand, providing a 32-bit branch address. The upper 8 bits of these 32 bits are a reserved area that is regarded as H'00. Branch addresses can be stored in the area from H'00000000 to H'000000FF. Note that the top area of this range is also used for the exception vector table.

- Stack structure

  In advanced mode, the program counter (PC) is pushed onto the stack in a subroutine call, and the PC and condition-code register (CCR) are pushed onto the stack in exception handling. They are stored as shown in figure 2.2. EXR is not pushed onto the stack in interrupt control mode 0. For details, see section 3, Exception Handling.



Notes: 1. When EXR is not used, it is not stored on the stack.
2. SP when EXR is not used.
3. Ignored when returning.

Figure 2.2 Stack Structure in Advanced Mode

2.3 Address Space

Figure 2.3 shows a memory map of the H8S/2000 CPU. The H8S/2000 CPU provides linear access to a maximum 16-Mbyte (architecturally 4-Gbyte) address space in advanced mode. The usable modes and address spaces differ depending on the product.

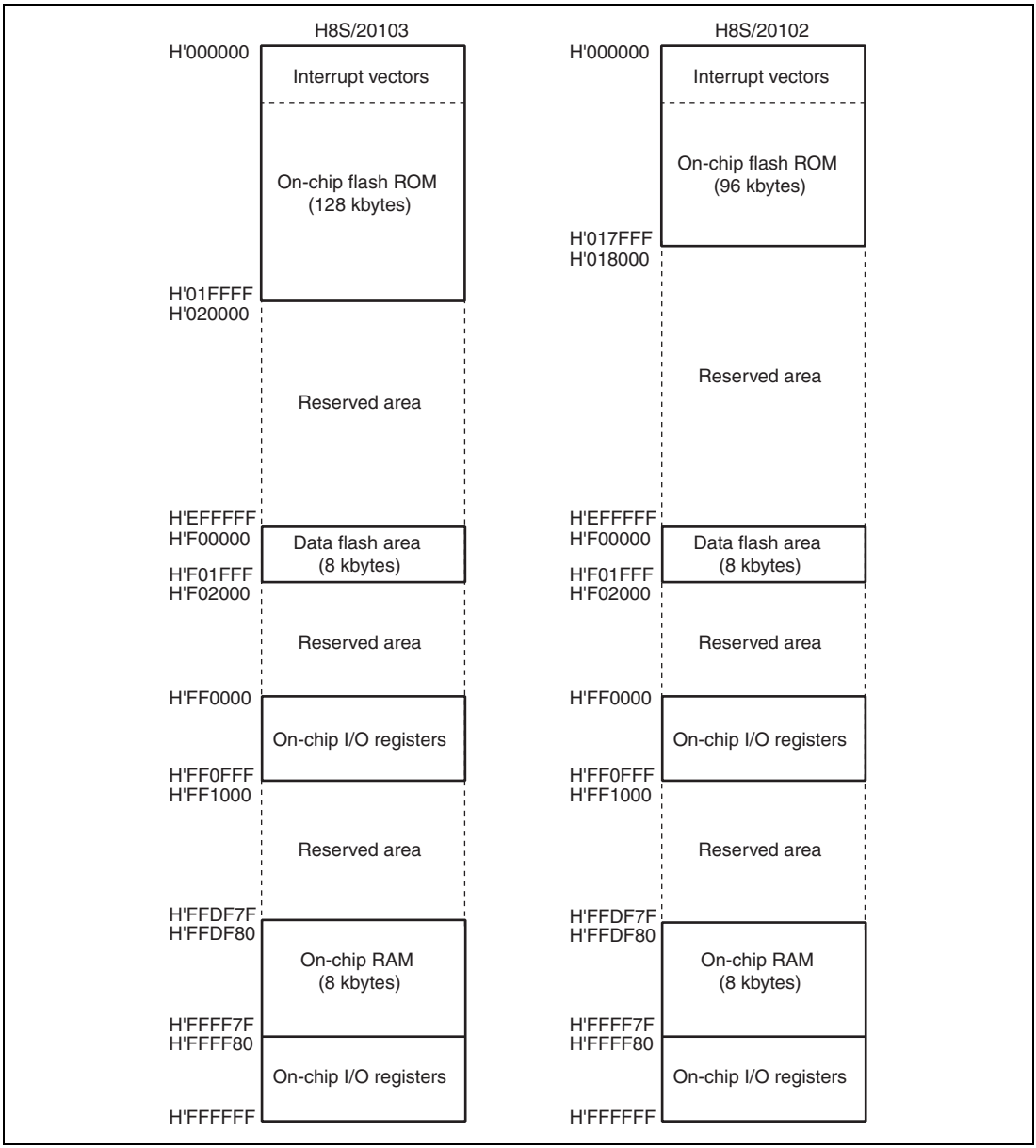


Figure 2.3 Memory Map (1) (H8S/20103 Group)

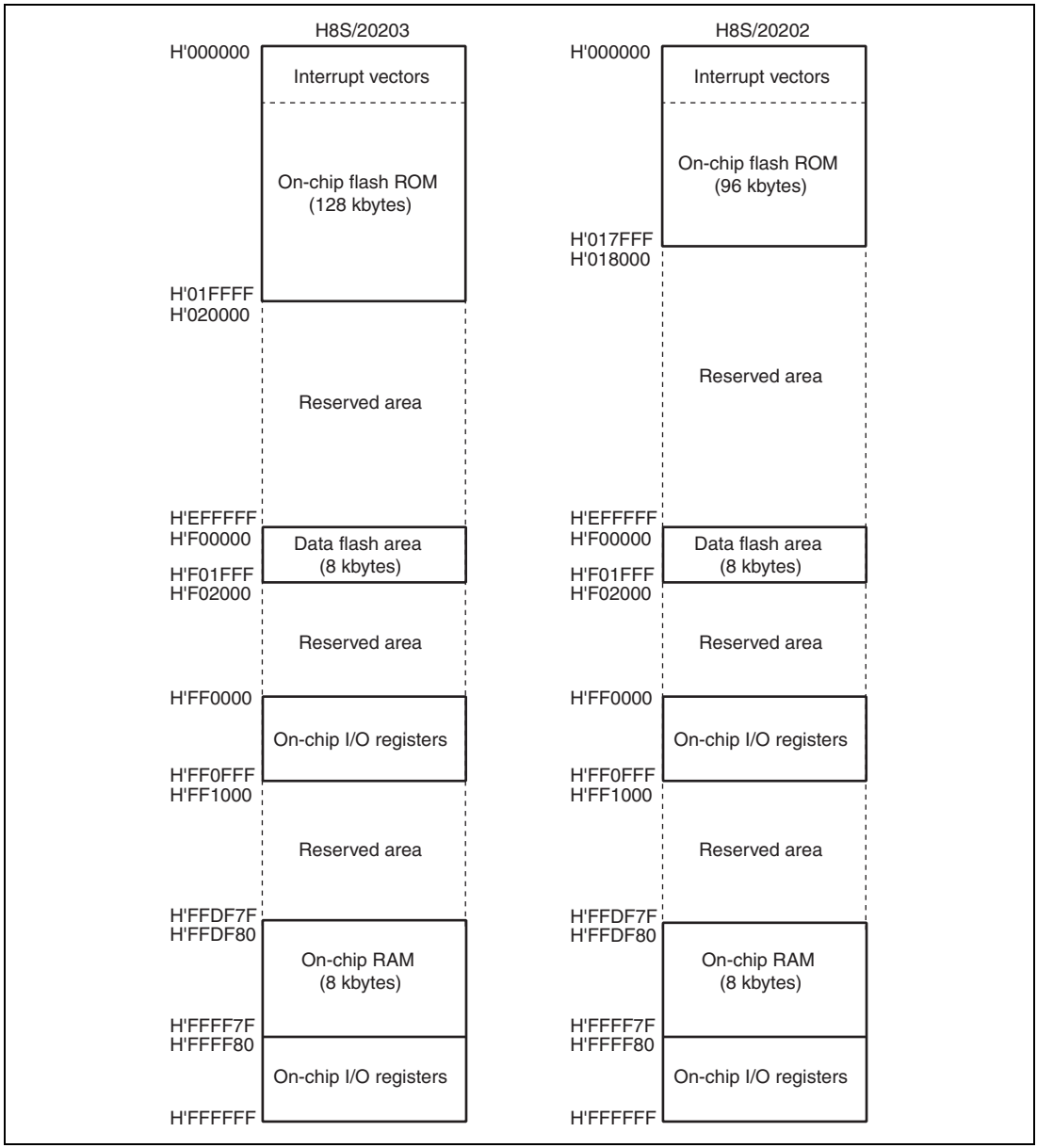


Figure 2.3 Memory Map (2) (H8S/20203 Group)

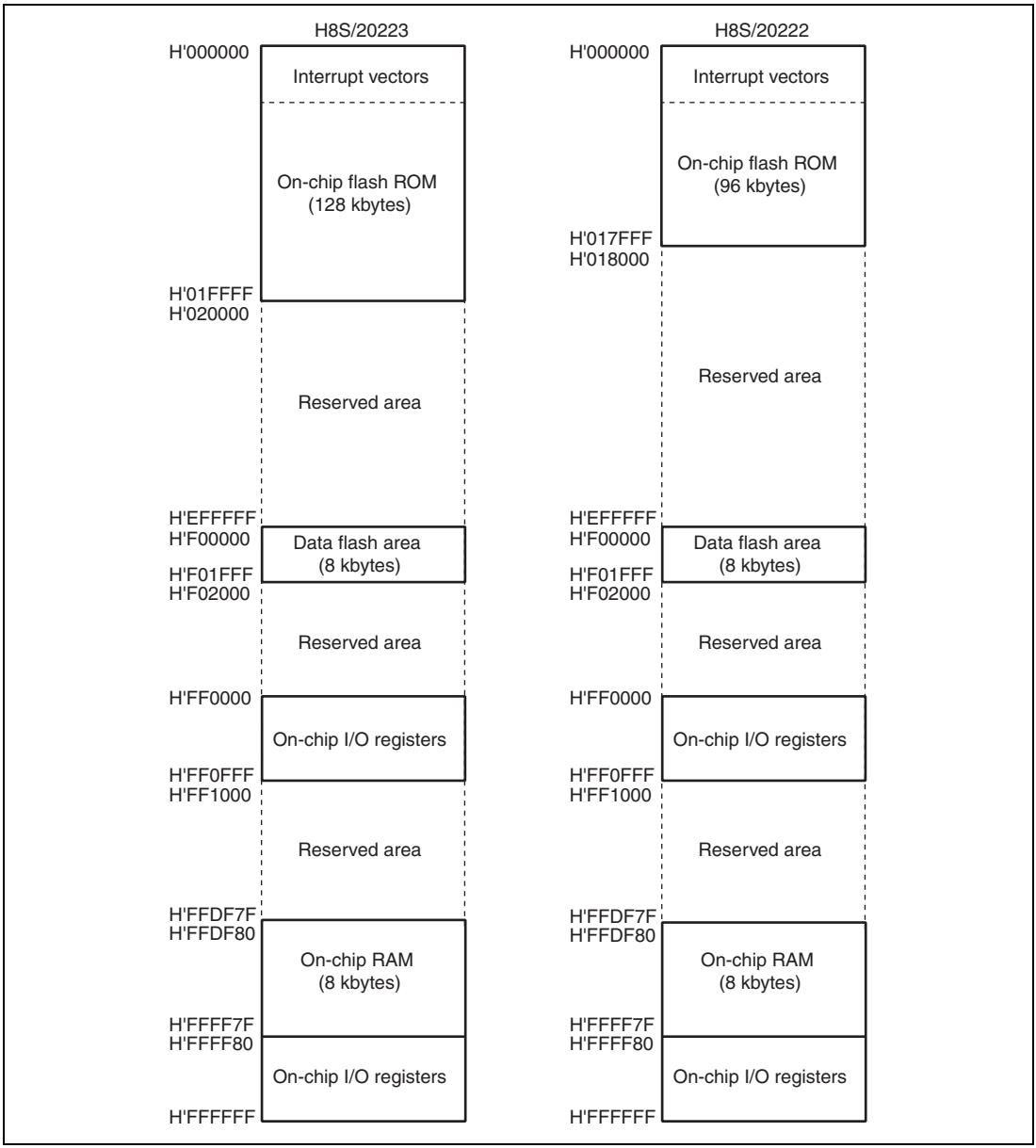


Figure 2.3 Memory Map (3) (H8S/20223 Group)

2.4 Register Configuration

The H8S/2000 CPU has the internal registers shown in figure 2.4. There are two types of registers: general registers and control registers. Control registers are a 24-bit program counter (PC), an 8-bit extended control register (EXR), and an 8-bit condition code register (CCR).

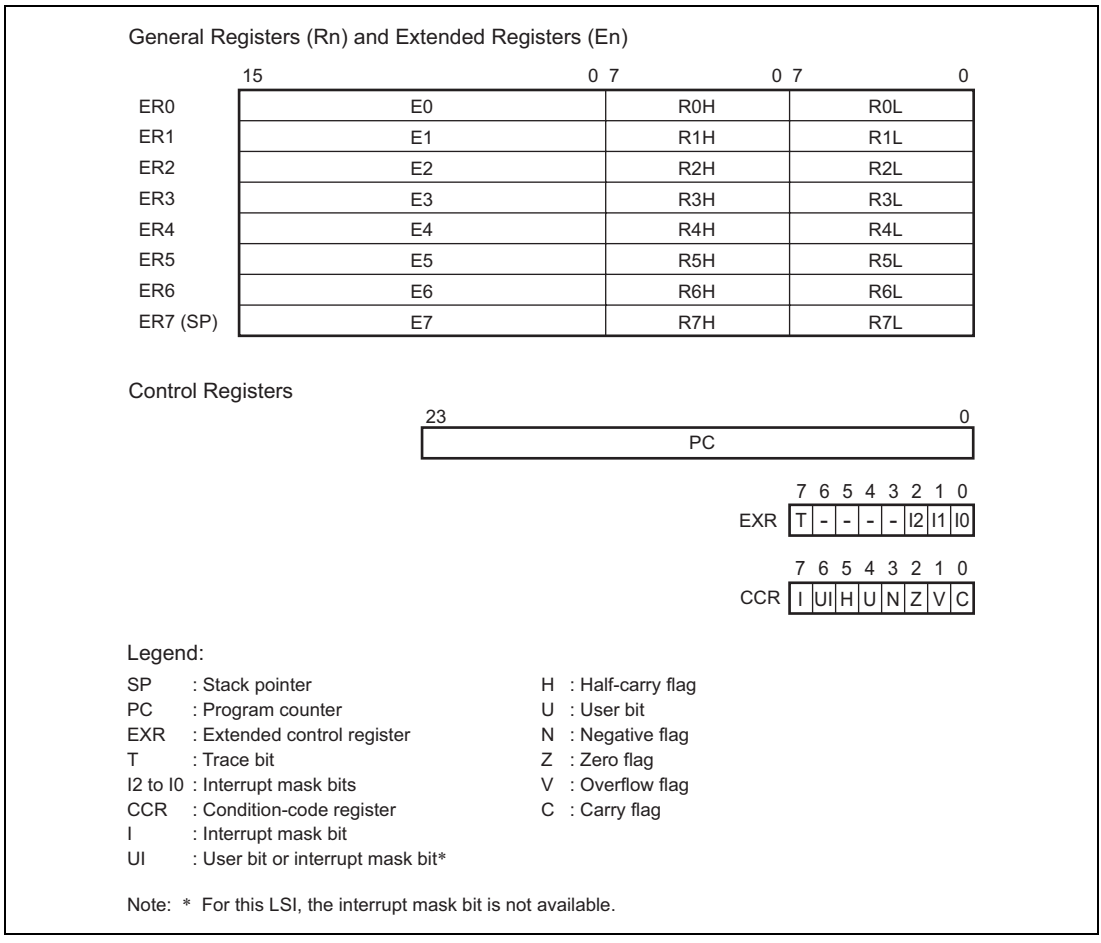


Figure 2.4 CPU Internal Registers

2.4.1 General Registers

The H8S/2000 CPU has eight 32-bit general registers. These general registers are all functionally alike and can be used as both address registers and data registers. When a general register is used as a data register, it can be accessed as a 32-bit, 16-bit, or 8-bit register. Figure 2.5 illustrates the usage of the general registers. When the general registers are used as 32-bit registers or address registers, they are designated by the letters ER (ER0 to ER7).

When the general registers are used as 16-bit registers, the ER registers are divided into 16-bit general registers designated by the letters E (E0 to E7) and R (R0 to R7). These registers are functionally equivalent, providing a maximum sixteen 16-bit registers. The E registers (E0 to E7) are also referred to as extended registers.

When the general registers are used as 8-bit registers, the R registers are divided into 8-bit general registers designated by the letters RH (R0H to R7H) and RL (R0L to R7L). These registers are functionally equivalent, providing a maximum sixteen 8-bit registers.

The usage of each register can be selected independently.

General register ER7 has the function of the stack pointer (SP) in addition to its general-register function, and is used implicitly in exception handling and subroutine calls. Figure 2.6 shows the stack.

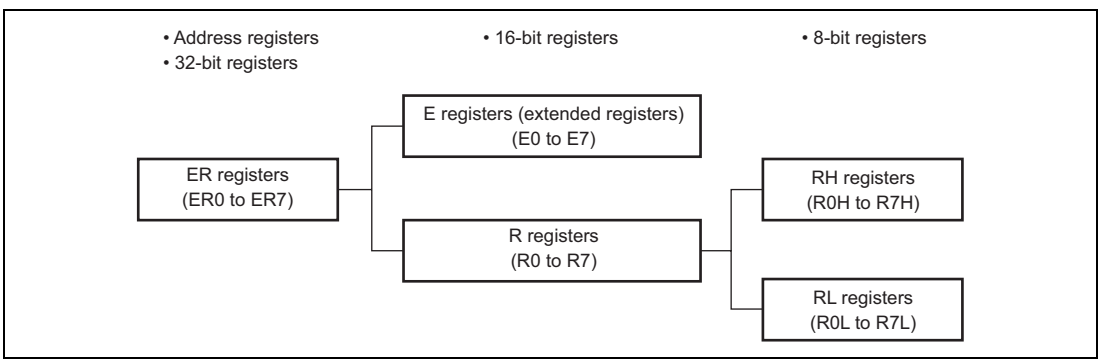


Figure 2.5 Usage of General Registers

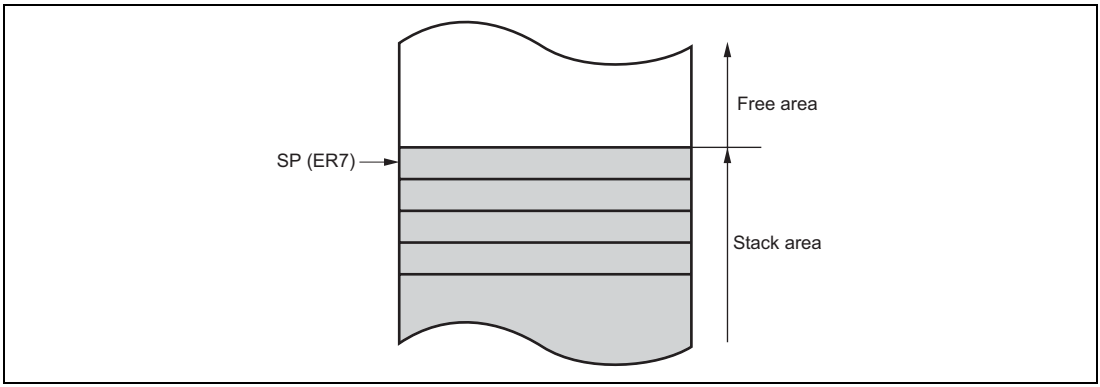


Figure 2.6 Stack

2.4.2 Program Counter (PC)

This 24-bit counter indicates the address of the next instruction the CPU will execute. The length of all CPU instructions is 2 bytes (one word), so the least significant PC bit is ignored. (When an instruction is fetched for read, the least significant PC bit is regarded as 0.)

2.4.3 Extended Control Register (EXR)

EXR is an 8-bit register that can be operated by the LDC, STC, ANDC, ORC, and XORC instructions. When an instruction other than STC is executed, all interrupts including NMI are masked in three states after the instruction is completed.

Bit	Symbol	Bit Name	Description	R/W
7	T	Trace bit	0: Consecutively executes instructions. 1: Starts trace exception processing each time an instruction is executed.	R/W
6 to 3	—	Reserved	These bits are always read as 1.	—
2 to 0	I2* I1 I0	Interrupt request mask level 2 to 0	These bits specify interrupt request mask levels (0 to 3). For details, see section 4, Interrupt Controller.	R/W

Note: * The I2-bit is reserved in this product. The I2 bit is set to 1 if an interrupt is accepted, but this does not affect the mask level for interrupt requests.

2.4.4 Condition-Code Register (CCR)

This 8-bit register contains internal CPU status information, including an interrupt mask bit (I) and half-carry (H), negative (N), zero (Z), overflow (V), and carry (C) flags.

Operations can be performed on the CCR bits by the LDC, STC, ANDC, ORC, and XORC instructions. The N, Z, V, and C flags are used as branching conditions for conditional branch (Bcc) instructions.

Bit	Symbol	Bit Name	Description	R/W
7	I	Interrupt mask bit	0: Does not mask interrupts. 1: Masks interrupts.	R/W
6	UI	User bit or interrupt mask bit	This bit does not affect this LSI operation.	R/W
5	H	Half-carry flag	[Setting conditions] • If there is a carry or borrow bit 3 when the ADD.B, ADDX.B, SUB.B, SUBX.B, CMP.B or NEG.B instruction is executed. • If there is a carry or borrow at bit 11 when the ADD.W, SUB.W, CMP.W, or NEG.W instruction is executed. • If there is a carry or borrow at bit 27 when the ADD.L, SUB.L, CMP.L, or NEG.L instruction is executed. [Clearing condition] When none of the above setting conditions are satisfied.	R/W
4	U	User bit	This bit does not affect the LSI operation.	R/W
3	N	Negative flag	[Setting condition] When the execution result is negative. [Clearing condition] When the execution result is not negative.	R/W

Bit	Symbol	Bit Name	Description	R/W
2	Z	Zero flag	[Setting condition] When data is zero. [Clearing condition] When data is not zero.	R/W
1	V	Overflow flag	[Setting condition] When an overflow occurs after an arithmetic instruction has been executed. [Clearing condition] When no overflow occurs after an arithmetic instruction has been executed.	R/W
0	C	Carry flag	[Setting condition] When a carry occurs after an instruction has been executed. [Clearing condition] When no carry occurs after an instruction has been executed.	R/W

- I (interrupt mask bit)

  This bit masks interrupts other than NMI when set to 1. NMI is accepted regardless of the I bit setting. The I bit is set to 1 at the start of an exception-handling sequence. For details, see section 4, Interrupt Controller.

- UI (user bit/interrupt mask bit)

  This bit can be written to and read from by software using the LDC, STC, ANDC, ORC, and XORC instructions.

  For this LSI, interrupt mask bit is not available.

- H (half carry flag)

  When the ADD.B, ADDX.B, SUB.B, SUBX.B, CMP.B or NEG.B instruction is executed, this flag is set to 1 if there is a carry or borrow at bit 3, and cleared to 0 otherwise. When the ADD.W, SUB.W, CMP.W, or NEG.W instruction is executed, the H flag is set to 1 if there is a carry or borrow at bit 11, and cleared to 0 otherwise. When the ADD.L, SUB.L, CMP.L, or NEG.L instruction is executed, the H flag is set to 1 if there is a carry or borrow at bit 27, and cleared to 0 otherwise.

- U (user bit)

  This bit can be written to and read from by software using the LDC, STC, ANDC, ORC, and XORC instructions.

- N (negative bit)

  This bit stores the value of the most significant bit of data as a sign bit.

- C (carry flag)

  This flag is set to 1 when a carry occurs, and cleared to 0 otherwise. Used by:

  — Add instructions, to indicate a carry

  — Subtract instructions, to indicate a borrow

  — Shift and rotate instructions, to indicate a carry

  The carry flag is also used as a bit accumulator by bit manipulation instructions.

2.4.5 Initial Register Values

Reset exception handling loads the CPU's program counter (PC) from the vector table, clears the trace (T) bit in EXR to 0, and sets the interrupt mask (I) bits in CCR and EXR to 1. The other CCR bits and the general registers are not initialized. Note that the stack pointer (ER7) is undefined. The stack pointer should therefore be initialized by an MOV.L instruction executed immediately after a reset.

2.5 Data Formats

The H8S/2000 CPU can process 1-bit, 4-bit BCD, 8-bit (byte), 16-bit (word), and 32-bit (longword) data. Bit-manipulation instructions operate on 1-bit data by accessing bit n (n = 0, 1, 2, …, 7) of byte operand data. The DAA and DAS decimal-adjust instructions treat byte data as two digits of 4-bit BCD data.

2.5.1 General Register Data Formats

Figure 2.7 shows the data formats of general registers.

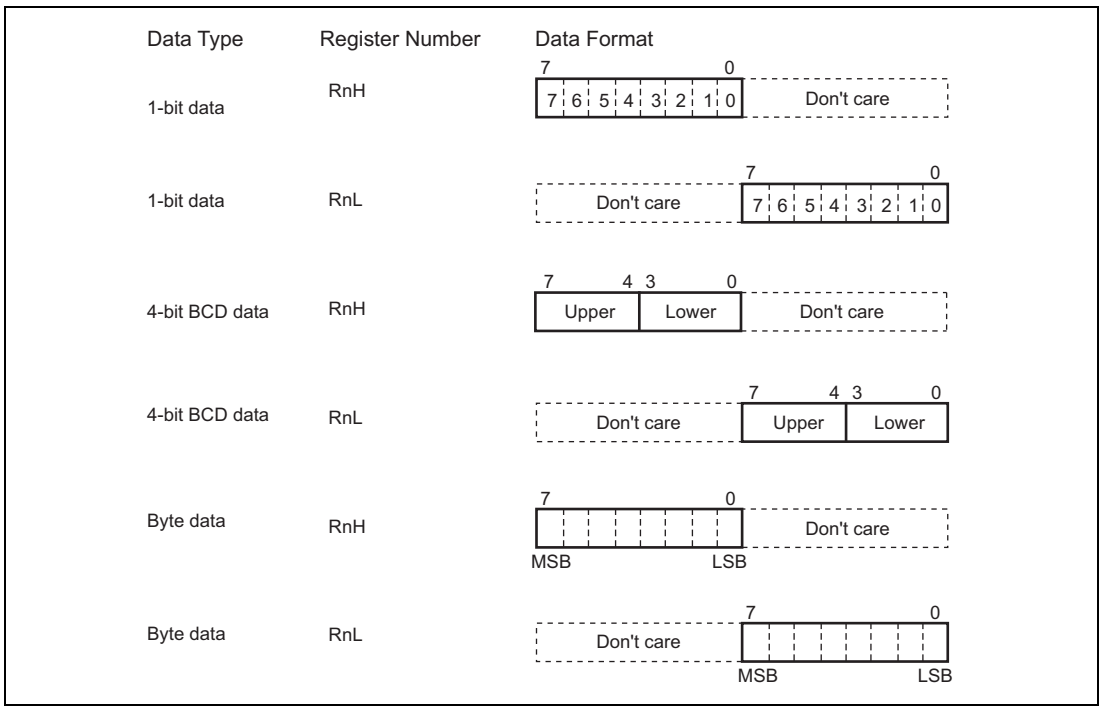


Figure 2.7 General Register Data Formats (1)

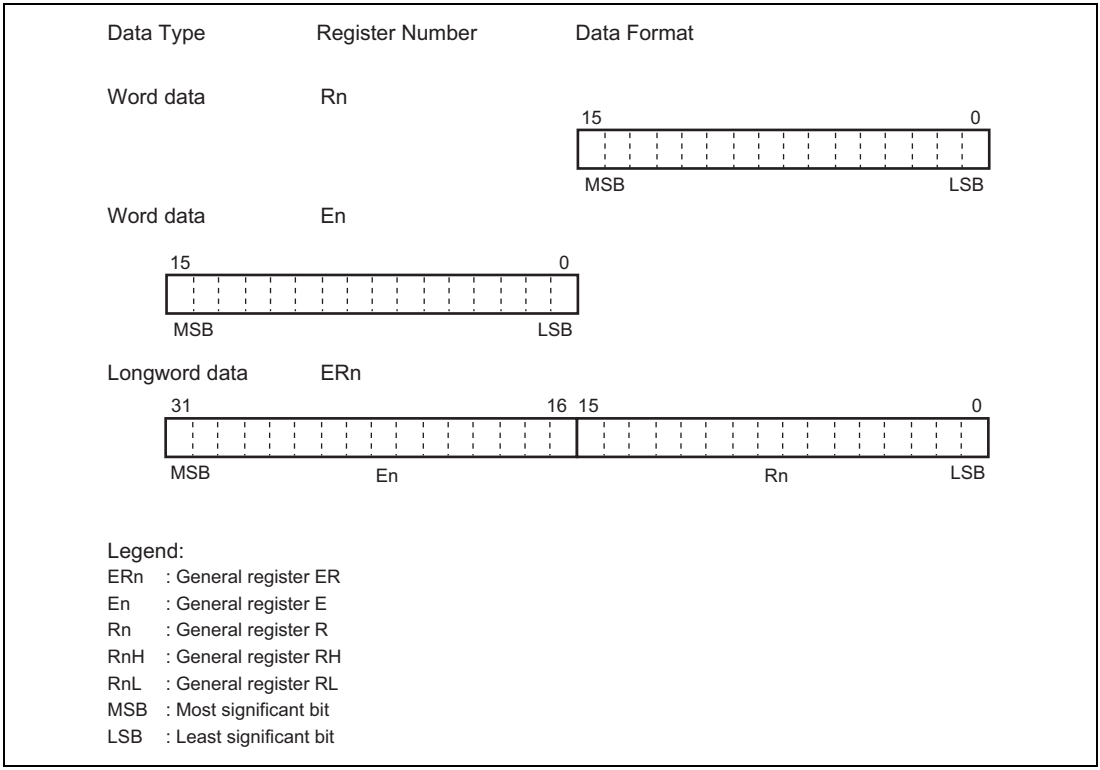


Figure 2.7 General Register Data Formats (2)

2.5.2 Memory Data Formats

Figure 2.8 shows the data formats in memory. The H8S/2000 CPU can access word data and longword data in memory, but word or longword data must begin at an even address. If an attempt is made to access word or longword data at an odd address, no address error occurs but the least significant bit of the address is regarded as 0, so the access starts at the preceding address. This also applies to instruction fetches.

When SP (ER7) is used as an address register to access the stack, the operand size should be word size or longword size.

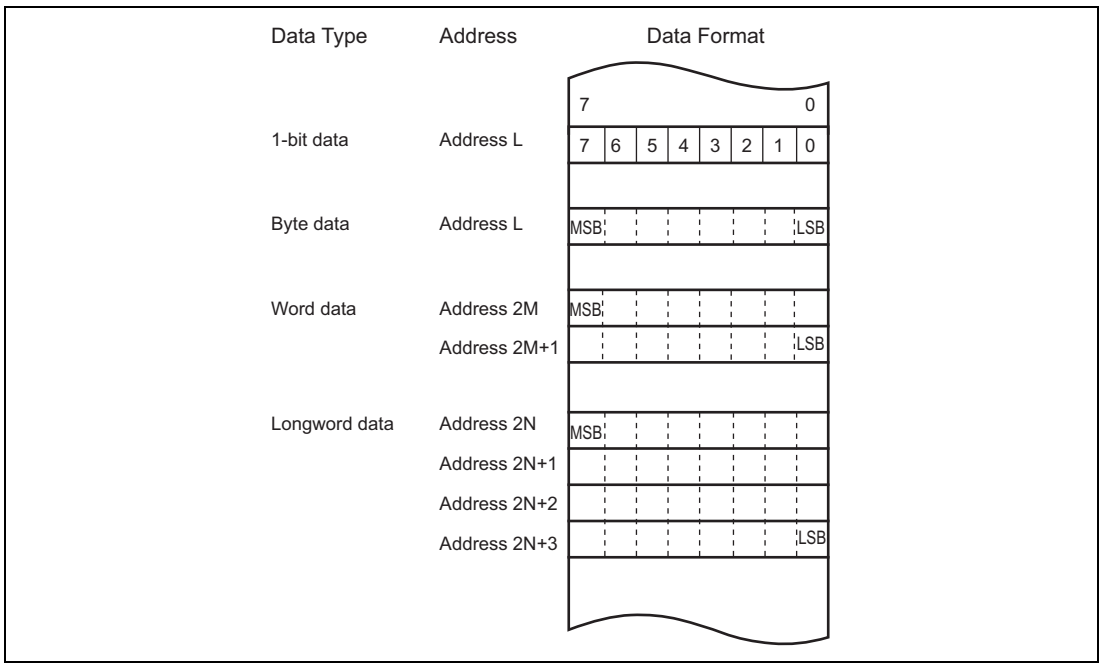


Figure 2.8 Memory Data Formats

2.6 Instruction Set

The H8S/2000 CPU has 65 types of instructions. The instructions are classified by function as shown in table 2.1.

Table 2.1 Instruction Classification

Function	Instructions	Size	Types
Data transfer	MOV	B/W/L	5
	POP*1, PUSH*1	W/L	
	LDM*5, STM*5	L	
	MOVFPE*3, MOVTPE*3	B	
Arithmetic operations	ADD, SUB, CMP, NEG	B/W/L	19
	ADDX, SUBX, DAA, DAS	B	
	INC, DEC	B/W/L	
	ADDS, SUBS	L	
	MULXU, DIVXU, MULXS, DIVXS	B/W	
	EXTU, EXTS	W/L	
	TAS*4	B	
Logic operations	AND, OR, XOR, NOT	B/W/L	4
Shift	SHAL, SHAR, SHLL, SHLR, ROTL, ROTR, ROTXL, ROTXR	B/W/L	8
Bit manipulation	BSET, BCLR, BNOT, BTST, BLD, BILD, BST, BIST, BAND, BIAND, BOR, BIOR, BXOR, BIXOR	B	14
Branch	B_{CC}*2, JMP, BSR, JSR, RTS	—	5
System control	TRAPA, RTE, SLEEP, LDC, STC, ANDC, ORC, XORC, NOP	—	9
Block data transfer	EEPMOV	—	1
			Total: 65

Notes: B: Byte size; W: Word size; L: Longword size.

1. POP.W Rn and PUSH.W Rn are identical to MOV.W @SP+, Rn and MOV.W Rn, @-SP. POP.L ERn and PUSH.L ERn are identical to MOV.L @SP+, ERn and MOV.L ERn, @-SP.
2. B_{CC} is the general name for conditional branch instructions.
3. Cannot be used in this LSI.
4. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.
5. The ER7 register is used as a stack pointer in an STM and LDM instructions. Accordingly, ER7 cannot be stored by STM or loaded by LDM.

2.6.1 Table of Instructions Classified by Function

Tables 2.3 to 2.10 summarize the instructions in each functional category. The notation used in tables 2.3 to 2.10 is defined below.

Table 2.2 Operation Notation

Symbol	Description
Rd	General register (destination)*
Rs	General register (source)*
Rn	General register*
ERn	General register (32-bit register)
(EAd)	Destination operand
(EAs)	Source operand
EXR	Extended control register
CCR	Condition-code register
N	N (negative) flag in CCR
Z	Z (zero) flag in CCR
V	V (overflow) flag in CCR
C	C (carry) flag in CCR
PC	Program counter
SP	Stack pointer
#IMM	Immediate data
disp	Displacement
+	Addition
–	Subtraction
×	Multiplication
÷	Division
∧	Logical AND
∨	Logical OR
⊕	Logical exclusive OR
→	Move
~	NOT (logical complement)
:8/:16/:24/:32	8-, 16-, 24-, or 32-bit length

Note: * General registers include 8-bit registers (R0H to R7H, R0L to R7L), 16-bit registers (R0 to R7, E0 to E7), and 32-bit registers (ER0 to ER7).

Table 2.3 Data Transfer Instructions

Instruction	Size*1	Function
MOV	B/W/L	(EAs) → Rd, Rs → (EAd) Moves data between two general registers or between a general register and memory, or moves immediate data to a general register.
MOVFPE	B	Cannot be used in this LSI.
MOVTPE	B	Cannot be used in this LSI.
POP	W/L	@SP+ → Rn Pops a general register from the stack. POP.W Rn is identical to MOV.W @SP+, Rn. POP.L ERn is identical to MOV.L @SP+, ERn
PUSH	W/L	Rn → @-SP Pushes a general register onto the stack. PUSH.W Rn is identical to MOV.W Rn, @-SP. PUSH.L ERn is identical to MOV.L ERn, @-SP.
LDM*2	L	@SP+ → Rn (register list) Pops two or more general registers from the stack.
STM*2	L	Rn (register list) → @-SP Pushes two or more general registers onto the stack.

Notes: 1. Size refers to the operand size.
B: Byte
W: Word
L: Longword
2. The ER7 register is used as a stack pointer in the STM and LDM instructions. Accordingly, ER7 cannot be stored by STM or loaded by LDM.

Table 2.4 Arithmetic Operations Instructions (1)

Instruction	Size*	Function
ADD	B/W/L	Rd ± Rs → Rd, Rd ± #IMM → Rd
SUB		Performs addition or subtraction on data in two general registers, or on immediate data and data in a general register. (Subtraction on immediate data and data in a general register cannot be performed in bytes. Use the SUBX or ADD instruction.)
ADDX	B	Rd ± Rs ± C → Rd, Rd ± #IMM ± C → Rd
SUBX		Performs addition or subtraction with carry on data in two general registers, or on immediate data and data in a general register.
INC	B/W/L	Rd ± 1 → Rd, Rd ± 2 → Rd
DEC		Adds or subtracts the value 1 or 2 to or from data in a general register. (Only the value 1 can be added to or subtracted from byte operands.)
ADDS	L	Rd ± 1 → Rd, Rd ± 2 → Rd, Rd ± 4 → Rd
SUBS		Adds or subtracts the value 1, 2, or 4 to or from data in a 32-bit register.
DAA	B	Rd (decimal adjust) → Rd
DAS		Decimal-adjusts an addition or subtraction result in a general register by referring to CCR to produce 4-bit BCD data.
MULXU	B/W	Rd × Rs → Rd
		Performs unsigned multiplication on data in two general registers: either 8 bits × 8 bits → 16 bits or 16 bits × 16 bits → 32 bits.
MULXS	B/W	Rd × Rs → Rd
		Performs signed multiplication on data in two general registers: either 8 bits × 8 bits → 16 bits or 16 bits × 16 bits → 32 bits.
DIVXU	B/W	Rd ÷ Rs → Rd
		Performs unsigned division on data in two general registers: either 16 bits ÷ 8 bits → 8-bit quotient and 8-bit remainder or 32 bits ÷ 16 bits → 16-bit quotient and 16-bit remainder.

Note: * Size refers to the operand size.
B: Byte
W: Word
L: Longword

Table 2.4 Arithmetic Operations Instructions (2)

Instruction	Size*1	Function
DIVXS	B/W	Rd ÷ Rs → Rd Performs signed division on data in two general registers: either 16 bits ÷ 8 bits → 8-bit quotient and 8-bit remainder or 32 bits ÷ 16 bits → 16-bit quotient and 16-bit remainder.
CMP	B/W/L	Rd – Rs, Rd – #IMM Compares data in a general register with data in another general register or with immediate data, and sets the CCR bits according to the result.
NEG	B/W/L	0 – Rd → Rd Takes the two's complement (arithmetic complement) of data in a general register.
EXTU	W/L	Rd (zero extension) → Rd Extends the lower 8 bits of a 16-bit register to word size, or the lower 16 bits of a 32-bit register to longword size, by padding with zeros on the left.
EXTS	W/L	Rd (sign extension) → Rd Extends the lower 8 bits of a 16-bit register to word size, or the lower 16 bits of a 32-bit register to longword size, by extending the sign bit.
TAS*2	B	@ERd – 0, 1 → (<bit 7> of @ERd) Tests memory contents, and sets the most significant bit (bit 7) to 1.

Notes: 1. Size refers to the operand size.
B: Byte
W: Word
L: Longword
2. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.

Table 2.5 Logic Operations Instructions

Instruction	Size*	Function
AND	B/W/L	Rd ∧ Rs → Rd, Rd ∧ #IMM → Rd Performs a logical AND operation on a general register and another general register or immediate data.
OR	B/W/L	Rd ∨ Rs → Rd, Rd ∨ #IMM → Rd Performs a logical OR operation on a general register and another general register or immediate data.
XOR	B/W/L	Rd ⊕ Rs → Rd, Rd ⊕ #IMM → Rd Performs a logical exclusive OR operation on a general register and another general register or immediate data.
NOT	B/W/L	~ Rd → Rd Takes the one's complement (logical complement) of data in a general register.

Note: * Size refers to the operand size.
B: Byte
W: Word
L: Longword

Table 2.6 Shift Instructions

Instruction	Size*	Function
SHAL	B/W/L	Rd (shift) → Rd
SHAR		Performs an arithmetic shift on data in a general register. 1-bit or 2 bit shift is possible.
SHLL	B/W/L	Rd (shift) → Rd
SHLR		Performs a logical shift on data in a general register. 1-bit or 2 bit shift is possible.
ROTL	B/W/L	Rd (rotate) → Rd
ROTR		Rotates data in a general register. 1-bit or 2 bit rotation is possible.
ROTXL	B/W/L	Rd (rotate) → Rd
ROTXR		Rotates data including the carry flag in a general register. 1-bit or 2 bit rotation is possible.

Note: * Size refers to the operand size.
B: Byte
W: Word
L: Longword

Table 2.7 Bit Manipulation Instructions (1)

Instruction	Size*	Function
BSET	B	1 → (<bit-No.> of <EAd>) Sets a specified bit in a general register or memory operand to 1. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BCLR	B	0 → (<bit-No.> of <EAd>) Clears a specified bit in a general register or memory operand to 0. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BNOT	B	~ (<bit-No.> of <EAd>) → (<bit-No.> of <EAd>) Inverts a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BTST	B	~ (<bit-No.> of <EAd>) → Z Tests a specified bit in a general register or memory operand and sets or clears the Z flag accordingly. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BAND	B	C ∧ (<bit-No.> of <EAd>) → C Logically ANDs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIAND	B	C ∧ (<bit-No.> of <EAd>) → C Logically ANDs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.
BOR	B	C ∨ (<bit-No.> of <EAd>) → C Logically ORs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIOR	B	C ∨ (~ <bit-No.> of <EAd>) → C Logically ORs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.

Note: * Size refers to the operand size.
B: Byte

Table 2.7 Bit Manipulation Instructions (2)

Instruction	Size*	Function
BXOR	B	C ⊕ (<bit-No.> of <EAd>) → C Logically exclusive-ORs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIXOR	B	C ⊕ ~ (<bit-No.> of <EAd>) → C Logically exclusive-ORs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.
BLD	B	(<bit-No.> of <EAd>) → C Transfers a specified bit in a general register or memory operand to the carry flag.
BILD	B	~ (<bit-No.> of <EAd>) → C Transfers the inverse of a specified bit in a general register or memory operand to the carry flag. The bit number is specified by 3-bit immediate data.
BST	B	C → (<bit-No.> of <EAd>) Transfers the carry flag value to a specified bit in a general register or memory operand.
BIST	B	~ C → (<bit-No.>. of <EAd>) Transfers the inverse of the carry flag value to a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data.

Note: * Size refers to the operand size.
B: Byte

Table 2.8 Branch Instructions

Instruction	Size	Function		
Bcc	—	Branches to a specified address if a specified condition is true. The branching conditions are listed below.		
		Mnemonic	**Description**	**Condition**
		BRA (BT)	Always (true)	Always
		BRN (BF)	Never (false)	Never
		BHI	High	$C \vee Z = 0$
		BLS	Low or same	$C \vee Z = 1$
		BCC (BHS)	Carry clear (high or same)	$C = 0$
		BCS (BLO)	Carry set (low)	$C = 1$
		BNE	Not equal	$Z = 0$
		BEQ	Equal	$Z = 1$
		BVC	Overflow clear	$V = 0$
		BVS	Overflow set	$V = 1$
		BPL	Plus	$N = 0$
		BMI	Minus	$N = 1$
		BGE	Greater or equal	$N \oplus V = 0$
		BLT	Less than	$N \oplus V = 1$
		BGT	Greater than	$Z \vee (N \oplus V) = 0$
		BLE	Less or equal	$Z \vee (N \oplus V) = 1$
JMP	—	Branches unconditionally to a specified address		
BSR	—	Branches to a subroutine at a specified address		
JSR	—	Branches to a subroutine at a specified address		
RTS	—	Returns from a subroutine		

Table 2.9 System Control Instructions

Instruction	Size*	Function
TRAPA	—	Starts trap-instruction exception handling.
RTE	—	Returns from an exception-handling routine.
SLEEP	—	Causes a transition to a power-down state.
LDC	B/W	(EAs) → CCR, (EAs) → EXR Moves the memory operand contents or immediate data to CCR or EXR. Although CCR and EXR are 8-bit registers, word-size transfers are performed between them and memory. The upper 8 bits are valid.
STC	B/W	CCR → (EAd), EXR → (EAd) Transfers CCR or EXR contents to a general register or memory operand. Although CCR and EXR are 8-bit registers, word-size transfers are performed between them and memory. The upper 8 bits are valid.
ANDC	B	CCR ∧ #IMM → CCR, EXR ∧ #IMM → EXR Logically ANDs the CCR or EXR contents with immediate data.
ORC	B	CCR ∨ #IMM → CCR, EXR ∨ #IMM → EXR Logically ORs the CCR or EXR contents with immediate data.
XORC	B	CCR ⊕ #IMM → CCR, EXR ⊕ #IMM → EXR Logically exclusive-ORs the CCR or EXR contents with immediate data.
NOP	—	PC + 2 → PC Only increments the program counter.

Note: * Size refers to the operand size.
B: Byte
W: Word

Table 2.10 Block Data Transfer Instructions

Instruction	Size	Function

EEPMOV.B	—	if R4L ≠ 0 then
		Repeat @ER5+ → @ER6+
		R4L–1 → R4L
		Until R4L = 0
		else next:

EEPMOV.W	—	if R4 ≠ 0 then
		Repeat @ER5+ → @ER6+
		R4–1 → R4
		Until R4 = 0
		else next:
		Transfers a data block. Starting from the address set in ER5, transfers data for the number of bytes set in R4L or R4 to the address location set in ER6.
		Execution of the next instruction begins as soon as the transfer is completed.

2.6.2 Basic Instruction Formats

The H8S/2000 CPU instructions consist of 2-byte (1-word) units. An instruction consists of an operation field (op), a register field (r), an effective address extension (EA), and a condition field (cc).

Figure 2.9 shows examples of instruction formats.

- Operation field

  Indicates the function of the instruction, the addressing mode, and the operation to be carried out on the operand. The operation field always includes the first four bits of the instruction. Some instructions have two operation fields.
- Register field

  Specifies a general register. Address registers are specified by 3 bits, and data registers by 3 bits or 4 bits. Some instructions have two register fields, and some have no register field.
- Effective address extension

  8, 16, or 32 bits specifying immediate data, an absolute address, or a displacement.
- Condition field

  Specifies the branching condition of Bcc instructions.

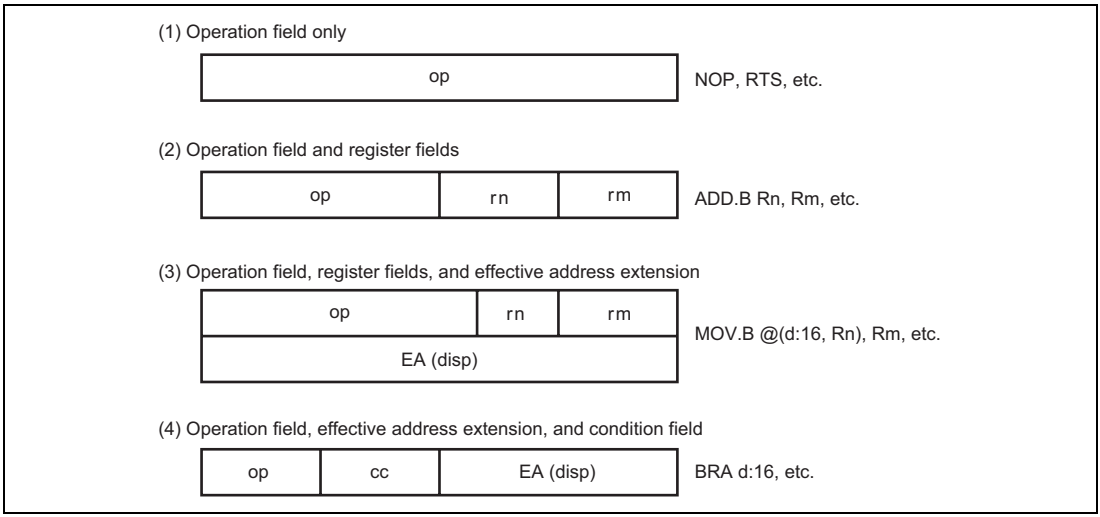


Figure 2.9 Instruction Formats (Examples)

2.7 Addressing Modes and Effective Address Calculation

The H8S/2000 CPU supports the eight addressing modes listed in table 2.11. Each instruction uses a subset of these addressing modes.

Arithmetic and logic operations instructions can use the register direct and immediate addressing modes. Data transfer instructions can use all addressing modes except program-counter relative and memory indirect. Bit manipulation instructions can use register direct, register indirect, or absolute addressing mode to specify an operand, and register direct (BSET, BCLR, BNOT, and BTST instructions) or immediate (3-bit) addressing mode to specify a bit number in the operand.

Table 2.11 Addressing Modes

No.	Addressing Mode	Symbol
1	Register direct	Rn
2	Register indirect	@ERn
3	Register indirect with displacement	@(d:16,ERn)/@(d:32,ERn)
4	Register indirect with post-increment	@ERn+
	Register indirect with pre-decrement	@–ERn
5	Absolute address	@aa:8/@aa:16/@aa:24/@aa:32
6	Immediate	#xx:8/#xx:16/#xx:32
7	Program-counter relative	@(d:8,PC)/@(d:16,PC)
8	Memory indirect	@@aa:8

2.7.1 Register Direct—Rn

The register field of the instruction code specifies an 8-, 16-, or 32-bit general register which contains the operand. R0H to R7H and R0L to R7L can be specified as 8-bit registers. R0 to R7 and E0 to E7 can be specified as 16-bit registers. ER0 to ER7 can be specified as 32-bit registers.

2.7.2 Register Indirect—@ERn

The register field of the instruction code specifies an address register (ERn) which contains the address of a memory operand. If the address is a program instruction address, the lower 24 bits are valid and the upper 8 bits are all assumed to be 0 (H'00).

2.7.3 Register Indirect with Displacement—@(d:16, ERn) or @(d:32, ERn)

A 16-bit or 32-bit displacement contained in the instruction code is added to an address register (ERn) specified by the register field of the instruction, and the sum gives the address of a memory operand. A 16-bit displacement is sign-extended when added.

2.7.4 Register Indirect with Post-Increment or Pre-Decrement—@ERn+ or @–ERn

(1) Register Indirect with Post-Increment—@ERn+

The register field of the instruction code specifies an address register (ERn) which contains the address of a memory operand. After the operand is accessed, 1, 2, or 4 is added to the address register contents and the sum is stored in the address register. The value added is 1 for byte access, 2 for word access, and 4 for longword access. For word or longword transfer instructions, the register value should be even.

(2) Register Indirect with Pre-Decrement—@–ERn

The value 1, 2, or 4 is subtracted from an address register (ERn) specified by the register field in the instruction code, and the result becomes the address of a memory operand. The result is also stored in the address register. The value subtracted is 1 for byte access, 2 for word access, and 4 for longword access. For word or longword transfer instructions, the register value should be even.

2.7.5 Absolute Address—@aa:8, @aa:16, @aa:24, or @aa:32

The instruction code contains the absolute address of a memory operand. The absolute address may be 8 bits long (@aa:8), 16 bits long (@aa:16), 24 bits long (@aa:24), or 32 bits long (@aa:32). Table 2.12 indicates the accessible absolute address ranges.

To access data, the absolute address should be 8 bits (@aa:8), 16 bits (@aa:16), or 32 bits (@aa:32) long. For an 8-bit absolute address, the upper 24 bits are all assumed to be 1 (H'FFFF). For a 16-bit absolute address, the upper 16 bits are a sign extension. For a 32-bit absolute address, the entire address space is accessed.

A 24-bit absolute address (@aa:24) indicates the address of a program instruction. The upper 8 bits are all assumed to be 0 (H'00).

Table 2.12 Absolute Address Access Ranges

Absolute Address		Advanced Mode
Data address	8 bits (@aa:8)	H'FFFF00 to H'FFFFFF
	16 bits (@aa:16)	H'000000 to H'007FFF, H'FF8000 to H'FFFFFF
	32 bits (@aa:32)	H'000000 to H'FFFFFF
Program instruction address	24 bits (@aa:24)	

2.7.6 Immediate—#xx:8, #xx:16, or #xx:32

The 8-bit (#xx:8), 16-bit (#xx:16), or 32-bit (#xx:32) immediate data contained in an instruction code can be used directly as an operand.

The ADDS, SUBS, INC, and DEC instructions implicitly contain immediate data in their instruction codes. Some bit manipulation instructions contain 3-bit immediate data in the instruction code, specifying a bit number. The TRAPA instruction contains 2-bit immediate data in its instruction code, specifying a vector address.

2.7.7 Program-Counter Relative—@(d:8, PC) or @(d:16, PC)

This mode can be used by the Bcc and BSR instructions. An 8-bit or 16-bit displacement contained in the instruction code is sign-extended to 24 bits and added to the 24-bit address indicated by the PC value to generate a 24-bit branch address. Only the lower 24 bits of this branch address are valid; the upper 8 bits are all assumed to be 0 (H'00). The PC value to which the displacement is added is the address of the first byte of the next instruction, so the possible branching range is –126 to +128 bytes (–63 to +64 words) or –32766 to +32768 bytes (–16383 to +16384 words) from the branch instruction. The resulting value should be an even number.

2.7.8 Memory Indirect—@@aa:8

This mode can be used by the JMP and JSR instructions. The instruction code contains an 8-bit absolute address specifying a memory operand which contains a branch address. The upper bits of the 8-bit absolute address are all assumed to be 0, so the address range is 0 to 255 (H'000000 to H'0000FF in advanced mode).

In advanced mode, the memory operand is a longword operand, the first byte of which is assumed to be 0 (H'00).

Note that the top area of the address range in which the branch address is stored is also used for the exception vector area. For further details, see section 3, Exception Handling.

If an odd address is specified in word or longword memory access, or as a branch address, the least significant bit is regarded as 0, causing data to be accessed or the instruction code to be fetched at the address preceding the specified address. (For further information, see section 2.5.2, Memory Data Formats.)

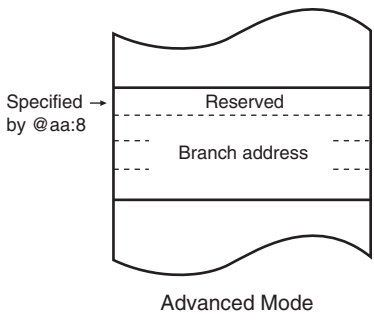


Figure 2.10 Branch Address Specification in Memory Indirect Addressing Mode

2.7.9 Effective Address Calculation

Table 2.13 indicates how effective addresses are calculated in each addressing mode.

Table 2.13 Effective Address Calculation

No	Addressing Mode and Instruction Format	Effective Address Calculation	Effective Address (EA)
1	Register direct (Rn) op rm rn		Operand is general register contents.
2	Register indirect (@ERn) op r	31 0 General register contents	31 24 23 0 Don't care
3	Register indirect with displacement @(d:16,ERn) or @(d:32,ERn) op r disp	31 0 General register contents 31 0 Sign extension disp	31 24 23 0 Don't care
4	Register indirect with post-increment or pre-decrement • Register indirect with post-increment @ERn+ op r • Register indirect with pre-decrement @-ERn op r	31 0 General register contents 1, 2, or 4 31 0 General register contents 1, 2, or 4 Operand Size / Offset: Byte 1; Word 2; Longword 4	31 24 23 0 Don't care 31 24 23 0 Don't care

No	Addressing Mode and Instruction Format	Effective Address Calculation	Effective Address (EA)
5	Absolute address @aa:8 op abs @aa:16 op abs @aa:24 op abs @aa:32 op abs		31 24 23 8 7 0 Don't care H'FFFF 31 24 23 16 15 0 Don't care Sign extension 31 24 23 0 Don't care 31 24 23 0 Don't care
6	Immediate #xx:8/#xx:16/#xx:32 op IMM		Operand is immediate data.
7	Program-counter relative @(d:8,PC)/@(d:16,PC) op disp	23 0 PC contents 23 0 Sign extension disp	31 24 23 0 Don't care
8	Memory indirect @@aa:8 • Normal mode* op abs • Advanced mode op abs	31 8 7 0 H'000000 abs 15 0 Memory contents 31 8 7 0 H'000000 abs 31 0 Memory contents	31 24 23 16 15 0 Don't care H'00 31 24 23 0 Don't care

Note: * For this LSI, normal mode is not available.

2.8 Processing States

The H8S/2000 CPU has five main processing states: the reset state, exception handling state, program execution state, bus-released state, and program stop state. Figure 2.11 indicates the state transitions.

- Reset state

  In this state the CPU and internal peripheral modules are all initialized and stopped. When the $\overline{\text{RES}}$ input goes low, all current processing stops and the CPU enters the reset state. All interrupts are masked in the reset state. Reset exception handling starts when the $\overline{\text{RES}}$ signal changes from low to high. For details, see section 3, Exception Handling.

  The reset state can also be entered by a watchdog timer overflow.

- Exception-handling state

  The exception-handling state is a transient state that occurs when the CPU alters the normal processing flow due to an exception source, such as, a reset, trace, interrupt, or trap instruction. The CPU fetches a start address (vector) from the exception vector table and branches to that address. For further details, see section 3, Exception Handling.

- Program execution state

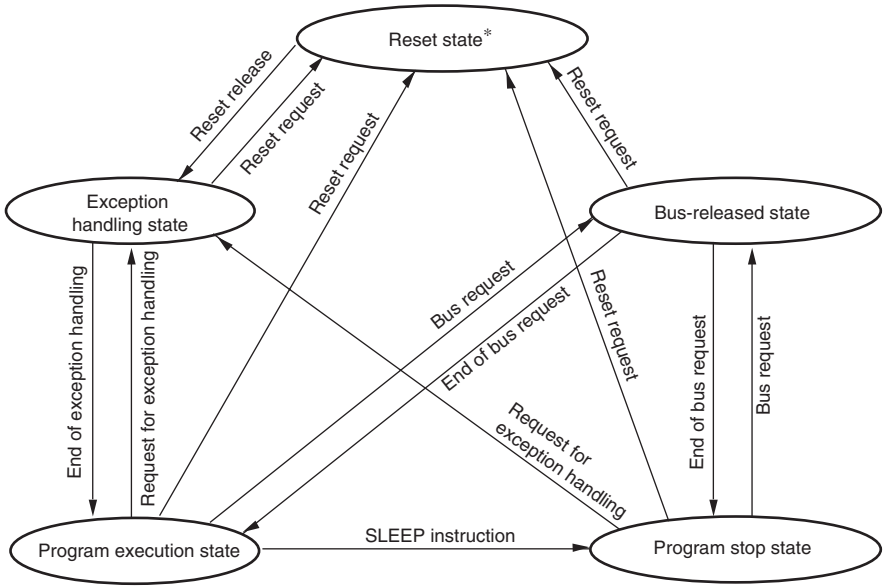
  In this state the CPU executes program instructions in sequence.

- Bus-released state

  The bus-released state occurs when the bus has been released in response to a bus request from a bus master other than the CPU. While the bus is released, the CPU halts operations.

- Program stop state

  This is a power-down state in which the CPU stops operating. The program stop state occurs when a SLEEP instruction is executed. For details, see section 6, Power-Down Modes.



Note: * A transition to the reset state occurs in any of the following cases.
1. When $\overline{\text{RES}}$ goes low in any state
2. When the watchdog timer overflows
3. When an LVD reset is caused by a low-voltage detection

Figure 2.11 State Transitions

2.9 Usage Notes

2.9.1 TAS Instruction

Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction. The H8S and H8/300 Series C/C++ Compiler of Renesas Technology Corp. does not generate a TAS instruction. Accordingly, when a TAS instruction is used as a user-defined embedded function, register ER0, ER1, ER4, or ER5 should be used.

2.9.2 STM and LDM Instructions

The ER7 register is used as a stack pointer in an STM and LDM instructions. Accordingly, ER7 cannot be stored by STM or loaded by LDM. Two, three, or four registers can be stored or loaded by a single STM or LDM instruction. The combination of registers that can be stored or loaded are as follows.

- Two registers: ER0 and ER1, ER2 and ER3, or ER4 and ER5
- Three registers: ER0 to ER2 or ER4 to ER6
- Four registers: ER0 to ER3

The H8S and H8/300 Series C/C++ Compiler of Renesas Technology Corp. does not generate an STM or LDM instruction that uses ER7.

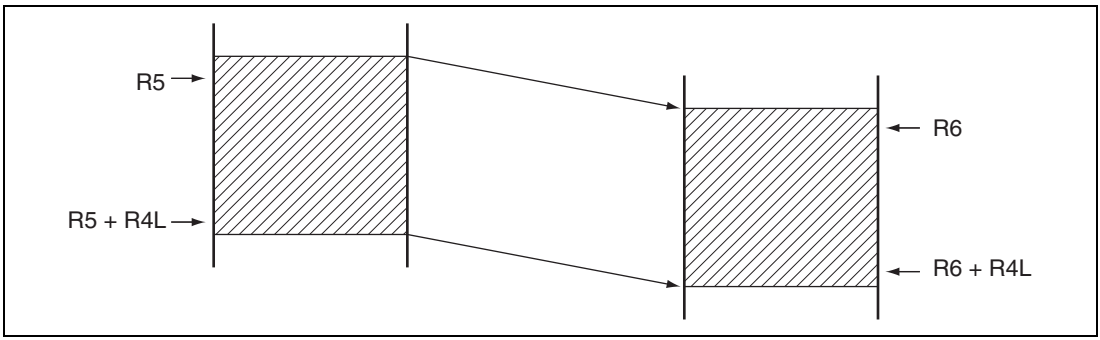
2.9.3 Note on Bit Manipulation Instructions

Bit manipulation instructions such as BSET, BCLR, BNOT, BST, and BIST read data in byte units, perform bit manipulation, and write data in byte units. Thus, care must be taken when these bit manipulation instructions are executed for a register or port including write-only bits.

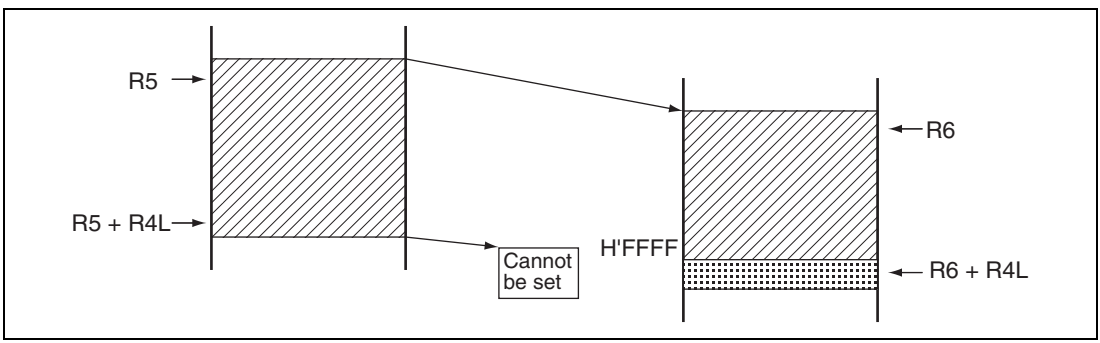
In addition, the BCLR instruction can be used to clear the flag of an internal I/O register. In this case, if the flag to be cleared has been set by an interrupt processing routine, the flag need not be read before executing the BCLR instruction.

2.9.4 EEPMOVE Instruction

1. The EEPMOVE instruction performs a block transfer. As shown in the following figure, EEPMOV transfers data whose start address is indicated by R5 for the number of bytes indicated by R4L to the address indicated by R6.



2. R4L and R6 should be set so that the end address (R6 + R4L) of the transfer destination does not exceed H'FFFF (R6 should not change from H'FFFF to H'0000 during EEPMOV instruction execution).



Section 3 Exception Handling

3.1 Exception Handling Types and Priority

As table 3.1 indicates, exception handling is caused by a reset, trace, NMI interrupt, trap instruction, or interrupt. Exception handling is prioritized as shown in table 3.1. If two or more exceptions occur simultaneously, they are accepted and processed in order of priority. Exception sources, the stack structure, and operation of the CPU vary depending on the interrupt control mode. For details on the interrupt control mode, see section 4, Interrupt Controller.

Table 3.1 Exception Handling Types and Priority

Priority	Exception Type	Start Timing of Exception Handling
High ▲	Reset	Started immediately after a low-to-high transition at the $\overline{\text{RES}}$ pin, or by other reset sources. The CPU enters the reset state when the $\overline{\text{RES}}$ pin is low.
	Trace*[1]	Started when execution of the current instruction or exception handling ends, if the trace (T) bit in EXR is set to 1.
	NMI	Generated when an edge of the $\overline{\text{NMI}}$ pin is input. An NMI interrupt request has the highest priority among interrupt requests. It is always accepted regardless of the value of the I bit in CCR.
	Trap instruction*[3]	Started by execution of a trap instruction (TRAPA).
Low	Interrupt	Started when execution of the current instruction or exception handling ends, if an interrupt request has been issued.*[2]

Notes: 1. Traces are enabled only in interrupt control mode 2. Trace exception handling is not executed after execution of an RTE instruction.
2. Interrupt detection is not performed on completion of ANDC, ORC, XORC, or LDC instruction execution, or on completion of reset exception handling.
3. Trap instruction exception handling requests are accepted at all times in program execution state.

3.2 Exception Handling Sources and Vector Table

Different vector addresses are assigned to different exception sources. For details on the exception sources and their vector addresses, see section 4, Interrupt Controller.

3.3 Reset

A reset has the highest exception handling priority. When the $\overline{\text{RES}}$ pin goes low, all processing halts and this LSI enters the reset. To ensure that this LSI is reset, hold the $\overline{\text{RES}}$ pin low for the specified time at power-on and during operation, hold the $\overline{\text{RES}}$ pin low for the specified time. A reset initializes the internal state of the CPU and the registers of on-chip peripheral modules, and selects low-speed on-chip oscillator as a system clock. The chip can also be reset by detection of the low-voltage, overflow of the watchdog timer, or software.

The interrupt control mode is 0 immediately after reset.

3.3.1 Reset Sources

This LSI enters the reset state by reset sources listed in table 3.2. If multiple reset sources occur simultaneously, a reset source having the highest priority will be accepted. A reset source can be identified by reading the reset source flag register (RSTFR).

For details on a low-voltage detection reset, see section 26, Low-Voltage Detection Circuits. For details on a watchdog timer overflow reset, see section 19, Watchdog Timer (WDT).

Table 3.2 List of Reset Sources

Reset Source	Description	Priority
Reset by $\overline{\text{RES}}$ pin	This LSI enters the reset state if the $\overline{\text{RES}}$ pin is held low for at least a specified period.	High
Low-voltage detection reset	This LSI enters the reset state if the power voltage becomes the specified voltage or lower.	
Watchdog timer overflow reset	This LSI enters the reset state if the counter in the watchdog timer overflows.	
Software reset	This LSI enters the reset state if the SRST bit in RSTCR is set to 1.	Low

(1) Reset Source Flag Register (RSTFR)

Address: H'FF0620

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	SWRST	PRST	LVD2RST	LVD1RST	PORRST	WRST
Value after reset:	0	0	(0)	(0)	(0)	(0)	(0)	(0)

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 0. The write value should be 0.	—
6	—			
5	SWRST	Software reset detection flag	1: Indicates that a reset by a software reset occurs. 0: Indicates that a reset by a software reset does not occur.	R/W
4	PRST	$\overline{\text{RES}}$ pin reset detection flag	1: Indicates that a reset by a $\overline{\text{RES}}$ pin reset occurs. 0: Indicates that a reset by a $\overline{\text{RES}}$ pin reset does not occur.	R/W
3	LVD2RST	LVD2 reset detection flag	1: Indicates that a reset by a LVD2 reset occurs. 0: Indicates that a reset by a LVD2 reset does not occur.	R/W
2	LVD1RST	LVD1 reset detection flag	1: Indicates that a reset by a LVD1 reset occurs. 0: Indicates that a reset by a LVD1 reset does not occur.	R/W
1	PORRST	LVD0 reset detection flag	1: Indicates that a reset by a LVD0 reset occurs. 0: Indicates that a reset by a LVD0 reset does not occur.	R/W
0	WRST	Watchdog timer reset detection flag	1: Indicates that a reset by a watchdog timer overflows. 0: Indicates that a reset by a watchdog timer does not occur.	R/W

Note: Each flag in this register can be cleared by writing 0 to it. The write value to the reserved bits should always be 0.

(2) Reset Control Register (RSTCR)

Address: H'FF06DA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	—	—	—	—	—	SRST
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE. [Clearing condition] When 0 is written to WI and WE.	R/W
5 to 1	—	Reserved	These bits are read as 0. The write value should be 0.	—
0	SRST	Software reset	0: Normal operation 1: A software reset is generated.	R/W

Note: A MOV instruction should be used to write to this register.

- WI bit (write inhibit)
  This register can be written to only when this bit is 0. This bit is always read as 1.
- WE bit (write enable)
  Bit 0 in this register can be written to when this bit is 1.
- SRST bit (software reset)
  A software reset is generated when this bit is 1.

3.3.2 Reset Exception Handling

When the $\overline{\text{RES}}$ pin goes high after being held low for the necessary time, this LSI starts reset exception handling as follows:

1. The internal state of the CPU and the registers of the on-chip peripheral modules are initialized, VOFR is cleared to H'0000, the T bit in EXR is cleared to 0, and the I bit in EXR and CCR is set to 1.
2. The low-speed on-chip oscillator is selected as a system clock.
3. After the reset exception handling vector address is read and transferred to the PC, program execution starts from the address indicated by the PC.

Figure 3.1 shows an example of the reset sequence.

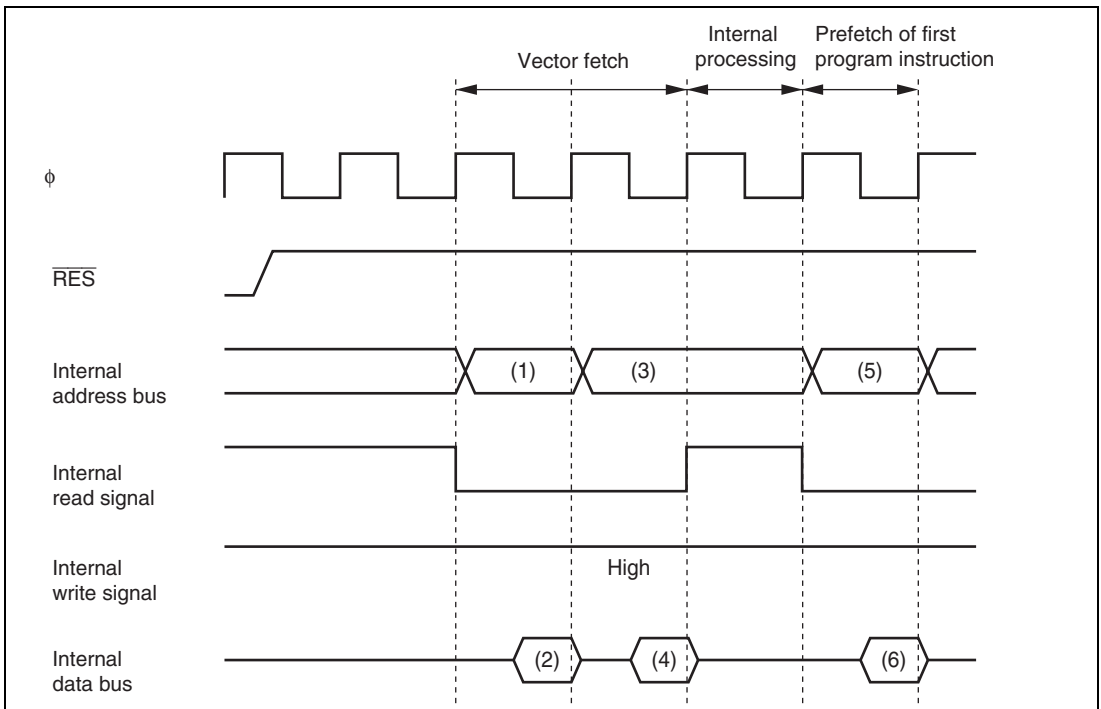


Figure 3.1 Reset Sequence

3.3.3 Interrupts immediately after Reset

If an interrupt is accepted after a reset but before the stack pointer (SP) is initialized, the PC and CCR will not be saved correctly, leading to a program crash. To prevent this, all interrupt requests, including NMI, are disabled immediately after a reset. Since the first instruction of a program is always executed immediately after the reset state ends, make sure that this instruction initializes the stack pointer (example: MOV.L #xx: 32, SP).

3.3.4 On-Chip Peripheral Functions after Reset Release

After release from a reset, MSTCR is initialized, and the DTC and all modules other than timer RE enter module standby mode.

Consequently, on-chip peripheral module registers cannot be read or written to. Register reading and writing is enabled when module standby mode is exited.

3.4 Trace Exception Handling

Traces are enabled in interrupt control mode 2. Trace mode is not activated in interrupt control mode 0, irrespective of the state of the T bit. For details on interrupt control modes, see section 4, Interrupt Controller.

If the T bit in EXR is set to 1, trace mode is activated. In trace mode, a trace exception occurs on completion of each instruction. Trace mode is not affected by the interrupt masking bit in CCR. Table 3.3 shows the state of CCR and EXR after execution of trace exception handling. Trace mode is canceled by clearing the T bit in EXR to 0. The T bit saved on the stack retains its value of 1, and trace mode resumes when control is returned from the trace exception handling routine by the RTE instruction. Trace exception handling is not carried out after execution of the RTE instruction.

Interrupts are accepted even within the trace exception handling routine.

Table 3.3 Status of CCR and EXR after Trace Exception Handling

	CCR			EXR
Interrupt Control Mode	**I**	**UI**	**I2 to I0**	**T**
0	Trace exception handling cannot be used.			
2	1	—	—	0

[Legend]

1: Set to 1

0: Cleared to 0

—: Retains value prior to execution.

3.5 Interrupt Exception Handling

Interrupts are controlled by the interrupt controller. The interrupt controller has two interrupt control modes and can assign interrupts other than NMI to four priority/mask levels to enable multiplexed interrupt control. The source to start interrupt exception handling and the vector address differ depending on the product. For details, see section 4, Interrupt Controller.

The interrupt exception handling is as follows:

1. The values in the program counter (PC), condition code register (CCR), and extended register (EXR) are saved in the stack.
2. The interrupt mask bit is updated and the T bit is cleared to 0.
3. A vector address corresponding to the interrupt source is generated, the start address is loaded from the vector table to the PC, and program execution starts from that address.

3.6 Trap Instruction Exception Handling

Trap instruction exception handling starts when a TRAPA instruction is executed. Trap instruction exception handling can be executed at all times in the program execution state.

The trap instruction exception handling is as follows:

1. The values in the program counter (PC), condition code register (CCR), and extended register (EXR) are saved in the stack.
2. The interrupt mask bit is updated and the T bit is cleared to 0.
3. A vector address corresponding to the interrupt source is generated, the start address is loaded from the vector table to the PC, and program execution starts from that address.

The TRAPA instruction fetches a start address from a vector table entry corresponding to a vector number from 0 to 3, as specified in the instruction code.

Table 3.4 shows the status of CCR and EXR after execution of trap instruction exception handling.

Table 3.4 Status of CCR and EXR after Trap Instruction Exception Handling

	CCR			EXR
Interrupt Control Mode	**I**	**UI**	**I2 to I0**	**T**
0	1	—	—	—
2	1	—	—	0

[Legend]

1: Set to 1

0: Cleared to 0

—: Retains value prior to execution.

3.7 Stack Status after Exception Handling

Figure 3.2 shows the stack after completion of trap instruction exception handling and interrupt exception handling.

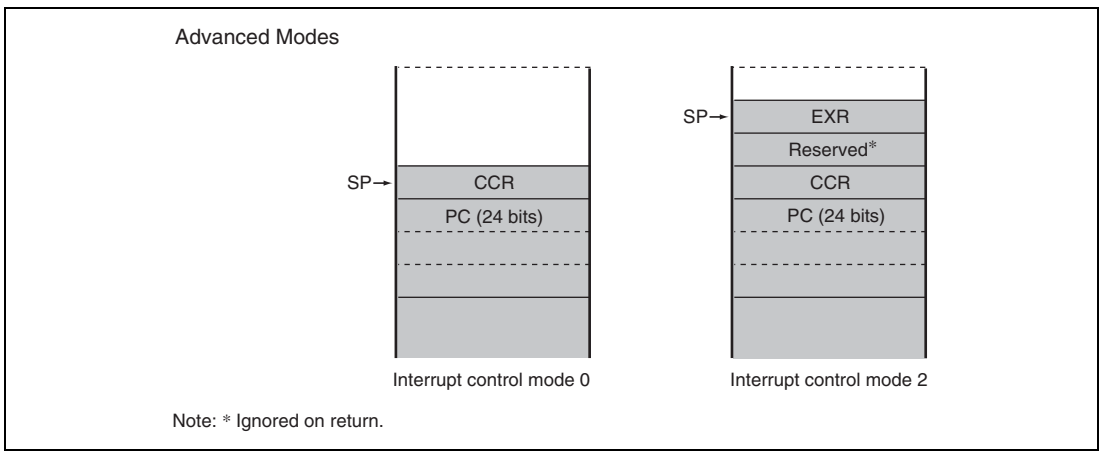


Figure 3.2 Stack Status after Exception Handling

3.8 Usage Note

When accessing word data or longword data, this LSI assumes that the lowest address bit is 0. The stack should always be accessed by word transfer instruction or longword transfer instruction, and the value of the stack pointer (SP, ER7) should always be kept even.
Use the following instructions to save registers:

```
PUSH.W   Rn    (or MOV.W Rn, @-SP)
PUSH.L   ERn   (or MOV.L ERn, @-SP)
```

Use the following instructions to restore registers:

```
POP.W    Rn    (or MOV.W @SP+, Rn)
POP.L    ERn   (or MOV.L @SP+, ERn)
```

Setting SP to an odd value may lead to a malfunction. Figure 3.3 shows an example of operation when the SP value is odd.

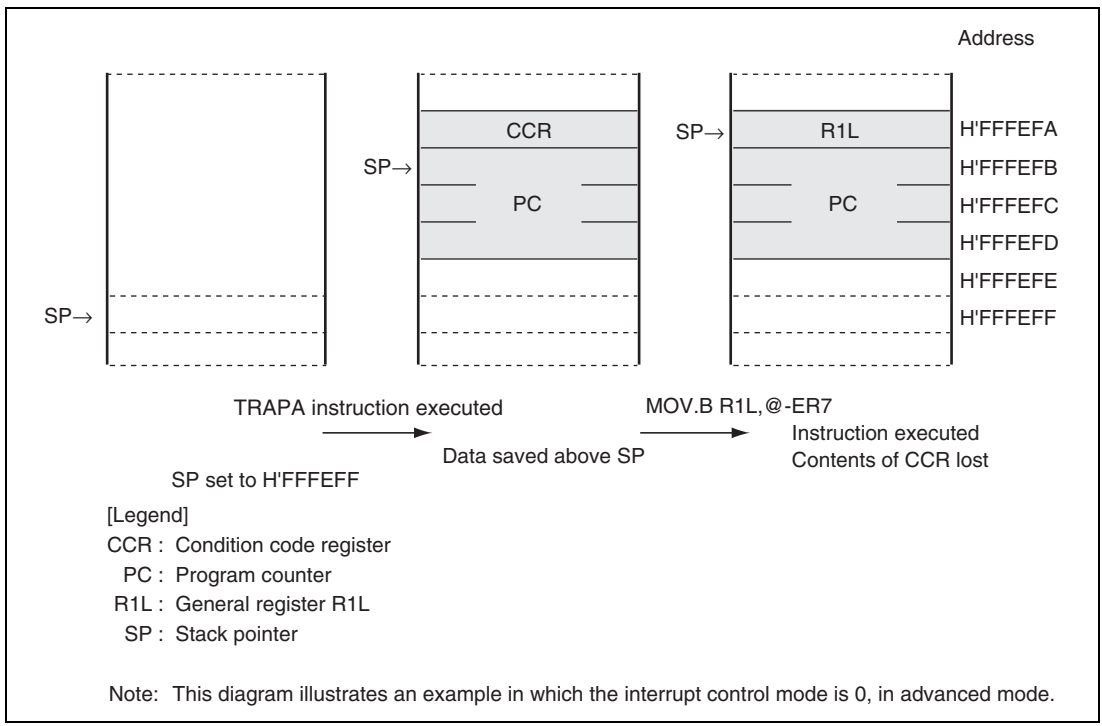


Figure 3.3 Operation when SP Value Is Odd

Section 4 Interrupt Controller

4.1 Features

- Two interrupt control modes

  Either of the two interrupt control modes can be selected by means of the INTM1 and INTM0 bits in the interrupt control register (INTCR).
- Priorities settable with IPR

  An interrupt priority register (IPR) is provided for setting interrupt priorities. Four priority levels can be set for each module for all interrupts except NMI. NMI and some flash memory interrupts are assigned the highest priority level of 3, and can be accepted at all times.
- Independent vector addresses

  Most interrupt sources are assigned independent vector addresses, making it unnecessary for the source to be identified in the interrupt handling routine.
- Nine external interrupts

  NMI is the highest-priority interrupt, and is accepted at all times. Rising edge or falling edge can be selected for NMI. Falling edge, rising edge, or both edges can be selected independently for $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$.
- DTC control

  DTC activation is performed by means of interrupt requests.

A block diagram of the interrupt controller is shown in figure 4.1.

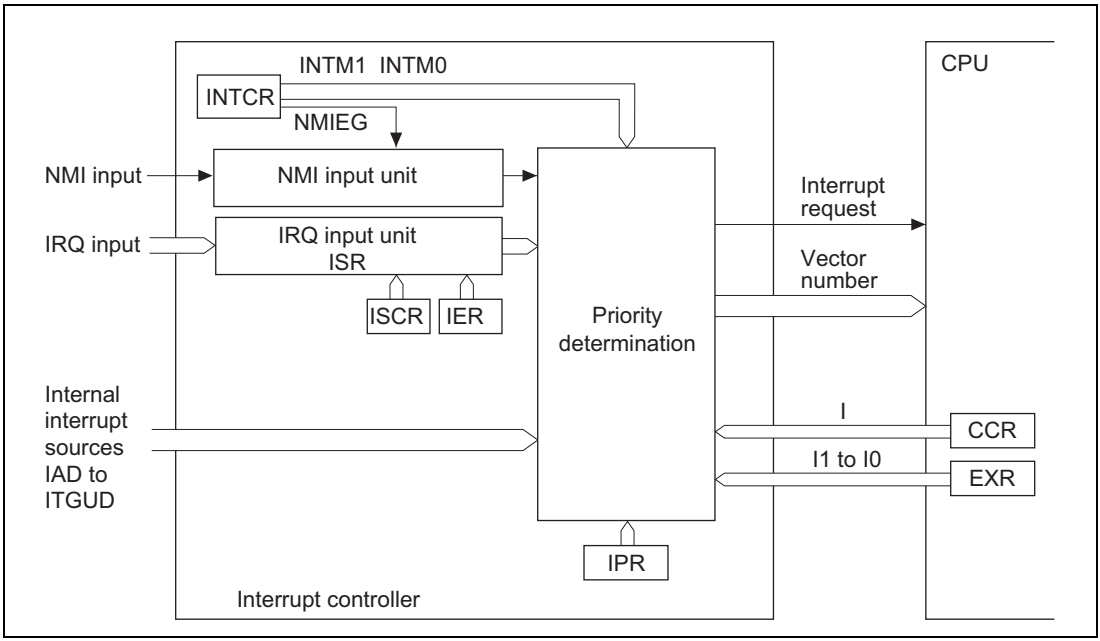


Figure 4.1 Block Diagram of Interrupt Controller

Table 4.1 shows the pin configuration of the interrupt controller.

Table 4.1 Pin Configuration

Name	I/O	Function
NMI	Input	Nonmaskable external interrupt Rising or falling edge can be selected.
$\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$	Input	Maskable external interrupts Rising, falling, or both edges can be selected independently.

4.2 Register Descriptions

- Interrupt control register (INTCR)
- IRQ sense control register H (ISCRH)
- IRQ sense control register L (ISCRL)
- IRQ enable register (IER)
- IRQ status register (ISR)
- Interrupt priority register A (IPRA)
- Interrupt priority register B (IPRB)
- Interrupt priority register C (IPRC)
- Interrupt priority register D (IPRD)
- Interrupt priority register E (IPRE)
- Interrupt priority register F (IPRF)
- Interrupt priority register G (IPRG)
- Interrupt priority register H (IPRH)
- Interrupt priority register I (IPRI)
- Interrupt vector offset register (VOFR)
- IRQ noise canceler control register (INCCR)
- Event link interrupt control status register (ELCSR)

4.2.1 Interrupt Control Register (INTCR)

Address: H'FF0520

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	INTM[1:0]		NMIEG	ADTRG1	ADTRG0	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5 4	INTM[1:0]	Interrupt control select mode 1 and 0	00: Interrupt control mode 0 Interrupts are controlled by the I bit. 01: Setting prohibited 10: Interrupt control mode 2 Interrupts are controlled by bits I1 and I0, and IPR. 11: Setting prohibited	R/W
3	NMIEG	NMI edge select	0: Interrupt request is generated at falling edge of NMI input. 1: Interrupt request is generated at rising edge of NMI input.	R/W
2	ADTRG1	$\overline{\text{ADTRG2}}$ edge select	0: AD1 or AD2 conversion is started at falling edge of $\overline{\text{ADTRG2}}$ input. 1: AD1 or AD2 conversion is started at rising edge of $\overline{\text{ADTRG2}}$ input.	R/W
1	ADTRG0	$\overline{\text{ADTRG1}}$ edge select	0: AD1 or AD2 conversion is started at falling edge of $\overline{\text{ADTRG1}}$ input. 1: AD1 or AD2 conversion is started at rising edge of $\overline{\text{ADTRG1}}$ input.	R/W
0	—	Reserved	This bit is read as 0. The write value should be 0.	—

- INTM1 and INTM0 bits (interrupt control select mode 1 and 0)
  These bits select the interrupt control mode for the interrupt controller.

- NMIEG bit (NMI edge select)
  Selects the input edge for the $\overline{\text{NMI}}$ pin.

- ADTRG1 and ADTRG0 bits ($\overline{\text{ADTRG2}}$ and $\overline{\text{ADTRG1}}$ edge select)
  These bits select the input edge for the $\overline{\text{ADTRG2}}$ and $\overline{\text{ADTRG1}}$ pins.

4.2.2 Interrupt Priority Registers A to I (IPRA to IPRI)

- IPRA to IPRK

Address: H'FF0529 to H'FF0531

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IPRn[7:6]		IPRn[5:4]		IPRn[3:2]		IPRn[1:0]	
Value after reset:	1	1	1	1	1	1	1	1

(n = A to I)

Bit	Symbol	Bit Name	Description	R/W
7 6	IPRn[7:6]	Interrupt priority 7 and 6	00: Priority level 0 (lowest) 01: Priority level 1 10: Priority level 2 11: Priority level 3 (highest)	R/W
5 4	IPRn[5:4]	Interrupt priority 5 and 4	00: Priority level 0 (lowest) 01: Priority level 1 10: Priority level 2 11: Priority level 3 (highest)	R/W
3 2	IPRn[3:2]	Interrupt priority 3 and 2	00: Priority level 0 (lowest) 01: Priority level 1 10: Priority level 2 11: Priority level 3 (highest)	R/W
1 0	IPRn[1:0]	Interrupt priority 1 and 0	00: Priority level 0 (lowest) 01: Priority level 1 10: Priority level 2 11: Priority level 3 (highest)	R/W

[Legend]
n = A to I

- IPR7 to IPR0 bits (Interrupt priority 7 to 0)

IPR are nine 8-bit readable/writable registers that set priorities (levels 3 to 0) for interrupt sources other than Nonmaskable interrupt request (NMI). The correspondence between interrupt sources and IPR settings is shown in table 4.2. Setting a value in the range from H'0 to H'3 in the 2-bit groups of bits 7 and 6, 5and 4, 3 and 2, and, 1 and 0 determines the priority of the corresponding interrupt requests.

Table 4.2 Correspondence between Interrupt Sources and IPR Settings

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IPRA	Flash memory		WDT		LVD		CPG	
IPRB	IRQ0		IRQ1		IRQ2		IRQ3	
IPRC	IRQ4		IRQ5		IRQ6		IRQ7	
IPRD	A/D converter unit 1		A/D converter unit 2*[1]		DTC		ELC	
IPRE	SCI3 channel 1		SCI3 channel 2		SCI3 channel 3		—	
IPRF	—		—		IIC2/SSU		—	
IPRG	—		Timer RA		Timer RB		Timer RC*[2]	
IPRH	Timer RD unit 0 channel 0		Timer RD unit 0 channel 1		Timer RD unit 1 channel 2*[3]		Timer RD unit 1 channel 3*[3]	
IPRI	Timer RE		—		Timer RG		—	

Notes: —: Reserved

1. Provided for the H8S/20223 group only.
2. Provided for the H8S/20103 group only.
3. Not provided for the H8S/20103 group.

4.2.3 IRQ Enable Register (IER)

Address: H'FF0521

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IRQ7E	IRQ6E	IRQ5E	IRQ4E	IRQ3E	IRQ2E	IRQ1E	IRQ0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	IRQ7E	IRQ7 enable	0: IRQ7 interrupts are disabled. 1: IRQ7 interrupts are enabled.	R/W
6	IRQ6E	IRQ6 enable	0: IRQ6 interrupts are disabled. 1: IRQ6 interrupts are enabled.	R/W
5	IRQ5E	IRQ5 enable	0: IRQ5 interrupts are disabled. 1: IRQ5 interrupts are enabled.	R/W
4	IRQ4E	IRQ4 enable	0: IRQ4 interrupts are disabled. 1: IRQ4 interrupts are enabled.	R/W
3	IRQ3E	IRQ3 enable	0: IRQ3 interrupts are disabled. 1: IRQ3 interrupts are enabled.	R/W
2	IRQ2E	IRQ2 enable	0: IRQ2 interrupts are disabled. 1: IRQ2 interrupts are enabled.	R/W
1	IRQ1E	IRQ1 enable	0: IRQ1 interrupts are disabled. 1: IRQ1 interrupts are enabled.	R/W
0	IRQ0E	IRQ0 enable	0: IRQ0 interrupts are disabled. 1: IRQ0 interrupts are enabled.	R/W

4.2.4 IRQ Sense Control Register H and L (ISCRH and ISCRL)

- ISCRH

Address: H'FF0522

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IRQ7SCB	IRQ7SCA	IRQ6SCB	IRQ6SCA	IRQ5SCB	IRQ5SCA	IRQ4SCB	IRQ4SCA
Value after reset:	0	1	0	1	0	1	0	1

- ISCRL

Address: H'FF0523

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0SCA
Value after reset:	0	1	0	1	0	1	0	1

- ISCRH

Bit	Symbol	Bit Name	Description	R/W
7	IRQ7SCB	IRQ7 sense control B and A	00: Reserved (setting prohibited)	R/W
6	IRQ7SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ7}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ7}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ7}}$ input.	
5	IRQ6SCB	IRQ6 sense control B and A	00: Reserved (setting prohibited)	R/W
4	IRQ6SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ6}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ6}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ6}}$ input.	

Bit	Symbol	Bit Name	Description	R/W
3	IRQ5SCB	IRQ5 sense control B and A	00: Reserved (setting prohibited)	R/W
2	IRQ5SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ5}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ5}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ5}}$ input.	
1	IRQ4SCB	IRQ4 sense control B and A	00: Reserved (setting prohibited)	R/W
0	IRQ4SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ4}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ4}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ4}}$ input.	

- ISCRL

Bit	Symbol	Bit Name	Description	R/W
7	IRQ3SCB	IRQ3 sense control B and A	00: Reserved (setting prohibited)	R/W
6	IRQ3SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ3}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ3}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ3}}$ input.	
5	IRQ2SCB	IRQ2 sense control B and A	00: Reserved (setting prohibited)	R/W
4	IRQ2SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ2}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ2}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ2}}$ input.	
3	IRQ1SCB	IRQ1 sense control B and A	00: Reserved (setting prohibited)	R/W
2	IRQ1SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ1}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ1}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ1}}$ input.	
1	IRQ0SCB	IRQ0 sense control B and A	00: Reserved (setting prohibited)	R/W
0	IRQ0SCA		01: Interrupt request is generated at falling edge of $\overline{\text{IRQ0}}$ input.	
			10: Interrupt request is generated at rising edge of $\overline{\text{IRQ0}}$ input.	
			11: Interrupt request is generated at both falling and rising edges of $\overline{\text{IRQ0}}$ input.	

4.2.5 IRQ Status Register (ISR)

Address: H'FF0524

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F	IRQ0F
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	IRQ7F	IRQ7 flag	[Setting condition] • When the interrupt source selected by ISCR occurs. [Clearing conditions] • When 1 is read from the bit and then 0 is written to the same bit. • When IRQn interrupt exception handling is executed while falling, rising, or both-edge detection is set. • When the DTC is activated by an IRQn interrupt and the DISEL bit in MRB of the DTC is 0.	R/W
6	IRQ6F	IRQ6 flag		R/W
5	IRQ5F	IRQ5 flag		R/W
4	IRQ4F	IRQ4 flag		R/W
3	IRQ3F	IRQ3 flag		R/W
2	IRQ2F	IRQ2 flag		R/W
1	IRQ1F	IRQ1 flag		R/W
0	IRQ0F	IRQ0 flag		R/W

4.2.6 IRQ Noise Canceler Control Register (INCCR)

Address: H'FF0525

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	INCCR[5:4]		INCCR[3:2]		INCCR[1:0]	
Value after reset:	0	0	1	1	1	1	1	1

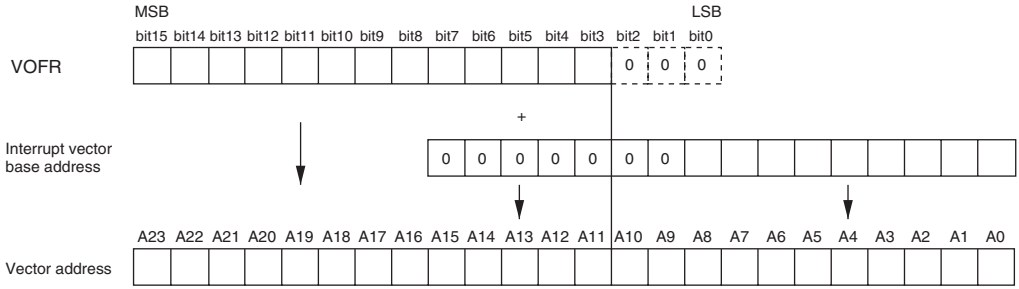
Bit	Bit Name	Initial Value	Description	R/W
7 6	—	Reserved	These bits are always read as 0. The write value should always be 0.	—
5 4	INCCR[5:4]	Noise cancel performance setting 5 and 4 for $\overline{\text{NMI}}$ pin	00: TBD 01: Twice of the TBD 10: Four times of the TBD 11: Eight times of the TBD	R/W
3 2	INCCR[3:2]	Noise cancel performance setting 3 and 2 for $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ4}}$ pins	00: TBD 01: Twice of the TBD 10: Four times of the TBD 11: Eight times of the TBD	R/W
1 0	INCCR[1:0]	Noise cancel performance setting 1 and 0 for $\overline{\text{IRQ3}}$ to $\overline{\text{IRQ0}}$ pins	00: TBD 01: Twice of the TBD 10: Four times of the TBD 11: Eight times of the TBD	R/W

Note: Noise cancel performance varies according to the manufacturing condition, temperature, and V_{cc}.

4.2.7 Interrupt Vector Offset Register (VOFR)

Address: H'FF0526

Bit:	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



VOFR is a 16-bit readable/writable register that sets an offset for an interrupt vector address. Interrupt vector areas other than the trace interrupt area and trap instruction interrupt area can be varied with the offset. The upper 13 bits are used to set the offset for the interrupt vector address (A23 to A11). Bits 2 to 0 are reserved. The write value should always be 0. This register also can be accessed in 8-bit units.

The vector address can be obtained by adding the VOFR value to the interrupt vector base address as shown above, except for the trace interrupt and trap instruction interrupt.

This register is initialized to H'0000 by a reset.

4.2.8 Event Link Interrupt Control Status Register (ELCSR)

Address: H'FF0528

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	ELIE2	ELIE1	ELF2	ELF1
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	—	Reserved	These bits are read as 0. The write value should be 0.	—
3	ELIE2	ELC interrupt 2 enable	0: ELF2 interrupts are disabled. 1: ELF2 interrupts are enabled.	R/W
2	ELIE1	ELC interrupt 1 enable	0: ELF1 interrupts are disabled. 1: ELF1 interrupts are enabled.	R/W
1	ELF2	ELC interrupt flag 2	[Setting condition] • When the event selected by ELSR30 occurs*[1] [Clearing conditions] • When 1 is read from this bit and then 0 is written to the same bit. • When the DTC is activated by an ELF2 interrupt, and the DISEL bit in MRB of the DTC is 0.*[2]	R/W
0	ELF1	ELC interrupt flag 1	[Setting condition] • When the event selected by ELSR12 occurs*[1] [Clearing conditions] • When 1 is read from this bit and then 0 is written to the same bit. • When the DTC is activated by an ELF1 interrupt, and the DISEL bit in MRB of the DTC is 0.*[2]	R/W

Notes: 1. For details, see section 12, Event Link Controller.
2. When the DTC is activated by an ELF1 or ELF2 interrupt, the event link source module is not affected.

4.3 Interrupt Sources

4.3.1 External Interrupt sources

There are nine external interrupts: NMI and IRQ7 to IRQ0. These external interrupts can be used to cause the device to exit from standby mode.

(1) NMI Interrupt

The nonmaskable interrupt request (NMI) is the highest-priority interrupt, and always accepted by the CPU regardless of the interrupt control mode or the status of the CPU interrupt mask bits. The NMIEG bit in INTCR can be used to select whether an interrupt is requested at a rising edge or a falling edge on the NMI pin.

(2) IRQ7 to IRQ0 Interrupts

Interrupts IRQ7 to IRQ0 are generated by an input signal at pins $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$. IRQ7 to IRQ0 interrupts have the following features:

- Using ISCR, it is possible to select whether an interrupt on the $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input pins is generated by a falling edge, rising edge, or both edges.
- Enabling or disabling of interrupt requests IRQ7 to IRQ0 can be selected with IER.
- The interrupt priority level can be set with IPR.
- The status of interrupt requests IRQ7 to IRQ0 is indicated in ISR. ISR flags can be cleared to 0 by software.

A block diagram of interrupts IRQ7 to IRQ0 is shown in figure 4.2.

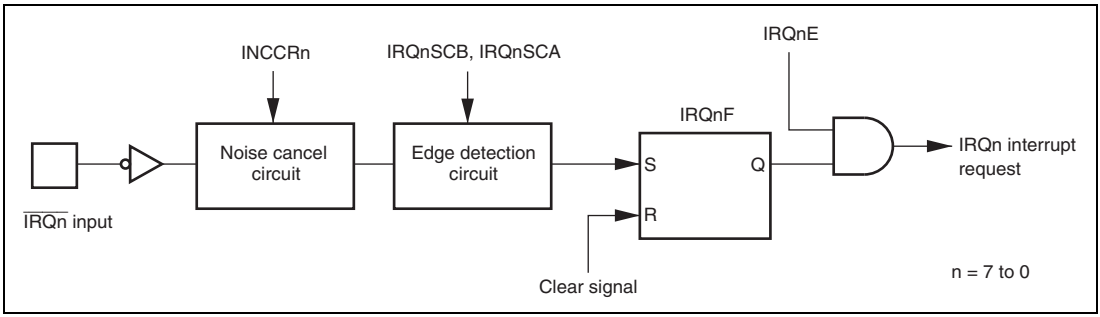


Figure 4.2 Block Diagram of IRQ7 to IRQ0 Interrupt

4.3.2 Internal Interrupts

The sources for internal interrupts from on-chip peripheral modules have the following features:

- For each on-chip peripheral module there are flags that indicate the interrupt request status, and enable bits that select enabling or disabling of these interrupts. They can be controlled independently. When the enable bit is set to 1, an interrupt request is issued to the interrupt controller.
- The interrupt priority level can be set by means of IPR.
- The DTC can be activated by a peripheral module interrupt request.
- When the DTC is activated by an interrupt request, it is not affected by the interrupt control mode or CPU interrupt mask bit.

4.4 Interrupt Exception Handling Vector Table

Table 4.3 shows interrupt exception handling sources, vector addresses, and interrupt priorities.

For default priorities, the lower the vector number, the higher the priority. When interrupt control mode 2 is set, priorities among modules can be changed by the IPR. Modules set at the same priority will conform to their default priorities. Priorities within a module are fixed.

Table 4.3 Interrupt Sources, Vector Addresses, and Interrupt Priorities

Origin of Interrupt Source	Interrupt Source	Vector Number	Vector Address*[1]	DTCER	IPR	Priority
$\overline{\text{RES}}$ Pin	Reset	0	H'0000 to H'0003	—	—	High
WDT	1. $\overline{\text{RES}}$ pin reset					▲
VLD	2. WDT overflow					
	3. LVD reset					
	4. Software reset					
—	Reserved	1 to 4	H'0004 to H'0013	—	—	
CPU	Trace	5	H'0014 to H'0017	—	—	
—	Reserved	6	H'0018 to H'001B	—	—	
External pin	NMI	7	H'001C to H'001F	—	—	
CPU	TRAPA0 (TRAPA #0 instruction)	8	H'0020 to H'0023	—	—	
	TRAPA0 (TRAPA #1 instruction)	9	H'0024 to H'0027	—	—	
	TRAPA0 (TRAPA #2 instruction)	10	H'0028 to H'002B	—	—	
	TRAPA0 (TRAPA #3 instruction)	11	H'002C to H'002F	—	—	
—	Reserved	12 to 15	H'0030 to H'003F	—	—	
FLASH	IFMBSYA (access when flash memory busy)	16	H'0040 to H'0043	—	—	
	IFLRDY (flash memory ready)	17	H'0044 to H'0047	—	IPRA7 and IPRA6	
WDT	IWDT (WDT periodic interrupt)	18	H'0048 to H'004B	—	IPRA5 and IPRA4	
LVD	ILVINT1 (low-voltage detected interrupt 1)	19	H'004C to H'004F	—	IPRA3 and IPRA2	
	ILVINT2 (low-voltage detected interrupt 2)	20	H'0050 to H'0053	—		
CPG	ICKSW (clock switching interrupt)	21	H'0054 to H'0057	—	IPRA1 and IPRA0	▼ Low

Origin of Interrupt Source	Interrupt Source	Vector Number	Vector Address*[1]	DTCER	IPR	Priority
External pin	IRQ0	22	H'0058 to H'005B	DTCEA7	IPRB7 and IPRB6	High
	IRQ1	23	H'005C to H'005F	DTCEA6	IPRB5 and IPRB4	
	IRQ2	24	H'0060 to H'0063	DTCEA5	IPRB3 and IPRB2	
	IRQ3	25	H'0064 to H'0067	DTCEA4	IPRB1 and IPRB0	
	IRQ4	26	H'0068 to H'006B	DTCEA3	IPRC7 and IPRC6	
	IRQ5	27	H'006C to H'006F	DTCEA2	IPRC5 and IPRC4	
	IRQ6	28	H'0070 to H'0073	DTCEA1	IPRC3 and IPRC2	
	IRQ7	29	H'0074 to H'0077	DTCEA0	IPRC1 and IPRC0	
A/D converter unit 1	IADEND_1 (conversion end)	30	H'0078 to H'007B	DTCEB7	IPRD7 and IPRD6	
	IADCMP_1 (compare condition match)	31	H'007C to H'007F	DTCEB6		
A/D converter unit 2*[2]	IADEND_2 (conversion end)	32	H'0080 to H'0083	DTCEB5	IPRD5 and IPRD4	
	IADCMP_2 (compare condition match)	33	H'0084 to H'0087	DTCEB4		
DTC	ISWDTEND (data transfer end)	34	H'0088 to H'008B	—	IPRD3 and IPRD2	
ELC	ELC1FP (ELSR12 event generation)	35	H'008C to H'008F	DTCEB3	IPRD1 and IPRD0	
	ELC2FP (ELSR30 event generation)	36	H'0090 to H'0093	DTCEB2		Low

Origin of Interrupt Source	Interrupt Source	Vector Number	Vector Address*[1]	DTCER	IPR	Priority
SCI3 channel 1	SCI3_1 ERI 1. Overrun error 2. Parity error 3. Framing error	37	H'0094 to H'0097	—	IPRE7 and IPRE6	High
	SCI3_1 RXI	38	H'0098 to H'009B	DTCEB1		
	SCI3_1 TXI	39	H'009C to H'009F	DTCEB0		
	SCI3_1 TEI	40	H'00A0 to H'00A3	—		
SCI3 channel 2	SCI3_2 ERI 1. Overrun error 2. Parity error 3. Framing error	41	H'00A4 to H'00A7	—	IPRE5 and IPRE4	
	SCI3_2 RXI	42	H'00A8 to H'00AB	DTCEC7		
	SCI3_2 TXI	43	H'00AC to H'00AF	DTCEC6		
	SCI3_2 TEI	44	H'00B0 to H'00B3	—		
SCI3 channel 3	SCI3_3 ERI 1. Overrun error 2. Parity error 3. Framing error	45	H'00B4 to H'00B7	—	IPRE3 and IPRE2	
	SCI3_3 RXI	46	H'00B8 to H'00BB	DTCEC5		
	SCI3_3 TXI	47	H'00BC to H'00BF	DTCEC4		
	SCI3_3 TEI	48	H'00C0 to H'00C3	—		
—	Reserved	49 to 58	H'00C4 to H'00EB	—	—	
IIC2/SSU	1. IIC-BUS mode — NAKI — STPI 2. Clock synchronous mode — Overrun 3. SSU mode — Overrun (OEI) — Conflict (CEI)	59	H'00EC to H'00EF	—	IPRF3 and IPRF2	
	RXI	60	H'00F0 to H'00F3	DTCED7		
	TXI	61	H'00F4 to H'00F7	DTCED6		
	TEI	62	H'00F8 to H'00FB	—		Low

Origin of Interrupt Source	Interrupt Source	Vector Number	Vector Address*[1]	DTCER	IPR	Priority
—	Reserved	63 to 68	H'00FC to H'0113	—	—	High
Timer RA/ HW-LIN	1. Timer RA — ITAUD 2. HW-LIN — Bus conflict detection (BCDCT) — Sync Break detection (SBDCT) — Sync Field measurement end (SFDCT)	69	H'0114 to H'0117	—	IPRG5 and IPRG4	
Timer RB	ITBUD	70	H'0118 to H'011B	—	IPRG3 and IPRG2	
Timer RC*[3]	ITCMA (input capture A/compare match A)	71	H'011C to H'011F	DTCED3	IPRG1 and IPRG0	
	ITCMB (input capture B/compare match B)	72	H'0120 to H'0123	DTCED2		
	ITCMC (input capture C/compare match C)	73	H'0124 to H'0127	DTCED1		
	ITCMD (input capture D/compare match D)	74	H'0128 to H'012B	DTCED0		
	ITCOV counter overflow	75	H'012C to H'012F	—		
Timer RD unit 0 channel 0	ITDMA0_0 (input capture A/compare match A)	76	H'0130 to H'0133	DTCEE7	IPRH7 and IPRH6	
	ITDMB0_0 (input capture B/compare match B)	77	H'0134 to H'0137	DTCEE6		Low

Origin of Interrupt Source	Interrupt Source	Vector Number	Vector Address*[1]	DTCER	IPR	Priority
Timer RD unit 0 channel 0	ITDMC0_0 (input capture C/compare match C)	78	H'0138 to H'013B	DTCEE5	IPRH7 and IPRH6	High
	ITCMD0_0 (input capture D/compare match D)	79	H'013C to H'013F	DTCEE4		
	ITDOV0_0 overflow	80	H'0140 to H'0143	—		
	ITDUD0_0 underflow	81	H'0144 to H'0147	—		
Timer RD unit 0 channel 1	ITDMA0_1 (input capture A/compare match A)	82	H'0148 to H'014B	DTCEE3	IPRH5 and IPRH4	
	ITDMB0_1 (input capture B/compare match B)	83	H'014C to H'014F	DTCEE2		
	ITDMC0_1 (input capture C/compare match C)	84	H'0150 to H'0153	DTCEE1		
	ITCMD0_1 (input capture D/compare match D)	85	H'0154 to H'0157	DTCEE0		
	ITDOV0_1 overflow	86	H'0158 to H'015B	—		
Timer RD unit 1 channel 2*[4]	ITDMA1_2 (input capture A/compare match A)	87	H'015C to H'015F	DTCEF7	IPRH3 and IPRH2	
	ITDMB1_2 (input capture B/compare match B)	88	H'0160 to H'0163	DTCEF6		
	ITDMC1_2 (input capture C/compare match C)	89	H'0164 to H'0167	DTCEF5		
	ITCMD1_2 (input capture D/compare match D)	90	H'0168 to H'016B	DTCEF4		
	ITDOV1_2 overflow	91	H'016C to H'016F	—		
	ITDUD1_2 underflow	92	H'0170 to H'0173	—		Low

Origin of Interrupt Source	Interrupt Source	Vector Number	Vector Address*[1]	DTCER	IPR	Priority
Timer RD unit 1 channel 3*[3]	ITDMA1_3 (input capture A/compare match A)	93	H'0174 to H'0177	DTCEE3	IPRH1 and IPRH0	High
	ITDMB1_3 (input capture B/compare match B)	94	H'0178 to H'017B	DTCEE2		
	ITDMC1_3 (input capture C/compare match C)	95	H'017C to H'017F	DTCEE1		
	ITCMD1_3 (input capture D/compare match D)	96	H'0180 to H'0183	DTCEE0		
	ITDOV1_3 overflow	97	H'0184 to H'0187	—		
—	Reserved	98, 99	H'0188 to H'018F	—	—	
Timer RE	Second interrupt	100	H'0190 to H'0193	DTCEG4	IPRI7 and IPRI6	
	Minute interrupt	101	H'0194 to H'0197	DTCEG3		
	Hour interrupt	102	H'0198 to H'019B	DTCEG2		
	Day interrupt	103	H'019C to H'019F	DTCEG1		
	Week interrupt	104	H'01A0 to H'01A3	DTCEG0		
	Compare match	105	H'01A4 to H'01A7	—		
—	Reserved	106 to 108	H'01A8 to H'01B3	—	—	
Timer RG	ITGMA (input capture A/compare match A)	109	H'01B4 to H'01B7	DTCEH3	IPRI3 and IPRI2	
	ITGMB (input capture B/compare match B)	110	H'01B8 to H'01BB	DTCEH2		
	ITGOV	111	H'01BC to H'01BF	—		
	ITGUD	112	H'01C0 to H'01C3	—		Low

Notes: 1. Lower 16 bits of the vector address when VOFR = H'0000
2. Provided for the H8S/20223 group only. This area is reserved for the other groups.
3. Provided for the H8S/20103 group only. This area is reserved for the other groups.
4. Not provided for the H8S/20103 group.

4.5 Interrupt Control Modes and Interrupt Operation

The interrupt controller has two modes: interrupt control mode 0 and interrupt control mode 2. Interrupt operations differ depending on the interrupt control mode. The interrupt control mode is selected by INTCR. Table 4.4 shows the differences between interrupt control mode 0 and interrupt control mode 2.

Table 4.4 Interrupt Control Modes

Interrupt Control Mode	Priority Setting Registers	Interrupt Mask Bits	Description
0	Default	I	The priorities of interrupt sources are fixed at the default settings. Interrupt sources except for NMI is masked by the I bit.
2	IPR	I1 and I0	Four priority levels except for NMI can be set with IPR. Four-level interrupt mask control is performed by bits I1 and I0.

4.5.1 Interrupt Control Mode 0

In interrupt control mode 0, interrupt requests except for NMI is masked by the I bit in CCR of the CPU. Figure 4.3 shows a flowchart of the interrupt acceptance operation in this case.

1. If an interrupt source occurs when the corresponding interrupt enable bit is set to 1, an interrupt request is sent to the interrupt controller.
2. If the I bit is set to 1, only an NMI interrupt is accepted, and other interrupt requests are held pending. If the I bit is cleared, an interrupt request is accepted.
3. When interrupt requests are sent to the interrupt controller, the highest-ranked interrupt request according to the priority system is accepted, and other interrupt requests are retained.
4. When the CPU accepts an interrupt request, it starts interrupt exception handling after execution of the current instruction has been completed.
5. The PC and CCR are saved to the stack area by interrupt exception handling. The PC saved on the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
6. The I bit in CCR is set to 1. This masks all interrupts except NMI.
7. The CPU generates a vector address for the accepted interrupt request and starts execution of the interrupt handling routine at the address indicated by the contents of the start address in the vector table.

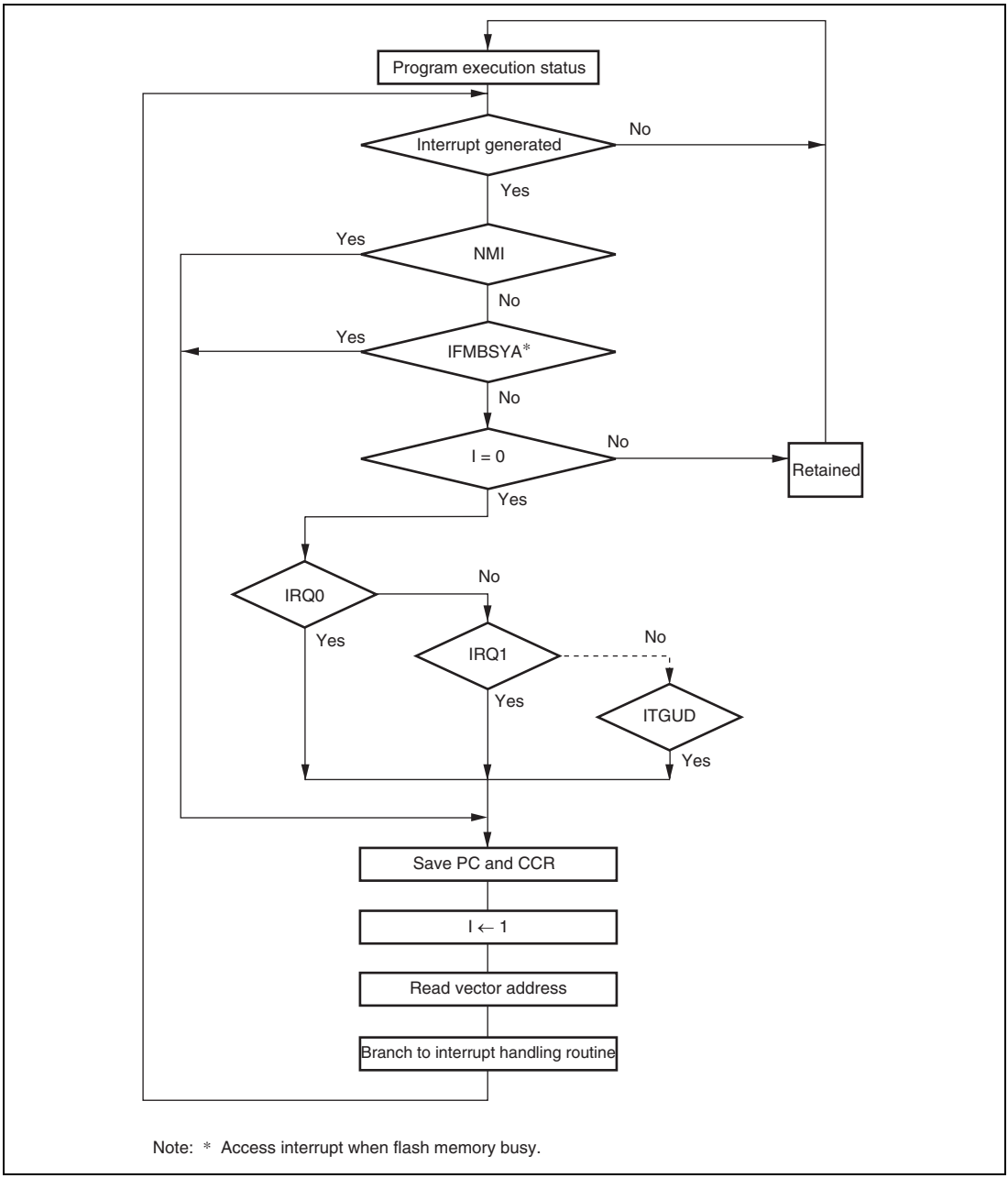


Figure 4.3 Flowchart of Procedure Up to Interrupt Acceptance in Interrupt Control Mode 0

4.5.2 Interrupt Control Mode 2

In interrupt control mode 2, mask control is executed in four levels for interrupt requests except NMI by comparing the EXR interrupt mask level (I1 and I0 bits*) in the CPU and the IPR setting. Figure 4.4 shows a flowchart of the interrupt acceptance operation.

1. If an interrupt source occurs when the corresponding interrupt enable bit is set to 1, an interrupt request is sent to the interrupt controller.
2. When interrupt requests are sent to the interrupt controller, the interrupt with the highest priority according to the interrupt priority levels set in IPR is selected, and lower-priority interrupt requests are held pending. If the same priority are generated at the same time, the interrupt request is selected according to the default priority system shown in table 4.3.
3. Next, the priority of the selected interrupt request is compared with the interrupt mask level set in EXR. An interrupt request with a priority no higher than the mask level set at that time is held pending, and only an interrupt request with a priority higher than the interrupt mask level is accepted.
4. When the CPU accepts an interrupt request, it starts interrupt exception handling after execution of the current instruction has been completed.
5. The PC, CCR, and EXR are saved to the stack area by interrupt exception handling. The PC saved on the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
6. The T bit in EXR is cleared to 0. The interrupt mask level is rewritten with the priority level of the accepted interrupt. If the accepted interrupt is NMI, the interrupt mask level is set to H'3.
7. The CPU generates a vector address for the accepted interrupt request and starts execution of the interrupt handling routine at the address indicated by the contents of the start address in the vector table.

Note: * The I2 bit does not affect the mask control.

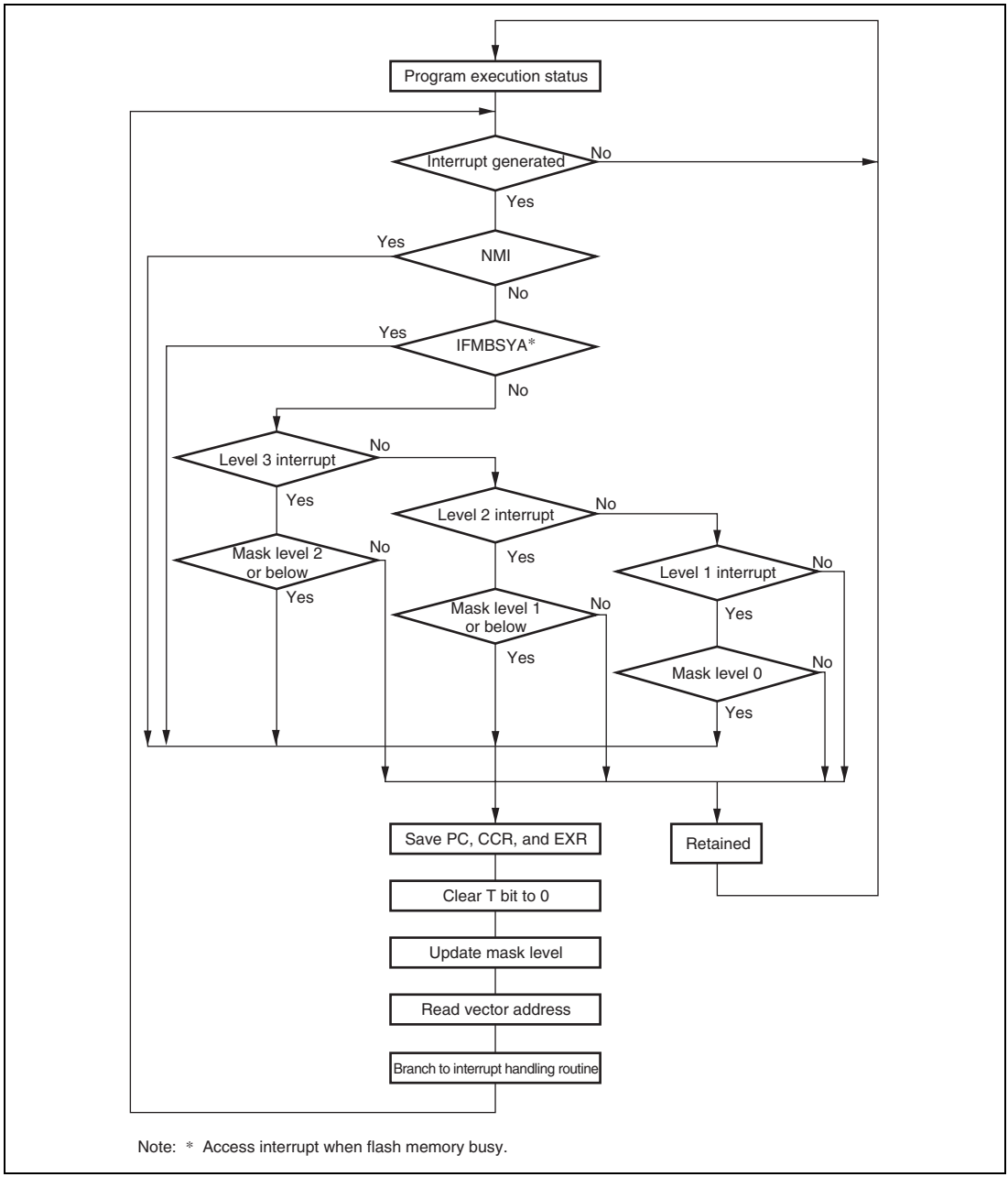


Figure 4.4 Flowchart of Procedure Up to Interrupt Acceptance in Interrupt Control Mode 2

4.5.3 Interrupt Exception Handling Sequence

Figure 4.5 shows the interrupt exception handling sequence. The example shown is for the case where interrupt control mode 0, the program area, and stack area are in on-chip memory.

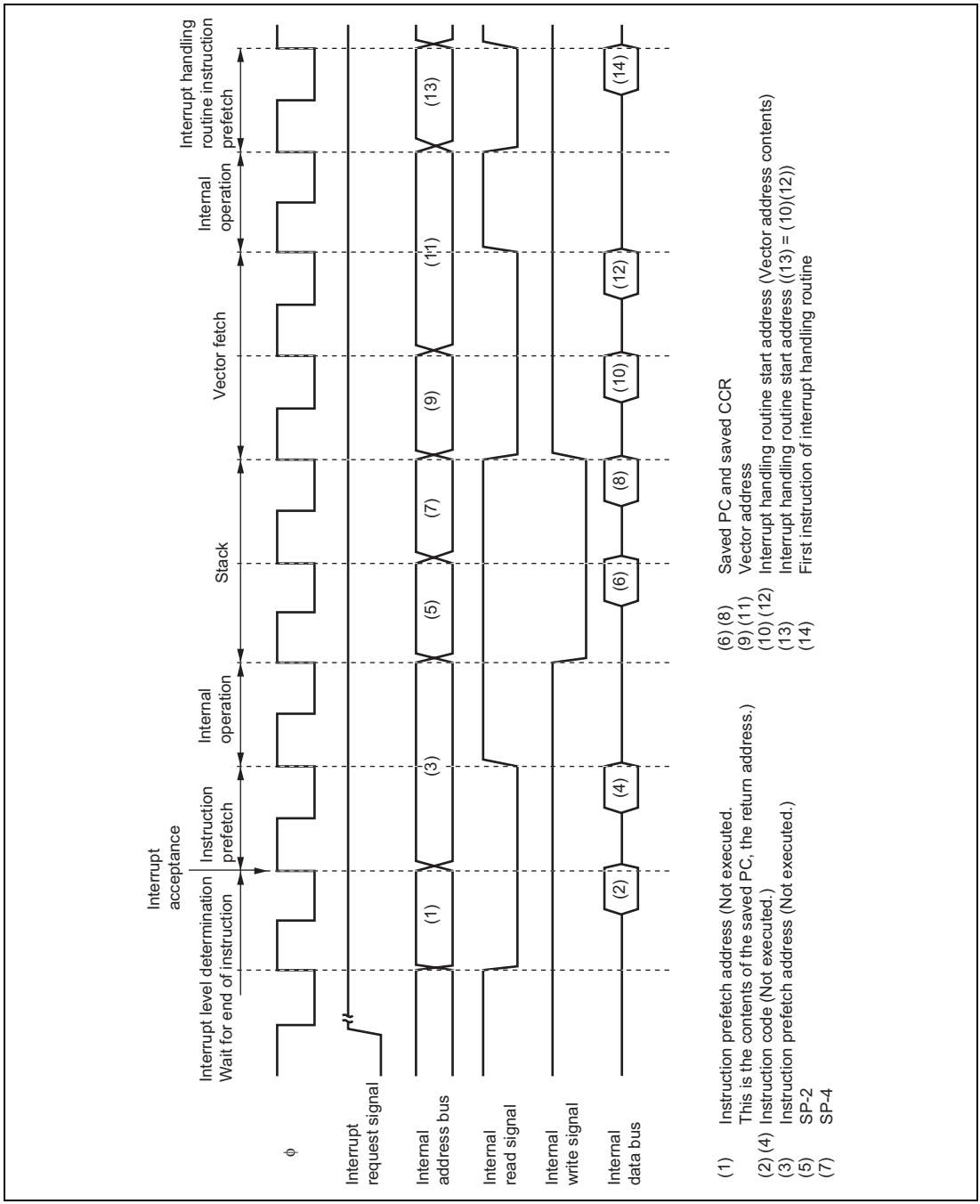


Figure 4.5 Interrupt Exception Handling

4.5.4 Interrupt Response Time

Table 4.5 shows interrupt response time, the interval between generation of an interrupt request and execution of the first instruction in the interrupt handling routine.

Table 4.5 Interrupt Response Times

No.	Execution Status	Interrupt Control Mode 0	Interrupt Control Mode 2
1	Interrupt priority determination*1	3	
2	Number of wait states until executing instruction ends*2	1 to 21	
3	PC, CCR, EXR stack	2	3
4	Vector fetch	2	
5	Instruction fetch*3	2	
6	Internal processing*4	2	
Total (using on-chip memory)		12 to 32	13 to 33

Notes: 1. Two states in case of internal interrupt
2. Refers to MULXS and DIVXS instructions.
3. Prefetch after interrupt acceptance and interrupt handling routine prefetch
4. Internal processing after interrupt acceptance and internal processing after vector fetch

4.5.5 DTC Activation by Interrupt

The DTC can be activated by an interrupt request. In this case, the following options are available:

1. Interrupt request to CPU
2. Activation request to DTC
3. Both of the above

For details of interrupt requests that can be used to activate the DTC, see table 4.3 and section 11, Data Transfer Controller (DTC).

4.6 Usage Notes

4.6.1 Conflict between Interrupt Generation and Disabling

When an interrupt enable bit is cleared to 0 to mask interrupt requests, the masking becomes effective after execution of the instruction. When an interrupt enable bit is cleared to 0 by an instruction such as BCLR or MOV, if an interrupt is generated during execution of the instruction, the interrupt concerned is still enabled on completion of the instruction, and so interrupt exception handling for that interrupt will be executed after completion of the instruction. However, if there is an interrupt request of higher priority than that interrupt, interrupt exception handling with the higher-priority interrupt is executed, and that lower-priority interrupt will be ignored. The same also applies when an interrupt source flag is cleared to 0. Figure 4.6 shows an example in which the IRQ0E bit in IER is cleared to 0. The above conflict does not occur if an enable bit or interrupt source flag is cleared to 0 while the interrupt is masked.

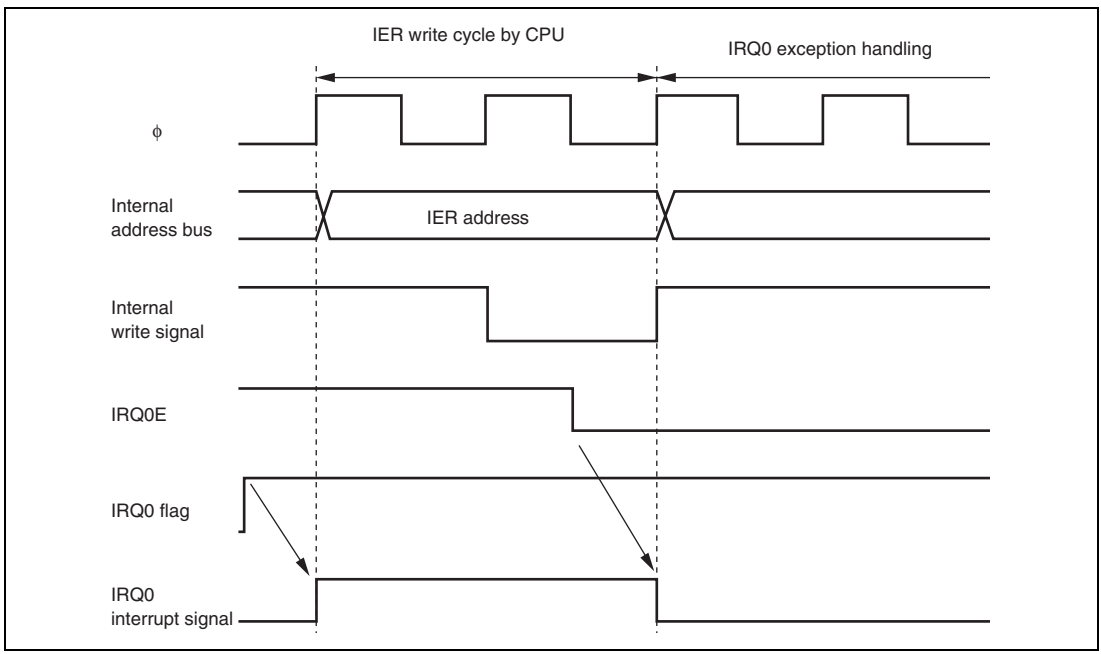


Figure 4.6 Conflict between Interrupt Generation and Disabling

4.6.2 Instructions that Disable Interrupts

Instructions that disable interrupts are LDC, ANDC, ORC, and XORC. After any of these instructions is executed, all interrupts including NMI are disabled and the next instruction is always executed. When the I bit is set by one of these instructions, the new value becomes valid after two states that execution of the instruction ends.

4.6.3 Time when Interrupts are Disabled

There are time when interrupt acceptance is disabled by the interrupt controller. The interrupt controller disables interrupt acceptance for a 3-state period after the CPU has updated the mask level with an LDC, ANDC, ORC, or XORC instruction.

4.6.4 Interrupts during Execution of EEPMOV Instruction

Interrupt operation differs between the EEPMOV.B instruction and the EEPMOV.W instruction.

With the EEPMOV.B instruction, an interrupt request (including NMI) issued during the transfer is not accepted until the transfer is completed.

With the EEPMOV.W instruction, if an interrupt request is issued during the transfer, interrupt exception handling starts at a break in the transfer cycle. The PC value saved on the stack in this case is the address of the next instruction. Therefore, if an interrupt is generated during execution of an EEPMOV.W instruction, the following coding should be used.

```
L1:   EEPMOV.W
      MOV.W     R4,R4
      BNE       L1
```

4.6.5 Changing PMR, ISCRH, ISCRL and INCCR

When the PMR, ISCRH, ISCRL, and INCCR are modified to change an IRQ7 to IRQ0 interrupt function, the interrupt request flag bit may be set to 1 at an unintended time. To prevent this, the pin function should be changed when the interrupt request is disabled, then the interrupt request flag should be cleared to 0 after a specific interval time*.

Figure 4.7 shows the procedure to modify PMR (port mode register), ISCRH, ISCRL, and INCCR and clear the interrupt request flags.

Note: Two states + a minimum interval for input (t_{IH}/t_{IL})

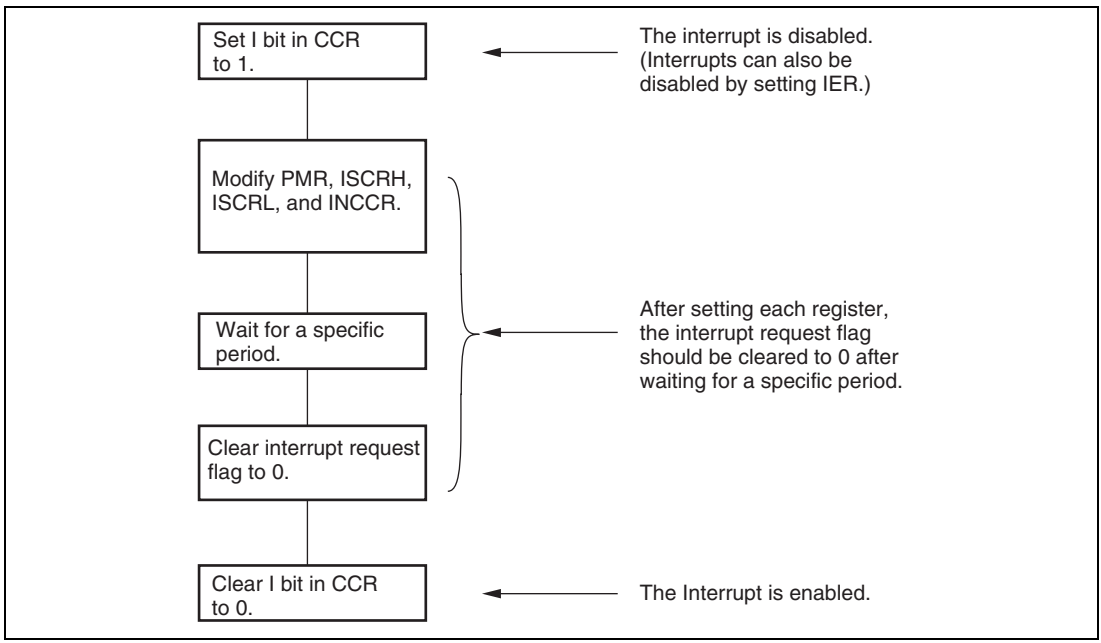


Figure 4.7 Procedure to Modify PMR, ISCRH, ISCRL, and INCCR and Clear Interrupt Request Flag

4.6.6 IRQ Status Register (ISR)

Depending on the pin state after a reset, IRQnF may be set to 1. Therefore, always read ISR and clear it to 0 after resets.

4.6.7 NMI Pin

The NMI pin is also used to set up entry to boot mode on exit from the reset state. In using the NMI pin, note that the low-level should not be being applied to the NMI pins on exit from the reset state (including power-on reset). In general, it is recommended that the connection of a pull-up resistor to the NMI pin.

Section 5 Clock Pulse Generator

The clock pulse generator is comprised of a high-speed on-chip oscillator (OCO), a 1/2 divider for the high-speed OCO, the main oscillator, a duty correction circuit, a low-speed, OCO, a sub-oscillator, a clock selection circuit, a system clock divider, a PSC divider for peripheral modules, and a φs divider for the bus master and memory.

Table 5.1 lists clock source symbols and their meanings used in this manual.

Table 5.1 Clock Source Symbols

Symbol	Description
φ40	High-speed OCO output
φhoco	High-speed OCO frequency/2
φloco	Low-speed OCO output
φosc	Main oscillator output clock
φsub	Sub-oscillator output clock
φhigh	High-speed clock (φhoco or φosc)
φlow	Low-speed clock (φloco or φsub)
φbase	System base clock
φ	System operation clock
φs	Bus master operation clock

5.1 Overview

- Choice of four clock sources:
  ϕloco, ϕsub, ϕhoco and ϕosc
- Choice of two frequencies of the high-speed OCO by the user software:
  40 MHz and 32 MHz
  The signal generated by dividing the above clock by 2 can be used as a ϕbase and the above clock can be used as the clock source for timer RA, timer RC, timer RD, and timer RG.
- Trimmable high-speed OCO oscillation frequencies
  Although the high-speed OCO is trimmed to 40 MHz in its initial state, it can also be trimmed to accommodate specific user operation conditions.
- Main oscillation backup function
  By detecting a ϕosc stop, it is possible to automatically switch the system clock to either ϕhoco or ϕlow.
- Clock switching interrupt function
  When the system clock is switched from ϕosc to ϕhoco or ϕloco, a CPU interrupt can be generated if enabled.

Figure 5.1 shows a block diagram of the clock pulse generation circuit.

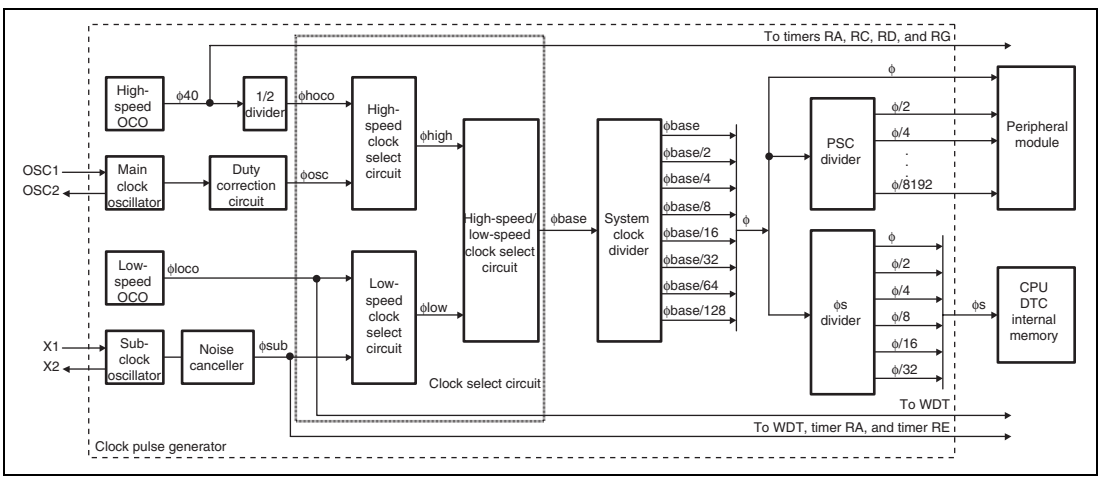


Figure 5.1 Block Diagram of Clock Pulse Generation Circuit

The system base clock (ϕbase) is the basic clock on which the CPU and on-chip peripheral modules operate. ϕbase can be divided by a value from 1 to 128 in the system clock divider, and the divided clock is supplied as the system clock ϕ. The system clock ϕ is divided by a value from 2 to 8192 in the PSC divider, and the divided clock can be supplied to on-chip peripheral modules. The system clock ϕ is also divided by a value from 1 to 32 in the ϕs divider, and the divided clock can be supplied to the bus master and memory.

After release from a reset, ϕbase is switched to the low-speed OCO.

5.2 Register Descriptions

- Backup control register (BAKCR)
- System clock control register (SYSCCR)
- Power-down control register 1 (LPCR1)
- Power-down control register 2 (LPCR2)
- Power-down control register 3 (LPCR3)
- OSC oscillation settling control status register (OSCCSR)
- High-speed OCO control register (HOCR)
- High-speed OCO trimming data protect register (HOTRMDPR)
- High-speed OCO trimming data register 1 (HOTRMDR1)
- High-speed OCO trimming data register 2 (HOTRMDR2)
- High-speed OCO trimming data register 3 (HOTRMDR3)
- High-speed OCO trimming data register 4 (HOTRMDR4)

5.2.1 Backup Control Register (BACKR)

Address: H'FF06D4

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	OSCBAKE	BAKCKSEL	CKSWIE	CKSWIF	OSCHLT	—
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE at the same time. [Clearing condition] When 0 is written to WI and WE at the same time.	R/W
5	OSCBAKE	External clock backup enable	0: External clock backup is disabled. 1: External clock backup is enabled.	R/W
4	BAKCKSEL	Backup destination clock source select	0: φlow 1: φhoco	R/W
3	CKSWIE	Clock switching interrupt enable	0: Interrupt requests are disabled. 1: Interrupt requests are enabled.	R/W
2	CKSWIF	Clock switching interrupt flag	0: A clock switching interrupt request has not been generated. 1: A clock switching interrupt request has been generated. [Setting condition] When the system clock for the LSI is switched from φosc to φhoco or φlow while OSCBAKE is 1. [Clearing condition] When 1 is read from the bit and then 0 is written to the same bit.	R/W

Bit	Symbol	Bit Name	Description	R/W
1	OSCHLT	Main oscillator stop detect flag	0: The external main oscillator is oscillating. 1: The external main oscillator is stopped. [Setting condition] When the external main oscillator is stopped while OSCBAKE is 1.	R
0	—	Reserved	This bit is read as 0. The write value should be 0.	—

Note: A MOV instruction should be used to write to this register.

- WI bit (write inhibit)
  This register can be written to only when this bit is 0. This bit is always read as 1.
- WE bit (write enable)
  Bits 5 to 2 in this register can be written to when this bit is 1.
- OSCBAKE bit (external clock backup enable)
  The main oscillator stop detect circuit is enabled when this bit is 1. When this LSI operates at the external main oscillator clock, the backup function is enabled.
  By detecting a ϕosc stop, the system clock is automatically switched to either ϕhoco or ϕlow.
- CKSWIE bit (clock switching interrupt enable)
  The main clock switching interrupt requests are enabled when this bit is 1.
- CKSWIF bit (clock switching interrupt enable)
  This is a clock switching interrupt request flag.
- OSCHLT bit (main oscillator stop detect flag)
  When the OSCBAKE bit is 1, this bit indicates the results of external oscillator stop detection. This bit, however, simply indicates whether the oscillator is active or not; it does not indicate a stable oscillation. When OSCBAKE is 0, this bit is always read as 0. An oscillator stop is detected when the external oscillator is between 0 to 2 MHz.

5.2.2 System Clock Control Register (SYSCCR)

Address: H'FF06D0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	PHIHSEL	PHILSEL	—	SUBNC[1:0]		—
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE at the same time. [Clearing condition] When 0 is written to WI and WE at the same time.	R/W
5	PHIHSEL	ϕhigh clock source select	0: ϕhoco 1: ϕosc [Setting condition] When 1 is written to this bit while CKSWIF in BAKCR is 0. [Clearing conditions] • When 0 is written to this bit. • When the main oscillator stop state is detected while the system clock selects ϕosc and OSCBAKE and BAKCKSEL in BAKCR are 1, respectively.	R/W
4	PHILSEL	ϕlow clock source select	0: ϕloco 1: ϕsub	R/W
3	—	Reserved	This bit is read as 0. The write value should be 0.	—

Bit	Symbol	Bit Name	Description	R/W
2, 1	SUBNC [1:0]*	ϕsub noise canceler sampling function setting	00: The sampling circuit is disabled. 01: Sampling is performed at ϕbase/4. 10: Sampling is performed at ϕbase/16. 11: Setting prohibited	R/W
0	—	Reserved	This bit is read as 0. The write value should be 0.	—

Note: A MOV instruction should be used to write to this register.

* When the operation clock of the CPU selects ϕlow, the sampling circuit is disabled regardless of this bit setting.

- WI bit (write inhibit)

  This register can be written to only when this bit is 0. This bit is always read as 1.

- WE bit (write enable)

  Bits 5, 4, 2, and 1 in this register can be written to when this bit is 1.

- PHIHSEL bit (ϕhigh clock source select)

  This bit is 1 when 0 is written to the WI bit in BAKCR at CKSWIF = 0 and WE = 1 and then 1 is written to this bit. If 0 is written to WI and this bit at WE = 1, this bit remains 0. If the main oscillator stop is detected while the system clock selects ϕosc and OSCBAKE and BAKCKSEL in BAKCR are 1, respectively, this bit is 0.

- PHILSEL bit (ϕlow clock source select)

  When 0 is written to WI and 1 is written to this bit at WE = 1, this bit is 1.

  When 0 is written to WI and this bit at WE = 1, this bit is 0.

- SUBNC1 and SUBNC0 bits (ϕsub noise canceler sampling function setting)

  Selects a sampling clock for the subclock oscillator noise canceler. The sampling circuit is disabled in standby mode, when ϕbase is stopped during clock switching, and when ϕlow has been selected as ϕbase, regardless of the setting of this bit. When timer RE is to be used in real-time clock mode, the sampling circuit should be enabled.

Note: The frequency of the low-speed on-chip oscillator varies greatly according to the power supply voltage and operating temperature. In designing application systems, allow sufficient margins for frequency variation.

5.2.3 Power-Down Control Register 1 (LPCR1)

Address: H'FF06D1

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	SSBY	PSCSTP	SLEEPRS	STBYRS	—	PHIBSEL
Value after reset:	1	0	0	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE at the same time. [Clearing condition] When 0 is written to WI and WE at the same time.	R/W
5	SSBY	Software standby	0: A transition is made to sleep mode. 1: A transition is made to standby mode.	R/W
4	PSCSTP	PSC divider stop	0: PSC divider is operating. 1: PSC divider is stopped*.	R/W
3	SLEEPRS	ϕ source select for recovery from sleep mode	0: ϕlow 1: ϕhigh	R/W
2	STBYRS	ϕ source select for recovery from standby mode	0: ϕlow 1: ϕhigh	R/W
1	—	Reserved	This bit is read as 0. The write value should be 0.	—

Bit	Symbol	Bit Name	Description	R/W
0	PHIBSEL	ϕbase clock source select	0: ϕlow 1: ϕhigh [Setting conditions] • When 1 is written to this bit. • When the system returns from sleep mode while SLEEPRS is 1. • When the system returns from standby mode while STBYRS is 1. [Clearing conditions] • When 0 is written to this bit. • When the main oscillator backup is generated while BAKCKSEL in BAKCR is 0. • When the system returns from sleep mode while SLEEPRS is 0. • When the system returns from standby mode while STBYRS is 0.	R/W

Note: A MOV instruction should be used to write to this register.

* Operations of the peripheral modules using the ϕ clock are not affected by this bit setting.

- WI bit (write inhibit)

  This register can be written to only when this bit is 0. This bit is always read as 1.

- WE bit (write enable)

  Bits 5 to 2 in this register can be written to when this bit is 1.

- SSBY bit (software standby)

  Selects a mode to be entered after the SLEEP instruction is executed.

- PSCSTP bit (PSC divider stop)

  Stops the PSC divider circuit when this bit is 1. Peripheral modules using ϕ/2 to ϕ/8192 clocks stop operation. (The register values are retained.)

- SLEEPRS bit (ϕ source select for recovery from sleep mode)

  Selects a clock source to be used when a transition is made from sleep mode to active mode.

- STBYRS bit (φ source select for recovery from standby mode)
  Selects a clock source to be used when a transition is made from standby mode to active mode.

- PHIBSEL bit (φbase clock source select)
  Selects a clock source for the φbase to be used in active mode or sleep mode.

5.2.4 Power-Down Control Register 2 (LPCR2)

Address: H'FF06D2

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	—	—	—	PHI[2:0]		
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE at the same time. [Clearing condition] When 0 is written to WI and WE at the same time.	R/W
5 to 3	—	Reserved	These bits are read as 0. The write value should be 0.	—
2 to 0	PHI[2:0]	System clock φ select	000: φbase 001: φbase/2 010: φbase/4 011: φbase/8 100: φbase/16 101: φbase/32 110: φbase/64 111: φbase/128	R/W

Note: A MOV instruction should be used to write to this register.

- WI (write inhibit)
  This register can be written to only when this bit is 0. This bit is always read as 1.

- WE bit (write enable)
  Bits 2 to 0 in this register can be written to when this bit is 1.

- PHI2 bit to PHI0 bit (system clock ϕ select)
  Selects a clock source for the system clock ϕ to be used in active mode or sleep mode. The clock is changed immediately after this bit is set.

5.2.5 Power-Down Control Register 3 (LPCR3)

Address: H'FF06D3

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	STBYINT	SLEEPINT	—	PHIS[2:0]		
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE at the same time. [Clearing condition] When 0 is written to WI and WE at the same time.	R/W
5	STBYINT	Standby mode interrupt generation flag	0: No interrupt has occurred in standby mode. 1: An interrupt has occurred in standby mode. [Setting condition] When an interrupt is generated in standby mode. [Clearing condition] When an interrupt is generated in states other than standby mode.	R/W

Bit	Symbol	Bit Name	Description	R/W
4	SLEEPINT	Sleep mode interrupt generation flag	0: No interrupt has occurred in sleep mode. 1: An interrupt has occurred in sleep mode. [Setting condition] When an interrupt is generated in sleep mode. [Clearing condition] When an interrupt is generated in states other than sleep mode.	R/W
3	—	Reserved	This bit is read as 0. The write value should be 0.	—
2 to 0	PHIS[2:0]	Bus master operation clock φs select	000: φ 001: φ/2 010: φ/4 011: φ/8 100: φ/16 101: φ/32 110: Setting prohibited 111: Setting prohibited	R/W

Note: A MOV instruction should be used to write to this register.

- WI bit (write inhibit)

  This register can be written to only when this bit is 0. This bit is always read as 1.

- WE bit (write enable)

  Bits 2 to 0 in this register can be written to when this bit is 1.

- STBYINT bit (standby mode interrupt generation flag)

  This bit is set to 1 when an interrupt is generated in standby mode. This bit is cleared to 0 when an interrupt is generated in the other state.

- SLEEPINT bit (sleep mode interrupt generation flag)

  This bit is set to 1 when an interrupt is generated in sleep mode. This bit is cleared to 0 when an interrupt is generated in the other state.

- PHIS2 bit to PHIS0 bit (bus master operation clock φs select)

  Selects a clock source for the bus master operation clock φs to be used in active mode or sleep mode. The clock is changed immediately after this bit is set.

5.2.6 OSC Oscillation Settling Control Status Register (OSCCSR)

Address: H'FF06D5

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	STS[3:0]			
Value after reset:	0	0	0	0	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as unknown value. The write value should be 0.	—
6 to 4	—	Reserved	These bits are read as 0. The write value should be 0.	—
3 to 0	STS[3:0]	ϕosc oscillation settling time select 3 to 0	Specifies the number of wait states for a stable ϕosc oscillation. For the relationship between assigned values and the numbers of wait states, see table 5.2.	R/W

- STS3 bit to STS0 bit (ϕosc oscillation settling time select 3 to 0)

  Specifies the number of wait states for a stable ϕosc oscillation. The count clock is ϕosc. Table 5.2 shows the relationship between assigned values and the numbers of wait states. If the system base clock is ϕosc when the system returns from the standby mode, or when the system base clock is switched to ϕosc, set these bits so that wait time will be 6.5 ms or greater depending on the frequency of the oscillator.

  If the ϕosc is already oscillating stably or the ϕosc is an external clock input, wait time can be selected from 16 states (STS[3:0]=B'0000).

Table 5.2 Relationship between Operation Frequency and Number of Wait States

Bit				Number of	Operation Frequency				
STS3	STS2	STS1	STS0	Wait States	20 MHz	16 MHz	10 MHz	8 MHz	4 MHz
0	0	0	0	16 states	0.00	0.00	0.00	0.00	0.00
0	0	0	1	32 states	0.00	0.00	0.00	0.00	0.01
0	0	1	0	64 states	0.00	0.00	0.01	0.01	0.02
0	0	1	1	128 states	0.01	0.01	0.01	0.02	0.03
0	1	0	0	256 states	0.01	0.02	0.03	0.03	0.06
0	1	0	1	512 states	0.03	0.03	0.05	0.06	0.13
0	1	1	0	1024 states	0.05	0.06	0.10	0.13	0.26
0	1	1	1	2048 states	0.10	0.13	0.20	0.26	0.51
1	0	0	0	4096 states	0.20	0.26	0.41	0.51	1.02
1	0	0	1	8192 states	0.41	0.51	0.82	1.02	2.05
1	0	1	0	16384 states	0.82	1.02	1.64	2.05	4.10
1	0	1	1	32768 states	1.64	2.05	3.28	4.10	8.19
1	1	0	0	65536 states	3.28	4.10	6.55	8.19	16.38
1	1	0	1	131072 states	6.55	8.19	13.11	16.38	32.77
1	1	1	0	262144 states	13.11	16.38	26.21	32.77	65.54
1	1	1	1	Reserved	—	—	—	—	—

5.2.7 High-Speed OCO Control Register (HOCR)

Address: H'FF062A

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

Bit	Symbol	Bit Name	Description	R/W
7	HOCOE	High-speed OCO enable	0: The high-speed OCO is not used (standby state). 1: The high-speed OCO is used.	R/W
6 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

- HOCOE bit (high-speed OCO enable)
  Controls operation of the high-speed OCO.

5.2.8 High-Speed OCO Trimming Data Protect Register (HOTRMDPR)

Address: H'FF062B

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	WI	WE	LOCKDW	TRMDRWE	–	–	–	–
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WI	Write inhibit	0: Writing is permitted. 1: Writing is inhibited.	W
6	WE	Write enable	0: Writing is disabled. 1: Writing is enabled. [Setting condition] When 0 is written to WI and 1 is written to WE at the same time. [Clearing condition] When 0 is written to WI and WE at the same time.	R/W
5	LOCKDW	Trimming data register lock down	0: HOTRMDR1 can be written to. 1: HOTRMDR1 cannot be written to. [Setting condition] When 0 is written to WI and 1 is written to LOCKDW while WE is 1. [Clearing condition] Reset.	R/W
4	TRMDRWE	Trimming data register write enable	0: Writing to HOTRMDR1 is prohibited. 1: Writing to HOTRMDR1 is permitted. [Setting condition] When 0 is written to WI and 1 is written to TRMDRWE while WE is 1. [Clearing condition] When 0 is written to WI and TRMDRWE while WE is 1.	R/W
3 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

Note: A MOV instruction should be used to write to this register.

- WI bit (write inhibit)
  This register can be written to only when this bit is 0. This bit is always read as 1.

- WE bit (write enable)
  Bits 5 and 4 in this register can be written to when this bit is 1.

- LOCKDW bit (trimming data register lock down)
  HOTRMDR1 cannot be written to when this bit is 1. Once this bit is set to 1, writing to HOTRMDR1 is prohibited, even if 0 is written to this bit, until a reset is applied.

- TRMDRWE bit (trimming data register write enable)
  Writing to HOTRMDR1 is enabled when LOCKDW is 0 and TRMDRWE is 1.

5.2.9 High-Speed OCO Trimming Data Register 1 (HOTRMDR1)

Address: H'FF062C

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	HOTRMDR1[7:0]							
Value after reset:	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined

Bit	Symbol	Bit Name	Description	R/W
7 to 0	HOTRMDR1 [7:0]	Trimming data 1	High-speed OCO frequency trimming data (40 MHz)	R/W

- HOTRMDR17 bit to HOTRMDR10 bit (trimming data 17 to 10)
  Immediately after a reset, trimming data that produces a 40-MHz oscillation is loaded into the LSI, and the data is written to this register. Reading these bits yields an undefined value.
  If this register is to be used for timing a 32-MHz oscillation, before setting the HOCOE bit in HOCR to 1, write the value stored in HOTRMDR3 into HOTRMDR1.
  By rewriting bits 7 to 0 of this register, the high-speed OCO can be trimmed to the desired frequency. When these bits are rewritten, the oscillator frequency of the high-speed OCO is modified after the oscillation has become stable.
  The frequency changes as follows:
  B'00000000 (minimum frequency) → B'11111111 (maximum frequency)

5.2.10 High-Speed OCO Trimming Data Register 2 (HOTRMDR2)

Address: H'FF062D

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	HOTRMDR2[7:0]							
Value after reset:	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined

Bit	Symbol	Bit Name	Description	R/W
7 to 0	HOTRMDR2 [7:0]	Trimming data 2	High-speed OCO frequency trimming data (40 MHz)	R/W

Note: Bit 7 should not be modified when the frequency is trimmed to a desired frequency.

- HOTRMDR27 bit to HOTRMDR20 bit (trimming data 27 to 20)

  Immediately after a reset, trimming data that produces a 40-MHz oscillation is loaded into the LSI, and the data is written to this register. Reading these bits yields an undefined value.

  If this register is to be used for timing a 32-MHz oscillation, before setting the HOCOE bit in HOCR to 1, write the value stored in HOTRMDR4 into HOTRMDR2.

5.2.11 High-Speed OCO Trimming Data Register 3 (HOTRMDR3)

Address: H'FF062E

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	HOTRMDR3[7:0]							
Value after reset:	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined

Bit	Symbol	Bit Name	Description	R/W
7 to 0	HOTRMDR3 [7:0]	Trimming data 3	High-speed OCO frequency trimming data (32 MHz)	R/W

Note: Bit 7 should not be modified when the frequency is trimmed to a desired frequency.

- HOTRMDR37 bit to HOTRMDR30 bit (trimming data 37 to 30)

  Immediately after a reset, trimming data that produces a 32-MHz oscillation is loaded into the LSI, and the data is written to this register. Reading these bits yields an undefined value.

  If 32-MHz oscillation is required then before setting the HOCOE bit in HOCR to 1, copy the value stored in this register to HOTRMDR1.

5.2.12 High-Speed OCO Trimming Data Register 4 (HOTRMDR4)

Address: H'FF062F

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	HOTRMDR4[7:0]							
Value after reset:	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined

Bit	Symbol	Bit Name	Description	R/W
7 to 0	HOTRMDR4 [7:0]	Trimming data 4	High-speed OCO frequency trimming data (32 MHz)	R/W

Note: Bit 7 should not be modified when the frequency is trimmed to a desired frequency.

- HOTRMDR47 bit to HOTRMDR40 bit (trimming data 47 to 40)

  Immediately after a reset, trimming data that produces a 32-MHz oscillation is loaded into the LSI, and the data is written to this register. Reading these bits yields an undefined value.

  If 32-MHz oscillation is required, then before setting the HOCOE bit in HOCR to 1, copy the value stored in this register to HOTRMDR2.

5.3 Operation of Selection of System Base Clock

After a reset, this LSI enters active mode operating in low-speed clocks. The user, by means of software, can change the system base clock from a low-speed OCO clock to a high-speed OCO clock, the main oscillator clock, or a sub-oscillator clock.

Figure 5.2 shows a transition diagram between system base clock states. Table 5.3 shows conditions under which clock sources can be switched.

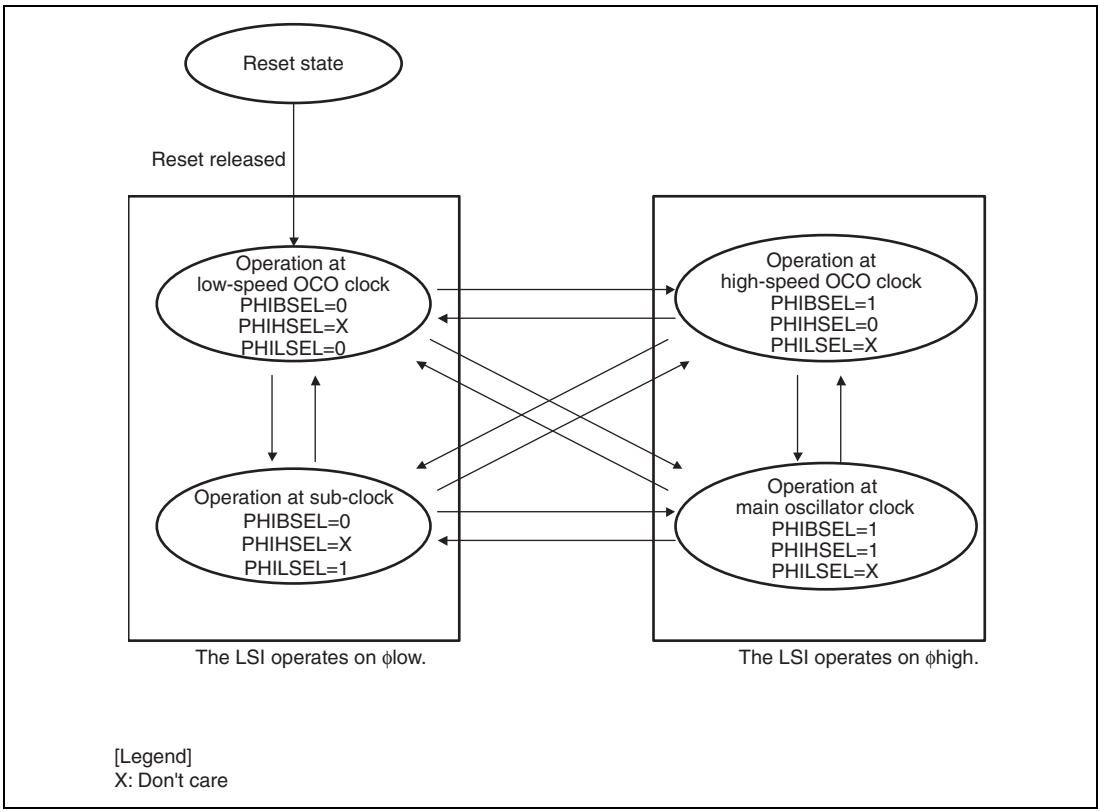


Figure 5.2 Transition Diagram between LSI System Base Clock States

Table 5.3 Clock Source Switching

Bit			
PHIBSEL	**PHIHSEL**	**PHILSEL**	**Switching Operation**
0	Don't care	0 → 1	φloco → φsub
0	Don't care	1 → 0	φsub → φloco
1	0 → 1	Don't care	φhoco → φosc
1	1 → 0	Don't care	φosc → φhoco
0 → 1	0	0	φloco → φhoco
1 → 0	0	0	φhoco → φloco
0 → 1	0	1	φsub → φhoco
1 → 0	0	1	φhoco → φsub
0 → 1	1	0	φhoco → φosc
1 → 0	1	0	φosc → φhoco
0 → 1	1	1	φsub → φosc
1 → 0	1	1	φosc → φsub

Table 5.4 shows the high-speed OCO, low-speed OCO, main oscillator, and sub-oscillator operation states in each operating mode (system state).

Table 5.4 Clock Operation States in Each Operating Mode

System State	System Clock	High-Speed OCO Sate	Main Oscillator State	Low-Speed OCO State	Sub-Oscillator State
Reset released	φloco	Stopped	Stopped	Oscillating	Oscillating*4
Active mode, sleep mode	φhoco	Oscillating	Depending on user setting*2	Oscillating	
	φosc	Depending on user setting*1	Depending on user setting*3	Oscillating	
	φloco	Depending on user setting*1	Depending on user setting*2	Oscillating	
	φsub	Depending on user setting*1	Depending on user setting*2	Oscillating	
Standby mode	None	Stopped	Stopped	Oscillating	

Notes: 1. Can be set with the HOCOE bit in HOCR.
2. Can be set with the PMRJ[1:0] bits in PMRJ.
3. Backup operation is performed by selecting the oscillation stop with the PMRJ[1:0] bits in PMRJ when the backup function is enabled.
4. A crystal resonator should be connected when a sub-oscillator clock is used. To switch the system base clock to φsub immediately after the power-on, oscillation settling time for the sub-oscillator should be ensured.

5.3.1 Switching System Base Clock to ϕhoco

Figure 5.3 shows a flowchart of the process in which the LSI automatically ensures oscillation settling time for the high-speed OCO and switches from ϕloco to a high-speed OCO. Figure 5.4 shows a flowchart of the process in which a user ensures high-speed OCO settling time and switches from ϕloco to a high-speed OCO.

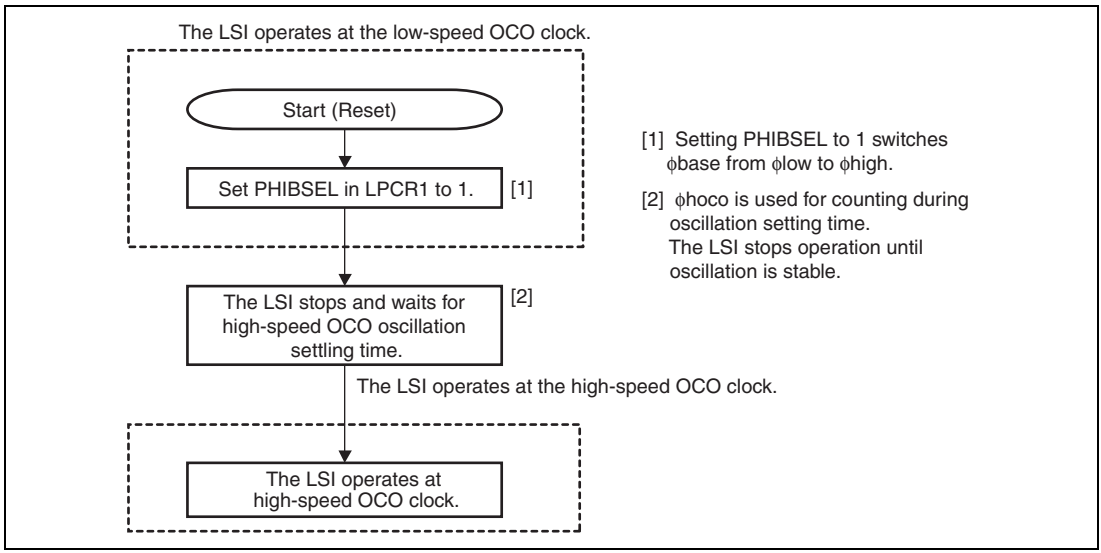


Figure 5.3 Flowchart for Automatically Ensuring Oscillation Settling Time and Switching from ϕloco to High-Speed OCO

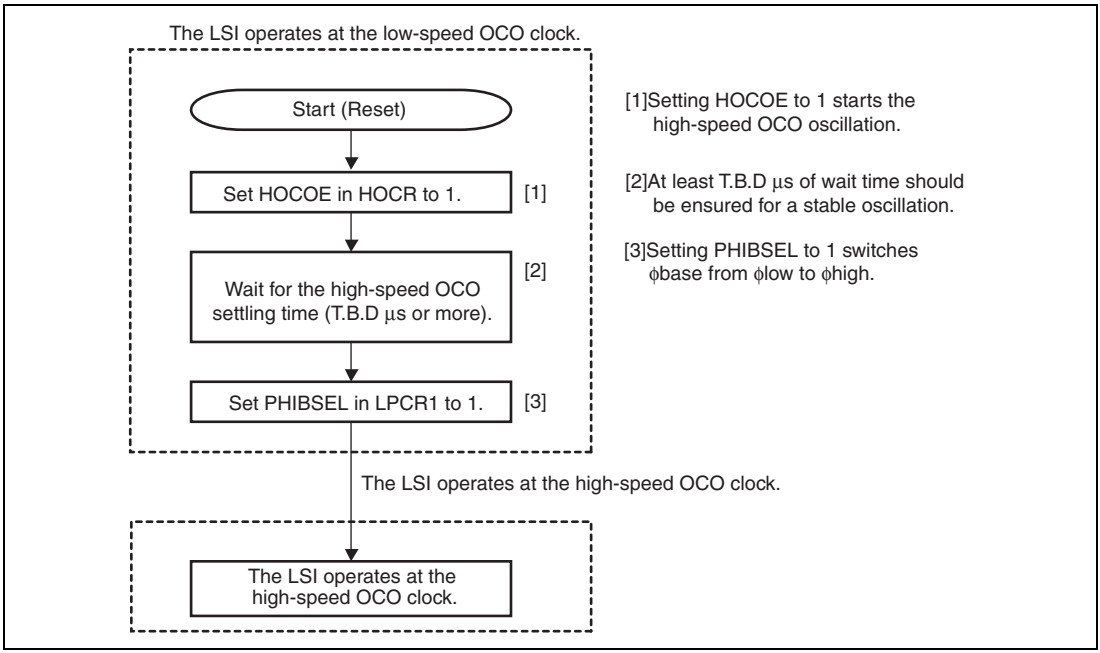


Figure 5.4 Flowchart for Ensuring Oscillation Settling Time by User and Switching from ϕloco to High-Speed OCO

5.3.2 Switching System Base Clock to ϕosc

Figure 5.5 shows a flowchart of the process in which the system base clock is switched from ϕloco to ϕosc.

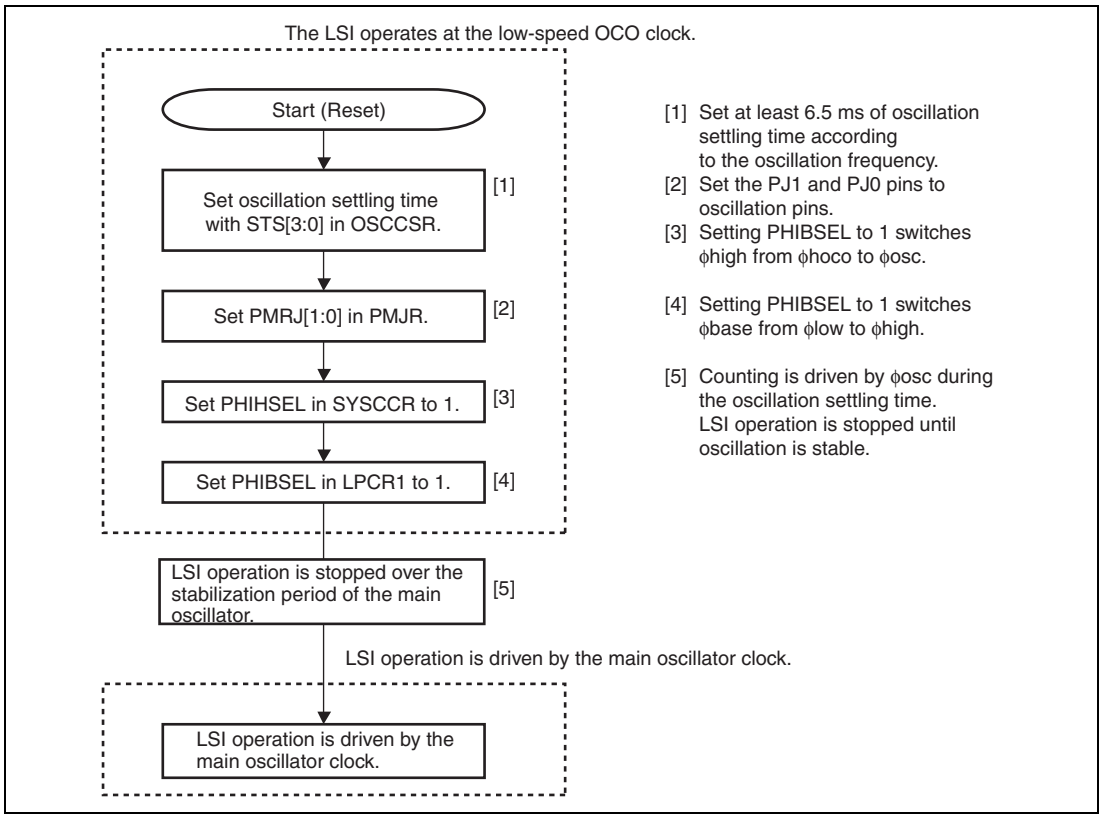


Figure 5.5 Flowchart of Clock Switching from ϕloco to ϕosc

5.3.3 Clock Change Timing

(1) Switching Division Ratio for the Same Clock Source

Figure 5.6 shows a division ratio switching timing chart for the same clock source.

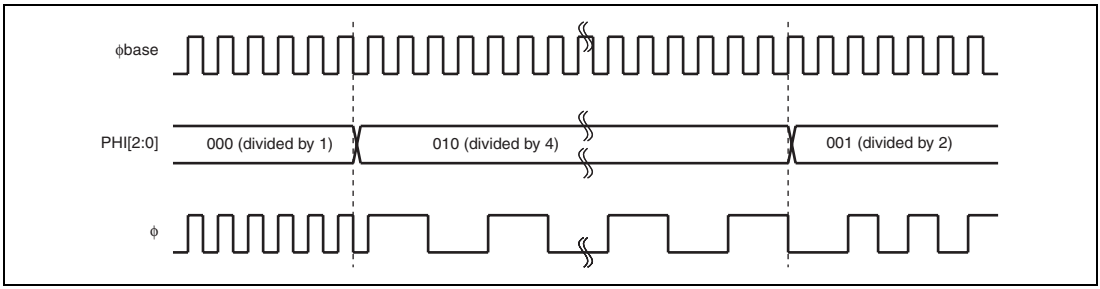
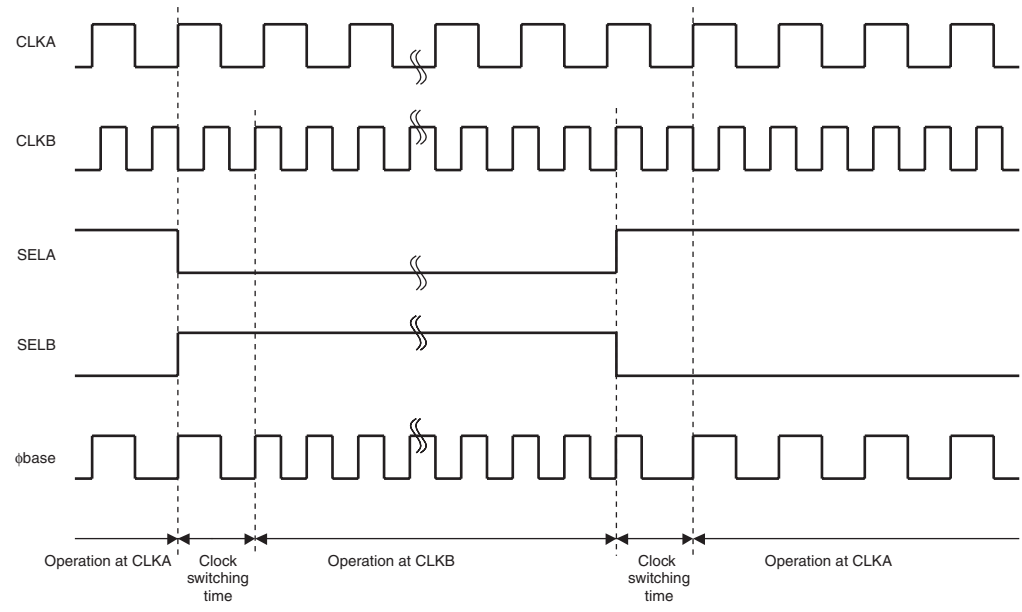


Figure 5.6 Timing of Division Ratio Switching for the Same Clock Source

(2) Switching System Base Clock Source

Figures 5.7 and 5.8 show clock source switching timing charts for the system base clock.



[Legend]
CLKA: Clock A
CLKB: Clock B
SELA: CLKA select signal
SELB: CLKB select signal
φbase: System base clock

Note: Clock switching time is a period from the clock select signal change to the second high level of the destination clock.

Figure 5.7 Timing of Clock Source Switching (When the switching destination clock source is active)

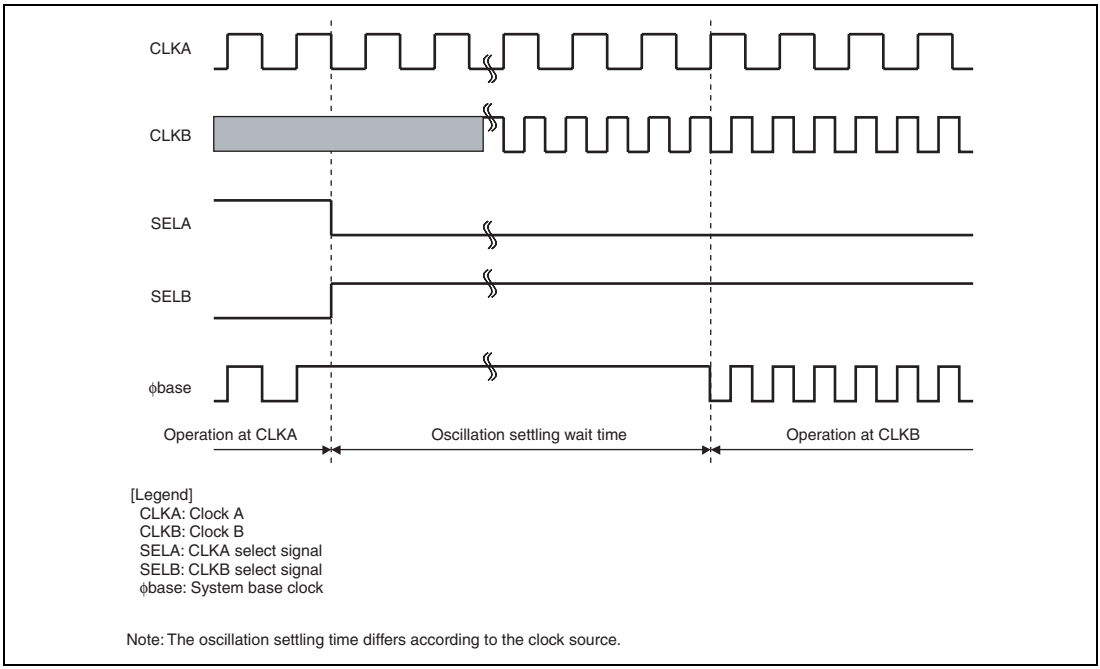


Figure 5.8 Timing of Clock Source Switching (When the switching destination clock source is stopped)

Oscillation stabilization wait time varies with switching destination clock sources. If the destination clock is ϕosc, wait time is specified by the STS[3:0] bit of the OSCCSR. For oscillation stabilization wait time values, see table 5.2. If the destination clock is ϕhoco, wait time is automatically fixed to approximately TBD us.

During oscillation stabilization wait time, the ϕbase stops; therefore, any module that operates with the ϕbase as a base, including the bus master, stops. The register retains the pre-switching value.

5.3.4 Backup Operation

If the operating clock for the system is ϕosc and the backup function is enabled, when the main oscillator detects an oscillation halt condition, the system clock automatically switches to either ϕhoco or ϕlow, according to BAKCKSEL in BAKCR. The period from the stopping of the main oscillator to the time the system clock is operating from ϕhoco or ϕlow will be clock halt detection time + oscillation stabilization wait time for the backup clock. Time to wait for oscillation stabilization is 0 ms if the target backup clock is already oscillating when stopping of the main oscillator is detected.

To reduce power consumption, it is also possible to set the target backup clock to a stopped state when the backup function is enabled. In that case, the target backup clock is automatically activated when stopping of the main clock oscillator is detected. The system clock is then changed after a certain amount of oscillation settling time (approximately T.B.D. µs in the case of ϕhoco). This LSI circuit may malfunction during operation with the back-up function. Accordingly, usage with the watchdog timer is recommended.

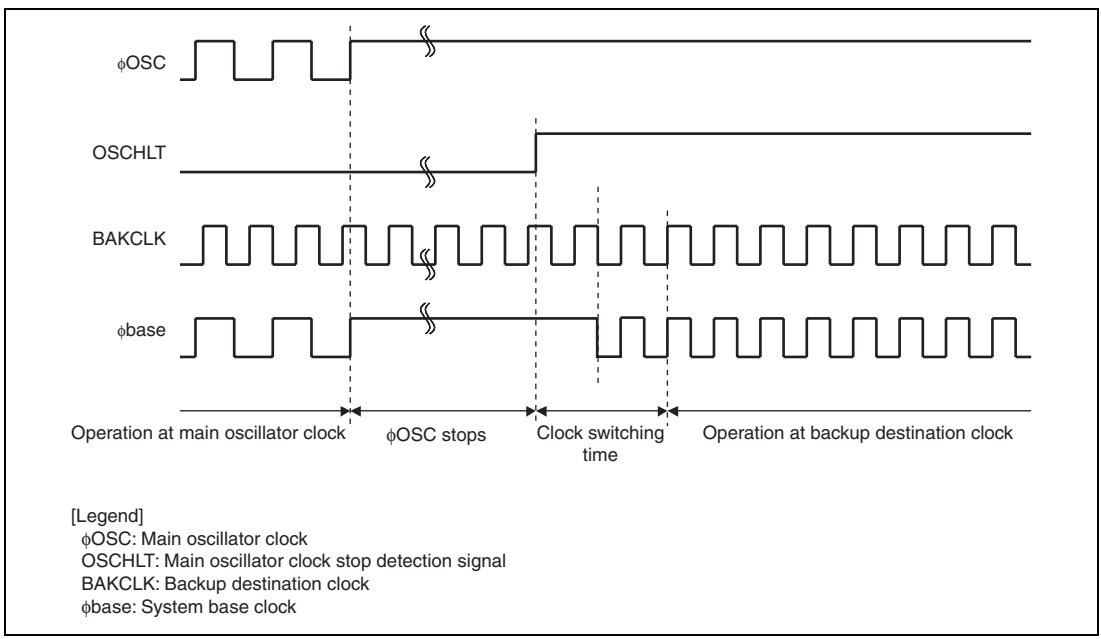


Figure 5.9 Timing of Backup Operation When Main Oscillator Stops at High Level (When the backup destination clock is active)

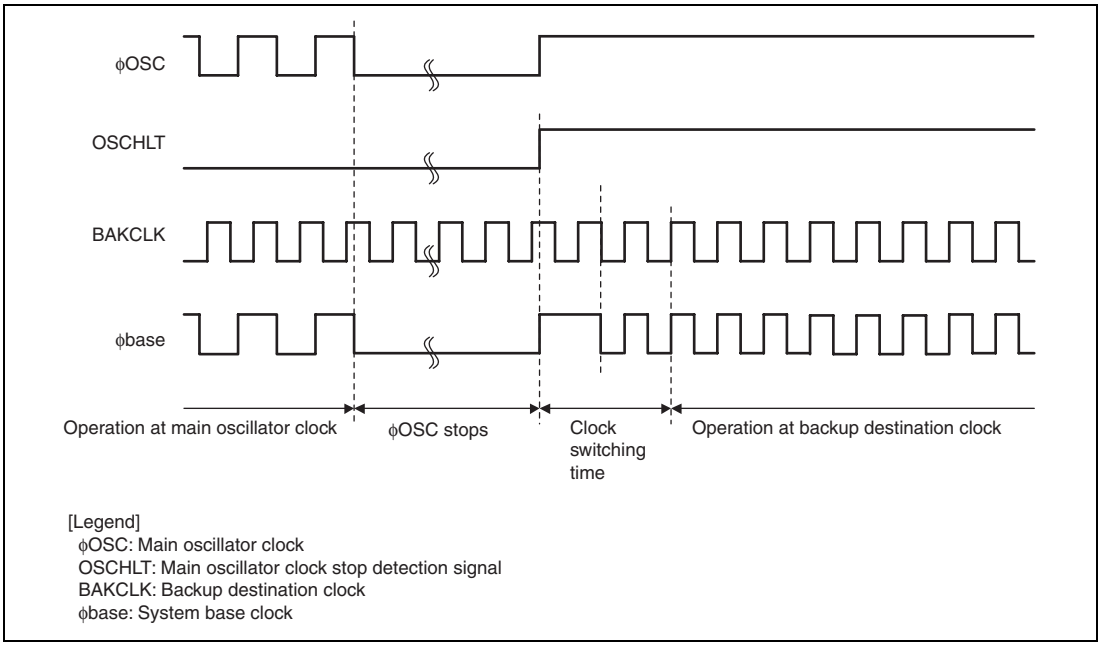


Figure 5.10 Timing of Backup Operation When Main Oscillator Stops at Low Level (When the backup destination clock is active)

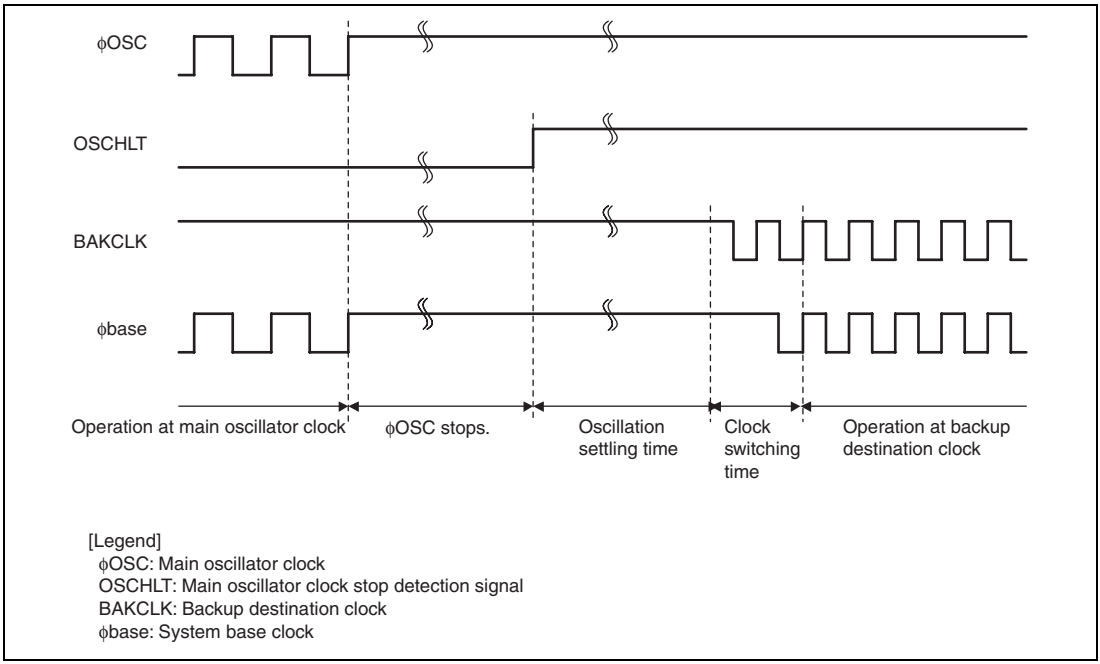


Figure 5.11 Timing of Backup Operation When Main Oscillator Stops at High Level (When the backup destination clock is stopped)

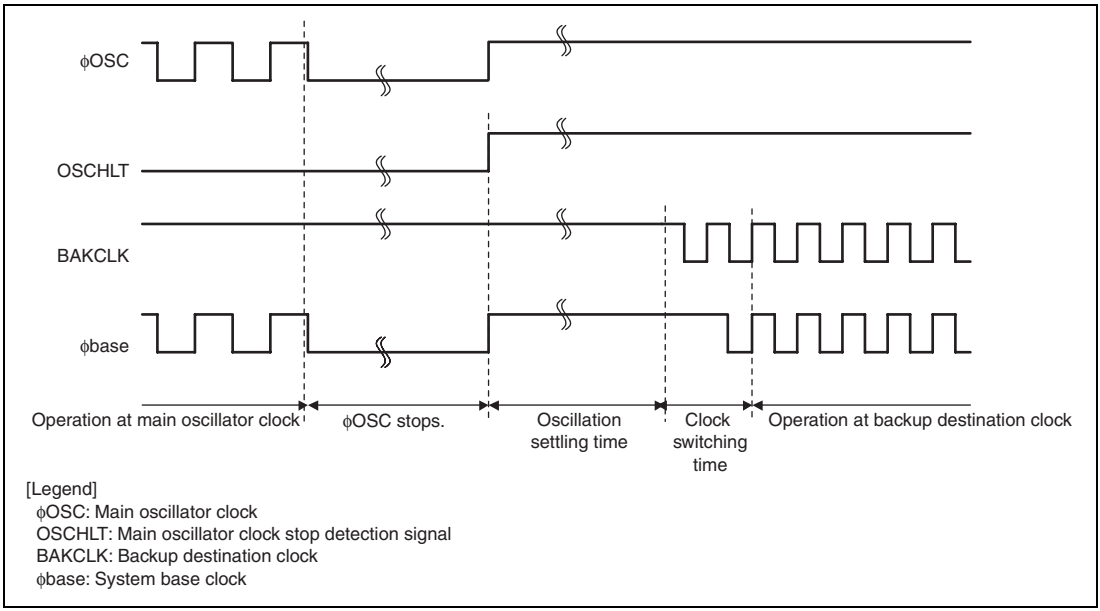


Figure 5.12 Timing of Backup Operation When Main Oscillator Stops at Low Level (When the backup destination clock is stopped)

5.4 High-Speed On-Chip Oscillator

5.4.1 Procedures for Switching to 32MHz

After release from a reset, the high-speed OCO is trimmed so that it will oscillate at 40 MHz. Figure 5.13 shows a flowchart for the switching of the oscillation frequency of the high-speed OCO to 32 MHz. Frequencies should be changed when the high-speed OCO is at reset.

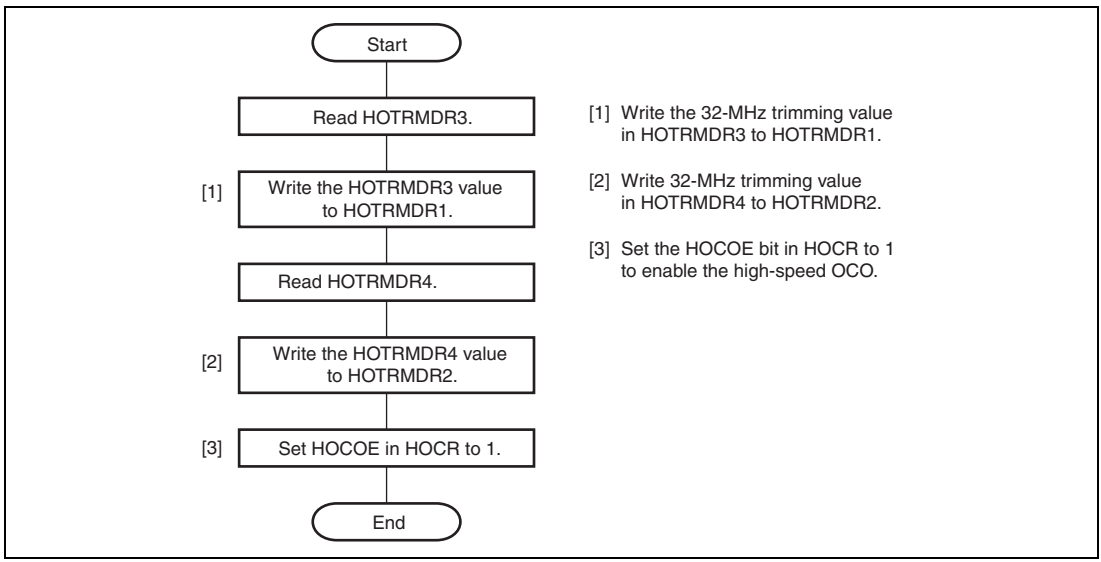


Figure 5.13 Flowchart for Switching High-Speed OCO Frequency to 32 MHz

5.4.2 Trimming of High-Speed OCO

Users can trim the on-chip oscillator frequency, supplying the external reference pulses with the input capture function in the on-chip timer. An example of trimming flow using timer RC and a timing chart are shown in figures 5.14 and 5.15, respectively. Because HOTRMDR1 is initialized by a reset, when users have trimmed the oscillators, some operations after a reset are necessary, such as trimming it again or saving the trimming value in an external device for later reloading.

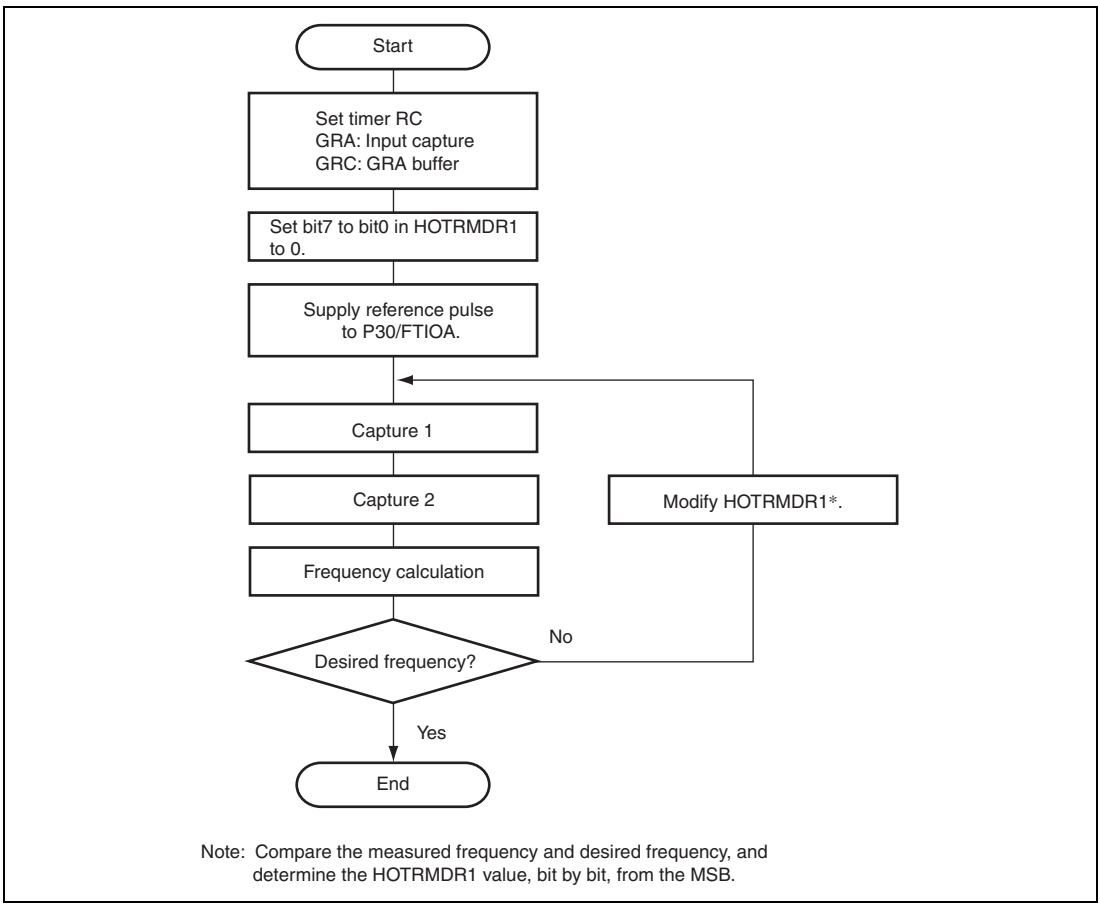


Figure 5.14 Example of Flow for Trimming High-Speed OCO Frequency

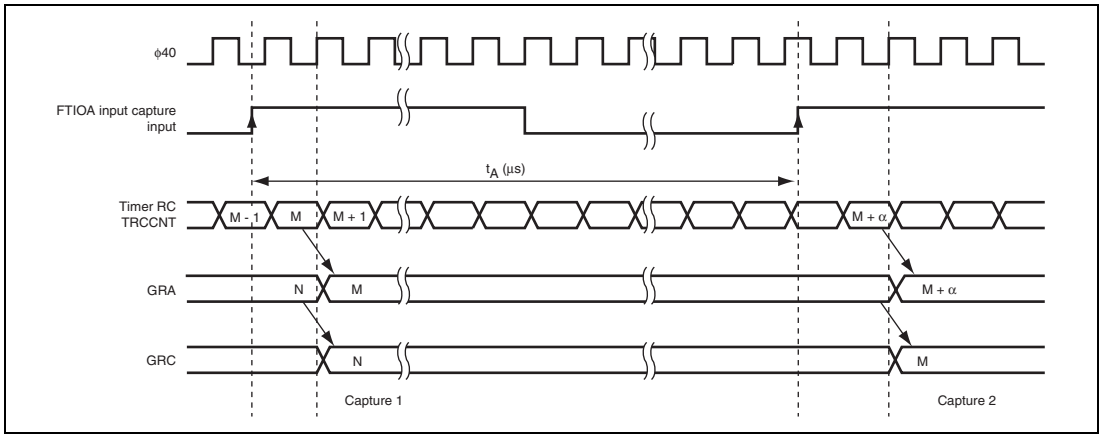


Figure 5.15 Timing Chart of Trimming of High-Speed OCO Frequency

The high-speed OCO frequency is obtained by the expression below. Since the input-capture input is sampled at the rate of the high-speed OCO, the calculated result includes a sampling error of ±1 clock cycle.

$$Foco = \frac{(M + \alpha) - M}{t_A} \text{ (MHz)}$$

Foco = High-speed OCO frequency

t_A = Cycle of base clock (us)

M = Timer RC counter value

Note: For the H8S/20203 and H8S/20223 groups, timer RD should be used instead of timer RC.

5.5 Main Clock Oscillator

This LSI has two methods to supply external clock pulses into it: connecting a crystal or ceramic resonator, and an external clock. For setting the oscillation pins PJ0/OSC1 and PJ1/OSC2/CLKOUT to resonator pins or an external clock input pin, see section 10.10.1, Port Mode Register J (PMRJ). Figure 5.16 shows a block diagram of the Main clock oscillator.

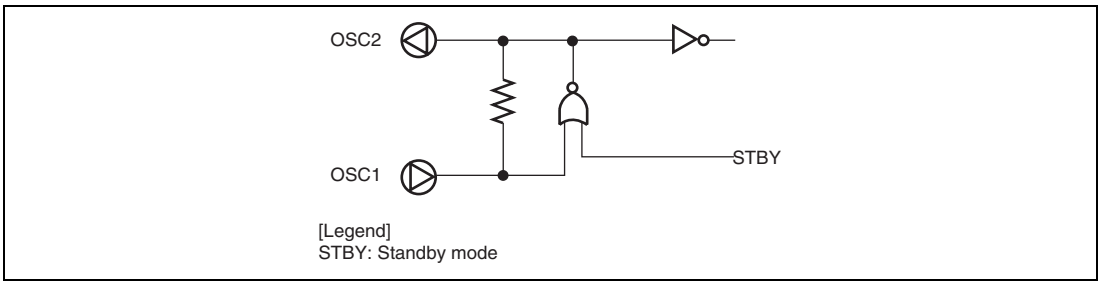


Figure 5.16 Block Diagram of Main Clock Oscillator

5.5.1 Connecting Crystal Resonator

Figure 5.17 shows an example of connecting a crystal resonator. An AT-cut parallel-resonance crystal resonator should be used. A damping resistor Rd should be added, if necessary. Since the resistor values vary depending on the resonator, use values recommended by the resonator manufacturer.

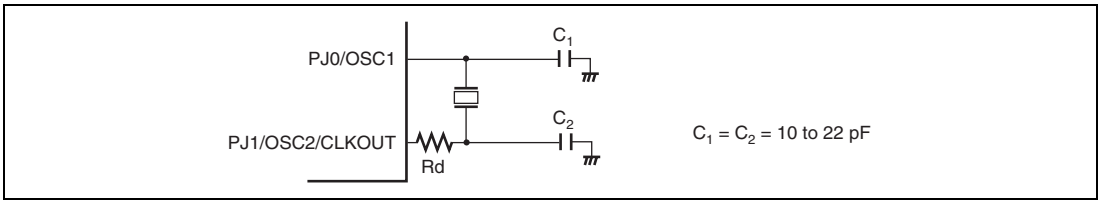


Figure 5.17 Example of Connection to Crystal Resonator

5.5.2 Connecting Ceramic Resonator

Figure 5.18 shows an example of connecting a ceramic resonator. A damping resistor Rd should be added, if necessary. Since the resistor values vary depending on the resonator, use values recommended by the resonator manufacturer.

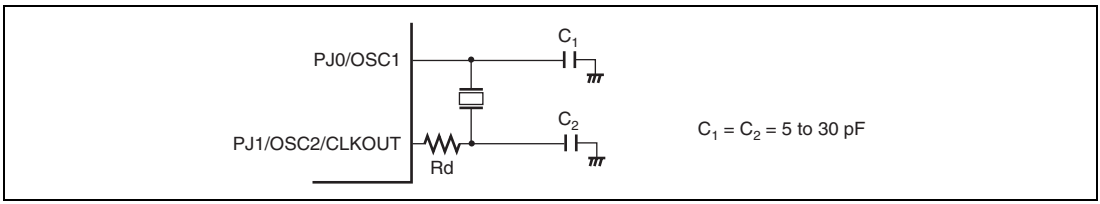


Figure 5.18 Example of Connection to Ceramic Resonator

5.5.3 External Clock Input Method

To use the external clock, input the external clock on pin OSC1. Figure 5.19 shows an example of connection. The duty cycle of the external clock signal must be 45 to 55%.

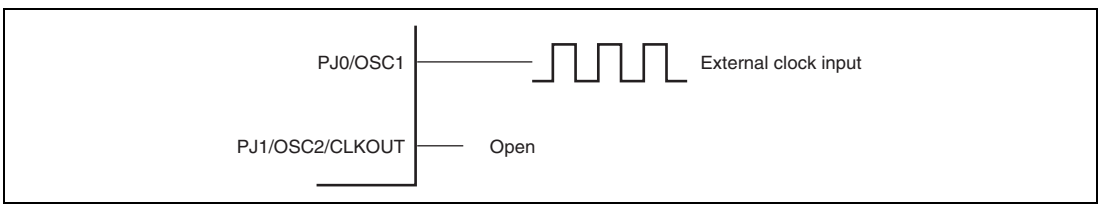


Figure 5.19 Example of External Clock Input

Note: To input the external clock, set the PMRJ[1:0] bits to 01. Do not input the external clock while PMRJ[1:0] bits are set to 11.

5.6 Subclock Generator

Figure 5.20 shows a block diagram of the subclock generator.

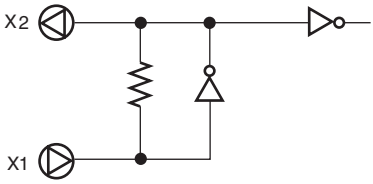


Figure 5.20 Block Diagram of Subclock Generator

5.6.1 Connecting 32.768-kHz Crystal Resonator

Clock pulses can be supplied to the subclock divider by connecting a 32.768-kHz crystal resonator, as shown in figure 5.21. A damping resistor Rd should be added, if necessary. Since the resistor values vary depending on the resonator, use values recommended by the resonator manufacturer.

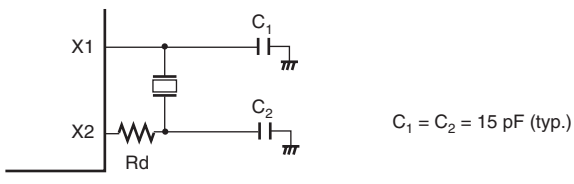


Figure 5.21 Typical Connection to 32.768-kHz Crystal Resonator

5.6.2 Pin Connection when not Using Subclock

When the subclock is not used, connect pin X1 to VSS and leave pin X2 open, as shown in figure 5.22.

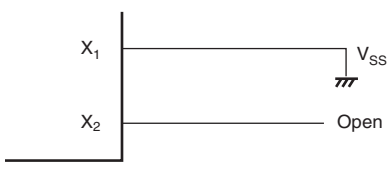


Figure 5.22 Pin Connection when not Using Subclock

5.7 Prescaler

The prescaler is a 13-bit counter using the system clock (ϕ) as its input clock. The outputs, which are divided clocks, are used as internal clocks by the on-chip peripheral modules. The prescaler is initialized to H'0000 and stops counting after a reset. It starts counting when the PSCSTP bit in LPCR1 is cleared. The prescaler counter cannot be accessed by the CPU.

The outputs from the prescaler is shared by the on-chip peripheral modules. The division ratio can be set separately for each on-chip peripheral module. The clock input to the prescaler is a system clock with the division ratio specified by bits PHI2 to PHI0 in LPCR2.

5.8 Usage Notes

5.8.1 Note on Resonators

Resonator characteristics are closely related to board design and should be carefully evaluated by the user, referring to the examples shown in this section. Resonator circuit parameters will differ depending on the resonator element, stray capacitance of the PCB, and other factors. Suitable values should be determined in consultation with the resonator element manufacturer. Design the circuit so that the resonator element never receives voltages exceeding its maximum rating.

5.8.2 Notes on Board Design

When using a crystal resonator (ceramic resonator), place the resonator and its load capacitors as close as possible to pins OSC1 and OSC2. Other signal lines should be routed away from the oscillator circuit to prevent induction from interfering with correct oscillation (see figure 5.23).

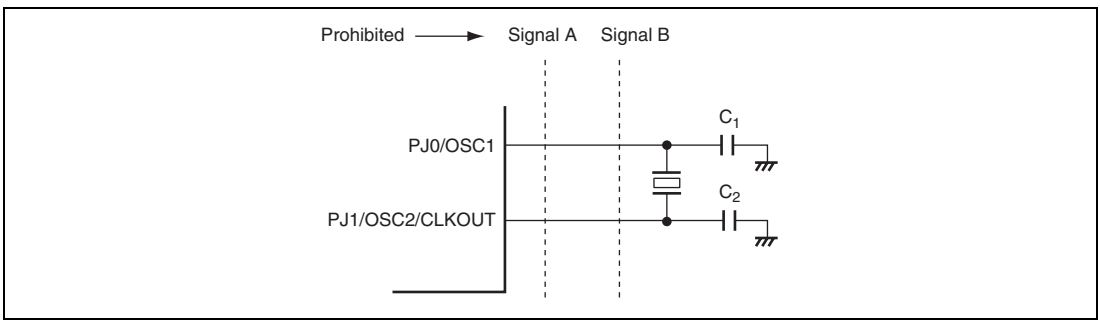


Figure 5.23 Example of Incorrect Board Design

Section 6 Power-Down Modes

In addition to normal active mode, this LSI can enter either of the two power-down modes after release from a reset, in which power consumption is reduced. As other measures for reduced power consumption, this LSI also has a bus-master-clock division function for the low-speed-operation of bus masters, module standby function which allows the selective stopping of on-chip peripheral modules, and a PSC-divider stopping function. Further power consumption is possible by selecting the low-speed on-chip oscillator clock ϕloco, or sub-oscillator clock ϕsub as the source of the system clock ϕ to operate the LSI at a low speed. After release from a reset, all of the peripheral functions except timer RE are in the module standby state. Make the settings for the operation of module in the corresponding registers after the module standby state is released.

- Active Mode

  The CPU and on-chip peripheral modules operate on the system clock ϕ. The system clock frequency can be selected from among ϕbase to ϕbase/128, where ϕbase is the system base clock.

- Sleep Mode

  The CPU is stopped. On-chip peripheral modules operate on the system clock ϕ.

- Standby Mode

  The CPU and all the on-chip peripheral modules are stopped. However, timer RE (TMRE) can operate when the realtime clock mode is selected. The watchdog timer (WDT) also operates when the low-speed OCO is selected as the WDT clock source.

- Bus Master Clock Division Function

  For the bus masters CPU and DTC, ROM, and RAM, the operating clock ϕs can be divided independently of the clock supplied to the peripheral modules. The bus master clock ϕs can be selected from among ϕ to ϕ/32.

- PSC Divider Stop Function

  The PSC divider can be stopped through software setting. Specifically, the peripheral modules using ϕ/2 to ϕ/8192 are stopped (register values are retained), whereas the ones using ϕ remain operating.

- Module Standby Function

  Power consumption can be reduced by halting individual on-chip peripheral modules that are not in use.

6.1 Register Descriptions

The registers related to power-down modes are listed below.

- Power-down control register 1 (LPCR1)
- Power-down control register 2 (LPCR2)
- Power-down control register 3 (LPCR3)
- Module standby control register 1 (MSTCR1)
- Module standby control register 2 (MSTCR2)
- Module standby control register 3 (MSTCR3)

6.1.1 Power-Down Control Registers 1, 2, and 3 (LPCR1, LPCR2, LPCR3)

LPCR1, LPCR2, and LPCR3 control power-down modes. For details, see section 5, Clock Pulse Generator.

6.1.2 Module Standby Control Register 1 (MSTCR1)

Address: H'FFFFDC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	MSTWDT	—	MSTAD1	MSTAD2	MSTDA	MSTDTC	—	—
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7	MSTWDT	Watchdog timer module standby	0: Operating state 1: Standby state	R/W
6	—	Reserved	This bit is read as 0. The write value should be 0.	—
5	MSTAD1	A/D converter unit 1 module standby	0: Operating state 1: Standby state	R/W
4	MSTAD2	A/D converter unit 2 module standby*	0: Operating state 1: Standby state	R/W
3	MSTDA	D/A converter module standby	0: Operating state 1: Standby state	R/W

Bit	Symbol	Bit Name	Description	R/W
2	MSTDTC	DTC module standby	0: Operating state 1: Standby state	R/W
1, 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

Notes: * When a peripheral module is in the module standby state, the registers of the module cannot be accessed.

- MSTWDT bit (watchdog timer module standby)

  When this bit is set to 1, the WDT enters the standby state. Note that if the low-speed OCO is selected as the WDT count clock, the WDT operates regardless of the setting of this bit but the WDT registers cannot be accessed.

- MSTAD1 bit (A/D converter unit 1 module standby)

  When this bit is set to 1, A/D converter unit 1 enters the standby state.

- MSTAD2 bit (A/D converter unit 2 module standby)

  When this bit is set to 1, A/D converter unit 2 enters the standby state.

  A/D converter unit 2 is not available on the H8S/20103 and H8S/20203 groups; this bit is reserved on these devices. For a write-access, write 1 to this bit.

- MSTDA bit (D/A converter module standby)

  When this bit is set to 1, the D/A converter enters the standby state.

- MSTDTC bit (DTC module standby)

  When this bit is set to 1, the DTC enters the standby state.

6.1.3 Module Standby Control Register 2 (MSTCR2)

Address: H'FFFFDD

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	MSTSCI3_1	MSTSCI3_2	MSTSCI3_3	—	—	MSTICSU	—	—
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7	MSTSCI3_1	SCI3 channel 1 module standby	0: Operating state 1: Standby state	R/W
6	MSTSCI3_2	SCI3 channel 2 module standby	0: Operating state 1: Standby state	R/W
5	MSTSCI3_3	SCI3 channel 3 module standby	0: Operating state 1: Standby state	R/W
4, 3	—	Reserved	These bits are read as 1. The write value should be 1.	—
2	MSTICSU	IIC2/SSU module standby	0: Operating state 1: Standby state	R/W
1, 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

Notes: 1. When a peripheral module is in the module standby state, the registers of the module cannot be accessed.
2. When writing to this register, write 1s to the reserved bits.

- MSTSCI3_1 (SCI3 channel 1 module standby)
  When this bit is set to 1, SCI3 channel 1 enters the standby state.
- MSTSCI3_2 (SCI3 channel 2 module standby)
  When this bit is set to 1, SCI3 channel 2 enters the standby state.
- MSTSCI3_3 (SCI3 channel 3 module standby)
  When this bit is set to 1, SCI3 channel 3 enters the standby state.
- MSTICSU (IIC2/SSU module standby)
  When this bit is set to 1, the IIC2 or SSU enters the standby state.

6.1.4 Module Standby Control Register 3 (MSTCR3)

Address: H'FFFFDE

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	MSTTMRA	MSTTMRB	MSTTMRC	MSTTMRD1	MSTTMRD2	MSTTMRG	—	MSTTMRE
Value after reset:	1	1	1	1	1	1	1	0

Bit	Symbol	Bit Name	Description	R/W
7	MSTTMRA	Timer RA module standby	0: Operating state 1: Standby state	R/W
6	MSTTMRB	Timer RB module standby	0: Operating state 1: Standby state	R/W
5	MSTTMRC	Timer RC module standby	0: Operating state 1: Standby state	R/W
4	MSTTMRD1	Timer RD unit 0 module standby	0: Operating state 1: Standby state	R/W
3	MSTTMRD2	Timer RD unit 1 module standby	0: Operating state 1: Standby state	R/W
2	MSTTMRG	Timer RG module standby	0: Operating state 1: Standby state	R/W
1	—	Reserved	This bit is read as 1. The write value should be 1.	—
0	MSTTMRE	Timer RE module standby	0: Operating state 1: Standby state	R/W

Notes: 1. When a peripheral module is in the module standby state, the registers of the module cannot be accessed.
2. When writing to this register, write 1s to the reserved bits.

- MSTTMRA bit (timer RA module standby)
  When this bit is set to 1, timer RA enters the standby state.

- MSTTMRB bit (timer RB module standby)
  When this bit is set to 1, timer RB enters the standby state.

- MSTTMRC bit (timer RC module standby)
  When this bit is set to 1, timer RC enters the standby state.
  Timer RC is not available on the H8S/20203 and H8S/20223 groups; this bit is reserved on these devices. For a write-access, write 1 to this bit.

- MSTTMRD1 bit (timer RD unit 0 module standby)
  When this bit is set to 1, timer RD unit 0 enters the standby state.

- MSTTMRD2 bit (timer RD unit 1 module standby)
  When this bit is set to 1, timer RD unit 1 enters the standby state.
  Timer RD unit 1 is not available on the H8S/20103 group; this bit is reserved on the device. For a write-access, write 1 to this bit.

- MSTTMRG bit (timer RG module standby)
  When this bit is set to 1, timer RG enters the standby state.

- MSTTMRE bit (timer RE module standby)
  When this bit is set to 1, timer RE enters the standby state. Note that if the ϕsub is selected as the count clock in realtime clock mode or output-compare mode, timer RE operates regardless of the setting of this bit but the timer RE registers cannot be accessed.

6.2 Mode Transitions and States of LSI

Figure 6.1 shows the possible transitions among the operating modes. SLEEP instructions are used to cause a transition from the program execution state to the program halt state. Interrupts are used to return from the program halt state to the program execution state. When the $\overline{RES}$ pin is driven low or any other internal reset occurs, this LSI is placed in the reset state from any mode. After release from a reset, this LSI is placed in active mode.

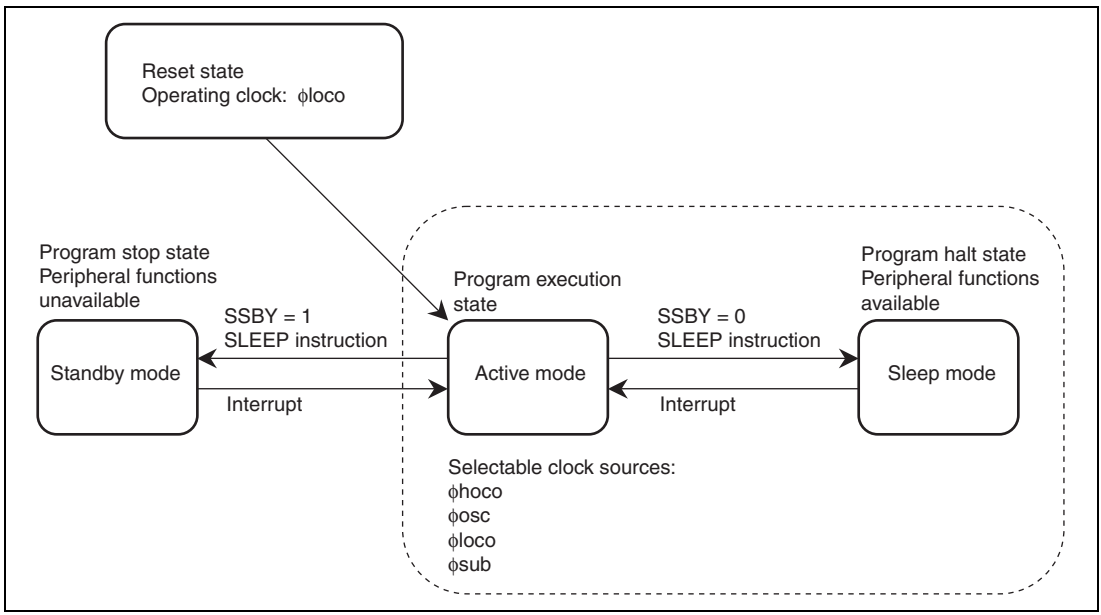


Figure 6.1 Mode Transition Diagram

Table 6.1 shows the internal states of the LSI in each mode.

Table 6.1 Internal State in Each Operating Mode

		LPCR1 PSCSTP = 0		LPCR1 PSCSTP = 1		
Function		**Active Mode**	**Sleep Mode**	**Active Mode**	**Sleep Mode**	**Standby Mode**
System clock		Functioning	Functioning	Functioning	Functioning	Stopped
CPU	Instruction execution	Functioning	Stopped	Functioning	Stopped	Stopped
	Registers	Functioning	Retained	Functioning	Retained	Retained
DTC		Functioning	Functioning	Functioning	Functioning	Stopped
ELC		Functioning	Functioning	Functioning*1	Functioning*1	Retained
RAM		Functioning	Functioning	Functioning	Functioning	Retained
I/O ports		Functioning	Functioning	Functioning	Functioning	Register contents are retained, but output goes to the high-impedance state.
External interrupts	IRQ7 to IRQ0, $\overline{\text{NMI}}$	Functioning	Functioning	Functioning	Functioning	Functioning
Peripheral modules	Timer RA, timer RB, timer RC, timer RD_0, timer RD_1	Functioning	Functioning	Retained*2	Retained*2	Retained
	Timer RE	Functioning	Functioning	Functioning in realtime clock mode and retained in output-compare mode.		Functioning
	Timer RG	Functioning	Functioning	Retained*2	Retained*2	Retained
	Watchdog timer	Functioning	Functioning	Retained*3	Retained*3	Retained*3
	SCI3_1, SCI3_2, SCI3_3	Functioning	Functioning	Retained*2	Retained*2	Reset

Function		LPCR1 PSCSTP = 0 Active Mode	LPCR1 PSCSTP = 0 Sleep Mode	LPCR1 PSCSTP = 1 Active Mode	LPCR1 PSCSTP = 1 Sleep Mode	Standby Mode
Peripheral modules	IIC2/SSU	Functioning	Functioning	Retained	Retained	Reset
	A/D converter_1, A/D converter_2	Functioning	Functioning	Retained*4	Retained*4	Reset
	D/A converter	Functioning	Functioning	Functioning	Functioning	Reset

Notes: 1. The timers are stopped if φ/2 to φ/8192 is selected as the clock source of the event-generation timer.
2. The timers operate if φ is selected as the count clock. The timers are stopped if φ/2 to φ/8192 is selected as the count clock.
3. The WDT operates if the low-speed OCO is selected as its clock source.
4. The A/D converters operate when A/D conversion time = 43 states (max) is selected. The A/D converters are retained when the other conversion time is set.

6.2.1 Active Mode

In active mode, the CPU, DTC, and all the on-chip peripheral modules operate on the system clock φ. The system clock frequency can be selected from among φbase, φbase/2, φbase/4, φbase/8, φbase/16, φbase/32, φbase/64, and φbase/128 according to the PHI[2:0] setting in LPCR2.

6.2.2 Sleep Mode

When a SLEEP instruction is executed in active mode with the SSBY bit = 0 in LPCR1, a transition to sleep mode is made. In sleep mode, the CPU is stopped but the DTC and all the on-chip peripheral modules operate on the system clock. CPU register contents are retained.

When an interrupt is requested, sleep mode is canceled causing a transition to active mode and interrupt exception handling starts. Sleep mode cannot be canceled if the I bit in CCR is 1 or the requested interrupt is masked by the interrupt enable bit. After sleep mode is canceled, the high-speed or low-speed clock is selected as the system clock source depending on the SLEEPRS bit setting in LPCR1.

When the $\overline{\text{RES}}$ pin is driven low or any other internal reset occurs, sleep mode is canceled causing a transition to the reset state.

6.2.3 Standby Mode

When a SLEEP instruction is executed in active mode with the SSBY bit = 1 in LPCR1, a transition to standby mode is made. In standby mode, clock oscillation is stopped and thus the CPU, DTC, and all the on-chip peripheral modules (except timer RE and WDT) are stopped. However, as long as the rated voltage is supplied, the following contents are retained: the CPU registers, the registers of some on-chip peripheral modules, and on-chip RAM. Additionally, on-chip RAM contents will be retained as long as the voltage rated as the RAM data retention voltage is provided. The I/O ports go to the high-impedance state.

When an interrupt is requested, standby mode is canceled causing a transition to active mode and interrupt exception handling starts. Standby mode cannot be canceled if the I bit in CCR is 1 or the requested interrupt is masked by the interrupt enable bit. After standby mode is canceled, the high-speed or low-speed clock is selected as the system clock source depending on the STBYRS bit setting in LPCR1.

When the $\overline{\text{RES}}$ pin is driven low or any other internal reset occurs, standby mode is canceled causing a transition to the reset state.

6.3 Bus Master Clock Division Function

In active or sleep mode, the operating clock for the CPU, DTC, on-chip ROM, and on-chip RAM can be divided independently of the clock supplied to the peripheral modules. Using a divided clock can reduce power consumption.

The operating clock ϕs for the bus masters and the on-chip ROM and on-chip RAM can be selected from among ϕ, ϕ/2, ϕ/4, ϕ/8, ϕ/16, and ϕ/32 according to the PHIS[2:0] setting in LPCR3.

6.3.1 Reset States

For reset states, see section 3.3, Reset.

6.4 Module Standby Function

The module standby function is available for any peripheral module. When a module is set to the module standby state, the clock supply to the module stops placing the module in the power-down state. Setting the corresponding bit to the module in MSTCR to 1 places the module in the module standby state and clearing the bit cancels the module standby state. After release from a reset, all the modules except timer RE are in the module standby state; to use a module, cancel the module standby state of it.

Note that the registers of the module in the module standby state cannot be accessed.

6.5 PSC Divider Stop Function

When the peripheral modules do not use the PSC divider output, the PSC divider can be stopped by setting the PSCSTP bit in LPCR1 to 1.

When the PSC divider is stopped, the peripheral modules using $\phi/2$ to $\phi/8192$ can be stopped as shown in table 6.1 (register values are retained). Before setting the PSCSTP bit to 1, set the peripheral modules using the PSC divider output to the module standby state.

After release from a reset, the PSC divider is stopped since the PSCSTP bit is set to 1. For the PSCSTP bit, see section 5.2.3, Power-Down Control Register 1 (LPCR1).

Section 7 ROM

The features of the on-chip flash memory are described below.

7.1 Overview

- Programming/erasing method

  Four bytes are programmed simultaneously. A single block is erased at a time; only one block should be erased at a time even when the entire ROM area is to be erased.
- Programming/erasing time

  Program ROM programming time: 150 µs (typ.) for 4-byte simultaneous programming, i.e., 38 µs (typ.) per byte

  Data flash programming time: 300 µs (typ.) for 4-byte simultaneous programming, i.e., 75 µs (typ.) per byte

  Erasing time: 200 ms (typ.) per block for the program ROM and data flash areas.
- Reprogramming capability: The program ROM area can be reprogrammed up to 1000 times and the data flash area can be reprogrammed up to 10000 times.
- Two on-board programming modes

  Boot mode: The on-chip SCI can be used for programming/erasing the user ROM area. In this mode, the communication bit rate between the host and this LSI can be automatically adjusted.

  User mode: Any interface can be used for programming/erasing the user ROM area.
- Programmer mode

  A PROM programmer is used for programming/erasing.
- Protection function

  Flash memory can be protected against erroneous programming and erasure.

  Lock-bit protection function can be set through software.
- PROM-programmer protection/Boot-mode protection

  By writing specified data to a specified address range in user ROM, protection of the user-ROM area in boot mode and PROM-programmer mode can be established.
- Access cycle

  Program ROM: One state

  Data flash: Two states

7.2 Block Configuration

Figure 7.1 shows the blocks of the flash memory. The user ROM area contains the program ROM area for storing the microcomputer's operating program and the data flash area for storing data. In the figure, the thick-line frames each indicate an erasure block (erasing unit); the thin-line frames each indicate a programming unit. The values in the frames are addresses. Erasure can be done in erasure-block units shown in the figure 7.1. Programming can be done in 2-word or 4-byte units, each of which begins at the address whose lower four-bit value is H'0, H'4, H'8, or H'C.

H8S/20103, H8S/20203, and H8S/20223
(program ROM: 128 kbytes, data flash: 8 kbytes)

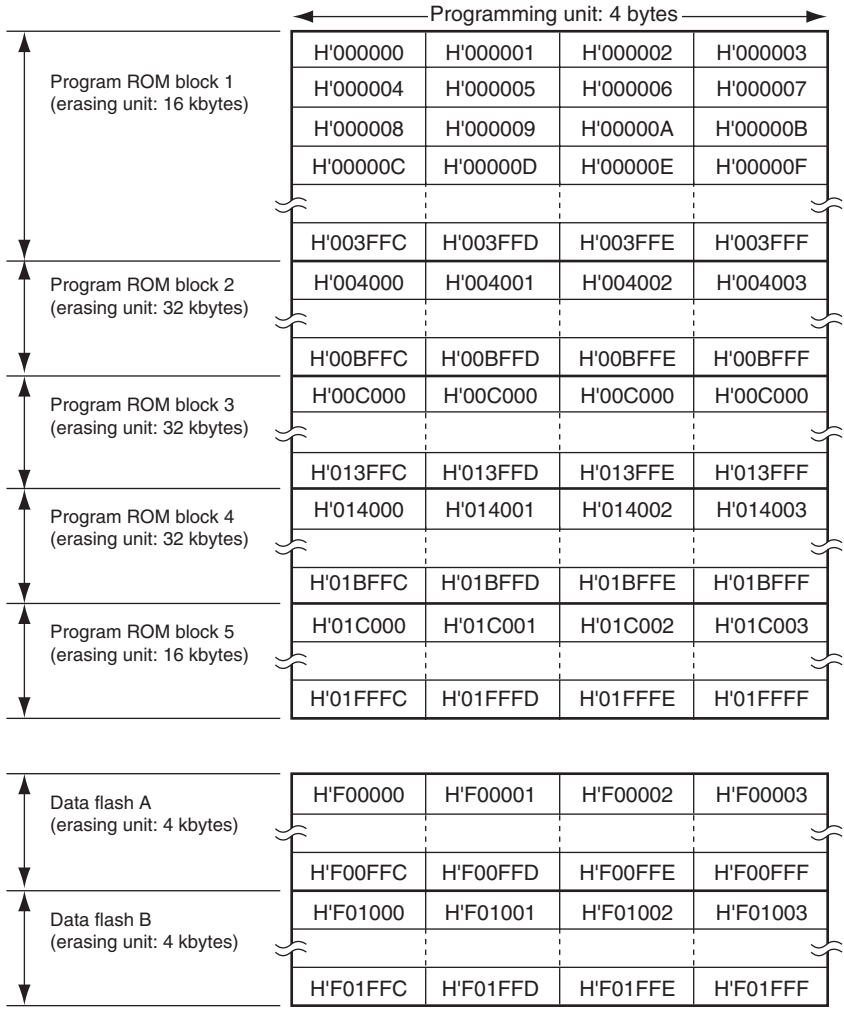


Figure 7.1 Block Configuration of Flash Memory (1)

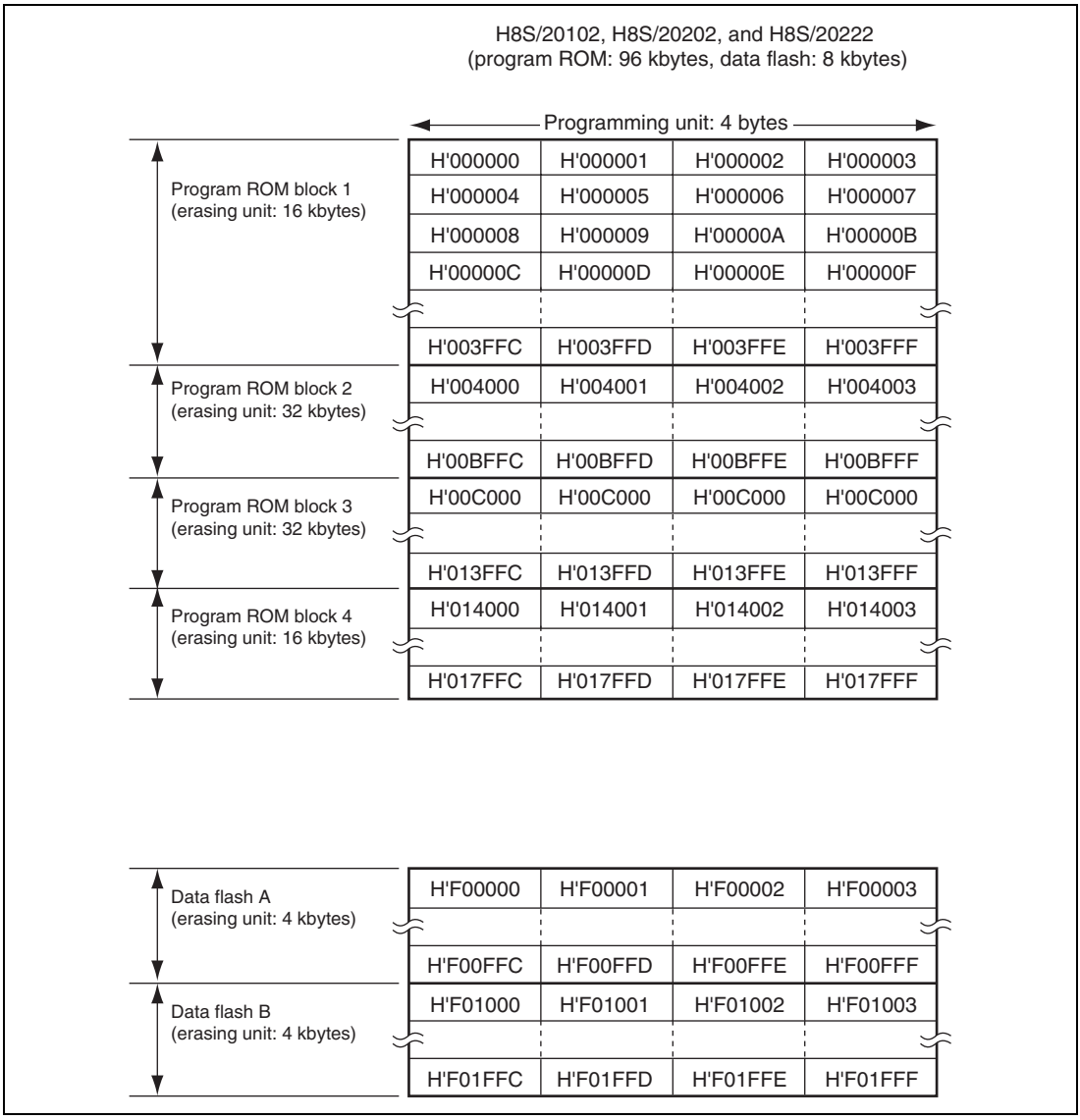


Figure 7.1 Block Configuration of Flash Memory (2)

7.3 CPU Reprogramming Mode

In CPU reprogramming mode, the user ROM area can be reprogrammed by executing the software commands by the CPU. The software commands should be issued to the specific area to be reprogrammed in the user ROM area.

If an interrupt is requested during erasure operation in CPU reprogramming mode, erasure can be suspended to process the interrupt. This is referred to as erase-suspend function. In erase-suspend mode, the user ROM area can be read through programming.

The CPU has two reprogramming modes, EW0 mode and EW1 mode. Table 7.1 shows differences between the two modes.

Table 7.1 Differences between EW0 Mode and EW1 Mode

Item	EW0 Mode	EW1 Mode
Area in which a reprogramming-control program can be located	User ROM area	User ROM area
Area in which a reprogramming-control program can be executed	A reprogramming-control program must be transferred to RAM before execution.	A reprogramming-control program can be executed in the user ROM area.
Area which can be reprogrammed	User ROM area	User ROM area excluding the blocks in which a reprogramming-control program is located.
Limitations on software commands	None	The program and erasure commands must not be executed on any block in which a reprogramming-control program is located.
Mode after software command execution	Read-array mode	Read-array mode

Item	EW0 Mode	EW1 Mode
CPU state during auto-programming and auto-erasure	Operating state	Hold state (I/O ports retain the states in which they have been before the command is executed.)
Flash memory state detection	Read the FMPRSF, FMERSF, and FMEBSF bits in FLMSTR in a program.	
Conditions of transition to erase-suspend state	Both the FMSPEN and FMSPREQ bits in FLMCR2 are set to 1. Or, both the FMSPEN and FMISPE bits in FLMCR2 are set to 1 and an interrupt is requested.	The FMSPEN bit in FLMCR2 is set to 1 and an interrupt is requested.
Conditions of Interrupt generation	• The flash memory returns from the busy state to the ready state*[1]. • The user ROM area is read in the busy state*[1].	Use of interrupts prohibited.
Usage of DTC	Usable*[2]	Usable*[2]*[3]

Note: 1. To avoid the generation of access to the user ROM area, set VOFR so that the variable vectors and interrupt processing routines are allocated to RAM.
2. Allocate DTC vectors and processing routines to RAM. Do not use the DTC for access to the user ROM area during E/W processing. If this is ignored, values read will be invalid.
3. Do not use the DTC if the reprogramming-control program is allocated to RAM.

7.3.1 EW0 Mode

EW0 mode can be selected by transferring the reprogramming-control program to the RAM, branching to the program in the RAM, setting the FMEWMOD bit in FLMCR1 to 0, and setting the FMCMDEN bit in FLMCR1 to 1 (to enable software commands), in this order.

Programming and erasure operations can be controlled through software commands. Completion of the software command and related information can be read out from the FLMSTR register.

To cause a transition to erase-suspend mode during erasure, set both the FMSPEN and FMSPREQ bits in FLMCR2 to 1 (to enable a transition to erase-suspend mode and to request a transition to erase-suspend mode, respectively). Then wait for the transition time to erase-suspend mode (approximately 50 µs), check that the FMRDY bit in FLMSTR is 1 (ready state), and access the user ROM area. Setting the FMSPREQ bit to 0 resumes erasure.

When the interrupt is used, set the interrupt vector offset register (VOFR) such that access to the user ROM area is not generated. That is, the vectors should have addresses within the RAM and point to interrupt processing routine that are also in the RAM.

7.3.2 EW1 Mode

EW1 mode can be selected by setting the FMEWMOD bit in FLMCR1 to 1, and then setting the FMCMDEN bit in FLMCR1 to 1 (to enable software commands).

Programming and erasure operations can be controlled through software commands. Completion of the software command and related information can be read out from the FLMSTR register.

To cause a transition to erase-suspend mode during erasure, set the FMSPEN bit in FLMCR2 to 1 (to enable a transition to erase-suspend mode), and then execute the erasure command. Note that the interrupt for causing a transition to erase-suspend mode must be enabled beforehand. This allows the interrupt request to be accepted when the transition time to erase-suspend mode has elapsed after the erasure command is executed.

When an interrupt is requested, the FMSPREQ bit is automatically set to 1 (to request a transition to erase-suspend mode), thus suspending erasure. If erasure has not been completed at the end of interrupt processing (FMERCF = 1 in FLMSTR), resume erasure by setting the FMSPREQ bit to 0.

7.4 Register Descriptions

- Flash memory control register 1 (FLMCR1)
- Flash memory control register 2 (FLMCR2)
- Flash memory data flash protect register (DFPR)
- Flash memory status register (FLMSTR)

7.4.1 Flash Memory Control Register 1 (FLMCR1)

Address: H'FF0660

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	FMLBD	FMWUS	FMEWMOD	FMCMDEN
Value after reset:	0	0	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5, 4	—	Reserved		—
3	FMLBD*1*2	Lock bit disable	0: The lock bits are enabled. 1: The lock bits are disabled.	R/W
2	FMWUS	CPU reprogramming-instruction select	0: Reprogramming through byte instructions 1: Reprogramming through word instructions	R/W
1	FMEWMOD	EW mode select	0: EW0 mode 1: EW1 mode	R/W
0	FMCMDEN *1*2*3*4	Flash memory software command enable	0: Flash memory software commands are disabled. 1: Flash memory software commands are enabled.	R/W

Notes: 1. When setting the bit to 1, first clear the bit to 0 and then immediately set the bit to 1; do not allow any interrupt to be generated between these operations.
2. The bit is cleared to 0 when the FMRDY bit changes from 0 to 1.
3. Set the FMEWMOD bit and then set the FMCMDEN bit to 1.
4. When setting the FMCMDEN bit to 1 while the FMEWMOD bit is 0, be sure to execute the program in the RAM.

FLMCR1 enables/disables reprogramming/erasure, selects the reprogramming/erasure mode, enables/disables lock bits, and selects the reprogramming unit of the flash memory. For specific use, see section 7.6, Programming/Erasing.

- FMLBD bit (lock bit disable)

  This bit disables the lock-bit function. Setting FMLBD to 1 enables erasing/programming the block to which the lock-bit protection is applied. For the relationship between the FMLBD bit and the lock bit for the block, see table 7.2 below. Command sequence error occurs when the erasing/programming command is executed while disabling the erase program.

Table 7.2 Relationship between FMLBD, Lock Bit, and Corresponding Erasure/Programming Operation

FMLBD	Lock Bit	Erasure/Programming Operation
1	—	Erasure/programming possible
0	1 (erased state)	
	0 (programmed state)	Erasure/programming impossible

- FMWUS bit (CPU reprogramming-instruction select)

  Setting the FMWUS bit to 0 enables software commands to be issued through byte instructions. Setting the FMWUS bit to 1 enables software commands to be issued through word instructions. For software commands, see section 7.6.1, Software Commands.

- FMEWMOD bit (EW mode select)

  Setting the FMEWMOD bit to 0 and the FMCMDEN bit to 1 selects EW0 mode. Setting the FMEWMOD and FMCMDEN bits to 1 selects EW1.

- FMCMDEN bit (flash memory software command enable)

  Setting the FMCMDEN bit to 1 enables software commands to be accepted. For issuing software commands to the data flash areas, appropriately set the flash memory data flash protect register (DFPR), which is described in section 7.4.3.

7.4.2 Flash Memory Control Register 2 (FLMCR2)

Address: H'FF0661

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	FMRDYIE	FMBSYRDIE	FMISPE	FMSPREQ	FMSPEN
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5	—	Reserved		—
4	FMRDYIE *1*2	Flash read-ready interrupt enable	0: The ready interrupt is disabled. 1: The ready interrupt is enabled.	R/W
3	FMBSYRDIE *1*3	Flash busy-read interrupt enable	0: The busy-read interrupt is disabled. 1: The busy-read interrupt is enabled.	R/W
2	FMISPE*4	Suspend-request enable by interrupt request	0: Transition to erase-suspend mode by an interrupt request is disabled. 1: Transition to erase-suspend mode by an interrupt request is enabled.	R/W
1	FMSPREQ *1*5*6*7	Erase suspend	0: Erasure is resumed. 1: Transition to erase-suspend mode is made.	R/W
0	FMSPEN *4*8	Erase-suspend enable	0: Erase suspend is disabled. 1: Erase suspend is enabled.	R/W

Notes:
1. For programming the flash memory, set the FMSPEN bit to 1.
2. The FMRDYIE bit is cleared to 0 when the FMRDY bit changes from 0 to 1.
3. The FMBSYRDIE bit is cleared to 0 when the FMRDY bit changes from 0 to 1.
4. When setting the bit to 1, first clear the bit to 0 and then immediately set the bit to 1; do not allow any interrupt to be generated between these operations.
5. The FMSPREQ bit is set to 1 when an interrupt is generated if the FMSPEN bit is 1 in EW1 mode.
6. The FMSPREQ bit is set to 1 when an interrupt is generated if the FMSPEN and FMISPE bits are 1 in EW0 mode.
7. The FMSPREQ bit is cleared to 0 when the FMRDY bit changes from 0 to 1 upon completion of E/W.
8. The FMSPEN bit is cleared to 0 when the FMRDY bit changes from 0 to 1 if the FMSPREQ bit is 0.

FLMCR2 enables/disables flash memory interrupts, enables/controls a transition to erase-suspend mode.

- FMRDYIE bit (flash read-ready interrupt enable)
  Setting the FMRDYIE bit to 1 enables an interrupt to be generated when the flash memory changes from the busy state to the ready state.

- FMBSYRDIE bit (flash busy-read interrupt enable)
  Setting the FMBSYRDIE bit to 1 enables an interrupt to be generated when the user ROM area is accessed while the flash memory is in the busy state.

- FMISPE bit (suspend-request enable by interrupt request)
  Setting the FMISPE bit to 1 in EW0 mode allows the FMSPREQ bit to be automatically set to 1 (to request a transition to erase-suspend mode) thus causing a transition to erase-suspend mode when an interrupt is requested.

- FMSPREQ bit (erase suspend)
  Setting the FMSPREQ bit to 1 causes a transition to erase-suspend mode. To resume erasure, set the FMSPREQ bit to 0.

- FMSPEN bit (erase-suspend enable)
  Setting the FMSPEN bit to 1 enables a transition to erase-suspend mode.

7.4.3 Flash Memory Data Flash Protect Register (DFPR)

Address: H'FF0662

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	DFPR1	DFPR0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 2	—	Reserved	These bits are read as 0. The write value should be 0.	—
1	DFPR1	Data flash B E/W disable*1*2	0: E/W of data flash B is enabled. 1: E/W of data flash B is disabled.	R/W
0	DFPR0	Data flash A E/W disable*1*2	0: E/W of data flash A is enabled. 1: E/W of data flash A is disabled.	R/W

Notes: 1. When setting the bit to 0, first set the bit to 1 and then immediately set the bit to 0; do not allow any interrupt to be generated between these operations.
2. The DFPR bits are set to 1 when the FMCMDEN bit changes from 0 to 1.

DFPR enables/disables reprogramming of data flash areas in block units. Before reprogramming the data flash areas, cancel the protection against reprogramming.

- DFPR1 bit (data flash B E/W disable)

  Setting the DFPR1 bit to 1 disables software commands to be issued to data flash B. Setting the DFPR1 bit to 0 enables software commands to be issued to data flash B.

- DFPR0 bit (data flash A E/W disable)

  Setting the DFPR0 bit to 1 disables software commands to be issued to data flash A. Setting the DFPR0 bit to 0 enables software commands to be issued to data flash A.

7.4.4 Flash Memory Status Register (FLMSTR)

Address: H'FF0663

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	FMRDYIF	FMBSYRDIF	FMEBSF	FMERSF	FMPRSF	—	—	FMRDY
Value after reset:	0	0	0	0	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
7	FMRDYIF *1*2*3	Flash read-ready interrupt request flag	0: The flash read-ready interrupt is not being requested. 1: The flash read-ready interrupt is being requested. [Setting condition] • FMRDY changes from 0 to 1. [Clearing condition] • "1" is read from FMRDYIF and then the bit is cleared to 0.	R/W
6	FMBSYRDIF *2*3*4	Flash busy-read interrupt request flag	0: The flash busy-read interrupt is not being requested. 1: The flash busy-read interrupt is being requested. [Setting condition] • The user ROM area is accessed while the FMRDY is 0. [Clearing condition] • "1" is read from FMBSYRDIF and then the bit is cleared to 0.	R/W
5	FMEBSF *3*5	Erasure/blank-checking status flag	0: Successful end 1: End with an error [Setting condition] • The erasure command is executed and results in unsuccessful erasure. • The blank-checking command is executed and it is detected that the specified block is not blank. [Clearing condition] • The clear-status command is issued.	R

Bit	Symbol	Bit Name	Description	R/W
4	FMERSF	Erase-suspend flag	0: Erase-suspend function is not being used. 1: Erase-suspend function is being used. [Setting condition] • Erase-suspend mode is being used. [Clearing condition] • Erase-suspend mode is not being used.	R
3	FMPRSF *3*5	Programming status flag	0: Successful end 1: End with an error [Setting conditions] • The programming command is executed and results in unsuccessful programming. • The lock-bit programming command is executed and results in unsuccessful programming. [Clearing condition] • The clear-status command is issued.	R
2	—	Reserved	This bit is read as 0. The write value should be 0.	—
1	—	Reserved	Reading this bit returns the value same as the FMRDY value. The write value should be 1.	—
0	FMRDY	Flash memory ready/busy status flag	0: Busy (programming or erasure in progress) 1: Ready [Setting condition] • The flash memory is not being programmed or erased. [Clearing condition] • The flash memory is being programmed or erased.	R

Notes: 1. The FMRDYIF bit is set to 1 when the FMRDY bit changes from 0 to 1.
2. When setting the bit to 0, first read 1 from the bit and then write 0 to the bit.
3. The bit cannot be set to 1 through software.
4. The FMBSYRDIF bit is set to 1 when the ROM area is accessed while the FMRDY bit is 0.
5. The bit is cleared to 0 when the clear-status command is executed.

- FMRDYIF (flash read-ready interrupt request flag)

  The FMRDYIF bit indicates that the flash memory has changed from the busy state to the ready state. When the FMRDYIF bit is set to 1 while the FMRDYIE bit is 1, an interrupt request is generated.

- FMBSYRDIF (flash busy-read interrupt request flag)

  The FMBSYRDIF bit indicates that the user ROM area is accessed while the flash memory is in the busy state. When the FMBSYRDIF bit is set to 1 while the FMBSYRDIE bit is 1, an interrupt request is generated.

- FMEBSF (erasure/blank-checking status flag)

  The FMEBSF bit is a read-only bit indicating the state when erasure/blank-checking command is executed.

- FMERSF (erase-suspend flag)

  The FMERSF bit is a read-only bit indicating the state of erase-suspend mode.

- FMPRSF (programming status flag)

  The FMPRSF bit is a read-only bit indicating the state when programming command is executed.

- FMRDY (flash memory ready/busy status flag)

  The FMRDY bit indicates the state of flash memory operation.

7.5 On-Board Programming

The flash memory can be programmed/erased on board (boot mode and user mode), or by using a PROM programmer (programmer mode). When the reset is released, this LSI enters one of these modes depending on the levels of the signals input on the TEST, $\overline{\text{NMI}}$, and ports, as shown in table 7.3. The levels of these signals must be fixed at least TBD states before the reset is released.

When this LSI enters boot mode, the built-in boot program is initiated. The boot program transfers the programming-control program to the on-chip RAM, erases the flash memory areas entirely, and then executes the programming-control program. Boot mode is useful for on-board initial programming as well as forced recovery when programming/erasure in user mode is disabled. User mode is useful for erasing and reprogramming the specified blocks, which function is achieved by branching to the programming/erasure processing programs prepared by the user.

Table 7.3 Pin Levels and Programming Mode Selection

TEST	NMI	P85	PB3	PB2	PB1	PB0	LSI Modes after Release from a Reset
0	1	×	×	×	×	×	User mode
0	0	1	×	×	×	×	Boot mode
1	×	×	0	0	0	0	Programmer mode

Note: ×: Do not care.

7.5.1 Boot Mode

In boot mode, control commands and data for programming are transmitted from the externally connected host via SCI3_1 to program/erase the user ROM area.

In boot mode, it is necessary to prepare the tool for transmitting control commands and data for programming, and the data for programming in the host. Asynchronous mode is used for serial communication. Figure 7.2 shows the system configuration in boot mode. Although interrupt requests are ignored in boot mode, interrupt requests should be disabled by the system.

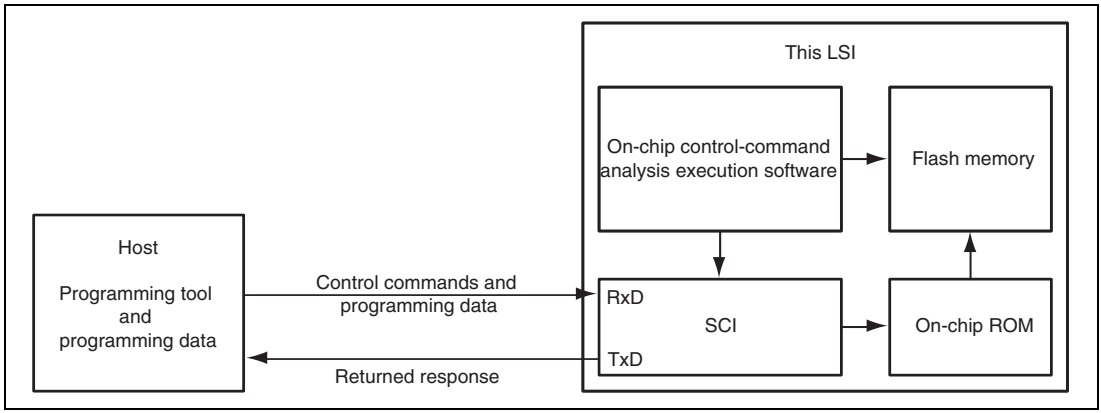


Figure 7.2 System Configuration in Boot Mode

(1) Serial Interface Settings by Host

SCI3_1 is set to asynchronous mode, in which the serial transmission/reception format is set to 8-bit data, one stop-bit, and no parity.

When this LSI enters boot mode, the built-in boot program is initiated. When the boot program is initiated, this LSI measures the low-level period of asynchronous serial communication data (H'00) transmitted continuously from the host. This LSI then calculates the bit rate of transmission from the host, and adjusts the SCI bit rate so that it should match that of the host.

After completing the bit rate adjustment, this LSI transmits one H'00 byte to the host to signal completion of bit rate adjustment. When successfully having received this completion signal, the host should transmit one H'55 byte to this LSI. When not, boot mode should be initiated again. Depending on the combination of the host's transfer bit rate and system clock frequency of this LSI, there might be a discrepancy between the bit rates of the host and this LSI. To prevent this, the transfer bit rate of the host and system clock frequency of this LSI should be set in the range of the value listed in table 7.4.

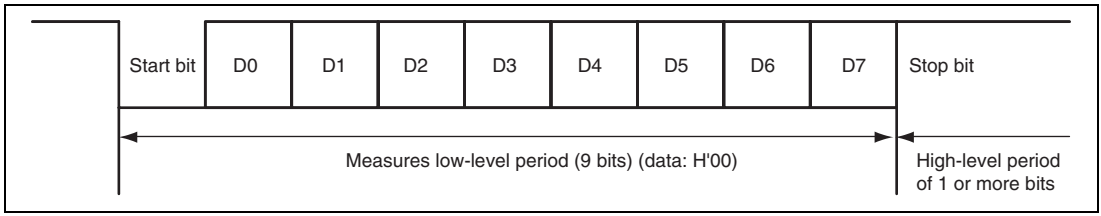


Figure 7.3 Automatic Adjustment of Bit Rates

Table 7.4 System Clock Frequencies at which Automatic Adjustment of Bit Rates is Possible

Host Bit Rate	System Clock Frequency Range of LSI
9600 bps	On-chip oscillator (10 MHz)
4800 bps	
2400 bps	

(2) State Transition

Figure 7.4 shows the state transitions in boot mode.

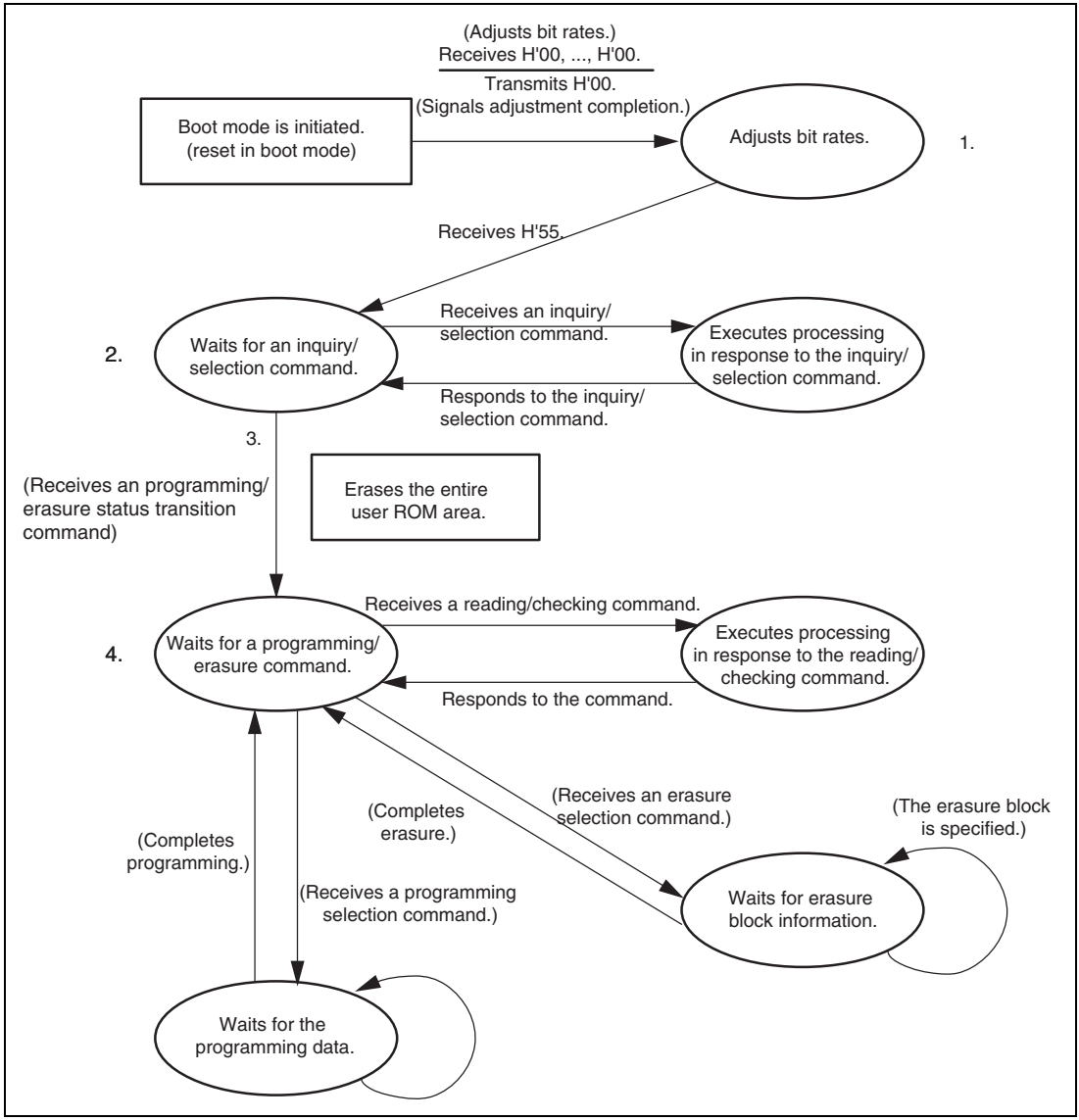


Figure 7.4 State Transitions in Boot Mode

1. After boot mode is initiated, this LSI adjusts the SCI3_1 bit rate so that it should match the host's bit rate.
2. This LSI sends the requested information to the host in response to inquiries regarding the size, configuration, and start addresses of the user ROM areas, information on the supported devices, etc.
3. On receiving transmission of a programming/erasure status command, this LSI erases the entire user ROM area automatically.
4. When completing erasure of the user ROM area, this LSI enters the programming/erasure-command wait state. After transmission of the programming selection command, the host should transmit the address at which the programming should start and the programming data. When programming is completed, the host should transmit H'FFFFFFFF as the programming start address to terminate programming. This allows this LSI to return to the programming/erasure-command wait state from the programming-data wait state. If the above programming-termination command is once issued to an area in an erasure block and when that block is to be programmed again, erase the block before programming. Figure 7.5 shows an example of an erasure block containing the area that has been already programmed.

   On receiving an erasure selection command, this LSI enters the erasure-block-information wait state. After transmission of the erasure selection command, the host should transmit the erasure block number. When erasure is completed, the host should transmit H'FF as the erasure block number. This allows this LSI to return to the programming/erasure-command wait state from the erasure-block-information wait state. Note that erasure is necessary only when programming is once done in boot mode and then only a specific block is to be reprogrammed without applying a reset-start. If the necessary programming can be done in a single operation, such erasure processing is unnecessary because all the blocks are erased before this LSI enters the wait state for programming, erasure, or other commands. In addition to the programming/erasure commands, there are commands for sum checking and blank checking (erasure checking) of the user ROM areas, memory reading, and acquiring the current state information.

Note that data can be read from the user ROM area only after the MAT has been automatically erased and then programmed.

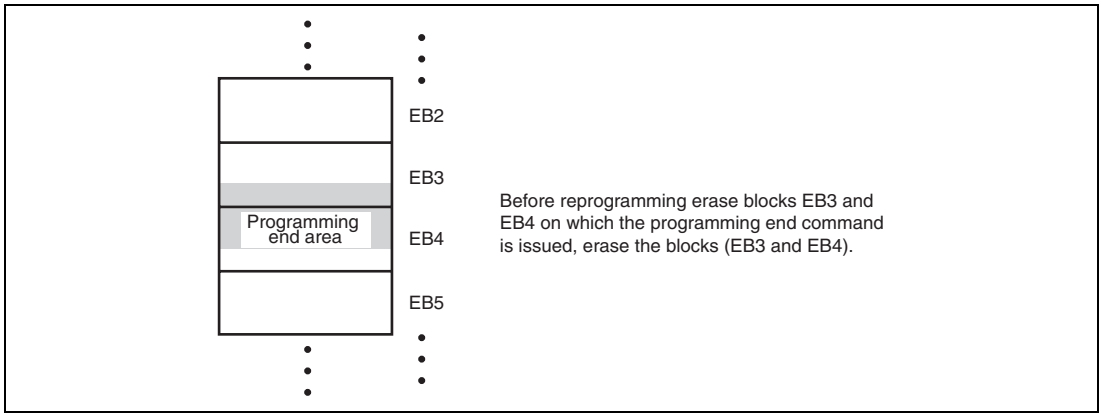


Figure 7.5 Example of Erase Block Including Programmed Area

7.5.2 Specifications of Standard Serial Communication Interface in Boot Mode

The boot program activated in boot mode communicates with the host via the on-chip SCI3_1. The following describes the specifications of the serial communication interface between the host and the boot program.

The boot program has three states.

1. Bit-rate adjustment state

   In this state, the boot program adjusts the SCI3_1 bit rate to match that of the host to perform serial communication with the host. When this LSI is started up in boot mode, the boot program is activated and enters the bit-rate adjustment state, in which it receives command from the host and adjusts the bit rate accordingly. After bit rate adjustment is completed, the boot program enters the inquiry/selection state.
2. Inquiry/selection state

   In this state, the boot program responds to inquiry commands from the host. The device, clock mode, and bit rate are selected. Upon completion of selection, the boot program enters the programming/erasure state in response to the command for transition-to-programming/erasure state. Before entering the programming/erasure state, the boot program transfers the erasure-related libraries to the on-chip RAM and erases the user ROM areas.
3. Programming/erasure state

   In this state, the boot program executes programming/erasure. The boot program transfers the program for programming/erasure to the on-chip RAM according to the command transmitted from the host and executes programming/erasure. The boot program also executes sum checking and blank checking as directed using the corresponding commands.

Figure 7.6 shows the boot program states and processing flow.

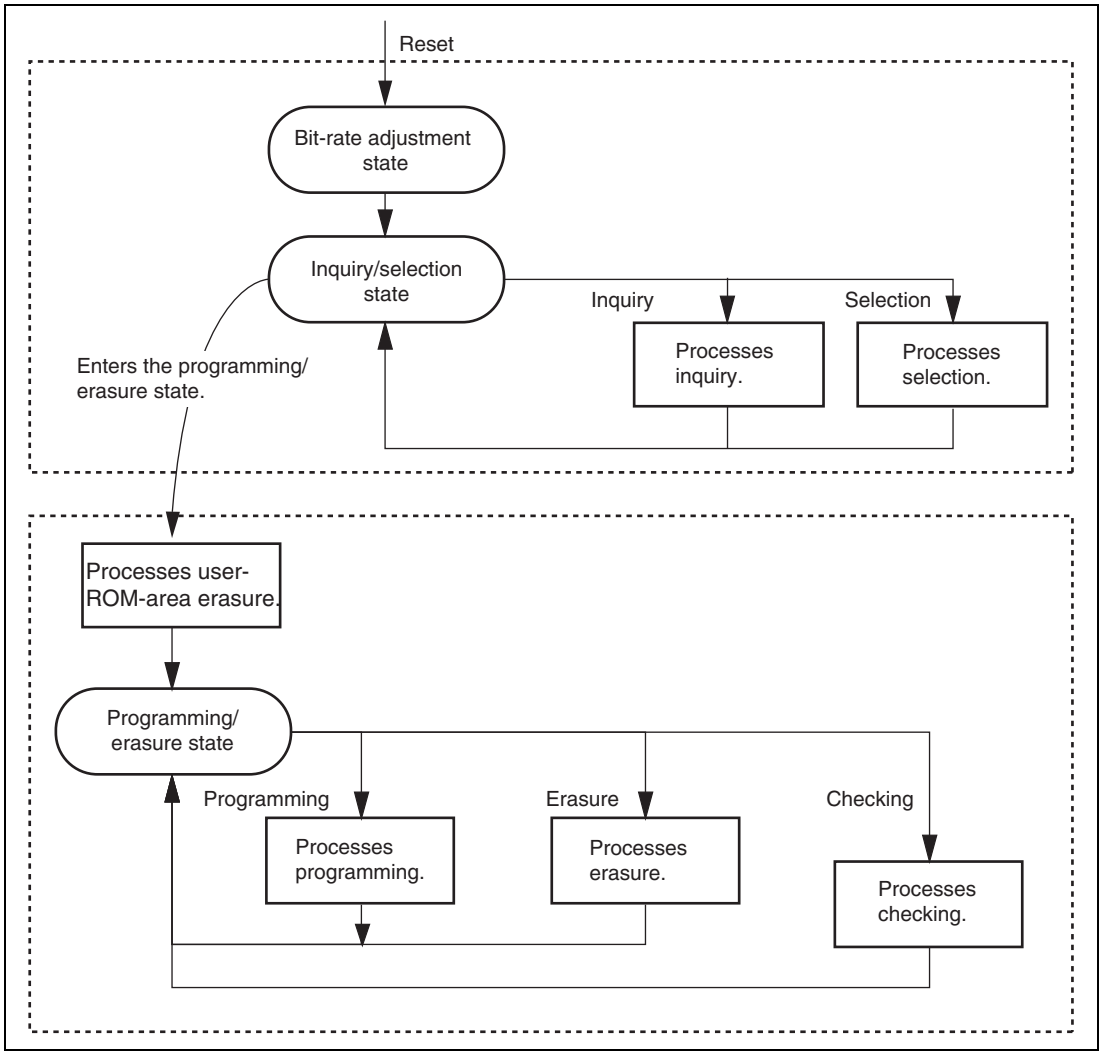


Figure 7.6 Boot Program States and Processing Flow

(1) Bit-Rate Adjustment State

In the bit-rate adjustment state, the boot program measures the low-level period of H'00 transmitted from the host and calculates the bit rate according to the measurement. The bit rate can be changed using the new-bit-rate selection command. On completion of bit rate adjustment, the boot program enters the inquiry/selection state. Figure 7.7 shows the sequence of bit rate adjustment.

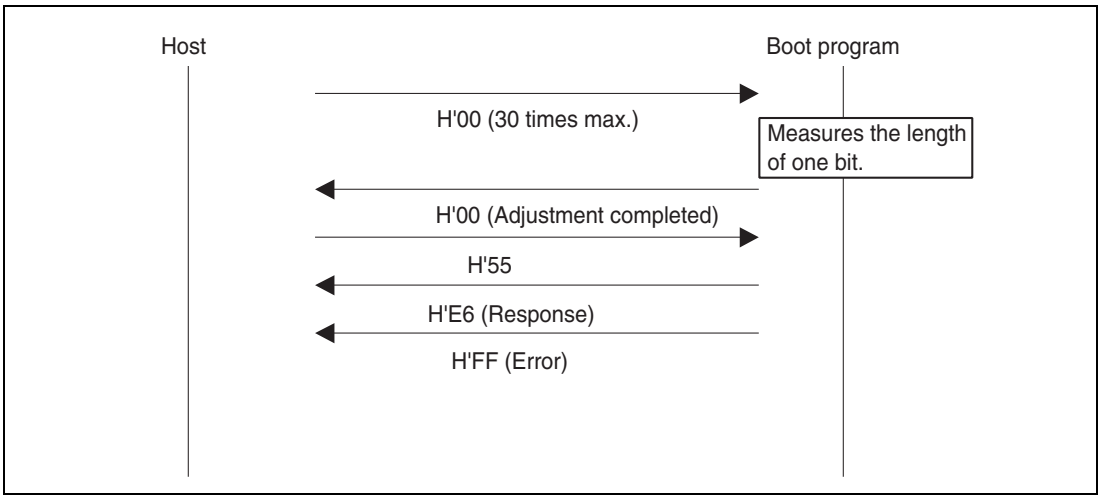


Figure 7.7 Sequence of Bit Rate Adjustment

(2) Communication Protocol

1. One-character command or one-character response

   A command or response consisting of one character used for inquiry or ACK code indicating a successful end.

2. n-character command or n-character response

   A command or response requiring 128 bytes of data used as a selection command or a response to an inquiry. The length of programming data is defined separately and so data size (length) is omitted here.

3. Error response

   Response to a command which has caused an error; two bytes, consisting of the error response and error code.

4. 128-byte programming command

   This command does not include its data size information. The data size can be acquired from the response to the programming-size inquiry command.

5. Response to memory reading command
   This response includes 4-byte size information.

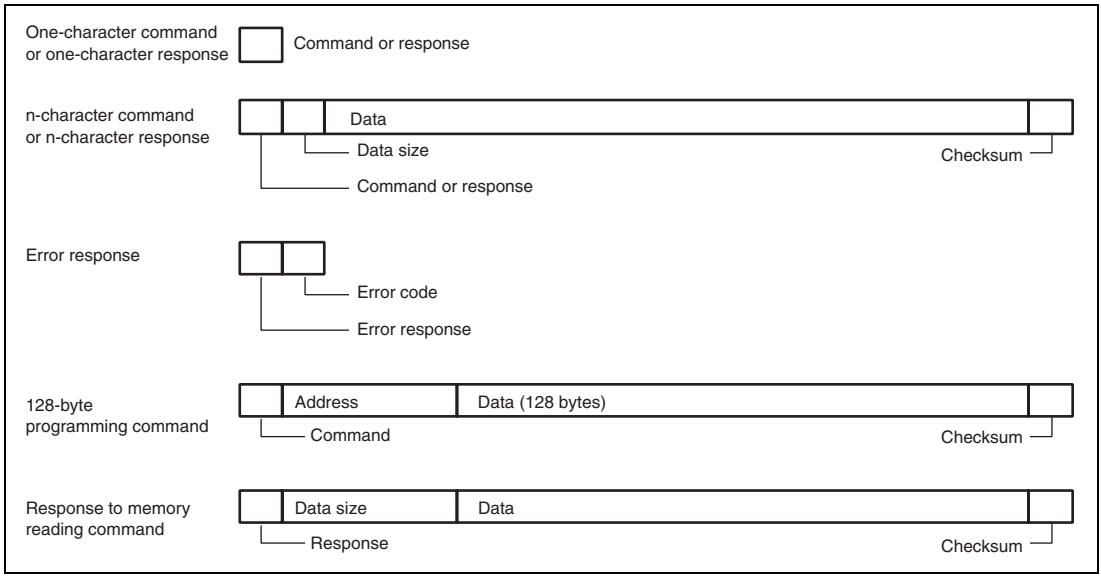


Figure 7.8 Formats in Communication Protocol

- Command (1 byte): Inquiry, selection, programming, erasure, checking, etc.
- Response (1 byte): Response to an inquiry
- Size (1 or 2 bytes): The size of transmit/receive data excluding the command code, response, size, and checksum.
- Data (n bytes): Particular data for a command or response
- Checksum (1 byte): This is set so that the total sum of the values from the command- code field or response through the SUM field should be H'00.
- Error response (1 byte): Error response to a command
- Error code (1 byte): Type of an error that has occurred
- Address (4 bytes): Address for programming
- Data (128 bytes): Data for programming
- Data size (4 bytes): Four-byte length included in the response to the memory reading command.

(3) Inquiry/Selection State

In this state, the boot program returns the information on the flash ROM in response to inquiry commands from the host, and selects the device, clock mode, and bit rate in response to the relevant selection commands.

Table 7.5 lists inquiry/selection commands.

Table 7.5 Inquiry/Selection Commands

Command	Command Name	Function
H'20	Supported-device inquiry	Inquires about the device code and product name.
H'10	Device selection	Selects the device (code).
H'21	Clock mode inquiry	Inquires about the number of selectable clock modes and each clock mode's value.
H'11	Clock mode selection	Selects the clock mode.
H'22	Frequency-division-ratio inquiry	Inquires about the number of frequency types, the number of frequency division ratios, and the specific frequency division ratio values.
H'23	Operating-frequency inquiry	Inquires about the maximum and minimum operating frequencies for the main and peripheral clocks.
H'25	User-ROM-area information inquiry	Inquires about the number of user ROM areas and first and last addresses of each MAT area.
H'26	Erasure-block information inquiry	Inquires about the number of blocks and first and last addresses of each block
H'27	Programming-size inquiry	Inquires about the size of a unit for programming.
H'3F	New bit-rate selection	Selects the new bit rate.
H'40	Transition-to-programming/erasure state	Erases the user ROM areas and enters the programming/erasure state.
H'4F	Boot-program state inquiry	Inquires about the processing state of the boot program.

The selection commands should be transmitted from the host in the following order: device selection (H'10), clock mode selection (H'11), and new bit-rate selection (H'3F). If the same selection command is transmitted more than one time, the last one is valid.

All the commands in table 7.5 except for the boot-program-state inquiry command (H'4F) are valid until the boot program accepts the transition-to-programming/erasure-state command (H'40). That is, until the transition command is accepted, the host can repeatedly send inquiry and selection commands in table 7.5. The boot-program-state inquiry command (H'4F) is valid even after the boot program accepts the transition-to-programming/erasure-state command (H'40).

(a) Inquiry about Supported Devices

In response to the command for inquiry about the supported devices, the boot program returns the device codes of the supported devices and the product name of the boot program.

Command	H'20

- Command H'20 (1 byte): Inquiry about supported devices

Response	H'30	Size	Number of devices	
	Number of characters	Device code		Product name
	SUM			

- Response H'30 (1 byte): Response to the inquiry about supported devices
- Size (1 byte): The size of transmit/receive data excluding the response-command, size, and checksum fields. Here, it refers to the total size used by the number-of-devices, number-of-characters, device-code, and product-name fields.
- Number of devices (1 byte): The number of device types supported by the boot program in the microcomputer.
- Number of characters (1 byte): The number of characters in the device-code and product-name fields.
- Device code (4 bytes): Product names of the supported devices (ASCII code)
- Product name (128 bytes): Product code of the boot program (ASCII code)
- SUM (1 byte): Checksum

  This is set so that the total sum of the values from the response-code field through the SUM field should be H'00.

(b) Device Selection

In response to the device selection command, the boot program sets the specified supported device as the selected device. The boot program will return the information on the selected device in response to the subsequent inquiries.

Command	H'10	Size	Device code	SUM

- Command H'10 (1 byte): Device selection
- Size (1 byte): The number of characters in the device-code field (fixed to four).
- Device code (4 bytes): The device code that has been returned in response to the inquiry about supported devices (ASCII code)
- SUM (1 byte): Checksum

Response	H'06

- Response H'06 (1 byte): Response to device selection
  The ACK code is returned when the specified device code corresponds to one of the supported devices.

Error response

H'90	ERROR

- Error response H'90 (1 byte): Error response to device selection
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'21: Device code error indicating device code disagreement

(c) Inquiry about Clock Modes

In response to the command for inquiry about clock modes, the boot program returns the information on the selectable clock modes.

Command	H'21

- Command H'21 (1 byte): Inquiry about clock modes

Response	H'31	Size	Mode	…	SUM

- Response H'31 (1 byte): Response to the inquiry about clock modes
- Size (1 byte): The total size of the number-of-modes and mode fields
- Mode (1 byte): Selectable clock modes (example: H'01 denotes clock mode 1)
- SUM (1 byte): Checksum

(d) Clock Mode Selection

In response to the command for clock mode selection, the boot program sets the specified clock mode as the selected clock mode. The boot program will return the information on the selected clock mode in response to the subsequent inquiries.

The clock-mode selection command should be transmitted after the device selection command (H'10).

Command	H'11	Size	Mode	SUM

- Command H'11 (1 byte): Clock mode selection
- Size (1 byte): The number of characters in the mode field (fixed to one).
- Mode (1 byte): The clock mode that has been returned in response to the inquiry about clock modes.
- SUM (1 byte): Checksum

Response	H'06

- Response H'06 (1 byte): Response to clock mode selection
  The ACK code is returned when the specified clock mode corresponds to one of the selectable clock modes.

Error response

H'91	ERROR

- Error response H'91 (1 byte): Error response to clock mode selection
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'22: Clock mode error indicating clock mode disagreement

Even if value H'00 or H'01 has been returned in response to the clock-mode inquiry command as the number of modes, it is required to select the clock mode for each value.

(e) Inquiry about Frequency Division Ratios

In response to the command for inquiry about frequency division ratios, the boot program returns the information on the selectable frequency division ratios.

Command	H'22

- Command H'22 (1 byte): Inquiry about frequency division ratios

Response	H'32	Size	Number of types					
	Number of Frequency division ratios	Frequency division ratio	…					
	…							
	SUM							

- Response H'32 (1 byte): Response to the inquiry about frequency division ratios
- Size (1 byte): The total size of the number-of-types, number-of-frequency-division-ratios, and frequency-division-ratio fields.
- Number of types (1 byte): The number of operating clock signals for which frequency division ratios can be selected for the device.

  (For example, the value is H'02 if frequency division ratio settings can be made for the frequencies of the main and peripheral module operating clock signals.)
- Number of frequency division ratios (1 byte): The number of selectable frequency division ratios for each operating clock signal.

  (For example, the number of selectable frequency division ratios for the main or peripheral module operating clock signal.)
- Frequency division ratio (1 byte):

  The negative numerical value by which the frequency is divided. (Example: H'FE (-2) when the frequency is divided by two.)

  As many frequency-division-ratio fields are repeated as the number of corresponding frequency division ratios; and the combinations of the former and latter fields are repeated as many times as the number of types (= number of operating clock signals).
- SUM (1 byte): Checksum

(f) Inquiry about Operating Frequencies

In response to the command for inquiry about operating frequencies, the boot program returns the number of operating frequency types and the respective maximum and minimum frequencies.

Command	H'23

- Command H'23 (1 byte): Inquiry about operating frequencies

Response	H'33	Size	Number of operating frequencies
	Minimum operating frequency		Maximum operating frequency
	…		
	SUM		

- Response H'33 (1 byte): Response to the inquiry about operating frequencies
- Size (1 byte): The total size of the number-of-operating-frequencies, maximum-frequency, and minimum-frequency fields.
- Number of operating frequencies (1 byte): The number of operating frequency types required for the device

  (For example, the value is H'02 if the main and peripheral module operating frequencies are required.)
- Minimum operating frequency (2 bytes): The minimum frequency of a frequency-multiplied or divided clock signal

  The values in the minimum- and maximum-operating-frequency fields are obtained by multiplying the operating frequency (MHz; to the second decimal place) by 100. (For example, when the frequency is 20.00 MHz, 20.00 is multiplied by 100 to be 2000, and so H'07D0 is returned here.)
- Maximum operating frequency (2 bytes): The maximum frequency of a frequency-multiplied or divided clock signal.

  As many pairs of the minimum- and maximum-operating-frequency fields are continued as the number of operating frequencies (= number of operating frequency types).
- SUM (1 byte): Checksum

(g) Inquiry about User ROM Area

In response to the command for inquiry about the user ROM area, the boot program returns the number of user ROM areas and their addresses.

Command	H'25

- Command H'25 (1 byte): Inquiry about user ROM area

Response	H'35	Size	Number of areas	
	First address of the area			Last address of the area
	…			
	SUM			

- Response H'35 (1 byte): Response to the inquiry about user ROM area
- Size (1 byte): The total size of the number-of-areas, first-address-of-the-area, and last-address-of-the-area fields.
- Number of areas (1 byte): The number of consecutive user ROM areas
  (H'01 is returned when the user ROM areas are continuous.)
- First address of the area (4 bytes): The first address of the area
- Last address of the area (4 bytes): The last address of the area
  As many pairs of the first-address-of-the-area and last-address-of-the-area fields are continued as the number of areas.
- SUM (1 byte): Checksum

(h) Inquiry about Erasure Blocks

In response to the command for inquiry about erasure blocks, the boot program returns the number of erasure blocks and their addresses.

Command	H'26

- Command H'26 (1 byte): Inquiry about erasure blocks

Response	H'36	Size	Number of blocks	
	First address of the block			Last address of the block
	…			
	SUM			

- Response H'36 (1 byte): Response to the inquiry about erasure blocks
- Size (2 bytes): The total size of the number-of-blocks, first-address-of-the-block, and last-address-of-the-block fields.
- Number of blocks (1 byte): The number of flash memory blocks to be erased
- First address of the block (4 bytes): The first address of the block
- Last address of the block (4 bytes): The last address of the block

  As many pairs of the first-address-of-the-block and last-address-of-the-block fields are continued as the number of blocks.
- SUM (1 byte): Checksum

(i) Inquiry about Programming Size

In response to the command for inquiry about programming size, the boot program returns the size of a unit for programming.

Command	H'27

- Command H'27 (1 byte): Inquiry about programming size

Response	H'37	Size	Programming size	SUM

- Response H'37 (1 byte): Response to the inquiry about programming size
- Size (1 byte): The number of characters in the programming-size field (fixed to 2)
- Programming size (2 bytes): The size of a unit for programming

  Programming data is received in the unit specified here.
- SUM (1 byte): Checksum

(j) New Bit-Rate Selection

In response to the command for new bit-rate selection, the boot program changes the bit rate settings to those of the specified one, and responds to the acknowledgement from the host at the new bit rate.

The new bit-rate selection command should be transmitted after the clock-mode selection command.

Command	H'3F	Size	Bit rate	Input frequency
	Number of frequency division ratio types	Frequency division ratio 1	Frequency division ratio 2	
	SUM			

- Command H'3F (1 byte): New bit-rate selection
- Size (1 byte): The total size of the bit-rate, input-frequency, number-of-frequency-division-ratio-types, and frequency-division-ratio fields.
- Bit rate (2 bytes): New bit rate

  The value to be set here is obtained by dividing the desired bit rate by 100. (For example, to select the bit rate of 19200 bps, 19200 is divided by 100 to be 192, and so H'00C0 should be set.)
- Input frequency (2 bytes): The frequency of the clock input to the boot program.

  The value to be set here is obtained by multiplying the input frequency (MHz; to the second decimal place) by 100. (For example, to select the input frequency of 20.00 MHz, 20.00 is multiplied by 100 to be 2000, and so H'07D0 should be set.)
- Number of frequency division ratio types (1 byte): The number of selectable frequency division ratios for the device.

  (The value is usually H'02 because the main and peripheral module operating frequencies can be usually selected.)
- Frequency division ratio 1 (1 byte): Frequency division ratio for the main operating frequency.

  The negative numerical value by which the frequency is divided. (Example: H'FE (-2) when the frequency is divided by two.)
- Frequency division ratio 2 (1 byte): Frequency division ratio for the peripheral operating frequency.

  The negative numerical value by which the frequency is divided. (Example: H'FE (-2) when the frequency is divided by two.)

- SUM (1 byte): Checksum

Response	H'06

- Response H'06 (1 byte): Response to the new bit-rate selection command
  The ACK code is returned when selection is possible.

Error response

H'BF	ERROR

- Error response H'BF (1 byte): Error response to new bit-rate selection
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'24: Bit-rate selection error indicating that the specified bit rate is not selectable.
  H'25: Input frequency error indicating that the specified input frequency is not within the range from the minimum to maximum values.
  H'26: Frequency division ratio error indicating disagreement of frequency division ratios
  H'27: Operating frequency error indicating that the specified operating frequency is not within the range from the minimum to maximum values.

(4) Checking Received Data

The following describes how the received data is checked.

1. Input frequency
   The value of the received input frequency is checked to see if it is within the range from minimum to maximum values of the input frequency of the selected clock mode of the selected device. If not, an input frequency error is generated.
2. Frequency division ratio
   The value of the received frequency division ratio is checked to see if it corresponds to the frequency division ratio value of the selected clock mode of the selected device. If not, a frequency division ratio error is generated.

3. Operating frequency

The operating frequency is calculated from the received input frequency and frequency division ratio. The input frequency is the frequency of the clock signal supplied to the LSI, whereas the operating frequency is the frequency at which the LSI actually operates. The following formula is used for the calculation.

Operating frequency = input frequency/frequency division ratio

The obtained operating frequency is checked to see if it is within the range from the minimum to maximum values of the operating frequency of the selected clock mode of the selected device. If not, an operating frequency error is generated.

4. Bit rate

From the peripheral operating frequency (ϕ) and bit rate (B), the value (n) of the clock select bits (CKS) in the serial mode register (SMR) and the value (N) in the bit rate register (BRR) are calculated to determine the error. The error determined is checked to see if it is smaller than 4%. If not, a bit-rate selection error is generated. The following formula is used for the calculation.

$$\text{Error (\%)} = \left\{ \frac{\phi \times 10^6}{(N + 1) \times B \times 64 \times 2^{2n-1}} - 1 \right\} \times 100$$

When selection of the new bit rate is possible, the boot program returns an ACK code to the host and then makes the necessary register settings to select the new bit rate. The host then transmits an ACK code at the new bit rate and the boot program responds to it at the new bit rate.

Acknowledge	H'06

- Acknowledge H'06 (1 byte): Acknowledgement of the new bit rate

Response	H'06

- Response H'06 (1 byte): Response to acknowledgement of the new bit rate

Figure 7.9 shows the sequence of new bit-rate selection.

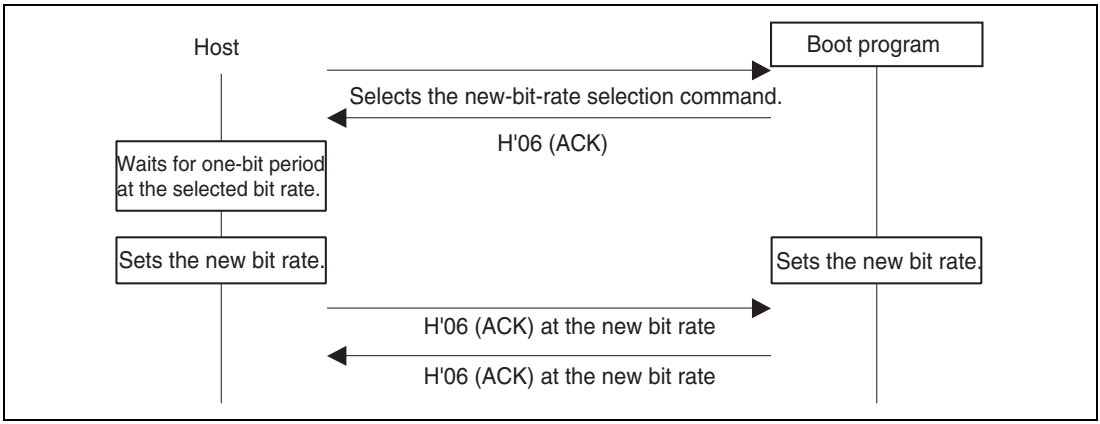


Figure 7.9 Sequence of New Bit-Rate Selection

(5) Transition to Programming/Erasure State

In response to the command for transition-to-programming/erasure state, the boot program transfers the erasure program to erase the data in the user ROM area. On completion of this erasure, the boot program returns the ACK code and enters the programming/erasure state.

Before transmitting the programming selection command and data for programming, the host should select the device, clock mode, and new bit rate for this LSI using the device selection, clock-mode selection, and new-bit-rate selection commands; and then transmit a transition-to-programming/erasure-state command to the boot program.

Command	H'40

- Command H'40 (1 byte): Transition to programming/erasure state

Response	H'06

- Response H'06 (1 byte): Response to the transition-to-programming/erasure-state command. The ACK code is returned when the user ROM area have been successfully erased after transfer of the erasure program.

Error response

H'C0	H'51

- Error response H'C0 (1 byte): Error response to the transition-to-programming/erasure-state command.

- Error code H'51 (1 byte): Erasure error indicating that erasure was unsuccessful because of an error.

(6) Command Errors

Command errors are caused by undefined commands, incorrect command sequence, and unacceptable commands. For example, sending a clock-mode selection command before a device selection command and sending an inquiry command after a transition-to-programming/erasure-state command both cause command errors.

Error response

H'80	H'xx

- Error response H'80 (1 byte): Command error
- Command H'xx (1 byte): Received command

(7) Order of Commands

In the inquiry/selection state, commands should be sent in the following order.

1. Send the supported-device inquiry command (H'20) to get the list of supported devices.
2. Select a device according to the returned device information, and send the device selection command (H'10).
3. Send the clock-mode inquiry command (H'21) to inquire about clock modes.
4. Select a clock mode from among the returned clock modes, and send the clock-mode selection command (H'11).
5. After selection of the device and clock mode, send the frequency-division-ratio inquiry command (H'22) and operating-frequency inquiry command (H'23) to get the information necessary for selecting a new bit rate.
6. Select a new bit rate according to the returned information on the frequency division ratios and operating frequencies, send the new bit-rate selection command (H'3F).
7. After selection of the new bit rate, send the user-ROM-area-information inquiry command (H'25), erasure-block-information inquiry command (H'26), and programming-size inquiry command (H'27) to get the information necessary for programming/erasing the user ROM area.
8. After each inquiry of step [7], send the transition-to-programming/erasure-state command (H'40) to cause a transition to the programming/erasure state.

(8) Programming/Erasure State

In the programming/erasure state, the boot program selects the form of programming in response to the programming selection command and then writes the data in response to the 128-byte programming command; or the boot program erases the desired blocks in response to the erasure selection and block erasure commands. Table 7.6 lists the programming/erasure commands.

Table 7.6 Programming/Erasure Commands

Command	Command Name	Function
H'43	User-ROM-area programming selection	Transfers the control program for user-ROM area programming.
H'50	128-byte programming	Executes 128-byte programming.
H'48	Erasure selection	Transfers the erasure-control program.
H'58	Block erasure	Erases the block data.
H'52	Memory reading	Reads data from memory.
H'4B	Sum checking of user ROM area	Executes sum checking of the user ROM area.
H'4D	Blank checking of user ROM area	Executes blank checking of the user ROM area.
H'4F	Boot-program state inquiry	Inquires about the processing state of the boot program.

1. Programming

   Programming is performed by using the programming selection command and the 128-byte programming command.

   First, the host sends the user-ROM-area-programming selection command.

   Next, the host sends the 128-byte programming command. The boot program assumes that the 128 bytes of data included in the 128-byte programming command should be programmed according to the form of programming selected by the preceding programming selection command. To program more than 128 bytes, repeatedly send 128-byte programming commands. To terminate programming, the host should send the 128-byte programming command with address H'FFFFFFFF. On completion of programming, the boot program waits for the next programming/erasure selection command.

   To perform programming according to a different form of programming or to program a different MAT area subsequently, start the process by sending a programming selection command.

   The sequence of programming by the programming selection command and 128-byte programming command is shown in figure 7.10.

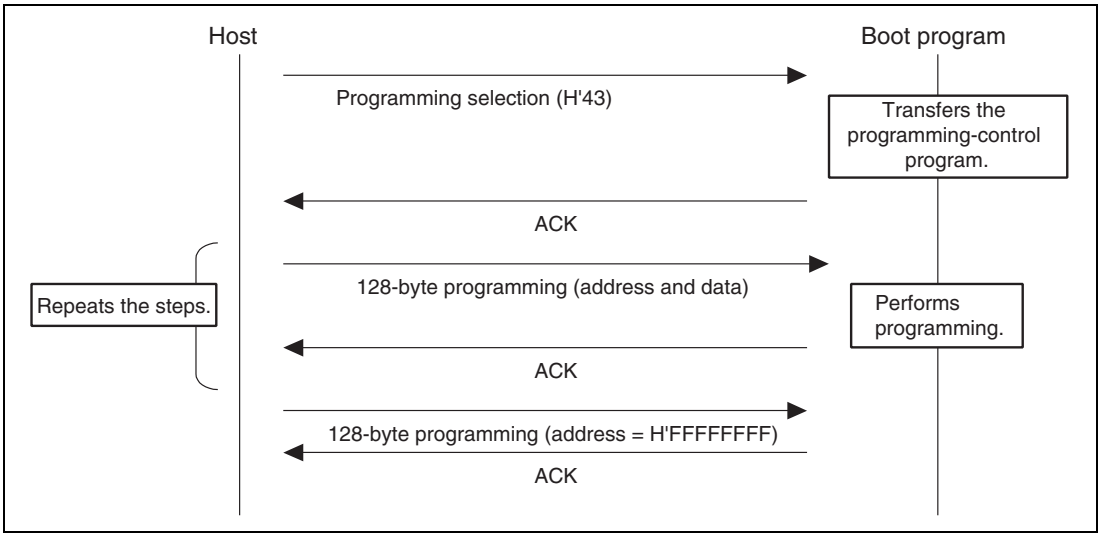


Figure 7.10 Programming Sequence

2. Erasure

   Erasure is performed by using the erasure selection command and the block erasure command.

   First, select erasure by the erasure selection command and then actually erase a specific block using the block erasure command. To erase multiple blocks, repeatedly send block erasure commands. To terminate erasure, the host should send the block erasure command with block number H'FF. On completion of erasure, the boot program waits for the next programming/erasure selection command.

   The sequence of erasure by the erasure selection command and block erasure command is shown in figure 7.11.

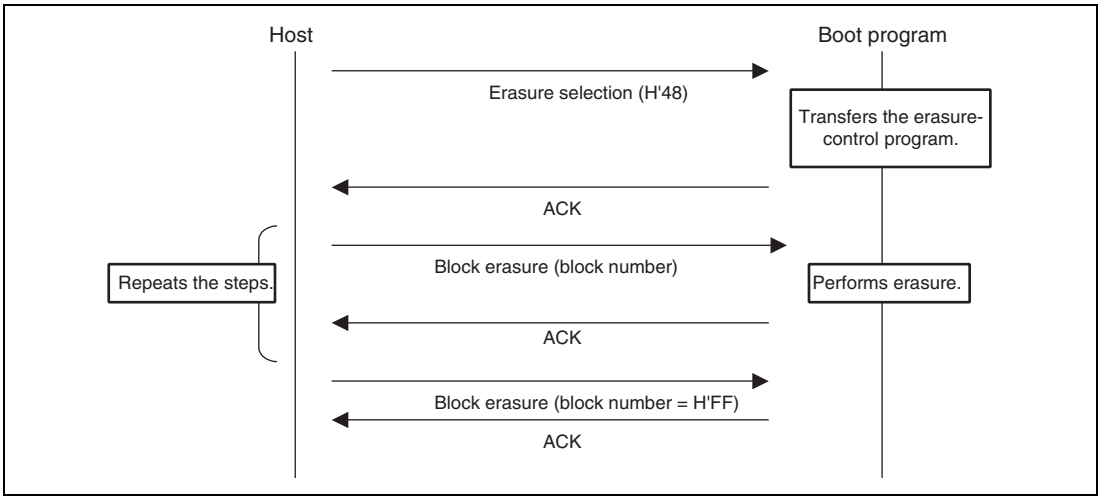


Figure 7.11 Erasure Sequence

(a) Selection of User-Rom Area Programming

In response to the command for selection of user-ROM area programming, the boot program transfers the relevant programming-control program according to which the user ROM area is programmed.

Command	H'43

- Command H'43 (1 byte): Selection of programming the user ROM area

Response	H'06

- Response H'06 (1 byte): Response to the user-ROM-area programming selection command. The ACK code is returned upon completion of transferring the programming-control program.

Error response

H'C3	ERROR

- Error response H'C3 (1 byte): Error response to the user-ROM-area programming selection command
- ERROR (1 byte): Error code
  H'54: Selection processing error (processing was not completed because of a transfer error)

(b) 128-Byte Programming

In response to the 128-byte programming command, the boot program programs the user ROM area according to the programming-control program transferred in response to the user-ROM-area programming selection command.

Command

H'50	Address						
Data	…						
…							
SUM							

- Command H'50 (1 byte): 128-byte programming
- Address for programming (4 bytes): Address at which programming starts
  The address should be the multiple of the size returned in response to the programming-size inquiry command.
  [Example] H'00, H01, H'00, H'00: H'00010000
- Programming data (128 bytes): Data for programming
  The size of the programming data is the size returned in response to the programming-size inquiry command.
- SUM (1 byte): Checksum

Response

H'06

- Response H'06 (1 byte): Response to the 128-byte programming command.
  The ACK code is returned upon completion of the requested programming.

Error response

H'D0	ERROR

- Error response H'D0 (1 byte): Error response to the 128-byte programming command
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'53: Programming error (programming failed because of an error in programming)

The specified address should be on a boundary corresponding to the unit of programming (programming size). For example, when the programming size is 128 bytes, the lower 8 bits of the address should be either H'00 or H'80. When less than 128 bytes of data are to be programmed, the host should transmit the data after padding the vacant bytes with H'FF.

To terminate programming, send the 128-byte programming command with H'FFFFFFFF in the address-for-programming field. This informs the boot program that the data has been completely sent; the boot program then waits for the next programming/erasure selection command.

Command	H'50	Address	SUM

- Command H'50 (1 byte): 128-byte programming
- Address for programming (4 bytes): Terminating code (H'FF, H'FF, H'FF, H'FF)
- SUM (1 byte): Checksum

Response	H'06

- Response H'06 (1 byte): Response to the 128-byte programming command.
  The ACK code is returned upon termination of the programming process.

Error response

H'D0	ERROR

- Error response H'D0 (1 byte): Error response to the 128-byte programming command
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'53: Programming error (programming failed because of an error in programming)

(c) Erasure Selection

In response to the erasure selection command, the boot program transfers the relevant erasure-control program. The data in the user ROM area is erased using the transferred erasure-control program.

Command	H'48

- Command H'48 (1 byte): Erasure selection

Response	H'06

- Response H'06 (1 byte): Response to the erasure selection command.
  The ACK code is returned upon completion of transferring the erasure-control program.

Error response

H'C8	ERROR

- Error response H'C8 (1 byte): Error response to Erasure selection command
- ERROR (1 byte): Error code
  H'54: Selection processing error (processing was not completed because of a transfer error)

(d) Block Erasure

In response to the block erasure command, the boot program erases the data in the specified block.

Command	H'58	Size	Block number	SUM

- Command H'58 (1 byte): Block erasure
- Size (1 byte): The number of characters in the block-number field (fixed to 1)
- Block number (1 byte): The number specific to the block to be erased
- SUM (1 byte): Checksum

Response	H'06

- Response H'06 (1 byte): Response to the block erasure command.
  The ACK code is returned when the specified block has been erased.

Error response

H'D8	ERROR

- Error response H'D8 (1 byte): Error response to the block erasure command
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'29: Block number error (the specified block number is incorrect)
  H'51: Erasure error (an error occurred during erasure)

On receiving the command with H'FF as the block number, the boot program terminates erasure processing and waits for the next programming/erasure selection command.

Command	H'58	Size	Block number	SUM

- Command H'58 (1 byte): Block erasure
- Size (1 byte): The number of characters in the block number field (fixed to 1)
- Block number (1 byte): H'FF (erasure terminating code)
- SUM (1 byte): Checksum

Response	H'06

- Response H'06 (1 byte): Response to the block erasure command for terminating erasure processing; ACK code is returned upon termination of the erasure process.

To perform erasure again after issuing the command with H'FF as the block number, start the process by sending an erasure selection command.

(e) Memory Reading

In response to the memory reading command, the boot program returns the data stored in the specified address.

Command	H'52	Size	Area	Address for reading	
	Reading size				SUM

- Command H'52 (1 byte): Memory reading
- Size (1 byte): The total size of the area, address-for-reading, and reading-size fields (fixed to 9)
- Area (1 byte):
  H'01: User ROM area
  Specifying an incorrect area causes an address error.
- Address for reading (4 bytes): Address where reading starts
- Reading size (4 bytes): The amount of data to be read
- SUM (1 byte): Checksum

Response	H'52	Reading address						
	Data	…						
	SUM							

- Response H'52 (1 byte): Response to the memory reading command
- Reading size (4 bytes): The amount of data to be read
- Data (128 bytes): The specified amount of data to be read out starting at the specified address
- SUM (1 byte): Checksum

Error response

H'D2	ERROR

- Error response H'D2 (1 byte): Error response to the memory reading command
- ERROR (1 byte): Error code
  H'11: Checksum error
  H'2A: Address error (the specified address for reading is not in the MAT)
  H'2B: Size error (the specified size (amount) is greater than the size of the MAT)

(f) Sum Checking of User ROM Area

In response to the command for sum checking of the user ROM area, the boot program adds all the data bytes in the user ROM area and returns the result.

Command	H'4B

- Command H'4B (1 byte): Sum checking of the user ROM area

Response	H'5B	Size	Checksum for the MAT	SUM

- Response H'5B (1 byte): Response to the command for sum checking of the user ROM area
- Size (1 byte): The number of characters in the checksum-for-the-MAT field (fixed to 4)
- Checksum for the MAT (4 bytes): Result of checksum calculation for the user ROM area; the total of all the data in the MAT, in byte units.
- SUM (1 byte): Checksum (for this response)

(g) Blank Checking of User ROM Area

In response to the command for blank checking of the user ROM area, the boot program checks to see if the whole area of the user ROM area is blank and returns the result.

Command	H'4D

- Command H'4D (1 byte): Blank checking of the user ROM area

Response	H'06

- Response H'06 (1 byte): Response to the command for blank checking of the user ROM area. The ACK code is returned when the whole area is blank (all bytes are H'FF).

Error response

H'CD	H'52

- Error response H'CD (1 byte): Error response to the command for blank checking of the user ROM area
- Error code H'52 (1 byte): Non-erased error

(h) Inquiry about Boot Program State

In response to the command for inquiry about the boot program state, the boot program returns its current state and error information. This inquiry can be made either in the inquiry/selection state or the programming/erasure state.

Command	H'4F

- Command H'4F (1 byte): Inquiry about boot program state

Response	H'5F	Size	STATUS	ERROR	SUM

- Response H'5F (1 byte): Response to the inquiry about boot program state
- Size (1 byte): The number of characters in the STATUS and ERROR fields (fixed to 2)
- STATUS (1 byte): State of the boot program
- ERROR (1 byte): Error information
  ERROR = 0: Success
  ERROR ≠ 0: Error
- SUM (1 byte): Checksum

Table 7.7 State Codes

Code	Description
H'11	Waiting for device selection
H'12	Waiting for clock mode selection
H'13	Waiting for bit rate selection
H'1F	Waiting for transition to programming/erasure state (bit rate selection completed)
H'31	Programming or erasure state (programming/erasure in progress)
H'3F	Waiting for programming/erasure selection (erasure completed)
H'4F	Waiting to receive data for programming (programming completed)
H'5F	Waiting for erasure block specification (erasure completed)

Table 7.8 Error Codes

Code	Description
H'00	No error
H'11	Checksum error
H'12	Programming size error
H'21	Device-code disagreement error
H'22	Clock-mode disagreement error
H'24	Bit-rate selection disable error
H'25	Input frequency error
H'26	Frequency division ratio error
H'27	Operating frequency error
H'29	Block number error
H'2A	Address error
H'2B	Data size error
H'51	Erasure error
H'52	Non-erased error
H'53	Programming error
H'54	Selection processing error
H'80	Command error
H'FF	Bit-rate-adjustment acknowledge error

7.5.3 Programming/Erasing in User Mode

On-board programming/erasing of individual flash memory blocks is also possible in user mode by branching to the user programming/erasure-control program. The user must set the branching conditions and provide the on-board means of supplying the programming data. The flash memory must contain the user programming/ erasure-control program or a program that allows the user programming/erasure-control program to be supplied externally. As the flash memory itself cannot be read during programming/erasing, transfer the user programming/erasure-control program to the on-chip RAM to execute, as in boot mode. Figure 7.12 shows a sample procedure for programming/erasing in user mode. Prepare user programming/erasure-control program in accordance with the description in section 7.6, Programming/Erasing.

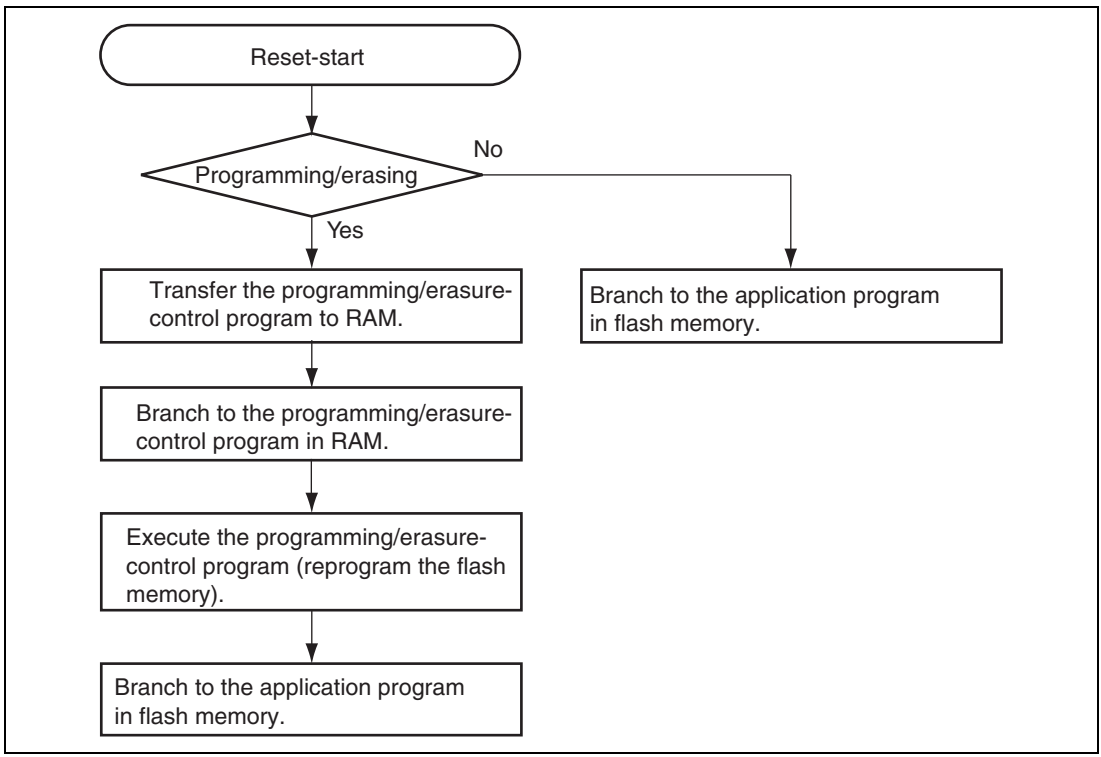


Figure 7.12 Sample Programming/Erasing Procedure in User Mode (EW0 Mode)

7.6 Programming/Erasing

The CPU reprogramming method is employed to program and erase flash memory on board, in which the CPU executes software commands.

7.6.1 Software Commands

Table 7.9 shows a list of software commands through word instructions and table 7.10 shows a list of software commands through byte instructions. Whether an instruction is to be byte-length or word-length is specified by the FMWUS bit in FLMCR1.

Table 7.9 Software Commands (in Word Instructions: FMWUS = 1)

Software Command	First Command Cycle			Second Command Cycle			Third Command Cycle			Command Use in Modes	
	Mode	Addr.	Data	Mode	Addr.	Data	Mode	Addr.	Data	EW0	EW1
Erasure	Write	×	H'2020	Write	BA	H'D0D0				Possible	Possible
Programming	Write	WA	H'4141	Write	WA	WD1	Write	WA	WD2	Possible	Possible
Blank checking	Write	×	H'2525	Write	BA	H'D0D0				Possible	Possible
Lock-bit programming	Write	×	H'7777	Write	BA	H'D0D0				Possible	Possible
Read-array	Write	×	H'FFFF							Possible	—
Clear-status	Write	×	H'5050							Possible	Possible
Lock-bit reading	Write	×	H'7171	Read	BA	H'xxxx				Possible	Impossible

[Legend]

×: Arbitrary address in the user ROM area

xx: Eight-bit arbitrary data

BA: Arbitrary address in a block

WA: Programming address. (The lower two bits of an address are ignored. WA should be the same in each command cycle.)

WDn: Programming data (16 bits)

Table 7.10 Software Commands (in Byte Instructions: FMWUS = 0)

Software Command	First Command Cycle			Second Command Cycle			Third Command to Fifth Command Cycle			Command Use in Modes	
	Mode	Addr.	Data	Mode	Addr.	Data	Mode	Addr.	Data	EW0	EW1
Erasure	Write	×	H'20	Write	BA	H'D0				Possible	Possible
Programming	Write	WA	H'41	Write	WA	WD1	Write	WA	WD2 to WD4	Possible	Possible
Blank checking	Write	×	H'25	Write	BA	H'D0				Possible	Possible
Lock-bit programming	Write	×	H'77	Write	BA	H'D0				Possible	Possible
Read-array	Write	×	H'FF							Possible	—
Clear-status	Write	×	H'50							Possible	Possible
Lock-bit reading	Write	×	H'71	Read	BA	H'xx				Possible	Impossible

[Legend]

×: Arbitrary address in the user ROM area

xx: Eight-bit arbitrary data

BA: Arbitrary address in a block

WA: Programming address. (The lower two bits of an address are ignored. WA should be the same in each command cycle.)

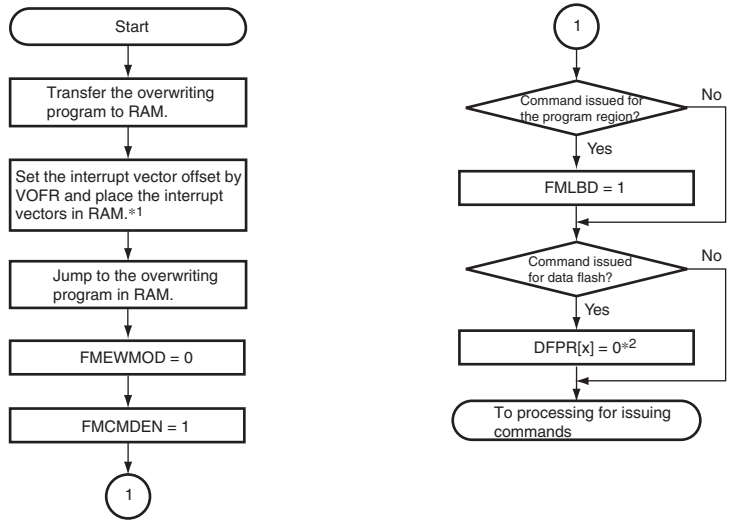
WDn: Programming data (8 bits)

(1) Initialization for CPU Reprogramming Mode

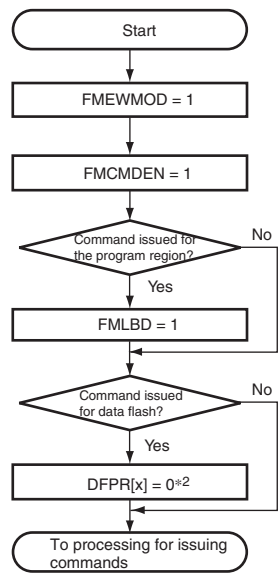
Before software commands are issued, settings for CPU reprogramming mode must be made and issuing of software commands must be permitted.

Figure 7.13 shows initialization for CPU reprogramming mode.

Flow of initialization for EW0 mode*1



Flow of initialization for EW1 mode*1



Notes: For any interrupts that are in use, allocate the interrupt vector entries and interrupt routines to RAM. If interrupts are not to be used, allocation to RAM is not necessary.
1. Within the flow, set the CPU overwriting unit selection bit (FMWUS) to select the unit of overwriting.
2. Set the DFPR according to the area of data-flash memory for which commands are to be issued.

Figure 7.13 Initialization for E/W Mode

(2) Erasure

When H'20 is written in the first command cycle and H'D0 is written to any address in the block in the second command cycle, erase/erase-verify of the specified block is automatically started.

Completion of erasure is indicated by the FMRDY bit in FLMSTR. The FMRDY bit is read as 0 during erasure, and read as 1 after erasure completion.

After erasure completion, the erasure result can be checked by reading the FMEBSF bit in FLMSTR. (See the description in (9) below, Full Status Checking.)

Note that if the lock bit is 0 (locked) in the specified block and the FMLBD bit is 0 (lock bit enabled), an erasure command is not accepted for the specified block.

Figures 7.14 and 7.15 show the flowcharts when the erase-suspend function is not used and when used, respectively.

When the erase-suspend function is being employed and erasure is resumed immediately after a period in erase-suspend mode, instruction fetching with normal incrimination of the program counter will not be possible. To avoid this problem, add two NOP instructions immediately after the instruction that writes FMSPRE = 0. Furthermore, do not use the DTC when erasure has been suspended in EW1 mode and the reprogramming control program has been allocated to RAM.

In EW1 mode, do not execute this command for the block in which the reprogramming-control program is located.

The FMRDY bit in FLMSTR changes to 0 when erasure is started, and changes to 1 when completed.

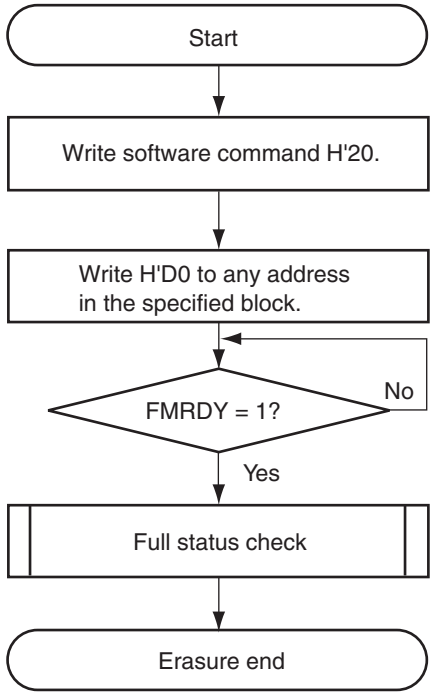
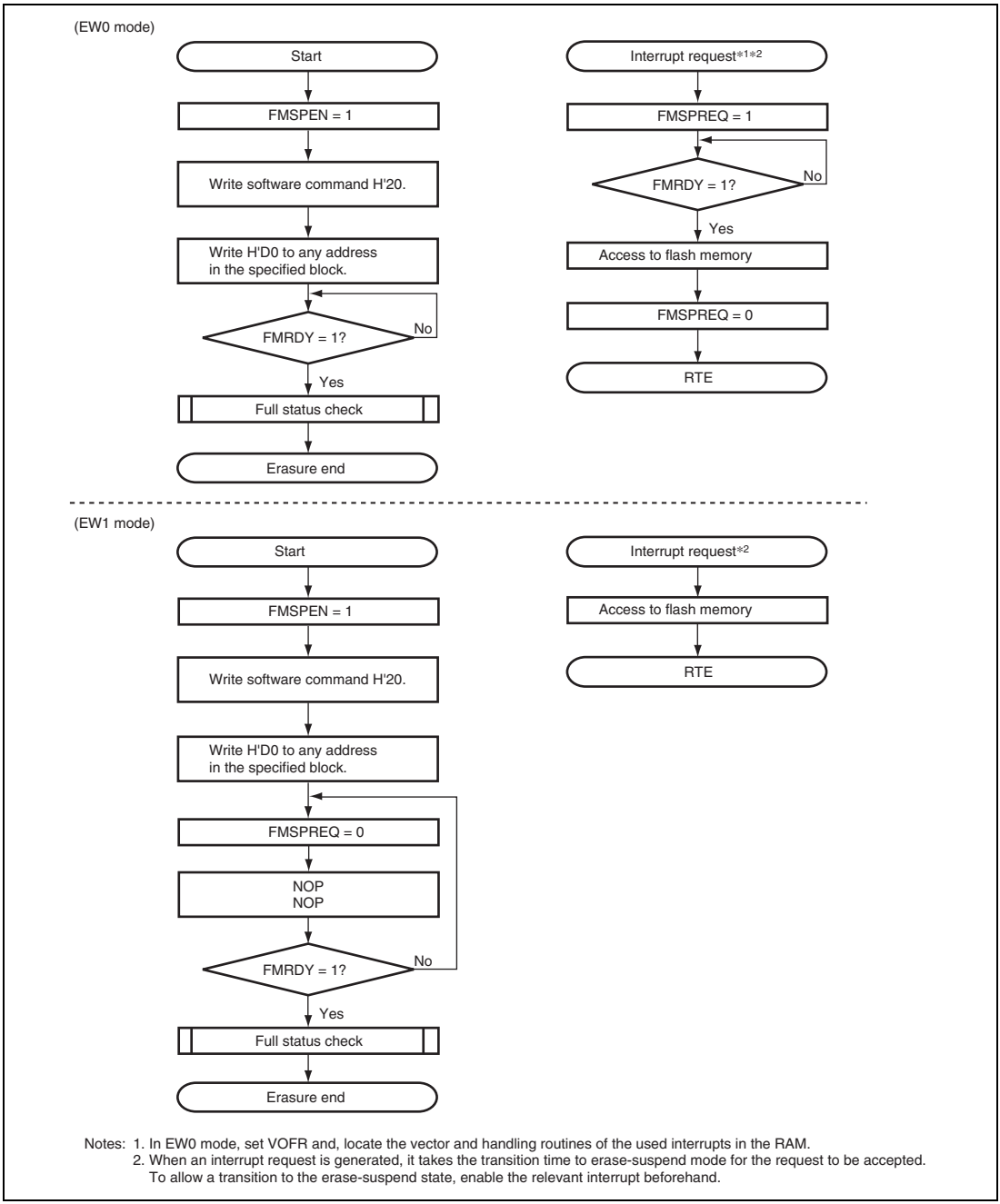


Figure 7.14 Flowchart When Erase-Suspend Function is Not Used



Notes: 1. In EW0 mode, set VOFR and, locate the vector and handling routines of the used interrupts in the RAM.
2. When an interrupt request is generated, it takes the transition time to erase-suspend mode for the request to be accepted. To allow a transition to the erase-suspend state, enable the relevant interrupt beforehand.

Figure 7.15 Flowchart When Erase-Suspend Function is Used

(3) Programming

A program command is used to program data in the flash memory in 4-byte units.

Command or data size can be set depending on the FMWUS bit in FLMCR1. Setting the FMWUS bit to 0 enables using byte instructions. When H'41 is written in the first command cycle and data is written to the programming address in the second through fifth command cycles, programming and verifying are automatically started*.

Setting the FMWUS bit to 1 enables using word instructions. When H'4141 is written in the first command cycle and data is written to the programming address in the second and third command cycles, programming and verifying are started*.

Completion of programming is indicated by the FMRDY bit in FLMSTR. The FMRDY bit is read as 0 during programming, and read as 1 after programming completion.

After programming completion, the programming result can be checked by reading the FMPRSF bit in FLMSTR. (See the description in (9) below, Full Status Checking.)

Figure 7.16 shows the programming flowchart.

Do not additionally program the already-programmed addresses.

Note that if the lock bit is 0 (locked) in the specified block and the FMLBD bit is 0 (lock bit enabled), a programming command is not accepted for the specified block.

In EW1 mode, do not execute this command for the block in which the reprogramming-control program is located.

The FMRDY bit in FLMSTR changes to 0 when programming is started, and changes to 1 when completed.

Note: * The lower two bits of the programming addresses are ignored.

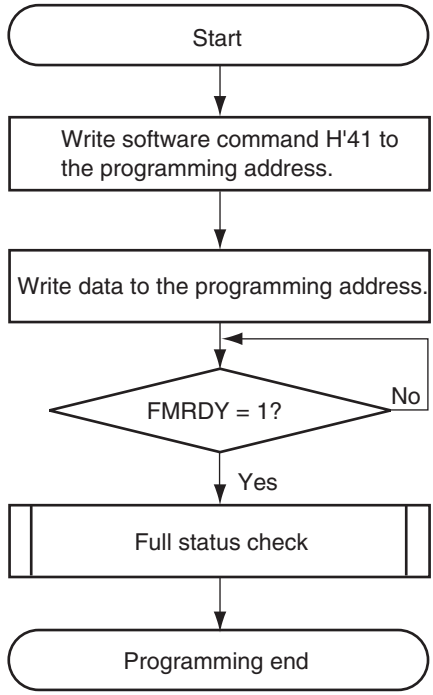


Figure 7.16 Programming Flowchart

(4) Blank Checking

When H'25 is written in the first command cycle and H'D0 is written to any address in the block in the second command cycle, blank checking of the specified block is started.

Completion of blank checking is indicated by the FMRDY bit in FLMSTR. The FMRDY bit is read as 0 during blank checking, and read as 1 after blank checking completion.

After blank checking completion, the blank checking result can be checked by reading the FMEBSF bit in FLMSTR. (See the description in (9) below, Full Status Checking.)

Figure 7.17 shows the blank checking flowchart.

The FMRDY bit in FLMSTR changes to 0 when blank checking is started, and changes to 1 when completed.

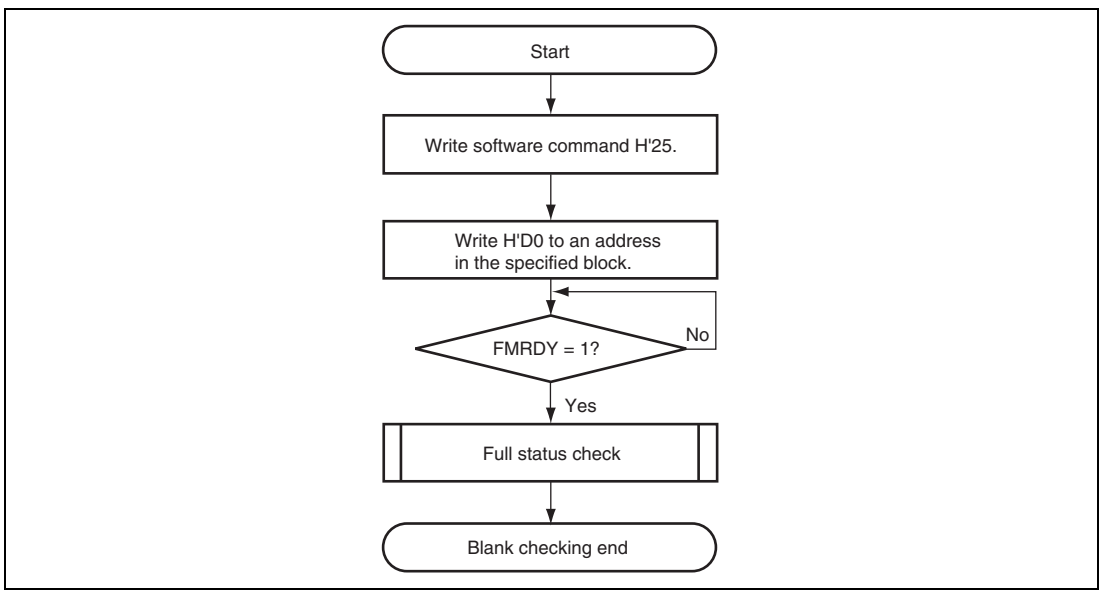


Figure 7.17 Blank Checking Flowchart

(5) Lock-Bit Programming

When H'77 is written in the first command cycle and H'D0 is written to any address in the block in the second command cycle, lock-bit programming of the specified block is started.

Completion of lock-bit programming is indicated by the FMRDY bit in FLMSTR. The FMRDY bit is read as 0 during lock-bit programming, and read as 1 after lock-bit programming completion.

After lock-bit programming completion, the lock-bit programming result can be checked by reading the FMPRSF bit in FLMSTR. (See the description in (9) below, Full Status Checking.)

Figure 7.18 shows the lock-bit programming flowchart.

The FMRDY bit in FLMSTR changes to 0 when lock-bit programming is started, and changes to 1 when completed.

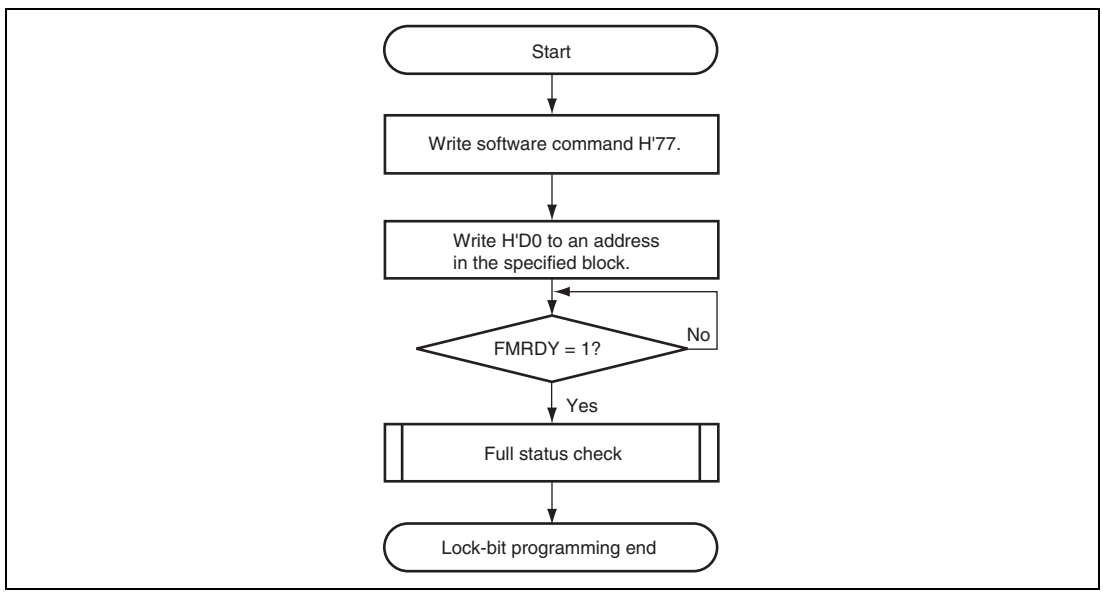


Figure 7.18 Lock-Bit Programming Flowchart

(6) Read-Array Command

A read-array command is to cause a transition to a mode in which data can be read from flash memory.

When H'FF is written in the first command cycle, a transition to read array mode is caused. When the specified addresses are read out in the subsequent command cycles, data is read from the specified addresses.

Since read-array mode is retained until any other command is written, multiple addresses can be read successively.

(7) Lock-Bit Reading Command

A lock-bit reading command is to cause a transition to a mode in which the lock bit in flash memory can be read.

When H'71 is written in the first command cycle and H'D0 is written to any address in the block in the second command cycle, lock-bit reading of the specified block is started.

After transition to lock-bit read mode, reading the specified block address BA returns the lock-bit value in the bit 14 value to be read. Do not execute a lock-bit read command in the ROM.

(8) Status Clearing Command

A clear-status command is used to clear the status flag to 0.

When H'50 is written in the first command cycle, the FMPRSF and FMEBSF bits in FLMSTR are cleared to 0.

(9) Full Status Checking

When any command (other than the read-array command, lock bit reading command and clear-status command) is issued, full-status checking is performed to confirm whether or not there was an error.

When an error occurs, the FMPRSF and FMEBSF bits in FLMSTR are set to 1, indicating the occurrence of the relevant errors.

Table 7.11 shows the bit values in FLMSTR and the corresponding errors. Figure 7.19 shows the full status checking flowchart and procedures of handling each error.

Table 7.11 Bit Values in FLMSTR and Corresponding Errors

Bit Values in FLMSTR			
FMEBSF	**FMPRSF**	**Error**	**Error Generation Conditions**
0	0	Successful end	
0	1	Programming error	The programming command is executed and results in unsuccessful programming.
		Lock-bit programming error	The lock-bit programming command is executed and results in unsuccessful programming.
1	0	Erasure error	The erasure command is executed and results in unsuccessful erasure.
		Blank checking error	The blank checking command is executed and it is detected that the specified block is not blank.
1	1	Command sequence error	• A command is not written correctly. • A data value other than H'D0 and H'FF is written in the last cycle of the command that consists of two command cycles. • The erasure command is input in erase-suspend mode. • The programming command is input for the suspended block in erase-suspend mode.

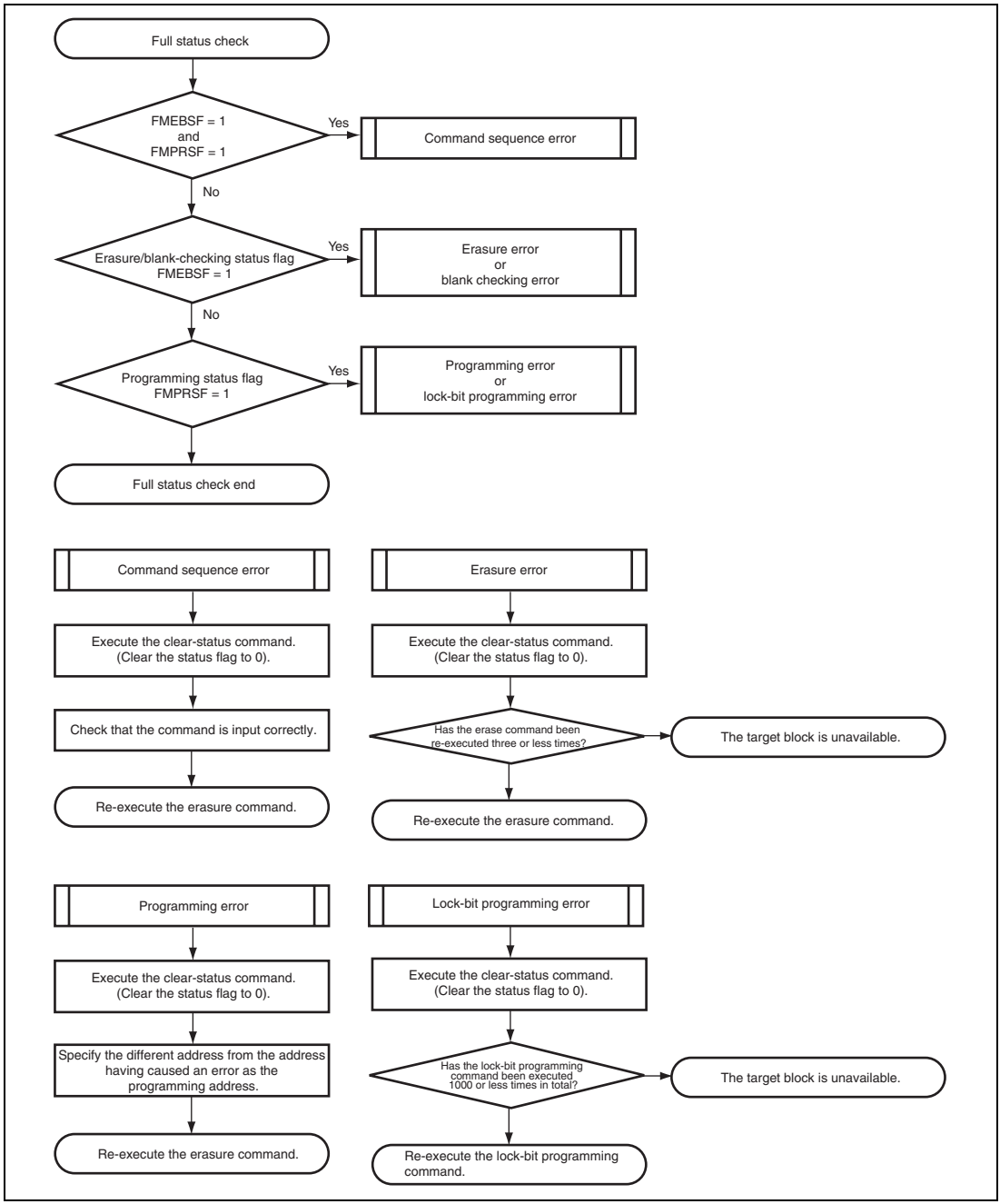


Figure 7.19 Full Status Checking Flowchart and Procedures of Handling Errors

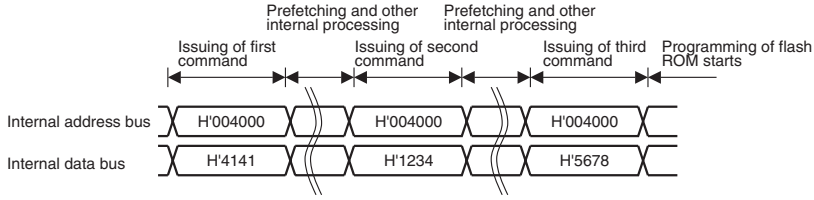
(10) Example of Issuing Commands

Figures 7.20 and 7.21 show examples of issuing programming commands and erasure commands, respectively. Figure 7.22 shows examples of issuing read-array commands.

● Using word-length instructions to issue programming commands (FMWUS = 1)

Target address for writing	Data
H'004000	H'12
H'004001	H'34
H'004002	H'56
H'004003	H'78

```
[Programming Example]
@MOV.W  #H'4141,R0          ; Programming command
@MOV.W  #H'1234,R1          ; Writing of data
@MOV.W  #H'5678,R2          ; Writing of data
@MOV.W  R0, @H'00004000     ; First command
@MOV.W  R1, @H'00004000     ; Second command
@MOV.W  R2, @H'00004000     ; Third command
```



● Using byte-length instructions to issue programming commands (FMWUS = 0)

Target address for writing	Data
H'004000	H'12
H'004001	H'34
H'004002	H'56
H'004003	H'78

```
[Programming Example]
@MOV.B  #H'41, R0L          ; Programming command
@MOV.W  #H'1234,R1          ; Writing of data
@MOV.W  #H'5678,R2          ; Writing of data
@MOV.B  R0L, @H'00004000    ; First command
@MOV.B  R1H, @H'00004000    ; Second command
@MOV.B  R1L, @H'00004000    ; Third command
@MOV.B  R2H, @H'00004000    ; Fourth command
@MOV.B  R2L, @H'00004000    ; Fifth command
```

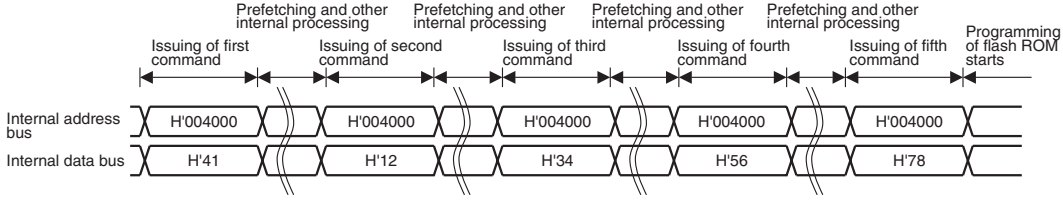


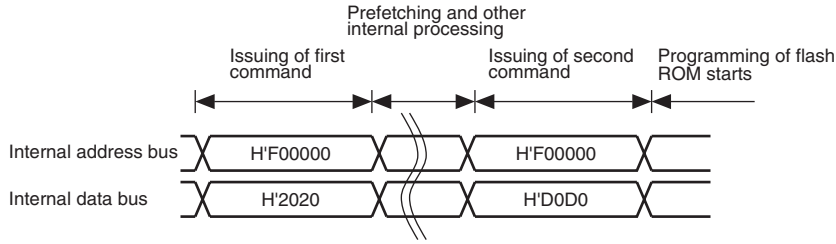
Figure 7.20 Examples of Issuing Programming Commands

● Using word-length instructions to issue erasure commands (FMWUS = 1)

[Erasure Setting]
Erasure block = Data flash A

[Programming Example]

```
@MOV.W   #H'2020,R0          ; Erasure command
@MOV.W   #H'D0D0,R1          ; Erasure command
@MOV.W   R0,@H'00F00000      ; First command
@MOV.W   R1,@H'00F00000      ; Second command
```



● Using byte-length instructions to issue erasure commands (FMWUS = 0)

[Erasure Setting]
Erasure block = Data flash A

[Programming Example]

```
@MOV.B   #H'20, R0L          ; Erasure command
@MOV.B   #H'D0, R0H          ; Erasure command
@MOV.B   R0L,@H'00F00000     ; First command
@MOV.B   R0H,@H'00F00000     ; Second command
```

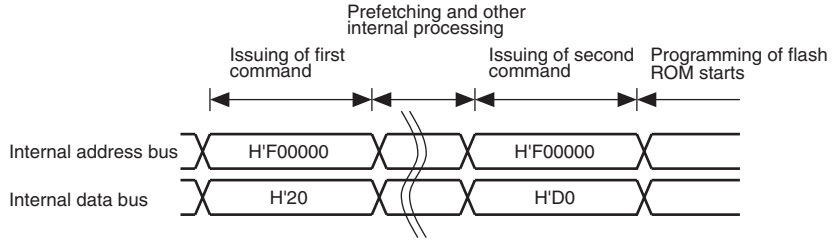


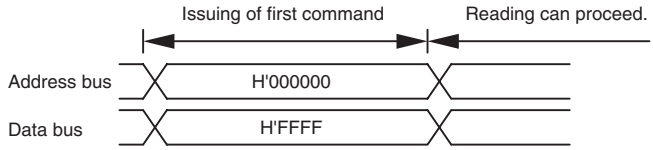
Figure 7.21 Examples of Issuing Erasure Commands

● Using word-length instructions to issue read-array commands (FMWUS = 1)

[Read-Array Setting]
Address = Program-ROM area

[Programming Example]

```
@MOV.W   #H'FFFF, R0          ; Read-array command
@MOV.W   R0, @H'00000000      ; First command
```



● Using byte-length instructions to issue read-array commands (FMWUS = 0)

[Read-Array Setting]
Address = Program-ROM area

[Programming Example]

```
@MOV.B   #H'FF, R0L           ; Read-array command
@MOV.B   R0L,@H'00000000      ; First command
```

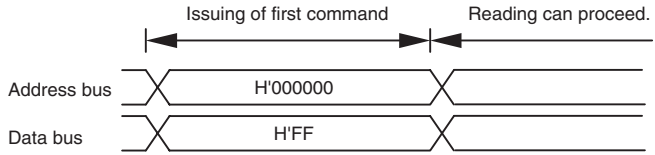


Figure 7.22 Examples of Issuing Read-Array Commands

7.7 Protection

Three modes are available to protect the flash memory against reading, programming, and erasing: software protection, lock-bit protection, and protection to restrict access in programmer mode and boot mode.

7.7.1 Software Protection

Software commands can be disabled by clearing the FMCMDEN bit in the flash memory control register (FLMCR1) through software. In this state, no software commands are executed even if input.

Data flash areas can be protected in block units by using the flash memory data flash protect register (DFPR). Setting bits DFPR1 and DFPR0 in DFPR to 1 places all the data flash areas in protect mode.

7.7.2 Lock-Bit Protection

The programming/erasure commands can be disabled by programming the lock bits using the lock-bit programming command. In this state, the erasure/programming commands are not executed even if input. This prevents flash memory from being erroneously erased or programmed due to CPU runaway.

The protection function can be temporarily disabled by setting the FMLBD bit in FLMCR1 to 1. To clear the lock bit, erase the specified block. Note that lock bits are unavailable in data flash areas.

7.7.3 PROM Programmer Protection/Boot Mode Protection

PROM programmer protection/boot mode protection is enabled by writing the specified data to the user ROM area shown in the table 7.12.

The protection function can be disabled by using a PROM programmer or on-board programmer to delete the entire user ROM area.

Table 7.13 shows the specifications for PROM programmer protection and table 7.14 shows the specifications of protection in boot mode.

Table 7.12 Address Range of the Protection Code in User ROM

	H'000004	H'000005	H'000006	H'000007	H'000010	H'000011	H'000012	H'000013
PROM programmer	Control code	Not used						
Boot mode		Authentication ID code (56 bits)						

Table 7.13 Specifications for PROM Programmer Protection

Control code*	Protection State	Operation to be Carried Out
H'FF	PROM programmer protection is disabled.	Possible operations; reading/programming/ erasing by PROM programmer.
Other than above	PROM programmer protection is enabled.	Possible operations; programming/erasing by PROM programmer. However, reading is not possible.

Note: * Used together with control code for boot mode protection.

Table 7.14 Specifications for Boot Mode Protection

Control code*	Protection State	Operation in Serial Connection
Other than above	Protection is disabled.	Entire blocks are deleted.
H'45	ID authentication protection 1*[2]	Possible for reading/programming/erasing if the ID was authenticated. If the ID was not authenticated, entire blocks are deleted.
H'52	ID authentication protection 2	Possible for reading/programming/erasing if the ID was authenticated. If the ID was not authenticated, authentication is performed again.
	ID authentication protection 2+*[3]	If control code is H'52 and the special code (H'50, H'72, H'6F, H'74, H'65, H'63 and H'74) is written to the authentication ID bytes, processing for serial connections will not be accepted.

Note: 1. Used together with the control code for the PROM programmer.
2. Re-authentication can be performed up to 3 times in case of error in the ID code.
3. Once this setting has been made, serial connections are not accepted unless a PROM programmer is used to delete the setting.

7.8 Programmer Mode

In programmer mode, flash memory areas can be programmed/erased using a PROM programmer via a socket adapter, just as a discrete flash memory can be. Use the PROM programmer that supports the Renesas Technology microcomputer device type with the on-chip 128-kbyte flash memory.

7.9 Usage Notes

(1) Prohibited Instruction

In EW0 mode, the following instruction cannot be used because it refers to the data in the flash memory area.

- TRAP

(2) Interrupts

Table 7.15 shows interrupt handling in CPU reprogramming mode.

Table 7.15 Interrupt Handling in CPU Reprogramming Mode

Mode	State	When Interrupt Request is Received	When Watchdog Timer Reset, LVD Reset, Software Reset, or Pin Reset, Interrupt Request is Generated
EW0	During erasure command	Interrupts can be handled if interrupt vectors are located in the RAM. For details, see section 4.2.7, Interrupt vector offset register (VOFR).	Immediately after a reset is generated, a software command is forcibly terminated, and flash memory and LSI are reset. Because of the forced termination, it might be impossible to read correct values from the block or address for which the software command has been executed; execute erasure again after restarting and confirm that erasure is completed successfully. The watchdog timer does not stop even during command execution; initialize the timer periodically.
	During programming command		
	During lock-bit programming command		
	During blank checking command		

Mode	State	When Interrupt Request is Received	When Watchdog Timer Reset, LVD Reset, Software Reset, or Pin Reset, Interrupt Request is Generated
EW1	During erasure command (erase-suspend function not used)	Erasure is given priority, keeping the interrupt request waiting. When erasure is completed, execution of the interrupt processing is started.	Immediately after a reset is generated, a software command is forcibly terminated, and flash memory and LSI are reset. Because of the forced termination, it might be impossible to read correct values from the block or address for which the software command has been executed; execute erasure again after restarting and confirm that erasure is completed successfully. Since the watchdog timer does not stop even during command execution, set the overflow time of the watchdog timer longer than the erasure/programming execution time.
	During erasure command (erase-suspend function used)	After the transition time to erase-suspend mode, erasure is suspended starting execution of the interrupt processing. When the interrupt processing is completed, setting the FMSPREQ bit in FLMCR2 to 0 resumes erasure.	
	During programming command	A software command is given priority, keeping the interrupt request waiting. When the software command is completed, execution of the interrupt processing is started.	
	During lock-bit programming command		
	During blank checking command		

(3) Method of Access

When writing values to the protected bits indicated below, start by writing 0 to the bit and then write 1 to it or by writing 1 to the bit and then write 0 to it. Do not allow the generation of any interrupt or any access to other I/O registers between the two operations. For writing, always use the MOV instruction.

(a) Bits that are set to 1 by writing 0 and then 1 consecutively

- FLMCR1: FMLBD and FMCMDEN bits
- FLMCR2: FMISPE and FMSPEN bits

(b) Bits that are cleared to 0 by writing 1 and then 0 consecutively

- DFPR: DFPR1 and DFPR0 bits

The example below is of code for use when the FMCMDEN and FMLBD bits in FLMCR1 are to be changed from 0 to 1.

```
MOV.B  @FLMCR1,R0L   :FLMCR1=H'04      R0L=H'04     R0H=H'xx
MOV.B  @FLMCR1,R0H   :FLMCR1=H'04      R0L=H'04     R0H=H'04
BSET   #0,R0H        :FLMCR1=H'04      R0L=H'04     R0H=H'05
BSET   #3,R0H        :FLMCR1=H'04      R0L=H'04     R0H=H'0D
MOV.B  R0L,@FLMCR1   :FLMCR1=H'04      R0L=H'04     R0H=H'0D
MOV.B  R0H,@FLMCR1   :FLMCR1=H'0D      R0L=H'04     R0H=H'0D
```

(4) Reprogramming User ROM Area

When it is necessary to reprogram the block containing the reprogramming-control program, use boot mode. This is because if the power supply voltage drops in EW0 mode while the block containing the reprogramming-control program is being reprogrammed, the reprogramming-control program cannot be correctly reprogrammed, and this might disable further reprogramming of the flash memory. Only proceed with overwriting of the programming-control program after securing ample stabilization time for the power supply.

(5) Program

Do not program the already-programmed addresses.

(6) LSI Mode Transition

During software command execution, do not cause a transition to standby mode or sleep mode.

(7) Reset during Execution of Software Command in Flash Memory

Do not apply a pin reset, LVD reset, or watchdog timer reset during execution of the programming, lock-bit programming, blank-checking, and erasure commands. If applied, the currently executed command is forcibly terminated. In this case, execute the erasure command of the specified block again and confirm that erasure is completed successfully.

Section 8 RAM

The H8S/20103, H8S/20203, and H8S/20223 Group LSIs have an on-chip high-speed static RAM. The RAM is connected to the CPU via a 16-bit data bus, enabling the CPU to access both byte data and word data in one state.

Product Classification			RAM Size	RAM Address
Flash memory version	64 pins	H8S/20103	8 kbytes	H'FFDF80 to H'FFFF7F
		H8S/20102	8 kbytes	H'FFDF80 to H'FFFF7F
	80 pins	H8S/20223	8 kbytes	H'FFDF80 to H'FFFF7F
		H8S/20222	8 kbytes	H'FFDF80 to H'FFFF7F
		H8S/20203	8 kbytes	H'FFDF80 to H'FFFF7F
		H8S/20202	8 kbytes	H'FFDF80 to H'FFFF7F

Section 9 Peripheral I/O Mapping Controller

The peripheral function mapping controller (PMC) is composed of registers that are used to select the functions of multiplexed pins. The multiplexed pins are divided into two groups: group 1 and group 2. Group 1 consists of ports 1 to 3, 5, and 6, and group 2 consists of ports 8, 9*, and A. Tables 9.1 and 9.2 list the functions of the multiplexed pins in each group.

Note: Port 9 is not available on the H8S/20103 group.

Table 9.1 Multiplexed Pin Functions (Ports 1, 2, 3, 5, and 6)

Group 1	Pin Name	Function 1	Function 2	Function 3	Function 4	Function 5	Function 6
Port 1 Port 2 Port 3 Port 5 Port 6	Pm7	$\overline{\text{IRQ7}}$ input	TXD_2 output	TXD_3 output	SCL/SSI input/output	FTIOD1 input/output	$\overline{\text{ADTRG2}}$ input
	Pm6	$\overline{\text{IRQ6}}$ input	RXD_2 input	RXD_3 input	SDA/$\overline{\text{SCS}}$ input/output	FTIOC1 input/output	$\overline{\text{ADTRG1}}$ input
	Pm5	$\overline{\text{IRQ5}}$ input	SCK3_2 input/output	SCK3_3 input/output	SSCK input/output	FTIOB1 input/output	$\overline{\text{TRDOI_1}}$ input
	Pm4	$\overline{\text{IRQ4}}$ input	$\overline{\text{TRDOI_0}}$ input	FTCI input*	SSO input/output	FTIOA1 input/output	TRAIO input/output
	Pm3	$\overline{\text{IRQ3}}$ input	$\overline{\text{TRCOI}}$ input*	FTIOD input/output*	TGIOB input/output	FTIOD0 input/output	TRAO output
	Pm2	$\overline{\text{IRQ2}}$ input	TXD output	FTIOC input/output*	TGIOA input/output	FTIOC0 input/output	TRBO output
	Pm1	$\overline{\text{IRQ1}}$ input	RXD input	FTIOB input/output*	TCLKB input	FTIOB0 input/output	TRGB input
	Pm0	$\overline{\text{IRQ0}}$ input	SCK3 input/output	FTIOA input/output*	TCLKA input	FTIOA0 input/output	TREO output
Initially mapped port		Port 1	Port 2	Port 3	Port 5	Port 6	None

[Legend] m = 1, 2, 3, 5 and 6

Note: The timer RC is not available on the H8S/20203 and H8S/20223 groups; therefore, the function cannot be selected for these groups.

Table 9.2 Multiplexed Pin Functions (Ports 8, 9, and A)

Group 2	Pin Name	Function 1	Function 2	Function 3	Function 4	Function 5*[2]	Function 6
Port 8 Port 9 Port A*[1]	Pm7	$\overline{\text{IRQ7}}$ input	—	TXD output	TREO output	FTIOD3 input/output	TXD_3 output
	Pm6	$\overline{\text{IRQ6}}$ input	—	RXD input	TRBO output	FTIOC3 input/output	RXD_3 input
	Pm5	$\overline{\text{IRQ5}}$ input	—	SCK3 input/output	TRAIO input/output	FTIOB3 input/output	SCK3_3 input/output
	Pm4	$\overline{\text{IRQ4}}$ input	—	—	TRGB input	FTIOA3 input/output	—
	Pm3	$\overline{\text{IRQ3}}$ input	—	—	TRAO output	FTIOD2 input/output	—
	Pm2	$\overline{\text{IRQ2}}$ input	—	—	—	FTIOC2 input/output	—
	Pm1	$\overline{\text{IRQ1}}$ input	—	—	—	FTIOB2 input/output	—
	Pm0	$\overline{\text{IRQ0}}$ input	—	—	—	FTIOA2 input/output	—
Initially mapped port		None	None	None	Port 8	Port 9	None

[Legend] n = 8, 9, and A
—: Reserved

Note: 1. Port A is multiplexed with A/D converter analog input in the H8S/20223 group. Therefore, the multiplexed functions cannot be selected for the port.
The PA3 to PA0 pins are multiplexed with A/D converter analog input in the H8S/20203 group. Therefore, the multiplexed functions cannot be selected for the port pins.
2. Function 5 cannot be selected for the H8S/20103 group.

9.1 Register Descriptions

- Peripheral function mapping register write-protect register (PMCWPR)
- Port 1 peripheral function mapping register 1 (PMCR11)
- Port 1 peripheral function mapping register 2 (PMCR12)
- Port 1 peripheral function mapping register 3 (PMCR13)
- Port 1 peripheral function mapping register 4 (PMCR14)
- Port 2 peripheral function mapping register 1 (PMCR21)
- Port 2 peripheral function mapping register 2 (PMCR22)
- Port 2 peripheral function mapping register 3 (PMCR23)
- Port 2 peripheral function mapping register 4 (PMCR24)
- Port 3 peripheral function mapping register 1 (PMCR31)
- Port 3 peripheral function mapping register 2 (PMCR32)
- Port 3 peripheral function mapping register 3 (PMCR33)
- Port 3 peripheral function mapping register 4 (PMCR34)
- Port 5 peripheral function mapping register 1 (PMCR51)
- Port 5 peripheral function mapping register 2 (PMCR52)
- Port 5 peripheral function mapping register 3 (PMCR53)
- Port 5 peripheral function mapping register 4 (PMCR54)
- Port 6 peripheral function mapping register 1 (PMCR61)
- Port 6 peripheral function mapping register 2 (PMCR62)
- Port 6 peripheral function mapping register 3 (PMCR63)
- Port 6 peripheral function mapping register 4 (PMCR64)
- Port 8 peripheral function mapping register 3 (PMCR83)
- Port 8 peripheral function mapping register 4 (PMCR84)
- Port 9 peripheral function mapping register 1 (PMCR91)*[1]
- Port 9 peripheral function mapping register 2 (PMCR92)*[1]
- Port 9 peripheral function mapping register 3 (PMCR93)*[1]
- Port 9 peripheral function mapping register 4 (PMCR94)*[1]
- Port A peripheral function mapping register 3 (PMCRA3)*[2]
- Port A peripheral function mapping register 4 (PMCRA4)*[2]

Notes: 1. PMCR91 to PMCR94 are not available on the H8S/20103 group.
2. PMCRA3 and PMCRA4 are not available on the H8S/20223 group.

9.1.1 Peripheral Function Mapping Register Write-Protect Register (PMCWPR)

Address: H'FF0065

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	B0WI	PMCRWE	—	—	—	—	—	—
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	B0WI	Bit 6 write protect	0: Writing to PMCRWE (bit 6 in this register) is enabled. 1: Writing to the PMCRWE bit is disabled.	W
6	PMCRWE	PMCR write enable	0: Writing to PMCR is disabled. 1: Writing to PMCR is enabled.	R/W
5 to 0	—	Reserved	These bits are always read as 0. The write value should always be 0.	—

Note: A MOV instruction should be used to rewrite this register.

- B0WI bit (Bit 6 write protect)

  Only when the write value to this bit is 0, PMCRWE (bit 6 in this register) can be modified. This bit is always read as 1.

9.1.2 Port Group 1

Peripheral Function Mapping Registers 1 to 4 (PMCRn1 to PMCRn4 (n = 1, 2, 3, 5, and 6))

(1) Port 1

(a) Port 1 Peripheral Function Mapping Register 1 (PMCR11)

Address: H'FF0040

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P11MD[2:0]			—	P10MD[2:0]		
Value after reset:	0	0	0	1	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P11MD[2:0]	P11 function select	000: Setting prohibited 001: $\overline{\text{IRQ1}}$ input (initial value) 010: RXD input (SCI3_1) 011: FTIOB input/output (timer RC)*2 100: TCLKB input (timer RG) 101: FTIOB0 input/output (timer RD_0) 110: TRGB input (timer RB) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P10MD[2:0]	P10 function select*1	000: Setting prohibited 001: $\overline{\text{IRQ0}}$ input (initial value) 010: SCK3 input/output (SCI3_1) 011: FTIOA input/output (timer RC)*2 100: TCLKA input (timer RG) 101: FTIOA0 input/output (timer RD_0) 110: TREO output (timer RE) 111: Setting prohibited	R/W

Notes: 1. For the H8S/20103 group, P10 is not provided and P10MD[2:0] are reserved. The initial value is B'001. The write value should be B'001.
2. This function cannot be selected for the H8S/20203 and H8S/20223 groups.

(b) Port 1 Peripheral Function Mapping Register 2 (PMCR12)

Address: H'FF0041

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P13MD[2:0]			—	P12MD[2:0]		
Value after reset:	0	0	0	1	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P13MD[2:0]	P13 function select	000: Setting prohibited 001: $\overline{\text{IRQ3}}$ input (initial value) 010: $\overline{\text{TRCOI}}$ input (timer RC)* 011: FTIOD input/output (timer RC)* 100: TGIOB input/output (timer RG) 101: FTIOD0 input/output (timer RD_0) 110: TRAO output (timer RA) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P12MD[2:0]	P12 function select	000: Setting prohibited 001: $\overline{\text{IRQ2}}$ input (initial value) 010: TXD output (SCI3_1) 011: FTIOC input/output (timer RC)* 100: TGIOA input/output (timer RG) 101: FTIOC0 input/output (timer RD_0) 110: TRBO output (timer RB) 111: Setting prohibited	R/W

Note: * This function cannot be selected for the H8S/20203 and H8S/20223 groups.

(c) Port 1 Peripheral Function Mapping Register 3 (PMCR13)

Address: H'FF0042

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P15MD[2:0]			—	P14MD[2:0]		
Value after reset:	0	0	0	1	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P15MD[2:0]	P15 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input (initial value) 010: SCK3_2 input/output (SCI3_2) 011: SCK3_3 input/output (SCI3_3) 100: SSCK input/output*4 (SSU) 101: FTIOB1 input/output (timer RD_0) 110: $\overline{\text{TRDOI_1}}$ input (timer RD_1)*2 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P14MD[2:0]	P14 function select*1	000: Setting prohibited 001: $\overline{\text{IRQ4}}$ input (initial value) 010: $\overline{\text{TRDOI_0}}$ input (timer RD_0) 011: FTCI input (timer RC)*3 100: SSO input/output*4 (SSU) 101: FTIOA1 input/output (timer RD_0) 110: TRAIO input/output (timer RA) 111: Setting prohibited	R/W

Notes: 1. For the H8S/20103 group, P14 is not provided and P14MD[2:0] are reserved. The initial value is B'001. The write value should be B'001.
2. This function cannot be selected for the H8S/20103 group.
3. This function cannot be selected for the H8S/20203 and H8S/20223 groups.
4. If the SSCK output pin or the SSO output pin is set, the NMOS open-drain output cannot be selected.

(d) Port 1 Peripheral Function Mapping Register 4 (PMCR14)

Address: H'FF0043

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P17MD[2:0]			—	P16MD[2:0]		
Value after reset:	0	0	0	1	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P17MD[2:0]	P17 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input (initial value) 010: TXD_2 output (SCI3_2) 011: TXD_3 output (SCI3_3) 100: SSI/SCL input/output*1 (SSU/IIC2) 101: FTIOD1 input/output (timer RD_0) 110: $\overline{\text{ADTRG2}}$ input (AD_2) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P16MD[2:0]	P16 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input (initial value) 010: RXD_2 input (SCI3_2) 011: RXD_3 input (SCI3_3) 100: $\overline{\text{SCS}}$/SDA input/output*1*2 (SSU/IIC2) 101: FTIOC1 input/output (timer RD_0) 110: $\overline{\text{ADTRG1}}$ input (AD_1) 111: Setting prohibited	R/W

Note: 1. When the IICS/SSU is used as the IIC2 function, the SCL and SDA functions should be allocated to the P56 and P57 pins because SCL and SDA require buffers dedicated for IIC input/output. When the ICSU is used for the SSU function except *2, there is no restriction.

2. If the $\overline{\text{SCS}}$ output pin of the SSU is set, the NMOS open-drain output cannot be selected.

(2) Port 2

(a) Port 2 Peripheral Function Mapping Register 1 (PMCR21)

Address: H'FF0044

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P21MD[2:0]			—	P20MD[2:0]		
Value after reset:	0	0	1	0	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P21MD[2:0]	P21 function select	000: Setting prohibited 001: $\overline{\text{IRQ1}}$ input 010: RXD input (SCI3_1) (initial value) 011: FTIOB input/output (timer RC)* 100: TCLKB input (timer RG) 101: FTIOB0 input/output (timer RD_0) 110: TRGB input (timer RB) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P20MD[2:0]	P20 function select	000: Setting prohibited 001: $\overline{\text{IRQ0}}$ input 010: SCK3 input/output (SCI3_1) (initial value) 011: FTIOA input/output (timer RC)* 100: TCLKA input (timer RG) 101: FTIOA0 input/output (timer RD_0) 110: TREO output (timer RE) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.

(b) Port 2 Peripheral Function Mapping Register 2 (PMCR22)

Address: H'FF0043

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P23MD[2:0]			—	P22MD[2:0]		
Value after reset:	0	0	1	0	0	0	1	0

Bit	Bit Name	Initial Value	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P23MD[2:0]	P23 function select	000: Setting prohibited 001: $\overline{\text{IRQ3}}$ input 010: $\overline{\text{TRCOI}}$ input (timer RC) (initial value) 011: FTIOD input/output (timer RC)* 100: TGIOB input/output (timer RG) 101: FTIOD0 input/output (timer RD_0) 110: TRAO output (timer RA) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P22MD[2:0]	P22 function select	000: Setting prohibited 001: $\overline{\text{IRQ2}}$ input 010: TXD output (SCI3_1) (initial value) 011: FTIOC input/output (timer RC)* 100: TGIOA input/output (timer RG) 101: FTIOC0 input/output (timer RD_0) 110: TRBO output (timer RB) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.

(c) Port 2 Peripheral Function Mapping Register 3 (PMCR23)

Address: H'FF0046

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P25MD[2:0]			—	P24MD[2:0]		
Value after reset:	0	0	1	0	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P25MD[2:0]	P25 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input 010: SCK3_2 input/output (SCI3_2) (initial value) 011: SCK3_3 input/output (SCI3_3) 100: SSCK input/output*3 (SSU) 101: FTIOB1 input/output (timer RD_0) 110: $\overline{\text{TRDOI_1}}$ input (timer RD_1)*1 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P24MD[2:0]	P24 function select	000: Setting prohibited 001: $\overline{\text{IRQ4}}$ input 010: $\overline{\text{TRDOI_0}}$ input (timer RD_0) (initial value) 011: FTCI input (timer RC)*2 100: SSO input/output*3 (SSU) 101: FTIOA1 input/output (timer RD_0) 110: TRAIO input/output (timer RA) 111: Setting prohibited	R/W

Notes: 1. This function cannot be selected for the H8S/20103 group.
2. This function cannot be selected for the H8S/20203 and H8S/20223 groups.
3. If the SSCK output pin or the SSO output pin is set, the NMOS open-drain output cannot be selected.

(d) Port 2 Peripheral Function Mapping Register 4 (PMCR24)

Address: H'FF0047

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P27MD[2:0]			—	P26MD[2:0]		
Value after reset:	0	0	1	0	0	0	1	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P27MD[2:0]	P27 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input 010: TXD_2 output (SCI3_2) (initial value) 011: TXD_3 output (SCI3_3) 100: SSI/SCL input/output*1 (SSU/IIC2) 101: FTIOD1 input/output (timer RD_0) 110: $\overline{\text{ADTRG2}}$ input (AD_2) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P26MD[2:0]	P26 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input 010: RXD_2 input (SCI3_2) (initial value) 011: RXD_3 input (SCI3_3) 100: $\overline{\text{SCS}}$/SDA input/output*1*2 (SSU/IIC2) 101: FTIOC1 input/output (timer RD_0) 110: $\overline{\text{ADTRG1}}$ input (AD_1) 111: Setting prohibited	R/W

Note: 1. When the IIC2/SSU is used as the IIC2 function, the SCL and SDA functions should be allocated to the P56 and P57 pins because SCL and SDA require buffers dedicated for IIC input/output. When the ICSU is used for the SSU function except *2, there is no restriction.

2. If the $\overline{\text{SCS}}$ output pin of the SSU is set, the NMOS open-drain output cannot be selected.

(3) Port 3

(a) Port 3 Peripheral Function Mapping Register 1 (PMCR31)

Address: H'FF0048

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P31MD[2:0]			—	P32MD[2:0]		
Value after reset:	0	0	1	1	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P31MD[2:0]	P31 function select	000: Setting prohibited 001: $\overline{\text{IRQ1}}$ input 010: RXD input (SCI3_1) 011: FTIOB input/output (timer RC)* (initial value) 100: TCLKB input (timer RG) 101: FTIOB0 input/output (timer RD_0) 110: TRGB input (timer RB) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P30MD[2:0]	P30 function select	000: Setting prohibited 001: $\overline{\text{IRQ0}}$ input 010: SCK3 input/output (SCI3_1) 011: FTIOA input/output (timer RC)* (initial value) 100: TCLKA input (timer RG) 101: FTIOA0 input/output (timer RD_0) 110: TREO output (timer RE) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. No function is selected in the initial state for these groups.

(b) Port 3 Peripheral Function Mapping Register 2 (PMCR32)

Address: H'FF0049

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P33MD[2:0]			—	P32MD[2:0]		
Value after reset:	0	0	1	1	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P33MD[2:0]	P33 function select	000: Setting prohibited 001: $\overline{\text{IRQ3}}$ input 010: $\overline{\text{TRCOI}}$ input (timer RC)* 011: FTIOD input/output (timer RC)* (initial value) 100: TGIOB input/output (timer RG) 101: FTIOD0 input/output (timer RD_0) 110: TRAO output (timer RA) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P32MD[2:0]	P32 function select	000: Setting prohibited 001: $\overline{\text{IRQ2}}$ input 010: TXD output (SCI3_1) 011: FTIOC input/output (timer RC)* (initial value) 100: TGIOA input/output (timer RG) 101: FTIOC0 input/output (timer RD_0) 110: TRBO output (timer RB) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. No function is selected in the initial state for these groups.

(c) Port 3 Peripheral Function Mapping Register 3 (PMCR33)

Address: H'FF004A

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P35MD[2:0]			—	P34MD[2:0]		
Value after reset:	0	0	1	1	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P35MD[2:0]	P35 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input 010: SCK3_2 input/output (SCI3_2) 011: SCK3_3 input/output (SCI3_3) (initial value) 100: SSCK input/output*3 (SSU) 101: FTIOB1 input/output (timer RD_0) 110: $\overline{\text{TRDOI_1}}$ input (timer RD_1)*1 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P34MD[2:0]	P34 function select	000: Setting prohibited 001: $\overline{\text{IRQ4}}$ input 010: $\overline{\text{TRDOI_0}}$ input (timer RD_0) 011: FTCI input (timer RC)*2 (initial value) 100: SSO input/output*3 (SSU) 101: FTIOA1 input/output (timer RD_0) 110: TRAIO input/output (timer RA) 111: Setting prohibited	R/W

Notes: 1. This function cannot be selected for the H8S/20103 group.
2. The timer RC is not available on the H8S/20203 and H8S/20223 groups. No function is selected in the initial state for these groups.
3. If the SSCK output pin or the SSO output pin is set, the NMOS open-drain output cannot be selected.

(d) Port 3 Peripheral Function Mapping Register 4 (PMCR34)

Address: H'FF004B

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P37MD[2:0]			—	P36MD[2:0]		
Value after reset:	0	0	1	1	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P37MD[2:0]	P37 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input 010: TXD_2 output (SCI3_2) 011: TXD_3 output (SCI3_3) (initial value) 100: SSI/SCL input/output*1 (SSU/IIC2) 101: FTIOD1 input/output (timer RD_0) 110: $\overline{\text{ADTRG2}}$ input (AD_2)*2 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P36MD[2:0]	P36 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input 010: RXD_2 input (SCI3_2) 011: RXD_3 input (SCI3_3) (initial value) 100: $\overline{\text{SCS}}$/SDA input/output*1*3 (SSU/IIC2) 101: FTIOC1 input/output (timer RD_0) 110: $\overline{\text{ADTRG1}}$ input (AD_1) 111: Setting prohibited	R/W

Notes: 1. When the IIC2/SSU is used as the IIC2 function, the SCL and SDA functions should be allocated to the P56 and P57 pins because SCL and SDA require buffers dedicated for IIC input/output. When the ICSU is used for the SSU function except *2, there is no restriction.
2. This function cannot be selected for the H8S/20103 and H8S/20203 groups.
3. If the $\overline{\text{SCS}}$ output pin of the SSU is set, the NMOS open-drain output cannot be selected.

(4) Port 5

(a) Port 5 Peripheral Function Mapping Register 1 (PMCR51)

Address: H'FF0050

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P51MD[2:0]			—	P50MD[2:0]		
Value after reset:	0	1	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P51MD[2:0]	P51 function select	000: Setting prohibited 001: $\overline{\text{IRQ1}}$ input 010: RXD input (SCI3_1) 011: FTIOB input/output (timer RC)* 100: TCLKB input (timer RG) (initial value) 101: FTIOB0 input/output (timer RD_0) 110: TRGB input (timer RB) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P50MD[2:0]	P50 function select	000: Setting prohibited 001: $\overline{\text{IRQ0}}$ input 010: SCK3 input/output (SCI3_1) 011: FTIOA input/output (timer RC)* 100: TCLKA input (timer RG) (initial value) 101: FTIOA0 input/output (timer RD_0) 110: TREO output (timer RE) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.

(b) Port 5 Peripheral Function Mapping Register 2 (PMCR52)

Address: H'FF0051

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P53MD[2:0]			—	P52MD[2:0]		
Value after reset:	0	1	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P53MD[2:0]	P53 function select	000: Setting prohibited 001: $\overline{\text{IRQ3}}$ input 010: $\overline{\text{TRCOI}}$ input (timer RC)* 011: FTIOD input/output (timer RC)* 100: TGIOB input/output (timer RG) (initial value) 101: FTIOD0 input/output (timer RD_0) 110: TRAO output (timer RA) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P52MD[2:0]	P52 function select	000: Setting prohibited 001: $\overline{\text{IRQ2}}$ input 010: TXD output (SCI3_1) 011: FTIOC input/output (timer RC)* 100: TGIOA input/output (timer RG) (initial value) 101: FTIOC0 input/output (timer RD_0) 110: TRBO output (timer RB) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.

(c) Port 5 Peripheral Function Mapping Register 3 (PMCR53)

Address: H'FF0052

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P55MD[2:0]			—	P54MD[2:0]		
Value after reset:	0	1	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P55MD[2:0]	P55 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input 010: SCK3_2 input/output (SCI3_2) 011: SCK3_3 input/output (SCI3_3) 100: SSCK input/output*3 (SSU) (initial value) 101: FTIOB1 input/output (timer RD_0) 110: $\overline{\text{TRDOI_1}}$ **!Unexpected End of Formula**input/output (timer RD_1)*1 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P54MD[2:0]	P54 function select	000: Setting prohibited 001: $\overline{\text{IRQ4}}$ input 010: $\overline{\text{TRDOI_0}}$ input (timer RD_0) 011: FTCI input (timer RC)*2 100: SSO input/output*3 (SSU) (initial value) 101: FTIOA1 input/output (timer RD_0) 110: TRAIO input/output (timer RA) 111: Setting prohibited	R/W

Notes: 1. This function cannot be selected for the H8S/20103 group.
2. The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.
3. If the NMOS open-drain output is selected for the SSCK output pin or the SSO output pin, use the PMC to allocate that pin from port 5

(d) Port 5 Peripheral Function Mapping Register 4 (PMCR54)

Address: H'FF0053

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P57MD[2:0]			—	P56MD[2:0]		
Value after reset:	0	1	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P57MD[2:0]	P57 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input 010: TXD_2 output (SCI3_2) 011: TXD_3 output (SCI3_3) 100: SSI/SCL input/output*1 (SSU/IIC2) (initial value) 101: FTIOD1 input/output (timer RD_0) 110: $\overline{\text{ADTRG2}}$ input (AD_2) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P56MD[2:0]	P56 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input 010: RXD_2 input (SCI3_2) 011: RXD_3 input (SCI3_3) 100: $\overline{\text{SCS}}$/SDA input/output*1*2 (SSU/IIC2) (initial value) 101: FTIOC1 input/output (timer RD_0) 110: $\overline{\text{ADTRG1}}$ input (AD_1) 111: Setting prohibited	R/W

Note: 1. When the IIC2/SSU is used as the IIC2 function, the SCL and SDA functions should be allocated to the P56 and P57 pins because SCL and SDA require buffers dedicated for IIC input/output. When the ICSU is used for the SSU function except *2, there is no restriction.
The P56 and P57 pins have different characteristics from other pins. When these pins are used as the SCL and SDA pins for the IIC2, they provide NMOS open drain output. When the P56 and P57 pins are used for other output functions, they provide NMOS push-pull output and characteristics of the high level output is different from that of the CMOS output.

2. If the NMOS open-drain output is selected for the $\overline{SCS}$ output pin, use the PMC to allocate that pin from port 5

(5) Port 6

(a) Port 6 Peripheral Function Mapping Register 1 (PMCR61)

Address: H'FF0054

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P61MD[2:0]			—	P60MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P61MD[2:0]	P61 function select	000: Setting prohibited 001: $\overline{\text{IRQ1}}$ input 010: RXD input (SCI3_1) 011: FTIOB input/output (timer RC)* 100: TCLKB input (timer RG) 101: FTIOB0 input/output (timer RD_0) (initial value) 110: TRGB input (timer RB) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P60MD[2:0]	P60 function select	000: Setting prohibited 001: $\overline{\text{IRQ0}}$ input 010: SCK3 input/output (SCI3_1) 011: FTIOA input/output (timer RC)* 100: TCLKA input (timer RG) 101: FTIOA0 input/output (timer RD_0) (initial value) 110: TREO output (timer RE) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.

(b) Port 6 Peripheral Function Mapping Register 2 (PMCR62)

Address: H'FF0055

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P63MD[2:0]			—	P62MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P63MD[2:0]	P63 function select	000: Setting prohibited 001: $\overline{\text{IRQ3}}$ input 010: $\overline{\text{TRCOI}}$ input (timer RC)* 011: FTIOD input/output (timer RC)* 100: TGIOB input/output (timer RG) 101: FTIOD0 input/output (timer RD_0) (initial value) 110: TRAO output (timer RA) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P62MD[2:0]	P62 function select	000: Setting prohibited 001: $\overline{\text{IRQ2}}$ input 010: TXD output (SCI3_1) 011: FTIOC input/output (timer RC)* 100: TGIOA input/output (timer RG) 101: FTIOC0 input/output (timer RD_0) (initial value) 110: TRBO output (timer RB) 111: Setting prohibited	R/W

Note: * The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.

(c) Port 6 Peripheral Function Mapping Register 3 (PMCR63)

Address: H'FF0056

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P65MD[2:0]			—	P64MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P65MD[2:0]	P65 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input 010: SCK3_2 input/output (SCI3_2) 011: SCK3_3 input/output (SCI3_3) 100: SSCK input/output*3 (SSU) 101: FTIOB1 input/output (timer RD_0) (initial value) 110: $\overline{\text{TRDOI_1}}$ input (timer RD_1)*1 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P64MD[2:0]	P64 function select	000: Setting prohibited 001: $\overline{\text{IRQ4}}$ input 010: $\overline{\text{TRDOI_0}}$ input (timer RD_0) 011: FTCI input (timer RC)*2 100: SSO input/output*3 (SSU) 101: FTIOA1 input/output (timer RD_0) (initial value) 110: TRAIO input/output (timer RA) 111: Setting prohibited	R/W

Notes: 1. This function cannot be selected for the H8S/20103 group.
2. The timer RC is not available on the H8S/20203 and H8S/20223 groups. These bits are reserved and the function cannot be selected for these groups.
3. If the SSCK output pin or the SSO output pin is set, the NMOS open-drain output cannot be selected.

(d) Port 6 Peripheral Function Mapping Register 4 (PMCR64)

Address: H'FF0057

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P67MD[2:0]			—	P66MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P67MD[2:0]	P67 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input 010: TXD_2 output (SCI3_2) 011: TXD_3 output (SCI3_3) 100: SSI/SCL input/output*1 (SSU/IIC2) 101: FTIOD1 input/output (timer RD_0) (initial value) 110: $\overline{\text{ADTRG2}}$ input (AD_2) *2 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P66MD[2:0]	P66 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input 010: RXD_2 input (SCI3_2) 011: RXD_3 input (SCI3_3) 100: $\overline{\text{SCS}}$/SDA input/output*1*3 (SSU/IIC2) 101: FTIOC1 input/output (timer RD_0) (initial value) 110: $\overline{\text{ADTRG1}}$ input (AD_1) 111: Setting prohibited	R/W

Notes: 1. When the IIC2/SSU is used as the IIC2 function, the SCL and SDA functions should be allocated to the P56 and P57 pins because SCL and SDA require buffers dedicated for IIC input/output. When the ICSU is used for the SSU function except *2, there is no restriction.

2. This function cannot be selected for the H8S/20103 and H8S/20203 groups.

3. If the $\overline{\text{SCS}}$ output pin of the SSU is set, the NMOS open-drain output cannot be selected.

9.1.3 Port Group 2

Peripheral Function Mapping Registers 1 to 4 (PMCRn1 to PMCRn4 (n = 8, 9, and A)

(1) Port 8

(a) Port 8 Peripheral Function Mapping Register 3 (PMCR83)

Address: H'FF005E

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P85MD[2:0]			—	—	—	—
Value after reset:	0	1	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P85MD[2:0]	P85 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input 010: Setting prohibited 011: SCK3 input/output (SCI3_1) 100: TRAIO input/output (timer RA) (initial value) 101: FTIOB3 input/output (timer RD_1)* 110: SCK3_3 input/output (SCI3_3) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	—	Reserved	This bit is always read as B'100. The write value should always be B'100.	—

Note: * This function cannot be selected for the H8S/20103 group.

(b) Port 8 Peripheral Function Mapping Register 4 (PMCR84)

Address: H'FF005F

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P87MD[2:0]			—	P86MD[2:0]		
Value after reset:	0	1	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P87MD[2:0]	P87 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input 010: Setting prohibited 011: TXD output (SCI3_1) 100: TREO output (timer RE) (initial value) 101: FTIOD3 input/output (timer RD_1)* 110: TXD_3 output (SCI3_3) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P86MD[2:0]	P86 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input 010: Setting prohibited 011: RXD input (SCI3_1) 100: TRBO output (timer RB) (initial value) 101: FTIOC3 input/output (timer RD_1)* 110: RXD_3 input (SCI3_3) 111: Setting prohibited	R/W

Note: * This function cannot be selected for the H8S/20103 group.

(2) Port 9

(a) Port 9 Peripheral Function Mapping Register 1 (PMCR91)

Address: H'FF0060

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P91MD[2:0]			—	P90MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P91MD[2:0]	P91 function select	000: Setting prohibited 001: $\overline{\text{IRQ1}}$ input 010: Setting prohibited 011: Setting prohibited 100: Setting prohibited 101: FTIOB2 input/output (timer RD_1) (initial value) 110: Setting prohibited 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P90MD[2:0]	P90 function select	000: Setting prohibited 001: $\overline{\text{IRQ0}}$ input 010: Setting prohibited 011: Setting prohibited 100: Setting prohibited 101: FTIOA2 input/output (timer RD_1) (initial value) 110: Setting prohibited 111: Setting prohibited	R/W

Note: PMCR91 is not available on the H8S/20103 group.

(b) Port 9 Peripheral Function Mapping Register 2 (PMCR92)

Address: H'FF0061

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P93MD[2:0]			—	P92MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P93MD[2:0]	P93 function select	000: Setting prohibited 001: $\overline{\text{IRQ3}}$ input 010: Setting prohibited 011: Setting prohibited 100: TRAO output (timer RA) 101: FTIOD2 input/output (timer RD_1) (initial value) 110: Setting prohibited 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P92MD[2:0]	P92 function select	000: Setting prohibited 001: $\overline{\text{IRQ2}}$ input 010: Setting prohibited 011: Setting prohibited 100: Setting prohibited 101: FTIOC2 input/output (timer RD_1) (initial value) 110: Setting prohibited 111: Setting prohibited	R/W

Note: PMCR92 is not available on the H8S/20103 group.

(c) Port 9 Peripheral Function Mapping Register 3 (PMCR93)

Address: H'FF0062

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P95MD[2:0]			—	P94MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P95MD[2:0]	P95 function select	000: Setting prohibited 001: $\overline{\text{IRQ5}}$ input 010: Setting prohibited 011: SCK3 input/output (SCI3_1) 100: TRAIO input/output (timer RA) 101: FTIOB3 input/output (timer RD_1) (initial value) 110: SCK3_3 input/output (SCI3_3) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P94MD[2:0]	P94 function select	000: Setting prohibited 001: $\overline{\text{IRQ4}}$ input 010: Setting prohibited 011: Setting prohibited 100: TRGB input (timer RB) 101: FTIOA3 input/output (timer RD_1) (initial value) 110: Setting prohibited 111: Setting prohibited	R/W

Note: PMCR93 is not available on the H8S/20103 group.

(d) Port 9 Peripheral Function Mapping Register 4 (PMCR94)

Address: H'FF0063

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	P97MD[2:0]			—	P96MD[2:0]		
Value after reset:	0	1	0	1	0	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	P97MD[2:0]	P97 function select	000: Setting prohibited 001: $\overline{\text{IRQ7}}$ input 010: Setting prohibited 011: TXD output (SCI3_1) 100: TREO output (timer RE) 101: FTIOD3 input/output (timer RD_1) (initial value) 110: TXD_3 output (SCI3_3) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	P96MD[2:0]	P96 function select	000: Setting prohibited 001: $\overline{\text{IRQ6}}$ input 010: Setting prohibited 011: RXD input (SCI3_1) 100: TRBO output (timer RB) 101: FTIOC3 input/output (timer RD_1) (initial value) 110: RXD_3 input (SCI3_3) 111: Setting prohibited	R/W

Note: PMCR94 is not available on the H8S/20103 group.

(3) Port A

(a) Port A Peripheral Function Mapping Register 3 (PMCRA3)

Address: H'FF0066

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	PA5MD[2:0]			—	PA4MD[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	PA5MD[2:0]	PA5 function select	000: No function selected (initial value) 001: $\overline{\text{IRQ5}}$ input 010: Setting prohibited 011: SCK3 input/output (SCI3_1) 100: TRAIO input/output (timer RA) 101: FTIOB3 input/output (timer RD_1)* 110: SCK3_3 input/output (SCI3_3) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	PA4MD[2:0]	PA4 function select	000: No function selected (initial value) 001: $\overline{\text{IRQ4}}$ input 010: Setting prohibited 011: Setting prohibited 100: TRGB input (timer RB) 101: FTIOA3 input/output (timer RD_1)* 110: Setting prohibited 111: Setting prohibited	R/W

Note: PMCRA3 is not available on the H8S/20223 group.

* This function cannot be selected for the H8S/20103 group.

(b) Port A Peripheral Function Mapping Register 4 (PMCRA4)

Address: H'FF0067

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	PA7MD[2:0]			—	PA6MD[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
6 to 4	PA7MD[2:0]	PA7 function select	000: No function selected (initial value) 001: $\overline{\text{IRQ7}}$ input 010: Setting prohibited 011: TXD output (SCI3_1) 100: TREO output (timer RE) 101: FTIOD3 input/output (timer RD_1)* 110: TXD_3 output (SCI3_3) 111: Setting prohibited	R/W
3	—	Reserved	This bit is always read as 0. The write value should always be 0.	—
2 to 0	PA6MD[2:0]	PA6 function select	000: No function selected (initial value) 001: $\overline{\text{IRQ6}}$ input 010: Setting prohibited 011: RXD input (SCI3_1) 100: TRBO output (timer RB) 101: FTIOC3 input/output (timer RD_1)* 110: RXD_3 input (SCI3_3) 111: Setting prohibited	R/W

Note: PMCRA4 is not available on the H8S/20223 group.

* This function cannot be selected for the H8S/20103 group.

9.2 Usage Notes

9.2.1 Procedures for Setting Multiplexed Port Functions

Use the following procedures to set a function for a multiplexed port.

1. Clear the relevant port mode register (PMR) bit to 0 to select the general input function.
2. Set PMCWPR to enable writing to the relevant peripheral function mapping register (PMCR).
3. Select a function using the peripheral function mapping register (PMCR).
4. Set the PMCRWE bit in PMCWPR to 0 to disable writing to PMCR.
5. Set the PMR bit to 1 as necessary to activate the selected multiplexed function.

9.2.2 Notes on Setting PMC Registers

1. A function of a multiplexed port should be set when the relevant PMR bit is 0. If a function is set when PMR is 1, an unintended edge may be input for the input function or unintended pulses may be output for the output function.
2. Only the functions that can be selected by PMCR should be set. If the other functions are set, operation cannot be guaranteed.
3. The same function must not be assigned to multiple pins by the PMC.
4. Port A also has an analog input function for the A/D converter. When port A is used as analog input, the relevant bit in PMRA should be set to 0 to select general I/O.

Section 10 I/O Ports

The H8S/20103 group has fifty-five general I/O ports, and the H8S/20223 and H8S/20203 groups each have sixty-nine general I/O ports. The general I/O ports are divided into three groups: the digital I/O ports that can also be used as I/O pins of the on-chip peripheral modules or external interrupt input pins, the ports that can also be used as analog input ports, and the ports that can also be used as external oscillation pins. Although all the ports are set as general input ports immediately after a reset, the pin functions can be selected by setting the appropriate register.

Pin functions of the digital I/O ports are selected by the peripheral function mapping controller (PMC). For details, see section 9, Peripheral I/O Mapping Controller. All pins of general I/O ports can be set as high-power ports. For the permissible total output current, see section 28, Electrical Characteristics.

10.1 Port 1

Figure 10.1 shows the pin configuration of port 1.

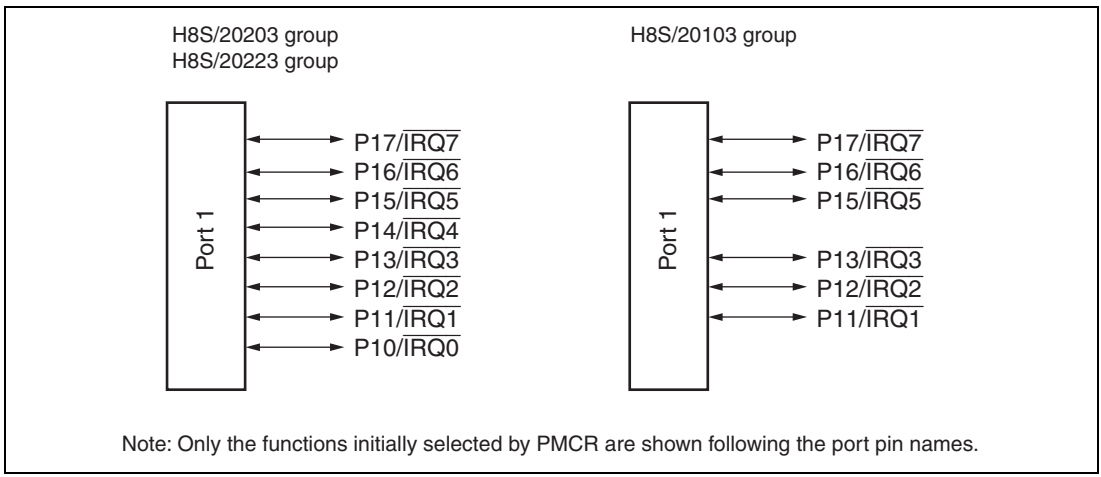


Figure 10.1 Port 1 Pin Configuration

Port 1 has the following registers.

- Port mode register 1 (PMR1)
- Port control register 1 (PCR1)
- Port data register 1 (PDR1)
- Port pull-up control register 1 (PUCR1)
- Port drive control register 1 (PDVR1)

10.1.1 Port Mode Register 1 (PMR1)

Address: H'FF0000

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR17	PMR16	PMR15	PMR14	PMR13	PMR12	PMR11	PMR10
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR17	Port 17 mode	0: General I/O port	R/W
6	PMR16	Port 16 mode	1: The function selected by the peripheral I/O mapping controller (PMC).	R/W
5	PMR15	Port 15 mode		R/W
4	PMR14	Port 14 mode	PMR1 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
3	PMR13	Port 13 mode		R/W
2	PMR12	Port 12 mode	In the H8S/20103 group, bits PMR14 and PMR10 are reserved. Only 0 should be written to these bits.	R/W
1	PMR11	Port 11 mode		R/W
0	PMR10	Port 10 mode		R/W

10.1.2 Port Control Register 1 (PCR1)

Address: H'FFFFF0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR17	PCR16	PCR15	PCR14	PCR13	PCR12	PCR11	PCR10
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR17	Port 17 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. When the corresponding pin is designated in PMR1 as a general I/O pin, setting a PCR bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port. In the H8S/20103 group, bits PCR14 and PCR10 are reserved. Only 0 should be written to these bits.	R/W
6	PCR16	Port 16 control		R/W
5	PCR15	Port 15 control		R/W
4	PCR14	Port 14 control		R/W
3	PCR13	Port 13 control		R/W
2	PCR12	Port 12 control		R/W
1	PCR11	Port 11 control		R/W
0	PCR10	Port 10 control		R/W

10.1.3 Port Data Register 1 (PDR1)

Address: H'FFFFE0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR17	PDR16	PDR15	PDR14	PDR13	PDR12	PDR11	PDR10
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR17	Port 17 data	0: Low level	R/W
6	PDR16	Port 16 data	1: High level	R/W
5	PDR15	Port 15 data	PDR1 is a register that stores output data for port 1 pins. When PCR1 bits are set to 1, the values stored in PDR1 are output.	R/W
4	PDR14	Port 14 data		R/W
3	PDR13	Port 13 data	When PDR1 is read while PCR1 bits are set to 1, the values stored in PDR1 are read. If PDR1 is read while PCR1 bits are cleared to 0, the pin states are read regardless of the value stored in PDR1.	R/W
2	PDR12	Port 12 data		R/W
1	PDR11	Port 11 data		R/W
0	PDR10	Port 10 data		R/W

10.1.4 Port Pull-Up Control Register 1 (PUCR1)

Address: H'FF0010

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCR17	PUCR16	PUCR15	PUCR14	PUCR13	PUCR12	PUCR11	PUCR10
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCR17	Port 17 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCR16	Port 16 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCR15	Port 15 pull-up control		R/W
4	PUCR14	Port 14 pull-up control		R/W
3	PUCR13	Port 13 pull-up control		R/W
2	PUCR12	Port 12 pull-up control		R/W
1	PUCR11	Port 11 pull-up control		R/W
0	PUCR10	Port 10 pull-up control		R/W

10.1.5 Port Drive Control Register 1 (PDVR1)

Address: H'FF0030

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDVR17	PDVR16	PDVR15	PDVR14	PDVR13	PDVR12	PDVR11	PDVR10
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDVR17	Port 17 drive control	0: Normal output 1: High-current drive output	R/W
6	PDVR16	Port 16 drive control	PDVR1 is a register that controls drive capability of the output pins in a bit unit.	R/W
5	PDVR15	Port 15 drive control	In the H8S/20103 group, bits PVDR14 and PVDR10 are reserved. Only 0 should be written to these bits.	R/W
4	PDVR14	Port 14 drive control		R/W
3	PDVR13	Port 13 drive control		R/W
2	PDVR12	Port 12 drive control		R/W
1	PDVR11	Port 11 drive control		R/W
0	PDVR10	Port 10 drive control		R/W

10.2 Port 2

Figure 10.2 shows the pin configuration of port 2.

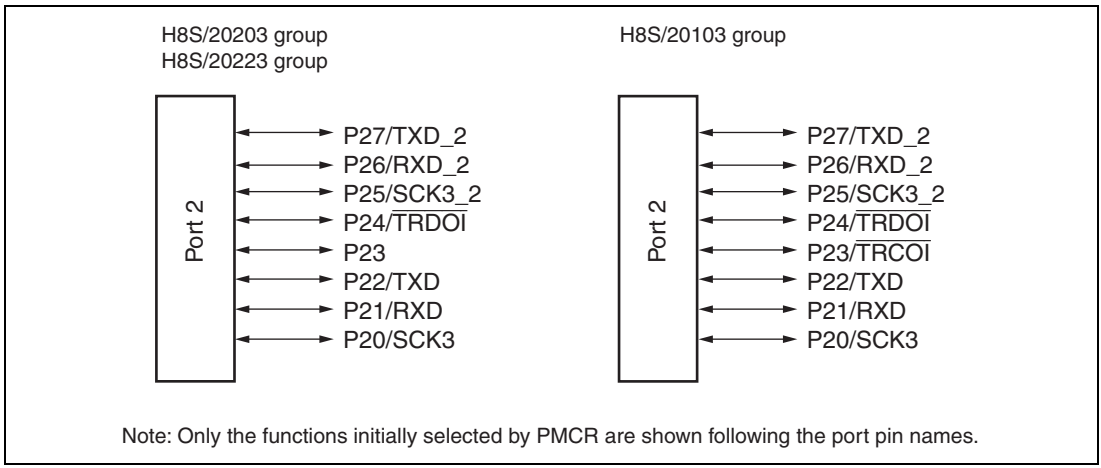


Figure 10.2 Port 2 Pin Configuration

Port 2 has the following registers.

- Port mode register 2 (PMR2)
- Port control register 2 (PCR2)
- Port data register 2 (PDR2)
- Port pull-up control register 2 (PUCR2)
- Port drive control register 2 (PDVR2)

10.2.1 Port Mode Register 2 (PMR2)

Address: H'FF0001

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR27	PMR26	PMR25	PMR24	PMR23	PMR22	PMR21	PMR20
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR27	Port 27 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMR2 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
6	PMR26	Port 26 mode		R/W
5	PMR25	Port 25 mode		R/W
4	PMR24	Port 24 mode		R/W
3	PMR23	Port 23 mode		R/W
2	PMR22	Port 22 mode		R/W
1	PMR21	Port 21 mode		R/W
0	PMR20	Port 20 mode		R/W

10.2.2 Port Control Register 2 (PCR2)

Address: H'FFFFF1

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR27	PCR26	PCR25	PCR24	PCR23	PCR22	PCR21	PCR20
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR27	Port 27 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCR2 is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port 2.	R/W
6	PCR26	Port 26 control		R/W
5	PCR25	Port 25 control		R/W
4	PCR24	Port 24 control		R/W
3	PCR23	Port 23 control		R/W
2	PCR22	Port 22 control		R/W
1	PCR21	Port 21 control		R/W
0	PCR20	Port 20 control		R/W

- PCR27 bit to PCR20 bit (port 27 to 20 control)

  When the corresponding pin is designated in PMR2 as a general I/O pin, setting a PCR2 bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.2.3 Port Data Register 2 (PDR2)

Address: H'FFFFE1

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR27	PDR26	PDR25	PDR24	PDR23	PDR22	PDR21	PDR20
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR27	Port 27 data	0: Low level	R/W
6	PDR26	Port 26 data	1: High level	R/W
5	PDR25	Port 25 data	PDR2 is a register that stores output data for port 2 pins. When PCR2 bits are set to 1, the values stored in PDR2 are output.	R/W
4	PDR24	Port 24 data		R/W
3	PDR23	Port 23 data	When PDR2 is read while PCR2 bits are set to 1, the values stored in PDR2 are read. If PDR2 is read while PCR2 bits are cleared to 0, the pin states are read regardless of the value stored in PDR2.	R/W
2	PDR22	Port 22 data		R/W
1	PDR21	Port 21 data		R/W
0	PDR20	Port 20 data		R/W

10.2.4 Port Pull-Up Control Register 2 (PUCR2)

Address: H'FF0011

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCR27	PUCR26	PUCR25	PUCR24	PUCR23	PUCR22	PUCR21	PUCR20
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCR27	Port 27 pull-up control	0: The pull-up MOS of corresponding pin is disabled. 1: The pull-up MOS of corresponding pin is enabled. PUCR2 is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
6	PUCR26	Port 26 pull-up control		R/W
5	PUCR25	Port 25 pull-up control		R/W
4	PUCR24	Port 24 pull-up control		R/W
3	PUCR23	Port 23 pull-up control		R/W
2	PUCR22	Port 22 pull-up control		R/W
1	PUCR21	Port 21 pull-up control		R/W
0	PUCR20	Port 20 pull-up control		R/W

- PUCR27 bit to PUCR20 bit (port 27 to 20 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

10.2.5 Port Drive Control Register 2 (PDVR2)

Address: H'FF0031

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDVR27	PDVR26	PDVR25	PDVR24	PDVR23	PDVR22	PDVR21	PDVR20
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDVR27	Port 27 drive control	0: Normal output 1: High-current drive output	R/W
6	PDVR26	Port 26 drive control	PDVR2 is a register that controls drive capability of the output pins in a bit unit.	R/W
5	PDVR25	Port 25 drive control		R/W
4	PDVR24	Port 24 drive control		R/W
3	PDVR23	Port 23 drive control		R/W
2	PDVR22	Port 22 drive control		R/W
1	PDVR21	Port 21 drive control		R/W
0	PDVR20	Port 20 drive control		R/W

10.3 Port 3

Figure 10.3 shows the pin configuration of port 3.

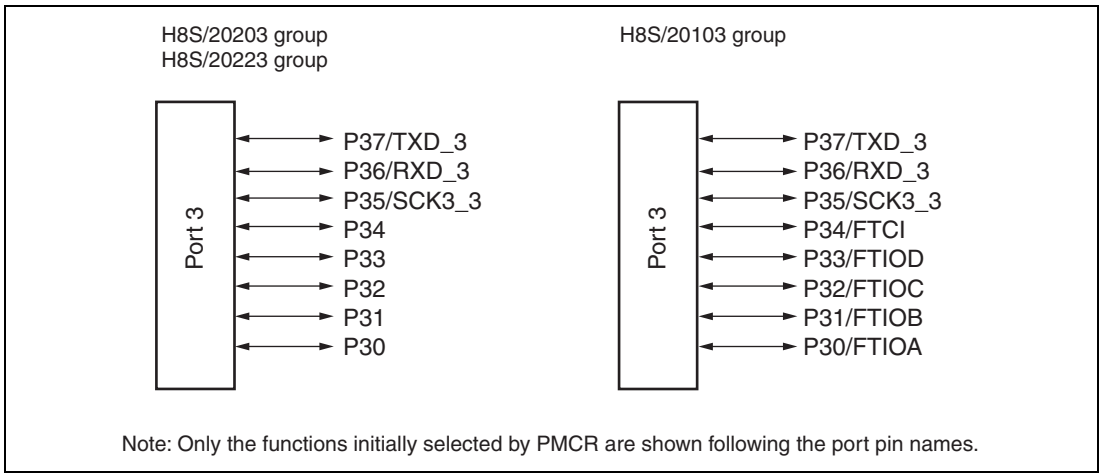


Figure 10.3 Port 3 Pin Configuration

Port 3 has the following registers.

- Port mode register 3 (PMR3)
- Port control register 3 (PCR3)
- Port data register 3 (PDR3)
- Port pull-up control register 3 (PUCR3)
- Port drive control register 3 (PDVR3)

10.3.1 Port Mode Register 3 (PMR3)

Address: H'FF0002

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR37	PMR36	PMR35	PMR34	PMR33	PMR32	PMR31	PMR30
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR37	Port 37 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMR3 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
6	PMR36	Port 36 mode		R/W
5	PMR35	Port 35 mode		R/W
4	PMR34	Port 34 mode		R/W
3	PMR33	Port 33 mode		R/W
2	PMR32	Port 32 mode		R/W
1	PMR31	Port 31 mode		R/W
0	PMR30	Port 30 mode		R/W

10.3.2 Port Control Register 3 (PCR3)

Address: H'FFFFF2

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR37	PCR36	PCR35	PCR34	PCR33	PCR32	PCR31	PCR30
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR37	Port 37 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCR3 is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port 3.	R/W
6	PCR36	Port 36 control		R/W
5	PCR35	Port 35 control		R/W
4	PCR34	Port 34 control		R/W
3	PCR33	Port 33 control		R/W
2	PCR32	Port 32 control		R/W
1	PCR31	Port 31 control		R/W
0	PCR30	Port 30 control		R/W

- PCR37 bit to PCR30 bit (port 37 to 30 control)

  When the corresponding pin is designated in PMR3 as a general I/O pin, setting a PCR3 bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.3.3 Port Data Register 3 (PDR3)

Address: H'FFFFE2

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR37	PDR36	PDR35	PDR34	PDR33	PDR32	PDR31	PDR30
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR37	Port 37 data	0: Low level	R/W
6	PDR36	Port 36 data	1: High level	R/W
5	PDR35	Port 35 data	PDR3 is a register that stores output data for port 3 pins. When PCR3 bits are set to 1, the values stored in PDR3 are output.	R/W
4	PDR34	Port 34 data		R/W
3	PDR33	Port 33 data	When PDR3 is read while PCR3 bits are set to 1, the values stored in PDR3 are read. If PDR3 is read while PCR3 bits are cleared to 0, the pin states are read regardless of the value stored in PDR3.	R/W
2	PDR32	Port 32 data		R/W
1	PDR31	Port 31 data		R/W
0	PDR30	Port 30 data		R/W

10.3.4 Port Pull-Up Control Register 3 (PUCR3)

Address: H'FF0012

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCR37	PUCR36	PUCR35	PUCR34	PUCR33	PUCR32	PUCR31	PUCR30
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCR37	Port 37 pull-up control	0: The pull-up MOS of corresponding pin is disabled. 1: The pull-up MOS of corresponding pin is enabled. PUCR3 is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
6	PUCR36	Port 36 pull-up control		R/W
5	PUCR35	Port 35 pull-up control		R/W
4	PUCR34	Port 34 pull-up control		R/W
3	PUCR33	Port 33 pull-up control		R/W
2	PUCR32	Port 32 pull-up control		R/W
1	PUCR31	Port 31 pull-up control		R/W
0	PUCR30	Port 30 pull-up control		R/W

- PUCR37 bit to PUCR30 bit (port 37 to 30 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

10.3.5 Port Drive Control Register 3 (PDVR3)

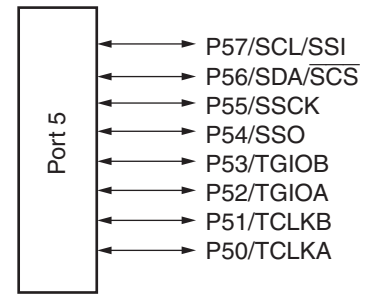
Address: H'FF0032

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDVR37	PDVR36	PDVR35	PDVR34	PDVR33	PDVR32	PDVR31	PDVR30
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDVR37	Port 37 drive control	0: Normal output 1: High-current drive output	R/W
6	PDVR36	Port 36 drive control	PDVR3 is a register that controls drive capability of the output pins in a bit unit.	R/W
5	PDVR35	Port 35 drive control		R/W
4	PDVR34	Port 34 drive control		R/W
3	PDVR33	Port 33 drive control		R/W
2	PDVR32	Port 32 drive control		R/W
1	PDVR31	Port 31 drive control		R/W
0	PDVR30	Port 30 drive control		R/W

10.4 Port 5

Figure 10.4 shows the pin configuration of port 5.



Note: Only the functions initially selected by PMCR are shown following the port pin names.

Figure 10.4 Port 5 Pin Configuration

Port 5 has the following registers.

- Port mode register 5 (PMR5)
- Port control register 5 (PCR5)
- Port data register 5 (PDR5)
- Port pull-up control register 5 (PUCR5)
- Port drive control register 5 (PDVR5)

10.4.1 Port Mode Register 5 (PMR5)

Address: H'FF0004

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR57	PMR56	PMR55	PMR54	PMR53	PMR52	PMR51	PMR50
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR57	Port 57 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMR5 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
6	PMR56	Port 56 mode		R/W
5	PMR55	Port 55 mode		R/W
4	PMR54	Port 54 mode		R/W
3	PMR53	Port 53 mode		R/W
2	PMR52	Port 52 mode		R/W
1	PMR51	Port 51 mode		R/W
0	PMR50	Port 50 mode		R/W

10.4.2 Port Control Register 5 (PCR5)

Address: H'FFFFF4

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR57	PCR56	PCR55	PCR54	PCR53	PCR52	PCR51	PCR50
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR57	Port 57 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCR5 is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port 5.	R/W
6	PCR56	Port 56 control		R/W
5	PCR55	Port 55 control		R/W
4	PCR54	Port 54 control		R/W
3	PCR53	Port 53 control		R/W
2	PCR52	Port 52 control		R/W
1	PCR51	Port 51 control		R/W
0	PCR50	Port 50 control		R/W

- PCR57 bit to PCR50 bit (port 57 to 50 control)

  When the corresponding pin is designated in PMR5 as a general I/O pin, setting a PCR5 bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.4.3 Port Data Register 5 (PDR5)

Address: H'FFFFE4

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR57	PDR56	PDR55	PDR54	PDR53	PDR52	PDR51	PDR50
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR57	Port 57 data	0: Low level	R/W
6	PDR56	Port 56 data	1: High level	R/W
5	PDR55	Port 55 data	PDR5 is a register that stores output data for port 5 pins. When PCR5 bits are set to 1, the values stored in PDR5 are output.	R/W
4	PDR54	Port 54 data		R/W
3	PDR53	Port 53 data	When PDR5 is read while PCR5 bits are set to 1, the values stored in PDR5 are read. If PDR5 is read while PCR5 bits are cleared to 0, the pin states are read regardless of the value stored in PDR5.	R/W
2	PDR52	Port 52 data		R/W
1	PDR51	Port 51 data		R/W
0	PDR50	Port 50 data		R/W

10.4.4 Port Pull-Up Control Register 5 (PUCR5)

Address: H'FF0014

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	PUCR55	PUCR54	PUCR53	PUCR52	PUCR51	PUCR50
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	These bits are read as 0. The write value should be 0.	—
6	—	Reserved		—
5	PUCR55	Port 55 pull-up control	0: The pull-up MOS of corresponding pin is disabled. 1: The pull-up MOS of corresponding pin is enabled. PUCR5 is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCR54	Port 54 pull-up control		R/W
3	PUCR53	Port 53 pull-up control		R/W
2	PUCR52	Port 52 pull-up control		R/W
1	PUCR51	Port 51 pull-up control		R/W
0	PUCR50	Port 50 pull-up control		R/W

- PUCR55 bit to PUCR50 bit (port 55 to 50 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

10.4.5 Port Drive Control Register 5 (PDVR5)

Address: H'FF0034

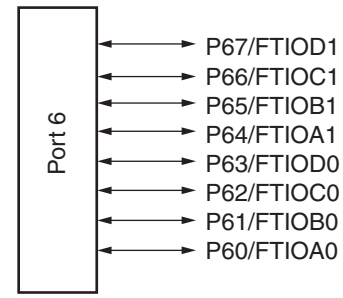
Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	PDVR55	PDVR54	PDVR53	PDVR52	PDVR51	PDVR50
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 0. The write value should be 0.	—
6	—	Reserved		—
5	PDVR55	Port 55 drive control	0: Normal output 1: High-current drive output	R/W
4	PDVR54	Port 54 drive control	PDVR5 is a register that controls drive capability of the output pins in a bit unit.	R/W
3	PDVR53	Port 53 drive control	When pins P56 and P57 are set as general output, they function as NMOS push-pull output and thus drive capability cannot be selected for them.	R/W
2	PDVR52	Port 52 drive control		R/W
1	PDVR51	Port 51 drive control		R/W
0	PDVR50	Port 50 drive control		R/W

Note: When pins P56 and P57 are set as general output, they function as NMOS push-pull output, and have characteristics different from those of other CMOS outputs. When set as SDA and SCL of IIC2, they function as NMOS open-drain output. For details, see section 28, Electrical Characteristics.

10.5 Port 6

Figure 10.5 shows the pin configuration of port 6.



Note: Only the functions initially selected by PMCR are shown following the port pin names.

Figure 10.5 Port 6 Pin Configuration

Port 6 has the following registers.

- Port mode register 6 (PMR6)
- Port control register 6 (PCR6)
- Port data register 6 (PDR6)
- Port pull-up control register 6 (PUCR6)
- Port drive control register 6 (PDVR6)

10.5.1 Port Mode Register 6 (PMR6)

Address: H'FF0005

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR67	PMR66	PMR65	PMR64	PMR63	PMR62	PMR61	PMR60
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR67	Port 67 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMR6 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
6	PMR66	Port 66 mode		R/W
5	PMR65	Port 65 mode		R/W
4	PMR64	Port 64 mode		R/W
3	PMR63	Port 63 mode		R/W
2	PMR62	Port 62 mode		R/W
1	PMR61	Port 61 mode		R/W
0	PMR60	Port 60 mode		R/W

10.5.2 Port Control Register 6 (PCR6)

Address: H'FFFFF5

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR67	PCR66	PCR65	PCR64	PCR63	PCR62	PCR61	PCR60
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR67	Port 67 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCR6 is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port 6.	R/W
6	PCR66	Port 66 control		R/W
5	PCR65	Port 65 control		R/W
4	PCR64	Port 64 control		R/W
3	PCR63	Port 63 control		R/W
2	PCR62	Port 62 control		R/W
1	PCR61	Port 61 control		R/W
0	PCR60	Port 60 control		R/W

- PCR67 bit to PCR60 bit (port 67 to 60 control)

  When the corresponding pin is designated in PMR6 as a general I/O pin, setting a PCR6 bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.5.3 Port Data Register 6 (PDR6)

Address: H'FFFFE5

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR67	PDR66	PDR65	PDR64	PDR63	PDR62	PDR61	PDR60
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR67	Port 67 data	0: Low level	R/W
6	PDR66	Port 66 data	1: High level	R/W
5	PDR65	Port 65 data	PDR6 is a register that stores output data for port 6 pins. When PCR6 bits are set to 1, the values stored in PDR6 are output.	R/W
4	PDR64	Port 64 data		R/W
3	PDR63	Port 63 data	When PDR6 is read while PCR6 bits are set to 1, the values stored in PDR6 are read. If PDR6 is read while PCR6 bits are cleared to 0, the pin states are read regardless of the value stored in PDR6.	R/W
2	PDR62	Port 62 data		R/W
1	PDR61	Port 61 data		R/W
0	PDR60	Port 60 data		R/W

10.5.4 Port Pull-Up Control Register 6 (PUCR6)

Address: H'FF0015

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCR67	PUCR66	PUCR65	PUCR64	PUCR63	PUCR62	PUCR61	PUCR60
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCR67	Port 67 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCR66	Port 66 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCR65	Port 65 pull-up control	PUCR6 is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCR64	Port 64 pull-up control		R/W
3	PUCR63	Port 63 pull-up control		R/W
2	PUCR62	Port 62 pull-up control		R/W
1	PUCR61	Port 61 pull-up control		R/W
0	PUCR60	Port 60 pull-up control		R/W

- PUCR67 bit to PUCR60 bit (port 67 to 60 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

10.5.5 Port Drive Control Register 6 (PDVR6)

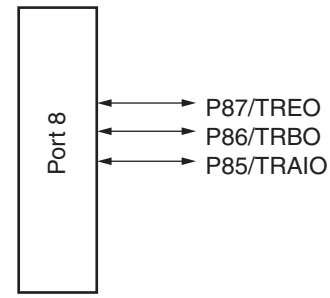
Address: H'FF0035

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDVR67	PDVR66	PDVR65	PDVR64	PDVR63	PDVR62	PDVR61	PDVR60
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDVR67	Port 67 drive control	0: Normal output 1: High-current drive output	R/W
6	PDVR66	Port 66 drive control	PDVR6 is a register that controls drive capability of the output pins in a bit unit.	R/W
5	PDVR65	Port 65 drive control		R/W
4	PDVR64	Port 64 drive control		R/W
3	PDVR63	Port 63 drive control		R/W
2	PDVR62	Port 62 drive control		R/W
1	PDVR61	Port 61 drive control		R/W
0	PDVR60	Port 60 drive control		R/W

10.6 Port 8

Figure 10.6 shows the pin configuration of port 8.



Note: Only the functions initially selected by PMCR are shown following the port pin names.

Figure 10.6 Port 8 Pin Configuration

Port 8 has the following registers.

- Port mode register 8 (PMR8)
- Port control register 8 (PCR8)
- Port data register 8 (PDR8)
- Port pull-up control register 8 (PUCR8)
- Port drive control register 8 (PDVR8)

10.6.1 Port Mode Register 8 (PMR8)

Address: H'FF0005

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR67	PMR66	PMR65	PMR64	PMR63	PMR62	PMR61	PMR60
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR87	Port 87 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMR8 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
6	PMR86	Port 86 mode		R/W
5	PMR85	Port 85 mode		R/W
4 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

10.6.2 Port Control Register 8 (PCR8)

Address: H'FFFFF7

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR87	PCR86	PCR85	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR87	Port 87 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCR8 is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port 8.	R/W
6	PCR86	Port 86 control		R/W
5	PCR85	Port 85 control		R/W
4 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

- PCR87 bit to PCR85 bit (port 87 to 85 control)

  When the corresponding pin is designated in PMR8 as a general I/O pin, setting a PCR8 bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.6.3 Port Data Register 8 (PDR8)

Address: H'FFFFE7

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR87	PDR86	PDR85	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR87	Port 87 data	0: Low level	R/W
6	PDR86	Port 86 data	1: High level	R/W
5	PDR85	Port 85 data	PDR8 is a register that stores output data for port 8 pins. When PCR8 bits are set to 1, the values stored in PDR8 are output. When PDR8 is read while PCR8 bits are set to 1, the values stored in PDR8 are read. If PDR8 is read while PCR8 bits are cleared to 0, the pin states are read regardless of the value stored in PDR8.	R/W
4 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

10.6.4 Port Pull-Up Control Register 8 (PUCR8)

Address: H'FF0017

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCR87	PUCR86	PUCR85	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCR87	Port 87 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCR86	Port 86 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCR85	Port 85 pull-up control	PUCR8 is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

- PUCR87 bit to PUCR85 bit (port 87 to 85 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

10.6.5 Port Drive Control Register 8 (PDVR8)

Address: H'FF0037

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDVR87	PDVR86	PDVR85	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

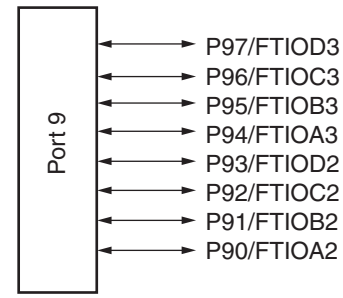
Bit	Symbol	Bit Name	Description	R/W
7	PDVR87	Port 87 drive control	0: Normal output 1: High-current drive output	R/W
6	PDVR86	Port 86 drive control	PDVR8 is a register that controls drive capability of the output pins in a bit unit.	R/W
5	PDVR85	Port 85 drive control		R/W
4 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

10.6.6 Notes on Using Port 8

When using on-chip debugger function, set port 8 as general I/O port using PMR8.

10.7 Port 9

Figure 10.7 shows the pin configuration of port 9. Port 9 is not available on the H8S/20103 group.



Note: Only the functions initially selected by PMCR are shown following the port pin names.

Figure 10.7 Port 9 Pin Configuration

Port 9 has the following registers.

- Port mode register 9 (PMR9)
- Port control register 9 (PCR9)
- Port data register 9 (PDR9)
- Port pull-up control register 9 (PUCR9)
- Port drive control register 9 (PDVR9)

10.7.1 Port Mode Register 9 (PMR9)

Address: H'FF0008

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMR97	PMR96	PMR95	PMR94	PMR93	PMR92	PMR91	PMR90
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMR97	Port 97 mode	0: General I/O port	R/W
6	PMR96	Port 96 mode	1: The function selected by the peripheral function mapping controller (PMC).	R/W
5	PMR95	Port 95 mode		R/W
4	PMR94	Port 94 mode	PMR9 is a register that selects the function of the multiplexed pins: general I/O function or the function selected by the PMC.	R/W
3	PMR93	Port 93 mode		R/W
2	PMR92	Port 92 mode		R/W
1	PMR91	Port 91 mode		R/W
0	PMR90	Port 90 mode		R/W

10.7.2 Port Control Register 9 (PCR9)

Address: H'FFFFF8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCR97	PCR96	PCR95	PCR94	PCR93	PCR92	PCR91	PCR90
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCR97	Port 97 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCR9 is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port 9.	R/W
6	PCR96	Port 96 control		R/W
5	PCR95	Port 95 control		R/W
4	PCR94	Port 94 control		R/W
3	PCR93	Port 93 control		R/W
2	PCR92	Port 92 control		R/W
1	PCR91	Port 91 control		R/W
0	PCR90	Port 90 control		R/W

- PCR97 bit to PCR90 bit (port 97 to 90 control)

  When the corresponding pin is designated in PMR9 as a general I/O pin, setting a PCR9 bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.7.3 Port Data Register 9 (PDR9)

Address: H'FFFFE8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDR97	PDR96	PDR95	PDR94	PDR93	PDR92	PDR91	PDR90
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDR97	Port 97 data	0: Low level	R/W
6	PDR96	Port 96 data	1: High level	R/W
5	PDR95	Port 95 data	PDR9 is a register that stores output data for port 9 pins. When PCR9 bits are set to 1, the values stored in PDR9 are output.	R/W
4	PDR94	Port 94 data		R/W
3	PDR93	Port 93 data	When PDR9 is read while PCR9 bits are set to 1, the values stored in PDR9 are read. If PDR9 is read while PCR9 bits are cleared to 0, the pin states are read regardless of the value stored in PDR9.	R/W
2	PDR92	Port 92 data		R/W
1	PDR91	Port 91 data		R/W
0	PDR90	Port 90 data		R/W

10.7.4 Port Pull-Up Control Register 9 (PUCR9)

Address: H'FF0018

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCR97	PUCR96	PUCR95	PUCR94	PUCR93	PUCR92	PUCR91	PUCR90
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCR97	Port 97 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCR96	Port 96 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCR95	Port 95 pull-up control	PUCR9 is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCR94	Port 94 pull-up control		R/W
3	PUCR93	Port 93 pull-up control		R/W
2	PUCR92	Port 92 pull-up control		R/W
1	PUCR91	Port 91 pull-up control		R/W
0	PUCR90	Port 90 pull-up control		R/W

- PUCR97 bit to PUCR90 bit (port 97 to 90 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

10.7.5 Port Drive Control Register 9 (PDVR9)

Address: H'FF0038

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDVR97	PDVR96	PDVR95	PDVR94	PDVR93	PDVR92	PDVR91	PDVR90
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDVR97	Port 97 drive control	0: Normal output 1: High-current drive output	R/W
6	PDVR96	Port 96 drive control	PDVR9 is a register that controls drive capability of the output pins in a bit unit.	R/W
5	PDVR95	Port 95 drive control		R/W
4	PDVR94	Port 94 drive control		R/W
3	PDVR93	Port 93 drive control		R/W
2	PDVR92	Port 92 drive control		R/W
1	PDVR91	Port 91 drive control		R/W
0	PDVR90	Port 90 drive control		R/W

10.8 Port A

Port A consists of general I/O pins that are also used as analog input pins for A/D converter unit 1 and unit 2 (only in the H8S/20223 group).

The functions of PA4 to PA7 can be selected with the peripheral function mapping register of the PMC (except for the H8S/20223 group).

For selection of functions by the peripheral function mapping controller, see section 9, Peripheral I/O Mapping Controller. Figure 10.8 shows the pin configuration of port A.

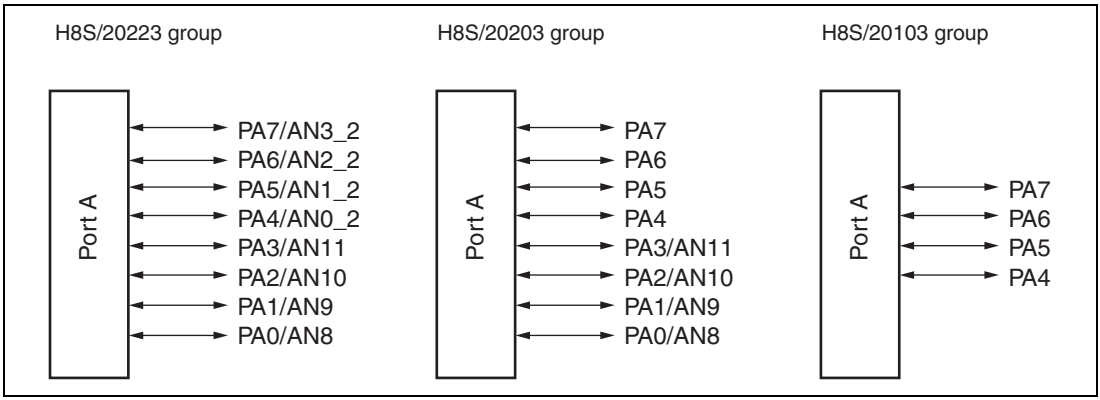


Figure 10.8 Port A Pin Configuration

Port A has the following registers.

- Port mode register A (PMRA)
- Port control register A (PCRA)
- Port data register A (PDRA)
- Port pull-up control register A (PUCRA)

- H8S/20103 group

10.8.1 Port Mode Register A (PMRA)

Address: H'FF0009

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMRA7	PMRA6	PMRA5	PMRA4	—	PMRA2	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMRA7	Port A7 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMRA is a register that selects the function of the port A multiplexed pins: general I/O function or the function selected by the PMC. PMRA also provides the bit to select the function of the PB0 pin.	R/W
6	PMRA6	Port A6 mode		R/W
5	PMRA5	Port A5 mode		R/W
4	PMRA4	Port A4 mode		R/W
3	—	Reserved	This bit is read as 0. The write value should be 0.	—
2	PMRA2	Port A2 mode	0: General I/O port 1: AN0 input pin	R/W
1, 0	—	Reserved	These bits read as 0. The write value should be 0.	—

- PMRA7 bit to PMRA4 bit (port A7 to A4 mode)

  These bits select the function of the multiplexed pins PA7 to PA4: general I/O function or the function selected by the PMC.
- PMRA2 bit (port A2 mode)

  This bit selects general I/O function or the analog input function for PB0.

10.8.2 Port Control Register A (PCRA)

Address: H'FFFFF9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCRA7	PCRA6	PCRA5	PCRA4	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCRA7	Port A7 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCRA is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port A.	R/W
6	PCRA6	Port A6 control		R/W
5	PCRA5	Port A5 control		R/W
4	PCRA4	Port A4 control		R/W
3 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

- PCRA7 bit to PCRA4 bit (port A7 to A4 control)

  When the corresponding pin is designated in PMRA as a general I/O pin, setting a PCRA bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.8.3 Port Data Register A (PDRA)

Address: H'FFFFE9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDRA7	PDRA6	PDRA5	PDRA4	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDRA7	Port A7 data	0: Low level	R/W
6	PDRA6	Port A6 data	1: High level	R/W
5	PDRA5	Port A5 data	PDRA is a register that stores output data for port A pins. When PCRA bits are set to 1, the values stored in PDRA are output.	R/W
4	PDRA4	Port A4 data		R/W
			When PDRA is read while PCRA bits are set to 1, the values stored in PDRA are read. If PDRA is read while PCRA bits are cleared to 0, the pin states are read regardless of the value stored in PDRA.	
3 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

10.8.4 Port Pull-Up Control Register A (PUCRA)

Address: H'FF0019

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCRA7	PUCRA6	PUCRA5	PUCRA4	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCRA7*	Port A7 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCRA6*	Port A6 pull-up control	1: The pull-up MOS of corresponding pin is not enabled.	R/W
5	PUCRA5*	Port A5 pull-up control	PUCRA is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCRA4*	Port A4 pull-up control		R/W
3 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

Note: * When PA7 to PA4 are set as the analog input pin, clear the corresponding bits to 0.

- PUCRA7 bit to PUCRA4 bit (port A7 to A4 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

- H8S/20203 group

10.8.5 Port Mode Register A (PMRA)

Address: H'FF0009

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PMRA7	PMRA6	PMRA5	PMRA4	—	PMRA2	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PMRA7	Port A7 mode	0: General I/O port 1: The function selected by the peripheral function mapping controller (PMC). PMRA is a register that selects the function of the port A multiplexed pins: general I/O function or the function selected by the PMC.	R/W
6	PMRA6	Port A6 mode		R/W
5	PMRA5	Port A5 mode		R/W
4	PMRA4	Port A4 mode		R/W
3	—	Reserved	This bit is read as 0. The write value should be 0.	—
2	PMRA2	Port A2 mode	0: General I/O port 1: AN0 input pin	R/W
1, 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

- PMRA7 bit to PMRA4 bit (port A7 to A4 mode)

  These bits select the function of the multiplexed pins PA7 to PA4: general I/O function or the function selected by the PMC.

- PMRA2 bit (port A2 mode)

  This bit selects general I/O function or the analog input function for PB0.

10.8.6 Port Control Register A (PCRA)

Address: H'FFFFF9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCRA7	PCRA6	PCRA5	PCRA4	PCRA3	PCRA2	PCRA1	PCRA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCRA7	Port A7 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCRA is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port A.	R/W
6	PCRA6	Port A6 control		R/W
5	PCRA5	Port A5 control		R/W
4	PCRA4	Port A4 control		R/W
3	PCRA3	Port A3 control		R/W
2	PCRA2	Port A2 control		R/W
1	PCRA1	Port A1 control		R/W
0	PCRA0	Port A0 control		R/W

- PCRA7 bit to PCRA0 bit (port A7 to A0 control)

  When the corresponding pin is designated in PMRA as a general I/O pin, setting a PCRA bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.8.7 Port Data Register A (PDRA)

Address: H'FFFFE9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDRA7	PDRA6	PDRA5	PDRA4	PDRA3	PDRA2	PDRA1	PDRA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDRA7	Port A7 data	0: Low level	R/W
6	PDRA6	Port A6 data	1: High level	R/W
5	PDRA5	Port A5 data	PDRA is a register that stores output data for port A pins. When PCRA bits are set to 1, the values stored in PDRA are output.	R/W
4	PDRA4	Port A4 data		R/W
3	PDRA3	Port A3 data	When PDRA is read while PCRA bits are set to 1, the values stored in PDRA are read. If PDRA is read while PCRA bits are cleared to 0, the pin states are read regardless of the value stored in PDRA.	R/W
2	PDRA2	Port A2 data		R/W
1	PDRA1	Port A1 data		R/W
0	PDRA0	Port A0 data		R/W
			When pins PA3 to PA0 are set as analog input channels by ADCSR and ADCR of the A/D converter, however, the corresponding PCRA bits are always read as 1 even if they are cleared to 0.	

10.8.8 Port Pull-Up Control Register A (PUCRA)

Address: H'FF0019

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCRA7	PUCRA6	PUCRA5	PUCRA4	PUCRA3	PUCRA2	PUCRA1	PUCRA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCRA7*	Port A7 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCRA6*	Port A6 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCRA5*	Port A5 pull-up control	PUCRA is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCRA4*	Port A4 pull-up control		R/W
3	PUCRA3*	Port A3 pull-up control		R/W
2	PUCRA2*	Port A2 pull-up control		R/W
1	PUCRA1*	Port A1 pull-up control		R/W
0	PUCRA0*	Port A0 pull-up control		R/W

Note: * When PA7 to PA4 are set as the analog input pin, clear the corresponding bits to 0.

- PUCRA7 bit to PUCRA0 bit (port A7 to A0 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC. However, this setting is invalid for the analog input pin.

- H8S/20223 group

10.8.9 Port Mode Register A (PMRA)

Address: H'FF0009

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	PMRA3	PMRA2	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	—	Reserved	These bits are read as 0. The write value should be 0.	—
3	PMRA3	Port A3 mode	0: General I/O port 1: AN0_2 input pin	R/W
2	PMRA2	Port A2 mode	0: General I/O port 1: AN0 input pin	R/W
1, 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

PMRA is a register that selects the function of the port A multiplexed pins: general I/O function or the function selected by the PMC. PMRA also provides the bit to select the function of the PB0 pin.

- PMRA3 bit (port A3 mode)
  This bit selects general I/O function or the function selected by the PMC.

- PMRA2 bit (port A2 mode)
  This bit selects general I/O function or the analog input function for PB0.

10.8.10 Port Control Register A (PCRA)

Address: H'FFFFF9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCRA7	PCRA6	PCRA5	PCRA4	PCRA3	PCRA2	PCRA1	PCRA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCRA7	Port A7 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCRA is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port A.	R/W
6	PCRA6	Port A6 control		R/W
5	PCRA5	Port A5 control		R/W
4	PCRA4	Port A4 control		R/W
3	PCRA3	Port A3 control		R/W
2	PCRA2	Port A2 control		R/W
1	PCRA1	Port A1 control		R/W
0	PCRA0	Port A0 control		R/W

- PCRA7 bit to PCRA0 bit (port A7 to A0 control)

  When the corresponding pin is designated in PMRA as a general I/O pin, setting a PCRA bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.8.11 Port Data Register A (PDRA)

Address: H'FFFFE9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDRA7	PDRA6	PDRA5	PDRA4	PDRA3	PDRA2	PDRA1	PDRA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDRA7	Port A7 data	0: Low level 1: High level PDRA is a register that stores output data for port A pins. When PCRA bits are set to 1, the values stored in PDRA are output. When PDRA is read while PCRA bits are set to 1, the values stored in PDRA are read. If PDRA is read while PCRA bits are cleared to 0, the pin states are read regardless of the value stored in PDRA.	R/W
6	PDRA6	Port A6 data		R/W
5	PDRA5	Port A5 data		R/W
4	PDRA4	Port A4 data		R/W
3	PDRA3	Port A3 data		R/W
2	PDRA2	Port A2 data		R/W
1	PDRA1	Port A1 data		R/W
0	PDRA0	Port A0 data		R/W

10.8.12 Port Pull-Up Control Register A (PUCRA)

Address: H'FF0019

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCRA7	PUCRA6	PUCRA5	PUCRA4	PUCRA3	PUCRA2	PUCRA1	PUCRA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCRA7*	Port A7 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCRA6*	Port A6 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCRA5*	Port A5 pull-up control	PUCRA is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCRA4*	Port A4 pull-up control		R/W
3	PUCRA3*	Port A3 pull-up control		R/W
2	PUCRA2*	Port A2 pull-up control		R/W
1	PUCRA1*	Port A1 pull-up control		R/W
0	PUCRA0*	Port A0 pull-up control		R/W

Note: * When PA7 to PA0 are set as the analog input pin, clear the corresponding bits to 0.

- PUCRA7 bit to PUCRA0 bit (port A7 to A0 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC. However, this setting is invalid for the analog input pin.

10.8.13 Notes on Using Port A

1. The PA4 pin is initially set as general I/O pin. If using this pin as the AN0_2 analog input pin for the A/D converter unit 2 in the H8S/20223 group, set the PMRA3 bit in PMRA to 1.
2. In the H8S/20223 group, pins PA7 to PA4 can be used as the general I/O pins or analog input pins. If using these pins as the general I/O pins, do not set bits CH3 to CH0 in ADCSR_2 of the A/D converter unit 2 to set these pins as the analog input pins.

10.9 Port B

Port B consists of general I/O pins that are also used as analog input pins for the A/D converter unit 1, or as analog output pins for the D/A converter. Figure 10.9 shows the pin configuration of port B.

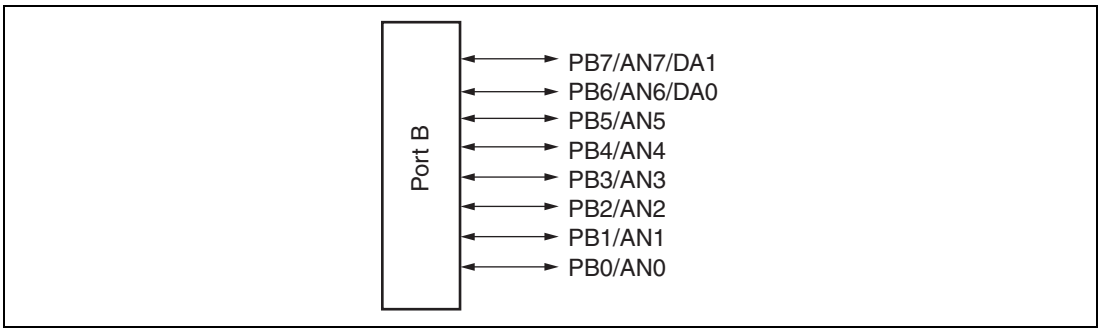


Figure 10.9 Port B Pin Configuration

Port B has the following registers.

- Port control register B (PCRB)
- Port data register B (PDRB)
- Port pull-up control register B (PUCRB)

10.9.1 Port Control Register B (PCRB)

Address: H'FFFFFA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PCRB7	PCRB6	PCRB5	PCRB4	PCRB3	PCRB2	PCRB1	PCRB0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PCRB7	Port B7 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCRB is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port B.	R/W
6	PCRB6	Port B6 control		R/W
5	PCRB5	Port B5 control		R/W
4	PCRB4	Port B4 control		R/W
3	PCRB3	Port B3 control		R/W
2	PCRB2	Port B2 control		R/W
1	PCRB1	Port B1 control		R/W
0	PCRB0	Port B0 control		R/W

- PCRB7 bit to PCRB0 bit (port B7 to B0 control)

  When the corresponding pin is designated in PMRB as a general I/O pin, setting a PCRB bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.9.2 Port Data Register B (PDRB)

Address: H'FFFFEA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDRB7	PDRB6	PDRB5	PDRB4	PDRB3	PDRB2	PDRB1	PDRB0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDRB7	Port B7 data	0: Low level	R/W
6	PDRB6	Port B6 data	1: High level	R/W
5	PDRB5	Port B5 data	When the pins are set as analog input channels by ADCSR and ADCR of the A/D converter, however, the corresponding PCRB bits are always read as 1 even if they are cleared to 0.	R/W
4	PDRB4	Port B4 data		R/W
3	PDRB3	Port B3 data		R/W
2	PDRB2	Port B2 data	Similarly, when pins PB6 and PB7 are set as analog output for the D/A converter by bit DAOE1 in DACR of the D/A converter, the corresponding PCRB bits are always read as 1 even if they are cleared to 0.	R/W
1	PDRB1	Port B1 data		R/W
0	PDRB0	Port B0 data		R/W

PDRB is a register that stores output data for port B pins.

10.9.3 Port Pull-Up Control Register B (PUCRB)

Address: H'FF001A

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PUCRB7	PUCRB6	PUCRB5	PUCRB4	PUCRB3	PUCRB2	PUCRB1	PUCRB0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PUCRB7	Port B7 pull-up control	0: The pull-up MOS of corresponding pin is disabled.	R/W
6	PUCRB6	Port B6 pull-up control	1: The pull-up MOS of corresponding pin is enabled.	R/W
5	PUCRB5	Port B5 pull-up control	PUCRB is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
4	PUCRB4	Port B4 pull-up control		R/W
3	PUCRB3	Port B3 pull-up control		R/W
2	PUCRB2	Port B2 pull-up control		R/W
1	PUCRB1	Port B1 pull-up control		R/W
0	PUCRB0	Port B0 pull-up control		R/W

- PUCRB7 bit to PUCRB0 bit (port B7 to B0 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC. However, this setting is invalid for the analog input pin.

10.9.4 Notes on Using Port B

1. The PB0 pin is initially set as general I/O pin. If using this pin as the analog input pin for the A/D converter, set the PMRA2 bit in PMRA to 1.
2. Pins PB7 and PB6 can be used as analog input pins for the A/D converter or analog output pins for the D/A converter. Do not set these pins as analog input pins and analog output pins at the same time.

10.10 Port J

Port J consists of pins PJ1 and PJ0. These pins can also be used as external oscillation pins and clock output pin. Figure 10.10 shows the pin configuration of port J. In selection of the function of these multiplexed pins, the PMRJ register setting is given priority.

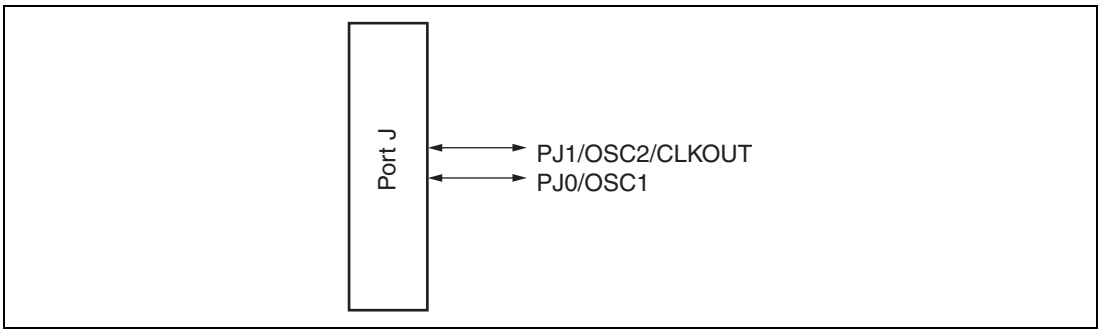


Figure 10.10 Port J Pin Configuration

Port J has the following registers.

- Port mode register J (PMRJ)
- Port control register J (PCRJ)
- Port data register J (PDRJ)
- Port pull-up control register J (PUCRJ)

10.10.1 Port Mode Register J (PMRJ)

Address: H'FF000C

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

Bit	Symbol	Bit Name	Description	R/W
7 to 2	—	Reserved	These bits are read as 0. The write value should be 0.	—
1, 0	PMRJ[1:0]	Port J[1:0] mode	Selects PJ1 and PJ0 pin functions.	R/W

PMRJ1	PMRJ0	PJ1 Pin	PJ0 Pin
0	0	PJ1 I/O	PJ0 I/O
0	1	PJ1 I/O	OSC1 input* (external clock input)
1	0	CLKOUT	PJ0 I/O
1	1	OSC2	OSC1

Note: * Set the PMRJ1 and PMRJ0 bits to 01 to input the external clock on the OSC1 pin. Do not apply the external clock to the OSC1 pin while the PMRJ1 and PMRJ0 bits are set to 11.

10.10.2 Port Control Register J (PCRJ)

Address: H'FFFFFC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	PCRJ1	PCRJ0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 2	—	Reserved	These bits are read as 0. The write value should be 0.	—
1	PCRJ1	Port J1 control	0: When the corresponding pin is designated as a general I/O port, the pin functions as an input port. 1: When the corresponding pin is designated as a general I/O port, the pin functions as an output port. PCRJ is a register that selects inputs/outputs in bit units for pins to be used as general I/O ports of port J.	R/W
0	PCRJ0	Port J0 control		R/W

- PCRJ1 bit and PCRJ0 bit (port J1 and J0 control)

  When the general I/O port function is selected by PMRJ, setting a PCRJ bit to 1 makes the corresponding pin an output port, while clearing the bit to 0 makes the pin an input port.

10.10.3 Port Data Register J (PDRJ)

Address: H'FFFFEC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	PDRJ1	PDRJ0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 2	—	Reserved	These bits are read as 0. The write value should be 0.	—
1	PDRJ1	Port J1 data	0: Low level	R/W
0	PDRJ0	Port J0 data	1: High level	R/W
			PDRJ is a register that stores output data for port J pins. When PCRJ bits are set to 1, the values stored in PDRJ are output.	
			When PDRJ is read while PCRJ bits are set to 1, the values stored in PDRJ are read. If PDRJ is read while PCRJ bits are cleared to 0, the pin states are read regardless of the value stored in PDRJ.	

10.10.4 Port Pull-Up Control Register J (PUCRJ)

Address: H'FF001C

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	PUCRJ1	PUCRJ0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 2	—	Reserved	These bits are read as 0. The write value should be 0.	—
1	PUCRJ1	Port J1 pull-up control	0: The pull-up MOS of corresponding pin is disabled. 1: The pull-up MOS of corresponding pin is enabled. PUCRJ is a register that controls the pull-up MOS in bit units of the pins set as the input ports.	R/W
0	PUCRJ0	Port J0 pull-up control		R/W

- PUCRJ1 bit and PUCRJ0 bit (port J1 and J0 pull-up control)

  This function is valid only for the pin set as general input, and for the input pin with a function selected by the PMC.

Section 11 Data Transfer Controller (DTC)

This LSI includes a data transfer controller (DTC). The DTC can be activated by an interrupt or software to transfer data.

Figure 11.1 shows a block diagram of the DTC.

11.1 Features

- Transfer possible over any number of channels
- Three transfer modes
  - — Normal mode
    One operation transfers one byte or one word of data.
    Memory address is incremented or decremented by 1 or 2.
    From 1 to 65,536 transfers can be specified.
  - — Repeat mode
    One operation transfers one byte or one word of data.
    Memory address is incremented or decremented by 1 or 2.
    Once the specified number of transfers (1 to 256) has ended, the initial state is restored, and transfer is repeated.
  - — Block transfer mode
    One operation transfers specified one block of data.
    The block size is 1 to 256 bytes or words.
    From 1 to 65,536 transfers can be specified.
    Either the transfer source or the transfer destination is designated as a block area.
- One activation source can trigger a number of data transfers (chain transfer)
- Direct specification of 16-Mbyte address space possible
- Activation by software is possible.
- Transfer can be set in byte or word units.
- A CPU interrupt can be requested for the interrupt that activated the DTC.
- Module standby mode can be set.

The DTC's register information is stored in the on-chip RAM. A 32-bit bus connects the DTC to the on-chip RAM, enabling 32-bit/1-state reading and writing of the DTC register information.

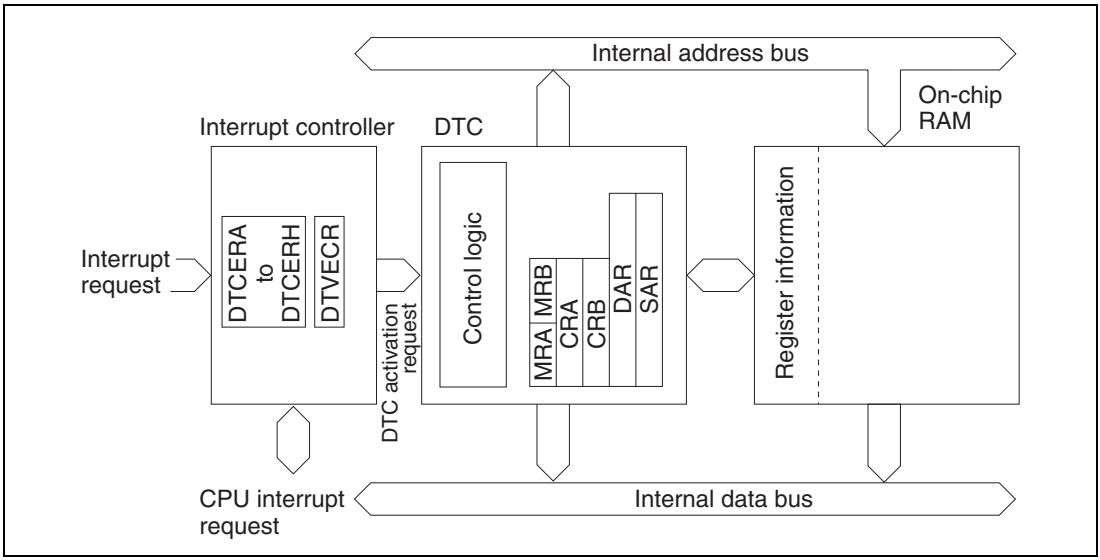


Figure 11.1 Block Diagram of DTC

11.2 Register Descriptions

DTC has the following registers.

- DTC mode register A (MRA)
- DTC mode register B (MRB)
- DTC source address register (SAR)
- DTC destination address register (DAR)
- DTC transfer count register A (CRA)
- DTC transfer count register B (CRB)

The above six registers cannot be directly accessed from the CPU. When the DTC activation source is generated, the DTC reads from a set of register information that is stored in an on-chip RAM to the corresponding DTC register information and transfers data. After the data transfer, it writes a set of updated register information back to the RAM.

- DTC enable register A (DTCERA)
- DTC enable register B (DTCERB)
- DTC enable register C (DTCERC)
- DTC enable register D (DTCERD)
- DTC enable register E (DTCERE)
- DTC enable register F (DTCERF)
- DTC enable register G (DTCERG)
- DTC enable register H (DTCERH)
- DTC vector register (DTVECR)

11.2.1 DTC Mode Register A (MRA)

Address: –

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	SM[1:0]		DM[1:0]		MD[1:0]		DTC	Sz
Value after reset:	–	–	–	–	–	–	–	–

Bit	Symbol	Bit Name	Description	R/W
7 6	SM[1:0]	Source address mode 1 and 0	0×: SAR is fixed 10: SAR is incremented after a transfer (by +1 when Sz = 0; by +2 when Sz = 1) 11: SAR is decremented after a transfer (by –1 when Sz = 0; by –2 when Sz = 1)	—
5 4	DM[1:0]	Destination address mode 1 and 0	0×: DAR is fixed 10: DAR is incremented after a transfer (by +1 when Sz = 0; by +2 when Sz = 1) 11: DAR is decremented after a transfer (by –1 when Sz = 0; by –2 when Sz = 1)	—
3 2	MD[1:0]	DTC mode 1 and 0	00: Normal mode 01: Repeat mode 10: Block transfer mode 11: Setting prohibited	—
1	DTC	DTC transfer mode select	0: Destination side is repeat area or block area. 1: Source side is repeat area or block area.	—
0	Sz	DTC data transfer size	0: Byte-size transfer 1: Word-size transfer	—

Legend:

×: Don't care

MRA selects the DTC operating mode.

- SM[1:0] bits (source address mode 1 and 0)
  These bits specify an SAR operation after data transfer.
- DM[1:0] bits (destination address mode 1 and 0)
  These bits specify a DAR operation after data transfer.
- MD[1:0] bits (DTC mode 1 and 0)
  These bits specify the DTC transfer mode.
- DTS bit (DTC transfer mode select)
  This bit specifies whether the source side or the destination side is set to be a repeat area or block area, in repeat mode or block transfer mode.
- Sz bit (DTC data transfer size)
  This bit specifies the size of data to be transferred.

11.2.2 DTC Mode Register B (MRB)

Address: —

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	CHNE	DISEL	CHNS	—	—	—	—	—
Value after reset:	—	—	—	—	—	—	—	—

Bit	Symbol	Bit Name	Description	R/W
7	CHNE	DTC chain transfer enable	0: Disables chain transfer. 1: Enables chain transfer.	—
6	DISEL	DTC interrupt select	0: Generates an interrupt request to the CPU only when the specified data transfer has been completed. 1: Generates an interrupt request to the CPU every time after the DTC transfer has been completed.	—
5	CHNS	Chain transfer select	0: Performs chain transfer consecutively. 1: Performs chain transfer only when transfer counter = 0	—
4 to 0	—	Reserved	These bits have no effect on DTC operation. The write value should be 0.	—

MRB selects the DTC operating mode.

- CHNE bit (DTC chain transfer enable)

  When this bit is set to 1, a chain transfer will be performed. For details, see section 11.5.4, Chain Transfer.

  In the data transfer with CHNE set to 1, determination of the end of the specified number of transfers, clearing of the activation source flag, and clearing of DTCER are not performed.

- DISEL bit (DTC interrupt select)

  When this bit is set to 1, a CPU interrupt request is generated every time the DTC transfer is performed (the interrupt source flags as the activation source are not cleared to 0 by the DTC). When this bit is cleared to 0, a CPU interrupt request is generated at the time when the specified number of data transfers ends (the interrupt source flags as the activation source is cleared to 0 by the DTC).

11.2.3 DTC Source Address Register (SAR)

Address: —

Bit:	b23	b22	b21	b20	b19	b18	b17	b16
	bit23	bit22	bit21	bit20	bit19	bit18	bit17	bit16
Value after reset:	—	—	—	—	—	—	—	—

Bit:	b15	b14	b13	b12	b11	b10	b9	b8
	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
Value after reset:	—	—	—	—	—	—	—	—

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Value after reset:	—	—	—	—	—	—	—	—

SAR designates the source address of data to be transferred by the DTC. For word-size transfer, specify an even source address.

11.2.4 DTC Destination Address Register (DAR)

Address: —

Bit:	b23	b22	b21	b20	b19	b18	b17	b16
	bit23	bit22	bit21	bit20	bit19	bit18	bit17	bit16
Value after reset:	—	—	—	—	—	—	—	—

Bit:	b15	b14	b13	b12	b11	b10	b9	b8
	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
Value after reset:	—	—	—	—	—	—	—	—

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Value after reset:	—	—	—	—	—	—	—	—

DAR designates the destination address of data to be transferred by the DTC. For word-size transfer, specify an even destination address.

11.2.5 DTC Transfer Count Register A (CRA)

Address: —

Bit:	b15	b14	b13	b12	b11	b10	b9	b8
	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
Value after reset:	—	—	—	—	—	—	—	—

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Value after reset:	—	—	—	—	—	—	—	—

CRA designates the number of times that data is to be transferred by the DTC.

In normal mode, the entire CRA functions as a 16-bit transfer counter (1 to 65,536). It is decremented by 1 every time data is transferred, and transfer ends when the count reaches H'0000.

In repeat mode or block transfer mode, the CRA is divided into two parts: the upper 8 bits (CRAH) and the lower 8 bits (CRAL). In repeat mode, CRAH holds the number of transfers while CRAL functions as an 8-bit transfer counter (1 to 256). In block transfer mode, CRAH holds the size of blocks while CRAL functions as a block-size counter. CRAL is decremented by 1 every time data is transferred, and the contents of CRAH are sent when the count value reaches H'00.

11.2.6 DTC Transfer Count Register B (CRB)

Address: —

Bit:	b15	b14	b13	b12	b11	b10	b9	b8
	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
Value after reset:	—	—	—	—	—	—	—	—

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Value after reset:	—	—	—	—	—	—	—	—

CRB is a 16-bit register that designates the number of times block data is to be transferred by the DTC in block transfer mode. It functions as a 16-bit transfer counter (1 to 65,536) that is decremented by 1 every time data is transferred, and transfer ends when the count reaches H'0000. The CRB is not available in normal and repeat modes.

11.2.7 DTC Enable Registers A to H (DTCERA to DTCERH)

Address: H'FF0534 to H'FF053B

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	DTCEn7	DTCEn6	DTCEn5	DTCEn4	DTCEn3	DTCEn2	DTCEn1	DTCEn0
Value after reset:	—	—	—	—	—	—	—	—

Bit	Symbol	Bit Name	Description	R/W
7	DTCEn7	DTC activation enable	0: A relevant interrupt source is not selected as a DTC activation source. 1: A relevant interrupt source is selected as a DTC activation source. [Setting condition] • Setting this bit to 1 specifies a relevant interrupt source to a DTC activation source. [Clearing conditions] • When the DISEL bit in MRB is set to 1 and the data transfer has ended. • When the specified number of data transfers has ended. These bits are not automatically cleared when the DISEL bit is 0 and the specified number of data transfers has not ended. • When 0 is written to DTCE after reading DTCE = 1.	R/W
6	DTCEn6			R/W
5	DTCEn5			R/W
4	DTCEn4			R/W
3	DTCEn3			R/W
2	DTCEn2			R/W
1	DTCEn1			R/W
0	DTCEn0			R/W

Notes: n = A to H
DTCE bits with no corresponding interrupt are reserved. The write value should always be 0.

DTCER, which is comprised of DTCERA to DTCERH, is a register that specifies DTC activation interrupt sources. The correspondence between interrupt sources and DTCE bits is shown in table 11.1. For DTCE bit setting, use bit manipulation instructions such as BSET and BCLR. If all interrupts are masked, multiple activation sources can be set at one time (only at the initial setting) by writing data after executing a dummy read on the relevant register.

Table 11.1 Correspondence between Interrupt Sources and DTCER

	Bit							
Register	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
DTCERA	IRQ0	IRQ1	IRQ2	IRQ3	IRQ4	IRQ5	IRQ6	IRQ7
DTCERB	IADEND_1	IADCMP_1	IADEND_2 *1	IADCMP_2 *1	ELC1FP	ELC2FP	SCI3_1_RXI	SCI3_1_TXI
DTCERC	SCI3_2_RXI	SCI3_2_TXI	SCI3_3_RXI	SCI3_3_TXI	—	—	—	—
DTCERD	IIC2/SSU_ RXI	IIC2/SSU_ TXI	—	—	ITCMA*2	ITCMB*2	ITCMC*2	ITCMD*2
DTCERE	ITDMA0_0	ITDMB0_0	ITDMC0_0	ITDMD0_0	ITDMA0_1	ITDMB0_1	ITDMC0_1	ITDMD0_1
DTCERF	ITDMA1_2 *3	ITDMB1_2 *3	ITDMC1_2 *3	ITDMD1_2 *3	ITDMA1_3 *3	ITDMB1_3 *3	ITDMC1_3 *3	ITDMD1_3 *3
DTCERG	—	—	—	ITESC	ITEMI	ITEHR	ITEDY	ITEWK
DTCERH	—	—	—	—	ITGMA	ITGMB	—	—

Notes: —: Reserved bit

1. Supported only in the H8S/20223 group.
2. Supported only in the H8S/20103 group.
3. Not supported in the H8S/20103 group.

11.2.8 DTC Vector Register (DTVECR)

Address: H'FF053D

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	SWDTE	DTC software activation enable	0: Disables the DTC activation by software. 1: Enables the DTC activation by software. Setting this bit to 1 activates DTC. Only 1 can be written to this bit. [Clearing conditions] • When the DISEL bit is 0 and the specified number of data transfers has not ended. • When 0 is written to the DISEL bit after a software-activated data transfer end interrupt (SWDTEND) request has been sent to the CPU. When the DISEL bit is 1 and data transfer has ended or when the specified number of data transfers has ended, this bit will not be cleared.	R/W
6	DTVEC6	DTC software activation vector 6 to 0	These bits specify a vector number for DTC activation by software. These bits specify a vector number for DTC software activation. The vector address is expressed as H'0400 + (vector number × 2). For example, when DTVEC6 to DTVEC0 = H'10, the vector address is H'0420. When the bit SWDTE is 0, these bits can be written.	R/W
5	DTVEC5			R/W
4	DTVEC4			R/W
3	DTVEC3			R/W
2	DTVEC2			R/W
1	DTVEC1			R/W
0	DTVEC0			R/W

DTVECR enables or disables DTC activation by software, and sets a vector number for the software activation interrupt.

11.3 Activation Sources

The DTC operates when activated by an interrupt request or by a write to DTVECR by software. An interrupt request can be designated by the DTCER bit. At the end of a data transfer (or the last consecutive transfer in the case of chain transfer), the activation source interrupt flag or corresponding bit to DTCER is cleared. For example, the activation source flag, in the case of SCI3_1_RXI, is the RDRF flag of SCI3_1.

When an interrupt has been designated a DTC activation source, existing CPU mask level and interrupt controller priorities have no effect. If there is more than one activation source at the same time, the DTC operates in accordance with the default priorities for the interrupt sources.

Table 11.2 shows a relationship between activation sources and DTCER clear conditions. Figure 11.2 shows a block diagram of DTC activation source control. For details, see section 4, Interrupt Controller.

Table 11.2 Relationship between Activation Sources and DTCER Clearing

Activation Source	DISEL = 0 and Specified Number of Transfers Has Not Ended	DISEL = 1 or Specified Number of Transfers Has Ended
Activation by software	SWDTE bit is cleared to 0	• SWDTE bit remains set to 1 • Interrupt request to CPU
Activation by an interrupt	• Corresponding DTCER bit remains set to 1. • Activation source flag is cleared to 0.	• Corresponding DTCER bit is cleared to 0. • Activation source flag remains set to 1. • Interrupt that became the activation source is requested to the CPU.

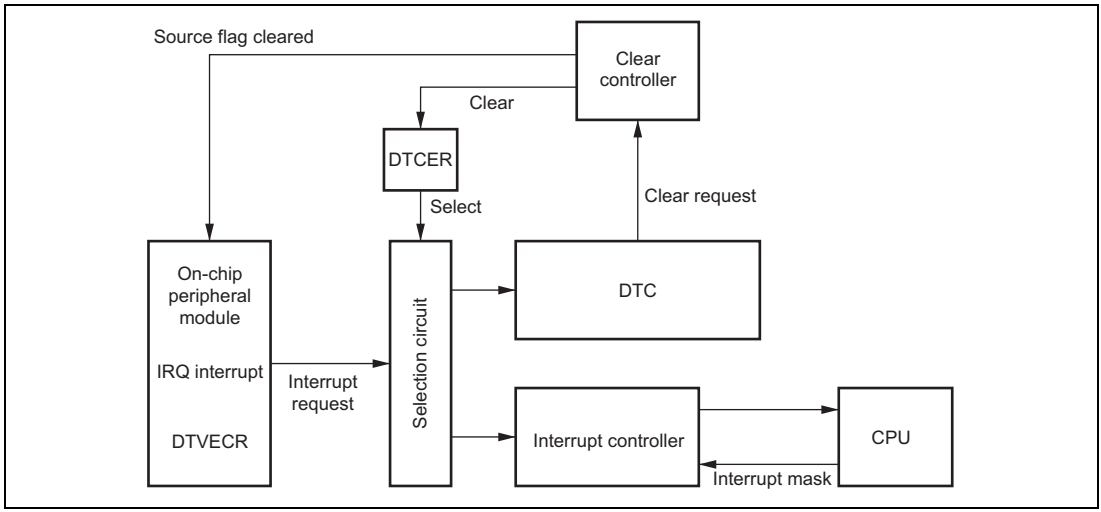


Figure 11.2 Block Diagram of DTC Activation Source Control

11.4 Location of Register Information and DTC Vector Table

Locate the register information in the on-chip RAM. Register information should be located at the address that is multiple of four. Locating the register information in address space is shown in figure 11.3. Locate the MRA, SAR, MRB, DAR, CRA, and CRB registers, in that order, from the start address of the register information. In the case of chain transfer, register information should be located in consecutive areas as shown in figure 11.3 and the register information start address should be located at the corresponding vector address to the activation source. Figure 11.4 shows correspondences between the DTC vector address and register information. The DTC reads the start address of the register information from the vector address set for each activation source, and then reads the register information from that start address.

When the DTC is activated by software, the vector address is obtained from: H'0400 + (DTVECR[6:0] × 2). For example, if VOFR and DTVECR are H'0000 and H'18 respectively, the vector address is H'0430.

The configuration of the vector address is a 2-byte unit. These two bytes specify the lower bits of the start address. Variable vector addresses can be used by setting VOFR. For details on VOFR settings, see section 4, Interrupt Controller.

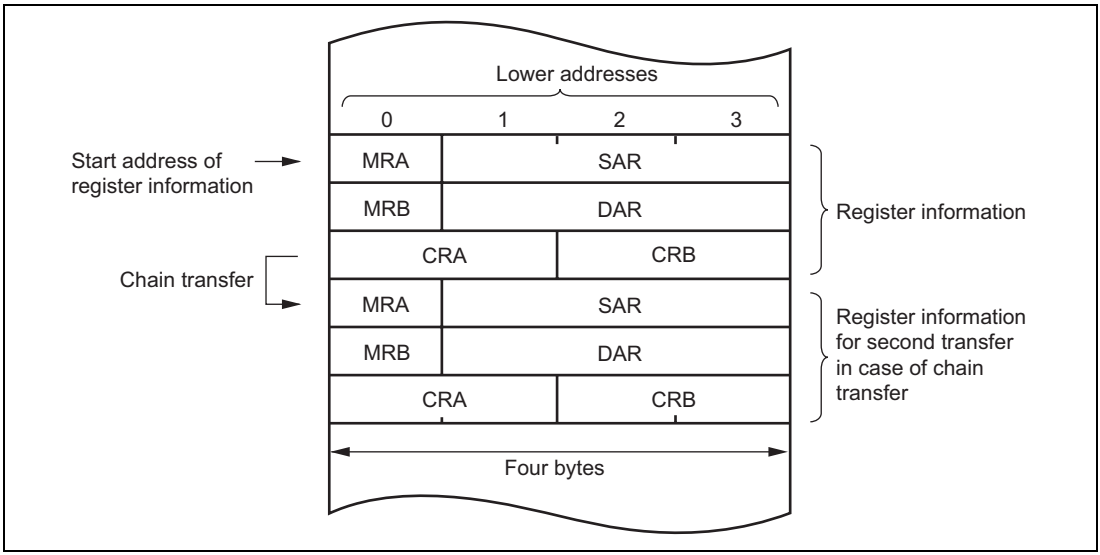


Figure 11.3 Locating DTC Register Information in Address Space

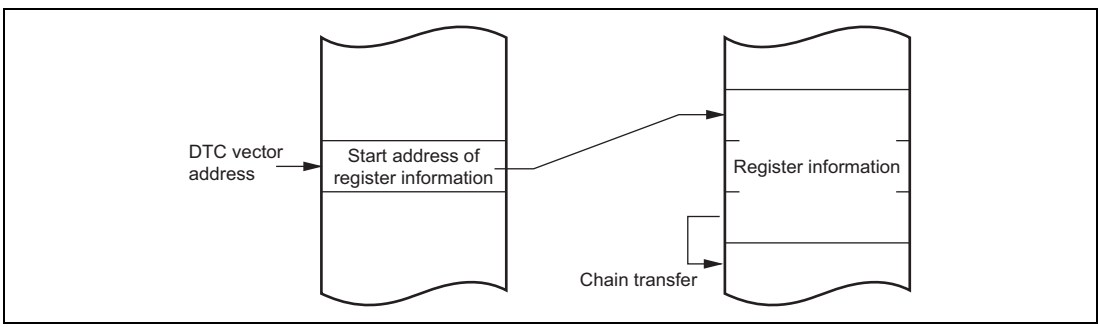


Figure 11.4 Correspondence between DTC Vector Address and Register Information

Table 11.3 Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs

Origin of Activation Source	Activation Source	Vector Number	Vector Address*1	DTCE*5	Priority
Software	Write to DTVECR	DTVECR	H'0400 + (DTVECR[6:0] × 2)	—	High
External pin	IRQ0	22	H'42C to H'42D	DTCEA7	
	IRQ1	23	H'42E to H'42F	DTCEA6	
	IRQ2	24	H'430 to H'431	DTCEA5	
	IRQ3	25	H'432 to H'433	DTCEA4	
	IRQ4	26	H'434 to H'435	DTCEA3	
	IRQ5	27	H'436 to H'437	DTCEA2	
	IRQ6	28	H'438 to H'439	DTCEA1	
	IRQ7	29	H'43A to H'43B	DTCEA0	
A/D converter unit 1	IADEND_1 (conversion completion)	30	H'43C to H'43D	DTCEB7	
	IADCMP_1 (compare condition match)	31	H'43E to H'43F	DTCEB6	
A/D converter unit 2*2	IADEND_2 (conversion completion)	32	H'442 to H'443	DTCEB5	
	IADCMP_2 (compare condition match)	33	H'444 to H'445	DTCEB4	
ELC	ELC1FP (ELSR12 event occurrence)	35	H'446 to H'447	DTCEB3	
	ELC2FP (ELSR30 event occurrence)	36	H'448 to H'449	DTCEB2	
SCI3 channel 1	SCI3_1 RXI	38	H'44C to H'44D	DTCEB1	
	SCI3_1 TXI	39	H'44E to H'44F	DTCEB0	
SCI3 channel 2	SCI3_2 RXI	42	H'454 to H'455	DTCEC7	
	SCI3_2 TXI	43	H'456 to H'457	DTCEC6	
SCI3 channel 3	SCI3_3 RXI	46	H'45C to H'45D	DTCEC5	
	SCI3_3 TXI	47	H'45E to H'45F	DTCEC4	
IIC2/SSU	IIC2/SSU_RXI	60	H'478 to H'479	DTCED7	
	IIC3/SSU_TXI	61	H'47A to H'47B	DTCED6	Low

Origin of Activation Source	Activation Source	Vector Number	Vector Address*1	DTCE*5	Priority
Timer RC*3	ITCMA Input capture A/ compare match A	71	H'48E to H'48F	DTCED3	High
	ITCMB Input capture B/ compare match B	72	H'490 to H'491	DTCED2	
	ITCMC Input capture C/ compare match C	73	H'492 to H'493	DTCED1	
	ITCMD Input capture D/ compare match D	74	H'494 to H'495	DTCED0	
Timer RD unit 0 channel 0	ITDMA0_0 Input capture A/ compare match A	76	H'498 to H'499	DTCEE7	
	ITDMB0_0 Input capture B/ compare match B	77	H'49A to H'49B	DTCEE6	
	ITDMC0_0 Input capture C/ compare match C	78	H'49C to H'49D	DTCEE5	
	ITDMD0_0 Input capture D/ compare match D	79	H'49E to H'49F	DTCEE4	
Timer RD unit 0 channel 1*4	ITDMA0_1 Input capture A/ compare match A	82	H'4A4 to H'4A5	DTCEE3	
	ITDMB0_1 Input capture B/ compare match B	83	H'4A6 to H'4A7	DTCEE2	
	ITDMC0_1 Input capture C/ compare match C	84	H'4A8 to H'4A9	DTCEE1	
	ITDMD0_1 Input capture D/ compare match D	85	H'4AA to H'4AB	DTCEE0	Low

Origin of Activation Source	Activation Source	Vector Number	Vector Address*1	DTCE*5	Priority
Timer RD unit 1 channel 2*4	ITDMA1_2 Input capture A/ compare match A	87	H'4AE to H'4AF	DTCEF7	High
	ITDMB1_2 Input capture B/ compare match B	88	H'4B0 to H'4B1	DTCEF6	
	ITDMC1_2 Input capture C/ compare match C	89	H'4B2 to H'4B3	DTCEF5	
	ITDMD1_2 Input capture D/ compare match D	90	H'4B4 to H'4B5	DTCEF4	
Timer RD unit 1 channel 3*4	ITDMA1_3 Input capture A/ compare match A	93	H'4BA to H'4BB	DTCEF3	
	ITDMB1_3 Input capture B/ compare match B	94	H'4BC to H'4BD	DTCEF2	
	ITDMC1_3 Input capture C/ compare match C	95	H'4BE to H'4BF	DTCEF1	
	ITDMD1_3 Input capture D/ compare match D	96	H'4C0 to H'4C1	DTCEF0	
Timer RE	ITESC	100	H'4C8 to H'4C9	DTCEG4	
	ITEMI	101	H'4CA to H'4CB	DTCEG3	
	ITEHR	102	H'4CC to H'4CD	DTCEG2	
	ITEDY	103	H'4CE to H'4CF	DTCEG1	
	ITEWK	104	H'4D0 to H'4D1	DTCEG0	
Timer RG	ITGMA Input capture A/ compare match A	109	H'4DA to H'4DB	DTCEH3	
	ITGMB Input capture B/ compare match B	110	H'4DC to H'4DD	DTCEH2	Low

Notes: 1. Vector address indicates the lower 11 bits of vector address when VOFR = H'0000.
2. Supported only in the H8S/20223 group and reserved in other products.
3. Supported only in the H8S/20103 group and reserved in other products.
4. Not supported in the H8S/20103 group and reserved in the H8S/20103 group.
5. DTCE bits with no corresponding interrupt are reserved. The write value should always be 0.

11.5 Operation

The DTC stores register information in the on-chip RAM. When activated, the DTC reads register information in the on-chip RAM and transfers data. After the data transfer, it writes updated register information back to the on-chip RAM. Pre-storage of register information in the on-chip RAM makes it possible to transfer data over any required number of channels. There are three transfer modes: normal mode, repeat mode, and block transfer mode. Setting the CHNE bit to 1 allows a number of transfers with a single activation (chain transfer). Setting the CHNS bit to 1 enables chain transfer only when the transfer counter value is 0.

The 24-bit SAR designates the DTC transfer source address and the 24-bit DAR designates the transfer destination address. After each transfer, SAR and DAR are independently incremented, decremented, or left fixed according to the register information.

Figure 11.5 shows a flowchart of DTC operation, and table 11.4 summarizes the chain transfer conditions (for performing the first and second transfers).

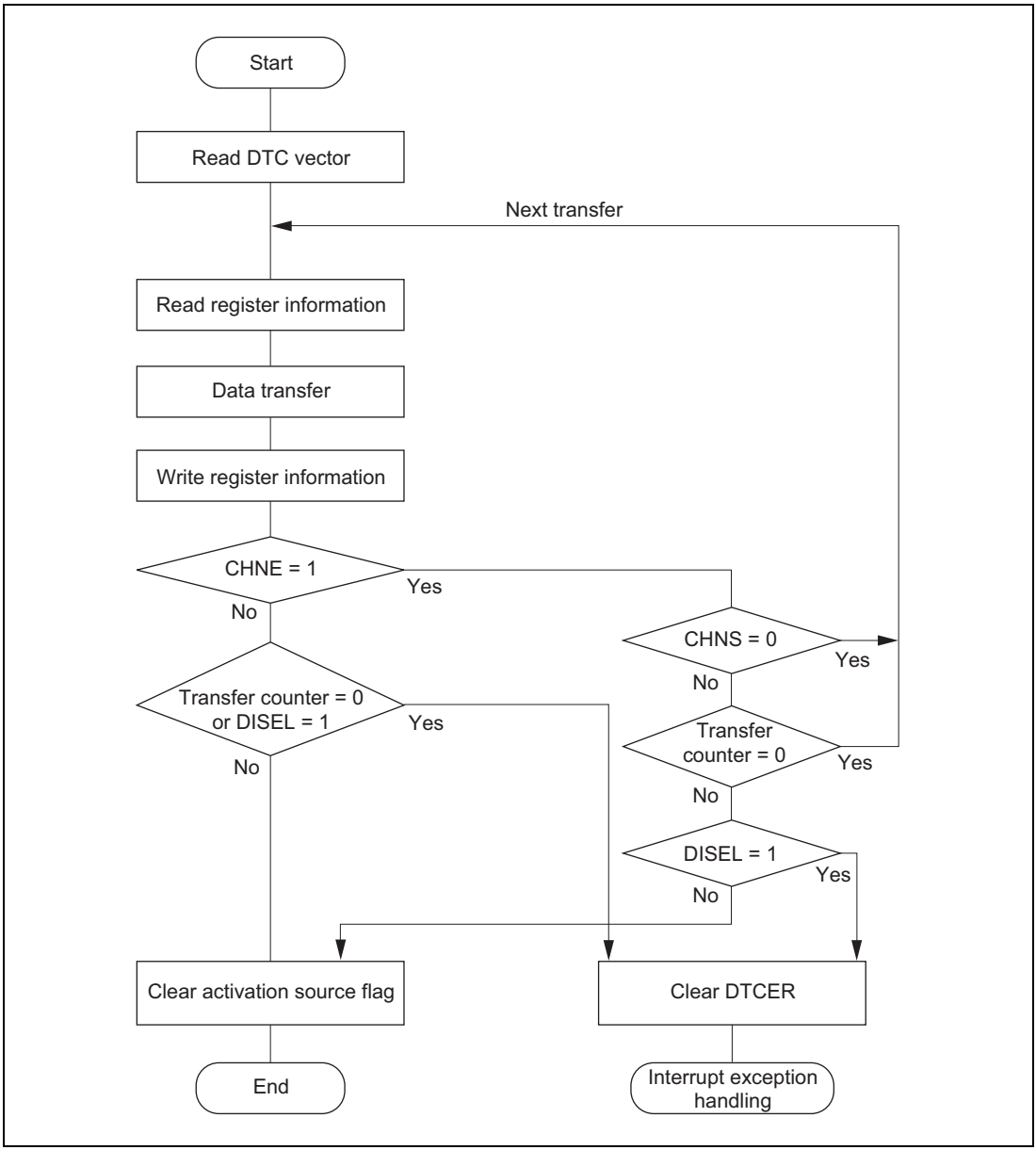


Figure 11.5 Flowchart of DTC Operation

Table 11.4 Chain Transfer Conditions

1st Transfer				2nd Transfer				
CHNE	**CHNS**	**DISEL**	**CR**	**CHNE**	**CHNS**	**DISEL**	**CR**	**DTC Transfer**
0	—	0	Except 0	—	—	—	—	Ends at 1st transfer
0	—	0	0	—	—	—	—	Ends at 1st transfer
0	—	1	—	—	—	—	—	Interrupt request to CPU
1	0	—	—	0	—	0	Except 0	Ends at 2nd transfer
				0	—	0	0	Ends at 2nd transfer
				0	—	1	—	Interrupt request to CPU
1	1	0	Except 0	—	—	—	—	Ends at 1st transfer
1	1	—	0	0	—	0	Except 0	Ends at 2nd transfer
				0	—	0	0	Ends at 2nd transfer
				0	—	1	—	Interrupt request to CPU
1	1	1	Except 0	—	—	—	—	Ends at 1st transfer
								Interrupt request to CPU

11.5.1 Normal Mode

In normal mode, one operation transfers one byte or one word of data. Table 11.5 lists the register function in normal mode. From 1 to 65,536 transfers can be specified. Once the specified number of transfers has ended, a CPU interrupt can be requested.

Table 11.5 Register Function in Normal Mode

Name	Abbreviation	Function
DTC source address register	SAR	Designates transfer source address
DTC destination address register	DAR	Designates transfer destination address
DTC transfer count register A	CRA	Designates transfer count
DTC transfer count register B	CRB	Not used

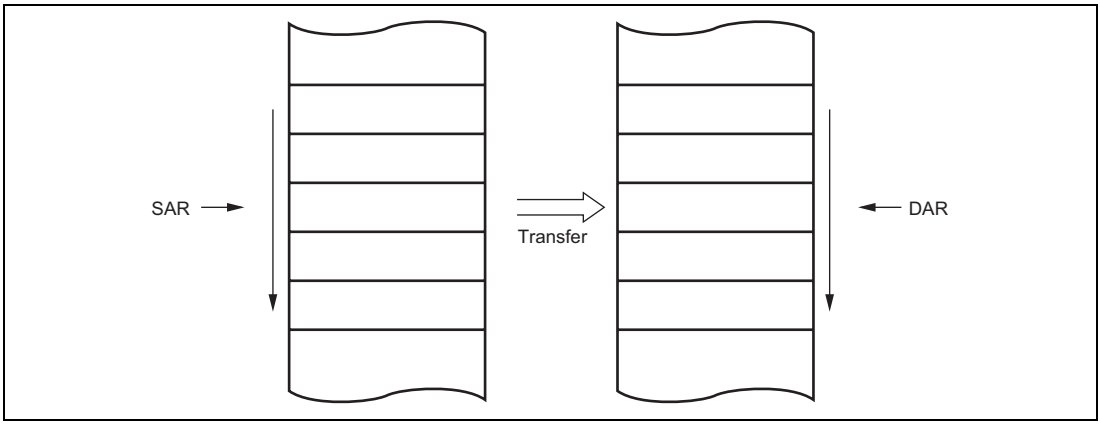


Figure 11.6 Memory Mapping in Normal Mode

11.5.2 Repeat Mode

In repeat mode, one operation transfers one byte or one word of data. Table 11.6 lists the register function in repeat mode. From 1 to 256 transfers can be specified. Once the specified number of transfers has ended, the initial state of the transfer counter and the address register specified as the repeat area is restored, and transfer is repeated. In repeat mode, the transfer counter value does not reach H'00, therefore CPU interrupts cannot be requested when DISEL = 0.

Table 11.6 Register Function in Repeat Mode

Name	Abbreviation	Function
DTC source address register	SAR	Designates transfer source address
DTC destination address register	DAR	Designates transfer destination address
DTC transfer count register AH	CRAH	Holds number of transfers
DTC transfer count register AL	CRAL	Designates transfer count
DTC transfer count register B	CRB	Not used

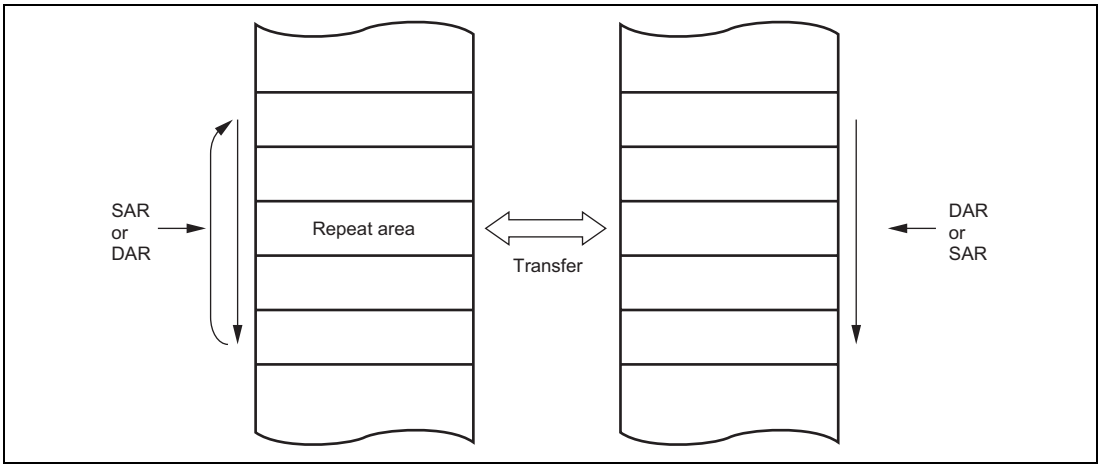


Figure 11.7 Memory Mapping in Repeat Mode

11.5.3 Block Transfer Mode

In block transfer mode, one operation transfers one block of data. Either the transfer source or the transfer destination is designated as a block area. Table 11.7 lists the register function in block transfer mode. The block size is 1 to 256. When the transfer of one block ends, the initial state of the block size counter and the address register specified as the block area is restored. The other address register is then incremented, decremented, or left fixed according to the register information. From 1 to 65,536 transfers can be specified. Once the specified number of transfers has ended, a CPU interrupt is requested.

Table 11.7 Register Function in Block Transfer Mode

Name	Abbreviation	Function
DTC source address register	SAR	Designates source address
DTC destination address register	DAR	Designates destination address
DTC transfer count register AH	CRAH	Holds block size
DTC transfer count register AL	CRAL	Designates block size count
DTC transfer count register B	CRB	Designates transfer count

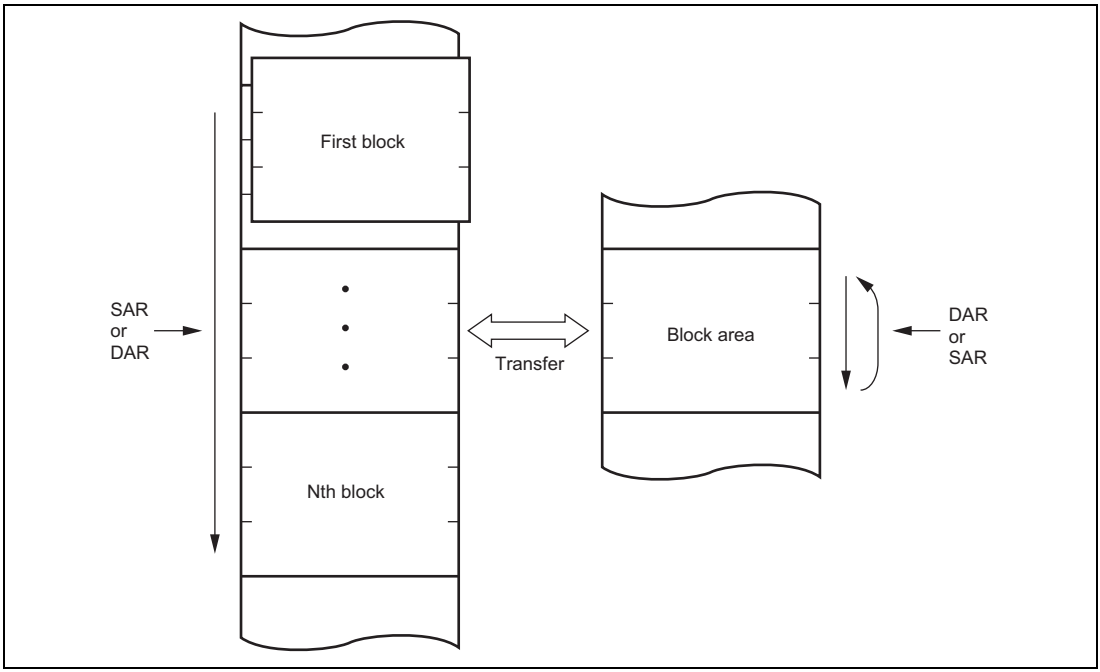


Figure 11.8 Memory Mapping in Block Transfer Mode

11.5.4 Chain Transfer

Setting the CHNE bit in MRB to 1 enables a number of data transfers to be performed consecutively in response to a single transfer request. SAR, DAR, CRA, CRB, MRA, and MRB can be set independently.

Figure 11.9 shows the operation of chain transfer. When activated, the DTC reads the register information start address stored at the vector address, and then reads the first register information at that start address. The CHNE bit in MRB is checked after the end of data transfer, if the value is 1, the next register information, which is located consecutively, is read and transfer is performed. This operation is repeated until the end of data transfer of register information with CHNE = 0. Setting both the CHNE bit and CHNS bit to 1 enables execution of chain transfer only when the transfer counter value is 0.

In the case of transfer with CHNE set to 1, an interrupt request to the CPU is not generated at the end of the specified number of transfers or by setting of the DISEL bit to 1, and the interrupt source flag for the activation source is not affected.

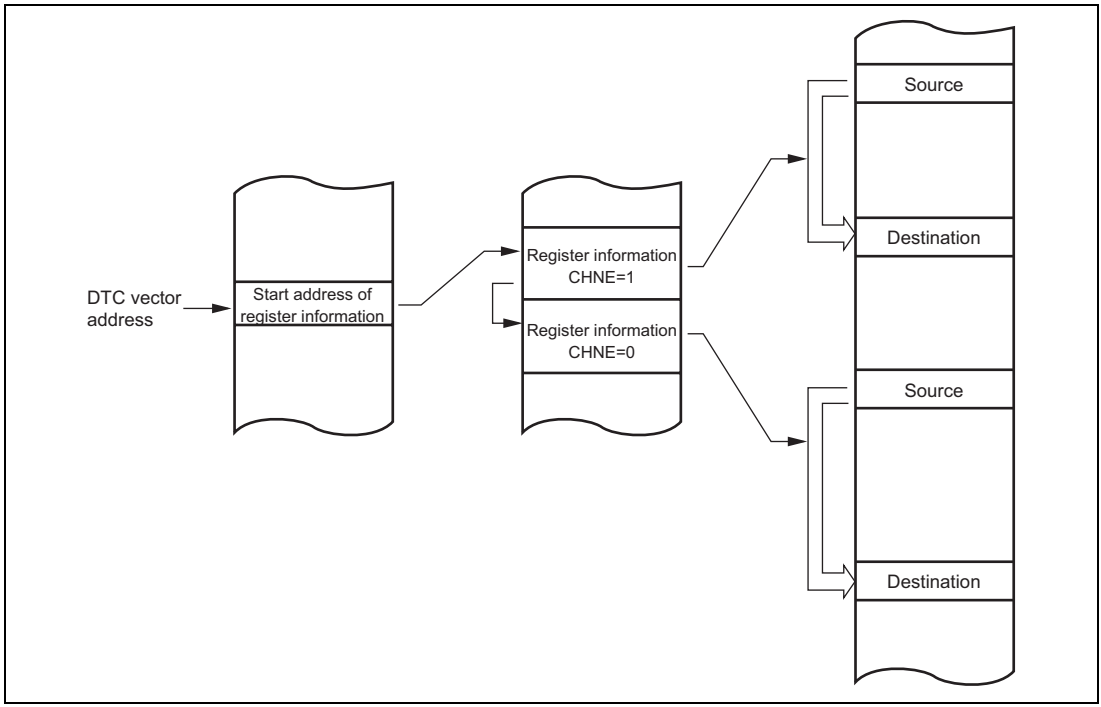


Figure 11.9 Operation of Chain Transfer

11.5.5 Interrupt Sources

An interrupt request is issued to the CPU when the DTC ends the specified number of data transfers, or when the DTC ends a data transfer for which the DISEL bit was set to 1. In the case of interrupt activation, the interrupt set as the activation source is generated. These interrupts to the CPU are subject to CPU mask level and interrupt controller priority level control.

In the case of activation by software, a software activated data transfer end interrupt (SWDTEND) is generated.

When the DISEL bit is 1 and one data transfer has ended or the specified number of transfers has ended, the SWDTE bit is held at 1 and an SWDTEND interrupt is generated after data transfer ends. The interrupt handling routine should clear the SWDTE bit to 0.

When the DTC is activated by software, an SWDTEND interrupt is not generated during a data transfer wait or during data transfer even if the SWDTE bit is set to 1.

11.5.6 Operation Timing

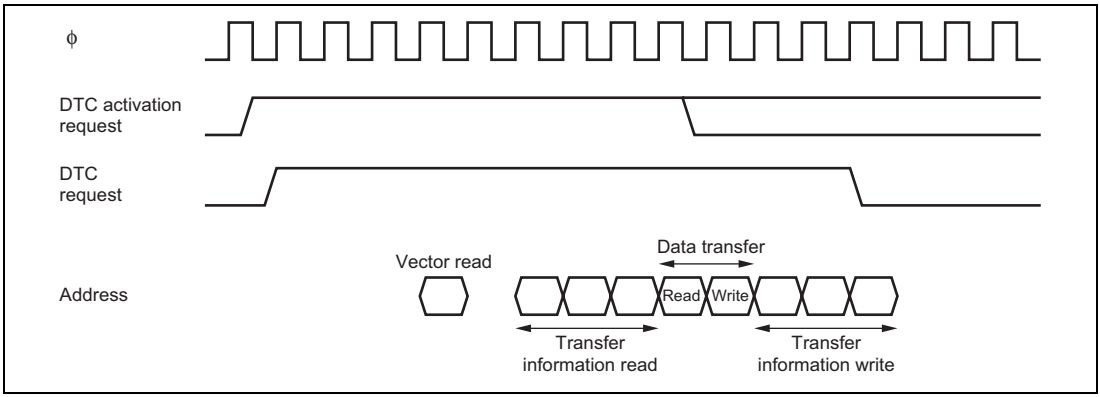


Figure 11.10 DTC Operation Timing (Example in Normal Mode or Repeat Mode)

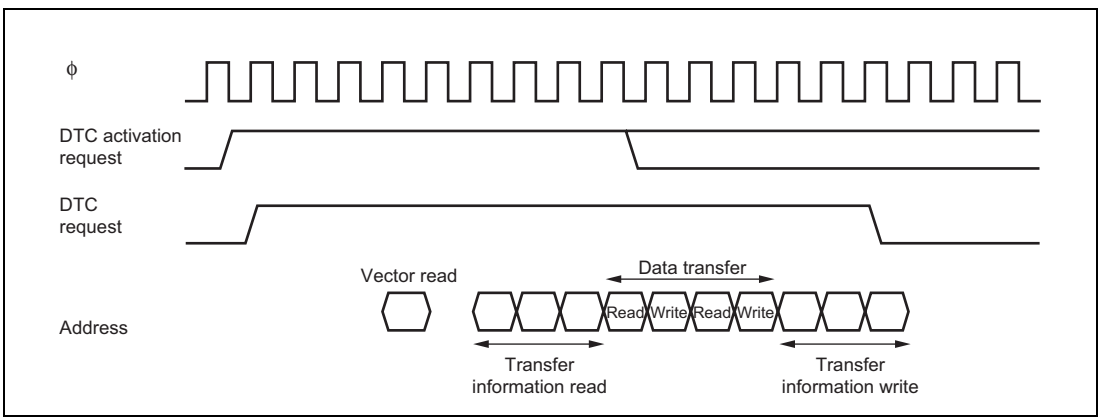


Figure 11.11 DTC Operation Timing (Example of Block Transfer Mode, with Block Size of 2)

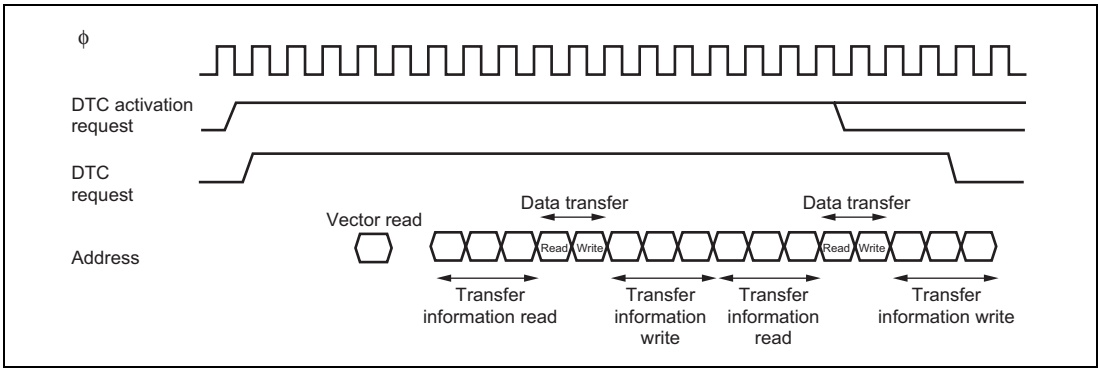


Figure 11.12 DTC Operation Timing (Example of Chain Transfer)

11.5.7 Number of DTC Execution States

Table 11.8 lists execution state for a single DTC data transfer, and table 11.9 shows the number of states required for each execution status.

Table 11.8 DTC Execution State

Mode	Vector Read I	Register Information Read/Write J	Data Read K	Data Write L	Internal Operations M
Normal	1	6	1	1	3
Repeat	1	6	1	1	3
Block transfer	1	6	N	N	3

Legend:

N: Block size (initial setting value of CRAH and CRAL)

Table 11.9 Number of States Required for Each Execution Status

Object to be Accessed		On-Chip RAM	On-Chip ROM	Internal I/O Register					
Bus width		32	16	8			16		
Access states		1	1	2	3	4	2	3	4
Execution state	Vector read S_I	1	1	2	3	4	2	3	4
	Register information read/write S_J	1	—	—	—	—	—	—	—
	Byte data read S_K	1	1	2	3	4	2	3	4
	Word data read S_K	1	1	4	6	8	2	3	4
	Byte data write S_L	1	1	2	3	4	2	3	4
	Word data write S_L	1	1	4	6	8	2	3	4
	Internal operation S_M	1							

The number of execution states is calculated from the formula below. Note that Σ means the sum of all transfers activated by one activation source (the number in which the CHNE bit is set to 1 + 1).

$$\text{Number of execution states} = I \cdot S_I + \Sigma (J \cdot S_J + K \cdot S_K + L \cdot S_L) + M \cdot S_M$$

For example, when the DTC vector address table is located in on-chip ROM and data is transferred from the on-chip ROM to an internal I/O register (two-state access) in normal mode, the time required for the DTC operation is 13 states. The time from activation to the end of the data write is 10 states.

11.6 Procedures for Using DTC

11.6.1 Activation by Interrupt

The procedure for using the DTC with interrupt activation is as follows:

1. Set the MRA, MRB, SAR, DAR, CRA, and CRB register information in the on-chip RAM.
2. Set the start address of the register information in the DTC vector address.
3. Set the corresponding bit in DTCER to 1.
4. Set the enable bits for the interrupt sources to be used as the activation sources to 1. The DTC is activated when an interrupt used as an activation source is generated.
5. After the end of one data transfer, or after the specified number of data transfers have ended, the DTCE bit is cleared to 0 and a CPU interrupt is requested. If the DTC is to continue transferring data, set the DTCE bit to 1.

11.6.2 Activation by Software

The procedure for using the DTC with software activation is as follows:

1. Set the MRA, MRB, SAR, DAR, CRA, and CRB register information in the on-chip RAM.
2. Set the start address of the register information in the DTC vector address.
3. Check that the SWDTE bit is 0.
4. Write 1 to the SWDTE bit and the vector number to DTVECR.
5. Check the vector number written to DTVECR.
6. After the end of one data transfer, if the DISEL bit is 0 and a CPU interrupt is not requested, the SWDTE bit is cleared to 0. If the DTC is to continue transferring data, set the SWDTE bit to 1. When the DISEL bit is 1, or after the specified number of data transfers has ended, the SWDTE bit is held at 1 and a CPU interrupt is requested. Clear the SWDTE bit to 0 by an interrupt processing routine.

11.7 Examples of Use of the DTC

11.7.1 Normal Mode

An example is shown in which the DTC is used to receive 128 bytes of data via the SCI3.

1. Set MRA to fixed source address (SM1 = SM0 = 0), incrementing destination address (DM1 = 1, DM0 = 0), normal mode (MD1 = MD0 = 0), and byte size (Sz = 0). The DTS bit can have any value. Set MRB for one data transfer by one interrupt (CHNE = 0, DISEL = 0). Set the RDR address in SCI3 of SAR, the start address of the RAM area where the data is stored in DAR, and 128 (H'0080) in CRA. CRB can be set to any value.
2. Set the start address of the register information at the DTC vector address.
3. Set the corresponding bit in DTCER to 1.
4. Set the SCI3 to the appropriate receive mode. Set the RIE bit in SCR to 1 to enable the reception complete (RXI) interrupt. Since the generation of a receive error during the SCI reception operation will disable subsequent reception, the CPU should be enabled to accept receive error interrupts.
5. Each time reception of one byte of data ends on the SCI3, the RDRF flag in SSR is set to 1, an RXI interrupt is generated, and the DTC is activated. The receive data is transferred from RDR to RAM by the DTC. DAR is incremented and CRA is decremented. The RDRF flag is automatically cleared to 0.
6. When CRA becomes 0 after the 128 data transfers have ended, the RDRF flag is held at 1, the DTCE bit is cleared to 0, and an RXI interrupt request is sent to the CPU. The interrupt handling routine should perform termination processing.

11.7.2 Chain Transfer when Transfer Counter = 0

By executing the second data transfer, and performing re-setting of the first data transfer, only when the counter value is 0, 256 or more repeat transfers can be performed.

An example is shown in which a 128-kbyte input buffer is configured. The input buffer is assumed to have been set to start at lower address H'0000. Figure 11.13 shows overview of the chain transfer when the counter value is 0.

1. For the first transfer, set the normal mode for input data. Set fixed transfer source address (G/A, etc.), CRA = H'0000 (65,536 times), and CHNE = 1, CHNS = 1, and DISEL = 0.
2. Prepare the upper 8-bit addresses of the start addresses for each of the 65,536 transfer start addresses for the first data transfer in a separate area (in ROM, etc.). For example, if the input buffer comprises H'200000 to H'21FFFF, prepare H'21 and H'20.
3. For the second transfer, set repeat mode (with the source side as the repeat area) for re-setting the transfer destination address for the first data transfer. Use the upper 8 bits of DAR in the first register information area as the transfer destination. Set CHNE = DISEL = 0. If the above input buffer is specified as H'200000 to H'21FFFF, set the transfer counter to 2.
4. Execute the first data transfer 65,536 times by means of interrupts. When the transfer counter for the first data transfer reaches 0, the second data transfer is started. Set the upper 8 bits of the transfer source address for the first data transfer to H'21. The lower 16 bits of the transfer destination address of the first data transfer and the transfer counter are H'0000.
5. Next, execute the first data transfer the 65,536 times specified for the first data transfer by interrupts. When the transfer counter for the first data transfer reaches 0, the second data transfer is started. Set the upper 8 bits of the transfer source address for the first data transfer to H'20. The lower 16 bits of the transfer destination address of the first data transfer is H'0000.
6. Steps 4 and 5 are repeated endlessly. As repeat mode is specified for the second data transfer, an interrupt request is not sent to the CPU.

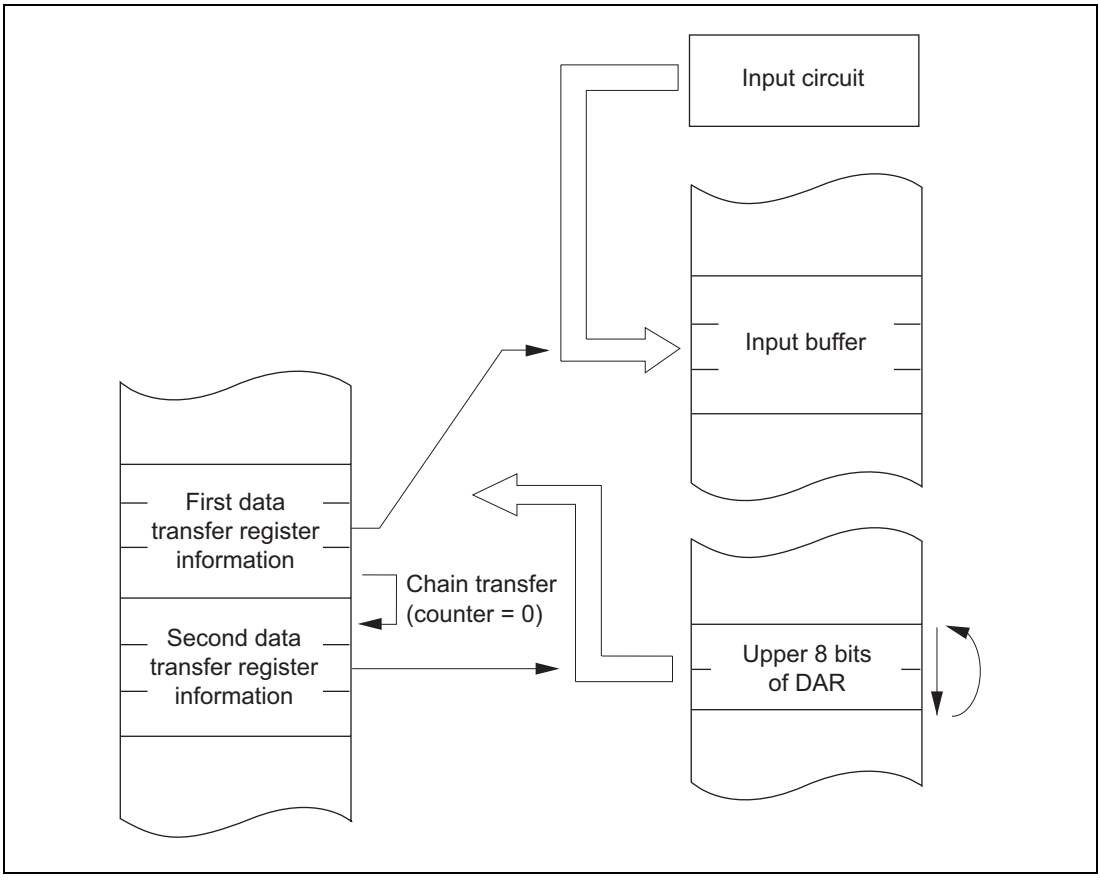


Figure 11.13 Chain Transfer when Counter = 0

11.7.3 Software Activation

An example is shown in which the DTC is used to transfer a block of 128 bytes of data by software activation. The transfer source address is H'1000 and the destination address is H'2000. The vector number is H'60, so the vector address is H'04C0.

1. Set MRA to incrementing source address (SM1 = 1, SM0 = 0), incrementing destination address (DM1 = 1, DM0 = 0), block transfer mode (MD1 = 1, MD0 = 0), and byte size (Sz = 0). The DTS bit can have any value. Set MRB for one block transfer by one interrupt (CHNE = 0). Set the transfer source address (H'1000) in SAR, the transfer destination address (H'2000) in DAR, and 128 (H'8080) in CRA. Set 1 (H'0001) in CRB.
2. Set the start address of the register information at the DTC vector address (H'04C0).
3. Check that the SWDTE bit in DTVECR is 0. Check that there is currently no transfer activated by software.
4. Write 1 to the SWDTE bit and the vector number (H'60) to DTVECR. The write data is H'E0.
5. Read DTVECR again and check that H'60 is set to the vector number. If it is not, this indicates that the write has failed. This is because an interrupt occurred between steps 3 and 4 and led to a different software activation. To activate this transfer, go back to step 3.
6. If the write was successful, the DTC is activated and a block of 128 bytes of data is transferred.
7. After the transfer, an SWDTEND interrupt occurs. The interrupt handling routine should clear the SWDTE bit to 0 and perform other wrap-up processing.

11.8 Usage Notes

11.8.1 Module Standby Mode Setting

DTC operation can be disabled or enabled using the module standby control register. The initial value is for DTC operation to be disabled. When the DTC is used, cancel module standby mode. Register access is disabled in module standby mode. Module standby mode cannot be set while the DTC is activated. For details, see section 6, Power-Down Modes.

11.8.2 DTCE Bit Setting

For DTCE bit setting, use bit manipulation instructions such as BSET and BCLR. If all interrupts are disabled, multiple activation sources can be set at one time (only at the initial setting) by writing data after executing a dummy read on the relevant register.

11.8.3 DTC Activation by SCI3, IIC2/SSU and A/D Converter Interrupt Sources

Interrupts and activation sources of the SCI3, IIC2/SSU, and A/D converter are cleared when the DTC reads or writes the prescribed register. Therefore, when the DTC is activated by an interrupt or activation source, the interrupt or activation source will be retained if a read/write of the relevant register is not included in the last chained data transfer.

The above operation is performed regardless of the DISEL bit setting.

Section 12 Event Link Controller

The event link controller (ELC) connects the events generated by the various peripheral modules to different modules. This function allows direct cooperation between the modules without CPU intervention. A block diagram of the ELC is shown in figure 12.1.

12.1 Overview

- Fifty-nine event signals can be directly connected to modules.
- The operation of timer modules can be selected when an event is input to the timer module.
- Events can be connected to ports 3 and 6.

  Single port-pin: An event link can be set for a single specific pin of a port.

  Port group: An event link can be set for a specific group of bits within an 8-bit port.

  In addition, in the specified single pin or group within a port, an event is generated by a change in the value of the linked signals.
- Four channels of events can be generated in arbitrary setting interval using the event-generation timer.

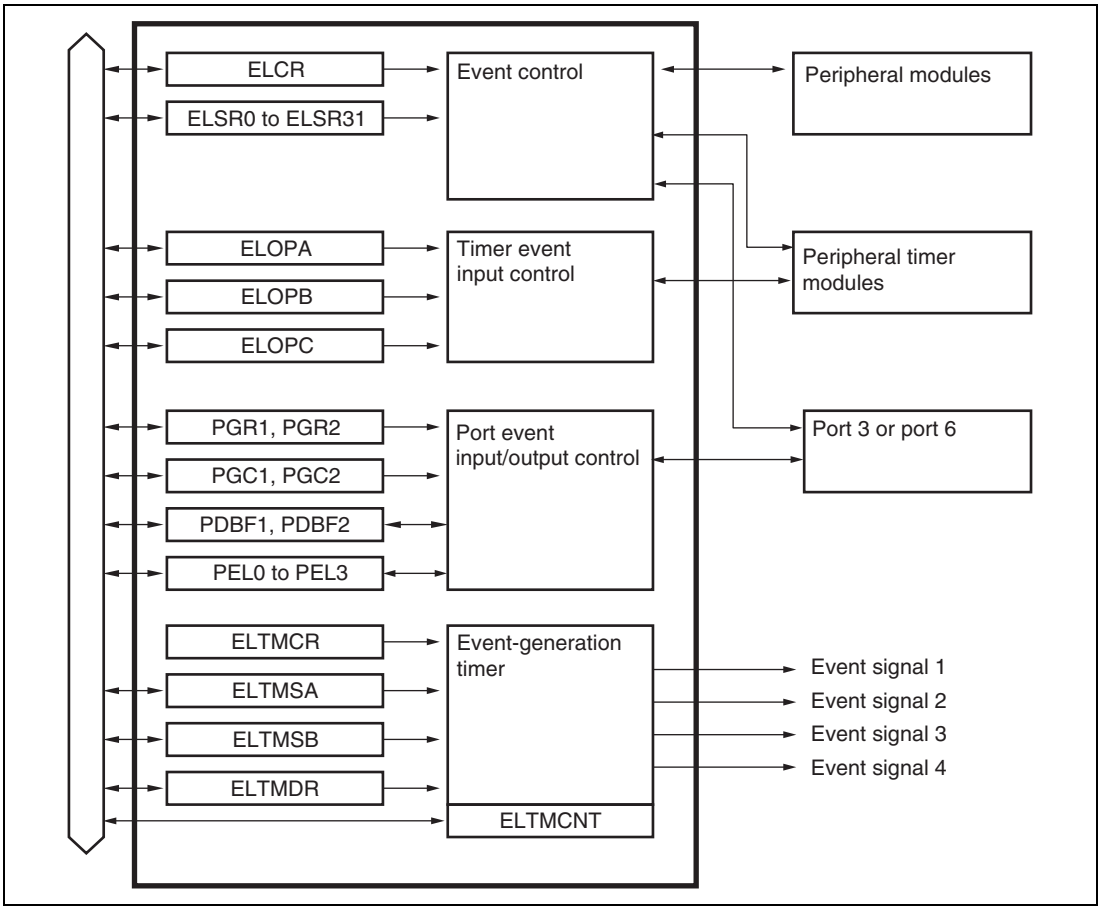


Figure 12.1 Block Diagram of Event Link Controller

12.2 Register Descriptions

The ELC has the following registers.

- Event link control register (ELCR)
- Event link setting registers 0 to 32 (ELSR0 to ELSR32)
- Event link option setting register A (ELOPA)
- Event link option setting register B (ELOPB)
- Event link option setting register C (ELOPC)
- Port-group setting registers 1 and 2 (PGR1, PGR2)
- Port-group control registers 1 and 2 (PGC1, PGC2)
- Port buffer registers 1 and 2 (PDBF1 and PDBF2)
- Event link port setting registers 0 to 3 (PEL0 to PEL3)
- Event-generation timer control register (ELTMCR)
- Event-generation timer interval setting register A (ELTMSA)
- Event-generation timer interval setting register B (ELTMSB)
- Event-generation timer delay selection register (ELTMDR)
- ELC timer counter (ELTMCNT)

12.2.1 Event Link Control Register (ELCR)

Address: H'FF06BC

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

Bit	Symbol	Bit Name	Description	R/W
7	ELCON	All event link enable	0: Linkage of all the events are disabled. 1: Linkage of all the events are enabled.	R/W
6 to 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

ELCR controls the operation of the event link controller (ELC) collectively.

12.2.2 Event Link Setting Registers 0 to 32 (ELSR0 to ELSR32)

Address: H'FF0680 to H'FF0684, H'FF0688, H'FF068A to H'FF068C, H'FF068E, H'FF068F, H'FF0692, H'FF0693, H'FF0695 to H'FF0698, H'FF069D to H'FF06A0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	ELSn7	ELSn6	ELSn5	ELSn4	ELSn3	ELSn2	ELSn1	ELSn0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	ELSn7	Event link select n7	00000000: Linkage of the event is disabled. 0000001 to 01100001: Set the number specific to the event signal to be linked. Other than the above: Setting prohibited.	R/W
6	ELSn6	Event link select n6		R/W
5	ELSn5	Event link select n5		R/W
4	ELSn4	Event link select n4		R/W
3	ELSn3	Event link select n3		R/W
2	ELSn2	Event link select n2		R/W
1	ELSn1	Event link select n1		R/W
0	ELSn0	Event link select n0		R/W

[Legend]

n: 0 to 32 (except 5 to 7, 9, 13, 16, 17, 20, and 25 to 28)

Each of ELSR0 to ELSR32 specifies an event signal to be linked for the peripheral module. Table 12.1 shows the correspondence between ELSR0 to ELSR31 and the peripheral modules. Table 12.2 shows the correspondence between the event signal names and the numbers specific to the signals.

Table 12.1 Correspondence between ELSR and Peripheral Modules

Register Name	Peripheral Module (Functions)
ELSR0	Timer RA
ELSR1	Timer RB
ELSR2*1	Timer RC
ELSR3	Timer RD_0 channel 0
ELSR4	Timer RD_0 channel 1
ELSR8	Timer RG
ELSR10	AD converter unit 1
ELSR11*2	AD converter unit 2
ELSR12	Interrupts 1
ELSR14	Output port-group 2
ELSR15	Output port-group 3
ELSR18	Input port-group 2
ELSR19	Input port-group 3
ELSR21	Single-port 1
ELSR22	Single-port 2
ELSR23	Single-port 3
ELSR24	Single-port 4
ELSR29	Clock oscillator
ELSR30	Interrupts 2
ELSR31	DA converter channel 0
ELSR32	DA converter channel 1

Note: 1. Supported only in the H8S/20103 group.
2. Supported only in the H8S/20223 group.

Table 12.2 Correspondence between Event Signal Names and ELSn Bit Values

ELSn7 to ELSn0 Bit Value (Signal Number)	Name of Event Signal to Set ELSR
00000001 (H'01)	Timer RA underflow
00000010 (H'02)	Timer RB underflow
00000011 (H'03)*[1]	Timer RC overflow
00000100 (H'04)*[1]	Timer RC compare-match A
00000101 (H'05)*[1]	Timer RC compare-match B
00000110 (H'06)*[1]	Timer RC compare-match C
00000111 (H'07)*[1]	Timer RC compare-match D
00001000 (H'08)	Timer RD_0 channel 0 overflow
00001001 (H'09)	Timer RD_0 channel 0 compare-match A
00001010 (H'0A)	Timer RD_0 channel 0 compare-match B
00001011 (H'0B)	Timer RD_0 channel 0 compare-match C
00001100 (H'0C)	Timer RD_0 channel 0 compare-match D
00001101 (H'0D)	Timer RD_0 channel 1 overflow
00001110 (H'0E)	Timer RD_0 channel 1 underflow
00001111 (H'0F)	Timer RD_0 channel 1 compare-match A
00010000 (H'10)	Timer RD_0 channel 1 compare-match B
00010001 (H'11)	Timer RD_0 channel 1 compare-match C
00010010 (H'12)	Timer RD_0 channel 1 compare-match D
00100001 (H'21)	Timer RG overflow
00100010 (H'22)	Timer RG underflow
00100011 (H'23)	Timer RG compare-match A
00100100 (H'24)	Timer RG compare-match B
00101001 (H'29)	AD conversion end in AD converter unit 1
00101010 (H'2A)*[2]	AD conversion end in AD converter unit 2
00101100 (H'2C)	Input edge detection on input port-group 1
00101101 (H'2D)	Input edge detection on input port-group 2
00101111 (H'2F)	Input edge detection on single input port 1
00110000 (H'30)	Input edge detection on single input port 2
00110001 (H'31)	Input edge detection on single input port 3
00110010 (H'32)	Input edge detection on single input port 4
00110111 (H'37)	Voltage-drop detection in LVD

ELSn7 to ELSn0 Bit Value (Signal Number)	Name of Event Signal to Set ELSR
00111000 (H'38)	Voltage-drop reset detection in LVD
00111001 (H'39)	CPG backup start
00111010 (H'3A)	WDT increment
00111011 (H'3B)	WDT reset
00111100 (H'3C)	Timer RE interval (week, day, hour, minute, or second)
00111101 (H'3D)	DTC transfer end
00111110 (H'3E)	Transmit-buffer empty in IIC2/SSU
00111111 (H'3F)	Transmit end in IIC2/SSU
01000000 (H'40)	Receive-buffer full in IIC2/SSU
01000001 (H'41)	Stop-condition detection in IIC2/SSU
01000010 (H'42)	Arbitration loss/overrun error in IIC2/SSU
01000011 (H'43)	NACK detection/conflict error in IIC2/SSU
01001010 (H'4A)	SCI3_1 transmit-buffer empty
01001011 (H'4B)	SCI3_1 transmit end
01001100 (H'4C)	SCI3_1 receive-buffer full
01001101 (H'4D)	SCI3_1 transfer error
01001110 (H'4E)	SCI3_2 transmit-buffer empty
01001111 (H'4F)	SCI3_2 transmit end
01010000 (H'50)	SCI3_2 receive-buffer full
01010001 (H'51)	SCI3_2 transfer error
01010010 (H'52)	SCI3_3 transmit-buffer empty
01010011 (H'53)	SCI3_3 transmit end
01010100 (H'54)	SCI3_3 receive-buffer full
01010101 (H'55)	SCI3_3 transfer error
01011110 (H'5E)	Timer ELC event 0
01011111 (H'5F)	Timer ELC event 1
01100000 (H'60)	Timer ELC event 2
01100001 (H'61)	Timer ELC event 3
Other than the above: Setting prohibited	

Note: 1. Selected for the H8S/20103 group.
2. Selected for the H8S/20223 group.

12.2.3 Event Link Option Setting Register A (ELOPA)

Address: H'FF06B5

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TMRAM[2:1]		TMRBM[2:1]		TMRCM[2:1]		TMRD1M[2:1]	
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7 6	TMRAM [2:1]	Timer RA operation select	00: Timer starts counting. 01: Timer counts events. 10: Setting prohibited. 11: Events disabled.	R/W
5 4	TMRBM [2:1]	Timer RB operation select	00: Timer starts counting. 01: Timer counts events. 10: Setting prohibited. 11: Events disabled.	R/W
3 2	TMRCM [2:1]*1	Timer RC operation select	00: Timer starts counting. 01: Timer counts events. 10: Timer performs input-capture operation.*2 11: Events disabled.	R/W
1 0	TMRD1M [2:1]	Timer RD_0 channel 0 operation select	00: Timer starts counting. 01: Timer counts events. 10: Timer performs input-capture operation.*3 11: Events disabled.	R/W

Note: 1. Selected only for the H8S/20103 group and reserved in other products. When writing, b'11 should be written.
2. The TRCCNT value is captured by GRD.
3. The TRDCNT_0 value is captured by GRD_0.

ELOPA determines the operation of timer RA, timer RB, timer RC, and timer RD_0 when an event is input to the timer.

12.2.4 Event Link Option Setting Register B (ELOPB)

Address: H'FF06B6

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TMRD2M[2:1]		—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7, 6	TMRD2M [2:1]	Timer RD_0 channel 1 operation select	00: Timer starts counting. 01: Timer counts events. 10: Timer performs input-capture operation.* 11: Events disabled.	R/W
5 to 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

Note: * The TRDCNT_1 value is captured by GRD_1.

ELOPB determines the operation of timer RD_0 when an event is input to the timer.

12.2.5 Event Link Option Setting Register C (ELOPC)

Address: H'FF06B7

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TMRGM[2:1]		—	—	—	—	—	—
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7, 6	TMRGM [2:1]	Timer RG operation select	00: Timer starts counting. 01: Timer counts events. 10: Timer performs input-capture operation.* 11: Events disabled.	R/W
5 to 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

Note: * The TRGCNT value is captured by GRB.

ELOPC determines the operation of timer RG when an event is input to the timer.

12.2.6 Port-Group Setting Registers 1 and 2 (PGR1 and PGR2)

Address: H'FF06A2, H'FF06A3

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PGRn7	PGRn6	PGRn5	PGRn4	PGRn3	PGRn2	PGRn1	PGRn0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PGRn7	Port-group setting n7	0: The port bit is not specified as the member of the same group.	R/W
6	PGRn6	Port-group setting n6	1: The port bit is specified as the member of the same group.	R/W
5	PGRn5	Port-group setting n5		R/W
4	PGRn4	Port-group setting n4		R/W
3	PGRn3	Port-group setting n3		R/W
2	PGRn2	Port-group setting n2		R/W
1	PGRn1	Port-group setting n1		R/W
0	PGRn0	Port-group setting n0		R/W

[Legend]
n: 1 or 2

PGR specifies each port bit in the same 8-bit I/O port as the member of a group. One to eight port bits can be specified as the members of the same group as required. The correspondence between PGR and ports is shown in table 12.3.

12.2.7 Port-Group Control Registers 1 and 2 (PGC1 and PGC2)

Address: H'FF06A6, H'FF06A7

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	PGCOn[2:0]			—	PGCOVEn	PGCIn[1:0]	
Value after reset:	1	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6 to 4	PGCOn[2:0]	Port group operation select	000: 0 is output when the event is input. 001: 1 is output when the event is input. 010: The toggled (inverted) value is output when the event is input. 011: The buffer value is output when the event is input. 1XX: The bit value is sifted out in the group (from MSB to LSB) when the event is input.	R/W
3	—	Reserved	This bit is read as 1. The write value should be 1.	—
2	PGCOVEn	PDBF overwrite	0: Overwriting PDBF is disabled. 1: Overwriting PDBF is enabled.	R/W
1, 0	PGCIn[1:0]	Event output edge select	00: Event is generated upon detection of the rising edge of the external input signal. 01: Event is generated upon detection of the falling edge of the external input signal. 1X: Event is generated upon detection of both the rising and falling edge of the external input signal.	R/W

[Legend]
n: 1 or 2
X: Don't care.

For the output port-group, PGC specifies the form of outputting the signal externally via the port when the event signal is input. For the input port-group, PGC enables/disables overwriting of PDBF and specifies the conditions of event generation (edge of the externally input signal).

The correspondence between PGR and ports is shown in table 12.3.

12.2.8 Port Buffer Registers 1 and 2 (PDBF1 and PDBF2)

Address: H'FF06AA, H'FF06AB

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PDBFn7	PDBFn6	PDBFn5	PDBFn4	PDBFn3	PDBFn2	PDBFn1	PDBFn0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PDBFn7	Port buffer n7	Data is transferred between PDR and PDBF when an event is input. Write access to the bit specified as a member of the input port-group by the CPU is invalid. For details, see section 12.3, Operation.	R/W
6	PDBFn6	Port buffer n6		R/W
5	PDBFn5	Port buffer n5		R/W
4	PDBFn4	Port buffer n4		R/W
3	PDBFn3	Port buffer n3		R/W
2	PDBFn2	Port buffer n2		R/W
1	PDBFn1	Port buffer n1		R/W
0	PDBFn0	Port buffer n0		R/W

[Legend]
n: 1, 2

PDBF is an 8-bit readable/writable register used in combination with PGR. For PDBF operations, see section 12.3, Operation. The correspondence of PPBF and PDR is shown in table 12.3.

Table 12.3 Registers Related to Port-Groups and Corresponding Port Numbers

Port Group Setting Register (PGR)	Port Group Control Register (PGC)	Port Buffer Register (PDBF)	Port Number
PGR1	PGC1	PDBF1	Port 3
PGR2	PGC2	PDBF2	Port 6

12.2.9 Event Link Port Setting Registers 0 to 3 (PEL0 to PEL3)

Address: H'FF06AD to H'FF06B0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	PSMn[1:0]		PSPn[4:3]		PSPn[2:0]		
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6 5	PSMn[1:0]	Event link specification	• For the output port, data to be output from the port is specified. 00: 0 is output when the event is input. 01: 1 is output when the event is input. 1X: The toggled (inverted) value is output when the event is input. • For the input port, the edge on which the event is to be output is specified. 00: Event is output upon detection of the rising edge. 01: Event is output upon detection of the falling edge. 1X: Event is output upon detection of both the rising and falling edge.	R/W
4 3	PSPn[4:3]	Port number specification	00: Do not set this value. 01: Port 3 (corresponding to PGR1) 10: Port 6 (corresponding to PGR2) 11: Do not set this value.	R/W
2	PSPn2	Bit number specification	A bit number in an 8-bit port is specified.	R/W
1	PSPn1			R/W
0	PSPn0			R/W

[Legend]
n: 0 to 3
X: Don't care.

PEL specifies the 1-bit port (hereinafter referred to as a single-port) to which an event is to be linked, the port operation upon the event signal input, and the conditions of event generation. With this LSI, a total of four bits in either port 3 or port 6 (8-bit ports) can be specified as single-ports.

12.2.10 Event-Generation Timer Control Register (ELTMCR)

Address: H'FF06B8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TMRSTR	—	—	—	CLSRS[3:0]			
Value after reset:	0	1	1	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TMRSTR	Timer count start	0: Counter is stopped. 1: Counter is incremented.	R/W
6 to 4	—	Reserved	These bits are read as 1. The write value should be 1.	—
3 to 0	CLSRS[3:0]	Clock source (ϕELC) select	0000: ϕ 0001: ϕ/2 0010: ϕ/4 0011: ϕ/8 0100: ϕ/16 0101: ϕ/32 0110: ϕ/64 0111: ϕ/128 1000: ϕ/256 1001: ϕ/512 1010: ϕ/1024 1011: ϕ/2048 1100: ϕ/4096 1101: ϕ/8192 1110: Reserved (Counter is stopped.) 1111: Reserved (Counter is stopped.)	R/W

Note: Be sure to stop the counter before changing the clock source.

ELTMCR controls the ELTMCNT operation and selects the clock source.

12.2.11 Event-Generation Timer Interval Setting Register A (ELTMSA)

Address: H'FF06B9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	C1CLS[3:0]				C0CLS[3:0]			
Value after reset:	1	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	C1CLS[3:0]	Channel 1 event-generation interval select	0000: Clock source ϕELC/1	R/W
			0001: Clock source ϕELC/2	
			0010: Clock source ϕELC/4	
			0011: Clock source ϕELC/8	
			0100: Clock source ϕELC/16	
			0101: Clock source ϕELC/32	
			0110: Clock source ϕELC/64	
			0111: Clock source ϕELC/128	
			1000: Clock source ϕELC/256 (initial value)	
			1001: Clock source ϕELC/512	
			1010: Clock source ϕELC/1024	
			1011: Clock source ϕELC/2048	
			1100: Clock source ϕELC/4096	
			1101: Clock source ϕELC/8192	
			1110: Clock source ϕELC/16384	
			1111: Clock source ϕELC/32768	

Bit	Symbol	Bit Name	Description	R/W
3 to 0	C0CLS[3:0]	Channel 0 event-generation interval select	0000: Clock source ϕELC/1	R/W
			0001: Clock source ϕELC/2	
			0010: Clock source ϕELC/4	
			0011: Clock source ϕELC/8	
			0100: Clock source ϕELC/16	
			0101: Clock source ϕELC/32	
			0110: Clock source ϕELC/64	
			0111: Clock source ϕELC/128	
			1000: Clock source ϕELC/256 (initial value)	
			1001: Clock source ϕELC/512	
			1010: Clock source ϕELC/1024	
			1011: Clock source ϕELC/2048	
			1100: Clock source ϕELC/4096	
			1101: Clock source ϕELC/8192	
			1110: Clock source ϕELC/16384	
			1111: Clock source ϕELC/32768	

Note: Do not set B'0000 when the clock source is set to ϕs.

ELTMSA determines the event-generation interval for channels 0 and 1, and sets the division ratio for the clock source specified by ELTMCR.

12.2.12 Event-Generation Timer Interval Setting Register B (ELTMSB)

Address: H'FF06BA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	C3CLS[3:0]				C2CLS[3:0]			
Value after reset:	1	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	C3CLS[3:0]	Channel 3 event-generation interval select	0000: Clock source ϕELC/1	R/W
			0001: Clock source ϕELC/2	
			0010: Clock source ϕELC/4	
			0011: Clock source ϕELC/8	
			0100: Clock source ϕELC/16	
			0101: Clock source ϕELC/32	
			0110: Clock source ϕELC/64	
			0111: Clock source ϕELC/128	
			1000: Clock source ϕELC/256 (initial value)	
			1001: Clock source ϕELC/512	
			1010: Clock source ϕELC/1024	
			1011: Clock source ϕELC/2048	
			1100: Clock source ϕELC/4096	
			1101: Clock source ϕELC/8192	
			1110: Clock source ϕELC/16384	
			1111: Clock source ϕELC/32768	

Bit	Symbol	Bit Name	Description	R/W
3 to 0	C2CLS[3:0]	Channel 2 event-generation interval select	0000: Clock source ϕELC/1	R/W
			0001: Clock source ϕELC/2	
			0010: Clock source ϕELC/4	
			0011: Clock source ϕELC/8	
			0100: Clock source ϕELC/16	
			0101: Clock source ϕELC/32	
			0110: Clock source ϕELC/64	
			0111: Clock source ϕELC/128	
			1000: Clock source ϕELC/256 (initial value)	
			1001: Clock source ϕELC/512	
			1010: Clock source ϕELC/1024	
			1011: Clock source ϕELC/2048	
			1100: Clock source ϕELC/4096	
			1101: Clock source ϕELC/8192	
			1110: Clock source ϕELC/16384	
			1111: Clock source ϕELC/32768	

Note: Do not set B'0000 when the clock source is set to ϕs.

ELTMSB determines the event-generation interval for channels 2 and 3, and sets the division ratio for the clock source specified by ELTMCR.

12.2.13 Event-Generation Timer Delay Selection Register (ELTMDR)

Address: H'FF06BB

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	C3DLY[1:0]		C2DLY[1:0]		C1DLY[1:0]		C0DLY[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	C3DLY[1:0]	Channel 3 delay select	00: No delay 01: 1 clock cycle 10: 2 clock cycles 11: 3 clock cycles	R/W
5, 4	C2DLY[1:0]	Channel 2 delay select	00: No delay 01: 1 clock cycle 10: 2 clock cycles 11: 3 clock cycles	R/W
3, 2	C1DLY[1:0]	Channel 1 delay select	00: No delay 01: 1 clock cycle 10: 2 clock cycles 11: 3 clock cycles	R/W
1, 0	C0DLY[1:0]	Channel 0 delay select	00: No delay 01: 1 clock cycle 10: 2 clock cycles 11: 3 clock cycles	R/W

Note: There is no delay when the event-generation interval is set to clock source ϕ/1.

ELTMDR determines the necessary delay time, which is the time from the specified event-generation timing (= interval) to the actual generation timing of the event in terms of the cycles of the selected clock source.

12.2.14 ELC Timer Counter (ELTMCNT)

Address: H'FF06C0

Bit:	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

ELTMCNT is a 16-bit readable/writable up-counter. To select the input clock signal to be supplied to the counter, use the CLSRS[3:0] bits in ELTMCR. ELTMCNT cannot be accessed in 8-bit units; it must always be accessed in 16-bit units. The initial value of ELTMCNT is H'0000.

To set the event-generation interval to the time from starting of the timer to generation of the first event, set the counter to 0.

12.3 Operation

12.3.1 Relation between Interrupt Processing and Event Linking

The modules incorporated in this LSI are provided with the interrupt request status flags and the bits to enable/disable these interrupt requests. When an interrupt request is generated in a module, the corresponding interrupt request status flag is set. If the corresponding interrupt request is enabled then, the interrupt requested is issued to the CPU.

In contrast, the ELC uses interrupt requests (hereinafter referred to as events) generated in modules as event signals that directly activate other modules. This means that the event signal can be used whether or not the interrupt signal is enabled. Figure 12.2 shows the relation between the interrupt processing and ELC.

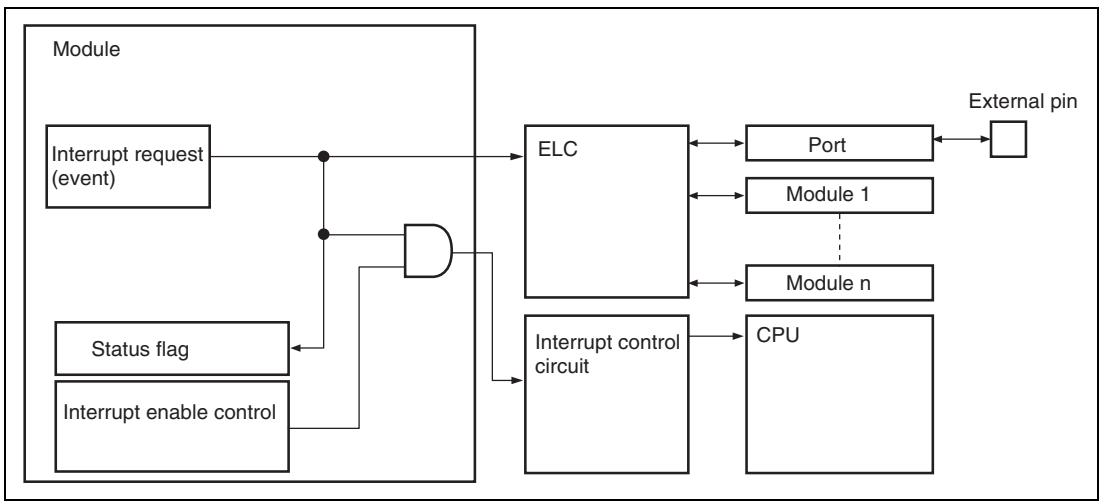


Figure 12.2 Relation between Interrupt Processing and ELC

12.3.2 Event Linkage

When an event has been set as a trigger in the event-link setting registers (ELSR0 to ELSR32) and then occurs, that event is linked with the corresponding module (activate the module). Only one type of event can be connected with one module. When a module is to be activated by the event-link controller, the operation of the module must be set up in advance. Table 12.4 lists the operations of modules when an event is input.

Table 12.4 Operations of Modules when Event is Input

Module	Operations when Event is Input		
Timer RA Timer RB Timer RC Timer RD Timer RG	Each timer operates differently depending on the setting of the relevant event link option setting register as below. • Starts counting when an event signal is input. • Counts the input events. • Performs input-capture operation when an event is input. (except timer RA and timer RB)		
A/D converter	Starts A/D conversion when an event signal is input.		
D/A converter	Starts D/A conversion when an event signal is input.		
Output ports	The value of PDR (port data register) changes when an event signal is input. (The value of the signal to be output from the relevant external pin changes.)	Port-groups	The port-group operates differently depending on the settings as below. • Changes the PDR value to the specified value. • Transfers the PDBF values to the PDR. • Shifts out the bit value.
		Single-ports	Changes the PDR value to the specified value.
Input ports	When the signal value of the input pin changes.	Port-groups	Generates an event.
		Single-ports	
	When an event is input	Port-groups	Transfers the signal value of the external pin to PDBF.
		Single-ports	Event connection is impossible.
Clock oscillator	Switches the clock source to the low-speed on-chip oscillator operation.		
Interrupt controller	Issues an interrupt request to the CPU, and the DTC starts to transfer data.		

12.3.3 Operation of Peripheral Timer Modules When Event is Input

Three different operations are performed depending on the ELOP settings when an event is input.

- Counting-Start Operation
  When an event is input, the timer starts counting, which sets the count start bit* in each timer control register to 1. An event that is input while the count start bit is 1 is invalid.
- Event-Counter Operation
  Event-input is selected as the timer clock source and the timer counts events.
- Input-Capture Operation
  When an event is input, the timer performs input-capture operation.

Note: * See the descriptions on the bit in the relevant timer section.

12.3.4 Operation of A/D and D/A Converters When Event is Input

The A/D and D/A converter start A/D and D/A conversion, respectively, which sets the start bits* in the A/D control register and the output enable bits* in the D/A control register to 1.

Note: * See the descriptions on the bit in the A/D and D/A converter sections.

12.3.5 Port Operation upon Event Input and Event Generation

The port operation to be performed upon event input to the port can be set and the operation causing the port to generate an event can be set.

(1) Single-Ports and Port-Groups

There are two event link modes: event link to single-ports and event link to port-groups. In the former mode, events can be connected to single-ports in an 8-bit port. In the latter mode, events can be connected to port-groups consisting of any two or more bits in the same 8-bit port.

A single-port can be set by specifying any one bit in the port* to which an event can be connected using the PEL register. A port-group can be set by specifying any two or more bits in the port* to which an event can be connected using the PGR register. One input port-group and one output port-group can be set in the same port.

If the port bit is specified as both a single-port and a member of a port-group, both functions are effective when the relevant port is input, whereas only the group-port function is effective when the relevant port is output.

The input or output direction of ports can be selected using the PCR register. PCR should be set so that all the bits in the same port-group should have the same direction.

Note: Port 3 and port 6

(2) Event Generation by Input Single-Ports

An input single-port generates an event when the signal value of the external pin connected to the relevant port changes. The event-generation condition is specified using the PEL0 to PEL3 registers. An example of operation is shown in figure 12.3.

(3) Output Single-Port Operation upon Event Input

When an event is input to an output single-port, the PDR value of the relevant port changes. The specific change of the PDR value is specified using the PEL0 to PEL3 registers. Thus, the change of the PDR value changes the signal value of the external pin connected to the relevant port. An example of operation is shown in figure 12.3.

(4) Input Port-Group Operation upon Event Input and Event Generation

An input port-group generates an event when the signal value of any one of the external pins connected to the relevant port-group changes. The event-generation condition is specified using the PGC1 and PGC2 registers. When an event is input to an input port-group, the signal value of the external pin upon event input is transferred to PDBF. In this case, only the values of the bits specified as members of the input port-group are transferred. An example of operation is shown in figure 12.4.

(5) Output Port-Group Operation upon Event Input

When an event is input to an output port-group, the PDR values change to the values according to the PGC1 or PGC2 settings. An example of operation is shown in figure 12.5.

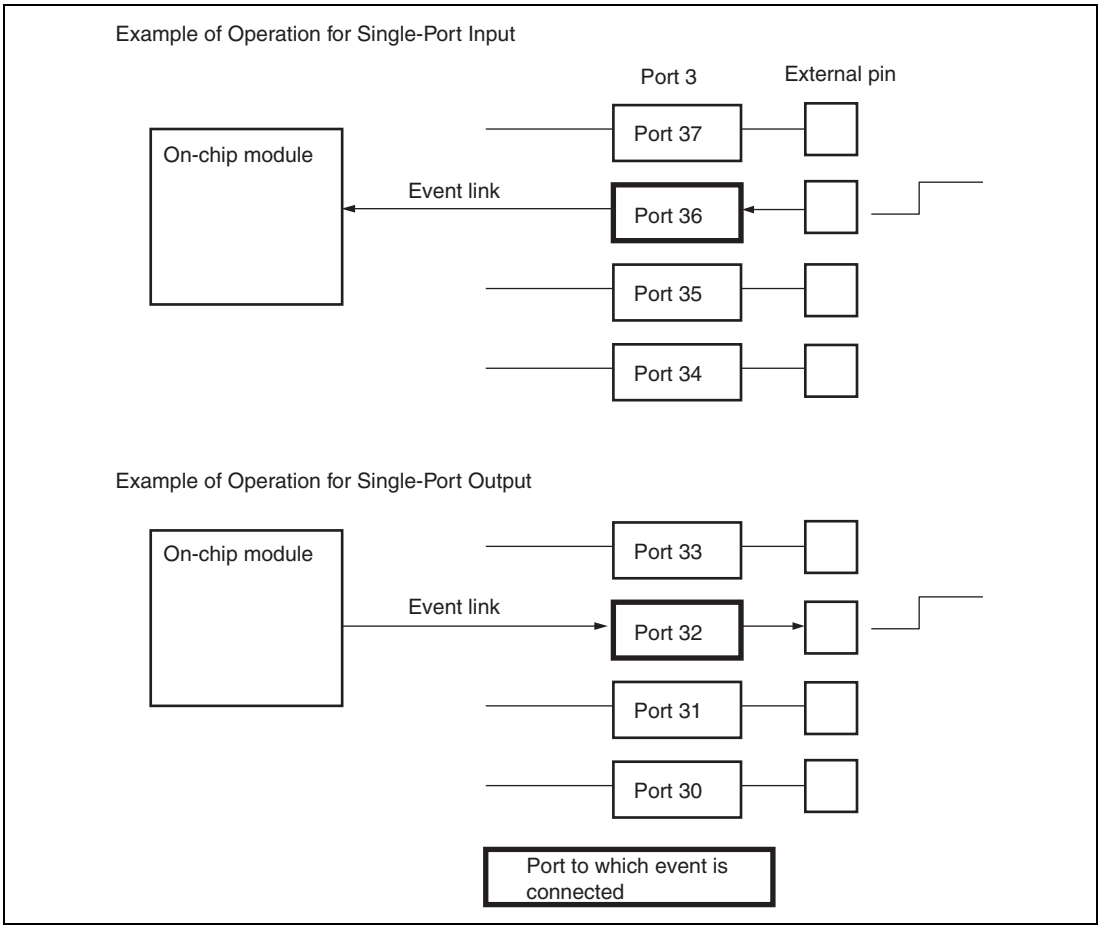


Figure 12.3 Event Linkage related to Single-Ports

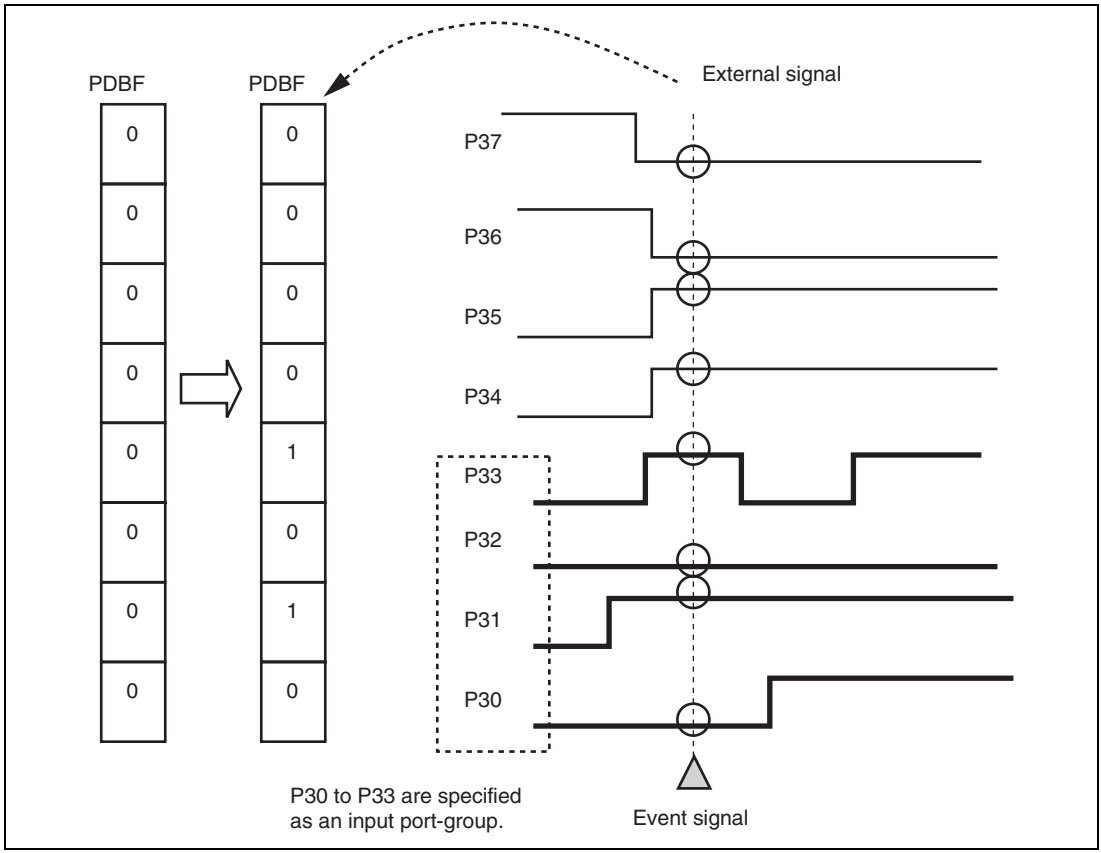


Figure 12.4 Event Linkage related to Input Port-Groups

(6) Operation of Port Buffer Registers

(a) Input Port-Groups

When an event is input to an input port-group, the signal value of the external pin of the bit specified as the members of the input port-group is transferred to PDBF. If another event is input to the input port-group in this state, the current PDR value is transferred or not depending on the PGCOVE bit setting in PGC as described below.

- PGCOVE = 0 (overwriting PDBF is disabled)
  If the PDBF value that has been transferred upon the latest event input has already been read by the CPU (or transferred by the DTC), the signal value of the external pin is transferred to PDBF. If not read, the signal value of the external pin is not transferred and the input event is invalid.
- PGCOVE = 1 (overwriting PDBF is enabled)
  When another event is input to an input port-group, the signal value of the external pin is transferred to PDBF.

(b) Output Port-Groups

If an output port-group is specified so that it should output the PDBF value, the PDBF value is transferred to PDR when an event is input to the output port-group. In this case, only the values of the bits specified as the members of the output port-group are transferred

If an output port-group is specified so that it should shift out the bit values in the group (PGCO bits = 1xx in PGC), the PDBF data is transferred to PDR, and then the PDR value is shifted bit by bit from MSB to LSB. The initial value to be output to the port-group should be provided in PDBF.

Examples of operation are shown in figures 12.5 and 12.6.

(7) Restrictions on Writing to PDR or PDBF by CPU

When the ELCON bit in ELCR is set to 1, write access to the following registers is invalid.

- If bits are specified as members of the input port-group and the event-linkage is set for the port-group, write access to the relevant bits in PDBF by the CPU is invalid.
- If port bits are specified as members of the output port-group, write access to the relevant bits in PDR by the CPU is invalid.
- If a port bit is specified as an output single-port and the event-linkage is set (by ELSR) for the port, write access to the relevant bit in PDR by the CPU is invalid.

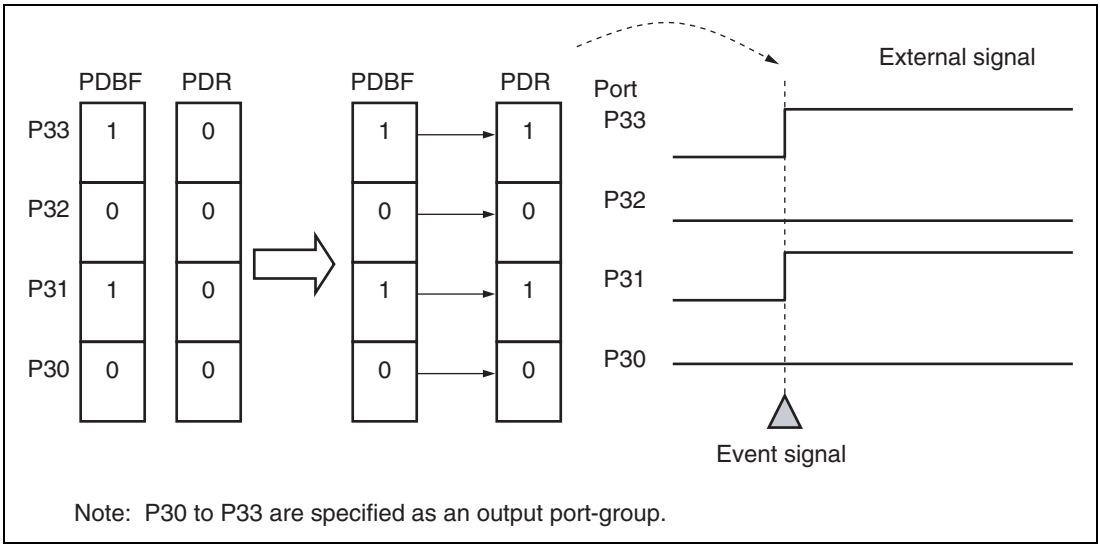


Figure 12.5 Event Linkage related to Output Port-Groups

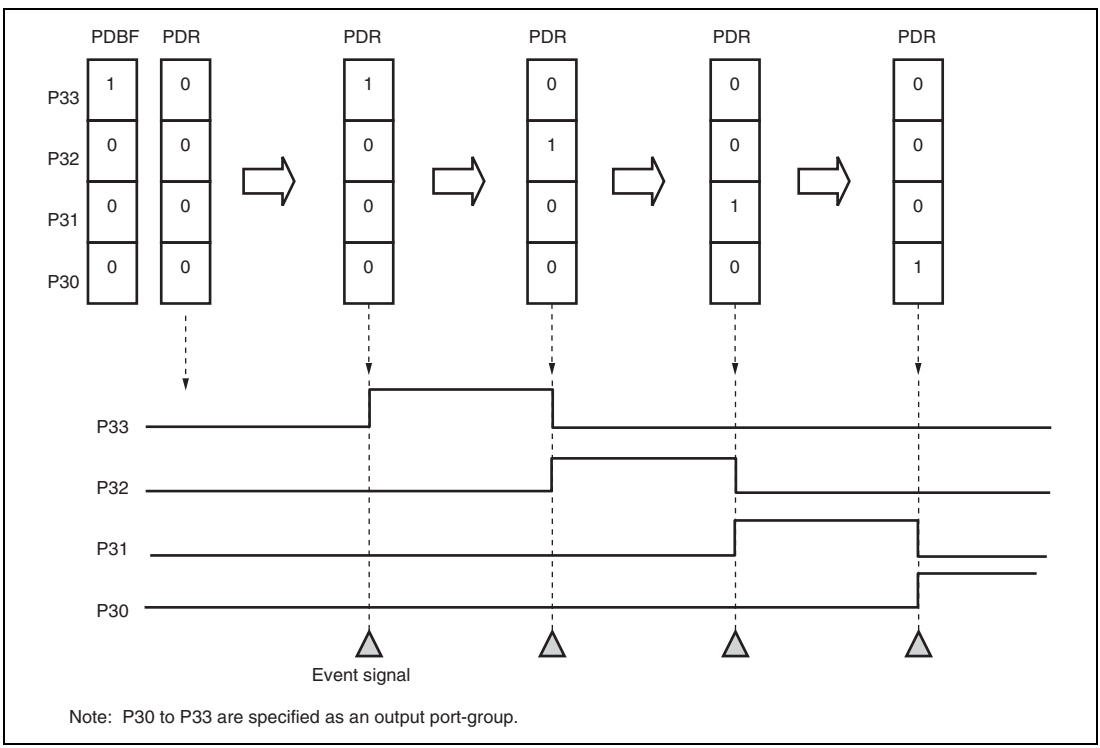


Figure 12.6 Bit-Shifting Operation of Output Port-Groups

12.3.6 Event-Generation Timer

The event-generation timer can generate an event at specified interval. The generated event can be connected to another module. The features of the timer are given below.

- The interval can be generated using the 16-bit free-running counter.
- The delay time (of 0 to 3 counter clock cycles) can be set, which is the time from the set event-generation timing (= interval) to actual generation of the event.
- Four-channel event output is available (figure 12.8).

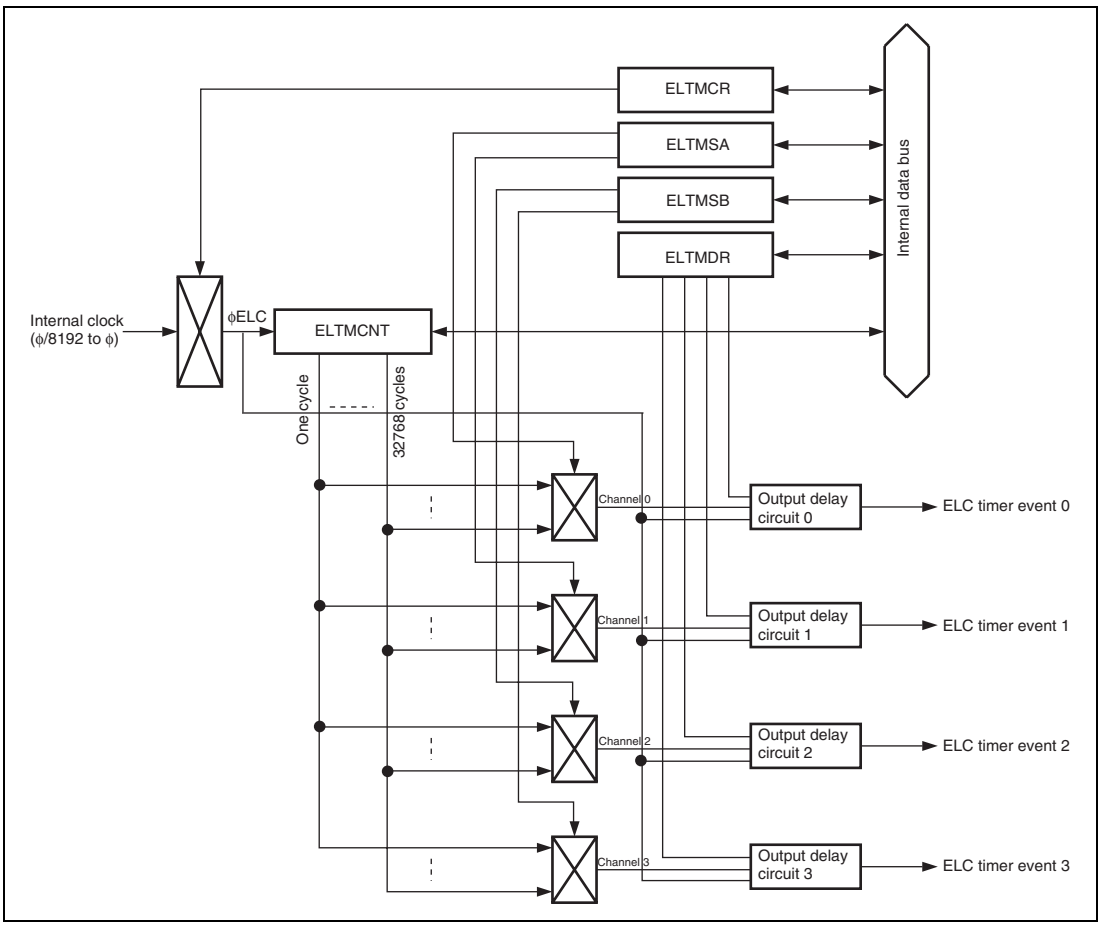


Figure 12.7 Block Diagram of Event-Generation Timer

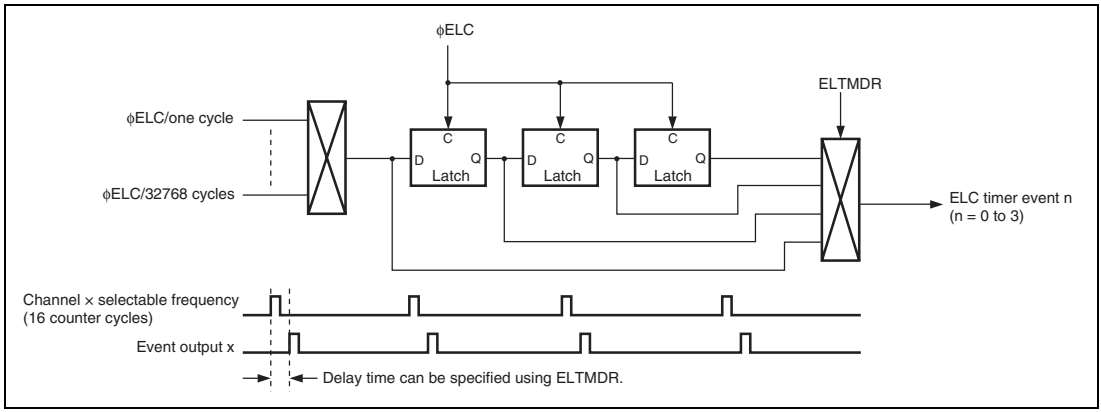


Figure 12.8 Operation of Event-Generation Timer

12.3.7 Procedure for Linking Events

The following describes the procedure for linking events.

1. Set the operation of the module to which an event is to be linked.
2. To the ELSRn register corresponding to the module to which an event signal is to be linked, set the number of the event signal.
3. If events are to be linked to timers, set the ELOPA to ELOPC registers corresponding to the timers as required.
4. Set the ELCON bit in ELCR to 1, which enables linkage of all the events.
5. Set the operation of the module from which an event is output, and start the module. This allows the event output from the module to start the module to which an event is linked as specified.
6. To stop event linkage of some independent modules, set B'00000000 to the ELSn7 to ELSn0 bits in the ELSRn corresponding to the modules. To stop linkage of all the events, clear the ELCON bit in ELCR to 0.

   If events are linked to ports, set the registers corresponding to the ports as below.

   — PDR: Set the initial values of the output ports.
   — PCR: Set the I/O direction of the ports.
   — PGR: If ports are used as a port-group, set the ports (in bit units) to be grouped.
   — PGC: Set the operation of the port-group.
   — PEL: If ports are used as single-ports, set the ports, the operation of the ports when an event is input, and the condition when an event is generated.

Section 13 Timer RA

The timer RA is an 8-bit reload timer with a prescaler. The prescaler and the timer are comprised of a reload register and a counter, respectively.

13.1 Overview

- Operating mode: 5 modes

  Timer mode: Counts internal count sources.

  Pulse output mode: Counts internal count sources and produces a toggle output in timer underflow.

  Event counter mode: Counts external events.

  Pulse width measurement mode: Measures the pulse width of external pulses.

  Pulse cycle measurement mode: Measures the pulse cycle of external pulses.
- Selection of nine count sources

  ϕ, ϕ/2, ϕ/8, ϕ/32, ϕ/64, ϕ/128, ϕ40, ϕsub, or an external event input to the TRAIO pin.
- An interrupt generated on an underflow of the counter

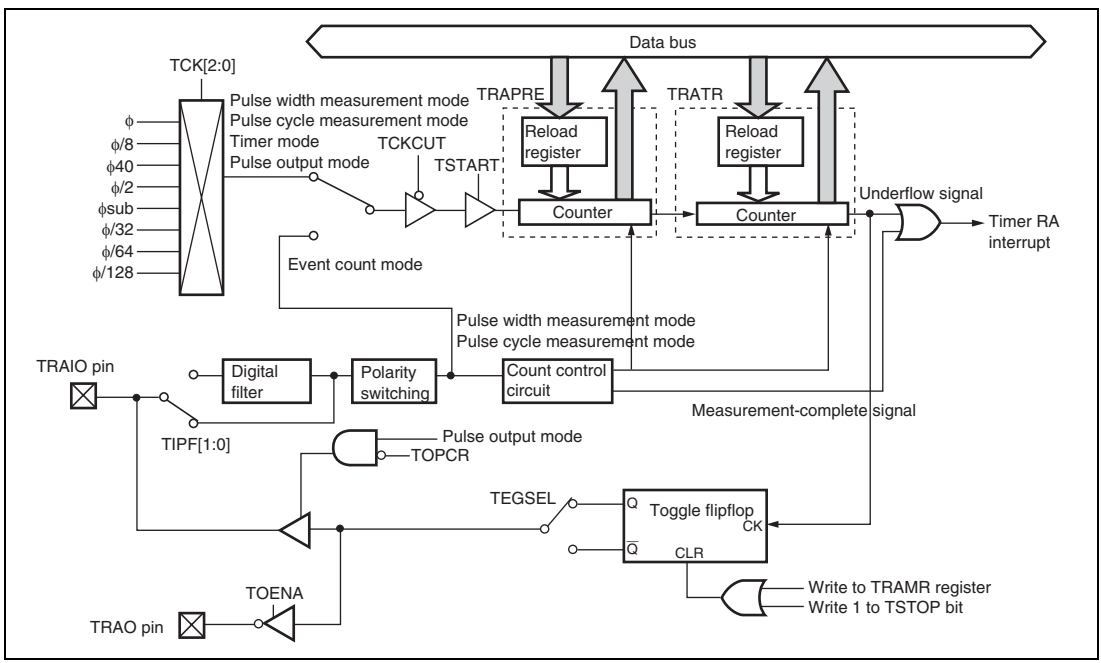


Figure 13.1 Block Diagram of Timer RA

Table 13.1 shows the timer RA input/output pins.

Table 13.1 Pin Configuration

Name	Abbreviation	I/O	Function
Timer RA input/output	TRAIO	I/O	External event input and pulse input/output
Timer RA output	TRAO	Output	Inverted pulse output of TRAIO output

13.2 Register Descriptions

The timer RA has the following registers:

- Timer RA control register (TRACR)
- Timer RA I/O control register (TRAIOC)
- Timer RA mode register (TRAMR)
- Timer RA prescaler register (TRAPRE)
- Timer RA timer register (TRATR)
- Timer RA interrupt request status register (TRAIR)

13.2.1 Timer RA Control Register (TRACR)

Address: H'FF06F0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	TUNDF	TEDGF	—	TSTOP	TCSTF	TSTART
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write valued should be 0.	—
5	TUNDF	Timer RA underflow flag	[Setting condition] • When timer RA underflows from H'00 to H'FF. [Clearing condition] • When 0 is written to this bit*	R/W
4	TEDGF	Valid edge detection flag	[Setting condition] • When the pulse width measurement is completed with TSTART in TRACR = 1, in pulse width measurement mode. • When the timer RA prescaler underflows at the second time after a valid edge of the measurement pulse is input, in pulse cycle measurement mode. [Clearing condition] • When 0 is written to this bit*	R/W
3	—	Reserved	This bit is read as 0. The write value should be 0.	—
2	TSTOP	Timer RA count forced stop	0: Timer RA counting is continued. 1: Timer RA counting is forcedly stopped.	R/W

Bit	Symbol	Bit Name	Description	R/W
1	TCSTF	Timer RA count status flag	0: Timer RA counting has been stopped. 1: Timer RA counting is in progress. [Setting condition] • When 1 is written to TSTART and counting is started. • The start of counting after ELOPA of the event link controller is selected counting by timer RA, the specified event is occurred, and the TSTART bit is set to 1. [Clearing condition] • When 0 is written to TSTART and counting is stopped. • When 1 is written to TSTOP and counting is stopped.	R
0	TSTART	Timer RA count start	0: Timer RA counting is stopped. 1: Timer RA counting is started.	R/W

Note: 1. A MOV instruction should be used to write 0 to this register.
2. The timer RA registers should not be accessed until the TCSIF bit changes after the TSTART bit is set, apart from TRACR which can be read at any time during timer operation.

TRACR controls the timer RA counter and indicates the timer RA state.

- TSTOP bit (timer RA count forced stop)

  Setting this bit to 1 initializes the counter of the timer and the prescaler, bits TSTART and TCSTF, and timer outputs. This bit is always read as 0.

13.2.2 Timer RA I/O Control Register (TRAIOC)

Address: H'FF06F1

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TIOGT[1:0]		TIPF[1:0]		TIOSEL	TOENA	TOPCR	TEDGSEL
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	TIOGT[1:0]	TRAIO event input control	00: Input control is not performed. (Events are always enabled.) 01: Input control is performed. (Events are enabled when IRQ2 input is high.) 10: Setting prohibited 11: Setting prohibited	R/W
5, 4	TIPF[1:0]	TRAIO input filter select	00: No filter operation 01: Filtered (Sampled at ϕ) 10: Filtered (Sampled at ϕ/8) 11: Filtered (Sampled at ϕ/32) These bits should be set to B'00 in timer mode and pulse output mode.	R/W
3	TIOSEL	TRAIO input select	0: Input from the TRAIO pin 1: Input from the LIN	R/W
2	TOENA	TRAO output enable	0: TRAO outputs are disabled. 1: TRAO outputs are enabled. This bit should be set to 0 except in event counter mode and pulse output mode.	R/W
1	TOPCR	TRAIO output control	0: TRAIO outputs are enabled. 1: TRAIO outputs are disabled. This bit should be set to 0 except in pulse output mode.	R/W

Bit	Symbol	Bit Name	Description	R/W
0	TEDGSEL	Input/output polarity switch	• Timer mode This bit should be set to 0. • Pulse output mode 0: The initial value of TRAIO output is set at a high level. 1: The initial value of TRAIO output is set at a low level. • Event count mode 0: Counter incremented at the TRAIO input rising edge. The initial value of TRAIO output is set at a low level. 1: Counter incremented at the TRAIO input falling edge. The initial value of TRAIO output is set at a high level. • Pulse width measurement mode 0: Measures the low-level width of TRAIO input. 1: Measures the high-level width of TRAIO input. • Pulse cycle measurement mode 0: Measures from the rising edge of the measurement pulse to the next rising edge. 1: Measures from the falling edge of the measurement pulse to the next falling edge.	R/W

Note: When TCSTF = 1, do not rewrite this register.

- TIOGT1 bit and TIOGT0 bit (TRAIO event input control 1 and 0)
  These bits control input events in event counter mode.

- TIPF1 bit and TIPF0 bit (TRAIO input filter select 1 and 0)
  If filtered operation is selected, the input is determined when the same value is sampled three times in succession from the TRAIO pin.

13.2.3 Timer RA Mode Register (TRAMR)

Address: H'FF06F2

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TCKCUT	TCK[2:0]			—	TMOD[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TCKCUT	Timer RA count source cutoff	0: Count source is supplied. 1: Count source is cut off.	R/W
6 to 4	TCK[2:0]*2	Timer RA count source select	000: φ 001: φ/8 010: φ/40 011: φ/2 100: φsub 101: φ/32 110: φ/64 111: φ/128	R/W
3	—	Reserved	This bit is read as 0. The write value should be 0.	—
2 to 0	TMOD[2:0]	Timer RA operating mode select	000: Timer mode 001: Pulse output mode 010: Event count mode 011: Pulse width measurement mode 100: Pulse cycle measurement mode 101: Setting prohibited 110: Setting prohibited 111: Setting prohibited	R/W

Note: 1. The counting should be stopped (when both the TSTART and TCSTF bits in TRACR are 0) when this register is modified.
2. If the internal φ/40 clock is selected, the high-speed on-chip oscillator must be operating. As long as the internal φ40 clock is selected, do not stop the high-speed on-chip oscillator.

- TCK2 bit and TCK0 bit (timer RA count source select)
  A count source is selected if the mode is not the event count mode.

- TMOD2 bit to TMOD0 bit (timer RA operating mode select)
  Writing to TRAMR initializes the output level.

13.2.4 Timer RA Interrupt Enable Status Register (TRAIR)

Address: H'FF06F5

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

Bit	Symbol	Bit Name	Description	R/W
7	TRAIE	Timer RA interrupt request enable	0: Timer RA interrupt requests are disabled. 1: Timer RA interrupt requests are enabled.	R/W
6	TRAIF	Timer RA interrupt request flag	[Setting condition] • When the timer RA underflows. • When the input pulse measurement is completed in pulse width measurement mode. • When the timer RA prescaler underflows at the second time after a valid edge of measurement pulse is input, in pulse cycle measurement mode. [Clearing condition] • When 1 is read from the bit and then 0 is written to. • When the DTC is activated by a TRAIF interrupt, and the DISEL bit in MRB of the DTC is 0.	R/W
5 to 0	—	Reserved	This bit is read as 0. The write value should be 0.	—

13.2.5 Timer RA Prescaler Register (TRAPRE)

Address: H'FF06F3

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

TRAPRE consists of a reload register and an 8-bit counter, each with an initial value of H'FF.

If a down-count is performed using the count source selected with TRAMR and an underflow occurs, the value of the reload register is loaded to the counter. The underflow becomes a count source for TRATR.

The reload register and the counter are assigned to the same address. On write, a value is written to the reload register, and on read, a counter value is read. During a write to TRAPRE the load timing from the reload register to the counter differs between counting in progress and counting stopped. Writing to TRAPRE when counting is stopped causes the data to be written to both the reload register and the counter. Writing to TRAPRE during counting causes the new value to be written to the reload register after four cycles of count source, and to be loaded to the counter in synchronization with the next count source.

13.2.6 Timer RA Timer Register (TRATR)

Address: H'FF06F4

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

TRATR consists of a reload register and an 8-bit counter, each with an initial value of H'FF. TRATR performs a down-count of the prescaler underflows. When an underflow occurs in TRATR, the value of the reload register is loaded to the counter and a timer RA interrupt request is generated at the same time.

The reload register and the counter are assigned to the same address. On write, a value is written to the reload register, and on read, a counter value is read. However, on read in pulse cycle measurement mode, a value in the read buffer is read. During a write to TRATR the load timing from the reload register to the counter differs between counting in progress and counting stopped. Writing to TRATR when counting is stopped causes the data to be written to both the reload register and the counter. Writing to TRATR during counting causes the new value to be written to the reload register in synchronization with an underflow of the prescaler first after four counts of the count source, and to be loaded to the counter in synchronization with the next underflow of the prescaler.

TRAPRE and TRATR should not be set to H'00 at the same time.

13.3 Operation

13.3.1 Operations Common to Various Modes

(1) Starting and Stopping Operation

Writing the value 1 to the TSTART bit in TRACR starts counting in a set operating mode; writing the value 0 to the TSTART bit stops the counting. The prescaler counts down in the counter clock cycle to be input into the prescaler. The timer counts down using the underflow of the prescaler as a count source.

(2) Forced Termination of Operation

Writing 1 to the TSTOP bit in TRACR stops the counting forcibly. When the counting is stopped, the timer counter, the prescaler counter, and any associated flags are initialized while the reload registers of the prescaler and the timer counter are retained.

(3) Interrupt Request

An interrupt request is generated on the underflow of the timer RA counter.

(4) Reading and Writing Count Value

Reading registers TRAPRE and TRATR reads count values from each register. If a write is performed to TRAPRE or TRATR when the counting is stopped, a specified value is written to both the reload register and the counter.

If a write is performed to the TRAPRE register during counting, first a set value is written to the reload register in synchronization with the count source after four cycles of count source, and the set value is then transferred to the prescaler counter in synchronization with the next count source. If a write is performed to the TRATR register, a set value is written to the reload register in synchronization with the underflow of the prescaler, and the set value is transferred to the timer counter in synchronization the next underflow of the prescaler. For this reason, if a write is performed to TRAPRE or TRATR during counting, the value of the counter is not updated immediately after the execution of the write command. Figure 13.2 shows an example operation where a count value is rewritten when the timer RA is counting.

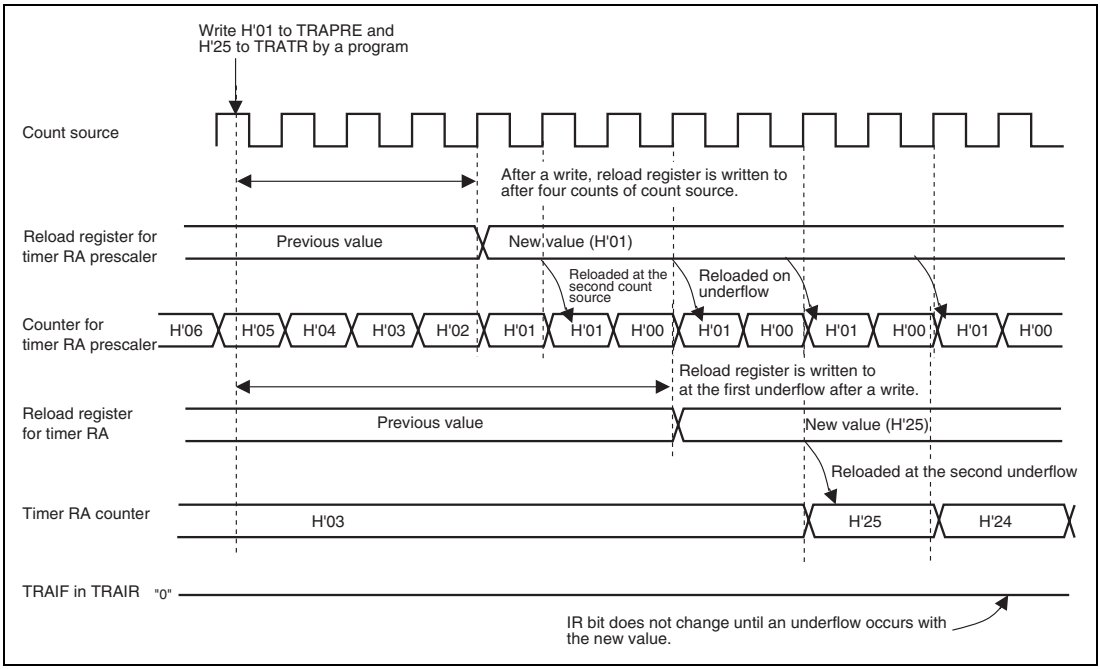


Figure 13.2 Rewriting Count Value When Timer RA Counting is in Progress

13.3.2 Timer Mode

This mode counts internal clocks as a count source. Setting the TMOD[2:0] bits in TRAMR to B'000 activates the timer mode operation. A count source is selected in terms of the TCK[2:0] bits in TRAMR.

13.3.3 Pulse Output Mode

This mode counts internal clocks as a count source, and toggle-outputs pulses from the TRAIO pin each time the counter underflows. Setting the TMOD[2:0] bits in TRAMR to B'001 activates pulse the output mode operation. A count source is selected using the TCK[2:0] bits in TRAMR. The initial output value of the pin is set using the TEDGSEL bit in TRAIOC. By setting the TOENA bit in TRAIOC, a reverse output can be output from the TRAO pin to the TRAIO pin.

13.3.4 Event Counter Mode

This mode counts external events that are input from the TRAIO pin as a count source. Setting the TMOD[2:0] bits in TRAMR to B'010 activates the event-counter mode operation. By setting the TEDGSEL bit in TRAIOC, it is possible to specify whether counting is to be performed on the rising or falling edge of an input event from the TRAIO pin. Also, by setting the TIOGT[1:0] bits in TRAIOC, a function enables external event input when the IRQ2 pin is at a high level. Setting the TIPF[1:0] bits in TRAIOC allows applying a filter to external event input. Similar to the pulse output operation mode, a toggle can be output from the TRAO pin in synchronization with an underflow of the timer counter. In event counter mode, even if 1 is written to the TSTART bit, the value of the TCSTF bit will not become 1 unless the corresponding event signal is input. If the event signal is input while TCSTF = 0, the counter value will be the number of times the event has occurred minus 3. If the event signal is input while TCSTF=1, the number time the event has occurred = counter value.

13.3.5 Pulse Width Measurement Mode

This mode measures the pulse width of external signals that are input from the TRAIO pin. Setting the TMOD[2:0] bits in TRAMR to B'011 activates the pulse width measurement mode operation. A count source is selected in terms of the TCK[2:0] bits in TRAMR. The TEDGSEL bit in TRAIOC can be used to specify whether the low-level width or the high-level width of input pulses is to be measured. Setting the TIPF[1:0] bits in TRAIOC allows applying a filter to external pulse input. Figure 13.3 shows an operation example of pulse width measurement mode.

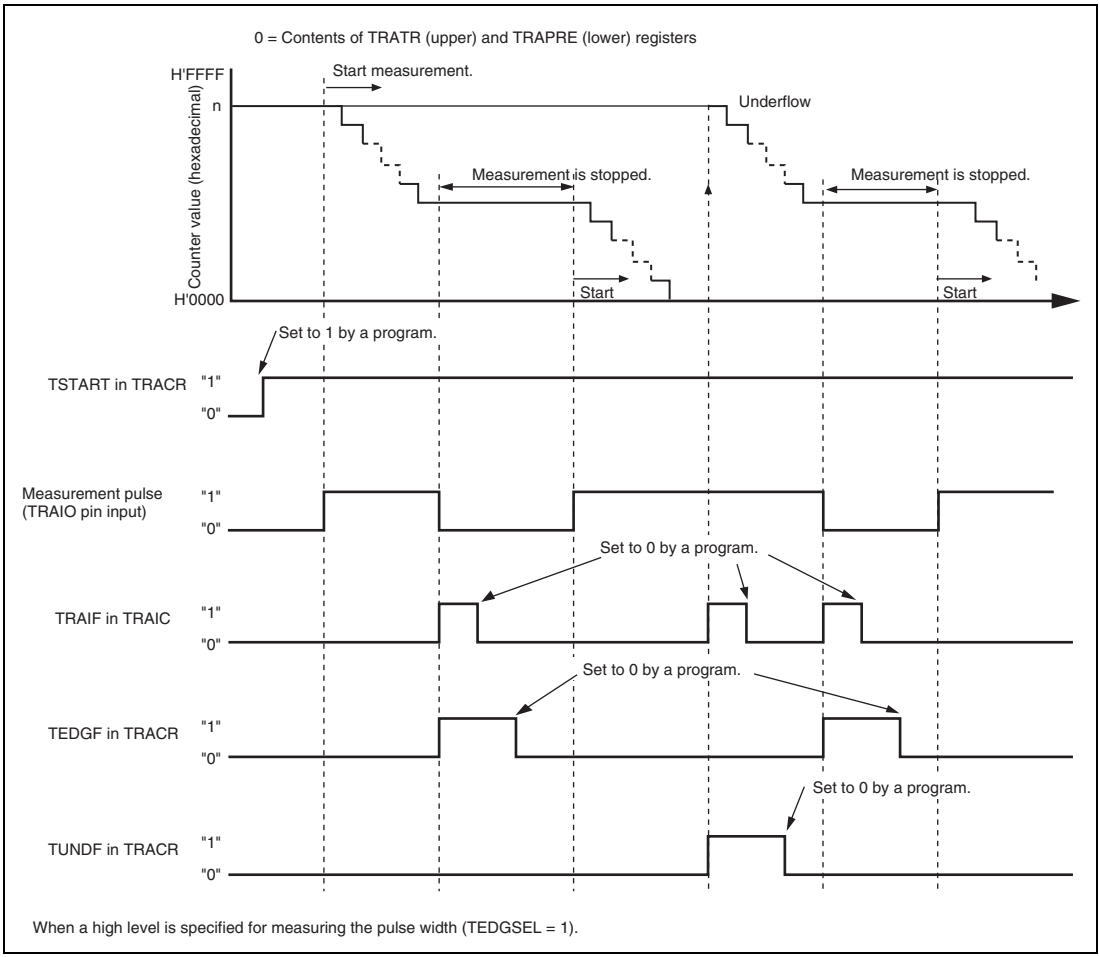


Figure 13.3 Operation Example of Pulse Width Measurement Mode

13.3.6 Pulse Cycle Measurement Mode

This mode measures the cycle of external pulses that are input from the TRAIO pin. Setting the TMOD[2:0] bits in TRAMR to B'100 activates the pulse cycle measurement operation. The TEDGSEL in TRAIOC can be used to specify whether the period from the falling edge to another falling edge of the input pulse of the TRAIO pin is to be measured or the period from the rising edge to another rising edge is to be measured. Setting the TIPF[1:0] bits in TRAIOC also enables to apply a filter to external pulse input. Count sources are selected using the TCK[2:0] bits in TRAMR.

After the start of timer counting, each time a valid input edge is input from the TRAIO pin, a value is transferred from the counter of the timer RA to the read buffer in synchronization with the underflow of the timer RA prescaler. The value in the read buffer is retained until the timer RA register is read. Also, after a value is transferred to the read buffer, a value is transferred from the reload register to the counter in synchronization with the next underflow of the timer RA prescaler. Reading of the read buffer should not be performed until the TEDGF bit in TRACR is set to 1. An interrupt request is generated either when the TEDGF bit in TRACR is set to 1 or when the timer RA counter underflows.

For pulse input to the TRAIO pin, pulses with a cycle greater than double the cycle of the timer RA prescaler should be input. Also, input pulses for which the high pulse width and the low pulse width are greater than the cycle of the timer RA prescaler. If pulses with a short cycle are input, the input is ignored in some cases.

Figure 13.4 shows an operation example of pulse cycle measurement mode.

13.3.7 Operation through an Event Link

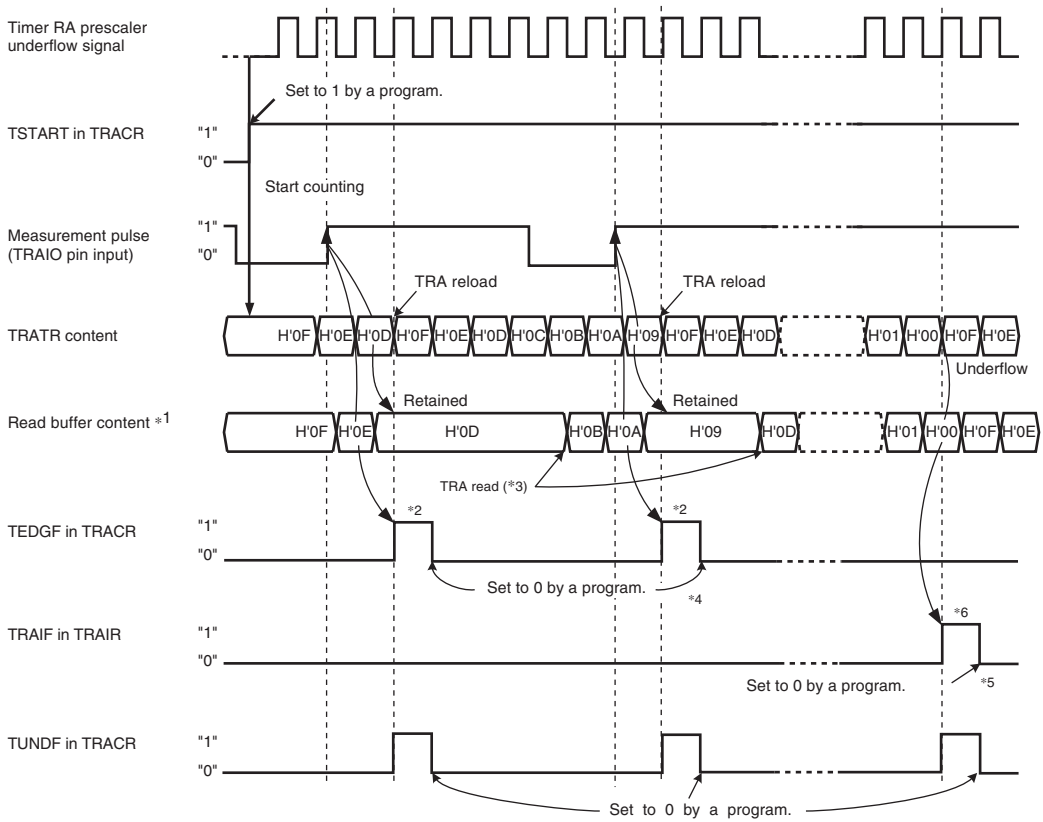
Using the event link controller (ELC), timer RA can be made to operate in the following ways in relation to events occurring in other modules.

(1) Starting Counter Operation

The start of counting operations by timer RA can be selected by the ELOPA register of the ELC. When the event specified in ELSR0 occurs, the TSTART bit in the TRACR is set to 1, which starts counting by timer RA. However, if the specified event occurs when the TCSTF flag has already been set to 1, that event is not effective.

(2) Counting Events

The counting of events by timer RA can be selected by the ELOPA register of the ELC. When the event specified in ELSR0 occurs, event-counter operation proceeds with that event as the source to drive counting, regardless of the setting in TRAMR. When event-counter operation is to be employed, set the TSTART bit in TRACR to 1 beforehand. When the value of the counter is read, the value read out is the actual number of input events minus three.



Measurement condition: The initial value of TRATR is H'0F and the width from the rising edge to the next rising edge of measurement pulse is measured (TEDGSEL = 0).

Notes:
1. When TRATR is read in pulse cycle measurement mode, the value in the read buffer can be read.
2. The TEDGF bit in TRACR is set to 1 (valid edge exists) on the second underflow of the timer RA prescaler after a valid edge of the measurement pulses is input.
3. TRATR should be read between the TEDGF bit setting to 1 (valid edge exists) and the next valid edge input.
   The value in the read buffer is retained until TRATR is read. Therefore, if the value is not read before the next valid edge input, the measurement result of the previous cycle remains.
4. The MOV instruction should be used to write 0 to the TEDGF bit in TRACR using a program.
   Here, 1 should be written to the TUNDF bit .
5. The MOV instruction should be used to write 0 to the TUNDF bit in TRACR using a program.
   Here, 1 should be written to the TEDGF bit.
6. If an underflow of timer RA and reloading of timer RA by valid edge input occur at the same time, both the TUNDF and TEDGF bits are set to 1. In this case, the effectiveness of the TUNDF bit should be determined according to the read buffer contents.

Figure 13.4 Operation Example of Pulse Cycle Measurement Mode

13.4 Usage Notes

1. The prescaler and timer are read out per byte inside the microcomputer even when they are read out in 16-byte unit. Therefore, the timer value can be updated while those two registers are read out.
2. The TEDGF and TUNDF bits in TRACR used in pulse width and pulse cycle measurement modes assume the value 0 when 0 is written by a program and do not change if 1 is written. If one flag is set to 0 by a program, use the MOV instruction to write 1 to the other flag. In this manner, unintended flag changes can be prevented.
3. When a transition is made to pulse width or pulse cycle measurement mode from another mode, the TEDGF and TUNDF bits are undefined. Timer RA counting should be started by writing 0 to the TEDGF and TUNDF bits.
4. In some cases, the TEDGF bit becomes 1 on the first timer RA prescaler underflow signal that is generated after the start of counting.
5. When using the pulse cycle measurement mode, set the TEDGF bit to 0 by allowing a length of time 2 cycles or greater of the timer RA prescaler after the counting process is started.
6. After 1 is written to the TSTART bit when counting is stopped, the TCSTF bit remains 0 for the number of cycle of count source. Registers associated with the timer RA except the TRACR for reading should not be accessed until the TCSTF bit becomes 1. Counting starts from a valid edge of the first count source after the TCSTF bit becomes 1.

   After 0 is written to the TSTART bit when counting is in progress, the TCSTF bit remains 1 for the number of cycle of count source. Registers associated with the timer RA except the TRACR for reading should not be accessed until the TCSTF bit becomes 0. Counting stops when the TCSTF bit becomes 0.
7. When writing successively to TRAPRE during counting (TCSTF=1), allow a minimum write interval of 4 cycles of count source.
8. When writing successively to TRATR during counting (TCSTF=1), allow a minimum write interval of 4 cycles of count source underflow.

Section 14 Timer RB

The timer RB is an 8-bit reload timer with an 8-bit prescaler. The prescaler and the timer are each comprised of a reload register and a counter. The timer RB has two reload registers: timer RB primary register and timer RB secondary register.

14.1 Overview

- Four operating modes
  Timer mode: Counts either internal count sources or timer RA underflows.
  Programmable waveform generation mode: Outputs any pulse widths continuously.
  Programmable one-shot generation mode: Outputs one-shot pulses.
  Programmable wait one-shot generation mode: Outputs delayed one-shot pulses.
- Selection of eight count sources
  ϕ, ϕ/2, ϕ/4, ϕ/8, ϕ/32, ϕ/64, ϕ/128, or an underflow of timer RA
- An interrupt generated on an underflow of the timer RB counter

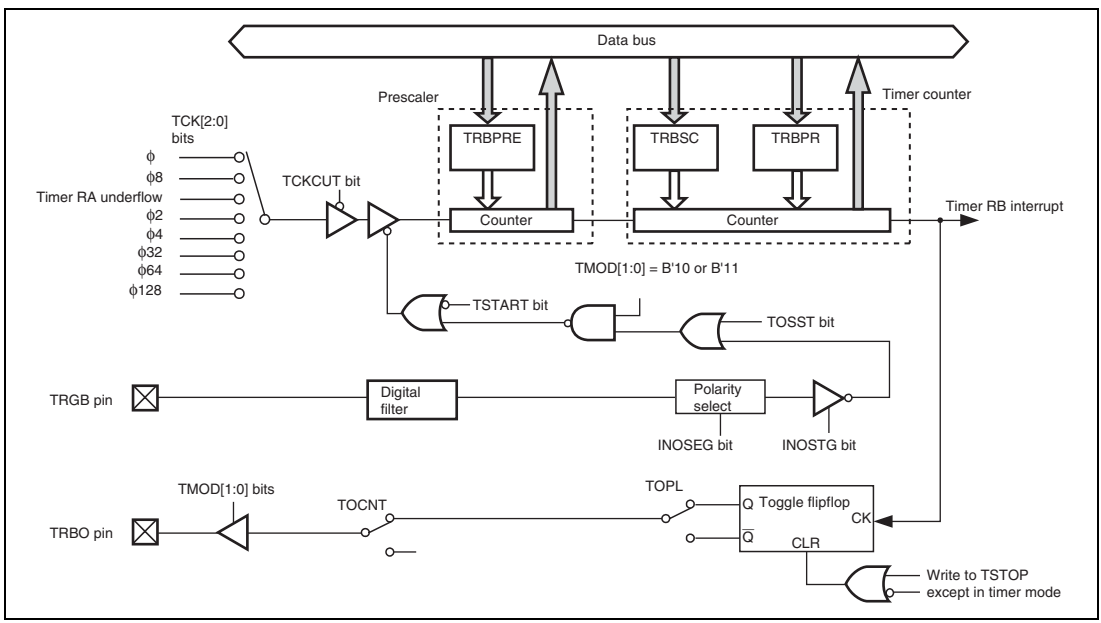


Figure 14.1 Block Diagram of Timer RB

Table 14.1 shows the timer RB input/output pins.

Table 14.1 Pin Configuration

Name	I/O	Function
TRGB	Input	External trigger input
TRBO	Output	Successive pulse output or one-shot pulse output

14.2 Register Descriptions

The timer RB has the following registers:

- Timer RB control register (TRBCR)
- Timer RB one-shot control register (TRBOCR)
- Timer RB I/O control register (TRBIOC)
- Timer RB mode register (TRBMR)
- Timer RB interrupt request status register (TRBIR)
- Timer RB prescaler register (TRBPRE)
- Timer RB secondary register (TRBSC)
- Timer RB primary register (TRBPR)

14.2.1 Timer RB Control Register (TRBCR)

Address: H'FFFFA0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TSTOP	TCSTF	TSTART
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 3	—	Reserved	These bits are read as 0. The write value should be 0.	—
2	TSTOP	Count forced stop	0: Timer RB counting is continued. 1: Timer RB counting is forcedly stopped.	R/W
1	TCSTF	Count status flag	0: Timer RB counting is stopped. 1: Timer RB counting is in progress. [Setting conditions] • When 1 is written to TSTART and counting is started. • The start of counting after ELOPA of the event link controller is selected counting by timer RB, the specified event is occurred, and the TATRT bit is set to 1. [Clearing conditions] • When 0 is written to TSTART and counting is stopped. • When 1 is written to TSTOP and counting is stopped.	R
0	TSTART	Count start	0: Timer RB counting is stopped. 1: Timer RB counting is started.	R/W

Notes: 1. A MOV instruction should be used to write to this register.
2. The timer RB registers should not be accessed until the TCSTF bit changes after the TSTART bit is set, apart from TRBCR which can be read at any time during timer operation.

- TSTOP bit (count forced stop)

  Setting this bit to 1 stops counting forcibly. At this time, the counter of the timer RB prescaler and the timer RB counter are initialized. Also, bits TSTART and TCSTF in TRBCR, bits TOSSTF, TOSSP, TOSST in TRBOCR, and TRBO outputs are initialized. The reload register of the prescaler and the timer RB counter are hold. This bit is always read as 0.

14.2.2 Timer RB One-Shot Control Register (TRBOCR)

Address: H'FFFFA1

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	TOSSTF	TOSSP	TOSST
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 3	—	Reserved	These bits are read as 0. The write value should be 0.	—
2	TOSSTF	One-shot status flag	0: Timer RB one-shot function has been stopped. 1: Timer RB one-shot function is active (including wait time). [Setting conditions] • When 1 is written to the TOSST bit. • When trigger inputs to the TRGB pin are enabled. [Clearing conditions] • When 1 is written to the TOSSP bit. • When 0 is written to the TSTART bit in TRBCR. • When 1 is written to the TSTOP bit in TRBCR. [In programmable one-shot generation mode] • When the timer counter reaches H'00 and the reloading is performed. [In programmable wait on-shot generation mode] When the counter value reaches H'00 during the secondary counting and the reloading is performed.	R
1	TOSSP*[1]	One-shot stop	0: Timer RB counting is not stopped. 1: Timer RB counting is stopped.	R/W
0	TOSST*[2]	One-shot start	0: Timer RB counting is stopped. 1: Timer RB counting is started.	R/W

Note: 1. The TOSSP bit should be modified to 1 when the TOSSTF bit is 1.
2. The TOSST bit should be modified to 1 when the TOSSTF bit is 1.

- TOSSP bit (one-shot stop)

  Writing 1 to this bit stops the timer counting. This bit is always read as 0

- TOSST bit (one-shot start)

  In programmable one-shot generation mode or programmable wait one-shot generation mode, writing 1 to this bit starts the timer counting and one-shot pulse output in synchronization with the count source. This bit is always read as 0.

14.2.3 Timer RB I/O Control Register (TRBIOC)

Address: H'FFFFA2

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	TIPF[1:0]		INOSEG	INOSTG	TOCNT	TOPL
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5, 4	TIPF[1:0]	TRGB input filter select	00: No filter operation 01: Filtered (Sampled at ϕ) 10: Filtered (Sampled at ϕ/8) 11: Filtered (Sampled at ϕ/32) These bits should be set to B'00 for timer mode or pulse output mode.	R/W
3	INOSEG	One-shot trigger polarity select	0: Triggered at a falling edge. 1: Triggered at a rising edge.	R/W
2	INOSTG	One-shot trigger control	0: The one-shot trigger function for the TRGB pin is disabled. 1: The one-shot trigger function for TRGB pin is enabled.	R/W
1	TOCNT	Timer RB output switch	0: Waveform is output from timer RB. 1: Waveform output is disabled.	R/W

Bit	Symbol	Bit Name	Description	R/W
0	TOPL	Timer RB output level select	Programmable Waveform Generation Mode 0: A high-level signal is output in primary period, a low-level signal in secondary period and a low-level signal when the timer stops. 1: A low-level signal is output in primary period, a high-level signal in secondary period, and a high-level signal when the timer stops. Programmable one-shot generation mode 0: A high-level signal is output for one-shot pulse output and a low-level signal when the timer stops. 1: A low-level signal is output for one-shot pulse output and a high-level signal when the timer stops. Programmable wait one-shot generation mode 0: A high-level signal is output for one-shot pulse output and a low-level signal during the wait time or the time when the timer stops. 1: A low-level signal is output for one-shot pulse output and a high-level signal during the wait time or the time when the timer stops. This bit should be 0 in timer mode.	R/W

- INOSEG bit (one-shot trigger polarity select)

  Selects an edge for the one-shot trigger signal input from the TRGB pin in programmable one-shot generation mode or programmable wait one-shot generation mode. This bit should be 0 in timer mode or programmable waveform generation mode.

- INOSTG bit (one-shot trigger control)

  Enables or disables one-shot trigger signal input from the TRGB pin. This bit should be 0 in timer mode or programmable waveform generation mode.

- TOCNT bit (timer RB output switch)

  For TRBO output state or output change conditions in each mode, see section 14.3.6, TOCNT Settings and Pin State Update Conditions.

- TOPL bit (timer RB output level select)

  This bit should be 0 in timer mode.

14.2.4 Timer RB Mode Register (TRBMR)

Address: H'FFFFA3

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TCKCUT	TCK[2:0]			TWRC	—	TMOD[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TCKCUT*[1]	Count source cutoff	0: Timer RB clock source is supplied. 1: Timer RB clock source is cut off.	R/W
6 to 4	TCK[2:0]*[1]	Count source select	000: ϕ 001: ϕ/8 010: Underflow of timer RA 011: ϕ/2 100: ϕ4 101: ϕ/32 110: ϕ/64 111: ϕ/128	R/W
3	TWRC	Write control	0: Both the reload register and counter are written to. 1: Only the reload register is written to.	
2	—	Reserved	This bit is read as 0. The write value should be 0.	—
1, 0	TMOD[1:0]*[2]	Operating mode select	00: Timer mode 01: Programmable waveform generation mode 10: Programmable one-shot generation mode 11: Programmable wait one-shot generation mode	R/W

Notes: 1. A count source should not be switched or cut off during counting. The count source should be switched or cut off when both the TSTART and TCSTF bits in TRBCR are 0 (when the timer counting is stopped).
2. An operating mode should be selected when the counting is stopped (when both the TSTART and TCSTF bits in TRBCR are 0).

- TWRC bit (write control)

  Controls the timing when the counter reflects the value of the reload register. This bit should be 1 except in timer mode.

14.2.5 Timer RB Interrupt Enable Status Register (TRBIR)

Address: H'FFFFA7

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

Bit	Symbol	Bit Name	Description	R/W
7	TRBIE	Interrupt enable	0: Timer RB interrupt requests are disabled. 1: Timer RB interrupt requests are enabled.	R/W
6	TRBIF	Interrupt request flag	[Setting conditions] Timer mode • When the timer RA underflows. Programmable waveform generation mode • A half cycle of the count source after the counter underflow in the secondary period Programmable one-shot generation mode. • A half cycle of the count source after the counter underflow Programmable wait one-shot generation mode • A half cycle of the counter source after the counter underflow in the secondary period [Clearing conditions] • When 1 is read from the bit and then 0 is written to. • When the DTC is activated by a TRBAIF interrupt, and the DISEL bit in MRB of the DTC is 0.	R/W
5 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

14.2.6 Timer RB Prescaler Register (TRBPRE)

Address: H'FFFFA4

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

TRBPRE is a reload register for the timer RB prescaler. The timer RB prescaler consists of a reload register and an 8-bit counter.

If a down-count is performed using the count source selected on TRBMR and an underflow occurs, the value of the reload register is loaded to the counter. The underflow becomes a count source for TRBTR.

TRBPRE and the counter are assigned to the same address. On write, a value is written to the reload register, and on read, a counter value is read. During a write to TRBPRE, the load timing from the reload register to the counter differs between counting in progress and counting stopped by the setting of the TWRC bit in TRBMR. For details, see descriptions of each operating mode.

The initial values of TRBPRE and the counter are H'FF.

14.2.7 Timer RB Secondary Register (TRBSC)

Address: H'FFFFA5

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

TRBSC is an 8-bit write-only register that sets the secondary period for the timer RB counter. This register is used only in programmable waveform generation mode and programmable wait one-shot generation mode. This register is not used in timer mode or programmable one-shot generation mode.

When TRBSC is written to in any operating mode where TRBSC is used, both the TRBSC and TRBPR should be written to in this order. Even if only TRBSC is to be modified, TRBPR should also be set to the previous value. The initial value is H'FF.

14.2.8 Timer RB Primary Register (TRBPR)

Address: H'FFFFA6

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

TRBPR is an 8-bit reload register that sets the cycle or primary period for the timer RB counter. The timer RB counter consists of two registers, primary and secondary registers, and a counter. The primary register and counter are assigned to the same address. On write to TRBPR, a value is written to the reload register, and on read from TRBPR, a counter value is read.

During a write to TRBPR the load timing from the reload register to the counter differs between counting in progress and counting stopped. For details, see descriptions of each operating mode.

The initial values of TRBPR and the counter are H'FF.

14.3 Operation

14.3.1 Timer Mode

The internal clock pulses or timer RA underflows are counted as a count source in timer mode. When an underflow occurs on the timer RB counter, the value of TRBPR is reloaded and counting is continued. TRBOCR and TRBSC are not used in timer mode. A count source is selected with the TCK[2:0] bits in TRBMR.

(1) Starting and Stopping Operation

Writing the value 1 to the TSTART bit in TRBCR starts counting; writing the value 0 to the TSTART bit stops the counting.

(2) Forced Termination of Operation

Writing 1 to the TSTOP bit in TRBCR stops the counting forcedly. When the counting is forcedly stopped, the timer RB counter, the prescaler counter, and any associated flags are initialized.

(3) Interrupt Request

An interrupt request is generated on the underflow of the timer RB counter.

(4) Reading and Writing Count Value

Reading TRBPRE and TRBTR reads count values from each register.

If a write is performed to TRBPRE or TRBTR when the counting is stopped, a specified value is written to both the reload register and the counter.

If a write is performed to TRBPRE during counting when TWRC in TRBMR is 0, first a set value is written to the reload register, and the set value is then transferred to the prescaler counter in synchronization with the count source. If a write is performed to TRBPR, a set value is written to the reload register in synchronization with the underflow of the prescaler after four cycles of the count source of the prescaler, and the set value is transferred to the timer counter in synchronization with the next underflow of the prescaler.

For this reason, if a write is performed to TRBPRE or TRBPR during counting when TWRC is 1, the value is written only to the reload register. Loading to the counter is performed in synchronization with the underflow of the prescaler or timer counter.

14.3.2 Programmable Waveform Generation Mode

This mode alternately reloads and counts values of TRBPR and TRBSC, and produces toggle output from the TRBO pin each time the counter underflows. At the start of counting, this mode counts beginning with the value assigned to TRBPR. TRBOCR is not used when programmable waveform generation mode is used.

(1) Starting and Stopping Operation

Writing the value 1 to the TSTART bit in TRBCR starts counting; writing the value 0 to the TSTART bit stops the counting.

(2) Forced Termination of Operation

Writing 1 to the TSTOP bit in TRBCR stops the counting forcedly. When the counting is forcedly stopped, the timer RB counter, the prescaler counter, and any associated flags are initialized.

(3) Interrupt Request

An interrupt request is generated on the underflow of the timer RB counter during the secondary period counting.

(4) Reading and Writing Count Value

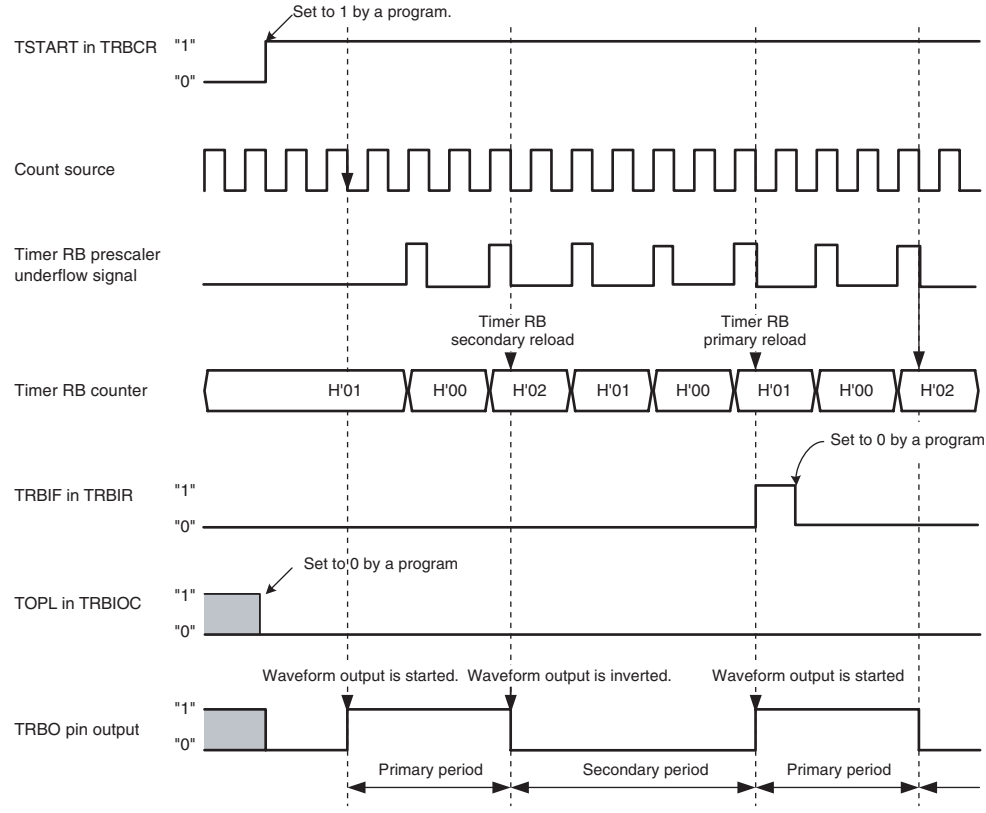
Reading TRBPRE and TRBTR reads count values from each register.

If a write is performed to TRBPRE, TRBPR, or TRBSC when counting is stopped, set values are written to both the reload register and the counter.

If a write is performed to TRBPRE, TRBPR, or TRBSC when counting is in progress, data is written only to the respective reload registers. The output of a waveform reflects a set value beginning with the next primary period after data is written to TRBPR.

However, if writing to TRBSC or TRBPR proceeds when the value of the counter is H'00, updating of the waveform will be suspended for one cycle.

Figure 14.2 shows an operation example of the timer RB in programmable waveform generation mode.



Conditions for the above operation:

TRBPRE=H'01, TRBPR=H'01, TRBSC=H'02
TOCNT = 0 in TRBIOC (Timer RB waveform is output from the TRBO pin.)

Figure 14.2 Operation in Programmable Waveform Generation Mode

14.3.3 Programmable One-Shot Generation Mode

This mode outputs one-shot pulses from the TRBO pin, based on either program or external trigger input. When a trigger is generated, beginning with that point in time the timer operates only once for any length of time specified in TRBPR. TRBSC is not used in this mode. In this mode, TRBPRE or TRBPR should not be set to H'00.

(1) Starting and Stopping Operation

The counting is started when 1 is written to the TOSST bit in TRBOCR or a valid trigger signal is input to the TRGB pin after the TSTART bit in TRBCR is set to 1 and the TCSTF flag is set to 1. For a trigger input, the pulse must be longer than one cycle of the clock source for counting.

The counting is stopped when reloading is performed with an underflow of the counter, when 1 is written to the TOSSP bit in TRBOCR, or when 0 is written to the TSTART bit in TRBCR.

(2) Forced Termination of Operation

Writing 1 to the TSTOP bit in TRBCR stops the counting forcedly. When the counting is forcedly stopped, the timer RB counter, the prescaler counter, and any associated flags are initialized.

(3) Interrupt Request

An interrupt request is generated on the underflow of the timer RB counter.

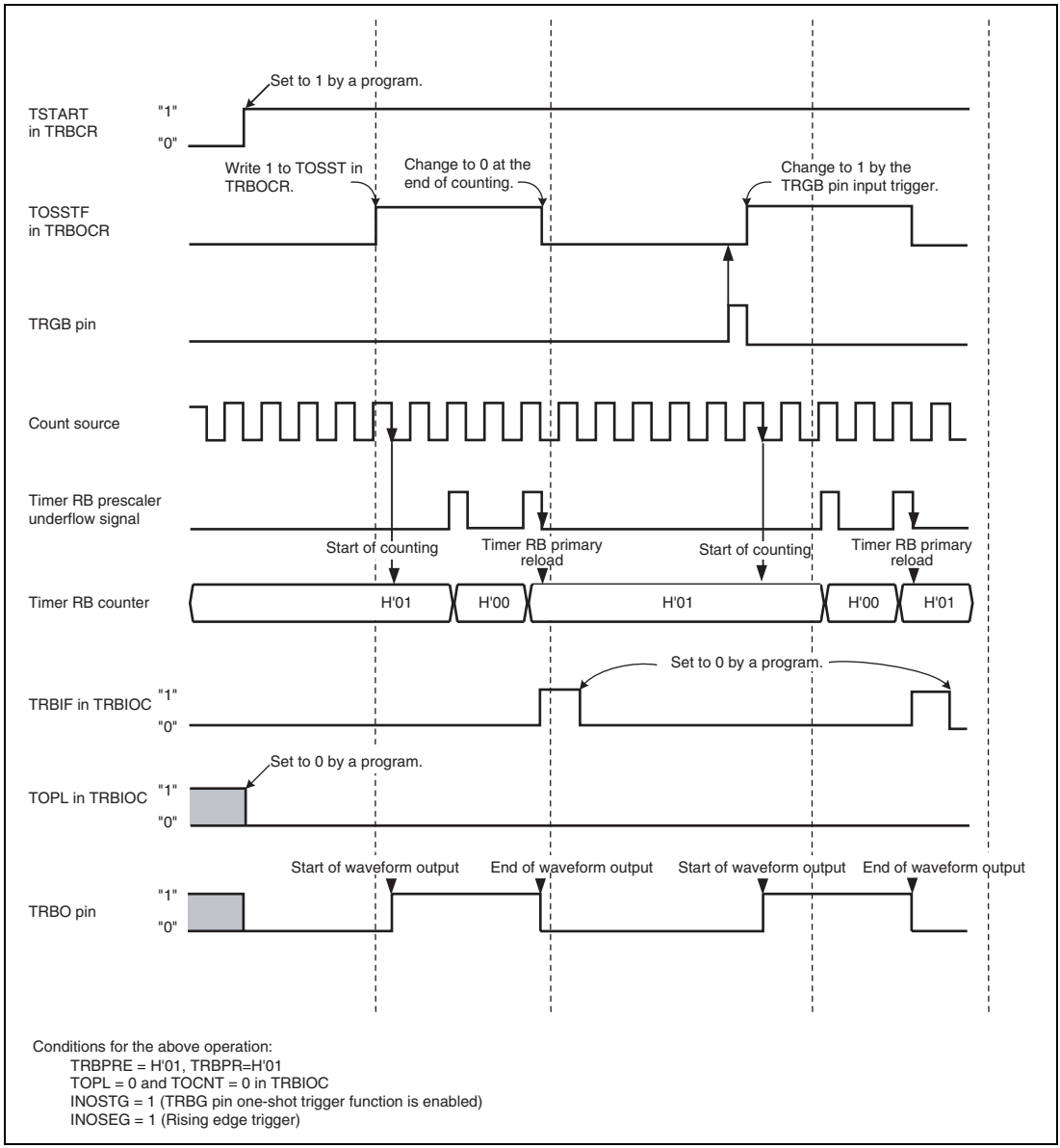
(4) Reading and Writing Count Value

Reading TRBPRE and TRBTR reads count values from each register.

If a write is performed to TRBPRE or TRBPR when counting is stopped, set values are written to both the reload register and the counter.

If a write is performed to TRBPRE or TRBPR during counting, data is written only to the respective reload registers. The value written to TRBPRE takes effect in synchronization with the underflow of the prescaler. The value written to TRBPR takes effect during the next one-shot pulse.

Figure 14.3 shows an operation example of the timer RB in programmable one-shot generation mode.



Conditions for the above operation:
TRBPRE = H'01, TRBPR=H'01
TOPL = 0 and TOCNT = 0 in TRBIOC
INOSTG = 1 (TRBG pin one-shot trigger function is enabled)
INOSEG = 1 (Rising edge trigger)

Figure 14.3 Operation in Programmable One-Shot Generation Mode

14.3.4 Programmable Wait One-Shot Generation Mode

This mode outputs one-shot pulses from the TRBO pin after a fixed amount of time based on either program or external trigger input. When a trigger is generated, beginning with that point in time, pulses are output only once for any length of time set in TRBSC, after any length of time set in TRBPR.

(1) Starting and Stopping Operation

The counting is started when 1 is written to the TOSST bit in TRBOCR or a valid trigger signal is input to the TRGB pin after the TSTART bit in TRBCR is set to 1 and the TCSTF flag is set to 1. For a trigger input, the pulse must be longer than one cycle of the clock source for counting.

The counting is stopped when reloading is performed with an underflow of the timer RB counter during the secondary period counting , when 1 is written to the TOSSP bit in TRBOCR, or when 0 is written to the TSTART bit in TRBMR.

(2) Forced Termination of Operation

Writing 1 to the TSTOP bit in TRBCR stops the counting forcedly. When the counting is forcedly stopped, the timer RB counter, the prescaler counter, and any associated flags are initialized.

(3) Interrupt Request

An interrupt request is generated on the underflow of the timer RB counter during the secondary period counting.

(4) Reading and Writing Count Value

Reading TRBPRE and TRBTR reads count values from each register.

If a write is performed to TRBPRE, TRBPR, or TRBSC when counting is stopped, set values are written to both the reload register and the counter.

If a write is performed to TRBPRE, TRBPR, or TRBSC during counting, data is written only to the respective reload registers. The value written to TRBPRE takes effect in synchronization with the underflow of the prescaler. The value written to TRBPR takes effect during the next one-shot pulse.

After writing to TRBSC and TRBPR when TCSTF = 1 or TOSSTF = 0, if a write is successively performed to TRBSC and then to TRBPR, allow an interval of 5 cycles of the clock source for counting before writing 1 to the TOSST bit.

In this mode, TRBPRE or TRBPR should not be set to H'00.

Figure 14.4 shows an operation example of the timer RB in programmable wait one-shot generation mode.

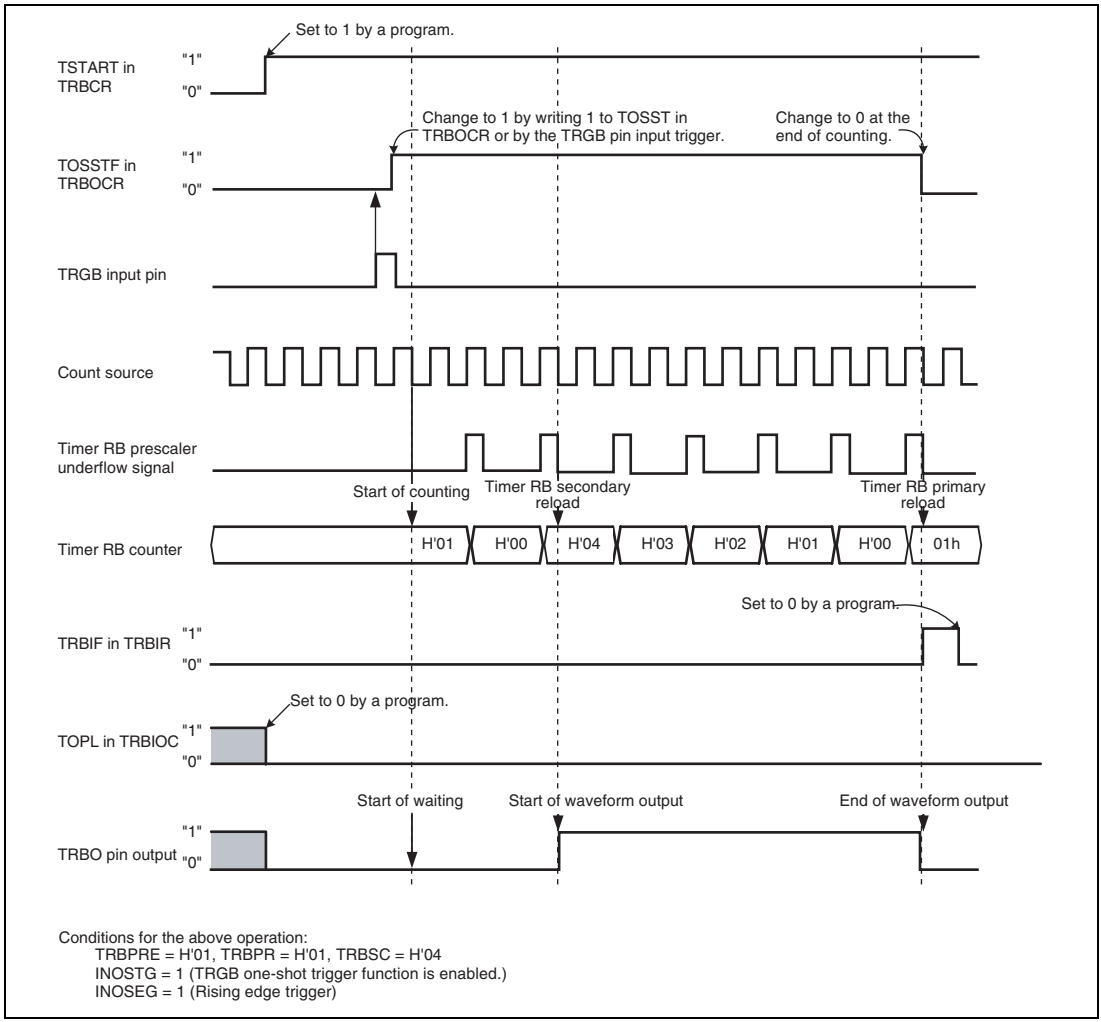


Figure 14.4 Operation in Programmable Wait One-Shot Generation Mode

14.3.5 Timing at Which Values Take Effect in Prescaler or Counter Depending on TWRC Bit

Depending on the value assigned to the TWRC bit in TRBMR, the timing at which the value written to TRBPRE, TRBPR, or TRBSC during timer operation takes effect in the counter can vary.

If TWRC is set to 1 and value is written only to the register, the counter value is updated between cycles, thus preventing the occurrence of fractional cycles. In modes other than the timer mode, TWRC should be set to 1.

Figure 14.5 shows operation examples on the prescaler and the counter when the value of TWRC is 0 and 1.

If TCSTF is 1, even when TWRC is cleared to 0, any transfer to the prescaler or the counter is performed in synchronization with the count source; therefore, the counter value is not updated immediately after the execution of a write instruction.

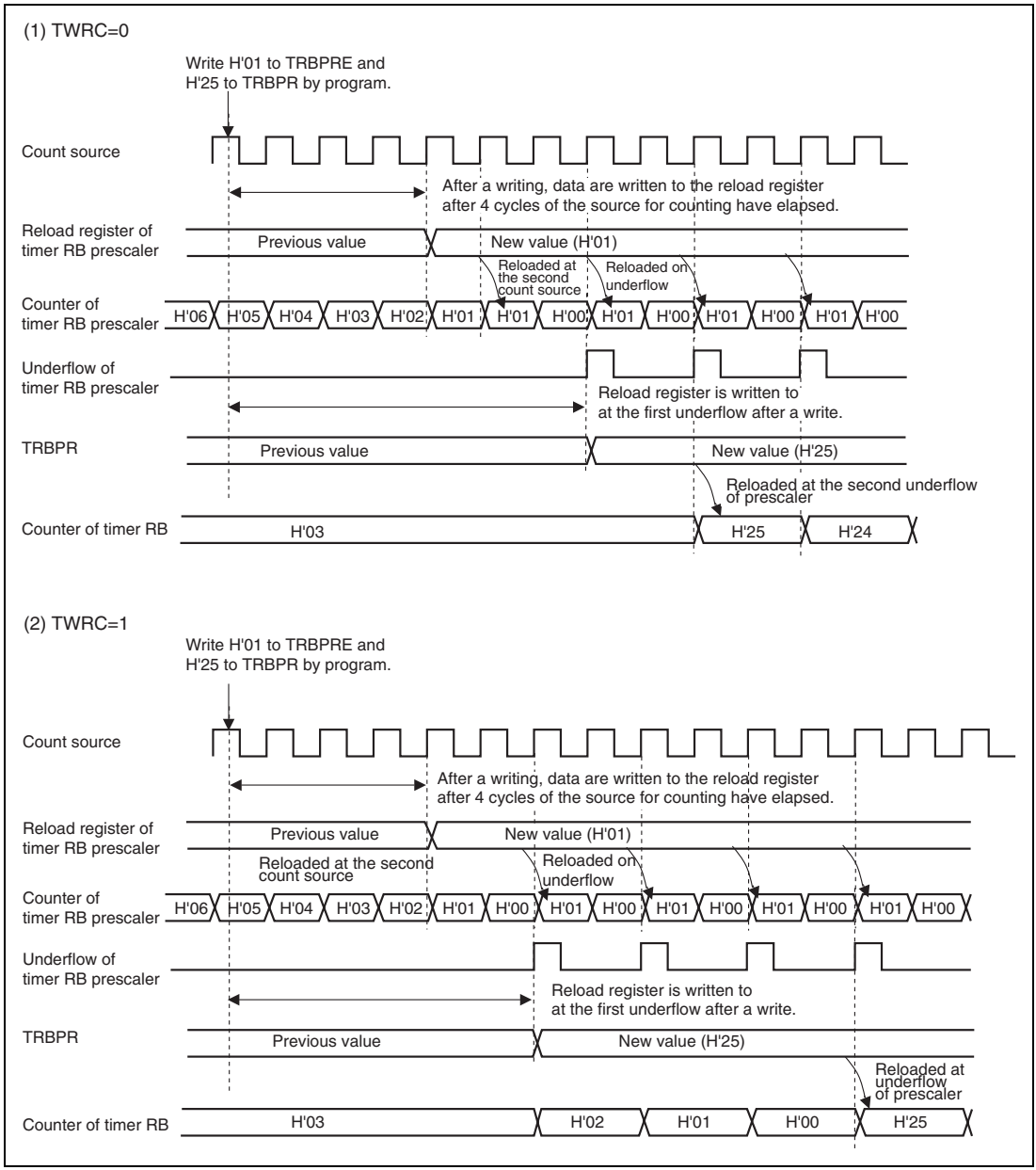


Figure 14.5 TWRC Settings and Operation of Prescaler and Counter

14.3.6 TOCNT Settings and Pin State Update Conditions

Depending on the TOCNT bit in TRBIOC and the corresponding bit in PMR, the user can select whether the pin is used as a general I/O port or as a specific timer waveform output. In the case of timer mode, however, the pin operates as a general I/O port, irrespective of TOCNT bit settings.

When the TOCNT bit is rewritten, the pin state is not updated immediately; the change takes effect when either of the following conditions occurs:

Pin state update conditions:

- When the TSTART bit in TRBCR is changed from 0 to 1
- When TRBPR is reloaded to the counter

14.3.7 Operation through an Event Link

Using the event link controller (ELC), timer RB can be made to operate in the following ways in relation to events occurring in other modules.

(1) Starting Counter Operation

The start of counting operations by timer RB can be selected by the ELOPA register of the ELC. When the event specified in ELSR1 occurs, the TSTART bit in the TRBCR is set to 1, which starts counting by timer RB. However, if the specified event occurs when the TCSTF flag has already been set to 1, that event is not effective.

(2) Counting Events

The counting of events by timer RB can be selected by the ELOPA register of the ELC. When the event specified in ELSR1 occurs, event counter operation proceeds with that event as the source to drive counting, regardless of the setting in TRBMR. When event-counter operation is to be employed, set the TSTART bit in TRBCR to 1 beforehand. When the value of the counter is read, the value read out is the actual number of input events minus three.

14.4 Interrupt Request

This module provides a timer RB interrupt enable bit (the TRBIE bit in TRBIR) and a timer RB interrupt request flag (the TRBIF bit in TRBIR). An interrupt request is issued to the CPU when the TRBIE bit is set to 1 while the TRBIF bit is 1, or when the TRBIE bit changes from 0 to 1 while the TRBIF bit is 1. Since the condition under which the TRBIF bit is set varies with operation modes, see the explanation on the TRBIF bit and the description of the various operation modes.

14.5 Usage Notes

1. In programmable one-shot generation mode and programmable wait one-shot generation mode, if the counting is stopped by clearing the TSTART bit in TRBCR to 0, the timer counter holds a count value, and then stops.
2. After 1 is written to the TSTART bit when the counting is stopped, the TCSTF bit remains 0 for the number of cycles of the count source. The timer RB related registers*, with the exception of the TRBCR for reading should not be accessed until the TCSTF bit is set to 1.

   After 0 is written to the TSTART bit during counting, the TCSTF bit remains 1 for the number of cycles of the count source. The timer RB related registers*, with the exception of the TRBCR for reading should not be accessed until the TCSTF bit is cleared to 0.

Note: Timer RB-related registers refer to registers TRBCR, TRBOCR, TRBIOC, TRBMR, TRBPRE, TRBSC, and TRBPR.

3. TRBPRE and TRBPR should not be set to H'00 at the same time.
4. When rewriting the bits TRBPRE, TRBPR, and TRBSC at TSTART = 0, set TSTART to 1 after the passage of at least ϕ2-cycle of the system clock.
5. When TSTART = 1 or TCSTF = 1, TRBIOC, or TRBMR should not be rewritten.
6. When writing 1 to the TOSST bit, read the TCSTF bit and write by verifying the value 1.
7. In programmable waveform generation mode or programmable wait one-shot mode, make sure another write to TRBSC does not occur between writing to TRBPR and reloading to the counter.
8. When writing successively to TRBPRE during counting (TCSTF=1), allow a minimum write interval of 4 cycles of count source.
9. When writing successively to TRBPR and TRBSC during counting (TCSTF=1), allow a minimum write interval of 4 cycles of count source.
10. When 1 is written to the TOSST or TOSSP bit in TRBOCR, the value of the TOSSTF bit changes accordingly after 1 to 2 cycles of the source for counting. If 1 is written to the TOSSP bit during the period between the TOSST bit having been set to 1 and the value of the TOSSTF bit becoming 1, the value of the TOSSTF bit will become 0 in some cases and 1 in others, depending on the internal state. In the same way, if 1 is written to the TOSST bit during the period between the TOSSP bit having been set to 1 and the value of the TOSSTF bit becoming 0, whether the value of the TOSSTF bit will become 0 or 1 is not defined.

Section 15 Timer RC

Timer RC is a 16-bit timer having output compare and input capture functions. Timer RC can count external events and output pulses with a desired duty cycle using the compare match function between the timer counter and four general registers. Thus, it can be applied to various systems.

Note: Timer RC is not supported in H8S/20223 and H8S/20203 groups.

15.1 Features

- Selection of seven counter clock sources
  Six internal clocks (φ, φ/2, φ/4, φ/8, φ/32, and φ40) and an external clock (for counting external events)
- Capability to process up to four pulse outputs or four pulse inputs
- Four general registers
  Can be used as output compare or input capture registers independently
  Can be used as buffer registers for the output compare or input capture registers
- Timer inputs and outputs
  - Timer mode
    Output compare function (Selection of 0 output, 1 output, or toggle output)
    Input capture function (Rising edge, falling edge, or both edges can be detected.)
    Counter clearing function (Counter cycle can be set.)
  - PWM mode
    Generates up to three-phase PWM output.
  - PWM2 mode
    Generates pulses with a desired period and duty cycle.
- Any initial timer output value can be set
- Five interrupt sources
  Four compare match/input capture interrupts and an overflow interrupt.

Table 15.1 summarizes the timer RC functions, and figure 15.1 shows a block diagram of timer RC.

Table 15.1 Timer RC Functions

Item		Counter	Input/Output Pins			
			FTIOA	FTIOB	FTIOC	FTIOD
Count clock		Internal clocks: φ, φ/2, φ/4, φ/8, φ/32, and φ40 External clock: FTCI				
General registers (output compare/input capture registers)		Period specified in GRA	GRA	GRB	GRC (buffer register for GRA in buffer mode)	GRD (buffer register for GRB in buffer mode)
Counter clearing function		GRA input capture/ compare match	GRA input capture/ compare match	—	—	—
		TGRC input	—	—	—	—
Initial output value setting function		—	Yes	Yes	Yes	Yes
Buffer function		—	Yes	Yes	—	—
Compare match output	0 output	—	Yes	Yes	Yes	Yes
	1 output	—	Yes	Yes	Yes	Yes
	Toggle output	—	Yes	Yes	Yes	Yes
Input capture function		—	Yes	Yes	Yes	Yes
PWM mode		—	—	Yes	Yes	Yes
PWM2 mode		—	—	Yes	—	—
Interrupt sources		Overflow	Compare match/input capture	Compare match/input capture	Compare match/input capture	Compare match/input capture

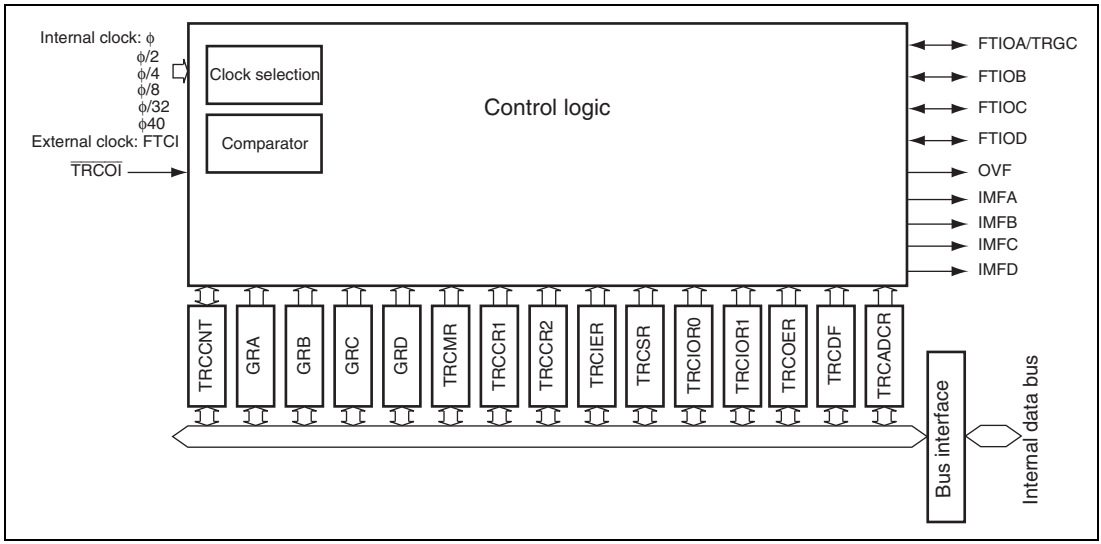


Figure 15.1 Timer RC Block Diagram

Table 15.2 summarizes the timer RC pins.

Table 15.2 Pin Configuration

Pin Name	Input/ Output	Function
FTCI	Input	External clock input pin
FTIOA/TRGC	I/O	Output pin for GRA output compare/input pin for GRA input capture/ external trigger input pin (TRGC)
FTIOB	I/O	Output pin for GRB output compare/input pin for GRB input capture/ PWM output pin in PWM mode
FTIOC	I/O	Output pin for GRC output compare/input pin for GRC input capture/ PWM output pin in PWM mode
FTIOD	I/O	Output pin for GRD output compare/input pin for GRD input capture/ PWM output pin in PWM mode
$\overline{\text{TRCOI}}$	Input	Input pin for timer output disabling signal

15.2 Register Descriptions

The timer RC has the following registers.

- Timer RC mode register (TRCMR)
- Timer RC control register 1 (TRCCR1)
- Timer RC control register 2 (TRCCR2)
- Timer RC interrupt enable register (TRCIER)
- Timer RC status register (TRCSR)
- Timer RC I/O control register 0 (TRCIOR0)
- Timer RC I/O control register 1 (TRCIOR1)
- Timer RC output enable register (TRCOER)
- Timer RC digital filtering function select register (TRCDF)
- Timer RC A/D conversion start trigger control register (TRCADCR)
- Timer RC counter (TRCCNT)
- General register A (GRA)
- General register B (GRB)
- General register C (GRC)
- General register D (GRD)

15.2.1 Timer RC Mode Register (TRCMR)

Address: H'FFFF8A

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	CTS	—	BUFEB	BUFEA	PWM2	PWMD	PWMC	PWMB
Value after reset:	0	1	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	CTS	Counter start	0: TRCCNT stops counting. 1: TRCCNT starts counting. [Setting conditions] • When 1 is written in CTS • When the specified event is occurred after ELOPA of the event link controller is selected counting by timer RC. [Clearing conditions] • When 0 is written in CTS • In PWM2 mode, when the CSTP bit in TRCCR2 is set to 1 and a compare match signal is generated.	R/W
6	—	Reserved	This bit is read as 1. The write value should be 1.	—
5	BUFEB	Buffer operation B	0: GRD functions as an input capture/output compare register 1: GRD functions as the buffer register for GRB	R/W
4	BUFEA	Buffer operation A	0: GRC functions as an input capture/output compare register 1: GRC functions as the buffer register for GRA	R/W
3	PWM2	PWM2 mode	0: Timer RC functions in PWM2 mode. The following settings are invalid: TRCIOR0, TRCIOR1, and the PWMB, PWMC, and PWMD bits in TRCMR. 1: Timer RC functions in timer mode or PWM mode. The following settings are valid: TRCIOR0, TRCIOR1, and the PWMB, PWMC, and PWMD bits in TRCMR.	R/W

Bit	Symbol	Bit Name	Description	R/W
2	PWMD	PWM mode D	Selects the output mode of the FTIOD pin. 0: Functions in timer mode 1: Functions in PWM mode	R/W
1	PWMC	PWM mode C	Selects the output mode of the FTIOC pin. 0: Functions in timer mode 1: Functions in PWM mode	R/W
0	PWMB	PWM mode B	Selects the output mode of the FTIOB pin. 0: Functions in timer mode 1: Functions in PWM mode	R/W

15.2.2 Timer RC Control Register 1 (TRCCR1)

Address: H'FFFF8B

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	CCLR	CKS[2:0]			TOD	TOC	TOB	TOA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	CCLR	Counter clear	0: TRCCNT functions as a free-running counter. 1: The TRCCNT value is cleared by input capture A/compare match A.	R/W
6 to 4	CKS[2:0]*[3]	Clock select 2 to 0	Select the source of the clock input to TRCCNT. 000: TRCCNT counts the internal clock ϕ. 001: TRCCNT counts the internal clock $\phi/2$. 010: TRCCNT counts the internal clock $\phi/4$. 011: TRCCNT counts the internal clock $\phi/8$. 100: TRCCNT counts the internal clock $\phi/32$. 101: TRCCNT counts the rising edge of the external event (FTCI). 110: TRCCNT counts the internal clock $\phi 40$.*[1] 111: Reserved (setting prohibited)	R/W

Bit	Symbol	Bit Name	Description	R/W
3	TOD	Timer output level setting D	0: Output value is 0*2. 1: Output value is 1*2.	R/W
2	TOC	Timer output level setting C	0: Output value is 0*2. 1: Output value is 1*2.	R/W
1	TOB	Timer output level setting B	0: Output value is 0*2. 1: Output value is 1*2.	R/W
0	TOA	Timer output level setting A	0: Output value is 0*2. 1: Output value is 1*2.	R/W

Notes: 1. If the internal ϕ/40 clock is selected, the high-speed on-chip oscillator must be operating. As long as the internal ϕ40 clock is selected, do not stop the high-speed on-chip oscillator. Restrictions on access to registers are applied when the internal ϕ/40 clock is selected. For details, see 6 in section 15.5, Usage Notes. 6.
2. The change of the setting is immediately reflected in the output value.
3. When the counter clock is switched over, the counter should be halted.

- TOD bit (timer output level setting D)

  Sets the output value of the FTIOD pin until the first compare match D is generated. In PWM mode, controls the output polarity of the FTIOD pin.

- TOC bit (timer output level setting C)

  Sets the output value of the FTIOC pin until the first compare match C is generated. In PWM mode, controls the output polarity of the FTIOC pin.

- TOB bit (timer output level setting B)

  Sets the output value of the FTIOB pin until the first compare match B is generated. In PWM mode, controls the output polarity of the FTIOB pin.

- TOA bit (timer output level setting A)

  Sets the output value of the FTIOA pin until the first compare match A is generated. In PWM mode, controls the output polarity of the FTIOA pin.

15.2.3 Timer RC Control Register 2 (TRCCR2)

Address: H'FFFF90

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TCEG[1:0]		CSTP	—	—	POLD	POLC	POLB
Value after reset:	0	0	0	1	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	TCEG[1:0]	TRGC input edge select	00: A trigger input on TRGC is disabled. 01: The rising edge is selected. 10: The falling edge is selected. 11: Both edges are selected.	R/W
5	CSTP	Count stop	0: TRCCNT counting up continues. 1: TRCCNT counting up is halted.	R/W
4, 3	—	Reserved	These bits are read as 1. The write value should be 1.	—
2	POLD	PWM mode output level control D	0: The TRCIOD output is active low. 1: The TRCIOD output is active high.	R/W
1	POLC	PWM mode output level control C	0: The TRCIOC output is active low. 1: The TRCIOC output is active high.	R/W
0	POLB	PWM mode output level control B	0: The TRCIOB output is active low. 1: The TRCIOB output is active high.	R/W

- TCEG[1:0] bits (TRGC input edge select)

  These bits select the input edge of the TRGC signal. This function is only enabled when the PWM2 bit in TRCMR is set to 0.

- CSTP bit (count stop)

  Specifies whether TRCCNT counting up is halted by the compare match A signal. This function is enabled in all operating modes. To resume counting after counting has been stopped on a compare match, set the CTS bit in the timer RC mode register (TRCMR) to 1.

15.2.4 Timer RC Interrupt Enable Register (TRCIER)

Address: H'FFFF8C

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	OVIE	—	—	—	IMIED	IMIEC	IMIEB	IMIEA
Value after reset:	0	1	1	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	OVIE	Timer overflow interrupt enable	0: An interrupt (FOVI) requested by the OVF flag in TRCSR is disabled. 1: An interrupt (FOVI) requested by the OVF flag in TRCSR is enabled.	R/W
6 to 4	—	Reserved	These bits are read as 1. The write value should be 1.	—
3	IMIED	Input capture/ compare match interrupt enable D	0: An interrupt (IMID) requested by the IMFD flag in TRCSR is disabled. 1: An interrupt (IMID) requested by the IMFD flag in TRCSR is enabled.	R/W
2	IMIEC	Input capture/ compare match interrupt enable C	0: An interrupt (IMIC) requested by the IMFC flag in TRCSR is disabled. 1: An interrupt (IMIC) requested by the IMFC flag in TRCSR is enabled.	R/W
1	IMIEB	Input capture/ compare match interrupt enable B	0: An interrupt (IMIB) requested by the IMFB flag in TRCSR is disabled. 1: An interrupt (IMIB) requested by the IMFB flag in TRCSR is enabled.	R/W
0	IMIEA	Input capture/ compare match interrupt enable A	0: An interrupt (IMIA) requested by the IMFA flag in TRCSR is disabled. 1: An interrupt (IMIA) requested by the IMFA flag in TRCSR is enabled.	R/W

15.2.5 Timer RC Status Register (TRCSR)

Address: H'FFFF8D

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	OVF	—	—	—	IMFD	IMFC	IMFB	IMFA
Value after reset:	0	1	1	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	OVF	Timer overflow flag	0: TRCCNT has not overflowed. 1: TRCCNT has overflowed. [Setting condition] • When TRCCNT overflows from H'FFFF to H'0000. [Clearing condition] • Read OVF when OVF = 1, then write 0 in OVF.	R/W
6 to 4	—	Reserved	These bits are read as 1. The write value should be 1.	—
3	IMFD	Input capture/ compare match flag D	[Setting conditions] • TRCCNT = GRD when GRD functions as an output compare register. • The TRCCNT value is transferred to GRD by an input capture signal when GRD functions as an input capture register. • TRCCNT = GRD when the PWMD bit is set to 1 or the PWM2 bit to 0 in TRCMR. [Clearing conditions] • Read IMFD when IMFD = 1, then write 0 in IMFD. • The DTC is activated by an IMFD interrupt and the DISEL bit in MRB of DTC is 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
2	IMFC	Input capture/ compare match flag C	[Setting conditions] • TRCCNT = GRC when GRC functions as an output compare register. • The TRCCNT value is transferred to GRC by an input capture signal when GRC functions as an input capture register. • TRCCNT = GRC when the PWMC bit is set to 1 or the PWM2 bit to 0 in TRCMR. [Clearing conditions] • Read IMFC when IMFC = 1, then write 0 in IMFC. • The DTC is activated by an IMFC interrupt when the DISEL bit in MRB of DTC is 0.	R/W
1	IMFB	Input capture/ compare match flag B	[Setting conditions] • TRCCNT = GRB when GRB functions as an output compare register. • The TRCCNT value is transferred to GRB by an input capture signal when GRB functions as an input capture register. • TRCCNT = GRB when the PWMB bit is set to 1 or the PWM2 bit to 0 in TRCMR. [Clearing conditions] • Read IMFB when IMFB = 1, then write 0 in IMFB. • The DTC is activated by an IMFB interrupt when the DISEL bit in MRB of DTC is 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
0	IMFA	Input capture/ compare match flag A	[Setting conditions] • TRCCNT = GRA when GRA functions as an output compare register. • The TRCCNT value is transferred to GRA by an input capture signal when GRA functions as an input capture register. [Clearing condition] • Read IMFA when IMFA = 1, then write 0 in IMFA. The DTC is activated by an IMFA interrupt when the DISEL bit in MRB of DTC is 0.	R/W

15.2.6 Timer RC I/O Control Register 0 (TRCIOR0)

Address: H'FFFF8E

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	IOB2	IOB[1:0]		—	IOA2	IOA[1:0]	
Value after reset:	1	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6	IOB2	I/O control B2	Selects the GRB function. 0: GRB functions as an output compare register 1: GRB functions as an input capture register	R/W
5, 4	IOB[1:0]	I/O control B1 and B0	When IOB2 = 0, 00: No output on compare match 01: 0 output to the FTIOB pin on compare match of GRB 10: 1 output to the FTIOB pin on compare match of GRB 11: Toggle output to the FTIOB pin on compare match of GRB When IOB2 = 1, 00: Input capture to GRB at rising edge at the FTIOB pin 01: Input capture to GRB at falling edge at the FTIOB pin 1X: Input capture to GRB at rising and falling edges of the FTIOB pin	R/W
3	—	Reserved	This bit is read as 1. The write value should be 1.	—
2	IOA2	I/O control A2	Selects the GRA function. 0: GRA functions as an output compare register 1: GRA functions as an input capture register	R/W

Bit	Symbol	Bit Name	Description	R/W
1, 0	IOA[1:0]	I/O control A1 and A0	When IOA2 = 0, 00: No output on compare match 01: 0 output to the FTIOA pin on compare match of GRA 10: 1 output to the FTIOA pin on compare match of GRA 11: Toggle output to the FTIOA pin on compare match of GRA When IOA2 = 1, 00: Input capture to GRA at rising edge of the FTIOA pin 01: Input capture to GRA at falling edge of the FTIOA pin 1X: Input capture to GRA at rising and falling edges of the FTIOA pin	R/W

[Legend]

X: Don't care.

Notes: 1. When a GR register functions as a buffer register for a paired GR register, the settings in the IOA2 and IOB2 bits in TRCIOR0 and the IOC2 and IOD2 bits in TRCIOR1 of both registers should be the same.

2. The setting of TRCIOR is invalid in PWM mode and PWM2 mode.

TRCIOR0 selects the functions of GRA and GRB, and specifies the functions of the FTIOA and FTIOB pins.

15.2.7 Timer RC I/O Control Register 1 (TRCIOR1)

Address: H'FFFF8F

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IOD3	IOD2	IOD[1:0]		IOC3	IOC2	IOC[1:0]	
Value after reset:	1	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	IOD3	I/O control D3	0: GRD is used as GR for the FTIOB pin 1: GRD is used as GR for the FTIOD pin	—
6	IOD2	I/O control D2	0: GRD functions as an output compare register 1: GRD functions as an input capture register	R/W
5, 4	IOD[1:0]	I/O control D1 and D0	When IOD3 = 0, 00: No output on compare match 01: 0 output to the FTIOB pin on compare match of GRD 10: 1 output to the FTIOB pin on compare match of GRD 11: Toggle output to the FTIOB pin on compare match of GRD When IOD3 = 1 and IOD2 = 0, 00: No output on compare match 01: 0 output to the FTIOD pin on compare match of GRD 10: 1 output to the FTIOD pin on compare match of GRD 11: Toggle output to the FTIOD pin on compare match of GRD When IOD3 = 1 and IOD2 = 1, 00: Input capture to GRD at rising edge of the FTIOD pin 01: Input capture to GRD at falling edge of the FTIOD pin 1X: Input capture to GRD at rising and falling edges of the FTIOD pin	R/W

Bit	Symbol	Bit Name	Description	R/W
3	IOC3	I/O control C3	0: GRC is used as GR for the FTIOA pin 1: GRC is used as GR for the FTIOC pin	R/W
2	IOC2	I/O control C2	0: GRC functions as an output compare register 1: GRC functions as an input capture register	R/W
1, 0	IOC[1:0]	I/O control C1 and C0	When IOC3 = 0, 00: No output on compare match 01: 0 output to the FTIOA pin on compare match of GRC 10: 1 output to the FTIOA pin on compare match of GRC 11: Toggle output to the FTIOA pin on compare match of GRC When IOC3 = 1 and IOC2 = 0, 00: No output on compare match 01: 0 output to the FTIOC pin on compare match of GRC 10: 1 output to the FTIOC pin on compare match of GRC 11: Toggle output to the FTIOC pin on compare match of GRC When IOC3 = 1 and IOC2 = 1, 00: Input capture to GRC at rising edge of the FTIOC pin 01: Input capture to GRC at falling edge of the FTIOC pin 1X: Input capture to GRC at rising and falling edges of the FTIOC pin	R/W

[Legend]

X: Don't care.

Notes: 1. When a GR register functions as a buffer register for a paired GR register, the settings in the IOA2 and IOB2 bits in TRCIOR0 and the IOC2 and IOD2 bits in TRCIOR1 of both registers should be the same.

2. The setting of TRCIOR1 is invalid in PWM mode and PWM2 mode.

15.2.8 Timer RC Output Enable Register (TRCOER)

Address: H'FFFF92

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PTO	—	—	—	ED	EC	EB	EA
Value after reset:	0	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7	PTO	Timer output disabled mode	0: The ED, EC, EB and EA bits are not set to 1 by the low level input of the $\overline{\text{TRCOI}}$ signal. 1: The ED, EC, EB and EA bits are set to 1 by the low level input of the $\overline{\text{TRCOI}}$ signal.	R/W
6 to 4	—	Reserved	These bits are read as 1. The write value should be 1.	—
3	ED	Master enable D	0: The FTIOD output is enabled according to the TRCMR and TRCIOR1 settings 1: The FTIOD output is disabled regardless of the TRCMR and TRCIOR1 settings.	R/W
2	EC	Master enable C	0: The FTIOC output is enabled according to the TRCMR and TRCIOR1 settings. 1: The FTIOC output is disabled regardless of the TRCMR and TRCIOR1 settings.	R/W
1	EB	Master enable B	0: The FTIOB output is enabled according to the TRCMR and TRCIOR0 settings 1: The FTIOB output is disabled regardless of the TRCMR and TRCIOR0 settings.	R/W
0	EA	Master enable A	0: The FTIOA output is enabled according to the TRCIOR0 settings 1: The FTIOA output is disabled regardless of the TRCIOR0 settings.	R/W

TRCOER enables or disables the timer outputs. When setting the PTO bit to 1 and driving the TRCOI signal low, the ED, EC, EB and EA bits are set to 1 and timer RC outputs are disabled.

15.2.9 Timer RC Digital Filtering Function Select Register (TRCDF)

Address: H'FFFF91

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	DFCK[1:0]		—	DFTRG	DFD	DFC	DFB	DFA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	DFCK[1:0]	Digital filter clock select	These bits select the clock to be used by the digital filter. 00: ϕ/32 01: ϕ/8 10: ϕ 11: Clock specified by bits CKS2 to CKS0 in TRCCR1	R/W
5	—	Reserved	This bit is read as 0. The write value should be 0.	—
4	DFTRG	Digital filter function trigger pin	0: Disables the digital filter for the TRGC pin 1: Enables the digital filter for the TRGC pin	R/W
3	DFD	Digital filter function D	0: Disables the digital filter for the FTIOD pin 1: Enables the digital filter for the FTIOD pin	R/W
2	DFC	Digital filter function C	0: Disables the digital filter for the FTIOC pin 1: Enables the digital filter for the FTIOC pin	R/W
1	DFB	Digital filter function B	0: Disables the digital filter for the FTIOB pin 1: Enables the digital filter for the FTIOB pin	R/W
0	DFA	Digital filter function A	0: Disables the digital filter for the FTIOA pin 1: Enables the digital filter for the FTIOA pin	R/W

Note: The setting in this register is valid on the corresponding pin when the FTIOA to FTIOD inputs are enabled by TRCIOR0 and TRCIOR1 and the TRGC input is selected by bits TCEG1 and TCEG0 in TRCCR2.

15.2.10 Timer RC A/D Conversion Start Trigger Control Register (TRCADCR)

Address: H'FFFF93

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	ADTRGAE	ADTRGBE	ADTRGCE	ADTRGDE
Value after reset:	1	1	1	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	—	Reserved	These bits are read as 1. The write value should be 1.	—
3	ADTRGAE	A/D conversion start trigger A enable	0: A/D conversion start trigger is not generated by compare match of GRA 1: A/D conversion start trigger is generated by compare match of GRA	R/W
2	ADTRGBE	A/D conversion start trigger B enable	0: A/D conversion start trigger is not generated by compare match of GRB 1: A/D conversion start trigger is generated by compare match of GRB	R/W
1	ADTRGCE	A/D conversion start trigger C enable	0: A/D conversion start trigger is not generated by compare match of GRC 1: A/D conversion start trigger is generated by compare match of GRC	R/W
0	ADTRGDE	A/D conversion start trigger D enable	0: A/D conversion start trigger is not generated by compare match of GRD 1: A/D conversion start trigger is generated by compare match of GRD	R/W

TRCADCR selects the trigger source to start A/D conversion. A/D conversion start trigger is generated by a corresponding compare match.

15.2.11 Timer RC Counter (TRCCNT)

Address: H'FFFF80

Bit:	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

TRCCNT is a 16-bit readable/writable up-counter. The input clock is selected by bits CKS2 to CKS0 in TRCCR1. TRCCNT can be cleared to H'0000 through a compare match of GRA by setting the CCLR bit in TRCCR1 to 1. When TRCCNT overflows from H'FFFF to H'0000, the OVF flag in TRCSR is set to 1. If the OVIE bit in TRCIER is set to 1 at this time, an interrupt request is generated. TRCCNT must always be read from or written to in units of 16 bits; 8-bit accesses are not allowed. The initial value of TRCCNT is H'0000.

15.2.12 General Registers A, B, C, and D (GRA, GRB, GRC, and GRD)

GRA

Address:	H'FFFF82															
Bit:	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

GRB

Address:	H'FFFF84															
Bit:	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

GRC

Address:	H'FFFF86															
Bit:	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

GRD

Address:	H'FFFF88															
Bit:	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

Each general register is a 16-bit readable/writable register that can function as either an output-compare register or an input-capture register. The function is selected by settings in TRCIOR0 and TRCIOR1.

When a general register is used as an input-compare register, its value is constantly compared with the TRCCNT value. When the two values match (a compare match), the corresponding flag (the IMFA, IMFB, IMFC, or IMFD bit) in TRCSR is set to 1. An interrupt request is generated at this time, when the IMIEA, IMIEB, IMIEC, or IMIED bit in TRCIER is set to 1. A compare match output can be selected in TRCIOR.

When a general register is used as an input-capture register, an external input-capture signal is detected and the current TRCCNT value is stored in the general register. The corresponding flag (the IMFA, IMFB, IMFC, or IMFD bit) in TRCSR is set to 1. If the corresponding interrupt-enable bit (the IMIEA, IMIEB, IMIEC, or IMIED bit) in TRIER is set to 1 at this time, an interrupt request is generated. The edge of the input-capture signal is selected in TRCIOR.

GRC and GRD can be used as buffer registers of GRA and GRB, respectively, by setting BUFEA and BUFEB in TRCMR.

For example, when GRA is set as an output-compare register and GRC is set as the buffer register for GRA, the value in the buffer register GRC is sent to GRA whenever compare match A is generated.

When GRA is set as an input-capture register and GRC is set as the buffer register for GRA, the value in TRCCNT is transferred to GRA and the value in the buffer register GRA is transferred to GRC whenever an input capture is generated.

GRA to GRD must be written or read in 16-bit units; 8-bit access is not allowed. GRA to GRD are initialized to H'FFFF by a reset.

15.3 Operation

Timer RC has the following operating modes.

- Timer mode operation
  Enables output compare and input capture functions by setting the IOA2 to IOA0 and IOB2 to IOB0 bits in TRCIOR0 and the IOC3 to IOC0 and IOD3 to IOD0 bits in TRCIOR1.
- PWM mode operation
  Enables PWM mode operation by setting the PWMD, PWMC, and PWMB bits in TRCMR.
- PWM2 mode operation
  Enables PWM2 mode operation by setting the PWM2 bit in TRCMR.

The FTIOA to FTIOD pins indicate the timer output mode by each register setting. Set 1 to the PMCR and PMR bits corresponding to the pins selected by the PMC.

Table 15.3 FTIOA Pin Functions

Register Name	TRCOER	TRCMR	TRCIOR0	
Bit Name	**EA**	**PWM2**	**IOA2 to IOA0**	**Function**
Setting values	0	1	001, 01X	Timer mode waveform output (output compare function)
	X	1	1XX	Timer mode (input capture function)
	X	1	000	General input port (when PCR = 0 on the corresponding pin)
	Other than above			Setting prohibited

[Legend]
X: Don't care.

Table 15.4 FTIOB Pin Functions

Register Name	TRCOER	TRCMR		TRCIOR0	
Bit Name	**EB**	**PWM2**	**PWMB**	**IOB2 to IOB0**	**Function**
Setting values	0	0	X	XXX	PWM2 mode waveform output
	0	1	1	XXX	PWM mode waveform output
	0	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	1	0	1XX	Timer mode (input capture function)
	X	1	0	000	General input port (when PCR = 0 on the corresponding pin)
	Other than above				Setting prohibited

[Legend]
X: Don't care.

Table 15.5 FTIOC Pin Functions

Register Name	TRCOER	TRCMR		TRCIOR1	
Bit Name	**EC**	**PWM2**	**PWMC**	**IOC2 to IOC0**	**Function**
Setting values	0	1	1	XXX	PWM mode waveform output
	0	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	1	0	1XX	Timer mode (input capture function)
	X	1	0	000	General input port (when PCR = 0 on the corresponding pin)
	Other than above				Setting prohibited

[Legend]
X: Don't care.

Table 15.6 FTIOD Pin Functions

Register Name	TRCOER	TRCMR		TRCIOR1	
Bit Name	ED	PWM2	PWMD	IOD2 to IOD0	Function
Setting values	0	1	1	XXX	PWM mode waveform output
	0	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	1	0	1XX	Timer mode (input capture function)
	X	1	0	000	General input port (when PCR = 0 on the corresponding pin)
	Other than above				Setting prohibited

[Legend]
X: Don't care.

15.3.1 Timer Mode Operation

TRCCNT performs free-running or periodic counting operations. After a reset, TRCCNT is set as a free-running counter. When the CTS bit in TRCMR is set to 1, TRCCNT starts counting. When the TRCCNT value overflows from H'FFFF to H'0000, the OVF flag in TRCSR is set to 1. If the OVIE in TRCIER is set to 1, an interrupt request is generated. Figure 15.2 shows an example of free-running counting.

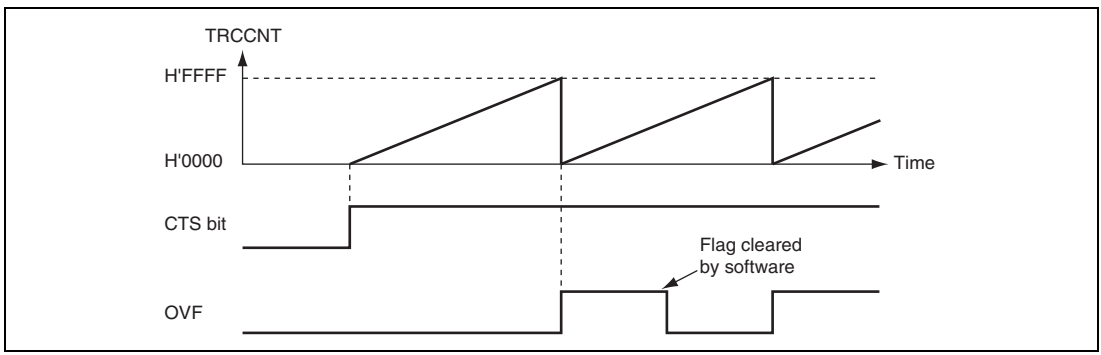


Figure 15.2 Free-Running Counter Operation

Periodic counting operation can be performed when GRA is set as an output compare register and the CCLR bit in TRCCR1 is set to 1. When the counter value matches GRA, TRCCNT is cleared to H'0000, and the IMFA flag in TRCSR is set to 1. If the corresponding IMIEA bit in TRCIER is set to 1, an interrupt request is generated. TRCCNT continues counting from H'0000. Figure 15.3 shows an example of periodic counting.

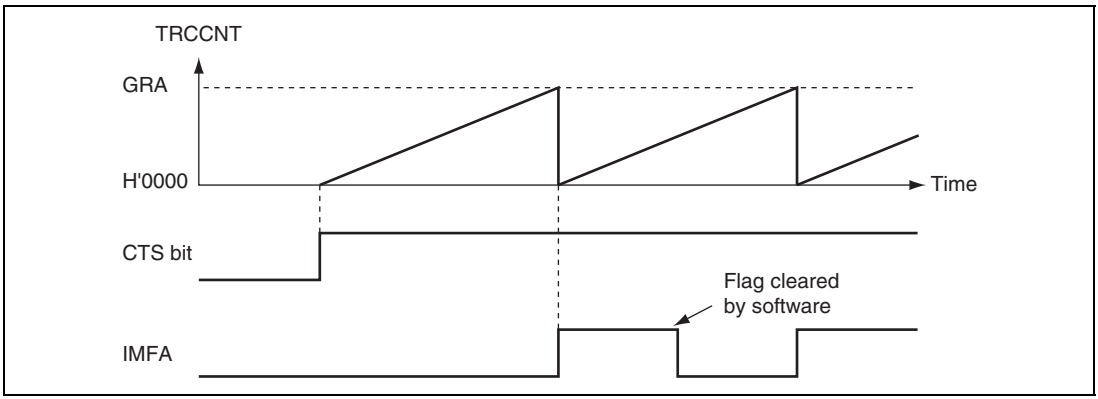


Figure 15.3 Periodic Counter Operation

By setting a general register as an output compare register, the specified level of a signal can be output on the FTIOA, FTIOB, FTIOC, or FTIOD pin on compare match A, B, C, or D. The output level can be selected from 0, 1, or toggle. Figure 15.4 shows an example of TRCCNT functioning as a free-running counter. In this example, 1 is output on compare match A and 0 is output on compare match B. When the signal level is already at the selected output level, it is not changed on a compare match.

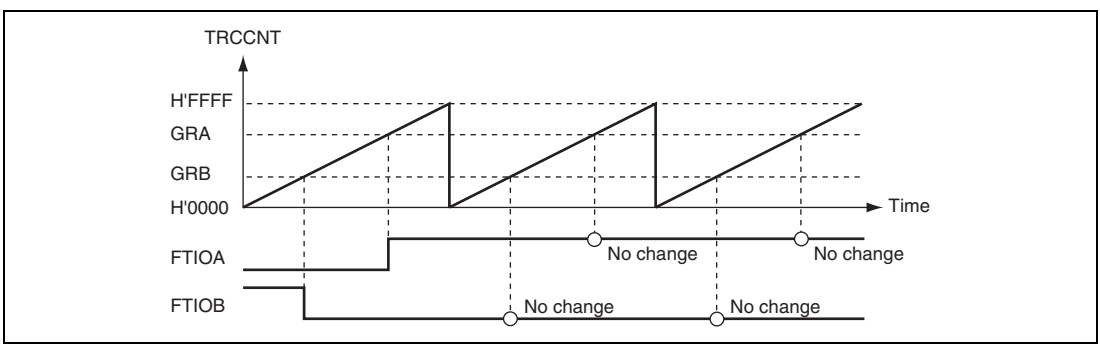


Figure 15.4 0 and 1 Output Example (TOA = 0, TOB = 1)

Figure 15.5 shows an example of toggled output when TRCCNT functions as a free-running counter, and the toggled output is selected for both compare matches A and B.

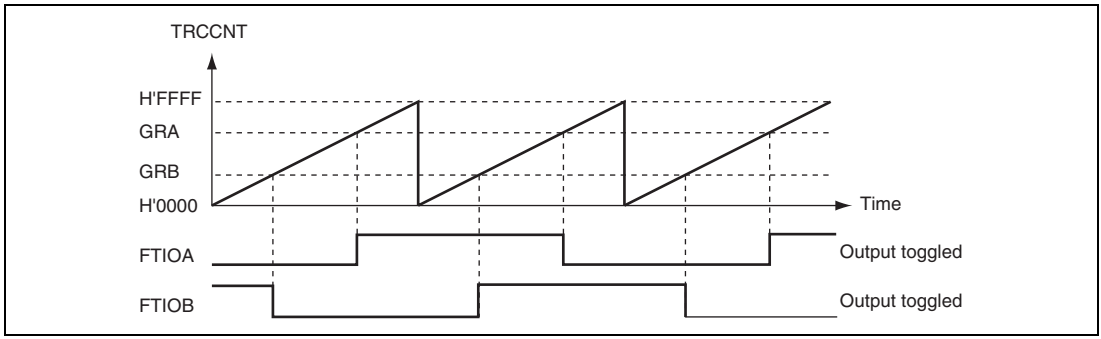


Figure 15.5 Toggle Output Example (TOA = 0, TOB = 1)

Figure 15.6 shows another example of toggled output when TRCCNT functions as a periodic counter on both compare matches A and B.

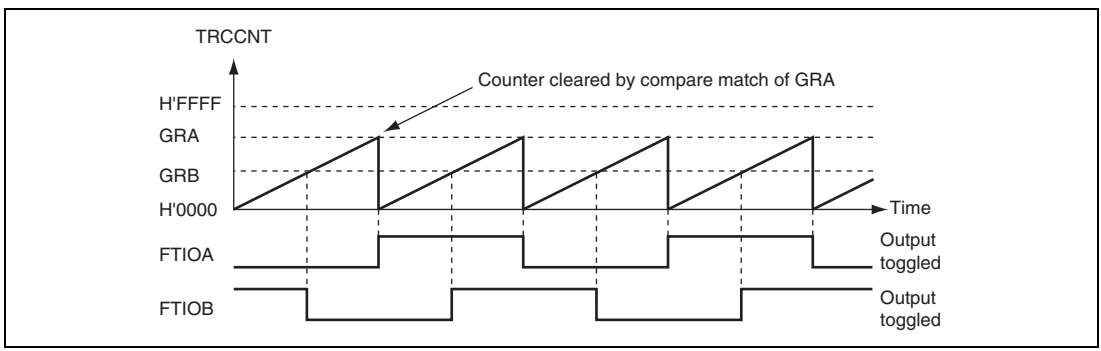


Figure 15.6 Toggle Output Example (TOA = 0, TOB = 1)

The TRCCNT value can be captured into a general register (GRA, GRB, GRC, or GRD) when signal levels are changed on an input-capture pin (FTIOA, FTIOB, FTIOC, or FTIOD) by specifying the general register as an input capture register. The capture timing can be selected from the rising, falling, or both edges. By using the input-capture function, the width or cycle of a pulse can be measured. Figure 15.7 shows an example of an input capture when both edges of the FTIOA signal and the falling edge of the FTIOB signal are selected as capture timings. TRCCNT functions as a free-running counter.

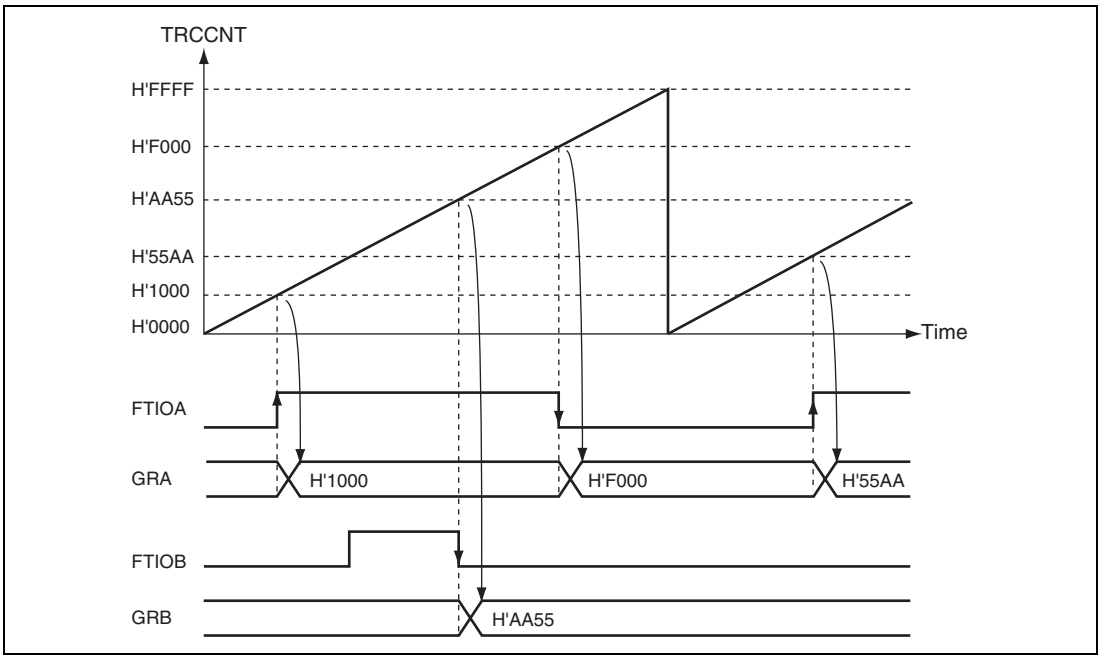


Figure 15.7 Input Capture Operating Example

Figure 15.8 shows an example of buffer operation when GRA is set as an input-capture register and GRC is set as the buffer register for GRA. TRCCNT functions as a free-running counter and is captured at both rising and falling edges of the FTIOA signal. Due to the buffer operation, the GRA value is transferred to GRC on an input-capture A and the TRCCNT value is stored in GRA.

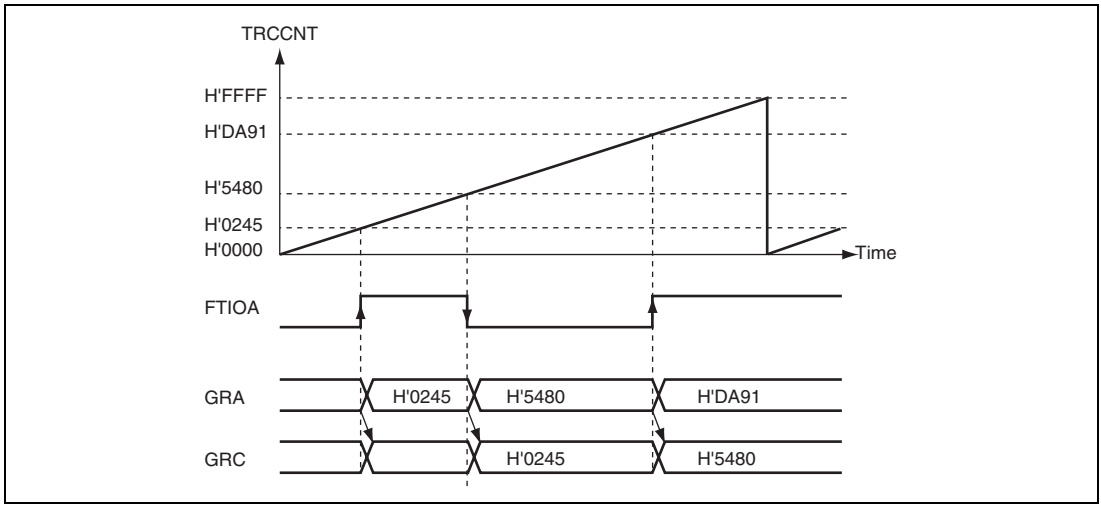


Figure 15.8 Buffer Operation Example (Input Capture)

15.3.2 PWM Mode Operation

In PWM mode, PWM waveforms are generated by using GRA as the cycle register and GRB, GRC, and GRD as duty cycle registers. PWM waveforms are output from the FTIOB, FTIOC, and FTIOD pins. Up to three-phase PWM waveforms can be output. In PWM mode, a general register functions as an output compare register automatically. The initial output level of each pin depends on the settings in TRCCR1 and TRCCR2. Table 15.7 shows an example of the initial output level of the FTIOB pin.

Table 15.7 Initial Output Level of FTIOB Pin

Bit TOB (TRCCR1)	Bit POLB (TRCCR2)	Initial Output Level
0	0	1
0	1	0
1	0	0
1	1	1

The output level of each pin is determined by the value of the corresponding PWM mode output level control bit (POLB, POLC, or POLD) in TRCCR2. When POLB is 0, the FTIOB output pin is set to 0 on compare match B, and set to 1 on compare match A, whereas when POLB is 1, the FTIOB output pin is set to 1 on compare match B, and set to 0 on compare match A. When an output pin is set to PWM mode, the settings in TRCIOR0 and TRCIOR1 are ignored. If the same value is set in the cycle register and duty cycle register, output levels are not changed when a compare match occurs.

Figure 15.9 shows an example of operation in PWM mode. The output signals go 1 and TRCCNT is cleared on compare match A, and the output signals go 0 on compare match B, C, and D.

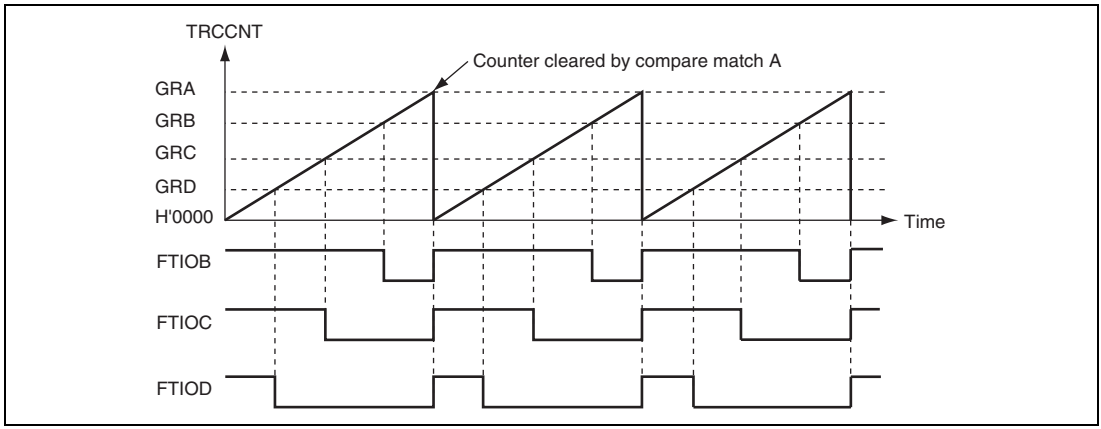


Figure 15.9 PWM Mode Example (1)

Figure 15.10 shows another example of operation in PWM mode. The output signals go 0 and TRCCNT is cleared on compare match A, and the output signals go 1 on compare match B, C, and D.

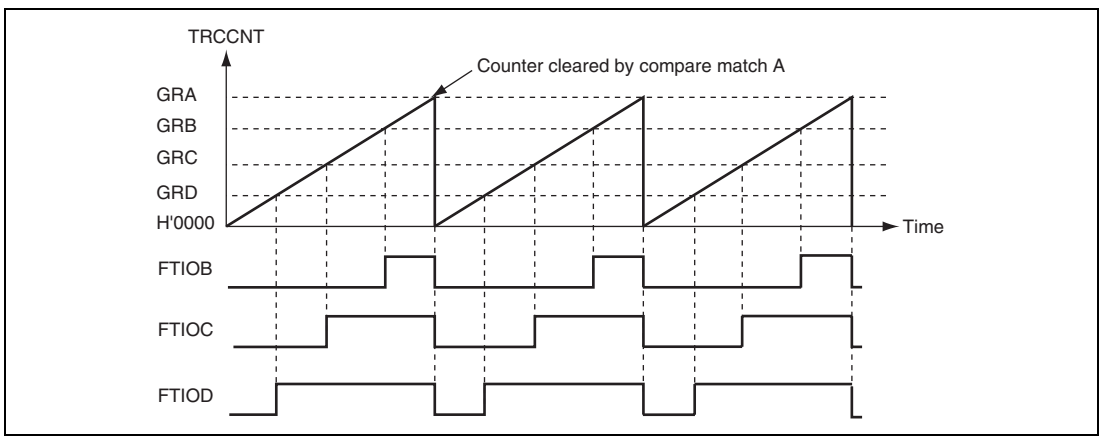


Figure 15.10 PWM Mode Example (2)

Figure 15.11 shows an example of buffer operation when the FTIOB pin is set to PWM mode and GRD is set as the buffer register for GRB. TRCCNT is cleared on compare match A, and the FTIOB pin outputs 1 on compare match B and 0 on compare match A.

Due to the buffer operation, the FTIOB output levels are changed and the value of buffer register GRD is transferred to GRB whenever compare match B occurs. This procedure is repeated every time compare match B occurs.

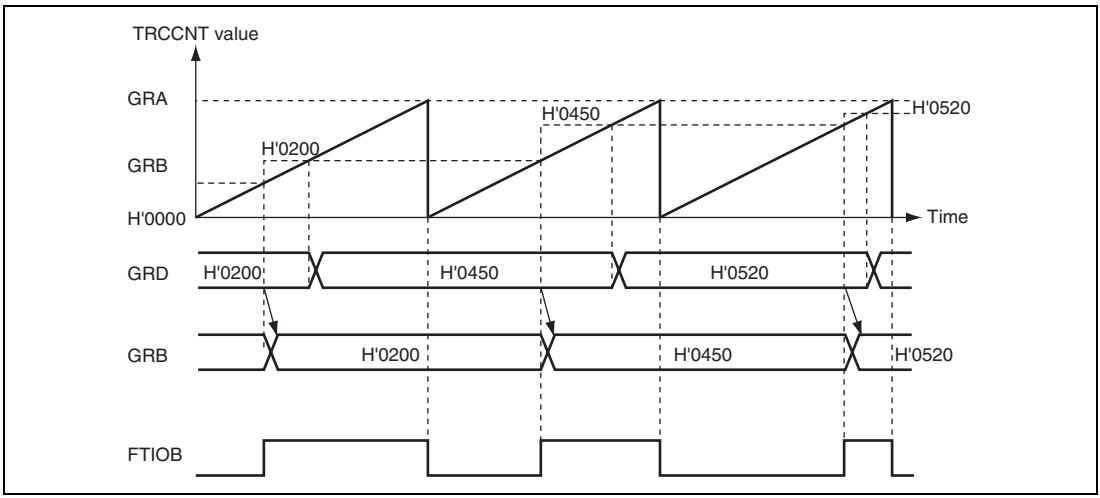


Figure 15.11 Buffer Operation Example (Output Compare)

Figures 15.12 and 15.13 show examples of the output of PWM waveforms with duty cycles of 0% and 100%.

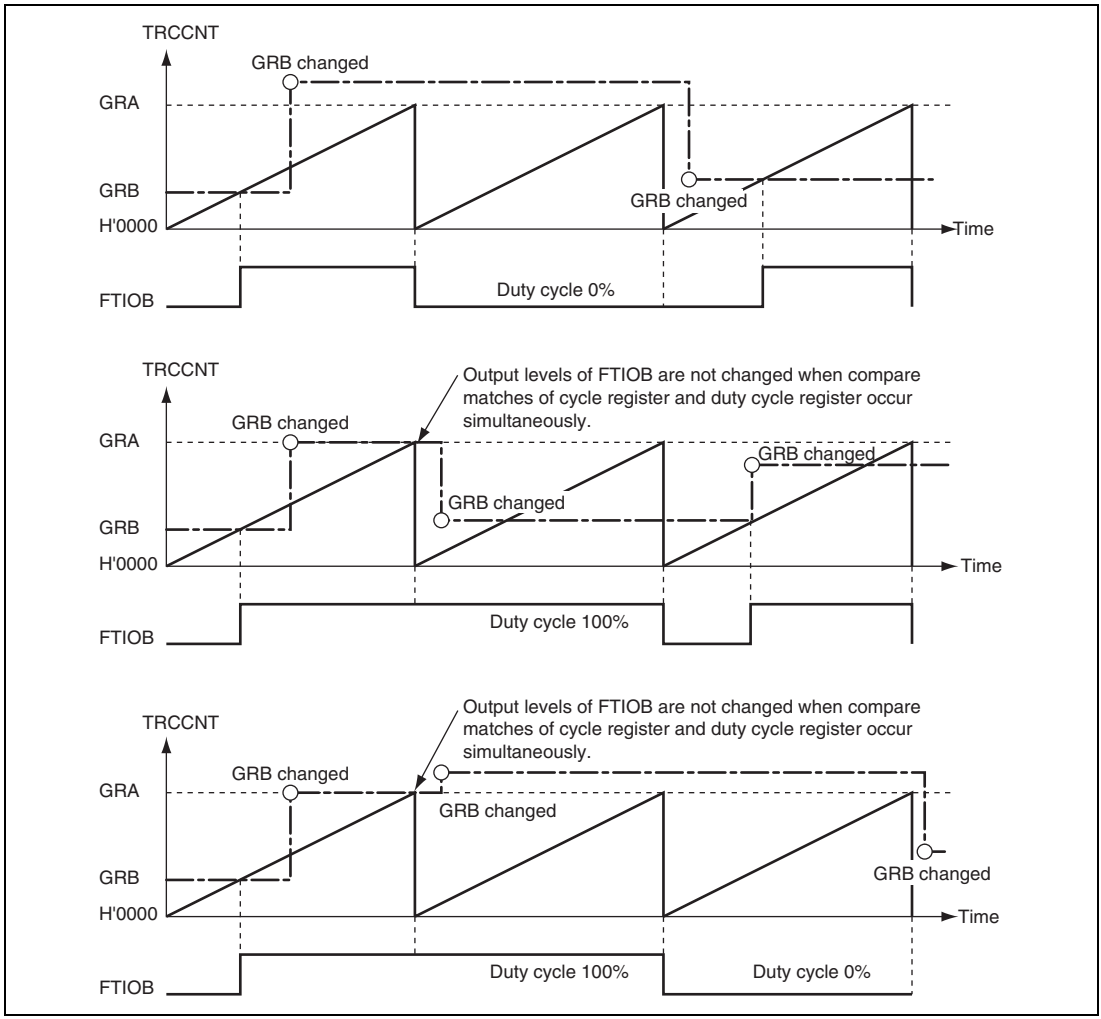


Figure 15.12 PWM Mode Example (Initial Output Set to 0)

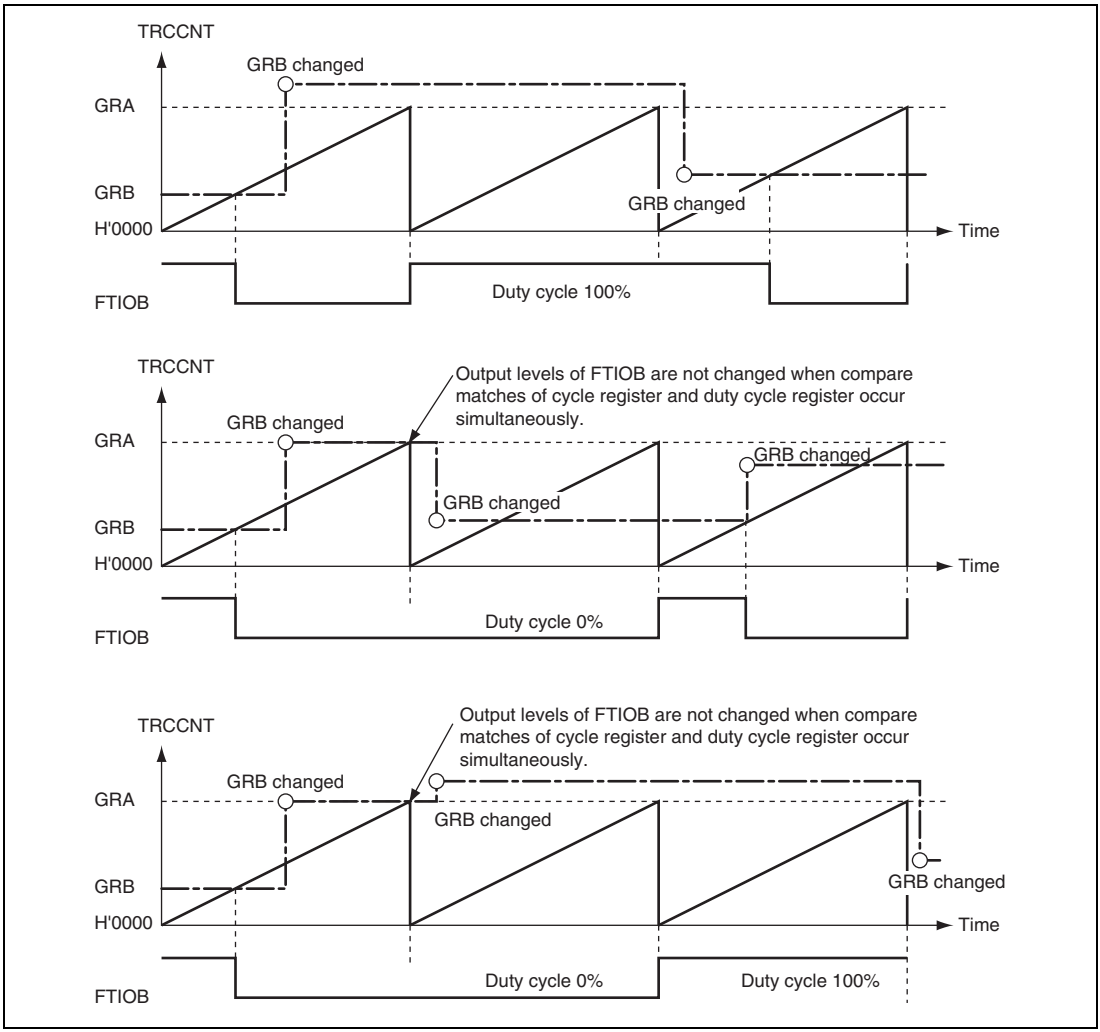


Figure 15.13 PWM Mode Example (Initial Output Set to 1)

15.3.3 PWM2 Mode Operation

In PWM2 mode, waveforms are output on the FTIOB pin when a compare match occurs on GRB or GRC. GRD functions as a buffer register for GRB by setting the BUFEB bit in TRCMR to 1. The output level of the FTIOB signal is specified by the TOB bit in TRCCR1. When TOB = 0, 1 is output on a compare match of GRC and 0 is output on a compare match of GRB. When TOB = 1, 0 is output on a compare match of GRC and 1 is output on a compare match of GRB.

Table 15.8 shows the correspondence between the pin configuration and GR registers and figure 15.14 is a block diagram in PWM2 mode.

Figures 15.15 and 15.16 show the GRD and GRB buffer operating timing in PWM2 mode.

In PWM2 mode, the value of GRD is transferred to GRB on a compare match of GRA and the counter is cleared. Note, however, that the counter is only cleared when the CCLR bit in TRCCR1 is set to 1. Moreover, when the trigger input is enabled by the TCEG1 and TCEG0 bits in TRCCR2, the value of GRD is transferred to GRB by the trigger signal and the counter is cleared. The input/output pins of timers which do not operate in PWM2 mode are only used as general I/O ports.

Table 15.8 Pin Configuration in PWM2 Mode and GR Registers

Pin Name	Input/Output	Compare Match Register	Buffer Register
FTIOA	I/O	Port*/TRGC	Port*/TRGC
FTIOB	Output	GRB	GRD
		GRC	—
FTIOC	I/O	Port*	Port*
FTIOD	I/O	Port*	Port*

Note: * When the port functions, clear the PMR bit on the corresponding pin to 0.

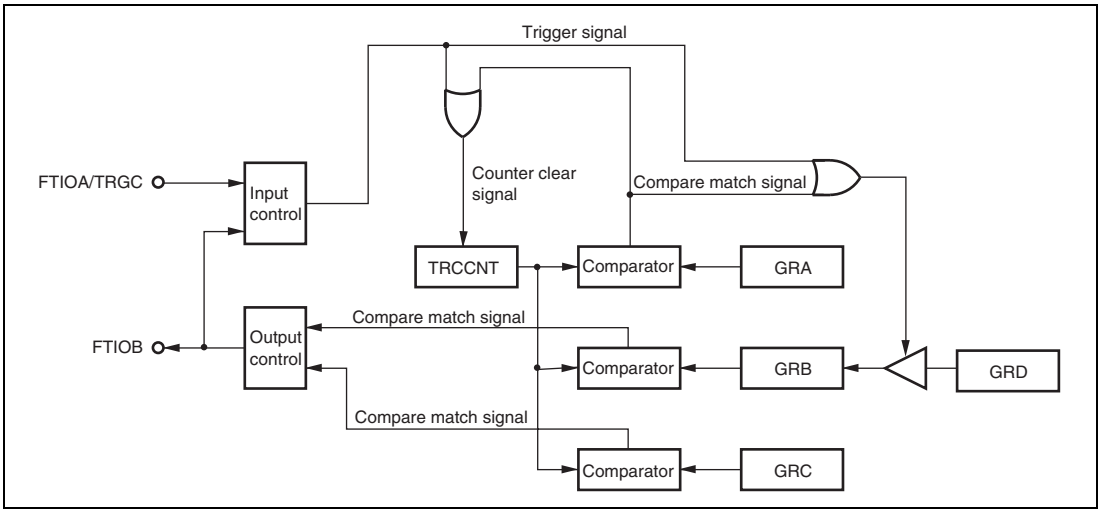


Figure 15.14 Block Diagram in PWM2 Mode

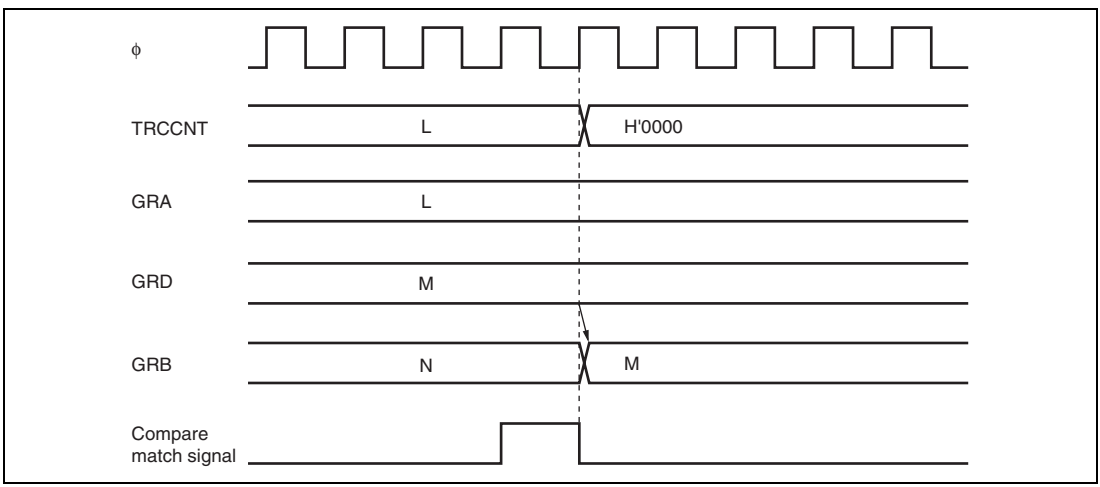


Figure 15.15 GRD and GRB Buffer Operating Timing in PWM2 Mode (1)

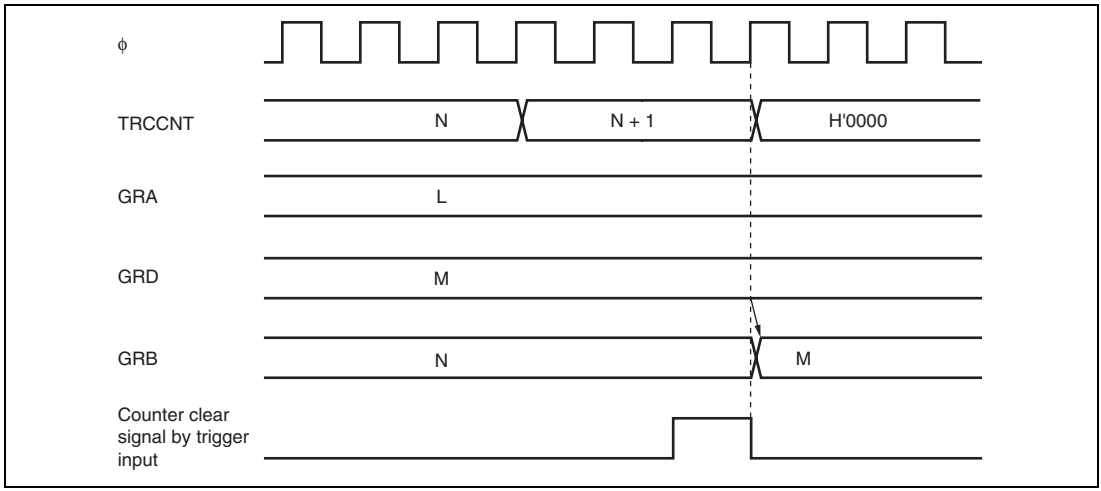


Figure 15.16 GRD and GRB Buffer Operating Timing in PWM2 Mode (2)

In PWM2 mode, a pulse with arbitrary pulse width and delay time to the TRGC input can be output from the FTIOB pin

Figures 15.17 and 15.18 show these examples in PWM2 mode. In these examples, the falling edge of the TRGC input is selected by TRCCR2 (setting the TCEG1 bit to 1 and clearing the TCEG0 bit to 0), TRCCNT continues counting-up on compare match A of GRA (clearing the CSTP bit in TRCCR2 to 0), and GRD is set as the buffer register (setting the BUFEB bit in TRCMR to 1). The initial value of the output signal is set to either 0 or 1 by TRCCR1 (clearing the TOB bit to 0 or setting the TOB bit to 1), TRCCNT is cleared on compare match A (setting the CCLR bit in TRCCR1 to 1), and the waveform is output from the FTIOB pin (clearing the PWM2 bit in TRCMR to 0).

When the TOB bit in TRCCR1 is cleared to 0 with the PWM2 mode function, the input edge is ignored while the FTIOB pin is driven high. Whereas, when the TOB bit is set to 1, the input edge is ignored while the FTIOB pin is driven low. The transfer from GRD to GRB is carried out on a compare match of GRA and the TRGC input. However, if the TRGC input is canceled due to the change of the FTIOB level, the transfer from GRD to GRB is not carried out.

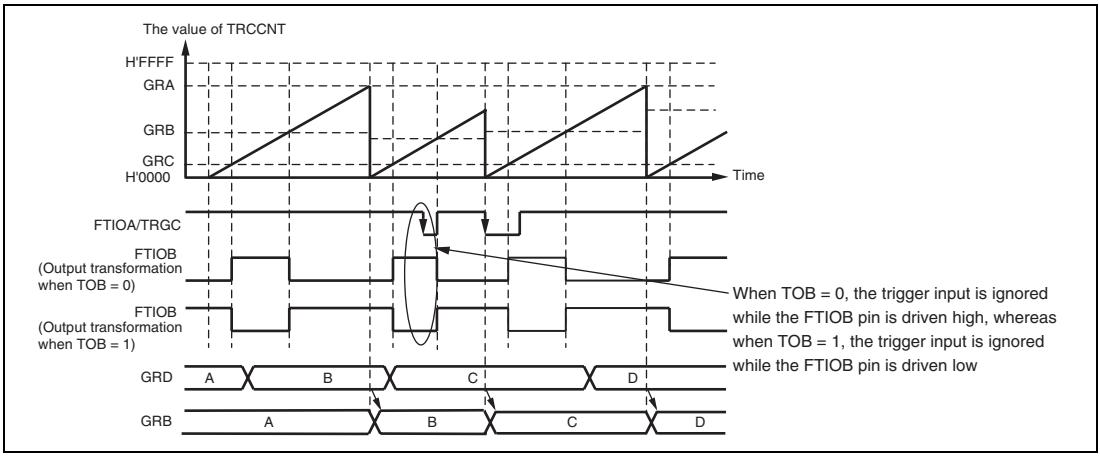


Figure 15.17 Example (1) of TRGC Synchronous Operation in PWM2 Mode

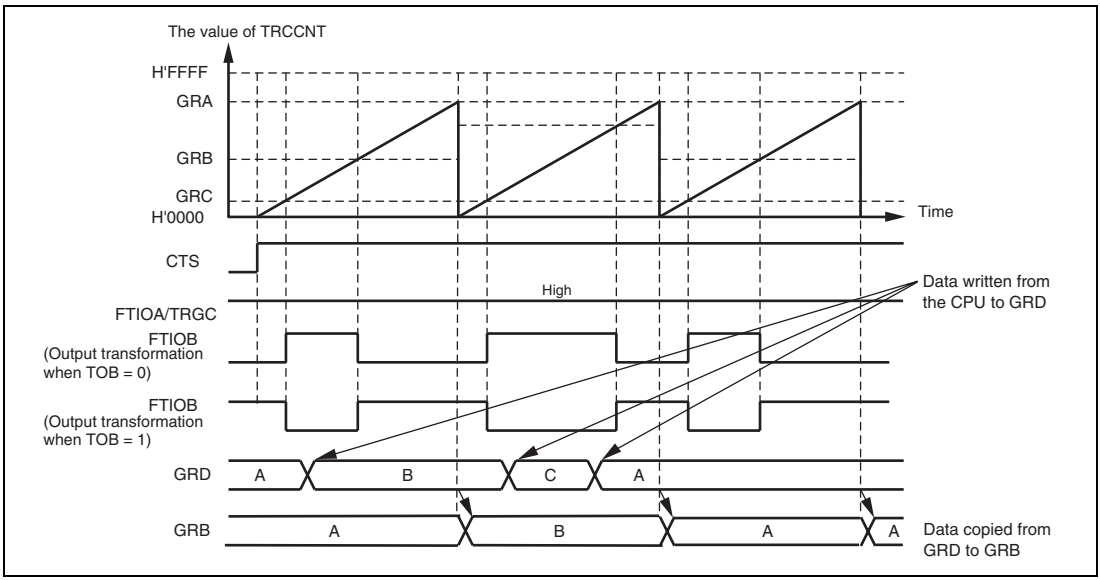


Figure 15.18 Example (2) of TRGC Synchronous Operation in PWM2 Mode

The following is an example of stopping operation of the counter in PWM2 mode. When the CSTP bit in TRCCR2 is set to 1 and the CCLR bit in TRCCR1 is set to 1, TRCCNT is cleared to H'0000 on a compare match with GRA and stops counting. Moreover, TRCCNT is forcibly stopped and cleared to the initial value when the CTS bit in TRCMR is cleared to 0. Figure 15.19 shows such an example when the TOB bit in TRCCR1 is cleared to 0 and set to 1.

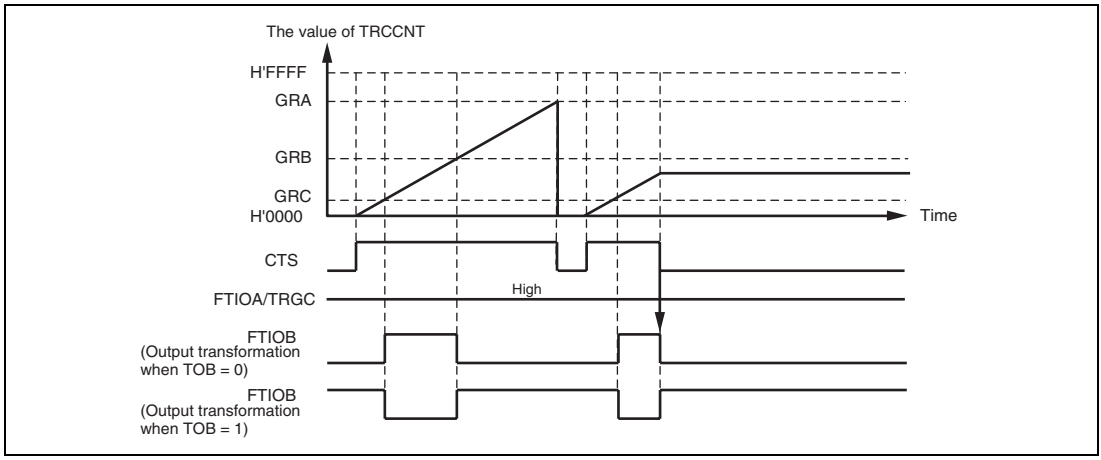


Figure 15.19 Example of Stopping Operation of the Counter in PWM2 Mode

The following is an example of output operation of the one-shot pulse waveform in PWM2 mode. When the TRGC input is disabled by TRCCR2 (clearing the TCEG1 and TCEG0 bits to 0), TRCCNT is set to stop counting-up on compare match A with GRA (setting the CSTP bit in TRCCR2 to 1), TRCCNT is cleared on compare match A (setting the CCRL bit in TRCCR1 to 1), and the initial value of the output signal is set to 0 by TRCCR1 (clearing the TOB bit to 0), TRCCNT starts counting when the CTS bit in TRCMR is set to 1. Then, TRCCNT is cleared to H'0000 on a compare match with GRA and stops counting, and the one-shot pulse waveform is output. Figure 15.20 shows such an example.

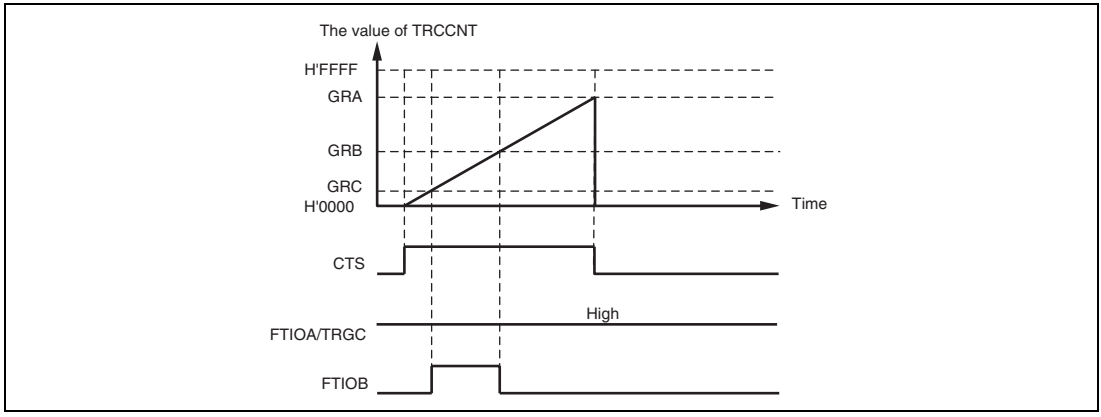


Figure 15.20 Example (1) of Output Operation of One-Shot Pulse Waveform in PWM2 Mode

The following is an example of operation when TRCCNT starts counting by the TRGC input and the one-shot pulse waveform is output in PWM2 mode. When the falling edge of the TRGC input is selected by TRCCR2 (setting the TCEG1 bit to 1 and clearing the TCEG0 bit to 0), TRCCNT is set to counting-up on compare match A with GRA (setting the CSTP bit in TRCCR2 to 1), TRCCNT is cleared on compare match A (setting the CCRL bit in TRCCR1 to 1), and the initial value of the output signal is set to 0 by TRCCR1 (clearing the TOB bit to 0), TRCCNT starts counting at the falling edge of FTIOA/TRGC after the CTS bit in TRCMR has been set to 1. Then, TRCCNT is cleared to H'0000 on a compare match with GRA and stops counting, and the one-shot pulse waveform is output. Figure 15.21 shows such an example.

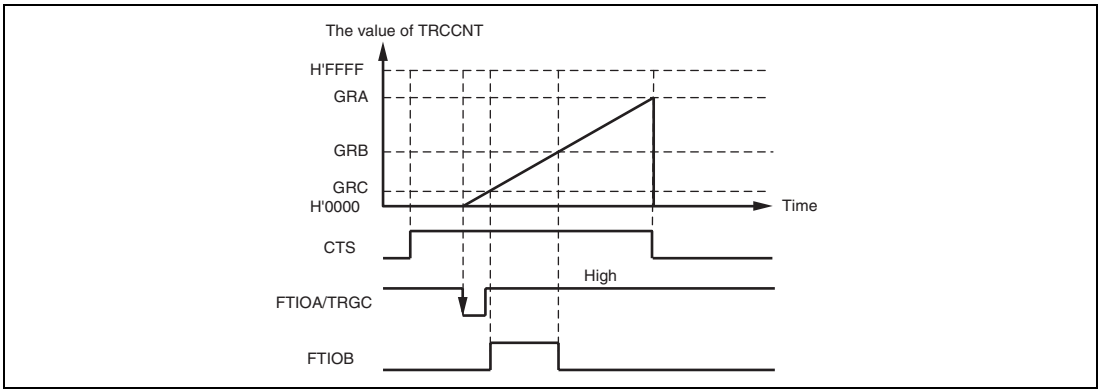


Figure 15.21 Example (2) of Output Operation of One-Shot Pulse Waveform in PWM2 Mode

15.3.4 Digital Filtering Function for Input Capture Inputs

Input signals on the FTIOA to FIOD and TRGC pin can be input via the digital filters. The digital filter includes three latches connected in series and a match detector circuit. The input signals on the FTIOA to FTIOD or TRGC pins are using on the sampling clock specified by the DFCK1 and DFCK0 bits in TRCDF. When outputs of the three latches match, the match detector circuit outputs the signal level of the input. Otherwise, the output remains unchanged. That is, when a pulse width is equal to or greater than three sampling clock cycles, the pulse is input as a signal. When a pulse width is less than three sampling clock cycles, the pulse is considered as noise to be removed.

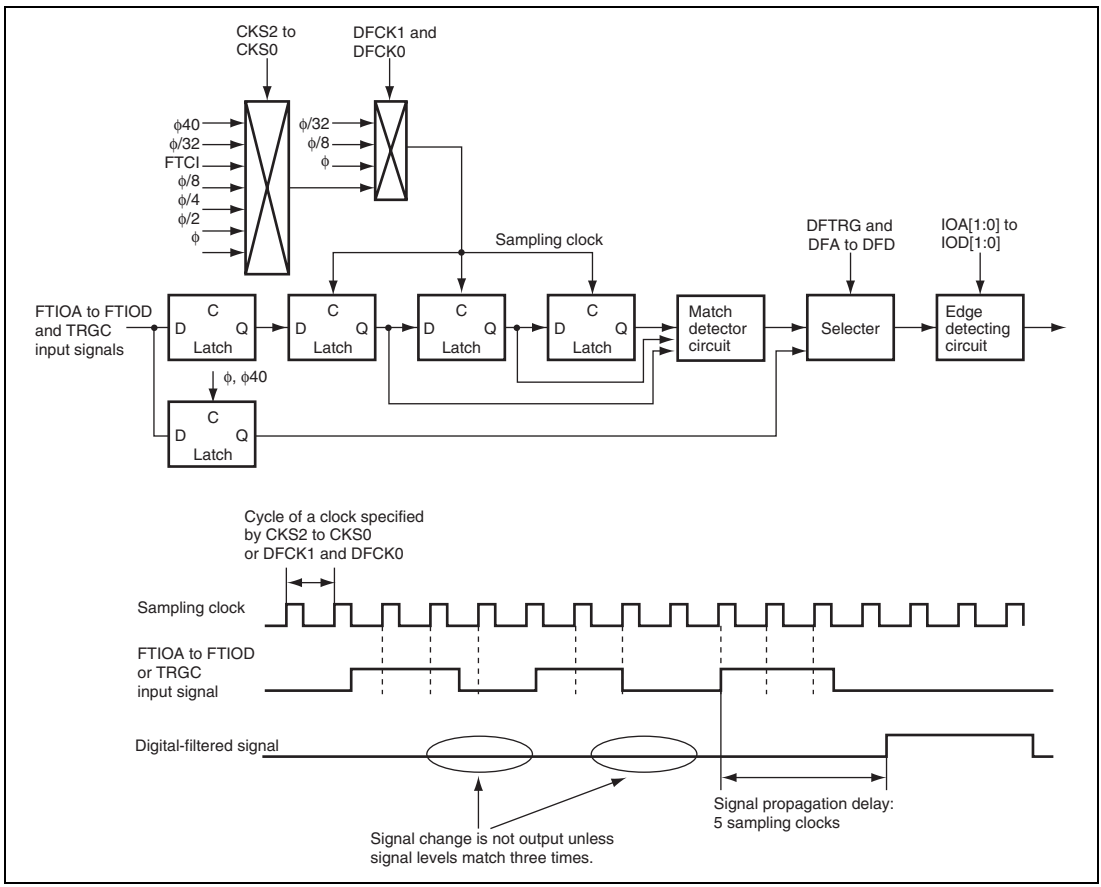


Figure 15.22 Block Diagram of Digital Filter

15.3.5 A/D Conversion Start Trigger Setting Function

Timer RC can generate the A/D conversion start trigger signal on compare matches A, B, C, and D by setting the timer RC A/D conversion start trigger control register (TRCADCR). Figure 15.23 shows an example where the A/D conversion start trigger signal is set to be output on compare matches B and C.

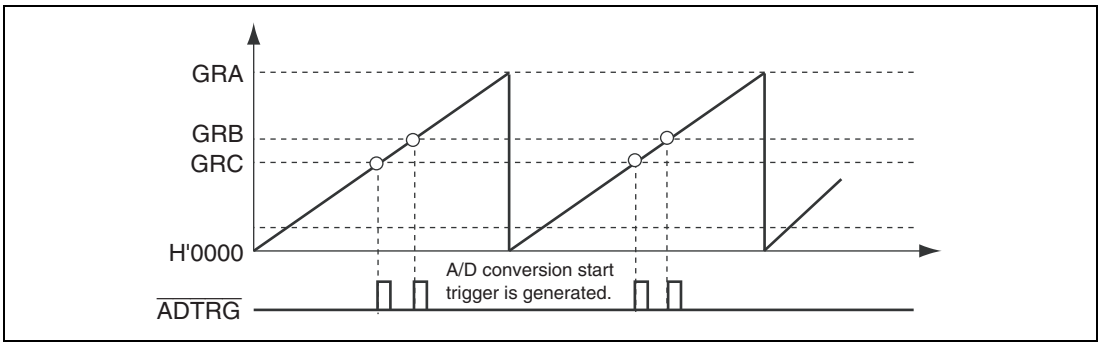


Figure 15.23 Example of Compare Match

In buffer operation, a buffer register cannot be used to generate the A/D conversion start trigger. Moreover, GRC cannot serve as a buffer register for GRA in PWM2 mode. Table 15.9 shows the A/D conversion start trigger source in each operating mode.

Table 15.9 A/D Conversion Start Trigger Generation in Each Operating Mode

		A/D Conversion Start Trigger Generation			
Operating Mode	**Buffer Operation**	**GRA**	**GRB**	**GRC**	**GRD**
Input capture	Enabled	×	×	×	×
	Disabled	×	×	×	×
Compare match	Enabled	O	O	×	×
	Disabled	O	O	O	O
PWM mode	Enabled	O	O	×	×
	Disabled	O	O	O	O
PWM2 mode	Enabled	O	O	O	×
	Disabled	O	O	O	O

[Legend]

O: The A/D conversion start trigger signal is generated.

×: The A/D conversion start trigger signal is not generated.

15.3.6 Function of Changing Output Pins for GR

With the settings of bits IOC3 and IOD3 in TRCIOR1, pins for outputs of compare match signals for GRC and GRD can be changed from the FTIOC and FTIOD pins to the FTIOA and FTIOB pins. This means that the compare match A signal with the compare match C signal can be output on the FTIOA pin. The compare match B with the compare match D signal can be output on the FTIOB pin. Figure 15.24 is a block diagram of this function. Channel 0 and channel 1 can be set independently.

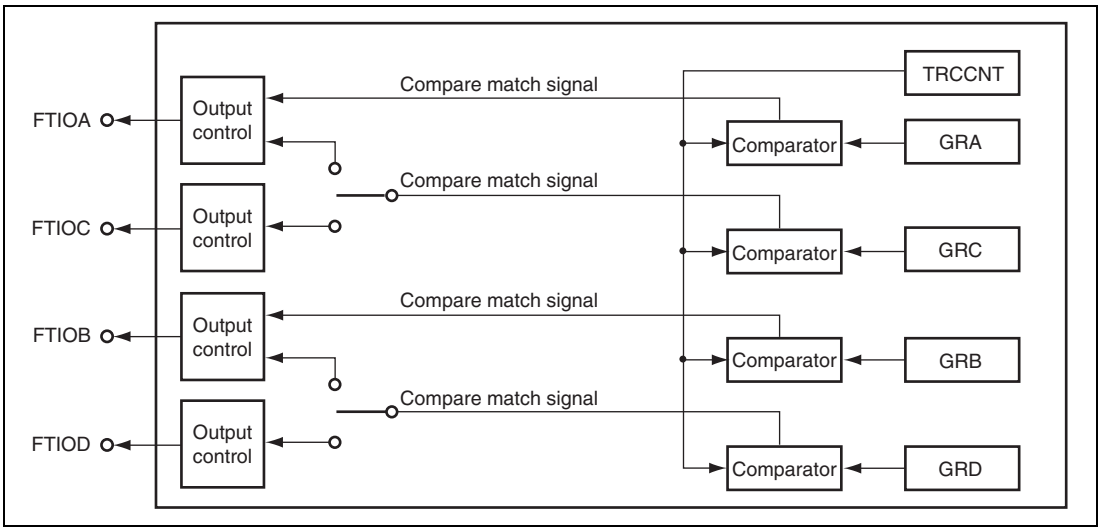


Figure 15.24 Block Diagram of Output Pins for GR

Figure 15.25 is an example when non-overlapped pulses are output on pins FTIOA and FTIOB. In this example, TRCCNT functions as a periodic counter which is cleared on compare match A (bit CCLR in TRCCR1 is set to 1), an output signal is toggled on compare match A (bits IOA2 to IOA0 in TRCIOR0 are set to B'011), the output signal on the FTIOA pin is toggled on compare match C (GRC) (bits IOC3 to IOC0 in TRCIOR1are set to B'0X11), an output signal is toggled on compare match B (GRB) (bits IOB2 to IOB0 in TRCIOR0 are set to B'011), and the output signal on the FTIOB pin is toggled on compare match D (GRD) (bits IOD3 to IOD0 in TRCIOR1 are set to B'0X11). The cycle of the pulse is arbitrary.

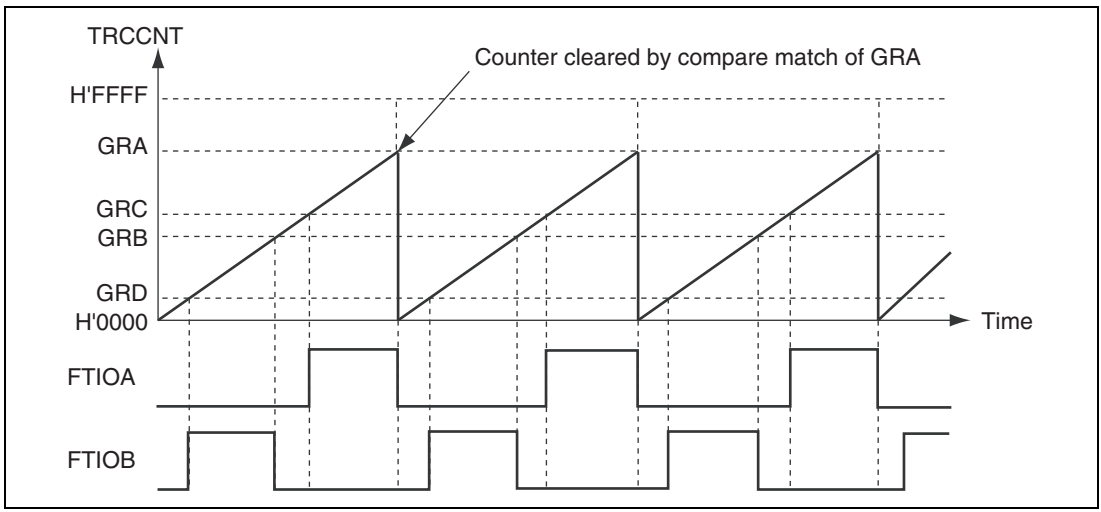


Figure 15.25 Example of Non-Overlapped Pulses Output on Pins FTIOA and FTIOB (TRCCNT Used)

15.3.7 Operation through an Event Link

Using the event link controller (ELC), timer RC can be made to operate in the following ways in relation to events occurring in other modules.

(1) Staring Counter Operation

The start of counting operations by timer RC can be selected by ELOPA of the ELC. When the event specified by ELSR2 occur, the CTS bit in TRCMR is set to 1, which stars counting by timer RC. However, if the specified event occurs when the CTS bit has already been set to 1, the event is not effective.

(2) Counting Event

The counting of events by timer RC can be selected by ELOPA of the ELC. When the event specified in ELSR2 occurs, event counter operation proceeds with that event as the source to drive counting, regardless of the setting of the CKS[2:0] bits in TRCCR1. When the value of the counter is read, the value read out is the actual number of input events.

(3) Input Capture

Input capture operation of timer RC can be selected by ELOPA of the ELC. When the event specified in ELSR2 occurs, GRD captures the value of TRCCNT. When input capture operation initiated by an event link is in use, set the IOD[3:0] bits = b'1101 in TRCIOR1 of timer RC, set the CTS bit in TRCMR to 1, and then start the counter. Since input on the FTIOD pin becomes valid at the same time, fix the input to the FTIOD pin or take other measures such as not allocating the FTIOD pin to the port in the PMC, etc.

15.4 Operation Timing

15.4.1 TRCCNT Counting Timing

Figure 15.26 shows the TRCCNT count timing when the internal clock source is selected. Figure 15.27 shows the timing when the external clock source is selected.

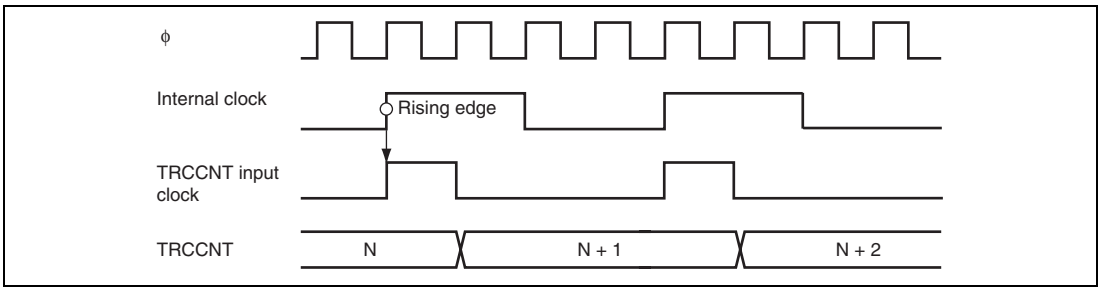


Figure 15.26 Count Timing for Internal Clock Source

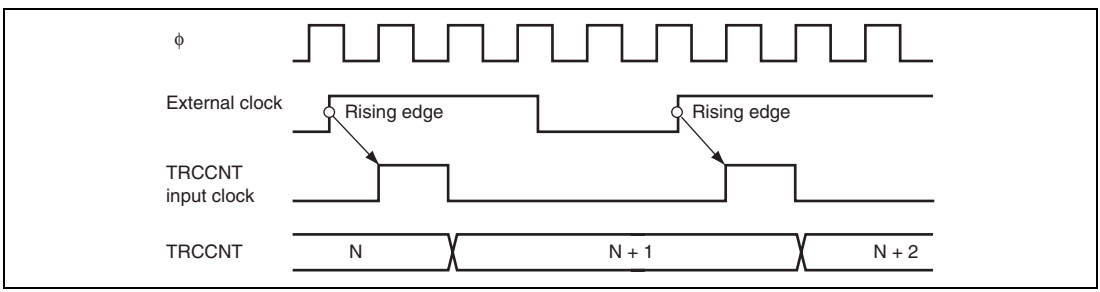


Figure 15.27 Count Timing for External Clock Source

15.4.2 Output Compare Output Timing

The compare match signal is generated in the last state in which TRCCNT and GR match (when TRCCNT changes from the matching value to the next value). When the compare match signal is generated, the output value selected in TRCIOR is output on the compare match output pin (FTIOA, FTIOB, FTIOC, or FTIOD).

When TRCCNT matches GR, the compare match signal is generated only after the next counter clock pulse is input.

Figure 15.28 shows the output compare timing.

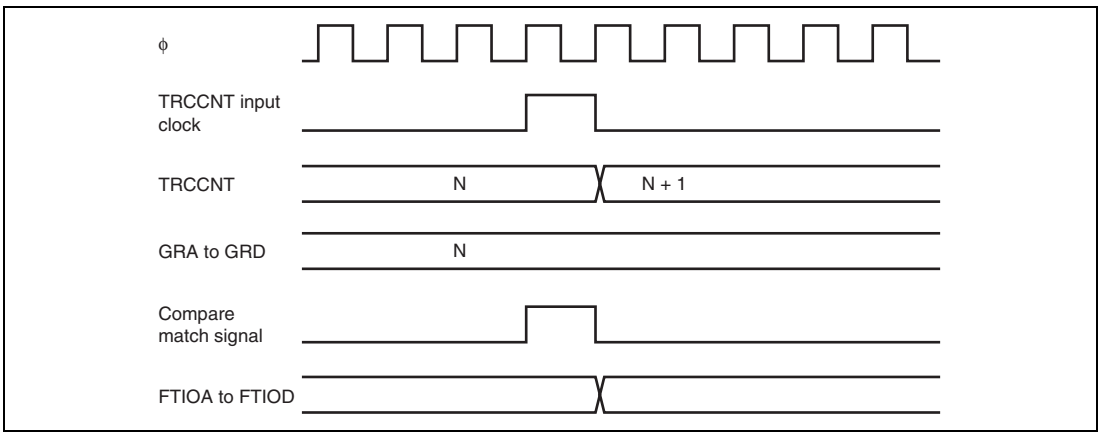


Figure 15.28 Output Compare Output Timing

15.4.3 Input Capture Timing

Input capture on the rising edge, falling edge, or both edges can be selected through settings in TRCIOR0 and TRCIOR1. Figure 15.29 shows the timing when the falling edge is selected.

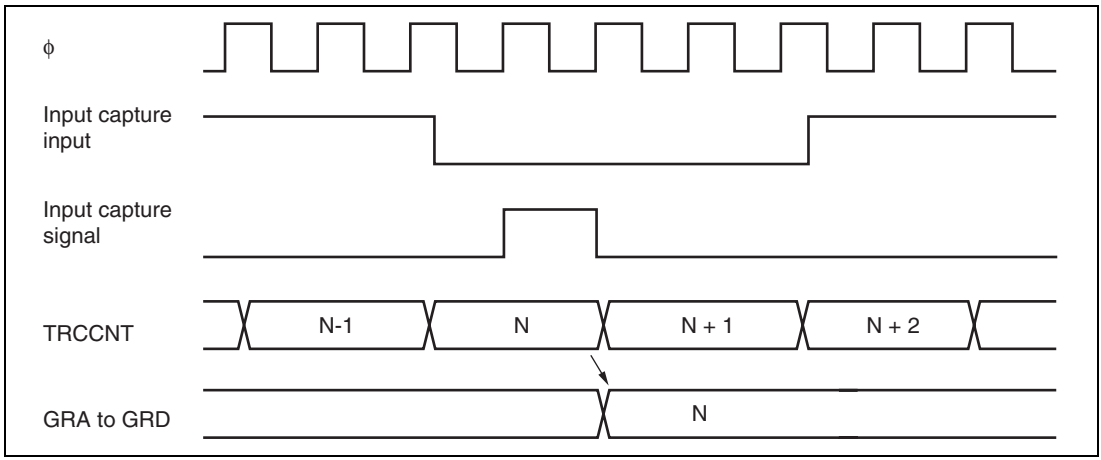


Figure 15.29 Input Capture Input Signal Timing

15.4.4 Timing of Counter Clearing by Compare Match

Figure 15.30 shows the timing when the counter is cleared by compare match A. When the GRA value is N, the counter counts from 0 to N, and its cycle is N + 1.

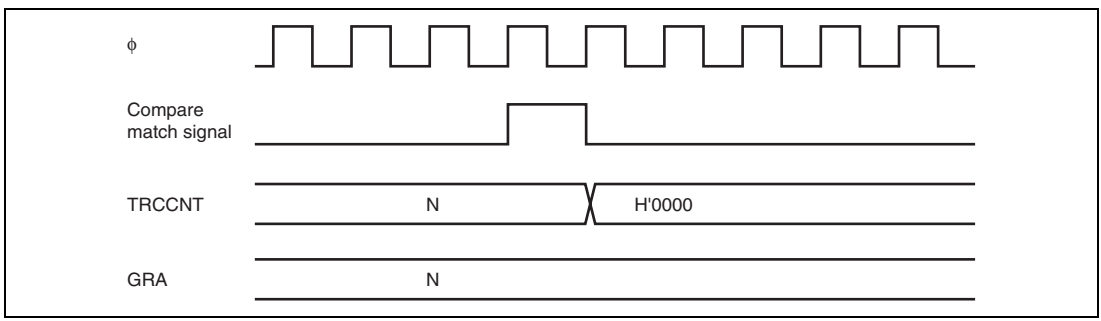


Figure 15.30 Timing of Counter Clearing by Compare Match

15.4.5 Buffer Operation Timing

Figures 15.31 and 15.32 show the buffer operation timing.

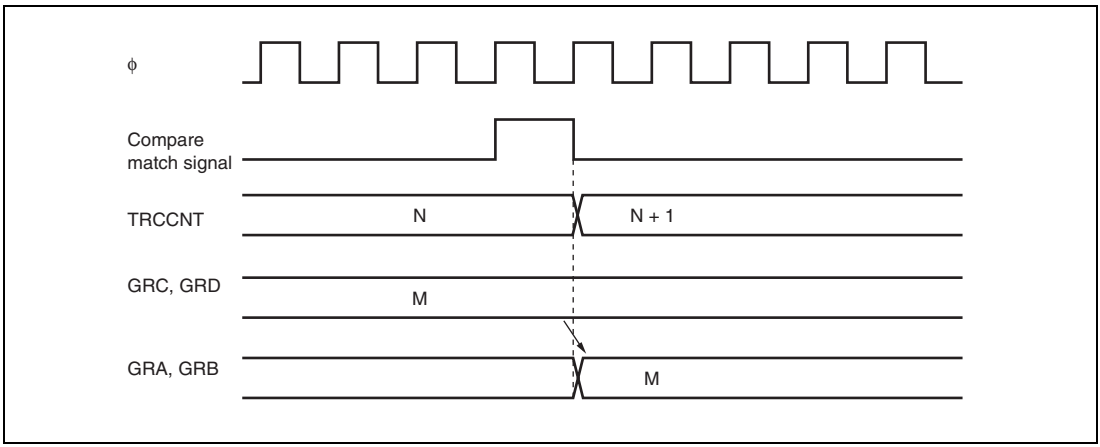


Figure 15.31 Buffer Operation Timing (Compare Match)

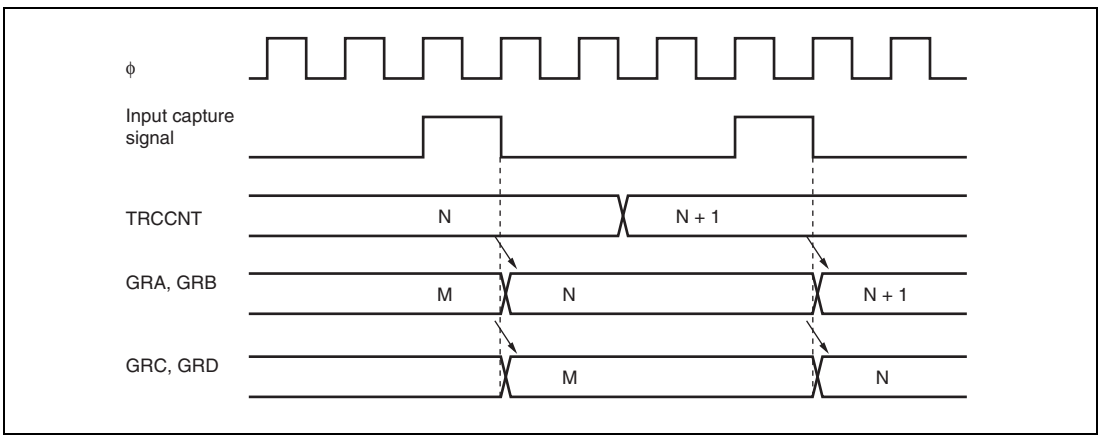


Figure 15.32 Buffer Operation Timing (Input Capture)

15.4.6 Timing of IMFA to IMFD Flag Setting at Compare Match

If a general register (GRA, GRB, GRC, or GRD) matches TRCCNT, the corresponding IMFA to IMFD flag which is used as output compare register is set to 1.

The compare match signal is generated in the last state in which the values match (when TRCCNT is updated from the matching count to the next count). Therefore, when TRCCNT matches a general register (GRA, GRB, GRC, or GRD), the compare match signal is generated only after the next TRCCNT clock pulse is input.

Figure 15.33 shows the timing of the IMFA to IMFD flag setting at compare match.

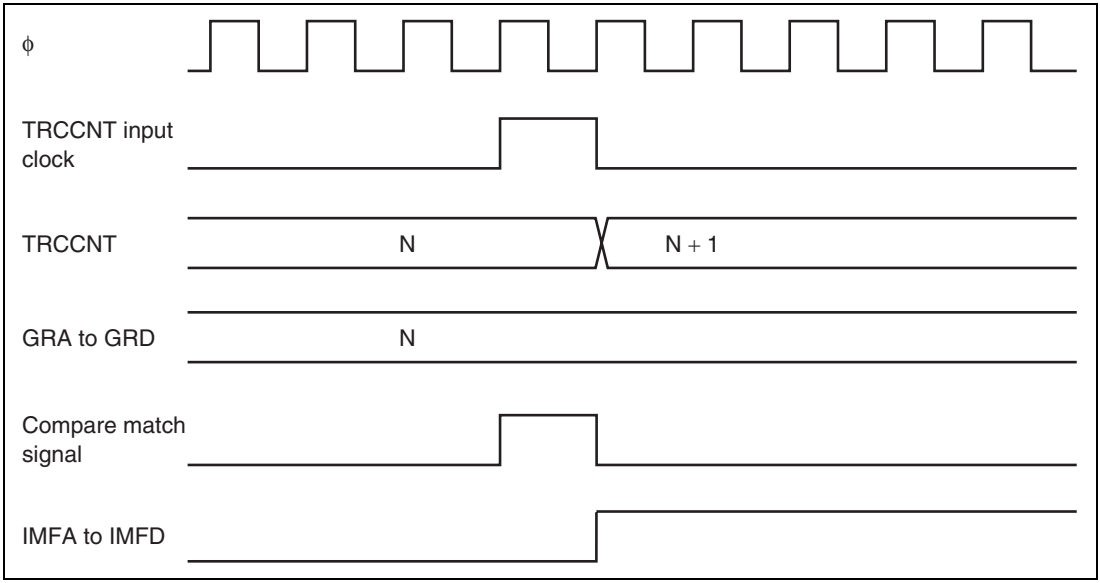


Figure 15.33 Timing of IMFA to IMFD Flag Setting at Compare Match

15.4.7 Timing of IMFA to IMFD Setting at Input Capture

The corresponding IMFA, IMFB, IMFC, or IMFD flag which functions as a general register is set to 1 when an input capture occurs. Figure 15.34 shows the timing of the IMFA to IMFD flag setting at input capture.

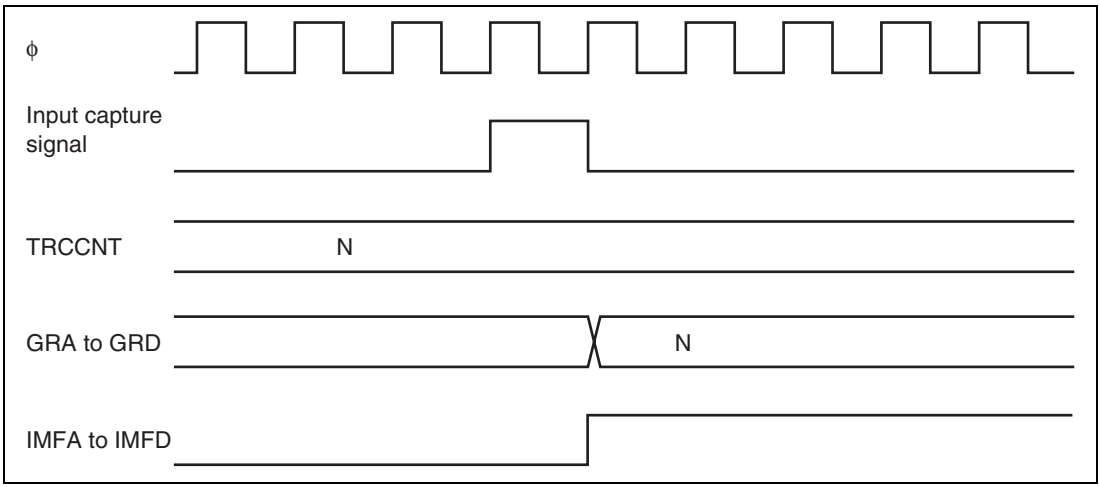


Figure 15.34 Timing of IMFA to IMFD Flag Setting at Input Capture

15.4.8 Timing of Status Flag Clearing

When the CPU reads a status flag while it is set to 1, then writes 0 in the status flag, the status flag is cleared. Figure 15.35 shows the status flag clearing timing.

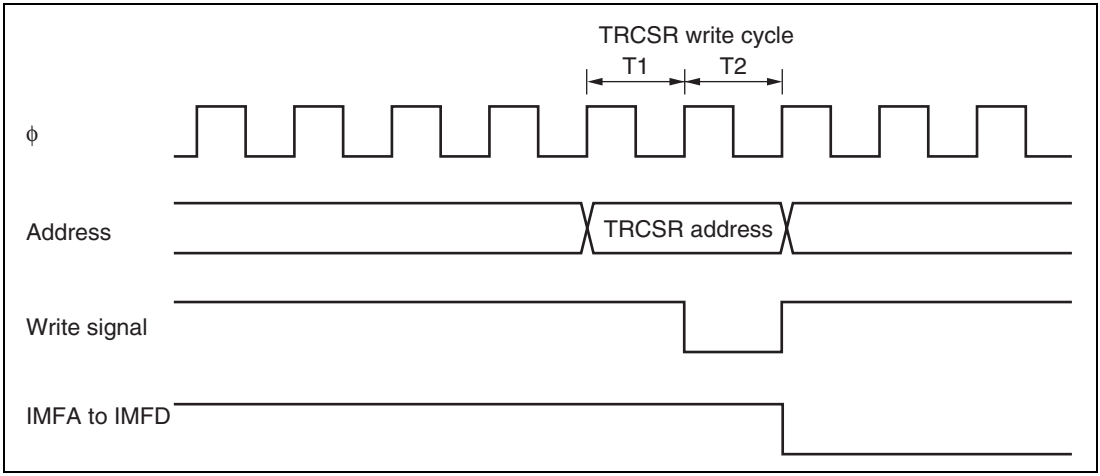


Figure 15.35 Timing of Status Flag Clearing by CPU

15.4.9 Timing of A/D Conversion Start Trigger Generation on Compare Match

Figure 15.36 shows the timing of the A/D conversion start trigger generation on compare match.

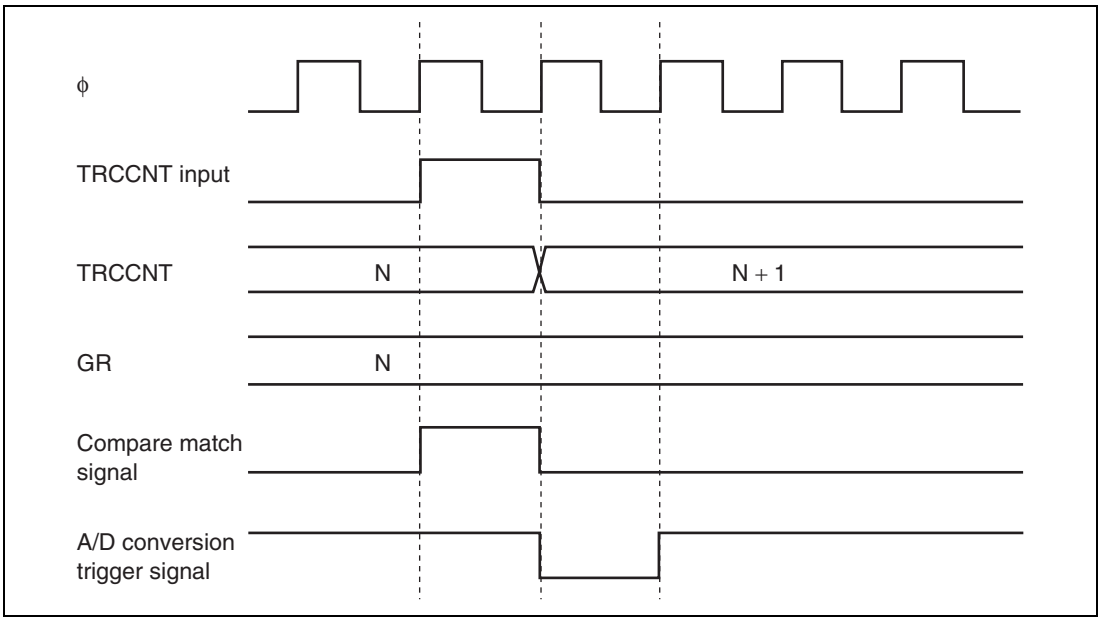


Figure 15.36 Timing of A/D Conversion Start Trigger Generation on Compare Match

15.5 Usage Notes

The following types of contention or operation can occur in timer RC operation.

1. When the digital filtering function for input is not in use, the pulse width of the input clock signal and the input capture signal must be at least three system clock (ϕ) cycles when the CKS2 to CKS0 bits in TRCCR1 = B'0XX or B'10X, and at least 3 × ϕ40 cycles for B'110; shorter pulses will not be detected correctly.
2. Writing to registers is performed in the T2 state of a TRCCNT write cycle.

   If counter clear signal occurs in the T2 state of a TRCCNT write cycle, clearing of the counter takes priority and the write is not performed, as shown in figure 15.37. If the TRCCNT write cycle contends with the TRCCNT counting-up, writing takes precedence.
3. TRCCNT may erroneously count up depends on the timing of switching internal clocks. The count clock is generated by detecting the rising edge of the divided system clock (ϕ) when the internal clock is selected. If clocks are switched as shown in figure 15.38, the change from the low level of the previous clock to the high level of the new clock is considered as the rising edge. In this case, TRCCNT counts up the clock erroneously.
4. If timer RC enters the module standby mode while an interrupt is being requested, the interrupt request cannot be cleared. Before entering the module standby mode, disable interrupt requests.

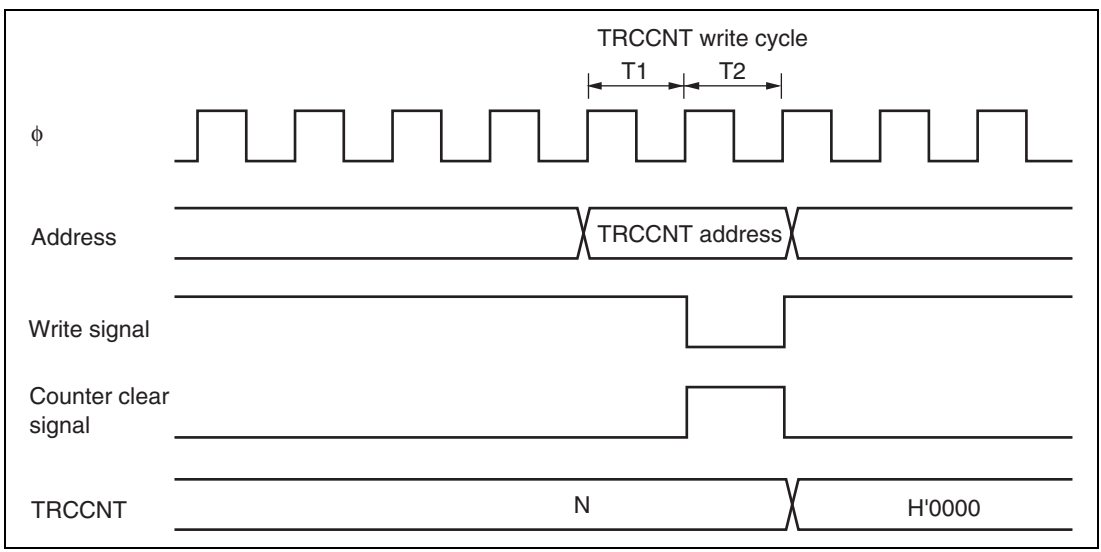


Figure 15.37 Contention between TRCCNT Write and Clear

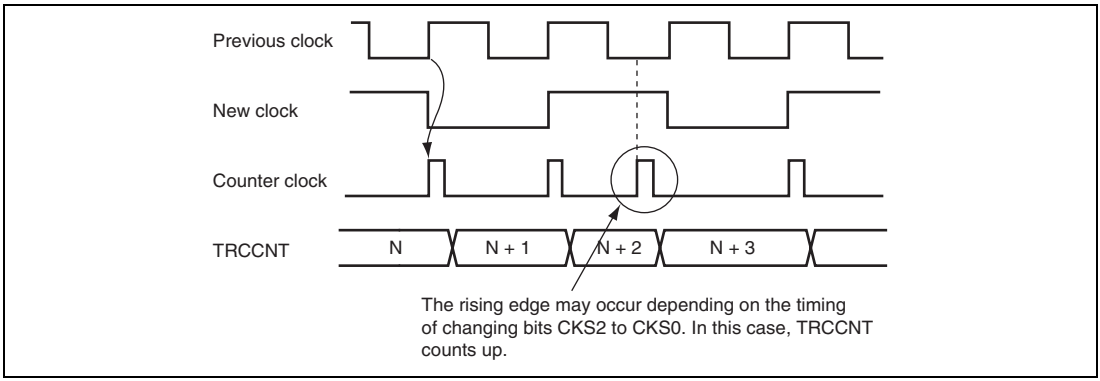


Figure 15.38 Internal Clock Switching and TRCCNT Operation

5. The TOA to TOD bits in TRCCR1 decide the output value of the FTIO pin until the first compare match occurs. Once a compare match occurs and this compare match changes the values of FTIOA to FTIOD output, the values of the FTIOA to FTIOD pin output and the values read from the TOA to TOD bits may differ. Moreover, when the writing to TRCCR1 and the generation of the compare match A to D occur at the same timing, the writing to TRCCR1 has the priority. Thus, output change due to the compare match is not reflected to the FTIOA to FTIOD pins. Therefore, when bit manipulation instruction is used to write to TRCCR1, the values of the FTIOA to FTIOD pin output may result in an unexpected result. When TRCCR1 is to be written to while compare match is operating, stop the counter once before accessing to TRCCR1, read the port H state to reflect the values of FTIOA to FTIOD output, to TOA to TOD, and then restart the counter. Figure 15.39 shows an example when the compare match and the bit manipulation instruction to TRCCR1 occur at the same timing.

TRCCR1 has been set to H'06. Compare match B and compare match C are used. The FTIOB pin output 1, and is set to the toggle output or the 0 output on compare match B.
When the TOC bit is cleared (the FTIOC signal is low) by execution of BCLR #2,@TRCCR1 and compare match B occurs at the same timing as shown below, writing H'02 to TRCCR1 has priority and the FTIOB signal is not driven low on compare match B; the FTIOB signal remains high.

Bit	7	6	5	4	3	2	1	0
TRCCR1	CCLR	CKS2	CKS1	CKS0	TOD	TOC	TOB	TOA
Setting	0	0	0	0	0	1	1	0

BCLR #2,@TRCCR1
(1) TRCCR1 is read as H'06.
(2) TRCCR1 is modified from H'06 to H'02.
(3) H'02 is written to TRCCR1.

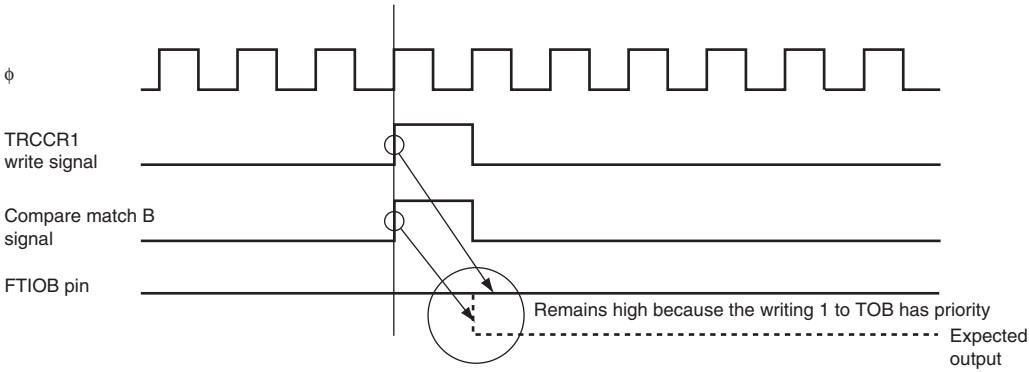


Figure 15.39 When Compare Match and Bit Manipulation Instruction to TRCCR1 Occur at the Same Timing

6. When the internal ϕ40 clock is selected as the counter source (the CKS[2:0] bits in TRCCR1 = B'110), if any register of timer RC is to be read immediately after writing to another register in a given module, proceed with reading after having executed one NOP instruction.

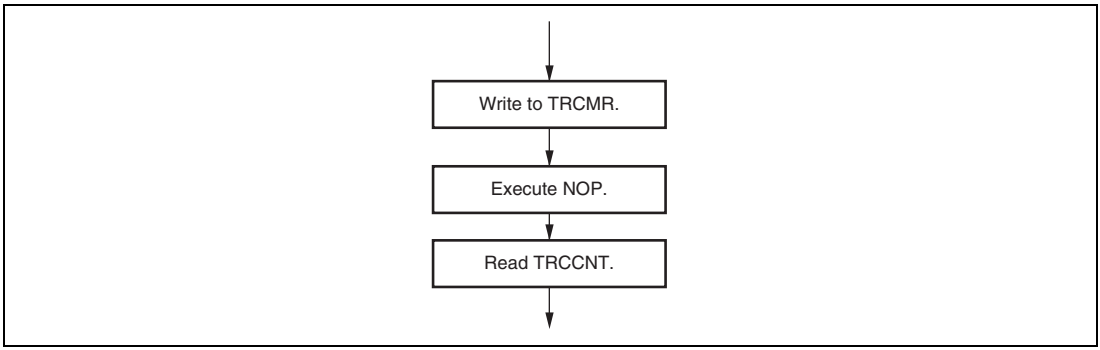


Figure 15.40 Example of Flow for Reading Immediately after Writing to a Register

Section 16 Timer RD

This LSI has two units of 16-bit timers (timer RD_0 and timer RD_1), each of which has two channels. Table 16.1 lists the timer RD functions, table 16.2 lists the channel configuration of timer RD, and figure 16.1 is a block diagram of the entire timer RD. Block diagrams of channels 0 and 1 are shown in figures 16.2 and 16.3.

Timer RD_0 has the same functions as timer RD_1. Therefore, the unit number (_0 or _1) is not explicitly mentioned in this section unless otherwise noted.

16.1 Features

- Capability to process up to eight inputs/outputs
- Eight general registers (GR): four registers for each channel
  Independently assignable output compare or input capture functions
- Selection of seven counter clock sources: six internal clocks (φ, φ/2, φ/4, φ/8, φ/32, and φ40M) and an external clock
- Seven selectable operating modes
  - — Timer mode
    Output compare function (Selection of 0 output, 1 output, or toggle output)
    Input capture function (Rising edge, falling edge, or both edges)
  - — Synchronous operation
    Timer counters_0 and _1 (TRDCNT_0 and TRDCNT_1) can be written simultaneously.
    Simultaneous clearing by compare match or input capture is possible.
  - — PWM mode
    Up to six-phase PWM output can be provided with desired duty ratio.
  - — PWM3 mode
    One-phase PWM output for non-overlapped normal and counter phases
  - — Reset synchronous PWM mode
    Three-phase PWM output for normal and counter phases
  - — Complementary PWM mode
    Three-phase PWM output for non-overlapped normal and counter phases
    The A/D conversion start trigger can be set for PWM cycles.
  - — Buffer operation
    The input capture register can be consisted of double buffers.
    The output compare register can automatically be modified.

- High-speed access by the internal 16-bit bus
  16-bit TRDCNT and GR registers can be accessed in high speed by a 16-bit bus interface
- Any initial timer output value can be set
- Output of the timer is disabled by external trigger
- Eleven interrupt sources
  Four compare match/input capture interrupts and an overflow interrupt are available for each channel. An underflow interrupt can be set for channel 1.

Table 16.1 Timer RD Functions (One Unit)

Item		Channel 0	Channel 1
Count clock		Internal clocks: φ, φ/2, φ/4, φ/8, φ/32, φ40M External clock: FTIOA0 (TCLK)	
General registers (output compare/input capture registers)		GRA_0, GRB_0, GRC_0, GRD_0	GRA_1, GRB_1, GRC_1, GRD_1
Buffer register		GRC_0, GRD_0	GRC_1, GRD_1
I/O pins		FTIOA0, FTIOB0, FTIOC0, FTIOD0	FTIOA1, FTIOB1, FTIOC1, FTIOD1
Counter clearing function		Compare match/input capture of GRA_0, GRB_0, GRC_0, or GRD_0	Compare match/input capture of GRA_1, GRB_1, GRC_1, or GRD_1
Compare match output	0 output	Yes	Yes
	1 output	Yes	Yes
	Toggle output	Yes	Yes
Input capture function		Yes	Yes
Synchronous operation		Yes	Yes
PWM mode		Yes	Yes
PWM3 mode		Yes	Yes
Reset synchronous PWM mode		Yes	Yes
Complementary PWM mode		Yes	Yes
Buffer function		Yes	Yes
Interrupt sources		Compare match/ input capture A0 to D0 Overflow	Compare match/ input capture A1 to D1 Overflow Underflow

Table 16.2 Channel Configuration of Timer RD

Unit	Channel	Pin
Timer RD_0	0	FTIOA0
(Unit 0)		FTIOB0
		FTIOC0
		FTIOD0
	1	FTIOA1
		FTIOB1
		FTIOC1
		FTIOD1
	Shared by channels 0 and 1	$\overline{\text{TRDOI_0}}$
Timer RD_1	2	FTIOA2
(Unit 1)		FTIOB2
		FTIOC2
		FTIOD2
	3	FTIOA3
		FTIOB3
		FTIOC3
		FTIOD3
	Shared by channels 2 and 3	$\overline{\text{TRDOI_1}}$

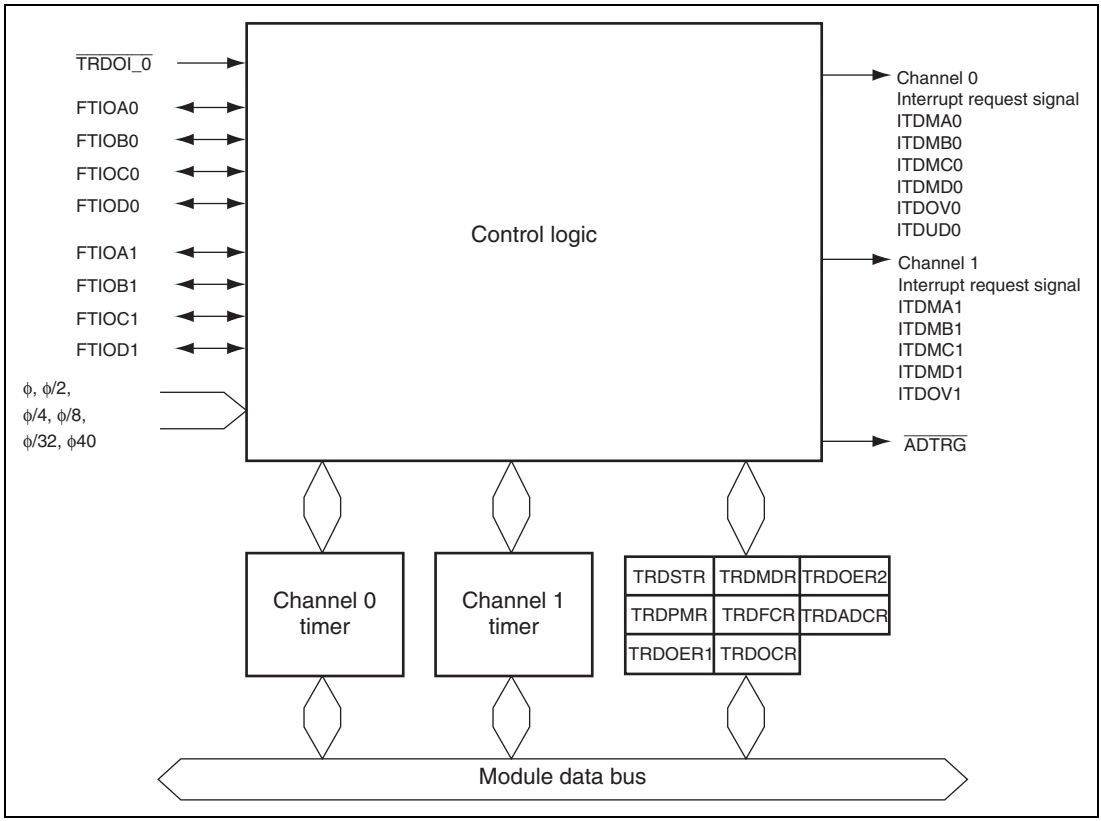


Figure 16.1 Timer RD (One Unit) Block Diagram

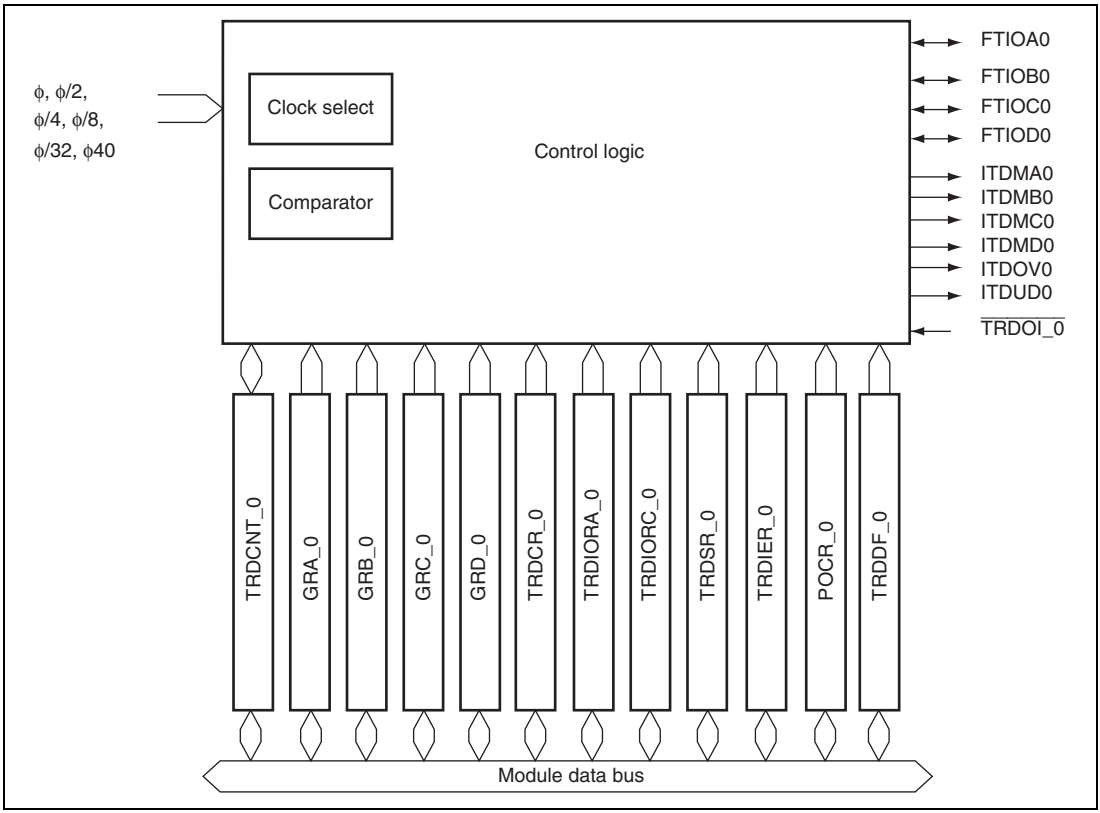


Figure 16.2 Timer RD (Channel 0) Block Diagram

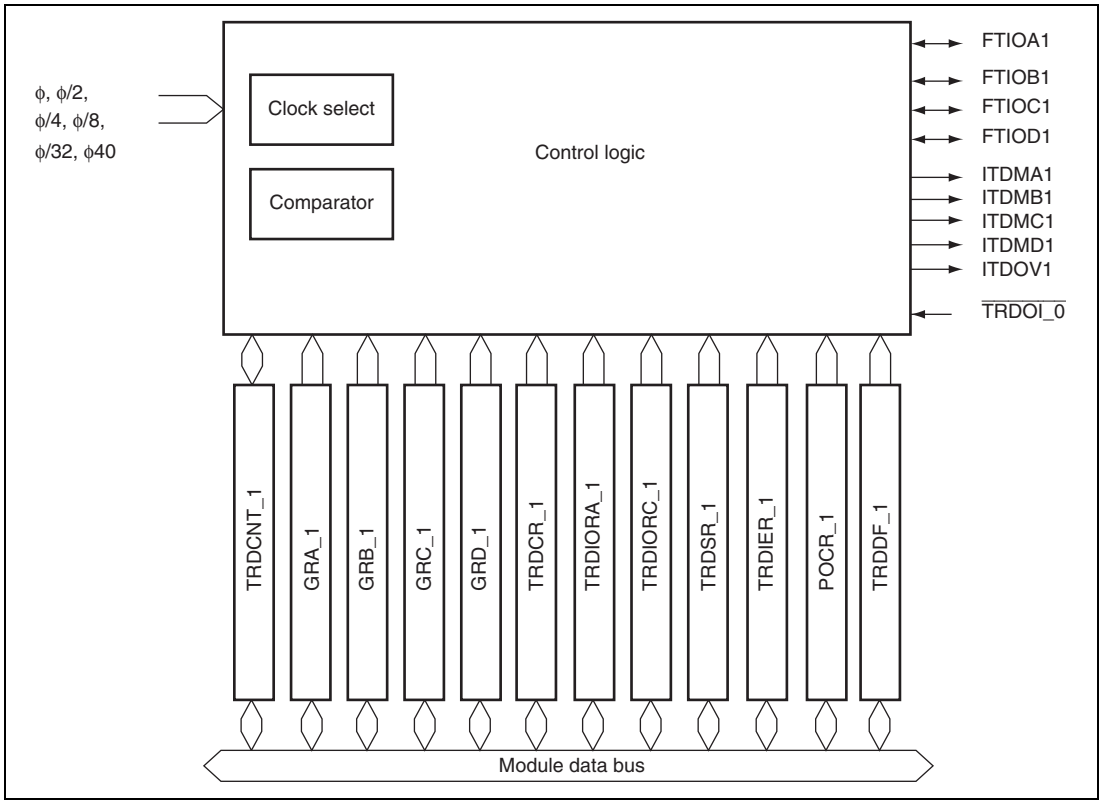


Figure 16.3 Timer RD (Channel 1) Block Diagram

Table 16.3 summarizes the timer RD pins.

Table 16.3 Pin Configuration (One Unit)

Pin Name	Input/Output	Function
FTIOA0	I/O	GRA_0 output compare output, GRA_0 input capture input, or external clock input (TCLK)
FTIOB0	I/O	GRB_0 output compare output, GRB_0 input capture input, or PWM output
FTIOC0	I/O	GRC_0 output compare output, GRC_0 input capture input, or PWM synchronous output (in reset synchronous PWM and complementary PWM modes)
FTIOD0	I/O	GRD_0 output compare output, GRD_0 input capture input, or PWM output
FTIOA1	I/O	GRA_1 output compare output, GRA_1 input capture input, or PWM output (in reset synchronous PWM and complementary PWM modes)
FTIOB1	I/O	GRB_1 output compare output, GRB_1 input capture input, or PWM output
FTIOC1	I/O	GRC_1 output compare output, GRC_1 input capture input, or PWM output
FTIOD1	I/O	GRD_1 output compare output, GRD_1 input capture input, or PWM output
$\overline{\text{TRDOI_0}}$	Input	Input pin for timer output disabling signal

16.2 Register Descriptions

Timer RD has the following registers.

Common

- Timer RD start register (TRDSTR)
- Timer RD mode register (TRDMDR)
- Timer RD PWM mode register (TRDPMR)
- Timer RD function control register (TRDFCR)
- Timer RD output master enable register 1 (TRDOER1)
- Timer RD output master enable register 2 (TRDOER2)
- Timer RD output control register (TRDOCR)
- Timer RD A/D conversion start trigger control register (TRDADCR)

Channel 0

- Timer RD control register_0 (TRDCR_0)
- Timer RD I/O control register A_0 (TRDIORA_0)
- Timer RD I/O control register C_0 (TRDIORC_0)
- Timer RD status register_0 (TRDSR_0)
- Timer RD interrupt enable register_0 (TRDIER_0)
- PWM mode output level control register_0 (POCR_0)
- Timer RD digital filtering function select register_0 (TRDDF_0)
- Timer RD counter_0 (TRDCNT_0)
- General register A_0 (GRA_0)
- General register B_0 (GRB_0)
- General register C_0 (GRC_0)
- General register D_0 (GRD_0)

Channel 1

- Timer RD control register_1 (TRDCR_1)
- Timer RD I/O control register A_1 (TRDIORA_1)
- Timer RD I/O control register C_1 (TRDIORC_1)
- Timer RD status register_1 (TRDSR_1)
- Timer RD interrupt enable register_1 (TRDIER_1)
- PWM mode output level control register_1 (POCR_1)
- Timer RD digital filtering function select register_1 (TRDDF_1)
- Timer RD counter_1 (TRDCNT_1)
- General register A_1 (GRA_1)
- General register B_1 (GRB_1)
- General register C_1 (GRC_1)
- General register D_1 (GRD_1)

16.2.1 Timer RD Start Register (TRDSTR)

Address: H'FFFFD2

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	CSTPN1	CSTPN0	STR1	STR0
Value after reset:	1	1	1	1	1	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	—	Reserved	These bits are read as 1. The write value should be 1.	—
3	CSTPN1	Channel 1 counter stop	0: Counting is stopped on a compare match of TRDCNT_1 and GRA_1 1: Counting is continued on a compare match of TRDCNT_1 and GRA_1 Set this bit to 1 to restart counting after the counting has been stopped on a compare match.	R/W
2	CSTPN0	Channel 0 counter stop	0: Counting is stopped on a compare match of TRDCNT_0 and GRA_0 1: Counting is continued on a compare match of TRDCNT_0 and GRA_0 Set this bit to 1 to restart counting after the counting has been stopped on a compare match.	R/W
1	STR1	Channel 1 counter start	0: TRDCNT_1 stops counting. 1: TRDCNT_1 starts counting. [Setting conditions] • When 1 is written in STR1 • When the specified event is occurred after ELOPB of the event link controller is selected counting by timer RD_0 for channel 1. [Clearing conditions] • When 0 is written in STR1 while CSTPN1 = 1 • When the compare match A1 signal is generated while CSTPN1 = 0	R/W

Bit	Symbol	Bit Name	Description	R/W
0	STR0	Channel 0 counter start	0: TRDCNT_0 stops counting. 1: TRDCNT_0 starts counting. [Setting conditions] • When 1 is written in STR0 • When the specified event is occurred after ELOPA of the event link controller is selected counting by timer RD_0 for channel 0. [Clearing conditions] • When 0 is written in STR0 while CSTPN0 = 1 • When the compare match A1 signal is generated while CSTPN0 = 0	R/W

Note: Use a MOV instruction to modify this register.

16.2.2 Timer RD Mode Register (TRDMDR)

Address: H'FFFFD3

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BFD1	BFC1	BFD0	BFC0	—	—	—	SYNC
Value after reset:	0	0	0	0	1	1	1	0

Bit	Symbol	Bit Name	Description	R/W
7	BFD1	Buffer operation D1	0: GRD_1 operates normally 1: GRB_1 and GRD_1 are used together for buffer operation	R/W
6	BFC1	Buffer operation C1	0: GRC_1 operates normally 1: GRA_1 and GRC_1 are used together for buffer operation	R/W
5	BFD0	Buffer operation D0	0: GRD_0 operates normally 1: GRB_0 and GRD_0 are used together for buffer operation	R/W
4	BFC0	Buffer operation C0	0: GRC_0 operates normally 1: GRA_0 and GRC_0 are used together for buffer operation	R/W
3 to 1	—	Reserved	These bits are read as 1. The write value should be 1.	—
0	SYNC	Timer synchronization	0: TRDCNT_1 and TRDCNT_0 operate as independent timer counters 1: TRDCNT_1 and TRDCNT_0 operate synchronously TRDCNT_1 and TRDCNT_0 can be pre-set or cleared synchronously.	R/W

16.2.3 Timer RD PWM Mode Register (TRDPMR)

Address: H'FFFFD4

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	PWMD1	PWMC1	PWMB1	—	PWMD0	PWMC0	PWMB0
Value after reset:	1	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6	PWMD1	PWM mode D1	0: FTIOD1 operates normally 1: FTIOD1 operates in PWM mode	R/W
5	PWMC1	PWM mode C1	0: FTIOC1 operates normally 1: FTIOC1 operates in PWM mode	R/W
4	PWMB1	PWM mode B1	0: FTIOB1 operates normally 1: FTIOB1 operates in PWM mode	R/W
3	—	Reserved	This bit is read as 1. The write value should be 1.	—
2	PWMD0	PWM mode D0	0: FTIOD0 operates normally 1: FTIOD0 operates in PWM mode	R/W
1	PWMC0	PWM mode C0	0: FTIOC0 operates normally 1: FTIOC0 operates in PWM mode	R/W
0	PWMB0	PWM mode B0	0: FTIOB0 operates normally 1: FTIOB0 operates in PWM mode	R/W

16.2.4 Timer RD Function Control Register (TRDFCR)

Address: H'FFFFD5

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	PWM3	STCLK	ADEG	ADTRG	OLS1	OLS0	CMD[1:0]	
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	PWM3	PWM3 mode select	0: PWM3 mode is selected 1: PWM3 mode is not selected*[1]	R/W
6	STCLK	External clock input select	0: External clock input is disabled 1: External clock input is enabled	R/W
5	ADEG	A/D trigger edge select	0: The A/D trigger signal is asserted when TRDCNT_0 matches GRA_0 in complementary PWM mode 1: The A/D trigger signal is asserted when TRDCNT_1 underflows in complementary PWM mode	R/W
4	ADTRG	External trigger disable	0: A/D trigger for PWM cycles is disabled in complementary PWM mode 1: A/D trigger for PWM cycles is enabled in complementary PWM mode*[2]	R/W
3	OLS1	Output level select 1	0: Initial output is high and the active level is low. 1: Initial output is low and the active level is high.	R/W
2	OLS0	Output level select 0	0: Initial output is high and the active level is low. 1: Initial output is low and the active level is high.	R/W

Bit	Symbol	Bit Name	Description	R/W
1, 0	CMD[1:0]	Combination mode 1 and 0	00: Channel 0 and channel 1 operate normally 01: Channel 0 and channel 1 are used together to operate in reset synchronous PWM mode 10: Channel 0 and channel 1 are used together to operate in complementary PWM mode (transferred when TRDCNT_0 matches GRA_0) 11: Channel 0 and channel 1 are used together to operate in complementary PWM mode (transferred when TRDCNT_1 underflows) Note: When the reset synchronous PWM mode or complementary PWM mode is selected by these bits, this setting has the priority to the settings for PWM mode by each bit in TRDPMR. Stop TRDCNT_0 and TRDCNT_1 before making settings for reset synchronous PWM mode or complementary PWM mode.	R/W

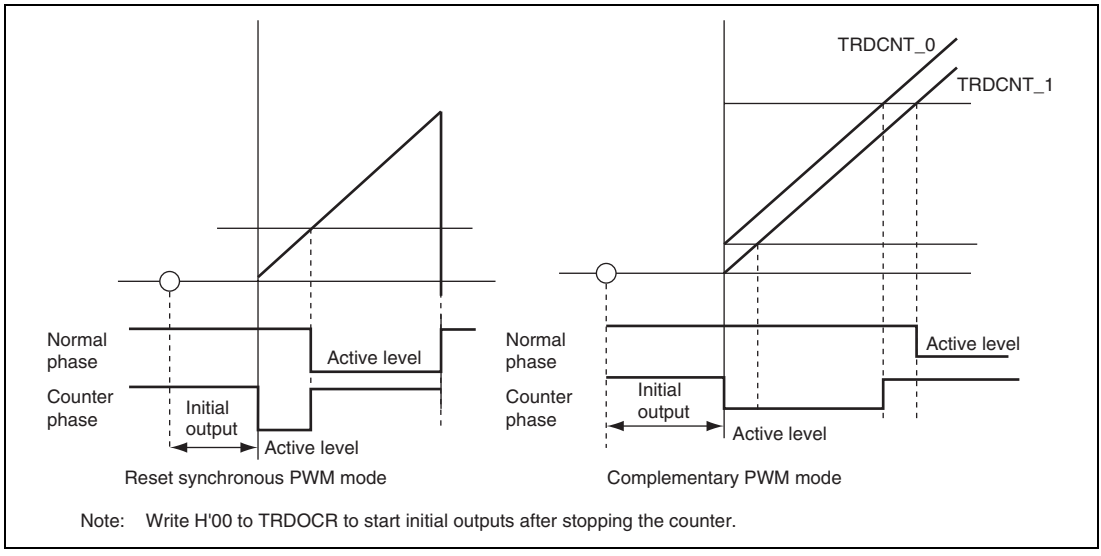
Notes: 1. This bit is valid when both bits CMD1 and CMD0 are cleared to 0. When PWM3 mode is selected, TRDPMR, TRDIORA, and TRDIORC are invalid.
2. The A/D converter registers should be set so that A/D conversion is started by an external trigger.

- OLS1 bit (output level select 1)

  This bit selects the output level for counter phase in reset synchronous PWM mode and complementary PWM mode.

- OLS0 bit (output level select 0)

  This bit selects the output level for normal phase in reset synchronous PWM mode and complementary PWM mode.



Note: Write H'00 to TRDOCR to start initial outputs after stopping the counter.

Figure 16.4 Example of Outputs in Reset Synchronous PWM Mode and Complementary PWM Mode

16.2.5 Timer RD Output Master Enable Register 1 (TRDOER1)

Address: H'FFFFD6

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	ED1	EC1	EB1	EA1	ED0	EC0	EB0	EA0
Value after reset:	1	1	1	1	1	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7	ED1	Master enable D1	0: FTIOD1 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORC_1 settings 1: FTIOD1 pin output is disabled regardless of the TRDMR, TRDFCR, and TRDIORC_1 settings (FTIOD1 pin is operated as an I/O port).	R/W
6	EC1	Master enable C1	0: FTIOC1 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORC_1 settings 1: FTIOC1 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORC_1 settings (FTIOC1 pin is operated as an I/O port).	R/W

Bit	Symbol	Bit Name	Description	R/W
5	EB1	Master enable B1	0: FTIOB1 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORA_1 settings 1: FTIOB1 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORA_1 settings (FTIOB1 pin is operated as an I/O port).	R/W
4	EA1	Master enable A1	0: FTIOA1 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORA_1 settings 1: FTIOA1 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORA_1 settings (FTIOA1 pin is operated as an I/O port).	R/W
3	ED0	Master enable D0	0: FTIOD0 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORC_0 settings 1: FTIOD0 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORC_0 settings (FTIOD0 pin is operated as an I/O port).	R/W
2	EC0	Master enable C0	0: FTIOC0 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORC_0 settings 1: FTIOC0 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORC_0 settings (FTIOC0 pin is operated as an I/O port).	R/W
1	EB0	Master enable B0	0: FTIOB0 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORA_0 settings 1: FTIOB0 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORA_0 settings (FTIOB0 pin is operated as an I/O port).	R/W
0	EA0	Master enable A0	0: FTIOA0 pin output is enabled according to the TRDPMR, TRDFCR, and TRDIORA_0 settings 1: FTIOA0 pin output is disabled regardless of the TRDPMR, TRDFCR, and TRDIORA_0 settings (FTIOA0 pin is operated as an I/O port).	R/W

TRDOER1 enables/disables the outputs for channel 0 and channel 1. When $\overline{\text{TRDOI}}$ is selected for inputs, if a low level signal is input to $\overline{\text{TRDOI}}$, the bits in TRDOER1 are set to 1 to disable the output for timer RD.

16.2.6 Timer RD Output Master Enable Register 2 (TRDOER2)

Address: H'FFFFD7

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

Bit	Symbol	Bit Name	Description	R/W
7	PTO	Timer output disabled mode	0: The corresponding bit in TRDOER1 is not set to 1 when the low level is input to the $\overline{\text{TRDOI}}$ pin 1: The corresponding bit in TRDOER1 is set to 1 when the low level is input to the $\overline{\text{TRDOI}}$ pin	R/W
6 to 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

16.2.7 Timer RD Output Control Register (TRDOCR)

Address: H'FFFFD8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TOD1	TOC1	TOB1	TOA1	TOD0	TOC0	TOB0	TOA0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TOD1	Output level select D1	0: 0 output at the FTIOD1 pin* 1: 1 output at the FTIOD1 pin*	R/W
6	TOC1	Output level select C1	0: 0 output at the FTIOC1 pin* 1: 1 output at the FTIOC1 pin*	R/W
5	TOB1	Output Level Select B1	0: 0 output at the FTIOB1 pin* 1: 1 output at the FTIOB1 pin*	R/W
4	TOA1	Output level select A1	0: 0 output at the FTIOA1 pin* 1: 1 output at the FTIOA1 pin*	R/W
3	TOD0	Output level select D0	0: 0 output at the FTIOD0 pin* 1: 1 output at the FTIOD0 pin*	R/W

Bit	Symbol	Bit Name	Description	R/W
2	TOC0	Output level select C0	0: 0 output at the FTIOC0 pin* 1: 1 output at the FTIOC0 pin*	R/W
1	TOB0	Output level select B0	• In modes other than PWM3 mode 0: 0 output at the FTIOB0 pin* 1: 1 output at the FTIOB0 pin* • In PWM3 mode 0: 1 output at the FTIOB0 pin on GRB_1 compare match and 0 output at the FTIOB0 pin on GRB_0 compare match 1: 0 output at the FTIOB0 pin on GRB_1 compare match and 1 output at the FTIOB0 pin on GRB_0 compare match	R/W
0	TOA0	Output level select A0	• In modes other than PWM3 mode 0: 0 output at the FTIOA0 pin* 1: 1 output at the FTIOA0 pin* • In PWM3 mode 0: 1 output at the FTIOB0 pin on GRA_1 compare match and 0 output at the FTIOB0 pin on GRA_0 compare match 1: 0 output at the FTIOB0 pin on GRA_1 compare match and 1 output at the FTIOB0 pin on GRA_0 compare match	R/W

Note: * The change of the setting is immediately reflected in the output value.

TRDOCR selects the initial outputs before the first occurrence of a compare match. Note that bits OLS1 and OLS0 in TRDFCR set these initial outputs in reset synchronous PWM mode and complementary PWM mode.

In PWM3 mode, TRDOCR selects the output level of the FTIOA0 and FTIOB0 pins.

16.2.8 Timer RD A/D Conversion Start Trigger Control Register (TRDADCR)

Address: H'FFFFD9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	ADTRGD1E	ADTRGC1E	ADTRGB1E	TDTRGA1E	ADTRGD0E	ADTRGC0E	ADTRGB0E	ADTRGA0E
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	ADTRGD1E	A/D conversion start trigger D1 enable	0: A/D conversion start trigger is not generated by compare match of GRD_1 1: A/D conversion start trigger is generated by compare match of GRD_1	R/W
6	ADTRGC1E	A/D conversion start trigger C1 enable	0: A/D conversion start trigger is not generated by compare match of GRC_1 1: A/D conversion start trigger is generated by compare match of GRC_1	R/W
5	ADTRGB1E	A/D conversion start trigger B1 enable	0: A/D conversion start trigger is not generated by compare match of GRB_1 1: A/D conversion start trigger is generated by compare match of GRB_1	R/W
4	ADTRGA1E	A/D conversion start trigger A1 enable	0: A/D conversion start trigger is not generated by compare match of GRA_1 1: A/D conversion start trigger is generated by compare match of GRA_1	R/W
3	ADTRGD0E	A/D conversion start trigger D0 enable	0: A/D conversion start trigger is not generated by compare match of GRD_0 1: A/D conversion start trigger is generated by compare match of GRD_0	R/W
2	ADTRGC0E	A/D conversion start trigger C0 enable	0: A/D conversion start trigger is not generated by compare match of GRC_0 1: A/D conversion start trigger is generated by compare match of GRC_0	R/W
1	ADTRGB0E	A/D conversion start trigger B0 enable	0: A/D conversion start trigger is not generated by compare match of GRB_0 1: A/D conversion start trigger is generated by compare match of GRB_0	R/W

Bit	Symbol	Bit Name	Description	R/W
0	ADTRGA0E	A/D conversion start trigger A0 enable	0: A/D conversion start trigger is not generated by compare match of GRA_0 1: A/D conversion start trigger is generated by compare match of GRA_0	R/W

TRDADCR selects the trigger source to start A/D conversion. A/D conversion start trigger is generated by a corresponding compare match.

16.2.9 Timer RD Counter (TRDCNT)

Address: H'FFFFB0, H'FFFFBA

Bit:	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

Timer RD has two TRDCNT counters (TRDCNT_0 and TRDCNT_1), one for each channel. The TRDCNT counters are 16-bit readable/writable registers that increment/decrement according to input clocks. Input clocks can be selected by bits TPSC2 to TPSC0 in TRDCR. TRDCNT_0 and TRDCNT_1 increment/decrement in complementary PWM mode while they only increment in other modes.

The TRDCNT counters are initialized to H'0000 by compare matches with corresponding GRA, GRB, GRC, or GRD, or input captures to GRA, GRB, GRC, or GRD (counter clearing function). When the TRDCNT counters overflow, an OVF flag in TRDSR for the corresponding channel is set to 1. When TRDCNT_1 underflows, an UDF flag in TRDSR is set to 1. The TRDCNT counters cannot be accessed in 8-bit units; they must always be accessed as a 16-bit unit.

16.2.10 General Registers A, B, C, and D (GRA, GRB, GRC, and GRD)

GRA

Address: H'FFFFB2, H'FFFFBC

Bit:	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

GRB

Address: H'FFFFB4, H'FFFFBE

Bit:	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

GRC

Address: H'FFFFB6, H'FFFFC0

Bit:	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

GRD

Address: H'FFFFB8, H'FFFFC2

Bit:	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

GR are 16-bit registers. Timer RD has eight general registers (GR), four for each channel. The GR registers are dual function 16-bit readable/writable registers, functioning as either output compare or input capture registers. Functions can be switched by TRDIORA and TRDIORC.

The values in GR and TRDCNT are constantly compared with each other when the GR registers are used as output compare registers. When the both values match, the IMFA to IMFD flags in TRDSR are set to 1. Compare match outputs can be selected by TRDIORA and TRDIORC.

When the GR registers are used as input capture registers, the TRDCNT value is stored after detecting external signals. At this point, IMFA to IMFD flags in the corresponding TRDSR are set to 1. Detection edges for input capture signals can be selected by TRDIORA and TRDIORC.

When PWM mode, complementary PWM mode, or reset synchronous PWM mode is selected, the values in TRDIORA and TRDIORC are ignored. Upon reset, the GR registers are set as output compare registers (no output) and initialized to H'FFFF. The GR registers cannot be accessed in 8-bit units; they must always be accessed as a 16-bit unit.

16.2.11 Timer RD Control Register (TRDCR)

Address: H'FFFFCA, H'FFFFD1

Bit:	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
7 to 5	CCLR[2:0]	Counter clear 2 to 0	000: Disables TRDCNT clearing 001: Clears TRDCNT by GRA compare match/input capture*[1] 010: Clears TRDCNT by GRB compare match/input capture*[1] 011: Synchronization clear; Clears TRDCNT in synchronous with counter clearing of the other channel's timer*[2] 100: Disables TRDCNT clearing 101: Clears TRDCNT by GRC compare match/input capture*[1] 110: Clears TRDCNT by GRD compare match/input capture*[1] 111: Synchronization clear; Clears TRDCNT in synchronous with counter clearing of the other channel's timer*[2]	R/W
4, 3	CKEG[1:0]	Clock edge 1 and 0	00: Count at rising edge 01: Count at falling edge 1X: Count at both edges	R/W

Bit	Symbol	Bit Name	Description	R/W
2 to 0	TPSC[2:0] *3*4	Time prescaler 2 to 0	000: Internal clock: count by φ	R/W
			001: Internal clock: count by φ/2	
			010: Internal clock: count by φ/4	
			011: Internal clock: count by φ/8	
			100: Internal clock: count by φ/32	
			101: External clock: count by FTIOA0 (TCLK) pin input	
			110: Internal clock: count by φ40M	
			111: Reserved (setting prohibited)	

[Legend]

X: Don't care

Notes: 1. When GR functions as an output compare register, TRDCNT is cleared by compare match. When GR functions as input capture, TRDCNT is cleared by input capture.

2. Synchronous operation is set by TRDMDR.

3. If the internal φ/40 clock is selected, the high-speed on-chip oscillator must be operating. As long as the internal φ40 clock is selected, do not stop the high-speed on-chip oscillator. When the counter clock is switched over, the counter should be halted.

4. When the internal φ40 clock is selected, restrictions on access to registers are applied. For details, see section 16.5, Usage Notes. (11) Restrictions on Access to Registers when Internal φ40 Clock is Selected as Counter Clock.

TRDCR selects a TRDCNT counter clock, an edge when an external clock is selected, and counter clearing sources. Timer RD has a total of two TRDCR registers, one for each channel.

16.2.12 Timer RD I/O Control Registers (TRDIORA and TRDIORC)

• TRDIORA

Address: H'FFFFC5, H'FFFFCC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	IOB2	IOB[1:0]		—	IOA2	IOA[1:0]	
Value after reset:	1	0	0	0	1	0	0	0

• TRDIORC

Address: H'FFFFD6, H'FFFFCD

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IOD3	IOD2	IOD[1:0]		IOC3	IOC2	IOC[1:0]	
Value after reset:	2	0	0	0	1	0	0	0

- TRDIORA

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6	IOB2	I/O control B2	Selects the GRB function. 0: GRB functions as an output compare register 1: GRB functions as an input capture register	R/W
5, 4	IOB[1:0]	I/O control B1 and B0	When IOB2 = 0, 00: No output at compare match 01: 0 output to the FTIOB pin at GRB compare match 10: 1 output to the FTIOB pin at GRB compare match 11: Output toggles to the FTIOB pin at GRB compare match When IOB2 = 1, 00: Input capture to GRB at rising edge at the FTIOB pin 01: Input capture to GRB at falling edge at the FTIOB pin 1X: Input capture to GRB at rising and falling edges at the FTIOB pin	R/W

Bit	Symbol	Bit Name	Description	R/W
3	—	Reserved	This bit is read as 1. The write value should be 1.	—
2	IOA2	I/O control A2	Selects the GRA function. 0: GRA functions as an output compare register 1: GRA functions as an input capture register	R/W
1, 0	IOA[1:0]	I/O control A1 and A0	When IOA2 = 0, 00: No output at compare match 01: 0 output to the FTIOA pin at GRA compare match 10: 1 output to the FTIOA pin at GRA compare match 11: Output toggles to the FTIOA pin at GRA compare match When IOA2 = 1, 00: Input capture to GRA at rising edge at the FTIOA pin 01: Input capture to GRA at falling edge at the FTIOA pin 1X: Input capture to GRA at rising and falling edges at the FTIOA pin	R/W

[Legend]

X: Don't care.

Notes: 1. When a GR register functions as a buffer register for a paired GR register, the settings in the IOA2 and IOB2 bits in TRDIORA and the IOC2 and IOD2 bits in TRDIORC of both registers should be the same. The IOA3 bit exists only in TRDIORA_0.

2. In PWM mode, PWM3 mode, complementary PWM mode, and reset synchronous PWM mode, the settings of TRDIORA are invalid.

TRDIORA selects whether GRA or GRB is used as an output compare register or an input capture register. When an output compare register is selected, the output setting is selected. When an input capture register is selected, an input edge of an input capture signal is selected. TRDIORA also selects the function of FTIOA or FTIOB pin.

- TRDIORC

Bit	Symbol	Bit Name	Description	R/W
7	IOD3	I/O control D3	Specifies GRD to be used as GR for the FTIOB or FTIOD pin. 0: GRD is used as GR for the FTIOB pin 1: GRD is used as GR for the FTIOD pin	R/W
6	IOD2	I/O control D2	Selects the GRD function. 0: GRD functions as an output compare register 1: GRD functions as an input capture register	R/W
5, 4	IOD[1:0]	I/O control D1 and D0	When IOD3 = 0, 00: No output at compare match 01: 0 output to the FTIOB pin at GRD compare match 10: 1 output to the FTIOB pin at GRD compare match 11: Output toggles to the FTIOB pin at GRD compare match When IOD3 = 1 and IOD2 = 0, 00: No output at compare match 01: 0 output to the FTIOD pin at GRD compare match 10: 1 output to the FTIOD pin at GRD compare match 11: Output toggles to the FTIOD pin at GRD compare match When IOD3 = 1 and IOD2 = 1, 00: Input capture to GRD at rising edge at the FTIOD pin 01: Input capture to GRD at falling edge at the FTIOD pin 1X: Input capture to GRD at rising and falling edges at the FTIOD pin	R/W
3	IOC3	I/O control C3	Specifies GRC to be used as GR for the FTIOA or FTIOC pin. 0: GRC is used as GR for the FTIOA pin 1: GRC is used as GR for the FTIOC pin	R/W

Bit	Symbol	Bit Name	Description	R/W
2	IOC2	I/O control C2	Selects the GRC function. 0: GRC functions as an output compare register 1: GRC functions as an input capture register	R/W
1, 0	IOC[1:0]	I/O control C1 and C0	When IOC3 = 0, 00: No output at compare match 01: 0 output to the FTIOA pin at GRC compare match 10: 1 output to the FTIOA pin at GRC compare match 11: Output toggles to the FTIOA pin at GRC compare match When IOC3 = 1 and IOC2 = 0, 00: No output at compare match 01: 0 output to the FTIOC pin at GRC compare match 10: 1 output to the FTIOC pin at GRC compare match 11: Output toggles to the FTIOC pin at GRC compare match When IOC3 = 1 and IOC2 = 1, 00: Input capture to GRC at rising edge at the FTIOC pin 01: Input capture to GRC at falling edge at the FTIOC pin 1X: Input capture to GRC at rising and falling edges at the FTIOC pin	R/W

[Legend]

X: Don't care.

Notes: 1. When a GR register functions as a buffer register for a paired GR register, the settings in the IOA2 and IOB2 bits in TRDIORA and the IOC2 and IOD2 bits in TRDIORC of both registers should be the same.

2. In PWM mode, PWM3 mode, complementary PWM mode, and reset synchronous PWM mode, the settings of TRDIORC are invalid.

TRDIORC selects whether GRC or GRD is used as an output compare register or an input capture register. When an output compare register is selected, the output setting is selected. When an input capture register is selected, an input edge of an input capture signal is selected. TRDIORC also selects the function of the FTIOA to FTIOD pins.

16.2.13 Timer RD Status Register (TRDSR)

Address: H'FFFFC7, H'FFFFCE

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	UDF	OVF	IMFD	IMFC	IMFB	IMFA
Value after reset:	1	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 1. The write value should be 1.	—
5	UDF*	Underflow flag	0: TRDCNT_1 has not underflowed. 1: TRDCNT_1 has underflowed. [Setting condition] • When TRDCNT underflows [Clearing condition] • When 0 is written to UDF after reading UDF = 1	R/W
4	OVF	Overflow flag	0: TRDCNT has not overflowed. 1: TRDCNT has overflowed. [Setting condition] • When TRDCNT value is underflowed [Clearing condition] When 0 is written to OVF after reading OVF = 1	R/W
3	IMFD	Input capture/ compare match flag D	[Setting conditions] • When TRDCNT = GRD and GRD is functioning as output compare register • When TRDCNT = GRD while the FTIOD pin operates in PWM mode • When TRDCNT = GRD in PWM3 mode, reset synchronous PWM mode, or complementary PWM mode • When TRDCNT value is transferred to GRD by input capture signal and GRD is functioning as input capture register [Clearing conditions] • When the DTC is activated by an IMFD interrupt and the DISEL bit in MRB of the DTC is 0 • When 0 is written to IMFD after reading IMFD = 1	R/W

Bit	Symbol	Bit Name	Description	R/W
2	IMFC	Input capture/ compare match flag C	[Setting conditions] • When TRDCNT = GRC and GRC is functioning as output compare register • When TRDCNT = GRC while the FTIOC pin operates in PWM mode • When TRDCNT = GRC in PWM3 mode, reset synchronous PWM mode, or complementary PWM mode • When TRDCNT value is transferred to GRC by input capture signal and GRC is functioning as input capture register [Clearing conditions] • When the DTC is activated by an IMFC interrupt and the DISEL bit in MRB of the DTC is 0 • When 0 is written to IMFC after reading IMFC = 1	R/W
1	IMFB	Input capture/ compare match flag B	[Setting conditions] • When TRDCNT = GRB and GRB is functioning as output compare register • When TRDCNT = GRB while the FTIOB pin operates in PWM mode • When TRDCNT = GRB in PWM mode, PWM3 mode, reset synchronous PWM mode, or complementary PWM mode (in reset synchronous PWM mode, however, while TRDCNT_0 = GRB_1 and TRDCNT_0 = GRB_0) • When TRDCNT value is transferred to GRB by input capture signal and GRB is functioning as input capture register [Clearing conditions] • When the DTC is activated by an IMFB interrupt and the DISEL bit in MRB of the DTC is 0 • When 0 is written to IMFB after reading IMFB = 1	R/W

Bit	Symbol	Bit Name	Description	R/W
0	IMFA	Input capture/ compare match flag A	[Setting conditions] • When TRDCNT = GRA and GRA is functioning as output compare register • When TRDCNT = GRA in PWM mode, PWM3 mode, reset synchronous PWM mode, or complementary PWM mode (in reset synchronous PWM mode, however, while TRDCNT_0 = GRA_1 and TRDCNT_0 = GRA_0) • When TRDCNT value is transferred to GRA by input capture signal and GRA is functioning as input capture register [Clearing conditions] • When the DTC is activated by an IMFA interrupt and the DISEL bit in MRB of the DTC is 0 • When 0 is written to IMFA after reading IMFA = 1	R/W

Note: * Bit 5 is not the UDF flag in TRDSR_0. It is a reserved bit. It is always read as 1.

TRDSR is each interrupt request flag of the timer RD. If an interrupt is enabled by a corresponding bit in TRDIER, TRDSR requests an interrupt for the CPU. Timer RD has two TRDSR registers, one for each channel.

16.2.14 Timer RD Interrupt Enable Register (TRDIER)

Address: H'FFFFC8, H'FFFFCF

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	OVIE	IMIED	IMIEC	IMIEB	IMIEA
Value after reset:	1	1	1	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 5	—	Reserved	These bits are read as 1. The write value should be 1.	—
4	OVIE	Overflow interrupt enable	0: Interrupt requests (OVI) by OVF or UDF flag are disabled. 1: Interrupt requests (OVI) by OVF or UDF flag are enabled.	R/W
3	IMIED	Input capture/ compare match interrupt enable D	0: Interrupt requests (IMID) by IMFD flag are disabled. 1: Interrupt requests (IMID) by IMFD flag are enabled.	R/W
2	IMIEC	Input capture/ compare match interrupt enable C	0: Interrupt requests (IMIC) by IMFC flag are disabled. 1: Interrupt requests (IMIC) by IMFC flag are enabled.	R/W
1	IMIEB	Input capture/ compare match interrupt enable B	0: Interrupt requests (IMIB) by IMFB flag are disabled. 1: Interrupt requests (IMIB) by IMFB flag are enabled.	R/W
0	IMIEA	Input capture/ compare match interrupt enable A	0: Interrupt requests (IMIA) by IMFA flag are disabled. 1: Interrupt requests (IMIA) by IMFA flag are enabled.	R/W

Timer RD has two TRDIER registers, one for each channel.

16.2.15 PWM Mode Output Level Control Register (POCR)

Address: H'FFFFC9, H'FFFFD0

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	POLD	POLC	POLB
Value after reset:	1	1	1	1	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 3	—	Reserved	These bits are read as 1. The write value should be 1.	—
2	POLD	PWM mode output level control D	0: The output level of FTIOD is active low. 1: The output level of FTIOD is active high.	R/W
1	POLC	PWM mode output level control C	0: The output level of FTIOC is active low. 1: The output level of FTIOC is active high.	R/W
0	POLB	PWM mode output level control B	0: The output level of FTIOB is active low. 1: The output level of FTIOB is active high.	R/W

Timer RD has two POCR registers, one for each channel.

16.2.16 Timer RD Digital Filtering Function Select Register (TRDDF)

Address: H'FFFFCA, H'FFFFD1

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	DFCK[1:0]		—	—	DFD	DFC	DFB	DFA
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	DFCK[1:0]	Digital filter clock select	00: ϕ/32 01: ϕ/8 10: ϕ 11: Clock specified by bits TPSC2 to TPSC0 in TRDCR	R/W
5, 4	—	Reserved	These bits are read as 0. The write value should be 0.	—
3	DFD	Digital filter function D	0: Disables the digital filter for the FTIOD pin 1: Enables the digital filter for the FTIOD pin	R/W
2	DFC	Digital filter function C	0: Disables the digital filter for the FTIOC pin 1: Enables the digital filter for the FTIOC pin	R/W
1	DFB	Digital filter function B	0: Disables the digital filter for the FTIOB pin 1: Enables the digital filter for the FTIOB pin	R/W
0	DFA	Digital filter function A	0: Disables the digital filter for the FTIOA pin 1: Enables the digital filter for the FTIOA pin	R/W

Note: The setting in this register is valid on the corresponding pin when the FTIOA to FTIOD inputs are enabled by TRDIORA and TRDIORC.

Timer RD has two TRDDF registers, one for each channel.

16.2.17 Interface with CPU

(1) 16-Bit Register

TRDCNT and GR are 16-bit registers. Reading/writing in a 16-bit unit is enabled but disabled in an 8-bit unit since the data bus with the CPU is 16-bit width. These registers must always be accessed in a 16-bit unit. Figure 16.5 shows an example of accessing the 16-bit registers.

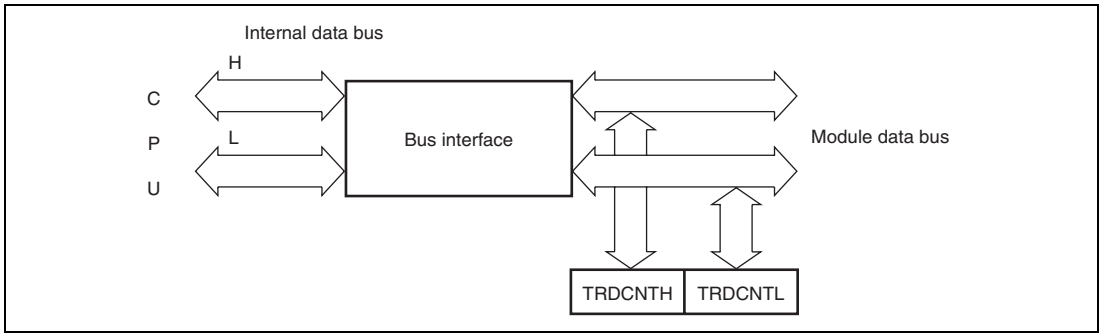


Figure 16.5 Accessing Operation of 16-Bit Register (between CPU and TRDCNT (16 bits))

(2) 8-Bit Register

Registers other than TRDCNT and GR are 8-bit registers that are connected internally with the CPU in an 8-bit width. Figure 16.6 shows an example of accessing the 8-bit registers.

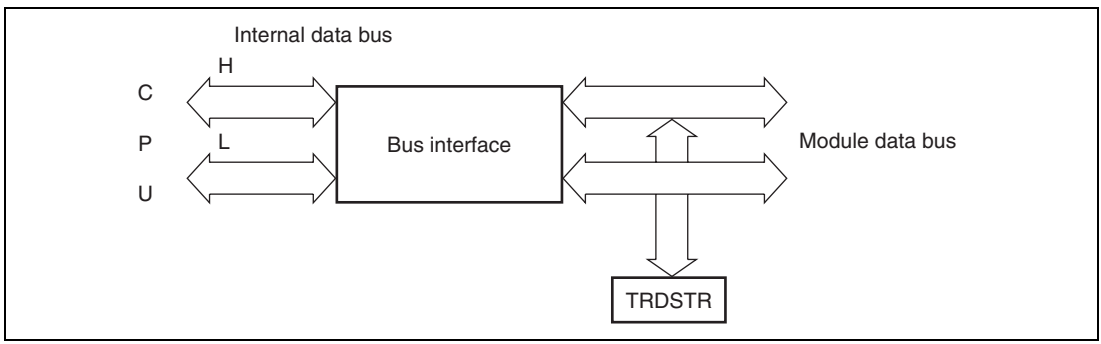


Figure 16.6 Accessing Operation of 8-Bit Register (between CPU and TRDSTR (8 bits))

16.3 Operation

Timer RD has the following operating modes.

- Timer mode operation

  Enables output compare and input capture functions by setting the IOA2 to IOA0 and IOB2 to IOB0 bits in TRDIORA and the IOC3 to IOC0 and IOD3 to IOD0 bits in TRDIORC
- PWM mode operation

  Enables PWM mode operation by setting TRDPMR
- PWM3 mode operation

  Enables PWM3 mode operation by setting the PWM3 bit in TRDFCR
- Reset synchronous PWM mode operation

  Enables reset synchronous PWM mode operation by setting the CMD1 and CMD0 bits in TRDFCR
- Complementary PWM mode operation

  Enables complementary PWM mode operation by setting the CMD1 and CMD0 bits in TRDFCR

The following tables show the operating modes of the FTIOA0 to FTIOD0 and FTIOA1 to FTIOD1 pins set by the appropriate bits in the registers mentioned above. Set 1 to the PMR bits corresponding to the pins allocated by the PMC.

- FTIOA0 pin

Register Name	TRDOER1		TRDFCR		TRDIORA	
Bit Name	EA0	STCLK	CMD1, CMD0	PWM3	IOA2 to IOA0	Function
Setting values	0	0	00	0	XXX	PWM3 mode waveform output
	0	0	00	1	001, 01X	Timer mode waveform output (output compare function)
	X	0	00	1	1XX	Timer mode (input capture function)
	X	0	00	1	000	General input port (when the corresponding pin PCR = 0)
	X	1	XX	X	0XX	External clock input
	Other than above					Setting prohibited

- FTIOB0 pin

Register Name	TRDOER1	TRDFCR		TRDPMR	TRDIORA	
Bit Name	EB0	CMD1, CMD0	PWM3	PWMB0	IOB2 to IOB0	Function
Setting values	0	10, 11	X	X	XXX	Complementary PWM mode waveform output
	0	01	X	X	XXX	Reset synchronous PWM mode waveform output
	0	00	0	X	XXX	PWM3 mode waveform output
	0	00	1	1	XXX	PWM mode waveform output
	0	00	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	0	1XX	Timer mode (input capture function)
	X	00	1	0	000	General input port (when the corresponding pin PCR = 0)
	Other than above					Setting prohibited

- FTIOC0 pin

Register Name	TRDOER1	TRDFCR		TRDPMR	TRDIORC	
Bit Name	EC0	CMD1, CMD0	PWM3	PWMC0	IOC2 to IOC0	Function
Setting values	0	10, 11	X	X	XXX	Complementary PWM mode waveform output
	0	01	X	X	XXX	Reset synchronous PWM mode waveform output
	0	00	1	1	XXX	PWM mode waveform out
	0	00	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	0	1XX	Timer mode (input capture function)
	X	00	1	0	000	General input port (when the corresponding pin PCR = 0)
	Other than above					Setting prohibited

- FTIOD0 pin

Register Name	TRDOER1	TRDFCR		TRDPMR	TRDIORC	
Bit Name	ED0	CMD1, CMD0	PWM3	PWMD0	IOD2 to IOD0	Function
Setting values	0	10, 11	X	X	XXX	Complementary PWM mode waveform output
	0	01	X	X	XXX	Reset synchronous PWM mode waveform output
	0	00	1	1	XXX	PWM mode waveform out
	0	00	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	0	1XX	Timer mode (input capture function)
	X	00	1	0	000	General input port (when the corresponding pin PCR = 0)
	Other than above					Setting prohibited

- FTIOA1 pin

Register Name	TRDOER1	TRDFCR		TRDIORA	
Bit Name	EA1	CMD1, CMD0	PWM3	IOA2 to IOA0	Function
Setting values	0	10, 11	X	XXX	Complementary PWM mode waveform output
	0	01	X	XXX	Reset synchronous PWM mode waveform output
	0	00	1	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	1XX	Timer mode (input capture function)
	X	00	1	000	General input port (when the corresponding pin PCR = 0)
		Other than above			Setting prohibited

- FTIOB1 pin

Register Name	TRDOER1	TRDFCR		TRDPMR	TRDIORA	
Bit Name	**EB1**	**CMD1, CMD0**	**PWM3**	**PWMB1**	**IOB2 to IOB0**	**Function**
Setting values	0	10, 11	X	X	XXX	Complementary PWM mode waveform output
	0	01	X	X	XXX	Reset synchronous PWM mode waveform output
	0	00	1	1	XXX	PWM mode waveform out
	0	00	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	0	1XX	Timer mode (input capture function)
	X	00	1	0	000	General input port (when the corresponding pin PCR = 0)
	Other than above					Setting prohibited

- FTIOC1 pin

Register Name	TRDOER1	TRDFCR		TRDPMR	TRDIORC	
Bit Name	EC1	CMD1, CMD0	PWM3	PWMC1	IOC2 to IOC0	Function
Setting values	0	10, 11	X	X	XXX	Complementary PWM mode waveform output
	0	01	X	X	XXX	Reset synchronous PWM mode waveform output
	0	00	1	1	XXX	PWM mode waveform out
	0	00	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	0	1XX	Timer mode (input capture function)
	X	00	1	0	000	General input port (when the corresponding pin PCR = 0)
	Other than above					Setting prohibited

- FTIOD1 pin

Register Name	TRDOER1	TRDFCR		TRDPMR	TRDIORC	
Bit Name	ED1	CMD1, CMD0	PWM3	PWMD1	IOD2 to IOD0	Function
Setting values	0	10, 11	X	X	XXX	Complementary PWM mode waveform output
	0	01	X	X	XXX	Reset synchronous PWM mode waveform output
	0	00	1	1	XXX	PWM mode waveform out
	0	00	1	0	001, 01X	Timer mode waveform output (output compare function)
	X	00	1	0	1XX	Timer mode (input capture function)
	X	00	1	0	000	General input port (when the corresponding pin PCR = 0)
	Other than above					Setting prohibited

16.3.1 Counter Operation

When one of bits STR0 and STR1 in TRDSTR is set to 1, the TRDCNT counter for the corresponding channel begins counting. TRDCNT can operate as a free-running counter, periodic counter, for example. Figure 16.7 shows an example of the counter operation setting procedure.

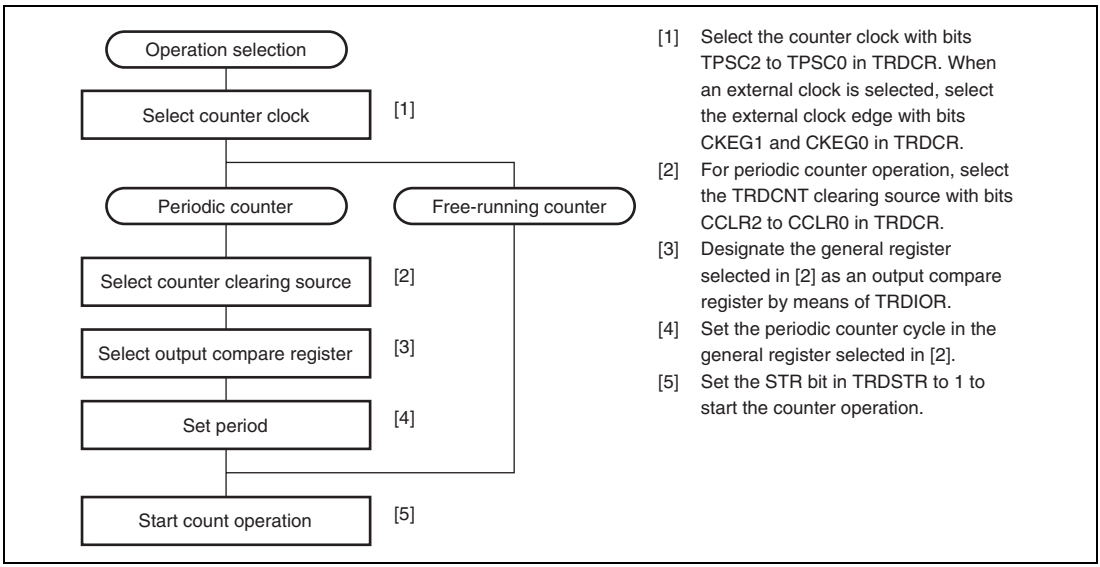


Figure 16.7 Example of Counter Operation Setting Procedure

(1) Free-Running Count Operation and Periodic Count Operation

Immediately after a reset, the TRDCNT counters for channels 0 and 1 are all designated as free-running counters. When the relevant bit in TRDSTR is set to 1, the corresponding TRDCNT counter starts an increment operation as a free-running counter. When TRDCNT overflows, the OVF flag in TRDSR is set to 1. If the value of the OVIE bit in the corresponding TRDIER is 1 at this point, timer RD requests an interrupt. After overflow, TRDCNT starts an increment operation again from H'0000.

Figure 16.8 illustrates free-running counter operation.

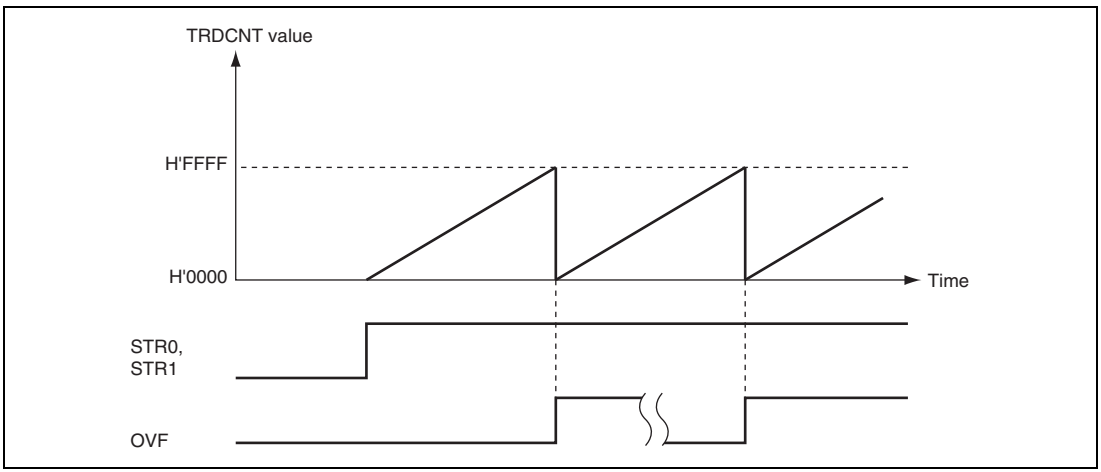


Figure 16.8 Free-Running Counter Operation

When compare match is selected as the TRDCNT clearing source, the TRDCNT counter for the relevant channel performs periodic count operation. The GR registers for setting the period are designated as output compare registers, and counter clearing by compare match is selected by means of bits CCLR1 and CCLR0 in TRDCR. After the settings have been made, TRDCNT starts an increment operation as a periodic counter when the corresponding bit in TRDSTR is set to 1. When the count value matches the value in GR, the IMFA, IMFB, IMFC, or IMFD flag in TRDSR is set to 1 and TRDCNT is cleared to H'0000. If the value of the corresponding IMIEA, IMIEB, IMIEC, or IMIED bit in TRDIER is 1 at this point, timer RD requests an interrupt. After a compare match, TRDCNT starts an increment operation again from H'0000.

Figure 16.9 illustrates periodic counter operation.

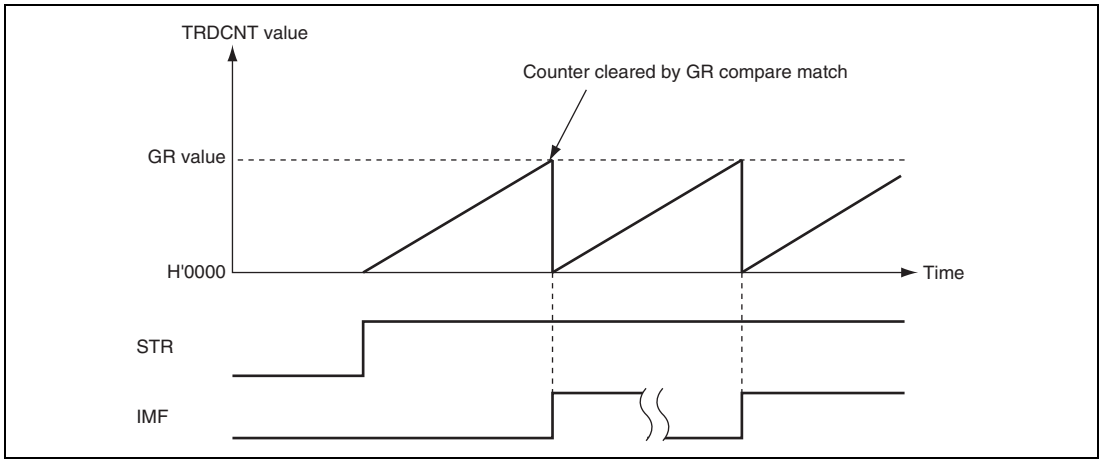


Figure 16.9 Periodic Counter Operation

(2) TRDCNT Count Timing

- Internal clock operation

  A system clock (ϕ), four types of clocks (ϕ/2, ϕ/4, ϕ/8, or ϕ/32) that are generated by dividing the system clock, or on-chip oscillator clock (ϕ40M) can be selected by bits TPSC2 to TPSC0 in TRDCR.

  Figure 16.10 illustrates this timing.

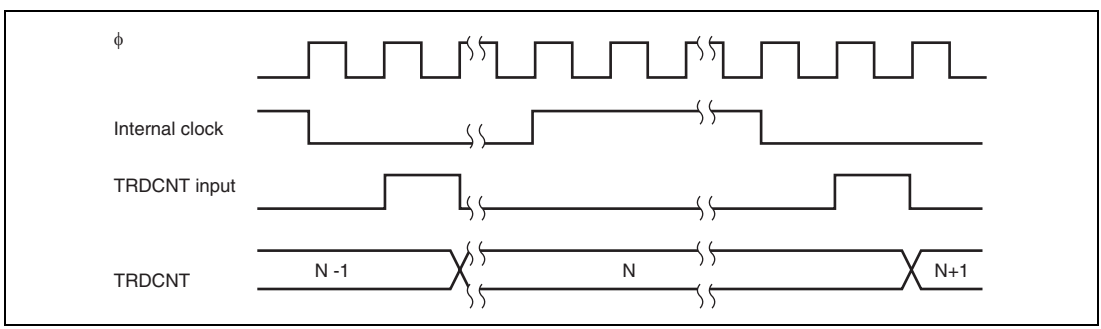


Figure 16.10 Count Timing in Internal Clock Operation

- External clock operation

  An external clock input pin (TCLK) can be selected by bits TPSC2 to TPSC0 in TRDCR, and a detection edge can be selected by bits CKEG1 and CKEG0. To detect an external clock, the rising edge, falling edge, or both edges can be selected.

  Figure 16.11 illustrates the detection timing of the rising and falling edges.

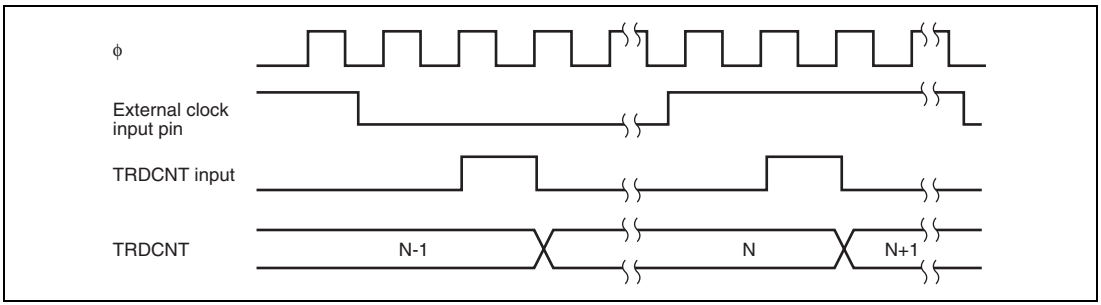


Figure 16.11 Count Timing in External Clock Operation (Both Edges Detected)

16.3.2 Waveform Output by Compare Match

Timer RD can perform 0, 1, or toggle output from the corresponding FTIOA, FTIOB, FTIOC, or FTIOD output pin using compare match A, B, C, or D.

Figure 16.12 shows an example of the setting procedure for waveform output by compare match.

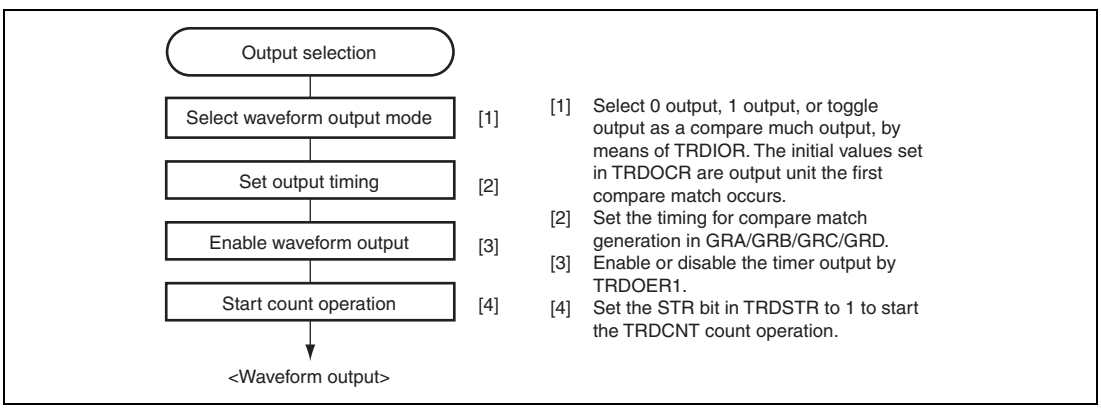


Figure 16.12 Example of Setting Procedure for Waveform Output by Compare Match

(1) Examples of Waveform Output Operation

Figure 16.13 shows an example of 0 output/1 output.

In this example, TRDCNT has been designated as a free-running counter, and settings have been made such that 0 is output by compare match A, and 1 is output by compare match B. When the set level and the pin level coincide, the pin level does not change.

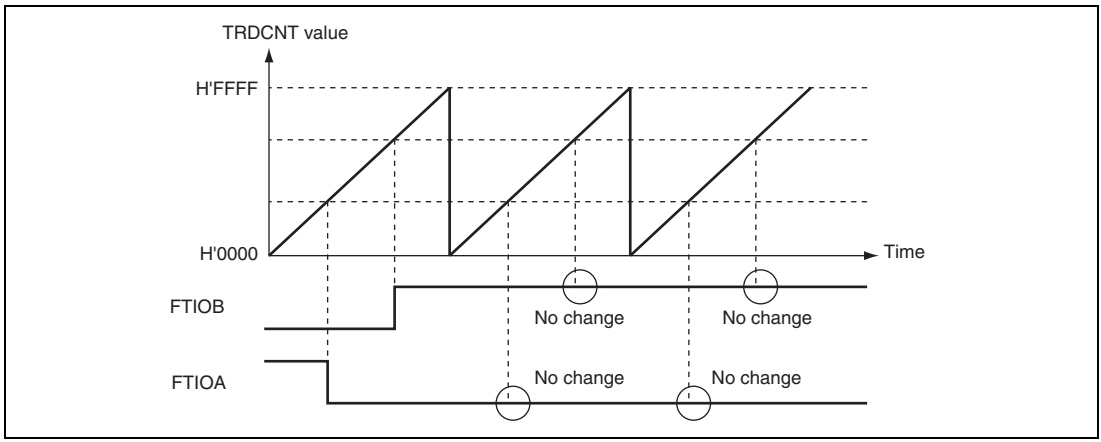


Figure 16.13 Example of 0 Output/1 Output Operation

Figure 16.14 shows an example of toggle output.

In this example, TRDCNT has been designated as a periodic counter (with counter clearing on compare match B), and settings have been made such that the output is toggled by both compare match A and compare match B.

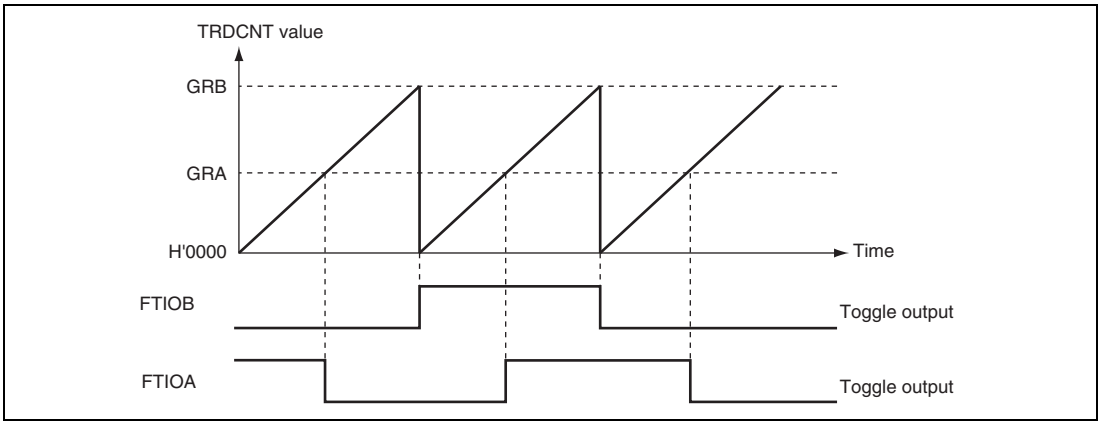


Figure 16.14 Example of Toggle Output Operation

(2) Output Compare Timing

The compare match signal is generated in the last state in which TRDCNT and GR match (when TRDCNT changes from the matching value to the next value). When the compare match signal is generated, the output value selected in TRDIOR is output at the compare match output pin (FTIOA, FTIOB, FTIOC, or FTIOD). When TRDCNT matches GR, the compare match signal is generated only after the next TRDCNT input clock pulse is input.

Figure 16.15 shows an example of the output compare timing.

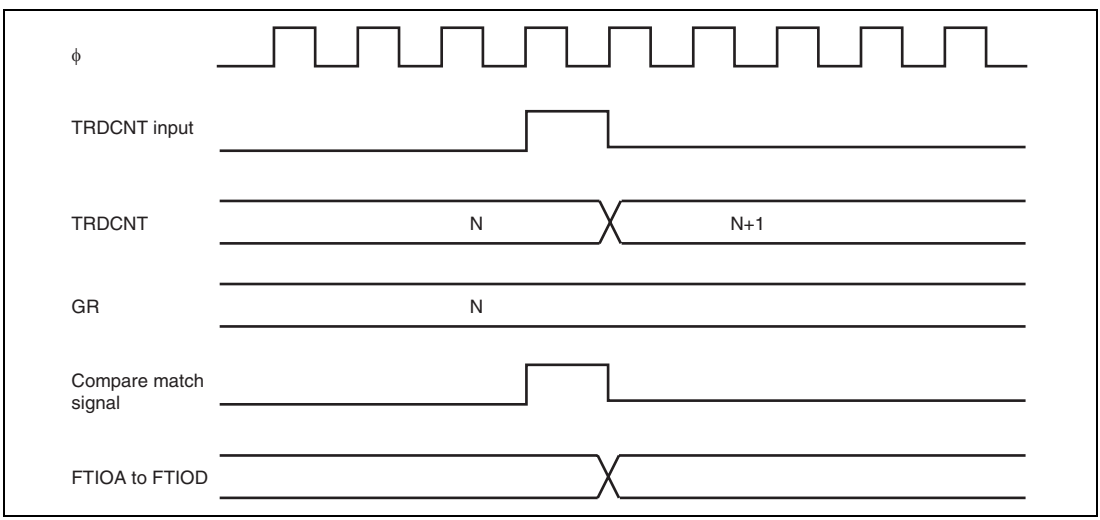


Figure 16.15 Output Compare Timing

16.3.3 Input Capture Function

The TRDCNT value can be transferred to GR on detection of the input edge of the input capture/output compare pin (FTIOA, FTIOB, FTIOC, or FTIOD). Rising edge, falling edge, or both edges can be selected as the detected edge. When the input capture function is used, the pulse width or period can be measured.

Figure 16.16 shows an example of the input capture operation setting procedure.

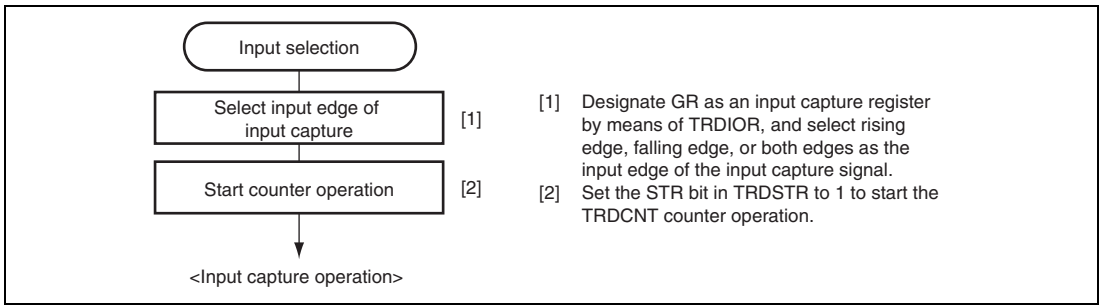


Figure 16.16 Example of Input Capture Operation Setting Procedure

(1) Example of Input Capture Operation

Figure 16.17 shows an example of input capture operation.

In this example, both rising and falling edges have been selected as the FTIOA pin input capture input edge, the falling edge has been selected as the FTIOB pin input capture input edge, and counter clearing by GRB input capture has been designated for TRDCNT.

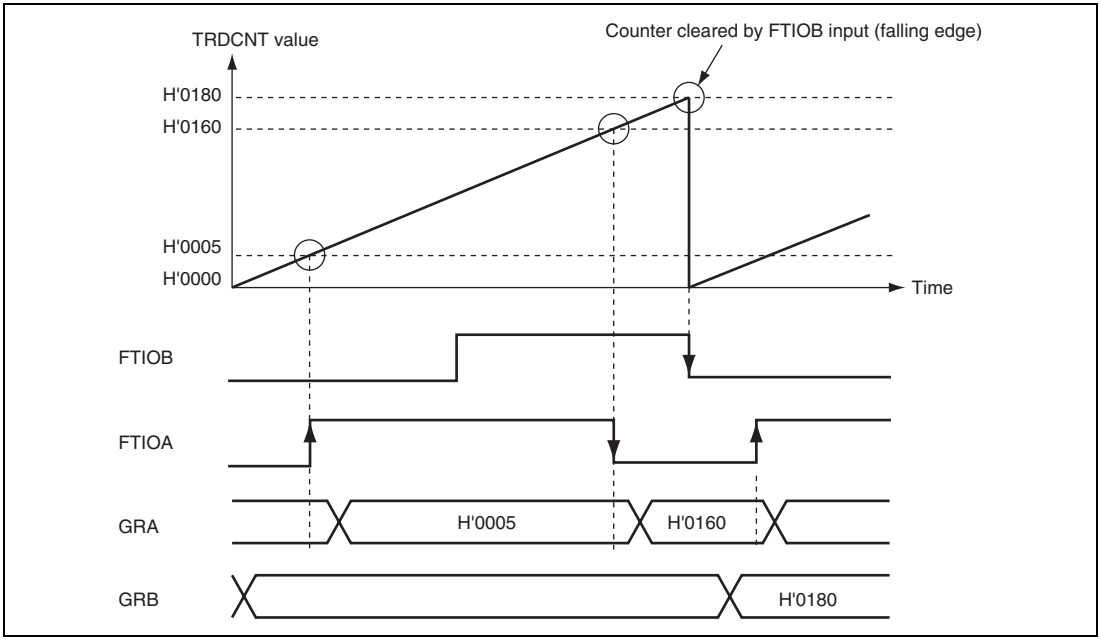


Figure 16.17 Example of Input Capture Operation

(2) Input Capture Signal Timing

Input capture on the rising edge, falling edge, or both edges can be selected through settings in TRDIOR. Figure 16.18 shows the timing when the rising edge is selected.

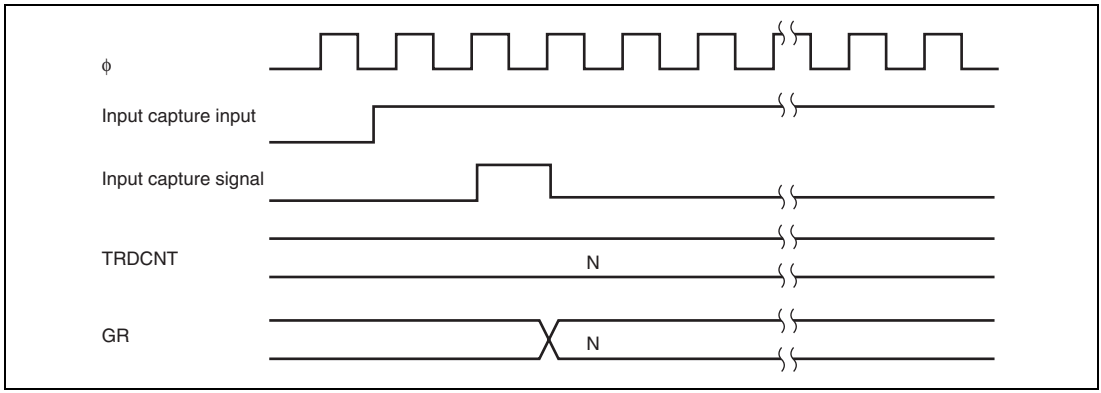
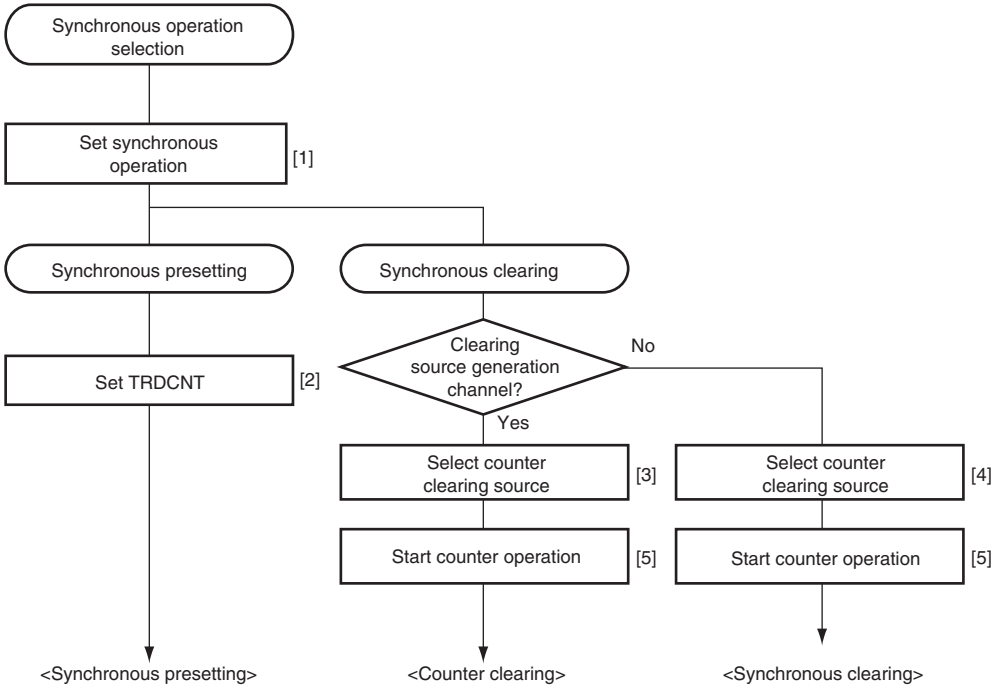


Figure 16.18 Input Capture Signal Timing

16.3.4 Synchronous Operation

In synchronous operation, the values in a number of TRDCNT counters can be rewritten simultaneously (synchronous presetting). Also, a number of TRDCNT counters can be cleared simultaneously by making the appropriate setting in TRDCR (synchronous clearing). Synchronous operation enables GR to be increased with respect to a single time base.

Figure 16.19 shows an example of the synchronous operation setting procedure.



[1] Set the SYNC bits in TRDMDR to 1.
[2] When a value is written to either of the TRDCNT counters, the same value is simultaneously written to the other TRDCNT counter.
[3] Set bits CCLR1 and CCLR0 in TRDCR to specify counter clearing by compare match/input capture.
[4] Set bits CCLR1 and CCLR0 in TRDCR to designate synchronous clearing for the counter clearing source.
[5] Set the STR bit in TRDSTR to 1 to start the count operation.

Figure 16.19 Example of Synchronous Operation Setting Procedure

Figure 16.20 shows an example of synchronous operation. In this example, synchronous operation has been selected, FTIOB0 and FTIOB1 have been designated for PWM mode, GRA_0 compare match has been set as the channel 0 counter clearing source, and synchronous clearing has been set for the channel 1 counter clearing source. The same input clock has been set for the channel 0 and channel 1 counter input clocks. Two-phase PWM waveforms are output from pins FTIOB0 and FTIOB1. At this time, synchronous presetting and synchronous operation by GRA_0 compare match are performed by TRDCNT counters.

For details on PWM mode, see section 16.3.5, PWM Mode.

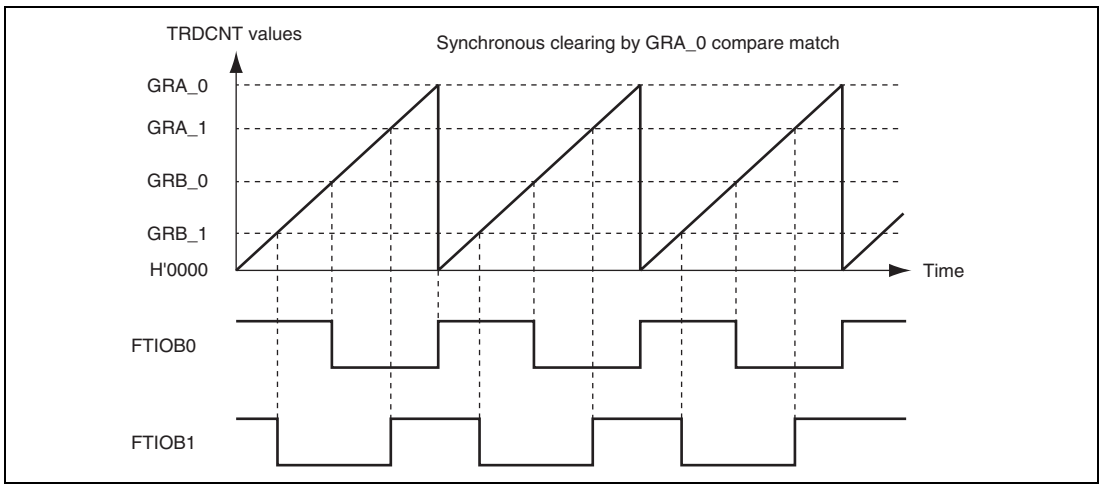


Figure 16.20 Example of Synchronous Operation

16.3.5 PWM Mode

In PWM mode, PWM waveforms are output from the FTIOB, FTIOC, and FTIOD output pins with GRA as a cycle register and GRB, GRC, and GRD as duty registers. The initial output level of the corresponding pin depends on the setting values of TRDOCR and POCR. Table 16.4 shows an example of the initial output level of the FTIOB0 pin.

The output level is determined by the POLB to POLD bits corresponding to POCR. When POLB is 0, the FTIOB output pin is set to 0 by compare match B and set to 1 by compare match A. When POLB is 1, the FTIOB output pin is set to 1 by compare match B and cleared to 0 by compare match A. In PWM mode, maximum 6-phase PWM outputs are possible.

Figure 16.21 shows an example of the PWM mode setting procedure.

Table 16.4 Initial Output Level of FTIOB0 Pin

TOB0	POLB	Initial Output Level
0	0	1
0	1	0
1	0	0
1	1	1

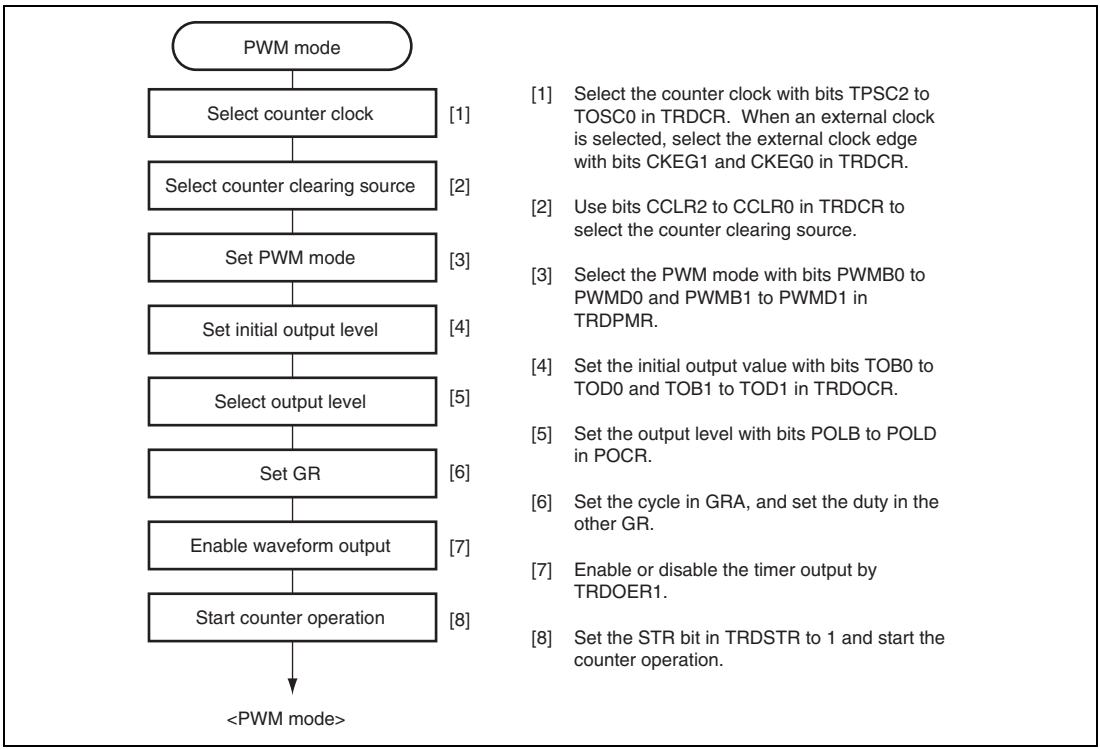


Figure 16.21 Example of PWM Mode Setting Procedure

Figure 16.22 shows an example of operation in PWM mode. The output signals go to 1 and TRDCNT is reset at compare match A, and the output signals go to 0 at compare match B, C, and D (TOB, TOC, and TOD = 0, POLB, POLC, and POLD = 0).

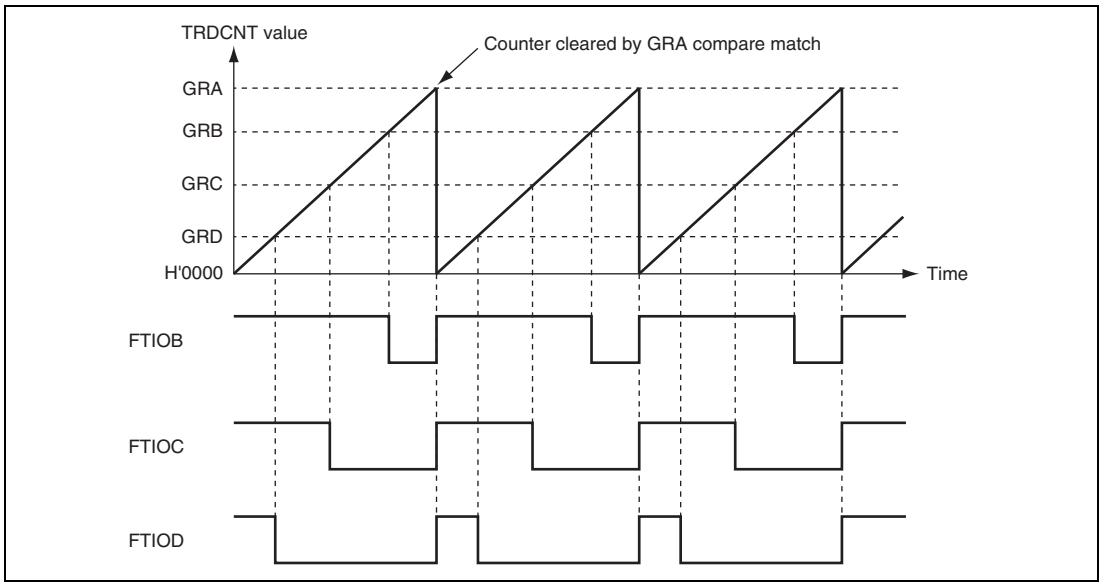


Figure 16.22 Example of PWM Mode Operation (1)

Figure 16.23 shows another example of operation in PWM mode. The output signals go to 0 and TRDCNT is reset at compare match A, and the output signals go to 1 at compare match B, C, and D (TOB, TOC, and TOD = 0, POLB, POLC, and POLD = 1).

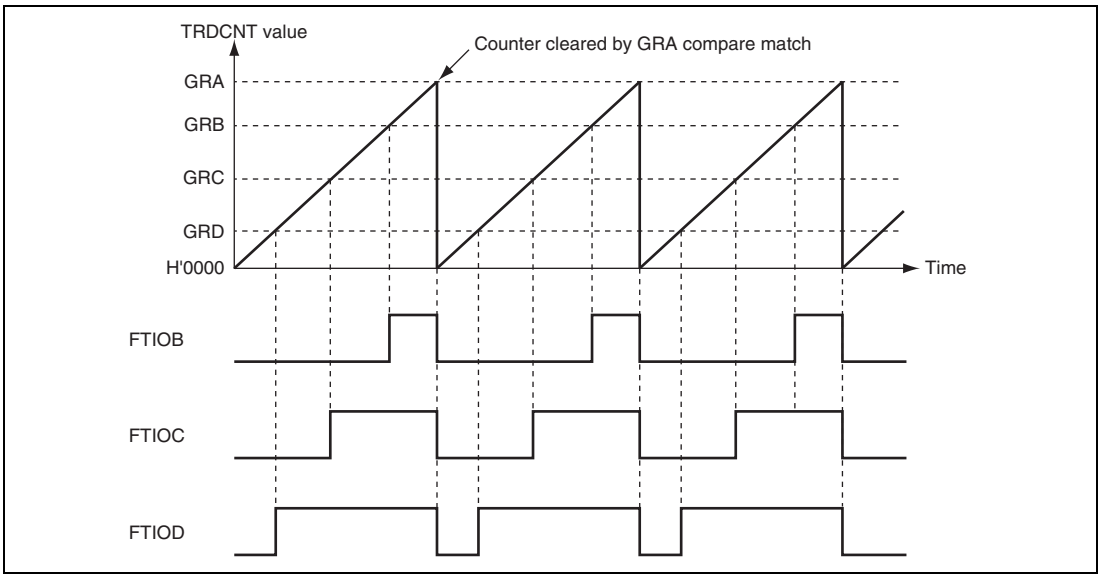


Figure 16.23 Example of PWM Mode Operation (2)

Figures 16.24 (when TOB, TOC, and TOD = 0, POLB, POLC, and POLD = 0) and 16.25 (when TOB, TOC, and TOD = 0, POLB, POLC, and POLD = 1) show examples of the output of PWM waveforms with duty cycles of 0% and 100% in PWM mode.

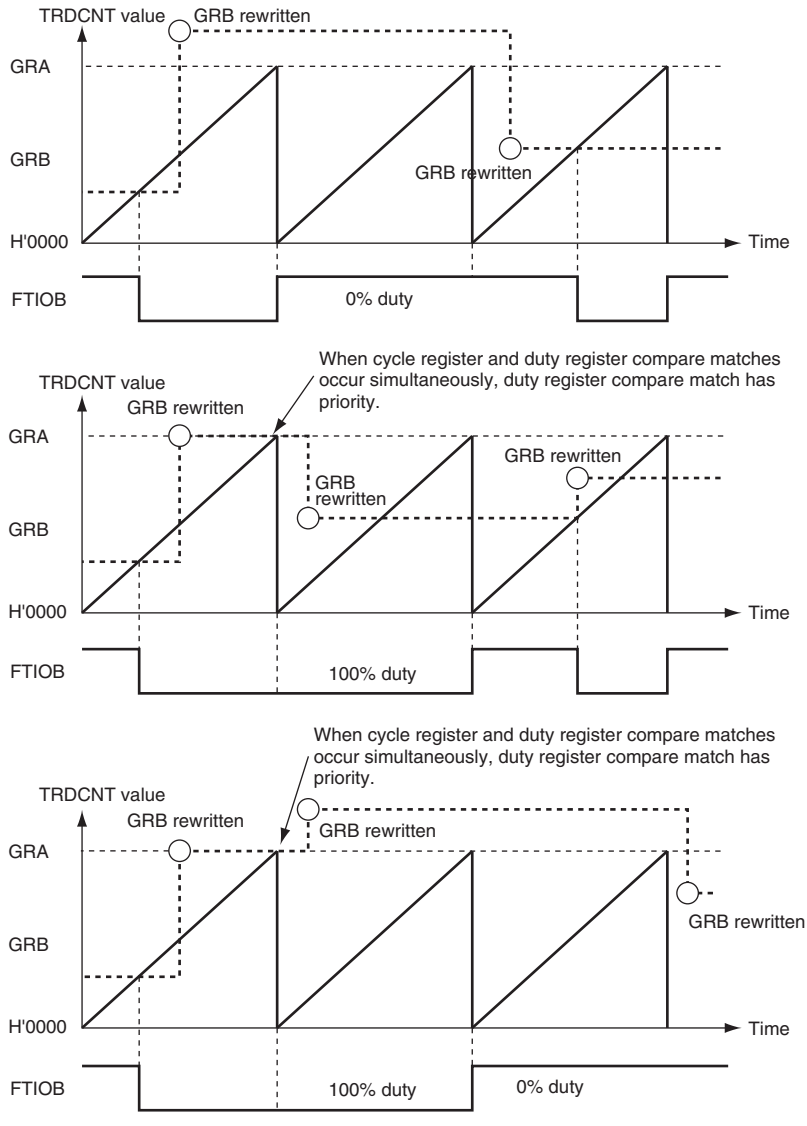


Figure 16.24 Example of PWM Mode Operation (3)

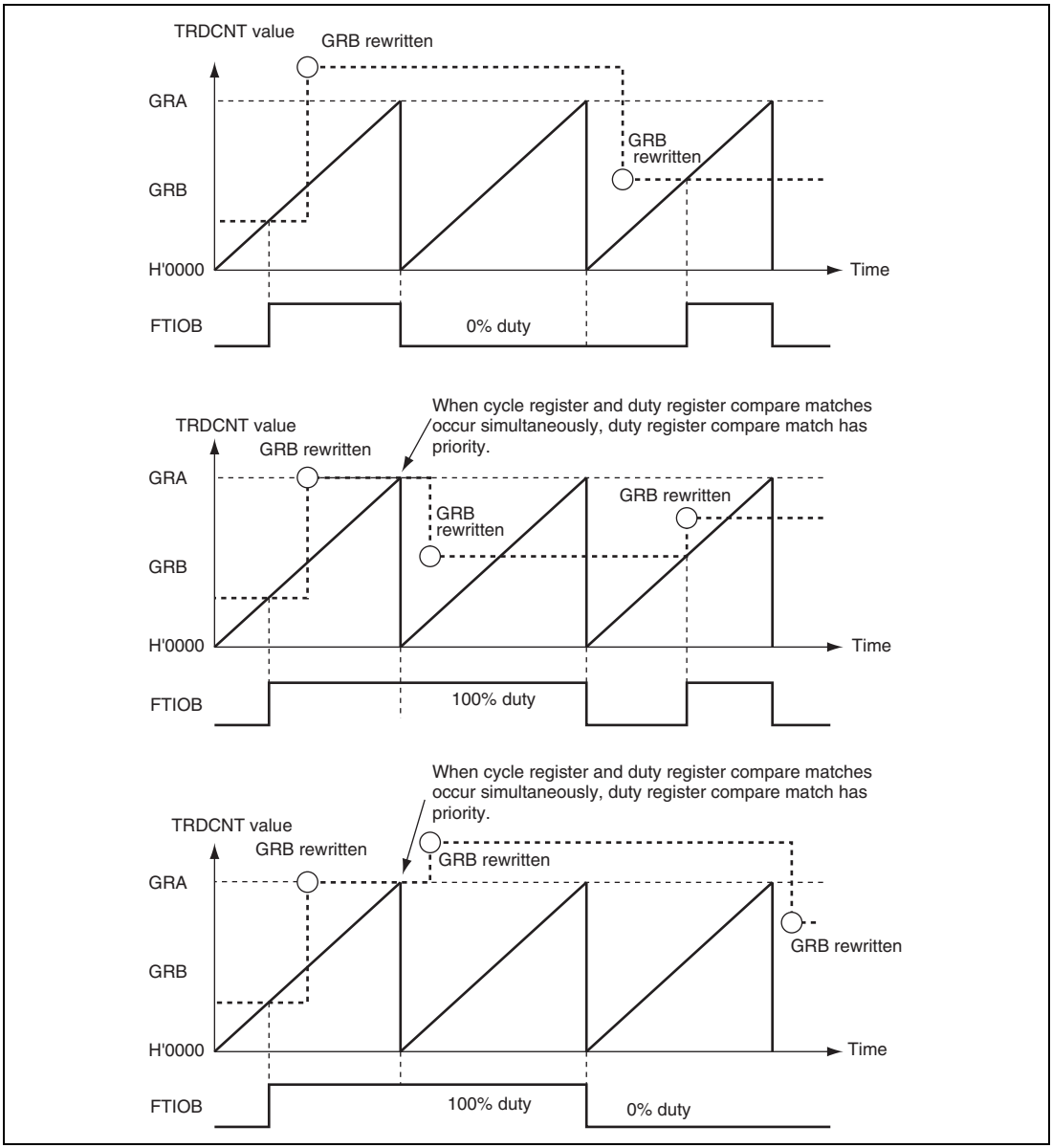


Figure 16.25 Example of PWM Mode Operation (4)

16.3.6 Reset Synchronous PWM Mode

Three normal- and counter-phase PWM waveforms are output by combining channels 0 and 1 that one of changing points of waveforms will be common.

In reset synchronous PWM mode, the FTIOB0 to FTIOD0 and FTIOA1 to FTIOD1 pins become PWM-output pins automatically. TRDCNT_0 performs an increment operation. Tables 16.5 and 16.6 show the PWM-output pins used and the register settings, respectively.

Figure 16.29 shows the example of reset synchronous PWM mode setting procedure.

Table 16.5 Output Pins in Reset Synchronous PWM Mode

Channel	Pin Name	Input/Output	Pin Function
0	FTIOC0	Output	Toggle output in synchronous with PWM cycle
0	FTIOB0	Output	PWM output 1
0	FTIOD0	Output	PWM output 1 (counter-phase waveform of PWM output 1)
1	FTIOA1	Output	PWM output 2
1	FTIOC1	Output	PWM output 2 (counter-phase waveform of PWM output 2)
1	FTIOB1	Output	PWM output 3
1	FTIOD1	Output	PWM output 3 (counter-phase waveform of PWM output 3)

Table 16.6 Register Settings in Reset Synchronous PWM Mode

Register	Description
TRDCNT_0	Initial setting of H'0000
TRDCNT_1	Not used (independently operates)
GRA_0	Sets counter cycle of TRDCNT_0
GRB_0	Set a changing point of the PWM waveform output from pins FTIOB0 and FTIOD0.
GRA_1	Set a changing point of the PWM waveform output from pins FTIOA1 and FTIOC1.
GRB_1	Set a changing point of the PWM waveform output from pins FTIOB1 and FTIOD1.

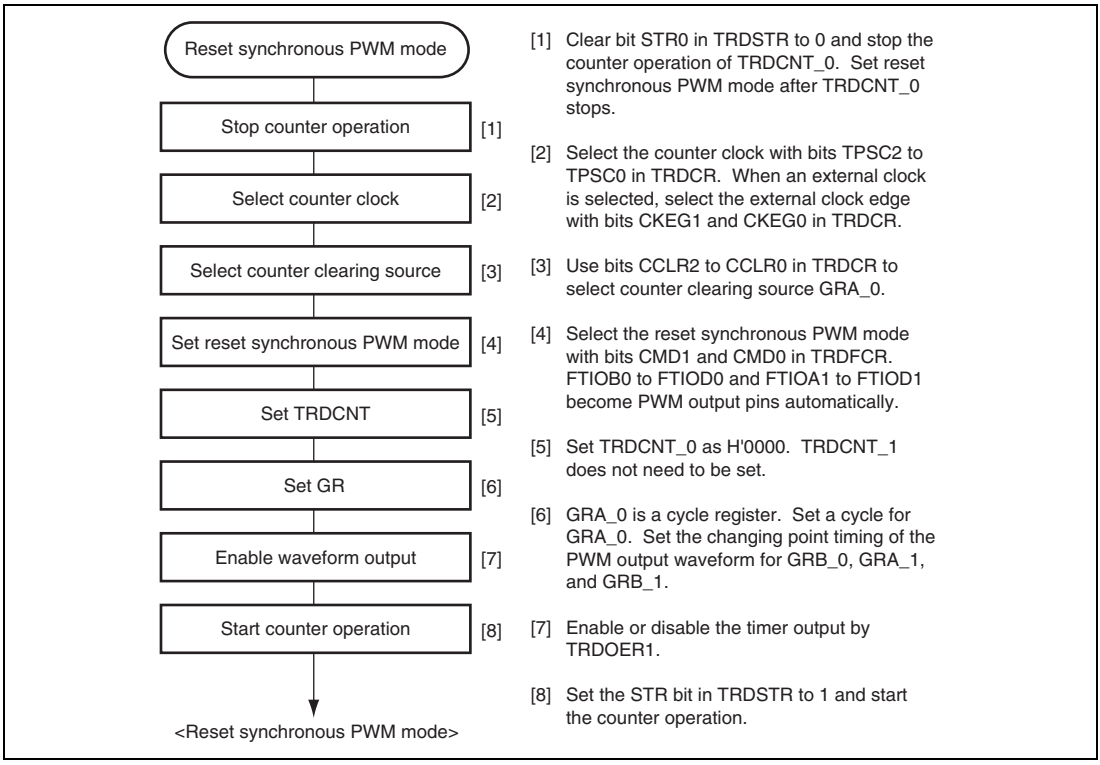


Figure 16.26 Example of Reset Synchronous PWM Mode Setting Procedure

Figures 16.27 and 16.28 show examples of operation in reset synchronous PWM mode.

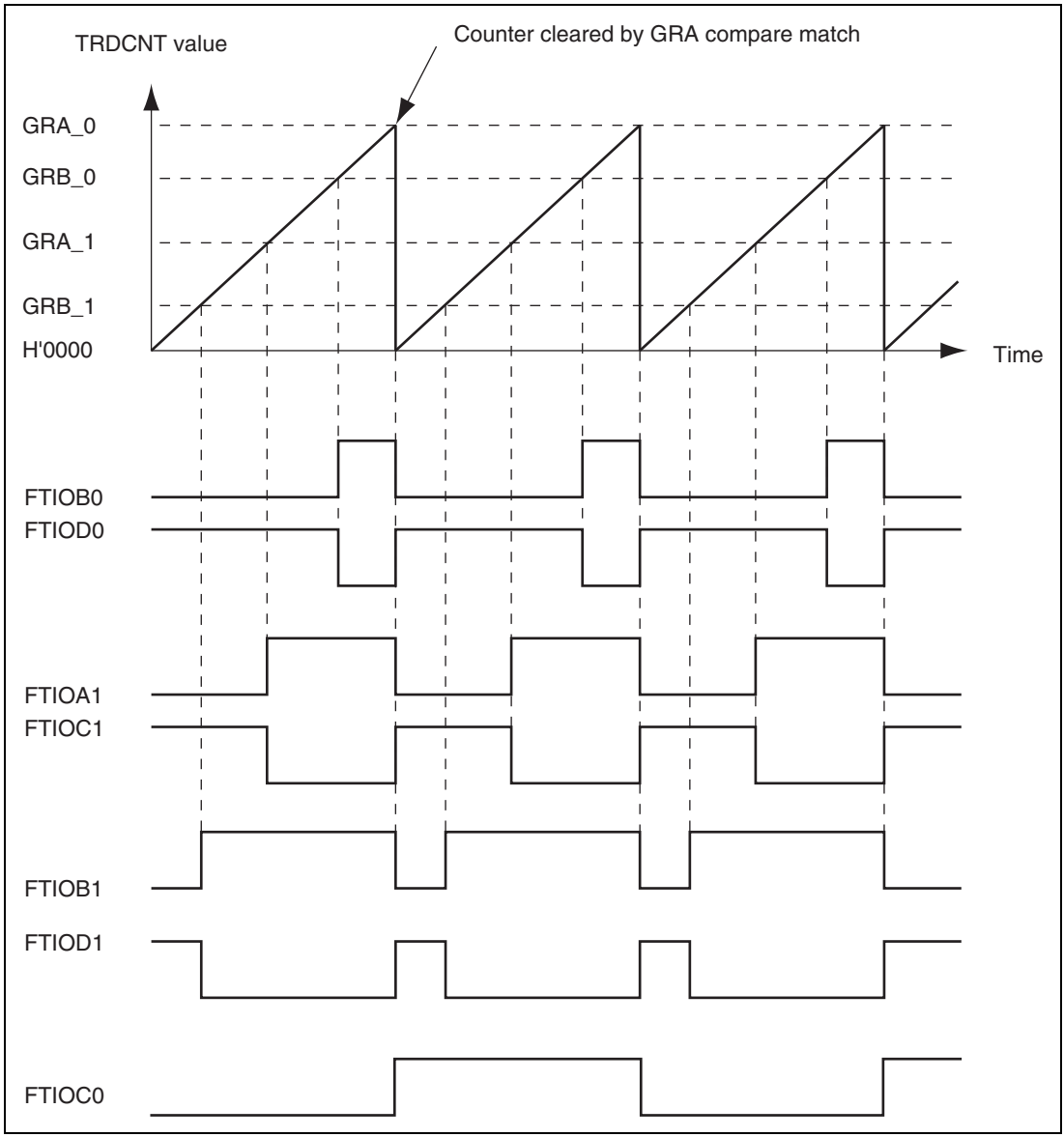


Figure 16.27 Example of Reset Synchronous PWM Mode Operation (OLS0 = OLS1 = 1)

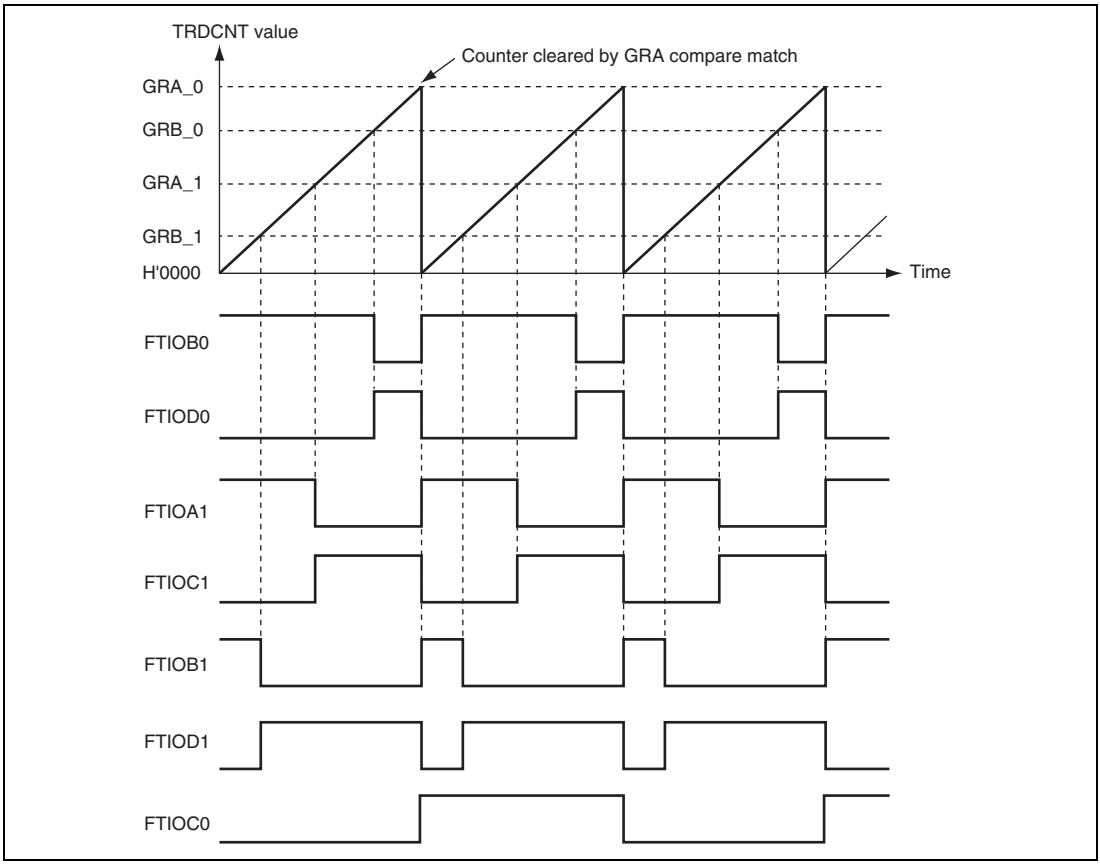


Figure 16.28 Example of Reset Synchronous PWM Mode Operation (OLS0 = OLS1 = 0)

In reset synchronous PWM mode, TRDCNT_0 and TRDCNT_1 perform increment and independent operations, respectively. However, GRA_1 and GRB_1 are separated from TRDCNT_1. When a compare match occurs between TRDCNT_0 and GRA_0, a counter is cleared and an increment operation is restarted from H'0000.

The PWM pin outputs 0 or 1 whenever a compare match between GRB_0, GRA_1, GRB_1 and TRDCNT_0 or counter clearing occur.

For details on operations when reset synchronous PWM mode and buffer operation are simultaneously set, see section 16.3.9, Buffer Operation.

16.3.7 Complementary PWM Mode

Three PWM waveforms for non-overlapped normal and counter phases are output by combining channels 0 and 1.

In complementary PWM mode, the FTIOB0 to FTIOD0 and FTIOA1 to FTIOD1 pins become PWM-output pins automatically. TRDCNT_0 and TRDCNT_1 perform an increment or decrement operation. Tables 16.7 and 16.8 show the output pins and register settings in complementary PWM mode, respectively.

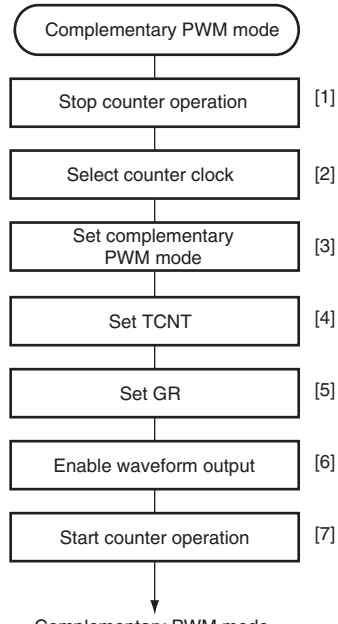
Figure 16.29 shows the example of complementary PWM mode setting procedure.

Table 16.7 Output Pins in Complementary PWM Mode

Channel	Pin Name	Input/Output	Pin Function
0	FTIOC0	Output	Toggle output in synchronous with PWM cycle
0	FTIOB0	Output	PWM output 1
0	FTIOD0	Output	PWM output 1 (counter-phase waveform non-overlapped with PWM output 1)
1	FTIOA1	Output	PWM output 2
1	FTIOC1	Output	PWM output 2 (counter-phase waveform non-overlapped with PWM output 2)
1	FTIOB1	Output	PWM output 3
1	FTIOD1	Output	PWM output 3 (counter-phase waveform non-overlapped with PWM output 3)

Table 16.8 Register Settings in Complementary PWM Mode

Register	Description
TRDCNT_0	Initial setting of non-overlapped periods (non-overlapped periods are differences with TRDCNT_1)
TRDCNT_1	Initial setting of H'0000
GRA_0	Sets (upper limit value – 1) of TRDCNT_0
GRB_0	Set a changing point of the PWM waveform output from pins FTIOB0 and FTIOD0.
GRA_1	Set a changing point of the PWM waveform output from pins FTIOA1 and FTIOC1.
GRB_1	Set a changing point of the PWM waveform output from pins FTIOB1 and FTIOD1.



[1] Clear bits STR0 and STR1 in TRDSTR to 0, and stop the counter operation of TRDCNT_0. Stop TRDCNT_0 and TRDCNT_1 and set complementary PWM mode.

[2] Use bits TPSC2 to TPSC0 in TRDCR to select the same counter clock for channels 0 and 1. When an external clock is selected, select the edge of the external clock by bits CKEG1 and CKEG0 in TRDCR. Set bits CCLR2 to CCLR0 in TRDCR so that the counter is not cleared.

[3] Use bits CMD1 and CMD0 in TRDFCR to set complementary PWM mode. FTIOB0 to FTIOD0 and FTIOA1 to FTIOD1 automatically become PWM output pins.

[4] TRDCNT_1 must be H'0000. Set a non-overlapped period to TRDCNT_0.

[5] GRA_0 is a cycle register. Set the cycle to GRA_0. Set the timing to change the PWM output waveform to GRB_0, GRA_1, and GRB_1. The settings must be set so that a compare match occurs on TRDCNT_0 and TRDCNT_1. $T \leq X$ (X: Initial value in GRB_0, GRA_1, or GRB_1).

[6] Use TRDOER1 to enable or disable the timer output.

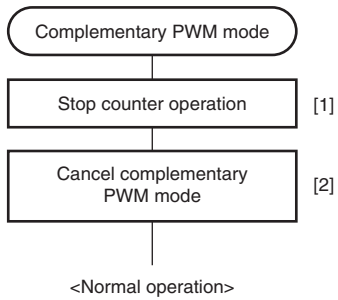
[7] Set the STR0 and STR1 bits in TRDSTR to 1 to start the count operation.

Note: To modify the settings for the complementary PWM mode, clear settings other than those for the mode. After that, repeat setting from step [1].

Figure 16.29 Example of Complementary PWM Mode Setting Procedure

(1) Canceling Procedure of Complementary PWM Mode

Figure 16.30 shows the complementary PWM mode canceling procedure.



[1] Clear bit CMD1 in TRDFCR to 0, and set channels 0 and 1 to normal operation.

[2] After setting channels 0 and 1 to normal operation, clear bits STR0 and STR1 in TRDSTR to 0 and stop TRDCNT_0 and TRDCNT_1.

Figure 16.30 Canceling Procedure of Complementary PWM Mode

(2) Examples of Complementary PWM Mode Operation

Figure 16.31 shows an example of complementary PWM mode operation. In complementary PWM mode, TRDCNT_0 and TRDCNT_1 perform an increment or decrement operation. When TRDCNT_0 and GRA_0 are compared and their contents match, the counter is decremented. And when TRDCNT_1 underflows, the counter is incremented. In GRA_0, GRA_1, and GRB_1, compare match is carried out in the order of TRDCNT_0 → TRDCNT_1 → TRDCNT_1 → TRDCNT_0 and PWM waveform is output, during one cycle of an up/down counter. In this mode, the initial setting will be TRDCNT_0 > TRDCNT_1.

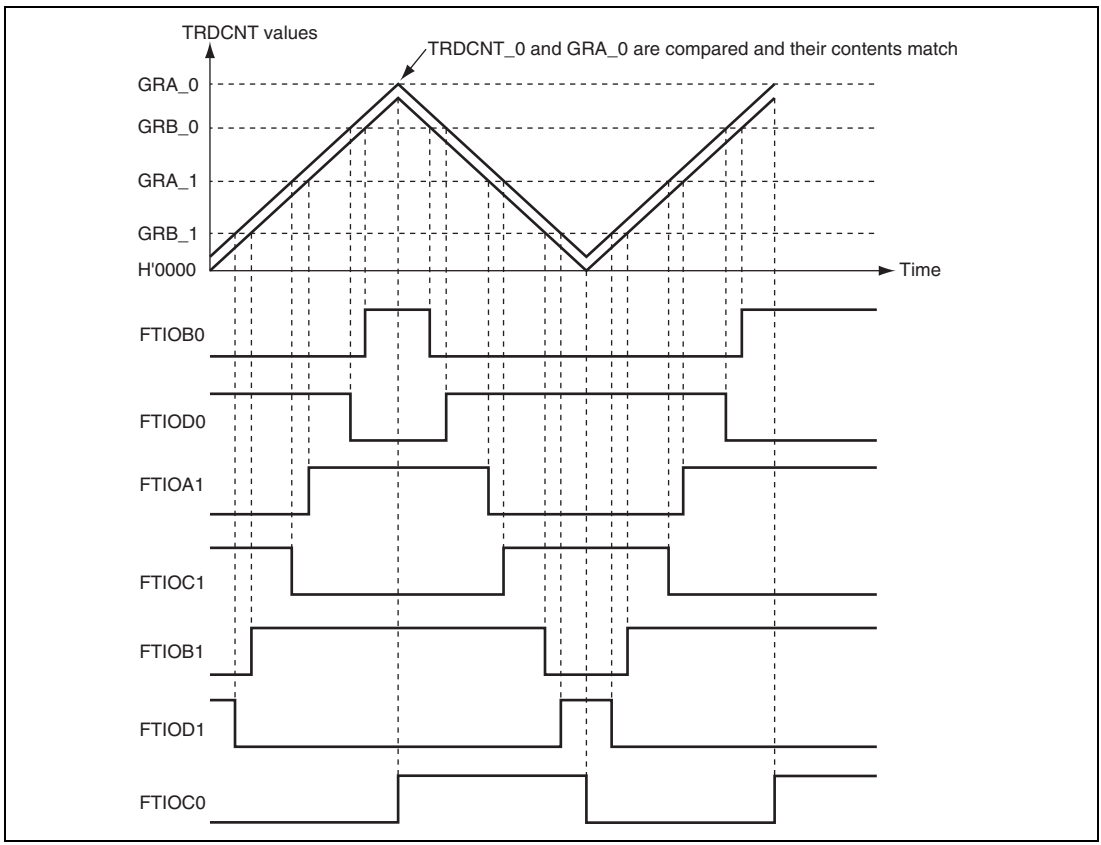


Figure 16.31 Example of Complementary PWM Mode Operation (1)

Figure 16.32 shows an example of PWM waveform output with 0% duty and 100% duty in complementary PWM mode (for one phase).

In this figure, GRB_0 is set to a value equal to or greater than GRA_0 and H'0000. The waveform with a duty cycle of 0% and 100% can be output. When buffer operation is used together, the duty cycles can easily be changed, including the above settings, during operation. For details on buffer operation, see section 16.3.9, Buffer Operation.

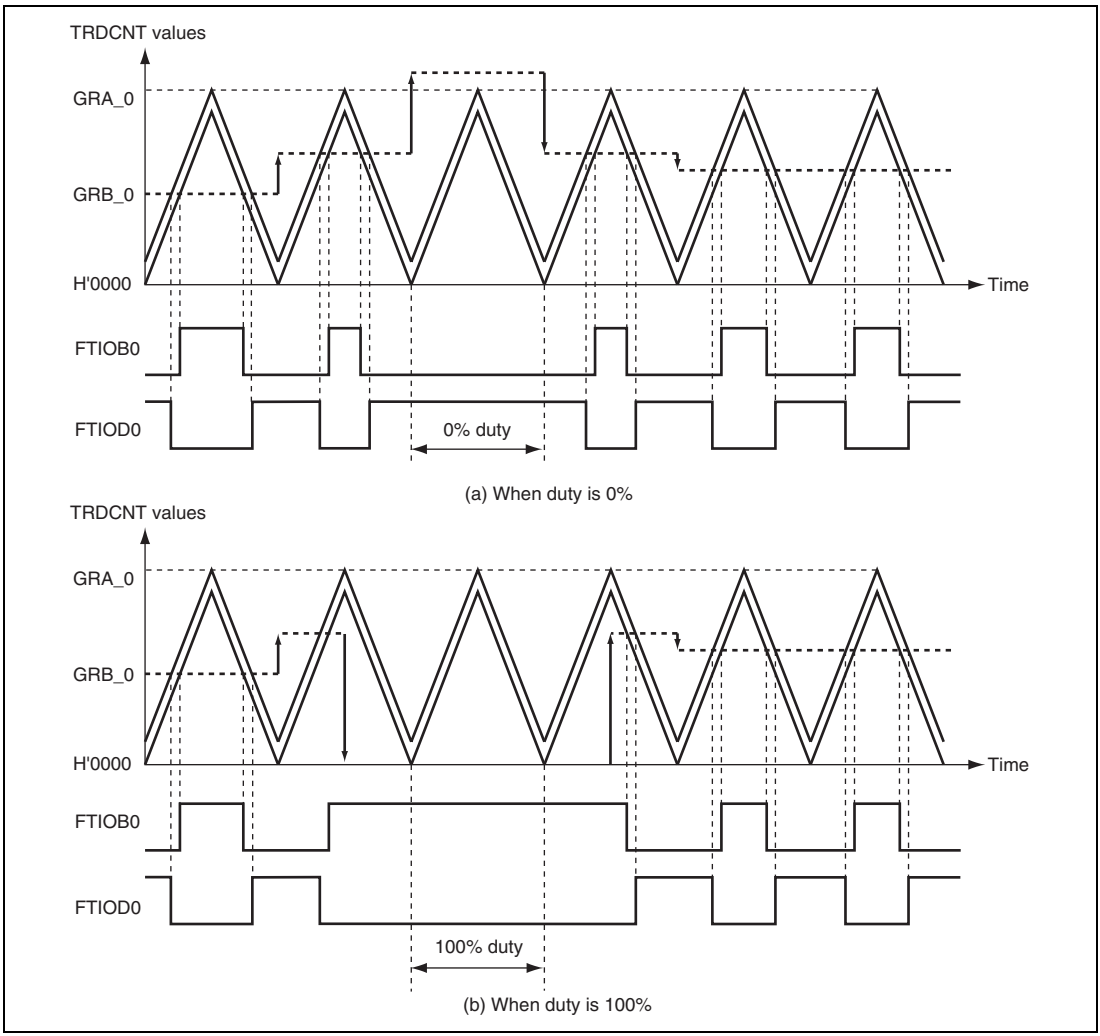


Figure 16.32 Example of Complementary PWM Mode Operation (2)

In complementary PWM mode, when the counter switches from up-counter to down-counter or vice versa, TRDCNT_0 and TRDCNT_1 overshoots or undershoots, respectively. In this case, the conditions to set the IMFA flag in channel 0 and the UDF flag in channel 1 differ from usual settings. Also, the transfer conditions in buffer operation differ from usual settings. Such timings are shown in figures 16.33 and 16.34.

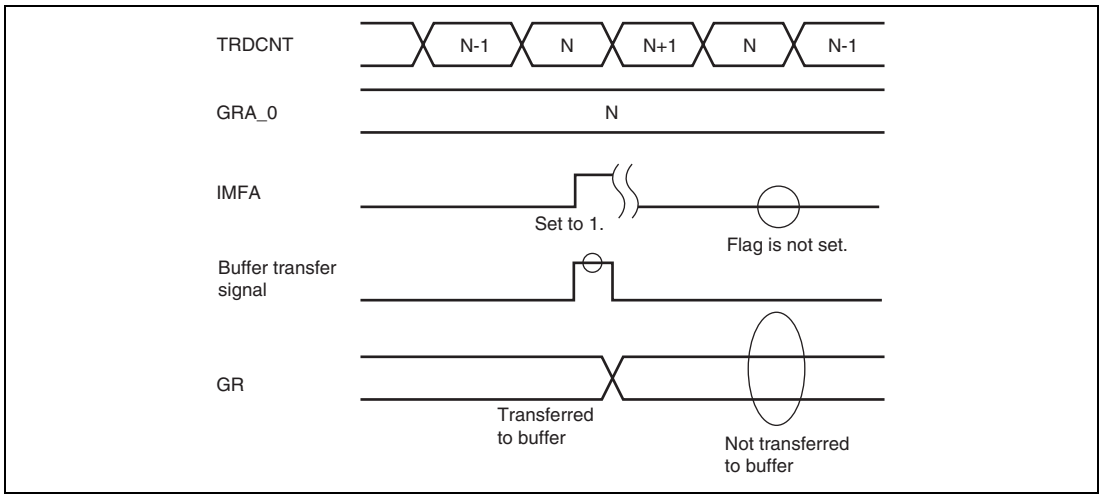


Figure 16.33 Timing of Overshooting

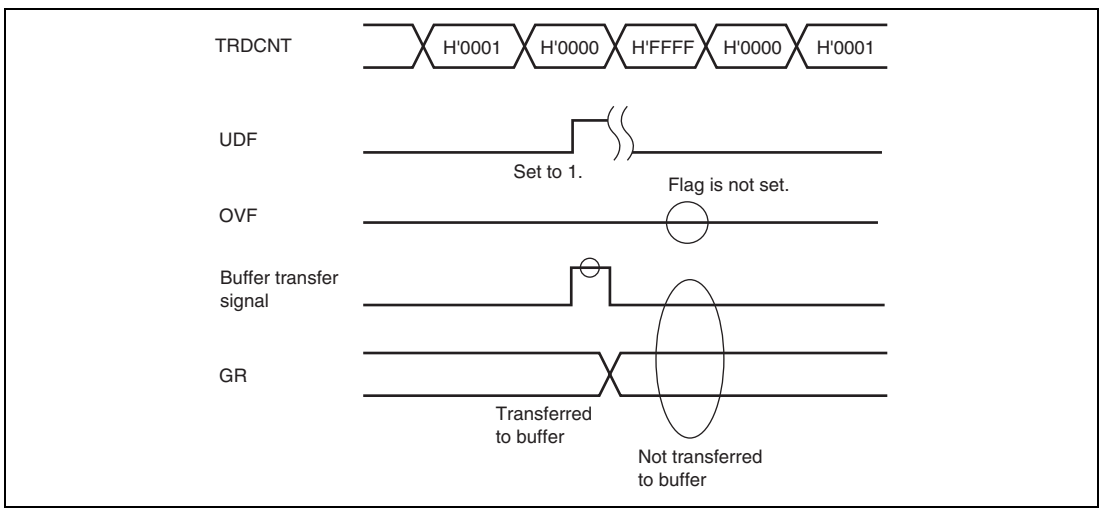


Figure 16.34 Timing of Undershooting

When the counter is incremented or decremented, the IMFA flag of channel 0 is set to 1, and when the register is underflowed, the UDF flag of channel 0 is set to 1. After buffer operation has been designated for GR, the value in the buffer registers is transferred to GR when the counter is incremented by compare match A0 or when TRDCNT_1 is underflowed. In complementary PWM mode, the OVF flag is not set to 1 at the timing that the counter value changes from H'FFFF to H'0000 as shown in figure 16.34.

(3) Setting GR Value in Complementary PWM Mode

To set the general register (GR) or modify GR during operation in complementary PWM mode, see the following notes.

1. Initial value
   - H'0000 to T – 1 (T: Initial value of TRDCNT_0) must not be set for the initial value.
   - GRA_0 – (T – 1) or more must not be set for the initial value.
   - When using buffer operation, the same values must be set in the buffer registers and corresponding general registers.
2. Modifying the setting value
   - Use the buffer operation to change the GR value. If the GR value is changed by writing to it directly, the intended waveform may not be output.
   - Do not change settings of GRA_0 during operation.

16.3.8 PWM3 Mode Operation

In PWM3 mode, single-phase PWM waveforms can be output using TRDCNT_0. The waveform does not overlap its counter-phase waveform.

When the PWM3 mode is selected, the FTIOA0 and FTIOB0 pins are automatically set to output pins for the PWM function using TRDCNT_0 regardless of the TRDPMR value. The waveform is output on a GRA_0, GRA_1, GRB_0, or GRB_1 compare match according to bits TOA0 and TOB0 in TRDOCR regardless of the TRDIORA and TRDIORC settings.

- When TOA0 = 0, 1 is output on a compare match of GRA_1 and 0 is output on a compare match of GRA_0 on the FTIOA0 pin.
- When TOA0 = 1, 0 is output on a compare match of GRA_1 and 1 is output on a compare match of GRA_0 on the FTIOA0 pin.
- When TOB0 = 0, 1 is output on a compare match of GRB_1 and 0 is output on a compare match of GRB_0 on the FTIOB0 pin.
- When TOB0 = 1, 0 is output on a compare match of GRB_1 and 1 is output on a compare match of GRB_0 on the FTIOB0 pin.

Table 16.9 lists the correspondence between pin functions and GR registers, figure 16.35 shows a block diagram in PWM3 mode, and figure 16.36 shows a flowchart of setting in PWM3 mode.

When the buffer operation is used, set TRDMDR. The timer input/output pins, which are not used in PWM3 mode, can be used as general port pins. When the buffer operation is not set, since GRC or GRD is not used, a compare match interrupt can be generated when GRC or GRD matches with TRDCNT_1.

Table 16.9 Pin Configuration in PWM3 Mode and GR Registers

Channel	Pin Name	Input/Output	Compare Match Register	Buffer Register
0	FTIOA0	Output	GRA_0	GRC_0
			GRA_1	GRC_1
	FTIOB0		GRB_0	GRD_0
			GRB_1	GRD_1
	FTIOC0	I/O	General I/O port	General I/O port
	FTIOD0			
1	FTIOA1			
	FTIOB1			
	FTIOC1			
	FTIOD1			

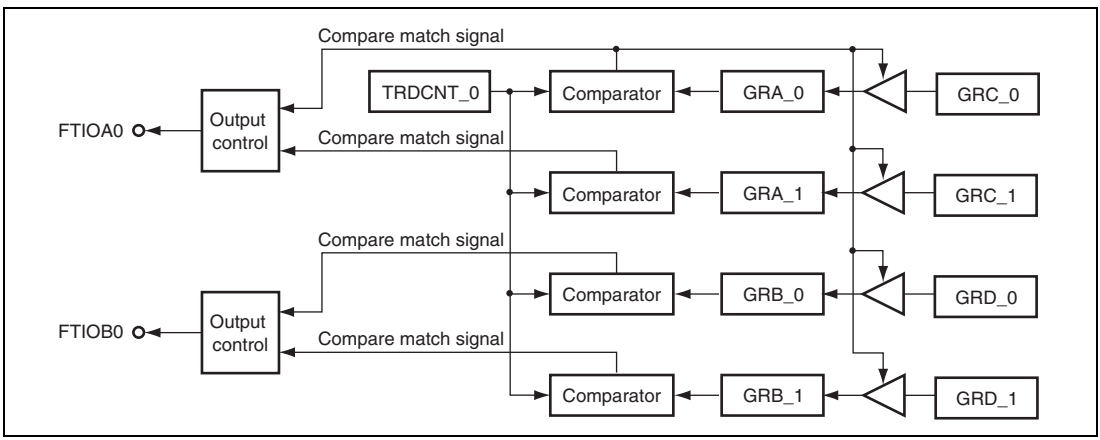
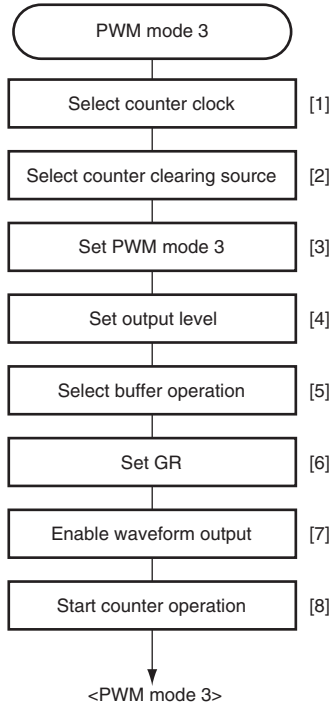


Figure 16.35 Block Diagram in PWM3 Mode



[1] Select the counter clock with bits TPSC2 to TPSC0 in TRDCR. When an external clock is selected, select the external clock edge with bits CKEG1 and CKEG0 in TRDCR.

[2] Use bits CCLR2 to CCLR0 in TRDCR to select counter clearing source GRA_0.

[3] Select PWM mode 3 with bit PWM3 in TRDFCR.

[4] Set output levels with bits TOB0 and TOA0 in TRDOCR.

[5] Set the GR buffer operation with bits BFC0, BFC1, BFD0, and BFD1 in TRDMDR.

[6] Set a cycle in GRA. Set the duty cycle in other GR registers.

[7] Enable or disable the timer output by TRDOER.

[8] Set the STR bit in TRDSTR to 1 and start the counter operation.

Figure 16.36 Flowchart of Setting in PWM3 Mode

Figure 16.37 is an example when non-overlapped pulses are output on pins FTIOA0 and FTIOB0. In this example, TRDCNT_0 functions as a periodic counter which is cleared on compare match A0 (bits CCLR2 to CCLR0 in TRDCR_0 are set to B'001), and PWM3 mode is selected (bit PWM3 in TRDFCR is cleared to 0). The cycle of the pulse is arbitrary.

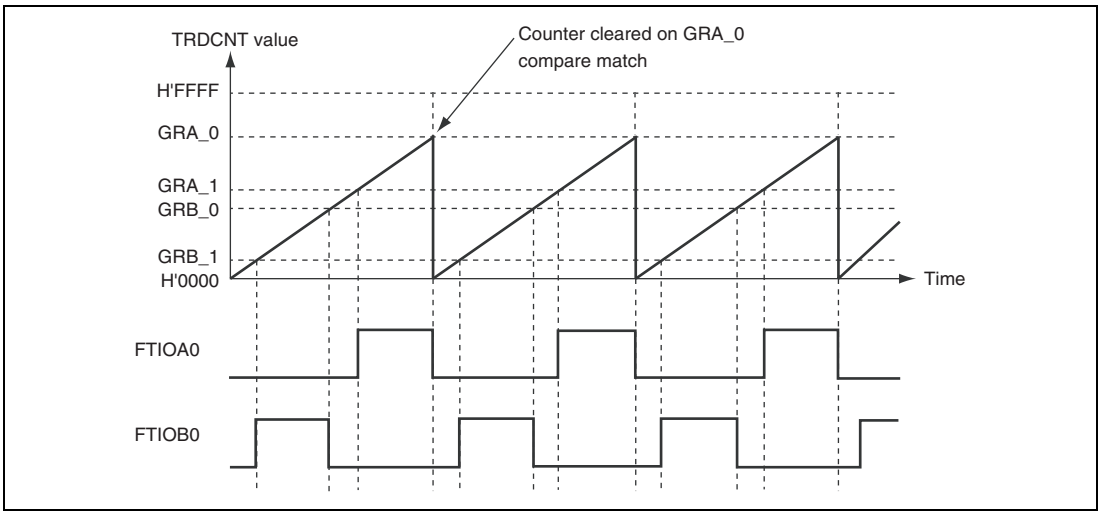


Figure 16.37 Example of Non-Overlap Pulses

Figures 16.38 and 16.39 show examples of stopping operation of the counter in PWM3 mode, when the CCLR2 to CCLR0 bits in TRDCR are set to clear TRDCNT_0 on GRA_0 compare match. For details on PWM3 mode, see section 16.3.8, PWM3 Mode Operation.

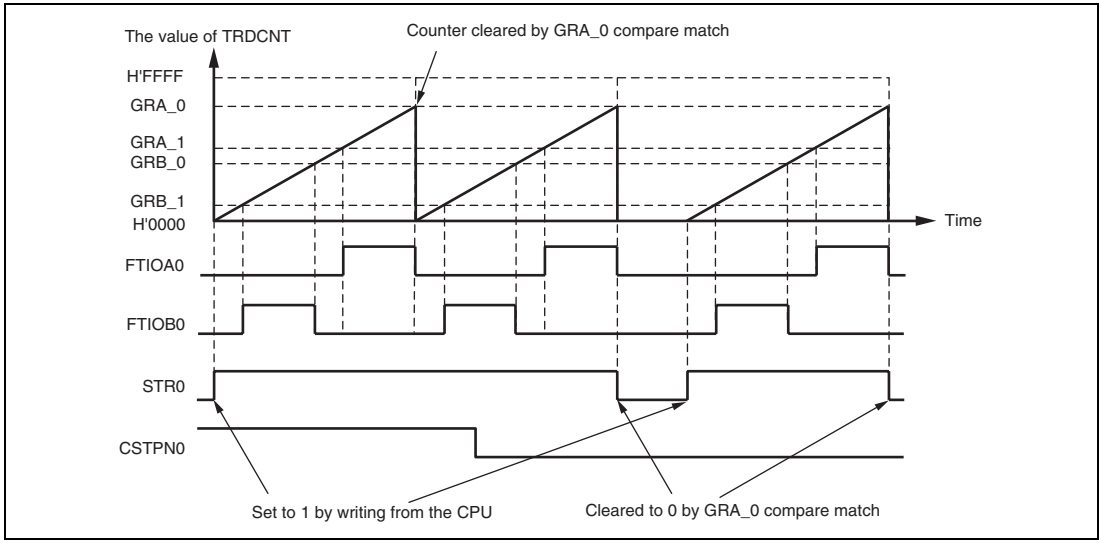


Figure 16.38 Example (1) of Stopping Operation of the Counter (in PWM3 Mode)

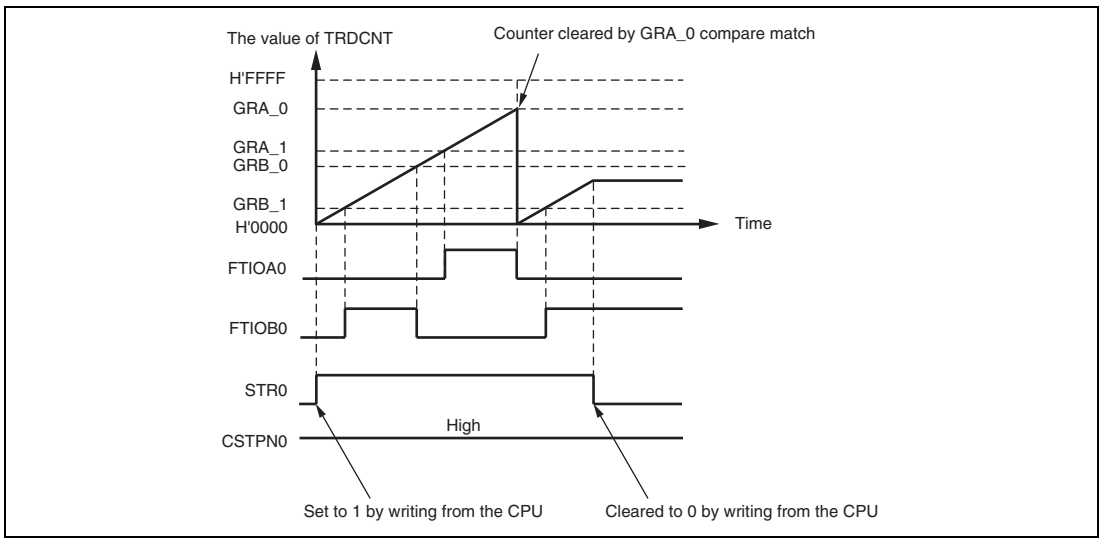


Figure 16.39 Example (2) of Stopping Operation of the Counter (in PWM3 Mode)

Figure 16.40 shows an example of starting and stopping operations of counters in PWM3 mode, when TRDCNT_0 is set to be cleared and stopped on GRA_0 compare match (CCLR2 to CCLR0 = 001, CSTPNT0 = 0) and TRDCNT_1 is used as a free-running counter. When TRDCNT_1 starts counting by setting the STR1 bit to 1 after TRDCNT_0 has started counting by setting the STR0 bit to 1, set 0 in the STR0 bit and 1 in the STR1 bit by using a MOV instruction. If the bit manipulation instruction is used to set 1 in the STR1 bit, there is a possibility that the STR0 bit is set to 1 after the counting has stopped on GRA_0 compare match, and that TRDCNT_0 starts counting again.

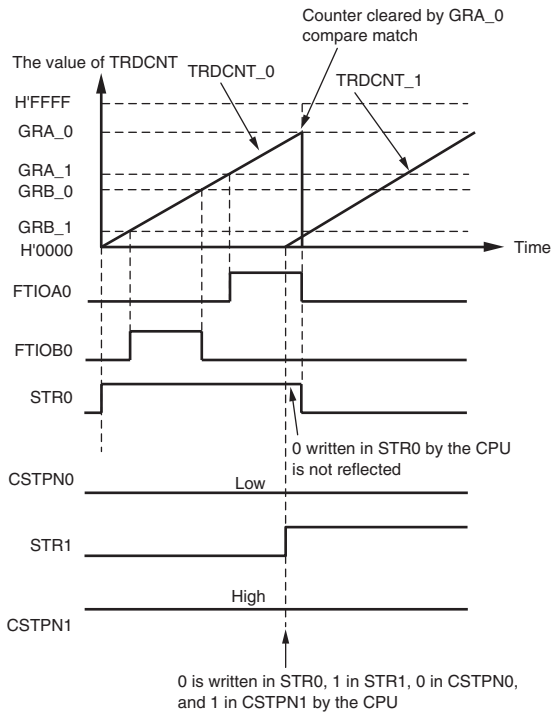


Figure 16.40 Example of Starting and Stopping Operations of Counters (in PWM3 Mode)

16.3.9 Buffer Operation

Buffer operation differs depending on whether GR has been designated for an input capture register or an output compare register, or in reset synchronous PWM mode or complementary PWM mode.

Table 16.10 shows the register combinations used in buffer operation.

Table 16.10 Register Combinations in Buffer Operation

General Register (GR)	Buffer Register
GRA	GRC
GRB	GRD

(1) When GR is an Output Compare Register

When a compare match occurs, the value in the buffer register of the corresponding channel is transferred to the general register.

This operation is illustrated in figure 16.41.

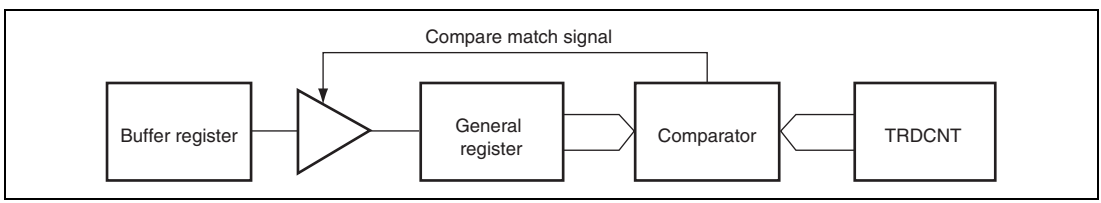


Figure 16.41 Compare Match Buffer Operation

(2) When GR is an Input Capture Register

When an input capture occurs, the value in TRDCNT is transferred to GR and the value previously stored in the general register is transferred to the buffer register.

This operation is illustrated in figure 16.42.

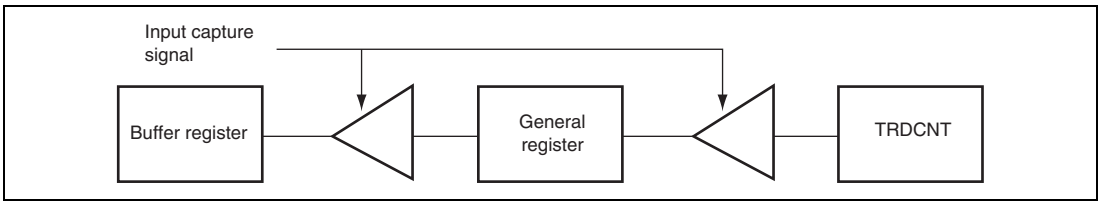


Figure 16.42 Input Capture Buffer Operation

(3) PWM3 Mode

When compare match A0 occurs, the value of the buffer register is transferred to GR.

(4) Complementary PWM Mode

When the counter switches from counting up to counting down or vice versa, the value of the buffer register is transferred to GR. Here, the value of the buffer register is transferred to GR in the following timing:

- When TRDCNT_0 and GRA_0 are compared and their contents match
- When TRDCNT_1 underflows

(5) Reset Synchronous PWM Mode

When compare match A0 occurs, the value in the buffer register is transferred to GR.

(6) Example of Buffer Operation Setting Procedure

Figure 16.43 shows an example of the buffer operation setting procedure.

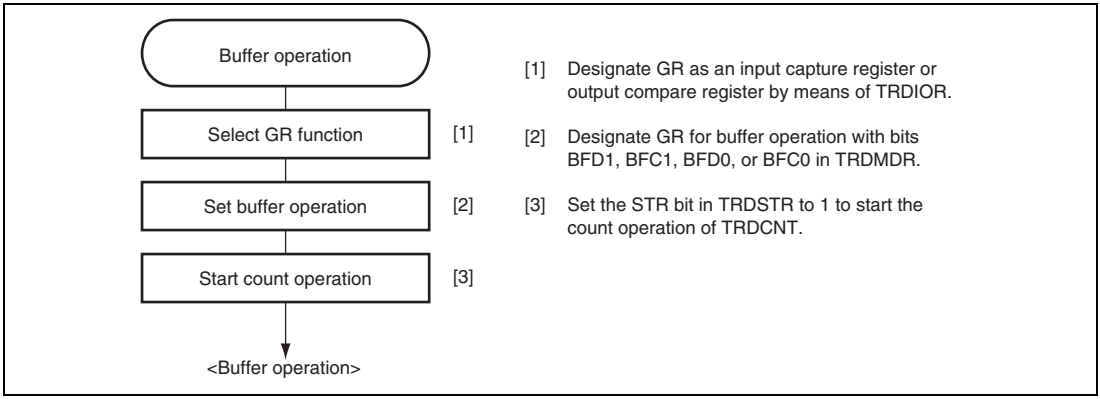


Figure 16.43 Example of Buffer Operation Setting Procedure

(7) Examples of Buffer Operation

Figure 16.44 shows an operation example in which GRA has been designated as an output compare register, and buffer operation has been designated for GRA and GRC.

This is an example of TRDCNT operating as a periodic counter cleared by compare match B.

Pins FTIOA and FTIOB are set for toggle output by compare match A and B.

As buffer operation has been set, when compare match A occurs, the FTIOA pin performs toggle outputs and the value in buffer register is simultaneously transferred to the general register. This operation is repeated each time that compare match A occurs.

The timing to transfer data is shown in figure 16.45.

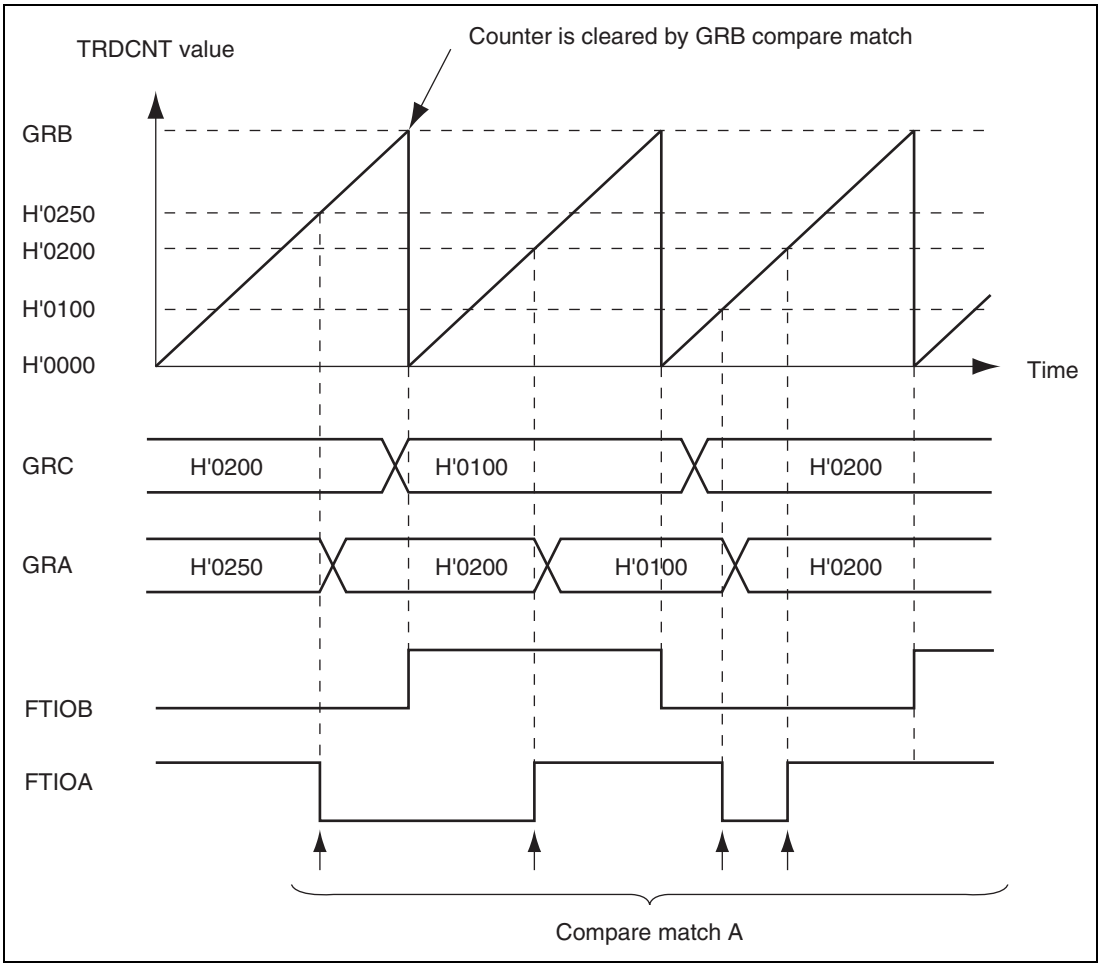


Figure 16.44 Example of Buffer Operation (1)
(Buffer Operation for Output Compare Register)

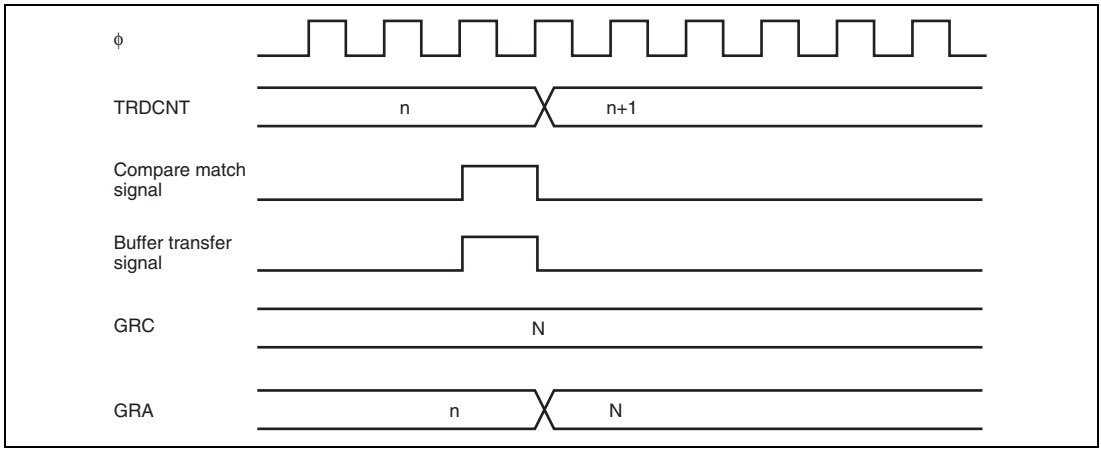


Figure 16.45 Example of Compare Match Timing for Buffer Operation

Figure 16.46 shows an operation example in which GRA has been designated as an input capture register, and buffer operation has been designated for GRA and GRC.

Counter clearing by input capture B has been set for TRDCNT, and falling edges have been selected as the FIOCB pin input capture input edge. And both rising and falling edges have been selected as the FIOCA pin input capture input edge.

As buffer operation has been set, when the TRDCNT value is stored in GRA upon the occurrence of input capture A, the value previously stored in GRA is simultaneously transferred to GRC. The transfer timing is shown in figure 16.47.

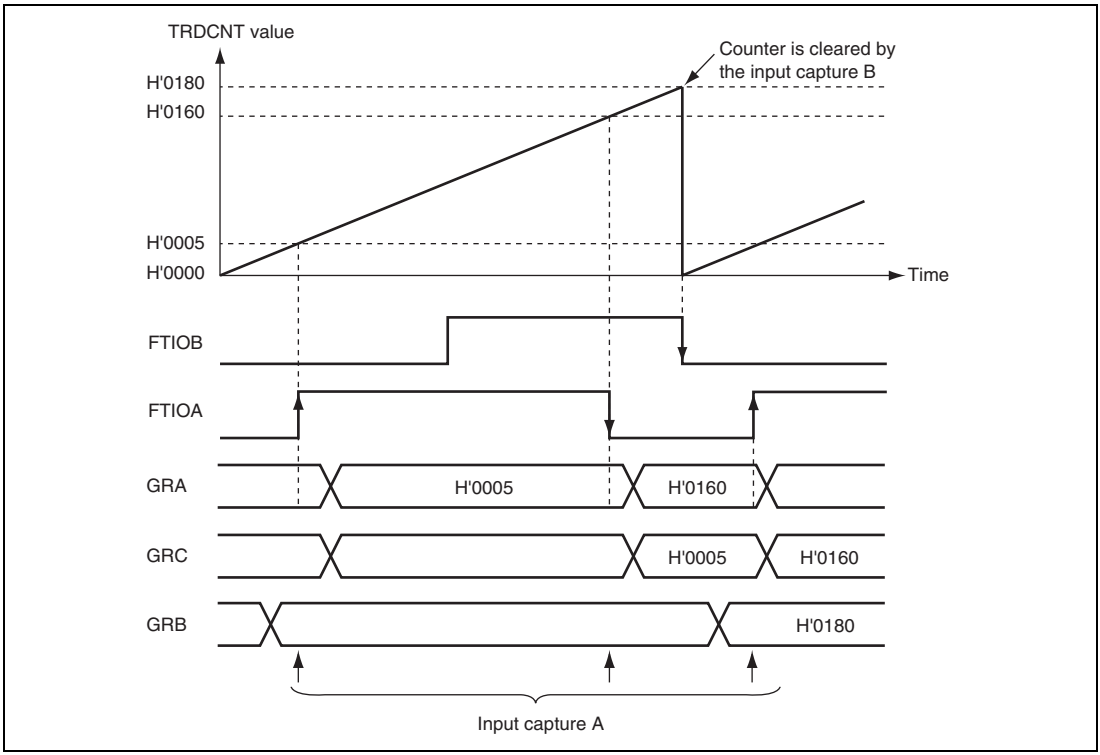


Figure 16.46 Example of Buffer Operation (2)
(Buffer Operation for Input Capture Register)

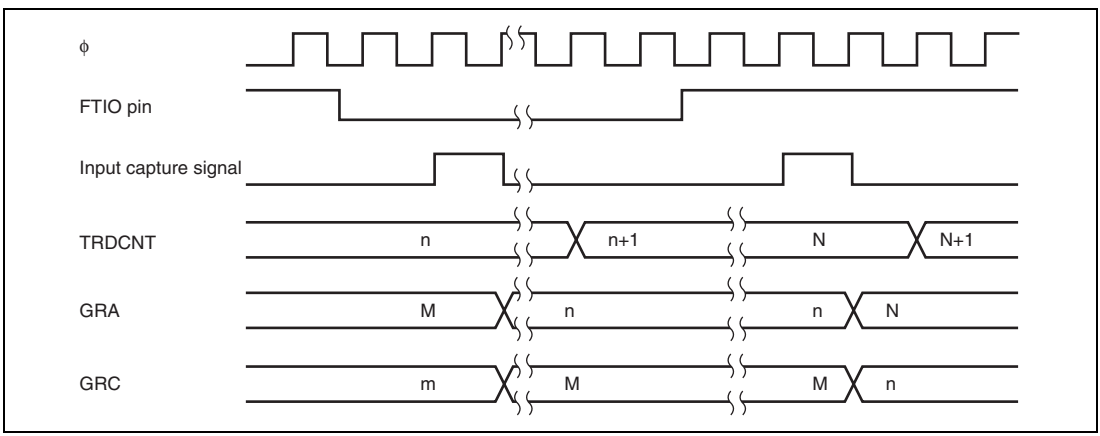


Figure 16.47 Input Capture Timing of Buffer Operation

Figures 16.48 and 16.49 show the operation examples when buffer operation has been designated for GRB_0 and GRD_0 in complementary PWM mode. These are examples when a PWM waveform of 0% duty is created by using the buffer operation and performing GRD_0 ≥ GRA_0. Data is transferred from GRD_0 to GRB_0 according to the settings of CMD0 and CMD1 when TRDCNT_0 and GRA_0 are compared and their contents match or when TRDCNT_1 underflows. However, when GRD_0 ≥ GRA_0, data is transferred from GRD_0 to GRB_0 when TRDCNT_1 underflows regardless of the setting of CMD0 and CMD1. When GRD_0 = H'0000, data is transferred from GRD_0 to GRB_0 when TRDCNT_0 and GRA_0 are compared and their contents match regardless of the settings of CMD0 and CMD1.

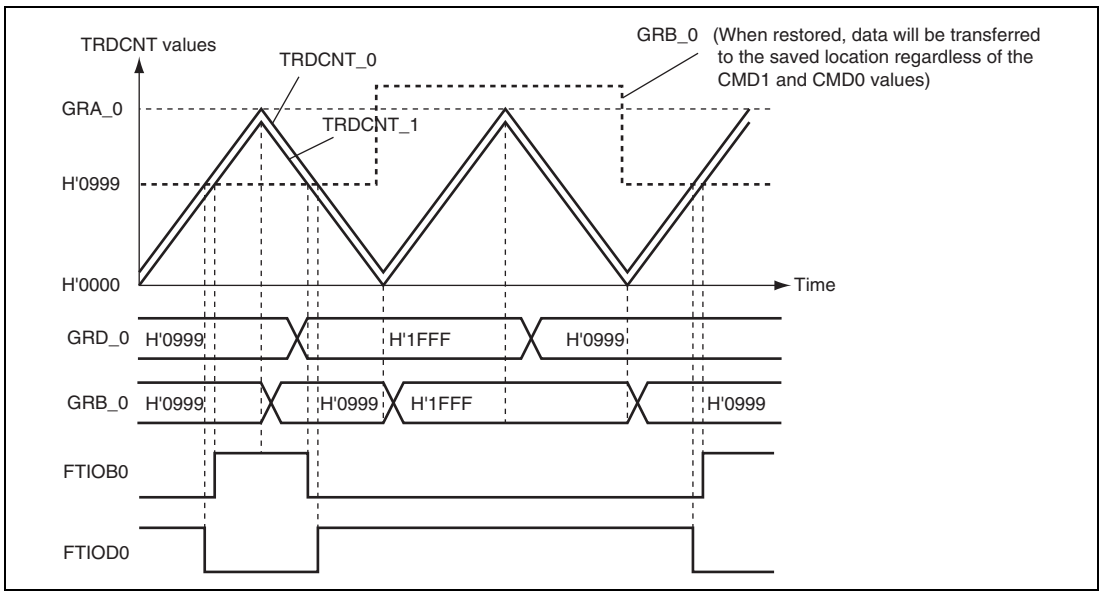


Figure 16.48 Buffer Operation (3)
(Buffer Operation in Complementary PWM Mode CMD1 = CMD0 = 1)

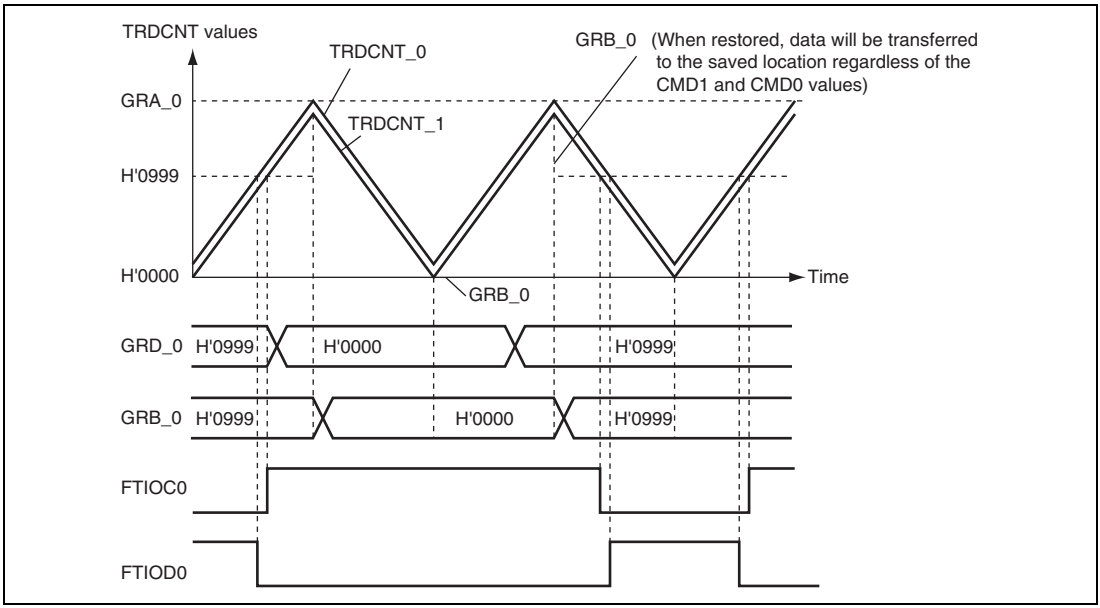


Figure 16.49 Buffer Operation (4)
(Buffer Operation in Complementary PWM Mode CMD1 =1, CMD0 = 0)

16.3.10 Timer RD Output Timing

The outputs of channels 0 and 1 can be disabled or inverted by the settings of TRDOER1 and TRDOCR and the external level.

(1) Output Disable/Enable Timing of Timer RD by TRDOER1

Setting the master enable bit in TRDOER1 to 1 disables the output of timer RD. By setting the PCR and PDR of the corresponding I/O port beforehand, any value can be output. Figure 16.50 shows the timing to enable or disable the output of timer RD by TRDOER1.

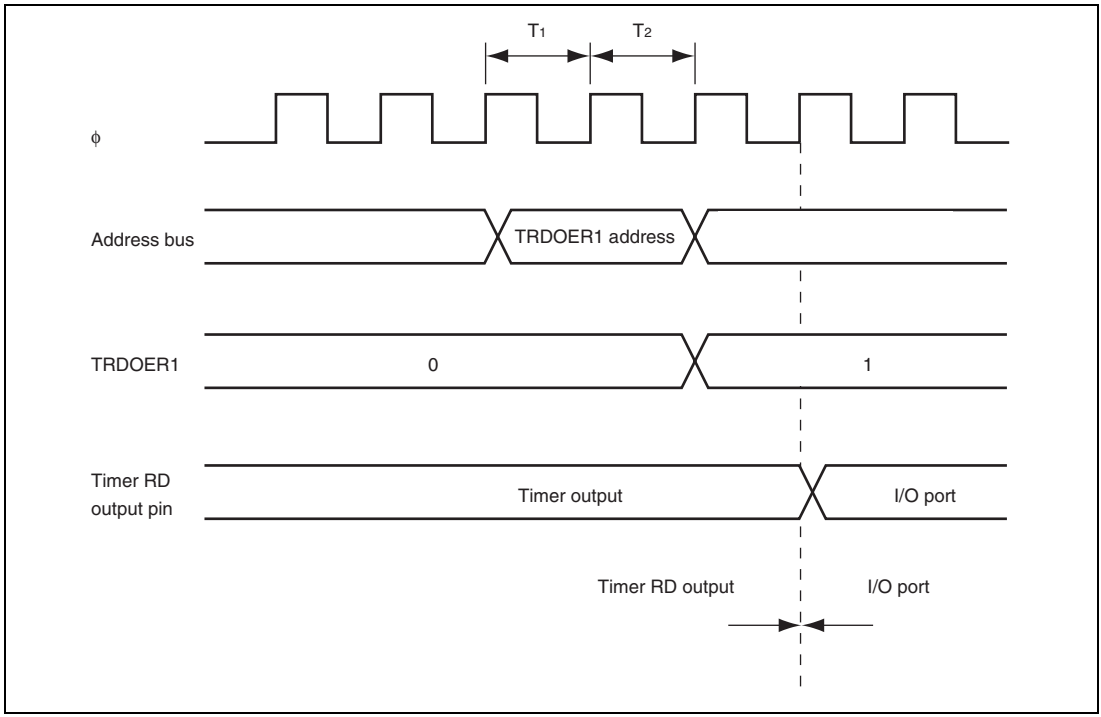


Figure 16.50 Example of Output Disable Timing of Timer RD by Writing to TRDOER1

(2) Output Disable Timing of Timer RD by External Trigger

When PH5/$\overline{\text{TRDOI_0}}$ (or PH6/$\overline{\text{TRDOI_1}}$) is set as a $\overline{\text{TRDOI}}$ input pin, and low level is input to $\overline{\text{TRDOI}}$, the master enable bit in TRDOER1 is set to 1 and the output of timer RD will be disabled.

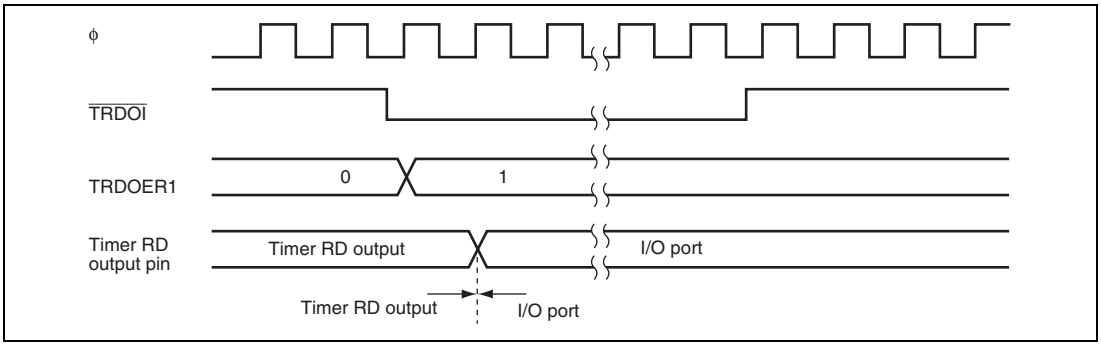


Figure 16.51 Example of Output Disable Timing of Timer RD by External Trigger

(3) Output Inverse Timing by TRDFCR

The output level can be inverted by inverting the OLS1 and OLS0 bits in TRDFCR in reset synchronous PWM mode or complementary PWM mode. Figure 16.52 shows the timing.

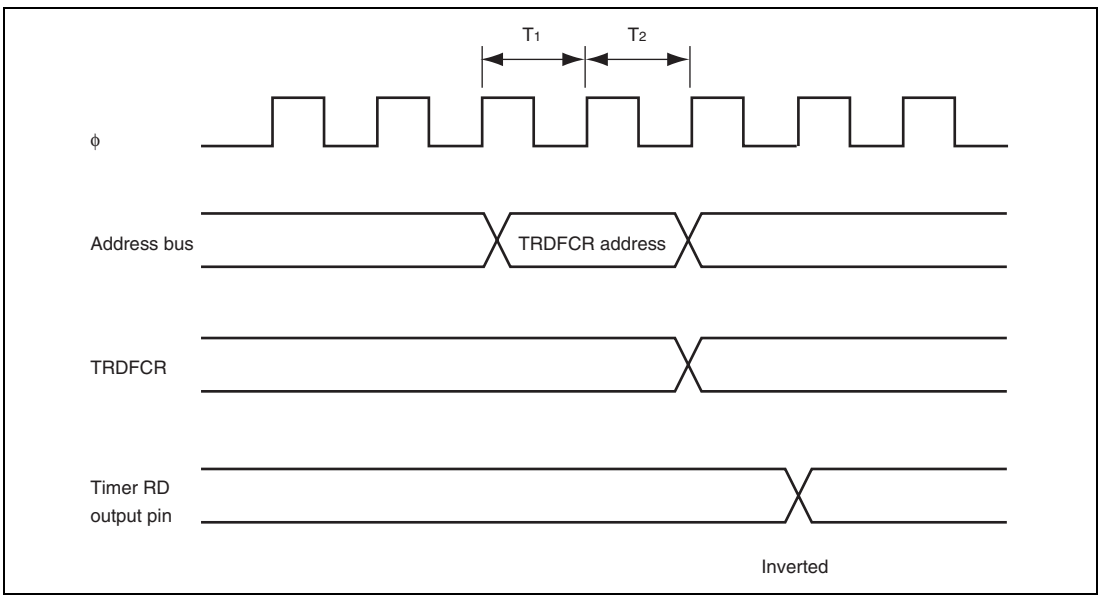


Figure 16.52 Example of Output Inverse Timing of Timer RD by Writing to TRDFCR

(4) Output Inverse Timing by POCR

The output level can be inverted by inverting the POLD, POLC, and POLB bits in POCR in PWM mode. Figure 16.53 shows the timing.

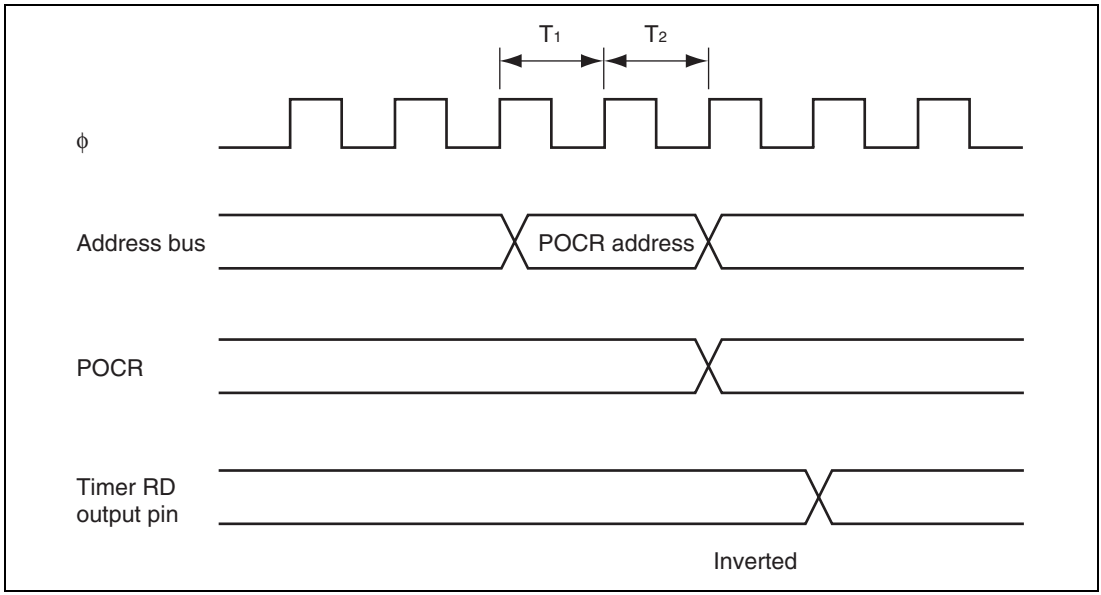


Figure 16.53 Example of Output Inverse Timing of Timer RD by Writing to POCR

16.3.11 Digital Filtering Function for Input Capture Inputs

Input signals on the FTIOA to FTIOD pins can be input via the digital filters. The digital filter includes three latches connected in series and a match detector circuit. The latches operate on the sampling clock specified by bits DFCK1 and DFCK0 in TRDDF and stores an input signal on the FTIOA to FTIOD pins. When outputs of the three latches match, the match detector circuit outputs the signal level of the input. Otherwise, the output remains unchanged. That is, when a pulse width is equal to or greater than three sampling clock cycles, the pulse is input as a signal. When a pulse width is less than three sampling clock cycles, the pulse is considered as a noise to be removed.

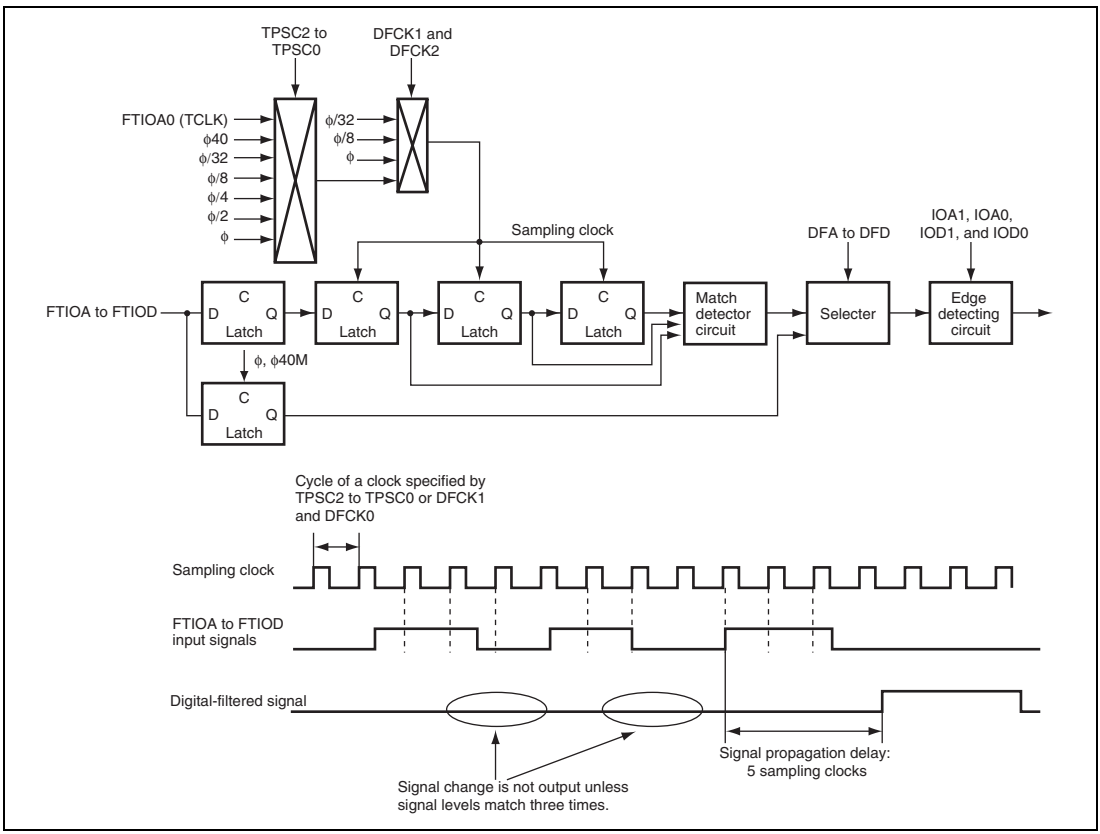


Figure 16.54 Block Diagram of Digital Filter

16.3.12 Function of Changing Output Pins for GR

With the settings of bits IOC3 and IOD3 in TRDIORC, pins for outputs of compare match signals for GRC and GRD can be changed from the FTIOC and FTIOD pins to the FTIOA and FTIOB pins. This means that the compare match A signal ORed with the compare match C signal can be output on the FTIOA pin. The compare match B ORed with the compare match D signal can be output on the FTIOB pin. Figure 16.55 is a block diagram of this function. The setting for channel 0 is independent of that for channel 1.

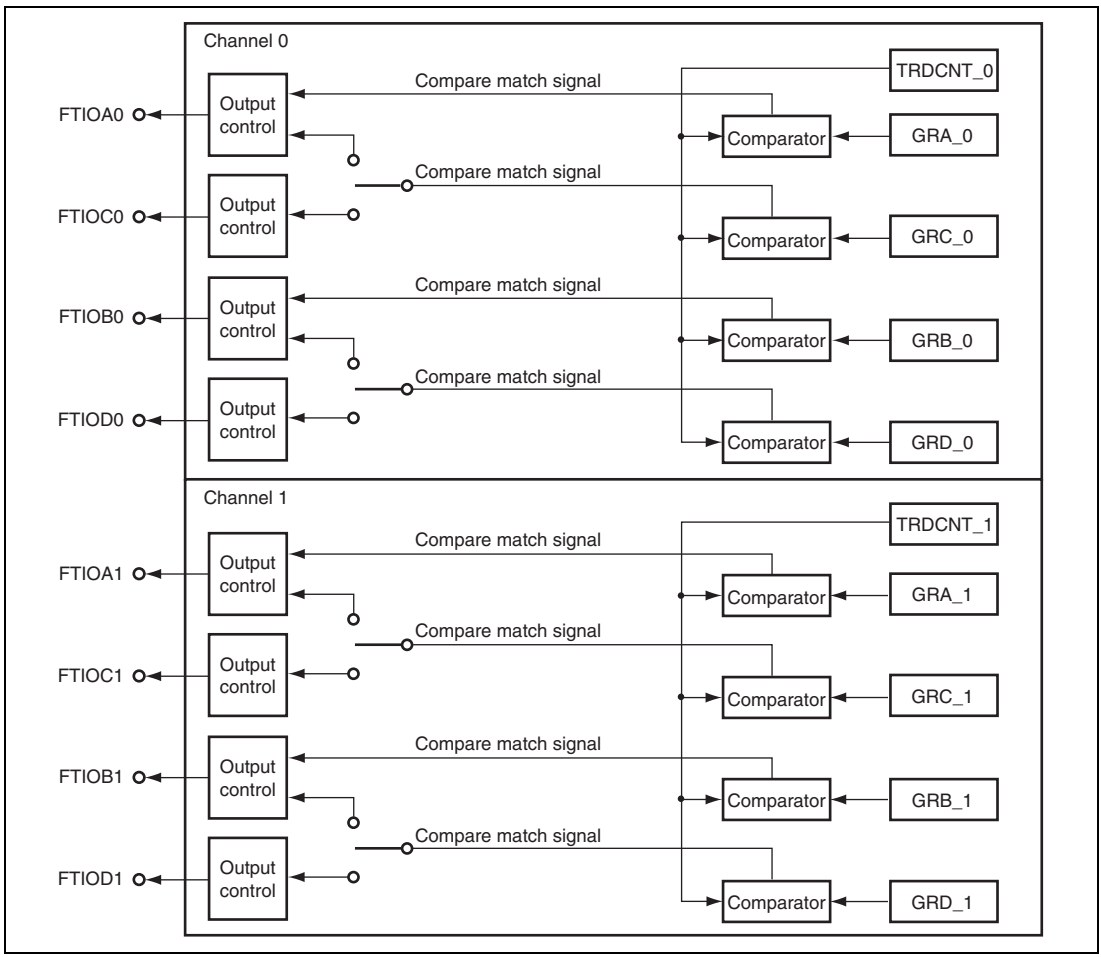


Figure 16.55 Block Diagram of Output Pins for GR

Figure 16.56 is an example when non-overlapped pulses are output on pins FTIOA0 and FTIOB0. In this example, TRDCNT_0 functions as a periodic counter which is cleared on compare match A0 (bits CCLR2 to CCLR0 in TRDCR_0 are set to B'001), an output signal is toggled on compare match A (bits IOA2 to IOA0 in TRDIORA_1 are set to B'011), the output signal on the FTIOA pin is toggled on compare match C (GRC_0) (bits IOC3 to IOC0 in TRDIORC_1 are set to B'0X11), an output signal is toggled on compare match B (GRB_0) (bits IOB2 to IOB0 in TRDIORA_1 are set to B’011), and the output signal on the FTIOB pin is toggled on compare match D (GRD_0) (bits IOD3 to IOD0 in TRDIORC_1 are set to B'0X11). The cycle of the pulse is arbitrary.

Similarly, figure 16.57 is an example when non-overlapped pulses are output using TRDCNT_1.

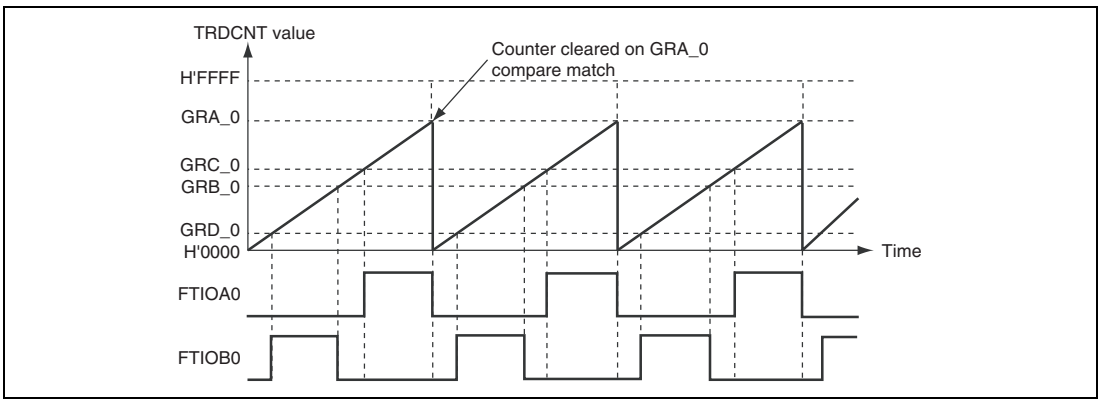


Figure 16.56 Example of Non-Overlapped Pulses Output on Pins FTIOA0 and FTIOB0 (TRDCNT_0 Used)

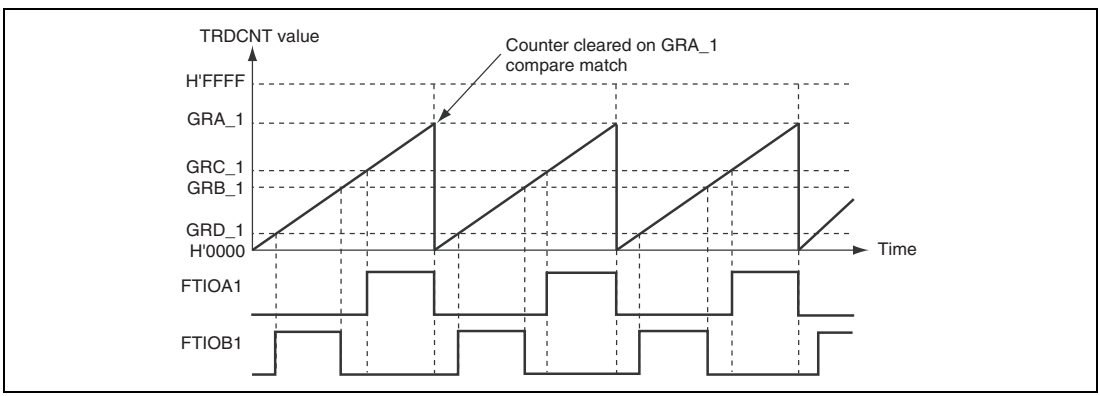


Figure 16.57 Example of Non-Overlapped Pulses Output on Pins FTIOA1 and FTIOB1 (TRDCNT_1 Used)

16.3.13 A/D Conversion Start Trigger Setting Function

Timer RD can generate the A/D conversion start trigger signal by setting the timer RD A/D conversion start trigger control register (TRDADCR) or bits ADEG and ADTRG in the timer RD function control register (TRDFCR).

Figures 16.58 and 16.59 show examples of the A/D conversion trigger signal generation in complementary PWM mode.

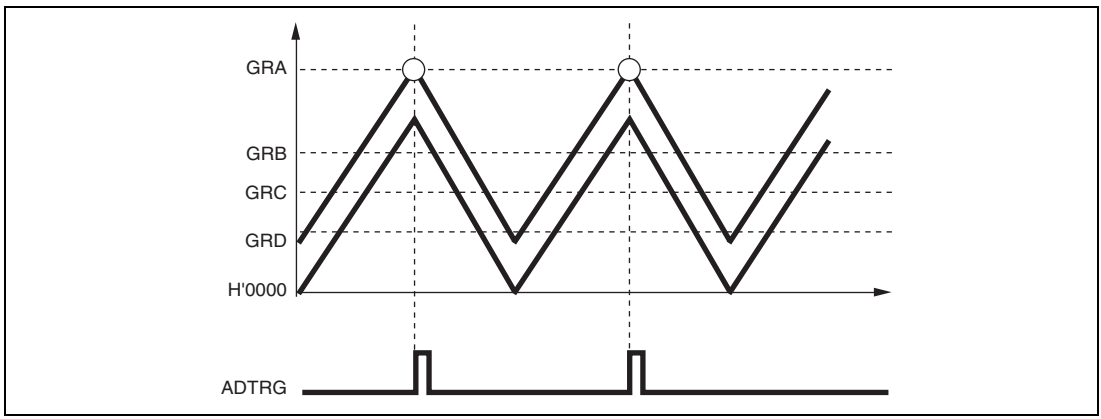


Figure 16.58 Example of A/D Conversion Trigger Signal Generation in Complementary PWM Mode
(Trigger Asserted When TRDCNT_0 Matches GRA_0: ADEG = 0, ADTRG = 1)

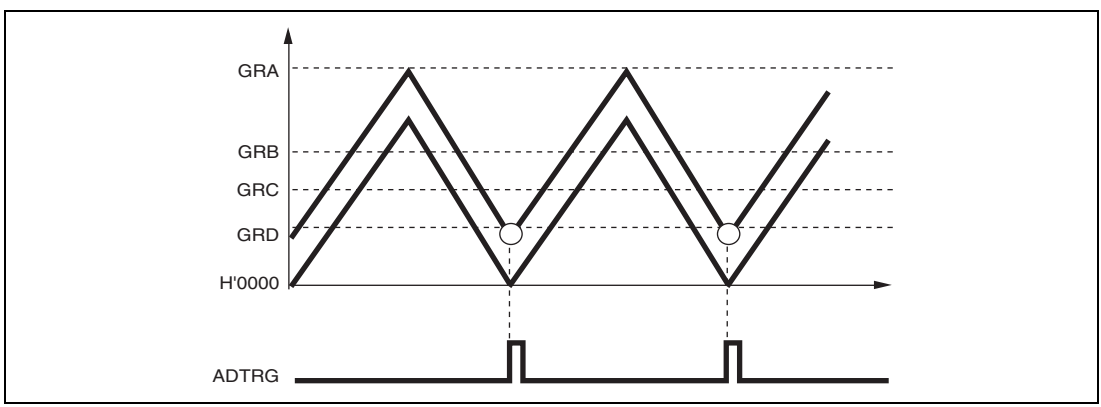


Figure 16.59 Example of A/D Conversion Trigger Signal Generation in Complementary PWM Mode
(Trigger Asserted When TRDCNT_1 Underflows: ADEG = 1, ADTRG = 1)

Figure 16.60 shows an example where the A/D conversion start trigger signal is generated by compare match. In this case, the TRDADCR register must be set.

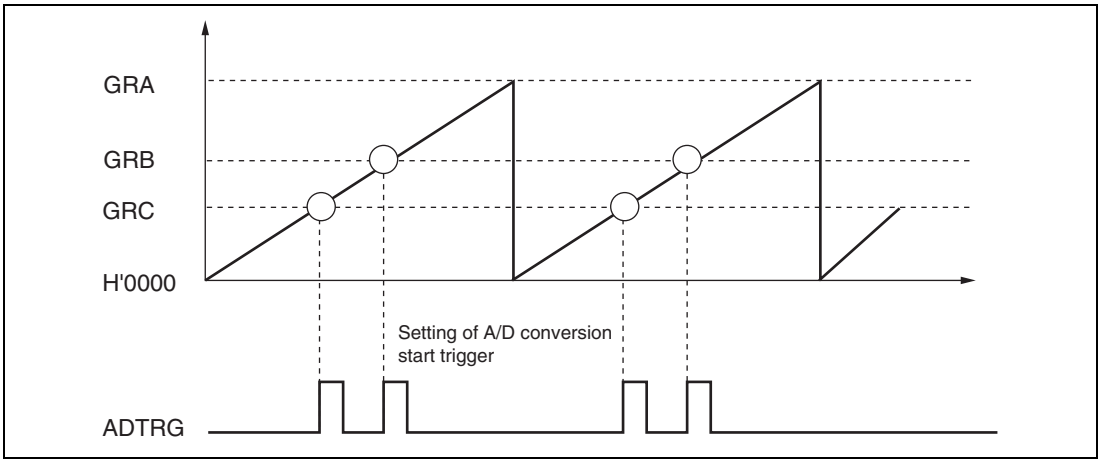


Figure 16.60 Example of A/D Conversion Trigger Signal Generation by Compare Match

Figure 16.61 shows the timing for generating the A/D conversion start trigger by compare match.

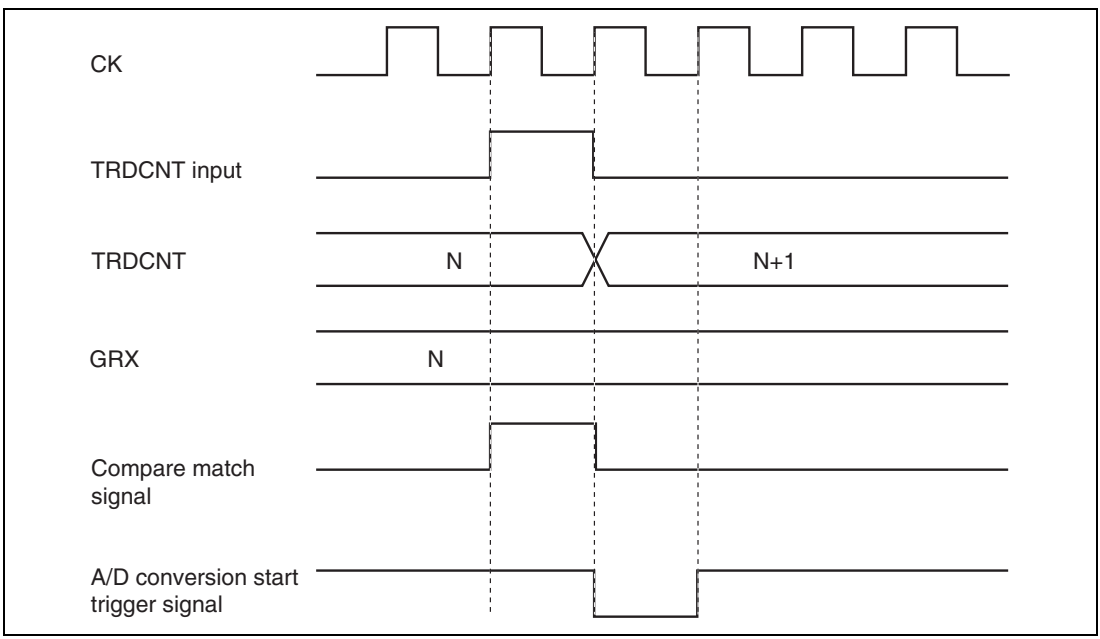


Figure 16.61 Timing of A/D Conversion Start Trigger Generation

16.3.14 Operation by Event Clear

Using the event link controller (ELC), timer RD unit 0 can be made to operate in the following ways in relation to events occurring in other modules. Each channel 0 and 1 can be specified independently.

(1) Staring Counter Operation

The start of counting operations by timer RD can be selected by ELOPA and ELOPB of the ELC. When the event specified by ELSR3 and ELSR4 occur, the STR[1:0] bits in TRDSTR are set to 1, which stars counting by timer RD. However, if the specified event occurs when the STR bit has already been set to 1, the event is not effective.

(2) Counting Event

The counting of events by timer RD can be selected by ELOPA and ELOPB of the ELC. When the event specified in ELSR3 and ELSR4 occurs, event counter operation proceeds with that event as the source to drive counting, regardless of the setting of the TPSC[2:0] bits in TRDCR1. When the value of the counter is read, the value read out is the actual number of input events.

(3) Input Capture

Input capture operation of timer RD can be selected by ELOPA and ELOPB of the ELC. When the event specified in ELSR3 and ELSR4 occurs, GRD captures the value of TRDCNT. When input capture operation initiated by an event link is in use, set the IOD[3:0] bits = b'1101 in TRDIORC of timer RD, set the STR bit in TRDSTR to 1, and then start the counter. Since input on the FTIOD pin becomes valid at the same time, fix the input to the FTIOD pin or take other measures such as not allocating the FTIOD pin to the port in the PMC, etc.

16.4 Interrupt Sources

There are three kinds of timer RD interrupt sources; input capture/compare match, overflow, and underflow. An interrupt is requested when the corresponding interrupt request flag is set to 1 while the corresponding interrupt enable bit is set to 1.

16.4.1 Status Flag Set Timing

(1) IMF Flag Set Timing

The IMF flag is set to 1 by the compare match signal that is generated when the GR matches with the TRDCNT. The compare match signal is generated at the last state of matching (timing to update the counter value when the GR and TRDCNT match). Therefore, when the TRDCNT and GR matches, the compare match signal will not be generated until the TRDCNT input clock is generated. Figure 16.62 shows the timing to set the IMF flag.

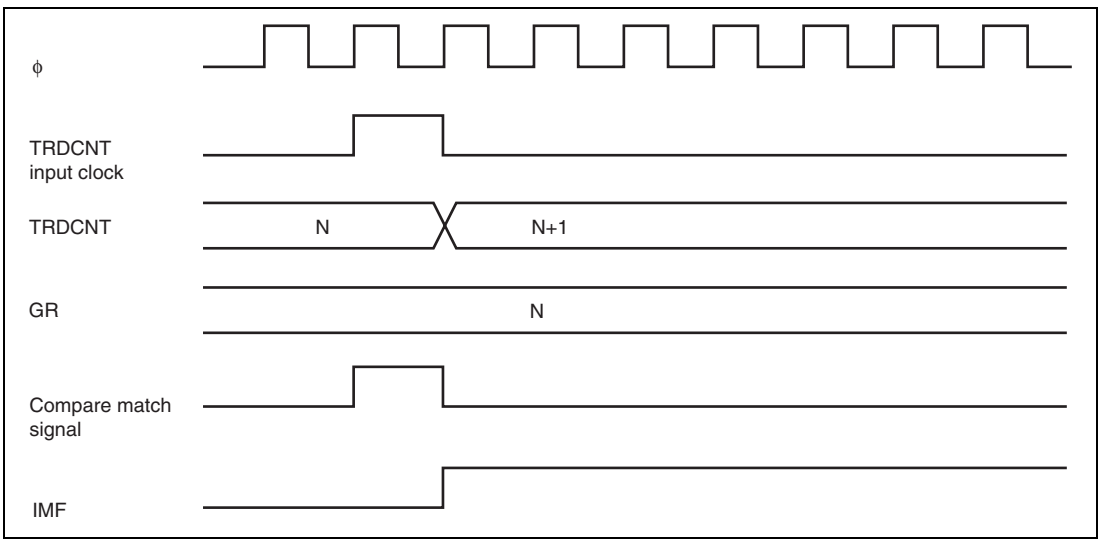


Figure 16.62 IMF Flag Set Timing when Compare Match Occurs

(2) IMF Flag Set Timing at Input Capture

When an input capture signal is generated, the IMF flag is set to 1 and the value of TRDCNT is simultaneously transferred to corresponding GR. Figure 16.63 shows the timing.

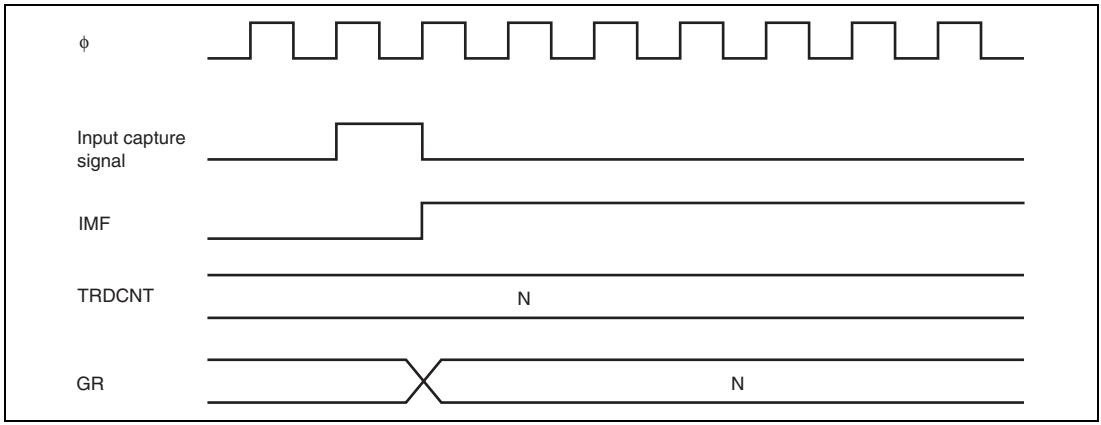


Figure 16.63 IMF Flag Set Timing at Input Capture

(3) Overflow Flag (OVF) Set Timing

The overflow flag is set to 1 when the TRDCNT overflows. Figure 16.64 shows the timing.

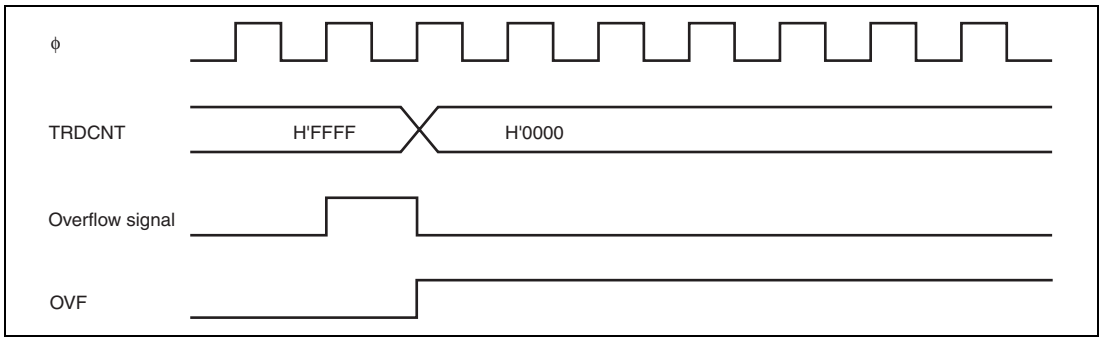


Figure 16.64 OVF Flag Set Timing

16.4.2 Status Flag Clearing Timing

The status flag can be cleared by writing 0 after reading 1 from the CPU. Figure 16.65 shows the timing in this case.

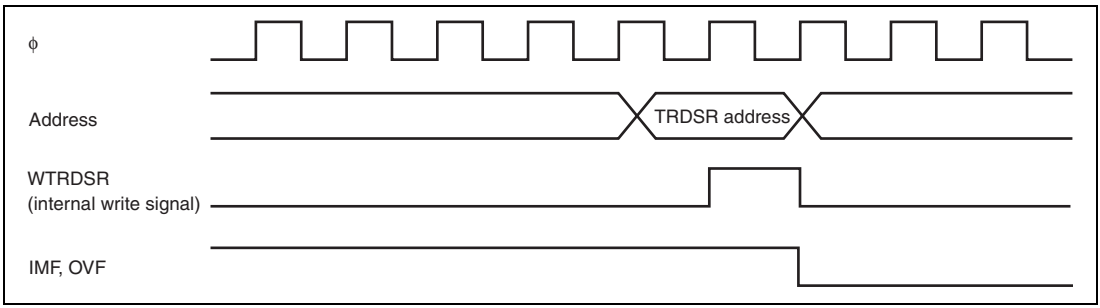


Figure 16.65 Status Flag Clearing Timing

16.5 Usage Notes

(1) Input Pulse Width of Input Clock Signal and Input Capture Signal

When the digital filtering function for input is not in use, the pulse width of the input clock signal and the input capture signal must be at least three system clock (ϕ) cycles when the TPSC2 to TPSC0 bits in TRDCR = B'0XX or B'10X, and at least 3 × ϕ40 cycles for B'110; shorter pulses will not be detected correctly.

(2) Conflict between TRDCNT Write and Clear Operations

If a counter clear signal is generated in the T_2 state of a TRDCNT write cycle, TRDCNT clearing has priority and the TRDCNT write is not performed. Figure 16.66 shows the timing in this case.

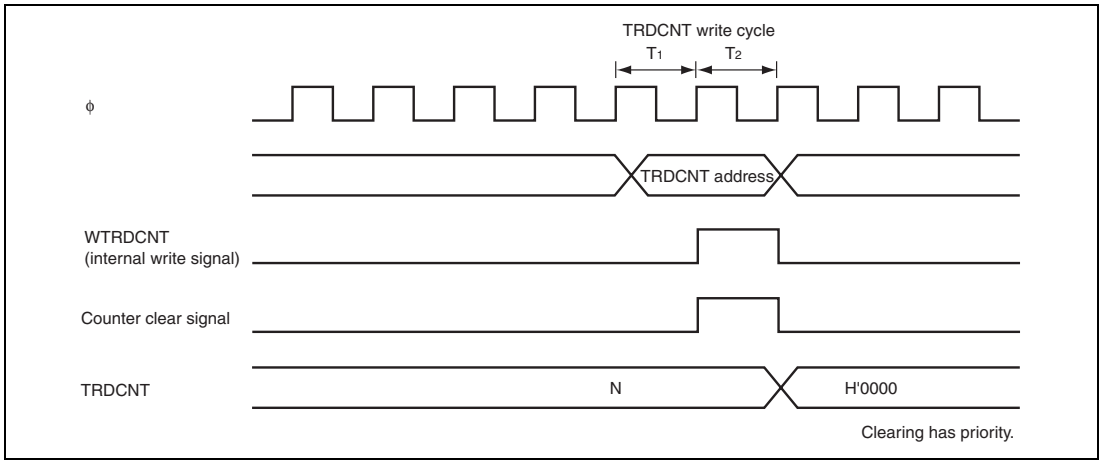


Figure 16.66 Conflict between TRDCNT Write and Clear Operations

(3) Conflict between TRDCNT Write and Increment Operations

If TRDCNT is incremented in the T_2 state of a TRDCNT write cycle, writing has priority. Figure 16.67 shows the timing in this case.

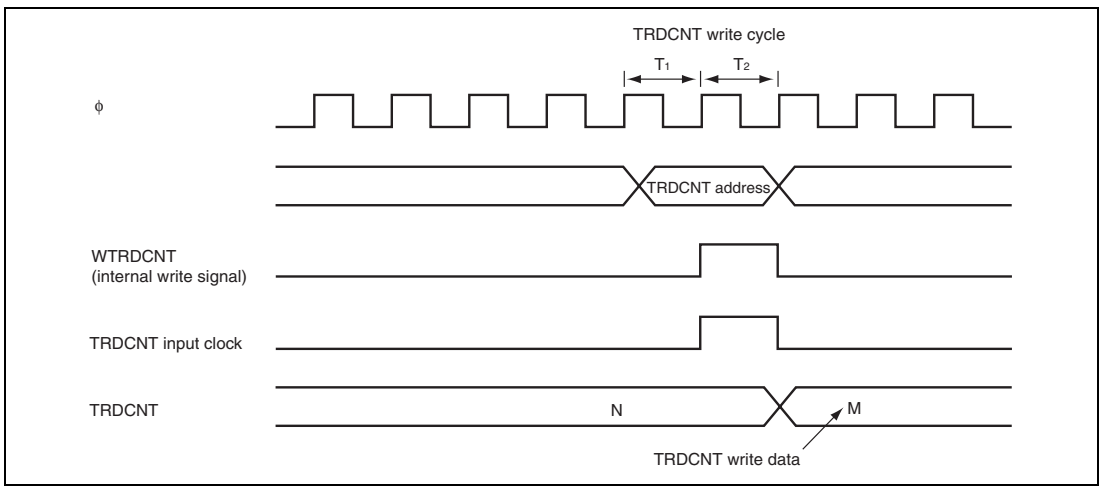


Figure 16.67 Conflict between TRDCNT Write and Increment Operations

(4) Conflict between GR Write and Compare Match

If a compare match occurs in the T_2 state of a GR write cycle, GR write has priority and the compare match signal is disabled. Figure 16.68 shows the timing in this case.

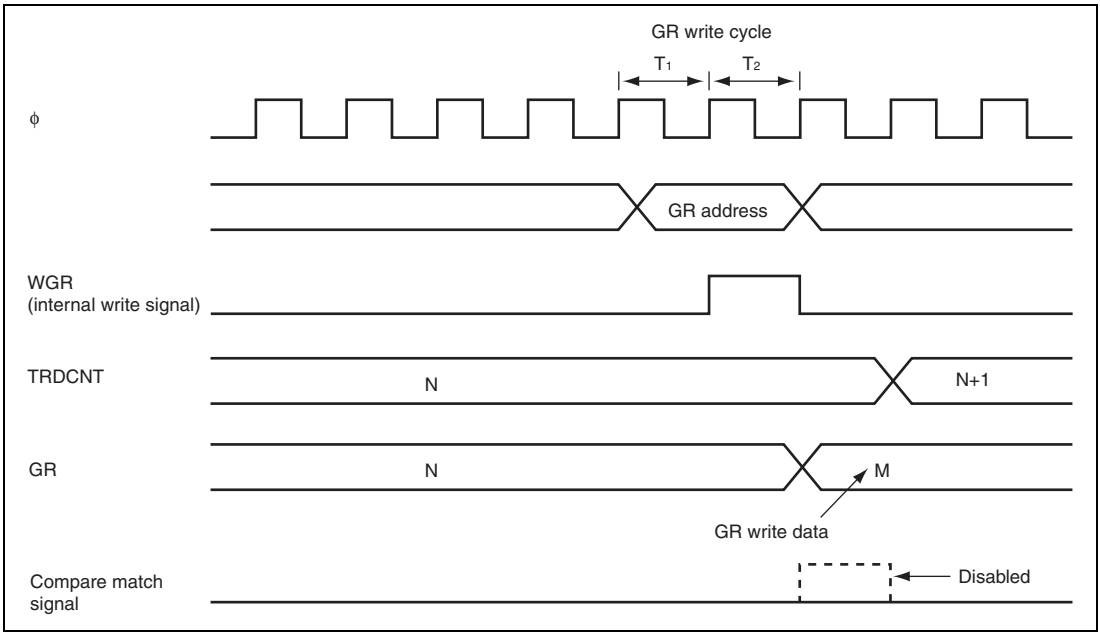


Figure 16.68 Conflict between GR Write and Compare Match

(5) Conflict between TRDCNT Write and Overflow/Underflow

If overflow/underflow occurs in the T_2 state of a TRDCNT write cycle, TRDCNT write has priority without an increment operation. At this time, the OVF flag is set to 1. Figure 16.69 shows the timing in this case.

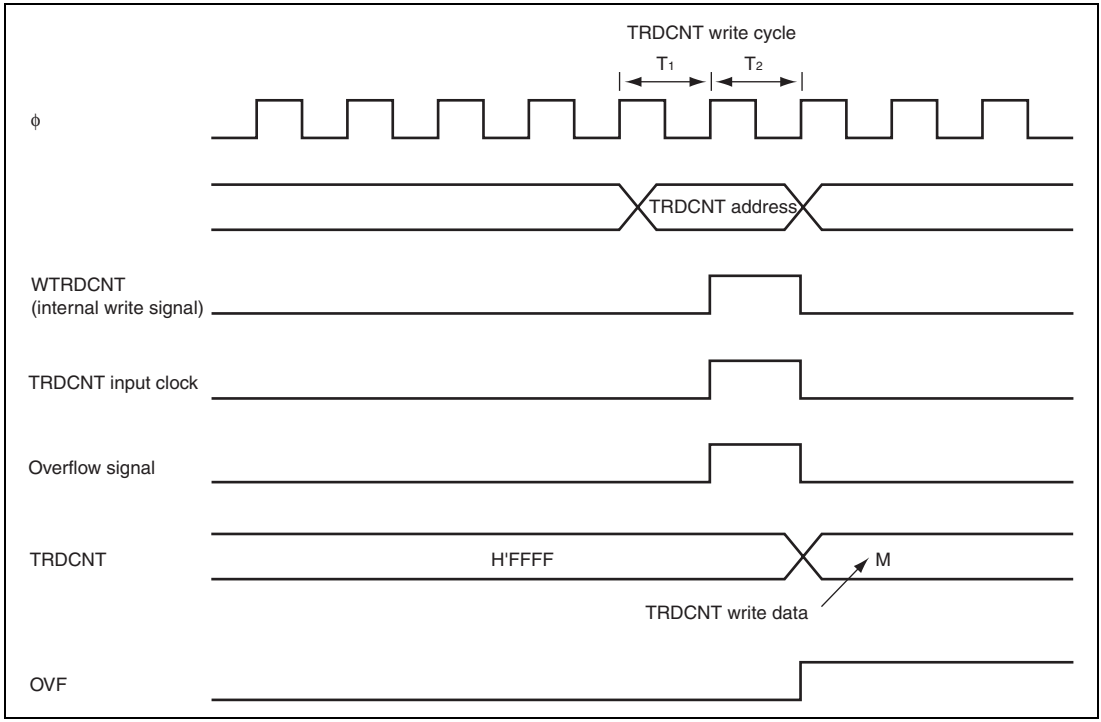


Figure 16.69 Conflict between TRDCNT Write and Overflow

(6) Conflict between GR Read and Input Capture

If an input capture signal is generated in the T_2 state of a GR read cycle, the data that is read will be transferred before input capture transfer. Figure 16.70 shows the timing in this case.

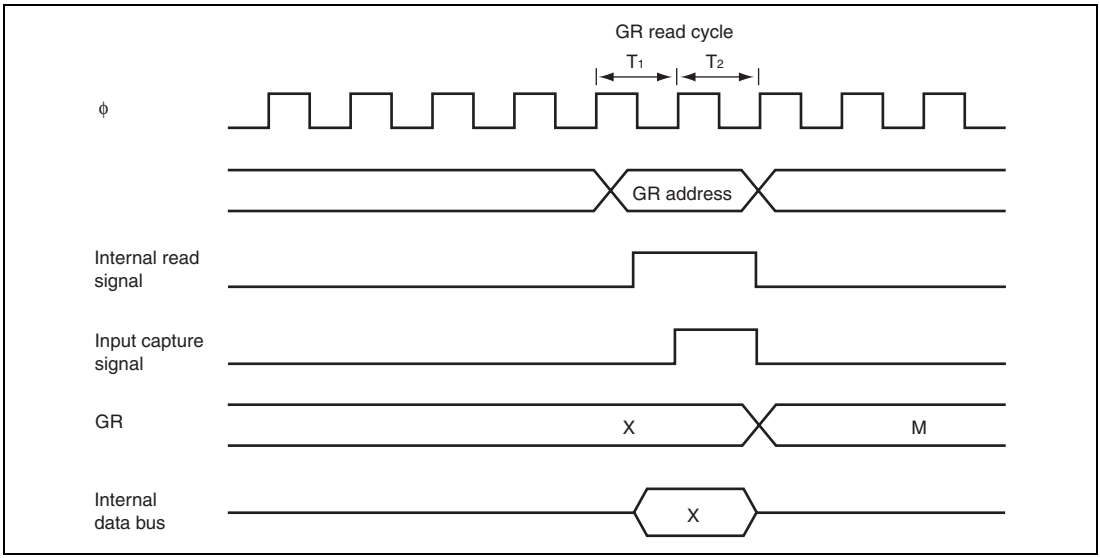


Figure 16.70 Conflict between GR Read and Input Capture

(7) Conflict between Count Clearing and Increment Operations by Input Capture

If an input capture and increment signals are simultaneously generated, count clearing by the input capture operation has priority without an increment operation. The TRDCNT contents before clearing counter are transferred to GR. Figure 16.71 shows the timing in this case.

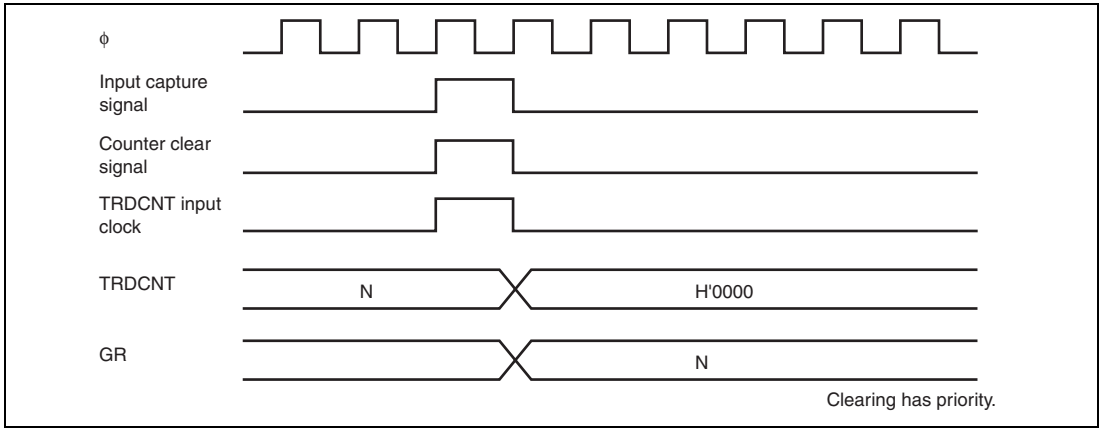


Figure 16.71 Conflict between Count Clearing and Increment Operations by Input Capture

(8) Conflict between GR Write and Input Capture

If an input capture signal is generated in the T_2 state of a GR write cycle, the input capture operation has priority and the write to GR is not performed. Figure 16.72 shows the timing in this case.

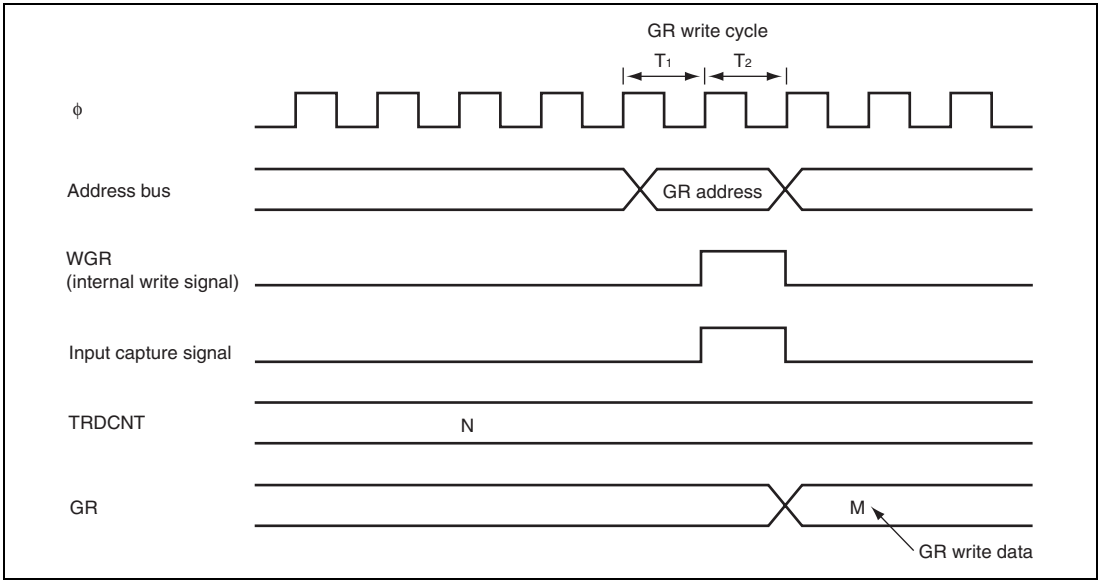


Figure 16.72 Conflict between GR Write and Input Capture

(9) Notes on Setting Reset Synchronous PWM Mode/Complementary PWM Mode

When bits CMD1 and CMD0 in TRDFCR are set, note the following:

- Write bits CMD1 and CMD0 while TRDCNT_1 and TRDCNT_0 are halted.
- Changing the settings of reset synchronous PWM mode to complementary PWM mode or vice versa is disabled. Set reset synchronous PWM mode or complementary PWM mode after the normal operation (bits CMD1 and CMD0 are cleared to 0) has been set.

(10) Note on Writing to the TOA0 to TOD0 Bits and the TOA1 to TOD1 Bits in TRDOCR

The TOA0 to TOD0 bits and the TOA1 to TOD1 bits in TRDOCR decide the value of the FTIO pin, which is output until the first compare match occurs. Once a compare match occurs and this compare match changes the values of FTIOA0 to FTIOD0 and FTIOA1 to FTIOD1 output, the values of the FTIOA0 to FTIOD0 and FTIOA1 to FTIOD1 pin output and the values read from the TOA0 to TOD0 and TOA1 to TOD1 bits may differ. Moreover, when the writing to TRDOCR and the generation of the compare match A0 to D0 and A1 to D1 occur at the same timing, the writing to TRDOCR has the priority. Thus, output change due to the compare match is not reflected to the FTIOA0 to FTIOD0 and FTIOA1 to FTIOD1 pins. Therefore, when bit manipulation instruction is used to write to TRDOCR, the values of the FTIOA0 to FTIOD0 and FTIOA1 to FTIOD1 pin output may result in an unexpected result. When TRDOCR is to be written to while compare match is operating, stop the counter once before accessing to TRDOCR, read the port 6 state to reflect the values of FTIOA0 to FTIOD0 and FTIOA1 to FTIOD1 output, to TOA0 to TOD0 and TOA1 to TOD1, and then restart the counter. Figure 16.73 shows an example when the compare match and the bit manipulation instruction to TRDOCR occur at the same timing.

TRDOCR has been set to H'06. Compare match B0 and compare match C0 are used. The FTIOB0 pin is in the 1 output state, and is set to the toggle output or the 0 output by compare match B0.
When BCLR#2, @TRDOCR is executed to clear the TOC0 bit (the FTIOC0 signal is low) and compare match B0 occurs at the same timing as shown below, the H'02 writing to TRDOCR has priority and compare match B0 does not drive the FTIOB0 signal low; the FTIOB0 signal remains high.

Bit	7	6	5	4	3	2	1	0
TRDOCR	TOD1	TOC1	TOB1	TOA1	TOD0	TOC0	TOB0	TOA0
Set value	0	0	0	0	0	1	1	0

BCLR#2, @TRDOCR
(1) TRDOCR read operation: Read H'06
(2) Modify operation: Modify H'06 to H'02
(3) Write operation to TRDOCR: Write H'02

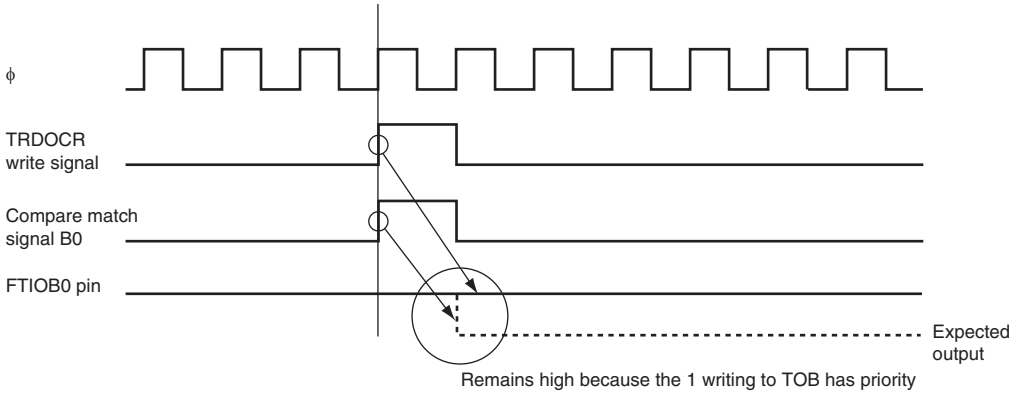


Figure 16.73 When Compare Match and Bit Manipulation Instruction to TRDOCR Occur at the Same Timing

(11) Restrictions on Access to Registers when Internal ϕ40 Clock is Selected as Counter Clock

When the internal ϕ40 clock is selected as the counter clock (the TPSC[2:0] bits in TRDCR = 110), if any register of timer RD is to be read immediately after writing to another register in a given module, proceed with reading after having executed one NOP instruction.

Timer RD unit 0 and 1 are considered to be separate modules, but channels 0 and 1 (or channels 2 and 3) of the same unit are considered to be in the same module.

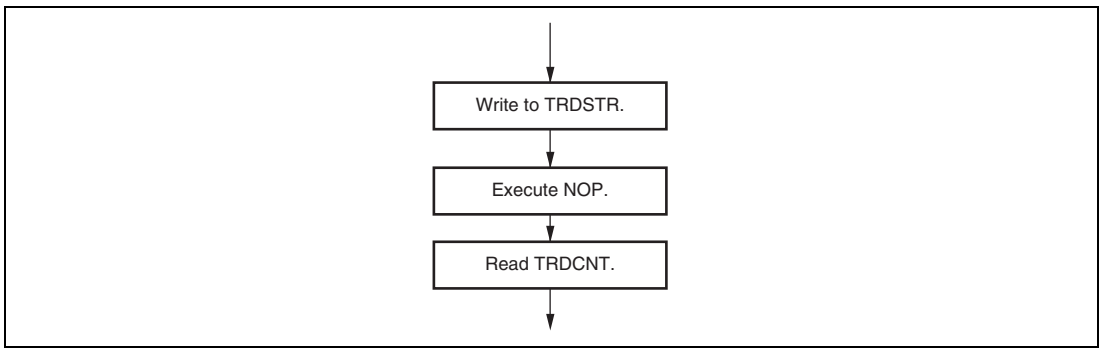


Figure 16.74 Example of Flow for Reading Immediately after Writing to a Register

Section 17 Timer RE

Timer RE is a timer that provides a realtime clock function to count time ranging from a second to a week and a compare-match function. Figure 17.1 shows a block diagram of the timer RE.

17.1 Features

- Realtime clock mode
  - Counts seconds, minutes, hours, and day-of-week
  - Start/stop function
  - Reset function
  - Readable/writable counter of seconds, minutes, hours, and day-of-week with BCD codes
  - Periodic (seconds, minutes, hours, days, and weeks) interrupts
- Output-compare mode
  - 8-bit counter with a compare-match function
  - Selection of clock source
  - Compare-match interrupt

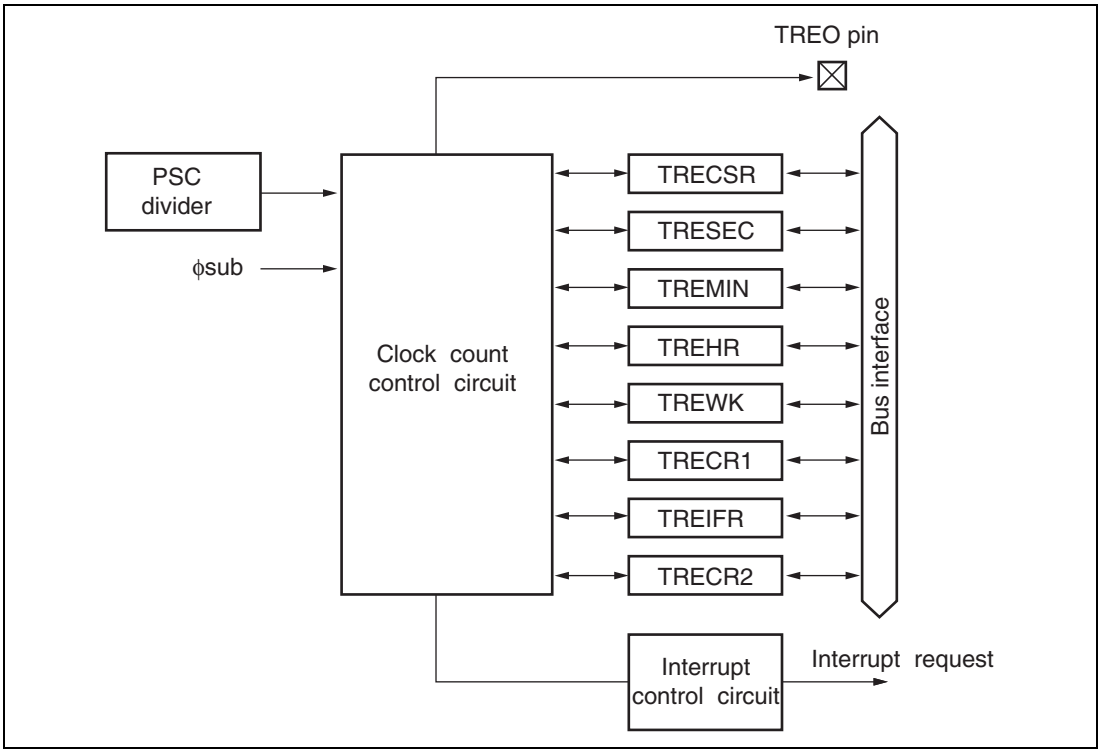


Figure 17.1 Block Diagram of Timer RE

Table 17.1 shows the timer RE input/output pin.

Table 17.1 Pin Configuration

Pin Name	I/O	Function
TREO	Output	Clock or compare-match output

17.2 Register Descriptions

The timer RE has the following registers.

- Timer RE second data register/counter data register (TRESEC)
- Timer RE minute data register (TREMIN)
- Timer RE hour data register (TREHR)
- Timer RE day-of-week data register (TREWK)
- Timer RE control register 1 (TRECR1)
- Timer RE control register 2 (TRECR2)
- Timer RE clock source select register (TRECSR)
- Timer RE interrupt flag register (TREIRF)

17.2.1 Timer RE Second Data Register/Counter Data Register (TRESEC)

Address: H'FFFFA8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BSY	SC12	SC11	SC10	SC03	SC02	SC01	SC00
Value after reset:	—	—	—	—	—	—	—	—

- Realtime clock mode

Bit	Symbol	Bit Name	Description	R/W
7	BSY	Timer RE busy	This bit is set to 1 when the timer RE is updating (calculating) the values of second, minute, hour, and day-of-week data registers. When this bit is 0, the values of second, minute, hour, and day-of-week data registers must be adopted.	R
6	SC12	Counting ten's position of seconds	Counts on 0 to 5 for 60-second counting.	R/W
5	SC11			R/W
4	SC10			R/W
3	SC03	Counting one's position of seconds	Counts on 0 to 9 once per second. When a carry is generated, 1 is added to the ten's position.	R/W
2	SC02			R/W
1	SC01			R/W
0	SC00			R/W

- Output-compare mode

Bit	Symbol	Bit Name	Description	R/W
7	BSY	—	Used as an 8-bit register for reading the counter data.	R
6	SC12		The counter value is retained when counting is stopped.	R/W
5	SC11		This register is initialized to H’00 with a compare-match.	R/W
4	SC10			R/W
3	SC03			R/W
2	SC02			R/W
1	SC01			R/W
0	SC00			R/W

TRESEC counts the BCD-coded second value in realtime clock mode. TRESEC is incremented from decimal 00 to 59. TRESEC is used as an 8-bit register for reading the counter data in output-compare mode.

17.2.2 Timer RE Minute Data Register/Compare Data Register (TREMIN)

Address: H'FFFFA9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BSY	MN12	MN11	MN10	MN03	MN02	MN01	MN00
Value after reset:	—	—	—	—	—	—	—	—

- Realtime clock mode

Bit	Symbol	Bit Name	Description	R/W
7	BSY	Timer RE busy	This bit is set to 1 when the timer RE is updating (calculating) the values of second, minute, hour, and day-of-week data registers. When this bit is 0, the values of second, minute, hour, and day-of-week data registers must be adopted.	R
6	MN12	Counting ten's position of minutes	Counts on 0 to 5 for 60-minute counting.	R/W
5	MN11			R/W
4	MN10			R/W
3	MN03	Counting one's position of minutes	Counts on 0 to 9 once per minute. When a carry is generated, 1 is added to the ten's position.	R/W
2	MN02			R/W
1	MN01			R/W
0	MN00			R/W

- Output-compare mode

Bit	Symbol	Bit Name	Description	R/W
7	BSY	—	Used as an 8-bit register for storing the compare data. The setting range is H'01 to H'FF. This register can be written to only when counting is stopped (when TSTART and TCSTF in TRECR1 are 0).	R
6	MN12			R/W
5	MN11			R/W
4	MN10			R/W
3	MN03			R/W
2	MN02			R/W
1	MN01			R/W
0	MN00			R/W

TREMIN counts the BCD-coded minute value on the carry generated once per minute by the TRESEC counting in realtime clock mode. TREMIN is incremented from decimal 00 to 59. TREMIN is used as an 8-bit register for storing the compare data in output-compare mode.

17.2.3 Timer RE Hour Data Register (TREHR)

Address: H'FFFFAA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BSY	—	HR11	HR10	HR03	HR02	HR01	HR00
Value after reset:	—	0	—	—	—	—	—	—

Bit	Symbol	Bit Name	Description	R/W
7	BSY	Timer RE busy	This bit is set to 1 when the timer RE is updating (calculating) the values of second, minute, hour, and day-of-week data registers. When this bit is 0, the values of second, minute, hour, and day-of-week data registers must be adopted.	R
6	—	Reserved	This bit is read as 0. The write value should be 0.	—
5	HR11	Counting ten's position of hours	Counts on 0 to 2 for ten's position of hours	R/W
4	HR10			R/W
3	HR03	Counting one's position of hours	Counts on 0 to 9 once per hour. When a carry is generated, 1 is added to the ten's position.	R/W
2	HR02			R/W
1	HR01			R/W
0	HR00			R/W

TREHR is used in realtime clock mode and counts the BCD-coded hour value on the carry generated once per hour by TREMIN. TREHR is incremented either from decimal 00 to 11 or 00 to 23 by the selection of the 12/24 bit in TRECR1. This register is not used in output-compare mode.

17.2.4 Timer RE Day-of-Week Data Register (TREWK)

Address: H'FFFFAB

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

Bit	Symbol	Bit Name	Description	R/W
7	BSY	Timer RE busy	This bit is set to 1 when the timer RE is updating (calculating) the values of second, minute, hour, and day-of-week data registers. When this bit is 0, the values of second, minute, hour, and day-of-week data registers must be adopted.	R
6 to 3	—	Reserved	These bits are read as 0. The write value should be 0.	—
2 to 0	WK[2:0]	Day-of-week counting	000: Sunday 001: Monday 010: Tuesday 011: Wednesday 100: Thursday 101: Friday 110: Saturday 111: Setting prohibited	R/W

TREWK is used in realtime clock mode and counts the BCD-coded day-of-week value on the carry generated once per day by TREHR. Bits WK[2:0] indicate the day of the week with a binary code, ranging from decimal 0 to 6. This register is not used in output-compare mode.

17.2.5 Timer RE Control Register 1 (TRECR1)

Address: H'FFFFAC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TSTART	H12_H24	PM	TRERST	INT	TOENA	TCSTF	—
Value after reset:	—	—	—	0	0	0	—	0

- Realtime clock mode

Bit	Symbol	Bit Name	Description	R/W
7	TSTART	Counter operation start	0: Stops timer counter operation 1: Starts timer counter operation	R/W
6	H12_H24*[1]	Operating mode	0: The timer RE operates in 12-hour mode. TREHR counts on 0 to 11. 1: The timer RE operates in 24-hour mode. TREHR counts on 0 to 23.	R/W
5	PM*[1]	a.m./p.m.	0: Indicates a.m. when the timer RE is in the 12-hour mode. 1: Indicates p.m. when the timer RE is in the 12-hour mode.	R/W
4	TRESET	Reset	0: Normal operation 1: Resets all the registers and control circuits, except TRECSR and the TOENA and TRESET bits in this register. Clear this bit to 0 after having been set to 1.	R/W
3	INT*[1]	Interrupt generation timing	0: Generates a second, minute, hour, or day-of-week periodic interrupt during timer RE busy period. 1: Generates a second, minute, hour, or day-of-week periodic interrupt immediately after completing timer RE busy period.*[2]	R/W
2	TOENA	TREO pin output enable	0: Disables timer RE divided clock output. 1: Enables timer RE divided clock output.	R/W
1	TCSTF	Operation status flag	0: Indicates that timer RE operation has been stopped. 1: Indicates that timer RE operation is in progress.	R
0	—	Reserved	This bit is read as 0. The write value should be 0.	—

Note: 1. Bits H12_H24, PM, and INT should be set when the timer RE operation is stopped.
2. This bit should be set to 1 in realtime clock mode and cleared to 0 in output compare mode.

TRECR1 controls start/stop and reset of the counter. For the definition of time expression, see figure 17.2.

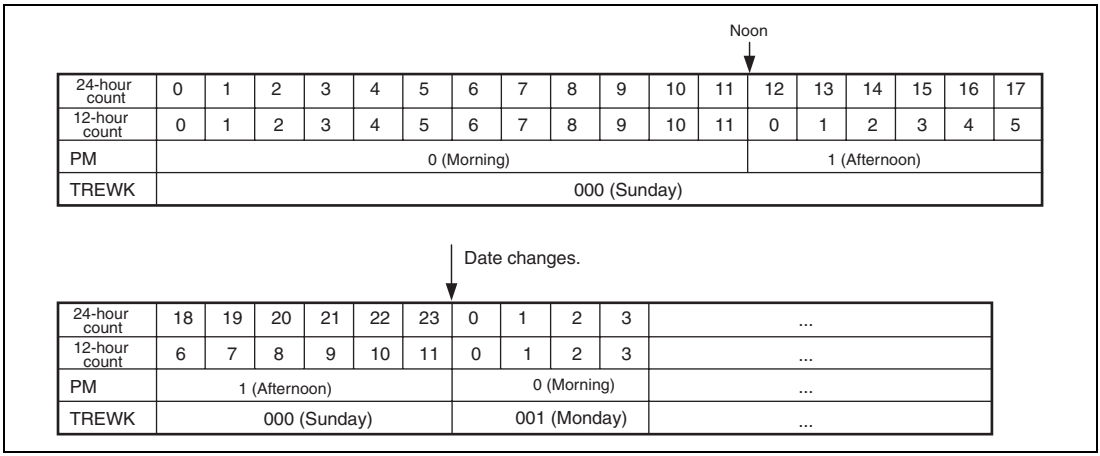


Figure 17.2 Definition of Time Expression

- Output-compare mode

Bit	Symbol	Bit Name	Description	R/W
7	TSTART	Counter operation start	0: Stops timer counter operation. 1: Starts timer counter operation.	R/W
6	H12_H24	Operating mode	0 should be written to this bit in output-compare mode.	R/W
5	PM	a.m./p.m.	0 should be written to this bit in output-compare mode.	R/W
4	TRESET	Reset	0: Normal operation 1: Resets all the registers and control circuits, except TRECSR and the TOENA and TRESET bits in this register. Clear this bit to 0 after having been set to 1.	R/W
3	INT	Interrupt generation timing	0 should be written to this bit in output-compare mode.	R/W
2	TOENA	TREO pin output enable	0: Disables timer RE divided clock output. 1: Enables timer RE divided clock output.	R/W
1	TCSTF	Operation status flag	0: Indicates that timer RE operation has been stopped. 1: Indicates that timer RE operation is in progress.	R
0	—	Reserved	This bit is read as 0. The write value should be 0.	—

Note: After writing 1 to TSTART, the timer RE should not be accessed before reading 1 from TCSTF, with the exception of reading TCSTF. Similarly, after writing 0 to TSTART, the timer RE should not be accessed before reading 0 from TCSTF, with the exception of reading TCSTF.

17.2.6 Timer RE Control Register 2 (TRECR2)

Address: H'FFFFAD

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	COMIE	WKIE	DYIE	HRIE	MNIE	SEIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5	COMIE	Compare-match interrupt enable	0: Disables a compare-match interrupt 1: Enables a compare-match interrupt This bit should be 0 in realtime clock mode.	R/W
4	WKIE	Week periodic interrupt enable	0: Disables a week periodic interrupt 1: Enables a week periodic interrupt This bit should be 0 in output-compare mode.	R/W
3	DYIE	Day periodic interrupt enable	0: Disables a day periodic interrupt 1: Enables a day periodic interrupt This bit should be 0 in output-compare mode.	R/W
2	HRIE	Hour periodic interrupt enable	0: Disables an hour periodic interrupt 1: Enables an hour periodic interrupt This bit should be 0 in output-compare mode.	R/W
1	MNIE	Minute periodic interrupt enable	0: Disables a minute periodic interrupt 1: Enables a minute periodic interrupt This bit should be 0 in output-compare mode.	R/W
0	SEIE	Second periodic interrupt enable	0: Disables a second periodic interrupt 1: Enables a second periodic interrupt This bit should be 0 in output-compare mode.	R/W

Notes: 1. When using interrupts, this register should be set last after other registers are set.
2. The COMIE bit should be set when counting operation is stopped.
3. Bits WKIE, DYIE, HRIE, MNIE, and SEIE should be set when timer RE operation is stopped.

TRECR2 controls timer RE periodic interrupts of weeks, days, hours, minutes, and seconds in realtime clock mode. Enabling interrupts of weeks, days, hours, minutes, and seconds sets the interrupt request flag to 1 in the timer RE interrupt flag register (TREIFR) when an interrupt occurs. It also controls a compare-match interrupt when output-compare mode is used.

17.2.7 Timer RE Interrupt Flag Register (TREIFR)

Address: H'FFFFAE

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	COMF	WKF	DYF	HRF	MNF	SECE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5	COMF	Compare-match interrupt request flag	[Setting condition] • When the counter value matches the value set in TREMIN in output-compare mode. [Clearing condition] • When 1 is read from the bit and then 0 is written to the bit.	R/W
4	WKF	Week periodic interrupt request flag	[Setting condition] • When bits WK[2:0] in TREWK reach B'000 in realtime clock mode. [Clearing condition] • When 1 is read from the bit and then 0 is written to the bit. When the DTC is activated with a week periodic interrupt and the DISEL bit in the MRB register of the DTC is 1.	R/W
3	DYF	Day periodic interrupt request flag	[Setting condition] • Each time TREWK is updated in realtime clock mode. (Occurs every day) [Clearing conditions] • When 1 is read from the bit and then 0 is written to the bit. • When the DTC is activated with a day periodic interrupt and the DISEL bit in the MRB register of the DTC is 1.	R/W

Bit	Symbol	Bit Name	Description	R/W
2	HRF	Hour periodic interrupt request flag	[Setting condition] • Each time TREHR is updated in realtime clock mode. (Occurs every hour) [Clearing conditions] • When 1 is read from the bit and then 0 is written to the bit. • When the DTC is activated with an hour periodic interrupt and the DISEL bit in the MRB register of the DTC is 1.	R/W
1	MNF	Minute periodic interrupt request flag	[Setting condition] • Each time TREMIN is updated in realtime clock mode. (Occurs every minute) [Clearing conditions] • When 1 is read from the bit and then 0 is written to the bit. • When the DTC is activated with a minute periodic interrupt and the DISEL bit in the MRB register of the DTC is 1.	R/W
0	SECF	Second periodic interrupt request flag	[Setting condition] • Each time TRESEC is updated in realtime clock mode. (Occurs every second) [Clearing conditions] • When 1 is read from the bit and then 0 is written to the bit. • When the DTC is activated with a second periodic interrupt and the DISEL bit in the MRB register of the DTC is 1.	R/W

17.2.8 Timer RE Clock Source Select Register (TRECSR)

Address: H'FFFFAF

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	RCS[6:4]			RCS3	RCS2	RCS[1:0]	
Value after reset:	0	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 0. The write value should be 0.	—
6 to 4	RCS[6:4]*2	Clock output select	000: ϕ/2 001: ϕ/4 010: ϕ/8 011: Compare-match output (Only valid in output-compare mode) 100: ϕ/sub (32.768 kHz) 101: 1 Hz (Only valid in realtime clock mode) 11x: Setting prohibited	R/W
3	RCS3	Mode select	0: Output-compare mode 1: Realtime clock mode	R/W
2	RCS2	4-bit counter select	(Only valid in output-compare mode) 0: Does not use the 4-bit counter. 1: Uses the 4-bit counter.	R/W
1, 0	RCS[1:0] *1*3	Clock source select	00: ϕ/2 01: ϕ/4 10: ϕ/8 11: ϕ/sub	R/W

[Legend]

X: Don't care

Notes: 1. RCS[1:0] should be set when realtime clock mode is used or when counter operation is stopped.

2. RCS[6:4] should be set when the TOENA bit in TRECR1 is 0.

3. In output compare mode, when the CPU is in a ϕsub clock mode, do not select the ϕsub clock as the clock source for the timer.

TRECSR selects clock output, operating mode, and clock source.

- RCS6 to RCS4 (clock output select)
  Selects a clock output from the TREO pin when the TOENA bit in TRECR1 is set to 1.
- RCS1 and RCS0 (clock source select)
  Selects a clock source for output-compare mode. For realtime clock mode, the subclock ϕsub (32.768 kHz) is selected regardless of the setting of these bits.

17.3 Operation of Realtime Clock Mode

17.3.1 Initial Settings of Registers after Power-On

The timer RE registers that contain second, minute, hour, and day-of-week data are not initialized by a reset by the $\overline{\text{RES}}$ pin, LVD, or watchdog timer. Therefore, all registers must be set to their initial values after power-on. Once the register settings are made, the timer RE provides an accurate time as long as power is supplied regardless of the $\overline{\text{RES}}$ pin, VLD, or watchdog timer reset.

17.3.2 Initial Setting Procedure

Figure 17.3 shows the procedure for the initial setting of the timer RE to be used in realtime clock mode. To set the timer RE again, also follow this procedure.

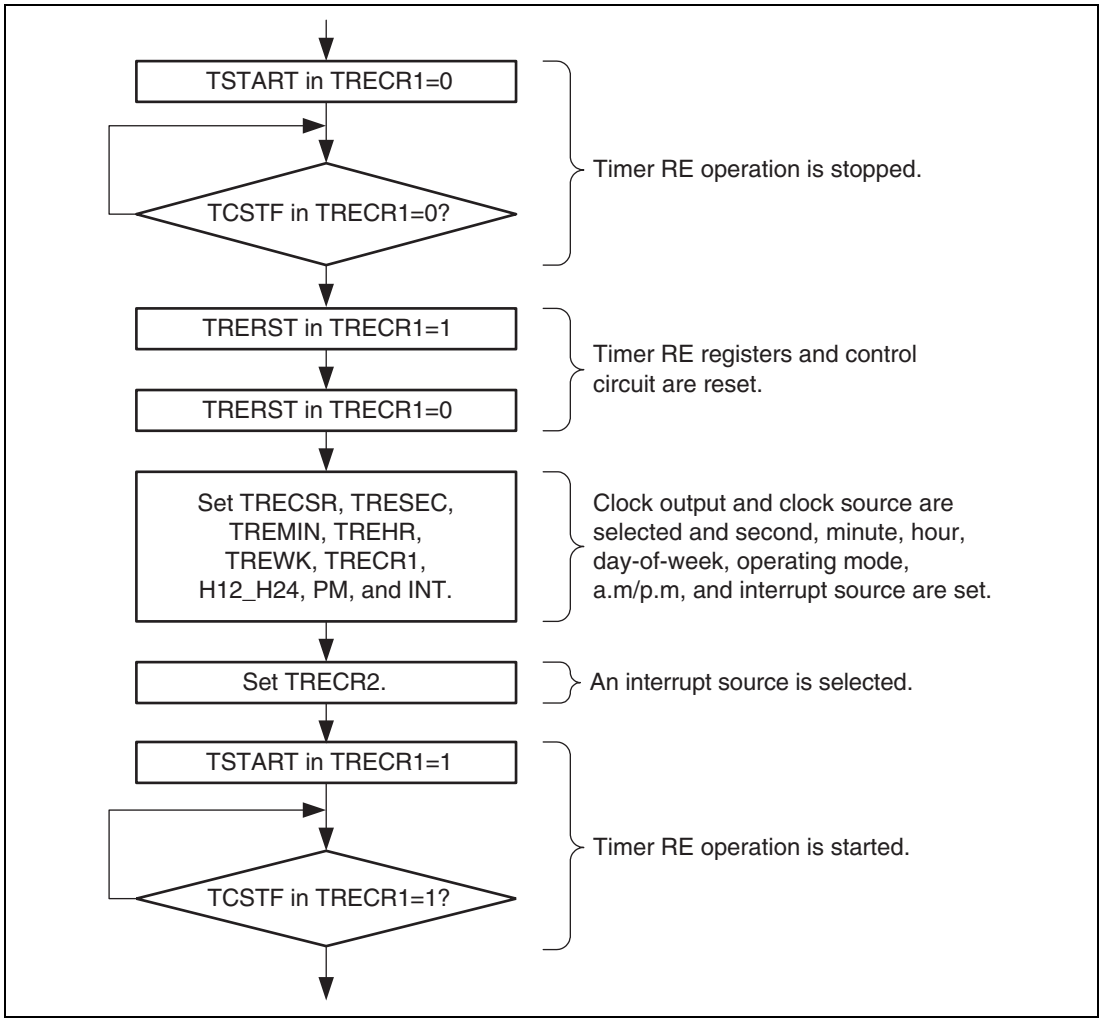


Figure 17.3 Initial Setting Procedure

17.3.3 Data Reading Procedure in Realtime Clock Mode

When the seconds, minutes, hours, or day-of-week datum is updated while time data is being read, the data obtained may not be correct, and so the time data must be read again. Figure 17.4 shows an example in which correct data is not obtained. In this example, since only TRESEC is read after data update, about 1-minute inconsistency occurs.

The following three methods can be used to avoid reading in this timing:

1. Check the setting of the BSY bit, and when the BSY bit changes from 1 to 0, read from the second, minute, hour, and day-of-week registers. When about 62.5 ms is passed after the BSY bit is set to 1, the registers are updated, and the BSY bit is cleared to 0.
2. Making use of interrupts, read from the second, minute, hour, and day-of week registers after the SECF flag in TREIFR is set to 1 and the BSY bit is confirmed to be 0.
3. Read from the second, minute, hour, and day-of week registers twice in a row, and if there is no change in the read data, the read data is used.

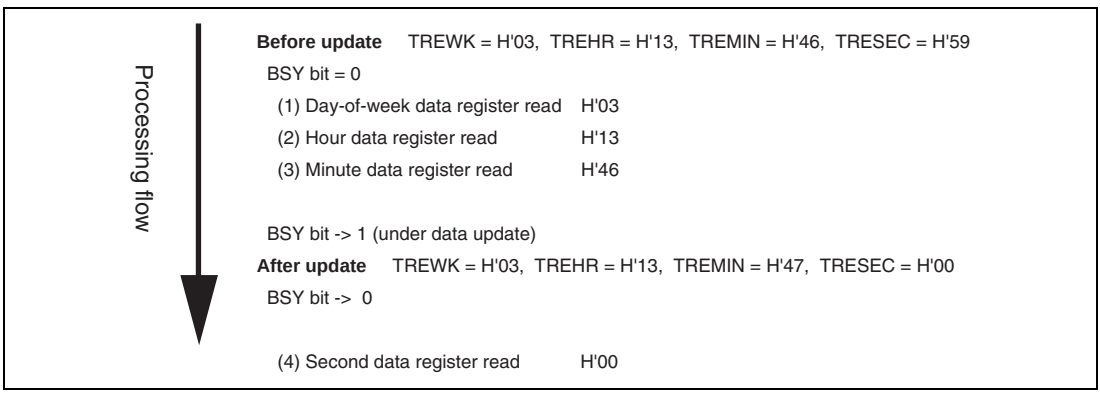


Figure 17.4 Example: Reading of Inaccurate Time Data

17.3.4 Operation in Realtime Clock Mode

Figure 17.5 shows an example of realtime clock mode operation.

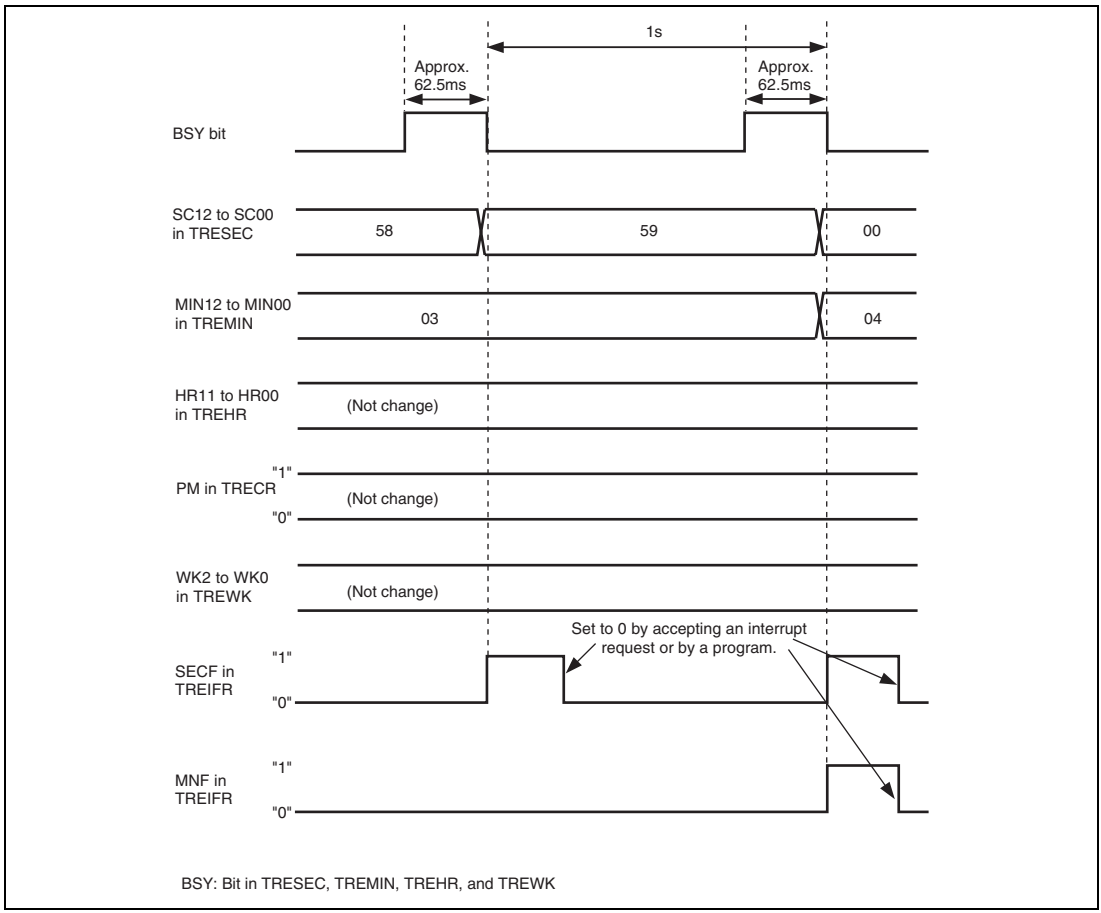


Figure 17.5 Example of Realtime Clock Mode Operation

17.4 Operation of Output Compare Mode

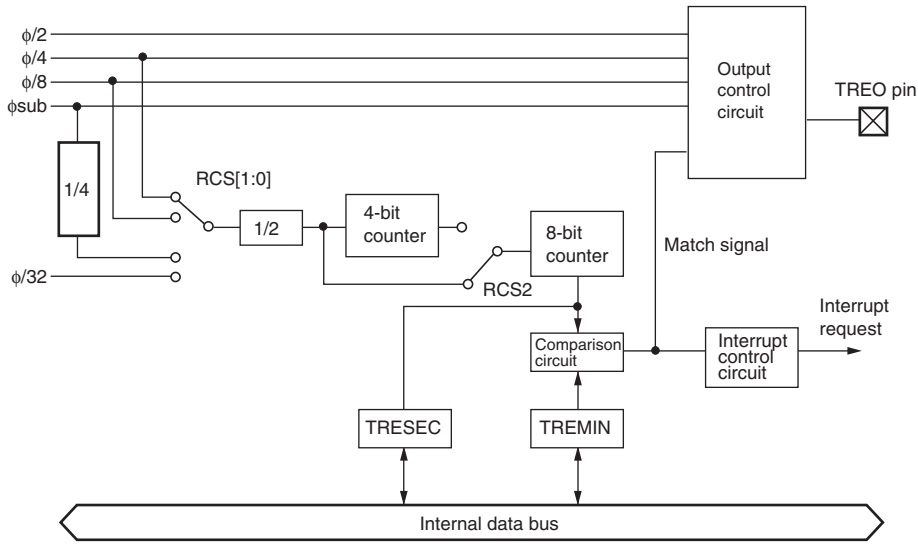
Writing 0 to the RCS3 bit in TRECSR sets the timer RE in output compare mode and causes it to operate as a counter provided with an 8-bit compare match function. Four count sources can be selected. When used in output compare mode, the timer RE should be initialized in reference to figure 17.3.

The count source selected by the RCS1 and RCS0 bits is divided into two and counted with an 8-bit counter. Setting 1 to the RCS2 bit in TRECSR causes the count source divided into two to be counted with a 4-bit counter, and the 8-bit counter counts overflows of the 4-bit counter.

TREMIN sets a compare value. By reading TRESEC, it is possible to read values from the 8-bit counter. In this mode, TREHR or TREWK is not used. Setting bits RCS6 to RCS4 in TRECSR to B'011 and setting the TOENA bit in TRECR1 to 1 produces toggle output from the TREO pin each time the value of the 8-bit counter matches the value of TREMIN (initial value: low output).

Also, by setting the COMIE bit in TRECR2 to 1, it is possible to generate a compare match interrupt request. The counter, using the TSTART bit in TRECR1, controls the start/stop of counter operation.

Figure 17.6 shows a block diagram of output compare mode; figure. 17.7 shows an operation example.



[Legend]
TRESEC: Timer RE second data register/counter data register
TREMIN: Timer RE minute data register/compare data register
RCS2 to RCS0: Bits 2 to 0 in TRECSR

Figure 17.6 Block Diagram of Output Compare Mode

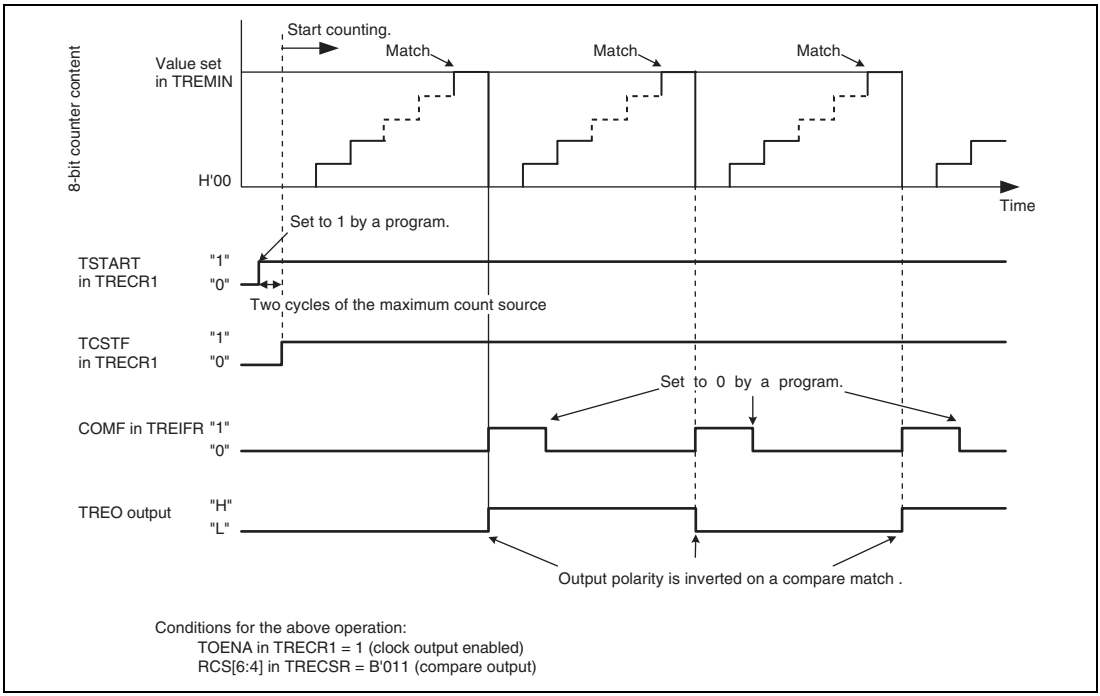


Figure 17.7 Example of Output Compare Mode Operation

17.5 Interrupt Sources

There are six kinds of timer RE interrupts: week interrupts, day interrupts, hour interrupts, minute interrupts, and second interrupts in realtime clock mode, and compare-match interrupts in output compare mode. Table 17.2 shows the interrupt sources.

When using an interrupt, initiate the timer RE last after other registers are set. Independent vector addresses are allocated to each timer RE interrupt source.

Table 17.2 Interrupt Sources

Interrupt Name	Interrupt Source	Interrupt Enable Bit
Compare-match interrupt	Occurs when the count value matches the compare data.	COMIE
Week periodic interrupt	Occurs every week when the day-of-week data register value becomes 0.	WKIE
Day periodic interrupt	Occurs every day when the day-of-week data register value is incremented.	DYIE
Hour periodic interrupt	Occurs every hour when the hour date register value is incremented.	HRIE
Minute periodic interrupt	Occurs every minute when the minute data register value is incremented.	MNIE
Second periodic interrupt	Occurs every second when the second data register value is incremented.	SCIE

17.6 Usage Notes

(1) Starting and Stopping Counting Process

The timer RE includes a TSTART bit that directs the start or stop of the counting process, and a TCSTF bit that indicates that the counting process has started or stopped.

Setting the TSTART bit to 1 causes the timer RE to start counting and assigns 1 to the TCSTF bit. From the time the TSTART bit is set to 1 and to the time the TCSTF bit turns 1, a maximum of 2 cycles of count sources are required. During this time period, the timer RE related registers*, with the exception of the TCSTF bit, should not be accessed.

Similarly, clearing the TSTART bit to 0 causes the timer RE to stop counting, and assigns 0 to the TCSTF bit. From the time the TSTART bit is set to 0 and to the time the TCSTF bit turns 0, the timer RE related registers*, with the exception of the TCSTF bit, should not be accessed.

Note: Timer RE related registers: TRESEC, TREMIN, TREHR, TREWK, TRECR1, TRECR2, and TRECSR

(2) Register Settings of Timer RE

The following registers and bits should be written when the timer RE is stopped.

The condition "timer RE stopped" refers to the condition in which both the TSTART and TCSTF bits in TRECR1 are 0. Set TRECR2 at the end of setting the above registers and bits (before the timer RE counting process is started).

- Registers TRESEC, TREMIN, TREHR, TREWK, and TRECR2
- Bits H12_H24 bit, PM, and INT in TRECR1
- Bits RCS0 to RCS3 in TRECSR

(3) Sampling Circuit for Noise Canceler in ϕ Subclock Signal

In realtime clock mode, always enable the sampling circuit with the SUBNC[1:0] bits in SYSCCR. For details of the SUBNC[1:0] bits, see section 5.2.2, System Clock Control Register (SYSCCR).

(4) Restrictions on Clock Selection in Output Compare Mode

In output compare mode, do not select the ϕ subclock as the clock source for the timer if the CPU is in ϕsub mode.

Section 18 Timer RG

Timer RG is a 16-bit timer with output compare and input capture functions. Timer RG can count using a number of internal or external clocks and output pulses with a desired duty cycle using the compare match function between the timer counter and two general registers. Timer RG is also able to decode the phase difference between two external clocks and increment. Timer RG therefore provides an ideal solution for many systems with a requirement to decide position based on a rotary encoder or tachometer as well as a wide range of other applications.

18.1 Features

- Selection of seven counter clock sources
  Internal clocks: ϕ, ϕ/2, ϕ/4, ϕ/8, ϕ/32 and ϕ40
  External clocks: TCLKA, TCLKB
- Timer mode
  Waveform output by compare match (Selection of 0 output, 1 output, or toggle output)
  Input capture function (Rising edge, falling edge, or both edges)
- PWM mode
  Generates pulses with a desired period and duty cycle.
- Phase counting mode
  Detects phase difference between two external clock inputs and increments/decrements the TCNT.
- Fast access via internal 16-bit bus
  Performs high-speed accesses to the timer counter and general registers using the 16-bit bus interface.
- Four interrupt sources
  TRGCNT overflow, TRGCNT underflow, compare match, and input capture

Table 18.1 Functions of Timer RG

Item		Counter	Input/Output Pins TGIOA	Input/Output Pins TGIOB
Counter clock		Internal clocks: φ, φ/2, φ/4, φ/8, φ/32, and φ40 External clock: TCLKA, TCLKB		
General registers (multiplexed registers with output compare/input capture)		—	GRA	GRB
Buffer register		—	BRA	BRB
Counter clearing function		—	Compare match/ input capture	Compare match/ input capture
Initial output value setting function		—	—	—
Buffer operation		—	Yes	Yes
Compare match output	0 output	—	Yes	Yes
	1 output	—	Yes	Yes
	Toggle output	—	Yes	Yes
Input capture function		—	Yes	Yes
PWM mode		—	Yes	Yes
Phase counting mode		—	Yes	Yes
Interrupt sources		Overflow Underflow	Compare match/ input capture	Compare match/ input capture

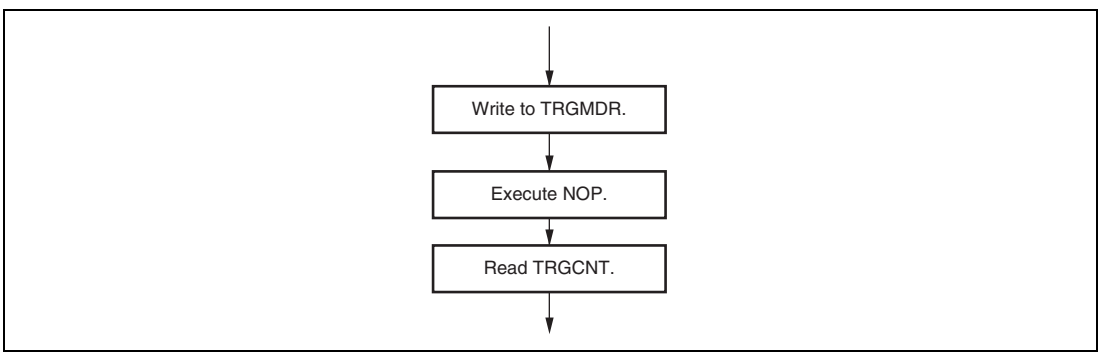


Figure 18.1 Timer RG Block Diagram

Table 18.2 summarizes the timer RG pins.

Table 18.2 Pin Configuration

Pin Name	I/O	Function
TCLKA	Input	External clock A input pin (Phase A input pin in phase counting mode)
TCLKB	Input	External clock B input pin (Phase B input pin in phase counting mode)
TGIOA	I/O	GRA output compare output pin/ GRA input capture input pin/ PWM output pin in PWM mode
TGIOAB	I/O	GRB output compare output pin/ GRB input capture input pin

18.2 Register Descriptions

Timer RG has the following registers.

- Timer RG mode register (TRGMDR)
- Timer RG counter control register (TRGCNTCR)
- Timer RG control register (TRGCR)
- Timer RG I/O control register (TRGIOR)
- Timer RG status register (TRGSR)
- Timer RG interrupt enable register (TRGIER)
- Timer RG counter (TRGCNT)
- General register A (GRA)
- General register B (GRB)
- GRA buffer register (BRA)
- GRB buffer register (BRB)

18.2.1 Timer RG Mode Register (TRGMDR)

Address: H'FF0646

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	STR	—	DFCK[1:0]		DFB	DFA	MDF	PWM
Value after reset:	0	1	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	STR	Counter start	0: TRGCNT stops counting. 1: TRGCNT performs counting.	R/W
6	—	Reserved	This bit is read as 1. The write value should be 1.	—
5, 4	DFCK[1:0]	Digital filter clock select	00: φ/32 (initial value) 01: φ/8 10: φ 11: φ/32Clock specified by bits CKS2 to CKS0 in TRGCR	R/W
3	DFB	TGIOB pin digital filter function select	0: Disables the digital filter for the TGIOB pin. 1: Enables the digital filter for the TGIOB pin.	R/W
2	DFA	TGIOB pin digital filter function select	0: Disables the digital filter for the TGIOA pin. 1: Enables the digital filter for the TGIOA pin.	R/W
1	MDF	Phase counting mode select	0: Increments the counter.*1 1: Phase counting mode	R/W
0	PWM	PWM mode select	0: Usual mode*2 1: PWM mode	R/W

Note: 1. Select counting up in PWM mode.
2. Select normal mode here when the MDF bit is set for phase counting mode.

- STR bit (Counter start)

  Clearing this bit to 0 stops counting by TRGCNT. Counting by TRGCNT proceeds while this bit is set to 1.

  This bit is set to 1 if the specified event occurs when operation of timer RG has been selected in ELOPC of the event link controller.

- MDF bit (Phase counting mode select)

  When this bit is 0, the counter counts the clock pulses specified with the TPSC2 to TPSC0 bits in TRGCR. When this bit is 1, the counter counts the phases produced by TCLKA and TCLKB as specified in TRGCNTCR.

18.2.2 Timer RG Counter Control Register (TRGCNTCR)

Address: H'FF0647

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	CNTEN7	CNTEN6	CNTEN5	CNTEN4	CNTEN3	CNTEN2	CNTEN1	CNTEN0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	CNTEN7	Count enable bit 7	0: Not affected by the TCLKB rising edge when TCLKA is low. 1: Incremented at the TCLKB rising edge when TCLKA is low.	R/W
6	CNTEN6	Count enable bit 6	0: Not affected by the TCLKA rising edge when TCLKB is high. 1: Incremented at the TCLKA rising edge when TCLKB is high.	R/W
5	CNTEN5	Count enable bit 5	0: Not affected by the TCLKB falling edge when TCLKA is high. 1: Incremented at the TCLKB falling edge when TCLKA is high.	R/W
4	CNTEN4	Count enable bit 4	0: Not affected by the TCLKA falling edge when TCLKB is low. 1: Incremented at the TCLKA falling edge when TCLKB is low.	R/W
3	CNTEN3	Count enable bit 3	0: Not affected by the TCLKA falling edge when TCLKB is high. 1: Incremented at the TCLKA falling edge when TCLKB is high.	R/W
2	CNTEN2	Count enable bit 2	0: Not affected by the TCLKB falling edge when TCLKA is low. 1: Incremented at the TCLKB falling edge when TCLKA is low.	R/W
1	CNTEN1	Count enable bit 1	0: Not affected by the TCLKA rising edge when TCLKB is low. 1: Incremented at the TCLKA rising edge when TCLKB is low.	R/W
0	CNTEN0	Count enable bit 0	0: Not affected by the TCLKB rising edge when TCLKA is high. 1: Incremented at the TCLKB rising edge when TCLKA is high.	R/W

18.2.3 Timer RG Control Register (TRGCR)

Address: H'FF0648

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	CCLR[1:0]		CKEG[1:0]		TPSC[2:0]		
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6, 5	CCLR[1:0]	Counter clear source select	00: Disables clearing TRGCNT. 01: Clears TRGCNT with a GRA compare match/input capture. 1X: Clears TRGCNT with a GRB compare match/input capture.	R/W
4, 3	CKEG[1:0]	External clock detection edge select	00: Incremented at the rising edges. 01: Incremented at the falling edges. 1x: Incremented at the rising and falling edges.	R/W
2 to 0	TPSC[2:0]*	TRGCNT count clock select	000: TRGCNT counts the internal clock φ 001: TRGCNT counts the internal clock φ/2 010: TRGCNT counts the internal clock φ/4 011: TRGCNT counts the internal clock φ/8 100: TRGCNT counts the internal clock φ/32 101: TRGCNT counts the TCLKA pin input 110: TRGCNT counts the internal clock φ/40 111: TRGCNT counts the TCLKB pin input	R/W

[Legend]

X: Don't care.

Note: * If the internal φ/40 clock is selected, the high-speed on-chip oscillator must be operating. As long as the internal φ40 clock is selected, do not stop the high-speed on-chip oscillator. When the counter clock is switched over, the counter should be halted.
When the internal φ40 clock is selected, restrictions on access to registers are applied. For details, see section 18.4, Usage Note. (1) Restrictions on Access to Registers when Internal φ40 Clock is Selected as Counter Clock.

- CKEG1 bit and CLEG0 bit (external clock detection edge select)
  Selects an edge of the external clock to be detected. When phase counting mode is used, the phase counting operation is performed regardless of the CKEG[1:0] setting.

- TPSC2 bit to TPSC0 bit (TRGCNT count clock select)
  The settings are invalid in phase counting mode.

18.2.4 Timer RG I/O Control Register (TRGIOR)

Address: H'FF0649

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BUFB	IOB2	IOB[1:0]		BUFA	IOA2	IOA[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	BUFB	BRB function select	0: BRB does not function as the GRB buffer register. 1: BRB functions as the GRB buffer register.	R/W
6	IOB2	GRB function select	0: GRB is used as a compare match register. 1: GRB is used as an input capture register.	R/W
5, 4	IOB[1:0]	GRB I/O function select	When IOB2 = 0, 00: Disables pin output at a compare match. 01: Outputs 0 to the TGIOB pin at a GRB compare match. 10: Outputs 1 to the TGIOB pin at a GRB compare match. 11: Toggles the output to the TGIOB pin at a GRB compare match. When IOB2 = 1, 00: Input capture to GRB at the rising edge of the TGIOB pin. 01: Input capture to GRB at the falling edge of the TGIOB pin. 1X: Input capture to GRB at the rising and falling edges of the TGIOB pin.	R/W

Bit	Symbol	Bit Name	Description	R/W
3	BUFA	BRA function select	0: BRA does not function as the GRA buffer register. 1: BRA functions as the GRA buffer.	R/W
2	IOA2	GRA function select	0: GRA is used as a compare match register. 1: GRA is used as an input capture register.	R/W
1, 0	IOA[1:0]	GRA I/O function select	When IOA2 = 0, 00: Disables pin output at a compare match. 01: Outputs 0 to the TGIOA pin at a GRA compare match. 10: Outputs 1 to the TGIOA pin at a GRA compare match. 11: Toggles the output to the TGIOA pin at a GRA compare match. When IOA2 = 1, 00: Input capture to GRA at the rising edge of the TGIOA pin. 01: Input capture to GRA at the falling edge of the TGIOA pin. 1X: Input capture to GRA at the rising and falling edges of the TGIOA pin.	R/W

[Legend]

X: Don't care.

18.2.5 Timer RG Status Register (TRGSR)

Address: H'FF064A

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	DIRF	OVF	UDF	IMFB	IMFA
Value after reset:	1	1	1	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 5	—	Reserved	These bits are read as 1. The write value should be 1.	—
4	DIRF	Count direction flag	0: TRGCNT is decremented. 1: TRGCNT is incremented.	R
3	OVF	Overflow flag	[Setting condition] • When TRGCNT overflows from H'FFFF to H'0000 [Clearing condition] • When OVF is read when OVF = 1, then 0 is written to.	R/W
2	UDF	Underflow flag	[Setting condition] • When TRGCNT underflows from H'0000 to H'FFFF [Clearing condition] • When UDF is read when UDF = 1, then 0 is written to. UDF is valid when phase counting mode is used (MDF in TRGMDR is 1).	R/W
1	IMFB	Input capture/ compare match flag B	[Setting conditions] • TRGCNT = GRB when GRB functions as an output compare register • The TRGCNT value is transferred to GRB by an input capture signal when GRB functions as an input capture register [Clearing condition] • When the DTC is activated by a IMFB interrupt, and the DISEL bit in MRB of the DTC is 0. • When IMFB is read when IMBF = 1, then 0 is written to.	R/W

Bit	Symbol	Bit Name	Description	R/W
0	IMFA	Input capture/ compare match flag A	[Setting conditions] • TRGCNT = GRA when GRA functions as an output compare register • The TRGCNT value is transferred to GRA by an input capture signal when GRA functions as an input capture register [Clearing condition] • When the DTC is activated by an IMFA interrupt, and the DISEL bit in MRB of the DTC is 0. • When IMFA is read when IMAF = 1, then 0 is written to.	R/W

18.2.6 Timer RG Interrupt Enable Register (TRGIER)

TRGIER is a register that controls interrupt requests of timer RG.

Address: H'FF064B

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	OVIE	UDIE	IMIEB	IMIEA
Value after reset:	1	1	1	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	—	Reserved	These bits are read as 1. The write value should always be 1.	—
3	OVIE	Overflow interrupt enable	0: Interrupt by the OVF flag is disabled. 1: Interrupt by the OVF flag is enabled.	R/W
2	UDIE	Underflow interrupt enable	0: Interrupt by the UDF flag is disabled. 1: Interrupt by the UDF flag is enabled.	R/W
1	IMIEB	Input capture/ compare match B enable	0: Interrupt by the IMFB flag is disabled. 1: Interrupt by the IMFB flag is enabled.	R/W
0	IMIEA	Input capture/ compare match A enable	0: Interrupt by the IMFA flag is disabled. 1: Interrupt by the IMFA flag is enabled.	R/W

18.2.7 Timer RG Counter (TRGCNT)

Address: H'FF0640

Bit:	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

TRGCNT is a 16-bit readable/writable register that performs count operation with an input clock. The input clock is selected by bits TPSC2 to TPSC0 in TRGCR.

TRGCNT is incremented or decremented in phase counting mode and is only incremented in other modes.

TRGCNT can be cleared to H'0000 by a compare match with the relevant GRA or GRB or by an input capture to GRA or GRB (counter clearing function).

When TRGCNT overflows (changes from H'FFFF to H'0000), the OVF flag in TRGSR is set to 1. When TRGCNT underflows (changes from H'0000 to H'FFFF), the UDF flag in TRGSR is set to 1.

TRGCNT must always be read from or written to in units of 16 bits; 8-bit accesses are not allowed. TRGCNT is initialized to H'0000 by a reset.

18.2.8 General Registers A and B (GRA, GRB), GRA and GRB Buffer Registers (BRA, BRB)

GRA

Address: H'FF0642															
Bit:	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

GRB

Address: H'FF0644															
Bit:	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

BRA

Address: H'FF064C															
Bit:	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

BRB

Address: H'FF064E															
Bit:	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

Each of GRA and GRB is a 16-bit readable/writable register that can function as either an output-compare register or an input-capture register. The function is selected with TRGIOR.

When a general register is used as an output-compare register, its value is constantly compared with the TRGCNT value. When the two values match (a compare match), the corresponding flag (the IMFA or IMFB bit) in TRGSR is set to 1. A compare match output can be selected in TRGIOR.

When a general register is used as an input-capture register, an external input-capture signal is detected and the current TRGCNT value is stored in the general register. The corresponding flag (the IMFA or IMFB bit) in TRGSR is set to 1. The edge of the input-capture signal is selected in TRGIOR. The setting of TRGIOR is ignored in PWM mode.

BRA and BRB can be used as buffer registers of GRA and GRB, respectively, by setting BUFA and BUFB in TRGIOR.

For example, when GRA is set as an output-compare register and BRA is set as the buffer register for GRA, the value in TRGCNT is sent to GRA whenever compare match A is generated.

When GRA is set as an input-capture register and BRA is set as the buffer register for GRA, the value in TRGCNT is transferred to GRA and the value in GRA is transferred to the buffer register BRA whenever an input capture is generated.

General registers and buffer registers must be written or read in 16-bit units. General registers are set as output compare registers and initialized to H'FFFF by a reset.

18.3 Operation

Timer RG has the following operating modes.

- Timer mode (the waveform output function by a compare match, and the input-capture function)
- PWM mode
- Phase counting mode

The TGIOA and TGIOB pins indicate the functions by each register setting.

- TGIOA pin

Register Name	PMR	PCR	TRGMDR	TRGIOR	
Bit Name	**PMR**	**PCR**	**PWM**	**IOA2 to IOA0**	**Function**
Setting values	1	X	1	XXX	PWM mode waveform output
		X	0	001, 01X	Timer mode waveform output (output compare function)
		X	0	1XX	Timer mode (input capture function)
	0	1	X	XXX	General output port
		0	X	XXX	General input port

[Legend]

X: Don't care.

Note: In timer mode (input capture function), do not select the relevant I/O pin to be an output in the port control register.

- TGIOB pin

Register Name	PMR	PCR	TRGMDR	TRGIOR	
Bit Name	**PMR**	**PCR**	**PWM**	**IOB2 to IOB0**	**Function**
Setting values	1	X	X	001, 01X	Timer mode waveform output (output compare function)
		X	X	1XX	Timer mode (input capture function)
	0	1	X	XXX	General output port
		0	X	XXX	General input port

[Legend]

X: Don't care.

Note: In timer mode (input capture function), do not select the relevant I/O pin to be an output in the port control register.

18.3.1 Timer Mode

TRGCNT performs up-counting, and is also capable of free-running operation, periodic counting, and external event counting.

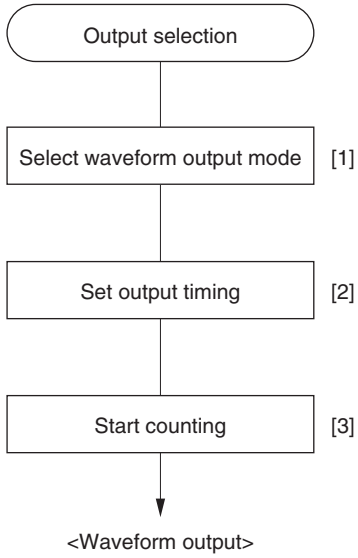
Each of GRA and GRB can be used as an input capture register or output compare register.

(1) Waveform Output by Compare Match:

The TPU can perform 0, 1, or toggle output from the corresponding output pin using a compare match.

(a) Example of setting procedure for waveform output by compare match

Figure 18.2 shows an example of the setting procedure for waveform output by a compare match.



[1] Select 0 output, 1 output, or toggle output for compare match output by means of TRGIOR. When waveform output mode is selected, the port functions for compare-match output (TGIOA, TGIOB).

[2] Set the timing for compare match generation in GRA/GRB.

[3] Set the STR bit in TRGMDR to 1 to start the TRGCNT count operation.

Figure 18.2 Example of Setting Procedure for Waveform Output by Compare Match

Table 18.3 Initial Output Values until the First Compare Match Occurs

Pin	0 is Output by Compare Match	1 is Output by Compare Match	Output is Toggled by Compare Match
TGIOA	1	0	0*
TGIOB	1	0	0*

Note: * When the initial toggled output immediately after release from the reset state is selected. In case where switching was from another output, the output value is that which preceded the switch.

(b) Examples of waveform output operation

Figure 18.3 shows an example of 0 output/1 output.

In this example, TRGCNT has been designated as a free-running counter, and settings have been made so that 1 is output by compare match A, and 0 is output by compare match B. When the set level and the pin level match, the pin level does not change.

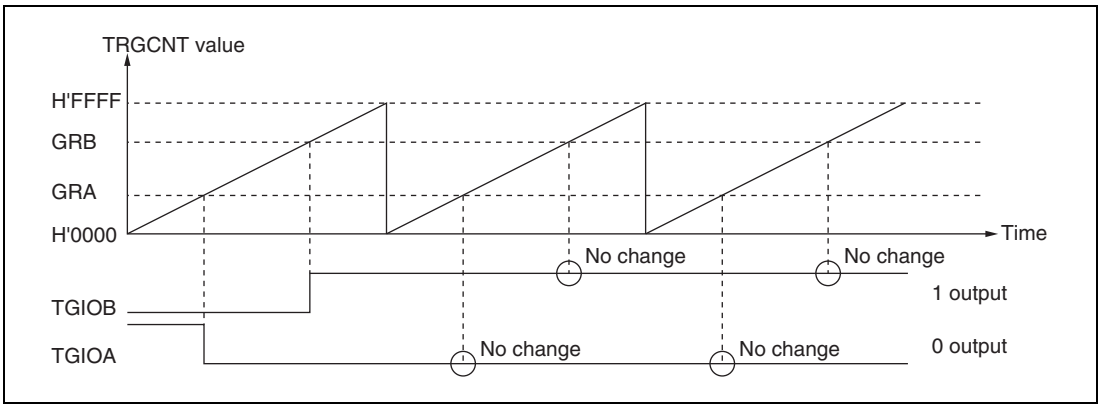


Figure 18.3 Example of 0 Output/1 Output Operation

Figure 18.4 shows an example of toggle output. In this example TRGCNT has been designated 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.

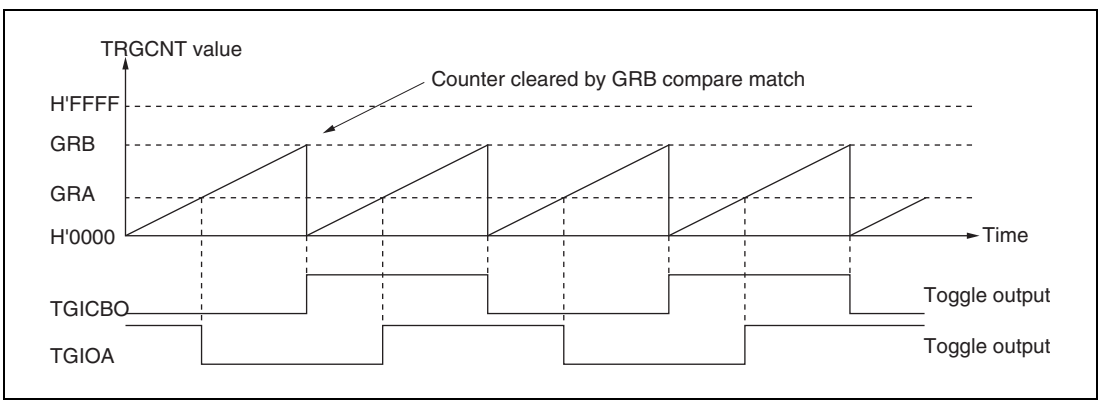


Figure 18.4 Example of Toggle Output Operation

(c) Output compare output timing

A compare match signal is generated in the final state in which TRGCNT and GR match (the point at which the count value matched by TRGCNT is updated). When a compare match signal is generated, the output value set in TRGIOR is output at the output compare output pin (TGIOA, TGIOB). After a match between TRGCNT and GR, the compare match signal is not generated until the TRGCNT input clock is generated.

Figure 18.5 shows output compare output timing.

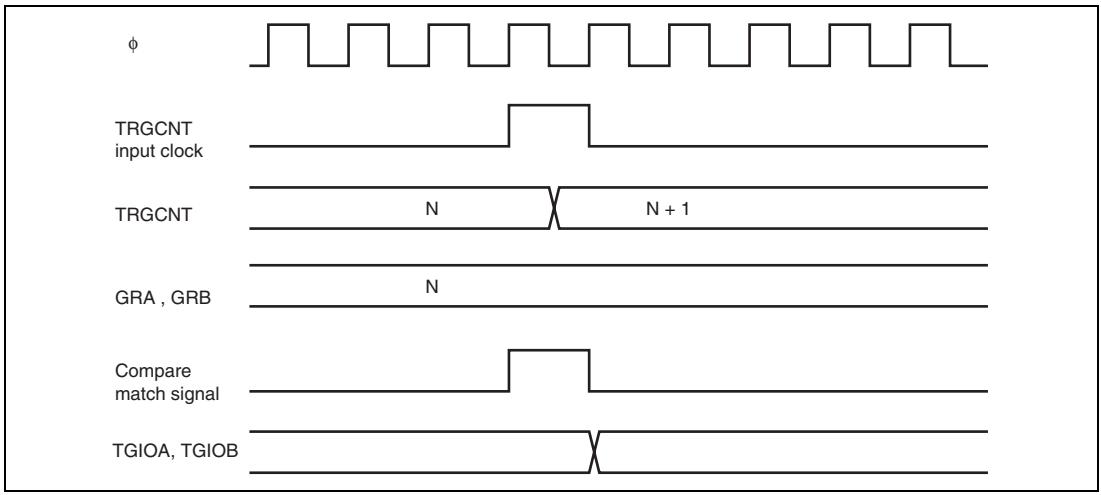


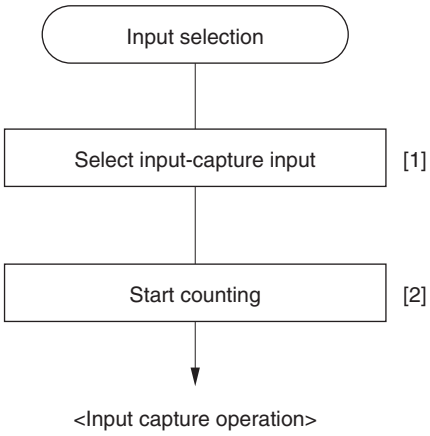
Figure 18.5 Output Compare Output Timing

(2) Input Capture Function

The TRGCNT value can be transferred to GR on detection of the input-capture/output-compare pin (TGIOA, TGIOB) input edge. Rising edge, falling edge, or both edges can be selected as the detection edge. The pulse width and cycle period can be measured using the input capture function.

(a) Example of setting procedure for input capture operation

Figure 18.6 shows an example of the setting procedure for input capture operation.



[1] Designate GR as an input capture register by means of TRGIOR, and select the input capture signal input edge (rising edge, falling edge, or both edges).
[2] Set the STR bit in TRGMDR to 1 to start the TRGCNT count operation.

Figure 18.6 Example of Setting Procedure for Input Capture Operation

(b) Example of input capture operation

Figure 18.7 shows an example of input capture operation.

In this example both rising and falling edges have been selected as the TGIOA pin input capture input edge, falling edge has been selected as the TGIOB pin input capture input edge, and counter clearing by GRB input capture has been designated for TRGCNT.

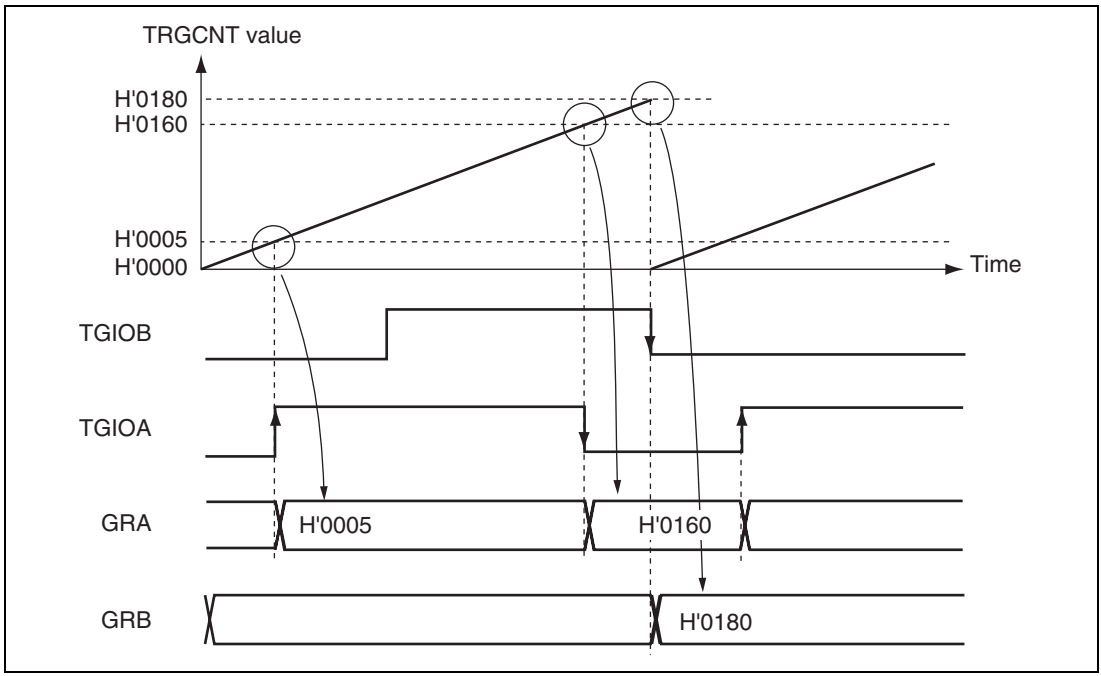


Figure 18.7 Example of Input Capture Operation

(c) Input capture signal timing

Rising edge, falling edge, or both edges can be selected as the detection edge for input capture with TRGIOR.

Figure 18.8 shows input capture signal timing when the falling edge has been selected.

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.

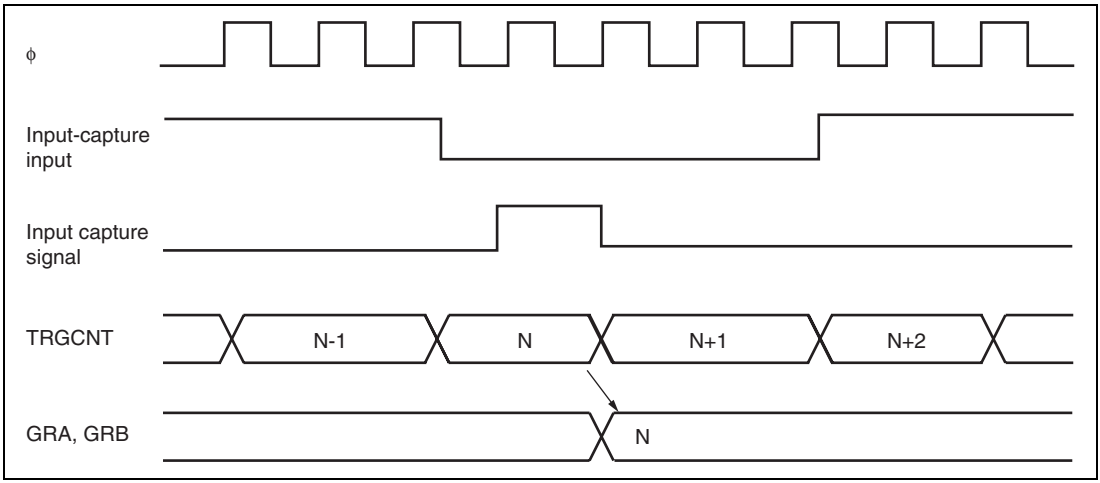


Figure 18.8 Input Capture Input Signal Timing

18.3.2 PWM Mode

In PWM mode, the PWM waveform is output from the TGIOA output pin by using GRA and GRB as a pair. When an output pin is set for PWM mode, the TRGIOR output setting is ignored. The high level output timing for PWM waveform is set in GRA and the low level output timing in GRB.

Designating GRA or GRB compare match as the TRGCNT counter clearing source enables outputting a PWM waveform in the range of 0% to 100% duty cycle from the TGIOA pin.

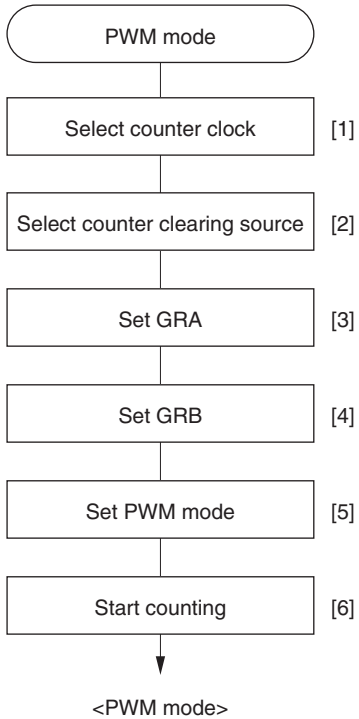
The correspondence between PWM output pins and registers is shown in table 18.4. When the same value is set in GRA and GRB, the output value does not change even if a compare match occurs.

Table 18.4 PWM Output Pins and Registers

Output Pin	Output 1	Output 0
TGIOA	GRA	GRB
TGIOB	Functions as general I/O port	

(1) Example of PWM Mode Setting Procedure

Figure 18.9 shows an example of the PWM mode setting procedure.



[1] Select the counter clock with bits TPSC2 to TPSC0 in TRGCR. When an external clock is selected, select the external clock edge with bits CKEG1 and CKEG0 in TRGCR.

[2] Use bits CCLR1 and CCLR0 in TRGCR to select the counter clearing source.

[3] Set the 1-output timing for the output PWM waveform with GRA.

[4] Set the 0-output timing for the output PWM waveform with GRB.

[5] Select the PWM mode with the PWM bit in TRGMDR. When PWM mode is set, GRA and GRB are used as output compare registers for setting 1-output/0-output for PWM output waveform, regardless of the TRGIOR setting. At this time, the TGIOA pin is automatically designated as a PWM output pin and the TGIOB pin is used as a general I/O for the relevant port.

[6] Set the STR bit in TRGMDR to 1 to start the count operation.

Figure 18.9 Example of PWM Mode Setting Procedure

(2) Examples of PWM Mode Operation

Figure 18.10 shows examples of PWM mode operation.

When PWM mode is set, the TGIOA pin is automatically set as an output pin. The TGIOA pin outputs 1 on a GRA compare match and outputs 0 on a GRB compare match. The TGIOB pin always functions as an I/O pin for the relevant port.

In the examples shown in the figure, GRA and GRB compare matches are set as the TRGCNT clearing source. The initial value of TGIOA differs according to the counter clearing source. The correspondence between counter clearing sources and initial values is shown in table 18.5.

Table 18.5 Correspondence between Counter Clearing Sources and TGIOA Initial Values

Counter Clearing Source	TGIOA Initial Value
GRA compare match	1
GRB compare match	0

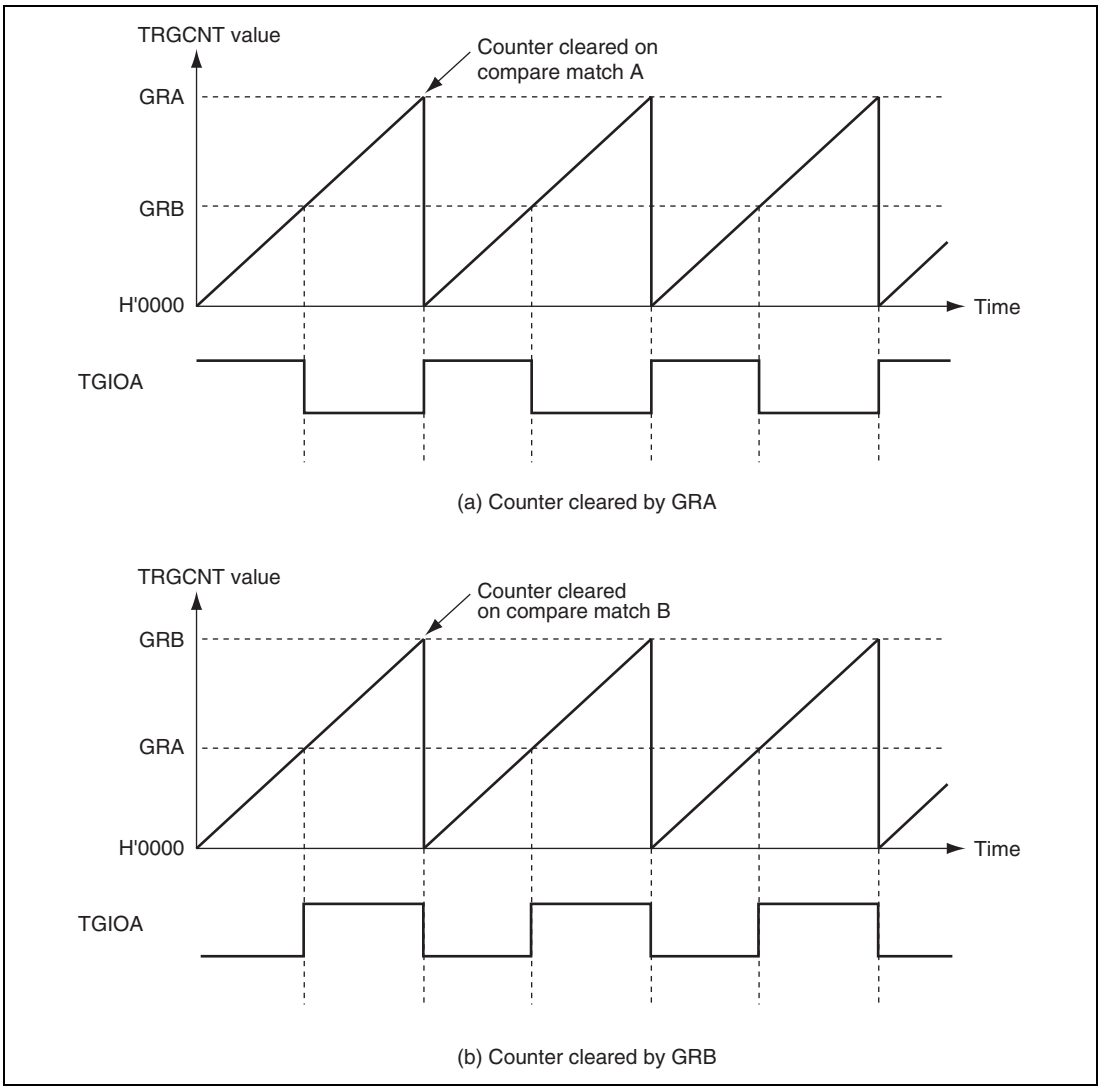


Figure 18.10 Example of PWM Mode Operation (1)

Figure 18.11 shows examples of PWM waveform output with 0% duty cycle and 100% duty cycle in PWM mode. When GRB compare match is set as the counter clearing source and the set value in GRA is greater than the value in GRB, the duty cycle of the PWM waveform is 0%. When GRA compare match is set as the counter clearing source and the set value in GRB is greater than the value in GRA, the duty cycle is 100%.

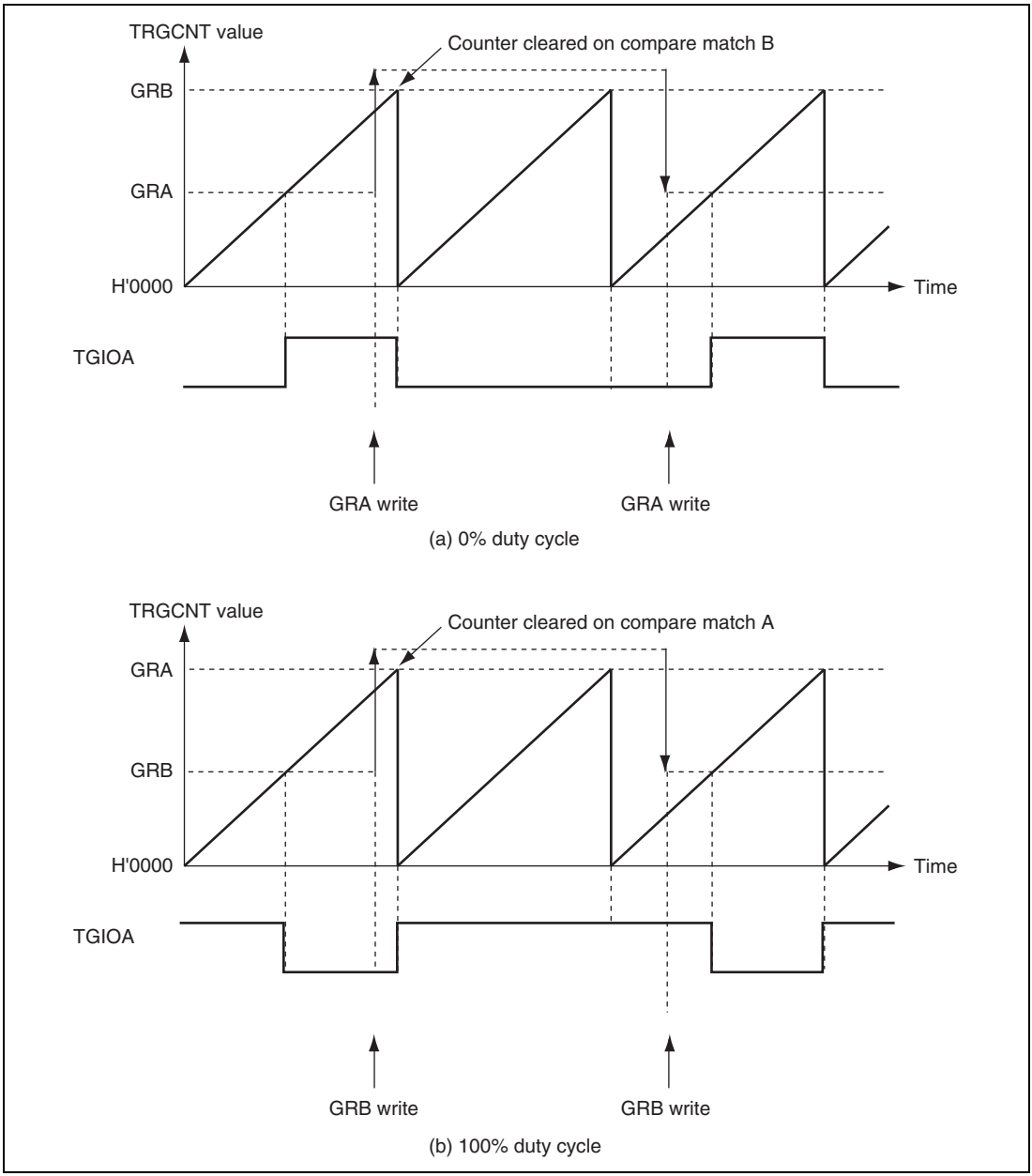


Figure 18.11 Example of PWM Mode Operation (2)

18.3.3 Phase Counting Mode

In phase counting mode, the phase difference between two external clock inputs (TCLKA and TCLKB pins) is detected and TRGCNT is incremented/decremented accordingly.

When phase counting mode is set, the TCLKA and TCLK pins function as external clock input pins and TRGCNT operates as an up/down-counter regardless of the setting of bits TPSC2 to TPSC0 and bits CKEG1 and CKEG0 in TRGCR.

(1) Example of Phase Counting Mode Setting Procedure

Figure 18.12 shows an example of the phase counting mode setting procedure.

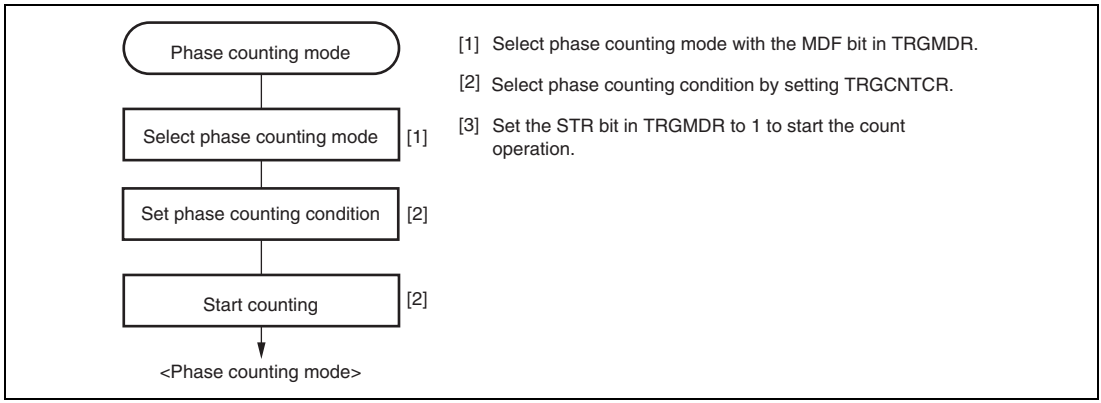


Figure 18.12 Example of Phase Counting Mode Setting Procedure

(2) Examples of Phase Counting Mode Operation

Figures 18.13 to 18.16 show examples of phase counting mode operation, and tables 18.6 to 18.9 summarize the TRGCNT increment/decrement conditions.

Table 18.6 Increment/Decrement Conditions in Phase Counting Mode Operation Example 1 (TRGCNTCR = H'FF)

TRGCNTCR	Set Value	TCLKA	TCLKB	Operation
CNTEN7	1	Low level	↑	Increment
CNTEN6	1	↑	High level	
CNTEN5	1	High level	↓	
CNTEN4	1	↓	Low level	
CNTEN3	1	↓	High level	Decrement
CNTEN2	1	Low level	↓	
CNTEN1	1	↑	Low level	
CNTEN0	1	High level	↑	

[Legend]
↑ : Rising edge
↓ : Falling edge

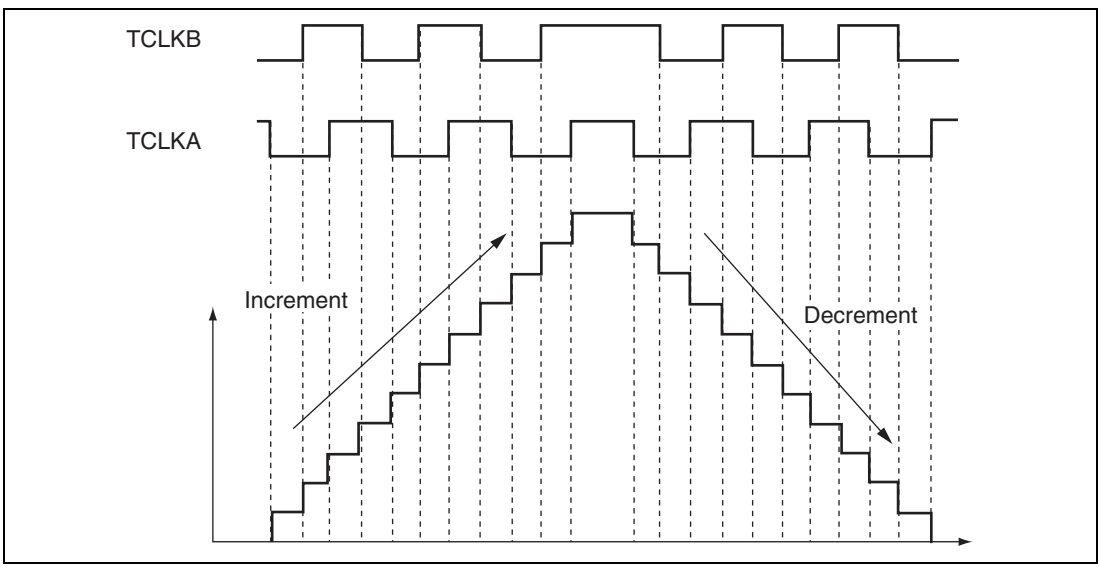


Figure 18.13 Phase Counting Mode Operation Example 1 (TRGCNTCR = H'FF)

Table 18.7 Increment/Decrement Conditions in Phase Counting Mode Operation Example 2 (TRGCNTCR = H'24)

TRGCNTCR	Set Value	TCLKA	TCLKB	Operation
CNTEN7	0	Low level	↑	Don't care
CNTEN6	0	↑	High level	
CNTEN5	1	High level	↓	Increment
CNTEN4	0	↓	Low level	Don't care
CNTEN3	0	↓	High level	
CNTEN2	1	Low level	↓	Decrement
CNTEN1	0	↑	Low level	Don't care
CNTEN0	0	High level	↑	

[Legend]
↑ : Rising edge
↓ : Falling edge

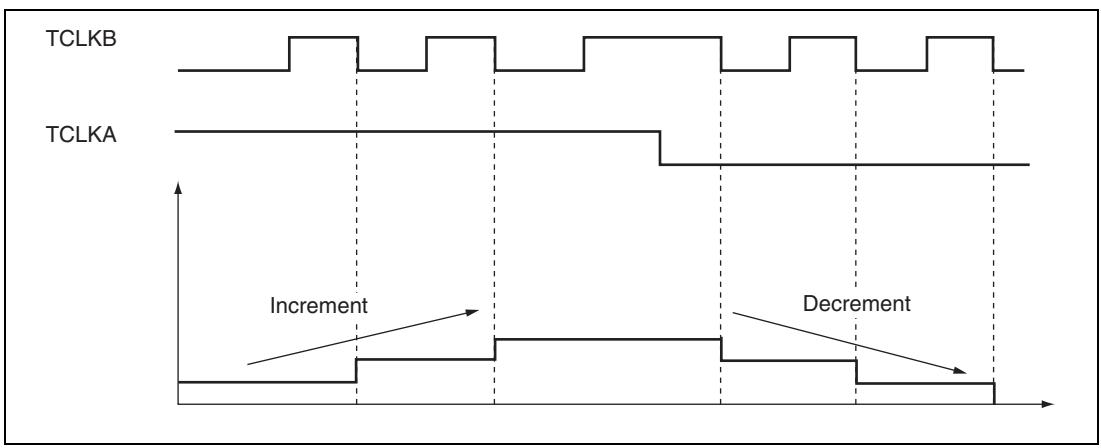


Figure 18.14 Phase Counting Mode Operation Example 2 (TRGCNTCR = H'24)

Table 18.8 Increment/Decrement Conditions in Phase Counting Mode Operation Example 3 (TRGCNTCR = H'28)

TRGCNTCR	Set Value	TCLKA	TCLKB	Operation
CNTEN7	0	Low level	↑	Don't care
CNTEN6	0	↑	High level	
CNTEN5	1	High level	↓	Increment
CNTEN4	0	↓	Low level	Don't care
CNTEN3	1	↓	High level	Decrement
CNTEN2	0	Low level	↓	Don't care
CNTEN1	0	↑	Low level	
CNTEN0	0	High level	↑	

[Legend]
↑ : Rising edge
↓ : Falling edge

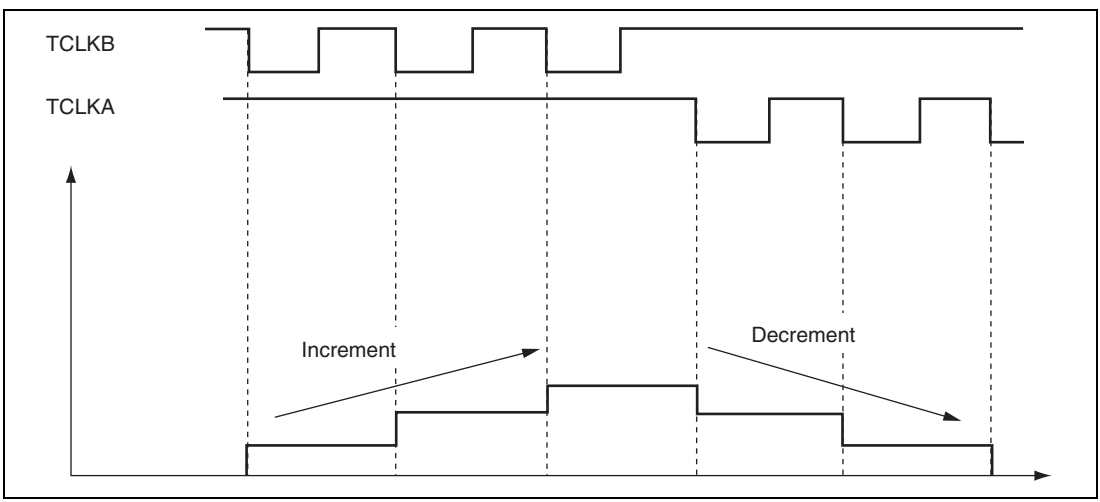


Figure 18.15 Phase Counting Mode Operation Example 3 (TRGCNTCR = H'28)

Table 18.9 Increment/Decrement Conditions in Phase Counting Mode Operation Example 4 (TRGCNTCR = H'5A)

TRGCNTCR	Set Value	TCLKA	TCLKB	Operation
CNTEN7	0	Low level	↑	Don't care
CNTEN6	1	↑	High level	Increment
CNTEN5	0	High level	↓	Don't care
CNTEN4	1	↓	Low level	Increment
CNTEN3	1	↓	High level	Decrement
CNTEN2	0	Low level	↓	Don't care
CNTEN1	1	↑	Low level	Decrement
CNTEN0	0	High level	↑	Don't care

[Legend]
↑ : Rising edge
↓ : Falling edge

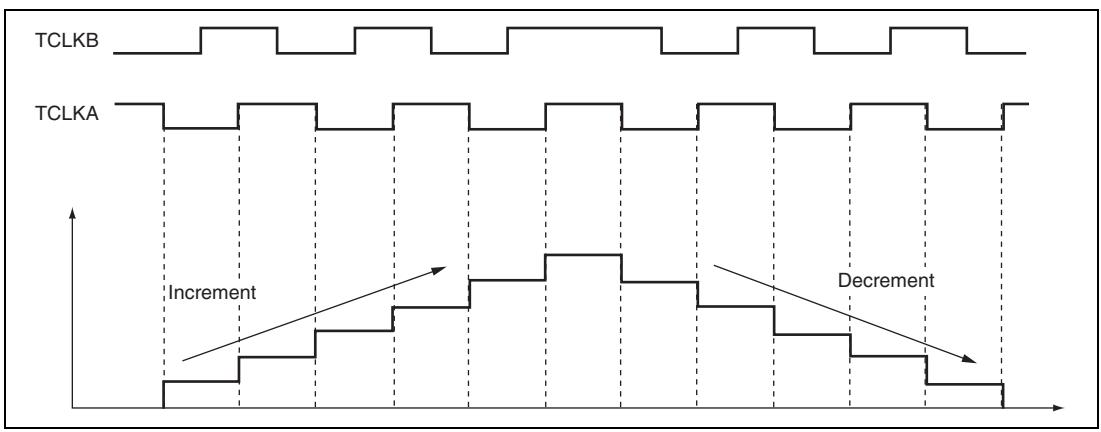


Figure 18.16 Phase Counting Mode Operation Example 4 (TRGCNTCR = H'5A)

(3) Note on Phase Counting Mode

In phase counting mode, the phase difference and overlap between TCLKA and TCLKB must be at least 1.5 × ϕ cycle of the system clock when bits TPSC2 to TPSC0 in TRGCR = B'0XX or B'100, and the pulse width must be at least 3 × ϕ cycle. If B'110 is selected as the value, the phase difference and overlap must be at least 1.5 × ϕ40 cycles and the pulse width at least 3 × ϕ40 cycles. Figure 18.17 shows the input clock conditions in phase counting mode.

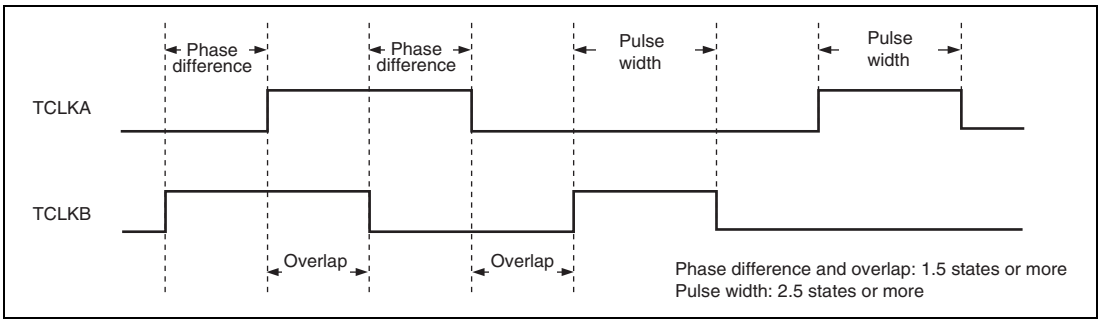


Figure 18.17 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode

Note: When CNTEN7 to CNTEN0 in TRGCNTCR are cleared, the counting is not performed even if an increment/decrement condition matches.

18.3.4 Buffer Operation

Buffer operation differs depending on whether GR has been designated as an input capture register or a compare match register.

Table 18.10 shows the register combinations used in buffer operation.

Table 18.10 Register Combinations in Buffer Operation

General Register	Buffer Register
GRA	BRA
GRB	BRB

(1) When GR is an output compare register

When a compare match occurs, the value in the buffer register for the corresponding channel is transferred to the general register. This operation is illustrated in figure 18.18.

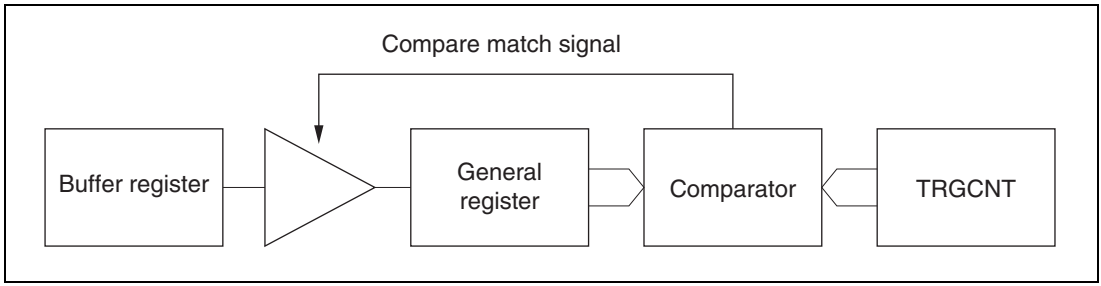


Figure 18.18 Compare Match Buffer Operation

(2) When TGR is an input capture register

When input capture occurs, the value in TRGCNT is transferred to GR and the value previously held in the general register is transferred to the buffer register. This operation is illustrated in figure 18.19.

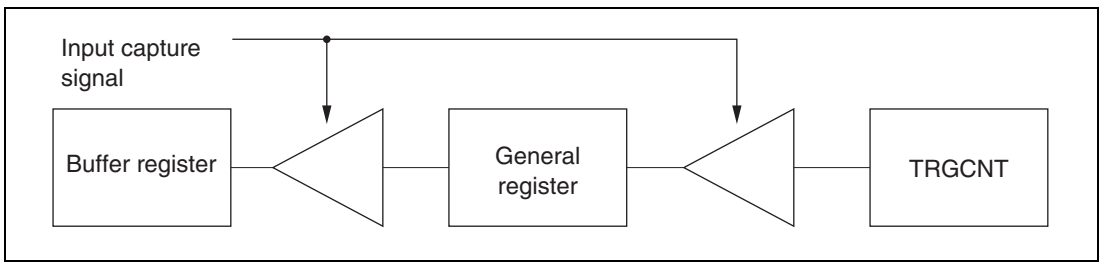


Figure 18.19 Input Capture Buffer Operation

Figures 18.20 and 18.21 show the timings in buffer operation.

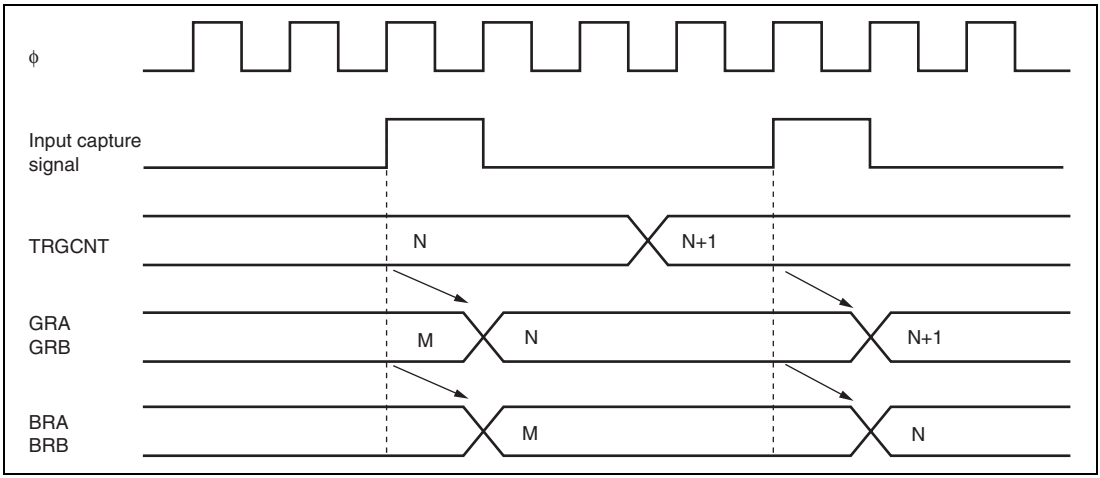


Figure 18.20 Buffer Operation Timing (Compare Match)

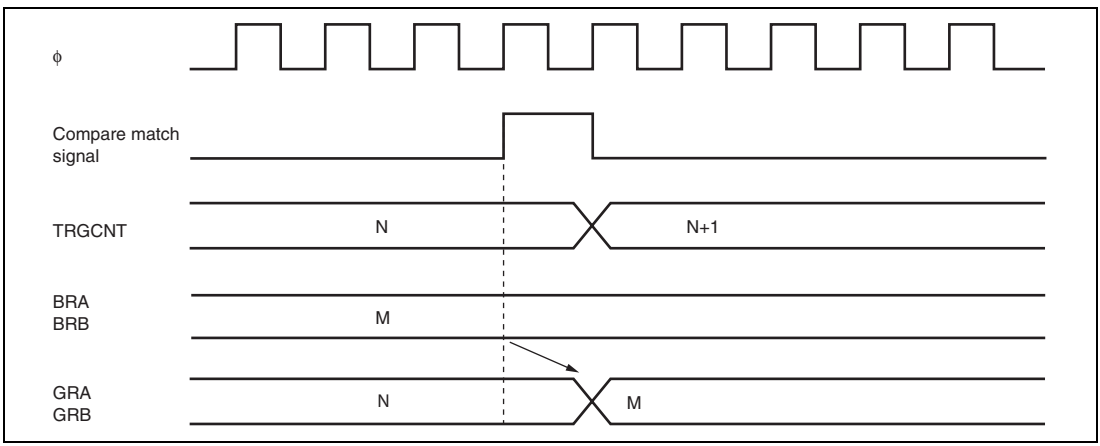


Figure 18.21 Buffer Operation Timing (Input Capture)

18.3.5 Operation through an Event Link

Using the event link controller (ELC), timer RG can be made to operate in the following ways in relation to events occurring in other modules.

(1) Staring Counter Operation

The start of counting operations by timer RG can be selected by ELOPC of the ELC. When the event specified by ELSR8 occur, the STR bit in TRGMDR is set to 1, which starts counting by timer RG. However, if the specified event occurs when the STR bit has already been set to 1, the event is not effective.

(2) Counting Event

The counting of events by timer RG can be selected by ELOPC of the ELC. When the event specified in ELSR8 occurs, event counter operation proceeds with that event as the source to drive counting, regardless of the setting of TPSC[2:0] bits in TRGCR. When the value of the counter is read, the value read out is the actual number of input events.

(3) Input Capture

Input capture operation of timer RG can be selected by ELOPC of the ELC. When the event specified in ELSR8 occurs, GRB captures the value of TRGCNT. When input capture operation initiated by an event link is in use, set IOB[2:0] = b'101 in the TRGIOR register of timer RG, set the STR bit in TRGMDR, and then start the counter. Since input on the TGIOB pin becomes valid at the same time, fix the input to the TGIOB pin or take other measures such as not allocating the TGIOB pin to the port in the PMC, etc.

18.3.6 Digital Filtering Function for Input Capture Inputs

Input signals on the TGIOA and TGIOB pins can be input via the digital filters. The digital filter includes three latches connected in series and a matching detecting circuit. The input signals on the TGIOA and TGIOB pins are operated on the sampling clock specified by the DFCK1 and DFCK0 bits in TRGMDR. When outputs of the three latches match, the matching detecting circuit outputs the signal level of the input. Otherwise, the output remains unchanged. That is, when a pulse width is equal to or greater than three sampling clock cycles, the pulse is input as a signal. When a pulse width is less than three sampling clock cycles, the pulse is considered as a noise to be removed.

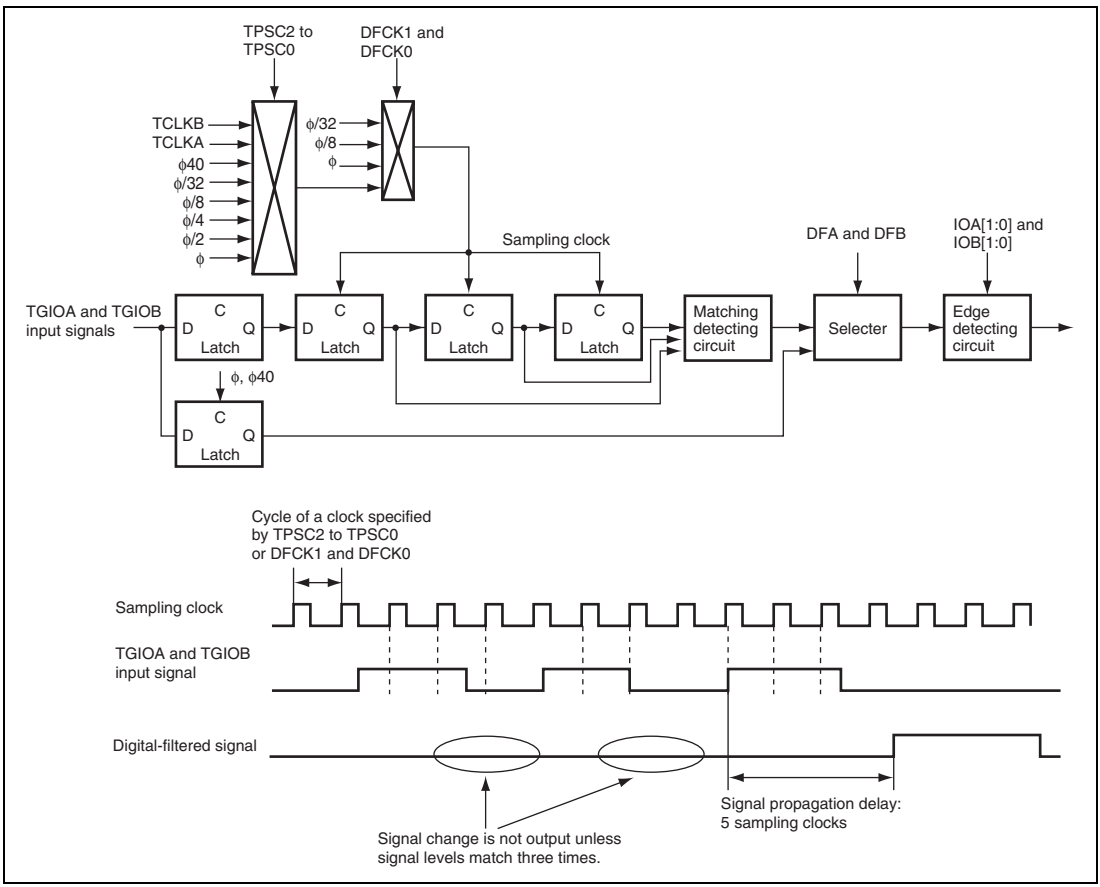


Figure 18.22 Block Diagram of Digital Filter

18.4 Usage Note

18.4.1 Restrictions on Access to Registers when Internal ϕ40 Clock is Selected as Counter Clock

When the internal ϕ40 clock is selected as the counter clock (the TPSC[2:0] bits in TRGCR = 110), if any register of timer RG is to be read immediately after writing to another register in a given module, proceed with reading after having executed one NOP instruction.

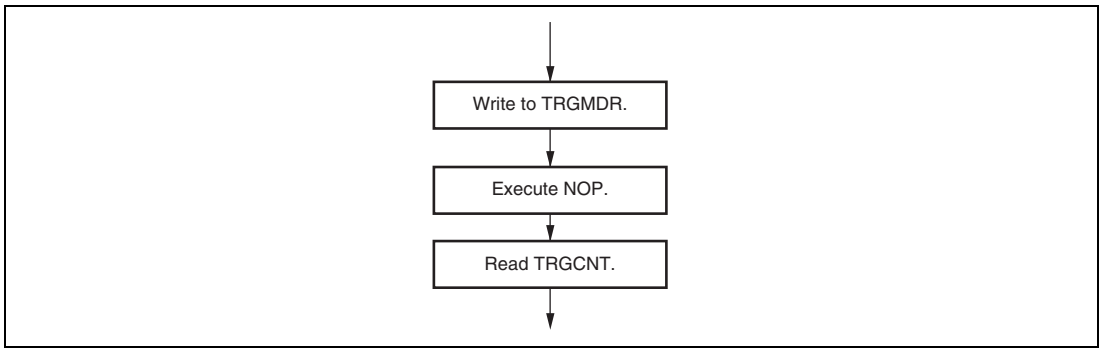


Figure 18.23 Example of Flow for Reading Immediately after Writing to a Register

Section 19 Watchdog Timer (WDT)

The watchdog timer (WDT) is an 8-bit timer that can generate an internal reset signal for this LSI if a system crash prevents the CPU from writing to the timer counter, thus allowing it to overflow.

The block diagram of the watchdog timer is shown in figure 19.1.

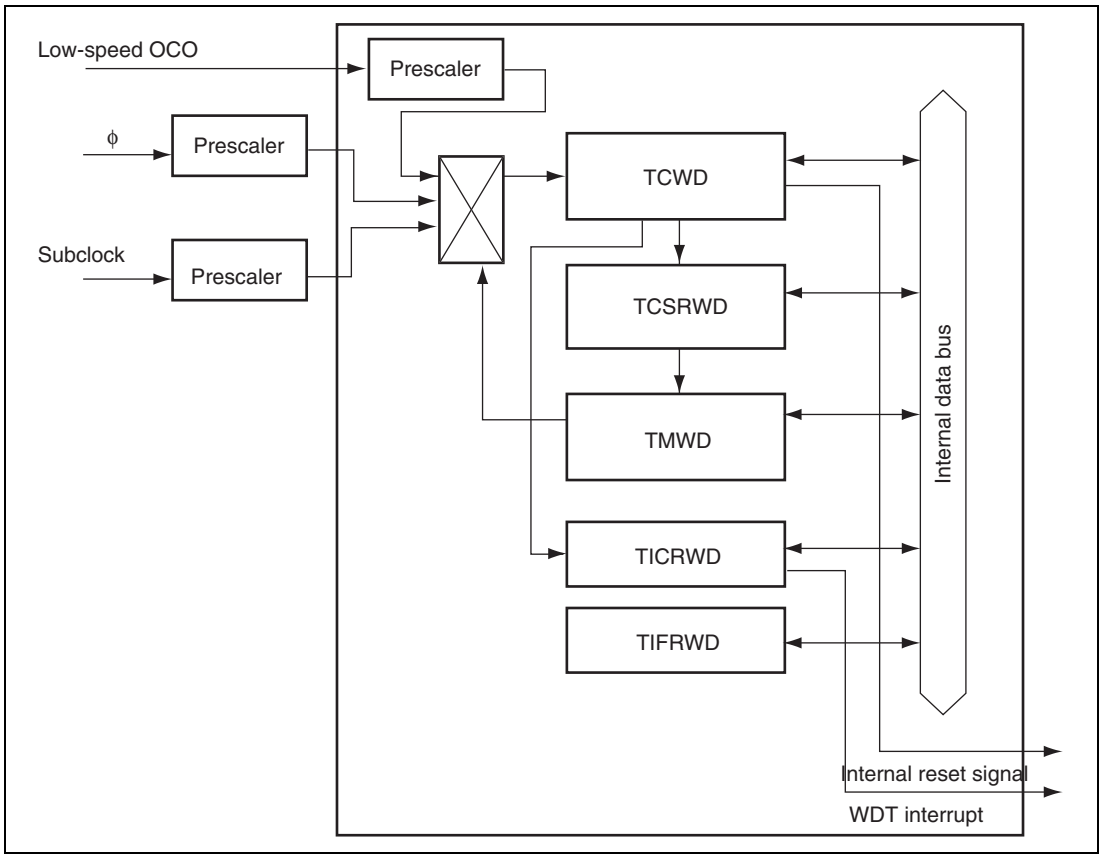


Figure 19.1 Block Diagram of Watchdog Timer

19.1 Features

- Selectable from fifteen clock sources
  - Eight clocks generated by dividing ϕ: ϕ/64, ϕ/128, ϕ/256, ϕ/512, ϕ/1024, ϕ/2048, ϕ/4096, and ϕ/8192
  - Five clocks generated by dividing low-speed OCO clock: ϕloco/8, ϕloco/32, ϕloco/128, ϕloco/512, and ϕloco/1024
  - Two clocks generated by dividing subclock: ϕsub/4 and ϕsub/256

  When the low-speed OCO clock or subclock is selected, the WDT operates as the watchdog timer in any operating mode.
- Reset signal generated on counter overflow

  An overflow period of 1 to 256 times the selected clock can be set.
- The watchdog timer is enabled in the initial state.

  The watchdog timer starts operating after a reset is released.
- Periodic timer function

  The timer counter can also be used as a periodic timer. Interrupts can be generated with a specific count value.

19.2 Register Descriptions

The watchdog timer has the following registers.

- Timer control/status register WD (TCSRWD)
- Timer counter WD (TCWD)
- Timer mode register WD (TMWD)
- Timer interrupt control/status register WD (TICRWD)
- Timer interrupt flag register WD (TIFRWD)

19.2.1 Timer Control/Status Register WD (TCSRWD)

Address: H'FFFF9A

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	B6WI	TCWE	B4WI	TCSRWE	TMWLOCK	TMWI	—	—
Value after reset:	1	0	1	0	0	1	1	1

Bit	Symbol	Bit Name	Description	R/W
7	B6WI	Bit 6 write inhibit	0: Writing to the TCWE bit (bit 6 in this register) is enabled. 1: Writing to the TCWE bit (bit 6 in this register) is disabled. This bit is always read as 1.	R/W
6	TCWE	Timer counter WD write enable	0: Writing to the TCWD register is disabled. 1: Writing to the TCWD register is enabled. Before writing data to this bit, the B6WI bit must be cleared to 0.	R/W
5	B4WI	Bit 4 write inhibit	0: Writing to the TCSRWE bit (bit 4) is enabled. 1: Writing to the TCSRWE bit (bit 4) is disabled. This bit is always read as 1.	R/W
4	TCSRWE	Timer control/status register WD write enable	0: Writing to TMWLOCK and TMWI (bits 3 and 2 in this register) is disabled. 1: 0: Writing to TMWLOCK and TMWI (bits 3 and 2 in this register) is enabled. Before writing data to this bit, the B4WI bit must be cleared to 0.	R/W

Bit	Symbol	Bit Name	Description	R/W
3	TMWLOCK	Timer mode register WD lockdown	This register is write-protected when this bit is 1. Once this bit is set to 1, this bit can be cleared only by a reset. 0: Writing to the TMWD register is enabled. 1: Writing to the TMWD register is disabled. [Setting condition] • When 1 is written to this bit [Clearing condition] • Resetting	R/W
2	TMWI	Timer mode register write inhibit	0: Writing to the TMWD register is enabled. 1: Writing to the TMWD register is disabled. [Setting conditions] • This bit is automatically set to 1 after TMWD is written to. • When 1 is written to this bit. [Clearing condition] • When 0 is written to TMWI while TMWI is 1	R/W
1, 0	—	Reserved	These bits are read as 1. The write value should always be 1.	—

Note: TCSRWD must be rewritten by using the MOV instruction. The bit manipulation instruction cannot be used to change the setting value.

19.2.2 Timer Counter WD (TCWD)

Address: H'FFFF98

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

TCWD is an 8-bit readable/writable up-counter. When TCWD overflows from H'FF to H'00, the internal reset signal is generated. TCWD is initialized to H'00. TCWD can also be used as a periodic timer. It issues an interrupt request to the CPU when the upper two bits in TCWD are B'01, B'10, or B'11 according to the TICRWD setting.

19.2.3 Timer Mode Register WD (TMWD)

Address: H'FFFF99

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	CKS[3:0]			
Value after reset:	1	1	1	1	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 4	—	Reserved	These bits are read as 1. The write value should always be 1.	—
3 to 0	CKS[3:0]	Clock select	0000: Internal clock: counts on φloco/8 (initial value)	R/W
			0001: Internal clock: counts on φloco/32	
			0010: Internal clock: counts on φloco/128	
			0011: Internal clock: counts on φloco/512	
			0100: Internal clock: counts on φloco/1024	
			0101: Internal clock: counts on sub/4	
			0110: Internal clock: counts on φsub/256	
			0111: Clock input prohibited.	
			1000: Internal clock: counts on φ/64	
			1001: Internal clock: counts on φ/128	
			1010: Internal clock: counts on φ/256	
			1011: Internal clock: counts on φ/512	
			1100: Internal clock: counts on φ/1024	
			1101: Internal clock: counts on φ/2048	
			1110: Internal clock: counts on φ/4096	
			1111: Internal clock: counts on φ8192	

- CK3[3:0] bits (clock select)

  The method by which this register is written differs from other registers. The register must be written by using the MOV instruction twice in succession. First, write the data to be loaded to TMWD in a first operation, then write a bit reversal value of the data to be loaded in a second operation. When correct operation is executed, CKS[3:0] bits are rewritten after the second write. If the first data and the second reversal data do not match, all bits are not modified. Set CK3[3:0] bits to B'0111 (clock input prohibited) to stop WDT operation.

19.2.4 Timer Interrupt Control Register WD (TICRWD)

Address: H'FFFF9B

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

Bit	Symbol	Bit Name	Description	R/W
7, 6	INTSEL[1:0]	WDT periodic interrupt condition select	00: Setting prohibited 01: An interrupt is generated when the upper two bits in TCWD is B'01. 10: An interrupt is generated when the upper two bits in TCWD is B'10. 11: An interrupt is generated when the upper two bits in TCWD is B'11. (Initial value)	R/W
5	IWIE	WDT periodic interrupt enable	0: Periodic interrupt request is disabled. 1: Periodic interrupt request is enabled.	R/W
4 to 0	—	Reserved	These bits are read as 1. The write value should always be 1.	—

19.2.5 Timer Interrupt Flag Register WD (TIFRWD)

Address: H'FFFF9C

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

Bit	Symbol	Bit Name	Description	R/W
7	IWF	WDT periodic interrupt request flag	0: No periodic interrupt request 1: Periodic interrupt request is generated. [Setting condition] • When the upper two bits in the timer counter WD agree with the value set by the INTSEL[1:0] bits in TICRWD. [Clearing condition] • When 0 is written to IWF after reading IWF = 1.	R/W
6 to 0	—	Reserved	These bits are read as 1. The write value should always be 1.	—

19.3 Operation

19.3.1 Watchdog Timer Overflow Reset

The watchdog timer is provided with an 8-bit counter. After a reset is released, TCWD starts counting up. When the TCWD count value overflows H'FF, an internal reset signal is generated. Since TCWD is a writable counter, it starts counting from the value set in TCWD. An overflow period in the range of 1 to 256 input clock cycles can therefore be set, according to the TCWD set value.

When the watchdog timer is not used, write 0 simultaneously to TMWLOCK and TMWI in TCSRWD while the TCSRWE bit is 1 and set CKS[3:0] in TMWD to B'0111 (clock input prohibited).

Figure 19.2 shows an example of watchdog timer operation.

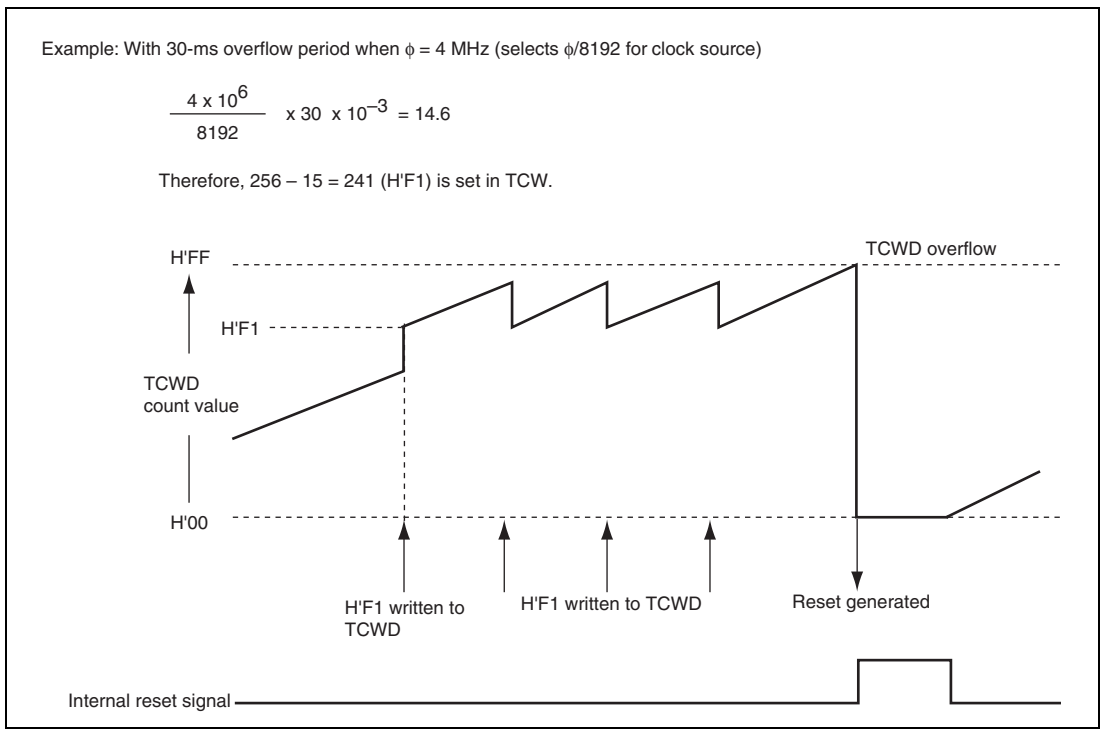


Figure 19.2 Watchdog Timer Operation Example

19.3.2 Watchdog Timer Setting Flow

The watchdog timer should be set using the procedure shown in figure 19.3.

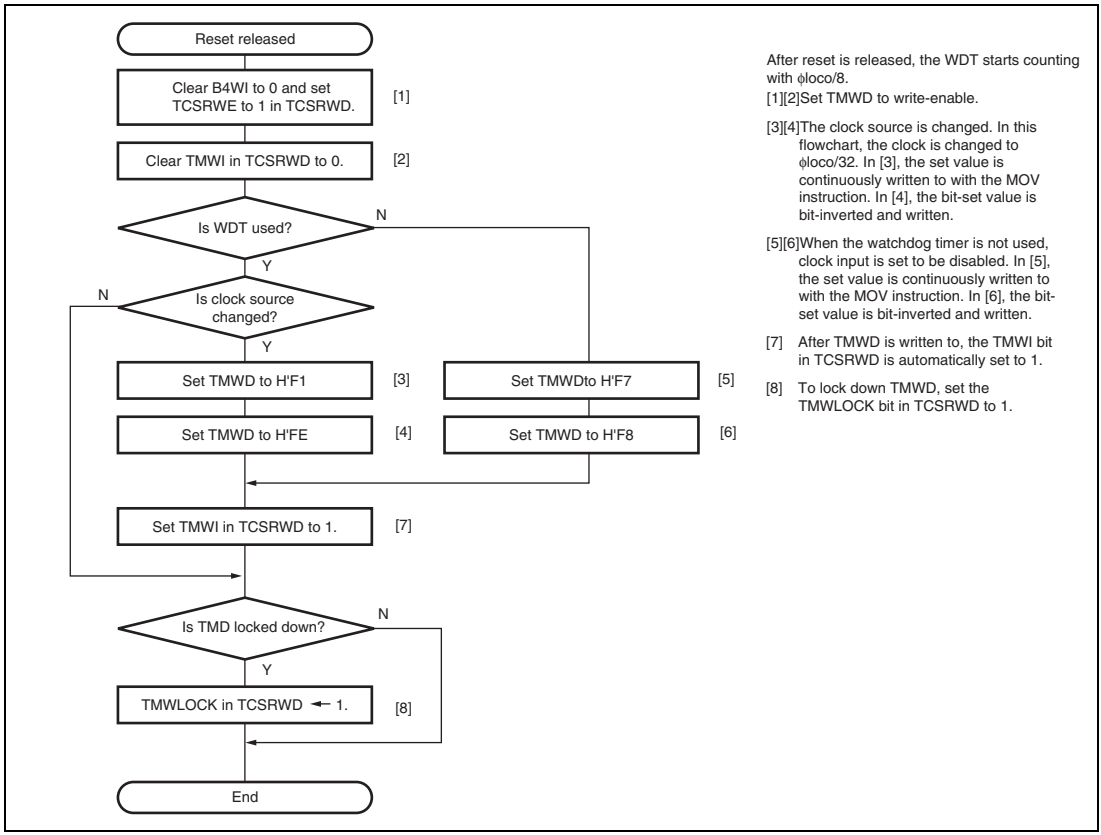


Figure 19.3 Watchdog Timer Setting Flow

19.3.3 Watchdog Timer Periodic Interrupt

When the INTSEL[1:0] bits in TICRWD are set and the timer WD counter reaches the set value, the IWF bit in TIRWD is set to 1. At this time, if the IWIE bit in TICRWD is 1, an interrupt request is generated. Figure 19.4 shows the interrupt generation timing when INTSEL is B'01.

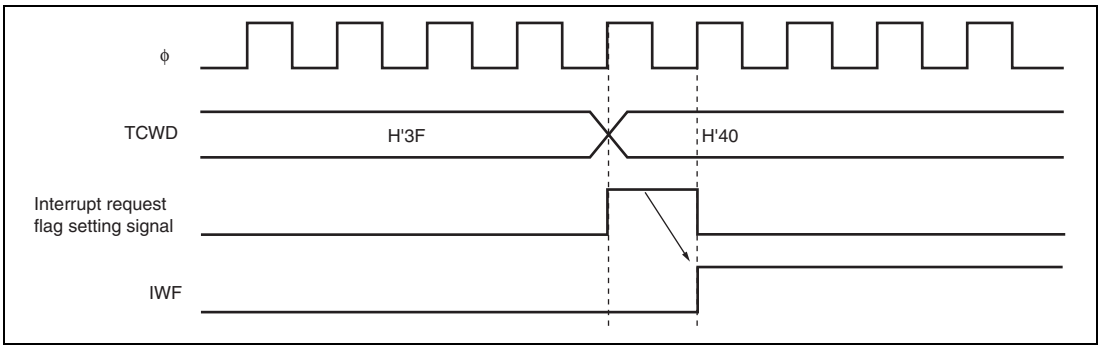


Figure 19.4 Periodic Interrupt Generation Timing (INTSEL = B'01)

19.4 Usage Notes

19.4.1 Notes on System Design

While the watchdog timer is a useful function that restores the LSI to normal condition if the system runs erratically for some reason, the watchdog timer may fail to be reset properly in situations such as the perpetuation of an endless loop in a specific programming routine in which a counter setting operation is executed. Also, there is a possibility of the watchdog timer not being reset properly despite an erratic system condition if an interrupt is enabled and a counter value is set within the interrupt processing.

These notes should be taken into consideration in the system design phases.

19.4.2 Notes on Stopping the Watchdog Timer or Switching the Count Clock

The MSTWDT bit in MSTCR1 is set to 1 after release from a reset, but the watchdog timer will operate since ϕloco/8 is selected as the counter clock. (and, since the WDT is in module standby mode, access to the registers is disabled). To stop the watchdog timer or switch the count clock, proceed after releasing the WDT from module standby by clearing the MSTWDT bit in MSTCR1 to 0.

Section 20 Serial Communication Interface 3 (SCI3, IrDA)

This LSI includes a serial communication interface 3 (SCI3), which has three independent channels. The SCI3 can handle both asynchronous and clocked synchronous serial communication. In asynchronous mode, serial data communication can be carried out using standard asynchronous communication chips such as a Universal Asynchronous Receiver/Transmitter (UART) or an Asynchronous Communication Interface Adapter (ACIA). A function is also provided for serial communication between processors (multiprocessor communication function).

Table 20.1 shows the SCI3 channel configuration and figure 20.1 shows a block diagram of the SCI3. Since pin functions are identical for each of the three channels (SCI3, SCI3_2, and SCI3_3), separate explanations are not given in this section.

20.1 Features

- Choice of asynchronous or clocked synchronous serial communication mode
- Full-duplex communication capability

  The transmitter and receiver are mutually independent, enabling transmission and reception to be executed simultaneously.

  Double-buffering is used in both the transmitter and the receiver, enabling continuous transmission and continuous reception.
- On-chip baud rate generator allows any bit rate to be selected
- External clock or on-chip baud rate generator can be selected as a transfer clock source.
- Six interrupt sources

  Transmit-end, transmit-data-empty, receive-data-full, overrun error, framing error, and parity error. The DTC can be activated by the transmit-data-empty interrupt and receive-data-full interrupt sources.

Asynchronous mode

- Data length: 7 or 8 bits
- Stop bit length: 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 the RXD pin level directly in the case of a framing error

Clocked synchronous mode

- Data length: 8 bits
- Receive error detection: Overrun errors

Table 20.1 Channel Configuration

Channel	Abbreviation	Pin	Register	Register Address	Noise Canceler
Channel 1	SCI3*[1]	SCK3 RXD TXD	SMR	H'FF0550	Available
			BRR	H'FF0551	
			SCR3	H'FF0552	
			TDR	H'FF0553	
			SSR	H'FF0554	
			RDR	H'FF0555	
			RSR	—	
			TSR	—	
			SPMR	H'FF0556	
Channel 2	SCI3_2*[2]	SCK3_2 RXD_2/IrRxD TXD_2/IrTxD	SMR_2	H'FF0558	Available
			BRR_2	H'FF0559	
			SCR3_2	H'FF055A	
			TDR_2	H'FF055B	
			SSR_2	H'FF055C	
			RDR_2	H'FF055D	
			RSR_2	—	
			TSR_2	—	
			SPMR	H'FF055E	
			IrCR	H'FF05DE	
Channel 3	SCI3_3	SCK3_3 RXD_3 TXD_3	SMR_3	H'FF0560	Available
			BRR_3	H'FF0561	
			SCR3_3	H'FF0562	
			TDR_3	H'FF0563	
			SSR_3	H'FF0564	
			RDR_3	H'FF0565	
			RSR_3	—	
			TSR_3	—	
			SPMR_3	H'FF0566	

Notes: 1. Channel 1 of the SCI3 is used in on-board programming mode by boot mode.
2. SCI3_2 provides IrDA (Infrared Data Association) communication waveform transmission/reception according IrDA standard version 1.0.

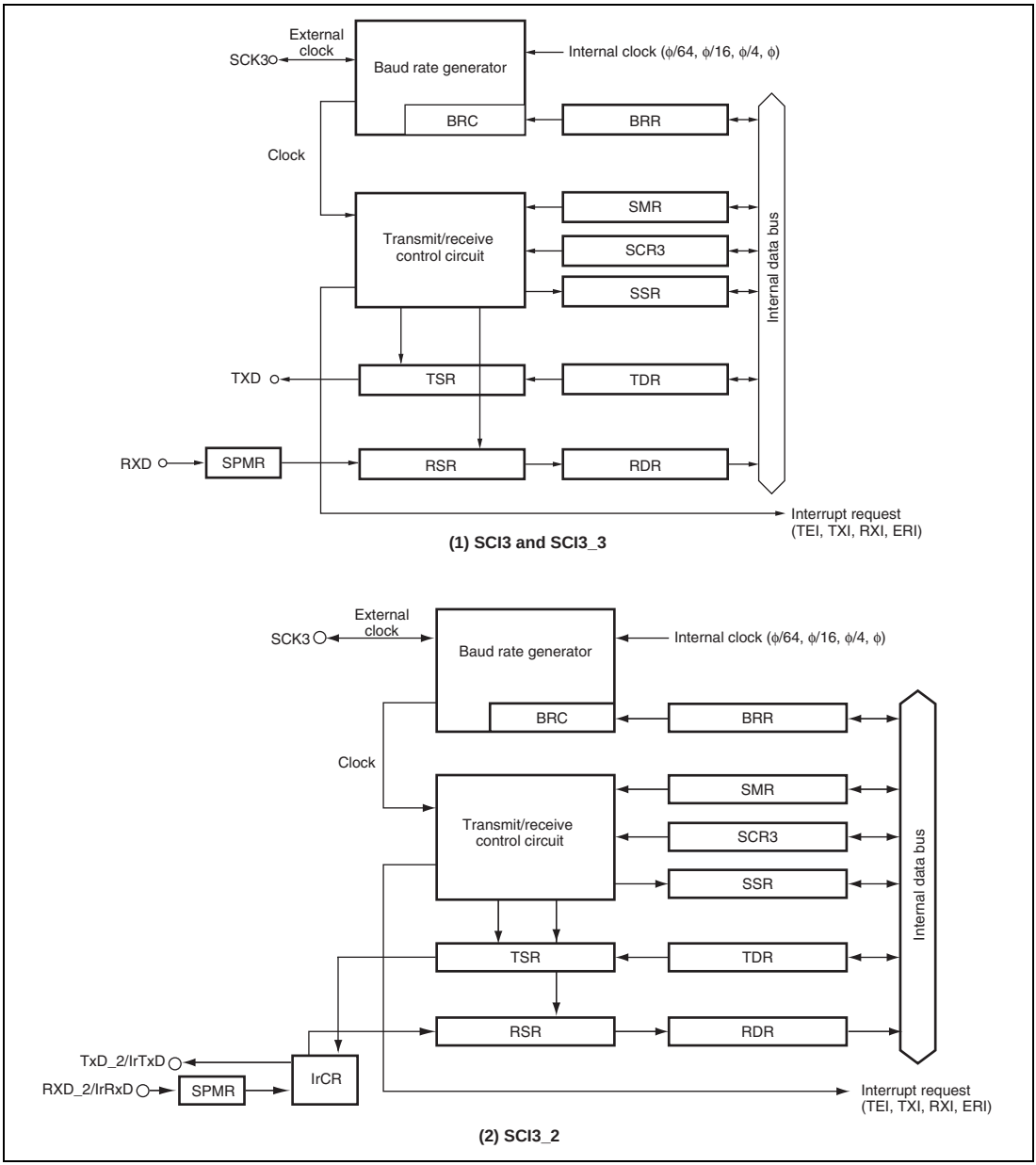


Figure 20.1 Block Diagram of SCI3

Table 20.2 shows the SCI3 pin configuration.

Table 20.2 Pin Configuration

Channel	Pin Name	I/O	Function
1	SCK3	I/O	Clock input/output for channel 1
	RXD	Input	Receive data input for channel 1
	TXD	Output	Transmit data output for channel 1
2	SCK3_2	I/O	Clock input/output for channel 2
	RXD_2/IrRxD	Input	Receive data input for channel 2/IrDA receive data input
	TXD_2/IrTxD	Output	Transmit data output for channel 2/IrDA transmit data output
3	SCK3_3	I/O	Clock input/output for channel 3
	RXD_3	Input	Receive data input for channel 3
	TXD_3	Output	Transmit data output for channel 3

20.2 Register Descriptions

The SCI3 has the following registers.

Channel 1
- Receive shift register (RSR)
- Receive data register (RDR)
- Transmit shift register (TSR)
- Transmit data register (TDR)
- Serial mode register (SMR)
- Serial control register (SCR3)
- Serial status register (SSR)
- Bit rate register (BRR)
- Sampling mode register (SPMR)

Channel 2
- Receive shift register (RSR)
- Receive data register (RDR)
- Transmit shift register (TSR)
- Transmit data register (TDR)
- Serial mode register (SMR)
- Serial control register (SCR3)
- Serial status register (SSR)
- Bit rate register (BRR)
- Sampling mode register (SPMR)
- IrDA control register (IrCR)

Channel 3
- Receive shift register (RSR)
- Receive data register (RDR)
- Transmit shift register (TSR)
- Transmit data register (TDR)
- Serial mode register (SMR)
- Serial control register (SCR3)
- Serial status register (SSR)
- Bit rate register (BRR)
- Sampling mode register (SPMR)

20.2.1 Receive Shift Register (RSR)

Address: —

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

RSR is a shift register that is used to receive serial data input from the RXD pin and convert 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)

Address: H'FF0555, H'FF055D, H'FF0565

Bit:	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 received data. When the SCI3 has received one frame of data, it transfers the received data from RSR to RDR, where it is stored. After this, RSR is receive-enabled. As RSR and RDR function as a double buffer in this way, continuous receive operations are possible. After confirming that the RDRF bit in SSR is set to 1, read RDR only once. RDR cannot be written to by the CPU. RDR is initialized to H'00.

20.2.3 Transmit Shift Register (TSR)

Address: —

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

TSR is a shift register that transmits serial data. To perform serial data transmission, the SCI3 first transfers transmit data from TDR to TSR automatically, then sends the data that starts from the LSB to the TXD pin. TSR cannot be directly accessed by the CPU.

20.2.4 Transmit Data Register (TDR)

Address: H'FF0553, H'FF055B, H'FF0563

Bit:	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 data for transmission. When the SCI3 detects that TSR is empty, it transfers the transmit data written in TDR to TSR and starts transmission. The double-buffered structure of TDR and TSR enables continuous transmission. If the next transmit data has already been written to TDR during transmission of one-frame data, the SCI3 transfers the written data to TSR to continue transmission. To achieve reliable serial transmission, write transmit data to TDR only once after confirming that the TDRE bit in SSR is set to 1. TDR is initialized to H'FF.

20.2.5 Serial Mode Register (SMR)

Address: H'FF0550, H'FF0558, H'FF0560

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	COM	CHR	PE	PM	STOP	MP	CKS[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	COM	Communication mode	0: Asynchronous mode	R/W
			1: Clocked synchronous mode	
6	CHR	Character length	(Enabled only in asynchronous mode)	R/W
			0: Selects 8 bits as the data length.	
			1: Selects 7 bits as the data length.	
5	PE	Parity enable	(Enabled only in asynchronous mode)	R/W
			0: Parity bit addition and parity check are disabled.	
			1: The parity bit is added in transmission and the parity bit is checked in reception.	

Bit	Symbol	Bit Name	Description	R/W
4	PM	Parity mode	(Enabled only when the PE bit is 1 in asynchronous mode) 0: Selects even parity. 1: Selects odd parity.	R/W
3	STOP	Stop bit length	(Enabled only in asynchronous mode) 0: 1 stop bit 1: 2 stop bits	R/W
2	MP	Multiprocessor mode	0: The multiprocessor communication function is disabled. 1: The multiprocessor communication function is enabled*2	R/W
1 0	CKS1 CKS0	Clock select 0 and 1	00: ϕ clock (n = 0) 01: ϕ/4 clock (n = 1) 10: ϕ/14 clock (n = 2) 11: ϕ/64 clock (n = 3)	R/W

Notes: 1. The SMR value is retained when (module) standby mode is entered.
2. In clocked synchronous mode, clear this bit to 0.

- STOP bit (stop bit length)

  Selects the stop bit length in transmission. For reception, only the first stop bit is checked, regardless of the value in the bit. If the second stop bit is 0, it is treated as the start bit of the next transmit character.

- MP bit (multiprocessor mode)

  When this bit is set to 1, the multiprocessor communication function is enabled. The PE bit and PM bit settings are invalid in multiprocessor mode.

- CKS1 bit and CKS0 bit (clock select 1, 0)

  These bits select the clock source for the baud rate generator.

  For the relationship between the bit rate register setting and the baud rate, see section 20.2.8, Bit Rate Register (BRR). n is the decimal representation of the value of n in BRR (see section 20.2.8, Bit Rate Register (BRR)).

20.2.6 Serial Control Register 3 (SCR3)

Address: H'FF0552, H'FF055A, H'FF0562

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	RIE	TE	RE	MPIE	TEIE	CKE[1:0]	
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TIE	Transmit interrupt enable	0: The TXI interrupt request is disabled. 1: The TXI interrupt request is enabled.	R/W
6	RIE	Receive interrupt enable	0: RXI and ERI interrupt requests are disabled. 1: RXI and ERI interrupt requests are enabled.	R/W
5	TE	Transmit enable	0: Transmission is disabled. 1: Transmission is enabled.	R/W
4	RE	Receive enable	0: Reception is disabled. 1: Reception is enabled.	R/W
3	MPIE	Multiprocessor interrupt enable	(Enabled only when the MP bit in SMR is 1 in asynchronous mode) When this bit is set to 1, receive data in which the multiprocessor bit is 0 is skipped, and setting of the RDRF, FER, and OER status flags in SSR is disabled. On receiving data in which the multiprocessor bit is 1, this bit is automatically cleared and normal reception is resumed. For details, see section 20.5, Multiprocessor Communication Function.	R/W
2	TEIE	Transmit end interrupt enable	0: The TEI interrupt request is disabled. 1: The TEI interrupt request is enabled.	R/W

Bit	Symbol	Bit Name	Description	R/W
1, 0	CKE1 CKE0	Clock enable 0 and 1	Selects the clock source. Asynchronous mode: 00: On-chip baud rate generator 01: On-chip baud rate generator Outputs a clock of the same frequency as the bit rate from the SCK3 pin. 10: External clock A clock with a frequency 16 times the bit rate should be input from the SCK3 pin. 11:Reserved Clocked synchronous mode: 00: On-chip clock (The SCK3 pin functions as clock output.) 01: Reserved 10: External clock (The SCK3 pin functions as clock input.) 11: Reserved	R/W

Notes: 1. The TE and RE bits are reset and the other bits are retained when (module) standby mode is entered.
2. For details on interrupt requests, see section 20.8, Interrupt Requests.

20.2.7 Serial Status Register (SSR)

Address: H'FF0554, H'FF055C, H'FF0564

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	RDRF	OER	FER	PER	TEND	MPBR	MPBT
Value after reset:	1	0	0	0	0	1	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TDRE	Transmit data register empty flag	[Setting conditions] • When the TE bit in SCR3 is 0 • When data is transferred from TDR to TSR [Clearing conditions] • When the CPU writes 0 after reading TDRE = 1. • When the CPU writes transmit data to TDR. • When the DTC transfers data to TDR with a TXI interrupt request and the DTC settings satisfy the flag clearing conditions.	R/W
6	RDRF	Receive data register full flag	[Setting condition] • When reception ends normally and receive data is transferred from RSR to RDR [Clearing conditions] • When the CPU writes 0 after reading RDRF = 1. • When the CPU reads data from RDR. • When the DTC transfers data from RDR with an RXI interrupt request and the DTC settings satisfy the flag clearing conditions. *	R/W
5	OER	Overrun error flag	[Setting condition] • When an overrun error occurs in reception [Clearing condition] • When the CPU writes 0 after reading OER = 1.	R/W

Bit	Symbol	Bit Name	Description	R/W
4	FER	Framing error flag	[Setting condition] • When a framing error occurs in reception [Clearing condition] • When the CPU writes 0 after reading FER = 1.	R/W
3	PER	Parity error flag	[Setting condition] • When a parity error is detected during reception [Clearing condition] • When the CPU writes 0 after reading PER = 1.	R/W
2	TEND	Transmit end flag	[Setting conditions] • When the TE bit in SCR3 is 0 • When TDRE = 1 at transmission of the last bit of a transmit character [Clearing conditions] • When 0 is written to TDRE after reading TDRE = 1 • When the transmit data is written to TDR	R/W
1	MPBR	Multiprocessor bit receive	Stores the multiprocessor bit in the receive character data. When the RE bit in SCR3 is cleared to 0, its state is retained.	R/W
0	MPBT	Multiprocessor bit transfer	Specifies the multiprocessor bit value to be added to the transmit character data.	R/W

Note: * The DTC clears the peripheral module flags when all of the following three conditions are satisfied:

1. The DISEL bit is 0.
2. The value in the transfer counter (count register CRA in normal and repeat modes or count register CRB in block mode) is not 0.
3. A chain transfer is not used.

20.2.8 Bit Rate Register (BRR)

Address: H'FF0551, H'FF0559, H'FF0561

Bit:	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. The initial value of BRR is H'FF. Table 20.3 shows the relationship between the N setting in BRR and the n setting in bits CKS1 and CKS0 SMR in asynchronous mode. Table 20.4 shows the maximum bit rate for each frequency in asynchronous mode. The values shown in both tables 20.3 and 20.4 are values in active (high-speed) mode. Table 20.5 shows of the relationship between the N setting in BRR and the n setting in bits CKS1 and CKS0 of SMR in clocked synchronous mode. The values shown in table 20.5 are values in active (high-speed) mode. The N setting in BRR and error for other operating frequencies and bit rates can be obtained by the following formulas:

Note: The BRR value is retained in (module) standby mode.

[Asynchronous Mode]

$$N = \frac{\phi}{64 \times 2^{2n-1} \times B} \times 10^6 - 1$$

$$\text{Error (\%)} = \left\{ \frac{\phi \times 10^6}{(N + 1) \times B \times 64 \times 2^{2n-1}} - 1 \right\} \times 100$$

[Clocked Synchronous Mode]

$$N = \frac{\phi}{8 \times 2^{2n-1} \times B} \times 10^6 - 1$$

[Legend]
B: Bit rate (bit/s)
N: BRR setting for baud rate generator ($0 \leq N \leq 255$)
ϕ: Operating frequency (MHz)
n: CSK1 and CSK0 settings in SMR ($0 \leq n \leq 3$)

Table 20.3 Examples of BRR Settings for Various Bit Rates (Asynchronous Mode)

	Operating Frequency ϕ (MHz)											
	4			4.9152			5			6		
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	70	0.03	2	86	0.31	2	88	–0.25	2	106	–0.44
150	1	207	0.16	1	255	0.00	2	64	0.16	2	77	0.16
300	1	103	0.16	1	127	0.00	1	129	0.16	1	155	0.16
600	0	207	0.16	0	255	0.00	1	64	0.16	1	77	0.16
1200	0	103	0.16	0	127	0.00	0	129	0.16	0	155	0.16
2400	0	51	0.16	0	63	0.00	0	64	0.16	0	77	0.16
4800	0	25	0.16	0	31	0.00	0	32	–1.36	0	38	0.16
9600	0	12	0.16	0	15	0.00	0	15	1.73	0	19	–2.34
19200	0	6	–6.99	0	7	0.00	0	7	1.73	0	9	–2.34
31250	0	3	0.00	0	4	–1.70	0	4	0.00	0	5	0.00
38400	0	2	8.51	0	3	0.00	0	3	1.73	0	4	–2.34

	Operating Frequency ϕ (MHz)											
	6.144			7.3728			8			9.8304		
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	108	0.08	2	130	–0.07	2	141	0.03	2	174	–0.26
150	2	79	0.00	2	95	0.00	2	103	0.16	2	127	0.00
300	1	159	0.00	1	191	0.00	1	207	0.16	1	255	0.00
600	1	79	0.00	1	95	0.00	1	103	0.16	1	127	0.00
1200	0	159	0.00	0	191	0.00	0	207	0.16	0	255	0.00
2400	0	79	0.00	0	95	0.00	0	103	0.16	0	127	0.00
4800	0	39	0.00	0	47	0.00	0	51	0.16	0	63	0.00
9600	0	19	0.00	0	23	0.00	0	25	0.16	0	31	0.00
19200	0	9	0.00	0	11	0.00	0	12	0.16	0	15	0.00
31250	0	5	2.40	0	6	5.33	0	7	0.00	0	9	–1.70
38400	0	4	0.00	0	5	0.00	0	6	-6.99	0	7	0.00

	Operating Frequency ϕ (MHz)											
	10			12			12.888			14		
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	177	–0.25	2	212	0.03	2	217	0.08	2	248	–0.17
150	2	129	0.16	2	155	0.16	2	159	0.00	2	181	0.16
300	2	64	0.16	2	77	0.16	2	79	0.00	2	90	0.16
600	1	129	0.16	1	155	0.16	1	159	0.00	1	181	0.16
1200	1	64	0.16	1	77	0.16	1	79	0.00	1	90	0.16
2400	0	129	0.16	0	155	0.16	0	159	0.00	0	181	0.16
4800	0	64	0.16	0	77	0.16	0	79	0.00	0	90	0.16
9600	0	32	–1.36	0	38	0.16	0	39	0.00	0	45	–0.93
19200	0	15	1.73	0	19	–2.34	0	19	0.00	0	22	–0.93
31250	0	9	0.00	0	11	0.00	0	11	2.40	0	13	0.00
38400	0	7	1.73	0	9	–2.34	0	9	0.00	—	—	—

	Operating Frequency ϕ (MHz)											
	14.7456			16			18			20		
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	64	0.70	3	70	0.03	3	79	–0.12	3	88	–0.25
150	2	191	0.00	2	207	0.16	2	233	0.16	3	64	0.16
300	2	95	0.00	2	103	0.16	2	114	0.16	2	129	0.16
600	1	191	0.00	1	207	0.16	1	233	0.16	2	64	0.16
1200	1	95	0.00	1	103	0.16	1	114	0.16	1	129	0.16
2400	0	191	0.00	0	207	0.16	0	233	0.16	1	64	0.16
4800	0	95	0.00	0	103	0.16	0	114	0.16	0	129	0.16
9600	0	47	0.00	0	51	0.16	0	58	–0.96	0	64	0.16
19200	0	23	0.00	0	25	0.16	0	28	1.02	0	32	–1.36
31250	0	14	–1.70	0	15	0.00	0	17	0.00	0	19	0.00
38400	0	11	0.00	0	12	0.16	0	14	–2.34	0	15	1.73

[Legend]

—: A setting is available but error occurs.

Table 20.4 Maximum Bit Rate for Each Frequency (Asynchronous Mode)

ϕ (MHz)	Maximum Bit Rate (bit/s)	n	N	ϕ (MHz)	Maximum Bit Rate (bit/s)	n	N
4	125000	0	0	12	375000	0	0
4.9152	153600	0	0	12.288	384000	0	0
5	156250	0	0	14	437500	0	0
6	187500	0	0	14.7456	460800	0	0
6.144	192000	0	0	16	500000	0	0
7.3728	230400	0	0	17.2032	537600	0	0
8	250000	0	0	18	562500	0	0
9.8304	307200	0	0	20	625000	0	0
10	312500	0	0				

Table 20.5 Examples of BRR Settings for Various Bit Rates (Clocked Synchronous Mode)

Bit Rate (bit/s)	Operating Frequency ϕ (MHz)											
	4		8		10		16		18		20	
	n	N	n	N	n	N	n	N	n	N	n	N
110												
250	2	249	3	124	—	—	3	249				
500	2	124	2	249	—	—	3	124	—	—	—	—
1k	1	249	2	124	—	—	2	249	—	—	—	—
2.5k	1	99	1	199	1	249	2	99	—	—	2	124
5k	0	199	1	99	1	124	1	199	1	224	1	249
10k	0	99	0	199	0	249	1	99	—	—	1	124
25k	0	39	0	79	0	99	0	159	0	179	0	199
50k	0	19	0	39	0	49	0	79	0	89	0	99
100k	0	9	0	19	0	24	0	39	0	44	0	49
250k	0	3	0	7	0	9	0	15	0	17	0	19
500k	0	1	0	3	0	4	0	7	0	8	0	9
1M	0	0*	0	1	—	—	0	3	0	4	0	4
2M			0	0*	—	—	0	1	—	—	—	—
2.5M					0	0*	—	—	—	—	0	1
5M											0	0*

[Legend]

Blank: No setting is available.

—: A setting is available but error occurs.

*: Continuous transfer is not possible.

20.2.9 Sampling Mode Register (SPMR)

Address: H'FF0556, H'FF055E, H'FF0566

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

Bit	Symbol	Bit Name	Description	R/W
7 to 3	—	Reserved	These bits are read as 1. The write value should be 1.	—
2	NFEN	Noise cancellation function select	0: The noise cancellation function is invalid for the RXD pin input. 1: The noise cancellation function is valid for the RXD pin input (when the COM bit in SMR is 0).	R/W
1, 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

Note: The SPMR value is retained in (module) standby mode.

- NFEN bit (noise cancellation function select)

  Performs noise cancellation for the RXD pin input when the COM bit in SMR is 0 and NFEN bit is 1.

20.2.10 IrDA Control Register (IrCR)

Address: H'FF05DE

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	IrE	IrCK[2:0]			IrTXINV	IrRXINV	—	—
Value after reset:	0	0	0	0	0	0	1	1

Bit	Symbol	Bit Name	Description	R/W
7	IrE	IrDA enable	0: The TXD_2/IrTXD and RXD_2/IrRXD pins function as the TXD_2 and RXD_2 pins. 1: The TXD_2/IrTXD and RXD_2/IrRXD pins function as the IrTXD and IrRXD pins.	R/W
6 to 4	IrCK[2:0]	IrDA clock select 2 to 0	000: Bit rate × 3/16 001: ϕ/2 010: ϕ/4 011: ϕ/8 100: ϕ/16 101: ϕ/32 110: ϕ/64 111: ϕ/128	R/W
3	IrTXINV	IrTX data polarity inversion	0: Transmit data is output from IrTXD as is. 1: Transmit data is inverted to be output from IrTXD.	R/W
2	IrRXINV	IrRX data polarity inversion	0: IrRXD input is used for receive data as is. 1: IrRXD input is inverted to be used for receive data.	R/W
1, 0	—	Reserved	These bits are read as 1. The write value should be 1.	—

Note: The IrCR value is retained in (module) standby mode.

- IrE bit (IrDA enable)

  Selects the SCI3_2 I/O pin function between the usual serial function and IrDA function.

- IrCK[2:0] bit (IrDA clock select 2 to 0)

  Sets the high pulse width for IrTXD output pulse encoding when the IrDA function is

- IrTXINV bit (IrTX data polarity inversion)

  Sets to invert the logic level of the IrTXD output. When inversion is specified, the high pulse width set with IrCR[2:0] is handled as low pulse width.

- IrRXINV bit (IrRX data polarity inversion)

  Sets to invert the logic level of the IrRXD input. When inversion is specified, the high pulse width set with IrCR[2:0] is handled as low pulse width.

20.3 Operation in Asynchronous Mode

Figure 20.2 shows the general format for asynchronous communication. One character (or frame) consists of a start bit (low level), followed by data (in LSB-first order), a parity bit (high or low level), and finally stop bits (high level). Inside the SCI3, the transmitter and receiver are independent units, enabling full-duplex. Both the transmitter and the receiver also have a double-buffered structure, so data can be read or written during transmission or reception, enabling continuous data transfer.

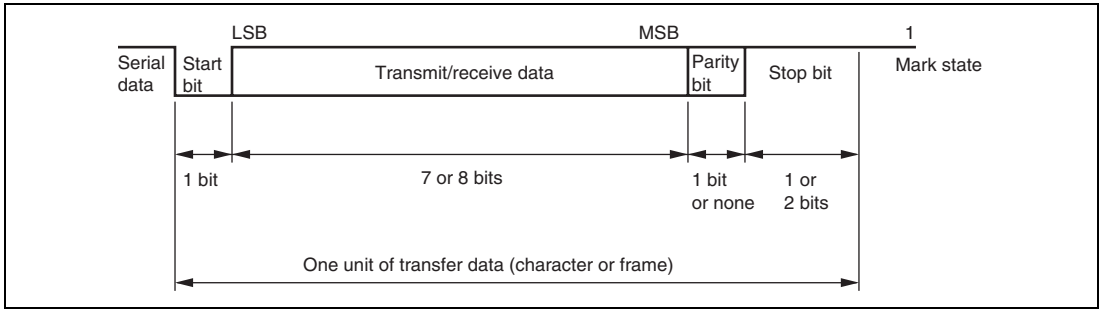


Figure 20.2 Data Format in Asynchronous Communication

20.3.1 Clock

Either an internal clock generated by the on-chip baud rate generator or an external clock input at the SCK3 pin can be selected as the SCI3's transfer clock, according to the setting of the COM bit in SMR and the CKE0 and CKE1 bits in SCR3. When an external clock is input at the SCK3 pin, the clock frequency should be 16 times the bit rate used.

When the SCI3 is operated on an internal clock, the clock can be output from the SCK3 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 20.3.

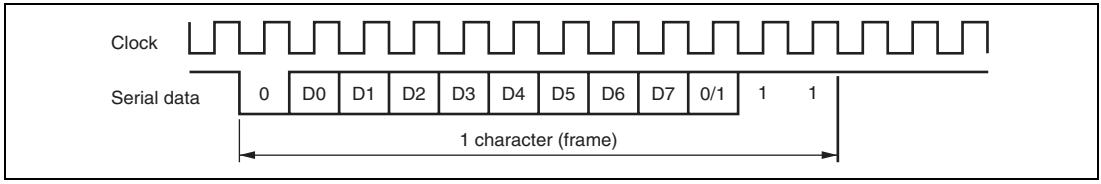
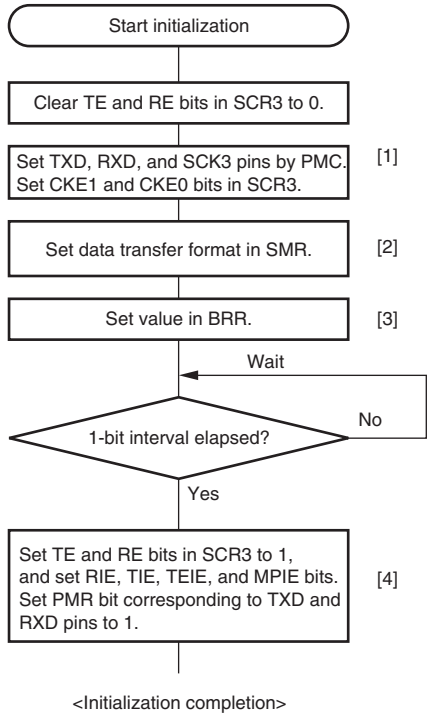


Figure 20.3 Relationship between Output Clock and Transfer Data Phase (Asynchronous Mode) (Example with 8-Bit Data, Parity, Two Stop Bits)

20.3.2 SCI3 Initialization

Figure 20.4 shows a sample flowchart to initialize the SCI3. When the TE bit is cleared to 0, the TDRE flag is set to 1. Note that clearing the RE bit to 0 does not initialize the contents of the RDRF, PER, FER, and OER flags, or the contents of RDR. When the external clock is used in asynchronous mode, the clock must be supplied even during initialization.



[1] With the PMC, select which of the TXD, RXD, and SCK3 pins are to be used. Set the clock selection in SCR3. Be sure to clear the other bits in SCR3 to 0. When clock output is selected in asynchronous mode, after the CKE1 and CKE0 settings have been made, output of the clock signal begins immediately upon setting of the PMR bits that correspond to pins selected by SCK3. When clock output is selected with reception in clock-synchronous mode, and CKE1, CKE0, and RE are set to 1, output of the clock signal begins immediately upon setting of the PMR bits that correspond to pins selected by SCK3.

[2] Set the data transfer format in SMR.

[3] Write the value corresponding to the bit rate to BRR. Not necessary if an external clock is used.

[4] Wait at least one bit interval, then set the TE bit or RE bit in SCR3 to 1. For transmission, enable use of the TXD output pin by setting the PMR bit for the pin selected as TXD by the PMC to 1. For reception, enable use of the RXD input pin by setting the PMR bit for the pin selected as RXD by the PMC to 1.

Also set the RIE, TIE, TEIE, and MPIE bits, according to the required interrupts. In asynchronous mode, SCI3 is in the mark state (active) for transmission and in the space state (idle) while waiting for the start bit during reception. After the TE bit has been set to 1 in the case of transmission, transmission is enabled after the output of a frame with all bits 1.

Figure 20.4 Sample Flowchart for Initializing SCI3

20.3.3 Data Transmission

Figure 20.5 shows an example of operation for transmission in asynchronous mode. In transmission, the SCI3 operates as described below.

1. The SCI3 monitors the TDRE flag in SSR. If the flag is cleared to 0, the SCI3 recognizes that data has been written to TDR, and transfers the data from TDR to TSR.
2. The SCI3 sets the TDRE flag to 1 and starts transmission. If the TIE bit is set to 1 at this time, a TXI interrupt request is generated. Continuous transmission is possible because the TXI interrupt routine writes next transmit data to TDR before transmission of the current transmit data has been completed.
3. The SCI3 checks the TDRE flag at the timing for sending the stop bit.
4. If the TDRE flag is 0, the data is transferred from TDR to TSR, the stop bit is sent, and then transmission of the next frame is started.
5. If the TDRE flag is 1, the TEND flag in SSR is set to 1, the stop bit is sent, and then the "mark state" is entered, in which 1 is output. If the TEIE bit in SCR3 is set to 1 at this time, a TEI interrupt request is generated.
6. Figure 20.6 shows a sample flowchart for transmission in asynchronous mode.

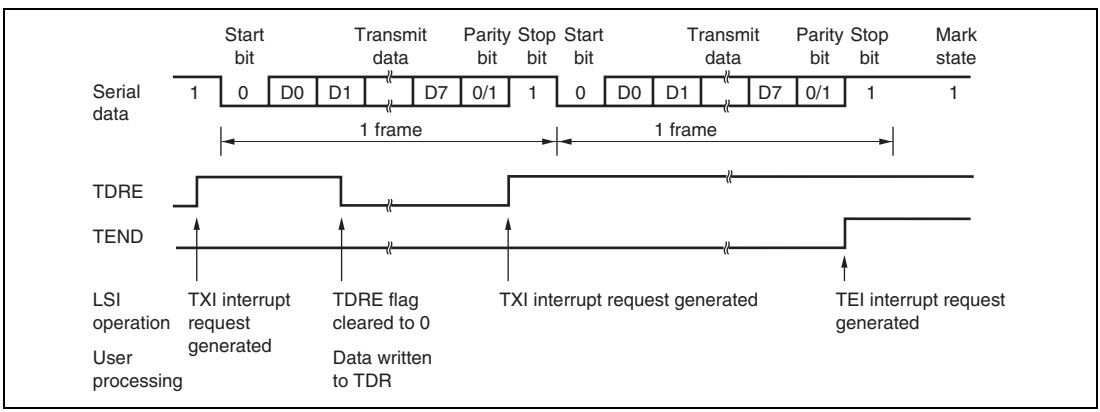
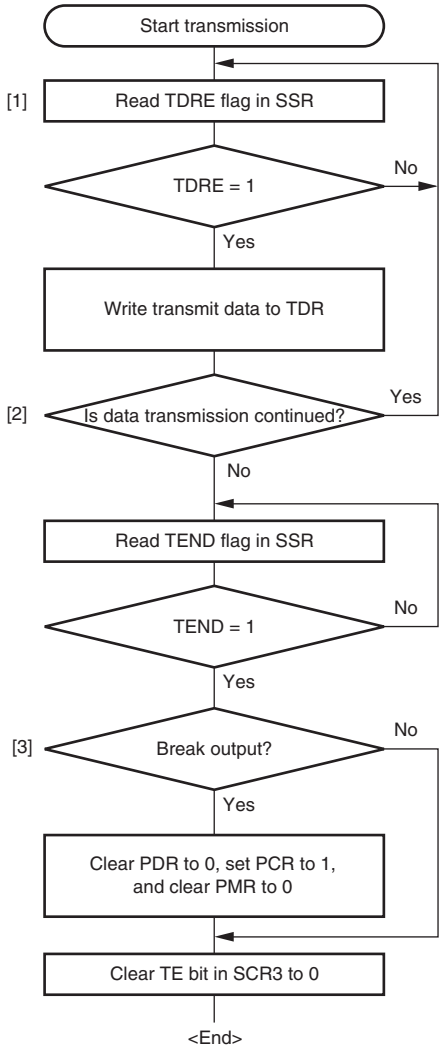


Figure 20.5 Example of Transmission in Asynchronous Mode (8-Bit Data, Parity, One Stop Bit)



[1] Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR. When data is written to TDR, the TDRE flag is automaticaly cleared to 0.

[2] To continue data transmission, read 1 from the TDRE flag to confirm that writing is possible, then write data to TDR. When data is written to TDR, the TDRE flag is automaticaly cleared to 0.
If data is transferred to TDR by the DTC with a transmit data empty interrupt (TXI) request, the TDRE flag is automatically checked and cleared.

[3] To output a break at the end of data transmission, clear PMR corresponding to TxD to 0, after setting PCR to 1 and PDR to 0, then clear the TE bit in SCR3 to 0.

Figure 20.6 Sample Flowchart for Transmitting Data (Asynchronous Mode)

20.3.4 Data Reception

Figure 20.7 shows an example of operation for reception in asynchronous mode. In reception, the SCI3 operates as described below.

1. The SCI3 monitors the communication line. If a start bit is detected, the SCI3 performs internal synchronization, receives receive data in RSR, and checks the parity bit and stop bit.
2. If an overrun error occurs (when reception of the next data is completed while the RDRF flag is still set to 1), the OER bit in SSR is set to 1. If the RIE bit in SCR3 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 SCR3 is set to 1 at this time, an ERI interrupt request is generated.
4. If a framing error is detected (when the stop bit is 0), the FER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR3 is set to 1 at this time, an ERI interrupt request is generated.
5. If reception is completed successfully, the RDRF bit in SSR is set to 1, and receive data is transferred to RDR. If the RIE bit in SCR3 is set to 1 at this time, an RXI interrupt request is generated. Continuous reception is possible because the RXI interrupt routine reads the receive data transferred to RDR before reception of the next receive data has been completed.

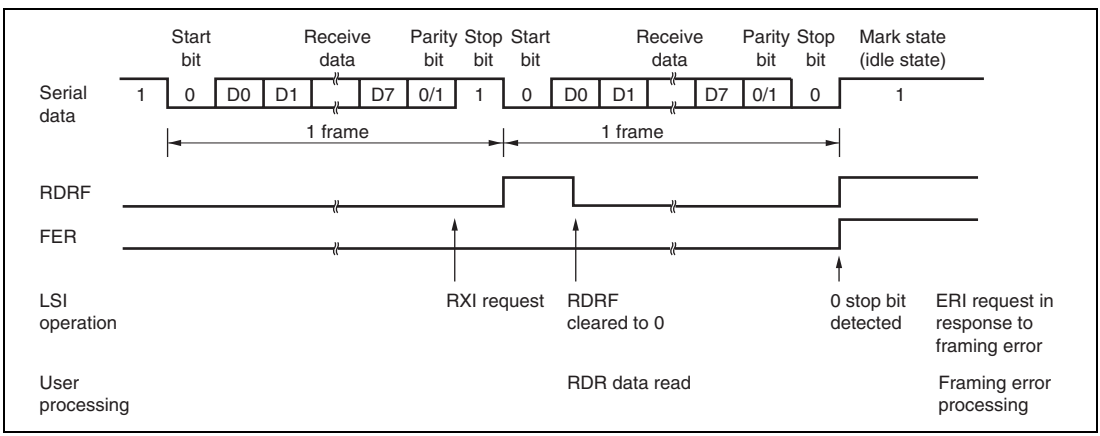


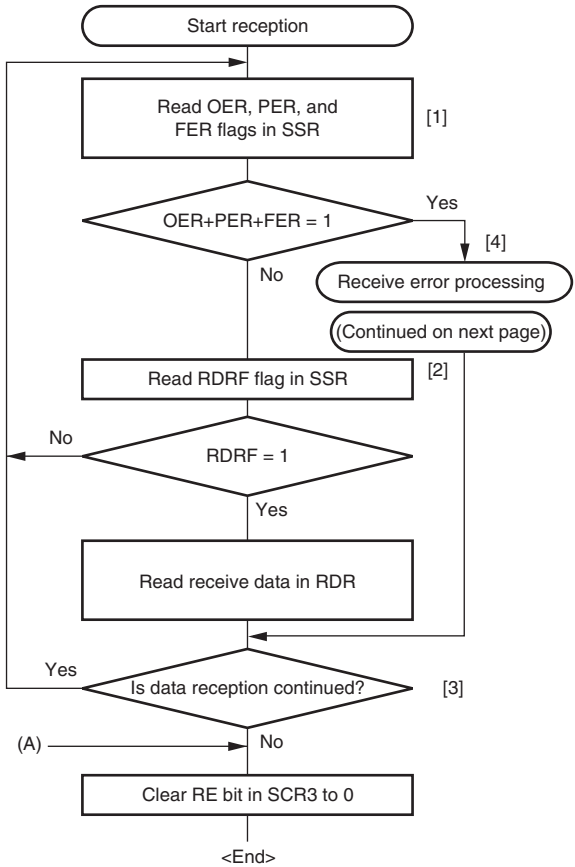
Figure 20.7 Example of Reception in Asynchronous Mode (8-Bit Data, Parity, One Stop Bit)

Table 20.6 shows the states of the SSR status flags and receive data handling when a receive error is detected. If a receive error is detected, the RDRF flag retains its state before receiving data. Reception cannot be resumed while a receive error flag is set to 1. Accordingly, clear the OER, FER, PER, and RDRF bits to 0 before resuming reception. Figure 20.8 shows a sample flowchart for data reception.

Table 20.6 SSR Status Flags and Receive Data Handling

SSR Status Flag					
RDRF*	**OER**	**FER**	**PER**	**Receive Data**	**Receive Error Type**
1	1	0	0	Lost	Overrun error
0	0	1	0	Transferred to RDR	Framing error
0	0	0	1	Transferred to RDR	Parity error
1	1	1	0	Lost	Overrun error + framing error
1	1	0	1	Lost	Overrun error + parity error
0	0	1	1	Transferred to RDR	Framing error + parity error
1	1	1	1	Lost	Overrun error + framing error + parity error

Note: * The RDRF flag retains the state it had before data reception.



[1] Read the OER, PER, and FER flags in SSR to identify the error. If a receive error occurs, performs the appropriate error processing.

[2] Read SSR and check that RDRF = 1, then read the receive data in RDR. The RDRF flag is cleared automatically.

[3] To continue data reception, before the stop bit for the current frame is received, read the RDRF flag and read RDR. The RDRF flag is cleared automatically by te RDR read.
If RDR data is transferred by the DTC which was activated by an RXI interrupt, the RDRF flag is cleared automatically.

[4] If a receive error occurs, read the OER, PER, and FER flags in SSR to identify the error. After performing the appropriate error processing, ensure that the OER, PER, and FER flags are all cleared to 0. Reception cannot be resumed if any of these flags are set to 1. In the case of a framing error, a break can be detected by reading the value of the RxD pin.

Figure 20.8 Sample Flowchart for Data Reception (Asynchronous Mode) (1)

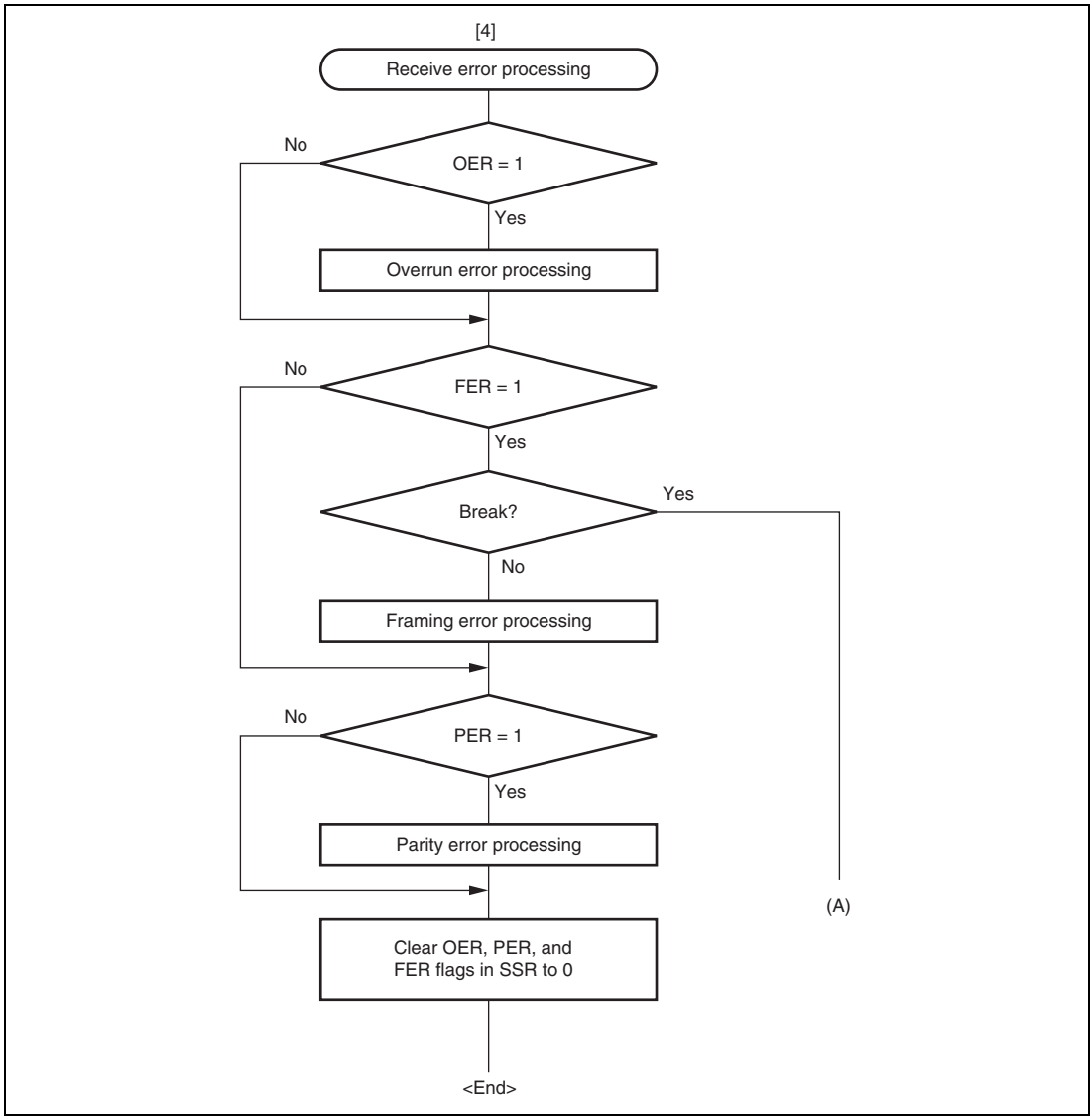


Figure 20.8 Sample Flowchart for Data Reception (Asynchronous Mode) (2)

20.4 Operation in Clocked Synchronous Mode

Figure 20.9 shows the format for clocked synchronous communication. In clocked synchronous mode, data is transmitted or received synchronous with clock pulses. A single character in the transmit data consists of the 8-bit data starting from the LSB. In transmission, data is output from one falling edge of the synchronization clock to the next. In reception, data is received in synchronization with the rising edge of the synchronization clock. After 8-bit data is output, the transmission line holds the MSB state. In clocked synchronous mode, no parity or multiprocessor bit is added. Inside the SCI3, the transmitter and receiver are independent units, enabling full-duplex communication through the use of a common clock. Both the transmitter and the receiver also have a double-buffered structure, so data can be read or written during transmission or reception, enabling continuous data transfer.

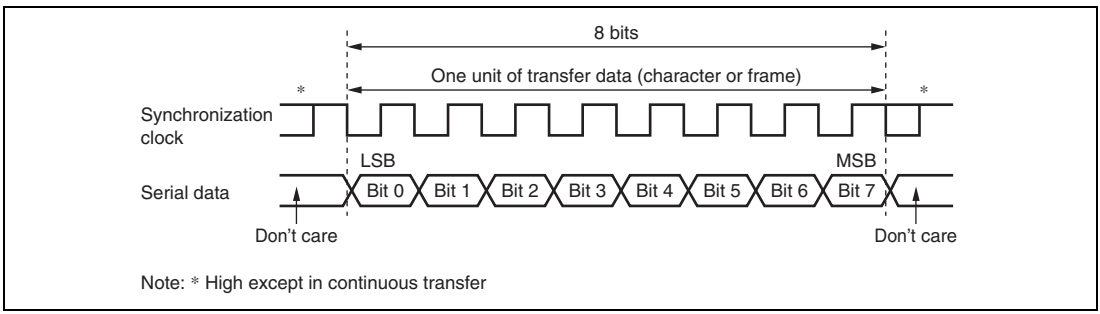


Figure 20.9 Data Format in Clocked Synchronous Communication

20.4.1 Clock

Either an internal clock generated by the on-chip baud rate generator or an external synchronization clock input at the SCK3 pin can be selected, according to the setting of the COM bit in SMR and CKE0 and CKE1 bits in SCR3. When the SCI3 is operated on an internal clock, the synchronization clock is output from the SCK3 pin. Eight synchronization clock pulses are output in the transfer of one character, and when no transfer is performed the clock is fixed high.

20.4.2 SCI3 Initialization

Before transmitting and receiving data, the SCI3 should be initialized as described in a sample flowchart in figure 20.4.

20.4.3 Data Transmission

Figure 20.10 shows an example of SCI3 operation for transmission in clocked synchronous mode. In transmission, the SCI3 operates as described below.

1. The SCI3 monitors the TDRE flag in SSR, and if the flag is 0, the SCI3 recognizes that data has been written to TDR, and transfers the data from TDR to TSR.
2. The SCI3 sets the TDRE flag to 1 and starts transmission. If the TIE bit in SCR3 is set to 1 at this time, a transmit data empty interrupt (TXI) is generated.
3. The SCI3 outputs eight synchronization clock pulses when clock output mode has been specified. Data is output in synchronization with the input clock when use of an external clock has been specified. Serial data is transmitted sequentially from the LSB (bit 0), from the TXD pin.
4. The SCI3 checks the TDRE flag at the timing for sending the MSB (bit 7).
5. If the TDRE flag is cleared to 0, data is transferred from TDR to TSR, and transmission of the next frame is started.
6. If the TDRE flag is set to 1, the TEND flag in SSR is set to 1, and the TDRE flag maintains the output state of the MSB. If the TEIE bit in SCR3 is set to 1 at this time, a TEI interrupt request is generated.
7. The SCK3 pin is fixed high at the end of transmission.

Figure 20.11 shows a sample flowchart for data transmission. Transmission will not start while a receive error flag (OER, FER, or PER) is set to 1. Make sure that the receive error flags are cleared to 0 before starting transmission.

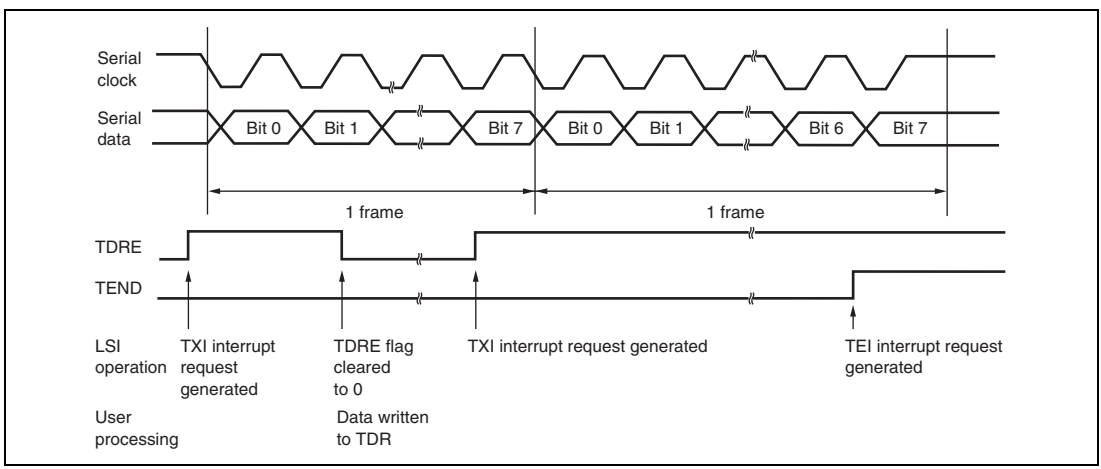
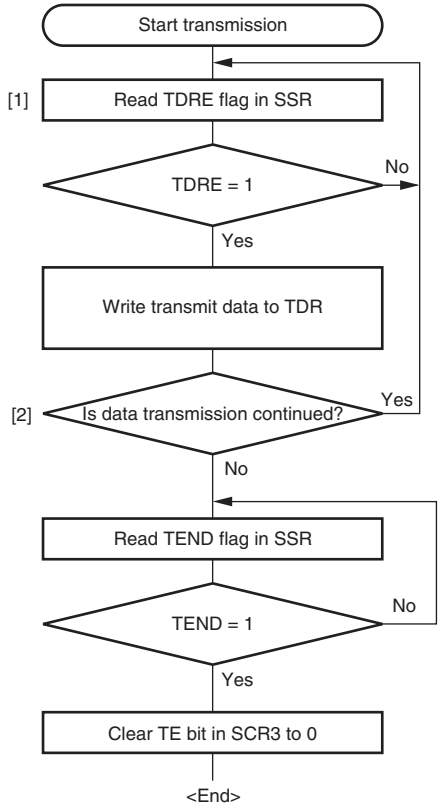


Figure 20.10 Example of Transmission in Clocked Synchronous Mode



[1] Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR. When data is written to TDR, the TDRE flag is automatically cleared to 0 and clocks are output to start the data transmission.
If data is transferred to TDR by the DTC with a transmit data empty interrupt (TXI) request, the TDRE flag is automatically checked and cleared.

[2] To continue data transmission, be sure to read 1 from the TDRE flag to confirm that writing is possible, then write data to TDR. When data is written to TDR, the TDRE flag is automatically cleared to 0.

Figure 20.11 Sample Flowchart for Data Transmission (Clocked Synchronous Mode)

20.4.4 Data Reception (Clocked Synchronous Mode)

Figure 20.12 shows an example of SCI3 operation for reception in clocked synchronous mode. In reception, the SCI3 operates as described below.

1. The SCI3 performs internal initialization synchronous with a synchronization clock input or output and starts receiving data.
2. The SCI3 stores the receive data in RSR.
3. If an overrun error occurs (when reception of the next data is completed while the RDRF flag in SSR is still set to 1), the OER bit in SSR is set to 1. If the RIE bit in SCR3 is set to 1 at this time, an ERI interrupt request is generated, receive data is not transferred to RDR, and the RDRF flag remains to be set to 1.
4. If reception is completed successfully, the RDRF bit in SSR is set to 1, and receive data is transferred to RDR. If the RIE bit in SCR3 is set to 1 at this time, an RXI interrupt request is generated.

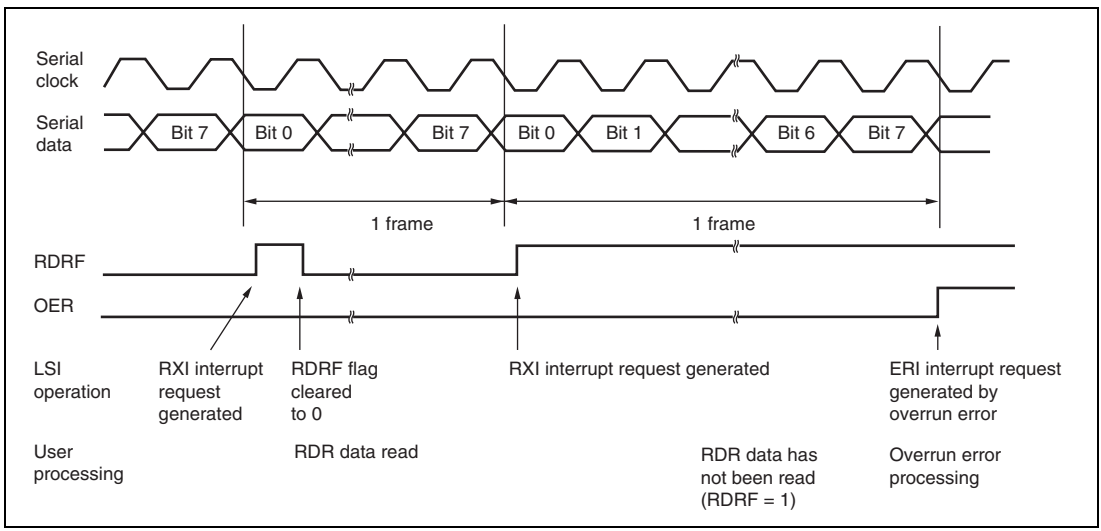
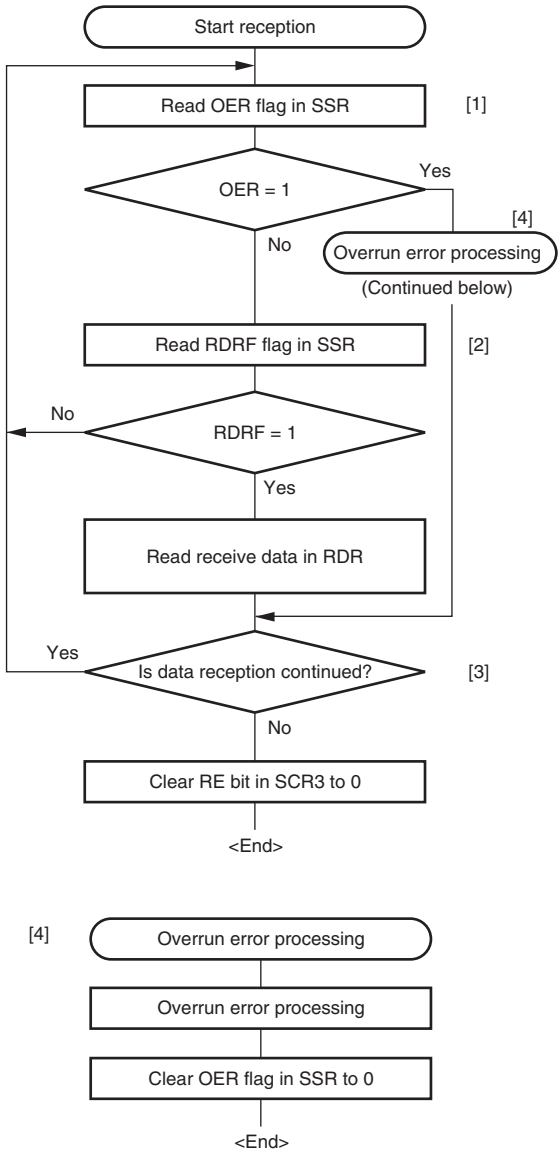


Figure 20.12 Example of Reception in Clocked Synchronous Mode

Reception cannot be resumed while a receive error flag is set to 1. Accordingly, clear the OER, FER, PER, and RDRF bits to 0 before resuming reception. Figure 20.13 shows a sample flowchart for data reception.



[1] Read the OER flag in SSR to determine if there is an error. If an overrun error has occurred, execute overrun error processing.

[2] Read SSR and check that the RDRF flag is set to 1, then read the receive data in RDR. When data is read from RDR, the RDRF flag is automatically cleared to 0.
If RDR data is transferred by the DTC with a receive data full interrupt (RXI) request, the RDRF flag is cleared automatically.

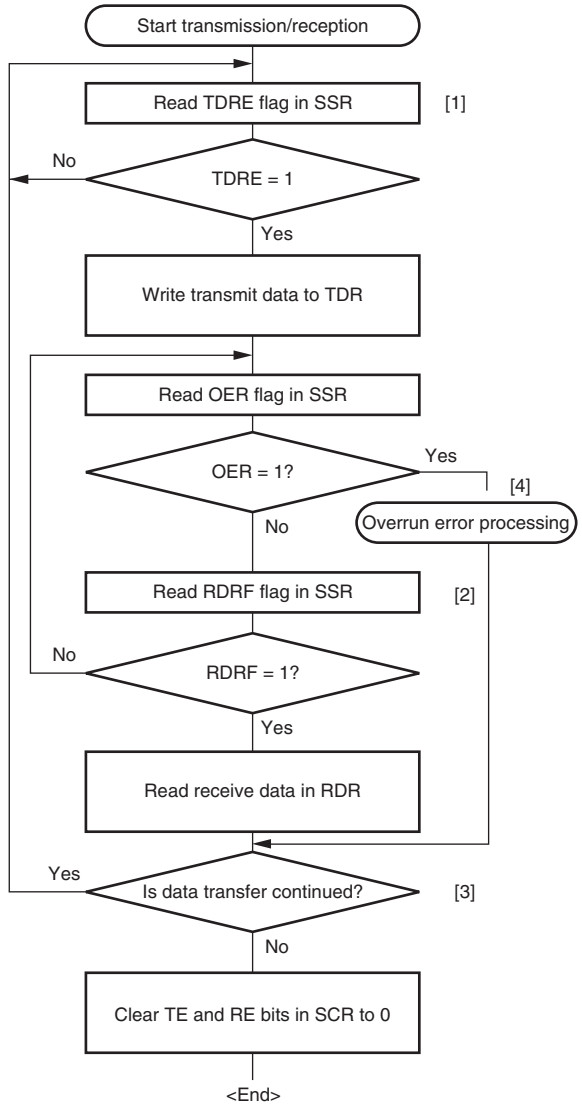
[3] To continue data reception, before the MSB (bit 7) of the current frame is received, reading the RDRF flag and reading RDR should be finished. When data is read from RDR, the RDRF flag is automatically cleared to 0.

[4] If an overrun error occurs, read the OER flag in SSR, and after performing the appropriate error processing, clear the OER flag to 0. Reception cannot be resumed if the OER flag is set to 1.

Figure 20.13 Sample Flowchart for Data Reception (Clocked Synchronous Mode)

20.4.5 Simultaneous Data Transmission and Reception

Figure 20.14 shows a sample flowchart for simultaneous transmit and receive operations. The following procedure should be used for simultaneous data transmit and receive operations. To switch from transmit mode to simultaneous transmit and receive mode, after checking that the SCI3 has finished transmission and the TDRE and TEND flags are set to 1, clear TE to 0. Then simultaneously set TE and RE to 1 with a single instruction. To switch from receive mode to simultaneous transmit and receive mode, after checking that the SCI3 has finished reception, clear RE to 0. Then after checking that the RDRF and receive error flags (OER, FER, and PER) are cleared to 0, simultaneously set TE and RE to 1 with a single instruction.



[1] Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR.
When data is written to TDR, the TDRE flag is automatically cleared to 0.

[2] Read SSR and check that the RDRF flag is set to 1, then read the receive data in RDR.
When data is read from RDR, the RDRF flag is automatically cleared to 0.

[3] To continue data transmission/ reception, before the MSB (bit 7) of the current frame is received, finish reading the RDRF flag, reading RDR. Also, before the MSB (bit 7) of the current frame is transmitted, read 1 from the TDRE flag to confirm that writing is possible. Then write data to TDR.
When data is written to TDR, the TDRE flag is automatically cleared to 0. When data is read from RDR, the RDRF flag is automatically cleared to 0.
If data is transferred to TDR by the DTC with a transmit data empty interrupt (TXI) request, the TDRE flag is automatically checked and cleared. If RDR data is transferred by the DTC with a receive data full iterrupt (RXI) request, the RDRF flag is automatically cleared.

[4] If an overrun error occurs, read the OER flag in SSR, and after performing the appropriate error processing, clear the OER flag to 0. Transmission/reception cannot be resumed if the OER flag is set to 1.
For overrun error processing, see figure 20.13.

Figure 20.14 Sample Flowchart of Simultaneous Transmit and Receive Operations (Clocked Synchronous Mode)

20.5 Multiprocessor Communication Function

Use of the multiprocessor communication function enables data transfer between a number of processors sharing communication lines by asynchronous serial communication using the multiprocessor format, in which a multiprocessor bit is added to the transfer data. When multiprocessor communication is performed, each receiving station is addressed by a unique ID code. The serial communication cycle consists of two component cycles; an ID transmission cycle that specifies the receiving station, and a data transmission cycle. The multiprocessor bit is used to differentiate between the ID transmission cycle and the data transmission cycle. If the multiprocessor bit is 1, the cycle is an ID transmission cycle; if the multiprocessor bit is 0, the cycle is a data transmission cycle. Figure 20.15 shows an example of inter-processor communication using the multiprocessor format. The transmitting station first sends the ID code of the receiving station with which it wants to perform serial communication as data with a 1 multiprocessor bit added. It then sends transmit data as data with a 0 multiprocessor bit added. When data with a 1 multiprocessor bit is received, the receiving station compares that data with its own ID. The station whose ID matches then receives the data sent next. Stations whose IDs do not match continue to skip data until data with a 1 multiprocessor bit is again received.

The SCI3 uses the MPIE bit in SCR3 to implement this function. When the MPIE bit is set to 1, transfer of receive data from RSR to RDR, error flag detection, and setting the SSR status flags, RDRF, FER, and OER, to 1, are inhibited until data with a 1 multiprocessor bit is received. On reception of a receive character with a 1 multiprocessor bit, the MPBR bit in SSR is set to 1 and the MPIE bit is automatically cleared, thus normal reception is resumed. If the RIE bit in SCR3 is set to 1 at this time, an RXI interrupt is generated.

When the multiprocessor format is selected, the parity bit setting is rendered invalid. All other bit settings are the same as those in normal asynchronous mode. The clock used for multiprocessor communication is the same as that in normal asynchronous mode.

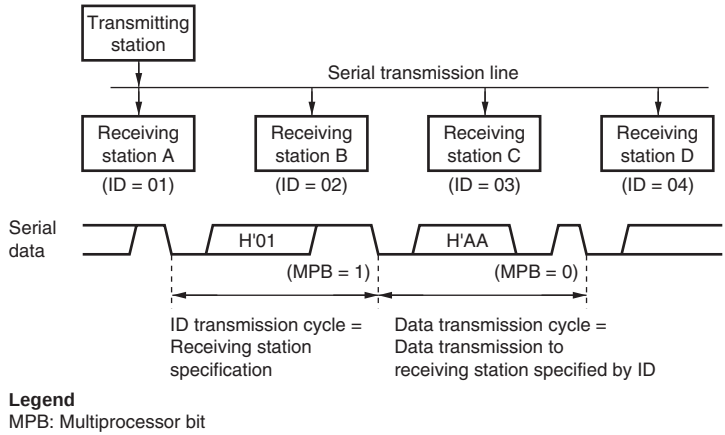
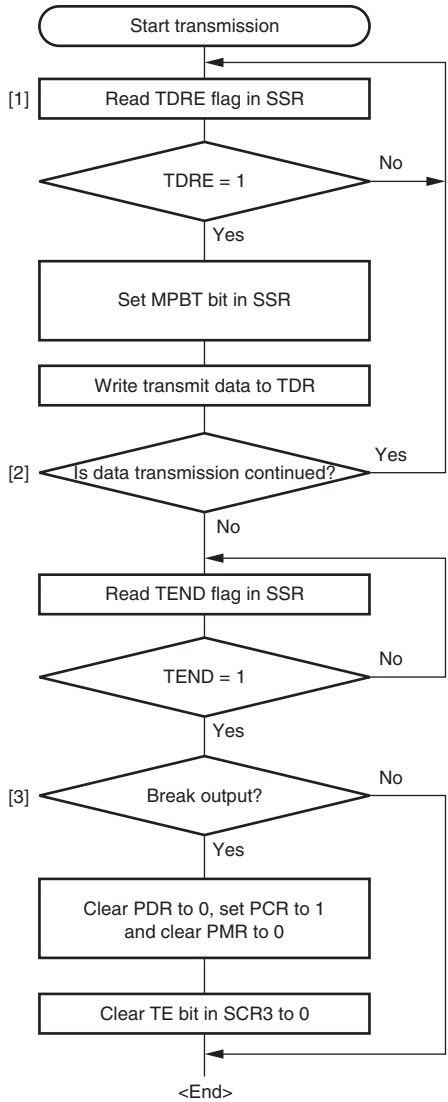


Figure 20.15 Example of Inter-Processor Communication Using Multiprocessor Format (Transmission of Data H'AA to Receiving Station A)

20.5.1 Multiprocessor Data Transmission

Figure 20.16 shows a sample flowchart for multiprocessor data transmission. For an ID transmission cycle, set the MPBT bit in SSR to 1 before transmission. For a data transmission cycle, clear the MPBT bit in SSR to 0 before transmission. All other SCI3 operations are the same as those in asynchronous mode.



[1] Read SSR and check that the TDRE flag is set to 1, set the MPBT bit in SSR to 0 or 1, then write transmit data to TDR. When data is written to TDR, the TDRE flag is automatically cleared to 0.

[2] To continue data transmission, be sure to read 1 from the TDRE flag to confirm that writing is possible, then write data to TDR. When data is written to TDR, the TDRE flag is automatically cleared to 0.
If data is transferred to TDR by the DTC with a transmit data empty interrupt (TXI) request, the TDRE flag is automatically checked and cleared.

[3] To output a break in serial transmission, set the port PCR to 1, clear PDR and PMR to 0, then clear the TE bit in SCR3 to 0.

Figure 20.16 Sample Flowchart for Multiprocessor Data Transmission

20.5.2 Multiprocessor Data Reception

Figure 20.17 shows a sample flowchart for multiprocessor data reception. If the MPIE bit in SCR3 is set to 1, data is skipped until data with a 1 multiprocessor bit is sent. On receiving data with a 1 multiprocessor bit, the receive data is transferred to RDR. An RXI interrupt request is generated at this time. All other SCI3 operations are the same as those in asynchronous mode. Figure 20.18 shows an example of SCI3 operation for multiprocessor data reception.

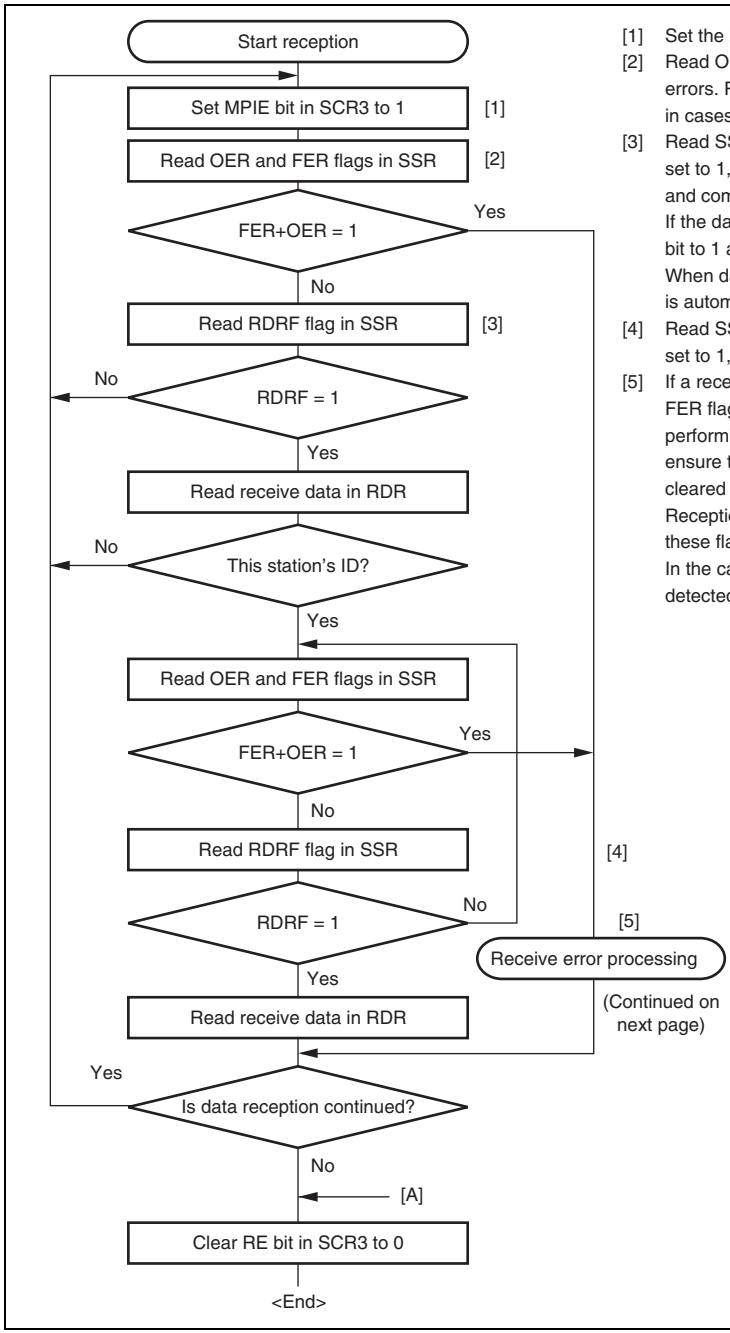


Figure 20.17 Sample Flowchart for Multiprocessor Data Reception (1)

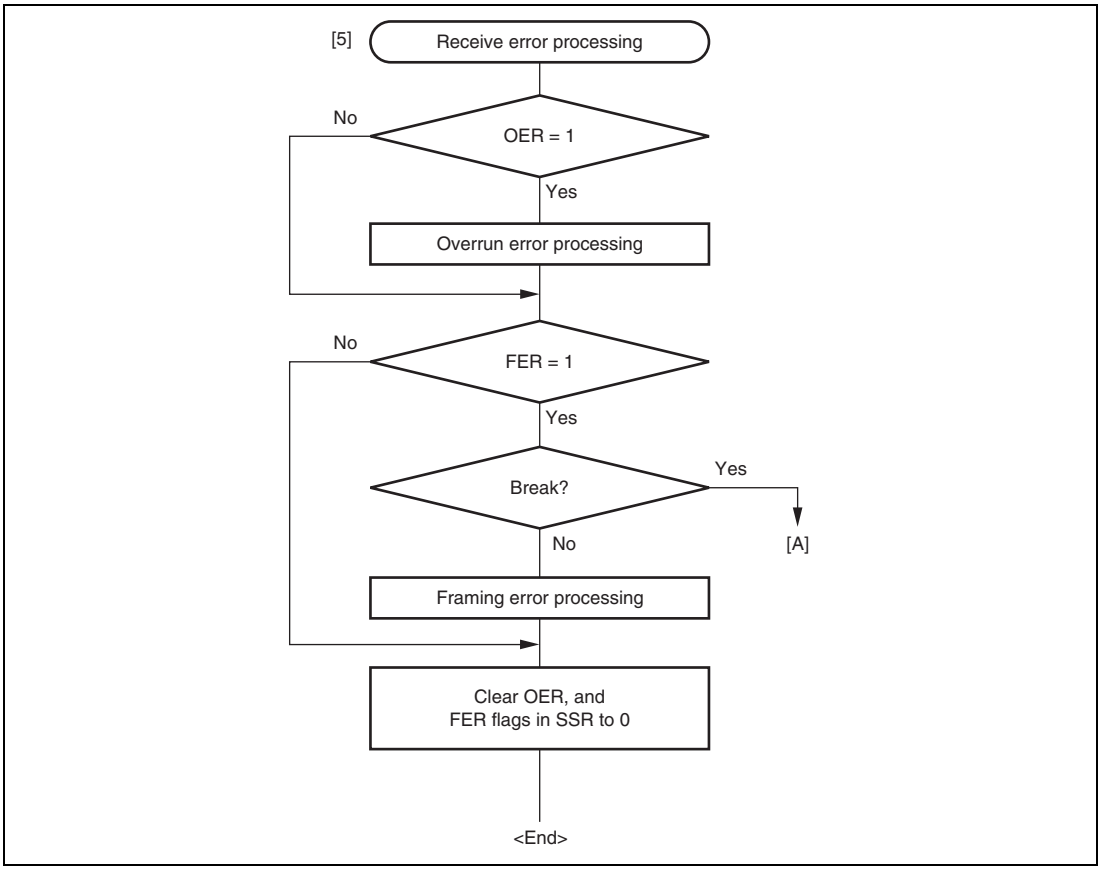
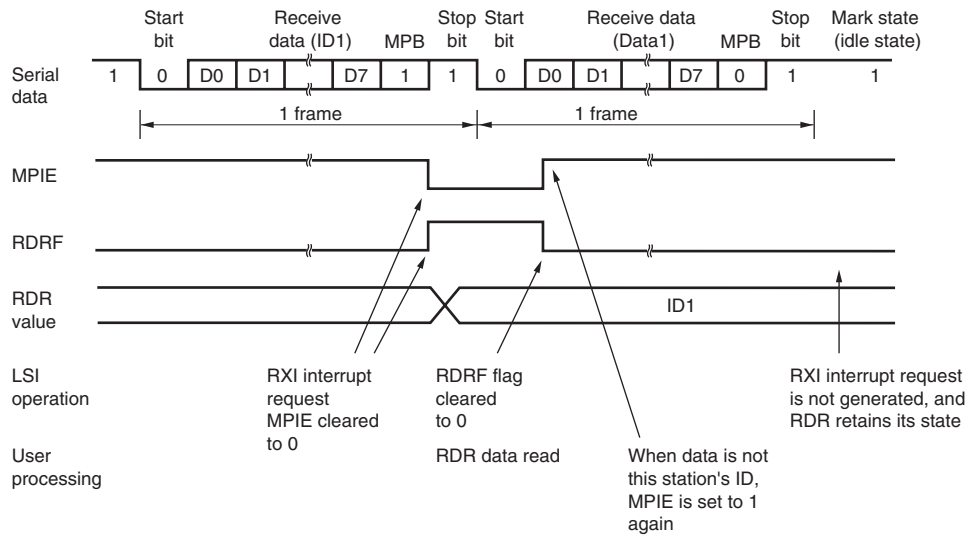
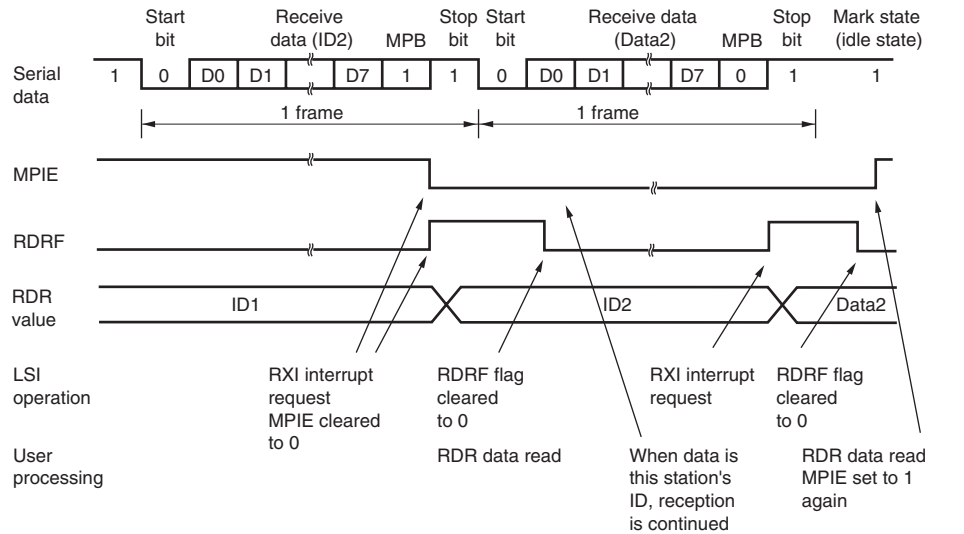


Figure 20.17 Sample Flowchart for Multiprocessor Data Reception (2)



(a) When data does not match this receiver's ID



(b) When data matches this receiver's ID

Figure 20.18 Example of Reception Using Multiprocessor Format (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)

20.6 IrDA Operation

The SCI3_2 provides the IrDA function. If the IrDA function is enabled using the IrE bit in IrCR, the TxD_2 and RxD_2 pins in SCI2_3 are allowed to encode and decode the waveform based on the IrDA Specifications version 1.0 (function as the IrTxD and IrRxD pins)*. Connecting these pins to the infrared data transceiver achieves infrared data communications based on the system defined by the IrDA Specifications version 1.0.

In the system defined by the IrDA Specifications version 1.0, communication is started at a transfer rate of 9600 bps, which can be modified later as required. Since the IrDA interface provided by this LSI does not incorporate the capability of automatic modification of the transfer rate, the transfer rate must be modified through programming.

Figure 20.19 is the IrDA block diagram.

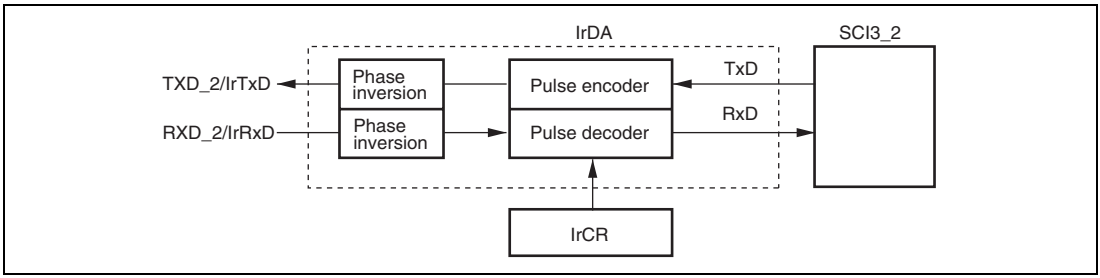


Figure 20.19 IrDA Block Diagram

IrDA operation should be set according to the following procedures.

(1) Set the corresponding pin in the MCR register or PMR register.
(2) Set the IrCR register.
(3) Set the register related to SCI3_2.

20.6.1 Transmission

During transmission, the output signals from the SCI3_2 (UART frames) are converted to IR frames using the IrDA interface (see figure 20.20). For serial data of level 0, a high-level pulse having a width of 3/16 of the bit rate (1-bit interval) is output (initial setting). The high-level pulse can be selected using the IrCKS2 to IrCKS0 bits in IrCR. The high-level pulse width is defined to be 1.41 µs at minimum and (3/16 + 2.5%) × bit rate or (3/16 × bit rate) +1.08 µs at maximum. For example, when the frequency of system clock ϕ is 20 MHz, a high-level pulse width of 1.6 µs can be specified because it is the smallest value in the range greater than 1.41 µs. For serial data of level 1, no pulses are output.

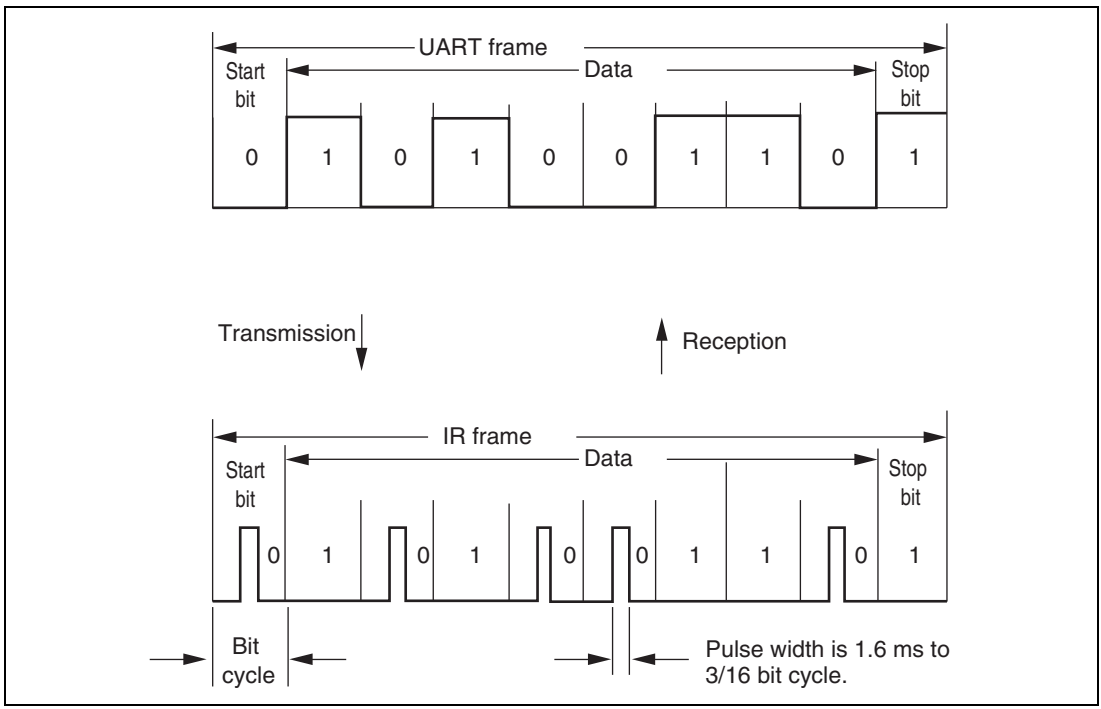


Figure 20.20 IrDA Transmission and Reception

20.6.2 Reception

During reception, IR frames are converted to UART frames using the IrDA interface before inputting to SCI3_2. 0 is output when the high level pulse is detected while 1 is output when no pulse is detected during one bit period. Note that a pulse shorter than the minimum pulse width of 1.41 µs is regarded as a 0 signal.

20.6.3 High-Level Pulse Width Selection

Table 20.7 shows possible settings for bits IrCKS2 to IrCKS0 (minimum pulse width), and this LSI's operating frequencies and bit rates, for making the pulse width shorter than 3/16 times the bit rate in transmission.

Table 20.7 Settings of Bits IrCKS2 to IrCKS0

Operating Frequency φ (MHz)	Bit Rate (bps) (Above)/Bit Period × 3/16 (Below)					
	2400	9600	19200	38400	57600	115200
	78.13	19.53	9.77	4.88	3.26	1.63
4.9152	011	011	011	011	011	011
5	011	011	011	011	011	011
6	100	100	100	100	100	100
6.144	100	100	100	100	100	100
7.3728	100	100	100	100	100	100
8	100	100	100	100	100	100
9.3804	100	100	100	100	100	100
10	100	100	100	100	100	100
12	101	101	101	101	101	101
12.288	101	101	101	101	101	101
14	101	101	101	101	101	101
14.7456	101	101	101	101	101	101
16	101	101	101	101	101	101
16.9344	101	101	101	101	101	101
17.2032	101	101	101	101	101	101
18	101	101	101	101	101	101
19.6608	101	101	101	101	101	101
20	101	101	101	101	101	101

20.7 Noise Canceler

Figure 20.21 shows a block diagram of the noise canceler circuit. When the noise canceler function is enabled, the RXD input signal is routed through the noise canceler before being provided internally. The noise canceler consists of three cascaded latches and a match detector. The RXD input signal is sampled at the basic clock frequency, 16 times the transfer rate, and when the outputs of three latches agree, the level is passed to the next circuit. If they do not agree, the previous value is held.

In other words, if the input level changes and the level remains the same for three or more clock cycles after the change, it is recognized as a signal. However, if the level remains the same for less than three clock cycles, it is recognized as a noise, not as a signal.

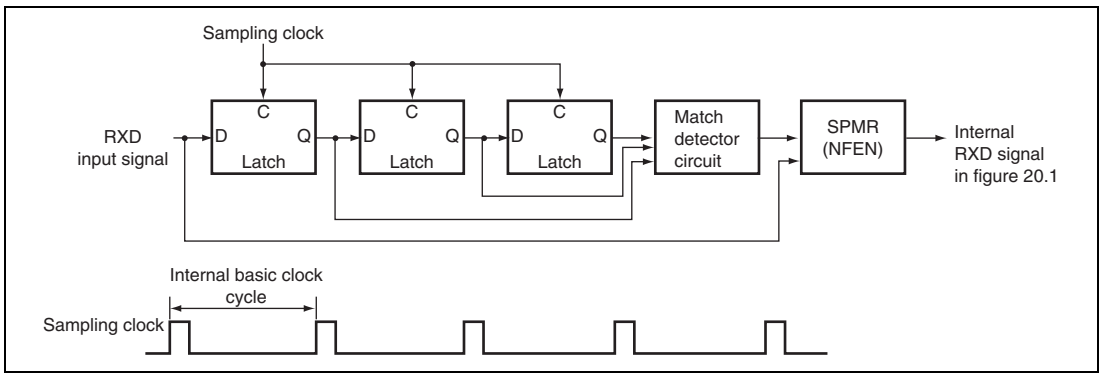


Figure 20.21 Block Diagram of Noise Canceler

20.8 Interrupt Requests

The SCI3 creates the following six interrupt requests: transmission end, transmit data empty, receive data full, and receive errors (overrun error, framing error, and parity error). Table 20.8 shows the interrupt sources.

Table 20.8 SCI3 Interrupt Requests

Interrupt Requests	Abbreviation	Interrupt Sources	DTC Activation
Receive Data Full	RXI	Setting RDRF in SSR	Possible
Transmit Data Empty	TXI	Setting TDRE in SSR	Possible
Transmission End	TEI	Setting TEND in SSR	Impossible
Receive Error	ERI	Setting OER, FER, and PER in SSR	Impossible

When the TDRE flag in SSR is set to 1, a TXI interrupt request is generated. When the TEND flag in SSR is set to 1, a TEI interrupt request is generated. The DTC can be activated to perform data transfers with the TXI interrupt request. The TDRE flag is automatically cleared to 0 by the DTC data transfer.

When the RDRF flag in SSR is set to 1, a RXI interrupt request is generated. When any of the ORER, PER and FER flags is set to 1, an ERI interrupt request is generated. The DTC can be activated to perform data transfers with the RXI interrupt request. The RDRE flag is automatically cleared to 0 by the DTC data transfer.

The TEI interrupt is generated if the TEND flag is set to 1 when the TEIE bit is 1. If the TEI and TXI interrupts are generated at the same time, the TXI interrupt is accepted first. Therefore, if the TDRE and TEND flags are to be simultaneously cleared in a TXI interrupt routine, branching to a TEI interrupt routine cannot be performed.

The initial value of the TDRE flag in SSR is 1. Thus, when the TIE bit in SCR3 is set to 1 before transferring the transmit data to TDR, a TXI interrupt request is generated even if the transmit data is not ready. The initial value of the TEND flag in SSR is 1. Thus, when the TEIE bit in SCR3 is set to 1 before transferring the transmit data to TDR, a TEI interrupt request is generated even if the transmit data has not been sent. It is possible to make use of the most of these interrupt requests efficiently by transferring the transmit data to TDR in the interrupt routine. To prevent the generation of these interrupt requests (TXI and TEI), set the enable bits (TIE and TEIE) that correspond to these interrupt requests to 1, after transferring the transmit data to TDR.

20.9 Usage Notes

20.9.1 Break Detection and Processing

When framing error detection is performed, a break can be detected by reading the RXD pin value directly. In a break, the input from the RXD pin becomes all 0s, setting the FER flag, and possibly the PER flag. Note that as the SCI3 continues the receive operation after receiving a break, even if the FER flag is cleared to 0, it will be set to 1 again.

20.9.2 Mark State and Break Sending

When the PMR bit corresponding to the pin selected by the PMC is 0, the TXD pin is used as an I/O port whose direction (input or output) and level are determined by PCR and PDR. This can be used to set the TXD pin to mark state (high level) or send a break during data transmission. To maintain the communication line at mark state until the PMR bit is set to 1, set both PCR and PDR to 1. As the PMR bit is cleared to 0 at this point, the TXD pin becomes an I/O port, and 1 is output from the TXD pin. To send a break during transmission, first set PCR to 1 and clear PDR to 0, and then clear the PMR bit to 0. When the PMR bit is cleared to 0, the transmitter is initialized regardless of the current transmission state, the TXD pin becomes an I/O port, and 0 is output from the TXD pin.

20.9.3 Receive Error Flags and Transmit Operations (Clocked Synchronous Mode Only)

Transmission cannot be started when a receive error flag (OER, PER, or FER) is set to 1, even if the TDRE flag is cleared to 0. Be sure to clear the receive error flags to 0 before starting transmission. Note also that receive error flags cannot be cleared to 0 even if the RE bit is cleared to 0.

20.9.4 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI3 operates on a basic clock with a frequency of 16 times the transfer rate. In reception, the SCI3 samples the falling edge of the start bit using the basic clock, and performs internal synchronization. Receive data is latched internally at the rising edge of the 8th pulse of the basic clock as shown in figure 20.22. Thus, the reception margin in asynchronous mode is given by formula (1) below.

$$M = \{(0.5 - \frac{1}{2N}) - \frac{D - 0.5}{N} - (L - 0.5) F \} \times 100\ (\%) \quad \text{... Formula 1}$$

... Formula (1)

[Legend]
N: Ratio of bit rate to clock (N = 16)
D: Clock duty (D = 0.5 to 1.0)
L: Frame length (L = 9 to 12)
F: Absolute value of clock rate deviation

Assuming values of F (absolute value of clock rate deviation) = 0 and D (clock duty) = 0.5 in formula (1), the reception margin can be given by the formula.

$$M = \{0.5 - 1/(2 \times 16)\} \times 100\ [\%] = 46.875\%$$

However, this is only the computed value, and a margin of 20% to 30% should be allowed for in system design.

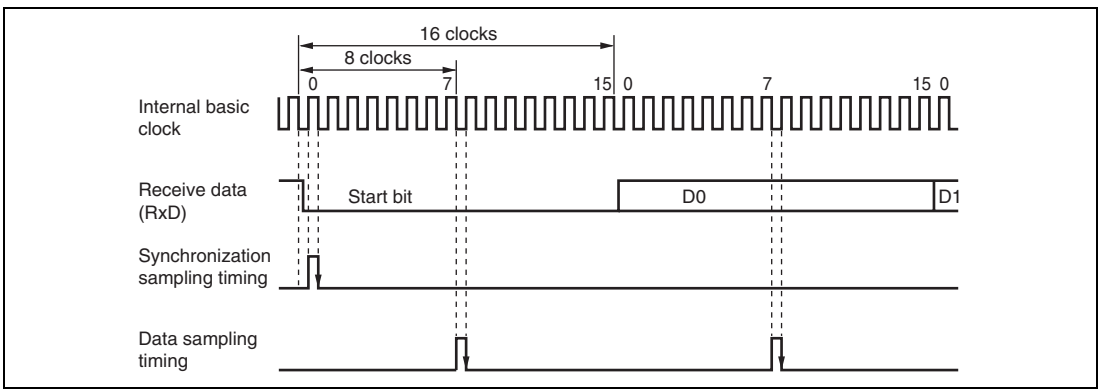


Figure 20.22 Receive Data Sampling Timing in Asynchronous Mode

20.9.5 Relation between Writes to TDR and TDRE Flag

Data can be written to TDR regardless of the state of the TDRE flag. However, if new data is written to TDR when the DRE flag is cleared to 0, the data stored in TDR will be lost since it has not yet been transferred to TSR. It is therefore essential to check that the TDRE flag is set to 1 before writing transmit data TDR.

20.9.6 Restrictions on Using DTC

When the external clock source is used as a synchronization clock, update TDR by the DTC or CPU and wait for at least five ϕ clock cycles before allowing the transmit clock to be input. If the transmit clock is input within four clock cycles after TDR modification, the SCI3 may malfunction (see figure 20.23).

When using the DTC to read RDR, be sure to set the receive end interrupt (RXI) for the relevant SCI3 as the DTC activation source.

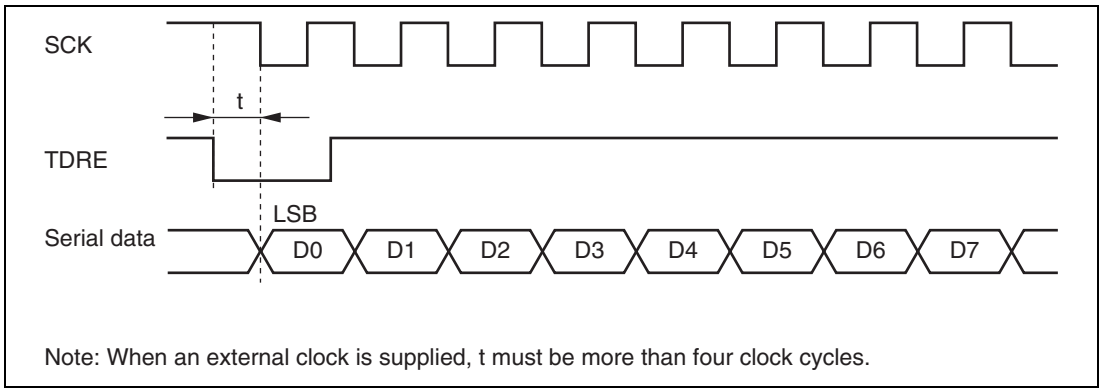


Figure 20.23 Example of DTC Transmission in Clock Synchronous Mode

Section 21 I²C Bus Interface 2 (IIC2)

The I²C bus interface 2 conforms to and provides a subset of the Philips I²C bus (inter-IC bus) interface functions. The register configuration that controls the I²C bus differs partly from the Philips configuration, however. Figure 21.1 shows a block diagram of the I²C bus interface 2. Figure 21.2 shows an example of I/O pin connections to external circuits.

Either the IIC2 or SSU incorporated in this LSI can be used at a time. Accordingly, when the IIC2 function is used, the SSU function is not available.

21.1 Features

- Selectable for I²C bus format or clock synchronous serial format
- Continuous transmission/reception

  Since the shift register, transmit data register, and receive data register are independent from each other, the continuous transmission/reception can be performed.

I²C Bus Format:

- Start and stop conditions generated automatically in master mode
- Selectable for acknowledge output levels when receiving
- Automatic loading of acknowledge bit when transmitting
- Bit synchronization/wait function stored

  In master mode, the state of SCL is monitored per bit, and the timing is synchronized automatically. If transmission/reception is not yet possible, set the SCL to low until preparations are completed.
- Six interrupt sources

  Transmit data empty (including slave-address match), transmit end, receive data full (including slave-address match), arbitration lost, NACK detection, and stop condition detection. The DTC can be activated by the transmit-data-empty and receive-data-full interrupts.
- Direct bus drive possible

  Two pins, SCL and SDA pins, function as NMOS open-drain outputs when the bus drive function is selected.

Clock Synchronous Format:

- Four interrupt sources

  Transmit-data-empty, transmit-end, receive-data-full, and overrun error. The DTC can be activated by the transmit-data-empty and receive-data-full interrupt sources.

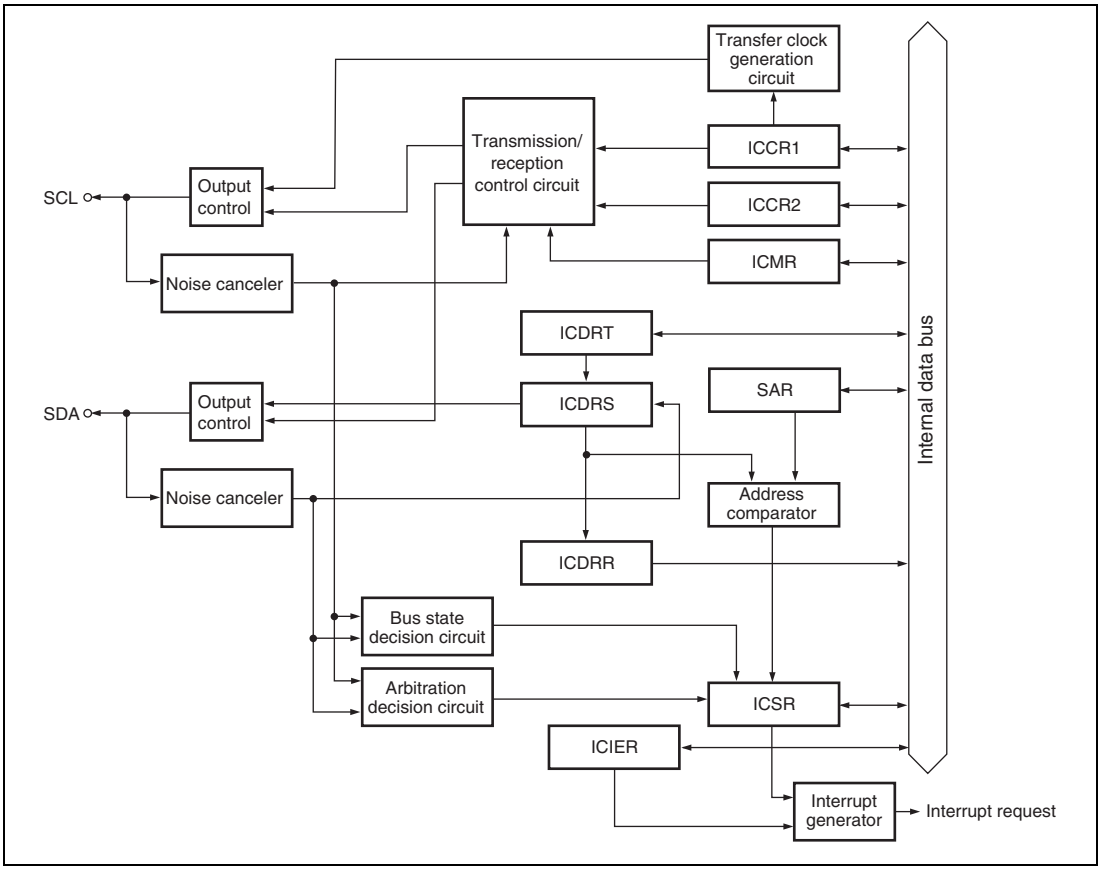


Figure 21.1 Block Diagram of I²C Bus Interface 2

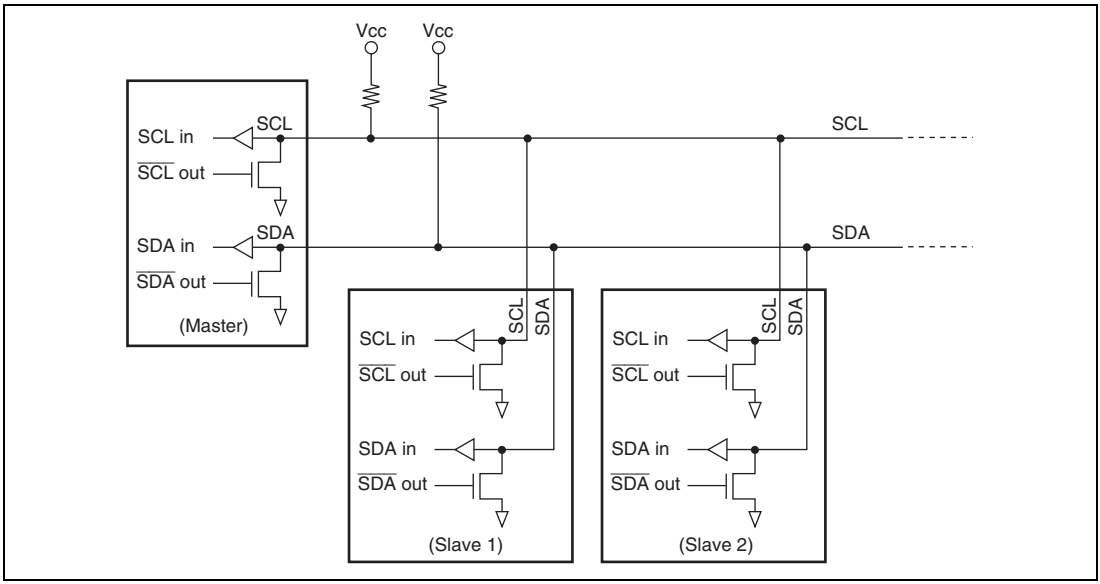


Figure 21.2 External Circuit Connections of I/O Pins

Table 21.1 summarizes the pin configuration used by the I²C bus interface 2.

Table 21.1 Pin Configuration

Pin Name	I/O	Function
SCL	I/O	IIC serial clock input/output
SDA	I/O	IIC serial data input/output

21.2 Register Descriptions

The IIC2 has the following registers.

- IIC2/SSU select register (ICSUSR)
- I²C bus control register 1 (ICCR1)
- I²C bus control register 2 (ICCR2)
- I²C bus mode register (ICMR)
- I²C bus interrupt enable register (ICIER)
- I²C bus status register (ICSR)
- I²C bus slave address register (SAR)
- I²C bus transmit data register (ICDRT)
- I²C bus receive data register (ICDRR)
- I²C bus shift register (ICDRS)

21.2.1 IIC2/SSU Select Register (ICSUSR)

Address: H'FF000B

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

Bit	Symbol	Bit Name	Description	R/W
7 to 1	—	Reserved	These bits are read as 0. The write value should be 0.	—
0	SELICSU	IIC2/SSU module function select	0: IIC2 function is selected.* 1: SSU function is selected.	R/W

Note: To select the IIC2 function, this bit should be set to 0 without fail.

21.2.2 I²C Bus Control Register 1 (ICCR1)

Address: H'FF05C8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	ICE	RCVD	MST	TRS	CKS[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	ICE	I²C bus interface 2 enable	0: This module is stopped. (SCL and SDA pins are set to port function.) 1: This bit is enabled for transfer operations. (SCL and SDA pins are bus drive state.)	R/W
6	RCVD	Reception disable	0: Enables next reception 1: Disables next reception	R/W
5	MST	Master/slave select	00: Slave receive mode 01: Slave transmit mode	R/W
4	TRS	Transmit/ receive select	10: Master receive mode 11: Master transmit mode	R/W
3 to 0	CKS[3:0]	Transfer clock select 3 to 0	These bits should be set according to the necessary transfer rate (see table 21.2) in master mode.	R/W

- RCVD bit (reception disable)

  Selects to enable or disable the next operation when TRS is 0 and ICDRR is read.

- MST bit (master/slave select) and TRS bit (transmit/receive select)

  In master mode with the I²C bus format, when arbitration is lost, MST and TRS are both reset by hardware, causing a transition to slave receive mode. Modification of the TRS bit should be performed between transfer frames.

  After data receive has been started in slave receive mode, when the first seven bits of the receive data agree with the slave address that is set to SAR and the eighth bit is 1, TRS is automatically set to 1. If an overrun error occurs in master mode with the clock synchronous serial format, MST is cleared to 0 and slave receive mode is entered.

  Operating modes are described above according to MST and TRS combination. When clock synchronous serial format is selected and MST is 1, clock is output.

- CKS[3:0] bits (transfer clock select 3 to 0)

  These bits should be set according to the necessary transfer rate (see table 21.2) in master mode. In slave mode, these bits are used for reservation of the data setup time in transmit mode. The time is 10 t_{cyc} when CKS3 = 0 and 20 t_{cyc} when CKS3 = 1.

Table 21.2 Transfer Rate

Bit 3	Bit 2	Bit 1	Bit 0		Transfer Rate				
CKS3	CKS2	CKS1	CKS0	Clock	φ = 5 MHz	φ = 8 MHz	φ = 10 MHz	φ = 16 MHz	φ = 20 MHz
0	0	0	0	φ/28	179 kHz	286 kHz	357 kHz	571 kHz	714 kHz
			1	φ/40	125 kHz	200 kHz	250 kHz	400 kHz	500 kHz
		1	0	φ/48	104 kHz	167 kHz	208 kHz	333 kHz	417 kHz
			1	φ/64	78.1 kHz	125 kHz	156 kHz	250 kHz	313 kHz
	1	0	0	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz	250 kHz
			1	φ/100	50.0 kHz	80.0 kHz	100 kHz	160 kHz	200 kHz
		1	0	φ/112	44.6 kHz	71.4 kHz	89.3 kHz	143 kHz	179 kHz
			1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz	156 kHz
1	0	0	0	φ/56	89.3 kHz	143 kHz	179 kHz	286 kHz	357 kHz
			1	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz	250 kHz
		1	0	φ/96	52.1 kHz	83.3 kHz	104 kHz	167 kHz	208 kHz
			1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz	156 kHz
	1	0	0	φ/160	31.3 kHz	50.0 kHz	62.5 kHz	100 kHz	125 kHz
			1	φ/200	25.0 kHz	40.0 kHz	50.0 kHz	80.0 kHz	100 kHz
		1	0	φ/224	22.3 kHz	35.7 kHz	44.6 kHz	71.4 kHz	89.3 kHz
			1	φ/256	19.5 kHz	31.3 kHz	39.1 kHz	62.5 kHz	78.1 kHz

21.2.3 I²C Bus Control Register 2 (ICCR2)

Address: H'FF05C9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BBSY	SCP	SDAO	SDAOP	SCLO	—	IICRST	—
Value after reset:	0	1	1	1	1	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	BBSY*[1]	Bus busy	This bit enables to confirm whether the I²C bus is occupied or released and to issue start/stop conditions in master mode. With the clock synchronous serial format, this bit has no meaning. With the I²C bus format, this bit is set to 1 when the SDA level changes from high to low under the condition of SCL = high, assuming that the start condition has been issued. This bit is cleared to 0 when the SDA level changes from low to high under the condition of SCL = high, assuming that the stop condition has been issued. Write 1 to BBSY and 0 to SCP to issue a start condition. Follow this procedure when also re-transmitting a start condition. Write 0 in BBSY and 0 in SCP to issue a stop condition. To issue start/stop conditions, use the MOV instruction.	R/W
6	SCP	Start/stop condition issue disable	The SCP bit controls the issue of start/stop conditions in master mode. To issue a start condition, write 1 in BBSY and 0 in SCP. A retransmit start condition is issued in the same way. To issue a stop condition, write 0 in BBSY and 0 in SCP. This bit is always read as 1. If 1 is written, the data is not stored.	R/W
5	SDAO	SDA output value control	This bit is used with SDAOP (bit 4) when modifying output level of SDA. This bit should not be manipulated during transfer. 0: When reading, SDA pin outputs low. When writing, SDA pin is changed to output low. 1: When reading, SDA pin outputs high. When writing, SDA pin is changed to output Hi-Z (outputs high by external pull-up resistance).	R/W

Bit	Symbol	Bit Name	Description	R/W
4	SDAOP	SDAO write protect	This bit controls change of output level of the SDA pin by modifying the SDAO bit. To change the output level, clear SDAO and SDAOP to 0 or set SDAO to 1 and clear SDAOP to 0 by the MOV instruction. This bit is always read as 1.	R/W
3	SCLO	SCL output level monitor	This bit monitors SCL output level. When reading and SCLO is 1, SCL pin outputs high. When reading and SCLO is 0, SCL pin outputs low.	R
2	—	Reserved	This bit is read as 1. The write value should be 1.	—
1	IICRST*[2]	IIC control part reset	This bit resets the control part except for I²C registers. If this bit is set to 1 when hang-up occurs because of communication failure during I²C operation, I²C control part can be reset without setting ports and initializing registers.	R/W
0	—	Reserved	This bit is read as 1. The write value should be 1.	—

Note: 1. In standby mode, the BBSY bit in ICCR2 is reset.
2. Clear IICRST to 0 by software since this bit is not cleared automatically.

21.2.4 I²C Bus Mode Register (ICMR)

Address: H'FF05CA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	MLS	WAIT	—	—	BCWP	BC[2:0]		
Value after reset:	0	0	0	1	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	MLS	MSB-first/LSB-first select	0: Transfer in MSB-first* 1: Transfer in LSB-first	R/W
6	WAIT	Wait insertion	0: Data and acknowledge bits are transferred consecutively with no wait inserted. 1: After the fall of the clock for the final data bit, low period is extended for two transfer clocks.	R/W
5	—	Reserved	This bit is read as 0. The write value should be 0.	—
4	—	Reserved	This bit is read as 1. The write value should be 1.	—
3	BCWP	BC write protect	0: When writing, modifying BC2 to BC0 values is valid. 1: When writing, modifying BC2 to BC0 values is invalid.	R/W
2 to 0	BC[2:0]	Bit counter 2 to 0	I²C Bus Format / Clock Synchronous Serial Format 000: 9 bits / 000: 8 bits 001: 2 bits / 001: 1 bits 010: 3 bits / 010: 2 bits 011: 4 bits / 011: 3 bits 100: 5 bits / 100: 4 bits 101: 6 bits / 101: 5 bits 110: 7 bits / 110: 6 bits 111: 8 bits / 111: 7 bits	R/W

Note: * Set this bit to 0 when the I²C bus format is used.

- WAIT bit (wait insertion)

  In master mode with the I²C bus format, this bit selects whether to insert a wait after data transfer except the acknowledge bit. When WAIT is set to 1, after the fall of the clock for the final data bit, low period is extended for two transfer clocks. If WAIT is cleared to 0, data and acknowledge bits are transferred consecutively with no wait inserted.

  The setting of this bit is invalid in slave mode with the I²C bus format or with the clock synchronous serial format.

- BCWP bit (BC write protect)

  Controls the BC2 to BC0 modifications. When modifying BC2 to BC0, this bit should be cleared to 0 and use the MOV instruction. In clock synchronous serial mode, BC should not be modified.

- BC[2:0] bits (bit counter 2 to 0)

  Specifies the number of bits to be transferred next. When read, the remaining number of transfer bits is indicated. With the I²C bus format, the data is transferred with one additional acknowledge bit. Bit BC2 to BC0 should be set during an interval between transfer frames. If bits BC2 to BC0 are set to a value other than 000, the setting should be made while the SCL pin is low. The value automatically returns to 000 at the end of a data transfer, including the acknowledge bit. With the clock synchronous serial format, these bits should not be modified.

21.2.5 I²C Bus Interrupt Enable Register (ICIER)

Address: H'FF05CB

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	TEIE	RIE	NAKIE	STIE	ACKE	ACKBR	ACKBT
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TIE	Transmit interrupt enable	0: Transmit data empty interrupt request (TXI) is disabled. 1: Transmit data empty interrupt request (TXI) is enabled.	R/W
6	TEIE	Transmit end interrupt enable	0: Transmit end interrupt request (TEI) is disabled. 1: Transmit end interrupt request (TEI) is enabled.	R/W

Bit	Symbol	Bit Name	Description	R/W
5	RIE	Receive interrupt enable	0: Receive data full interrupt request (RXI) is disabled. 1: Receive data full interrupt request (RXI) is enabled.	R/W
4	NAKIE	NACK receive interrupt enable	0: NACK receive interrupt request (NAKI) and overrun error interrupt request (ERI) with the clock synchronous format are disabled. 1: NACK receive interrupt request (NAKI) and overrun error interrupt request (ERI) with the clock synchronous format are enabled.	R/W
3	STIE	Stop condition detection interrupt enable	0: Stop condition detection interrupt request (STPI) is disabled. 1: Stop condition detection interrupt request (STPI) is enabled.	R/W
2	ACKE	Acknowledge bit judgment select	0: The value of the receive acknowledge bit is ignored, and continuous transfer is performed. 1: If the receive acknowledge bit is 1, continuous transfer is stopped.	R/W
1	ACKBR	Receive acknowledge	0: Receive acknowledge = 0 1: Receive acknowledge = 1	R
0	ACKBT	Transmit acknowledge	0: 0 is sent at the acknowledge timing. 1: 1 is sent at the acknowledge timing.	R/W

- TIE bit (transmit interrupt enable)

  When the TDRE bit in ICSR is set to 1, this bit enables or disables the transmit data empty interrupt (TXI).

- TEIE bit (transmit end interrupt enable)

  This bit enables or disables the transmit end interrupt (TEI) at the rising of the ninth clock while the TDRE bit in ICSR is 1. TEI can be canceled by clearing the TEND bit or the TEIE bit to 0.

- RIE bit (receive interrupt enable)

  This bit enables or disables the receive data full interrupt request (RXI) when a receive data is transferred from ICDRS to ICDRR and the RDRF bit in ICSR is set to 1. RXI can be canceled by clearing the RDRF or RIE bit to 0.

- NAKIE bit (NACK receive interrupt enable)

  This bit enables or disables the NACK receive interrupt request (NAKI) and the overrun error (setting of the OVE bit in ICSR) interrupt request (ERI) with the clock synchronous format, when the NACKF and AL bits in ICSR are set to 1. NAKI can be canceled by clearing the NACKF, OVE, or NAKIE bit to 0.

- STIE bit (stop condition detection interrupt enable)

  This bet should be set to 1 while the STOP bit in ICSR is 0.

- ACKBR bit (receive acknowledge)

  In transmit mode, this bit stores the acknowledge data that are returned by the receive device. This bit cannot be modified.

- ACKBT bit (transmit acknowledge)

  In receive mode, this bit specifies the bit to be sent at the acknowledge timing.

21.2.6 I²C Bus Status Register (ICSR)

Address: H'FF05CC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	TEND	RDRF	NACKF	STOP	AL_OVE	AAS	ADZ
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TDRE	Transmit data empty flag	[Setting conditions] • When data is transferred from ICDRT to ICDRS and ICDRT becomes empty • When TRS is set • When a start condition (including re-transfer) has been issued • When transmit mode is entered from receive mode in slave mode [Clearing conditions] • When 0 is written in TDRE after reading TDRE = 1 • When data is written to ICDRT with an instruction • When the DTC transfers data to ICDRT by a TXI interrupt request, and the DTC settings satisfy the flag clearing conditions.	R/W

Bit	Symbol	Bit Name	Description	R/W
6	TEND	Transmit end flag	[Setting conditions] • When the ninth clock of SCL rises with the I²C bus format while the TDRE flag is 1 • When the final bit of transmit frame is sent with the clock synchronous serial format [Clearing conditions] • When 0 is written in TEND after reading TEND = 1 • When data is written to ICDRT with an instruction	R/W
5	RDRF	Receive data register full flag	[Setting condition] • When a receive data is transferred from ICDRS to ICDRR [Clearing conditions] • When 0 is written in RDRF after reading RDRF = 1 • When ICDRR is read with an instruction • When the DTC transfers data to ICDRR by an RXI interrupt request, and the DTC settings satisfy the flag clearing conditions.	R/W
4	NACKF	No acknowledge detection flag	[Setting condition] • When no acknowledge is detected from the receive device in transmission while the ACKE bit in ICIER is 1 [Clearing condition] • When 0 is written in NACKF after reading NACKF = 1	R/W
3	STOP	Stop condition detection flag	[Setting conditions] • When a stop condition is detected after frame transfer end [Clearing condition] • When 0 is written in STOP after reading STOP = 1	R/W

Bit	Symbol	Bit Name	Description	R/W
2	AL_OVE	Arbitration lost flag/overrun error flag	[Setting conditions] • If the internal SDA and SDA pin disagree at the rise of SCL in master transmit mode • When the SDA pin outputs high in master mode while a start condition is detected • When the final bit is received with the clock synchronous format while RDRF = 1 [Clearing condition] • When 0 is written in AL/OVE after reading AL/OVE = 1	R/W
1	AAS	Slave address recognition flag	[Setting conditions] • When the slave address is detected in slave receive mode • When the general call address is detected in slave receive mode. [Clearing condition] • When 0 is written in AAS after reading AAS = 1	R/W
0	ADZ	General call address recognition flag	This bit is enabled in slave receive mode with I²C bus format. [Setting condition] • When the general call address is detected in slave receive mode [Clearing condition] • When 0 is written in ADZ after reading ADZ = 1	R/W

Notes: In standby mode, ICSR is reset.

* The DTC clears the peripheral module flags when all of the following three conditions are satisfied.

1. When the DISEL bit is 0.
2. When the transfer counter is not 0. (DTC transfer count register A (CRA) in normal mode and repeat mode, or DTC transfer count register B (CRB) in block mode)
3. When chain transfer is not used.

- AL_OVE bit (arbitration lost flag/overrun error flag)

  This flag indicates that arbitration was lost in master mode with the I²C bus format and that the final bit has been received while RDRF = 1 with the clock synchronous format.

  When two or more master devices attempt to seize the bus at nearly the same time, if the I²C bus interface detects data differing from the data it sent, it sets AL to 1 to indicate that the bus has been taken by another master.

- AAS bit (slave address recognition flag)

  In slave receive mode, this flag is set to 1 if the first frame following a start condition matches bits SVA6 to SVA0 in SAR.

21.2.7 Slave Address Register (SAR)

Address: H'FF05CD

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	SVA6	SVA5	SVA4	SVA3	SVA2	SVA1	SVA0	FS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7 to 1	SVA6 to SVA0	Slave address 6 to 0	These bits set a unique address in bits SVA6 to SVA0, differing form the addresses of other slave devices connected to the I²C bus.	R/W
0	FS	Format select	0: I²C bus format is selected. 1: Clock synchronous serial format is selected.	R/W

SAR selects the format and sets the slave address. When SAR is in slave mode with the I²C bus format, if the upper 7 bits of SAR match the upper 7 bits of the first frame received after a start condition, SAR operates as the slave device.

21.2.8 I²C Bus Transmit Data Register (ICDRT)

Address: H'FF05CE

Bit:	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 the transmit data. When ICDRT detects the space in the shift register (ICDRS), it transfers the transmit data which is written in ICDRT to ICDRS and starts transferring data. If the next transfer data is written to ICDRT during transferring data of ICDRS, continuous transfer is possible. If the MLS bit of ICMR is set to 1 and when the data is written to ICDRT, the MSB/LSB inverted data is read. The initial value of ICDRT is H'FF. ICDRT is reset in standby mode.

21.2.9 I²C Bus Receive Data Register (ICDRR)

Address: H'FF05CF

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

ICDRR is an 8-bit register that stores the receive data. When data of one byte is received, ICDRR transfers the receive data from ICDRS to ICDRR and the next data can be received. ICDRR is a receive-only register, therefore the CPU cannot write to this register. The initial value of ICDRR is H'FF. ICDRR is reset in standby mode.

21.2.10 I²C Bus Shift Register (ICDRS)

Address: —

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

ICDRS is a register that is used to transfer/receive data. In transmission, data is transferred from ICDRT to ICDRS and the data is sent from the SDA pin. In reception, data is transferred from ICDRS to ICDRR after data of one byte is received. This register cannot be read directly from the CPU. ICDRS is reset in standby mode.

21.3 Operation

The I²C bus interface 2 can communicate either in I²C bus mode or clock synchronous serial mode by setting FS in SAR.

21.3.1 I²C Bus Format

Figure 21.3 shows the I²C bus formats. Figure 21.4 shows the I²C bus timing. The first frame following a start condition always consists of 8 bits.

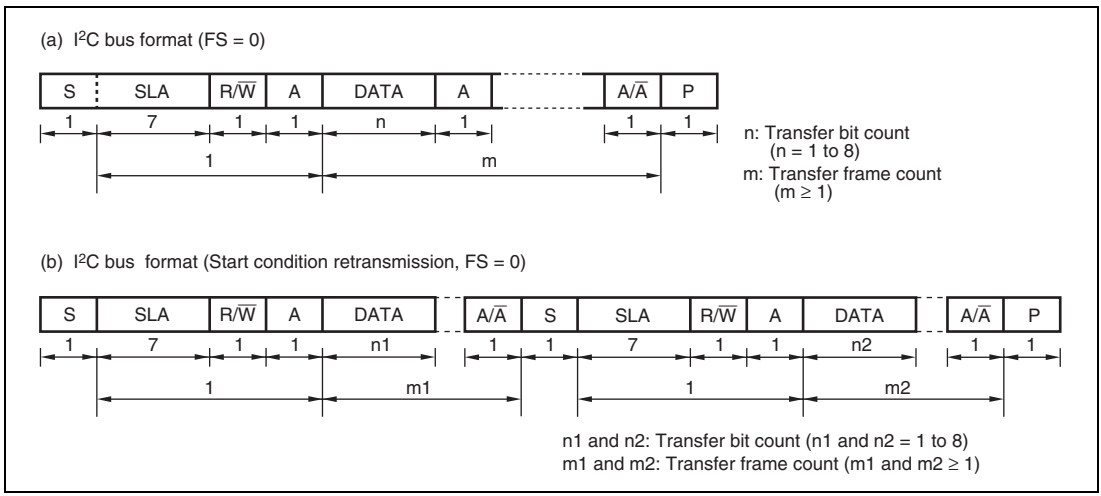


Figure 21.3 I²C Bus Formats

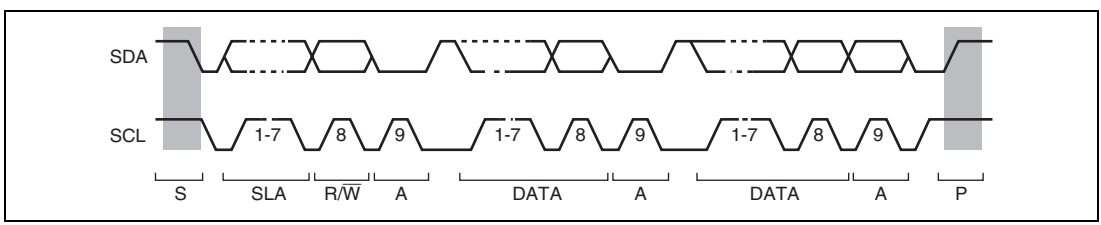


Figure 21.4 I²C Bus Timing

[Legend]

S: Start condition. The master device drives SDA from high to low while SCL is high.

SLA: Slave address

R/$\overline{W}$: Indicates the direction of data transfer: from the slave device to the master device when R/$\overline{W}$ is 1, or from the master device to the slave device when R/$\overline{W}$ is 0.

A: Acknowledge. The receive device drives SDA to low.

DATA: Transfer data

P: Stop condition. The master device drives SDA from low to high while SCL is high.

21.3.2 Master Transmit Operation

In master transmit mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal. For master transmit mode operation timing, see figures 21.5 and 21.6. The transmission procedure and operations in master transmit mode are described below.

1. Set the ICE bit in ICCR1 to 1. Set the MLS and WAIT bits in ICMR and the CKS3 to CKS0 bits in ICCR1 to 1. (Initial setting)
2. Read the BBSY flag in ICCR2 to confirm that the bus is released. Set the MST and TRS bits in ICCR1 to select master transmit mode. Then, write 1 to BBSY and 0 to SCP using MOV instruction. (Start condition issued) This generates the start condition.
3. After confirming that TDRE in ICSR has been set, write the transmit data (the first byte data show the slave address and R/$\overline{W}$) to ICDRT. At this time, TDRE is automatically cleared to 0, and data is transferred from ICDRT to ICDRS. TDRE is set again.
4. When transmission of one byte data is completed while TDRE is 1, TEND in ICSR is set to 1 at the rise of the 9th transmit clock pulse. Read the ACKBR bit in ICIER, and confirm that the slave device has been selected. Then, write second byte data to ICDRT. When ACKBR is 1, the slave device has not been acknowledged, so issue the stop condition. To issue the stop condition, write 0 to BBSY and SCP using MOV instruction. SCL is fixed low until the transmit data is prepared or the stop condition is issued.
5. The transmit data after the second byte is written to ICDRT every time TDRE is set.
6. Write the number of bytes to be transmitted to ICDRT. Wait until TEND is set (the end of last byte data transmission) while TDRE is 1, or wait for NACK (NACKF in ICSR = 1) from the receive device while ACKE in ICIER is 1. Then, issue the stop condition to clear TEND or NACKF.
7. When the STOP bit in ICSR is set to 1, the operation returns to the slave receive mode.

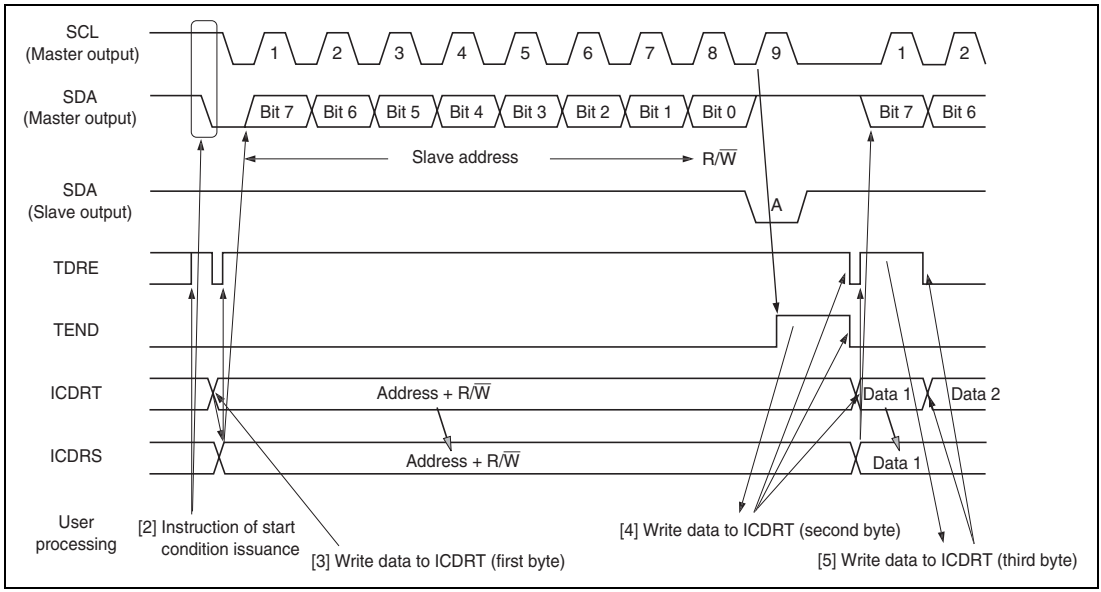


Figure 21.5 Master Transmit Mode Operation Timing (1)

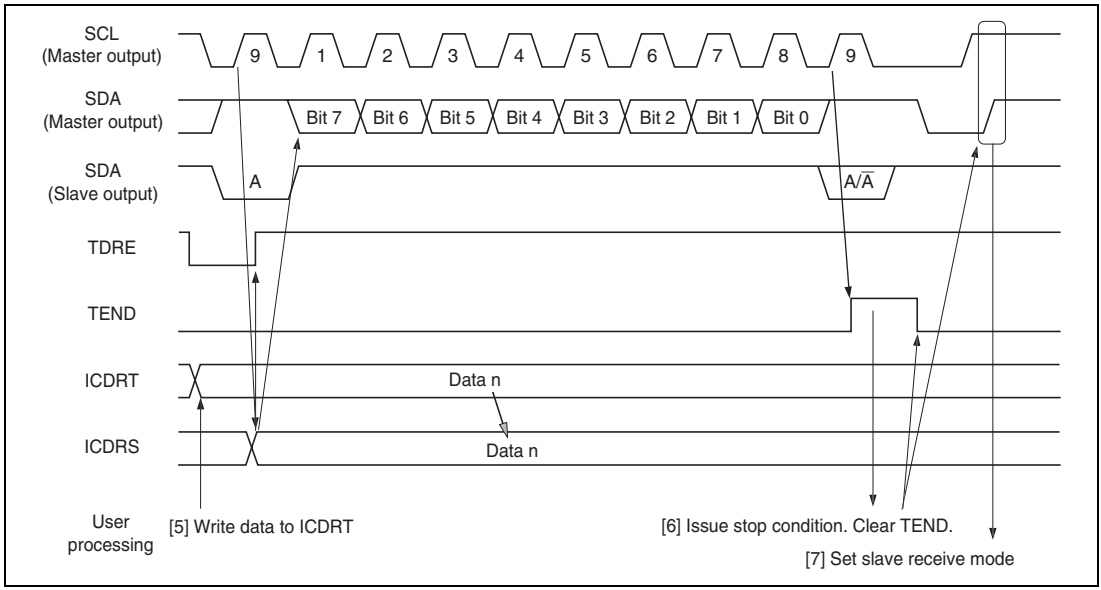


Figure 21.6 Master Transmit Mode Operation Timing (2)

21.3.3 Master Receive Operation

In master receive mode, the master device outputs the receive clock, receives data from the slave device, and returns an acknowledge signal. For master receive mode operation timing, see figures 21.7 and 21.8. The reception procedure and operations in master receive mode are shown below.

1. Clear the TEND bit in ICSR to 0, then clear the TRS bit in ICCR1 to 0 to switch from master transmit mode to master receive mode. Then, clear the TDRE bit to 0.
2. When ICDRR is read (dummy read), reception is started. And the receive clock is output to receive data in synchronization with the internal clock. The master device outputs the level specified by ACKBT in ICIER to SDA at the 9th receive clock pulse.
3. After the reception of first frame data is completed, the RDRF bit in ICSR is set to 1 at the rise of 9th receive clock pulse. At this time, the receive data is read by reading ICDRR, and RDRF is cleared to 0.
4. The continuous reception is performed by reading ICDRR every time RDRF is set. If 8th receive clock pulse falls after reading ICDRR by the other processing while RDRF is 1, SCL is fixed low until ICDRR is read.
5. If next frame is the last receive data, set the RCVD bit in ICCR1 to 1 before reading ICDRR. This enables the issuance of the stop condition after the next reception.
6. When the RDRF bit is set to 1 at rise of the 9th receive clock pulse, issue the stop condition.
7. When the STOP bit in ICSR is set to 1, read ICDRR. Then clear the RCVD bit to 0.
8. The operation returns to the slave receive mode.

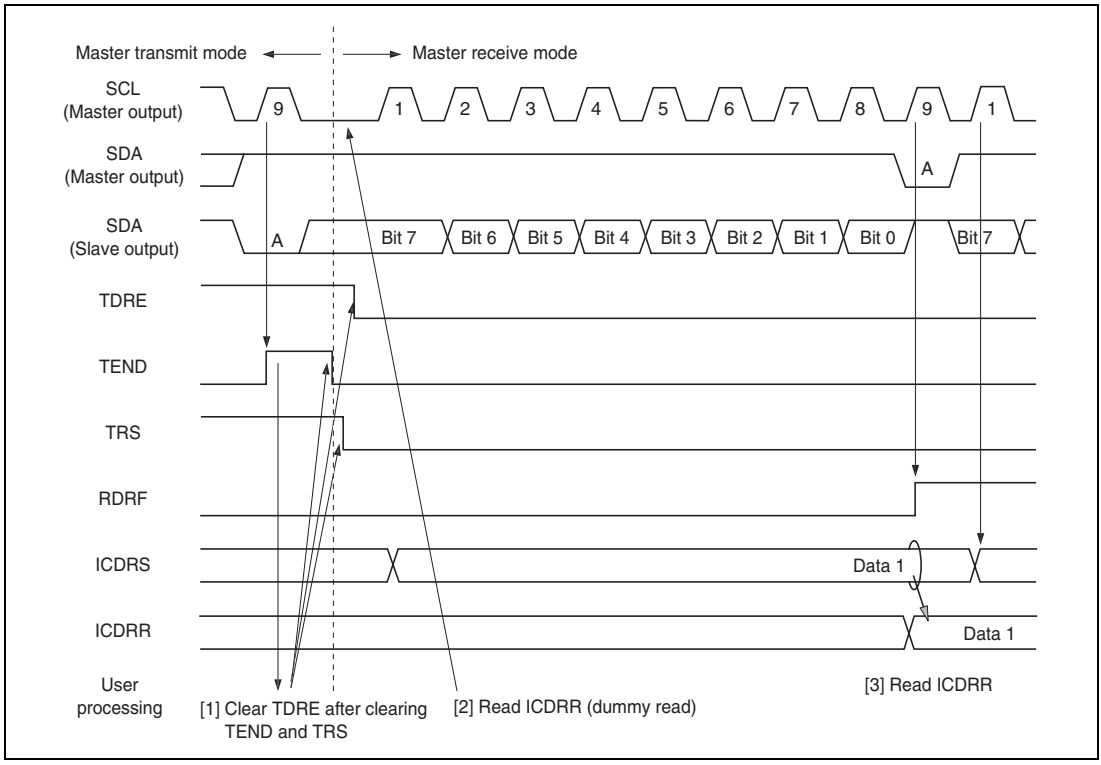


Figure 21.7 Master Receive Mode Operation Timing (1)

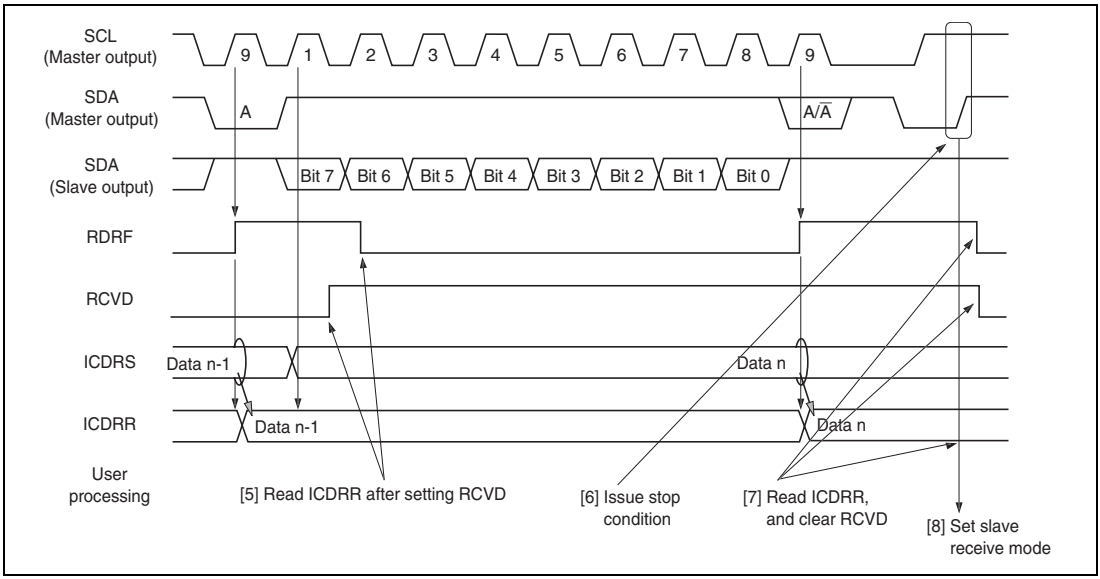


Figure 21.8 Master Receive Mode Operation Timing (2)

21.3.4 Slave Transmit Operation

In slave transmit mode, the slave device outputs the transmit data while the master device outputs the receive clock and returns an acknowledge signal. For slave transmit mode operation timing, see figures 21.9 and 21.10.

The transmission procedure and operations in slave transmit mode are described below.

1. Set the ICE bit in ICCR1 to 1. Set the MLS and WAIT bits in ICMR and the CKS3 to CKS0 bits in ICCR1 to 1 (Initial setting). Set the MST and TRS bits in ICCR1 to select slave receive mode, and wait until the slave address matches.
2. When the slave address matches in the first frame following detection of the start condition, the slave device outputs the level specified by ACKBT in ICIER to SDA at the rise of the 9th clock pulse. At this time, if the 8th bit data (R/$\overline{W}$) is 1, the TRS and ICSR bits in ICCR1 are set to 1, and the mode changes to slave transmit mode automatically. The continuous transmission is performed by writing transmit data to ICDRT every time TDRE is set.
3. If TDRE is set after writing last transmit data to ICDRT, wait until TEND in ICSR is set to 1, with TDRE = 1. When TEND is set, clear TEND.
4. Clear TRS for the end processing, and read ICDRR (dummy read). SCL is released.
5. Clear TDRE.

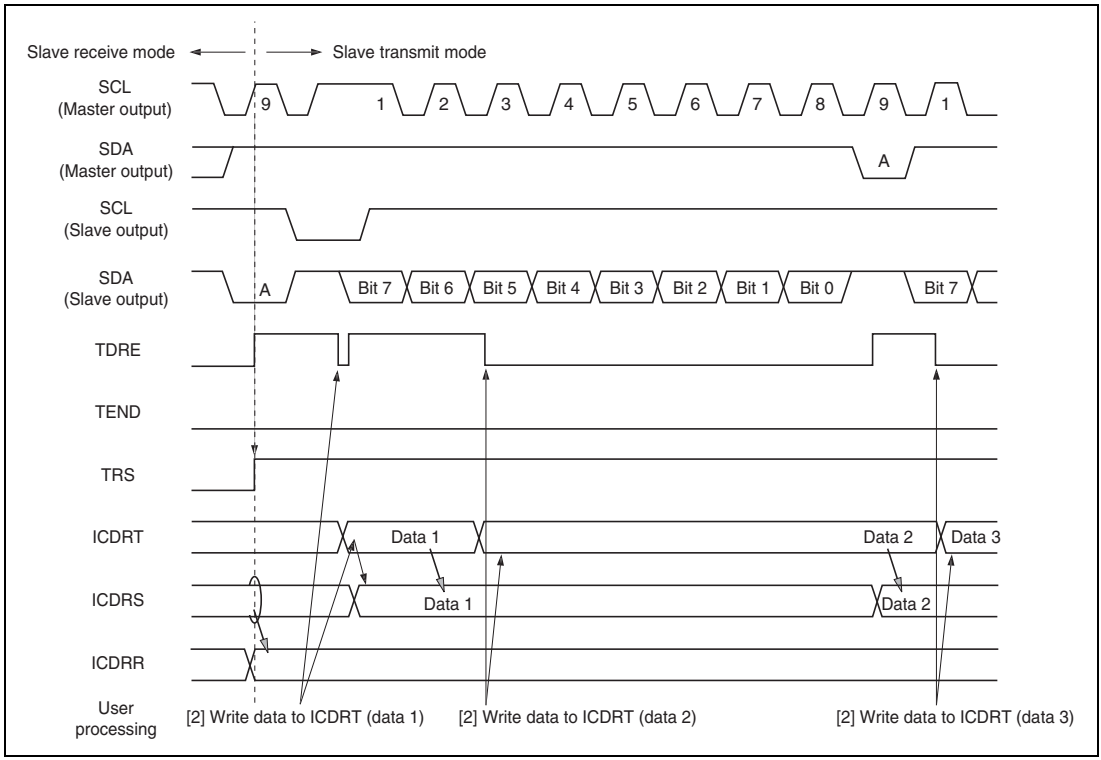


Figure 21.9 Slave Transmit Mode Operation Timing (1)

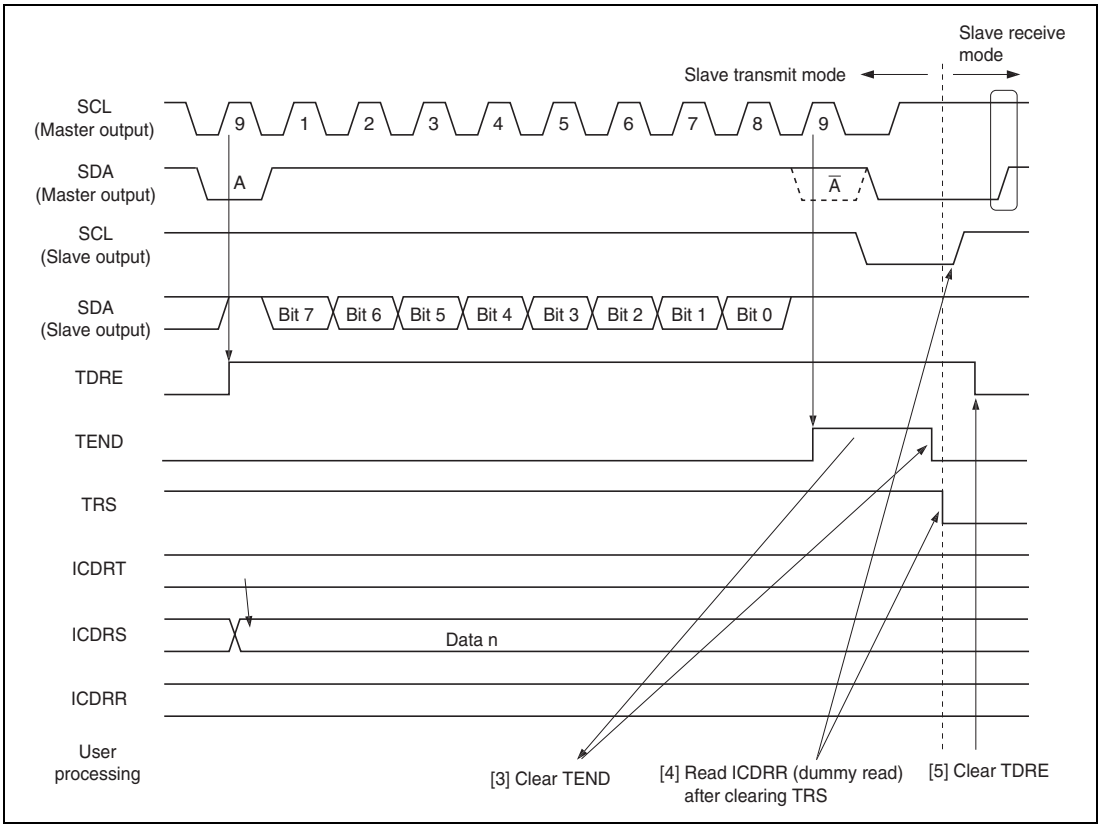


Figure 21.10 Slave Transmit Mode Operation Timing (2)

21.3.5 Slave Receive Operation

In slave receive mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal. For slave receive mode operation timing, see figures 21.11 and 21.12. The reception procedure and operations in slave receive mode are described below.

1. Set the ICE bit in ICCR1 to 1. Set the MLS and WAIT bits in ICMR and the CKS3 to CKS0 bits in ICCR1 to 1. (Initial setting) Set the MST and TRS bits in ICCR1 to select slave receive mode, and wait until the slave address matches.
2. When the slave address matches in the first frame following detection of the start condition, the slave device outputs the level specified by ACKBT in ICIER to SDA at the rise of the 9th clock pulse. At the same time, RDRF in ICSR is set to read ICDRR (dummy read). (Since the read data show the slave address + R/$\overline{W}$, it is not used.)
3. Read ICDRR every time RDRF is set. If 8th receive clock pulse falls while RDRF is set to 1, SCL is fixed low until ICDRR is read. The change of the acknowledge before reading ICDRR, which is returned to the master device, is reflected to the next transmit frame.
4. The last byte data is read by reading ICDRR.

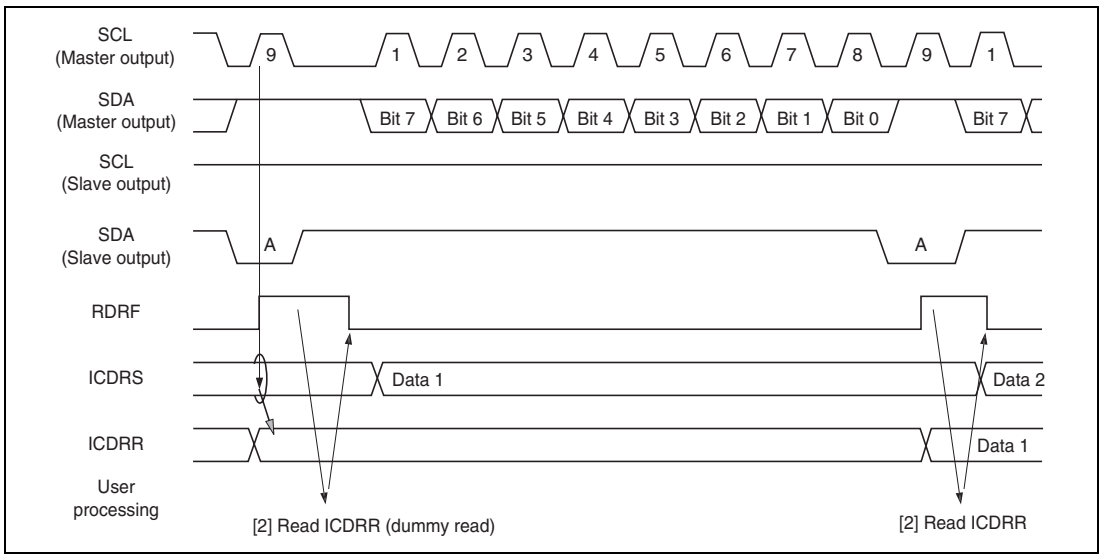


Figure 21.11 Slave Receive Mode Operation Timing (1)

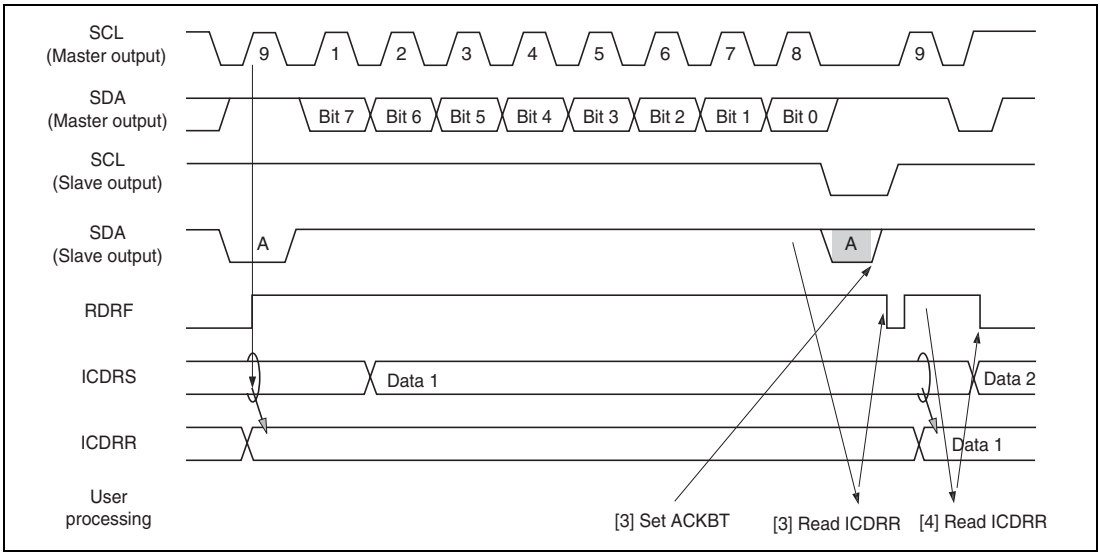


Figure 21.12 Slave Receive Mode Operation Timing (2)

21.3.6 Clock Synchronous Serial Format

This module can be operated with the clock synchronous serial format by setting the FS bit in SAR to 1. When the MST bit in ICCR1 is 1, the transfer clock output from SCL is selected. When MST is 0, the external clock input is selected.

(1) Data Transfer Format

Figure 21.13 shows the clock synchronous serial transfer format.

The transfer data is output from the rise to the fall of the SCL clock, and the data at the rising edge of the SCL clock is guaranteed. The MLS bit in ICMR sets the order of data transfer: in either the MSB first or LSB first. The output level of SDA can be changed during the transfer wait by the SDAO bit in ICCR2.

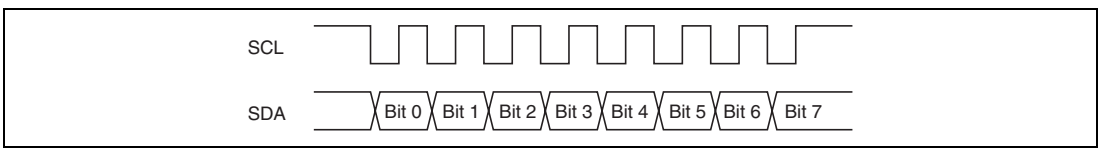


Figure 21.13 Clock Synchronous Serial Transfer Format

(2) Transmit Operation

In transmit mode, transmit data is output from SDA in synchronization with the fall of the transfer clock. The transfer clock is output when MST in ICCR1 is 1 and is input when MST is 0. For transmit mode operation timing, see figure 21.14. The transmission procedure and operations in transmit mode are described below.

1. Set the ICE bit in ICCR1 to 1. Set the MST and CKS3 to CKS0 bits in ICCR1 to 1 (Initial setting).
2. Set the TRS bit in ICCR1 to select the transmit mode. Then, TDRE in ICSR is set.
3. Confirm that TDRE has been set. Then, write the transmit data to ICDRT. The data is transferred from ICDRT to ICDRS, and TDRE is set automatically. The continuous transmission is performed by writing data to ICDRT every time TDRE is set. When changing from transmit mode to receive mode, clear TRS while TDRE is set to 1.

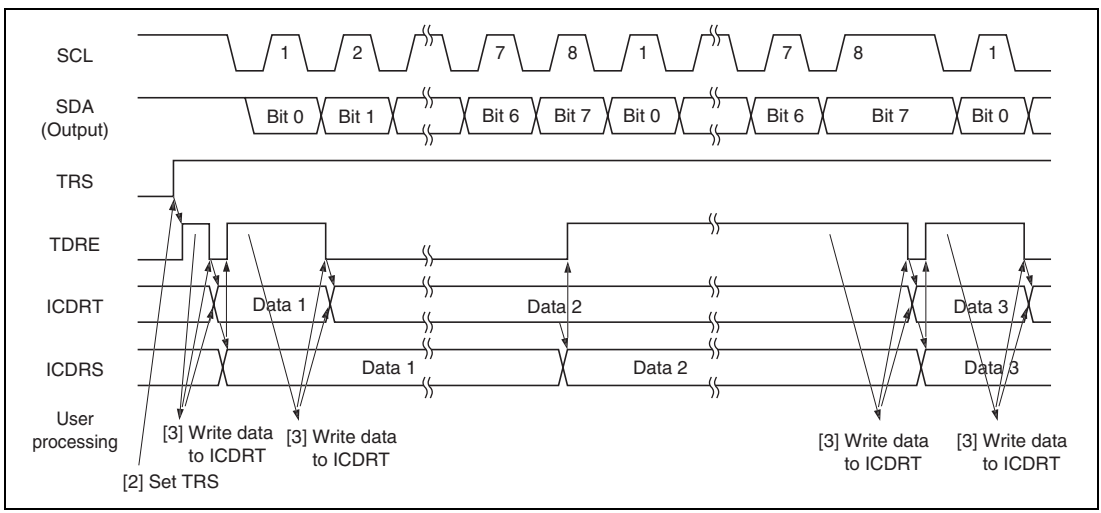


Figure 21.14 Transmit Mode Operation Timing

(3) Receive Operation

In receive mode, data is latched at the rise of the transfer clock. The transfer clock is output when MST in ICCR1 is 1 and is input when MST is 0. For receive mode operation timing, see figure 21.15. The reception procedure and operations in receive mode are described below.

1. Set the ICE bit in ICCR1 to 1. Set the MST and CKS3 to CKS0 bits in ICCR1 to 1 (Initial setting).
2. When the transfer clock is output, set MST to 1 to start outputting the receive clock.
3. When the receive operation is completed, data is transferred from ICDRS to ICDRR and RDRF in ICSR is set. When MST = 1, the next byte can be received, so the clock is continually output. The continuous reception is performed by reading ICDRR every time RDRF is set. When the 8th clock is risen while RDRF is set to 1, the overrun is detected and AL/OVE in ICSR is set. At this time, the previous reception data is retained in ICDRR.
4. To stop receiving when MST = 1, read ICDRR after setting RCVD in ICCR1 to 1. Then, SCL is fixed high after receiving the next byte data.

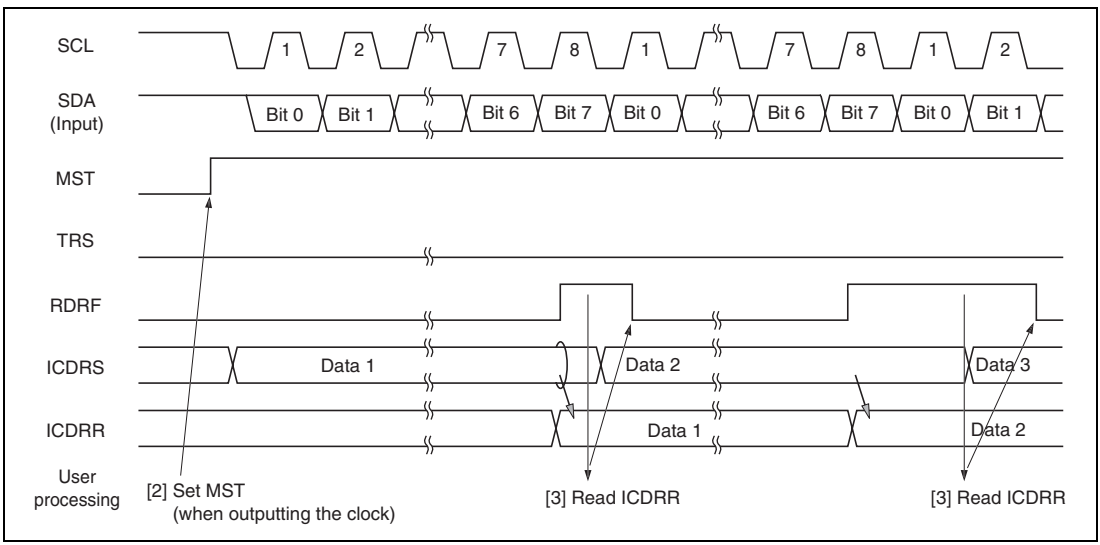


Figure 21.15 Receive Mode Operation Timing

21.3.7 Noise Filter Circuit

The signal state on the SCL and SDA pins are internally latched via the noise filter circuit. Figure 21.16 shows a block diagram of the noise filter circuit.

The noise filter consists of two cascaded latches and a match detector. The SCL (or SDA) input signal is sampled on the system clock. When both outputs of the latches match, its level is output to other blocks by the match detector circuit. If they do not match, the previous value is held.

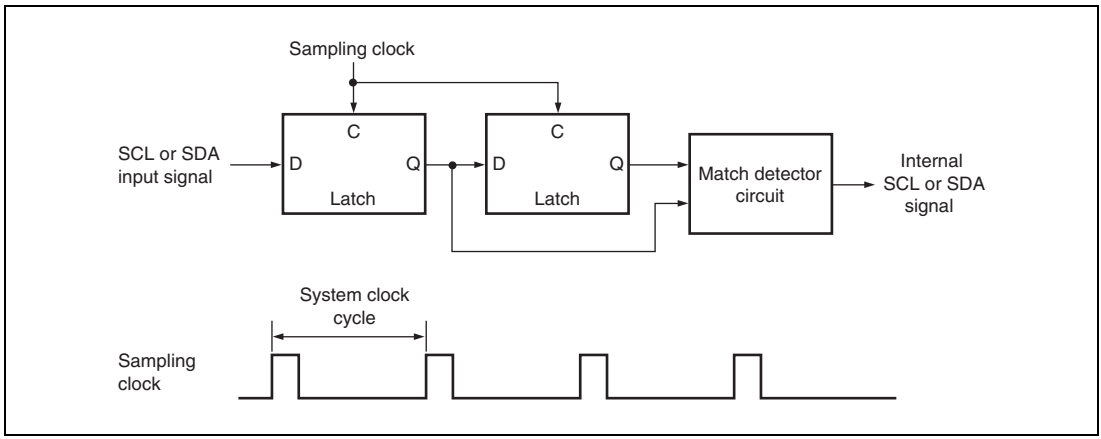


Figure 21.16 Block Diagram of Noise Filter Circuit

21.3.8 Example of Use

Flowcharts in respective modes that use the I²C bus interface 2 are shown in figures 21.17 to 21.20.

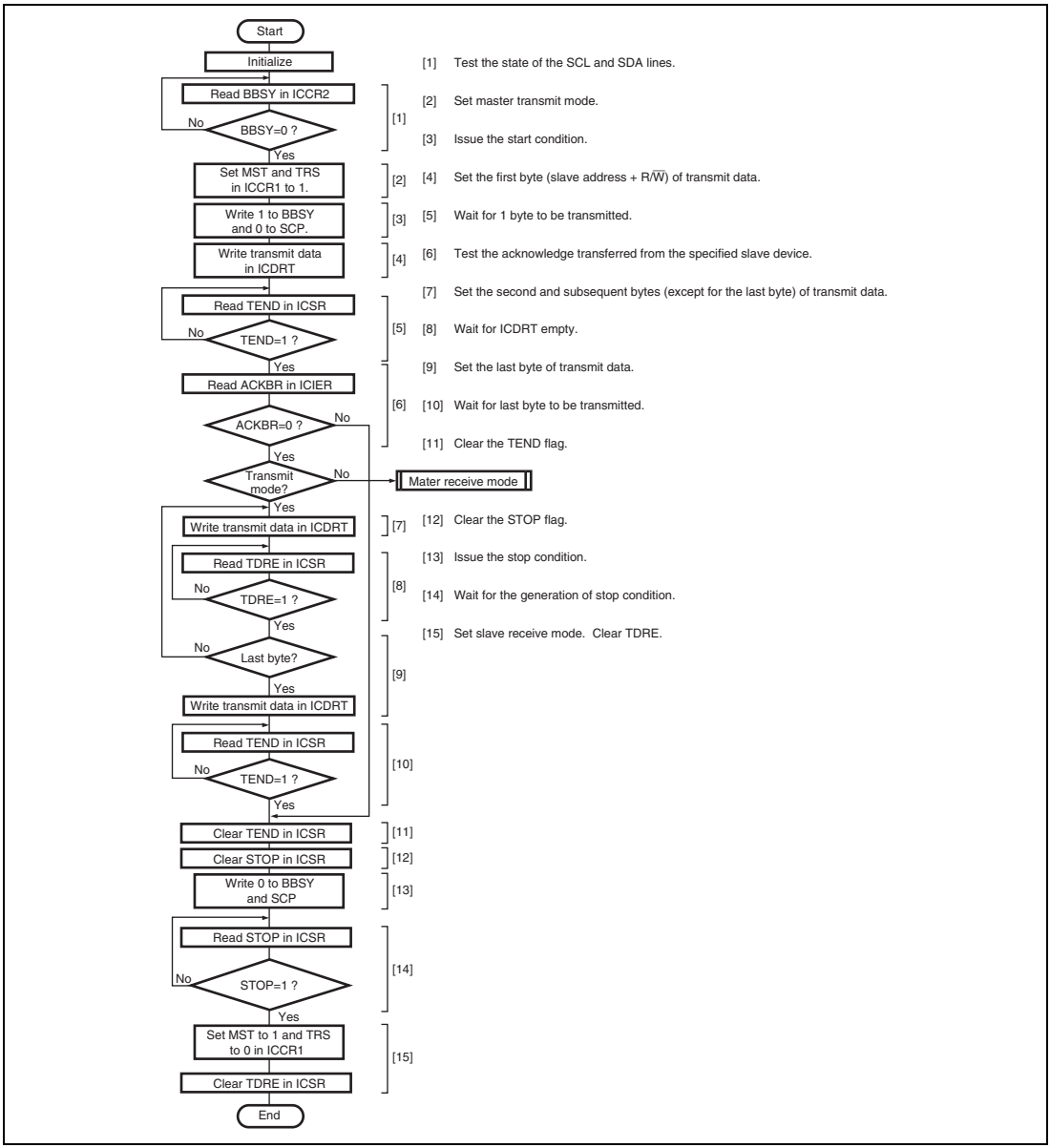
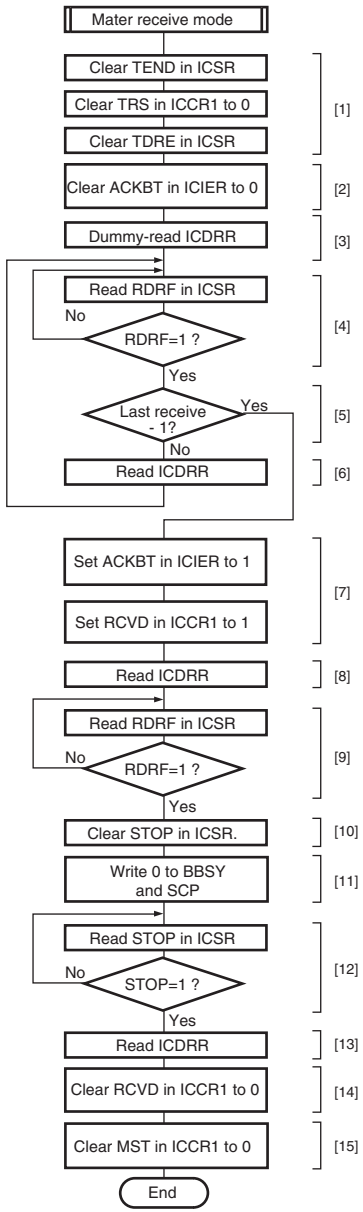


Figure 21.17 Sample Flowchart for Master Transmit Mode



[1] Clear TEND, select master receive mode, and then clear TDRE.*

[2] Set acknowledge to the transmit device.*

[3] Dummy-read ICDDR.*

[4] Wait for 1 byte to be received

[5] Check whether it is the (last receive - 1).

[6] Read the receive data.

[7] Set acknowledge of the last byte. Disable continuous reception (RCVD = 1).

[8] Read the (last byte - 1) of receive data.

[9] Wait for the last byte to be receive.

[10] Clear the STOP flag.

[11] Issue the stop condition.

[12] Wait for the generation of stop condition.

[13] Read the last byte of receive data.

[14] Clear RCVD.

[15] Set slave receive mode.

Note: Do not activate an interrupt during the execution of steps [1] to [3].

Supplementary explanation: When one byte is received, steps [2] to [6] are skipped after step [1] before jumping to step [7]. The step [8] is dummy-read in ICDRR.

Figure 21.18 Sample Flowchart for Master Receive Mode

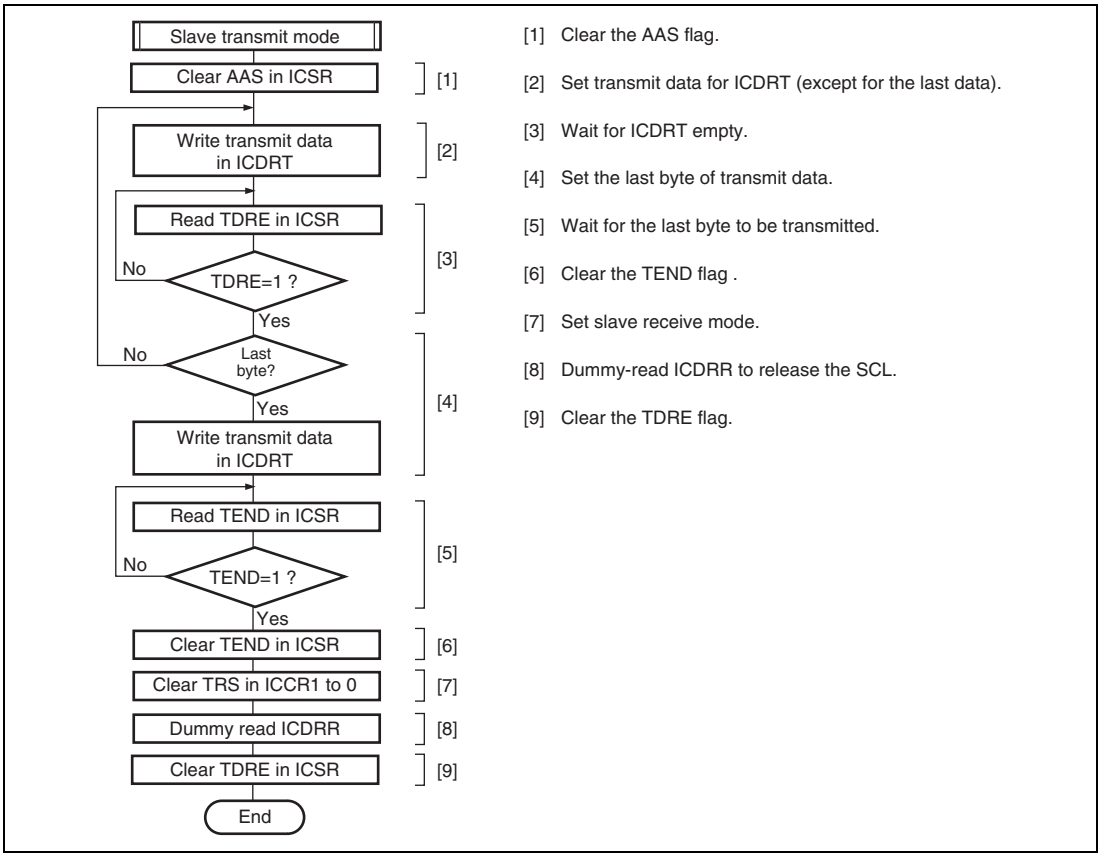
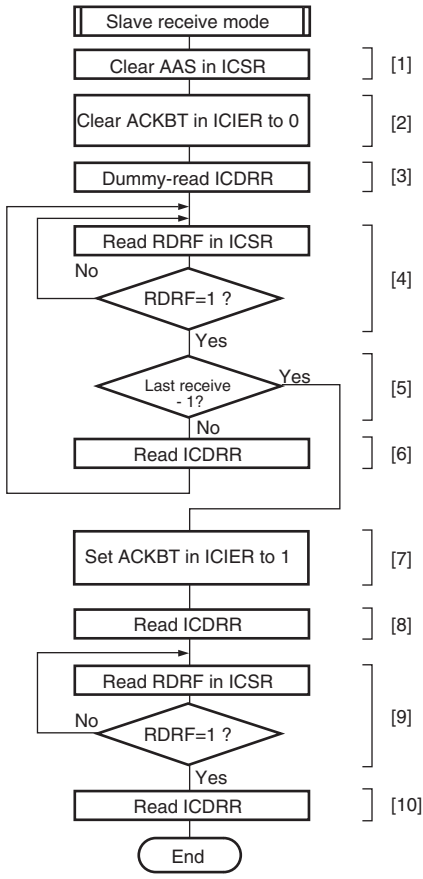


Figure 21.19 Sample Flowchart for Slave Transmit Mode



[1] Clear the AAS flag.

[2] Set acknowledge to the transmit device.

[3] Dummy-read ICDRR.

[4] Wait for 1 byte to be received.

[5] Check whether it is the (last receive - 1).

[6] Read the receive data.

[7] Set acknowledge of the last byte.

[8] Read the (last byte - 1) of receive data.

[9] Wait the last byte to be received.

[10] Read for the last byte of receive data.

Supplementary explanation: When one byte is received, steps [2] to [6] are skipped after step [1] before jumping to step [7]. The step [8] is dummy-read in ICDRR.

Figure 21.20 Sample Flowchart for Slave Receive Mode

21.4 Interrupt Request

There are six interrupt requests in this module; transmit data empty, transmit end, receive data full, NACK detection, STOP condition detection, and arbitration lost/overrun error. Table 21.3 shows the contents of each interrupt request.

Table 21.3 Interrupt Requests

Interrupt Request	Abbreviation	Interrupt Condition	I²C Mode	Clock Synchronous Mode
Transmit Data Empty	TXI	(TDRE=1) • (TIE=1)	O	O
Transmit End	TEI	(TEND=1) • (TEIE=1)	O	O
Receive Data Full	RXI	(RDRF=1) • (RIE=1)	O	O
STOP Condition Detection	STPI	(STOP=1) • (STIE=1)	O	×
NACK Detection	NAKI	{(NACKF=1)+(AL=1)} • (NAKIE=1)	O	×
Arbitration Lost/ Overrun Error			O	O

When an exception processing is executed under interrupt conditions described in table 21.3, interrupt sources should be cleared in the exception processing. TDRE and TEND are automatically cleared to 0 by writing the transmit data to ICDRT. RDRF are automatically cleared to 0 by reading ICDRR. TDRE is set to 1 again at the same time when transmit data is written to ICDRT. When TDRE is cleared to 0, then an excessive data of one byte may be transmitted.

The DTC can be activated by a TXI interrupt request to transfer data. The TDRE flag is automatically cleared upon data transfer by the DTC. The DTC can also be activated by an RXI interrupt request to transfer data. The RDRF flag is automatically cleared to 0 upon data transfer by the DTC.

21.5 Bit Synchronous Circuit

In master mode, this module has a possibility that high level period may be shortened in the two states described below.

- When SCL is driven to low by the slave device
- When the rising speed of SCL is lowered by the load of the SCL line (load capacitance or pull-up resistance)

Therefore, it monitors SCL and communicates by bit with synchronization.

Figure 21.21 shows the timing of the bit synchronous circuit and table 21.4 shows the time when SCL output changes from low to Hi-Z and then SCL is monitored.

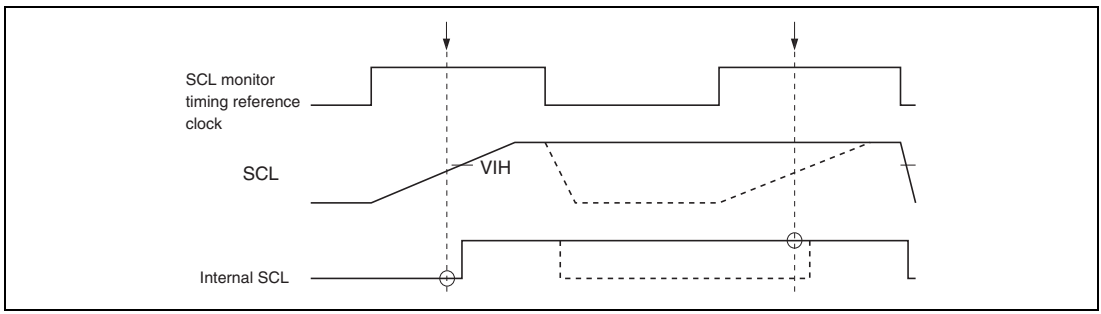


Figure 21.21 The Timing of the Bit Synchronous Circuit

Table 21.4 Time for Monitoring SCL

CKS3	CKS2	Time for Monitoring SCL
0	0	7.5 tcyc
	1	19.5 tcyc
1	0	17.5 tcyc
	1	41.5 tcyc

21.6 Usage Notes

21.6.1 SCL and SDA pins selected by PMC

This LSI incorporates the IIC2 and SSU modules, one of which module functions should be selected by the SELICSU bit in ICSUSR. Therefore, when assigning the pin functions using the peripheral function mapping controller (PMC), the SCL and SDA pin functions should be assigned to the P56 and P57 pins when the IIC2 function is selected. If these pin functions are assigned to other pins, correct operation cannot be guaranteed.

21.6.2 Restriction on Use of Bit Manipulation Instructions to Set MST and TRS in Multi-Master Usage

When master transmission is selected by consecutively manipulating the MST and TRS bits in multi-master usage, an arbitration loss during execution of the bit-manipulation instruction for TRS leads to the contradictory situation where AL in ICSR is 1 in master transmit mode (MST = 1, TRS = 1).

Ways to avoid this effect are listed below.

- Use the MOV instruction to set MST and TRS when used in multi-master mode.
- When arbitration is lost, confirm that MST = 0 and TRS = 0. If the setting of MST = 0 and TRS = 0 is not confirmed, then set MST = 0 and TRS = 0 again.

Section 22 Synchronous Serial Communication Unit (SSU)

Note: In this section, the synchronous serial communication unit is abbreviated as SSU for convenience.

The synchronous serial communication unit (SSU) can handle clocked synchronous serial data communication.

Figure 22.1 shows a block diagram of the SSU.

Either the SSU or IIC2 incorporated in this LSI can be used at a time. Accordingly, when the SSU function is used, the IIC2 function is not available.

22.1 Features

- Can be operated in clocked synchronous communication mode or four-line bus communication mode (including bidirectional communication mode)
- Can be operated as a master or a slave device
- Choice of seven internal clocks (φ/256, φ/128, φ/64, φ/32, φ/16, φ/8, φ/4) and an external clock as a clock source
- Clock polarity and phase of SSCK can be selected
- Choice of data transfer direction (MSB-first or LSB-first)
- Receive error detection: overrun error
- Multimaster error detection: conflict error
- Five interrupt sources: transmit-end, transmit-data-empty, receive-data-full, overrun error, and conflict error. The DTC can be activated by the transmit-data-empty and receive-data-full interrupts.
- The transmitter and receiver with buffer structure allow continuous transmission and reception of serial data.

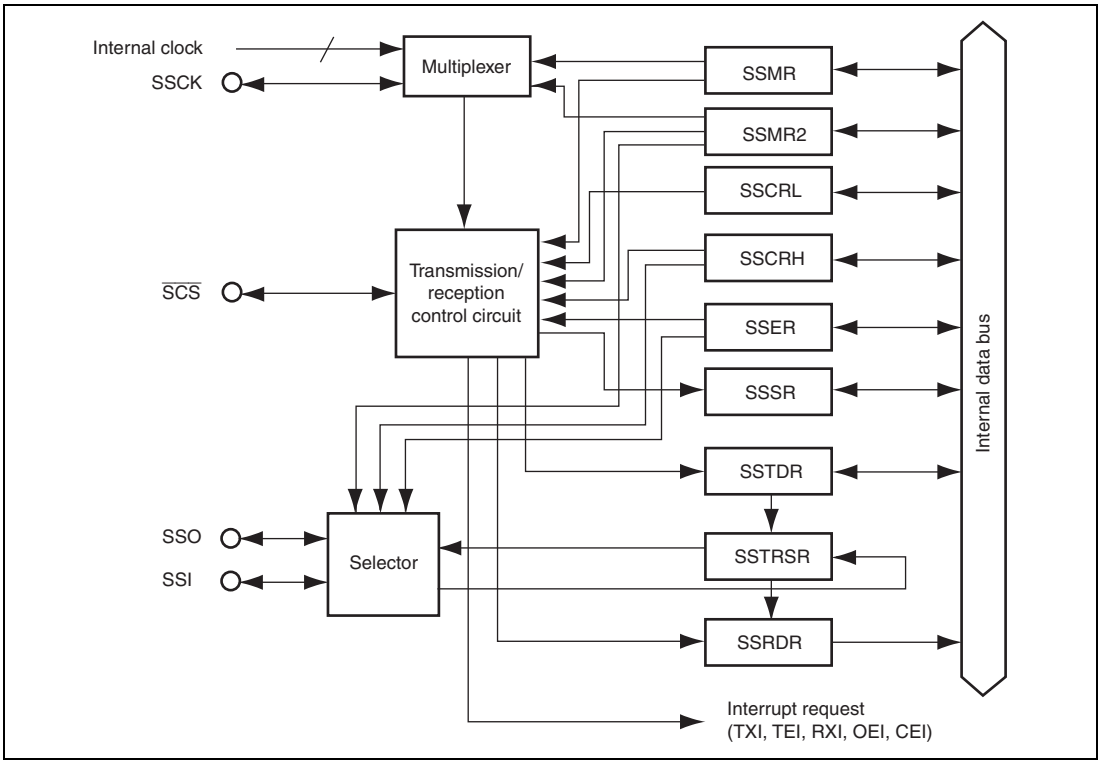


Figure 22.1 Block Diagram of SSU

Table 22.1 shows the pin configuration of the SSU.

Table 22.1 Pin Configuration

Pin Name	I/O	Function
SSCK	I/O	SSU clock input/output
SSI	I/O	SSU data input/output
SSO	I/O	SSU data input/output
$\overline{\text{SCS}}$	I/O	SSU chip select input/output

22.2 Register Descriptions

The SSU has the following registers.

- IIC2/SSU select register (ICSUSR)
- SS control register H (SSCRH)
- SS control register L (SSCRL)
- SS mode register (SSMR)
- SS mode register 2 (SSMR2)
- SS enable register (SSER)
- SS status register (SSSR)
- SS receive data register (SSRDR)
- SS transmit data register (SSTDR)
- SS shift register (SSTRSR)

22.2.1 IIC2/SSU Select Register (ICSUSR)

Address: H'FF000B

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

Bit	Symbol	Bit Name	Description	R/W
7 to 1	—	Reserved	These bits are read as 0. The write value should be 0.	—
0	SELICSU	IIC2/SSU module function select	0: IIC2 function is selected. 1: SSU function is selected.*	R/W

Note: * To select the SSU function, this bit should be set to 1 without fail.

22.2.2 SS Control Register H (SSCRH)

Address: H'FF05C8

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	RSSTP	MSB	—	—	CKS[2:0]		
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 0. The write value should be 0.	—
6	RSSTP	Receive single stop	0: After receiving 1 byte of data, reception continues. 1: After receiving 1 byte of data, reception ends.*	R/W
5	MSS	Master/slave device select	0: Operates as a slave device 1: Operates as a master device	R/W
4, 3	—	Reserved	These bits are read as 0. The write value should be 0.	—
2 to 0	CKS[2:0]	Transfer clock rate select	000: ϕ/256 001: ϕ/128 010: ϕ/64 011: ϕ/32 100: ϕ/16 101: ϕ/8 110: ϕ/4 111: Reserved	R/W

Note: * The setting of the RSSTP bit is invalid when the MSS bit is cleared to 0.

- MSS bit (master/slave device select)

  Selects whether this module is used as a master device or a slave device. When this module is used as a master device, transfer clock is output from the SSCK pin. When the CE bit in SSSR is set, this bit is automatically cleared.

- CKS[2:0] bits (transfer clock rate select)

  Sets transfer clock rate (prescaler division ratio) when the internal clock is selected.

22.2.3 SS Control Register L (SSCRL)

Address: H'FF05C9

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	SOL	SOLP	—	—	SRES	—
Value after reset:	0	1	1	1	1	1	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 0. The write value should be 0.	—
6	—	Reserved	This bit is read as 1. The write value should be 1.	—
5	SOL*[1]	Serial data output level setting	0: When reading, serial data output level is low. When writing, serial data output level is changed to low. 1: When reading, serial data output level is high. When writing, serial data output level is changed to high.	R/W
4	SOLP	SOL write protect	0: When writing, output level can be changed according to the value of the SOL bit. 1: When reading, this bit is always read as 1. When writing, modifying to the SOL bit is invalid.	—
3, 2	—	Reserved	These bits are read as 1. The write value should be 1.	—
1	SRES	Software reset	0: Does not reset. 1: The SSU internal sequencer is forcibly reset.*[2]	
0	—	Reserved	This bit is read as 1. The write value should be 1.	—

Note: 1. When the output level is changed, the SOLP bit (bit4) should be cleared to 0 and the MOV instruction should be used. If this bit is written during data transfer, erroneous operation may occur. Therefore this bit must not be manipulated during transmission.
2. This bit should always be cleared by software as this bit is not cleared automatically.

- SOL bit (serial data output level setting)

  Although the value in the last bit of transmit data is retained in the serial data output after the end of transmission, the output level of serial data can be changed by manipulating this bit before or after transmission.

- SOLP bit (SOL write protect)

  When output level of serial data is changed, the MOV instruction is used to set the SOL bit to 1 and clear this bit to 0 or to clear the SOL bit and this bit to 0.

- SRES bit (software reset)

  When this bit is set to 1, the SSU internal sequencer is forcibly reset. The register value in the SSU is retained.

22.2.4 SS Mode Register (SSMR)

Address: H'FF05CA

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	MLS	CPOS	CPHS	—	—	BC[2:0]		
Value after reset:	0	0	0	1	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	MLS	MSB-first/LSB-first select	0: Transfer by MSB-first 1: Transfer by LSB-first	R/W
6	CPOS	Clock polarity select	0: SSCK clock idling state = high 1: SSCK clock idling state = low	R/W
5	CPHS	Clock phase select	0: Data change at first edge 1: Data latch at first edge	R/W
4, 3	—	Reserved	This bit is read as 1. The write value should be 1.	—
2 to 0	BC[2:0]	Bit counter 2 to 0	000: 8 bits 001: 1 bit 010: 2 bits 011: 3 bits 100: 4 bits 101: 5 bits 110: 6 bits 111: 7 bits	R/W

- BC[2:0] bits (bit counter 2 to 0)

  When read, the remaining number of transfer bits is indicated.

22.2.5 SS Mode Register 2 (SSMR2)

Address: H'FF05CD

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	BIDE	SCKS	CSS[1:0]		SCKOS	SOOS	CSOS	SSUMS
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	BIDE	Bidirectional mode enable	0: Normal mode. Communication is performed by using two pins. 1: Bidirectional mode. Communication is performed by using only one pin.	R/W
6	SCKS	SSCK pin select	0: Functions as a port*1 1: Functions as a serial clock pin	R/W
5, 4	CSS[1:0]	$\overline{\text{SCS}}$ pin select	00: Functions as a port*1 01: Functions as an $\overline{\text{SCS}}$ input 1X: Functions as an $\overline{\text{SCS}}$ output (however, functions as an $\overline{\text{SCS}}$ input before starting transfer)	R/W
3	SCKOS	SSCK pin open-drain output select	0: CMOS output 1: NMOS open-drain output*2	R/W
2	SOOS	SSO pin open-drain output select	0: CMOS output 1: NMOS open-drain output*2	R/W
1	CSOS	$\overline{\text{SCS}}$ pin open-drain output select	0: CMOS output 1: NMOS open-drain output*2	R/W

Bit	Symbol	Bit Name	Description	R/W
0	SSUMS	SSU mode select	0: Clocked synchronous communication mode Data input: SSI pin, Data output: SSO pin 1: Four-line bus communication mode When MSS = 1 in SSCRH and BIDE = 0 in SSMR2: Data input: SSI pin, Data output: SSO pin When MSS = 0 in SSCRH and BIDE = 0 in SSMR2: Data input: SSO pin, Data output: SSI pin When BIDE = 1 in SSMR2: Data input and output: SSO pin	R/W

[Legend]

X: Don't care.

Note: 1. To function these pins as ports, clear the PMR bit corresponding to the pin to 0.

2. If the NMOS open-drain output is selected, use the PMC to allocate the pin from port 5. If the pin is allocated from a port other than port 5, only the CMOS output can be selected.

- BIDE bit (bidirectional mode enable)

  Selects whether the serial data input pin and the output pin are both used or only one pin is used. For details, see section 22.3.3, Relationship between Data Input/Output Pin and Shift Register. When the SSUMS bit in SSMR2 is 0, this setting is invalid.

- SCKS bit (SSCK pin select)

  Selects whether the SSCK pin functions as a port or a serial clock pin.

- CSS[1:0] bits ($\overline{\text{SCS}}$ pin select)

  Selects whether the $\overline{\text{SCS}}$ pin functions as a port, an $\overline{\text{SCS}}$ input, or $\overline{\text{SCS}}$ output. When the SSUMS bit in SSMR2 is 0, the $\overline{\text{SCS}}$ pin functions as a port regardless of the setting of this bit.

- SOOS bit (SSO pin open-drain output select)

  Selects whether the serial data output pin is CMOS output or NMOS open-drain output. The serial data output pin is changed according to the register setting value. For details, see section 22.3.3, Relationship between Data Input/Output Pin and Shift Register.

- SSUMS bit (SSU mode select)

  Selects which combination of the serial data input pin and serial data output pin is used.

  For details, see section 22.3.3, Relationship between Data Input/Output Pin and Shift Register.

22.2.6 SS Enable Register (SSER)

Address: H'FF05CB

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TIE	TEIE	RIE	TE	RE	—	—	CEIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TIE	Transmit interrupt enable	0: A TXI interrupt request is disabled. 1: A TXI interrupt request is enabled.	R/W
6	TEIE	Transmit end interrupt enable	0: A TEI interrupt request is disabled. 1: A TEI interrupt request is enabled.	R/W
5	RIE	Receive interrupt enable	0: An RXI and an OEI interrupt requests are disabled. 1: An RXI and an OEI interrupt requests are enabled.	R/W
4	TE*	Transmit enable	0: Transmit operation is disabled. 1: Transmit operation is enabled.	R/W
3	RE*	Receive enable	0: Receive operation is disabled. 1: Receive operation is enabled.	R/W
2, 1	—	Reserved	These bits are read as 0. The write value should be 0.	—
0	CEIE	Conflict error interrupt enable	0: A CEI interrupt request is disabled. 1: A CEI interrupt request is enabled.	R/W

Note: * The TE and RE bits are reset in standby mode.

22.2.7 SS Status Register (SSSR)

Address: H'FF05CC

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TDRE	TEND	RDRF	—	—	ORER	—	CE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	TDRE	Transmit data empty flag	[Setting conditions] • When the TE bit in SSER is 0 • When data transfer is performed from SSTDR to SSTRSR and data can be written in SSTDR [Clearing conditions] • When 0 is written to this bit after reading 1 • When data is written in SSTDR • When the DTC transfers data to SSTDR by a TXI interrupt request, and the DTC settings satisfy the flag clearing conditions.*	R/W
6	TEND	Transmit end flag	[Setting condition] • When the last bit of data is transmitted, the TDRE bit is 1 [Clearing conditions] • When 0 is written to this bit after reading 1 • When data is written in SSTDR	R/W
5	RDRF	Receive data register full flag	[Setting condition] • When serial reception is completed normally and receive data is transferred from SSTRSR to SSRDR [Clearing conditions] • When 0 is written to this bit after reading 1 • When data is read from SSRDR • When the DTC transfers data to SSRDR by an RXI interrupt request, and the DTC settings satisfy the flag clearing conditions.*	R/W

Bit	Symbol	Bit Name	Description	R/W
4, 3	—	Reserved	These bits are read as 0. The write value should be 0.	—
2	ORER	Overrun error flag	[Setting condition] • When the next serial reception is completed while RDRF = 1 [Clearing condition] • When 0 is written to this bit after reading 1	R/W
1	—	Reserved	These bits are read as 0. The write value should be 0.	—
0	CE	Conflict error flag	[Setting conditions] • When serial communication is started while SSUMS = 1 in SSMR2 and MSS = 1 in SSCRH, the $\overline{SCS}$ pin input is low • When the $\overline{SCS}$ pin level changes from low to high during transfer while SSUMS = 1 in SSMR2 and MSS = 0 in SSCRH [Clearing condition] • When 0 is written to this bit after reading 1	R/W

Notes: In standby mode, SSSR is reset.

* The DTC clears the peripheral module flags when all of the following three conditions are satisfied.

1. When the DISEL bit is 0.
2. When the transfer counter (DTC transfer count register A (CRA) in normal mode and repeat mode, or DTC transfer count register B (CRB) in block mode) is not 0.
3. When chain transfer is not used.

- ORER bit (overrun error flag)

  Indicates that the RDRF bit is abnormally terminated in reception because an overrun error has occurred. SSRDR retains received data before the overrun error occurs and the received data after the overrun error occurs is lost. When this bit is set to 1, subsequent serial reception cannot be continued. When the MSS bit in SSCRH is 1, this is also applied to serial transmission.

22.2.8 SS Receive Data Register (SSRDR)

Address: H'FF05CF

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

SSRDR is an 8-bit register that stores received serial data. When the SSU has received one byte of serial data, it transfers the received serial data from SSTRSR to SSRDR to end receive operation. After this, SSTRSR is receive-enabled. As SSTRSR and SSRDR function as a double buffer in this way, continuous receive operations are possible. SSRDR is a read-only register and cannot be written to by the CPU. SSRDR is initialized to H'FF. In standby mode, SSRDR is initialized.

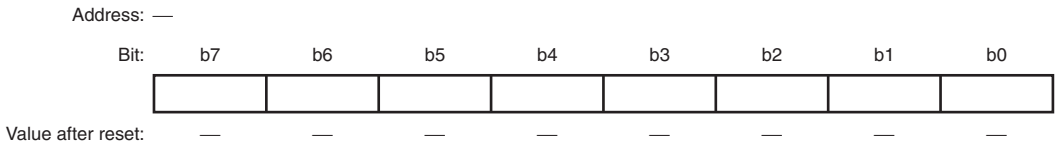
22.2.9 SS Transmit Data Register (SSTDR)

Address: H'FF05CE

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

SSTDR is an 8-bit register that stores serial data for transmission. SSTDR can be read or written to by the CPU at all times. When the SSU detects that SSTRSR is empty, it transfers the transmit data written in SSTDR to SSTRSR and starts serial transmission. If the next transmit data has already been written to SSTDR during serial transmission, continuous serial transmission is possible. SSTDR is initialized to H′FF. In standby mode, SSTDR is initialized.

22.2.10 SS Shift Register (SSTRSR)



SSTRSR is a shift register that transmits and receives serial data. When transmit data is transferred from SSTDR to SSTRSR, bit 0 in SSTDR is transferred to bit 0 in SSTRSR while the MLS bit in SSMR is 0 (LSB-first transfer) and bit 7 in SSTDR is transferred to bit 0 in SSTRSR while the MLS bit in SSMR is 1 (MSB-first transfer). SSTRSR cannot be directly accessed by the CPU. In standby mode, SSTRSR is initialized.

22.3 Operation

22.3.1 Transfer Clock

Transfer clock can be selected from seven internal clocks and an external clock. When this module is used, the SSCK pin must be selected as a serial clock by setting the SCKS bit in SSMR2 to 1. When the MSS bit in SSCRH is 1, an internal clock is selected and the SSCK pin is in the output state. If transfer is started, the SSCK pin outputs clocks of the transfer rate set in the CKS2 to CKS0 bits in SSCRH. When the MSS bit is 0, an external clock is selected and the SSCK pin is in the input state.

22.3.2 Relationship between Clock Polarity and Phase, and Data

Relationship between clock polarity and phase, and transfer data changes according to a combination of the SSUMS bit in SSMR2 and the CPOS and CPHS bits in SSMR. Figure 22.2 shows the relationship.

MSB-first transfer or LSB first transfer can be selected by the setting of the MLS bit in SSMR. When the MLS bit is 0, transfer is started from LSB to MSB. When the MLS bit is 1, transfer is started from MSB to LSB.

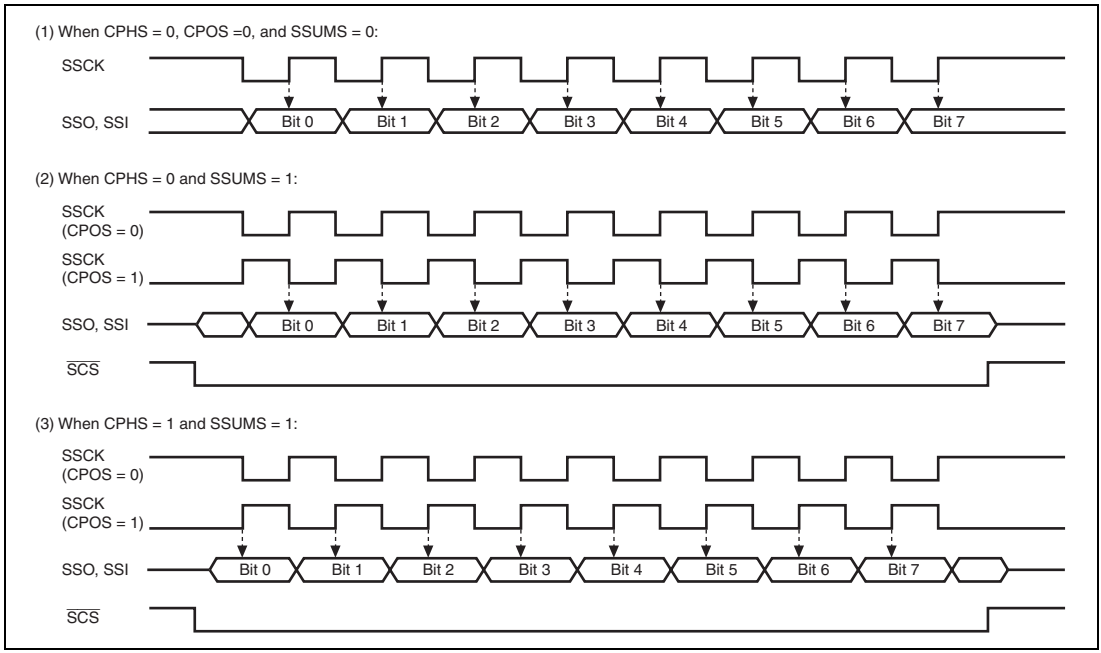


Figure 22.2 Relationship between Clock Polarity and Phase, and Data

22.3.3 Relationship between Data Input/Output Pin and Shift Register

Relationship of connection between the data input/output pin and SSTRSR changes according to a combination of the MSS bit in SSCRH and the SSUMS bit in SSMR2. It also changes by the BIDE bit in SSMR2. Figure 22.3 shows the relationship.

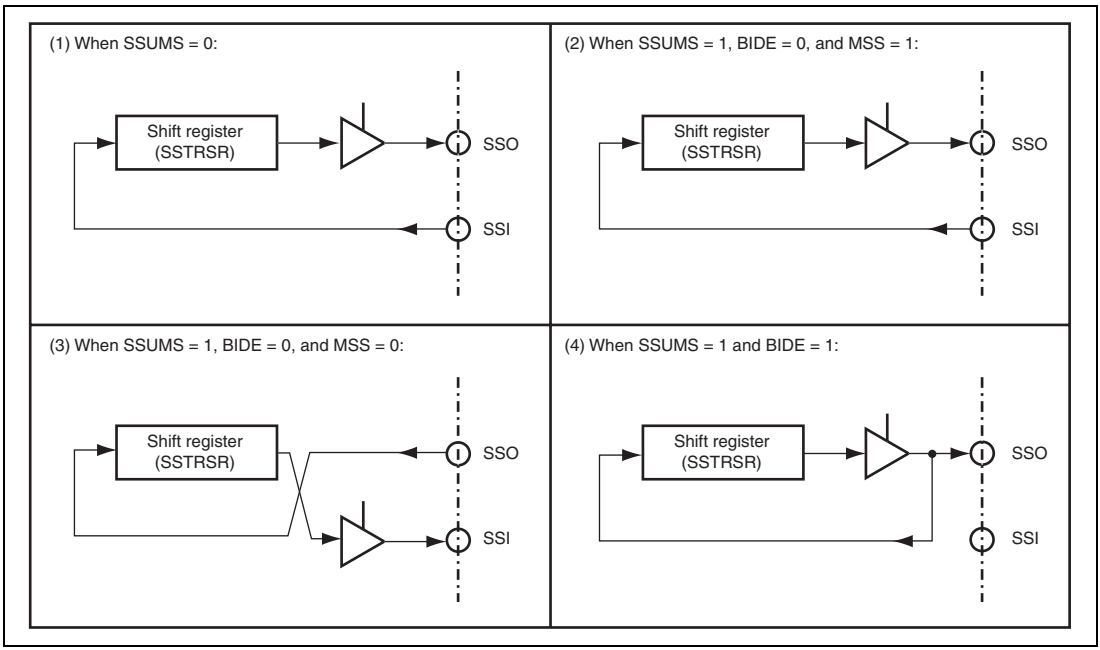


Figure 22.3 Relationship between Data Input/Output Pin and Shift Register

22.3.4 Communication Modes and Pin Functions

The SSU switches functions of the input/output pin in each communication mode according to the settings of the MSS bit in SSCRH and the RE and TE bits in SSER. Table 22.2 shows the relationship between communication modes and the input/output pins. In bidirectional communication mode, the TE and RE bits should not be set to 1 at the same time.

Table 22.2 Relationship between Communication Modes and Input/Output Pins

Communication Mode	Register State					Pin State		
	SSUMS	BIDE	MSS	TE	RE	SSI	SSO	SSCK
Clocked Synchronous Communication Mode	0	*	0	0	1	In	—	In
				1	0	—	Out	In
					1	In	Out	In
			1	0	1	In	—	Out
				1	0	—	Out	Out
					1	In	Out	Out
Four-Line Bus Communication Mode	1	0	0	0	1	—	In	In
				1	0	Out	—	In
					1	Out	In	In
			1	0	1	In	—	Out
				1	0	—	Out	Out
					1	In	Out	Out
Four-Line Bus (Bidirectional) Communication Mode	1	1	0	0	1	—	In	In
				1	0	—	Out	In
			1	0	1	—	In	Out
				1	0	—	Out	Out

[Legend]

—: Can be used as a general I/O port.

22.3.5 Operation in Clocked Synchronous Communication Mode

(1) Initialization in Clocked Synchronous Communication Mode

Figure 22.4 shows the initialization in clocked synchronous communication mode. Before transmitting and receiving data, the TE and RE bits in SSER should be cleared to 0, then the SSU should be initialized.

Note: When the operating mode, or transfer format, is changed for example, the TE and RE bits must be cleared to 0 before making the change using the following procedure. When the TE bit is cleared to 0, the TDRE flag is set to 1. Note that clearing the RE bit to 0 does not change the contents of the RDRF and ORER flags, or the contents of SSRDR.

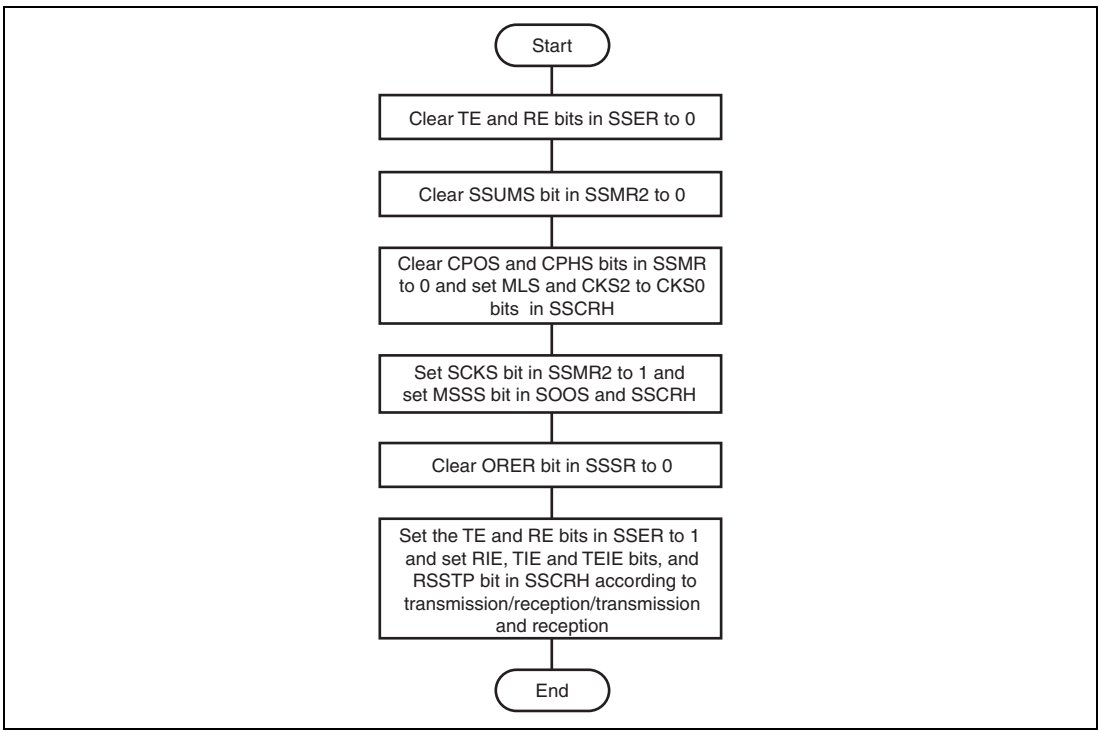


Figure 22.4 Initialization in Clocked Synchronous Communication Mode

(2) Serial Data Transmission

Figure 22.5 shows an example of the SSU operation for transmission. In serial transmission, the SSU operates as described below.

When the SSU is set as a master device, it outputs a synchronous clock and data. When the SSU is set as a slave device, it outputs data in synchronized with the input clock.

When the SSU writes transmit data in SSTDR after setting the TE bit to 1, the TDRE flag is automatically cleared to 0 and data is transferred from SSTDR to SSTRSR. Then the SSU sets the TDRE flag to 1 and starts transmission. If the TIE bit in SSER is set to 1 at this time, a TXI is generated.

When the TDRE flag is 0 and one frame of data has transferred, data is transferred from SSTDR to SSTRSR and serial transmission of the next frame is started. If the eighth bit is transmitted while the TDRE flag is 1, the TEND bit in SSSR is set to 1 and the state is retained. If the TEIE bit in SSER is set to 1 at this time, a TEI is generated. After transmission is ended, the SSCK pin is fixed high.

While the ORER bit in SSSR is set to 1, transmission cannot be performed. Therefore confirm that the ORER bit is cleared to 0 before transmission.

Figure 22.6 shows a sample flowchart for serial data transmission.

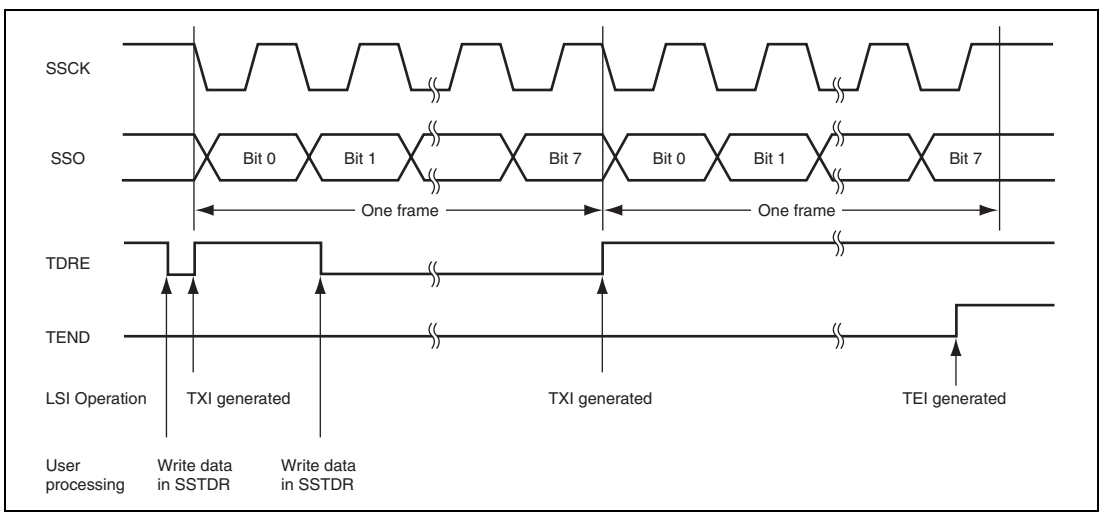


Figure 22.5 Example of Operation in Data Transmission

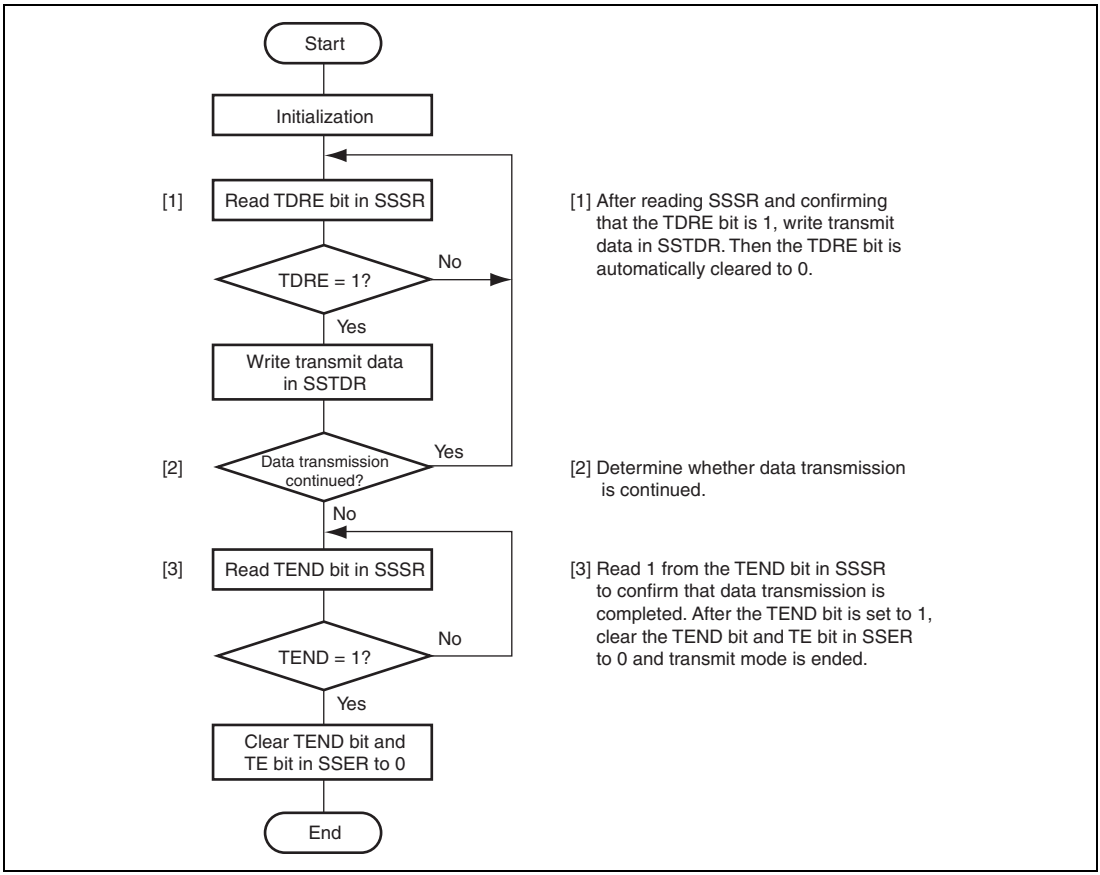


Figure 22.6 Sample Serial Transmission Flowchart

(3) Serial Data Reception

Figure 22.7 shows an example of the SSU operation for reception. In serial reception, the SSU operates as described below.

When the SSU is set as a master device, it outputs a synchronous clock and inputs data. When the SSU is set as a slave device, it inputs data in synchronized with the input clock. When the SSU is set as a master device, it outputs a receive clock and starts reception by performing dummy read on SSRDR.

After eight bits of data is received, the RDRF bit in SSSR is set to 1 and received data is stored in SSRDR. If the RIE bit in SSER is set to 1 at this time, a RXI is generated. If SSRDR is read, the RDRF bit is automatically cleared to 0.

When the SSU is set as a master device and reception is ended, received data is read after setting the RSSTP bit in SSCRH to 1. Then the SSU outputs eight bits of clocks and operation is stopped. After that, the RE and RSSTP bits are cleared to 0 and the last received data is read. Note that if SSRDR is read while the RE bit is set to 1, received clock is output again.

When the eighth clock rises while the RDRF bit is 1, the ORER bit in SSSR is set. Then an overrun error (OEI) is generated and operation is stopped. When the ORER bit in SSSR is set to 1, reception cannot be performed. Therefore confirm that the ORER bit is cleared to 0 before reception.

Figure 22.8 shows a sample flowchart for serial data reception.

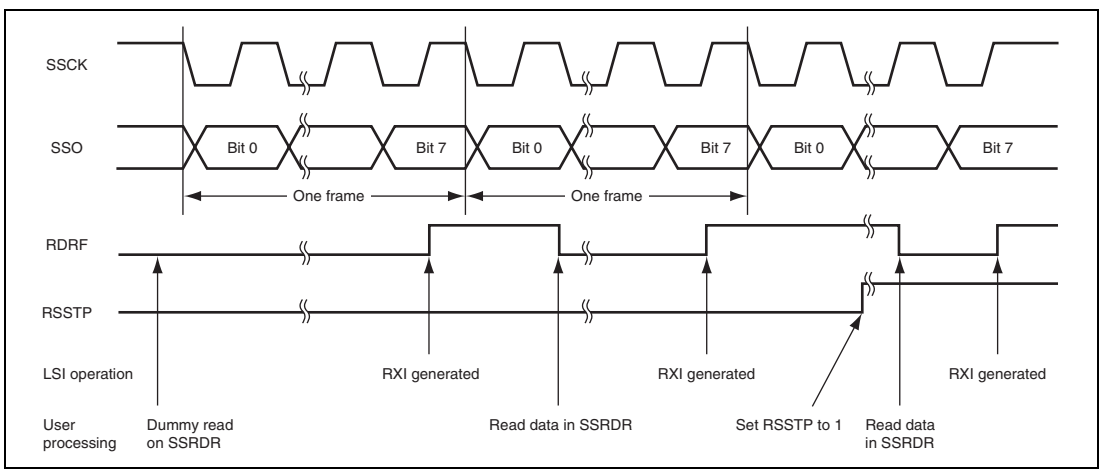


Figure 22.7 Example of Operation in Data Reception (MSS = 1)

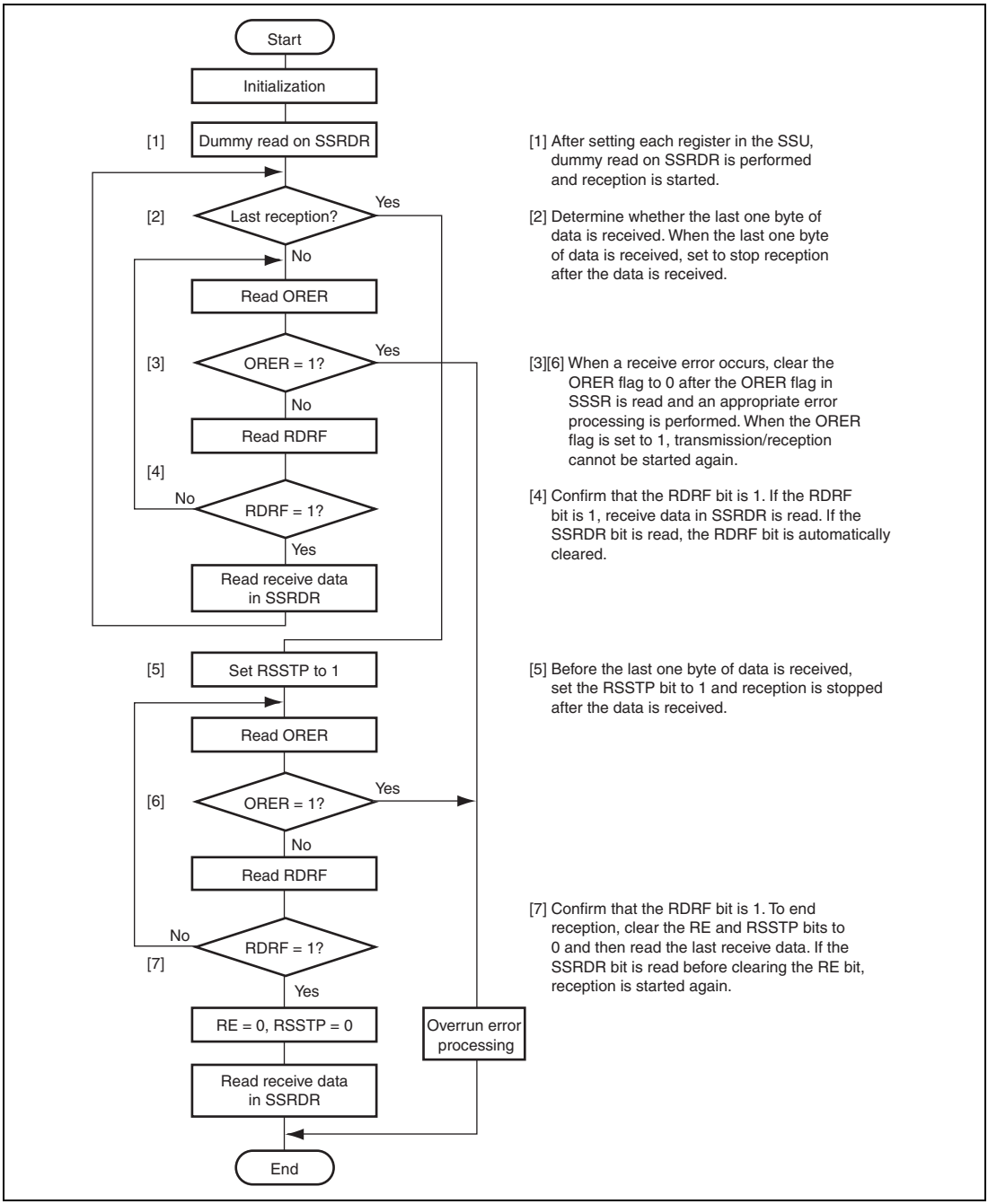


Figure 22.8 Sample Serial Reception Flowchart (MSS = 1)

(4) Serial Data Transmission and Reception

Data transmission and reception is a combined operation of data transmission and reception which are described before. Transmission and reception is started by writing data in SSTDR. When the eighth clock rises while the TDRE bit is set to 1 or the ORER bit is set to 1, transmission and reception is stopped.

To switch from transmit mode (TE = 1) or receive mode (RE = 1) to transmit and receive mode (TE = RE = 1), the TE and RE bits should be cleared to 0. After confirming that the TEND, RDRF, and ORER bits are cleared to 0, set the TE and RE bits to 1.

When the module is released from transmit and receive mode (TE = 1 and RE = 1), setting TE = 0 (and RE = 1) after the SSRDR has been read can cause output of the clock signal. For this reason, start by setting RE = 0 and only set TE = 0 after that (or set both RE = 0 and TE = 0 at the same time). When TE = 0 and RE = 1 is subsequently set, only set RE = 1 after changing SRES from 1 to 0.

Figure 22.9 shows a sample flowchart for serial transmit and receive operations.

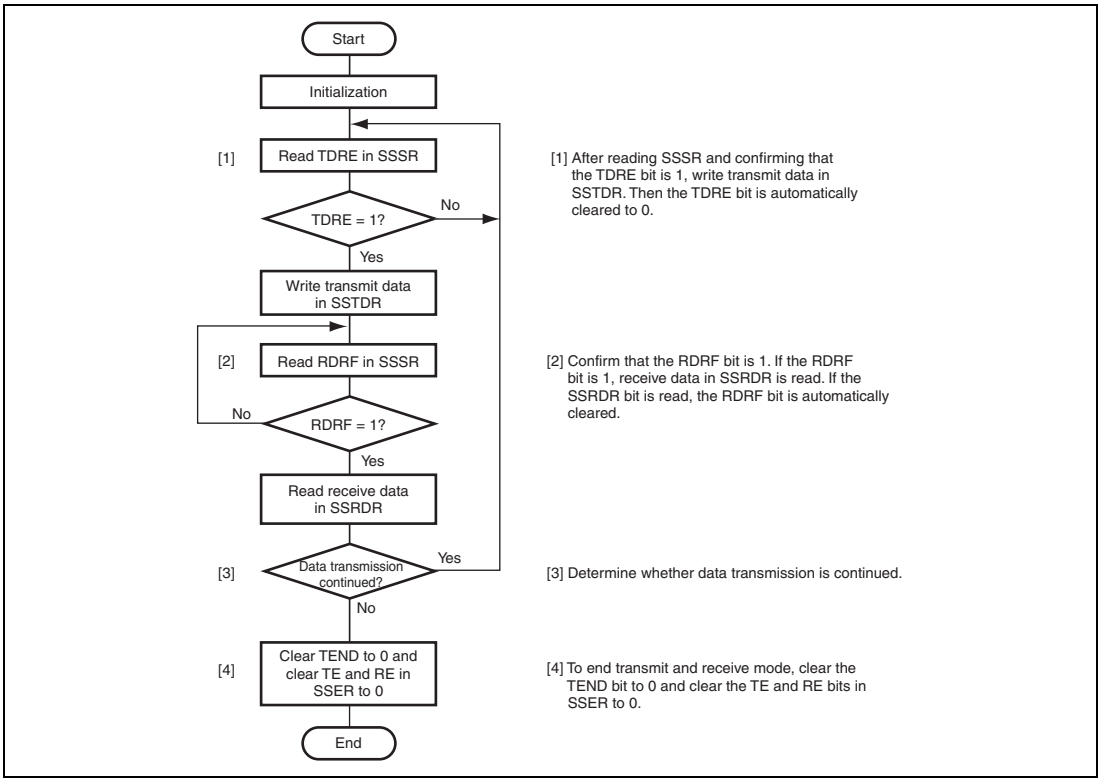


Figure 22.9 Sample Flowchart for Serial Transmit and Receive Operations

22.3.6 Operation in Four-Line Bus Communication Mode

Four-line bus communication mode is a mode which communicates with the four-line bus; a clock line, a data input line, a data output line, and a chip select line. This mode includes bidirectional mode in which the data input line and the data output line function as a single pin. The data input line and the data output line are changed according to the settings of the MSS bit in SSCRH and BIDE bit in SSMR2. For details, see section 22.3.3, Relationship between Data Input/Output Pin and Shift Register. In this mode, relationship between clock polarity and phase, and data can be set by the CPOS and CPHS bits in SSMR. For details, see section 22.3.2, Relationship between Clock Polarity and Phase, and Data.

When the SSU is set as a master device, the chip select line controls output. When the SSU is set as a slave device, the chip select line controls input. When the SSU is set as a master device, the chip select line controls output of the $\overline{\text{SCS}}$ pin or controls output of a general port by setting the CSS1 bit in SSMR2 to 1. When the SSU is set as a slave device, the chip select line sets the $\overline{\text{SCS}}$ pin as an input pin by setting the CSS1 and CSS0 bits in SSMR2 to 01.

In four-line bus communication mode, the MLS bit in SSMR is set to 1 and transfer is performed in MSB-first order.

(1) Initialization in Four-Line Bus Communication Mode

Figure 22.10 shows the initialization in four-line bus communication mode. Before transmitting and receiving data, the TE and RE bits in SSER should be cleared to 0, then the SSU should be initialized.

Note: When the operating mode, or transfer format, is changed for example, the TE and RE bits must be cleared to 0 before making the change using the following procedure. Note that clearing the RE bit to 0 does not change the contents of the RDRF and ORER flags, or the contents of SSRDR.

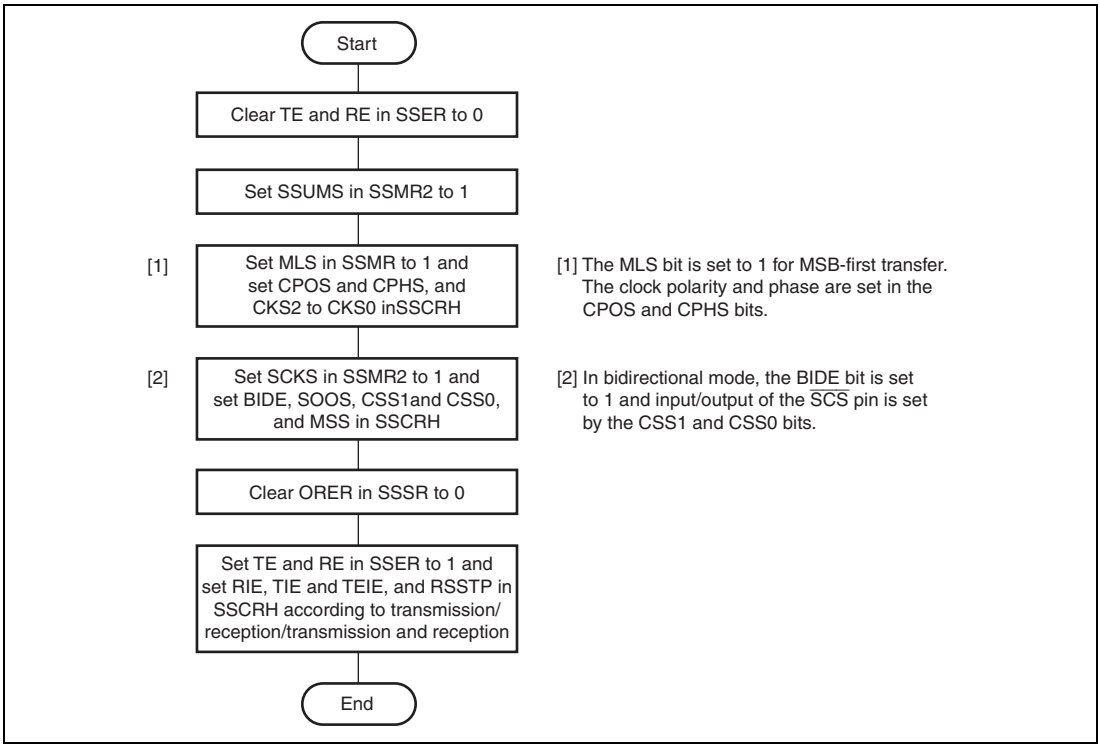


Figure 22.10 Initialization in Four-Line Bus Communication Mode

(2) Serial Data Transmission

Figure 22.11 shows an example of the SSU operation for transmission. In serial transmission, the SSU operates as described below.

When the SSU is set as a master device, it outputs a synchronous clock and data. When the SSU is set as a slave device, the $\overline{\text{SCS}}$ pin is in the low-input state and the SSU outputs data in synchronized with the input clock.

When the SSU writes transmit data in SSTDR after setting the TE bit to 1, the TDRE flag is automatically cleared to 0 and data is transferred from SSTDR to SSTRSR. Then the SSU sets the TDRE flag to 1 and starts transmission. If the TIE bit in SSER is set to 1 at this time, a TXI is generated.

When the TDRE flag is 0 and one frame of data has transferred, data is transferred from SSTDR to SSTRSR and serial transmission of the next frame is started. If the eighth bit is transmitted while the TDRE flag is 1, the TEND bit in SSSR is set to 1 and the state is retained. If the TEIE bit in SSER is set to 1 at this time, a TEI is generated. After transmission is ended, the SSCK pin is fixed high and the $\overline{\text{SCS}}$ pin goes high. When continuous transmission is performed with the $\overline{\text{SCS}}$ pin low, the next data should be written to SSTDR before transmitting the eighth bit of the frame.

While the ORER bit in SSSR is set to 1, transmission cannot be performed. Therefore confirm that the ORER bit is cleared to 0 before transmission.

The difference between this mode and clocked synchronous communication mode is as follows: when the SSU is set as a master device, the SSO pin is in the high impedance state if the $\overline{\text{SCS}}$ pin is in the high impedance state and when the SSU is set as a slave device, the SSI pin is in the high impedance state if the $\overline{\text{SCS}}$ pin is in the high-input state. The sample flowchart for serial data transmission is the same as that in clocked synchronous communication mode.

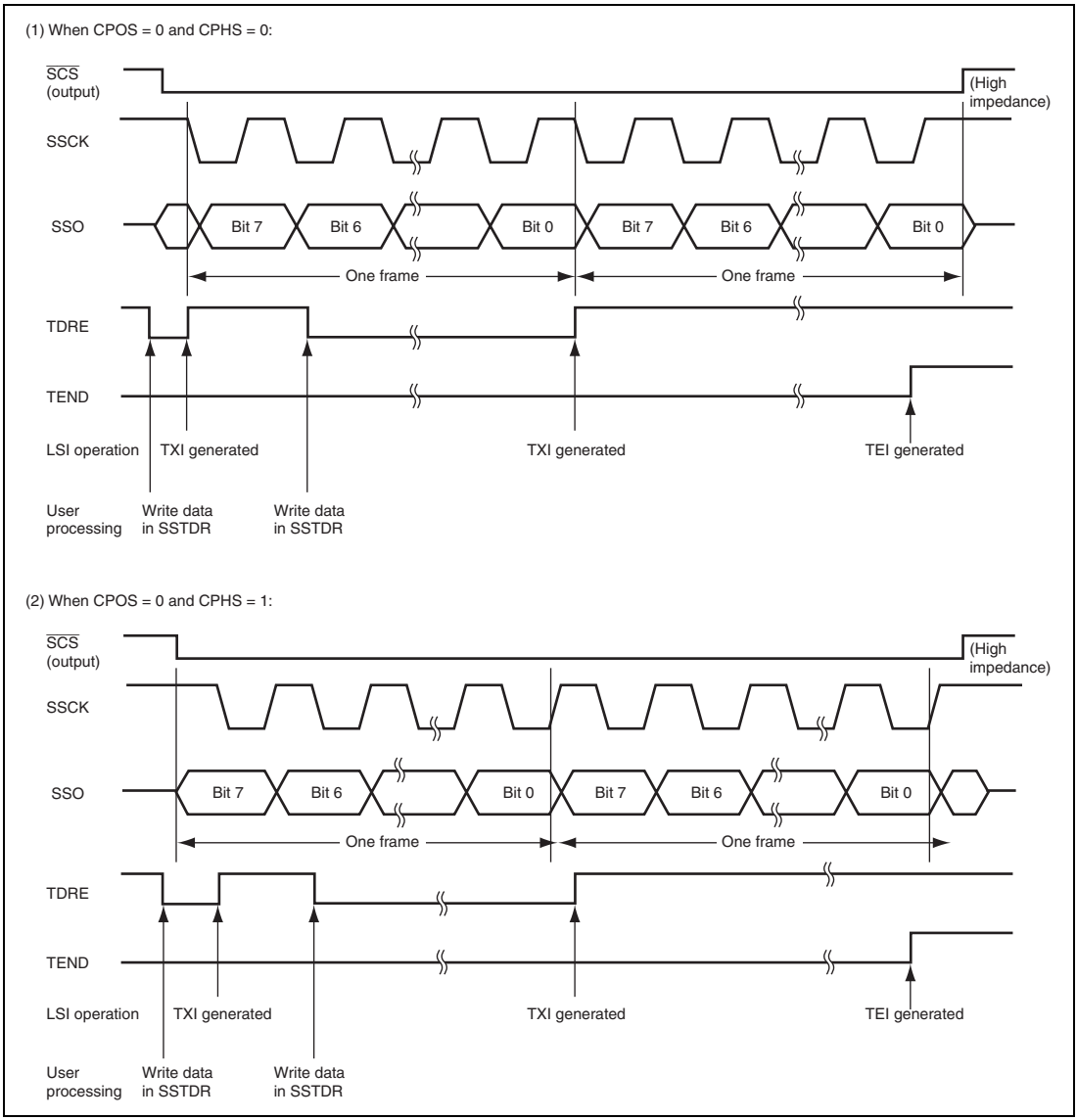


Figure 22.11 Example of Operation in Data Transmission (MSS = 1)

(3) Serial Data Reception

Figure 22.12 shows an example of the SSU operation for reception. In serial reception, the SSU operates as described below.

When the SSU is set as a master device, it outputs a synchronous clock and inputs data. When the SSU is set as a slave device, the $\overline{SCS}$ pin is in the low-input state and inputs data in synchronized with the input clock. When the SSU is set as a master device, it outputs a receive clock and starts reception by performing dummy read on SSRDR.

After eight bits of data is received, the RDRF bit in SSSR is set to 1 and received data is stored in SSRDR. If the RIE bit in SSER is set to 1 at this time, an RXI is generated. If SSRDR is read, the RDRF bit is automatically cleared to 0.

When the SSU is set as a master device and reception is ended, received data is read after setting the RSSTP bit in SSER to 1. Then the SSU outputs eight bits of clocks and operation is stopped. After that, the RE and RSSTP bits are cleared to 0 and the last received data is read. Note that if SSRDR is read while the RE bit is set to 1, received clock is output again.

When the eighth clock rises while the RDRF bit is 1, the ORER bit in SSSR is set. Then an overrun error (OEI) is generated and operation is stopped. When the ORER bit in SSSR is set to 1, reception cannot be performed. Therefore confirm that the ORER bit is cleared to 0 before reception.

The set timings of the RDRF and ORER flags differ according to the CPHS setting. These timings are shown in figure 22.2. When the CPHS bit is set to 1, the flag is set during the frame. Therefore care should be taken at the end of reception.

The sample flowchart for serial data reception is the same as that in clocked synchronous communication mode.

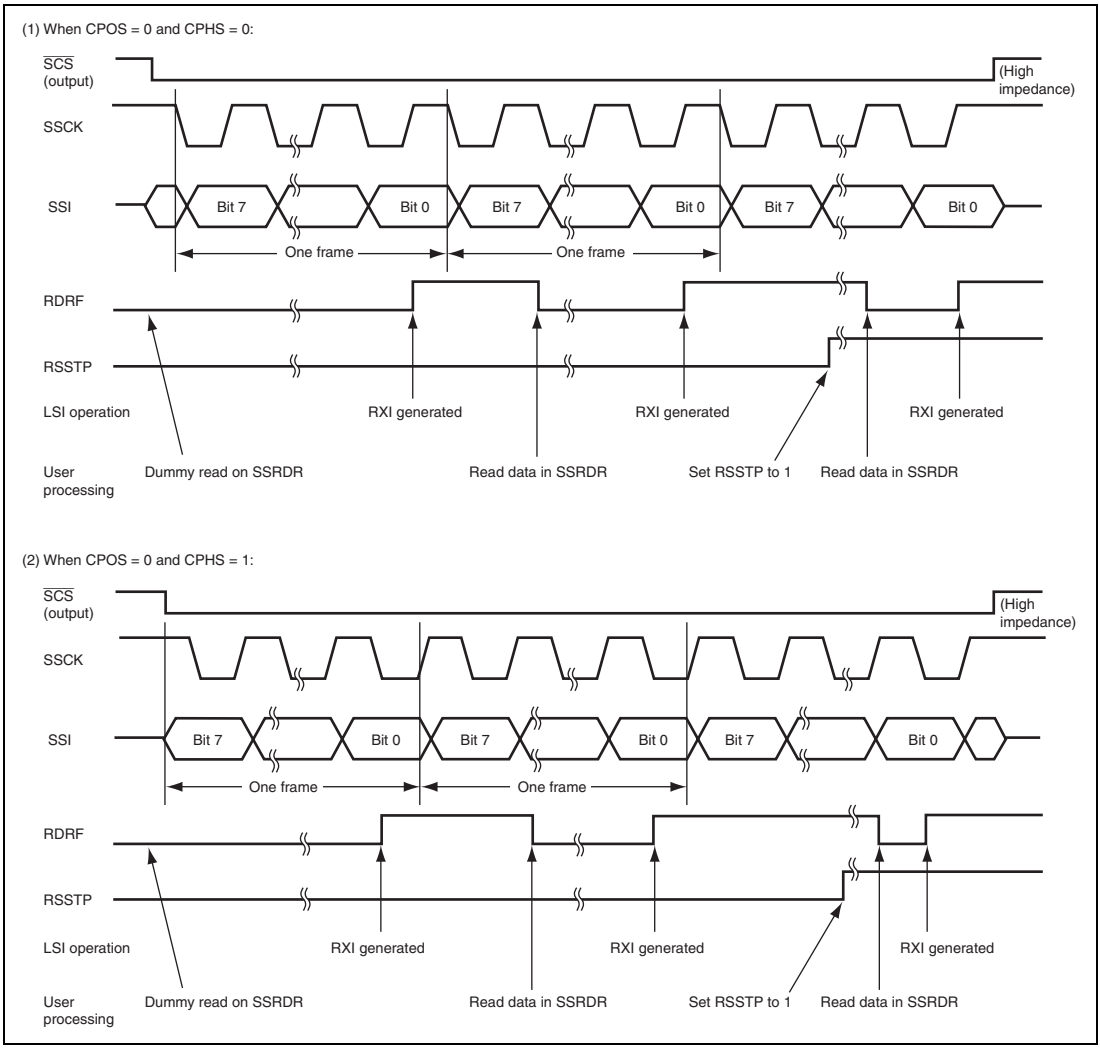


Figure 22.12 Example of Operation in Data Reception (MSS = 1)

22.3.7 $\overline{\text{SCS}}$ Pin Control and Arbitration

When the SSUMS bit in SSMR2 is set to 1 and the CSS1 bit is set to 1, the MSS bit in SSCRH is set to 1 and then the arbitration of the $\overline{\text{SCS}}$ pin is checked before starting serial transfer. If the SSU detects that the synchronized internal SCS pin goes low in this period, the CE bit in SSSR is set and the MSS bit in SSCRH is cleared.

Note: When a conflict error is set, subsequent transmit operation is not possible. Therefore the CE bit must be cleared to 0 before starting transmission.
When the multimaster error is used, the CSOS bit in SSMR2 should be set to 1.

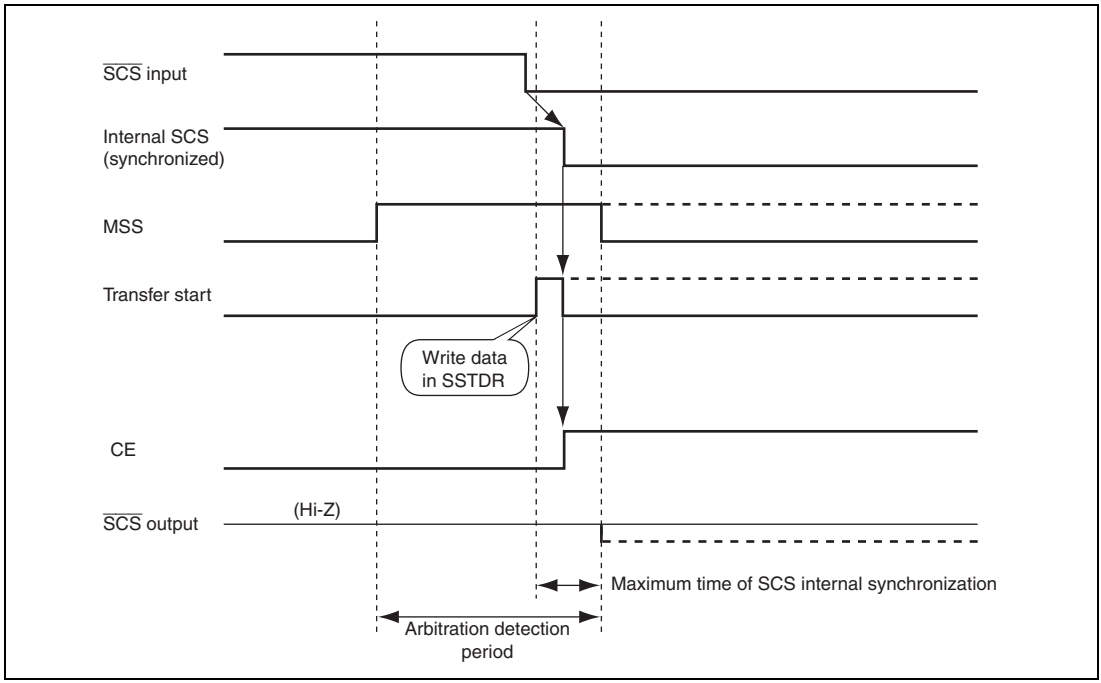


Figure 22.13 Arbitration Check Timing

22.4 Interrupt Requests

The SSU has five interrupt requests: transmit data empty, transmit end, receive data full, overrun error, and conflict error. Since these interrupt requests are assigned to the common vector address, interrupt sources must be determined by flags. Table 22.3 lists the interrupt requests.

Table 22.3 Interrupt Requests

Interrupt Request	Abbreviation	Interrupt Condition	DTC Activation
Transmit data empty	TXI	(TIE = 1), (TDRE = 1)	Possible
Transmit end	TEI	(TEIE = 1), (TEND = 1)	Impossible
Receive data full	RXI	(RIE = 1), (RDRF = 1)	Possible
Overrun error	OEI	(RIE = 1), (ORER = 1)	Impossible
Conflict error	CEI	(CEIE = 1), (CE = 1)	Impossible

When an interrupt exception handling by an interrupt source shown in table 22.4 is executed, each interrupt source must be cleared during the exception handling. Note that the TDRE and TEND bits are automatically cleared by writing transmit data in SSTDR and the RDRF bit is automatically cleared by reading SSRDR. When transmit data is written in SSTDR, the TDRE bit is set again at the same time. Then if the TDRE bit is cleared, additional one byte of data may be transmitted. The DTC can be activated by a TXI interrupt to transfer data. The TDRE flag is automatically cleared upon data transfer by the DTC. The DTC can also be activated by an RXI interrupt to transfer data. The RDRF flag is automatically cleared upon data transfer by the DTC.

22.5 Usage Notes

(1) If the NMOS open-drain output is selected for the SSCK output pin, the SSO output pin, and the $\overline{\text{SCS}}$ output pin, use the PMC to allocate that pin from port 5. If the pins are allocated from a port other than port 5, only the CMOS output is available.

Section 23 Hardware LIN

The hardware LIN works in cooperation with timer RA and SCI3_1 to provide LIN communications.

23.1 Overview

- Master mode
  Generates Sync Break.
  Detects bus conflicts.
- Slave mode
  Detects Sync Break.
  Measures Sync Field.
  Controls Sync Break and Sync Field signal inputs to SCI3_1.
  Detects bus conflicts.

Figure 23.1 shows a block diagram of the hardware LIN interface.

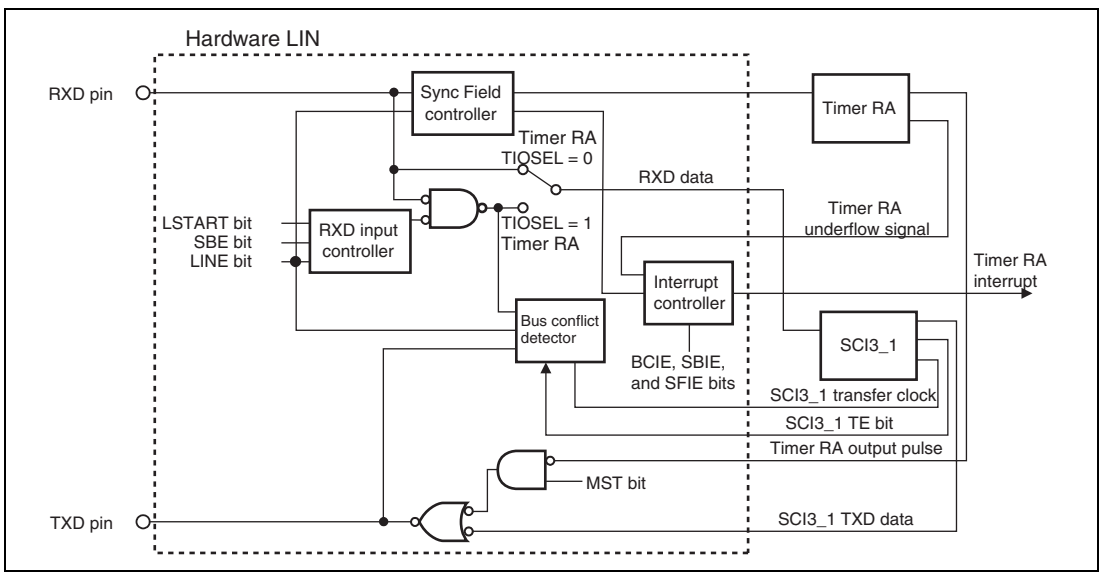


Figure 23.1 Block Diagram of Hardware LIN

Table 23.1 shows the hardware LIN pins.

Table 23.1 Pin Configuration

Pin Symbol	I/O	Description
RXD	Input	Receive-data input to the hardware LIN
TXD	Output	Transmit-data output from the hardware LIN

23.2 Register Configuration

The hardware LIN interface has the following registers.

- LIN control register (LINCR)
- LIN status register (LINST)

23.2.1 LIN Control Register (LINCR)

Address: H'FF0518

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	LINE	MST	SBE	LSTART	RXDSF	BCIE	SBIE	SFIE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	LINE	LIN start	0: Enables LIN operation. 1: Disables LIN operation.*1	R/W
6	MST	LIN operating mode setting*2	0: Slave mode (Enables the Sync Break detector.) 1: Master mode (Takes the OR between timer RA output and TXD data.)	R/W
5	SBE	RXD input mask cancellation timing select	(Valid only in slave mode) 0: Cancels the mask upon Sync Break detection. 1: Cancels the mask upon completion of Sync Field measurement.	R/W

Bit	Symbol	Bit Name	Description	R/W
4	LSTART	Sync Break detection start	0: Don't care. 1: Enables timer RA input and disables RXD input.	R/W
3	RXDSF	RXD input status flag	0: Indicates that RXD input has been enabled. 1: Indicates that RXD input has been disabled.	R
2	BCIE	Bus conflict detection interrupt enable	0: Disables a bus conflict detection interrupt. 1: Enables a bus conflict detection interrupt.	R/W
1	SBIE	Sync Break detection interrupt enable	0: Disables a Sync Break detection interrupt. 1: Enables a Sync Break detection interrupt.	R/W
0	SFIE	Sync Field measurement end interrupt enable	0: Disables a Sync Field measurement end interrupt. 1: Enables a Sync Field measurement end interrupt.	R/W

Note: 1. Immediately after setting this bit to 1, inputs to timer RA and SCI3_1 are prohibited.
2. Before switching the LIN operating modes, temporarily disable the LIN (LINE = 0).
3. After setting LSTART and then checking that the RXDSF flag is 1, start inputting Sync Break.

23.2.2 LIN Status Register (LINST)

Address: H'FF0519

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	B2CLR	B1CLR	B0CLR	BCDCT	SBDCT	SFDCT
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5	B2CLR	BCDCT flag clear	The BCDCT flag is cleared when 1 is written to this bit. This bit is always read as 0.	R/W
4	B1CLR	SBDCT flag clear	The SBDCT flag is cleared when 1 is written to this bit. This bit is always read as 0.	R/W
3	B0CLR	SFDCT flag clear	The SFDCT flag is cleared when 1 is written to this bit. This bit is always read as 0.	R/W
2	BCDCT	Bus conflict detection flag	0: No bus conflict is detected. 1: Indicates that bus conflict has been detected.	R
1	SBDCT	Sync Break detection flag	0: Sync Bread is not detected. 1: Indicates that Sync Break has been detected.	R
0	SFDCT	Sync Field measurement end flag	0: Sync Field measurement is not ended. 1: Indicates that Sync Field measurement has been ended.	R

23.3 Operation

23.3.1 Master Mode

Figure 23.2 shows the example of hardware LIN interface operation for transmitting the header field in master mode. Figures 23.3 and 23.4 show the flowcharts for header field transmission.

The hardware LIN interface operates as follows for header field transmission.

1. When 1 is written to the TSTART bit in TRACR register of timer RA, the hardware LIN keeps outputting a low level from the TXD pin for the period specified by the TRAPRE and TRATR registers of timer RA.
2. When timer RA underflows, the hardware LIN inverts the TXD pin output, thus setting the SBDCT flag in the LINST register to 1. In this case, if the SBIE bit in the LINCR register is set to 1, the timer RA/HW-LIN interrupt occurs.
3. The hardware LIN interface transmits H'55 using SCI3_1.
4. After completing H'55 transmission, the hardware LIN interface transmits the ID field using SCI3_1.
5. After completing ID field transmission, the hardware LIN interface performs response field communications.

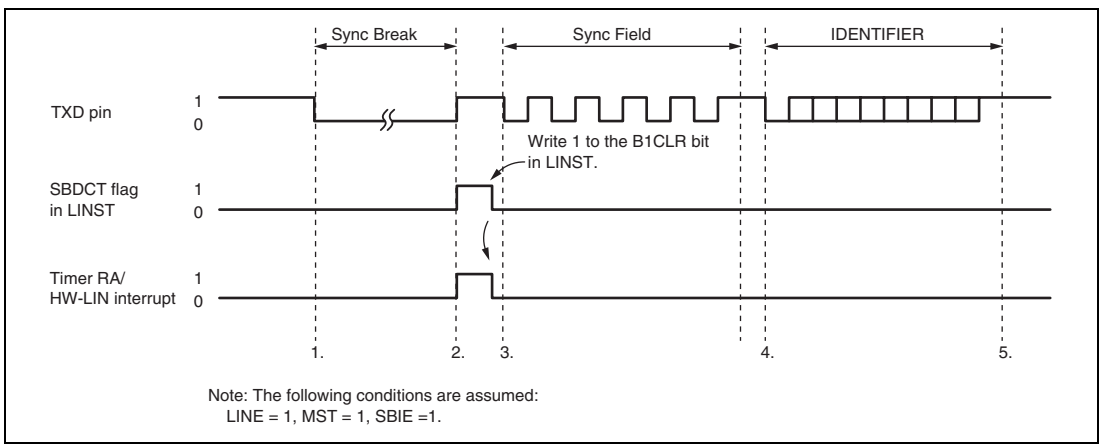
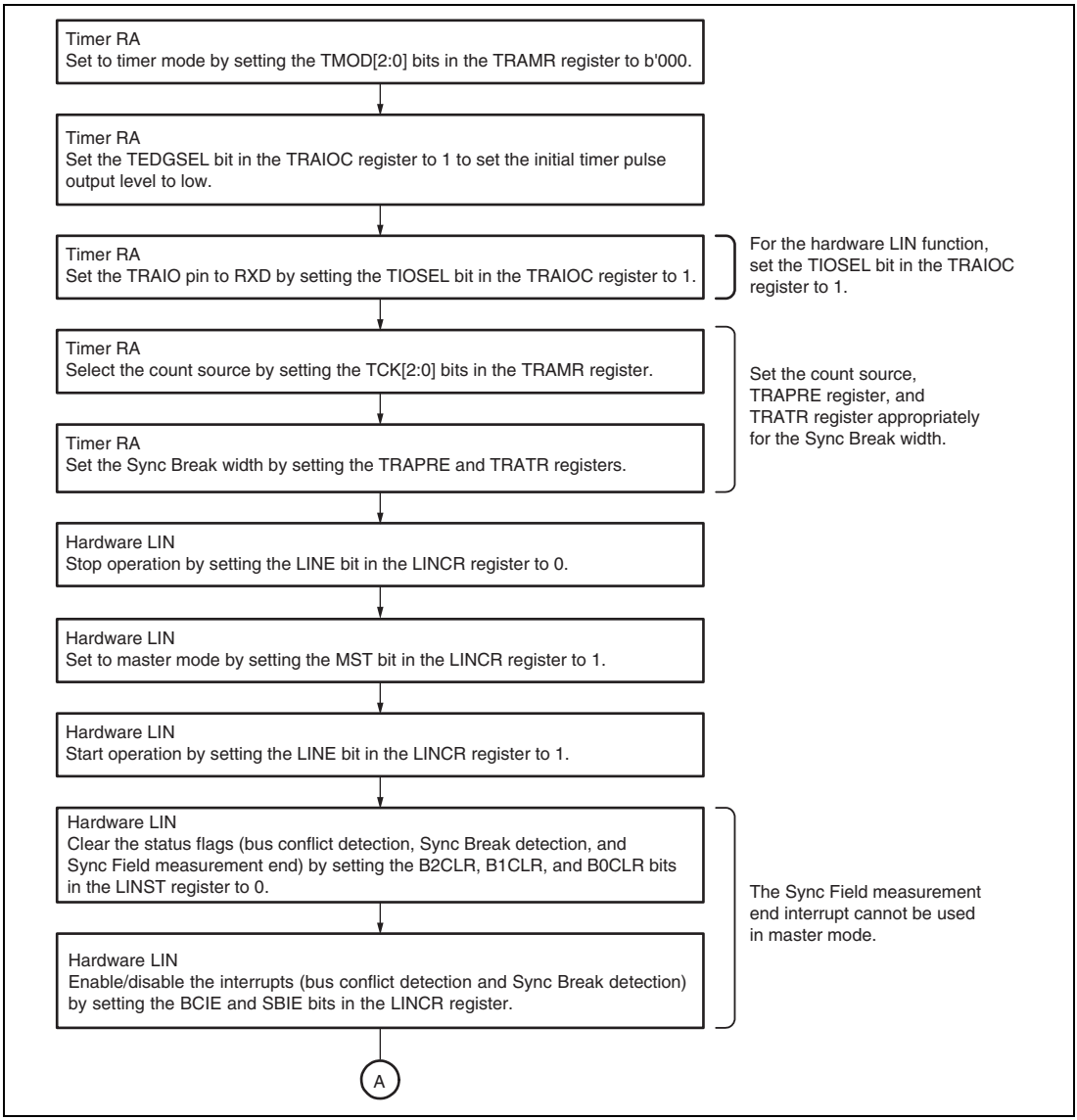
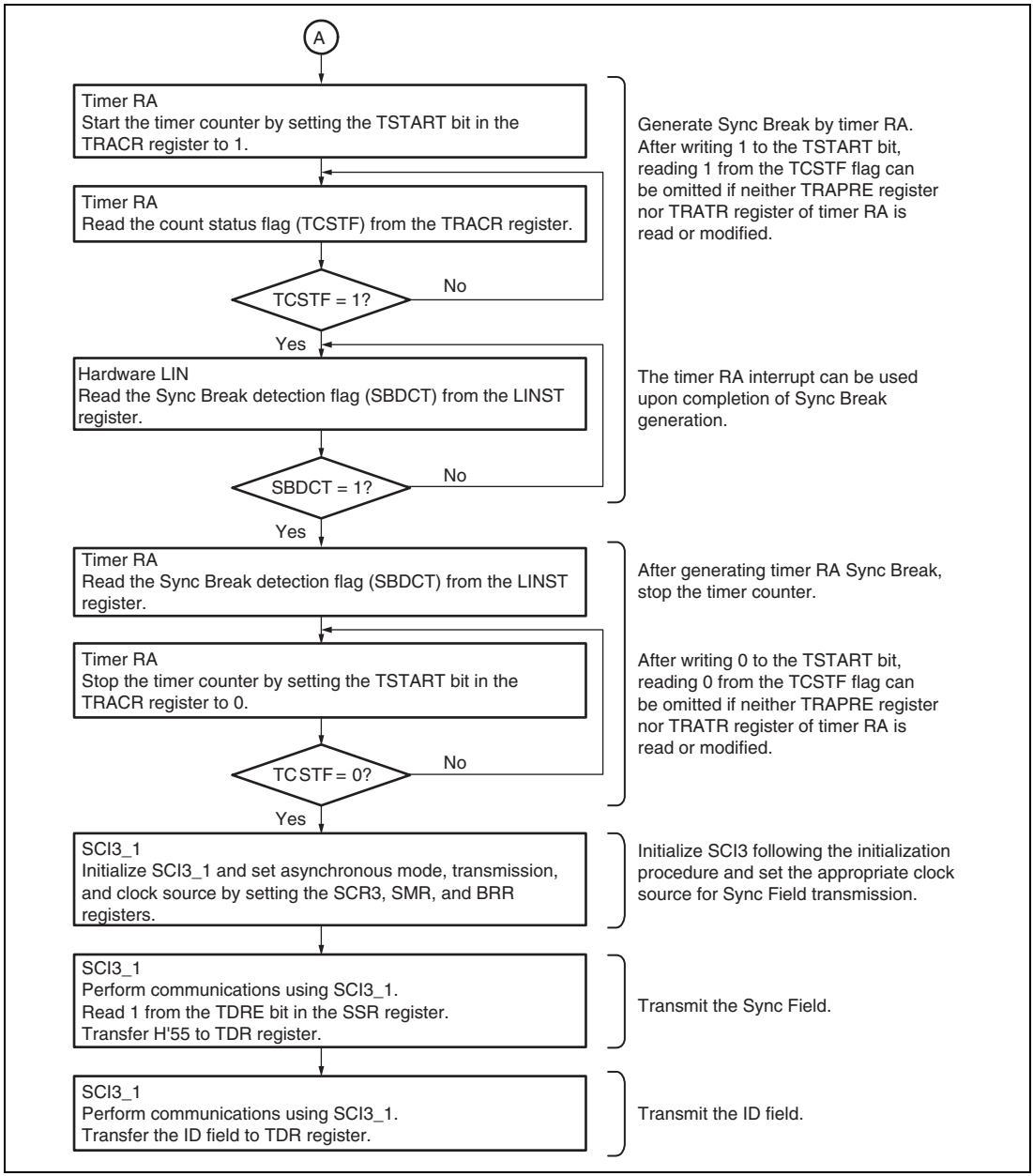


Figure 23.2 Example of LIN Operation for Transmitting Header Field



Figures 23.3 Header Field Transmission Flowchart (1)



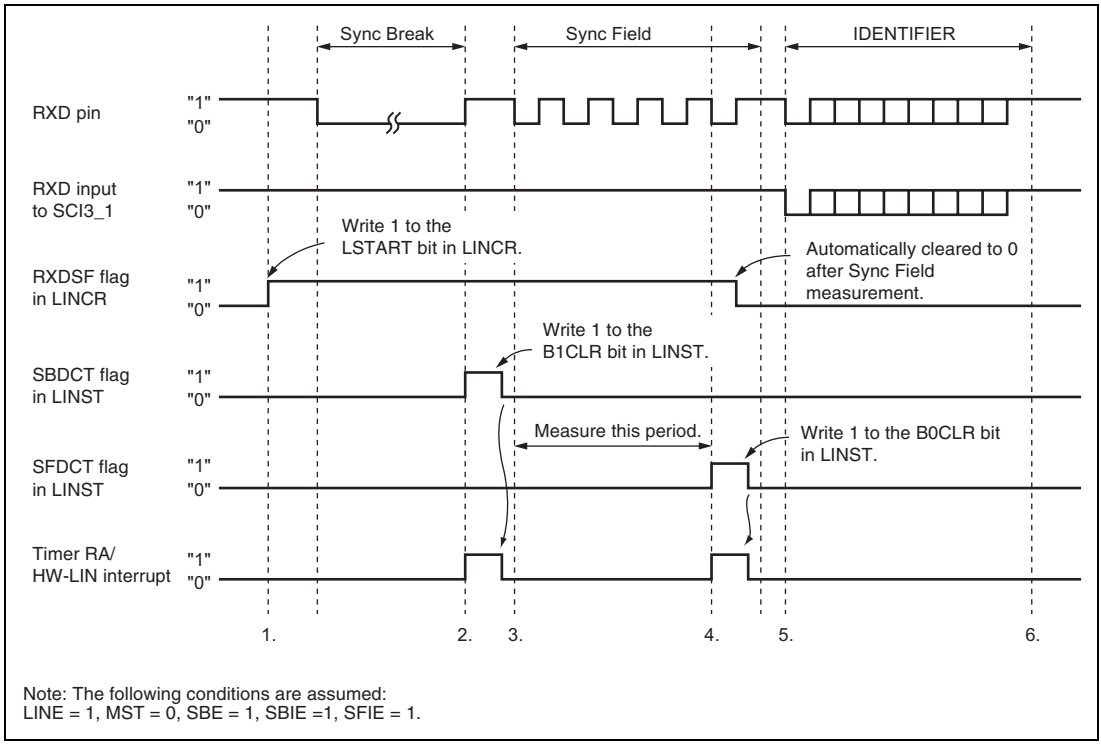
Figures 23.4 Header Field Transmission Flowchart (2)

23.3.2 Slave Mode

Figure 23.5 shows the example of hardware LIN interface operation for receiving the header field in slave mode. Figures 23.6 to 23.8 show the flowcharts for header field reception.

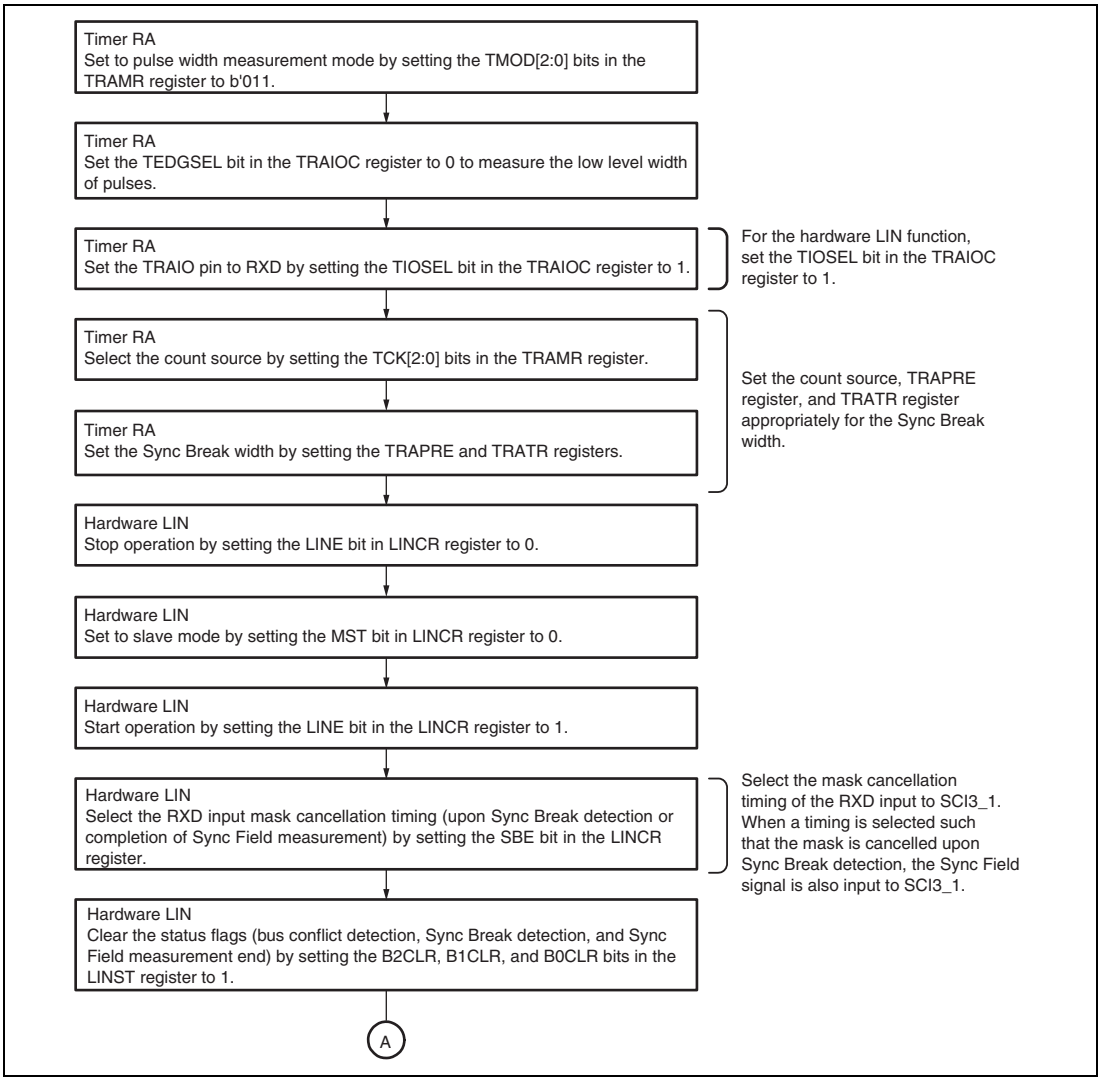
The hardware LIN interface operates as follows for header field reception.

1. When 1 is written to the LSTART bit in LINCR register of the hardware LIN interface, Sync Break detection is enabled.
2. When a low level input is longer than the time set in timer RA, it is detected as Sync Break, thus setting the SBDCT flag in the LINST register to 1. In this case, if the SBIE bit in the LINCR register is set to 1, the timer RA/HW-LIN interrupt occurs. The hardware LIN interface then measures the Sync Field.
3. The hardware LIN interface receives the Sync Field (H'55). During reception, the hardware LIN interface measures the time from the start bit through bit 6. Here, the Sync Field input to the SCI3 RXD can be either enabled or disabled depending on the SBE bit setting in the LINCR register.
4. Completion of Sync Field measurement sets the SFDCT flag in the LINST register to 1. In this case, if the SFIE bit in the LINCR register is 1, the timer RA/HW-LIN interrupt occurs.
5. After completing Sync Field measurement, the hardware LIN interface calculates the transfer rate from the timer RA count value and sets the rate in SCI3_1, and also updates the TRAPRE and TRATR registers in timer RA. Then the hardware LIN interface receives the ID field using SCI3_1.
6. After completing ID field reception, the hardware LIN interface performs response field communications.



Note: The following conditions are assumed:
LINE = 1, MST = 0, SBE = 1, SBIE =1, SFIE = 1.

Figure 23.5 Example of LIN Operation for Receiving Header Field



Figures 23.6 Header Field Reception Flowchart (1)

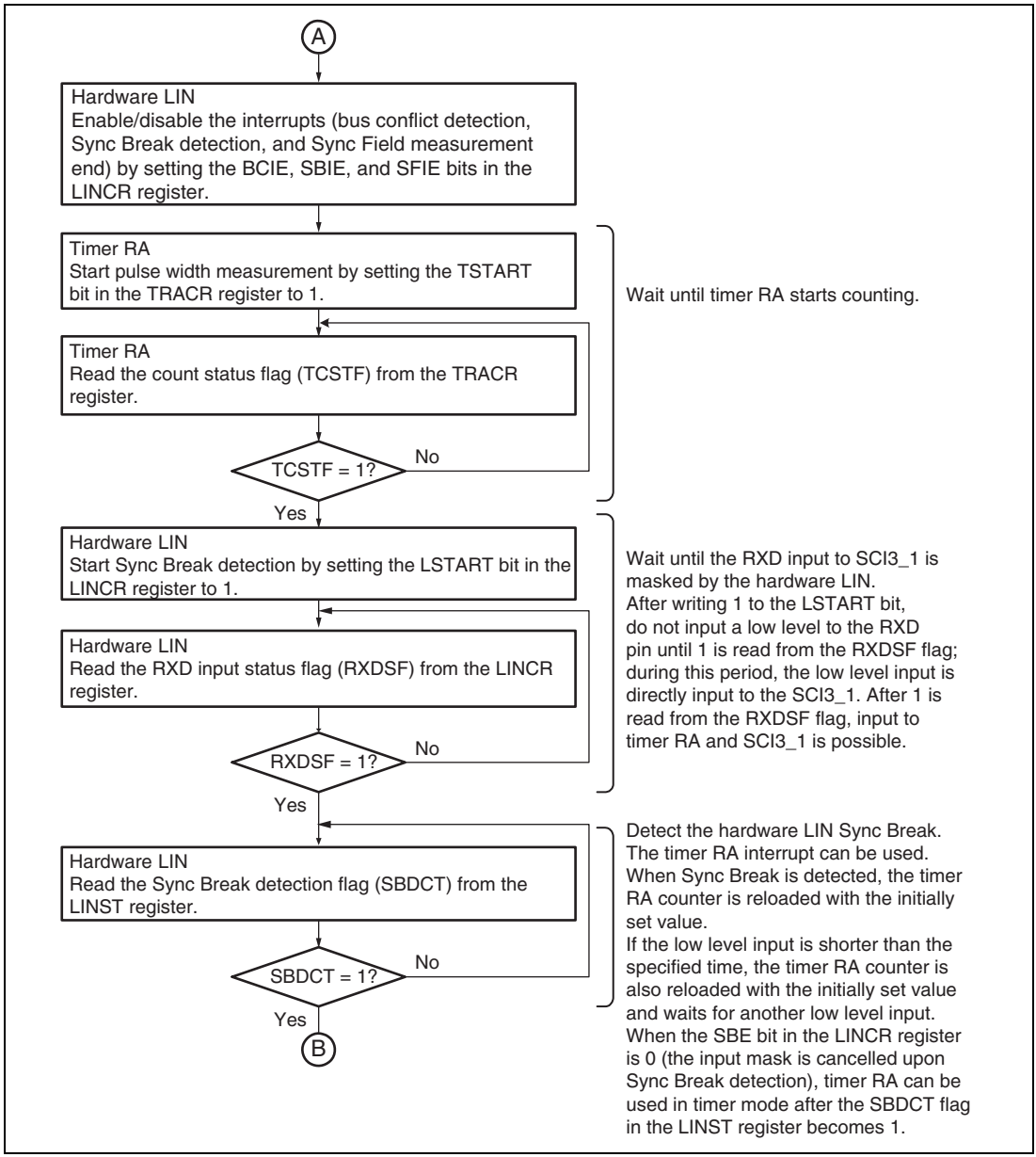


Figure 23.7 Header Field Reception Flowchart (2)

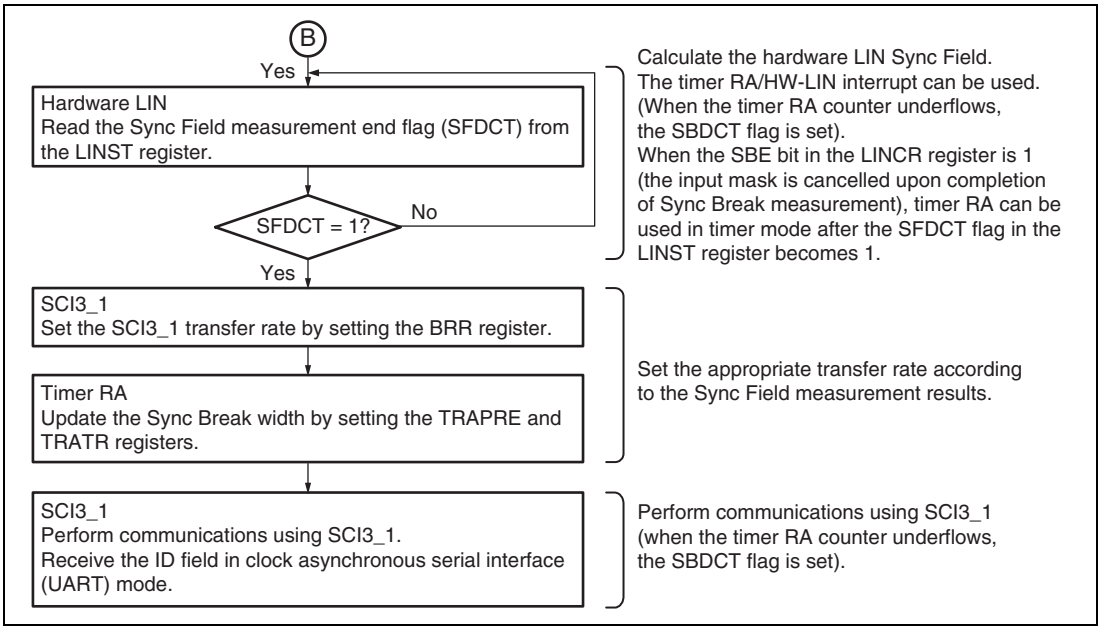


Figure 23.8 Header Field Reception Flowchart (3)

23.3.3 Bus Conflict Detection Function

The hardware LIN interface can detect bus conflicts if SCI3_1 is enabled for transmission (TE bit in SCR3_1 register is 1).

Figure 23.9 shows the example of hardware LIN interface operation for detecting bus conflicts.

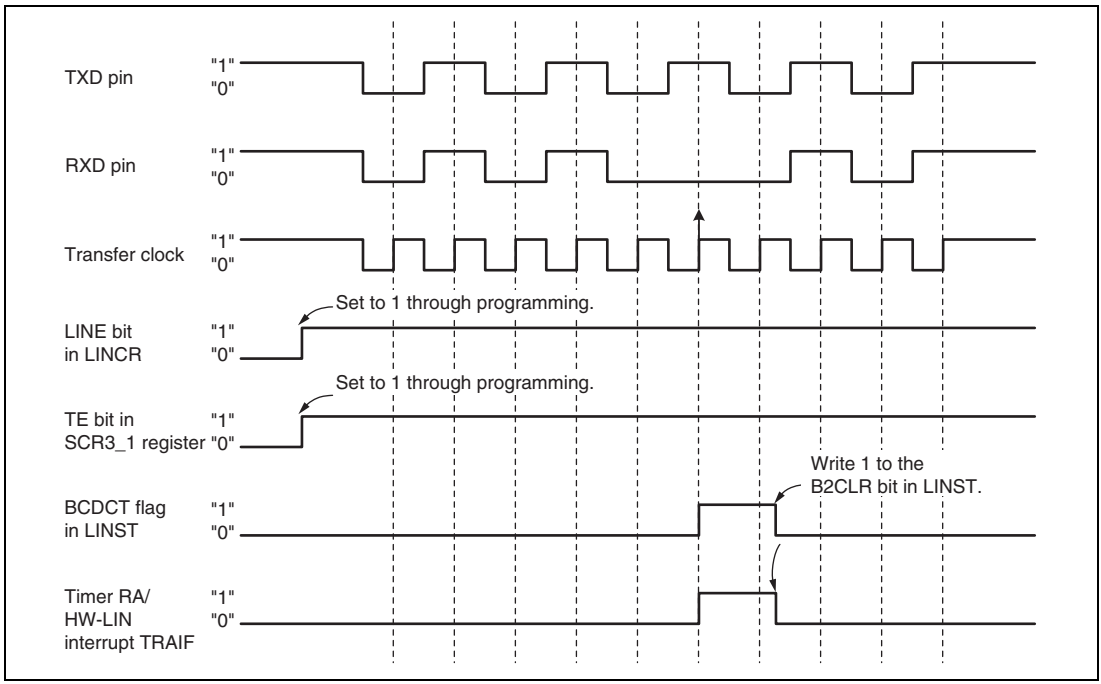


Figure 23.9 Example of LIN Operation for Detecting Bus Conflicts

23.3.4 Terminating Hardware LIN

Figure 23.10 shows the flowchart for terminating hardware LIN communications. The hardware LIN interface should be terminated at the following timing.

- Case 1: When the bus conflict detection function is used
  After checksum field transmission
- Case 2: When the bus conflict detection function is not used
  After header field transmission/reception

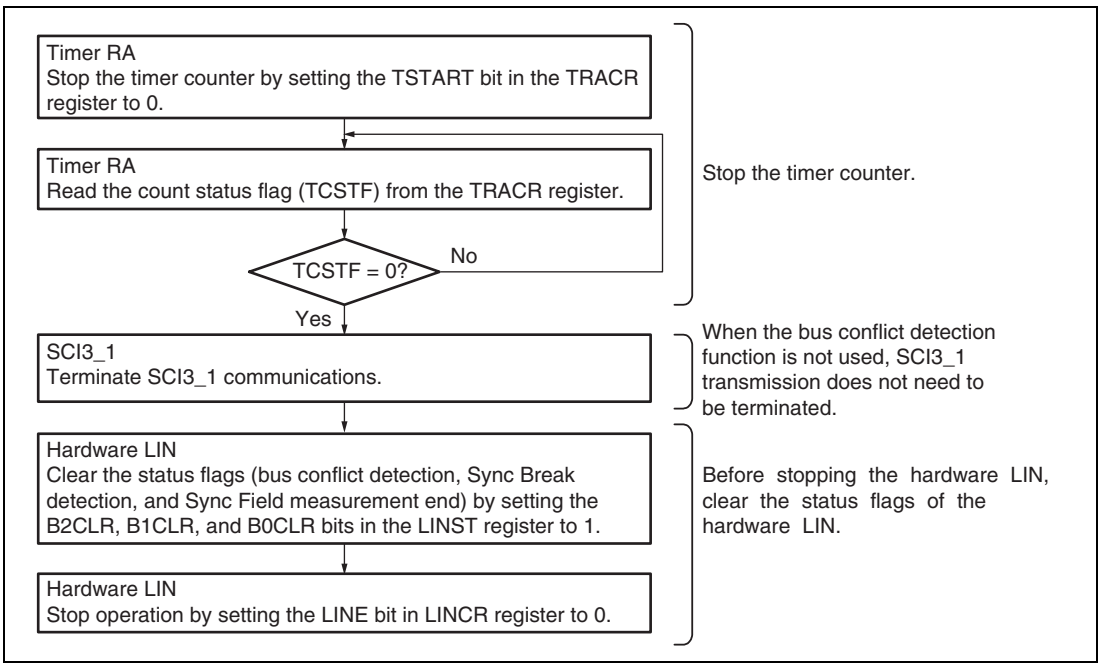


Figure 23.10 Flowchart for Terminating Hardware LIN Communications

23.4 Interrupt Requests

The hardware LIN interface can request four types of interrupts: Sync Break detection, Sync Break generation end, Sync Field measurement end, and bus conflict detection. All these interrupts are requested as the timer RA interrupt. Table 23.2 describes these interrupt requests.

Table 23.2 Interrupt Requests by Hardware LIN

Interrupt Request	Status Flag	Interrupt Source
Sync Break detection	SBDCT	• The low-level period of the RXD input is measured using timer RA and the counter underflows • The low-level period of the RXD input is longer than the Sync Break period during communications.
Sync Break generation end		The low level has been output via TXD for the period specified by timer RA.
Sync Field measurement end	SFDCT	Measuring the 8-bit Sync Field period has been completed using timer RA.
Bus conflict detection	BCDCT	The RXD input and TXD output values differ from each other when data is latched while SCI3_1 is enabled for transmission.

23.5 Usage Note

For processing the header and response field timeout, measure the time from the Sync Break detection interrupt using another timer.

Section 24 A/D Converter

This LSI includes a successive approximation type 10-bit A/D converter (one unit or two units) that allows up to sixteen analog input channels to be selected. Figures 24.1 and 24.2 show the block diagrams of A/D converters unit 1 and unit 2, respectively.

The differences between unit 1 and unit 2 are the number of analog input channels and the number of data registers. The other functions of units 1 and 2 are the same.

24.1 Features

- 10-bit resolution
- Input channels
  - Unit 1: 12 channels for the H8S/20223 and H8S/20203 groups and 8 channels for the H8S/20103 group
  - Unit 2: 4 channels for the H8S/20223 group
- Conversion time: 2 μs per channel (at 20 MHz operation)
- Operating modes: Two
  - A/D conversion mode: A selected analog input is A/D converted
  - Compare mode: A selected analog input is compared with the voltage specified by the user
- Channel select modes
  - Single mode: Single-channel A/D conversion or comparison
  - Scan mode: Continuous A/D conversion on 1 to 4 channels, or 1 to 8 channels
- Data registers: 8 data registers for unit 1 and 4 data registers for unit 2
  - Conversion results are held in a 16-bit data register for each channel
- Sample and hold function
- Three kinds of conversion start
  - Conversion can be started by software, conversion start trigger by 16-bit timer (timer RC or RD), or external trigger signal.
- Interrupt request
  - A/D conversion end interrupt (ADI) request can be generated
  - Compare result change interrupt (CMPI) request can be generated
- Module standby function can be set

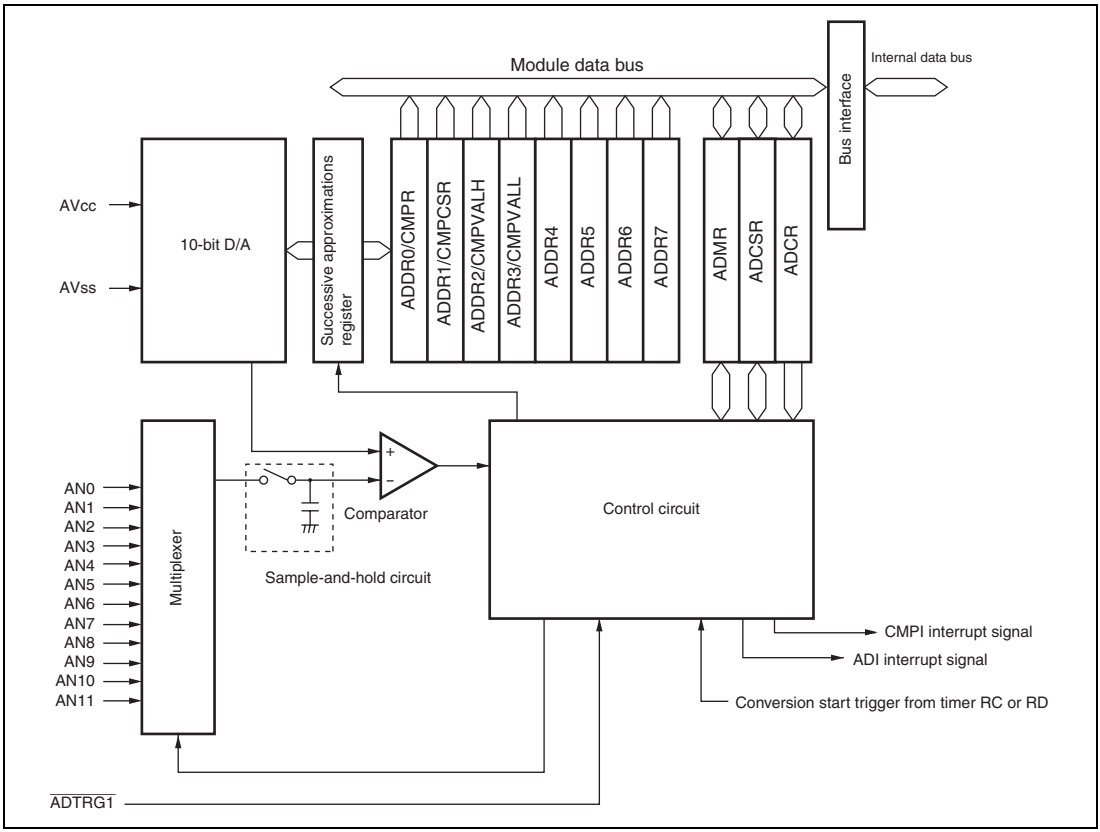


Figure 24.1 Block Diagram of A/D Converter (Unit 1)

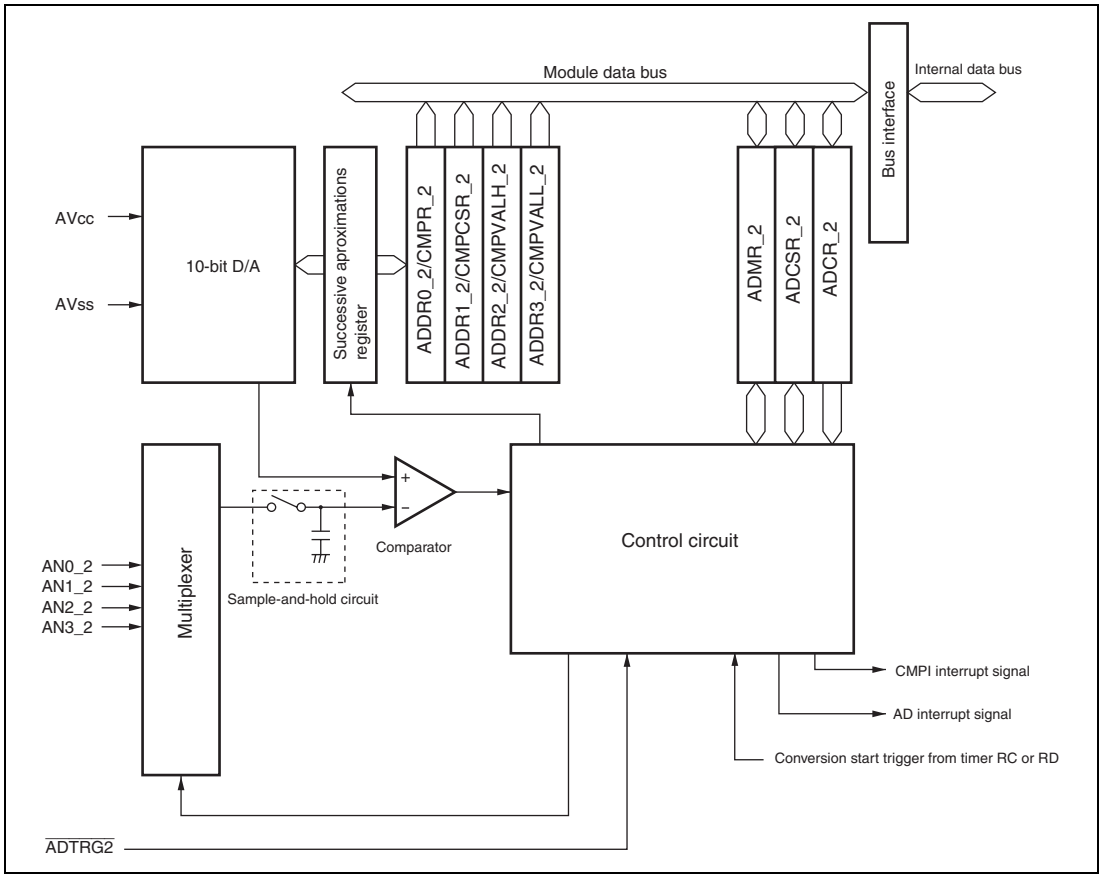


Figure 24.2 Block Diagram of A/D Converter (Unit 2)

Table 24.1 shows the pin configuration of the A/D converter.

The AV_{CC} and AV_{SS} pins are the power supply pins for the analog block in the A/D converter.

Unit 1 has 12 analog input pins; unit 2 has four analog input pins. Note that the actual number of analog inputs in units 1 and 2 depends on the product group.

Table 24.1 Pin Configuration

Unit	Pin Name	I/O	Function
Common	AV_{CC}	Input	Analog block power supply
	AV_{SS}	Input	Analog block ground
Unit 1	AN0	Input	Unit 1 group 0 analog inputs
	AN1	Input	
	AN2	Input	
	AN3	Input	
	AN4	Input	Unit 1 group 1 analog inputs
	AN5	Input	
	AN6	Input	
	AN7	Input	
	AN8	Input	Unit 1 group 2 analog inputs*[1]
	AN9	Input	
	AN10	Input	
	AN11	Input	
	$\overline{\text{ADTRG1}}$	Input	External trigger input 1 for starting A/D conversion
Unit 2	AN0_2	Input	Unit 2 group 0 analog inputs*[2]
	AN1_2	Input	
	AN2_2	Input	
	AN3_2	Input	
	$\overline{\text{ADTRG2}}$	Input	External trigger input 2 for starting A/D conversion

Notes: 1. Not supported in the H8S/20103 and H8S/20203 groups.
2. Supported only in the H8S/20223 group.

24.2 Register Description

The A/D converter has the following registers.

Unit 1:

- A/D data register 0 (ADDR0)
- A/D data register 1 (ADDR1)
- A/D data register 2 (ADDR2)
- A/D data register 3 (ADDR3)
- A/D data register 4 (ADDR4)
- A/D data register 5 (ADDR5)
- A/D data register 6 (ADDR6)
- A/D data register 7 (ADDR7)
- A/D control/status register (ADCSR)
- A/D control register (ADCR)
- A/D mode register (ADMR)
- Compare data register (CMPR)
- Compare control status register (CMPCSR)
- Compare voltage register H (CMPVALH)
- Compare voltage register L (CMPVALL)

Unit 2:

- A/D data register 0_2 (ADDR0_2)
- A/D data register 1_2 (ADDR1_2)
- A/D data register 2_2 (ADDR2_2)
- A/D data register 3_2 (ADDR3_2)
- A/D control/status register_2 (ADCSR_2)
- A/D control register_2 (ADCR_2)
- A/D mode register_2 (ADMR_2)
- Compare data register_2 (CMPR_2)
- Compare control status register_2 (CMPCSR_2)
- Compare voltage register H_2 (CMPVALH_2)
- Compare voltage register L_2 (CMPVALL_2)

24.2.1 A/D Data Registers 0 to 7 (ADDR0 to ADDR7)

Address: H'FF05E0 to H'FF05EE, H'FF0600 to H'FF0606

Bit:	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

ADDR registers are 16-bit read-only registers which are used to store the results of A/D conversion. Unit 1 incorporates eight registers ADDR0 to ADDR7. Unit 2 incorporates four registers ADDR0_2 to ADDR3_2. The ADDR registers, which store a conversion result for each channel, are shown in table 24.2.

The converted 10-bit data is stored to bits 15 to 6. The lower 6-bit data is always read as 0.

The data bus between the CPU and the A/D converter is 16-bit width. Data can be accessed in 16 bits at one time or 8 bits at two times.

Table 24.2 Analog Input Channels and Corresponding ADDR Registers

Analog Input Channel		A/D Data Register which Stores Conversion Result
Channel Set 0 (CH3 = 0)	**Channel Set 1 (CH3 = 1)**	
AN0	AN8	ADDR0
AN1	AN9	ADDR1
AN2	AN10	ADDR2
AN3	AN11	ADDR3
AN4	—	ADDR4
AN5	—	ADDR5
AN6	—	ADDR6
AN7	—	ADDR7

24.2.2 A/D Control/Status Register (ADCSR)

Address: H'FF05F0, H'FF0610

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	ADF	ADIE	ADST	—	CH[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	ADF	A/D end flag	0: A/D conversion or comparison is in progress. 1: A/D conversion or comparison has been completed. [Setting conditions] • When A/D conversion ends in single mode • When A/D conversion ends on all specified channels in scan mode [Clearing conditions] • When 0 is written after reading ADF = 1 • When the DTC is activated by an ADI interrupt and ADDR is read	R/W*
6	ADIE	A/D interrupt enable	0: Disables an ADF interrupt. 1: Enables an ADF interrupt.	R/W
5	ADST	A/D start	0: Stops A/D conversion and places the A/D converter in the wait state. 1: Starts A/D conversion.	R/W
4	—	Reserved bit	This bit is read as 0. The write value should be 0.	—
3 to 0	CH[3:0]	Channel select 3 to 0	When SCANE = 0 and SCANS = × 0000: AN0 0001: AN1 0010: AN2 0011: AN3 0100: AN4 0101: AN5 0110: AN6 0111: AN7 1000: AN8 1001: AN9 1010: AN10 1011: AN11 11xx: Setting prohibited	R/W

Bit	Symbol	Bit Name	Description	R/W
3 to 0	CH[3:0]	Channel select 3 to 0	When SCANE = 1 and SCANS = 0	R/W
			0000: AN0 0111: AN4 to AN7	
			0001: AN0 and AN1 1000: AN8	
			0010: AN0 to AN2 1001: AN8 and AN9	
			0011: AN0 to AN3 1010: AN8 to AN10	
			0100: AN4 1011: AN8 to AN11	
			0101: AN4 and AN5 11xx: Setting prohibited	
			0110: AN4 to AN6	
			When SCANE = 1 and SCANS = 1	
			0000: AN0 0111: AN0 to AN7	
			0001: AN0 and AN1 1000: AN8	
			0010: AN0 to AN2 1001: AN8 and AN9	
			0011: AN0 to AN3 1010: AN8 to AN10	
			0100: AN0 to AN4 1011: AN8 to AN11	
			0101: AN0 to AN5 11xx: Setting prohibited	
			0110: AN0 to AN6	

[Legend]

×: Don't care.

Notes: * Only 0 can be written in bit 7, to clear the flag.

1. The A/D converter should be stopped (ADST = 0) while the Input channels are being selected.
2. In unit 2, channels can be selected from four channels AN0_2 to AN3_2. Accordingly, the CH3 and CH2 bits should be cleared to 0 in unit 2.

- ADST bit (A/D start)

  Clearing this bit to 0 stops A/D conversion, and the A/D converter enters wait state. When this bit is set to 1 by software, timer RC, timer RD (conversion start trigger), or the $\overline{\text{ADTRG}}$ pin, A/D conversion starts. This bit remains set to 1 during A/D conversion. In single mode, this bit is cleared to 0 automatically when conversion on the specified channel ends. In scan mode, conversion continues sequentially on the specified channels until this bit is cleared to 0 by a reset, a transition to standby mode or software. ADST is cleared to 0 if A/D conversion of all the selected channels has been completed while the ADSTCLR bit is 1.

  The event link function can be used to set the ADST bit. When the event specified in ELSR10 or ELS11 of the ELC occurs, the corresponding ADST bits (in A/D converter unit 1 or A/D converter unit 2, respectively) are set and the A/D conversion starts.

24.2.3 A/D Control Register (ADCR)

Address: H'FF05F0, H'FF0611

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	TRGS[1:0]		SCANE	SCANS	CKS[1:0]		ADSTCLR	EXTRGS
Value after reset:	0	0	0	0	1	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	TRGS[1:0]	Trigger select 1 and 0	b0 b7 b6 0 0 0: A/D conversion start by external trigger is disabled. 0 0 1: A/D conversion start by external trigger pin 1 ($\overline{\text{ADTRG1}}$) is enabled. 0 1 0: A/D conversion start by external trigger pin 2 ($\overline{\text{ADTRG2}}$) is enabled.*1 0 1 1: A/D conversion start by external trigger (timer RC) is enabled.*2 1 0 0: A/D conversion start by external trigger (timer RD_0) is enabled. 1 0 1: A/D conversion start by external trigger (timer RD_1) is enabled.*3 1 1 x: Reserved (setting prohibited)	R/W
5	SCANE	Channel selection mode	0×: Single mode	R/W
4	SCANS		10: Scan mode (A/D conversion is performed continuously for channels 1 to 4) 11: Scan mode (A/D conversion is performed continuously for channels 1 to 8.)	
3, 2	CKS[1:0]*4	Clock select 1 to 0	00: Setting prohibited 01: Setting prohibited 10: A/D conversion time = 84 states (max) (initial value) 11: A/D conversion time = 43 states (max)	R/W
1	ADSTCLR	ADST clear	If ADSTCLR is set to 1 in scan mode, the ADST bit is automatically cleared to 0 when A/D conversion of all the selected channels has been completed.	R/W
0	EXTRGS	External trigger select	EXTRGS combined with the TRGS1 and TRGS0 bits selects a trigger signal. For details, see the above description for the TRGS1 and TRGS0 bits.	R/W

[Legend]

×: Don't care.

Note: 1. Selected only for the H8S/20223 group.
2. Selected only for the H8S/20103 group.
3. Not selected only for the H8S/20103 group.
4. Select these bits to fall the conversion time within the specified time.

- TRGS[1:0] bits (trigger select 1 and 0)

  These bits combined with the EXTRGS bit select enable or disable the A/D conversion start by a trigger signal.

- CKS[1:0] bits (clock select 1 to 0)

  These bits the A/D conversion time.

  The conversion time should be set while the A/D conversion is stopped (ADST = 0).

24.2.4 A/D Mode Register (ADMR)

Address: H'FF05F4, H'FF0614

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	ADM1	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7, 6	—	Reserved	These bits are read as 0. The write value should be 0.	—
5	ADM1	A/D converter operating mode selection	0: A/D conversion mode 1: Compare mode	R/W
4 to 0	—	All 0	These bits are read as 0. The write value should be 0.	—

Note: The A/D converter operating mode should be changed while the ADST bit in ADCSR is 0.

- ADM1 bit (A/D conversion mode selection)

  If the A/D converter operating mode changes from conversion mode to compare mode, CMPR, CMPCSR, and CMPVAL are initialized to H'00.

24.2.5 Compare Data Register (CMPR)

Address: H'FF05E0, H'FF0600

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	CMP7	CMP6	CMP5	CMP4	CMP3	CMP2	CMP1	CMP0
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	CMP7	Compare data 7	[Setting condition] When the voltage of the selected analog input channel is greater than the voltage set in the CMPVAL register in compare mode. [Clearing conditions] • When the A/D converter operating mode is changed from A/D conversion mode to compare mode according to the ADM bit in ADMR setting. • When the voltage of the selected analog input channel is equal to or lower than the voltage set in the CMPVAL register in compare mode.	R
6	CMP6	Compare data 6		R
5	CMP5	Compare data 5		R
4	CMP4	Compare data 4		R
3	CMP3	Compare data 3		R
2	CMP2	Compare data 2		R
1	CMP1	Compare data 1		R
0	CMP0	Compare data 0		R

[Legend]

×: Don't care.

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

CMPR holds the comparison result. CMPR is a read-only register that is assigned to the same address as ADDR0 and ADDR0_2. CMPR is valid in compare mode.

CMP bits and the corresponding analog input channels are shown in table 24.3.

Table 24.3 Relationship between CMP Bits and Corresponding Analog Input Channels

Unit	Channel		Corresponding Compare Data Bit
Unit 1	AN0	AN8	CMP0
	AN1	AN9	CMP1
	AN2	AN10	CMP2
	AN3	AN11	CMP3
	AN4	—	CMP4
	AN5	—	CMP5
	AN6	—	CMP6
	AN7	—	CMP7
Unit 2	AN0_2	—	CMP0
	AN1_2	—	CMP1
	AN2_2	—	CMP2
	AN3_2	—	CMP3

24.2.6 Compare Control Status Register (CMPCSR)

Address: H'FF05E2, H'FF0602

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	CMPF	CMPIE	CMPFC1	CMPFC0	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	CMPF	CMPI interrupt status	[Setting condition] If the condition specified by the CMPFC1 or CMPFC0 bit is satisfied when comparison has been completed. [Clearing conditions] • When the A/D converter operating mode is changed from A/D conversion mode to compare mode according to the ADM bit in ADMR setting. • When 0 is written to this bit after this bit is read as 1. • When the DTC is activated by a CMPI interrupt and the DISEL bit in MRB of the DTC is 0. • When this LSI enters standby mode or module standby mode.	R/W
6	CMPIE	CMPI interrupt enable	0: Disables a compare match interrupt (CMPI). 1: Enables a compare match interrupt (CMPI).	R/W

Bit	Symbol	Bit Name	Description	R/W
5	CMPFC1	CMPI interrupt condition 1	0: Does not generate an interrupt by a comparison result change. 1: In single compare mode: Sets the CMPF bit to 1 if the comparison result of the selected channel changes from 0 to 1. In scan compare mode: Sets the CMPF bit to 1 if the comparison result of any of the selected channels changes from 0 to 1.	R/W
4	CMPFC0	CMPI interrupt condition 0	0: Does not generate an interrupt by a comparison result change. 1: In single compare mode: Sets the CMPF bit to 1 if the comparison result of the selected channel changes from 0 to 1. In scan compare mode: Sets the CMPF bit to 1 if the comparison result of any of the selected channels changes from 0 to 1.	R/W
3 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

24.2.7 Compare Analog Level Registers H and L (CMPVALH and CMPVALL)

• CMPVALH

Address: H'FF05E4, H'FF0604

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	VAL9	VAL8
Value after reset:	0	0	0	0	0	0	0	0

• CMPVALL

Address: H'FF05E6, H'FF0606

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	VAL7	VAL6	VAL5	VAL4	VAL3	VAL2	VAL1	VAL0
Value after reset:	0	0	0	0	0	0	0	0

- CMPVALH

Bit	Symbol	Bit Name	Description	R/W
7 to 2	—	Reserved	This bit is read as 0. The write value should be 0.	—
1	VAL9	—	These bits set the compare voltage VAL[9:8].	R/W
0	VAL8	—		R/W

- CMPVALL

Bit	Symbol	Bit Name	Description	R/W
7	VAL7	—	These bits set the compare voltage VAL[7:0].	R/W
6	VAL6	—		R/W
5	VAL5	—		R/W
4	VAL4	—		R/W
3	VAL3	—		R/W
2	VAL2	—		R/W
1	VAL1	—		R/W
0	VAL0	—		R/W

CMPVALL and the lower 2 bits of CMPVALH specify the voltage to be compared.

CMPVALH and CMPVALL are assigned to the same addresses as ADDR2 (ADDR2_2) and ADDR3 (ADDR3_2), respectively. CMPVALH and CMPVALL become valid in compare mode.

Table 24.4 shows the correspondence between VAL[9:0] setting and the voltage to be compared.

Table 24.4 VAL[9:0] Setting and Corresponding Voltage to be Compared

VAL[9:0] Setting	Voltage to be Compared
B'0000000000	AVss
B'0000000001	AVcc × 1/1024
B'0000000010	AVcc × 2/1024
:	:
B'111111100	AVcc × 1020/1024
B'111111101	AVcc × 1021/1024
B'111111110	AVcc × 1022/1024
B'111111111	AVcc × 1023/1024

24.3 Operation

The A/D converter operates in two operating modes as shown in table 24.5. In A/D conversion mode, the A/D converter converts the analog input of the selected channel by successive approximation with 10-bit resolution. In compare mode, the analog input of the selected channel is compared with the voltage to be specified.

Each operating mode has two operating modes: single mode and scan mode. When changing the analog input channel, to prevent incorrect operation, first clear the ADST bit in ADCSR to 0. The ADST bit can be set at the same time as the operating mode or analog input channel is changed.

Table 24.5 A/D Converter Operating Mode

Operating Mode	Channel Selection Mode	Register Setting
A/D conversion mode	Single mode	ADM1 = 0, SCANE = 0
	Scan mode	ADM1 = 0, SCANE = 1
Compare mode	Single mode	ADM1 = 1, SCANE = 0
	Scan mode	ADM1 = 1, SCANE = 1

24.4 A/D Conversion Mode Operation

24.4.1 Single Mode in A/D Conversion Mode

In single mode in A/D conversion mode, A/D conversion is to be performed only once on the specified single channel. Operations are as follows.

1. A/D conversion is started when the ADST bit in ADCSR is set to 1, according to the software or external trigger input.
2. When A/D conversion is completed, the result is transferred to the A/D data register corresponding to the channel.
3. On completion of conversion, the ADF bit in ADCSR is set to 1. If the ADIE bit is set to 1 at this time, an ADI interrupt request is generated.
4. The ADST bit remains set to 1 during A/D conversion, and is automatically cleared to 0 when conversion ends. When the ADST bit is cleared to 0 during A/D conversion, A/D conversion stops and the A/D converter enters wait state.

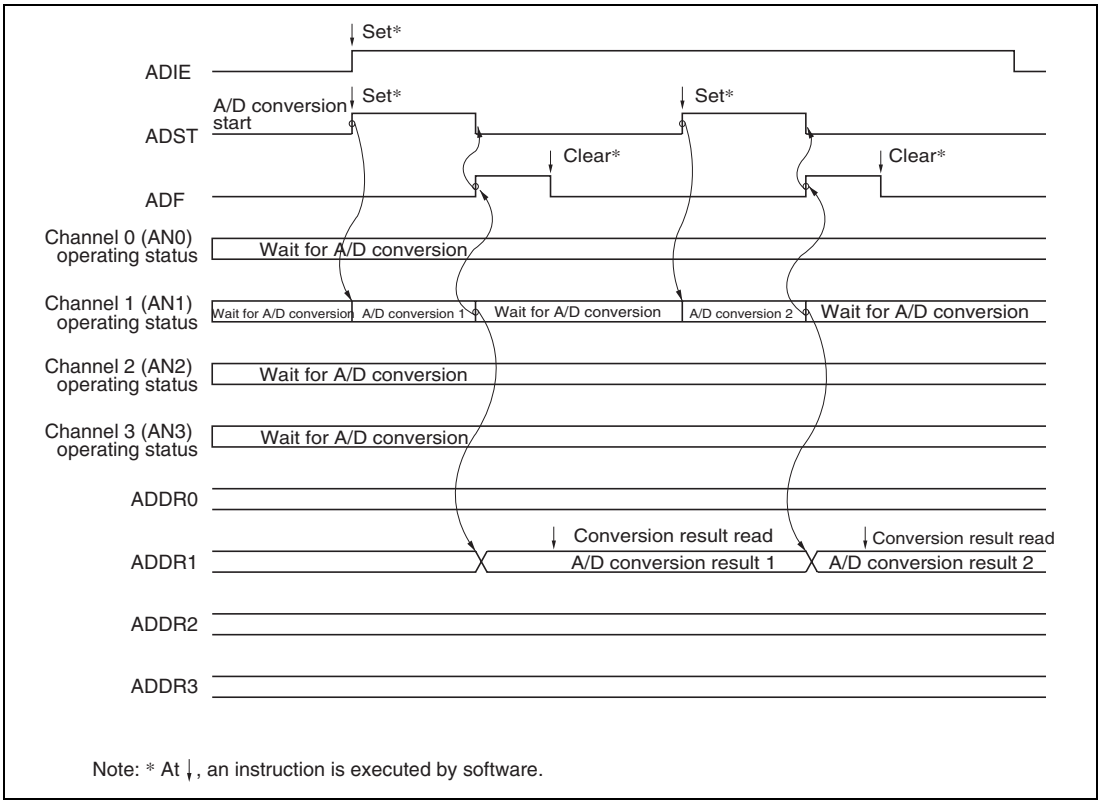


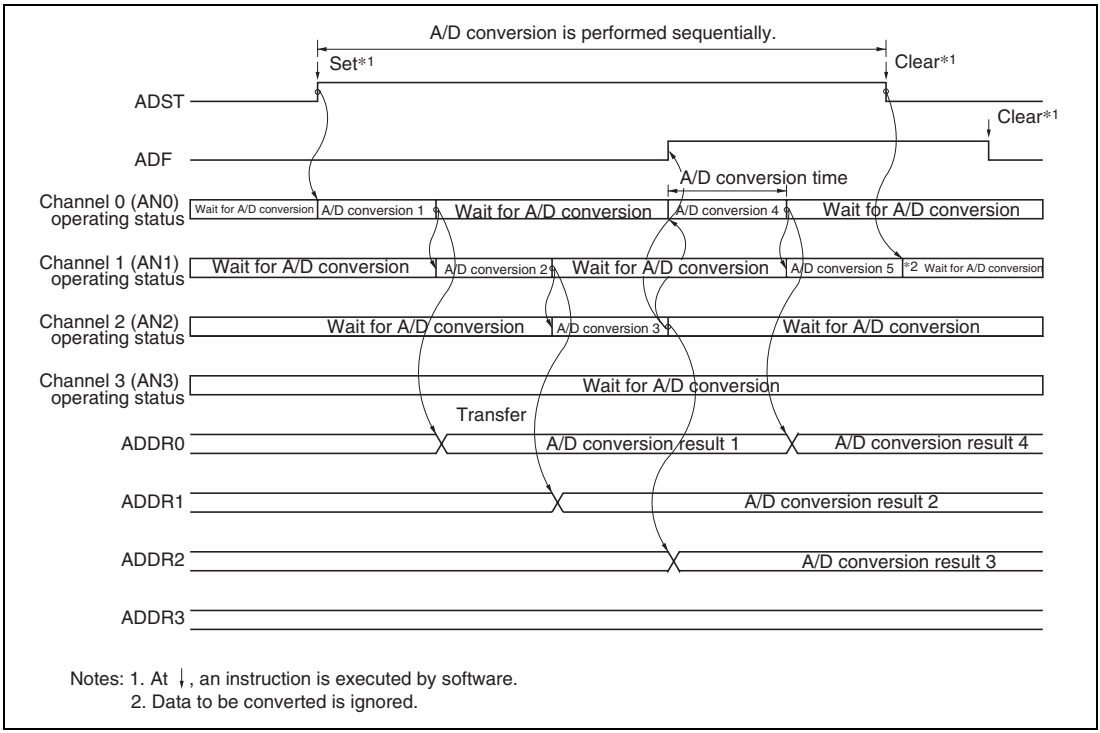
Figure 24.3 A/D Converter Operation in A/D Conversion Mode (When Channel 1 Is Selected in Single Mode)

24.4.2 Scan Mode in A/D Conversion Mode

In scan mode in A/D conversion mode, A/D conversion is to be performed sequentially on the specified channels: maximum four channels or maximum eight channels. Operations are as follows.

1. When the ADST bit in ADCSR is set to 1 by a software, timer RC, timer RD or external trigger input, A/D conversion starts on the first channel of the channel set.

   The consecutive A/D conversion on maximum four channels (SCANE = 1 and SCANS = 0) or on maximum eight channels (SCANE = 1 and SCANS = 1) can be selected. When the consecutive A/D conversion is performed on the four channels, the A/D conversion starts on AN0 when CH3 = 0 and CH2 =0, AN4 when CH3 = 0 and CH2 = 1, or AN8 when CH3 = 1 and CH2 = 0. When the consecutive A/D conversion is performed on the eight channels, the A/D conversion starts on AN0 when CH3 = 0 and CH2 = 0.
2. When A/D conversion for each channel is completed, the result is sequentially transferred to the A/D data register corresponding to each channel.
3. When conversion of all the selected channels is completed, the ADF bit in ADCSR is set to 1. If the ADIE bit is set to 1 at this time, an ADI interrupt is requested. The A/D conversion starts again from the first channel of the channel set again.
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. When the ADST bit is cleared to 0, A/D conversion stops and the A/D converter enters wait state. If the ADST bit is later set to 1, A/D conversion starts again from the first channel of the channel set.



Notes: 1. At ↓, an instruction is executed by software.
2. Data to be converted is ignored.

Figure 24.4 A/D Converter Operation in A/D Conversion Mode (When AN0 to AN2 Channels are Selected in Scan Mode)

24.5 Compare Mode Operation

24.5.1 Single Mode in Compare Mode

In single mode in compare mode, the analog input of one selected channel is compared with the specified voltage. Operations are as follows. The setting of the channel by the CH[3:0] bits in ADCSR is the same as that in A/D conversion mode.

1. Comparison between the analog input of the selected channel and the voltage specified by the VAL[9:0] bits is started when the ADST bit in ADCSR is set to 1 by software or external trigger input.
2. When the comparison is completed, the result is transferred to a bit corresponding to the channel.
3. On completion of comparison, the ADF bit in ADCSR is set to 1. If the ADIE bit is set to 1 at this time, an ADI interrupt request is generated. In addition, if a condition specified by the CMPFC1 or CMPFC0 bit is satisfied, the CMPF bit in CMPCSR is set to 1. If the CMPIE bit is set to 1 at this time, a CMPI interrupt is requested.
4. The ADST bit remains set to 1 during comparison, and is automatically cleared to 0 when comparison ends. When the ADST bit is cleared to 0 during comparison, the A/D converter stops operation and enters wait state.

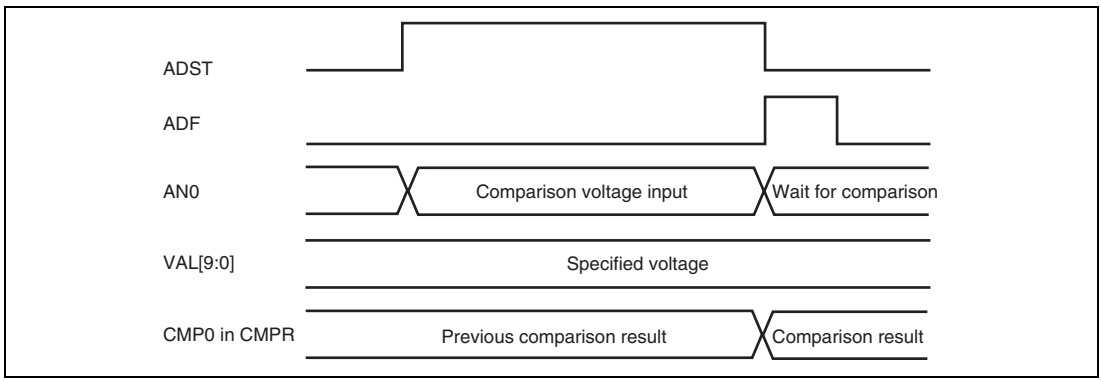


Figure 24.5 A/D Converter Operation in Compare Mode (When Channel 0 Is Selected in Single Mode)

24.5.2 Scan Mode in Comparison Mode

In scan mode in comparison mode, the analog input of the selected channels (four or eight maximum) are compared sequentially with the specified voltage. Operations are as follows.

1. When the ADST bit in ADCSR is set to 1 by a software, timer RC, timer RD or external trigger input, comparison between the analog input of the selected channels and the voltage specified by the VAL[9:0] bits is started.

   The comparison on maximum four channels (SCANE = 1 and SCANS= 0) or on maximum eight channels (SCANE = 1 and SCANS= 1) can be selected. When the consecutive comparison is performed on the four channels, the comparison starts on AN0 when CH3 = 0 and CH2 = 0, AN4 when CH3 = 0 and CH2 = 1, or AN8 when CH3 = 1 and CH2 = 0. When the consecutive comparison is performed on the eight channels, the comparison starts on AN0 when CH3 = 0 and CH2 = 0.
2. When comparison for each channel is completed, the result is sequentially transferred to a bit corresponding to each channel.
3. When comparison of all the selected channels is completed, the ADF bit in ADCSR is set to 1. If the ADIE bit is set to 1 at this time, an ADI interrupt is requested. In addition, if a condition specified by the CMPFC1 or CMPFC0 bits is satisfied in any of the selected channels, the CMPF bit in CMPCSR is set to 1. If the CMPIE bit is set to 1 at this time, a CMPI interrupt is requested. The A/D converter starts comparison from the first channel of the channel set.
4. The ADST bit is not cleared automatically when ADSTCLR = 0, and steps [2] to [3] are repeated as long as the ADST bit remains set to 1. When the ADST bit is cleared to 0 during comparison, the A/D converter stops operation and enters wait state. If the ADST bit is later set to 1, the A/D converter starts comparison from the first channel of the channel set.

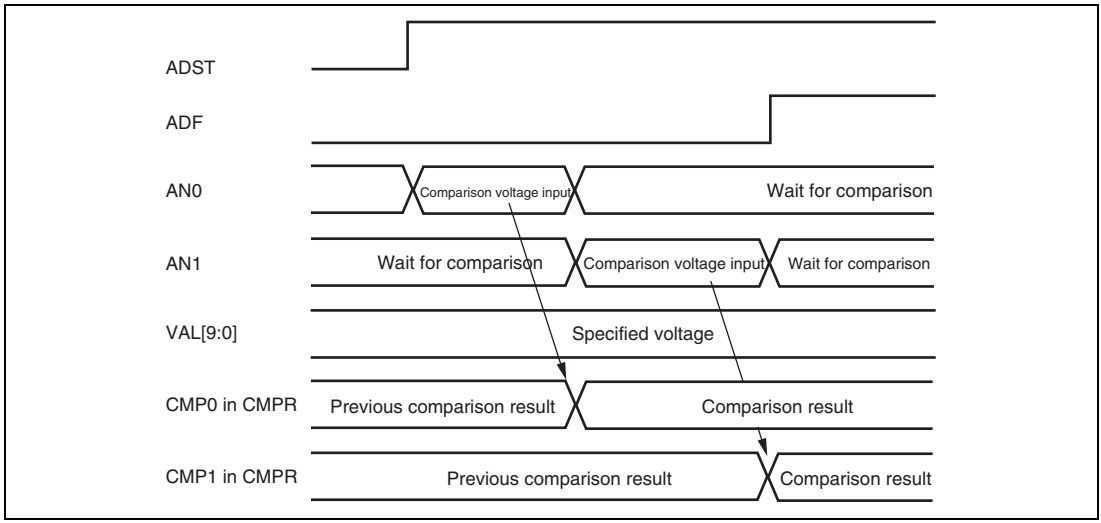


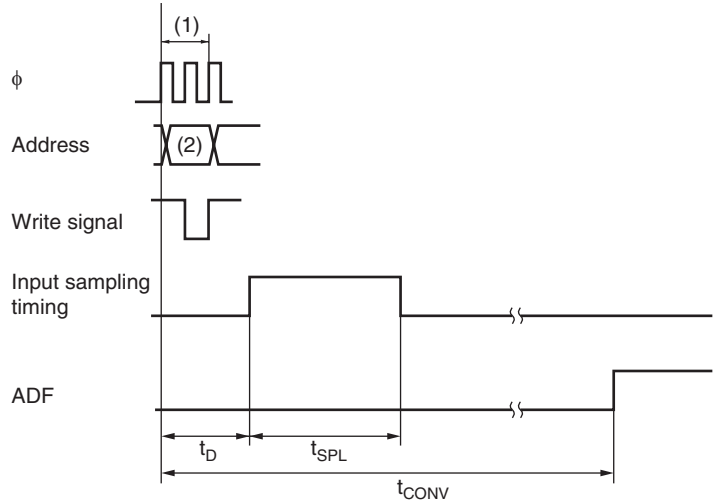
Figure 24.6 A/D Converter Operation in Compare Mode (When AN0 to AN2 Channels are Selected in Scan Mode)

24.5.3 Input Sampling and A/D Conversion Time

The A/D converter has a built-in sample-and-hold circuit. The A/D converter samples the analog input when A/D conversion start delay time (t_D) passes after the ADST bit is set to 1, then starts conversion. Figure 24.7 shows the A/D conversion timing. Table 24.6 indicates the A/D conversion time.

As indicated in figure 24.7, the A/D conversion time (t_{CONV}) includes t_D and the input sampling time (t_{SPL}). The length of t_D varies depending on the timing of the write access to ADCSR. The total conversion time therefore varies within the ranges indicated in tables 24.6.

In scan mode, the values given in table 24.6 apply to the first conversion time. The values given in table 24.7 apply to the second and subsequent conversions. In any conversions, the CKS[1:0] bits in ADCR should be set so that the conversion time should fall within the specified A/D conversion characteristics range.



Legend:
(1) : ADCSR write cycle
(2) : ADCSR address
t_D : A/D conversion start delay time
t_{SPL} : Input sampling time
t_{CONV} : A/D conversion time

Figure 24.7 A/D Conversion Timing

Table 24.6 A/D Conversion Time (Single Mode)

		CKS1 = 1					
		CKS0 = 0			CKS0 = 1		
Item	**Symbol**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**
A/D conversion start delay time	t_D	3	—	4	—	3	—
Input sampling time	t_{SPL}	—	30	—	—	15	—
A/D conversion time	t_{CONV}	83	—	84	—	43	—

Note: Values in the table are the number of states.

Table 24.7 A/D Conversion Time (Scan Mode)

CKS1	CKS0	Conversion Time (State)
1	0	80
	1	40

24.5.4 External Trigger Input Timing

A/D conversion can be externally triggered. When the EXTRGS, TRGS1 and TRGS0 bits are set to B' 000 in ADCR, external trigger input is enabled at the $\overline{\text{ADTRG}}$ pin. A falling edge of the $\overline{\text{ADTRG}}$ pin sets the ADST bit in ADCSR to 1, starting A/D conversion. Other operations, in both single and scan modes, are the same as when the bit ADST has been set to 1 by software. Figure 24.8 shows the timing.

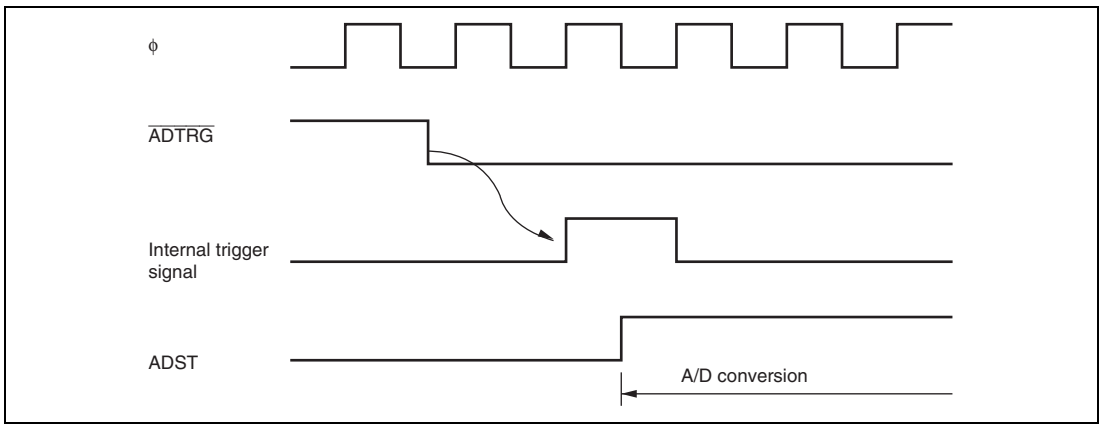


Figure 24.8 External Trigger Input Timing

24.6 Interrupt Source

In A/D conversion mode, an A/D conversion end interrupt (ADI) occurs at the end of A/D conversion. Specifically, the ADF bit in ADCSR is set to 1 when A/D conversion is completed; and if the ADIE bit is 1 at this time, the A/D converter generates an ADI interrupt.

In compare mode, a compare result change interrupt (CMPI) occurs if the comparison result of the specified channel changes (in three cases: from 1 to 0, from 0 to 1, and both). Specifically, the CMPF bit is set when the comparison result between the specified channel and the specified voltage satisfies the specified condition; and if the CMPIE bit is 1 at this time, the A/D converter generates a CMPI interrupt.

The DTC can be activated by an ADI or CMPI interrupt. Having the converted data read by the DTC in response to an ADI or CMPI interrupt enables continuous conversion to be achieved without imposing a load on software.

Table 24.8 A/D Converter Interrupt Source

Name	Interrupt Source	Interrupt Flag	DTC Activation
ADI	End of A/D conversion or comparison	ADF	Possible
CMPI	Comparison result change	CMPF	Possible

24.7 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 24.9).
- 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 B'0000000000 (H'000) to B'0000000001 (H'001) (see figure 24.10).
- Full-scale error

  The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from B'1111111110 (H'3FE) to B'1111111111 (H'3FF) (see figure 24.10).
- 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 24.10).
- Absolute precision

  The deviation between the digital value and the analog input value. Includes the offset error, full-scale error, quantization error, and nonlinearity error.

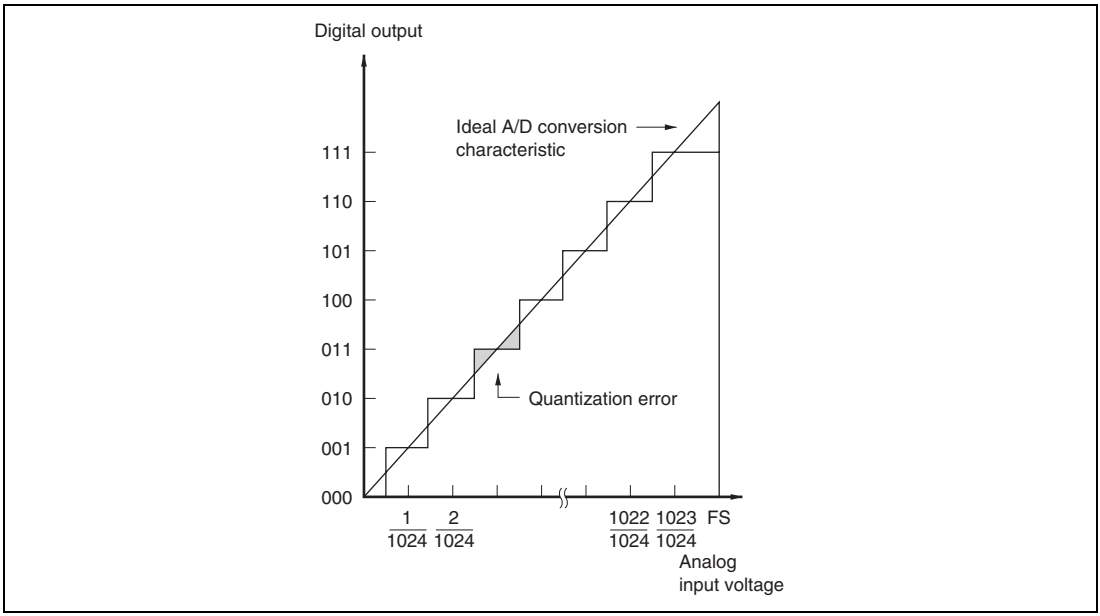


Figure 24.9 A/D Conversion Accuracy Definitions

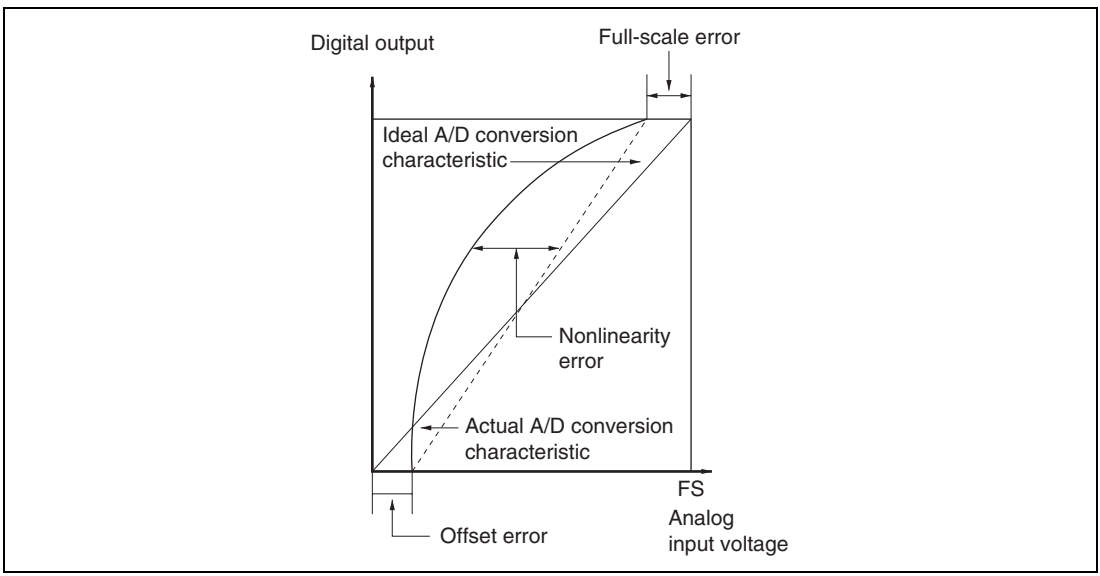


Figure 24.10 A/D Conversion Accuracy Definitions

24.8 Usage Notes

24.8.1 Module Standby Mode Setting

Operation of the A/D converter can be disabled or enabled using the module standby control register. The initial setting is for operation of the A/D converter to be halted. Register access is enabled by clearing module standby mode. For details, see section 6, Power-Down Modes.

24.8.2 Permissible Signal Source Impedance

This LSI's analog input is designed so that conversion precision is guaranteed for an input signal for which the signal source impedance is TBD kΩ or less. This specification is provided to enable the A/D converter's sample-and-hold circuit input capacitance to be charged within the sampling time; if the sensor output impedance exceeds TBD kΩ, charging may be insufficient and it may not be possible to guarantee the A/D conversion accuracy. However, if a large capacitance is provided externally for conversion in single mode, the input load will essentially comprise only the internal input resistance of TBD kΩ, and the signal source impedance is ignored. However, since a low-pass filter effect is obtained in this case, it may not be possible to follow an analog signal with a large differential coefficient (e.g., 5 mV/μs or greater) (see figure 24.11). When converting a high-speed analog signal or conversion in scan mode, a low-impedance buffer should be inserted.

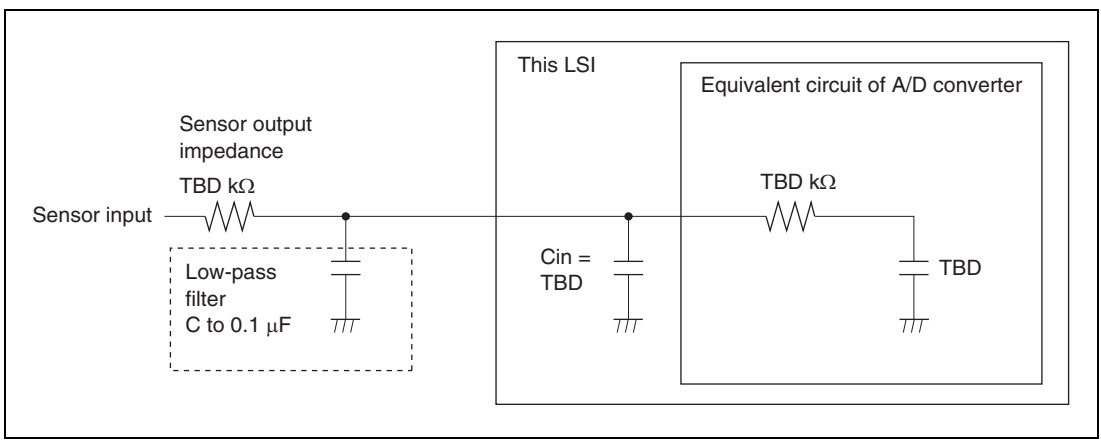


Figure 24.11 Example of Analog Input Circuit

24.8.3 Influences on Absolute Precision

Adding capacitance results in coupling with GND, and therefore noise in GND may adversely affect absolute precision. Be sure to make the connection to an electrically stable GND such as AVss.

Care is also required to insure that filter circuits do not communicate with digital signals on the mounting board, so acting as antennas.

24.8.4 Setting Range of Analog Power Supply and Other Pins

If conditions shown below are not met, the reliability of the device may be adversely affected.

- Analog input voltage range
  The voltage applied to analog input pin ANn during A/D conversion should be in the range AVss ≤ ANn ≤ AVcc.
- Relation between AVcc, AVss and Vcc, Vss
  As the relationship between AVcc, AVss and Vcc, Vss, set AVcc ≤ Vcc and AVss = Vss. If the A/D converter is not used, the AVcc and AVss pins must not be left open.

24.8.5 Notes on Board Design

In board design, digital circuitry and analog circuitry should be as mutually isolated as possible, and layout in which digital circuit signal lines and analog circuit signal lines cross or are in close proximity should be avoided as far as possible. Failure to do so may result in incorrect operation of the analog circuitry due to inductance, adversely affecting A/D conversion values.

Also, digital circuitry must be isolated from the analog input signals (AN0 to AN1, AN0_2 to AN3_2) and analog power supply (AVcc) by the analog ground (AVss). Also, the analog ground (AVss) should be connected at one point to a stable digital ground (Vss) on the board.

24.8.6 Notes on Noise Countermeasures

A protection circuit connected to prevent damage due to an abnormal voltage such as an excessive surge at the analog input pins (AN0 to AN11, AN0_2 to AN3_2) should be connected between AVcc and AVss as shown in figure 24.12. Also, the bypass capacitors connected to AVcc and the filter capacitor connected to AN0 to AN11 or AN0_2 to AN3_2 must be connected to AVss.

If a filter capacitor is connected, the input currents at the analog input pins (AN0 to AN1, AN0_2 to AN3_2) are averaged, and so an error may arise. Also, when A/D conversion is performed frequently, as in scan mode, if the current charged and discharged by the capacitance of the sample-and-hold circuit in the A/D converter exceeds the current input via the input impedance (R_{in}), an error will arise in the analog input pin voltage. Careful consideration is therefore required when deciding the circuit constants.

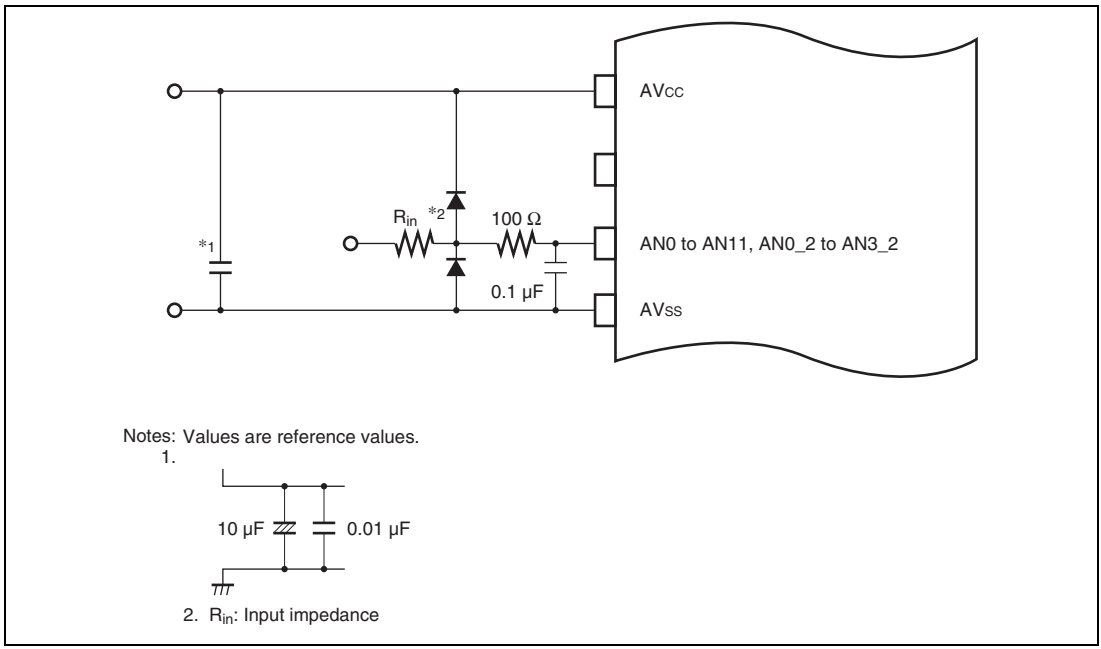


Figure 24.12 Example of Analog Input Protection Circuit

24.8.7 Notes on Analog Input Pins

Analog input pins (AN0 to AN11, AN0_2 to AN3_2) are multiplexed with general I/O ports. Accordingly, if the direction of input or output of the general I/O port is changed or the output value of the general I/O port is changed during A/D conversion, the conversion accuracy may be affected.

Before using an analog input pin multiplexed with general I/O port as a general I/O port, influence on the A/D conversion accuracy should be evaluated carefully.

Section 25 D/A Converter

25.1 Features

- 8-bit resolution
- Output channels: 2 channels
- Maximum conversion time of 3 μs (with 20 pF load capacitance)
- Output voltage of 0 V to AVcc
- Settable for the module standby mode

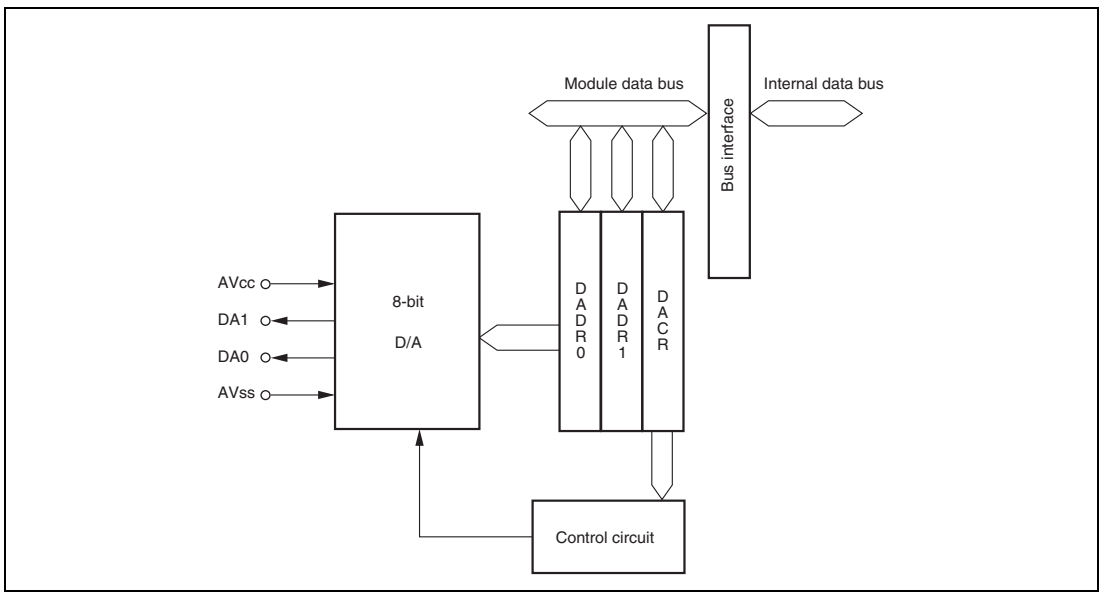


Figure 25.1 Block Diagram of D/A Converter

Table 25.1 shows the input/output pin configuration of the D/A converter.

Table 25.1 Pin Configuration

Pin Name	I/O	Function
AVcc	Input	Analog power supply
AVss	Input	Analog ground
DA0	Output	Channel 0 analog output
DA1	Output	Channel 1 analog output

25.2 Register Descriptions

- D/A data register 0 (DADR0)
- D/A data register 1 (DADR1)
- D/A control register (DACR)

25.2.1 D/A Data Registers 0 and 1 (DADR0 and DADR1)

- DADR0 and DADR1

• DADR0, DADR1

Address: H'FF05D4, H'FF05D5

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

DADR0 and DADR1 are 8-bit readable/writable registers that store data for conversion. Whenever analog output is enabled, the values in DADR are converted and output to the analog output pins. DADR is initialized to H'00 in standby mode or module standby.

25.2.2 D/A Control Register (DACR)

Address: H'FF05D6

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	DAOE1	DAOE0	—	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	DAOE1	D/A output enable 1	0: Disables the analog output on channel 1 (DA1). 1: Enables the channel 1 D/A conversion; enables the analog output (DA1).	R/W
6	DAOE0	D/A output enable 0	0: Disables the analog output on channel 0 (DA0). 1: Enables the channel 0 D/A conversion; enables the analog output (DA0).	R/W
5 to 0	—	Reserved	These bits are always read as 0 and cannot be modified.	—

Note: In standby mode or module standby mode, the contents of DACR are retained.

- DAOE1 bit and DAOE0 bit (D/A output enable 1 and 0)

  These bits control the D/A conversion and analog output.

  The event link function can be used to set the DAOE[1:0] bits. When the event specified in ELSR31 or ELSR32 of the ELC occurs, the corresponding DAOE1 or DAOE0 bit is set to 1, respectively and the D/A conversion starts.

25.3 Operation

The D/A converter includes D/A conversion circuits for two channels, each of which can operate independently. When DAOE bit in DACR is set to 1, D/A conversion is enabled and the conversion result is output. The operation example of D/A conversion on channel 0 is as follows. Figure 25.2 shows the timing of this operation.

1. Write the conversion data 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 t_{DCONV} has elapsed. The conversion result is continued 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:

$$\frac{\text{DADR contents}}{256} \times \text{AVcc}$$

3. If DADR0 is written to again, the conversion is immediately started. The conversion result is output after the conversion time t_{DCONV} has elapsed.

4. If the DAOE0 bit is cleared to 0, analog output is disabled.

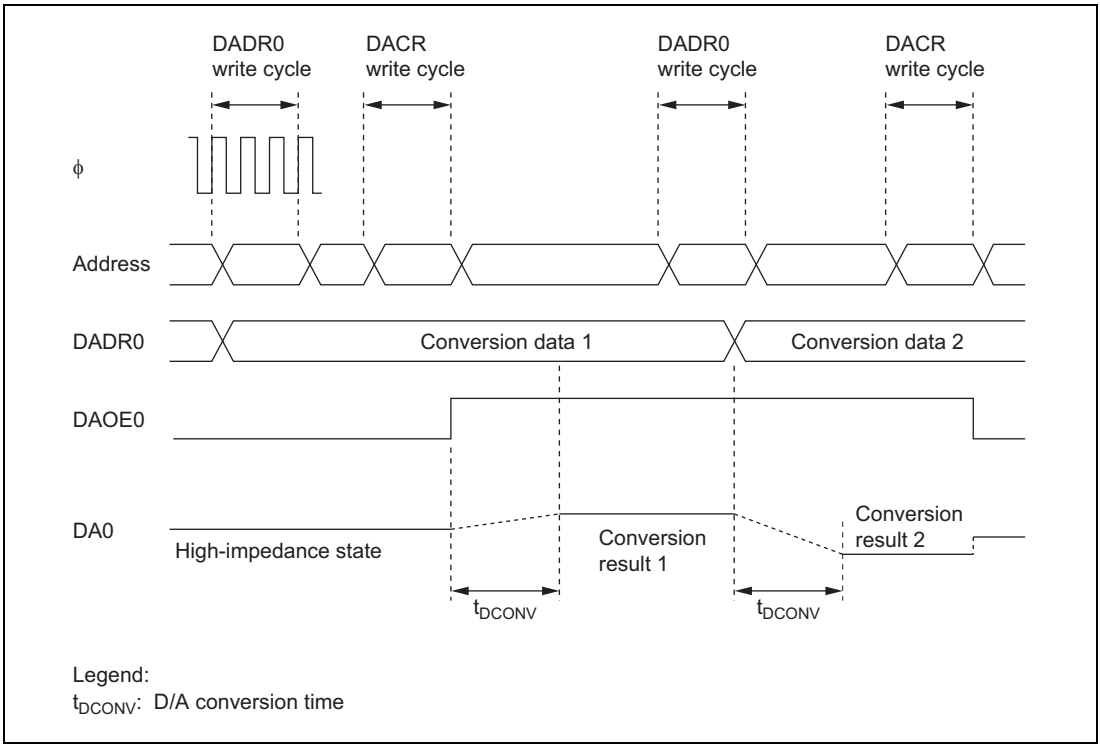


Figure 25.2 Example of D/A Converter Operation

25.4 Usage Notes

25.4.1 Setting for Module Stop Mode

The module standby control can select to enable/disable the D/A converter operation. The D/A converter does not operate by the initial value of the register. The register can be accessed by releasing the module standby mode. DADR is initialized in module standby.

25.4.2 Operation in Standby Mode

If D/A conversion is enabled and this LSI enters standby mode, DADR is initialized while DACR is held. When the analog power supply current is required to go low in software standby mode, the DAOE1 and DAOE0 bits should be cleared to 0, and D/A output should be disabled.

Section 26 Low-Voltage Detection Circuits

This microcontroller includes a low-voltage detection module consisting of three circuits, LVD0, LVD1, and LVD2.

The circuits are used to prevent abnormal operation (runaway execution) from occurring due to the power supply voltage falling and to recreate the state of the microcontroller before the power supply voltage fell when the power supply voltage rises again.

If the power supply voltage falls below a threshold voltage set by the users application, a warning can be given to the application so the application can shutdown in a controlled manner. If the power supply voltage continues to fall below a second programmable threshold voltage, the device can be safely placed in the reset state. This avoids the situation where the power supply voltage falls below the guaranteed operating voltage and the microcontroller enters an unstable state. Thus, system stability can be improved. If the power supply voltage rises again, active mode is automatically entered.

The circuits monitor the power-supply voltage, and generate a reset or an interrupt when the voltage falls below or rises above a specified value.

Figure 26.1 is a block diagram of the low-voltage detection circuits. Figures 26.2, 26.3, and 26.4 are block diagrams of the LVD2, LVD1 and LVD0 interrupt/reset generation circuits, respectively.

26.1 Features

- Power-on reset function

  Monitors the power-supply voltage input to the VCC pin to generate an internal reset signal when power is first supplied.

  Releases a reset when the power-supply voltage rises above the specified voltage.

- Low-voltage detection function

  Reset function: Monitors the power-supply voltage, and generates an internal reset signal when the voltage falls below a specified value.

  Interrupt function: Monitors the power-supply voltage, and generates an interrupt when the voltage falls below or rises above respective specified values.

  Detection levels: 11 levels are available for LVD1 and two levels are available for LVD0. (The level is fixed for LVD2.

  External voltage input function: For detection, external pins can be selected for a detection voltage and a reference voltage, respectively (LVD2 only).

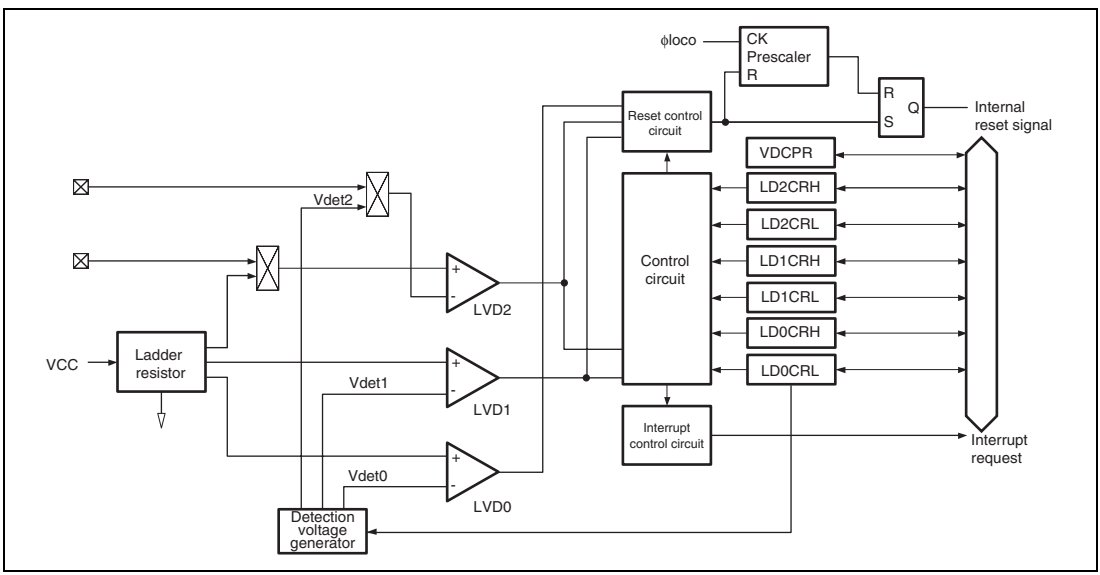


Figure 26.1 Block Diagram of Low-Voltage Detection Circuits

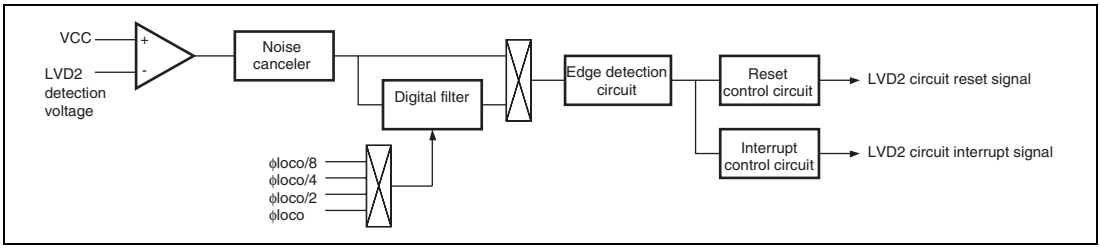


Figure 26.2 Block Diagram of LVD2 Interrupt/Reset Generation Circuit

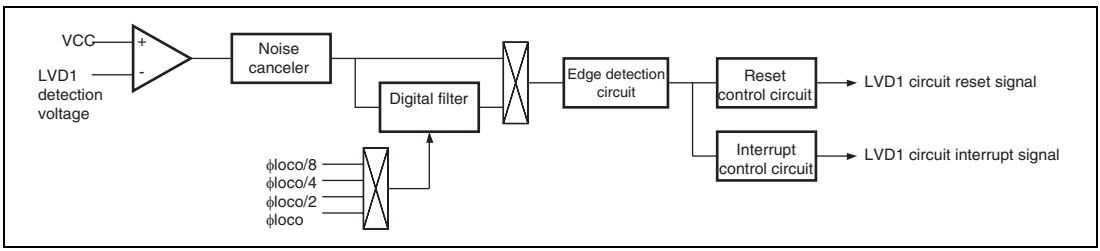


Figure 26.3 Block Diagram of LVD1 Interrupt/Reset Generation Circuit

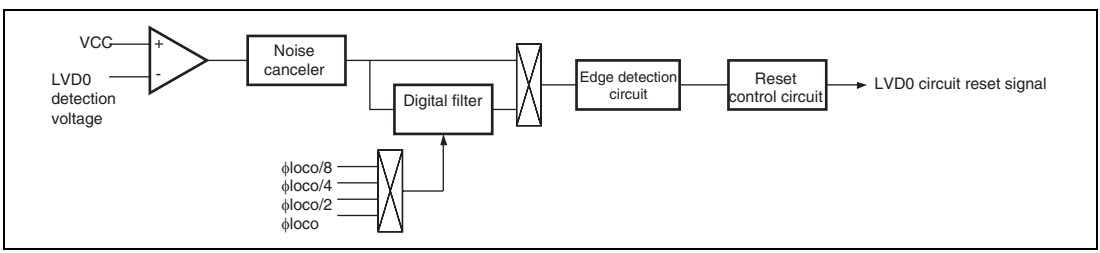


Figure 26.4 Block Diagram of LVD0 Reset Generation Circuit

26.2 Register Descriptions

This module has the following registers.

- Low-voltage detection circuit control protect register (VDCPR)
- Low-voltage detection circuit 2 control register H (LD2CRH)
- Low-voltage detection circuit 2 control register L (LD2CRL)
- Low-voltage detection circuit 1 control register H (LD1CRH)
- Low-voltage detection circuit 1 control register L (LD1CRL)
- Low-voltage detection circuit 0 control register H (LD0CRH)
- Low-voltage detection circuit 0 control register L (LD0CRL)

26.2.1 Low-Voltage Detection Circuit Control Protect Register (VDCPR)

Address: H'FF0628

Bit:	7	6	5	4	3	2	1	0
	WRI	—	—	—	—	—	—	LDPRC
Value after reset:	1	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	WRI	VDCPR write disable	0: Writing to the VDCPR bit is enabled. 1: Writing to the VDCPR bit is disabled.	R/W
6 to 1	—	Reserved	These bits are read as 0. The write value should always be 0.	—
0	LDPRC	Low-voltage detection circuit control register write enable	0: Writing to each low-voltage detection circuit control register is disabled. 1: Writing to each low-voltage detection circuit control register is enabled.	R/W

Note: Use a MOV instruction to modify this register.

- WRI bit (VDCPR write disable)

  Only when this bit is written to 0, writing to this register is enabled. This bit is always read as 1.

- LDPRC bit (Low-voltage detection circuit control register write enable)

  Only when the value of this bit is 1, writing to the low-voltage detection circuit control register (LD2CRH, LD2CRL, LD1CRH, LD1CRL, LD0CRH and LD0CRL) is enabled.

26.2.2 Low-Voltage Detection Circuit 2 Control Register H (LD2CRH)

Address: H'FF0622

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	VF2DF	VD2UF	VD2DFCK[1:0]		VD2DFS	VD2IRCS	VD2MS	VD2RE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	VD2DF	LVD2 power supply voltage drop flag	[Setting condition] • When the power-supply voltage falls below Vdet2. [Clearing conditions] • When 1 is read from this bit and then 0 is written to this bit. • When the LVD2 circuit is in standby mode.	R/W
6	VD2UF	LVD2 power supply voltage rise flag	[Setting condition] • When the power supply voltage falls below Vdet2 and rises to Vdet2 or higher before falling to Vdet0 or lower. [Clearing conditions] • When 1 is read from this bit and then 0 is written to this bit. • When the LVD2 circuit is in standby mode.	R/W
5, 4	VD2DFCK[1:0]	LVD2 digital filter sampling clock select	00: ϕloco/1 01: ϕloco/2 10: ϕloco/4 11: ϕloco/8	R/W
3	VD2DFS	LVD2 digital filter function select	0: Disables the digital filter function 1: Enables the digital filter function	R/W
2	VD2IRCS	LVD2 interrupt request generation condition select	0: when VCC rises to Vdet2 or higher. 1: when VCC falls to Vdet2 or lower. When VD2DFS = 1, an interrupt request is generated when the voltage reaches Vdet2, regardless of this bit setting. When VD2MS = 1, a reset request is generated when the voltage falls below Vdet2, regardless of this bit setting.	R/W

Bit	Symbol	Bit Name	Description	R/W
1	VD2MS	LVD2 mode select	0: Generates an interrupt request when the voltage reaches Vdet2. 1: Generates a reset request when the voltage reaches Vdet2.	R/W
0	VD2RE	LVD2 interrupt/ reset request enable	This bit is enabled when the VD2E bit is 1. 0: Disables interrupt/reset requests when the specified voltage level is detected. 1: Enables interrupt/reset requests when the specified voltage level is detected.	R/W

Table 26.1 shows the relationship between LD2CRH settings and the selection function. LD2CRH should be used according to table 26.1.

Table 26.1 LD2CRH Settings and Select Functions

LD2CRH Settings			Selection Function		
VD2MS	**VD2DFS**	**VD2IRCS**	**LVD2 Falling Reset**	**LVD2 Falling Interrupt**	**LVD2 Rising Interrupt**
1	x	x	O	—	—
0	1	x	—	O	O
0	0	1	—	O	—
0	0	0	—	—	O

[Legend] x: Don't care.

26.2.3 Low-Voltage Detection Circuit 2 Control Register L (LD2CRL)

Address: H'FF0623

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	VD2E	VD2CVS	VD2RVS	—	—	—	—	—
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	VD2E	LVD2 circuit enable	0: The LVD2 circuit is not used. (In standby mode) 1: The LVD2 circuit is used.	R/W
6	VD2CVS	LVD2 circuit reference voltage input select	0: VCC voltage is used as the reference voltage. 1: Externally input (PA7) voltage is used as the reference voltage.*	R/W
5	VD2RVS	LVD2 circuit detection voltage input select	0: Internally generated voltage is used as the detection voltage. 1: Externally input (PA6) voltage is used as the detection voltage.*	R/W
4 to 0	—	Reserved	These bits are read as 0. The write value should be 0.	—

Note: * When an externally input voltage is used as the reference voltage or detection voltage, the externally input voltage must not exceed ½ Vcc.

26.2.4 Low-Voltage Detection Circuit 1 Control Register H (LD1CRH)

Address: H'FF0624

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	VD1DF	VD1UF	VD1DFCK[1:0]		VD1DFS	VD1IRCS	VD1MS	VD1RE
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	VD1DF	LVD1 power supply voltage drop flag	[Setting condition] • When the power-supply voltage falls below Vdet1. [Clearing conditions] • When 1 is read from this bit and then 0 is written to. • When the LVD1 circuit is in standby mode.	R/W
6	VD1UF	LVD1 power supply voltage rise flag	[Setting condition] • When the power supply voltage falls below Vdet1 and rises to Vdet1 or higher before falling to Vdet0 or lower [Clearing conditions] • When 1 is read from this bit and then 0 is written to. • When the LVD1 circuit is in standby mode.	R/W
5, 4	VD1DFCK [1:0]	LVD1 digital filter sampling clock select	00: φloco/1 01: φloco/2 10: φloco/4 11: φloco/8	R/W
3	VD1DFS	LVD1 digital filter function select	0: Disables the digital filter function 1: Enables the digital filter function	R/W
2	VD1IRCS	LVD1 interrupt request generation condition select	0: Generates an interrupt request when VCC rises to Vdet1 or more. 1: Generates an interrupt request when VCC falls to Vdet1 or less. When VD1DFS = 1, an interrupt request is generated when the voltage reaches Vdet1, regardless of this bit setting. When VD1MS = 1, a reset request is generated when the voltage falls below Vdet1, regardless of this bit setting.	R/W

Bit	Symbol	Bit Name	Description	R/W
1	VD1MS	LVD1 mode select	0: Generates an interrupt request when the voltage reaches Vdet1. 1: Generates a reset request when the voltage reaches Vdet1.	R/W
0	LD1RE	LVD1 interrupt/ reset request enable	This bit is enabled when the VD1E bit is 1. 0: Disables interrupt/reset requests generated when the specified voltage level is detected. 1: Enables interrupt/reset requests generated when the specified voltage level is detected.	R/W

Table 26.2 shows the relationship between the LD1CRH settings and selection function. LD1CRH should be set according to table 26.2.

Table 26.2 LD1CRH Settings and Select Functions

LD1CRH			Select Functions		
VD1MS	**VD1DFS**	**VD1IRCS**	**LVD1 Falling Reset**	**LVD1 Falling Interrupt**	**LVD1 Rising Interrupt**
1	x	x	O	—	—
0	1	x	—	O	O
0	0	1	—	O	—
0	0	0	—	—	O

[Legend] x: Don't care.

26.2.5 Low-Voltage Detection Circuit 1 Control Register L (LD1CRL)

Address: H'FF0625

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	VD1E	—	—	—	VD1LS[3:0]			
Value after reset:	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
7	VD1E	LVD1 circuit enable	0: The LVD1 circuit is not used. (In standby mode) 1: The LVD1 circuit is used.	R/W
6 to 4	—	Reserved	These bits are read as 0. The write value should be 0.	—
3 to 0	VD1LS [3:0]	LVD1 detection voltage level select 3 to 0	0000: Setting prohibited 0001: Setting prohibited 0010: Setting prohibited 0011: Setting prohibited 0100: Setting prohibited 0101: 2.85 V (typ.) 0110: 2.92 V (typ.) 0111: 3.07 V (typ.) 1000: 3.22 V (typ.) 1001: 3.37 V (typ.) 1010: 3.52 V (typ.) 1011: 3.67 V (typ.) 1100: 3.82 V (typ.) 1101: 3.97 V (typ.) 1110: 4.12 V (typ.) 1111: 4.27 V (typ.)	R/W

26.2.6 Low-Voltage Detection Circuit 0 Control Register H (LD0CRH)

Address: H'FF0626

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	VD0DFCK[1:0]		VD0DFS	—	—	—
Value after reset:	—	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as undefined value. The write value should be 0.	—
6	—	Reserved	This bit is read as 0. The write value should be 0.	—
5, 4	VD0DFCK[1:0]	LVD0 digital filter sampling clock select	00: ϕloco/1 01: ϕloco/2 10: ϕloco/4 11: ϕloco/8	R/W
3	VD0DFS	LVD0 digital filter function select	0: Disables the digital filter function. 1: Enables the digital filter function.	R/W
2, 1	—	Reserved	These bits are read as 0. The write value should always be 0.	—
0	—	Reserved	This bit is read as 1. The write value should be 1.	—

26.2.7 Low-Voltage Detection Circuit 0 Control Register L (LD0CRL)

Address: H'FF0627

Bit:	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	—	—	—	—	VD0LS1	—
Value after reset:	1	0	0	0	0	0	0	1

Bit	Symbol	Bit Name	Description	R/W
7	—	Reserved	This bit is read as 1. The write value should be 1.	—
6 to 2	—	Reserved	This bit is read as 0. The write value should be 0.	—
1	VD0LS1	LVD0 detection voltage level select	0: 2.35 V (typ.) 1: 3.80 V (typ.)	R/W
0	—	Reserved	The write value should always be 0.	—

26.3 Operation

26.3.1 Power-On Reset Function

Figure 26.5 shows the operation timing of the power-on reset function. During the power-on reset function, the LVD0 circuit monitors the power-supply voltage level to initialize the entire chip.

When the power-supply voltage level rises above Vdet0, the prescaler is released from its reset state and it starts counting. The OVF signal is generated to release the internal reset signal after the prescaler has counted 128 ϕloco cycles. After a power-on reset, the LVD0 reset function is always enabled.

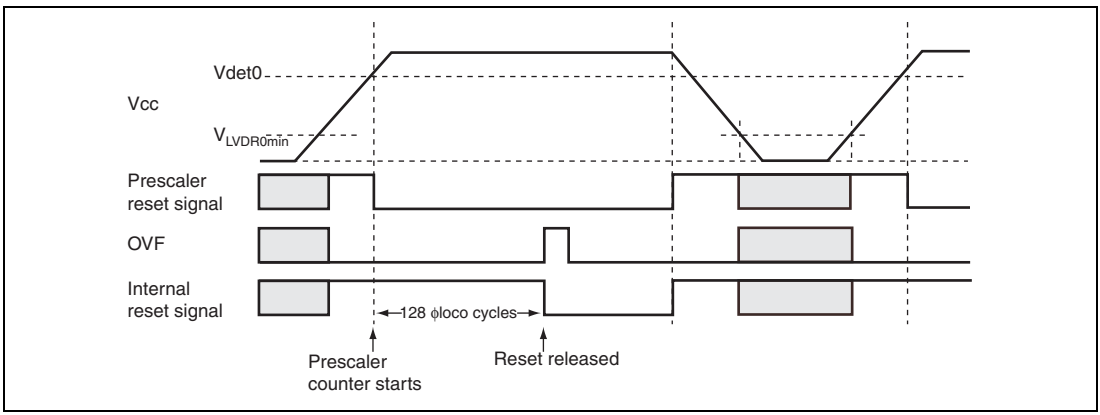


Figure 26.5 Operational Timing of Power-On Reset

26.3.2 Low-Voltage Detection Circuit

(1) Low Voltage Detect Reset 2 (LVDR2)

LVDR2 is a reset generated by the LVD2 circuit. Figure 26.6 shows the operation timing of the LVDR2.

The LVD2 enters the module-standby state after release from a power-on reset. To operate the LVDR2, set the VD2E bit in LD2CRL to 1, wait for TBD µs (t_{LVD2ON}) until the detection voltage and the low-voltage detection circuit 2 operation have stabilized using a software timer, etc., then set the VD2MS and VD2RE bits in LD2CRH to 1. After that, the output settings of I/O ports must be made. To cancel the LVDR2, first the VD2RE bit in LD2CRH should be cleared to 0 and then the VD2E bit in LD2CRL should be cleared to 0. Figure 26.7 shows the procedure to set the LVDR2.

When the power-supply voltage falls below Vdet2, the LVDR2 clears the $\overline{\text{LVDRES2}}$ signal to 0, and resets the prescaler. The low-voltage detection reset state remains in place until a power-on reset is generated. When the power-supply voltage rises above the Vdet2 voltage again, the prescaler starts counting. It counts 32 ϕloco cycles, and then releases the internal reset signal.

Note that if the power supply voltage falls below $V_{LVDR2min}$ = TBD V and then rises from that point, the LVDR2 may not occur. Such a case should be evaluated thoroughly.

If the power supply voltage falls below Vdet0, a power-on reset occurs.

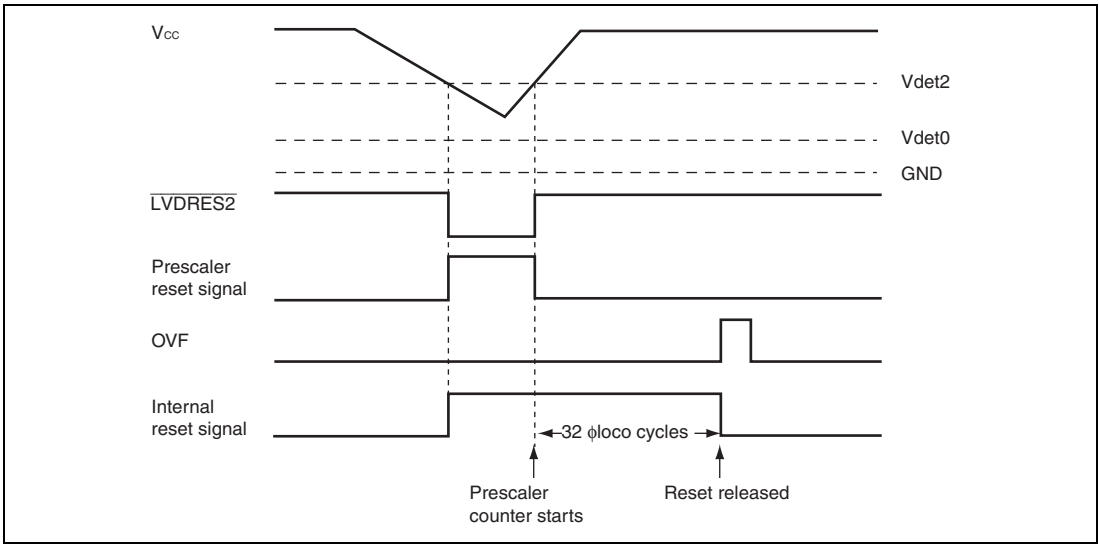


Figure 26.6 Operation Timing of LVDR2

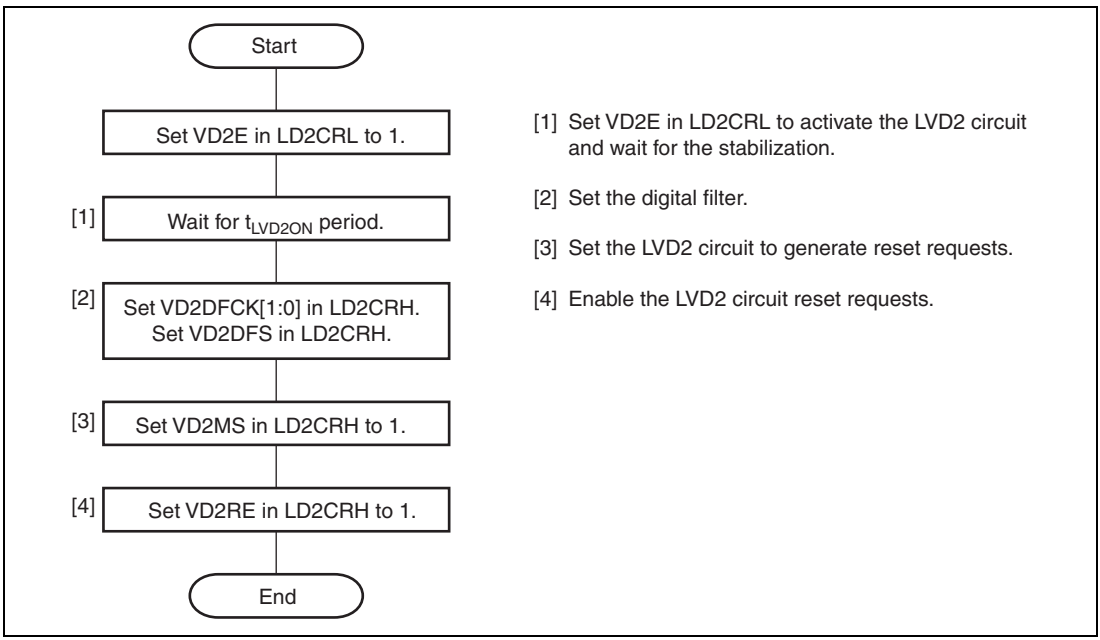


Figure 26.7 Procedure to Set LVDR2

(2) Low Voltage Detect Interrupt 2 (LVDI2)

LVDI2 is an interrupt generated by the LVD2 circuit. Figure 26.8 shows the operation timing of LVDI2.

The LVD2 enters the module-standby state after release from a power-on reset. To operate the LVDI2, set the VD2E bit in LD2CRL to 1, wait for TBD µs (t_{LVD2ON}) until the detection voltage and the low-voltage detection circuit 2 operation have stabilized using a software timer, etc., then clear the VD2MS bit to 0 and set the VD2RE bit to 1 in LD2CRH. After that, the output settings of I/O ports must be made. To cancel the LVDI2, first the VD2RE bit in LD2CRH should be cleared to 0 and then the VD2E bit in LD2CRL should be cleared to 0. Figure 26.9 shows the procedure to set the LVDI2.

When the power-supply voltage falls below Vdet2, the LVDI2 clears the $\overline{\text{LVDINT2}}$ signal to 0 and the VD2DFS bit in LD2CRH is set to 1. If the VD2DFS or VD2IRCS bit in LD2CRH is 1 at this time, an LVD2 interrupt request is simultaneously generated. In this case, the necessary data must be saved in the on-chip flash memory area or external EEPROM, etc, and a transition must be made to standby mode or sleep mode. Until this processing is completed, the power supply voltage must be higher than the lower limit of the guaranteed operating voltage.

When the power-supply voltage does not fall below Vdet0 but rises above Vdet2, the LVDI2 sets the $\overline{\text{LVDINT2}}$ signal to 1 and set the VD2UF bit in LD2CRH to 1. If the VD2DFS bit in LD2CRH is 1 or the VD2IRCS bit in LD2CRH is 0 at this time, an LVD2 interrupt request is simultaneously generated.

If the power supply voltage falls below Vdet0, a power-on reset occurs.

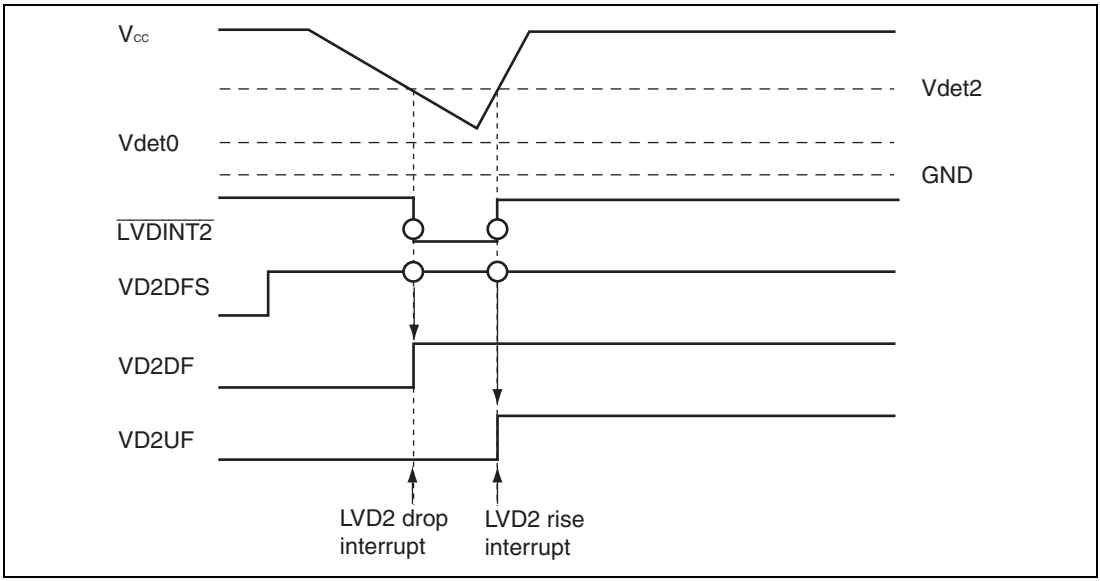


Figure 26.8 Operation Timing of LVDI2

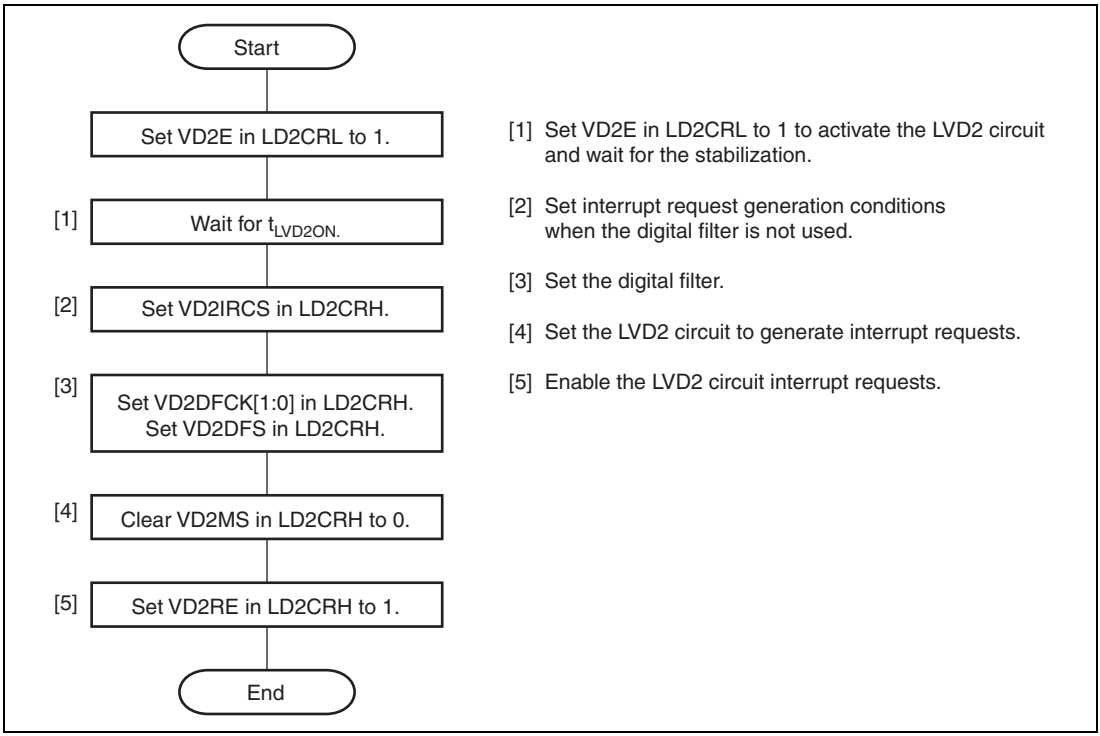


Figure 26.9 Procedure to Set LVDR2

(3) Low Voltage Detect Reset 1 (LVDR1)

LVDR1 is a reset generated by the LVD1 circuit. Figure 26.10 shows the operation timing of the LVDR1.

The LVD1 enters the module-standby state after release from a power-on reset. To operate the LVDR1, set the VD1E bit in LD1CRL to 1, wait for TBD µs (t_{LVD1ON}) until the detection voltage and the low-voltage detection circuit 1 operation have stabilized using a software timer, etc., then set the VD1MS and VD1RE bits in LD1CRH to 1. After that, the output settings of I/O ports must be made. To cancel the LVDR1, first the VD1RE bit in LD1CRH should be cleared to 0 and then the VD1E bit in LD1CRL should be cleared to 0. Figure 26.11 shows the procedure to set the LVDR1.

When the power-supply voltage falls below Vdet1, the LVDR1 clears the $\overline{\text{LVDRES1}}$ signal to 0, and resets the prescaler. The low-voltage detection reset state remains in place until a power-on reset is generated. When the power-supply voltage rises above the Vdet1 voltage again, the prescaler starts counting. It counts 32 ϕloco cycles, and then releases the internal reset signal.

Note that if the power supply voltage falls below $V_{LVDR1min}$ = TBD V and then rises from that point, the LVDR1 may not occur. Such a case should be evaluated thoroughly.

If the power supply voltage falls below Vdet0, a power-on reset occurs.

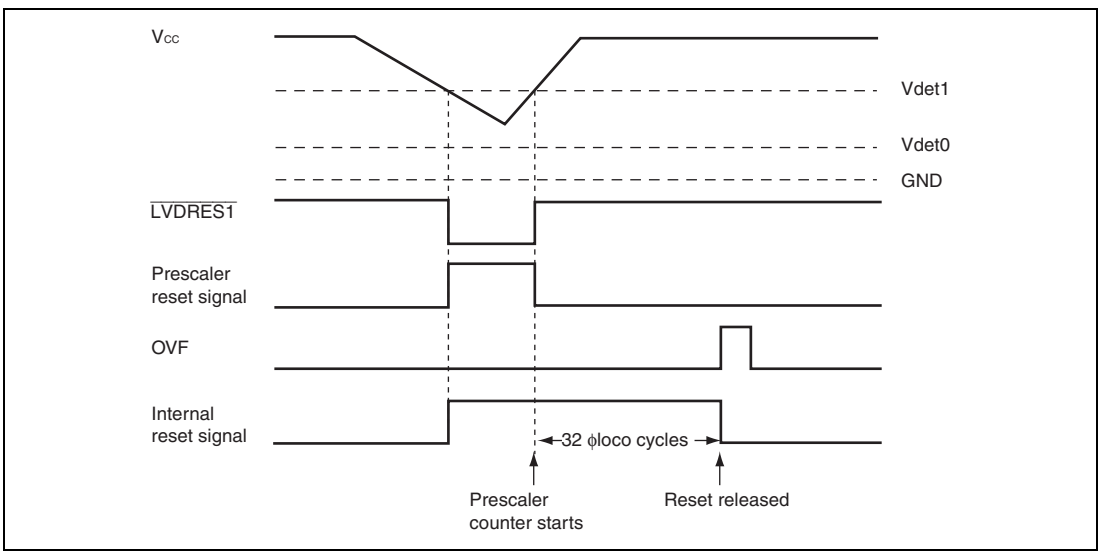


Figure 26.10 Operation Timing of LVDR1

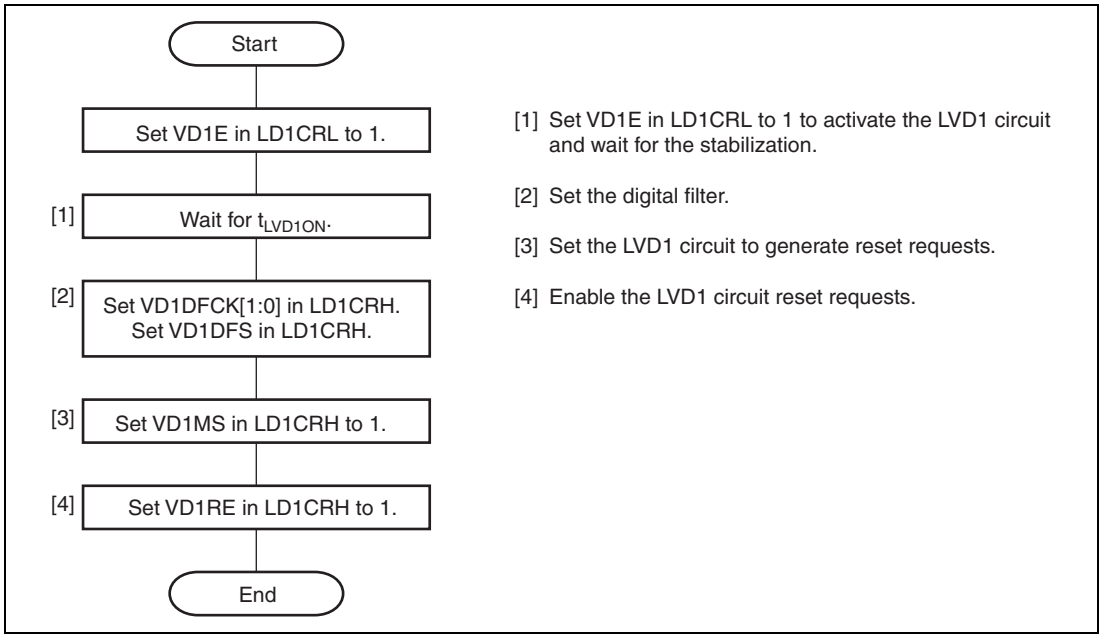


Figure 26.11 Procedure to Set LVDR1

(4) Low Voltage Detect Interrupt 1 (LVDI1)

LVDI1 is an interrupt generated by the LVD1 circuit. Figure 26.12 shows the operation timing of LVDI1.

The LVD1 enters the module-standby state after release from a power-on reset is canceled. To operate the LVDI1, set the VD1E bit in LD1CRL to 1, wait for TBD µs (t_{LVD1ON}) until the detection voltage and the low-voltage detection circuit 1 operation have stabilized using a software timer, etc., then clear the VD1MS bit to 0 and set the VD1RE bit to 1 in LD1CRH. After that, the output settings of I/O ports must be made. To cancel the LVDI1, first the VD1RE bit in LD1CRH should be cleared to 0 and then the VD1E bit in LD1CRL should be cleared to 0. Figure 26.13 shows the procedure to set the LVDI1.

When the power-supply voltage falls below Vdet1, the LVDI1 clears the $\overline{\text{LVDINT1}}$ signal to 0 and the VD1DFS bit in LD1CRH is set to 1. If the VD1DFS or VD1IRCS bit in LD1CRH is 1 at this time, an LVD1 interrupt request is simultaneously generated. In this case, the necessary data must be saved in the on-chip flash memory area or external EEPROM, etc, and a transition must be made to standby mode or sleep mode. Until this processing is completed, the power supply voltage must be higher than the lower limit of the guaranteed operating voltage.

When the power-supply voltage does not fall below Vdet0 but rises above Vdet1, the LVDI2 sets the $\overline{\text{LVDINT1}}$ signal to 1 and set the VD1UF bit in LD2CRH to 1. If the VD1DFS bit in LD1CRH is 1 or the VD1IRCS bit in LD1CRH is 0 at this time, an LVD1 interrupt request is simultaneously generated.

If the power supply voltage falls below Vdet0, a power-on reset occurs.

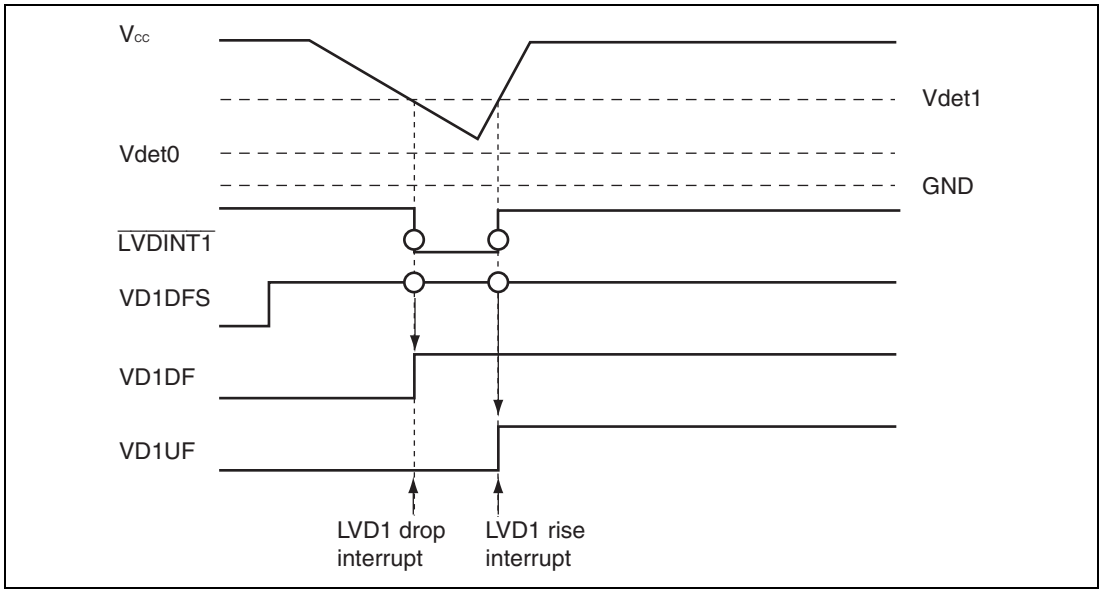


Figure 26.12 Operational Timing of LVDI1

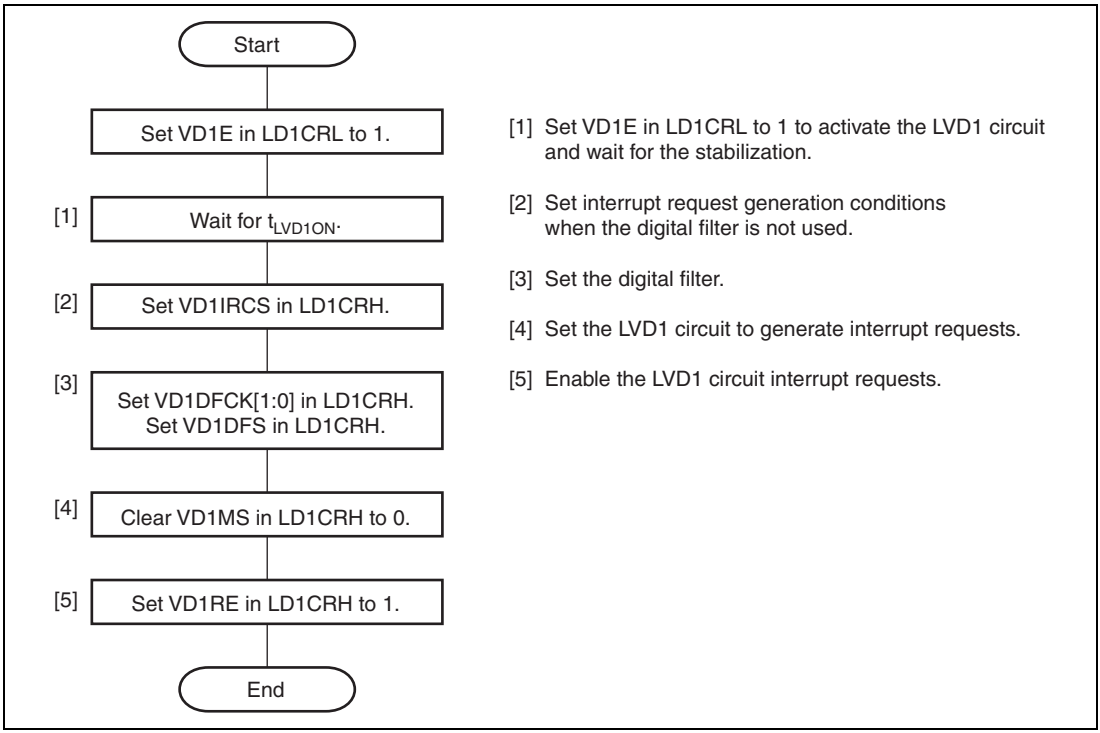


Figure 26.13 Procedure to Set LVDI1

(5) Low Voltage Detect Reset 0 (LVDR0)

LVDR0 is a reset generated by the LVD0 circuit. Figure 26.14 shows the operation timing of the LVDR0.

After a power-on reset is released, the LVD0 circuit is always enabled.

When the power-supply voltage falls below Vdet0, the LVDR0 clears the $\overline{\text{LVDRES0}}$ signal to 0, and resets the prescaler, and a power-on reset operation is enabled. When the power-supply voltage rises above the Vdet0 voltage again, the prescaler starts counting. It counts 128 ϕloco cycles, and then releases the internal reset signal.

Note that if the power supply voltage falls below $V_{LVDR0min}$ = TBD V and then rises from that point, the LVDR0 may not occur. Such a case should be evaluated thoroughly.

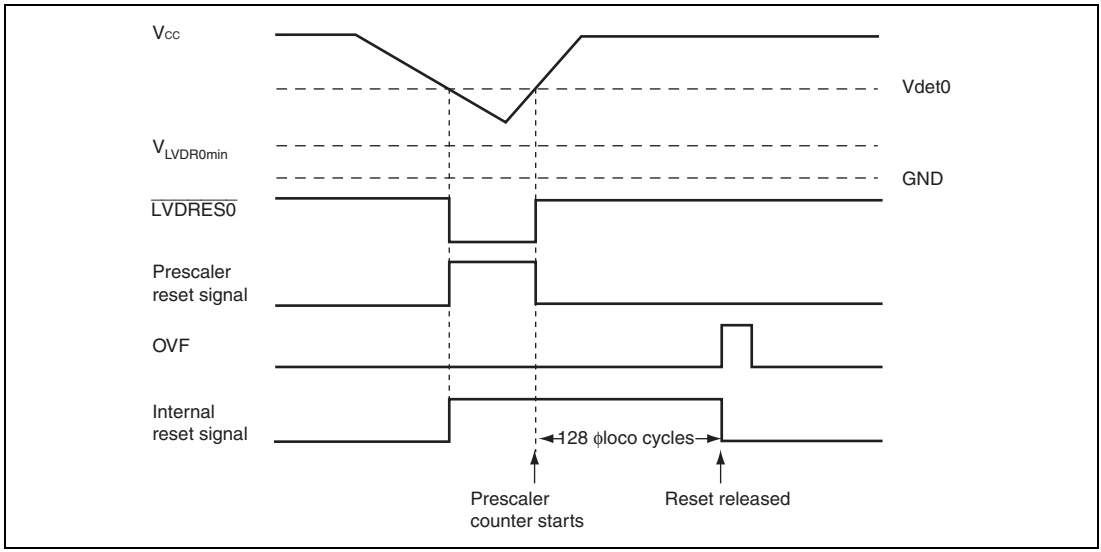


Figure 26.14 Operation Timing of LVDR0

Section 27 List of Registers

The address list gives information on the on-chip I/O register addresses, how the register bits are configured, and the register states in each operation mode. The information is given as shown below.

1. Register Addresses (address order)

- Registers are listed from the lower allocation addresses.
- Registers are classified by functional modules.
- The data bus width is indicated.
- The number of access states is indicated.

2. Register Bits

- Bit configurations of the registers are described in the same order as the register addresses (address order).
- Reserved bits are indicated by — in the bit name column.
- When registers consist of 16 bits, bits are described from the MSB side.

3. Register States in Each Operating Mode

- Register states are described in the same order as the register addresses (address order).
- The register states described here are for the basic operating modes. If there is a specific reset for an on-chip peripheral module, see the section on that on-chip peripheral module.

27.1 Register Addresses (Address Order)

The data-bus width column indicates the number of bits. The access-state column shows the number of states of the selected basic clock that is required for access to the register.

Note: Do not attempt to access undefined or reserved addresses. Correct operation of the access itself or later operations is not guaranteed when such an address is accessed.

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port mode register 1	PMR1	8	H'FF0000	I/O port	8	2
Port mode register 2	PMR2	8	H'FF0001	I/O port	8	2
Port mode register 3	PMR3	8	H'FF0002	I/O port	8	2
Port mode register 5	PMR5	8	H'FF0004	I/O port	8	2
Port mode register 6	PMR6	8	H'FF0005	I/O port	8	2
Port mode register 8	PMR8	8	H'FF0007	I/O port	8	2
Port mode register 9*[1]	PMR9	8	H'FF0008	I/O port	8	2
Port mode register A	PMRA	8	H'FF0009	I/O port	8	2
IIC/SSU select register	ICSUSR	8	H'FF000B	IIC/SSU	8	2
Port mode register J	PMRJ	8	H'FF000C	I/O port	8	2
Port pull-up control register 1	PUCR1	8	H'FF0010	I/O port	8	2
Port pull-up control register 2	PUCR2	8	H'FF0011	I/O port	8	2
Port pull-up control register 3	PUCR3	8	H'FF0012	I/O port	8	2
Port pull-up control register 5	PUCR5	8	H'FF0014	I/O port	8	2
Port pull-up control register 6	PUCR6	8	H'FF0015	I/O port	8	2
Port pull-up control register 8	PUCR8	8	H'FF0017	I/O port	8	2
Port pull-up control register 9*[1]	PUCR9	8	H'FF0018	I/O port	8	2
Port pull-up control register A	PUCRA	8	H'FF0019	I/O port	8	2
Port pull-up control register B	PUCRB	8	H'FF001A	I/O port	8	2
Port pull-up control register J	PUCRJ	8	H'FF001C	I/O port	8	2
Port drive control register 1	PDVR1	8	H'FF0030	I/O port	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port drive control register 2	PDVR2	8	H'FF0031	I/O port	8	2
Port drive control register 3	PDVR3	8	H'FF0032	I/O port	8	2
Port drive control register 5	PDVR5	8	H'FF0034	I/O port	8	2
Port drive control register 6	PDVR6	8	H'FF0035	I/O port	8	2
Port drive control register 8	PDVR8	8	H'FF0037	I/O port	8	2
Port drive control register 9*[1]	PDVR9	8	H'FF0038	I/O port	8	2
Port 1 peripheral function mapping register 1	PMCR11	8	H'FF0040	PMC	8	2
Port 1 peripheral function mapping register 2	PMCR12	8	H'FF0041	PMC	8	2
Port 1 peripheral function mapping register 3	PMCR13	8	H'FF0042	PMC	8	2
Port 1 peripheral function mapping register 4	PMCR14	8	H'FF0043	PMC	8	2
Port 2 peripheral function mapping register 1	PMCR21	8	H'FF0044	PMC	8	2
Port 2 peripheral function mapping register 2	PMCR22	8	H'FF0045	PMC	8	2
Port 2 peripheral function mapping register 3	PMCR23	8	H'FF0046	PMC	8	2
Port 2 peripheral function mapping register 4	PMCR24	8	H'FF0047	PMC	8	2
Port 3 peripheral function mapping register 1	PMCR31	8	H'FF0048	PMC	8	2
Port 3 peripheral function mapping register 2	PMCR32	8	H'FF0049	PMC	8	2
Port 3 peripheral function mapping register 3	PMCR33	8	H'FF004A	PMC	8	2
Port 3 peripheral function mapping register 4	PMCR34	8	H'FF004B	PMC	8	2
Port 5 peripheral function mapping register 1	PMCR51	8	H'FF0050	PMC	8	2
Port 5 peripheral function mapping register 2	PMCR52	8	H'FF0051	PMC	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port 5 peripheral function mapping register 3	PMCR53	8	H'FF0052	PMC	8	2
Port 5 peripheral function mapping register 4	PMCR54	8	H'FF0053	PMC	8	2
Port 6 peripheral function mapping register 1	PMCR61	8	H'FF0054	PMC	8	2
Port 6 peripheral function mapping register 2	PMCR62	8	H'FF0055	PMC	8	2
Port 6 peripheral function mapping register 3	PMCR63	8	H'FF0056	PMC	8	2
Port 6 peripheral function mapping register 4	PMCR64	8	H'FF0057	PMC	8	2
Port 8 peripheral function mapping register 3	PMCR83	8	H'FF005E	PMC	8	2
Port 8 peripheral function mapping register 4	PMCR84	8	H'FF005F	PMC	8	2
Port 9 peripheral function mapping register 1*1	PMCR91	8	H'FF0060	PMC	8	2
Port 9 peripheral function mapping register 2*1	PMCR92	8	H'FF0061	PMC	8	2
Port 9 peripheral function mapping register 3*1	PMCR93	8	H'FF0062	PMC	8	2
Port 9 peripheral function mapping register 4*1	PMCR94	8	H'FF0063	PMC	8	2
Peripheral function mapping register write-protect register	PMCWPR	8	H'FF0065	PMC	8	2
Port A peripheral function mapping register 3	PMCRA3	8	H'FF0066	PMC	8	2
Port A peripheral function mapping register 4	PMCRA4	8	H'FF0067	PMC	8	2
LIN control register	LINCR	8	H'FF0518	HW–LIN	8	2
LIN status register	LINST	8	H'FF0519	HW–LIN	8	2
Interrupt control register	INTCR	8	H'FF0520	Interrupt	8	2
IRQ enable register	IER	8	H'FF0521	Interrupt	8	2
IRQ sense control register H	ISCRH	8	H'FF0522	Interrupt	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
IRQ sense control register L	ISCRL	8	H'FF0523	Interrupt	8	2
IRQ status register	ISR	8	H'FF0524	Interrupt	8	2
IRQ noise canceler control register	INCCR	8	H'FF0525	Interrupt	8	2
Interrupt vector offset register	VOFR	16	H'FF0526	Interrupt	8	2
Event link interrupt control status register	ELCSR	8	H'FF0528	Interrupt	8	2
Interrupt priority register A	IPRA	8	H'FF0529	Interrupt	8	2
Interrupt priority register B	IPRB	8	H'FF052A	Interrupt	8	2
Interrupt priority register C	IPRC	8	H'FF052B	Interrupt	8	2
Interrupt priority register D	IPRD	8	H'FF052C	Interrupt	8	2
Interrupt priority register E	IPRE	8	H'FF052D	Interrupt	8	2
Interrupt priority register F*[1]	IPRF	8	H'FF052E	Interrupt	8	2
Interrupt priority register G	IPRG	8	H'FF052F	Interrupt	8	2
Interrupt priority register H	IPRH	8	H'FF0530	Interrupt	8	2
Interrupt priority register I	IPRI	8	H'FF0531	Interrupt	8	2
DTC enable register A	DTCERA	8	H'FF0534	DTC	8	2
DTC enable register B	DTCERB	8	H'FF0535	DTC	8	2
DTC enable register C	DTCERC	8	H'FF0536	DTC	8	2
DTC enable register D	DTCERD	8	H'FF0537	DTC	8	2
DTC enable register E	DTCERE	8	H'FF0538	DTC	8	2
DTC enable register F*[1]	DTCERF	8	H'FF0539	DTC	8	2
DTC enable register G	DTCERG	8	H'FF053A	DTC	8	2
DTC enable register H	DTCERH	8	H'FF053B	DTC	8	2
DTC vector register	DTVECR	8	H'FF053D	DTC	8	2
Serial mode register	SMR	8	H'FF0550	SCI	8	3
Bit rate register	BRR	8	H'FF0551	SCI	8	3
Serial control register 3	SCR3	8	H'FF0552	SCI	8	3
Transmit data register	TDR	8	H'FF0553	SCI	8	3
Transmit shift register	SSR	8	H'FF0554	SCI	8	3
Receive data register	RDR	8	H'FF0555	SCI	8	3
Sampling mode register	SPMR	8	H'FF0556	SCI	8	3

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Serial mode register_2	SMR_2	8	H'FF0558	SCI_2	8	3
Bit rate register_2	BRR_2	8	H'FF0559	SCI_2	8	3
Serial control register 3_2	SCR3_2	8	H'FF055A	SCI_2	8	3
Transmit data register_2	TDR_2	8	H'FF055B	SCI_2	8	3
Transmit shift register_2	SSR_2	8	H'FF055C	SCI_2	8	3
Receive data register_2	RDR_2	8	H'FF055D	SCI_2	8	3
Sampling mode register_2	SPMR_2	8	H'FF055E	SCI_2	8	3
Serial mode register_3	SMR_3	8	H'FF0560	SCI_3	8	3
Bit rate register_3	BRR_3	8	H'FF0561	SCI_3	8	3
Serial control register 3_3	SCR3_3	8	H'FF0562	SCI_3	8	3
Transmit data register_3	TDR_3	8	H'FF0563	SCI_3	8	3
Transmit shift register_3	SSR_3	8	H'FF0564	SCI_3	8	3
Receive data register_3	RDR_3	8	H'FF0565	SCI_3	8	3
Sampling mode register_3	SPMR_3	8	H'FF0566	SCI_3	8	3
Timer RD counter_2*[1]	TRDCNT_2	16	H'FF0570	Timer RD (unit 1, channel 2)	16*[2]	2
General register A_2*[1]	GRA_2	16	H'FF0572		16*[2]	2
General register B_2*[1]	GRB_2	16	H'FF0574		16*[2]	2
General register C_2*[1]	GRC_2	16	H'FF0576		16*[2]	2
General register D_2*[1]	GRD_2	16	H'FF0578		16*[2]	2
Timer RD counter_3*[1]	TRDCNT_3	16	H'FF057A	Timer RD (unit 1, channel 3)	16*[2]	2
General register A_3*[1]	GRA_3	16	H'FF057C		16*[2]	2
General register B_3*[1]	GRB_3	16	H'FF057E		16*[2]	2
General register C_3*[1]	GRC_3	16	H'FF0580		16*[2]	2
General register D_3*[1]	GRD_3	16	H'FF0582		16*[2]	2
Timer RD control register_2*[1]	TRDCR_2	8	H'FF0584	Timer RD (unit 1, channel 2)	8	2
Timer RD I/O control register A_2*[1]	TRDIORA_2	8	H'FF0585		8	2
Timer RD I/O control register C_2*[1]	TDRIORC_2	8	H'FF0586		8	2
Timer RD status register_2*[1]	TRDSR_2	8	H'FF0587		8	2
Timer RD interrupt enable register_2*[1]	TRDIER_2	8	H'FF0588		8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
PWM mode output level control register_2*[1]	POCR_2	8	H'FF0589	Timer RD (unit 1, channel 2)	8	2
Timer RD digital filtering function select register_2*[1]	TRDDF_2	8	H'FF058A		8	2
Timer RD control register_3*[1]	TRDCR_3	8	H'FF058B	Timer RD (unit 1, channel 3)	8	2
Timer RD I/O control register A_3*[1]	TRDIORA_3	8	H'FF058C		8	2
Timer RD I/O control register C_3*[1]	TDRIORC_3	8	H'FF058D		8	2
Timer RD status register_3*[1]	TRDSR_3	8	H'FF058E		8	2
Timer RD interrupt enable register_3*[1]	TRDIER_3	8	H'FF058F		8	2
PWM mode output level control register_3*[1]	POCR_3	8	H'FF0590		8	2
Timer RD digital filtering function select register_3*[1]	TRDDF_3	8	H'FF0591		8	2
Timer RD status register_23*[1]	TRDSTR_23	8	H'FF0592	Timer RD (unit 1, channels 2 and 3 in common)	8	2
Timer RD mode register_23*[1]	TRDMDR_23	8	H'FF0593		8	2
Timer RD PWM mode register_23*[1]	TRDPMR_23	8	H'FF0594		8	2
Timer RD function control register_23*[1]	TRDFCR_23	8	H'FF0595		8	2
Timer RD output master enable register 1_23*[1]	TRDOER1_23	8	H'FF0596		8	2
Timer RD output master enable register 2_23*[1]	TRDOER2_23	8	H'FF0597		8	2
Timer RD output control register_23*[1]	TRDOCR_23	8	H'FF0598		8	2
Timer RD A/D conversion start trigger control register_23*[1]	TRDADCR_23	8	H'FF0599		8	2
I^2C bus control register 1	ICCR1	8	H'FF05C8	IIC2/SSU	8	2
SS control register H	SSCRH				8	2
I^2C bus control register 2	ICCR2	8	H'FF05C9	IIC2/SSU	8	2
SS control register L	SSCRL				8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
I^2C bus mode register	ICMR	8	H'FF05CA	IIC2/SSU	8	2
SS mode register	SSMR				8	2
I^2C bus interrupt enable register	ICIER	8	H'FF05CB	IIC2/SSU	8	2
SS enable register	SSER				8	2
I^2C bus status register	ICSR	8	H'FF05CC	IIC2/SSU	8	2
SS status register	SSSR				8	2
Slave address register	SAR	8	H'FF05CD	IIC2/SSU	8	2
SS mode register 2	SSMR2				8	2
I^2C bus transmit data register	ICDRT	8	H'FF05CE	IIC2/SSU	8	2
SS transmit data register	SSTDR				8	2
I^2C bus receive data register	ICDRR	8	H'FF05CF	IIC2/SSU	8	2
SS receive data register	SSRDR				8	2
D/A data register 0	DADR0	8	H'FF05D4	D/A converter	8	2
D/A data register 1	DADR1	8	H'FF05D5	D/A converter	8	2
D/A control register	DACR	8	H'FF05D6	D/A converter	8	2
IrDA control register	IrCR	8	H'FF05DE	SCI3_2	8	2
A/D data register 0	ADDR0	16	H'FF05E0	A/D converter (unit 1)	16	2
Compare data register	CMPR	8	H'FF05E0	A/D converter (unit 1)	16*3	2
A/D data register 1	ADDR1	16	H'FF05E2	A/D converter (unit 1)	16	2
Compare control status register	CMPCSR	8	H'FF05E2	A/D converter (unit 1)	16*3	2
A/D data register 2	ADDR2	16	H'FF05E4	A/D converter (unit 1)	16	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Compare voltage register H	CMPVALH	8	H'FF05E4	A/D converter (unit 1)	16*3	2
A/D data register 3	ADDR3	16	H'FF05E6	A/D converter (unit 1)	16	2
Compare voltage register L	CMPVALL	8	H'FF05E6	A/D converter (unit 1)	16*3	2
A/D data register 4	ADDR4	16	H'FF05E8	A/D converter (unit 1)	16	2
A/D data register 5	ADDR5	16	H'FF05EA	A/D converter (unit 1)	16	2
A/D data register 6	ADDR6	16	H'FF05EC	A/D converter (unit 1)	16	2
A/D data register 7	ADDR7	16	H'FF05EE	A/D converter (unit 1)	16	2
A/D control/status register	ADCSR	8	H'FF05F0	A/D converter (unit 1)	8	2
A/D control register	ADCR	8	H'FF05F1	A/D converter (unit 1)	8	2
A/D mode register	ADMR	8	H'FF05F4	A/D converter (unit 1)	8	2
A/D data register 0_2*4	ADDR0_2	16	H'FF0600	A/D converter (unit 2)	16	2
Compare data register_2*4	CMPR_2	8	H'FF0600	A/D converter (unit 2)	16*3	2
A/D data register 1_2*4	ADDR1_2	16	H'FF0602	A/D converter (unit 2)	16	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Compare control status register_2*4	CMPCSR_2	8	H'FF0602	A/D converter (unit 2)	16*3	2
A/D data register 2_2*4	ADDR2_2	16	H'FF0604	A/D converter (unit 2)	16	2
Compare voltage register H_2*4	CMPVALH_2	8	H'FF0604	A/D converter (unit 2)	16*3	2
A/D data register 3_2*4	ADDR3_2	16	H'FF0606	A/D converter (unit 2)	16	2
Compare voltage register L_2*4	CMPVALL_2	8	H'FF0606	A/D converter (unit 2)	16*3	2
A/D control/status register_2*4	ADCSR_2	8	H'FF0610	A/D converter (unit 2)	8	2
A/D control register_2*4	ADCR_2	8	H'FF0611	A/D converter (unit 2)	8	2
A/D mode register_2*4	ADMR_2	8	H'FF0614	A/D converter (unit 2)	8	2
Reset source flag register	RSTFR	8	H'FF0620	Exception handling	8	2
Low-voltage detection circuit 2 control register H	LD2CRH	8	H'FF0622	Low-voltage-detection circuit	8	2
Low-voltage detection circuit 2 control register L	LD2CRL	8	H'FF0623		8	2
Low-voltage detection circuit 1 control register H	LD1CRH	8	H'FF0624		8	2
Low-voltage detection circuit 1 control register L	LD1CRL	8	H'FF0625		8	2
Low-voltage detection circuit 0 control register H	LD0CRH	8	H'FF0626		8	2
Low-voltage detection circuit 0 control register L	LD0CRL	8	H'FF0627		8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Low-voltage detection circuit control protect register	VDCPR	8	H'FF0628	Low-voltage-detection circuit	8	2
High-speed OCO control register	HOCR	8	H'FF062A	Clock oscillator	8	2
High-speed OCO trimming data protect register	HOTRMDPR	8	H'FF062B		8	2
High-speed OCO trimming data register 1	HOTRMDR1	8	H'FF062C		16*3	2
High-speed OCO trimming data register 2	HOTRMDR2	8	H'FF062D		16*3	2
High-speed OCO trimming data register 3	HOTRMDR3	8	H'FF062E		16*3	2
High-speed OCO trimming data register 4	HOTRMDR4	8	H'FF062F		16*3	2
Timer RG counter	TRGCNT	16	H'FF0640	Timer RG	16*2	2
General register A	GRA	16	H'FF0642	Timer RG	16*2	2
General register B	GRB	16	H'FF0644	Timer RG	16*2	2
Timer RG mode register	TRGMDR	8	H'FF0646	Timer RG	8	2
Timer RG counter control register	TRGCNTCR	8	H'FF0647	Timer RG	8	2
Timer RG control register	TRGCR	8	H'FF0648	Timer RG	8	2
Timer RG I/O control register	TRGIOR	8	H'FF0649	Timer RG	8	2
Timer RG status register	TRGSR	8	H'FF064A	Timer RG	8	2
Timer RG interrupt enable register	TRGIER	8	H'FF064B	Timer RG	8	2
GRA buffer register	BRA	16	H'FF064C	Timer RG	16*2	2
GRB buffer register	BRB	16	H'FF064E	Timer RG	16*2	2
Flash memory control register 1	FLMCR1	8	H'FF0660	FLASH	8	2
Flash memory control register 2	FLMCR2	8	H'FF0661	FLASH	8	2
Flash memory data flash protect register	DFPR	8	H'FF0662	FLASH	8	2
Flash memory status register	FLMSTR	8	H'FF0663	FLASH	8	2
Event link setting register 0	ELSR0	8	H'FF0680	ELC	8	2
Event link setting register 1	ELSR1	8	H'FF0681	ELC	8	2
Event link setting register 2*5	ELSR2	8	H'FF0682	ELC	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Event link setting register 3	ELSR3	8	H'FF0683	ELC	8	2
Event link setting register 4	ELSR4	8	H'FF0684	ELC	8	2
Event link setting register 8	ELSR8	8	H'FF0688	ELC	8	2
Event link setting register 10	ELSR10	8	H'FF068A	ELC	8	2
Event link setting register 11*6	ELSR11	8	H'FF068B	ELC	8	2
Event link setting register 12	ELSR12	8	H'FF068C	ELC	8	2
Event link setting register 14	ELSR14	8	H'FF068E	ELC	8	2
Event link setting register 15	ELSR15	8	H'FF068F	ELC	8	2
Event link setting register 18	ELSR18	8	H'FF0692	ELC	8	2
Event link setting register 19	ELSR19	8	H'FF0693	ELC	8	2
Event link setting register 21	ELSR21	8	H'FF0695	ELC	8	2
Event link setting register 22	ELSR22	8	H'FF0696	ELC	8	2
Event link setting register 23	ELSR23	8	H'FF0697	ELC	8	2
Event link setting register 24	ELSR24	8	H'FF0698	ELC	8	2
Event link setting register 29	ELSR29	8	H'FF069D	ELC	8	2
Event link setting register 30	ELSR30	8	H'FF069E	ELC	8	2
Event link setting register 31	ELSR31	8	H'FF069F	ELC	8	2
Event link setting register 32	ELSR32	8	H'FF06A0	ELC	8	2
Port-group setting register 1	PGR1	8	H'FF06A2	ELC	8	2
Port-group setting register 2	PGR2	8	H'FF06A3	ELC	8	2
Port-group control register 1	PGC1	8	H'FF06A6	ELC	8	2
Port-group control register 2	PGC2	8	H'FF06A7	ELC	8	2
Port buffer register 1	PDBF1	8	H'FF06AA	ELC	8	2
Port buffer register 2	PDBF2	8	H'FF06AB	ELC	8	2
Event link port setting register 0	PEL0	8	H'FF06AD	ELC	8	2
Event link port setting register 1	PEL1	8	H'FF06AE	ELC	8	2
Event link port setting register 2	PEL2	8	H'FF06AF	ELC	8	2
Event link port setting register 3	PEL3	8	H'FF06B0	ELC	8	2
Event link option setting register A	ELOPA	8	H'FF06B5	ELC	8	2
Event link option setting register B	ELOPB	8	H'FF06B6	ELC	8	2
Event link option setting register C	ELOPC	8	H'FF06B7	ELC	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Event-generation timer control register	ELTMCR	8	H'FF06B8	ELC	8	2
Event-generation timer interval setting register A	ELTMSA	8	H'FF06B9	ELC	8	2
Event-generation timer interval setting register B	ELTMSB	8	H'FF06BA	ELC	8	2
Even-generation delay time selection register	ELTMDR	8	H'FF06BB	ELC	8	2
Event link control register	ELCR	8	H'FF06BC	ELC	8	2
ELC timer counter	ELTMCNT	16	H'FF06C0	ELC	16*2	2
System clock control register	SYSCCR	8	H'FF06D0	SYSTEM	16*7	2
Power-down control register 1	LPCR1	8	H'FF06D1	SYSTEM	16*7	2
Power-down control register 2	LPCR2	8	H'FF06D2	SYSTEM	16*7	2
Power-down control register 3	LPCR3	8	H'FF06D3	SYSTEM	16*7	2
Backup control register	BAKCR	8	H'FF06D4	SYSTEM	16*7	2
OSC oscillation settling control status register	OSCCSR	8	H'FF06D5	Clock oscillator	16*7	2
Reset control register	RSTCR	8	H'FF06DA	Exception handling	16*7	2
Timer RA control register	TRACR	8	H'FF06F0	Timer RA	8	2
Timer RA I/O control register	TRAIOC	8	H'FF06F1	Timer RA	8	2
Timer RA mode register	TRAMR	8	H'FF06F2	Timer RA	8	2
Timer RA prescaler register	TRAPRE	8	H'FF06F3	Timer RA	8	2
Timer RA timer register	TRATR	8	H'FF06F4	Timer RA	8	2
Timer RA interrupt request status register	TRAIR	8	H'FF06F5	Timer RA	8	2
Timer RC counter*5	TRCCNT	16	H'FFFF80	Timer RC	16*2	2
General register A*5	GRA	16	H'FFFF82	Timer RC	16*2	2
General register B*5	GAB	16	H'FFFF84	Timer RC	16*2	2
General register C*5	GRC	16	H'FFFF86	Timer RC	16*2	2
General register D*5	GRD	16	H'FFFF88	Timer RC	16*2	2
Timer RC mode register*5	TRCMR	8	H'FFFF8A	Timer RC	8	2
Timer RC control register 1*5	TRCCR1	8	H'FFFF8B	Timer RC	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Timer RC interrupt enable register*[5]	TRCIER	8	H'FFFF8C	Timer RC	8	2
Timer RC status register*[5]	TRCSR	8	H'FFFF8D	Timer RC	8	2
Timer RC I/O control register 0*[5]	TRCIOR0	8	H'FFFF8E	Timer RC	8	2
Timer RC I/O control register 1*[5]	TRCIOR1	8	H'FFFF8F	Timer RC	8	2
Timer RC control register 2*[5]	TRCCR2	8	H'FFFF90	Timer RC	8	2
Timer RC digital filtering function select register*[5]	TRCDF	8	H'FFFF91	Timer RC	8	2
Timer RC output enable register*[5]	TRCOER	8	H'FFFF92	Timer RC	8	2
Timer RC A/D conversion start trigger control register*[5]	TRCADCR	8	H'FFFF93	Timer RC	8	2
Timer counter WD	TCWD	8	H'FFFF98	WDT	8	2
Timer mode register WD	TMWD	8	H'FFFF99	WDT	8	2
Timer control/status register WD	TCSRWD	8	H'FFFF9A	WDT	8	2
Timer interrupt control/status register WD	TICRWD	8	H'FFFF9B	WDT	8	2
Timer interrupt flag register WD	TIFRWD	8	H'FFFF9C	WDT	8	2
Timer RB control register	TRBCR	8	H'FFFFA0	Timer RB	8	2
Timer RB one-shot control register	TRBOCR	8	H'FFFFA1	Timer RB	8	2
Timer RB I/O control register	TRBIOC	8	H'FFFFA2	Timer RB	8	2
Timer RB mode register	TRBMR	8	H'FFFFA3	Timer RB	8	2
Timer prescaler register	TRBPRE	8	H'FFFFA4	Timer RB	8	2
Timer RB secondary register	TRBSC	8	H'FFFFA5	Timer RB	8	2
Timer RB primary register	TRBPR	8	H'FFFFA6	Timer RB	8	2
Timer RB interrupt request status register	TRBIR	8	H'FFFFA7	Timer RB	8	2
Timer RE second data register	TRESEC	8	H'FFFFA8	Timer RE	8	2
Timer RE minute data register	TREMIN	8	H'FFFFA9	Timer RE	8	2
Timer RE hour data register	TREHR	8	H'FFFFAA	Timer RE	8	2
Timer RE day-of-week data register	TREWK	8	H'FFFFAB	Timer RE	8	2
Timer RE control register 1	TRECR1	8	H'FFFFAC	Timer RE	8	2
Timer RE control register 2	TRECR2	8	H'FFFFAD	Timer RE	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Timer RE interrupt flag register	TREIFR	8	H'FFFFAE	Timer RE	8	2
Time RE clock source register	TRECSR	8	H'FFFFAF	Timer RE	8	2
Timer RD counter_0	TRDCNT_0	16	H'FFFFB0	Timer RD unit 0 (channel 0)	16*2	2
General register A_0	GRA_0	16	H'FFFFB2		16*2	2
General register B_0	GRB_0	16	H'FFFFB4		16*2	2
General register C_0	GRC_0	16	H'FFFFB6		16*2	2
General register D_0	GRD_0	16	H'FFFFB8		16*2	2
Timer RD counter_1	TRDCNT_1	16	H'FFFFBA	Timer RD unit 0 (channel 1)	16*2	2
General register A_1	GRA_1	16	H'FFFFBC		16*2	2
General register B_1	GRB_1	16	H'FFFFBE		16*2	2
General register C_1	GRC_1	16	H'FFFFC0		16*2	2
General register D_1	GRD_1	16	H'FFFFC2		16*2	2
Timer RD control register_0	TRDCR_0	8	H'FFFFC4	Timer RD unit 0 (channel 0)	8	2
Timer RD I/O control register A_0	TRDIORA_0	8	H'FFFFC5		8	2
Timer RD I/O control register C_0	TDRIORC_0	8	H'FFFFC6		8	2
Timer RD status register_0	TRDSR_0	8	H'FFFFC7		8	2
Timer RD interrupt enable register_0	TRDIER_0	8	H'FFFFC8		8	2
PWM mode output level control register_0	POCR_0	8	H'FFFFC9		8	2
Timer RD digital filtering function select register_0	TRDDF_0	8	H'FFFFCA		8	2
Timer RD control register_1	TRDCR_1	8	H'FFFFCB	Timer RD unit 0 (channel 1)	8	2
Timer RD I/O control register A_1	TRDIORA_1	8	H'FFFFCC		8	2
Timer RD I/O control register C_1	TDRIORC_1	8	H'FFFFCD		8	2
Timer RD status register_1	TRDSR_1	8	H'FFFFCE		8	2
Timer RD interrupt enable register_1	TRDIER_1	8	H'FFFFCF		8	2
PWM mode output level control register_1	POCR_1	8	H'FFFFD0		8	2
Timer RD digital filtering function select register_1	TRDDF_1	8	H'FFFFD1		8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Timer RD start register_01	TRDSTR_01	8	H'FFFFD2	Timer RD unit 0 (channels 0 and 1 in common)	8	2
Timer RD mode register_01	TRDMDR_01	8	H'FFFFD3		8	2
Timer RD PWM mode register_01	TRDPMR_01	8	H'FFFFD4		8	2
Timer RD function control register_01	TRDFCR_01	8	H'FFFFD5		8	2
Timer RD output master enable register 1_01	TRDOER1_01	8	H'FFFFD6		8	2
Time RD output master enable register 2_01	TRDOER2_01	8	H'FFFFD7		8	2
Timer RD output control register_01	TRDOCR_01	8	H'FFFFD8		8	2
Timer RC A/D conversion start trigger control register_01	TRDADCR_01	8	H'FFFFD9		8	2
Module standby control register 1	MSTCR1	8	H'FFFFDC	SYSTEM	8	2
Module standby control register 2	MSTCR2	8	H'FFFFDD	SYSTEM	8	2
Module standby control register 3	MSTCR3	8	H'FFFFDE	SYSTEM	8	2
Port data register 1	PDR1	8	H'FFFFE0	I/O Port	8	2
Port data register 2	PDR2	8	H'FFFFE1	I/O Port	8	2
Port data register 3	PDR3	8	H'FFFFE2	I/O Port	8	2
Port data register 5	PDR5	8	H'FFFFE4	I/O Port	8	2
Port data register 6	PDR6	8	H'FFFFE5	I/O Port	8	2
Port data register 8	PDR8	8	H'FFFFE7	I/O Port	8	2
Port data register 9*[1]	PDR9	8	H'FFFFE8	I/O Port	8	2
Port data register A	PDRA	8	H'FFFFE9	I/O Port	8	2
Port data register B	PDRB	8	H'FFFFEA	I/O Port	8	2
Port data register J	PDRJ	8	H'FFFFEC	I/O Port	8	2
Port control register 1	PCR1	8	H'FFFFF0	I/O Port	8	2
Port control register 2	PCR2	8	H'FFFFF1	I/O Port	8	2
Port control register 3	PCR3	8	H'FFFFF2	I/O Port	8	2
Port control register 5	PCR5	8	H'FFFFF4	I/O Port	8	2
Port control register 6	PCR6	8	H'FFFFF5	I/O Port	8	2
Port control register 8	PCR8	8	H'FFFFF7	I/O Port	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port control register 9*[1]	PCR9	8	H'FFFFF8	I/O Port	8	2
Port control register A	PCRA	8	H'FFFFF9	I/O Port	8	2
Port control register B	PCRB	8	H'FFFFFA	I/O Port	8	2
Port control register J	PCRJ	8	H'FFFFFC	I/O Port	8	2

Note: 1. Not provided for the H8S/20103 Group. These addresses are reserved.
2. Only 16-bit access is allowed.
3. Access in 8-bit unit.
4. Not provided for the H8S/20103 Group and H8S/20203 Group. These addresses are reserved.
5. Provided only for the H8S/20103 group. Addresses for the other groups are reserved.
6. Provided only for the H8S/20223 group. Addresses for the other groups are reserved.
7. Although these addresses are connected to the 16-bit bus, rewriting proceeds in byte units.

27.2 Register Bits

The addresses and bit names of the registers in the on-chip peripheral modules are listed below. The 16-bit register is indicated in two rows, 8 bits for each row.

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PMR1	PMR17	PMR16	PMR15	PMR14*1	PMR13	PMR12	PMR11	PMR10*1	I/O Port
PMR2	PMR27	PMR26	PMR25	PMR24	PMR23	PMR22	PMR21	PMR20	
PMR3	PMR37	PMR36	PMR35	PMR34	PMR33	PMR32	PMR31	PMR30	
PMR5	PMR57	PMR56	PMR55	PMR54	PMR53	PMR52	PMR51	PMR50	
PMR6	PMR67	PMR66	PMR65	PMR64	PMR63	PMR52	PMR61	PMR60	
PMR8	PMR87	PMR86	PMR85	—	—	—	—	—	
PMR9*1	PMR97	PMR96	PMR95	PMR94	PMR93	PMR92	PMR91	PMR90	
PMRA	PMRA7	PMRA6	PMRA5	PMRA4	PMRA3**2	PMRA2	—	—	
ICSUSR	—	—	—	—	—	—	—	SELISU	II2/SSU
PMRJ	—	—	—	—	—	—	PMRJ1	PMRJ0	I/O Port
PUCR1	PUCR17	PUCR16	PUCR15	PUCR14*1	PUCR13	PUCR12	PUCR11	PUCR10*1	
PUCR2	PUCR27	PUCR26	PUCR25	PUCR24	PUCR23	PUCR22	PUCR21	PUCR20	
PUCR3	PUCR37	PUCR36	PUCR35	PUCR34	PUCR33	PUCR32	PUCR31	PUCR30	
PUCR5	—	—	PUCR55	PUCR54	PUCR53	PUCR52	PUCR51	PUCR50	
PUCR6	PUCR67	PUCR66	PUCR65	PUCR64	PUCR63	PUCR62	PUCR61	PUCR60	
PUCR8	PUCR87	PUCR86	PUCR85	—	—	—	—	—	
PUCR9*1	PUCR97	PUCR96	PUCR95	PUCR94	PUCR93	PUCR92	PUCR91	PUCR90	
PUCRA	PUCRA7	PUCRA6	PUCRA5	PUCRA4	PUCRA3*1	PUCRA2*1	PUCRA1*1	PUCRA0*1	
PUCRB	PUCRB7	PUCRB6	PUCRB5	PUCRB4	PUCRB3	PUCRB2	PUCRB1	PUCRB0	
PUCRJ	—	—	—	—	—	—	PUCRJ1	PUCRJ0	
PDVR1	PVDR17	PVDR16	PVDR15	PVDR14*1	PVDR13	PVDR12	PVDR11	PVDR10*1	
PDVR2	PVDR27	PVDR26	PVDR25	PVDR24	PVDR23	PVDR22	PVDR21	PVDR20	
PDVR3	PVDR37	PVDR36	PVDR35	PVDR34	PVDR33	PVDR32	PVDR31	PVDR30	
PDVR5	—	—	PVDR55	PVDR54	PVDR53	PVDR52	PVDR51	PVDR50	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PDVR6	PVDR67	PVDR66	PVDR65	PVDR64	PVDR63	PVDR62	PVDR61	PVDR60	I/O Port
PDVR8	PVDR87	PVDR86	PVDR85	—	—	—	—	—	
PDVR9*[1]	PVDR97	PVDR96	PVDR95	PVDR94	PVDR93	PVDR92	PVDR91	PVDR90	
PMCR11	—		P11MD[2:0]		—		P10MD[2:0]*[1]		PMC
PMCR12	—		P13MD[2:0]		—		P12MD[2:0]		
PMCR13	—		P15MD[2:0]		—		P14MD[2:0]*[1]		
PMCR14	—		P17MD[2:0]		—		P16MD[2:0]		
PMCR21	—		P21MD[2:0]		—		P20MD[2:0]		
PMCR22	—		P23MD[2:0]		—		P22MD[2:0]		
PMCR23	—		P25MD[2:0]		—		P24MD[2:0]		
PMCR24	—		P27MD[2:0]		—		P26MD[2:0]		
PMCR31	—		P31MD[2:0]		—		P30MD[2:0]		
PMCR32	—		P33MD[2:0]		—		P32MD[2:0]		
PMCR33	—		P35MD[2:0]		—		P34MD[2:0]		
PMCR34	—		P37MD[2:0]		—		P36MD[2:0]		
PMCR51	—		P51MD[2:0]		—		P50MD[2:0]		
PMCR52	—		P53MD[2:0]		—		P52MD[2:0]		
PMCR53	—		P55MD[2:0]		—		P54MD[2:0]		
PMCR54	—		P57MD[2:0]		—		P56MD[2:0]		
PMCR61	—		P61MD[2:0]		—		P60MD[2:0]		
PMCR62	—		P63MD[2:0]		—		P62MD[2:0]		
PMCR63	—		P65MD[2:0]		—		P64MD[2:0]		
PMCR83	—		P85MD[2:0]		—	—	—	—	
PMCR84	—		P87MD[2:0]		—		P86MD[2:0]		
PMCR91*[1]	—		P91MD[2:0]		—		P90MD[2:0]		
PMCR92*[1]	—		P93MD[2:0]		—		P92MD[2:0]		
PMCR93*[1]	—		P95MD[2:0]		—		P94MD[2:0]		
PMCR94*[1]	—		P97MD[2:0]		—		P96MD[2:0]		
PMCWPR	B0WI	PMCRWE	—	—	—	—	—	—	
PMCRA3	—		PA5[MD2:0]		—		PA4[MD2:0]		

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PMCRA4	—		PA7[MD2:0]		—		PA6[MD2:0]		PMC
LINCR	LINE	MST	SBE	LSTART	RXDSF	BCIE	SBIE	SFIE	HW-LIN
LINST	—	—	B2CLR	B1CLR	B0CLR	BCDCT	SBDCT	SFDCT	
INTCR	—	—	INTM[1:0]		NMIEG	ADTRG1	ADTRG0	—	Interrupt
IER	IRQ7E	IRQ6E	IRQ5E	IRQ4E	IRQ3E	IRQ2E	IRQ1E	IRQ0E	
ISCRH	[IRQ7CB:IRQ7CA]		[IRQ6CB:IRQ6CA]		[IRQ5CB:IRQ5CA]		[IRQ4CB:IRQ4CA]		
ISCRL	[IRQ3CB:IRQ3CA]		[IRQ2CB:IRQ2CA]		[IRQ1CB:IRQ1CA]		[IRQ0CB:IRQ0CA]		
ISR	IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F	IRQ0F	
INCCR	—	—	INCCR[5:4]		INCCR[3:2]		INCCR[1:0]		
VOFR									
						—	—	—	
ELCSR	—	—	—	—	ELIE2	ELIE1	ELF2	ELF1	
IPRA	IPRA[7:6]		IPRA[5:4]		IPRA[3:2]		IPRA[1:0]		
IPRB	IPRB[7:6]		IPRB[5:4]		IPRB[3:2]		IPRB[1:0]		
IPRC	IPRC[7:6]		IPRC[5:4]		IPRC[3:2]		IPRC[1:0]		
IPRD	IPRD[7:6]		IPRD[5:4]*2		IPRD[3:2]		IPRD[1:0]		
IPRE	IPRE[7:6]		IPRE[5:4]		IPRE[3:2]		—	—	
IPRF	—	—	—	—	IPRF[3:2]		—	—	
IPRG	—	—	IPRG[5:4]		IPRG[3:2]		IPRG[1:0]*3		
IPRH	IPRH[7:6]		IPRH[5:4]		IPRH[3:2]*4		IPRH[1:0]*4		
IPRI	IPRI[7:6]		—	—	IPRI[3:2]		—	—	
DTCERA	DTCEA7	DTCEA6	DTCEA5	DTCEA4	DTCEA3	DTCEA2	DTCEA1	DTCEA0	DTC
DTCERB	DTCEB7	DTCEB6	DTCEB5	DTCEB4	DTCEB3	DTCEB2	DTCEB1	DTCEB0	
DTCERC	DTCEC7	DTCEC6	DTCEC5	DTCEC4	—	—	—	—	
DTCERD	DTCED7	DTCED6	—	—	DTCED3	DTCED2	DTCED1	DTCED0	
DTCERE	DTCEE7	DTCEE6	DTCEE5	DTCEE4	DTCEE3	DTCEE2	DTCEE1	DTCEE0	
DTCERF	DTCEF7	DTCEF6	DTCEF5	DTCEF4	DTCEF3	DTCEF2	DTCEF1	DTCEF0	
DTCERG	—	—	—	DTCEG4	DTCEG3	DTCEG2	DTCEG1	DTCEG0	
DTCERH	—	—	—	—	DTCEH3	DTCEH2	—	—	
DTVECR	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
SMR	COM	CHR	PE	PM	STOP	MP	CKS1	CKS0	SCI3_1
BRR									
SCR3	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	
TDR									
SSR	TDRE	RDRF	OER	FER	PER	TEND	MPBR	MPBT	
RDR									
SPMR	—	—	—	—	—	NFEN	—	—	
SMR_2	COM	CHR	PE	PM	STOP	MP	CKS1	CKS0	SCI3_2
BRR_2									
SCR3_2	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	
TDR_2									
SSR_2	TDRE	RDRF	OER	FER	PER	TEND	MPBR	MPBT	
RDR_2									
SPMR_2	—	—	—	—	—	NFEN	—	—	
SMR_3	COM	CHR	PE	PM	STOP	MP	CKS1	CKS0	SCI3_3
BRR_3									
SCR3_3	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	
TDR_3									
SSR_3	TDRE	RDRF	OER	FER	PER	TEND	MPBR	MPBT	
RDR_3									
SPMR_3	—	—	—	—	—	NFEN	—	—	
TRDCNT_2※5									Timer RD Unit 1 (channel 2)
GRA_2※5									
GRB_2※5									
GRC_2※5									
GRD_2※5									

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TRDCNT_3*5									Timer RD Unit 1 (channel 3)
GRA_3*5									
GRB_3*5									
GRC_3*5									
GRD_3*5									
TRDCR_2*5		CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		Timer RD Unit 1 (channel 2)
TRDIORA_2*5	—		IOB[2:0]		—		IOA[2:0]		
TRDIORC_2*5			IOD[3:0]				IOC[3:0]		
TRDSR_2*5	—	—	—	OVF	IMFD	IMFC	IMFB	IMFA	
TRDIER_2*5	—	—	—	OVIE	IMIED	IMIEC	IMIEB	IMIEA	
POCR_2*5	—	—	—	—	—	POLD	POLC	POLB	
TRDDF_2*5		DFCK[1:0]	—	—	DFD	DFC	DFB	DFA	
TRDCR_3*5		CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		Timer RD Unit 1 (channel 3)
TRDIORA_3*5	—		IOB[2:0]		—		IOA[2:0]		
TRDIORC_3*5			IOD[3:0]				IOC[3:0]		
TRDSR_3*5	—	—	UDF	OVF	IMFD	IMFC	IMFB	IMFA	
TRDIER_3*5	—	—	—	OVIE	IMIED	IMIEC	IMIEB	IMIEA	
POCR_3*5	—	—	—	—	—	POLD	POLC	POLB	
TRDDF_3*5		DFCK[1:0]	—	—	DFD	DFC	DFB	DFA	
TRDSTR_23*5	—	—	—	—	CSTPN1	CSTPN0	STR1	STR0	Timer RD Unit 1 (channels 2 and 3 in common)
TRDMDR_23*5	BFD1	BFC1	BFD0	BFC0	—	—	—	SYNC	
TRDPMR_23*5	—	PWMD1	PWMC1	PWMB1	—	PWMD0	PWMC0	PWMB0	
TRDFCR_23*5	PWM3	STCLK	ADEG	ADTRG	OLS1	OLS0	CMD[1:0]		
TRDOER1_23*5	ED1	EC1	EB1	EA1	ED0	EC0	EB0	EA0	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TRDOER2_23*5	PTO	—	—	—	—	—	—	—	Timer RD Unit 1 (channels 2 and 3 in common)
TRDOCR_23*5	TOD1	TOC1	TOB1	TOA1	TOD0	TOC0	TOB0	TOA0	
TRDADCR_23	ADTRGD1E	ADTRGC1E	ADTRGB1E	ADTRGA1E	ADTRGD0E	ADTRGC0E	ADTRGB0E	ADTRGA0E	
ICCR1	ICE	RCVD	MST	TRS	CKS[3:0]				IIC2/SSU
SSCRH	—	RSSTP	MSS	—	—	CKS[2:0]			
ICCR2	BBSY	SCP	SDAO	SDAOP	SCLO	—	IICRST	—	
SSCRL	—	—	SOL	SOLP	—	—	SRES	—	
ICMR	MLS	WAIT	—	—	BCWP	BC[2:0]			
SSMR	MLS	CPOS	CPHS	—	—	BC[2:0]			
ICIER	TIE	TEIE	RIE	NAKIE	STIE	ACKE	ACKBR	ACKBT	
SSER	TIE	TEIE	RIE	TE	RE	—	—	CEIE	
ICSR	TDRE	TEND	RDRF	NACKF	STOP	AL_OVE	AAS	ADZ	
SSSR	TDRE	TEND	RDRF	—	—	ORER	—	CE	
SAR	SAV6	SAV5	SAV4	SAV3	SAV2	SAV1	SAV0	FS	
SSMR2	BIDE	SCKS	CSS1	CSS0	SCKOS	SOOS	SCOS	SSUMS	
ICDRT									
SSTDR									
ICDRR									
SSRDR									
DADR0									D/A converter
DADR1									
DACR	DAOE1	DAOE0	—	—	—	—	—	—	
IrCR	IrE		IrCK[2:0]		IrTXINV	IrRXINV	—	—	SCI3_2 (IrDA)
ADDR0									A/D converter (unit 1)
			—	—	—	—	—	—	
CMPR	CMP7	CMP6	CMP5	CMP4	CMP3	CMP2	CMP1	CMP0	
ADDR1									
			—	—	—	—	—	—	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
CMPCSR	CMPF	CMPIE	CMPFC1	CMPFC0	—	—	—	—	A/D converter (unit 1)
ADDR2									
			—	—	—	—	—	—	
CMPVALH	—	—	—	—	—	—	VAL9	VAL8	
ADDR3									
			—	—	—	—	—	—	
CMPVALL	VAL7	VAL6	VAL5	VAL4	VAL3	VAL2	VAL1	VAL0	
ADDR4									
			—	—	—	—	—	—	
ADDR5									
			—	—	—	—	—	—	
ADDR6									
			—	—	—	—	—	—	
ADDR7									
			—	—	—	—	—	—	
ADCSR	ADF	ADIE	ADST	—			CH[3:0]		
ADCR		TRGS[1:0]	SCANE	SCANS		CKS[1:0]	ADSTCLR	EXTRGS	
ADMR	—	—	ADM1	—	—	—	—	—	
ADDR0_2*6									A/D converter (unit 2)*6
			—	—	—	—	—	—	
CMPR_2*6	—	—	—	—	CMP3	CMP2	CMP1	CMP0	
ADDR1_2*6									
			—	—	—	—	—	—	
CMPCSR*6	CMPF	CMPIE	CMPFC1	CMPFC0	—	—	—	—	
ADDR2_2*6									
			—	—	—	—	—	—	
CMPVALH_2*6	—	—	—	—	—	—	VAL9	VAL8	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
ADDR3_2*6									A/D converter (unit2) *6
			—	—	—	—	—	—	
CMPVALL_2*6	VAL7	VAL6	VAL5	VAL4	VAL3	VAL2	VAL1	VAL0	
ADCSR_2*6	ADF	ADIE	ADST	—	—		CH[2:0]		
ADCR_2*6	TRGS[1:0]		SCANE	SCANS	CKS[1:0]		ADSTCLR	EXTRGS	
ADMR_2*6	—	—	ADM1	—	—	—	—	—	
RSTFR	—	—	SWRST	PRST	LVD2RST	LVD1RST	PORRST	WRST	Low-voltage-detection circuit
LD2CRH	VD2DF	VD2UF	VD2DFCK1	VD2DFCK0	VD2DFS	VD2IRCS	VD2MS	VD2RE	
LD2CRL	VD2E	VD2CVS	VD2RVS	—	—	—	—	—	
LD1CRH	VD1DF	VD1UF	VD1DFCK1	VD1DFCK0	VD1DFS	VD1IRCS	VD1MS	VD1RE	
LD1CRL	VD1E	—	—	—	VD1LS3	VD1LS2	VD1LS1	VD1LS0	
LD0CRH	—	—	VD0DFCK1	VD0DFCK0	VD0DFS	—	—	—	
LD0CRL	—	—	—	—	—	—	VD0LS1	—	
VDCPR	WRI	—	—	—	—	—	—	LDPRC	
HOCR	HOCOE	—	—	—	—	—	—	—	Clock oscillator
HOTRMDPR	WI	WE	LOCKDW	TRMDRWE	—	—	—	—	
HOTRMDR1									
HOTRMDR2									
HOTRMDR3									
HOTRMDR4									
TRGCNT									Timer RG
GRA									
GRB									
TRGMDR	STR	—	DFCK[1:0]		DFB	DFA	MDF	PWM	
TRGCNTCR	CNTEN7	CNTEN6	CNTEN5	CNTEN4	CNTEN3	CNTEN2	CNTEN1	CNTEN0	
TRGCR	—	CCLR[1:0]		CKEG[1:0]			TPSC[2:0]		
TRGIOR	BUFB	IOB[2:0]			BUFA		IOA[2:0]		
TRGSR	—	—	—	DIRF	OVF	UDF	IMFB	IMFA	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TRGIER	—	—	—	—	OVIE	UDIE	IMIEB	IMIEA	Timer RG
BRA									
BRB									
FLMCR1	—	—	—	—	FMLBD	FMWUS	FMEWMOD	FMCMDEN	FLASH
FLMCR2	—	—	—	FMRDYIE	FMBSYRDIE	FMISPE	FMSPREQ	FMSPEN	
DFPR	—	—	—	—	—	—	DFPR1	DFPR0	
FLMSTR	FMRDYIF	FMBSYRDIF	FMEBSF	FMERSF	FMPRSF	—	—	FMRDY	
ELSR0	ELS07	ELS06	ELS05	ELS04	ELS03	ELS02	ELS01	ELS00	ELC
ELSR1	ELS17	ELS16	ELS15	ELS14	ELS13	ELS12	ELS11	ELS10	
ELSR2※7	ELS27	ELS26	ELS25	ELS24	ELS23	ELS22	ELS21	ELS20	
ELSR3	ELS37	ELS36	ELS35	ELS34	ELS33	ELS32	ELS31	ELS30	
ELSR4	ELS47	ELS46	ELS45	ELS44	ELS43	ELS42	ELS41	ELS40	
ELSR8	ELS87	ELS86	ELS85	ELS84	ELS83	ELS82	ELS81	ELS80	
ELSR10	ELS107	ELS106	ELS105	ELS104	ELS103	ELS102	ELS101	ELS100	
ELSR11※6	ELS117	ELS116	ELS115	ELS114	ELS113	ELS112	ELS111	ELS110	
ELSR12	ELS127	ELS126	ELS125	ELS124	ELS123	ELS122	ELS121	ELS120	
ELSR14	ELS147	ELS146	ELS145	ELS144	ELS143	ELS142	ELS141	ELS140	
ELSR15	ELS157	ELS156	ELS155	ELS154	ELS153	ELS152	ELS151	ELS150	
ELSR18	ELS187	ELS186	ELS185	ELS184	ELS183	ELS182	ELS181	ELS180	
ELSR19	ELS197	ELS196	ELS195	ELS194	ELS193	ELS192	ELS191	ELS190	
ELSR21	ELS217	ELS216	ELS215	ELS214	ELS213	ELS212	ELS211	ELS210	
ELSR22	ELS227	ELS226	ELS225	ELS224	ELS223	ELS222	ELS221	ELS220	
ELSR23	ELS237	ELS236	ELS235	ELS234	ELS233	ELS232	ELS231	ELS230	
ELSR24	ELS247	ELS246	ELS245	ELS244	ELS243	ELS242	ELS241	ELS240	
ELSR29	ELS297	ELS296	ELS295	ELS294	ELS293	ELS292	ELS291	ELS290	
ELSR30	ELS307	ELS306	ELS305	ELS304	ELS303	ELS302	ELS301	ELS300	
ELSR31	ELS317	ELS316	ELS315	ELS314	ELS313	ELS312	ELS311	ELS310	
ELSR32	ELS327	ELS326	ELS325	ELS324	ELS323	ELS322	ELS321	ELS320	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PGR1	PGR17	PGR16	PGR15	PGR14	PGR13	PGR12	PGR11	PGR10	ELC
PGR2	PGR27	PGR26	PGR25	PGR24	PGR23	PGR22	PGR21	PGR20	
PGC1	—		PGCO1[2:0]		—	PGCOVE1	PGCI1[1:0]		
PGC2	—		PGCO2[2:0]		—	PGCOVE2	PGCI2[1:0]		
PDBF1	PDBF17	PDBF16	PDBF15	PDBF14	PDBF13	PDBF12	PDBF11	PDBF10	
PDBF2	PDBF27	PDBF26	PDBF25	PDBF24	PDBF23	PDBF22	PDBF21	PDBF20	
PEL0	—	PSM0[1:0]		PSP0[4:3]		PSP02	PSP01	PSP00	
PEL1	—	PSM1[1:0]		PSP1[4:3]		PSP12	PSP11	PSP10	
PEL2	—	PSM2[1:0]		PSP2[4:3]		PSP22	PSP21	PSP20	
PEL3	—	PSM3[1:0]		PSP3[4:3]		PSP32	PSP31	PSP30	
ELOPA	TMRAM[2:1]		TMRBM[2:1]		TMRCM[2:1]*3		TMRDM[2:1]		
ELOPB	TMRD2M[2:1]		—	—	—	—	—	—	
ELOPC	TMRG1M[2:1]		—	—	—	—	—	—	
ELTMCR	TMRSTR	—	—	—		CLSRS[3:0]			
ELTMSA		C1CLS[3:0]				C0CLS[3:0]			
ELTMSB		C3CLS[3:0]				C2CLS[3:0]			
ELTMDR	C3DLY[1:0]		C2DLY[1:0]		C1DLY[1:0]		C0DLY[1:0]		
ELCR	ELCON	—	—	—	—	—	—	—	
ELTMCNT									
SYSCCR	WI	WE	PHIHSEL	PHILSEL	—	SUBNC1	SUBNC0		Clock oscillator
LPCR1	WI	WE	SSBY	PSCSTP	SLEEPRS	STBYRS	—	PHIBSEL	
LPCR2	WI	WE	—	—	—	PHI2	PHI1	PHI0	
LPCR3	WI	WE	STBYINT	SLEEPINT	—	PHIS2	PHIS1	PHIS0	
BAKCR	WI	WE	OSCBAKE	BAKCKSEL	CKSWIE	CKSWIF	OSCHLT	—	
OSCCSR	—	—	—	—	STS3	STS2	STS1	STS0	
RSTCR	WI	WE	—	—	—	—	—	SRST	
TRACR	—	—	TUNDF	TEDGF	—	TSTOP	TCSTF	TSTART	Timer RA
TRAIOC	TIOGT[1:0]		TIPF[1:0]		TIOSEL	TOENA	TOPCR	TEDGSEL	
TRAMR	TCKCUT		TCK[2:0]		—		TMOD[2:0]		

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TRAPRE									Timer RA
TRATR									
TRAIR	TRAIE	TRAIF	—	—	—	—	—	—	
TRCCNT*7									Timer RC
GRA*7									
GRB*7									
GRC*7									
GRD*7									
TRCMR*7	CTS	—	BUFEB	BUFEA	PWM2	PWMD	PWMC	PWMB	
TRCCR1*7	CCLR		CKS[2:0]		TOD	TOC	TOB	TOA	
TRCIER*7	OVIE	—	—	—	IMIED	IMIEC	IMIEB	IMIEA	
TRCSR*7	OVF	—	—	—	IMFD	IMFC	IMFB	IMFA	
TRCIOR0*7	—		IOB[2:0]		—		IOA[2:0]		
TRCIOR1*7			IOD[3:0]				IOC[3:0]		
TRCCR2*7		TCEG[1:0]	CSTP	—	—	POLD	POLC	POLB	
TRCDF*7		DFCK[1:0]	—	DFTRG	DFD	DFC	DFB	DFA	
TRCOER*7	PTO	—	—	—	ED	EC	EB	EA	
TRCADCR*7	—	—	—	—	ADTRGDE	ADTRGCE	ADTRGBE	ADTRGAE	
TCWD									WDT
TMWD	—	—	—	—			CKS[3:0]		
TCSRWD	B6WI	TCWE	B4WI	TCSRWE	TMWLOCK	TMWI	—	—	
TICRWD		INTSEL[1:0]	IWIE	—	—	—	—	—	
TIFRWD	IWF	—	—	—	—	—	—	—	
TRBCR	—	—	—	—	—	TSTOP	TCSTF	TSTART	Timer RB
TRBOCR	—	—	—	—	—	TOSSTF	TOSSP	TOSST	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TRBIOC	—	—	TIPF[1:0]		INOSEG	INOSTG	TOCNT	TOPL	Timer RB
TRBMR	TCKCUT	TCK[2:0]			TWRC	—	TMOD[1:0]		
TRBPRE									
TRBSC									
TRBPR									
TRBIR	TRBIE	TRBIF	—	—	—	—	—	—	
TRESEC	BSY	SCI2	SCI1	SCI0	SC03	SC02	SC01	SC00	Timer RE
TREMIN	BSY	MN12	MN11	MN10	MN03	MN02	MN01	MN00	
TREHR	BSY	—	HR11	HR10	HR03	HR02	HR01	HR00	
TREWK	BSY	—	—	—	—	WK2	WK1	WK0	
TRECR1	TSTART	H12_H24	PM	TRERST	INT	TOENA	TCSTF	—	
TRECR2	—	—	COMIE	WKIE	DYIE	HRIE	MNIE	SEIE	
TREIFR	—	—	COMF	WKF	DYF	HRF	MNF	SECF	
TRECSR	—	RCS6	RCS5	RCS4	RCS3	RCS2	RCS1	RCS0	
TRDCNT_0									Timer RD Unit 0 (channel 0)
GRA_0									
GRB_0									
GRC_0									
GRD_0									
TRDCNT_1									Timer RD Unit 0 (channel 1)
GRA_1									
GRB_1									

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
GRC_1									Timer RD Unit 0 (channel 1)
GRD_1									
TRDCR_0		CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		Timer RD Unit 0 (channel 0)
TRDIORA_0	—		IOB[2:0]		—		IOA[2:0]		
TRDIORC_0		IOD[3:0]					IOC[3:0]		
TRDSR_0	—	—	—	OVF	IMFD	IMFC	IMFB	IMFA	
TRDIER_0	—	—	—	OVIE	IMIED	IMIEC	IMIEB	IMIEA	
POCR_0	—	—	—	—	—	POLD	POLC	POLB	
TRDDF_0	DFCK[1:0]		—	—	DFD	DFC	DFB	DFA	
TRDCR_1		CCLR[2:0]			CKEG[1:0]		TPSC[2:0]		Timer RD Unit 0 (channel 1)
TRDIORA_1	—		IOB[2:0]		—		IOA[2:0]		
TRDIORC_1		IOD[3:0]					IOC[3:0]		
TRDSR_1	—	—	UDF	OVF	IMFD	IMFC	IMFB	IMFA	
TRDIER_1	—	—	—	OVIE	IMIED	IMIEC	IMIEB	IMIEA	
POCR_1	—	—	—	—	—	POLD	POLC	POLB	
TRDDF_1	DFCK[1:0]		—	—	DFD	DFC	DFB	DFA	
TRDSTR_01	—	—	—	—	CSTPN1	CSTPN0	STR1	STR0	Timer RD Unit 0 (channels 0 and 1 in common)
TRDMDR_01	BFD1	BFC1	BFD0	BFC0	—	—	—	SYNC	
TRDPMR_01	—	PWMD1	PWMC1	PWMB1	—	PWMD0	PWMC0	PWMB0	
TRDFCR_01	PWM3	STCLK	ADEG	ADTRG	OLS1	OLS0		CMD[1:0]	
TRDOER1_01	ED1	EC1	EB1	EA1	ED0	EC0	EB0	EA0	
TRDOER2_01	PTO	—	—	—	—	—	—	—	
TRDOCR_01	TOD1	TOC1	TOB1	TOA1	TOD0	TOC0	TOB0	TOA0	
TRDADCR_01	ADTRGD1E	ADTRGC1E	ADTRGB1E	ADTRGA1E	ADTRGD0E	ADTRGC0E	ADTRGB0E	ADTRGA0E	
MSTPCR1	MSTWDT	—	MSTAD1	MSTAD2*2	MSTDA	MSTDTC	—	—	Power-down
MSTPCR2	MSTSCI3_1	MSTSCI3_2	MSTSCI3_3	—	—	MSTICSU	—	—	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
MSTPCR3	MSTTMRA	MSTTMRB	MSTTMRC*3	MSTTMRD1	MSTTMRD2 *1	MSTTRMRG	—	MSTTMRE	Power-down
PDR1	PDR17	PDR16	PDR15	PDR14*1	PDR13	PDR12	PDR11	PDR10*1	I/O port
PDR2	PDR27	PDR26	PDR25	PDR24	PDR23	PDR22	PDR21	PDR20	
PDR3	PDR37	PDR36	PDR35	PDR34	PDR33	PDR32	PDR31	PDR30	
PDR5	PDR57	PDR56	PDR55	PDR54	PDR53	PDR52	PDR51	PDR50	
PDR6	PDR67	PDR66	PDR65	PDR64	PDR63	PDR62	PDR61	PDR60	
PDR8	PDR87	PDR86	PDR85	—	—	—	—	—	
PDR9*1	PDR97	PDR96	PDR95	PDR94	PDR93	PDR92	PDR91	PDR90	
PDRA	PDRA7	PDRA6	PDRA5	PDRA4	PDRA3*1	PDRA2*1	PDRA1*1	PDRA0*1	
PDRB	PDRB7	PDRB6	PDRB5	PDRB4	PDRB3	PDRB2	PDRB1	PDRB0	
PDRJ	—	—	—	—	—	—	PDRJ1	PDRJ0	
PCR1	PCR17	PCR16	PCR15	PCR14*1	PCR13	PCR12	PCR11	PCR10*1	
PCR2	PCR27	PCR26	PCR25	PCR24	PCR23	PCR22	PCR21	PCR20	
PCR3	PCR37	PCR36	PCR35	PCR34	PCR33	PCR32	PCR31	PCR30	
PCR5	PCR57	PCR56	PCR55	PCR54	PCR53	PCR52	PCR51	PCR50	
PCR6	PCR67	PCR66	PCR65	PCR64	PCR63	PCR62	PCR61	PCR60	
PCR8	PCR87	PCR86	PCR85	—	—	—	—	—	
PCR9*1	PCR97	PCR96	PCR95	PCR94	PCR93	PCR92	PCR91	PCR90	
PCRA	PCRA7	PCRA6	PCRA5	PCRA4	PCRA3*1	PCRA2*1	PCRA1*1	PCRA0*1	
PCRB	PCRB7	PCRB6	PCRB5	PCRB4	PCRB3	PCRB2	PCRB1	PCRB0	
PCRJ	—	—	—	—	—	—	PCRJ1	PCRJ0	

Notes: 1. Not provided for the H8S/20103 Group. These addresses and bits are reserved.
2. Provided for the H8S/20223 Group. These bits for the other groups are reserved.
3. Provided for the H8S/20103 Group. These bits for the other groups are reserved.
4. Not provided for the H8S/20103 Group. These bits are reserved.
5. Not provided for the H8S/20103 Group. These addresses are reserved.
6. Provided for the H8S/20223 Group. These addresses for the other groups are reserved.
7. Provided for the H8S/20103 Group. These addresses for the other groups are reserved.

Section 28 Electrical Characteristics

28.1 Absolute Maximum Ratings

Table 28.1 Absolute Maximum Ratings

Item		Symbol	Value	Unit	Remark
Power supply voltage		V_{CC}	–0.3 to +6.5	V	*1
Analog power supply voltage		AV_{CC}	–0.3 to +6.5	V	
Internal power supply voltage			–0.3 to +1.65	V	
Input voltage	All pins (other than AN pin, DA pin, OSC1, and X1)	V_{IN}	–0.3 to V_{CC} +0.3	V	
	AN pin, DA pin	V_{IN}	–0.3 to AV_{CC} +0.3	V	
	OSC1, X1	V_{IN}	–0.3 to +1.65	V	*2
	OSC1	V_{IN}	–0.3 to V_{CC} +0.3	V	*3
Operating temperature		T_{opr}	N version: –20 to +85	°C	
			D version: –40 to +85	°C	
Storage temperature		T_{stg}	–55 to +125	°C	

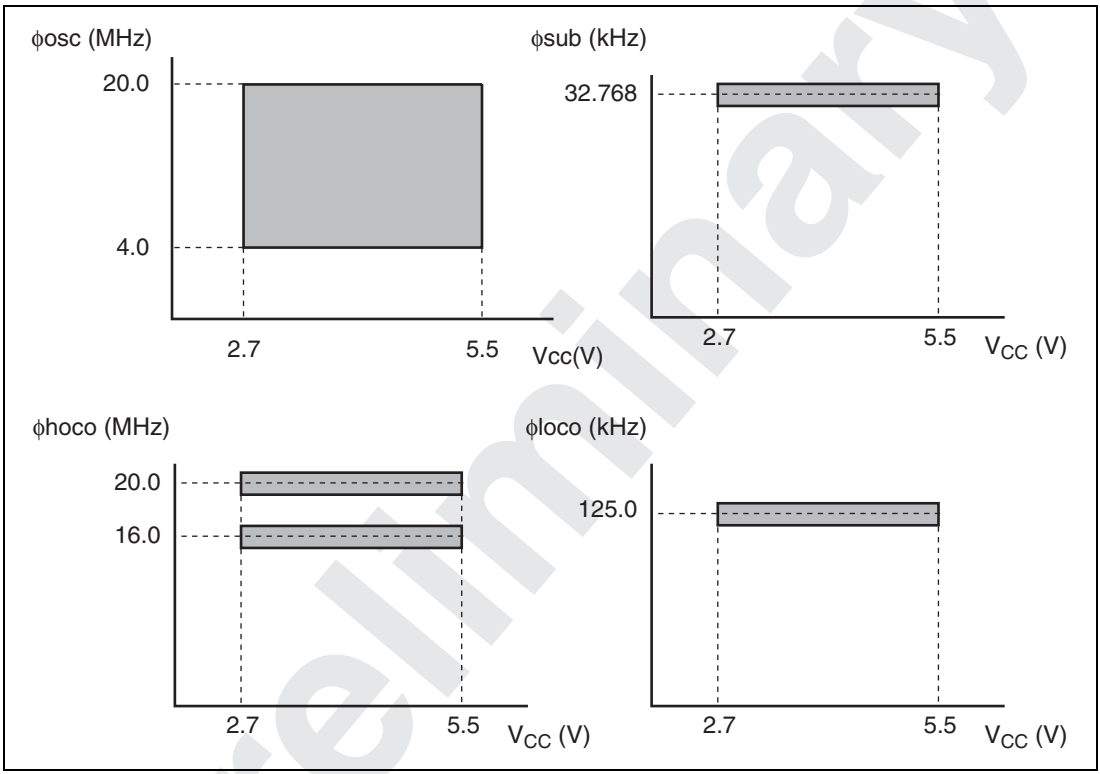
Note: 1. Permanent damage may result if maximum ratings are exceeded. Normal operation should be under the conditions specified in Electrical Characteristics. Exceeding these values can result in incorrect operation and reduced reliability.
2. The OSC1 pin is used when the external oscillator function is selected. (PMRJ1 = 1, PMRJ0 = 1)
3. When the external clock input function is selected. (PMRJ1 = 0, PMRJ0 = 1)

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28.2 Electrical Characteristics

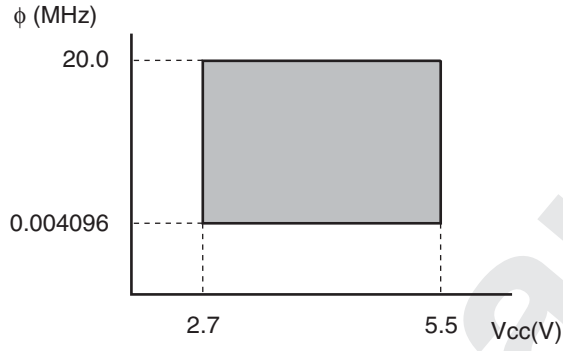
28.2.1 Power Supply Voltage and Operating Ranges

(1) Power Supply Voltage and Oscillation Frequency Range

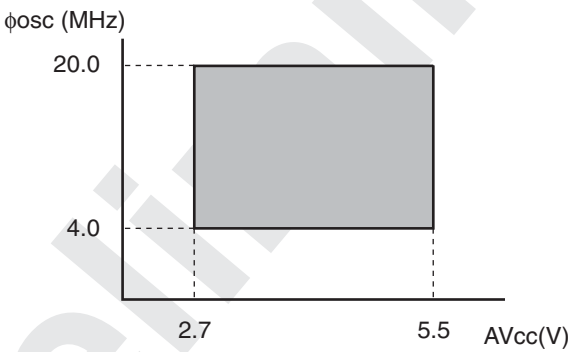


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(2) Power Supply Voltage and Operating Frequency Range



(3) Accuracy Guarantee Range of Analog Power Supply Voltage and A/D Converter



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28.3 DC Characteristics

Table 28.2 DC Characteristics (1)

Unless otherwise indicated, V_{cc} = 2.7 to 5.5 V, V_{ss} = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Applicable Pins	Test Condition	Value Min.	Value Typ.	Value Max.	Unit	Remark
Input high voltage	V_{IH}	$\overline{RES}$, $\overline{NMI}$ $\overline{IRQ0}$ to $\overline{IRQ7}$ TRAIO, TRGB, FTCI, TRGC, FTIOA, FTIOB, FTIOC, FTIOD, $\overline{TRCOI}$, FTIOA0 FTIOB0, FTIOC0, FTIOD0, FTIOA1, FTIOB1, FTIOC1, FTIOD1, $\overline{TRDOI_0}$, FTIOA2, FTIOB2, FTIOC2, FTIOD2, FTIOA3, FTIOB3, FTIOC3, FTIOD3, $\overline{TRDOI_1}$, TCLKA TCLKB, TGIOA TGIOB, SCK3, SCK3_2, SCK3_3 $\overline{ADTRG1}$, $\overline{ADTRG2}$ RXD, RXD_2, RXD_3 SCL, SDA, SSCK, $\overline{SCS}$, SSI, SSO	V_{cc} = 4.0 to 5.5 V	$V_{cc} \times 0.8$	—	V_{cc} + 0.3	V	
				$V_{cc} \times 0.9$	—	V_{cc} + 0.3	V	
		P10 to P17, P20 to P27, P30 to P37 P50 to P57, P60 to P67 P85 to P87, P90 to P97 PA0 to PA7, PB0 to PB7 PJ1, PJ0	V_{cc} = 4.0 to 5.5 V	$V_{cc} \times 0.7$	—	V_{cc} + 0.3	V	
				$V_{cc} \times 0.8$	—	V_{cc} + 0.3	V	
		OSC1	V_{cc} = 4.0 to 5.5 V PMRJ[1:0] = 01	V_{cc} – 0.5	—	V_{cc} + 0.3	V	
			PMRJ[1:0] = 01	V_{cc} – 0.3	—	V_{cc} + 0.3	V	

Note: Connect the TEST pin to Vss.

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Item	Symbol	Applicable Pins	Test Condition	Value Min.	Value Typ.	Value Max.	Unit	Remark
Input low voltage	V_{IL}	$\overline{RES}$, $\overline{NMI}$ $\overline{IRQ0}$ to $\overline{IRQ7}$ TRAIO, TRGB, FTCI, TRGC, FTIOA, FTIOB, FTIOC, FTIOD, $\overline{TRCOI}$ FTIOA0 FTIOB0, FTIOC0, FTIOD0, FTIOA1, FTIOB1, FTIOC1, FTIOD1, $\overline{TRDOI_0}$, FTIOA2, FTIOB2, FTIOC2, FTIOD2, FTIOA3, FTIOB3, FTIOC3, FTIOD3, $\overline{TRDOI_1}$, TCLKA TCLKB, TGIOA TGIOB, SCK3, SCK3_2, SCK3_3 $\overline{ADTRG1}$, $\overline{ADTRG2}$, RXD, RXD_2, RXD_3, SCL, SDA, SSCK, $\overline{SCS}$, SSI, SSO	V_{CC} = 4.0 to 5.5V	–0.3	—	$V_{CC} \times 0.2$	V	
				–0.3	—	$V_{CC} \times 0.1$	V	
		P10 to P17 P20 to P27 P30 to P37 P50 to P57 P60 to P67 P85 to P87	V_{CC} = 4.0 to 5.5V	–0.3	—	$V_{CC} \times 0.3$	V	
		P90 to P97 PA0 to PA7 PB0 to PB7 PJ, PJ0		–0.3	—	$V_{CC} \times 0.2$	V	
		OSC1	V_{CC} = 4.0 to 5.5V PMRJ[1:0] = 01	–0.3	—	0.5	V	
			PMRJ[1:0] = 01	–0.3	—	0.3	V	

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Item	Symbol	Applicable Pins	Setting Condition	Test Condition	Value Min.	Value Typ.	Value Max.	Unit	Remark
Output high voltage	V_{OH}	P10 to P17 P20 to P27 P30 to P37 P50 to P55 P60 to P67	PDVRn0 to 7 = 0 (n = 1, 2, 3, 5, 6, 8, 9)	V_{CC} = 4.0 to 5.5 V $-I_{OH}$ = 5.0mA	V_{CC} –1.0	—	—	V	
				$-I_{OH}$ = 0.1mA	V_{CC} –0.5	—	—	V	
		P85 to P87 P90 to P97	PDVRn0 to 7 = 1 (n = 1, 2, 3, 5, 6, 8, 9)	V_{CC} = 4.0 to 5.5V $-I_{OH}$ = 20.0mA	—	V_{CC} –1.5	—	V	Reference value
				V_{CC} = 4.0 to 5.5V $-I_{OH}$ = 10.0mA	—	V_{CC} –1.0	—	V	Reference value
				V_{CC} = 4.0 to 5.5V $-I_{OH}$ = 5.0mA	—	V_{CC} –0.5	—	V	Reference value
				$-I_{OH}$ = 0.1mA	—	V_{CC} –0.4	—	V	Reference value
		PA0 to PA7 PB0 to PB7 PJ0, PJ1		V_{CC} = 4.0 to 5.5V $-I_{OH}$ = 5.0mA	V_{CC} –1.0	—	—	V	
				$-I_{OH}$ = 0.1mA	V_{CC} –0.5	—	—	V	
		P56, P57		$4.0 \le V_{CC} \le 5.5V$ $-I_{OH}$ = 0.1mA	V_{CC} –2.5	—	—	V	
				$3.0 \le V_{CC} < 4.0V$ $-I_{OH}$ = 0.1mA	V_{CC} –2.0	—	—	V	

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Item	Symbol	Applicable Pins	Setting Condition	Test Condition	Value Min.	Value Typ.	Value Max.	Unit	Remark
Output low voltage	V_{OL}	P10 to P17 P20 to P27 P30 to P37 P50 to P57 P60 to P67 P85 to P87 P90 to P97	PDVRn0 to 7 = 0 (n = 1, 2, 3, 5, 6, 8, 9)	V_{CC} = 4.0 to 5.5V I_{OL} = 1.6mA	—	—	0.6	V	
				I_{OL} = 0.4mA	—	—	0.4	V	
			PDVRn0 to 7 = 1 (n = 1, 2, 3, 5, 6, 8, 9)	V_{CC} = 4.0 to 5.5V I_{OL} = 20.0mA	—	—	1.5	V	
				I_{OL} = 5.0mA	—	—	1.0	V	
				V_{CC} = 4.0 to 5.5V I_{OL} = 1.6mA	—	0.6	—	V	Reference value
				I_{OL} = 0.4mA	—	0.4	—	V	Reference value
		PA0 to PA7 PB0 to PB7 PJ0, PJ1		V_{CC} = 4.0 to 5.5V I_{OL} = 1.6mA	—	—	0.6	V	
				I_{OL} = 0.4mA	—	—	0.4	V	
		SCL, SDA		V_{CC} = 4.0 to 5.5V I_{OL} = 6.0mA	—	—	0.6	V	
				I_{OL} = 3.0mA	—	—	0.4	V	

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Item	Symbol	Applicable Pins	Test Condition	Value Min.	Value Typ.	Value Max	Unit	Remark
Input/output leakage current	$\lvert I_{IL} \rvert$	$\overline{NMI}$, $\overline{IRQ0}$ to $\overline{IRQ7}$ TRAIO,TRGB, FTCI, TRGC, FTIOA FTIOB, FTIOC, FTIOD, $\overline{TRCOI}$, FTIOA0, FTIOB0, FTIOC0, FTIOD0, FTIOA1, FTIOB1, FTIOC1, FTIOD1 $\overline{TRDOI_0}$, FTIOA2 FTIOB2, FTIOC2, FTIOD2 FTIOA3, FTIOB3, FTIOC3, FTIOD3 $\overline{TRDOI_1}$, TCLKA TCLKB, TGIOA TGIOB, SCK3 SCK3_2, SCK3_3 $\overline{ADTRG1}$, $\overline{ADTRG2}$ RXD, RXD_2, RXD_3 SCL, SDA SSCK, $\overline{SCS}$ SSI, SSO, OSC1	V_{IN} = 0.5 V to (V_{CC} - 0.5 V)	—	—	1.0	µA	
		P10 to P17 P20 to P27 P30 to P37 P50 to P57 P60 to P67 P85 to P87 P90 to P97 PA0 to PA7 PB0 to PB7 PJ1, PJ0						

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Item	Symbol	Applicable Pins	Test Condition	Value Min.	Value Typ.	Value Max	Unit	Remark
Pull-up MOS current	–Ip	P10 to P17 P20 to P27 P30 to P37 P50 to P57 P60 to P67 P85 to P87 P90 to P97 PA0 to PA7 PB0 to PB7 PJ1, PJ0	V_{CC} = 5.0 V, V_{IN} = 0.0 V	40.0	—	200.0	µA	
			V_{CC} = 3.0 V, V_{IN} = 0.0 V	—	40.0	—	µA	Reference value
Input capacitance	C_{IN}	All input pins except power supply pins	ϕ = 1MHz, V_{IN} = 0.0 V, Ta = 25°C	—	—	15.0	pF	
Active mode supply current	I_{OPE1}	V_{CC}	Active mode 1, ϕ_{OSC} = 20MHz	—	T.B.D	T.B.D	mA	*
			Active mode 1, ϕ_{OSC} = 10MHz	—	T.B.D	—	mA	Reference value*
	I_{OPE2}	V_{CC}	Active mode 2, ϕ_{OSC} = 20MHz	—	T.B.D	T.B.D	mA	*
			Active mode 2, ϕ_{OSC} = 10MHz	—	T.B.D	—	mA	Reference value*
	I_{OPE3}	V_{CC}	Active mode 3, ϕ_{OSC} = 20MHz	—	T.B.D	T.B.D	mA	*
			Active mode 3, ϕ_{OSC} = 10MHz	—	T.B.D	—	mA	Reference value*
	I_{OPE4}	V_{CC}	Active mode 4, ϕ_{SUB} = 32kHz	—	T.B.D	—	mA	*
	I_{OPE5}	V_{CC}	Active mode 5, ϕ_{SUB} = 32kHz	—	T.B.D	—	mA	Reference value*

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Item	Symbol	Applicable Pins	Test Condition	Value Min.	Value Typ.	Value Max	Unit	Remark
Sleep mode supply current	I_{SLEEP1}	V_{CC}	Sleep mode 1, ϕ_{OSC} = 20MHz	—	T.B.D	T.B.D	mA	*
			Sleep mode 1, ϕ_{OSC} = 10MHz	—	T.B.D	—	mA	Reference value*
	I_{SLEEP2}	V_{CC}	Sleep mode 2, ϕ_{OSC} = 20MHz	—	T.B.D	T.B.D	mA	*
			Sleep mode 2, ϕ_{OSC} = 10MHz	—	T.B.D	—	mA	Reference value*
	I_{SLEEP3}	V_{CC}	Sleep mode 3, ϕ_{OSC} = 20MHz	—	T.B.D	T.B.D	mA	*
			Sleep mode 3, ϕ_{OSC} = 10MHz	—	T.B.D	—	mA	
	I_{SLEEP4}	V_{CC}	Sleep mode 4, ϕ_{sub} = 32kHz	—	T.B.D	—	mA	*
	I_{SLEEP5}	V_{CC}	Sleep mode 5, ϕ_{sub} = 32kHz	—	T.B.D	—	mA	Reference value*
Standby mode supply current	I_{STBY}	V_{CC}	Ta ≤ 50 °C when 32-kHZ crystal resonator not used	—	—	T.B.D	µA	*
			Ta > 50 °C when 32-kHZ crystal resonator not used	—	—	T.B.D	µA	
RAM data retaining voltage	V_{RAM}	V_{CC}		2.0	—	—	V	

Note: * The following table shows pin states during the measurement of supply current except the current through pull-up MOS transistors and output buffers.

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Mode	$\overline{RES}$ Pin	Internal State	PSCSTP	Other Pins	Oscillator Pins
Active mode 1	V_{CC}	Operating ($\phi = \phi_{OSC}$)	0	V_{CC}	Main clock oscillator: Ceramic resonator or crystal resonator Subclock oscillator: Pin X1 = V_{SS}
Active mode 2		Operating ($\phi = \phi_{OSC}/64$)	0		
Active mode 3		Operating ($\phi = \phi_{OSC}/128$)	0		
Sleep mode 1	V_{CC}	Only timers operating	0	V_{CC}	
Sleep mode 2		Only timers operating ($\phi = \phi_{OSC}/64$)	0		
Sleep mode 3		Only timers operating ($\phi = \phi_{OSC}/128$)	0		
Active mode 4	V_{CC}	Operating ($\phi = \phi_{sub}$)	1	V_{CC}	Main clock oscillator: Ceramic resonator or crystal resonator Subclock oscillator: Crystal resonator
Active mode 5		Operating ($\phi = \phi_{sub}/8$)	1		
Sleep mode 4	V_{CC}	Only timers operating ($\phi = \phi_{sub}$)	1	V_{CC}	
Sleep mode 5		Only timers operating ($\phi = \phi_{sub}/8$)	1		
Standby mode	V_{CC}	Both CPU and timers stopped.	—	V_{CC}	Main clock oscillator: Ceramic resonator or crystal resonator Subclock oscillator: Pin X1 = V_{SS}

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Table 28.3 DC Characteristics (2)

Unless otherwise indicated, V_{CC} = 2.7 to 5.5 V, V_{SS} = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Applicable Pins	Setting Conditions	Test Conditions	Value Min.	Value Typ.	Value Max.	Unit
Allowable output low current (per pin)	I_{OL}	P10 to P17 P20 to P27 P30 to P37 P50 to P57 P60 to P67 P85 to P87 P90 to P97 PJ0, PJ1	PDVRn0 to 7 = 0 (n = 1, 2, 3, 5, 6, 8, 9, J)	V_{CC} = 4.0 to 5.5 V	—	—	2.0	mA
					—	—	0.5	mA
			PDVRn0 to 7 = 1 (n = 1, 2, 3, 5, 6, 8, 9, J)	V_{CC} = 4.0 to 5.5 V	—	—	20.0	mA
					—	—	5.0	mA
		PA0 to PA7, PB0 to PB7	—	V_{CC} = 4.0 to 5.5 V	—	—	2.0	mA
					—	—	0.5	mA
		SCL, SDA	—	V_{CC} = 4.0 to 5.5 V	—	—	6.0	mA
Allowable output low current (total)	ΣI_{OL}	All input pins	—	V_{CC} = 4.0 to 5.5 V	—	—	80	mA
					—	—	40	mA

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Item	Symbol	Applicable Pins	Setting Conditions	Test Conditions	Value Min.	Value Typ.	Value Max.	Unit
Allowable output high current (per pin)	$\lvert -I_{OH} \rvert$	P10 to P17 P20 to P27 P30 to P37 P50 to P55	PDVRn0 to 7 = 0 (n = 1, 2, 3, 5, 6, 8, 9, J)	V_{CC} = 4.0 to 5.5 V	—	—	5.0	mA
					—	—	0.2	mA
		P60 to P67 P85 to P87 P90 to P97 PJ0, PJ1	PDVRn0 to 7 = 1 (n = 1, 2, 3, 5, 6, 8, 9, J)	V_{CC} = 4.0 to 5.5 V	—	—	20.0	mA
					—	—	5.0	mA
		PA0 to PA7, PB0 to PB7		V_{CC} = 4.0 to 5.5 V	—	—	5.0	mA
					—	—	0.2	mA
		P56, P57		V_{CC} = 4.0 to 5.5 V	—	—	0.4	mA
					—	—	0.2	mA
Allowable output high current (total)	$\lvert -\Sigma I_{OH} \rvert$	All input pins		V_{CC} = 4.0 to 5.5 V	—	—	80	mA
					—	—	40	mA

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28.4 AC Characteristics

Table 28.4 AC Characteristics

Unless otherwise indicated, V_{CC} = 2.7 to 5.5 V, V_{SS} = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Applicable Pins	Test Conditions	Value				Reference Figure
				Min.	Typ.	Max.	Unit	
Oscillation frequency of the main oscillator	ϕ_{OSC}	OCS1, OSC2		4.0	—	20.0	MHz	
Oscillation frequency of the subclock oscillator	ϕ_{sub}	X1, XC		—	32.768	—	MHz	
Oscillation frequency of the low-speed on-chip oscillator	ϕ_{loco}			25	125	225	kHz	
Oscillation stabilization time of the low-speed on-chip oscillator	t_{rc}			—	—	T.B.D	µs	
Cycle time of the system reference clock (ϕ_{base})	t_{base}			1	—	1	ϕ_{OSC} ϕ_{sub} ϕ_{loco}	
				2	—	2	ϕ_{hoco}	
Cycle time of the system clock (ϕ)	t_{cyc}			1	—	128	t_{base}	*1
				—	—	244.2	µs	
Cycle time of the instruction				1	—	—	t_{cyc}	
Oscillation stabilization time (crystal resonator)	t_{rc}	OSC1, OSC2		—	—	6.5	ms	Figure 28.3
Oscillation stabilization time (ceramic resonator)	t_{rc}	OSC1, OSC2		—	—	6.5	ms	
Oscillation stabilization time	t_{rcx}	X1, X2		—	—	2.0	s	
External clock high width	t_{CPH}	OSC1	V_{CC} = 4.0 to 5.5 V	20.0	—	—	ns	Figure 28.1
				40.0	—	—	ns	
External clock low width	t_{CPL}	OSC1	V_{CC} = 4.0 to 5.5 V	20.0	—	—	ns	
				40.0	—	—	ns	

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Item	Symbol	Applicable Pins	Test Conditions	Value Min.	Value Min.	Value Min.	Unit	Reference Figure
External clock rising time	t_{CPr}	OSC1	V_{CC} = 4.0 to 5.5 V	—	—	10.0	ns	Figure 28.1
				—	—	15.0	ns	
External clock falling time	t_{CPf}	OSC1	V_{CC} = 4.0 to 5.5 V	—	—	10.0	ns	
				—	—	15.0	ns	
$\overline{RES}$ pin low width	t_{REL1}	$\overline{RES}$	At power-on or in mode other than below	T.B.D	—	—	ms	Figure 28.2
	t_{REL2}		In active mode or sleep mode	T.B.D	—	—	ms	
Width at high level for input pins	t_{IH}	$\overline{NMI}$		T.B.D	—	—		Figure 28.4
		$\overline{IRQ0}$ to $\overline{IRQ7}$		T.B.D	—	—		
		FTIOA to FTIOD, FTIOA0 to FTIOD0, FTIOA1 to FTIOD1, FTIOA2 to FTIOD2, FTIOA3 to FTIOD3, FTCI, TRGC, $\overline{TRCOI}$, $\overline{TRDOI_0}$, $\overline{TRDOI_1}$, TCLKA, TCLKB, TGIOA, TGIOB		3	—	—	ϕ_{tcyc} ϕ40*[2]	
		$\overline{ADTRG}$, $\overline{ADTRG_2}$		3	—	—	t_{cyc}	

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Item	Symbol	Applicable Pins	Test Conditions	Value Min.	Value Typ.	Value Max.	Unit	Reference Figure
Width at low level for input pins	t_{IL}	$\overline{NMI}$		T.B.D	—	—		Figure 28.4
		$\overline{IRQ0}$ to $\overline{IRQ7}$		T.B.D	—	—		
		FTIOA to FTIOD, FTIOA0 to FTIOD0, FTIOA1 to FTIOD1, FTIOA2 to FTIOD2, FTIOA3 to FTIOD3, FTCI, TRGC, $\overline{TRCOI}$, $\overline{TRDOI_0}$, $\overline{TRDOI_1}$, TCLKA, TCLKB, TGIOA, TGIOB		3	—	—	ϕ_{tcyc} $\phi 40$※2	
		$\overline{ADTRG}$, $\overline{ADTRG_2}$		3	—	—	ϕ_{tcyc}	

Note: 1. Determined by settings of the system clock control register (SYSCCR), power-down control register 1 (LPCR1), and power-down control register (LPCR2).
2. When the internal $\phi 40$ clock is selected as the counter clock.

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Table 28.5 Timing of I²C Bus Interface

Unless otherwise indicated, V_{CC} = 2.7 to 5.5 V, V_{SS} = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Test Conditions	Value			Unit	Reference Figure
			Min.	Typ.	Max.		
SCL input cycle time	t_{SCL}		$12t_{cyc}$ + 600	—	—	ns	Figure 28.5
SCL input high width	t_{SCLH}		$3t_{cyc}$ + 300	—	—	ns	
SCL input low width	t_{SCLL}		$5t_{cyc}$ + 300	—	—	ns	
Falling time for SCL and SDA inputs	t_{Sf}		—	—	300	ns	
Pulse width of spike on SCL and SD to be suppressed	t_{SP}		—	—	$1t_{cyc}$	ns	
SDA input bus-free time	t_{BUF}		$5t_{cyc}$	—	—	ns	
Start condition input hold time	t_{STAH}		$3t_{cyc}$	—	—	ns	
Repeated start condition input setup time	t_{STAS}		$3t_{cyc}$	—	—	ns	
Stop condition input setup time	t_{STOS}		$3t_{cyc}$	—	—	ns	
Data-input setup time	t_{SDAS}		$1t_{cyc}$ + 20	—	—	ns	
Data-input hold time	t_{SDAH}		0	—	—	ns	
Capacitive load of SCL and SDA	Cb		0	—	400	pF	
Falling time of SCL and SDA outputs	t_{Sf}	Vcc = 4.0 to 5.5V	—	—	250	ns	
			—	—	300	ns	

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Table 28.6 Timing of Serial Communication Interface (SCI)

Unless otherwise indicated, VCC = 2.7 to 5.5 V, VSS = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item		Symbol	Applicable Pins	Test Conditions	Value				Reference Figure
					Min.	Typ.	Max.	Unit	
Input clock cycle	Asynchronous	t_{scyc}	SCK3		4	—	—	t_{cyc}	Figure 28.6
	Clock synchronous				6	—	—	t_{cyc}	
Input clock pulse width		t_{SCKW}	SCK3		0.4	—	0.6	t_{scyc}	
Transmit data delay time (clock synchronous)		t_{TXD}	TXD	Vcc = 4.0 to 5.5 V	—	—	1	t_{cyc}	Figure 28.7
					—	—	1	t_{cyc}	
Receive data setup time (clock synchronous)		t_{RXS}	RXD	Vcc = 4.0 to 5.5 V	50.0	—	—	ns	
					100.0	—	—	ns	
Receive data hold time (clock synchronous)		t_{RXH}	RXD	Vcc = 4.0 to 5.5 V	50.0	—	—	ns	
					100.0	—	—	ns	

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Table 28.7 Timing of Synchronous Serial Communication Unit (SSU)

Unless otherwise indicated, VCC = 2.7 to 5.5 V, VSS = 0.0 V, Ta = -20 to +85 °C (N version)/ -40 to +85 °C (D version), C_L = 100 pF

Item		Symbol	Applicable Pins	Test Conditions	Value				Reference Figure
					Min.	Typ.	Max.	Unit	
Clock cycle		t_{SUCYC}	SSCK		4	—	—	t_{CYC}	Figures 28.8 to 28.12
Clock high pulse width		t_{HI}	SSCK		0.4	—	0.6	t_{SUCYC}	
Clock low pulse width		t_{LO}	SSCK		0.4	—	0.6	t_{SUCYC}	
Clock rising time	Master	t_{RISE}	SSCK		—	—	1	t_{CYC}	
	Slave				—	—	1.0	µs	
Clock falling time	Master	t_{FALL}	SSCK		—	—	1	t_{CYC}	
	Slave				—	—	1.0	µs	
Data input setup time		t_{SU}	SSO SSI		100	—	—	ns	
Data input hold time		t_H	SSO SSI		1	—	—	t_{CYC}	
$\overline{SCS}$ setup time	Slave	t_{LEAD}	$\overline{SCS}$		$1t_{CYC}$ + 50	—	—	ns	
$\overline{SCS}$ hold time	Slave	t_{LAG}	$\overline{SCS}$		$1t_{CYC}$ + 50	—	—	ns	
Data output delay time		t_{OD}	SSO SSI		—	—	1	t_{CYC}	
Slave access time		t_{SA}	SSI		—	—	$1.5t_{CYC}$ + 100	ns	
Slave out release time		t_{OR}	SSI		—	—	$1.5t_{CYC}$ + 100	ns	

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28.5 A/D Converter Characteristics

Table 28.8 A/D Converter Characteristics

Unless otherwise indicated, V_{CC} = 2.7 to 5.5 V, V_{SS} = AV_{SS} = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Applicable Pins	Test Conditions	Value			Unit	Remarks
				Min.	Typ.	Max.		
Analog power supply voltage	AVcc	AVcc		2.7	Vcc	5.5	V	*1
Analog input voltage	AV_{IN}	AN0 to AN11 AN0_2 to AN3_2		Vss – 0.3	—	Avcc + 0.3	V	
Analog power supply current	AI_{OPE}	AVcc	AVcc = 5.0V f_{osc} = 20MHz	—	—	T.B.D	mA	
	AI_{STOP1}	AVcc		—	T.B.D	—	µA	*2 Reference value
	AI_{STOP2}	AVcc		—	—	T.B.D	µA	*3
Analog input capacitance	C_{AIN}	AN0 to AN11 AN0_2 to AN3_2		—	—	30.0	pF	
Permissible signal source impedance	R_{AIN}	AN0 to AN11 AN0_2 to AN3_2		—	—	5.0	kΩ	
Resolution (data length)				10	10	10	bit	
Conversion time	t_{conv}			2.0	—	43	µs	
A/D conversion mode (single mode)		AN0 to AN11 AN0_2 to AN3_2	AVcc = 2.7 to 5.5V					
Nonlinearity error				—	—	T.B.D	LSB	
Offset error				—	—	T.B.D	LSB	
Full-scale error				—	—	T.B.D	LSB	
Quantization error				—	—	T.B.D	LSB	
Absolute precision				—	—	T.B.D	LSB	

Note: 1. Connect AVcc to Vcc when the A/D converter is not used.

Preliminary

2. AI_{STOP1} is the current flowing while the A/D converter is idle and the chip is in active mode or sleep mode.
3. AI_{STOP2} is the current flowing while the A/D converter is idle and the chip is in the reset state or in standby mode

Preliminary

28.6 D/A Converter Characteristics

Table 28.9 D/A Converter Characteristics

Unless otherwise indicated, V_{cc} = 2.7 to 5.5 V, V_{ss} = AV_{ss} = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Applicable Pins	Test Conditions	Value			Unit	Remarks
				Min.	Typ.	Max.		
Analog power supply voltage	AVcc	AVcc		2.7	Vcc	5.5	V	
Resolution				8	8	8	bit	
Conversion time		DA0 to DA1		—	—	3	µs	
Absolute precision		DA0 to DA1	Load resistance = 2MΩ	—	—	T.B.D	LSB	

Preliminary

28.7 Flash Memory Characteristics

Table 28.10 Flash Memory Characteristics

Unless otherwise indicated, V_{CC} = 2.7 to 5.5 V, V_{SS} = 0.0 V, VCC ≥ AVSS, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Test Conditions	Target Area	Value Min.	Value Typ.	Value Max.	Unit
Number of times programming/erasing is performed*1			Program ROM	1000*2	—	—	Times
			Data Flash	10000*2	—	—	
Programming time (per 4 bytes)			Program ROM	—	150	—	µs
			Data Flash	—	300	—	
Lock-bit programming time			Program ROM	—	70	—	µs
			Data Flash	—	140	—	
Erasing time (per 1-block)			Program ROM	—	300	—	ms
			Data Flash	—	300	—	
Time for transition to erase-suspend mode	$t_{d(SR-ES)}$		Program ROM	—	—	50 + CPU clock × 3 states	µs
			Data Flash				
Interval from the start of erasing to the request for suspension			Program ROM	0	—	—	µs
			Data Flash				
Interval from the start of erasing to the next request for suspension			Program ROM	150	—	—	µs
			Data Flash				
Interval from suspension to the resumption of erasing			Program ROM	—	—	50	µs
			Data Flash				
Voltage for programming/erasing			Program ROM	2.7	—	5.5	V
			Data Flash				
Reading voltage			Program ROM	2.7	—	5.5	V
			Data Flash				
Access states			Program ROM	1	—	—	States
			Data Flash	2	—	—	
Programming/erasing temperature			Program ROM	0	—	60	°C
			Data Flash	–20*3	—	85	

Preliminary

Notes: As a means of reducing the effective number of rewriting operations in a system where many rounds of rewriting proceed, go through the possible locations for programming in order until the remaining blank area has been minimized as much as is possible, and only then perform a round of erasure. For example, if data are being programmed in 16-byte sets, the number of effective reprogramming operations can be minimized by erasing once after having programmed the maximum of 256 sets.

To retain per-block information on the number of times erasure has been executed, setting up a control number is recommended.

If an erase-error occurs during erasure, execute the clear status command and then the erase command at least 3 times until the erase-error not occur.

1. Definition of number of times programming/erasing is performed
   The indicated number of times is the number of times programming/erasing can be performed per block. When the number of times is n (n = 1000, 10000), each block can be erased n times.

   Consider the 4-Kbyte blocks of data flash A as an example. When a block is erased after writing to the whole block has been performed by writing 4-byte units to the respective locations 1024 times, this counts as programming/erasure once. However, writing to a given address more than once after having erased the block is not possible (rewriting of values is prohibited).
2. This is the number of times for which all electrical characteristics can be guaranteed. (i.e. the values are guaranteed while the number of times is within the range from one to the minimum value.)
3. This becomes –40°C for the D version.

Preliminary

28.8 Electrical Characteristics for Low-Voltage Detection Circuits

Table 28.11 Electrical Characteristics for Low-Voltage Detection Circuit 0

Unless otherwise indicated, V_{CC} = 2.7 to 5.5 V, V_{SS} = 0.0 V, VCC ≥ AVCC, Ta = −20 to +85 °C (N version)/ −40 to +85 °C (D version)

			Value			
Item	**Symbol**	**Test Conditions**	**Min.**	**Typ.**	**Max.**	**Unit**
Voltage-detection level	V_{det0}	VD0LS1 = 0	T.B.D	2.35	T.B.D	V
		VD0LS1 = 1	T.B.D	3.80	T.B.D	
Minimum value of operating voltage for low-voltage detection circuit 0	$V_{LVDR0min}$		1.8	—	—	V

Preliminary

Table 28.12 Electrical Characteristics for Low-Voltage Detection Circuit 1

Unless otherwise indicated, VCC = 2.7 to 5.5 V, VSS = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

				Value			
Item	**Symbol**	**Test Conditions**		**Min.**	**Typ.**	**Max.**	**Unit**
Voltage-detection level	V_{det1}	VD1LS[3:0] = 0101	Falling voltage	T.B.D	2.85	T.B.D	V
			Rising voltage		3.07		
		VD1LS[3:0] = 0110	Falling voltage	T.B.D	2.92	T.B.D	
			Rising voltage		3.15		
		VD1LS[3:0] = 0111	Falling voltage	T.B.D	3.07	T.B.D	
			Rising voltage		3.30		
		VD1LS[3:0] = 1000	Falling voltage	T.B.D	3.22	T.B.D	
			Rising voltage		3.45		
		VD1LS[3:0] = 1001	Falling voltage	T.B.D	3.37	T.B.D	
			Rising voltage		3.60		
		VD1LS[3:0] = 1010	Falling voltage	T.B.D	3.52	T.B.D	
			Rising voltage		3.75		
		VD1LS[3:0] = 1011	Falling voltage	T.B.D	3.67	T.B.D	
			Rising voltage		3.90		
		VD1LS[3:0] = 1100	Falling voltage	T.B.D	3.82	T.B.D	
			Rising voltage		4.05		
		VD1LS[3:0] = 1101	Falling voltage	T.B.D	3.97	T.B.D	
			Rising voltage		4.20		
		VD1LS[3:0] = 1110	Falling voltage	T.B.D	4.12	T.B.D	
			Rising voltage		4.35		
		VD1LS[3:0] = 1111	Falling voltage	T.B.D	4.27	T.B.D	
			Rising voltage		4.50		
Voltage hysteresis between detection for rising and falling cases	$V_{LVD1HYS}$			—	0.22	—	V
Current drawn by low-voltage detection circuit 1		Vcc = 5.0V		—	T.B.D	—	µA

Preliminary

Item	Symbol	Test Conditions	Value Min.	Typ.	Max.	Unit
Time to wait for low-voltage detection circuit 1 to start operating	$t_{d(E-A)}$		—	—	T.B.D	µs
Minimum value of operating voltage for low-voltage detection circuit 1	$V_{LVDR1min}$		2.7	—	—	V

Table 28.13 Electrical Characteristics for Low-Voltage Detection Circuit 2

Unless otherwise indicated, VCC = 2.7 to 5.5 V, VSS = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Test Conditions	Value Min.	Typ.	Max.	Unit
Voltage-detection level	V_{det2}	Rising voltage Falling voltage	2.04	2.14	2.24	V
Current drawn by low-voltage detection circuit 1		Vcc = 5.0V	—	T.B.D	—	µA
Time to wait for low-voltage detection circuit 1 to start operating	$t_{d(E-A)}$		—	—	T.B.D	µs
Voltage-detection level for external input pins			T.B.D	1.33	T.B.D	
Range of input for voltage-detection of external inputs			0	—	1/2Vcc	V
Range of input for comparison voltage for external inputs			0	—	1/2Vcc	V

Preliminary

28.9 Electrical Characteristics for Power-On Reset Function

Table 28.14 Characteristics for Power-On Reset Function

Unless otherwise indicated, VCC = 2.7 to 5.5 V, VSS = 0.0 V, VCC ≥ AVCC, Ta = –20 to +85 °C (N version)/ –40 to +85 °C (D version)

Item	Symbol	Test Conditions	Value			Unit	Reference Figure
			Min.	Typ.	Max.		
Voltage where the power-on reset signal becomes effective	V_{por}		0	—	Vdet0	V	Figure 28.13
Slope of rise for external power supply Vcc	t_{rth}		0.5	—	T.B.D	V/msec	

Preliminary

28.10 Timing Charts

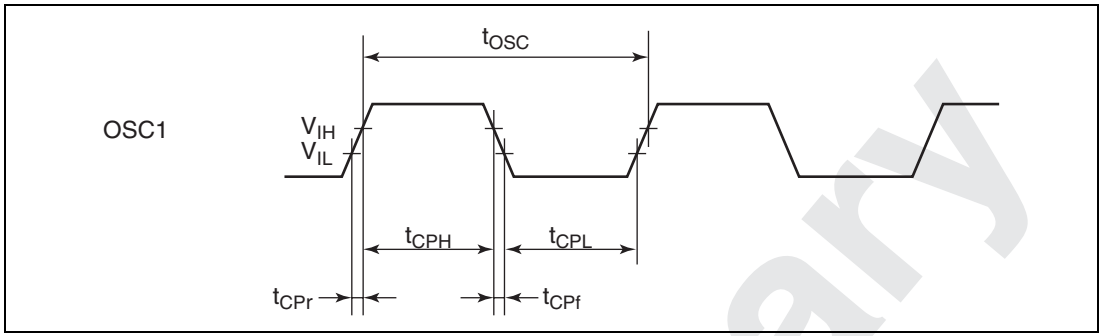


Figure 28.1 System Clock Input Timing

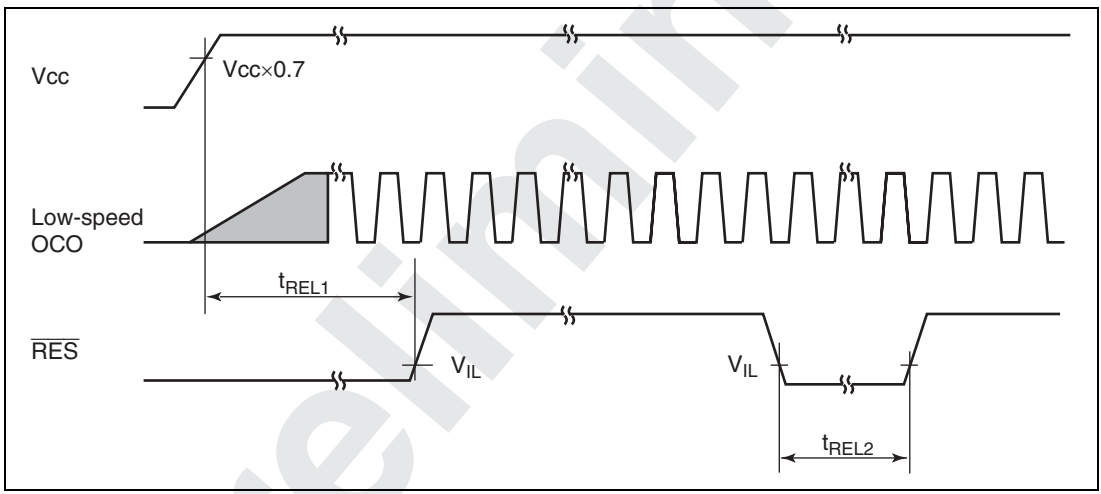


Figure 28.2 Timing of $\overline{RES}$ Pin Low Width

Preliminary

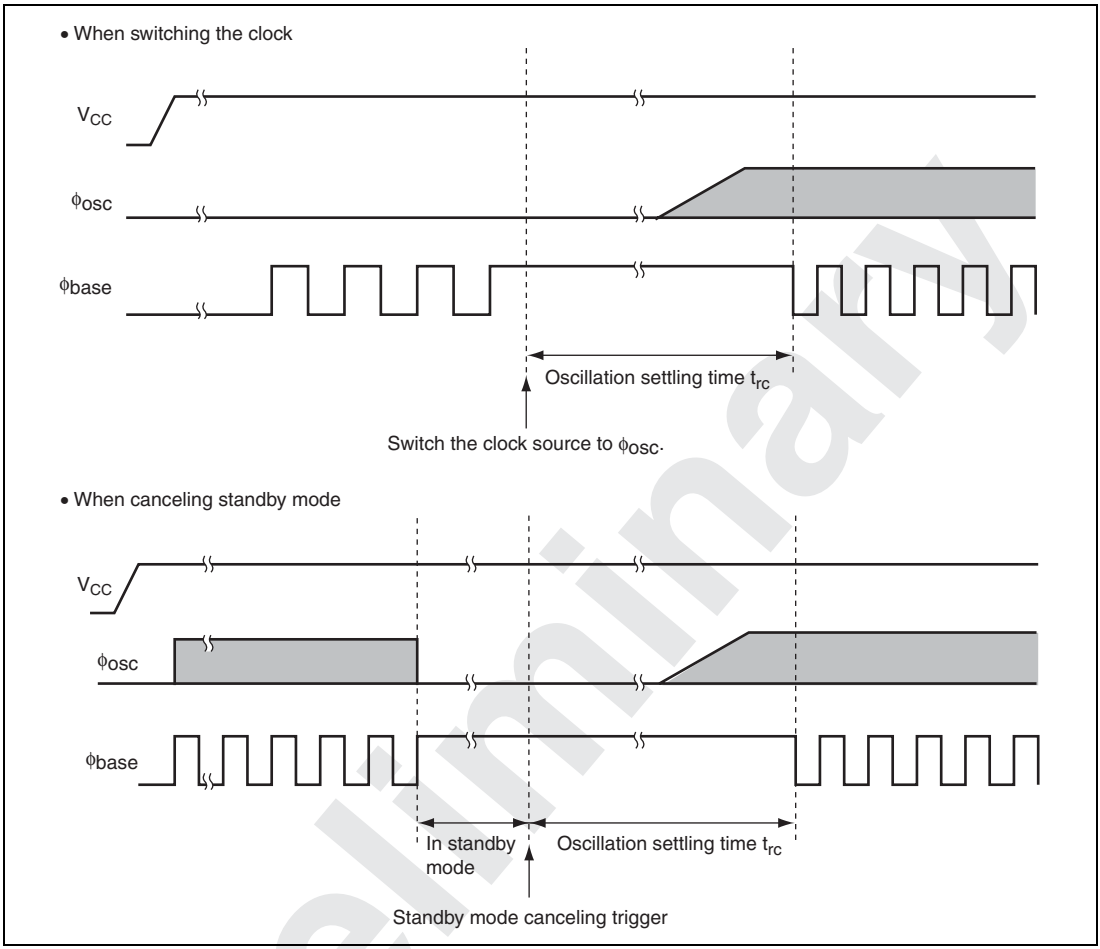


Figure 28.3 Timing of Oscillation Settling Time

Preliminary

$\overline{\text{NMI}}$, $\overline{\text{IRQ0}}$ to $\overline{\text{IRQ7}}$,
$\overline{\text{ADTRG}}$, $\overline{\text{ADTRG_2}}$,
FTIOA to FTIOD,
FTIOA0 to FTIOD0,
FTIOA1 to FTIOD1,
FTIOA2 to FTIOD2,
FTIOA3 to FTIOD3,
TCLKA, TCLKB,
FTCI, TGIOA , TRGC,
TGIOB, $\overline{\text{TRCOI}}$,
$\overline{\text{TRDOI_0}}$, $\overline{\text{TRDOI_1}}$

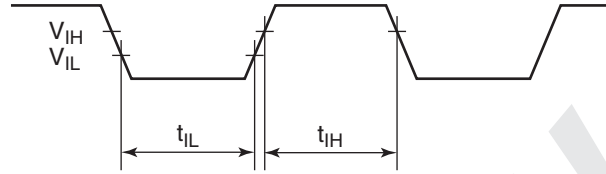
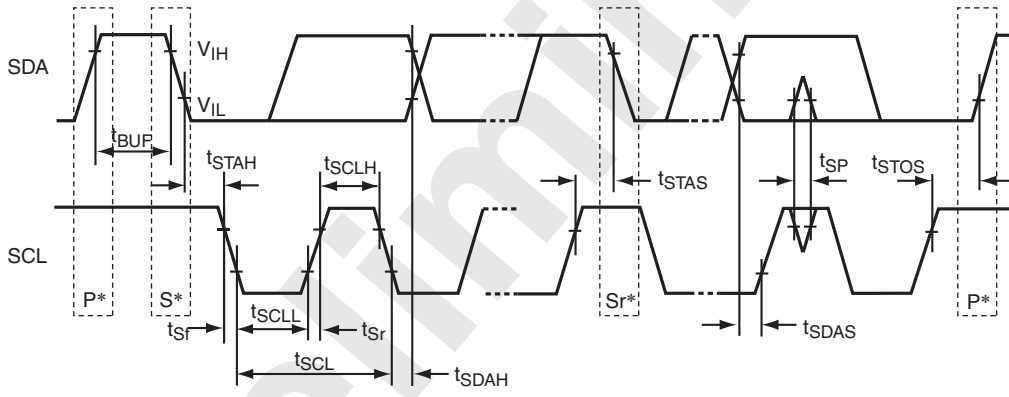


Figure 28.4 Input Timing



Notes: * S, P, and Sr represent the following:
S: Start condition
P: Stop condition
Sr: Repeated start condition

Figure 28.5 Timing of I²C Bus Interface Input/Output

Preliminary

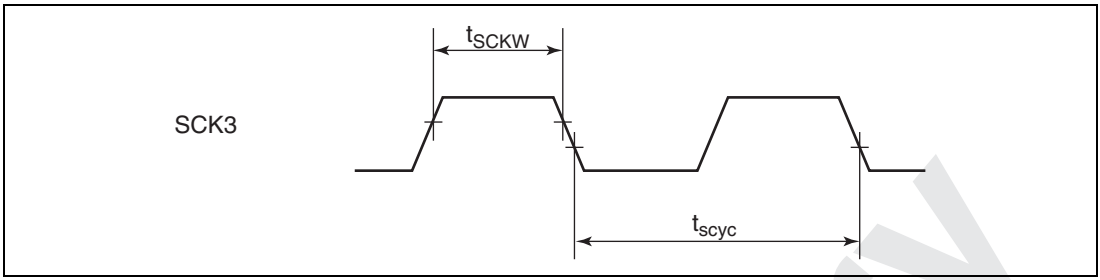
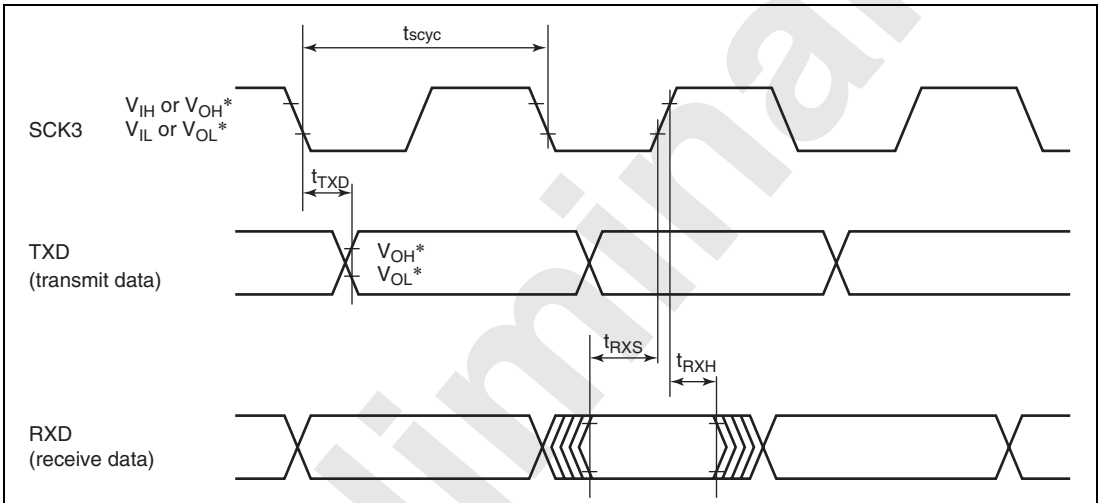


Figure 28.6 SCK3 Input Clock Timing



Note: * Output timing referenced levels

Output high	V_{OH} = 2.0V
Output low	V_{OL} = 0.8V

For load conditions, see figure 28.14.

Figure 28.7 SCI Input/Output Timing in Clock Synchronous Mode

Preliminary

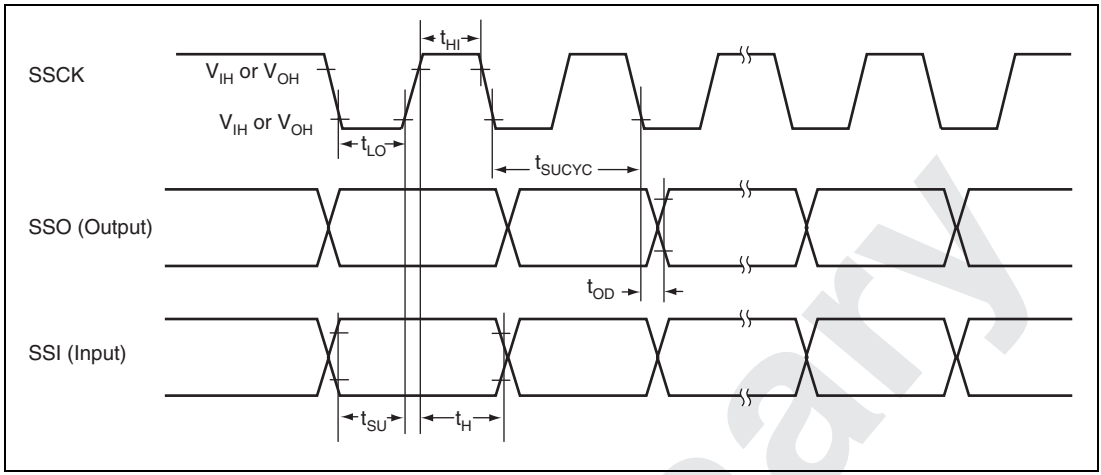


Figure 28.8 SSU Input Timing in Clock Synchronous Mode

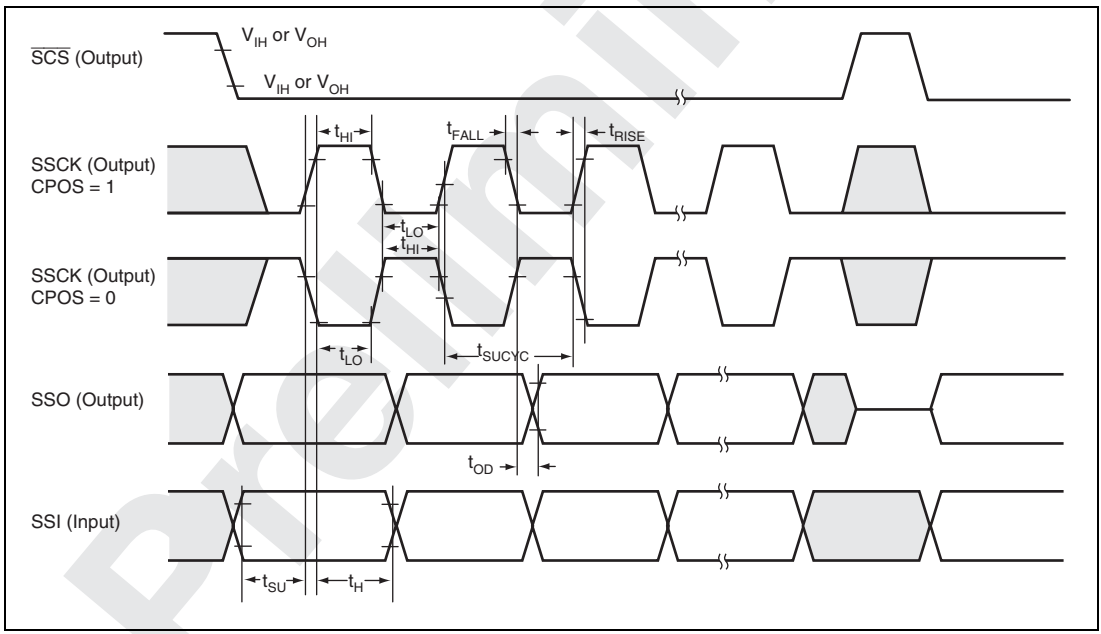


Figure 28.9 SSU Input/Output Timing
(Four-Line Bus Communication Mode, Master, CPHS = 1)

Preliminary

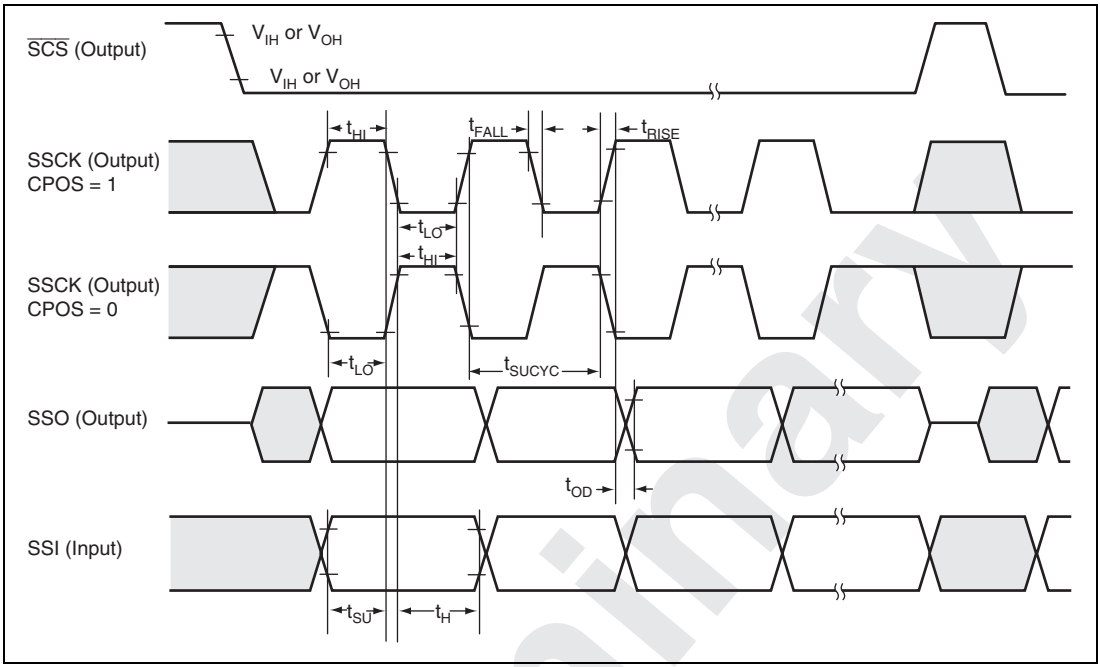


Figure 28.10 SSU Input/Output Timing
(Four-Line Bus Communication Mode, Master, CPHS = 0)

Preliminary

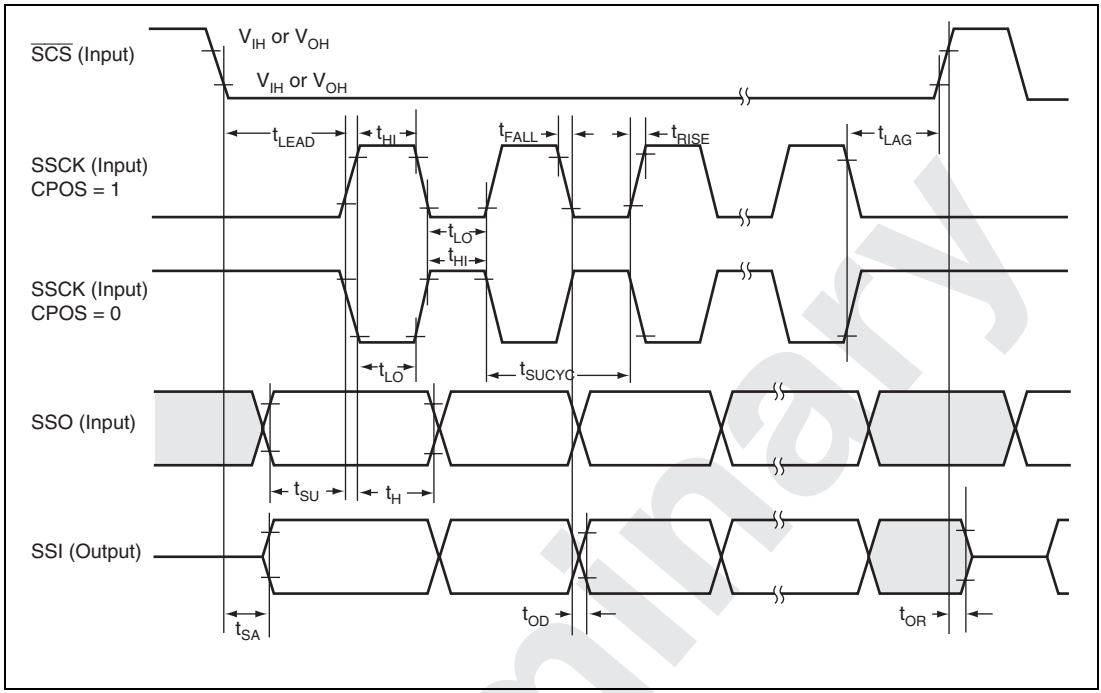


Figure 28.11 SSU Input/Output Timing
(Four-Line Bus Communication Mode, Slave, CPHS = 1)

Preliminary

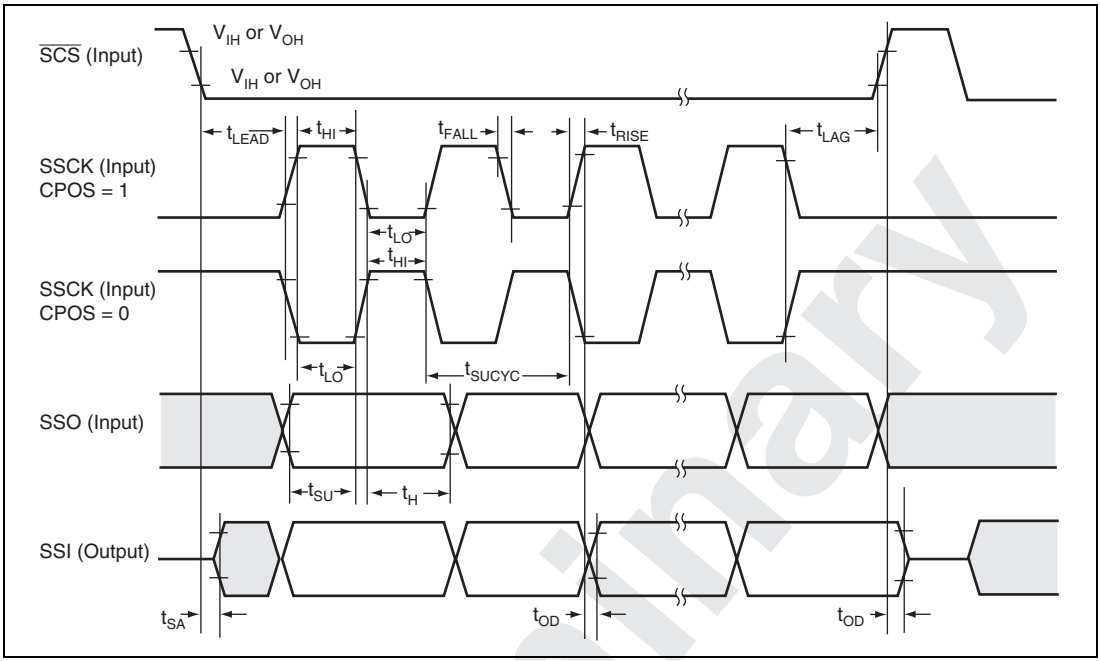
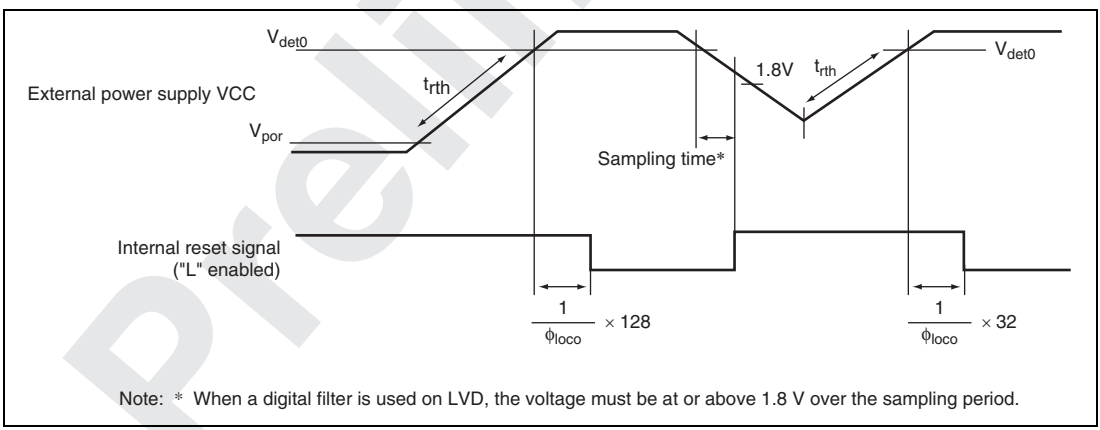


Figure 28.12 SSU Input/Output Timing
(Four-Line Bus Communication Mode, Slave, CPHS = 0)



Note: * When a digital filter is used on LVD, the voltage must be at or above 1.8 V over the sampling period.

Figure 28.13 Timing of Power-On Reset

Preliminary

28.11 Output Load Circuit

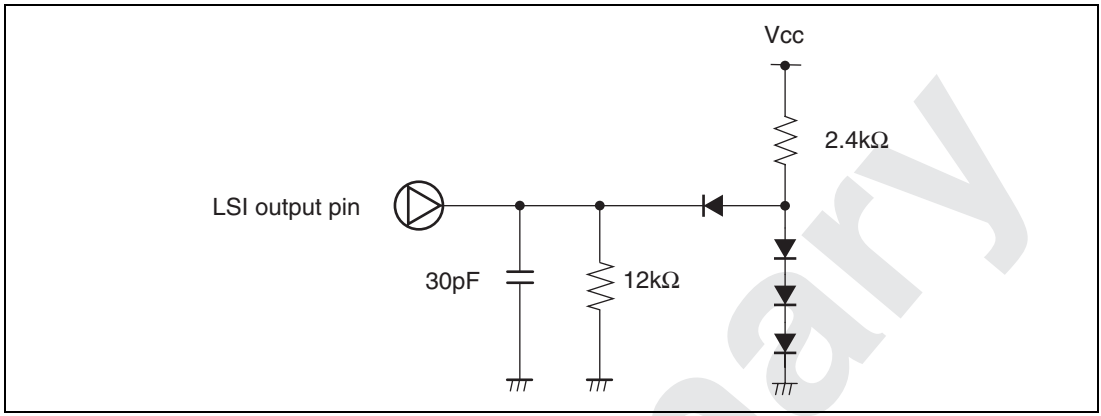


Figure 28.14 Output Load Circuit

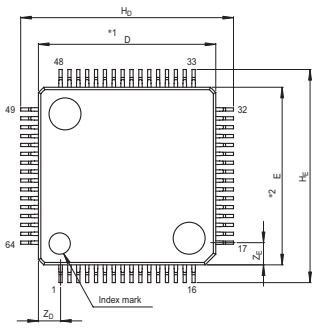
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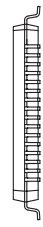
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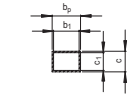
Appendix

A. Package Dimensions

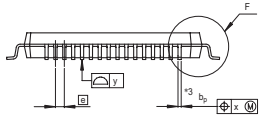
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP64-10x10-0.50	PLQP0064KB-A	64P6Q-A / FP-64K / FP-64KV	0.3g

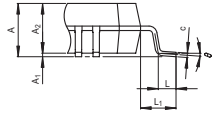






Terminal cross section





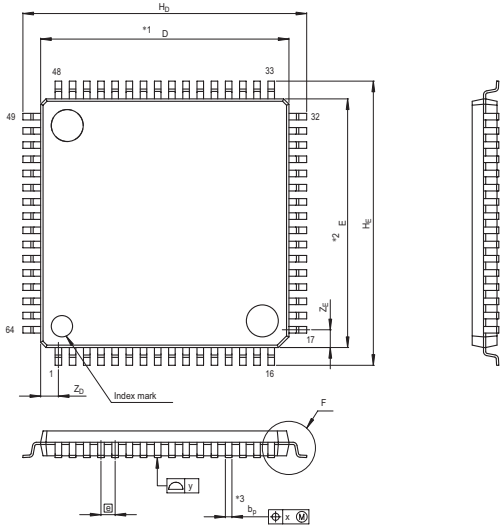
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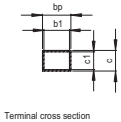
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	9.9	10.0	10.1
E	9.9	10.0	10.1
A_2	—	1.4	—
H_D	11.8	12.0	12.2
H_E	11.8	12.0	12.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.25	—
Z_E	—	1.25	—
L	0.35	0.5	0.65
L_1	—	1.0	—

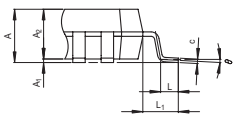
Figure A.1 Package Dimension (PLQP0064KB-A)

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP64-14x14-0.80	PLQP0064GA-A	64P6U-A	0.7g





Terminal cross section



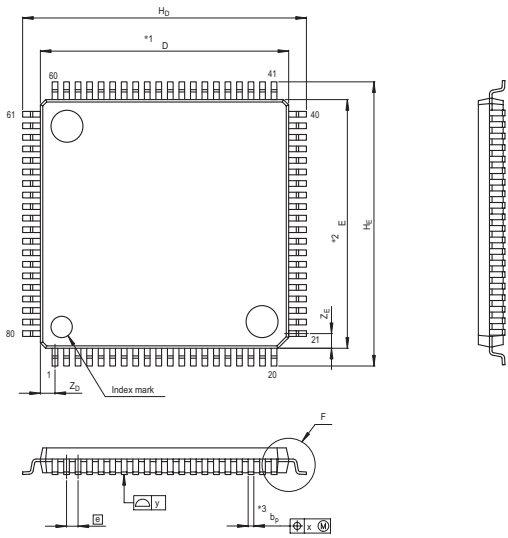
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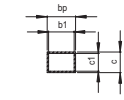
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0	0.1	0.2
b_p	0.32	0.37	0.42
b_1	—	0.35	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.8	—
x	—	—	0.20
y	—	—	0.10
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.3	0.5	0.7
L_1	—	1.0	—

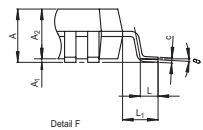
Figure A.2 Package Dimension (PLQP0064GA-A)

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP80-14x14-0.65	PLQP0080JA-A	FP-80W / FP-80WV	0.6g





Terminal cross section



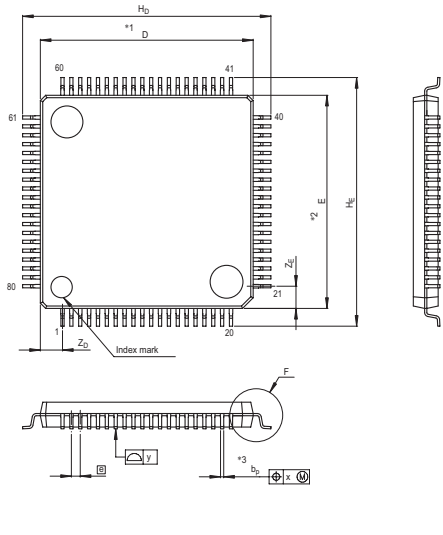
Detail F

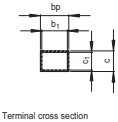
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.27	0.32	0.37
b_1	—	0.30	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.65	—
x	—	—	0.13
y	—	—	0.10
Z_D	—	0.825	—
Z_E	—	0.825	—
L	0.35	0.5	0.65
L_1	—	1.0	—

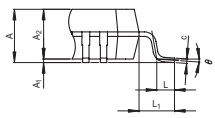
Figure A.3 Package Dimension (PLQP0080JA-A)

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP80-12x12-0.50	PLQP0080KB-A	80P6Q-A	0.5g





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	11.9	12.0	12.1
E	11.9	12.0	12.1
A_2	—	1.4	—
H_D	13.8	14.0	14.2
H_E	13.8	14.0	14.2
A	—	—	1.7
A_1	0	0.1	0.2
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	10°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.25	—
Z_E	—	1.25	—
L	0.3	0.5	0.7
L_1	—	1.0	—

Figure A.4 Package Dimension (PLQP0080KB-A)

B. Handling of Unused Pins

Table B.1 shows the handling of unused pins.

Table B.1 Handling of Unused Pins

Pin Name	Example of Handling Pins
$\overline{\text{RES}}$	Connect this pin to V_{CC} via a pull-up resister
$\overline{\text{NMI}}$	Connect this pin to V_{CC} via a pull-up resister
X1	Connect this pin to V_{SS}
X2	Leave this pin open
Port 1	Set the corresponding PMR bit or the PCR bit to 0 to set these pins in general purpose mode. Connect these pins to V_{CC} via a resister (pull-up) or to V_{SS} via a resister (pull-down), respectively.
Port 2	
Port 3	
Port 4	
Port 5	
Port 6	
Port 7	
Port 8	
Port 9	
Port A	
Port B	
Port J	
NC	Leave this pin open

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H8S/20103, H8S/20203, H8S/20223 Group

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