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Hitachi 16-Bit Single-Chip Microcomputer

H8S/2268 Series, H8S/2264 Series

H8S/2268

HD6432268, HD6432268W, HD64F2268

H8S/2266

HD6432266, HD6432266W, HD64F2266

H8S/2265

HD6432265, HD6432265W, HD64F2265

H8S/2264

HD6432264, HD6432264W, HD64F2264

H8S/2264R

HD6432264R, HD6432264RW, HD64F2264R

H8S/2262

HD6432262, HD6432262W,

H8S/2262R

HD6432262R, HD6432262RW

ADE-602-240A

Hardware Manual

Rev 2.0

09/17/02

Hitachi, Ltd.

RENESAS

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General Precautions on Handling of Product

1. Treatment of NC Pins

Note: Do not connect anything to the NC pins.

The NC (not connected) pins are either not connected to any of the internal circuitry or are used as test pins or to reduce noise. If something is connected to the NC pins, the operation of the LSI is not guaranteed.

2. Treatment of Unused Input Pins

Note: Fix all unused input pins to high or low level.

Generally, the input pins of CMOS products are high-impedance input pins. If unused pins are in their open states, intermediate levels are induced by noise in the vicinity, a pass-through current flows internally, and a malfunction may occur.

3. Processing before Initialization

Note: When power is first supplied, the product's state is undefined.

The states of internal circuits are undefined until full power is supplied throughout the chip and a low level is input on the reset pin. During the period where the states are undefined, the register settings and the output state of each pin are also undefined. Design your system so that it does not malfunction because of processing while it is in this undefined state. For those products which have a reset function, reset the LSI immediately after the power supply has been turned on.

4. Prohibition of Access to Undefined or Reserved Addresses

Note: Access to undefined or reserved addresses is prohibited.

The undefined or reserved addresses may be used to expand functions, or test registers may have been allocated to these addresses. Do not access these registers; the system's operation is not guaranteed if they are accessed.

Configuration of This Manual

This manual comprises the following items:

1. General Precautions on Handling of Product
2. Configuration of This Manual
3. Preface
4. Contents
5. Overview
6. Description of Functional Modules

- CPU and System-Control Modules
- On-Chip Peripheral Modules

The configuration of the functional description of each module differs according to the module. However, the generic style includes the following items:

- i) Feature
- ii) Input/Output Pin
- iii) Register Description
- iv) Operation
- v) Usage Note

When designing an application system that includes this LSI, take notes into account. Each section includes notes in relation to the descriptions given, and usage notes are given, as required, as the final part of each section.

7. List of Registers
8. Electrical Characteristics
9. Appendix
10. Main Revisions and Additions in this Edition (only for revised versions)

The list of revisions is a summary of points that have been revised or added to earlier versions. This does not include all of the revised contents. For details, see the actual locations in this manual.

11. Index

Preface

This LSI is a high-performance microcontroller (MCU) made up of the H8S/2000 CPU with an internal 32-bit configuration as its core, and the peripheral functions required to configure a system.

A single-power flash memory (F-ZTAT™)* version and a masked-ROM version are available for this LSI's ROM. The F-ZTAT version provides flexibility as it can be reprogrammed in no time to cope with all situations from the early stages of mass production to full-scale mass production. This is particularly applicable to application devices with specifications that will most probably change.

List of on-chip peripheral functions:

Series Name	H8S/2268 Series	H8S/2264 Series
Product Name	H8S/2268, 2266, 2265	H8S/2264, 2264R, 2262, 2262R
PC break controller (PBC)	X 2	—
Data transfer controller (DTC)	X 1	—
16-bit timer pulse unit (TPU)	X 3	X 2
8-bit timer (TMR_0 to TMR_3)	X 4	X 2
8-bit reload timer (TMR_4)	X 4	—
Watch dog timer (WDT)	X 2	X 2
Serial communication interface (SCI)	X 3	X 3
I ² C bus interface (IIC)	X 2 (option)	X 1 (option)
A/D converter	X 10	X 10
D/A converter	X 2	—
LCD controller/driver	40 SEG/4 COM	40 SEG/4 COM
DTMF generation circuit	X 1	—
Power-on reset circuit	—	X 1
Ports	1, 3, 4, 7, 9, F, H, J to N	1, 3, 4, 7, 9, F, H, J to L
External interrupts	14	13
Interrupt priorities	8 levels	—

Notes: * F-ZTAT™ is a trademark of Hitachi, Ltd.

Target Users: This manual was written for users who will be using the H8S/2268 Series and H8S/2264 Series in the design of application systems. Target users are expected to understand the fundamentals of electrical circuits, logical circuits, and microcomputers.

Objective: This manual was written to explain the hardware functions and electrical characteristics of the H8S/2268 Series and H8S/2264 Series to the target users. Refer to the H8S/2600 Series, H8S/2000 Series Programming Manual for a detailed description of the instruction set.

Notes on reading this manual:

- In order to understand the overall functions of the chip
Read the manual according to the contents. This manual can be roughly categorized into parts on the CPU, system control functions, peripheral functions and electrical characteristics.
- In order to understand the details of the CPU's functions
Read the H8S/2600 Series, H8S/2000 Series Programming Manual.
- In order to understand the details of a register when its name is known
Read the index that is the final part of the manual to find the page number of the entry on the register. The addresses, bits, and initial values of the registers are summarized in section 25, List of Registers.

Examples: **Register name:** The following notation is used for cases when the same or a similar function, e.g. 16-bit timer pulse unit or serial communication, is implemented on more than one channel: XXX_N (XXX is the register name and N is the channel number)

Bit order: The MSB is on the left and the LSB is on the right.

- Notes:**
1. When using the on-chip emulator (E10T) for the H8S/2264 Series program development and debugging, the following restrictions must be noted.
 - The WDT timer stops counting while the on-chip emulation is in break mode. Accordingly, after resuming from the break mode, the counter value may be invalid.
 - The FWE (BRK) pin is reserved for the E10T, and cannot be used.
 - Pins P77, P76, and P75 cannot be used. In order to use these pins, additional parts are required on the user board.
 - When the E10T is used, the FWE (BRK) pin is an input/output pin (open-drain in output mode), P75 and P76 are input pins, and P77 is an output pin.
 2. The emulator (E6000) does not support the following functions. They are only supported by the on-chip emulator (E10T).
 - Power-on reset (H8S/2264 Series)
 - Oscillation stabilization time shortened (H8S/2264R, 2262R)

- PH4/ ϕ , PH5 pin function (H8S/2264 Series)
- Selection of the input subclock source WDT_1, $\phi_{SUB}/4$, or $\phi_{SUB}/60$ (H8S/2264 Series)
- Selection of the segment driver in four bit units (H8S/2264 Series)

Related Manuals: The latest versions of all related manuals are available from our web site. Please ensure you have the latest versions of all documents you require.

<http://www.hitachisemiconductor.com/>

H8S/2268 Series, H8S/2264 Series manuals:

Manual Title	ADE No.
H8S/2268 Series, H8S/2264 Series Hardware Manual	This manual
H8S/2600 Series, H8S/2000 Series Programming Manual	ADE-602-083

User's manuals for development tools:

Manual Title	ADE No.
H8S, H8/300 Series C/C++ Compiler, Assembler, Optimized Linkage Editor User's Manual	ADE-702-247
H8S, H8/300 Series Simulator/Debugger User's Manual	ADE-702-282
H8S, H8/300 Series Hitachi Embedded Workshop, Hitachi Debugging Interface Tutorial	ADE-702-231
Hitachi Embedded Workshop User's Manual	ADE-702-201

Application Notes:

Manual Title	ADE No.
C/C++ Compiler Guide	ADE-702-189
F-ZTAT Technical Q & A	ADE-502-046

Contents

Section 1	Overview	1
1.1	Features	1
1.2	Internal Block Diagram	3
1.3	Pin Arrangement	5
1.4	Pin Functions	7
Section 2	CPU	13
2.1	Features	13
2.1.1	Differences between H8S/2600 CPU and H8S/2000 CPU	14
2.1.2	Differences from H8/300 CPU	15
2.1.3	Differences from H8/300H CPU	15
2.2	CPU Operating Modes	16
2.2.1	Normal Mode	16
2.2.2	Advanced Mode	17
2.3	Address Space	20
2.4	Register Configuration	21
2.4.1	General Registers	22
2.4.2	Program Counter (PC)	23
2.4.3	Extended Control Register (EXR) (H8S/2268 Series Only)	23
2.4.4	Condition-Code Register (CCR)	24
2.4.5	Initial Values of CPU Registers	25
2.5	Data Formats	26
2.5.1	General Register Data Formats	26
2.5.2	Memory Data Formats	28
2.6	Instruction Set	29
2.6.1	Table of Instructions Classified by Function	30
2.6.2	Basic Instruction Formats	39
2.7	Addressing Modes and Effective Address Calculation	40
2.7.1	Register Direct—Rn	41
2.7.2	Register Indirect—@ERn	41
2.7.3	Register Indirect with Displacement—@(d:16, ERn) or @(d:32, ERn)	41
2.7.4	Register Indirect with Post-Increment or Pre-Decrement—@ERn+ or @-ERn	41
2.7.5	Absolute Address—@aa:8, @aa:16, @aa:24, or @aa:32	41
2.7.6	Immediate—#xx:8, #xx:16, or #xx:32	42
2.7.7	Program-Counter Relative—@(d:8, PC) or @(d:16, PC)	42
2.7.8	Memory Indirect—@ @aa:8	42
2.7.9	Effective Address Calculation	43
2.8	Processing States	46
2.9	Usage Notes	48

2.9.1	TAS Instruction.....	48
2.9.2	STM/LDM Instruction.....	48
2.9.3	Bit Manipulation Instructions.....	48
Section 3 MCU Operating Modes		49
3.1	Operating Mode Selection.....	49
3.2	Register Description.....	49
3.2.1	Mode Control Register (MDCR).....	50
3.3	Operating Mode	50
3.4	Pin Functions in Each Operating Mode.....	50
3.5	Address Map.....	51
Section 4 Exception Handling.....		53
4.1	Exception Handling Types and Priority	53
4.2	Exception Sources and Exception Vector Table	54
4.3	Reset	55
4.3.1	Reset Exception Handling.....	55
4.3.2	Interrupts after Reset	56
4.3.3	State of On-Chip Peripheral Modules after Reset Release	56
4.4	Traces (Supported only by the H8S/2268 Series)	57
4.5	Interrupts	57
4.6	Trap Instruction	58
4.7	Stack Status after Exception Handling	59
4.8	Usage Note	59
Section 5 Interrupt Controller		61
5.1	Features	61
5.2	Input/Output Pins.....	64
5.3	Register Descriptions	64
5.3.1	System Control Register (SYSCR).....	65
5.3.2	Interrupt Priority Registers A to G, I to M, and O (IPRA to IPRG, IPRI to IPRM, IPRO) (H8S/2268 Series Only)	67
5.3.3	IRQ Enable Register (IER)	68
5.3.4	IRQ Sense Control Registers H and L (ISCRH and ISCRL)	69
5.3.5	IRQ Status Register (ISR).....	71
5.3.6	Wakeup Interrupt Request Register (IWPR).....	73
5.3.7	Interrupt Enable Register 1 (IENR1)	73
5.4	Interrupt Sources.....	74
5.4.1	External Interrupts.....	74
5.4.2	Internal Interrupts.....	77
5.4.3	Interrupt Exception Handling Vector Table.....	77
5.5	Operation.....	82
5.5.1	Interrupt Control Modes and Interrupt Operation.....	82

5.5.2	Interrupt Control Mode 0	85
5.5.3	Interrupt Control Mode 2 (H8S/2268 Series Only).....	87
5.5.4	Interrupt Exception Handling Sequence	88
5.5.5	Interrupt Response Times	90
5.5.6	DTC Activation by Interrupt (H8S/2268 Series Only).....	91
5.6	Usage Notes.....	91
5.6.1	Contention between Interrupt Generation and Disabling	91
5.6.2	Instructions that Disable Interrupts.....	92
5.6.3	When Interrupts Are Disabled.....	92
5.6.4	Interrupts during Execution of EEPMOV Instruction.....	92
Section 6 PC Break Controller (PBC).....		93
6.1	Features	93
6.2	Register Descriptions	94
6.2.1	Break Address Register A (BARA)	94
6.2.2	Break Address Register B (BARB)	94
6.2.3	Break Control Register A (BCRA).....	95
6.2.4	Break Control Register B (BCRB)	96
6.3	Operation.....	96
6.3.1	PC Break Interrupt Due to Instruction Fetch.....	96
6.3.2	PC Break Interrupt Due to Data Access.....	96
6.3.3	Notes on PC Break Interrupt Handling	97
6.3.4	Operation in Transitions to Power-Down Modes	97
6.3.5	When Instruction Execution Is Delayed by One State	98
6.4	Usage Notes.....	99
6.4.1	Module Stop Mode Setting	99
6.4.2	PC Break Interrupts	99
6.4.3	CMFA and CMFB	99
6.4.4	PC Break Interrupt when DTC Is Bus Master	99
6.4.5	PC Break Set for Instruction Fetch at Address Following BSR, JSR, JMP, TRAPA, RTE, or RTS Instruction.....	99
6.4.6	I Bit Set by LDC, ANDC, ORC, or XORC Instruction	99
6.4.7	PC Break Set for Instruction Fetch at Address Following Bcc Instruction	100
6.4.8	PC Break Set for Instruction Fetch at Branch Destination Address of Bcc Instruction.....	100
Section 7 Bus Controller		101
7.1	Basic Timing	101
7.1.1	On-Chip Memory Access Timing (ROM, RAM).....	101
7.1.2	On-Chip Peripheral Module Access Timing (H'FFFDAC to H'FFFFBF).....	102
7.1.3	On-Chip Peripheral Module Access Timing (H'FFFC30 to H'FFFC A3)	102
7.2	Bus Arbitration (H8S/2268 Series Only).....	103
7.2.1	Order of Priority of the Bus Masters.....	103

7.2.2	Bus Transfer Timing.....	104
7.2.3	Resets and the Bus Controller	104
Section 8 Data Transfer Controller (DTC)		105
8.1	Features	105
8.2	Register Descriptions	107
8.2.1	DTC Mode Register A (MRA).....	107
8.2.2	DTC Mode Register B (MRB)	109
8.2.3	DTC Source Address Register (SAR).....	109
8.2.4	DTC Destination Address Register (DAR).....	109
8.2.5	DTC Transfer Count Register A (CRA)	110
8.2.6	DTC Transfer Count Register B (CRB).....	110
8.2.7	DTC Enable Register (DTCER).....	110
8.2.8	DTC Vector Register (DTVECR)	111
8.3	Activation Sources	111
8.4	Location of Register Information and DTC Vector Table	112
8.5	Operation.....	115
8.5.1	Normal Mode	116
8.5.2	Repeat Mode	117
8.5.3	Block Transfer Mode.....	118
8.5.4	Chain Transfer.....	119
8.5.5	Interrupts.....	120
8.5.6	Operation Timing	121
8.5.7	Number of DTC Execution States	122
8.6	Procedures for Using DTC	123
8.6.1	Activation by Interrupt	123
8.6.2	Activation by Software	124
8.7	Examples of Use of the DTC.....	124
8.7.1	Normal Mode	124
8.7.2	Software Activation.....	125
8.8	Usage Notes.....	125
8.8.1	Module Stop Mode Setting	125
8.8.2	On-Chip RAM.....	126
8.8.3	DTCE Bit Setting	126
Section 9 I/O Ports.....		127
9.1	Port 1.....	133
9.1.1	Port 1 Data Direction Register (P1DDR).....	133
9.1.2	Port 1 Data Register (P1DR).....	134
9.1.3	Port 1 Register (PORT1).....	134
9.1.4	Pin Functions	135
9.2	Port 3.....	138
9.2.1	Port 3 Data Direction Register (P3DDR).....	139

9.2.2	Port 3 Data Register (P3DR)	139
9.2.3	Port 3 Register (PORT3)	140
9.2.4	Port 3 Open Drain Control Register (P3ODR)	140
9.2.5	Pin Functions	141
9.3	Port 4	144
9.3.1	Port 4 Register (PORT4)	144
9.3.2	Pin Functions	144
9.4	Port 7	145
9.4.1	Port 7 Data Direction Register (P7DDR)	145
9.4.2	Port 7 Data Register (P7DR)	145
9.4.3	Port 7 Register (PORT7)	146
9.4.4	Pin Functions	146
9.5	Port 9	148
9.5.1	Port 9 Register (PORT9)	148
9.5.2	Pin Functions	148
9.6	Port F	149
9.6.1	Port F Data Direction Register (PFDDR)	149
9.6.2	Port F Data Register (PFDR)	149
9.6.3	Port F Register (PORTF)	150
9.6.4	Pin Functions	150
9.7	Port H	150
9.7.1	Port H Data Direction Register (PHDDR)	151
9.7.2	Port H Data Register (PHDR)	152
9.7.3	Port H Register (PORTH)	153
9.7.4	Pin Functions	153
9.8	Port J	156
9.8.1	Port J Data Direction Register (PJDDR)	157
9.8.2	Port J Data Register (PJDR)	157
9.8.3	Port J Register (PORTJ)	158
9.8.4	Port J Pull-Up MOS Control Register (PJPCR)	158
9.8.5	Wakeup Control Register (WPCR)	159
9.8.6	Pin Functions	159
9.8.7	Input Pull-Up MOS Function	160
9.9	Port K	161
9.9.1	Port K Data Direction Register (PKDDR)	161
9.9.2	Port K Data Register (PKDR)	161
9.9.3	Port K Register (PORTK)	162
9.9.4	Pin Functions	162
9.10	Port L	163
9.10.1	Port L Data Direction Register (PLDDR)	163
9.10.2	Port L Data Register (PLDR)	164
9.10.3	Port L Register (PORTL)	164
9.10.4	Pin Functions	165

9.11	Port M (H8S/2268 Series Only).....	166
9.11.1	Port M Data Direction Register (PMDDR).....	166
9.11.2	Port M Data Register (PMDR).....	166
9.11.3	Port M Register (PORTM).....	167
9.11.4	Pin Functions	167
9.12	Port N (H8S/2268 Series Only)	168
9.12.1	Port N Data Direction Register (PNDDR).....	168
9.12.2	Port N Data Register (PNDR).....	168
9.12.3	Port N Register (PORTN).....	169
9.12.4	Pin Functions	169
Section 10 16-Bit Timer Pulse Unit (TPU).....		171
10.1	Features.....	171
10.2	Input/Output Pins.....	176
10.3	Register Descriptions	177
10.3.1	Timer Control Register (TCR)	178
10.3.2	Timer Mode Register (TMDR)	182
10.3.3	Timer I/O Control Register (TIOR).....	184
10.3.4	Timer Interrupt Enable Register (TIER)	192
10.3.5	Timer Status Register (TSR).....	194
10.3.6	Timer Counter (TCNT).....	199
10.3.7	Timer General Register (TGR).....	199
10.3.8	Timer Start Register (TSTR).....	199
10.3.9	Timer Synchro Register (TSYR).....	201
10.4	Interface to Bus Master	202
10.4.1	16-Bit Registers.....	202
10.4.2	8-Bit Registers.....	202
10.5	Operation.....	203
10.5.1	Basic Functions	203
10.5.2	Synchronous Operation	208
10.5.3	Buffer Operation (H8S/2268 Series Only).....	210
10.5.4	Operation with Cascaded Connection (H8S/2264 Series Only)	213
10.5.5	PWM Modes	215
10.5.6	Phase Counting Mode (H8S/2268 Series Only)	220
10.6	Interrupt Sources.....	225
10.7	DTC Activation (H8S/2268 Series Only).....	226
10.8	A/D Converter Activation	226
10.9	Operation Timing.....	227
10.9.1	Input/Output Timing.....	227
10.9.2	Interrupt Signal Timing	231
10.10	Usage Notes.....	234
10.10.1	Module Stop Mode Setting	234
10.10.2	Input Clock Restrictions	234

10.10.3	Caution on Period Setting	235
10.10.4	Contention between TCNT Write and Clear Operations	235
10.10.5	Contention between TCNT Write and Increment Operations	236
10.10.6	Contention between TGR Write and Compare Match	236
10.10.7	Contention between Buffer Register Write and Compare Match (H8S/2268 Series Only)	237
10.10.8	Contention between TGR Read and Input Capture.....	238
10.10.9	Contention between TGR Write and Input Capture.....	238
10.10.10	Contention between Buffer Register Write and Input Capture (H8S/2268 Series Only).....	239
10.10.11	Contention between Overflow/Underflow and Counter Clearing.....	240
10.10.12	Contention between TCNT Write and Overflow/Underflow.....	241
10.10.13	Multiplexing of I/O Pins	241
10.10.14	Interrupts in Module Stop Mode.....	241
Section 11	8-Bit Timers	243
11.1	8-Bit Timer Module (TMR_0, TMR_1, TMR_2 and TMR_3).....	243
11.1.1	Features.....	243
11.2	Input/Output Pins	245
11.3	Register Descriptions	245
11.3.1	Timer Counter (TCNT).....	246
11.3.2	Time Constant Register A (TCORA).....	246
11.3.3	Time Constant Register B (TCORB).....	246
11.3.4	Timer Control Register (TCR)	247
11.3.5	Timer Control/Status Register (TCSR).....	249
11.4	Operation.....	254
11.4.1	Pulse Output.....	254
11.5	Operation Timing.....	255
11.5.1	TCNT Incrementation Timing.....	255
11.5.2	Timing of CMFA and CMFB Setting When a Compare-Match Occurs	255
11.5.3	Timing of Timer Output When a Compare-Match Occurs.....	256
11.5.4	Timing of Compare-Match Clear When a Compare-Match Occurs	256
11.5.5	TCNT External Reset Timing	257
11.5.6	Timing of Overflow Flag (OVF) Setting	257
11.6	Operation with Cascaded Connection	258
11.6.1	16-Bit Count Mode.....	258
11.6.2	Compare-Match Count Mode.....	258
11.7	Interrupt Sources.....	259
11.7.1	Interrupt Sources and DTC Activation	259
11.7.2	A/D Converter Activation	259
11.8	Usage Notes.....	260
11.8.1	Contention between TCNT Write and Clear	260
11.8.2	Contention between TCNT Write and Increment	261

11.8.3	Contention between TCOR Write and Compare-Match	262
11.8.4	Contention between Compare-Matches A and B	262
11.8.5	Switching of Internal Clocks and TCNT Operation	263
11.8.6	Contention between Interrupts and Module Stop Mode	264
11.9	8-Bit Reload Timer (TMR_4) (H8S/2268 Series Only)	265
11.9.1	Features.....	265
11.9.2	Input/Output Pins	266
11.10	Register Descriptions	267
11.10.1	Timer Control Registers 4 to 7 (TCR_4 to TCR_7)	267
11.10.2	Timer Counters 4 to 7 (TCNT4 to TCNT7)	268
11.10.3	Time Reload Registers 4 to 7 (TLR_4 to TLR_7)	268
11.11	Operation.....	269
11.11.1	Interval Timer Operation	269
11.11.2	Automatic Reload Timer Operation	270
11.11.3	Cascaded Connection	270
11.12	Usage Notes.....	272
11.12.1	Conflict between Write to TLR and Count up/Automatic Reload.....	272
11.12.2	Switchover of the Internal Clock and TCNT Operation	272
11.12.3	Interrupt during Module Stop.....	272
Section 12	Watchdog Timer	273
12.1	Features	273
12.2	Register Descriptions	275
12.2.1	Timer Counter (TCNT).....	275
12.2.2	Timer Control/Status Register (TCSR).....	276
12.2.3	Reset Control/Status Register (RSTCSR) (only WDT_0)	280
12.3	Operation.....	281
12.3.1	Watchdog Timer Mode.....	281
12.3.2	Interval Timer Mode.....	282
12.3.3	Timing of Setting Overflow Flag (OVF)	283
12.3.4	Timing of Setting Watchdog Timer Overflow Flag (WOVF)	284
12.4	Interrupt Sources.....	284
12.5	Usage Notes.....	285
12.5.1	Notes on Register Access.....	285
12.5.2	Contention between Timer Counter (TCNT) Write and Increment	286
12.5.3	Changing Value of CKS2 to CKS0	286
12.5.4	Switching between Watchdog Timer Mode and Interval Timer Mode.....	286
12.5.5	Internal Reset in Watchdog Timer Mode.....	286
12.5.6	OVF Flag Clearing in Interval Timer Mode.....	287
Section 13	Serial Communication Interface (SCI).....	289
13.1	Features	289
13.2	Input/Output Pins	293

13.3	Register Descriptions	293
13.3.1	Receive Shift Register (RSR)	294
13.3.2	Receive Data Register (RDR)	294
13.3.3	Transmit Data Register (TDR)	294
13.3.4	Transmit Shift Register (TSR).....	294
13.3.5	Serial Mode Register (SMR).....	295
13.3.6	Serial Control Register (SCR).....	298
13.3.7	Serial Status Register (SSR).....	303
13.3.8	Smart Card Mode Register (SCMR).....	310
13.3.9	Bit Rate Register (BRR)	311
13.3.10	Serial Expansion Mode Register (SEMR_0).....	319
13.4	Operation in Asynchronous Mode	323
13.4.1	Data Transfer Format.....	323
13.4.2	Receive Data Sampling Timing and Reception Margin in Asynchronous Mode	325
13.4.3	Clock	326
13.4.4	SCI Initialization (Asynchronous Mode)	326
13.4.5	Serial Data Transmission (Asynchronous Mode)	327
13.4.6	Serial Data Reception (Asynchronous Mode)	330
13.5	Multiprocessor Communication Function	334
13.5.1	Multiprocessor Serial Data Transmission	335
13.5.2	Multiprocessor Serial Data Reception	337
13.6	Operation in Clocked Synchronous Mode	340
13.6.1	Clock	340
13.6.2	SCI Initialization (Clocked Synchronous Mode).....	340
13.6.3	Serial Data Transmission (Clocked Synchronous Mode).....	342
13.6.4	Serial Data Reception (Clocked Synchronous Mode).....	344
13.6.5	Simultaneous Serial Data Transmission and Reception (Clocked Synchronous Mode).....	346
13.7	Operation in Smart Card Interface	348
13.7.1	Pin Connection Example.....	348
13.7.2	Data Format (Except for Block Transfer Mode).....	348
13.7.3	Block Transfer Mode	350
13.7.4	Receive Data Sampling Timing and Reception Margin	350
13.7.5	Initialization	351
13.7.6	Serial Data Transmission (Except for Block Transfer Mode)	352
13.7.7	Serial Data Reception (Except for Block Transfer Mode)	355
13.7.8	Clock Output Control.....	356
13.8	Interrupt Sources.....	358
13.8.1	Interrupts in Normal Serial Communication Interface Mode	358
13.8.2	Interrupts in Smart Card Interface Mode	360
13.9	Usage Notes.....	360
13.9.1	Module Stop Mode Setting	360

13.9.2	Break Detection and Processing (Asynchronous mode only)	360
13.9.3	Mark State and Break Detection (Asynchronous mode only)	361
13.9.4	Receive Error Flags and Transmit Operations (Clocked Synchronous Mode Only)	361
13.9.5	Restrictions on Use of DTC (H8S/2268 Series Only)	361
13.9.6	Operation in Case of Mode Transition	362
13.9.7	Switching from SCK Pin Function to Port Pin Function:	365
13.9.8	Assignment and Selection of Registers	366
Section 14	I²C Bus Interface (IIC) (Option)	367
14.1	Features	367
14.2	Input/Output Pins	370
14.3	Register Descriptions	370
14.3.1	I ² C Bus Data Register (ICDR)	371
14.3.2	Slave Address Register (SAR)	373
14.3.3	Second Slave Address Register (SARX)	373
14.3.4	I ² C Bus Mode Register (ICMR)	374
14.3.5	Serial Control Register (SCRX)	377
14.3.6	I ² C Bus Control Register (ICCR)	378
14.3.7	I ² C Bus Status Register (ICSR)	382
14.3.8	DDC Switch Register (DDCSWR)	385
14.4	Operation	385
14.4.1	I ² C Bus Data Format	385
14.4.2	Master Transmit Operation	387
14.4.3	Master Receive Operation	388
14.4.4	Slave Receive Operation	391
14.4.5	Slave Transmit Operation	393
14.4.6	IRIC Setting Timing and SCL Control	396
14.4.7	Operation Using the DTC (H8S/2268 Series Only)	397
14.4.8	Noise Chancellor	398
14.4.9	Sample Flowcharts	398
14.5	Usage Notes	403
Section 15	A/D Converter	411
15.1	Features	411
15.2	Input/Output Pins	413
15.3	Register Descriptions	414
15.3.1	A/D Data Registers A to D (ADDRA to ADDRD)	414
15.3.2	A/D Control/Status Register (ADCSR)	415
15.3.3	A/D Control Register (ADCR)	417
15.4	Operation	418
15.4.1	Single Mode	418
15.4.2	Scan Mode	419

15.4.3	Input Sampling and A/D Conversion Time	420
15.4.4	External Trigger Input Timing	422
15.5	Interrupt Source	422
15.6	A/D Conversion Accuracy Definitions.....	423
15.7	Usage Notes.....	425
15.7.1	Module Stop Mode Setting	425
15.7.2	Permissible Signal Source Impedance	425
15.7.3	Influences on Absolute Accuracy	425
15.7.4	Range of Analog Power Supply and Other Pin Settings	426
15.7.5	Notes on Board Design	426
15.7.6	Notes on Noise Countermeasures	426
Section 16 D/A Converter		429
16.1	Features	429
16.2	Input/Output Pins	430
16.3	Register Description.....	430
16.3.1	D/A Data Registers 0 and 1 (DADR0 and DADR1).....	430
16.3.2	D/A Control Register (DACR)	431
16.4	Operation.....	432
16.5	Usage notes.....	433
16.5.1	Analog Power Supply Current in Software Standby Mode	433
16.5.2	Setting for Module Stop Mode	433
Section 17 LCD Controller/Driver.....		435
17.1	Overview	435
17.2	Input/Output Pins	437
17.3	Register Descriptions	437
17.3.1	LCD Port Control Register (LPCR).....	438
17.3.2	LCD Control Register (LCR)	441
17.3.3	LCD Control Register 2 (LCR2)	442
17.4	Operation.....	446
17.4.1	Settings up to LCD Display	446
17.4.2	Relationship between LCD RAM and Display.....	447
17.4.3	Triple Step-Up Voltage Circuit (Supported Only by the H8S/2268 Series).....	452
17.4.4	Operation in Power-Down Modes	453
17.4.5	Low-Power LCD Drive.....	454
17.4.6	Boosting the LCD Drive Power Supply	455
Section 18 DTMF Generation Circuit.....		457
18.1	Features	457
18.2	Input/Output Pins	458
18.3	Register Descriptions	458
18.3.1	DTMF Control Register (DTCR)	459

18.3.2	DTMF Load Register (DTLR)	460
18.4	Operation.....	462
18.4.1	Output Waveform.....	462
18.4.2	Operation Flow	463
18.5	Application Circuit Example	464
18.6	Usage Notes.....	464
Section 19 RAM.....		465
Section 20 ROM.....		467
20.1	Features.....	467
20.2	Mode Transitions	468
20.3	Block Configuration.....	472
20.4	Input/Output Pins.....	476
20.5	Register Descriptions	476
20.5.1	Flash Memory Control Register 1 (FLMCR1)	477
20.5.2	Flash Memory Control Register 2 (FLMCR2)	478
20.5.3	Erase Block Register 1 (EBR1).....	478
20.5.4	Erase Block Register 2 (EBR2).....	480
20.5.5	RAM Emulation Register (RAMER).....	480
20.5.6	Flash Memory Power Control Register (FLPWCR).....	482
20.5.7	Serial Control Register X (SCRX)	483
20.6	On-Board Programming Modes.....	484
20.6.1	Boot Mode	484
20.6.2	Programming/Erasing in User Program Mode	487
20.7	Flash Memory Emulation in RAM	488
20.8	Flash Memory Programming/Erasing	492
20.8.1	Program/Program-Verify	492
20.8.2	Erase/Erase-Verify	494
20.8.3	Interrupt Handling when Programming/Erasing Flash Memory	494
20.9	Program/Erase Protection.....	496
20.9.1	Hardware Protection.....	496
20.9.2	Software Protection	496
20.9.3	Error Protection.....	496
20.10	Interrupt Handling when Programming/Erasing Flash Memory	497
20.11	Programmer Mode	497
20.12	Power-Down States for Flash Memory	499
20.13	Flash Memory Programming and Erasing Precautions	500
20.14	Note on Switching from F-ZTAT Version to Masked ROM Version.....	505
Section 21 Clock Pulse Generator.....		507
21.1	Register Descriptions	509
21.1.1	System Clock Control Register (SCKCR)	509

21.1.2	System Clock Control Register 2 (SCKCR2) (Supported only by the H8S/2264 Series)	509
21.1.3	Low-Power Control Register (LPWRCR).....	512
21.2	System Clock Oscillator	514
21.2.1	Connecting a Crystal Resonator	514
21.2.2	Connecting a Ceramic Resonator	515
21.2.3	External Clock Input.....	516
21.2.4	Notes on Switching External Clock.....	517
21.3	Duty Adjustment Circuit	519
21.4	Medium-Speed Clock Divider	519
21.5	Bus Master Clock Selection Circuit	519
21.6	Subclock Oscillator	519
21.6.1	Connecting 32.768kHz Crystal Resonator	519
21.6.2	Handling Pins When Subclock Not Required	520
21.7	Subclock Waveform Generation Circuit.....	521
21.8	Usage Notes.....	521
21.8.1	Note on Crystal Resonator	521
21.8.2	Note on Board Design.....	521
21.8.3	Note on Using a Crystal Resonator (Except for a Ceramic Resonator).....	521
Section 22 Power-Down Modes		523
22.1	Register Description.....	526
22.1.1	Standby Control Register (SBYCR)	527
22.1.2	Module Stop Control Registers A to D (MSTPCRA to MSTPCRD)	529
22.2	Medium-Speed Mode.....	531
22.3	Sleep Mode.....	532
22.3.1	Sleep Mode	532
22.3.2	Exiting Sleep Mode	532
22.4	Software Standby Mode	533
22.4.1	Software Standby Mode.....	533
22.4.2	Clearing Software Standby Mode.....	533
22.4.3	Oscillation Settling Time after Clearing Software Standby Mode.....	534
22.4.4	Software Standby Mode Application Example	535
22.5	Hardware Standby Mode.....	536
22.5.1	Hardware Standby Mode	536
22.5.2	Clearing Hardware Standby Mode	536
22.5.3	Hardware Standby Mode Timing	537
22.6	Module Stop Mode.....	537
22.7	Watch Mode	538
22.7.1	Transition to Watch Mode	538
22.7.2	Exiting Watch Mode.....	538
22.8	Sub-Sleep Mode.....	539
22.8.1	Transition to Sub-Sleep Mode.....	539

22.8.2	Exiting Sub-Sleep Mode	539
22.9	Sub-Active Mode	540
22.9.1	Transition to Sub-Active Mode	540
22.9.2	Exiting Sub-Active Mode	540
22.10	Direct Transitions	541
22.10.1	Direct Transitions from High-Speed Mode to Sub-Active Mode	541
22.10.2	Direct Transitions from Sub-Active Mode to High-Speed Mode	541
22.11	Usage Notes.....	541
22.11.1	I/O Port Status.....	541
22.11.2	Current Dissipation during Oscillation Settling Wait Period	541
22.11.3	DTC Module Stop (Supported only by the H8S/2268 Series).....	541
22.11.4	On-Chip Peripheral Module Interrupt.....	542
22.11.5	Writing to MSTPCR.....	542
22.11.6	Entering Subactive / Watch mode and DTC Module Stop (Supported only by the H8S/2268 Series).....	542
Section 23	Power-On Reset Circuit.....	543
23.1	Features	543
23.2	Operation.....	543
23.2.1	Power-On Reset Circuit	543
Section 24	Power Supply Circuit	545
24.1	When the internal power step-down circuit is used.....	545
Section 25	List of Registers	547
25.1	Register Addresses (by function module, in address order)	547
25.2	Register Bits	555
25.3	Register States in Each Operating Mode	563
Section 26	Electrical Characteristics	571
26.1	Power Supply Voltage and Operating Frequency Range	571
26.2	Electrical Characteristics of the H8S/2268 Series.....	573
26.2.1	Absolute Maximum Ratings	573
26.2.2	DC Characteristics.....	574
26.2.3	AC Characteristics.....	589
26.2.4	A/D Conversion Characteristics	594
26.2.5	D/A Conversion Characteristics	595
26.2.6	LCD Characteristics	596
26.2.7	DTMF Characteristics	598
26.2.8	Flash Memory Characteristics.....	599
26.3	Electrical Characteristics of the H8S/2264 Series.....	600
26.3.1	Absolute Maximum Ratings	600
26.3.2	DC Characteristics.....	601

26.3.3	AC Characteristics	615
26.3.4	A/D Conversion Characteristics	620
26.3.5	LCD Characteristics	621
26.3.6	Flash Memory Characteristics	622
26.4	Operation Timing	624
26.4.1	Clock Timing	624
26.4.2	Control Signal Timings	625
26.4.3	Timing of On-Chip Peripheral Modules	625
26.5	Usage Note	627
Appendix A I/O Port States in Each Pin State		629
A.1	I/O Port State in Each Pin State of the H8S/2268 Series	629
A.2	I/O Port State in Each Pin State of the H8S/2264 Series	630
Appendix B Product Codes		632
Appendix C Package Dimensions		642
Main Revisions and Additions in this Edition		645
Index		655

Figures

Section 1 Overview

Figure 1.1	Internal Block Diagram of H8S/2268 Series	3
Figure 1.2	Internal Block Diagram of H8S/2264 Series	4
Figure 1.3	Pin Arrangement of H8S/2268 Series	5
Figure 1.4	Pin Arrangement of H8S/2264 Series	6

Section 2 CPU

Figure 2.1	Exception Vector Table (Normal Mode)	17
Figure 2.2	Stack Structure in Normal Mode	17
Figure 2.3	Exception Vector Table (Advanced Mode)	18
Figure 2.4	Stack Structure in Advanced Mode	19
Figure 2.5	Memory Map	20
Figure 2.6	CPU Registers	21
Figure 2.7	Usage of General Registers	22
Figure 2.8	Stack Status	23
Figure 2.9	General Register Data Formats (1)	26
Figure 2.9	General Register Data Formats (2)	27
Figure 2.10	Memory Data Formats	28
Figure 2.11	Instruction Formats (Examples)	40
Figure 2.12	Branch Address Specification in Memory Indirect Mode	43
Figure 2.13	State Transitions	47

Section 3 MCU Operating Modes

Figure 3.1	Address Map (1)	51
Figure 3.2	Address Map (2)	52

Section 4 Exception Handling

Figure 4.1	Reset Sequence (Advanced Mode with On-chip ROM Enabled)	56
Figure 4.2	Stack Status after Exception Handling (Advanced Mode)	59
Figure 4.3	Operation when SP Value Is Odd	60

Section 5 Interrupt Controller

Figure 5.1	Block Diagram of Interrupt Controller for H8S/2268 Series	62
Figure 5.2	Block Diagram of Interrupt Controller for H8S/2264 Series	63
Figure 5.3	Block Diagram of IRQn Interrupts	74
Figure 5.4	Set Timing for IRQnF	75
Figure 5.5	Block Diagram of Interrupts WKP7 to WKP0	76
Figure 5.6	IWPFn Setting Timing	76
Figure 5.7	Block Diagram of Interrupt Control Operation for H8S/2268 Series	83
Figure 5.8	Block Diagram of Interrupt Control Operation for H8S/2264 Series	83
Figure 5.9	Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 0	86
Figure 5.10	Flowchart of Procedure Up to Interrupt Acceptance in Control Mode 2	88

Figure 5.11 Interrupt Exception Handling	89
Figure 5.12 Contention between Interrupt Generation and Disabling	91

Section 6 PC Break Controller (PBC)

Figure 6.1 Block Diagram of PC Break Controller	94
Figure 6.2 Operation in Power-Down Mode Transitions.....	98

Section 7 Bus Controller

Figure 7.1 On-Chip Memory Access Cycle	101
Figure 7.2 On-Chip Peripheral Module Access Cycle (H'FFFDAC to H'FFFFBF)	102
Figure 7.3 On-Chip Peripheral Module Access Cycle (H'FFFC30 to H'FFFC A3).....	103

Section 8 Data Transfer Controller (DTC)

Figure 8.1 Block Diagram of DTC.....	106
Figure 8.2 Block Diagram of DTC Activation Source Control.....	112
Figure 8.3 The Location of the DTC Register Information in the Address Space.....	113
Figure 8.4 Correspondence between DTC Vector Address and Register Information	113
Figure 8.5 Flowchart of DTC Operation.....	116
Figure 8.6 Memory Mapping in Normal Mode.....	117
Figure 8.7 Memory Mapping in Repeat Mode.....	118
Figure 8.8 Memory Mapping in Block Transfer Mode.....	119
Figure 8.9 Chain Transfer Operation.....	120
Figure 8.10 DTC Operation Timing (Example in Normal Mode or Repeat Mode).....	121
Figure 8.11 DTC Operation Timing (Example of Block Transfer Mode, with Block Size of 2)	121
Figure 8.12 DTC Operation Timing (Example of Chain Transfer)	122

Section 9 I/O Ports

Figure 9.1 Types of Open Drain Outputs.....	141
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Section 10 16-Bit Timer Pulse Unit (TPU)

Figure 10.1 Block Diagram of TPU for H8S/2268 Series.....	174
Figure 10.2 Block Diagram of TPU for H8S/2264 Series.....	175
Figure 10.3 16-Bit Register Access Operation [Bus Master • TCNT (16 Bits)]	202
Figure 10.4 8-Bit Register Access Operation [Bus Master • TCR (Upper 8 Bits)]	202
Figure 10.5 8-Bit Register Access Operation [Bus Master • TMDR (Lower 8 Bits)]	203
Figure 10.6 8-Bit Register Access Operation [Bus Master • TCR and TMDR (16 Bits)]	203
Figure 10.7 Example of Counter Operation Setting Procedure	204
Figure 10.8 Free-Running Counter Operation.....	205
Figure 10.9 Periodic Counter Operation	205
Figure 10.10 Example of Setting Procedure for Waveform Output by Compare Match	206
Figure 10.11 Example of 0 Output/1 Output Operation.....	206
Figure 10.12 Example of Toggle Output Operation	207
Figure 10.13 Example of Input Capture Operation Setting Procedure	207
Figure 10.14 Example of Input Capture Operation	208
Figure 10.15 Example of Synchronous Operation Setting Procedure.....	209

Figure 10.16	Example of Synchronous Operation.....	210
Figure 10.17	Compare Match Buffer Operation.....	211
Figure 10.18	Input Capture Buffer Operation	211
Figure 10.19	Example of Buffer Operation Setting Procedure.....	211
Figure 10.20	Example of Buffer Operation (1)	212
Figure 10.21	Example of Buffer Operation (2)	213
Figure 10.22	Setting Procedure for Operation with Cascaded Operation	214
Figure 10.23	Example of Operation with Cascaded Connection.....	214
Figure 10.24	Example of PWM Mode Setting Procedure.....	216
Figure 10.25	Example of PWM Mode Operation (1)	217
Figure 10.26	Example of PWM Mode Operation (2)	218
Figure 10.27	Example of PWM Mode Operation (3)	219
Figure 10.28	Example of Phase Counting Mode Setting Procedure.....	220
Figure 10.29	Example of Phase Counting Mode 1 Operation.....	221
Figure 10.30	Example of Phase Counting Mode 2 Operation.....	222
Figure 10.31	Example of Phase Counting Mode 3 Operation.....	223
Figure 10.32	Example of Phase Counting Mode 4 Operation.....	224
Figure 10.33	Count Timing in Internal Clock Operation.....	227
Figure 10.34	Count Timing in External Clock Operation	227
Figure 10.35	Output Compare Output Timing	228
Figure 10.36	Input Capture Input Signal Timing	228
Figure 10.37	Counter Clear Timing (Compare Match).....	229
Figure 10.38	Counter Clear Timing (Input Capture)	229
Figure 10.39	Buffer Operation Timing (Compare Match).....	230
Figure 10.40	Buffer Operation Timing (Input Capture).....	230
Figure 10.41	TGI Interrupt Timing (Compare Match)	231
Figure 10.42	TGI Interrupt Timing (Input Capture).....	231
Figure 10.43	TCIV Interrupt Setting Timing	232
Figure 10.44	TCIU Interrupt Setting Timing (H8S/2268 Series Only).....	232
Figure 10.45	Timing for Status Flag Clearing by CPU.....	233
Figure 10.46	Timing for Status Flag Clearing by DTC Activation (H8S/2268 Series Only)	233
Figure 10.47	Phase Difference, Overlap, and Pulse Width in Phase Counting Mode (H8S/2268 Series Only)	234
Figure 10.48	Contention between TCNT Write and Clear Operations	235
Figure 10.49	Contention between TCNT Write and Increment Operations.....	236
Figure 10.50	Contention between TGR Write and Compare Match.....	237
Figure 10.51	Contention between Buffer Register Write and Compare Match.....	237
Figure 10.52	Contention between TGR Read and Input Capture	238
Figure 10.53	Contention between TGR Write and Input Capture	239
Figure 10.54	Contention between Buffer Register Write and Input Capture	239
Figure 10.55	Contention between Overflow and Counter Clearing.....	240
Figure 10.56	Contention between TCNT Write and Overflow.....	241

Section 11 8-Bit Timers

Figure 11.1	Block Diagram of 8-Bit Timer Module.....	244
Figure 11.2	Example of Pulse Output.....	254
Figure 11.3	Count Timing for Internal Clock Input	255
Figure 11.4	Count Timing for External Clock Input	255
Figure 11.5	Timing of CMF Setting.....	256
Figure 11.6	Timing of Timer Output.....	256
Figure 11.7	Timing of Compare-Match Clear.....	256
Figure 11.8	Timing of Clearing by External Reset Input.....	257
Figure 11.9	Timing of OVF Setting	257
Figure 11.10	Contention between TCNT Write and Clear.....	260
Figure 11.11	Contention between TCNT Write and Increment	261
Figure 11.12	Contention between TCOR Write and Compare-Match.....	262
Figure 11.13	Block Diagram of 8-Bit Reload Timer	266
Figure 11.14	Operation in Interval Timer Mode	269
Figure 11.15	Operation in Automatic Reload Timer Mode	270
Figure 11.16	Channel Relationship of Cascaded Connection	271

Section 12 Watchdog Timer

Figure 12.1	Block Diagram of WDT_0	274
Figure 12.2	Block Diagram of WDT_1 for H8S/2268 Series	274
Figure 12.3	Block Diagram of WDT_1 for H8S/2264 Series	275
Figure 12.4	Watchdog Timer Mode Operation	282
Figure 12.5	Interval Timer Mode Operation.....	283
Figure 12.6	Timing of OVF Setting	283
Figure 12.7	Timing of WOVF Setting.....	284
Figure 12.8	Writing to TCNT and TCSR (example for WDT_0)	285
Figure 12.9	Contention between TCNT Write and Increment	286

Section 13 Serial Communication Interface (SCI)

Figure 13.1	Block Diagram of SCI_0.....	291
Figure 13.2	Block Diagram of SCI_1 or SCI_2	292
Figure 13.3	Example of the Internal Base Clock When the Average Transfer Rate is Selected (1)	321
Figure 13.4	Example of the Internal Base Clock When the Average Transfer Rate is Selected (2)	322
Figure 13.5	Data Format in Asynchronous Communication (Example with 8-Bit Data, Parity, Two Stop Bits).....	323
Figure 13.6	Receive Data Sampling Timing in Asynchronous Mode.....	325
Figure 13.7	Relationship between Output Clock and Transfer Data Phase (Asynchronous Mode).....	326
Figure 13.8	Sample SCI Initialization Flowchart	327
Figure 13.9	Example of Operation in Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit).....	328

Figure 13.10	Sample Serial Transmission Flowchart	329
Figure 13.11	Example of SCI Operation in Reception (Example with 8-Bit Data, Parity, One Stop Bit).....	330
Figure 13.12	Sample Serial Reception Data Flowchart (1).....	332
Figure 13.12	Sample Serial Reception Data Flowchart (2).....	333
Figure 13.13	Example of Communication Using Multiprocessor Format (Transmission of Data H'AA to Receiving Station A)	335
Figure 13.14	Sample Multiprocessor Serial Transmission Flowchart	336
Figure 13.15	Example of SCI Operation in Reception (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)	337
Figure 13.16	Sample Multiprocessor Serial Reception Flowchart (1).....	338
Figure 13.16	Sample Multiprocessor Serial Reception Flowchart (2).....	339
Figure 13.17	Data Format in Synchronous Communication (For LSB-First)	340
Figure 13.18	Sample SCI Initialization Flowchart	341
Figure 13.19	Sample SCI Transmission Operation in Clocked Synchronous Mode.....	342
Figure 13.20	Sample Serial Transmission Flowchart	343
Figure 13.21	Example of SCI Operation in Reception	344
Figure 13.22	Sample Serial Reception Flowchart	345
Figure 13.23	Sample Flowchart of Simultaneous Serial Transmit and Receive Operations	347
Figure 13.24	Schematic Diagram of Smart Card Interface Pin Connections	348
Figure 13.25	Normal Smart Card Interface Data Format.....	349
Figure 13.26	Direct Convention ($SDIR = SIN\bar{V} = O/\bar{E} = 0$).....	349
Figure 13.27	Inverse Convention ($SDIR = SIN\bar{V} = O/\bar{E} = 1$)	349
Figure 13.28	Receive Data Sampling Timing in Smart Card Mode (Using Clock of 372 Times the Transfer Rate).....	351
Figure 13.29	Retransfer Operation in SCI Transmit Mode	353
Figure 13.30	TEND Flag Generation Timing in Transmission Operation	353
Figure 13.31	Example of Transmission Processing Flow	354
Figure 13.32	Retransfer Operation in SCI Receive Mode.....	355
Figure 13.33	Example of Reception Processing Flow	356
Figure 13.34	Timing for Fixing Clock Output Level.....	356
Figure 13.35	Clock Halt and Restart Procedure	357
Figure 13.36	Example of Clocked Synchronous Transmission by DTC.....	361
Figure 13.37	Sample Flowchart for Mode Transition during Transmission	363
Figure 13.38	Asynchronous Transmission Using Internal Clock	363
Figure 13.39	Synchronous Transmission Using Internal Clock	364
Figure 13.40	Sample Flowchart for Mode Transition during Reception.....	364
Figure 13.41	Operation when Switching from SCK Pin Function to Port Pin Function.....	365
Figure 13.42	Operation when Switching from SCK Pin Function to Port Pin Function (Example of Preventing Low-Level Output).....	366

Section 14 I²C Bus Interface (IIC) (Option)

Figure 14.1	Block Diagram of I ² C Bus Interface	369
-------------	---	-----

Figure 14.2	I ² C Bus Interface Connections (Example: This LSI as Master).....	370
Figure 14.3	I ² C Bus Data Formats (I ² C Bus Formats).....	386
Figure 14.4	I ² C Bus Data Format (Serial Format).....	386
Figure 14.5	I ² C Bus Timing.....	386
Figure 14.6	Master Transmit Mode Operation Timing Example (MLS = WAIT = 0)	388
Figure 14.7 (1)	Master Receive Mode Operation Timing Example (MLS = ACKB = 0, WAIT = 1)	390
Figure 14.7 (2)	Master Receive Mode Operation Timing Example (MLS = ACKB = 0, WAIT = 1)	390
Figure 14.8	Example of Slave Receive Mode Operation Timing (1) (MLS = ACKB = 0).....	392
Figure 14.9	Example of Slave Receive Mode Operation Timing (2) (MLS = ACKB = 0).....	393
Figure 14.10	Example of Slave Transmit Mode Operation Timing (MLS = 0)	395
Figure 14.11	IRIC Setting Timing and SCL Control.....	396
Figure 14.12	Block Diagram of Noise Chancellor	398
Figure 14.13	Sample Flowchart for Master Transmit Mode	399
Figure 14.14	Sample Flowchart for Master Receive Mode.....	400
Figure 14.15	Sample Flowchart for Slave Receive Mode.....	401
Figure 14.16	Sample Flowchart for Slave Transmit Mode	402
Figure 14.17	Points for Attention Concerning Reading of Master Receive Data.....	406
Figure 14.18	Flowchart and Timing of Start Condition Instruction Issuance for Retransmission	408
Figure 14.19	Timing of Stop Condition Issuance.....	409

Section 15 A/D Converter

Figure 15.1	Block Diagram of A/D Converter	412
Figure 15.2	Example of A/D converter Operation (Single Mode, Channel 1 Selected)	419
Figure 15.3	Example of A/D Converter Operation (Scan Mode, Channels AN0 to AN2 Selected)	420
Figure 15.4	A/D Conversion Timing.....	421
Figure 15.5	External Trigger Input Timing.....	422
Figure 15.6	A/D Conversion Accuracy Definitions (1)	424
Figure 15.7	A/D Conversion Accuracy Definitions (2)	424
Figure 15.8	Example of Analog Input Circuit.....	425
Figure 15.9	Example of Analog Input Protection Circuit	427
Figure 15.10	Analog Input Pin Equivalent Circuit	427

Section 16 D/A Converter

Figure 16.1	Block Diagram of D/A Converter	429
Figure 16.2	D/A Converter Operation Example.....	433

Section 17 LCD Controller/Driver

Figure 17.1	Block Diagram of LCD Controller/Driver.....	436
Figure 17.2	A waveform 1/2 duty 1/2 bias.....	444
Figure 17.3	Handling of LCD Drive Power Supply when Using 1/2 Duty	446
Figure 17.4	LCD RAM Map (1/4 Duty)	447
Figure 17.5	LCD RAM Map (1/3 Duty)	448
Figure 17.6	LCD RAM Map (1/2 Duty)	448
Figure 17.7	LCD RAM Map (Static Mode)	449
Figure 17.8	Output Waveforms for Each Duty Cycle (A Waveform)	450
Figure 17.9	Output Waveforms for Each Duty Cycle (B Waveform)	451
Figure 17.10	Connection when Triple Step-Up Voltage Circuit Used (Supported Only by the H8S/2268 Series)	453
Figure 17.11	Example of Low-Power-Consumption LCD Drive Operation.....	455
Figure 17.12	Connection of External Split-Resistance	456

Section 18 DTMF Generation Circuit

Figure 18.1	DTMF Frequencies	457
Figure 18.2	DTMF Generation Circuit Diagram	458
Figure 18.3	TONED Pin Output Equivalent Circuit.....	462
Figure 18.4	TONED Pin Output Waveform (Row or Column Group Alone).....	462
Figure 18.5	Example of HA16808ANT Connection	464

Section 20 ROM

Figure 20.1	Block Diagram of Flash Memory.....	468
Figure 20.2	Flash Memory State Transitions	469
Figure 20.3	Boot Mode	470
Figure 20.4	User Program Mode (Example)	471
Figure 20.5	Flash Memory Block Configuration (H8S/2268).....	473
Figure 20.6	Flash Memory Block Configuration (H8S/2266 and H8S/2265).....	474
Figure 20.7	Flash Memory Block Configuration (H8S/2264 and H8S/2264R)	475
Figure 20.8	Programming/Erasing Flowchart Example in User Program Mode	487
Figure 20.9	Flowchart for Flash Memory Emulation in RAM.....	488
Figure 20.10	Example of RAM Overlap Operation (H8S/2268 Series).....	490
Figure 20.11	Example of RAM Overlap Operation (H8S/2264 Series).....	491
Figure 20.12	Program/Program-Verify Flowchart	493
Figure 20.13	Erase/Erase-Verify Flowchart.....	495
Figure 20.14	Socket Adapter Pin Correspondence Diagram.....	498
Figure 20.15	Power-On/Off Timing (Boot Mode).....	502
Figure 20.16	Power-On/Off Timing (User Program Mode).....	503

Figure 20.17	Mode Transition Timing (Example: Boot Mode → User Mode ↔ User Program Mode)	504
--------------	--	-----

Section 21 Clock Pulse Generator

Figure 21.1	Block Diagram of Clock Pulse Generator (H8S/2268 Series)	507
Figure 21.2	Block Diagram of Clock Pulse Generator (H8S/2264 Series)	508
Figure 21.3	Connection of Crystal Resonator (Example)	514
Figure 21.4	Crystal Resonator Equivalent Circuit	515
Figure 21.5	Connection of Ceramic Resonator (Example)	515
Figure 21.6	External Clock Input (Examples)	516
Figure 21.7	External Clock Input Timing	517
Figure 21.8	External Clock Switching Circuit (Examples)	518
Figure 21.9	External Clock Switching Timing (Examples)	518
Figure 21.10	Example Connection of 32.768kHz Quartz Oscillator	519
Figure 21.11	Equivalence Circuit for 32.768kHz Oscillator	520
Figure 21.12	Pin Handling When Subclock Not Required	520
Figure 21.13	Note on Board Design of Oscillator Circuit	521

Section 22 Power-Down Modes

Figure 22.1	Mode Transition Diagram	525
Figure 22.2	Medium-Speed Mode Transition and Clearance Timing	532
Figure 22.3	Software Standby Mode Application Example	536
Figure 22.4	Hardware Standby Mode Timing	537

Section 23 Power-On Reset Circuit

Figure 23.1	Power-On Reset Circuit	543
Figure 23.2	Power-On Reset Circuit Operation Timing	544

Section 24 Power Supply Circuit

Figure 24.1	Power Supply Connections when an Internal Power Supply Step-Down Circuit is Used	545
-------------	--	-----

Section 26 Electrical Characteristics

Figure 26.1	Power Supply Voltage and Operating Ranges (1)	571
Figure 26.1	Power Supply Voltage and Operating Ranges (2)	572
Figure 26.2	Output Load Circuit	589
Figure 26.3	Output Load Circuit	615
Figure 26.4	Output Clock Timing	624
Figure 26.5	Oscillator Settling Timing	624
Figure 26.6	Reset Input Timing	625
Figure 26.7	Interrupt Input Timing	625
Figure 26.8	TPU Clock Input Timing	625
Figure 26.9	8-Bit Timer Clock Input Timing	626
Figure 26.10	SCK Clock Input Timing	626
Figure 26.11	SCI Input/Output Timing (Clock Synchronous Mode)	626
Figure 26.12	I ² C Bus Interface Input/Output Timing (Option)	627

Figure 26.13 TONED Load Circuit (Supported only by the H8S/2268 Series) 627

Appendix C Package Dimensions

Figure C.1 TFP-100B Package Dimensions..... 642

Figure C.2 TFP-100G Package Dimensions 643

Figure C.3 FP-100B Package Dimensions 644

Tables

Section 1 Overview

Table 1.1	Pin Functions	7
-----------	---------------------	---

Section 2 CPU

Table 2.1	Instruction Classification	29
Table 2.2	Operation Notation	30
Table 2.3	Data Transfer Instructions.....	31
Table 2.4	Arithmetic Operations Instructions (1)	32
Table 2.4	Arithmetic Operations Instructions (2)	33
Table 2.5	Logic Operations Instructions	34
Table 2.6	Shift Instructions	34
Table 2.7	Bit Manipulation Instructions (1)	35
Table 2.7	Bit Manipulation Instructions (2)	36
Table 2.8	Branch Instructions.....	37
Table 2.9	System Control Instructions.....	38
Table 2.10	Block Data Transfer Instructions.....	39
Table 2.11	Addressing Modes	40
Table 2.12	Absolute Address Access Ranges.....	42
Table 2.13	Effective Address Calculation (1)	44
Table 2.13	Effective Address Calculation (2)	45

Section 3 MCU Operating Modes

Table 3.1	MCU Operating Mode Selection.....	49
-----------	-----------------------------------	----

Section 4 Exception Handling

Table 4.1	Exception Types and Priority.....	53
Table 4.2	Exception Handling Vector Table	54
Table 4.3	Status of CCR and EXR after Trace Exception Handling.....	57
Table 4.4	Status of CCR and EXR* after Trap Instruction Exception Handling.....	58

Section 5 Interrupt Controller

Table 5.1	Pin Configuration	64
Table 5.2	Interrupt Sources, Vector Addresses, and Interrupt Priorities	78
Table 5.3	Interrupt Control Modes	82
Table 5.4	Interrupts Selected in Each Interrupt Control Mode (1).....	84
Table 5.5	Interrupts Selected in Each Interrupt Control Mode (2).....	84
Table 5.6	Operations and Control Signal Functions in Each Interrupt Control Mode	85
Table 5.7	Interrupt Response Times (States).....	90
Table 5.8	Number of States in Interrupt Handling Routine Execution Status	90

Section 8 Data Transfer Controller (DTC)

Table 8.1	Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs.....	114
Table 8.2	Register Information in Normal Mode	117
Table 8.3	Register Information in Repeat Mode.....	118
Table 8.4	Register Information in Block Transfer Mode	119
Table 8.5	DTC Execution Status	122
Table 8.6	Number of States Required for Each Execution Status	123

Section 9 I/O Ports

Table 9.1	H8S/2268 Series Port Functions (1)	128
Table 9.1	H8S/2264 Series Port Functions (2)	131
Table 9.2	Input Pull-Up MOS States (Port J).....	160

Section 10 16-Bit Timer Pulse Unit (TPU)

Table 10.1	TPU Functions	172
Table 10.2	TPU Pins.....	176
Table 10.3	CCLR0 to CCLR2 (channel 0) (H8S/2268 Series Only)	179
Table 10.4	CCLR0 to CCLR2 (channels 1 and 2)	179
Table 10.5	TPSC0 to TPSC2 (channel 0) (H8S/2268 Series Only)	180
Table 10.6	TPSC0 to TPSC2 (channel 1).....	180
Table 10.7	TPSC0 to TPSC2 (channels 2)	181
Table 10.8	MD0 to MD3.....	183
Table 10.9	TIORH_0 (Channel 0) (H8S/2268 Series Only).....	185
Table 10.10	TIORL_0 (Channel 0) (H8S/2268 Series Only)	186
Table 10.11	TIOR_1 (Channel 1).....	187
Table 10.12	TIOR_2 (Channel 2).....	188
Table 10.13	TIORH_0 (Channel 0) (H8S/2268 Series Only).....	189
Table 10.14	TIORL_0 (Channel 0) (H8S/2268 Series Only)	190
Table 10.15	TIOR_1 (Channel 1).....	191
Table 10.16	TIOR_2 (Channel 2).....	192
Table 10.17	Register Combinations in Buffer Operation.....	210
Table 10.18	Counter Combination in Operation with Cascaded Connection	213
Table 10.19	PWM Output Registers and Output Pins	216
Table 10.20	Phase Counting Mode Clock Input Pins	220
Table 10.21	Up/Down-Count Conditions in Phase Counting Mode 1	221
Table 10.22	Up/Down-Count Conditions in Phase Counting Mode 2	222
Table 10.23	Up/Down-Count Conditions in Phase Counting Mode 3	223
Table 10.24	Up/Down-Count Conditions in Phase Counting Mode 4	224
Table 10.25	TPU Interrupts.....	225

Section 11 8-Bit Timers

Table 11.1	Pin Configuration	245
Table 11.2	8-Bit Timer Interrupt Sources	259

Table 11.3	Timer Output Priorities	262
Table 11.4	Switching of Internal Clock and TCNT Operation	263

Section 12 Watchdog Timer

Table 12.1	Clock Selection When PSS = 1.	279
Table 12.2	WDT Interrupt Source	284

Section 13 Serial Communication Interface (SCI)

Table 13.1	Pin Configuration	293
Table 13.2	The Relationships between The N Setting in BRR and Bit Rate B.....	311
Table 13.3	BRR Settings for Various Bit Rates (Asynchronous Mode) (1)	312
Table 13.3	BRR Settings for Various Bit Rates (Asynchronous Mode) (2)	313
Table 13.3	BRR Settings for Various Bit Rates (Asynchronous Mode) (3)	314
Table 13.3	BRR Settings for Various Bit Rates (Asynchronous Mode) (4)	315
Table 13.4	Maximum Bit Rate for Each Frequency (Asynchronous Mode)	315
Table 13.5	Maximum Bit Rate with External Clock Input (Asynchronous Mode).....	316
Table 13.6	BRR Settings for Various Bit Rates (Clocked Synchronous Mode)	317
Table 13.7	Maximum Bit Rate with External Clock Input (Clocked Synchronous Mode)	317
Table 13.8	Examples of Bit Rate for Various BRR Settings (Smart Card Interface Mode) (When n = 0 and S = 372)	318
Table 13.9	Maximum Bit Rate at Various Frequencies (Smart Card Interface Mode) (when S = 372)	318
Table 13.10	Serial Transfer Formats (Asynchronous Mode)	324
Table 13.11	SSR Status Flags and Receive Data Handling	331
Table 13.12	Interrupt Sources of Serial Communication Interface Mode	359
Table 13.13	Interrupt Sources in Smart Card Interface Mode	360

Section 14 I²C Bus Interface (IIC) (Option)

Table 14.1	Pin Configuration	370
Table 14.2	Transfer Format	374
Table 14.3	I ² C Transfer Rate	376
Table 14.4	Flags and Transfer States	382
Table 14.5	Flags and Transfer States	397
Table 14.6	I ² C Bus Timing (SCL and SDA Output)	403
Table 14.7	Permissible SCL Rise Time (t _{sr}) Values	404
Table 14.8	I ² C Bus Timing (with Maximum Influence of t _{sr} /t _{sf})	405

Section 15 A/D Converter

Table 15.1	Pin Configuration	413
Table 15.2	Analog Input Channels and Corresponding ADDR Registers	414
Table 15.3	A/D Conversion Time (Single Mode)	421
Table 15.4	A/D Conversion Time (Scan Mode)	421
Table 15.5	A/D Converter Interrupt Source	422

Table 15.6	Analog Pin Specifications	427
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Section 16 D/A Converter

Table 16.1	Pin Configuration	430
Table 16.2	D/A Conversion Control	432

Section 17 LCD Controller/Driver

Table 17.1	Pin Configuration	437
Table 17.2	Duty Cycle and Common Function Selection	439
Table 17.3	Segment Driver Selection (1) (H8S/2268 Series)	439
Table 17.4	Segment Driver Selection (2) (H8S/2264 Series)	440
Table 17.5	Frame Frequency Selection	442
Table 17.6	Output Levels	452
Table 17.7	Power-Down Modes and Display Operation	454

Section 18 DTMF Generation Circuit

Table 18.1	Pin Configuration	458
Table 18.2	Frequency Deviation Between DTMF Output Signals And Typical Signals	463

Section 20 ROM

Table 20.1	Differences between Boot Mode and User Program Mode	469
Table 20.2	Pin Configuration	476
Table 20.3	Setting On-Board Programming Modes	484
Table 20.4	Boot Mode Operation	486
Table 20.5	System Clock Frequencies for which Automatic Adjustment of LSI Bit Rate is Possible	486
Table 20.6	Flash Memory Operating States	499
Table 20.7	Registers Present in F-ZTAT Version but Absent in Masked ROM Version	505

Section 21 Clock Pulse Generator

Table 21.1	ϕ Clock Output Control	510
Table 21.2	ϕ Clock Selection	511
Table 21.3	Damping Resistance Value	515
Table 21.4	Crystal Resonator Characteristics	515
Table 21.5	External Clock Input Conditions	516
Table 21.6	External Clock Input Conditions (Duty Adjustment Circuit not used)	517

Section 22 Power-Down Modes

Table 22.1	LSI Internal States in Each Mode	523
Table 22.2	Low Power Dissipation Mode Transition Conditions	526
Table 22.3	Oscillation Settling Time Settings (Normal Oscillation)	534
Table 22.4	Oscillation Settling Time Settings (Oscillation Settling Time Shortened: Crystal Oscillator)	535

Table 22.5	Oscillation Settling Time Settings (Oscillation Settling Time Shortened: Ceramic Oscillator).....	535
------------	--	-----

Section 26 Electrical Characteristics

Table 26.1	Absolute Maximum Ratings.....	573
Table 26.2	DC Characteristics (1)	574
Table 26.2	DC Characteristics (2)	576
Table 26.2	DC Characteristics (3)	578
Table 26.2	DC Characteristics (4)	580
Table 26.2	DC Characteristics (5)	582
Table 26.2	DC Characteristics (6) — Preliminary —	584
Table 26.3	Permissible Output Currents	586
Table 26.4	Bus Drive Characteristics (1)	587
Table 26.4	Bus Drive Characteristics (2)	588
Table 26.5	Clock Timing	590
Table 26.6	Control Signal Timing	591
Table 26.7	Timing of On-Chip Peripheral Modules	592
Table 26.8	I ² C Bus Timing	593
Table 26.9	A/D Conversion Characteristics	594
Table 26.10	D/A Conversion Characteristics	595
Table 26.11	LCD Characteristics	596
Table 26.12	DTMF Characteristics.....	598
Table 26.13	Flash Memory Characteristics.....	599
Table 26.14	Absolute Maximum Ratings.....	600
Table 26.15	DC Characteristics (1) — Preliminary —	601
Table 26.15	DC Characteristics (2) — Preliminary —	603
Table 26.15	DC Characteristics (3) — Preliminary —	605
Table 26.15	DC Characteristics (4) — Preliminary —	607
Table 26.15	DC Characteristics (5) — Preliminary —	609
Table 26.15	DC Characteristics (6) — Preliminary —	611
Table 26.16	Permissible Output Currents	613
Table 26.17	Bus Drive Characteristics (1)	614
Table 26.17	Bus Drive Characteristics (2)	615
Table 26.18	Clock Timing — Preliminary —	616
Table 26.19	Control Signal Timing	617
Table 26.20	Timing of On-Chip Peripheral Modules	618
Table 26.21	I ² C Bus Timing	619
Table 26.22	A/D Conversion Characteristics — Preliminary —	620
Table 26.23	LCD Characteristics	621
Table 26.24	Flash Memory Characteristics — Preliminary —	622

Section 1 Overview

1.1 Features

- High-speed H8S/2000 central processing unit with an internal 16-bit architecture
 - Upward-compatible with H8/300 and H8/300H CPUs on an object level
 - Sixteen 16-bit general registers
 - 65 basic instructions
- Various peripheral functions
 - Interrupt controller
 - PC break controller (supported only by the H8S/2268 Series)
 - Data transfer controller (DTC) (supported only by the H8S/2268 Series)
 - 16-bit timer-pulse unit (TPU)
 - 8-bit timer (TMR)
 - Watchdog timer (WDT)
 - Serial communication interface (SCI)
 - I²C bus interface (option)
 - A/D converter
 - D/A converter (supported only by the H8S/2268 Series)
 - LCD controller/driver
 - DTMF generation circuit (supported only by the H8S/2268 Series)
- On-chip memory

H8S/2268 Series:

ROM	Model	ROM	RAM	Remarks
Flash memory version	HD64F2268	256 kbytes	16 kbytes	
	HD64F2266	128 kbytes	8 kbytes	
	HD64F2265	128 kbytes	4 kbytes	
Masked ROM version	HD6432268	256 kbytes	16 kbytes	
	HD6432268W	256 kbytes	16 kbytes	
	HD6432266	128 kbytes	8 kbytes	
	HD6432266W	128 kbytes	8 kbytes	
	HD6432265	128 kbytes	4 kbytes	
	HD6432265W	128 kbytes	4 kbytes	

ROM	Model	ROM	RAM	Remarks
Flash memory version	HD64F2264	128 kbytes	4 kbytes	
	HD64F2264R	128 kbytes	4 kbytes	
Masked ROM version	HD6432264	128 kbytes	4 kbytes	
	HD6432264W	128 kbytes	4 kbytes	
	HD6432264R	128 kbytes	4 kbytes	
	HD6432264RW	128 kbytes	4 kbytes	
	HD6432262	64 kbytes	2 kbytes	
	HD6432262W	64 kbytes	2 kbytes	
	HD6432262R	64 kbytes	2 kbytes	
	HD6432262RW	64 kbytes	2 kbytes	

- General I/O ports
 - I/O pins: 67 (supported only by the H8S/2268 Series)
53 (supported only by the H8S/2264 Series)
 - Input-only pins: 11
- Supports various power-down states
- Compact package

Package	(Code)	Body Size	Pin Pitch
TQFP-100	TFP-100B	14.0 × 14.0 mm	0.5 mm
TQFP-100	TFP-100G	12.0 × 12.0 mm	0.4 mm
QFP-100	FP-100B	14.0 × 14.0 mm	0.5 mm

1.2 Internal Block Diagram

Figure 1.1 shows the internal block diagram of the H8S/2268 Series and figure 1.2 shows that of the H8S/2264 Series.

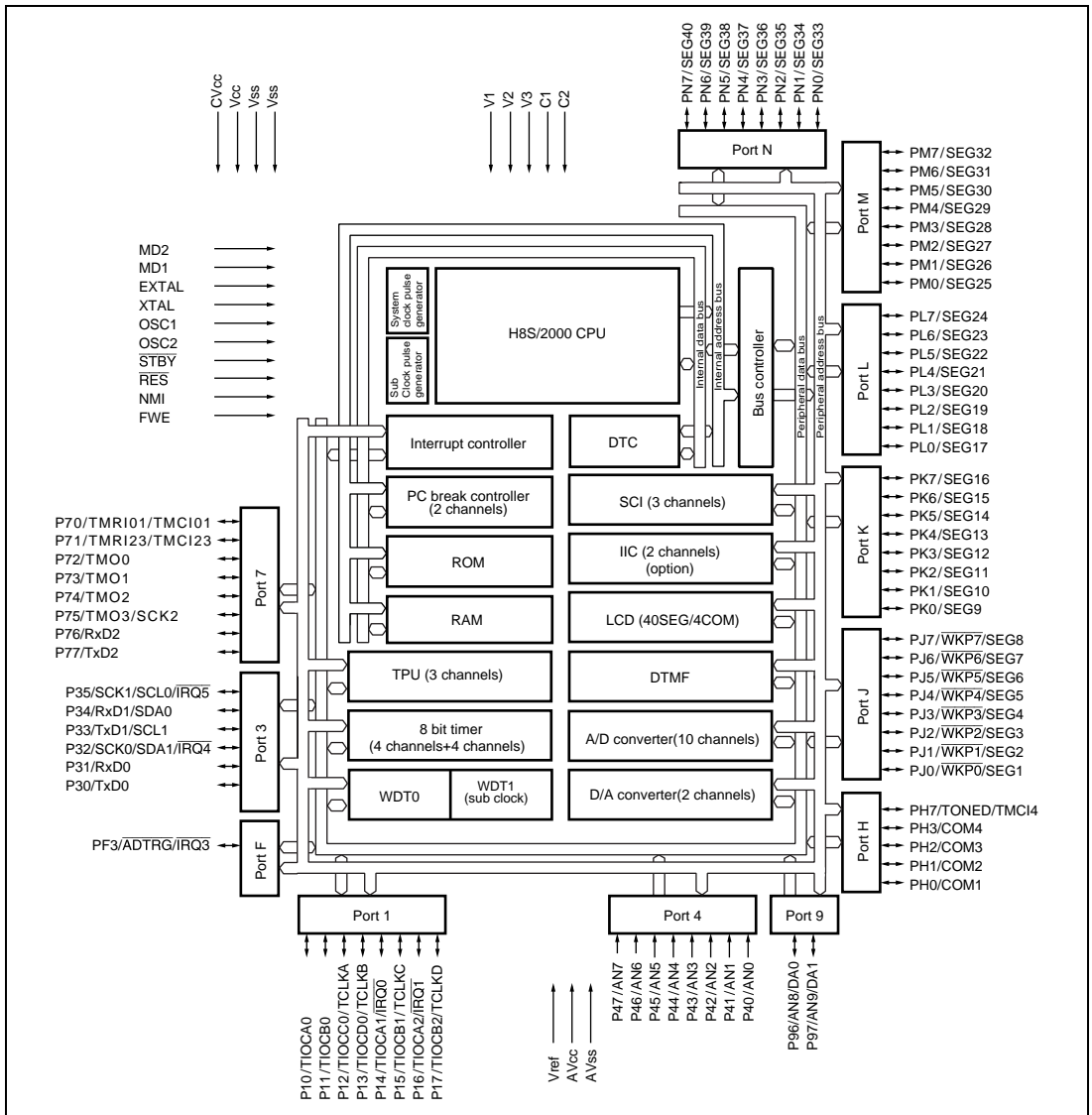


Figure 1.1 Internal Block Diagram of H8S/2268 Series

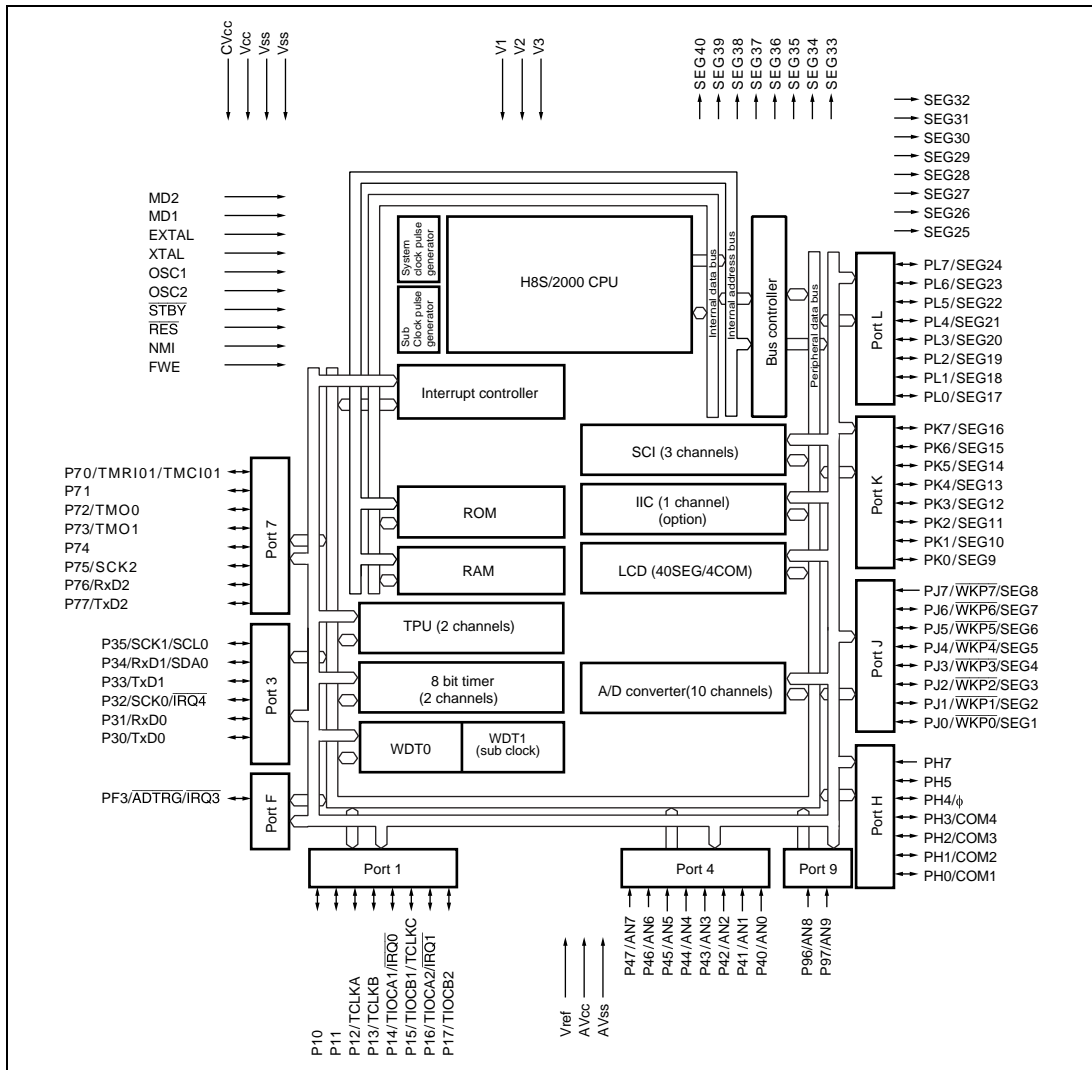


Figure 1.2 Internal Block Diagram of H8S/2264 Series

1.3 Pin Arrangement

Figure 1.3 shows the pin arrangement of the H8S/2268 Series and figure 1.4 shows that of the H8S/2264 Series.

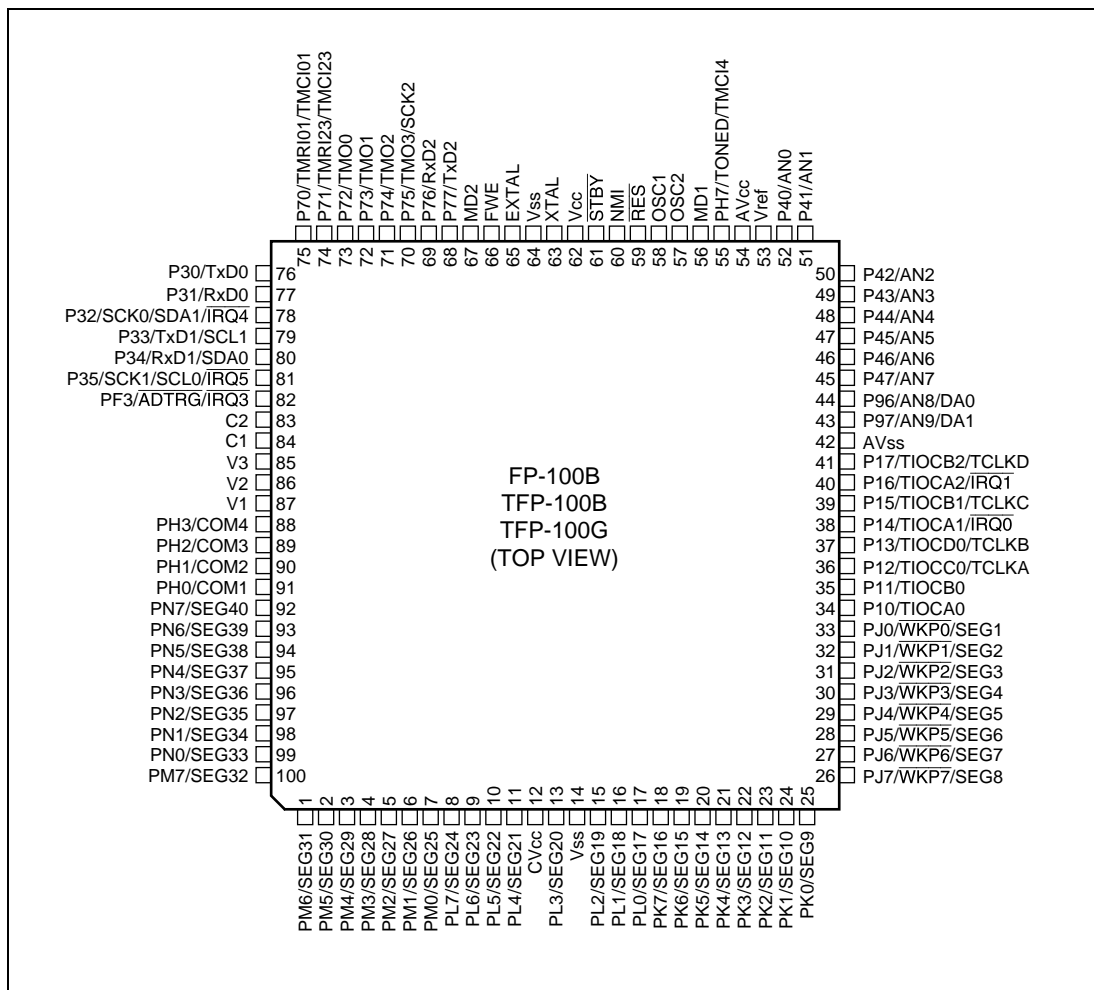


Figure 1.3 Pin Arrangement of H8S/2268 Series

1.4 Pin Functions

Table 1.1 lists the pins functions.

Table 1.1 Pin Functions

Type	Symbol	Pin NO.	I/O	Function
Power supply	VCC	62	Input	Power supply pin. Connect this pin to the system power supply.
	CVCC	12	Input	Connect this pin to VSS via a 0.1-μF capacitor for voltage stabilization. Note that applying a voltage exceeding 4.3 V, the absolute maximum rating, to the CVCC pin may cause fatal damages on this LSI. Do not connect the power supply to the CVCC pin. See section 24, Power Supply Circuit, for connecting examples.
	V3	85	Input	Power supply pins for the LCD controller/driver. With an internal power supply division resistor, these pins are normally left open. Power supply should be within the range of $V_{cc} \geq V1 \geq V2 \geq V3 \geq V_{ss}$. When the triple step-up voltage circuit* ² is used, the V3 pin is used for the LCD input reference power supply.
	V2	86		
	V1	87		
	VSS	14 64	Input	Ground pins. Connect this pin to the system power supply (0V).
Clock	XTAL	63	Input	For connection to a crystal resonator or a ceramic resonator* ³ . For examples of crystal or ceramic* ³ resonator connection and external clock input, see section 21, Clock Pulse Generator.
	EXTAL	65	Input	For connection to a crystal resonator or a ceramic resonator* ³ . This pin can be also used for external clock input. For examples of crystal or ceramic* ³ resonator connection and external clock input, see section 21, Clock Pulse Generator.
	OSC1	58	Input	Connects to a 32.768 kHz crystal resonator. See section 21, Clock Pulse Generator, for typical connection diagrams for a crystal resonator.
	OSC2	57	Input	Connects to a 32.768 kHz crystal resonator. See section 21, Clock Pulse Generator, for typical connection diagrams for a crystal resonator.
	ϕ^{*1}	84	Output	Supplies clock pulses to external devices.

Type	Symbol	Pin NO.	I/O	Function
Operating mode control	MD2, MD1	67 56	Input	Sets the operating mode. Inputs at these pins should not be changed during operation. Be sure to fix the levels of the mode pins (MD2, MD1) by pull-down or pull-up, except for mode changing.
System control	$\overline{\text{RES}}$	59	Input	Reset input pin. When this pin is low, the chip enters in the power-on reset state.
	$\overline{\text{STBY}}$	61	Input	When this pin is low, a transition is made to hardware standby mode.
	FWE	66	Input	Enables/disables programming the flash memory.
Interrupts	NMI	60	Input	Nonmaskable interrupt pin. If this pin is not used, it should be fixed-high.
	$\overline{\text{IRQ5}}^{*2}$	81	Input	These pins request a maskable interrupt.
	$\overline{\text{IRQ4}}$	78		
	$\overline{\text{IRQ3}}$	82		
	$\overline{\text{IRQ1}}$	40		
	$\overline{\text{IRQ0}}$	38		
	$\overline{\text{WKP7}}$ to $\overline{\text{WKP0}}$	26 to 33	Input	These pins request a wakeup interrupt. This interrupt is maskable.
16-bit timer-pulse unit (TPU)	TCLKD^{*2}	41	Input	These pins input an external clock.
	TCLKC	39		
	TCLKB	37		
	TCLKA	36		
	TIOCA0^{*2}	34	Input/ Output	Pins for the TGRA_0 to TGRD_0 input capture input or output compare output, or PWM output.
	TIOCB0^{*2}	35		
	TIOCC0^{*2}	36		
	TIOCD0^{*2}	37		
	TIOCA1	38	Input/ Output	Pins for the TGRA_1 and TGRB_1 input capture input or output compare output, or PWM output.
	TIOCB1	39		
	TIOCA2	40	Input/ Output	Pins for the TGRA_2 and TGRB_2 input capture input or output compare output, or PWM output.
	TIOCB2	41		
8-bit timer	TMO3^{*2}	70	Output	Compare-match output pins
	TMO2^{*2}	71		
	TMO1	72		
	TMO0	73		
	TMCi23^{*2}	74	Input	Pins for external clock input to the counter
	TMCi01	75		
	TMCi4^{*2}	55		
	TMRI23^{*2}	74	Input	Counter reset input pins.
	TMRI01	75		

Type	Symbol	Pin NO.	I/O	Function
Serial communication	TxD2	68	Output	Data output pins
	TxD1	79		
	TxD0	76		
Interface (SCI)/ smart card	RxD2	69	Input	Data input pins
	RxD1	80		
	RxD0	77		
interface	SCK2	70	Input/ Output	Clock input/output pins
	SCK1	81		
	SCK0	78		
I ² C bus interface (optional)	SCL1* ²	79	Input/ Output	I ² C clock input/output pins.
	SCL0	81		
	SDA1* ²	78	Input/ Output	I ² C data input/output pins.
	SDA0	80		
A/D converter	AN9 to AN0	43 to 52	Input	Analog input pins
	ADTRG	82	Input	Pin for input of an external trigger to start A/D conversion
D/A converter * ²	DA1	43	Output	Analog output pins for the D/A converter* ² .
	DA0	44		
A/D converter, D/A converter* ²	AVCC	54	Input	Power supply pin for the A/D converter, D/A converter* ² and DTMF generation circuit* ² . If none of the A/D converter, D/A converter* ² and DTMF generation circuit* ² is used, connect this pin to the system power supply (+5 V).
	AVSS	42	Input	Ground pin for the A/D converter, D/A converter* ² , and DTMF generator* ² . Connect this pin to the system power supply (0 V).
	Vref	53	Input	Reference voltage input pin for the A/D converter and D/A converter* ² . If neither the A/D converter nor D/A converter* ² is used, connect this pin to the system power supply (+5 V).
LCD controller/ driver	SEG40 to SEG 1	92 to 100, 1 to 11, 13, 15 to 33	Output	LCD segment output pins
	COM4 to COM1	88 to 91	Output	LCD common output pins
	C2* ² C1* ²	83 84	—	Pins for the step-up voltage capacitor of the LCD drive power supply.

Type	Symbol	Pin NO.	I/O	Function
DTMF generation circuit*2	TONED	55	Output	DTMF signal output pin.
I/O ports	P17 to P10	41 to 34	Input/Output	8-bit I/O pins
	P35 to P30	81 to 76	Input/Output	6-bit I/O pins
	P47 to P40	45 to 52	Input	8-bit input pins
	P77 to P70	68 to 75	Input/Output	8-bit I/O pins
	P97 P96	43 44	Input	2-bit input pins
	PF3	82	Input/Output	1-bit I/O pin
	PH7	55	Input	1-bit input pin
	PH5*1 PH4*1	83 84	Input/Output	2-bit I/O pins
	PH3 to PH0	88 to 91	Input/Output	4-bit I/O pins
	PJ7 to PJ0	26 to 33	Input/Output	8-bit I/O pins
	PK7 to PK0	18 to 25	Input/Output	8-bit I/O pins
	PL7 PL6 PL5 PL4 PL3 PL2 PL1 PL0	8 9 10 11 13 15 16 17	Input/Output	8-bit I/O pins
	PM7*2 PM6*2 PM5*2 PM4*2 PM3*2 PM2*2 PM1*2 PM0*2	100 1 2 3 4 5 6 7	Input/Output	8-bit I/O pins

Type	Symbol	Pin NO.	I/O	Function
I/O ports	PN7 to PN0* ²	92 to 99	Input/ Output	8-bit I/O pins

Notes: 1. Supported only by the H8S/2264 Series.
2. Supported only by the H8S/2268 Series.
3. Supported only by the H8S/2264R and H8S/2262R.

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. The usable modes and address spaces differ depending on the product. For details on each product, refer to section 3, MCU Operating Modes.

2.1 Features

- Upward-compatible with H8/300 and H8/300H CPU
 - 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 execute in one or two states
 - 8/16/32-bit register-register add/subtract : 1 state
 - 8×8 -bit register-register multiply : 12 states
 - $16 \div 8$ -bit register-register divide : 12 states
 - 16×16 -bit register-register multiply : 20 states
 - $32 \div 16$ -bit register-register divide : 20 states

- Two CPU operating modes
 - Normal mode*
 - Advanced mode
- Power-down state
 - Transition to power-down state by a SLEEP instruction
 - CPU clock speed selection

Note: * Normal mode is not available in this LSI.

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 shown below.

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

Instruction	Mnemonic	Execution States	
		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, and power-down modes, etc., depending on the model.

Note: * Supported only by the H8S/2268 Series.

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 expanded 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 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 execute 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 registers have been added.
- Enhanced instructions
 - Addressing modes of bit-manipulation instructions have been enhanced.
 - Two-bit shift 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 execute twice as fast.

2.2 CPU Operating Modes

The H8S/2000 CPU has two operating modes: normal and advanced. Normal mode supports a maximum 64-kbyte address space. Advanced mode supports a maximum 16-Mbyte total address space. The mode is selected by the mode pins.

2.2.1 Normal Mode

The exception vector table and stack have the same structure as in the H8/300 CPU.

- Address Space

Linear access is provided to a maximum address space of 64 kbytes.

- Extended Registers (En)

The extended registers (E0 to E7) can be used as 16-bit registers, or as the upper 16-bit segments of 32-bit registers. When En is used as a 16-bit register it can contain any value, even when the corresponding general register (Rn) is used as an address register. If the general register is referenced in the register indirect addressing mode with pre-decrement (@-Rn) or post-increment (@Rn+) and a carry or borrow occurs, however, the value in the corresponding extended register (En) will be affected.

- Instruction Set

All instructions and addressing modes can be used. Only the lower 16 bits of effective addresses (EA) are valid.

- Exception Vector Table and Memory Indirect Branch Addresses

In normal mode the top area starting at H'0000 is allocated to the exception vector table. One branch address is stored per 16 bits. Figure 2.1 shows the structure of the exception vector table in normal mode. For details of the exception vector table, see section 4, Exception Handling.

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 normal mode the operand is a 16-bit word operand, providing a 16-bit branch address. Branch addresses can be stored in the top area from H'0000 to H'00FF. Note that this area is also used for the exception vector table.

- Stack Structure

When the program counter (PC) is pushed onto the stack in a subroutine call, and the PC, condition-code register (CCR) and extended control register (EXR) 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 4, Exception Handling.

Note: * Normal mode is not available in this LSI.

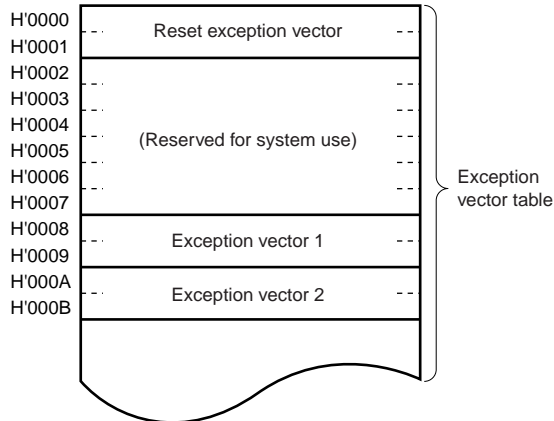
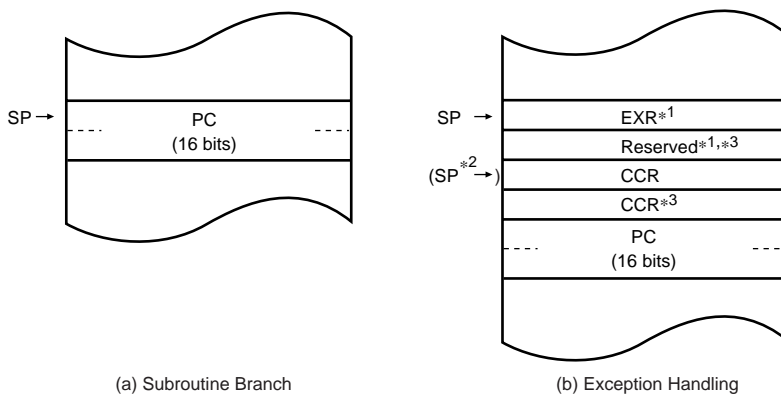


Figure 2.1 Exception Vector Table (Normal Mode)



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 Normal Mode

2.2.2 Advanced Mode

- Address Space

Linear access is provided to a maximum 16-Mbyte address space.

- Extended Registers (En)

The extended registers (E0 to E7) can be used as 16-bit registers, or 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 units of 32 bits. In each 32 bits, the upper 8 bits are ignored and a branch address is stored in the lower 24 bits (figure 2.3). For details of the exception vector table, see section 4, Exception Handling.

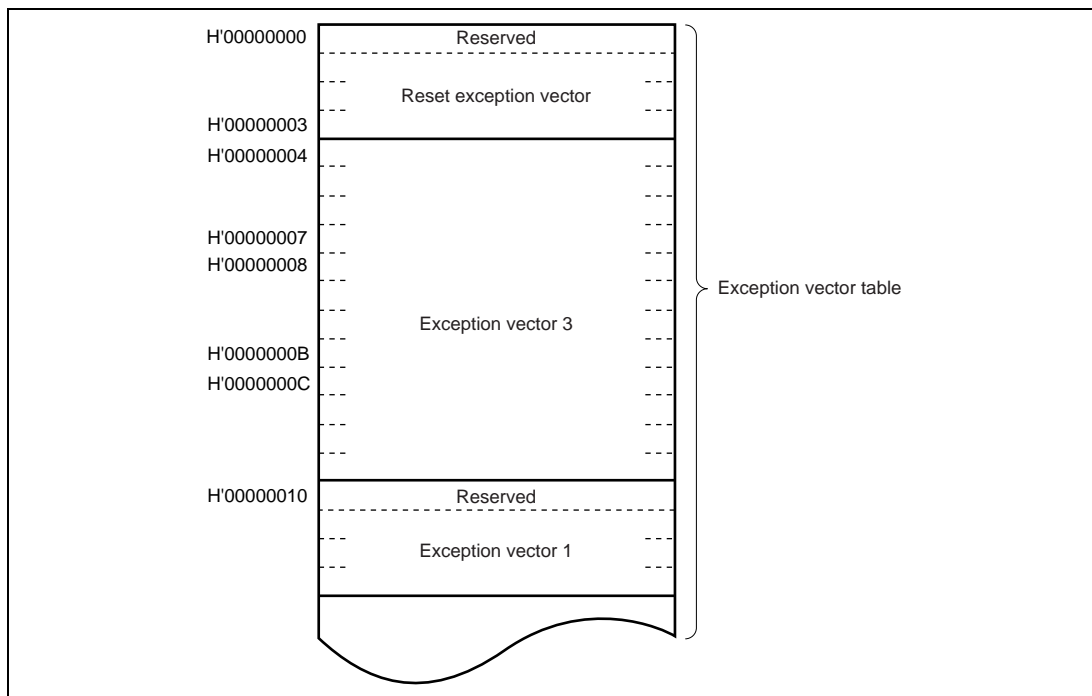


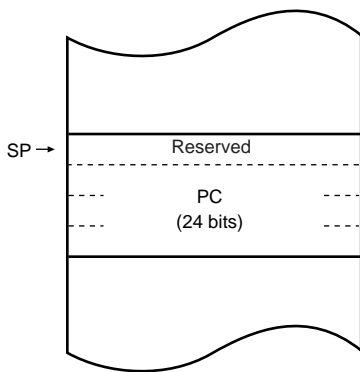
Figure 2.3 Exception Vector Table (Advanced Mode)

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 is 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 first part of this range is also the exception vector table.

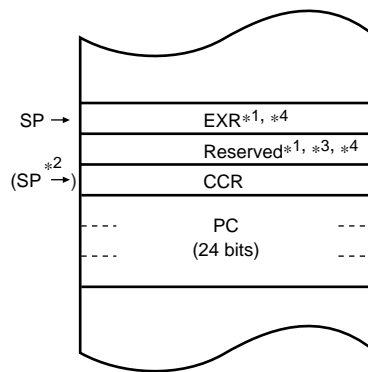
- Stack Structure

In advanced mode, when the program counter (PC) is pushed onto the stack in a subroutine call, and the PC, condition-code register (CCR), and extended control register (EXR*) are pushed onto the stack in exception handling, they are stored as shown in figure 2.4. When EXR* is invalid, it is not pushed onto the stack. For details, see section 4, Exception Handling.

Note: * Supported only by the H8S/2268 Series.



(a) Subroutine Branch



(b) Exception Handling

- Notes:
1. When EXR is not used it is not stored on the stack.
 2. SP when EXR is not used (The H8S/2264 Series SP always points here).
 3. Ignored when returning.
 4. Supported only by the H8S/2268 Series.

Figure 2.4 Stack Structure in Advanced Mode

2.3 Address Space

Figure 2.5 shows a memory map of the H8S/2000 CPU. The H8S/2000 CPU provides linear access to a maximum 64-kbyte address space in normal mode, and a maximum 16-Mbyte (architecturally 4-Gbyte) address space in advanced mode. The usable modes and address spaces differ depending on the product. For details on each product, refer to section 3, MCU Operating Modes.

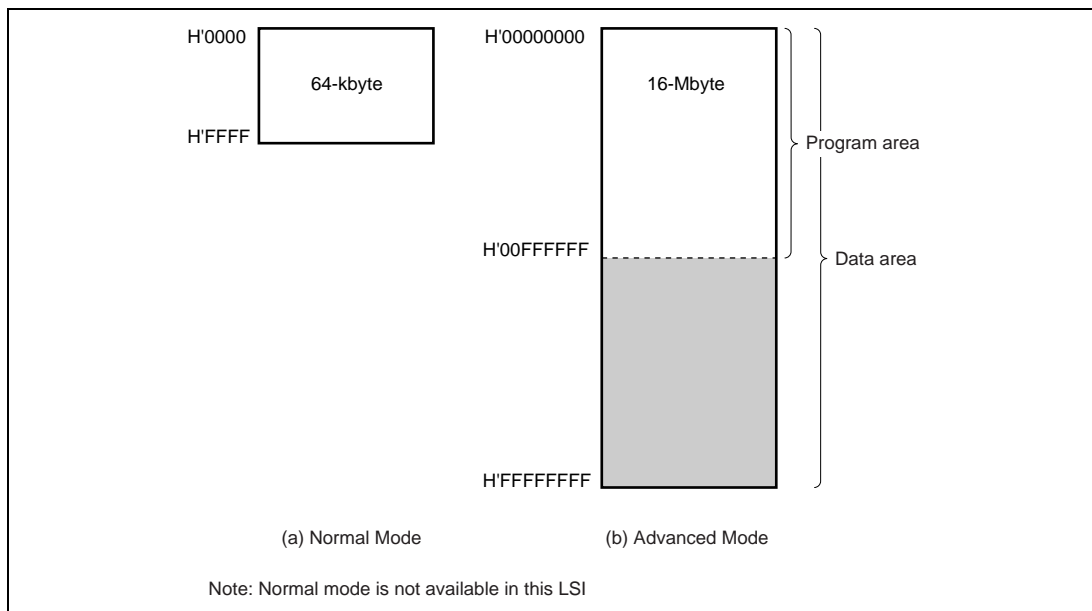


Figure 2.5 Memory Map

2.4 Register Configuration

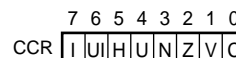
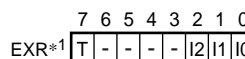
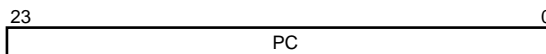
The H8S/2000 CPU has the internal registers shown in figure 2.6. There are two types of registers: general registers and control registers. Control registers are a 24-bit program counter (PC), an 8-bit extended control register (EXR*), and an 8-bit condition code register (CCR).

Note: * Supported only by the H8S/2268 Series.

General Registers (Rn) and Extended Registers (En)

	15	0 7	0 7	0
ER0	E0	R0H	R0L	
ER1	E1	R1H	R1L	
ER2	E2	R2H	R2L	
ER3	E3	R3H	R3L	
ER4	E4	R4H	R4L	
ER5	E5	R5H	R5L	
ER6	E6	R6H	R6L	
ER7 (SP)	E7	R7H	R7L	

Control Registers (CR)



Legend

SP	:Stack pointer	H	:Half-carry flag
PC	:Program counter	U	:User bit
EXR	:Extended control register*1	N	:Negative flag
T	:Trace bit*1	Z	:Zero flag
I2 to I0	:Interrupt mask bits*1	V	:Overflow flag
CCR	:Condition-code register*1	C	:Carry flag
I	:Interrupt mask bit		
UI	:User bit or interrupt mask bit*2		

Notes: 1. Supported only by the H8S/2268 Series.
2. The interrupt mask bit is not available in this LSI.

Figure 2.6 CPU 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 2.7 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).

The ER registers divide 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.

The R registers divide 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 stack pointer (SP) in addition to its general-register function, and is used implicitly in exception handling and subroutine calls. Figure 2.8 shows the stack.

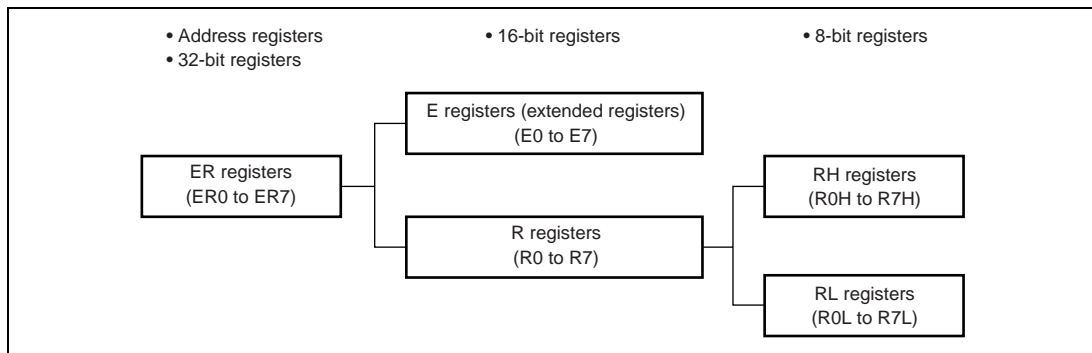


Figure 2.7 Usage of General Registers

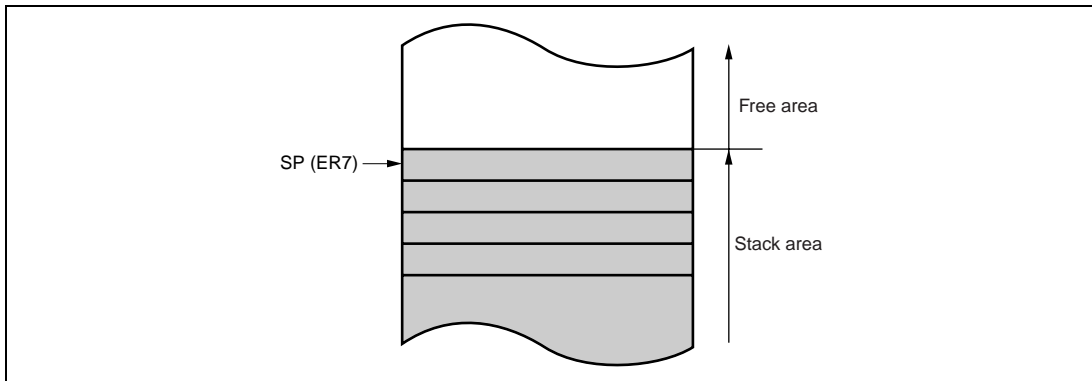


Figure 2.8 Stack Status

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, the least significant PC bit is regarded as 0.)

2.4.3 Extended Control Register (EXR) (H8S/2268 Series Only)

EXR is an 8-bit register that manipulates the LDC, STC, ANDC, ORC, and XORC instructions. When these instructions except for the STC instruction is executed, all interrupts including NMI will be masked for three states after execution is completed.

Bit	Bit Name	Initial Value	R/W	Description
7	T	0	R/W	Trace Bit When this bit is set to 1, a trace exception is generated each time an instruction is executed. When this bit is cleared to 0, instructions are executed in sequence.
6 to 3	—	1	—	Reserved These bits are always read as 1.
2	I2	1	R/W	These bits designate the interrupt mask level (0 to 7). For details, refer to section 5, Interrupt Controller.
1	I1	1	R/W	
0	I0	1	R/W	

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	Bit Name	Initial Value	R/W	Description
7	I	1	R/W	Interrupt Mask 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 by hardware at the start of an exception-handling sequence. For details, refer to section 5, Interrupt Controller.
6	UI	undefined	R/W	User Bit or Interrupt Mask Bit Can be written and read by software using the LDC, STC, ANDC, ORC, and XORC instructions. This bit cannot be used as an interrupt mask bit in this LSI.
5	H	undefined	R/W	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.
4	U	undefined	R/W	User Bit Can be written and read by software using the LDC, STC, ANDC, ORC, and XORC instructions.
3	N	undefined	R/W	Negative Flag Stores the value of the most significant bit of data as a sign bit.

Bit	Bit Name	Initial Value	R/W	Description
2	Z	undefined	R/W	Zero Flag Set to 1 to indicate zero data, and cleared to 0 to indicate non-zero data.
1	V	undefined	R/W	Overflow Flag Set to 1 when an arithmetic overflow occurs, and cleared to 0 at other times.
0	C	undefined	R/W	Carry Flag Set to 1 when a carry occurs, and cleared to 0 otherwise. Used by: <ul style="list-style-type: none"> • 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 Values of CPU Registers

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

Note: * Supported only by the H8S/2268 Series.

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 2.9 shows the data formats in general registers.

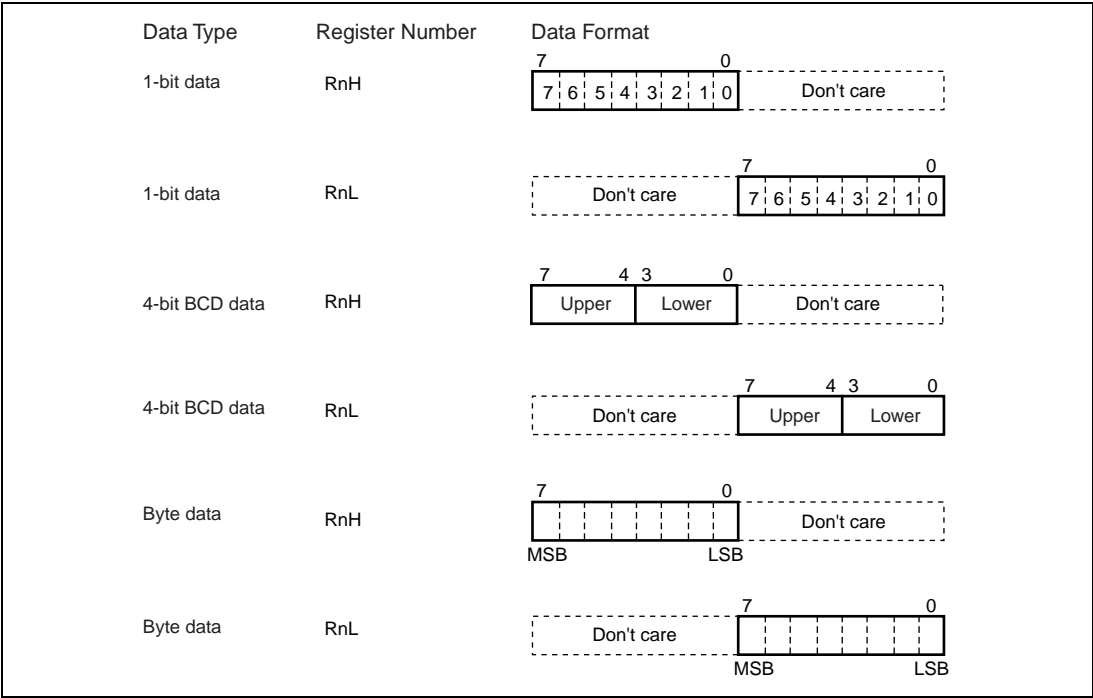


Figure 2.9 General Register Data Formats (1)

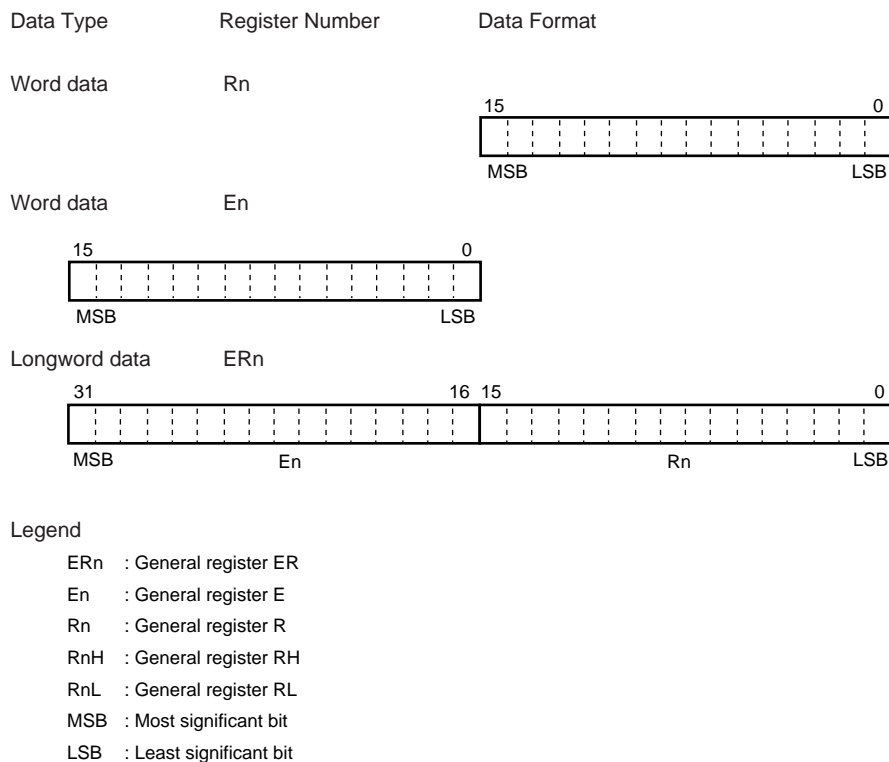


Figure 2.9 General Register Data Formats (2)

2.5.2 Memory Data Formats

Figure 2.10 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 ER7 is used as an address register to access the stack, the operand size should be word or longword.

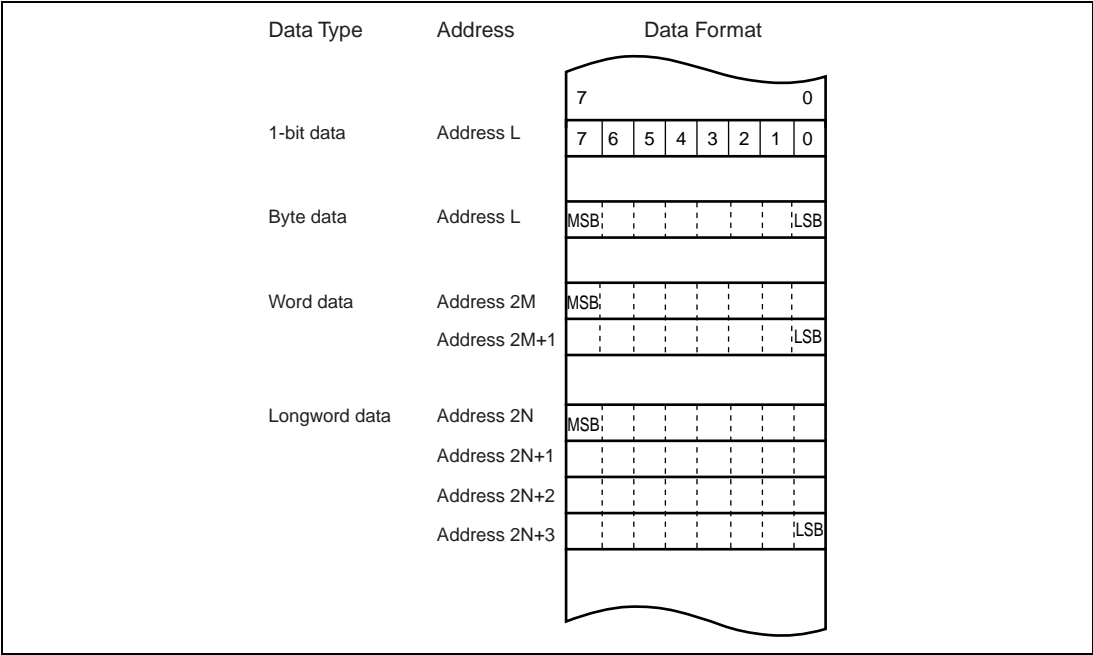


Figure 2.10 Memory Data Formats

2.6 Instruction Set

The H8S/2000 CPU has 65 types of instructions. The instructions are classified by function 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, STM	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	Bcc* 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; W-word; L-longword.

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. Bcc 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.

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) * ¹
Rs	General register (source) * ¹
Rn	General register* ¹
ERn	General register (32-bit register)
(EAd)	Destination operand
(EAs)	Source operand
EXR	Extended control register* ²
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 XOR
→	Move
¬	NOT (logical complement)
:8/:16/:24/:32	8-, 16-, 24-, or 32-bit length

Notes: 1. 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).

2. Supported only by the H8S/2268 Series.

Table 2.3 Data Transfer Instructions

Instruction	Size*	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	L	@SP+ → Rn (register list) Pops two or more general registers from the stack.
STM	L	Rn (register list) → @-SP Pushes two or more general registers onto the stack.

Note: * Refers to the operand size.

B: Byte

W: Word

L: Longword

Table 2.4 Arithmetic Operations Instructions (1)

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

Note: * 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	$Rd \div Rs \rightarrow Rd$ Performs signed division on data in two general registers: either 16 bits \div 8 bits \rightarrow 8-bit quotient and 8-bit remainder or 32 bits \div 16 bits \rightarrow 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 CCR bits according to the result.
NEG	B/W/L	$0 - Rd \rightarrow Rd$ Takes the two's complement (arithmetic complement) of data in a general register.
EXTU	W/L	$Rd \text{ (zero extension)} \rightarrow Rd$ 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	$Rd \text{ (sign extension)} \rightarrow Rd$ 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	$@ERd - 0, 1 \rightarrow (<\text{bit } 7> \text{ of } @ERd)$ Tests memory contents, and sets the most significant bit (bit 7) to 1.

Notes: 1. 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	$Rd \wedge Rs \rightarrow Rd$, $Rd \wedge \#IMM \rightarrow Rd$ Performs a logical AND operation on a general register and another general register or immediate data.
OR	B/W/L	$Rd \vee Rs \rightarrow Rd$, $Rd \vee \#IMM \rightarrow Rd$ Performs a logical OR operation on a general register and another general register or immediate data.
XOR	B/W/L	$Rd \oplus Rs \rightarrow Rd$, $Rd \oplus \#IMM \rightarrow Rd$ Performs a logical exclusive OR operation on a general register and another general register or immediate data.
NOT	B/W/L	$\neg (Rd) \rightarrow (Rd)$ Takes the one's complement of general register contents.

Note: * Refers to the operand size.

B: Byte

W: Word

L: Longword

Table 2.6 Shift Instructions

Instruction	Size*	Function
SHAL SHAR	B/W/L	$Rd \text{ (shift)} \rightarrow Rd$ Performs an arithmetic shift on general register contents. 1-bit or 2-bit shifts are possible.
SHLL SHLR	B/W/L	$Rd \text{ (shift)} \rightarrow Rd$ Performs a logical shift on general register contents. 1-bit or 2-bit shifts are possible.
ROTL ROTR	B/W/L	$Rd \text{ (rotate)} \rightarrow Rd$ Rotates general register contents. 1-bit or 2-bit rotations are possible.
ROTXL ROTXR	B/W/L	$Rd \text{ (rotate)} \rightarrow Rd$ Rotates general register contents through the carry flag. 1-bit or 2-bit rotations are possible.

Note: * Refers to the operand size.

B: Byte

W: Word

L: Longword

Table 2.7 Bit Manipulation Instructions (1)

Instruction	Size*	Function
BSET	B	$1 \rightarrow \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle$ 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	$0 \rightarrow \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle$ 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	$\neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle$ 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	$\neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow Z$ 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	$C \wedge \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ 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	$C \wedge \neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ 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	$C \vee \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ 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	$C \vee \neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ 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: * Refers to the operand size.

B: Byte

Table 2.7 Bit Manipulation Instructions (2)

Instruction	Size*	Function
BXOR	B	$C \oplus (\text{<bit-No.> of <EAd>}) \rightarrow C$ XORs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIXOR	B	$C \oplus \neg (\text{<bit-No.> of <EAd>}) \rightarrow C$ XORs 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	$(\text{<bit-No.> of <EAd>}) \rightarrow C$ Transfers a specified bit in a general register or memory operand to the carry flag.
BILD	B	$\neg (\text{<bit-No.> of <EAd>}) \rightarrow C$ 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	$C \rightarrow (\text{<bit-No.> of <EAd>})$ Transfers the carry flag value to a specified bit in a general register or memory operand.
BIST	B	$\neg C \rightarrow (\text{<bit-No.> of <EAd>})$ 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: * 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* ¹	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* ² Moves the source operand contents or immediate data to CCR or EXR* ² . Although CCR and EXR* ² 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* ² → (EAd) Transfers CCR or EXR* ² contents to a general register or memory. Although CCR and EXR* ² 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* ² Logically ANDs the CCR or EXR* ² contents with immediate data.
ORC	B	CCR ∨ #IMM → CCR, EXR ∨ #IMM → EXR* ² Logically ORs the CCR or EXR* ² contents with immediate data.
XORC	B	CCR ⊕ #IMM → CCR, EXR ⊕ #IMM → EXR* ² Logically XORs the CCR or EXR* ² contents with immediate data.
NOP	—	PC + 2 → PC Only increments the program counter.

Notes: 1. Refers to the operand size.

B: Byte

W: Word

2. Supported only by the H8S/2268 Series.

Table 2.10 Block Data Transfer Instructions

Instruction	Size	Function
EEPMOV.B	—	if $R4L \neq 0$ then Repeat @ER5+ \rightarrow @ER6+ $R4L-1 \rightarrow R4L$ Until $R4L = 0$ else next;
EEPMOV.W	—	if $R4 \neq 0$ then Repeat @ER5+ • @ER6+ $R4-1 \bullet R4$ 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

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

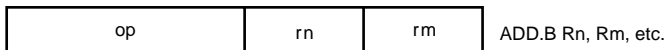
Figure 2.11 shows examples of instruction formats.

- **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. 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.

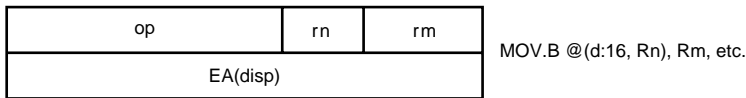
(1) Operation field only



(2) Operation field and register fields



(3) Operation field, register fields, and effective address extension



(4) Operation field, effective address extension, and condition field

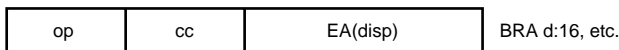


Figure 2.11 Instruction Formats (Examples)

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 instructions can use the register direct and immediate modes. Data transfer instructions can use all addressing modes except program-counter relative and memory indirect. Bit manipulation instructions use register direct, register indirect, or the 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 Register indirect with pre-decrement	@ERn+ @-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 specifies an 8-, 16-, or 32-bit general register containing 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 the operand on memory. 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 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

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 transfer instruction, or 4 for longword transfer instruction. For the word or longword transfer instructions, the register value should be even.

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 is 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 transfer instruction, or 4 for longword transfer instruction. For the 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. A 32-bit absolute address can access the entire address space.

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		Normal Mode*	Advanced Mode
Data address	8 bits (@aa:8)	H'FF00 to H'FFFF	H'FFFF00 to H'FFFFFF
	16 bits (@aa:16)	H'0000 to H'FFFF	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)		

Note: * Normal mode is not available in this LSI.

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

The instruction contains 8-bit (#xx:8), 16-bit (#xx:16), or 32-bit (#xx:32) immediate data as an operand.

The ADDS, SUBS, INC and DEC instructions contain immediate data implicitly. 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 is used in the Bcc and BSR instructions. An 8-bit or 16-bit displacement contained in the instruction is sign-extended and added to the 24-bit PC contents to generate a 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. This memory operand contains a branch address. The upper bits of the absolute address are all assumed to be 0, so the address range is 0 to 255 (H'0000 to H'00FF in normal mode*, H'000000 to H'0000FF in advanced mode). In normal mode, the memory operand is a word operand and the branch address is 16 bits long. 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 first part of the address range is also the exception vector area. For further details, refer to section 4, 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 instruction code to be fetched at the address preceding the specified address. (For further information, see section 2.5.2, Memory Data Formats.)

Note: * Normal mode is not available in this LSI.

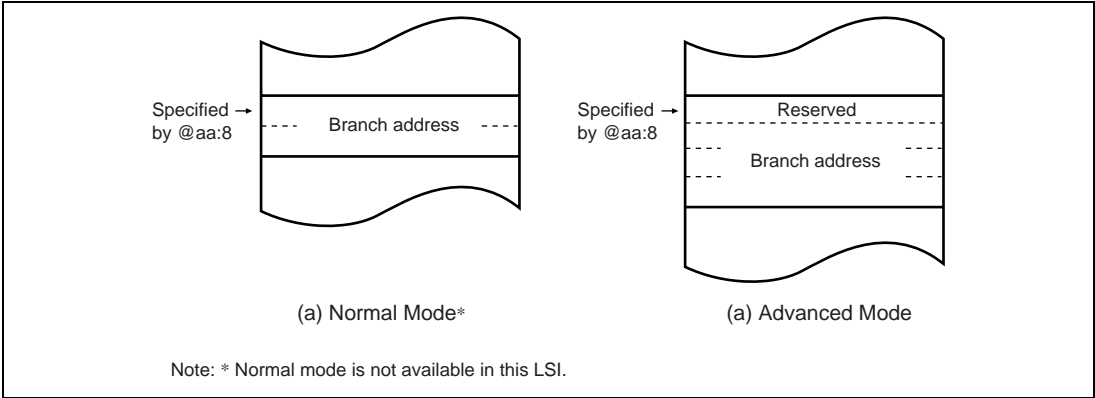


Figure 2.12 Branch Address Specification in Memory Indirect Mode

2.7.9 Effective Address Calculation

Table 2.13 indicates how effective addresses are calculated in each addressing mode. In normal mode the upper 8 bits of the effective address are ignored in order to generate a 16-bit address.

Table 2.13 Effective Address Calculation (1)

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

Operand Size	Offset
Byte	1
Word	2
Longword	4

Table 2.13 Effective Address Calculation (2)

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

Note: * Normal mode is not available in this LSI.

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 power-down state. Figure 2.13 indicates the state transitions.

- Reset State

In this state, the CPU and all on-chip peripheral modules are initialized and not operating. 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, refer to section 4, Exception Handling and section 23, Power-On Reset Circuit*.

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

Note: * Supported only by the H8S/2264 Series.

- 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, refer to section 4, Exception Handling.

- Program Execution State

In this state, the CPU executes program instructions in sequence.

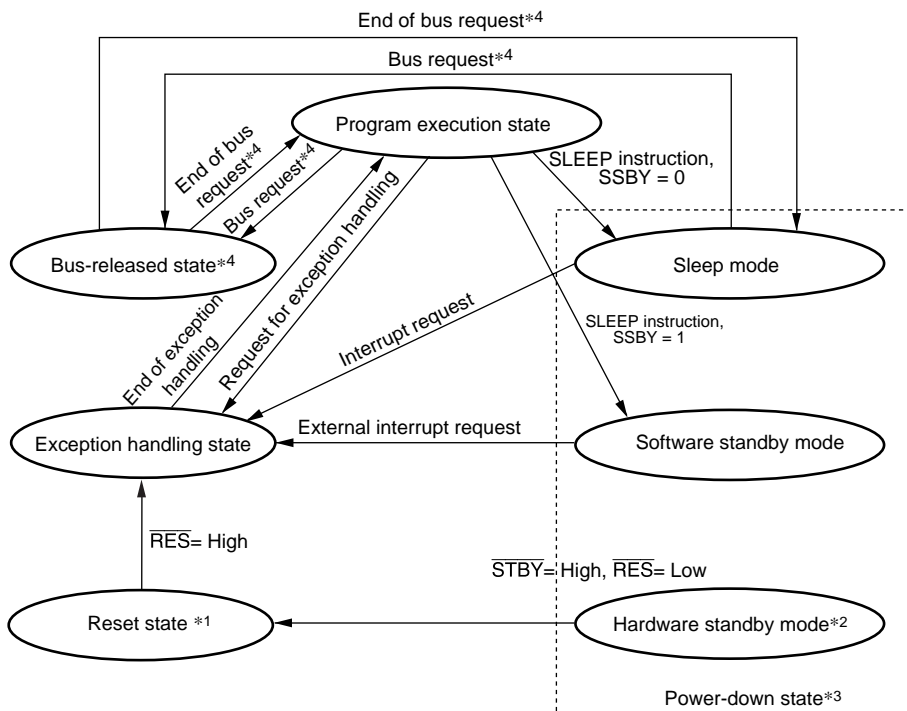
- Bus-Released State (H8S/2268 Series only)

In a product which has a bus master other than the CPU, such as a data transfer controller (DTC), 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.

- Power-down State

This is a power-down state in which the CPU stops operating. The program stop state occurs when a SLEEP instruction is executed or the CPU enters hardware standby mode. For further details, refer to section 22, Power-Down Modes.



- Notes: 1. From any state except hardware standby mode, a transition to the reset state occurs whenever \overline{RES} goes low. A transition can also be made to the reset state when the watchdog timer overflows.
2. From any state, a transition to hardware standby mode occurs when \overline{STBY} goes low.
3. Apart from these states, there are also the watch mode, subactive mode, and the subsleep mode. See section 22, Power-Down Modes.
4. Supported only by the H8S/2268 Series.

Figure 2.13 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 TAS instruction is not generated by the Hitachi H8S and H8/300 Series C/C++ compilers. If the TAS instruction is used as a user-defined intrinsic function, ensure that only register ER0, ER1, ER4, or ER5 is used.

2.9.2 STM/LDM Instruction

With the STM or LDM instruction, the ER7 register is used as the stack pointer, and thus cannot be used as a register that allows save (STM) or restore (LDM) operation.

With a single STM or LDM instruction, two to four registers can be saved or restored. The available registers are as follows:

For two registers: ER0 and ER1, ER2 and ER3, or ER4 and ER5

For three registers: ER0 to ER2, or ER4 to ER6

For four registers: ER0 to ER3

For the Hitachi H8S or H8/300 Series C/C++ Compiler, the STM/LDM instruction including ER7 is not created.

2.9.3 Bit Manipulation Instructions

The BSET, BCLR, BNOT, BST, and BIST instructions are used to read data in byte-wise, operate the data in bit-wise, and write the result of the bit-wise operation in bit-wise again. Therefore, special care is necessary to use these instructions for the registers and the ports that include write-only bit.

The BCLR instruction can be used to clear to 0 the flags in the internal I/O registers. In this time, if it is obvious that the flag has been set to 1 in the interrupt handler, there is no need to read the flag beforehand.

Section 3 MCU Operating Modes

3.1 Operating Mode Selection

This LSI supports only operating mode 7, that is, the advanced single-chip mode. The operating mode is determined by the setting of the mode pins (MD2 and MD1). Only mode 7 can be used in this LSI. The H8S/2268 Series does not include power-on reset circuit. Therefore, all mode pins must be fixed high. While the H8S/2264 Series includes a power-on reset circuit.. The power-on reset circuit can be enabled/disabled by mode pin settings.

Do not change the mode pin settings during operation.

Table 3.1 MCU Operating Mode Selection

MCU Operating Mode	MD2	MD1	CPU Operating Mode	Description	On-Chip ROM	External Data Bus		Power-on reset circuit
						Initial Width	Max. Width	
7	1	1	Advanced mode	Single-chip mode	Enabled	—	—	Disabled
7	0	1	Advanced mode	Single-chip mode	Enabled	—	—	Enabled*

Note: * Supported only by the H8S/2264 series.

3.2 Register Description

The following registers are related to the operating mode.

- Mode control register (MDCR)

3.2.1 Mode Control Register (MDCR)

MDCR monitors the current operating mode.

Bit	Bit Name	Initial Value	R/W	Descriptions
7	—	1	R/W	Reserved This bit is always read as 1 and cannot be modified.
6 to 3	—	All 0	—	Reserved These bits are always read as 0 and cannot be modified.
2	MDS2	—	R	Mode Select 2 and 1
1	MDS1	—	R	These bits indicate the input levels at pins MD2 and MD1 (the current operating mode). Bits MDS2 and MDS1 correspond to MD2 and MD1, respectively. MDS2 and MDS1 are read-only bits and they cannot be written to. The mode pin (MD2 and MD1) input levels are latched into these bits when MDCR is read. These latches are canceled by a reset. These latches are canceled by a reset.
0	—	1	—	Reserved This bit is always read as 1 and cannot be modified.

3.3 Operating Mode

The CPU can access a 16-Mbyte address space in advanced mode. On-chip ROM is valid and the external address cannot be used.

3.4 Pin Functions in Each Operating Mode

For details on pin functions in each operating mode, refer to section 1, Overview.

3.5 Address Map

Figures 3.1 and 3.2 show the address map in each operating mode.

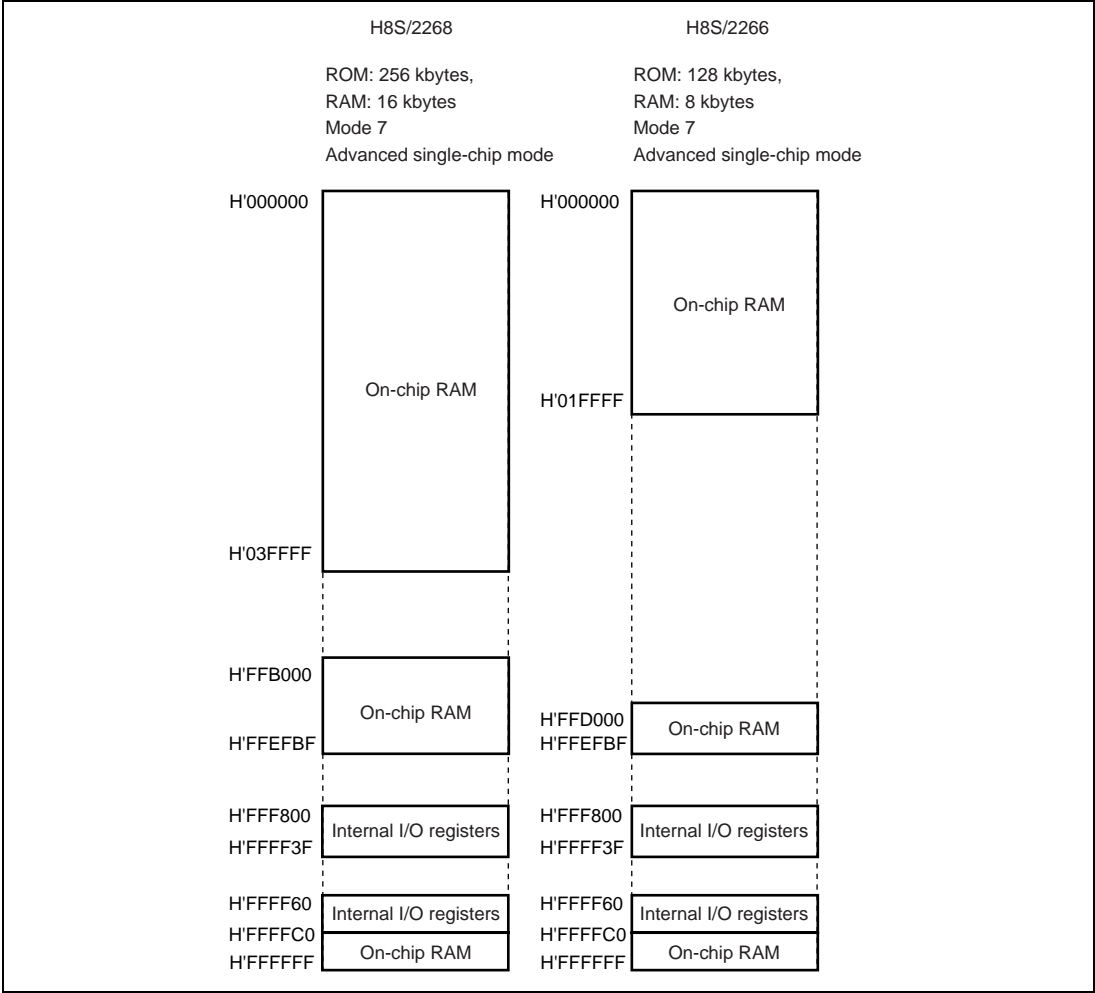


Figure 3.1 Address Map (1)

ROM: 128 kbytes,
RAM: 4 kbytes
Mode 7
Advanced single-chip mode

ROM: 64 kbytes,
RAM: 2 kbytes
Mode 7
Advanced single-chip mode

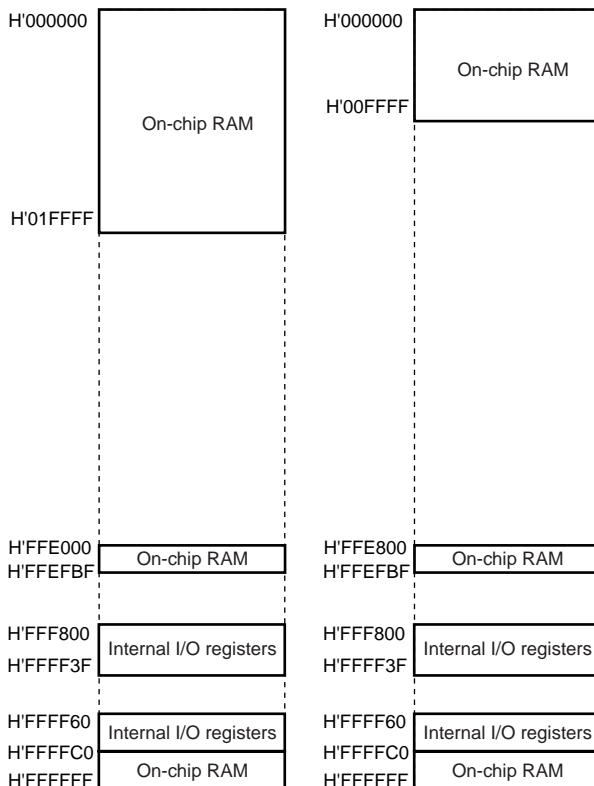


Figure 3.2 Address Map (2)

Section 4 Exception Handling

4.1 Exception Handling Types and Priority

As table 4.1 indicates, exception handling may be caused by a reset, trace*, trap instruction, or interrupt. Exception handling is prioritized as shown in table 4.1. If two or more exceptions occur simultaneously, they are accepted and processed in order of priority. Trap instruction exception handling requests are accepted at all times in program execution state.

Exception sources, the stack structure, and operation of the CPU vary depending on the interrupt control mode set by the INTM0 and INTM1 bits in SYSCR.

Table 4.1 Exception Types and Priority

Priority	Exception Type	Start of Exception Handling
High	Reset	Starts immediately after a low-to-high transition at the \overline{RES} pin, or when the watchdog timer overflows. The CPU enters the reset state when the \overline{RES} pin is low.
	Trace*	Starts when execution of the current instruction or exception handling ends, if the trace (T) bit in the EXR is set to 1. Traces are enabled only in interrupt control mode 2. Trace exception handling is not executed after execution of an RTE instruction.
	Interrupt	Starts when execution of the current instruction or exception handling ends, if an interrupt request has been issued. Interrupt detection is not performed on completion of ANDC, ORC, XORC, or LDC instruction execution, or on completion of reset exception handling.
Low	Trap instruction	Started by execution of a trap instruction (TRAPA). Trap instruction exception handling requests are accepted at all times in program execution state.

Note: * Supported only by the H8S/2268 Series.

4.2 Exception Sources and Exception Vector Table

Different vector addresses are assigned to different exception sources. Table 4.2 lists the exception sources and their vector addresses.

Table 4.2 Exception Handling Vector Table

Exception Source		Vector Number	Vector Address Advanced Mode* ¹
Reset		0	H'0000 to H'0003
Reserved for system use		1	H'0004 to H'0007
		2	H'0008 to H'000B
		3	H'000C to H'000F
		4	H'0010 to H'0013
Trace* ⁴		5	H'0014 to H'0017
Direct transitions* ³		6	H'0018 to H'001B
External interrupt (NMI)		7	H'001C to H'001F
Trap instruction (four sources)		8	H'0020 to H'0023
		9	H'0024 to H'0027
		10	H'0028 to H'002B
		11	H'002C to H'002F
Reserved for system use		12	H'0030 to H'0033
		13	H'0034 to H'0037
		14	H'0038 to H'003B
		15	H'003C to H'003F
External interrupt	IRQ0	16	H'0040 to H'0043
	IRQ1	17	H'0044 to H'0047
Reserved for system use		18	H'0048 to H'004B
External interrupt	IRQ3	19	H'004C to H'004F
	IRQ4	20	H'0050 to H'0053
	IRQ5* ⁴	21	H'0054 to H'0057

Exception Source	Vector Number	Vector Address Advanced Mode* ¹
Reserved for system use	22	H'0058 to H'005B
	23	H'005C to H'005F
Internal interrupt* ²	24	H'0060 to H'0063
	107	H'01AC to H'01AF
External interrupt WKPO to WKP7	108	H'01B0 to H'01B3
Internal interrupt	120	H'01E0 to H'01E3
	123	H'01EC to H'01EF

- Notes:
1. Lower 16 bits of the address.
 2. For details of internal interrupt vectors, see section 5.4.3, Interrupt Exception Handling Vector Table.
 3. For details on direct transitions, see section 22.10, Direct Transitions.
 4. Supported only by the H8S/2268 Series.

4.3 Reset

A reset has the highest exception priority.

When the $\overline{\text{RES}}$ pin goes low, all processing halts and this LSI enters the reset. A reset initializes the internal state of the CPU and the registers of on-chip peripheral modules. The interrupt control mode is 0 immediately after reset.

When the $\overline{\text{RES}}$ pin goes high from the low state, this LSI starts reset exception handling.

The chip can also be reset by overflow of the watchdog timer. For details see section 12, Watchdog Timer.

4.3.1 Reset Exception Handling

When the $\overline{\text{RES}}$ pin goes low, this LSI enters the reset. To ensure that this LSI is reset, hold the $\overline{\text{RES}}$ pin low for at least 20 ms at power-up. To reset the chip during operation, hold the $\overline{\text{RES}}$ pin low for at least 20 states. When the RES pin goes high after being held low for the necessary time, this LSI starts reset exception handling as follows. See section 23, Power-On Reset Circuit for the reset sequence when the power-on reset circuit is enabled in the H8S/2264 Series.

1. The internal state of the CPU and the registers of the on-chip peripheral modules are initialized, the T bit in EXR* is cleared to 0, and the I bits in EXR* and CCR is set to 1.
2. The reset exception handling vector address is read and transferred to the PC, and program execution starts from the address indicated by the PC.

Note: Supported only by the H8S/2268 Series.

Figure 4.1 shows an example of the reset sequence.

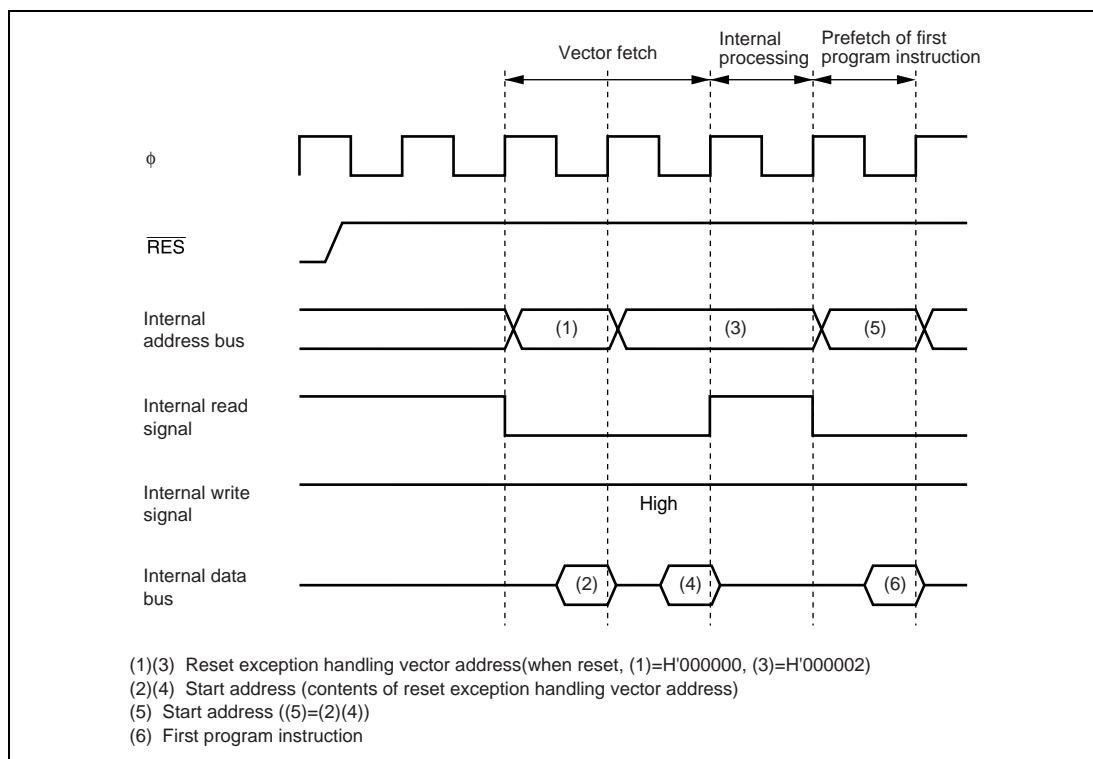


Figure 4.1 Reset Sequence (Advanced Mode with On-chip ROM Enabled)

4.3.2 Interrupts after Reset

If an interrupt is accepted after a reset and 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: SP`).

4.3.3 State of On-Chip Peripheral Modules after Reset Release

After reset release, MSTPCRA is initialized to H'3F, MSTPCRB to MSTPCRD are initialized to H'FF, and all modules except the DTC (only for the H8S/2268 Series) enter module stop mode. Consequently, on-chip peripheral module registers cannot be read or written to. Register reading and writing is enabled when the module stop mode is exited.

4.4 Traces (Supported only by the H8S/2268 Series)

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 of interrupt control modes, see section 5, 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 interrupt masking. Table 4.3 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. Interrupts are accepted even within the trace exception handling routine.

The T bit saved on the stack retains its value of 1, and when control is returned from the trace exception handling routine by the RTE instruction, trace mode resumes. Trace exception handling is not carried out after execution of the RTE instruction.

Table 4.3 Status of CCR and EXR after Trace Exception Handling

Interrupt Control Mode	CCR		EXR	
	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

4.5 Interrupts

Interrupts are controlled by the interrupt controller. The interrupt controller of the H8S/2268 Series has two interrupt control modes and can assign interrupts other than NMI to eight priority/mask levels to enable multiplexed interrupt control. For details, refer to section 5, Interrupt Controller.

Interrupt exception handling is conducted as follows:

1. The values in the program counter (PC), condition code register (CCR), and extended control register (EXR)* are saved to 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 begins from that address.

Note: * Supported only by the H8S/2268 Series.

4.6 Trap Instruction

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.

Trap instruction exception handling is conducted as follows:

1. The values in the program counter (PC), condition code register (CCR), and extended control register (EXR)* are saved to the stack.
2. The interrupt mask bit is updated and the T bit* is cleared.
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 4.4 shows the status of CCR and EXR* after execution of trap instruction exception handling.

Table 4.4 Status of CCR and EXR* after Trap Instruction Exception Handling

Interrupt Control Mode	CCR		EXR*	
	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

Note: * Supported only by the H8S/2268 series.

4.7 Stack Status after Exception Handling

Figure 4.2 shows the stack after completion of trap instruction exception handling and interrupt exception handling.

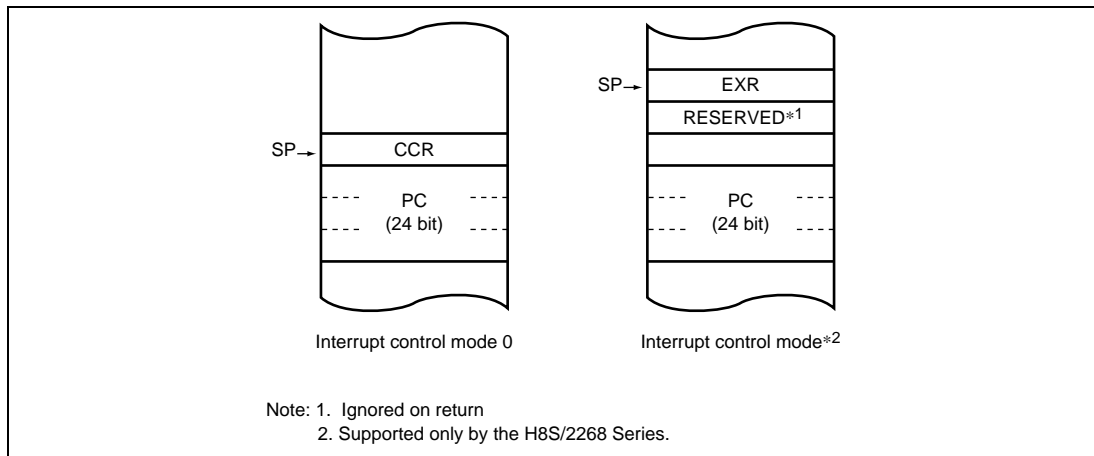


Figure 4.2 Stack Status after Exception Handling (Advanced Mode)

4.8 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 4.3 shows an example of what happens when the SP value is odd.

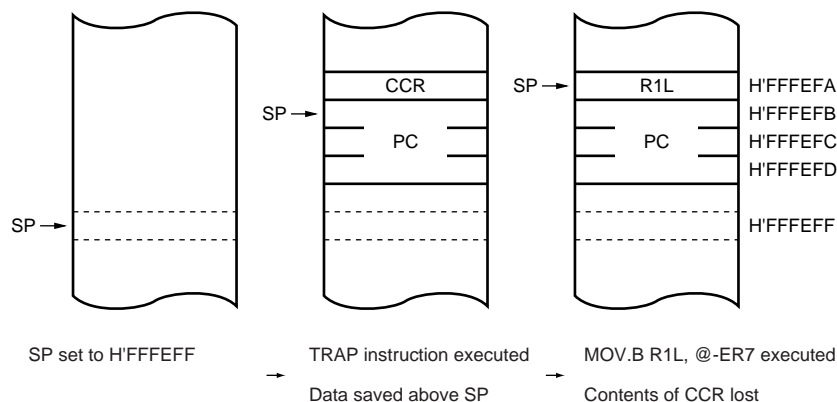


Figure 4.3 Operation when SP Value Is Odd

Section 5 Interrupt Controller

5.1 Features

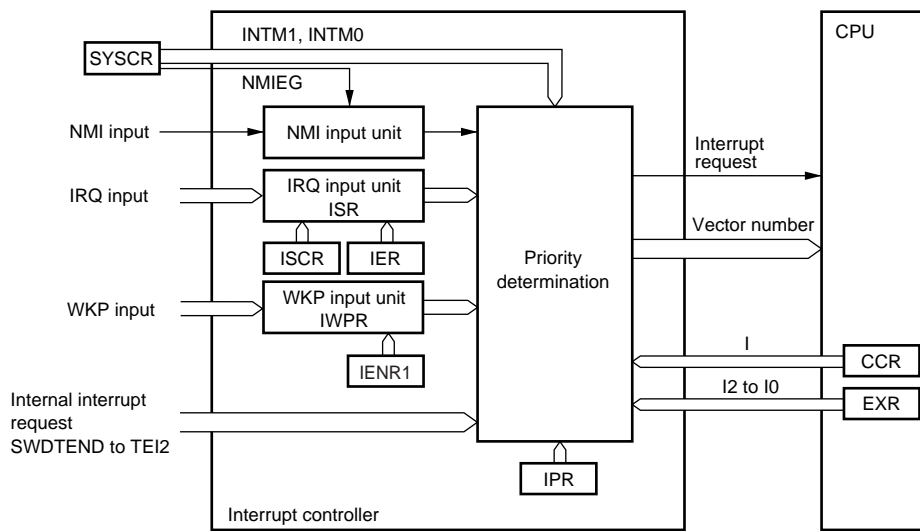
This LSI controls interrupts with the interrupt controller. The interrupt controller has the following features:

- Two interrupt control modes (H8S/2268 Series only)
 - Any of two interrupt control modes can be set by means of the INTM1 and INTM0 bits in the system control register (SYSCR).
- Priorities settable with IPR (H8S/2268 Series only)
 - An interrupt priority register (IPR) is provided for setting interrupt priorities. Eight priority levels can be set for each module for all interrupts except NMI. NMI is assigned the highest priority level of 8, and can be accepted at all times.
- Independent vector addresses
 - All interrupt sources except WKP7 to WKP0 are assigned independent vector addresses, making it unnecessary for the source to be identified in the interrupt handling routine.
- External interrupts

H8S/2268 Series: 14 (NMI, IRQ5 to IRQ3, IRQ1, IRQ0, and WKP7 to WKP0)
H8S/2264 Series: 13 (NMI, IRQ4, IRQ3, IRQ1, IRQ0, and WKP7 to WKP0)

 - 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 edge detection, or level sensing, can be independently selected for IRQ5 to IRQ3, IRQ1, and IRQ0.
WKP7 to WKP0 are accepted at a falling edge
- DTC control (H8S/2268 Series only)
 - The DTC can be activated by an interrupt request.

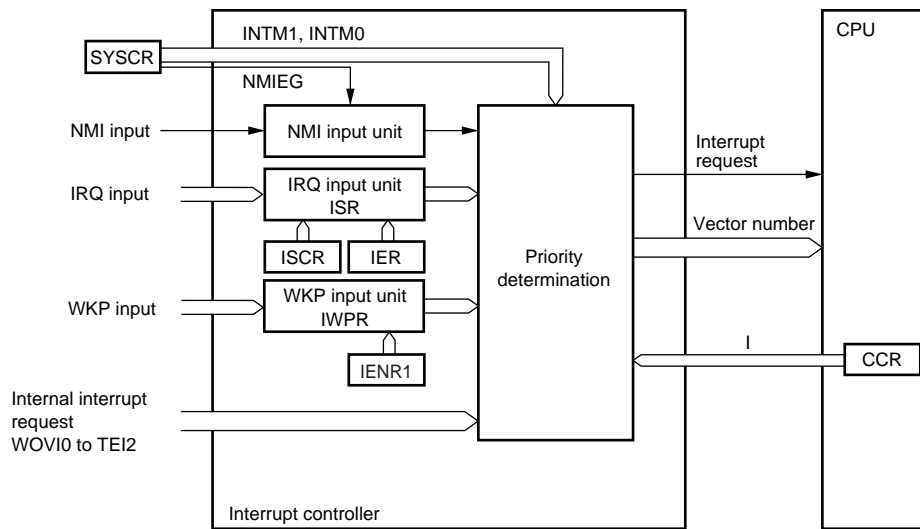
A block diagram of the interrupt controller for the H8S/2268 Series is shown in figure 5.1, and that for the H8S/2264 Series is shown in figure 5.2



Legend

ISCR : IRQ sense control register
 IER : IRQ enable register
 ISR : IRQ status register
 IENR1 : Interrupt enable register1
 IWPR : Wakeup interrupt request register
 IPR : Interrupt priority register
 SYSCR : System control register

Figure 5.1 Block Diagram of Interrupt Controller for H8S/2268 Series



Legend

ISCR : IRQ sense control register
 IER : IRQ enable register
 ISR : IRQ status register
 IENR1 : Interrupt enable register1
 IWPR : Wakeup interrupt request register
 SYSCR : System control register

Figure 5.2 Block Diagram of Interrupt Controller for H8S/2264 Series

5.2 Input/Output Pins

Table 5.1 summarizes the pins of the interrupt controller.

Table 5.1 Pin Configuration

Name	I/O	Function
NMI	Input	Nonmaskable external interrupt Rising or falling edge can be selected
$\overline{\text{IRQ5}}^*$	Input	Maskable external interrupts
$\overline{\text{IRQ4}}$	Input	Rising, falling, or both edges, or level sensing, can be selected
$\overline{\text{IRQ3}}$	Input	
$\overline{\text{IRQ2}}$	Input	
$\overline{\text{IRQ1}}$	Input	
$\overline{\text{IRQ0}}$	Input	
$\overline{\text{WKP7}}$	Input	Maskable external interrupts
$\overline{\text{WKP6}}$	Input	Accepted at a falling edge
$\overline{\text{WKP5}}$	Input	
$\overline{\text{WKP4}}$	Input	
$\overline{\text{WKP3}}$	Input	
$\overline{\text{WKP2}}$	Input	
$\overline{\text{WKP1}}$	Input	
$\overline{\text{WKP0}}$	Input	

Note: * Supported only by the H8S/2268 Series.

5.3 Register Descriptions

The interrupt controller has the following registers.

- System control register (SYSCR)
- 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 I (IPRI)*
- Interrupt priority register J (IPRJ)*
- Interrupt priority register K (IPRK)*
- Interrupt priority register L (IPRL)*
- Interrupt priority register M (IPRM)*
- Interrupt priority register O (IPRO)*
- Wakeup interrupt request register (IWPR)
- Interrupt enable register 1 (IENR1)

Note:* Supported only by the H8S/2268 Series.

5.3.1 System Control Register (SYSCR)

SYSCR selects the interrupt control mode and the detected edge for NMI.

Bit	Bit Name	Initial Value	R/W	Descriptions
7	—	0	R/W	Reserved The write value should always be 0.
6	—	0	—	Reserved This bit is always read as 0, and cannot be modified.
5	INTM1	0	R/W	Interrupt Control Mode 1 and 0
4	INTM0	0	R/W	H8S/2268 Series: These bits select the control mode of the interrupt controller. 00: Interrupt control mode 0 (interrupts are controlled by the I bit.) 01: Setting prohibited 10: Interrupt control mode 2 (Interrupts are controlled by the I2 to I0 bits and IPR.) 11: Setting prohibited H8S/2264 Series: The write value should always be 0. 00: Interrupt control mode 0 (interrupts are controlled by the I bit.) 01: Setting prohibited 10: Setting prohibited 11: Setting prohibited
3	NMIEG	0	R/W	NMI Edge Select Selects the valid edge of the NMI interrupt input. 0: An interrupt is requested at the falling edge of NMI input 1: An interrupt is requested at the rising edge of NMI input
2	—	0	R/W	Reserved The write value should always be 0.
1	—	0	—	Reserved This bit is always read as 0, and cannot be modified.
0	—	1	R/W	Reserved The write value should always be 0.

5.3.2 Interrupt Priority Registers A to G, I to M, and O (IPRA to IPRG, IPRI to IPRM, IPRO) (H8S/2268 Series Only)

The IPR registers are thirteen 8-bit readable/writable registers that set priorities (levels 7 to 0) for interrupts other than NMI. The correspondence between interrupt sources and IPR settings is shown in table 5.2. Setting a value in the range from H'0 to H'7 in the 3-bit groups of bits 0 to 2 and 4 to 6 sets the priority of the corresponding interrupt.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	—	Reserved This bit is always read as 0, and cannot be modified.
6	IPR6	1	R/W	Sets the priority of the corresponding interrupt source
5	IPR5	1	R/W	000: Priority level 0 (Lowest)
4	IPR4	1	R/W	001: Priority level 1 010: Priority level 2 011: Priority level 3 100: Priority level 4 101: Priority level 5 110: Priority level 6 111: Priority level 7 (Highest)
3	—	0	—	Reserved This bit is always read as 0, and cannot be modified.
2	IPR2	1	R/W	Sets the priority of the corresponding interrupt source.
1	IPR1	1	R/W	000: Priority level 0 (Lowest)
0	IPR0	1	R/W	001: Priority level 1 010: Priority level 2 011: Priority level 3 100: Priority level 4 101: Priority level 5 110: Priority level 6 111: Priority level 7 (Highest)

5.3.3 IRQ Enable Register (IER)

IER controls the enabling and disabling of interrupt requests $\overline{\text{IRQ}}_n$ (H8S/2268 Series: n = 5 to 3, 1, 0; H8S/2264 Series: n = 4, 3, 1, 0).

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	All 0	R/W	Reserved The write value should always be 0.
5	IRQ5E	0	R/W	H8S/2268 Series: IRQ5 Enable The IRQ5 interrupt request is enabled when this bit is 1. H8S/2264 Series: Reserved The write value should always be 0.
4	IRQ4E	0	R/W	IRQ4 Enable The IRQ4 interrupt request is enabled when this bit is 1.
3	IRQ3E	0	R/W	IRQ3 Enable The IRQ3 interrupt request is enabled when this bit is 1.
2	—	0	R/W	Reserved The write value should always be 0.
1	IRQ1E	0	R/W	IRQ1 Enable The IRQ1 interrupt request is enabled when this bit is 1.
0	IRQ0E	0	R/W	IRQ0 Enable The IRQ0 interrupt request is enabled when this bit is 1.

5.3.4 IRQ Sense Control Registers H and L (ISCRH and ISCR L)

The ISCR registers select the source that generates an interrupt request at pins $\overline{\text{IRQ}}_n$ (H8S/2268 Series: n = 5 to 3, 1, 0; H8S/2264 Series: n = 4, 3, 1, 0). Specifiable sources are the falling edge, rising edge, or both edge detection, and level sensing.

Bit	Bit Name	Initial Value	R/W	Description
15 to 12	—	All 0	R/W	Reserved The write value should always be 0.
11	IRQ5SCB	0	R/W	H8S/2268 Series:
10	IRQ5SCA	0	R/W	IRQ5 Sense Control B IRQ5 Sense Control A 00: Interrupt request generated at $\overline{\text{IRQ}}_5$ input level low 01: Interrupt request generated at falling edge of $\overline{\text{IRQ}}_5$ input 10: Interrupt request generated at rising edge of $\overline{\text{IRQ}}_5$ input 11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ}}_5$ input H8S/2264 Series: Reserved The write value should always be 0.
9	IRQ4SCB	0	R/W	IRQ4 Sense Control B
8	IRQ4SCA	0	R/W	IRQ4 Sense Control A 00: Interrupt request generated at $\overline{\text{IRQ}}_4$ input level low 01: Interrupt request generated at falling edge of $\overline{\text{IRQ}}_4$ input 10: Interrupt request generated at rising edge of $\overline{\text{IRQ}}_4$ input 11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ}}_4$ input

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ3SCB	0	R/W	IRQ3 Sense Control B
6	IRQ3SCA	0	R/W	IRQ3 Sense Control A
				00: Interrupt request generated at $\overline{\text{IRQ3}}$ input level low
				01: Interrupt request generated at falling edge of $\overline{\text{IRQ3}}$ input
				10: Interrupt request generated at rising edge of $\overline{\text{IRQ3}}$ input
				11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ3}}$ input
5, 4	—	All 0	R/W	Reserved
				The write value should always be 0.
3	IRQ1SCB	0	R/W	IRQ1 Sense Control B
2	IRQ1SCA	0	R/W	IRQ1 Sense Control A
				00: Interrupt request generated at $\overline{\text{IRQ1}}$ input level low
				01: Interrupt request generated at falling edge of $\overline{\text{IRQ1}}$ input
				10: Interrupt request generated at rising edge of $\overline{\text{IRQ1}}$ input
				11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ1}}$ input
1	IRQ0SCB	0	R/W	IRQ0 Sense Control B
0	IRQ0SCA	0	R/W	IRQ0 Sense Control A
				00: Interrupt request generated at $\overline{\text{IRQ0}}$ input level low
				01: Interrupt request generated at falling edge of $\overline{\text{IRQ0}}$ input
				10: Interrupt request generated at rising edge of $\overline{\text{IRQ0}}$ input
				11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ0}}$ input

5.3.5 IRQ Status Register (ISR)

ISR indicates the status of $\overline{\text{IRQn}}$ (H8S/2268 Series: n = 5 to 3, 1, 0; H8S/2264 Series: n = 4, 3, 1, 0) interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	All 0	R/W	Reserved The write value should always be 0.
5	IRQ5F	0	R/(W)* ¹	H8S/2268 Series: IRQ5 Flag Indicates the status of an IRQ5 interrupt request. [Setting condition] When the interrupt source selected by the ISCR registers occurs [Clearing conditions] Cleared by reading IRQ5F flag when IRQ5F = 1, then writing 0 to IRQ5F flag When interrupt exception handling is executed when low-level detection is set and $\overline{\text{IRQ5}}$ input is high level When IRQ5 interrupt exception handling is executed when falling, rising, or both-edge detection is set When the DTC is activated by an IRQ5 interrupt, and the DISEL bit in MRB of the DTC is cleared to 0 H8S/2264 Series: Reserved The write value should always be 0.

Bit	Bit Name	Initial Value	R/W	Description
4	IRQ4F	0	R/(W)* ²	IRQ4 and IRQ3 Flags
3	IRQ3F	0	R/(W)* ²	<p>Indicate the status of IRQ4 and IRQ3 interrupt requests.</p> <p>[Setting condition]</p> <p>When the interrupt source selected by the ISCR registers occurs</p> <p>[Clearing conditions]</p> <p>Cleared by reading IRQnF flag when IRQnF = 1, then writing 0 to IRQnF flag</p> <p>When interrupt exception handling is executed when low-level detection is set and $\overline{\text{IRQn}}$ input is high</p> <p>When IRQn interrupt exception handling is executed when falling, rising, or both-edge detection is set</p> <p>When the DTC is activated by an IRQn interrupt, and the DISEL bit in MRB of the DTC is cleared to 0 (H8S/2268 Series only)</p>
2	—	0	R/W	<p>Reserved</p> <p>The write value should always be 0.</p>
1	IRQ1F	0	R/(W)* ²	IRQ1 and IRQ0 Flags
0	IRQ0F	0	R/(W)* ²	<p>Indicate the status of IRQ1 and IRQ0 interrupt requests.</p> <p>[Setting condition]</p> <p>When the interrupt source selected by the ISCR registers occurs</p> <p>[Clearing conditions]</p> <p>Cleared by reading IRQnF flag when IRQnF = 1, then writing 0 to IRQnF flag</p> <p>When interrupt exception handling is executed when low-level detection is set and $\overline{\text{IRQn}}$ input is high</p> <p>When IRQn interrupt exception handling is executed when falling, rising, or both-edge detection is set</p> <p>When the DTC is activated by an IRQn interrupt, and the DISEL bit in MRB of the DTC is cleared to 0 (H8S/2268 Series only)</p>

Notes: 1. In the H8S/2268 Series, only 0 can be written to this bit to clear the flag. In the H8S/2264 Series, this bit is readable/writable.

2. Only 0 can be written to this bit to clear the flag.

5.3.6 Wakeup Interrupt Request Register (IWPR)

IWPR indicates the status of WKP7 to WKP0 interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	IWPF7	0	R/(W)*	Wakeup Interrupt Request Flags
6	IWPF6	0	R/(W)*	Indicate the status of WKP7 to WKP0 interrupt requests.
5	IWPF5	0	R/(W)*	
4	IWPF4	0	R/(W)*	[Setting condition]
3	IWPF3	0	R/(W)*	When $\overline{\text{WKP7}}$ to $\overline{\text{WKP0}}$ pins are set as wakeup inputs and these pins have a falling edge.
2	IWPF2	0	R/(W)*	
1	IWPF1	0	R/(W)*	[Clearing condition]
0	IWPF0	0	R/(W)*	When this bit reads 1 and then write 0.

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

5.3.7 Interrupt Enable Register 1 (IENR1)

IENR1 enables/disables wakeup interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	IENWP	0	R/W	Wakeup Interrupt Enable Enables/disables WKP7 to WKP0 interrupt requests 0: $\overline{\text{WKP7}}$ to $\overline{\text{WKP0}}$ pin interrupt requests are disabled. 1: $\overline{\text{WKP7}}$ to $\overline{\text{WKP0}}$ pin interrupt requests are enabled.
6 to 1	—	All 0	—	Reserved These bits are always read as 0 and cannot be modified.
0	—	0	R/W	Reserved This bit should always be 0 when it is read.

5.4 Interrupt Sources

5.4.1 External Interrupts

There are 14 external interrupts for the H8S/2268 Series: NMI, IRQ5 to IRQ3, IRQ1, IRQ0, and WKP7 to WKP0, and 13 external interrupts for the H8S/2264 Series: NMI, IRQ4, IRQ3, IRQ1, IRQ0, and WKP7 to WKP0. These interrupts can be used to restore this LSI from software standby mode.

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

IRQn Interrupts (H8S/2268 Series: n = 5 to 3, 1 and 0; H8S/2264 Series: n = 4, 3, 1 and 0): IRQn interrupts are requested by an input signal at IRQn pins. IRQn interrupts have the following features:

- Using ISCR, it is possible to select whether an interrupt is generated by a low level, falling edge, rising edge, or both edges, at IRQn pins.
- Enabling or disabling of IRQn interrupt requests can be selected with IER.
- The interrupt priority level can be set with IPR. (H8S/2268 Series only)
- The status of IRQn interrupt requests is indicated in ISR. ISR flags can be cleared to 0 by software.

A block diagram of IRQn interrupts is shown in figure 5.3.

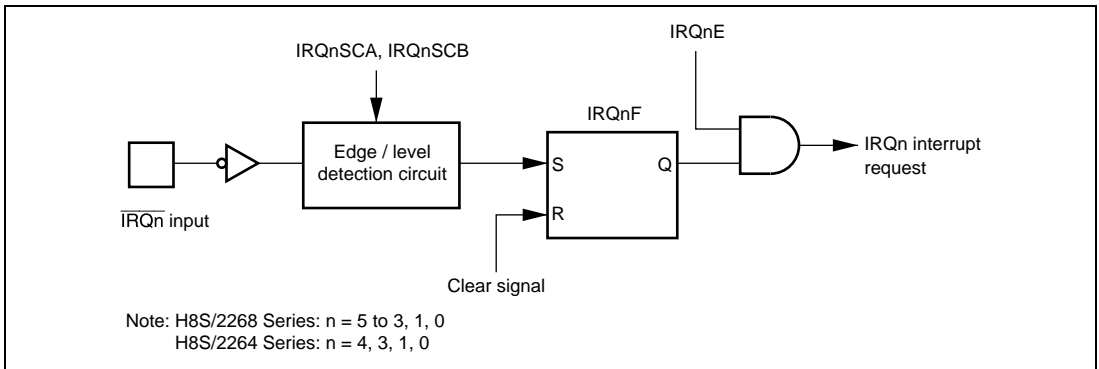


Figure 5.3 Block Diagram of IRQn Interrupts

The set timing for IRQnF is shown in figure 5.4.

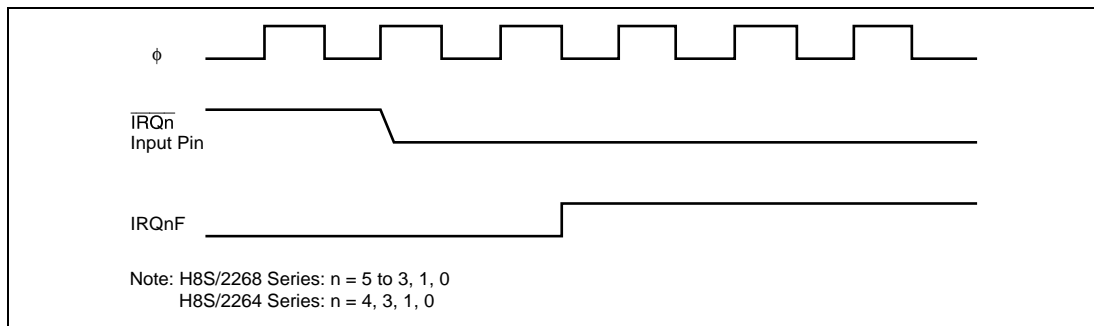


Figure 5.4 Set Timing for IRQnF

The detection of IRQn interrupts does not depend on whether the relevant pin has been set for input or output. However, when a pin is used as an external interrupt input pin, do not clear the corresponding DDR to 0; and use the pin as an I/O pin for another function. IRQnF interrupt request flag is set to 1 when the setting condition is satisfied, regardless of IER settings. Accordingly, refer to only necessary flags.

WKP7 to WKP0 Interrupts: WKP7 to WKP0 interrupts are requested by falling edge input signal at $\overline{\text{WKP7}}$ to $\overline{\text{WKP0}}$ pins. WKP7 to WKP0 interrupts have the following features:

- WPCR selects whether the $\text{PJn}/\overline{\text{WKPn}}/\text{SEGn+1}$ pin is used as the PJn pin or $\overline{\text{WKPn}}$ pin when the $\text{PJn}/\overline{\text{WKPn}}/\text{SEGn+1}$ pin is not used as the SEGn+1 pin. (n=7 to 0)
For pin switching, see 9.8.5 Wakeup Control Register (WPCR).
- IENR1 can be used to select enabling or disabling of WKP7 to WKP0 interrupt requests.
- IPR sets the interrupt priority level. (H8S/2268 Series only)
- IWPR indicates the status of WKP7 to WKP0 interrupt requests. IWPR flag can be cleared to 0 by software.

The block diagram of interrupts WKP7 to WKP0 is shown in figure 5.5.

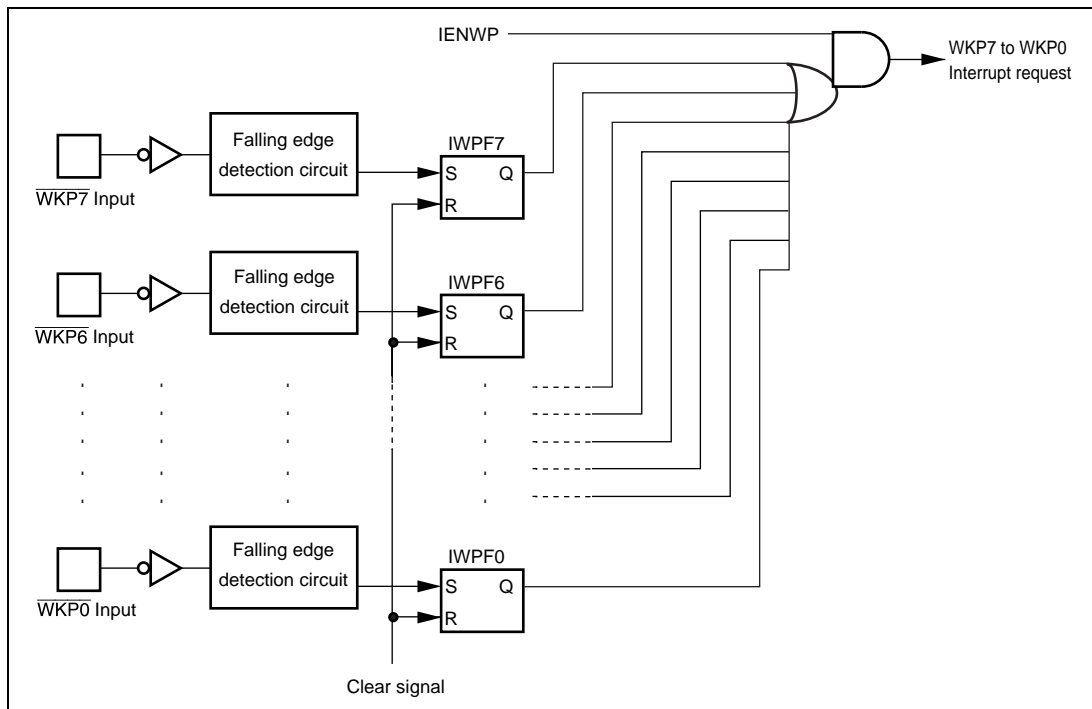


Figure 5.5 Block Diagram of Interrupts WKP7 to WKP0

Figure 5.6 shows the IWPFn setting timing.

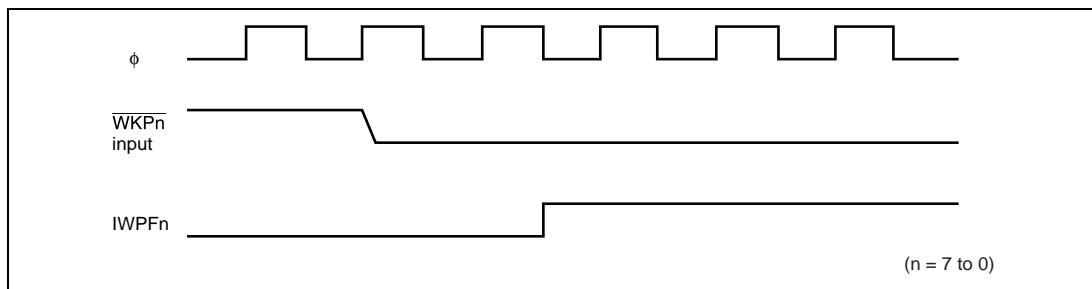


Figure 5.6 IWPFn Setting Timing

The vector number for the WKP7 to WKP0 interrupt exception handling is 108. Eight interrupt pins are assigned to one vector number. Accordingly, determine the source using an exception handling routine.

The detection of interrupts WKP7 to WKP0 does not depend on whether the relevant pin has been set for input or output. However, when a pin is used as an external interrupt input pin, do not clear the corresponding DDR to 0; and use the pin as an I/O pin for another function. IRQnF interrupt request flag is set to 1 when the setting condition is satisfied, regardless of IER settings. Accordingly, refer to only necessary flags.

5.4.2 Internal Interrupts

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. If both of these are set to 1 for a particular interrupt source, an interrupt request is issued to the interrupt controller.

5.4.3 Interrupt Exception Handling Vector Table

Table 5.2 shows interrupt exception handling sources, vector addresses, and interrupt priorities. For default priorities, the lower the vector number, the higher the priority.

Priorities among modules can be set by means of the IPR. (H8S/2268 Series only)

Modules set at the same priority will conform to their default priorities. Priorities within a module are fixed.

Table 5.2 Interrupt Sources, Vector Addresses, and Interrupt Priorities

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address* ¹	IPR* ^{2,3}	Priority
			Advanced Mode		
External Pin	NMI	7	H'001C		High ↑
	IRQ0	16	H'0040	IPRA6 to IPRA4	
	IRQ1	17	H'0044	IPRA2 to IPRA0	
	Reserved	18	H'0048	IPRB6 to IPRB4	
	IRQ3	19	H'004C		
	IRQ4	20	H'0050	IPRB2 to IPRB0	
	IRQ5* ³	21	H'0054		
	Reserved	22 23	H'0058 H'005C	IPRC6 to IPRC4	
DTC* ³	SWDTEND (completion of software initiation data transfer)	24	H'0060	IPRC2 to IPRC0	↓ Low
Watchdog timer 0	WOVI0 (interval timer 0)	25	H'0064	IPRD6 to IPRD4	
PC break* ³	PC break	27	H'006C	IPRE6 to IPRE4	
A/D	ADI (completion of A/D 28 conversion)		H'0070	IPRE2 to IPRE0	
Watchdog timer 1	WOVI1 (interval timer 1)	29	H'0074		
—	Reserved	30 31	H'0078 H'007C		
TPU channel 0* ³	TGI0A (TGR0A input capture/compare-match)	32	H'0080	IPRF6 to IPRF4	
	TGI0B (TGR0B input capture/compare-match)	33	H'0084		
	TGI0C (TGR0C input capture/compare-match)	34	H'0088		
	TGI0D (TGR0D input capture/compare-match)	35	H'008C		

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address* ¹	IPR* ² * ³	Priority
			Advanced Mode		
—	TCI0V (overflow 0)	36	H'0090		High
	Reserved	37	H'0094		
		38	H'0098		
		39	H'009C		
TPU channel 1	TGI1A (TGR1A input capture/compare-match)	40	H'00A0	IPRF2 to IPRF0	
	TGI1B (TGR1B input capture/compare-match)	41	H'00A4		
	TCI1V (overflow 1)	42	H'00A8		
	TCI1U (underflow 1) * ³	43	H'00AC		
TPU channel 2	TGI2A (TGR2A input capture/compare-match)	44	H'00B0	IPRG6 to IPRG4	
	TGI2B (TGR2B input capture/compare-match)	45	H'00B4		
	TCI2V (overflow 2)	46	H'00B8		
	TCI2U (underflow 2) * ³	47	H'00BC		
8-bit timer channel 0	CMIA0 (compare-match A0)	64	H'0100	IPRI6 to IPRI4	
	CMIB0 (compare-match B0)	65	H'0104		
	OVI0 (overflow 0)	66	H'0108		
—	Reserved	67	H'010C		Low

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address* ¹	IPR* ² * ³	Priority
			Advanced Mode		
8-bit timer channel 1	CMIA1 (compare-match A1)	68	H'0110	IPRI2 to IPRI0	<div>High</div> <div></div> <div>Low</div>
	CMIB1 (compare-match B1)	69	H'0114		
	OVI1 (overflow 1)	70	H'0118		
—	Reserved	71	H'011C		
SCI channel 0	ERI0 (receive error 0)	80	H'0140	IPRJ2 to IPRJ0	
	RXI0 (receive completion 0)	81	H'0144		
	TXI0 (transmit data empty 0)	82	H'0148		
	TEI0 (transmit end 0)	83	H'014C		
SCI channel 1	ERI1 (receive error 1)	84	H'0150	IPRK6 to IPRK4	
	RXI1 (receive completion 1)	85	H'0154		
	TXI1 (transmit data empty 1)	86	H'0158		
	TEI1 (transmit end 1)	87	H'015C		
8-bit timer channel 2* ³	CMIA2 (compare-match A2)	92	H'0170	IPRL6 to IPRL4	
	CMIB2 (compare-match B2)	93	H'0174		
	OVI2 (overflow 2)	94	H'0178		
—	Reserved	95	H'017C		

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address* ¹	IPR* ² * ³	Priority
			Advanced Mode		
8-bit timer channel 3* ³	CMIA3 (compare-match A3)	96	H'0180	IPRL2 to IPRL0	<div>High</div> <div>↑</div> <div>↓</div> <div>Low</div>
	CMIB3 (compare-match B3)	97	H'0184		
	OVI3 (overflow 3)	98	H'0188		
—	Reserved	99	H'018C		
IIC channel 0 (option)	IIC10 (1-byte transmission/reception completion)	100	H'0190		
	Reserved	101	H'0194		
IIC channel 1* ³ (option)	IIC11 (1-byte transmission/reception completion)	102	H'0198		
	Reserved	103	H'019C		
8-bit reload timer channels 4 to 7* ³	OVI4 (overflow 4)	104	H'01A0		
	OVI5 (overflow 5)	105	H'01A4		
	OVI6 (overflow 6)	106	H'01A8		
	OVI7 (overflow 7)	107	H'01AC		
External pins	WKP7 to WKP0	108	H'01B0	IPRM2 to IPRM0	
SCI channel 2	ERI2 (receive error 2)	120	H'01E0	IPRO6 to IPRO4	
	RXI2 (receive completion 2)	121	H'01E4		
	TXI2 (transmit data empty 2)	122	H'01E8		
	TEI2 (transmit end 2)	123	H'01EC		

Notes: 1. Lower 16 bits of the start address.

2. IPR6 to IPR4, and IPR2 to IPR0 bits are reserved, because these bits have no corresponding interruption. These bits are always read as 0 and cannot be modified.

3. Supported only by the H8S/2268 Series.

5.5 Operation

5.5.1 Interrupt Control Modes and Interrupt Operation

Interrupt operations in the H8S/2268 differ depending on the interrupt control mode.

NMI interrupts are accepted at all times except in the reset state and the hardware standby state. In the case of IRQ interrupts, WKP interrupts and on-chip peripheral module interrupts, an enable bit is provided for each interrupt. Clearing an enable bit to 0 disables the corresponding interrupt request. Interrupt sources for which the enable bits are set to 1 are controlled by the interrupt controller.

Table 5.3 shows the interrupt control modes.

The interrupt controller performs interrupt control according to the interrupt control mode set by the INTM1 and INTM0 bits in SYSCR, the priorities set in IPR*, and the masking state indicated by the I bit in the CPU's CCR, and bits I2 to I0 in EXR*.

Table 5.3 Interrupt Control Modes

Interrupt Control Mode	SYSCR		Priority Setting Registers*	Interrupt Mask Bits	Description
	INTM1	INTM0			
0	0	0	—	I	Interrupt mask control is performed by the I bit.
—	—	1	—	—	Setting prohibited
2*	1	0	IPR	I2 to I0	8-level interrupt mask control is performed by bits I2 to I0. 8 priority levels can be set with IPR.
—	—	1	—	—	Setting prohibited

Note: * Supported only by the H8S/2268 Series.

Figures 5.7 and 5.8 show block diagrams of the priority decision circuits for the H8S/2268 Series and H8S/2264 Series, respectively.

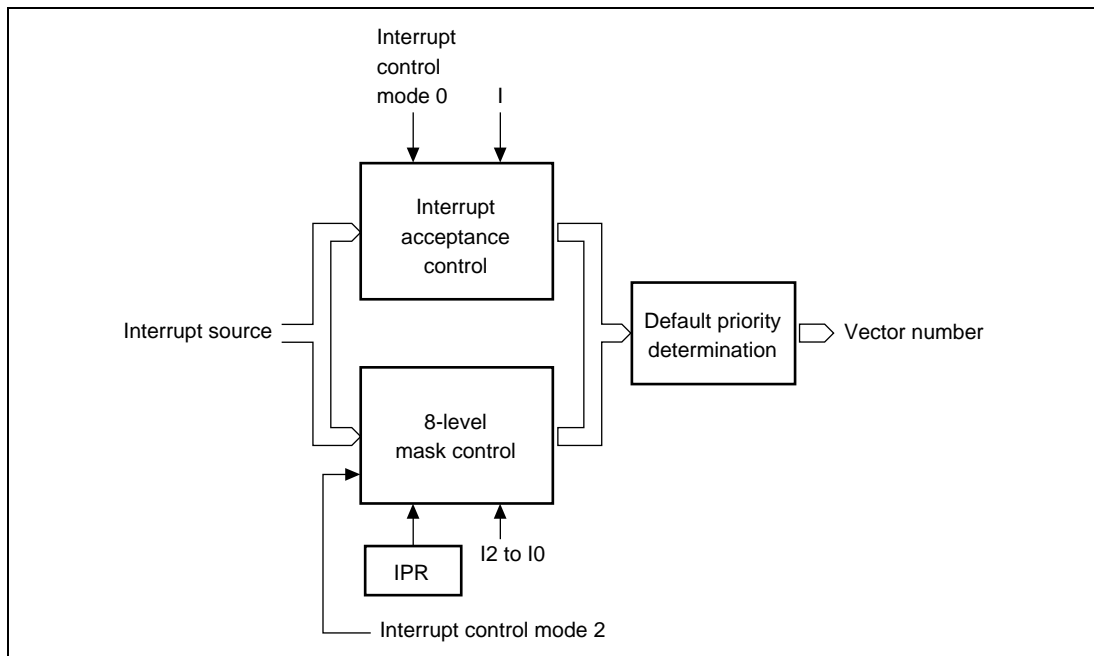


Figure 5.7 Block Diagram of Interrupt Control Operation for H8S/2268 Series

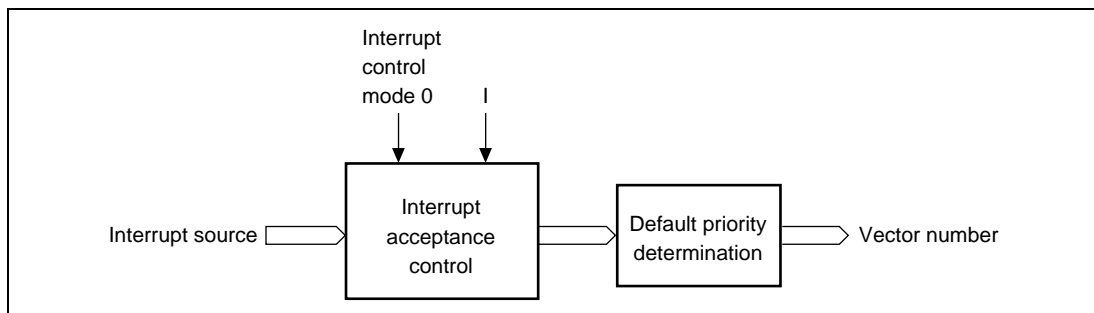


Figure 5.8 Block Diagram of Interrupt Control Operation for H8S/2264 Series

Interrupt Acceptance Control: In interrupt control mode 0, interrupt acceptance is controlled by the I bit in CCR.

Table 5.4 shows the interrupts selected in each interrupt control mode.

Table 5.4 Interrupts Selected in Each Interrupt Control Mode (1)

Interrupt Control Mode	Interrupt Mask Bits	
	I	Selected Interrupts
0	0	All interrupts
	1	NMI interrupts
2*	X	All interrupts

Legend: X: Don't care

Note: * Supported only by the H8S/2268 Series.

8-Level Control (H8S/2268 Series Only): In interrupt control mode 2, 8-level mask level determination is performed for the selected interrupts in interrupt acceptance control according to the interrupt priority level (IPR).

The interrupt source selected is the interrupt with the highest priority level, and whose priority level set in IPR is higher than the mask level.

Table 5.5 Interrupts Selected in Each Interrupt Control Mode (2)

Interrupt Control Mode	Selected Interrupts
0	All interrupts
2	Highest-priority-level (IPR) interrupt whose priority level is greater than the mask level (IPR > I2 to I0).

Default Priority Determination: When an interrupt is selected by 8-level control, its priority is determined and a vector number is generated.

If the same value is set for IPR, acceptance of multiple interrupts is enabled, and so only the interrupt source with the highest priority according to the preset default priorities is selected and has a vector number generated (H8S/2268 Series only).

Interrupt sources with a lower priority than the accepted interrupt source are held pending.

Table 5.6 shows operations and control signal functions in each interrupt control mode.

Table 5.6 Operations and Control Signal Functions in Each Interrupt Control Mode

Interrupt Control Mode	Setting		Interrupt Acceptance Control		8-Level Control ^{*3}			Default Priority	T
	INTM1	INTM0		I	I2 to I0 ^{*3}	IPR ^{*3}	Determination		(Trace)
0	0	0	O	IM	X —	— ^{*2}	O		—
2 ^{*3}	1	0	X	— ^{*1}	O IM	PR	O		T

Legend

- O : Interrupt operation control performed
- X : No operation. (All interrupts enabled)
- IM : Used as interrupt mask bit
- PR : Sets priority.
- : Not used.

- Notes: 1. Set to 1 when interrupt is accepted.
 2. Keep the initial setting.
 3. Supported only by the H8S/2268 Series.

5.5.2 Interrupt Control Mode 0

Enabling and disabling of IRQ interrupts, WKP interrupts and on-chip peripheral module interrupts can be set by means of the I bit in the CPU's CCR. Interrupts are enabled when the I bit is cleared to 0, and disabled when set to 1.

Figure 5.9 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. Interrupt requests are sent to the interrupt controller, the highest-ranked interrupt according to the priority system is accepted, and other interrupt requests are held pending.
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. Next, 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 and starts execution of the interrupt handling routine at the address indicated by the contents of the vector address in the vector table.

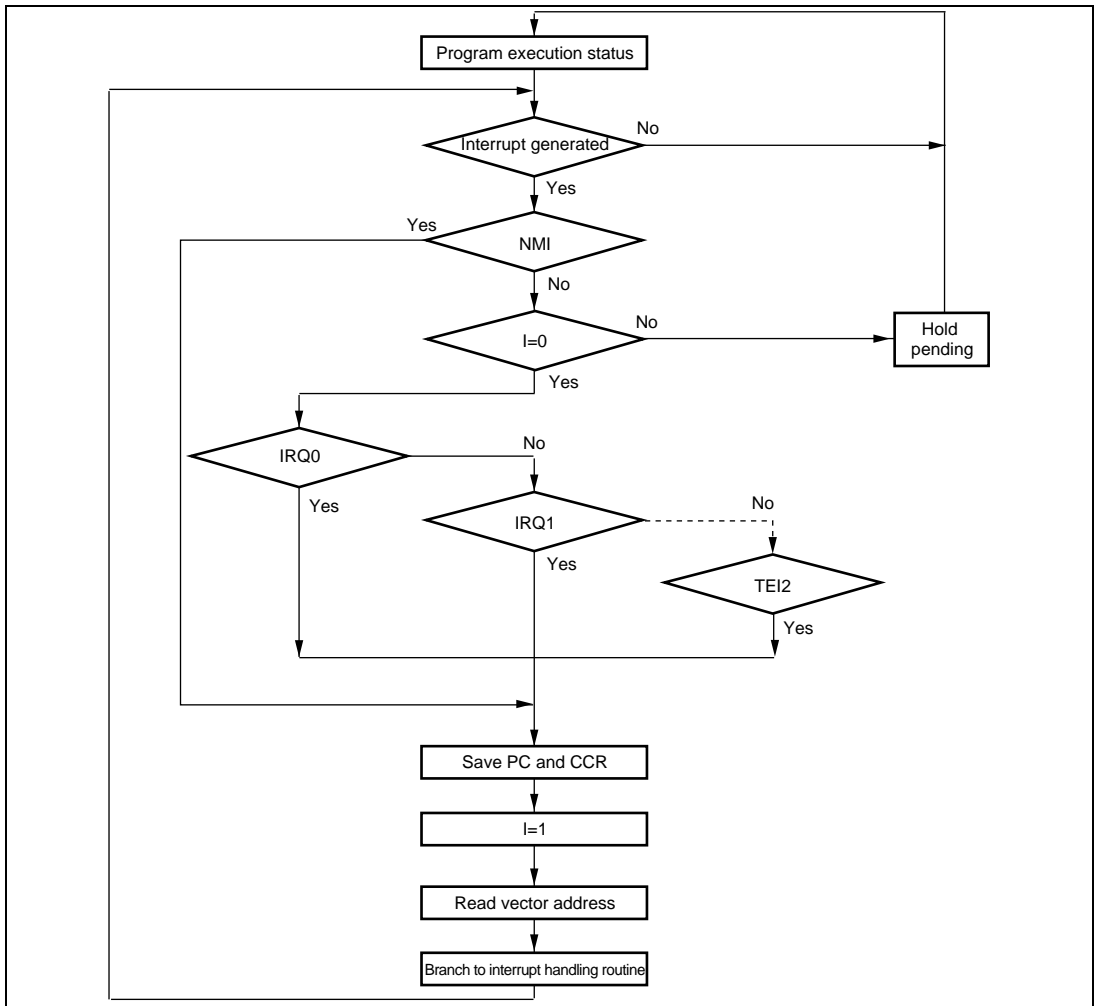


Figure 5.9 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 0

5.5.3 Interrupt Control Mode 2 (H8S/2268 Series Only)

Eight-level masking is implemented for IRQ interrupts, WKP interrupts and on-chip peripheral module interrupts by comparing the interrupt mask level set by bits I2 to I0 of EXR in the CPU with IPR.

Figure 5.10 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. 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 a number of interrupt requests with the same priority are generated at the same time, the interrupt request with the highest priority according to the priority system shown in table 5.2 is selected.
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'7.
7. The CPU generates a vector address for the accepted interrupt and starts execution of the interrupt handling routine at the address indicated by the contents of the vector address in the vector table.

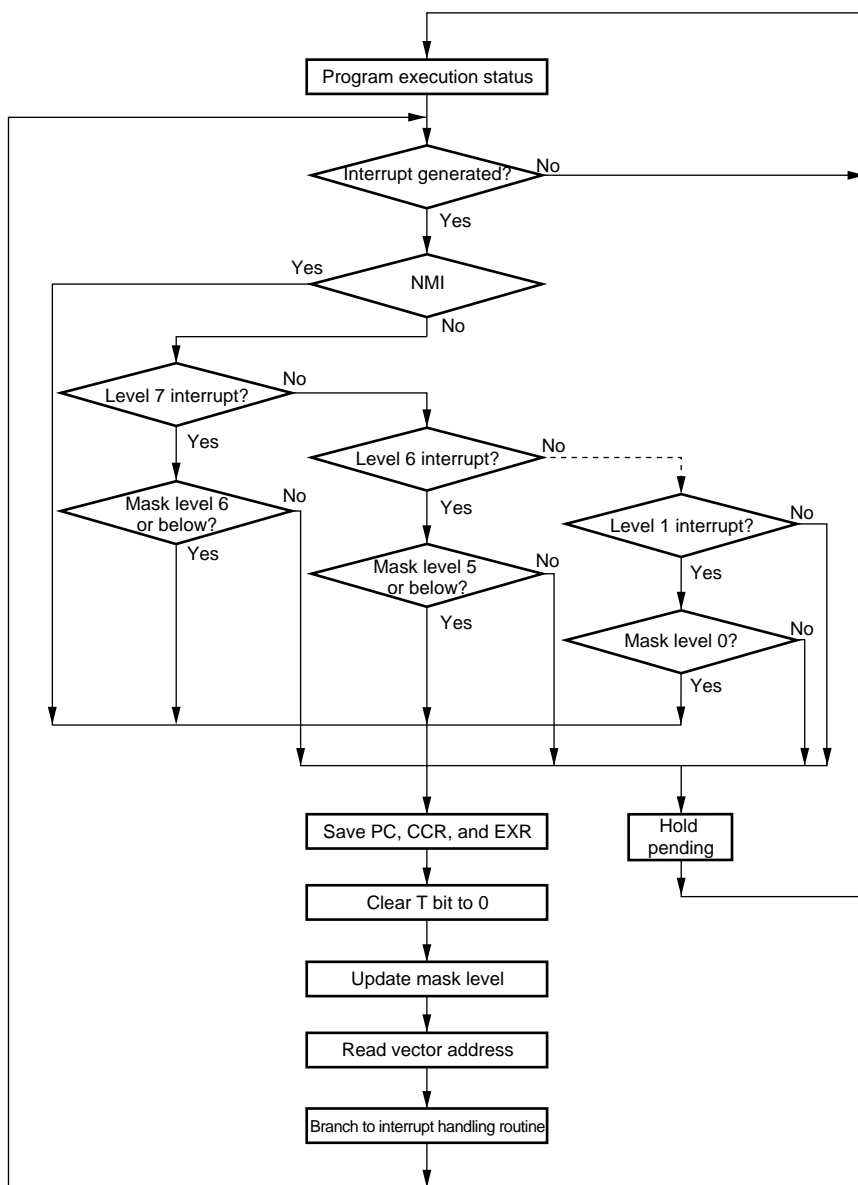


Figure 5.10 Flowchart of Procedure Up to Interrupt Acceptance in Control Mode 2

5.5.4 Interrupt Exception Handling Sequence

Figure 5.11 shows the interrupt exception handling sequence. The example shown is for the case where interrupt control mode 0 is set in advanced mode, and the program area and stack area are in on-chip memory.

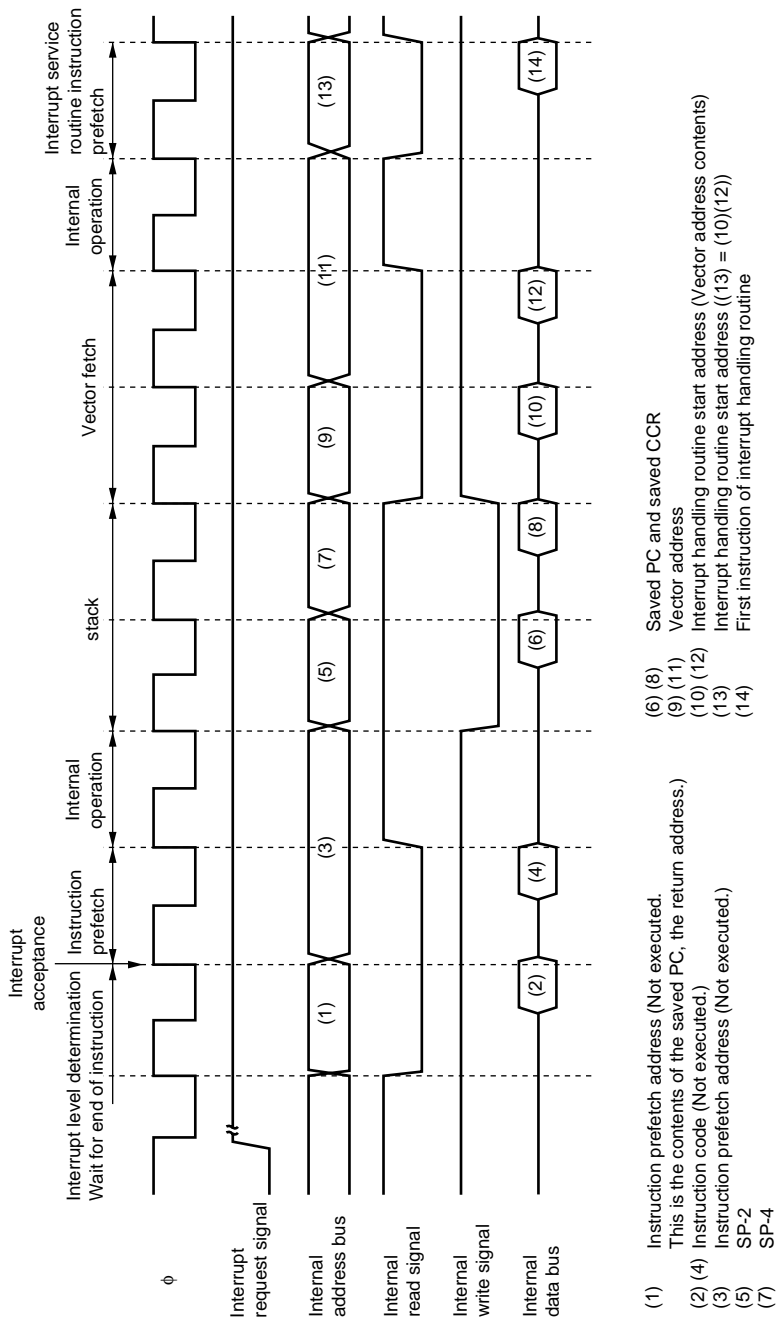


Figure 5.11 Interrupt Exception Handling

5.5.5 Interrupt Response Times

This LSI is capable of fast word transfer to on-chip memory, has the program area in on-chip ROM and the stack area in on-chip RAM, enabling high-speed processing.

Table 5.7 shows interrupt response times - the interval between generation of an interrupt request and execution of the first instruction in the interrupt handling routine. The execution status symbols used in table 5.7 are explained in table 5.8.

Table 5.7 Interrupt Response Times (States)

No.	Execution Status	Normal Mode* ⁵		Advanced Mode	
		INTM1 = 0	INTM1 = 1	INTM1 = 0	INTM1 = 1
1	Interrupt priority determination* ¹	3	3	3	3
2	Number of wait states until executing 1 to 19 + 2·S _I 1 to 19 + 2·S _I 1 to 19 + 2·S _I 1 to 19 + 2·S _I instruction ends* ²				
3	PC, CCR, EXR stack save	2·S _K	3·S _K	2·S _K	3·S _K
4	Vector fetch	S _I	S _I	2·S _I	2·S _I
5	Instruction fetch* ³	2·S _I	2·S _I	2·S _I	2·S _I
6	Internal processing* ⁴	2	2	2	2
Total (using on-chip memory)		11 to 31	12 to 32	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.

5. Not available in this LSI.

Table 5.8 Number of States in Interrupt Handling Routine Execution Status

Symbol		Object of Access				
		Internal Memory	External Device *			
			8 Bit Bus		16 Bit Bus	
			2-State Access	3-State Access	2-State Access	3-State Access
Instruction fetch	S _I	1	4	6 + 2m	2	3 + m
Branch address read	S _J					
Stack manipulation	S _K					

Legend

m : Number of wait states in an external device access.

Note:* Cannot be used in this LSI.

5.5.6 DTC Activation by Interrupt (H8S/2268 Series Only)

The DTC can be activated by an interrupt. For details, see section 8, Data Transfer Controller (DTC).

5.6 Usage Notes

5.6.1 Contention between Interrupt Generation and Disabling

When an interrupt enable bit is cleared to 0 to disable interrupts, the disabling becomes effective after execution of the instruction.

When an interrupt enable bit is cleared to 0 by an instruction such as BCLR or MOV, and if an interrupt is generated during execution of the instruction, the interrupt concerned will still be enabled on completion of the instruction, and so interrupt exception handling for that interrupt will be executed on completion of the instruction. However, if there is an interrupt request of higher priority than that interrupt, interrupt exception handling will be executed for the higher-priority interrupt, and the lower-priority interrupt will be ignored.

The same also applies when an interrupt source flag is cleared to 0.

Figure 5.12 shows an example in which the CMIEA bit in the TCR register of the 8-bit timer is cleared to 0.

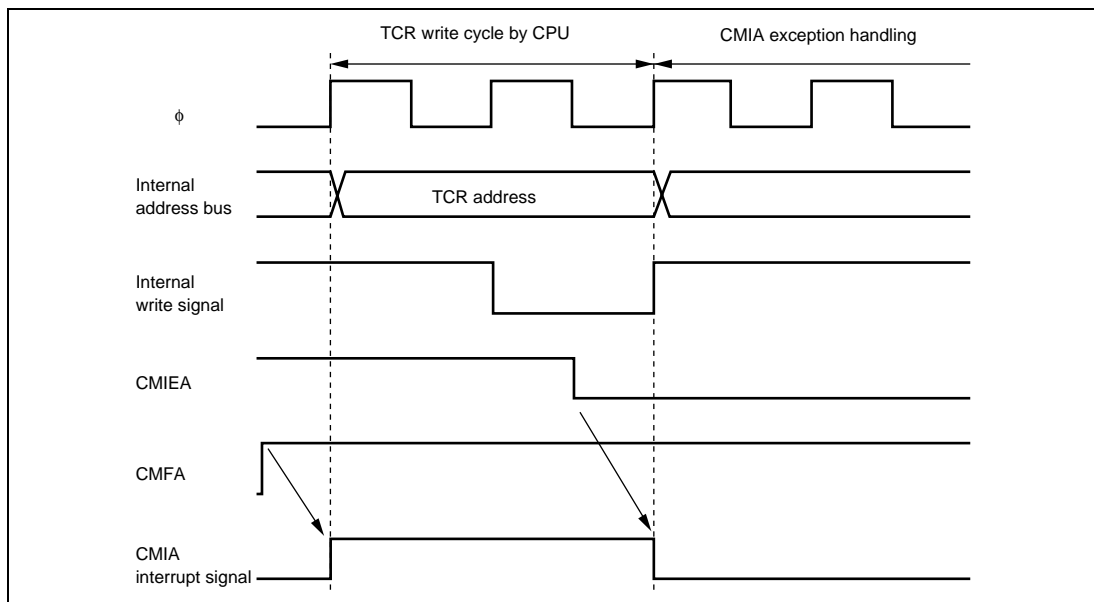


Figure 5.12 Contention between Interrupt Generation and Disabling

The above contention will not occur if an enable bit or interrupt source flag is cleared to 0 while the interrupt is masked.

5.6.2 Instructions that Disable Interrupts

The instructions that disable interrupts are LDC, ANDC, ORC, and XORC. After any of these instructions are 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 two states after execution of the instruction ends.

5.6.3 When Interrupts Are Disabled

There are times 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.

5.6.4 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 move 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
```

Section 6 PC Break Controller (PBC)

The H8S/2268 Series includes a PC break controller (PBC), while the H8S/2264 Series does not.

The PC break controller (PBC) provides functions that simplify program debugging. Using these functions, it is easy to create a self-monitoring debugger, enabling programs to be debugged with the chip alone, without using an in-circuit emulator. A block diagram of the PC break controller is shown in figure 6.1.

6.1 Features

- Two break channels (A and B)
- 24-bit break address
 - Bit masking possible
- Four types of break compare conditions
 - Instruction fetch
 - Data read
 - Data write
 - Data read/write
- Bus master
 - Either CPU or CPU/DTC can be selected
- The timing of PC break exception handling after the occurrence of a break condition is as follows:
 - Immediately before execution of the instruction fetched at the set address (instruction fetch)
 - Immediately after execution of the instruction that accesses data at the set address (data access)
- Module stop mode can be set

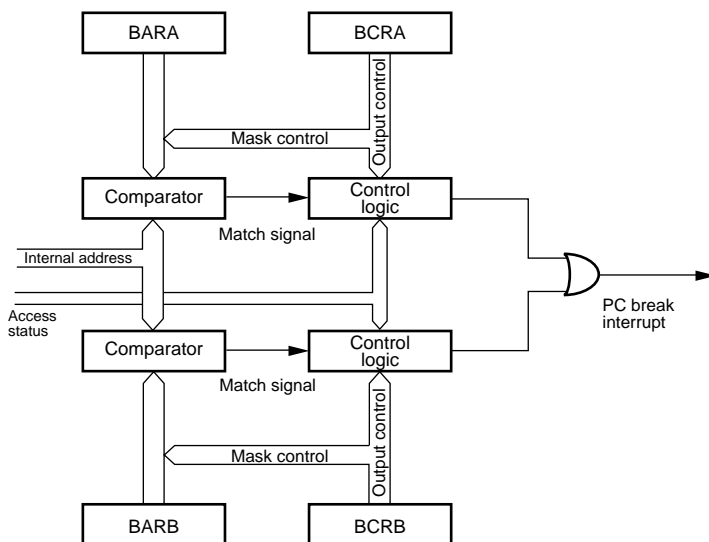


Figure 6.1 Block Diagram of PC Break Controller

6.2 Register Descriptions

The PC break controller has the following registers.

- Break address register A (BARA)
- Break address register B (BARB)
- Break control register A (BCRA)
- Break control register B (BCRB)

6.2.1 Break Address Register A (BARA)

BARA is a 32-bit readable/writable register that specifies the channel A break address.

Bit	Bit Name	Initial Value	R/W	Description
31 to 24	—	Undefined	—	Reserved These bits are read as an undefined value and cannot be modified.
23 to 0	BAA23 to BAA0	H'000000	R/W	These bits set the channel A PC break address.

6.2.2 Break Address Register B (BARB)

BARB is the channel B break address register. The bit configuration is the same as for BARA.

6.2.3 Break Control Register A (BCRA)

BCRA controls channel A PC breaks.

Bit	Bit Name	Initial Value	R/W	Description
7	CMFA	0	R/(W)* ¹	Condition Match Flag A [Setting condition] When a condition set for channel A is satisfied [Clearing condition] When 0 is written to CMFA after reading* ² CMFA = 1
6	CDA	0	R/W	CPU Cycle/DTC Cycle Select A Selects the channel A break condition bus master. 0: CPU 1: CPU or DTC
5	BAMRA2	0	R/W	Break Address Mask Register A2 to A0 These bits specify which bits of the break address set in BARA are to be masked. 000: BAA23–0 (All bits are unmasked) 001: BAA23–1 (Lowest bit is masked) 010: BAA23–2 (Lower 2 bits are masked) 011: BAA23–3 (Lower 3 bits are masked) 100: BAA23–4 (Lower 4 bits are masked) 101: BAA23–8 (Lower 8 bits are masked) 110: BAA23–12 (Lower 12 bits are masked) 111: BAA23–16 (Lower 16 bits are masked)
4	BAMRA1	0	R/W	
3	BAMRA0	0	R/W	
2	CSELA1	0	R/W	
1	CSELA0	0	R/W	
0	BIEA	0	R/W	Break Interrupt Enable When this bit is 1, the PC break interrupt request of channel A is enabled.

- Notes:
1. Only a 0 can be written to this bit to clear the flag.
 2. Read the state wherein CMFA = 1 twice or more, when the CMFA is polled after inhibiting the PC break interruption.

6.2.4 Break Control Register B (BCRB)

BCRB is the channel B break control register. The bit configuration is the same as for BCRA.

6.3 Operation

The operation flow from break condition setting to PC break interrupt exception handling is shown in section 6.3.1, PC Break Interrupt Due to Instruction Fetch, and 6.3.2, PC Break Interrupt Due to Data Access, taking the example of channel A.

6.3.1 PC Break Interrupt Due to Instruction Fetch

1. Set the break address in BARA.
For a PC break caused by an instruction fetch, set the address of the first instruction byte as the break address.
2. Set the break conditions in BCR.
Set bit 6 (CDA) to 0 to select the CPU because the bus master must be the CPU for a PC break caused by an instruction fetch. Set the address bits to be masked to bits 3 to 5 (BAMA2 to 0). Set bits 1 and 2 (CSELA1 to 0) to 00 to specify an instruction fetch as the break condition. Set bit 0 (BIEA) to 1 to enable break interrupts.
3. When the instruction at the set address is fetched, a PC break request is generated immediately before execution of the fetched instruction, and the condition match flag (CMFA) is set.
4. After priority determination by the interrupt controller, PC break interrupt exception handling is started.

6.3.2 PC Break Interrupt Due to Data Access

1. Set the break address in BARA.
For a PC break caused by a data access, set the target ROM, RAM, I/O, or external address space address as the break address. Stack operations and branch address reads are included in data accesses.
2. Set the break conditions in BCRA.
Select the bus master with bit 6 (CDA). Set the address bits to be masked to bits 3 to 5 (BAMA2 to 0). Set bits 1 and 2 (CSELA1 to 0) to 01, 10, or 11 to specify data access as the break condition. Set bit 0 (BIEA) to 1 to enable break interrupts.
3. After execution of the instruction that performs a data access on the set address, a PC break request is generated and the condition match flag (CMFA) is set.
4. After priority determination by the interrupt controller, PC break interrupt exception handling is started.

6.3.3 Notes on PC Break Interrupt Handling

- When a PC break interrupt is generated at the transfer address of an EEPMOV.B instruction PC break exception handling is executed after all data transfers have been completed and the EEPMOV.B instruction has ended.
- When a PC break interrupt is generated at a DTC transfer address PC break exception handling is executed after the DTC has completed the specified number of data transfers, or after data for which the DISEL bit is set to 1 has been transferred.

6.3.4 Operation in Transitions to Power-Down Modes

The operation when a PC break interrupt is set for an instruction fetch at the address after a SLEEP instruction is shown below.

- When the SLEEP instruction causes a transition from high-speed (medium-speed) mode to sleep mode:
After execution of the SLEEP instruction, a transition is not made to sleep mode, and PC break interrupt handling is executed. After execution of PC break interrupt handling, the instruction at the address after the SLEEP instruction is executed (figure 6.2 (A)).
- When the SLEEP instruction causes a transition from high speed (medium speed) mode to subactive mode (figure 6.2 (B)).
- When the SLEEP instruction causes a transition from subactive mode to high speed (medium speed) mode (figure 6.2 (C)).
- When the SLEEP instruction causes a transition to software standby mode:
After execution of the SLEEP instruction, a transition is made to the respective mode, and PC break interrupt handling is not executed. However, the CMFA or CMFB flag is set (figure 6.2 (D)).

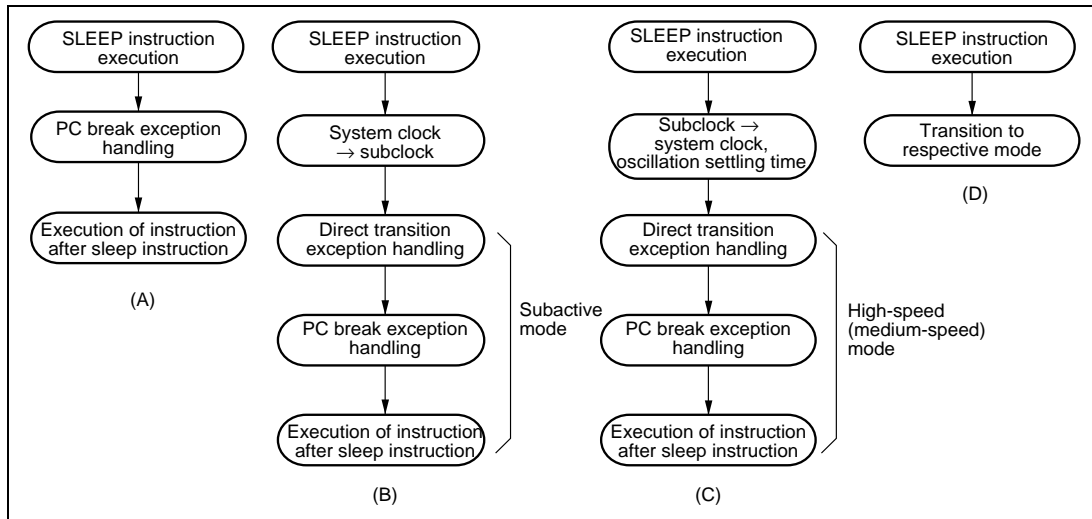


Figure 6.2 Operation in Power-Down Mode Transitions

6.3.5 When Instruction Execution Is Delayed by One State

While the break interrupt enable bit is set to 1, instruction execution is one state later than usual.

- For 1-word branch instructions (Bcc d:8, BSR, JSR, JMP, TRAPA, RTE, and RTS) in on-chip ROM or RAM.
- When break interruption by instruction fetch is set, the set address indicates on-chip ROM or RAM space, and that address is used for data access, the instruction that executes the data access is one state later than in normal operation.
- When break interruption by instruction fetch is set and a break interrupt is generated, if the executing instruction immediately preceding the set instruction has one of the addressing modes shown below, and that address indicates on-chip ROM or RAM, the instruction will be one state later than in normal operation.

Addressing modes: @ERn, @(d:16,ERn), @(d:32,ERn), @-ERn/ERn+, @aa:8, @aa:24, @aa:32, @(d:8,PC), @(d:16,PC), @@@aa:8

- When break interruption by instruction fetch is set and a break interrupt is generated, if the executing instruction immediately preceding the set instruction is NOP or SLEEP, or has #xx, Rn as its addressing mode, and that instruction is located in on-chip ROM or RAM, the instruction will be one state later than in normal operation.

6.4 Usage Notes

6.4.1 Module Stop Mode Setting

PBC operation can be disabled or enabled using the module stop control register. The initial setting is for PBC operation to be halted. Register access is enabled by clearing module stop mode. For details, refer to section 22, Power-Down Modes.

6.4.2 PC Break Interrupts

The PC break interrupt is shared by channels A and B. The channel from which the request was issued must be determined by the interrupt handler.

6.4.3 CMFA and CMFB

The CMFA and CMFB flags are not automatically cleared to 0, so 0 must be written to CMFA or CMFB after first reading the flag while it is set to 1. If the flag is left set to 1, another interrupt will be requested after interrupt handling ends.

6.4.4 PC Break Interrupt when DTC Is Bus Master

A PC break interrupt generated when the DTC is the bus master is accepted after the bus has been transferred to the CPU by the bus controller.

6.4.5 PC Break Set for Instruction Fetch at Address Following BSR, JSR, JMP, TRAPA, RTE, or RTS Instruction

When a PC break is set for an instruction fetch at an address following a BSR, JSR, JMP, TRAPA, RTE, or RTS instruction:

Even if the instruction at the address following a BSR, JSR, JMP, TRAPA, RTE, or RTS instruction is fetched, it is not executed, and so a PC break interrupt is not generated by the instruction fetch at the next address.

6.4.6 I Bit Set by LDC, ANDC, ORC, or XORC Instruction

When the I bit is set by an LDC, ANDC, ORC, or XORC instruction, a PC break interrupt becomes valid two states after the end of the executing instruction. If a PC break interrupt is set for the instruction following one of these instructions, since interrupts, including NMI, are disabled for a 3-state period in the case of LDC, ANDC, ORC, and XOR, the next instruction is always executed. For details, see section 5, Interrupt Controller.

6.4.7 PC Break Set for Instruction Fetch at Address Following Bcc Instruction

When a PC break is set for an instruction fetch at an address following a Bcc instruction:

A PC break interrupt is generated if the instruction at the next address is executed in accordance with the branch condition, and is not generated if the instruction at the next address is not executed.

6.4.8 PC Break Set for Instruction Fetch at Branch Destination Address of Bcc Instruction

When a PC break is set for an instruction fetch at the branch destination address of a Bcc instruction:

A PC break interrupt is generated if the instruction at the branch destination is executed in accordance with the branch condition, and is not generated if the instruction at the branch destination is not executed.

Section 7 Bus Controller

The H8S/2000 CPU is driven by a system clock, denoted by the symbol ϕ .

The bus controller controls a memory cycle and a bus cycle. Different methods are used to access on-chip memory and on-chip peripheral modules. In the H8S/2268 Series, the bus controller also has a bus arbitration function, and controls the operation of the internal bus masters: the CPU and data transfer controller (DTC).

7.1 Basic Timing

The period from one rising edge of ϕ to the next is referred to as a "state." The memory cycle or bus cycle consists of one, two, or four states. Different methods are used to access on-chip memory, on-chip peripheral modules, and the external address space.

7.1.1 On-Chip Memory Access Timing (ROM, RAM)

On-chip memory is accessed in one state. The data bus is 16 bits wide, permitting both byte and word transfer instruction. Figure 7.1 shows the on-chip memory access cycle.

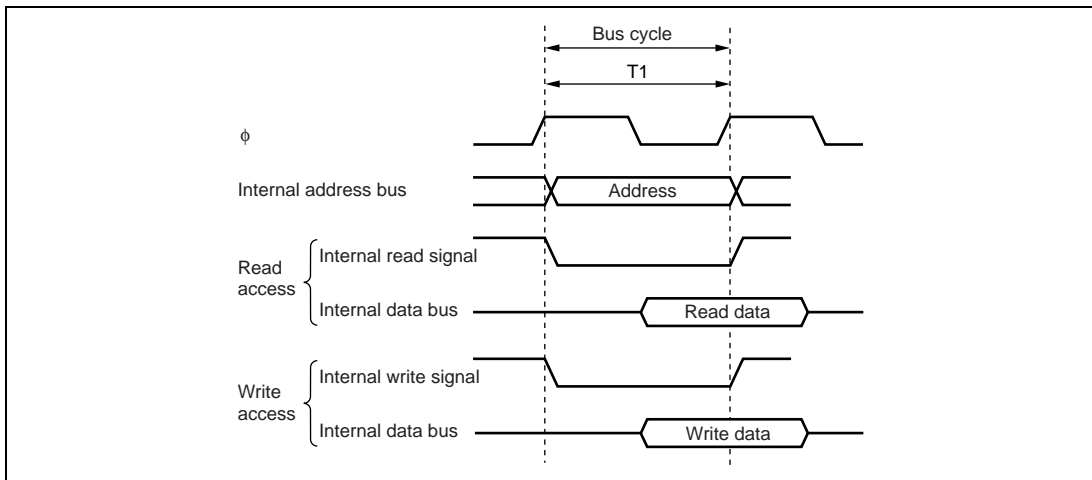


Figure 7.1 On-Chip Memory Access Cycle

7.1.2 On-Chip Peripheral Module Access Timing (H'FFFDAC to H'FFFFBF)

Addresses H'FFFDAC to H'FFFFBF in the on-chip peripheral modules are accessed in two states. The data bus is either 8 bits or 16 bits wide, depending on the particular internal I/O register being accessed. For details, refer to section 25, List of Registers. Figure 7.2 shows access timing for the on-chip peripheral modules (H'FFFDAC to H'FFFFBF).

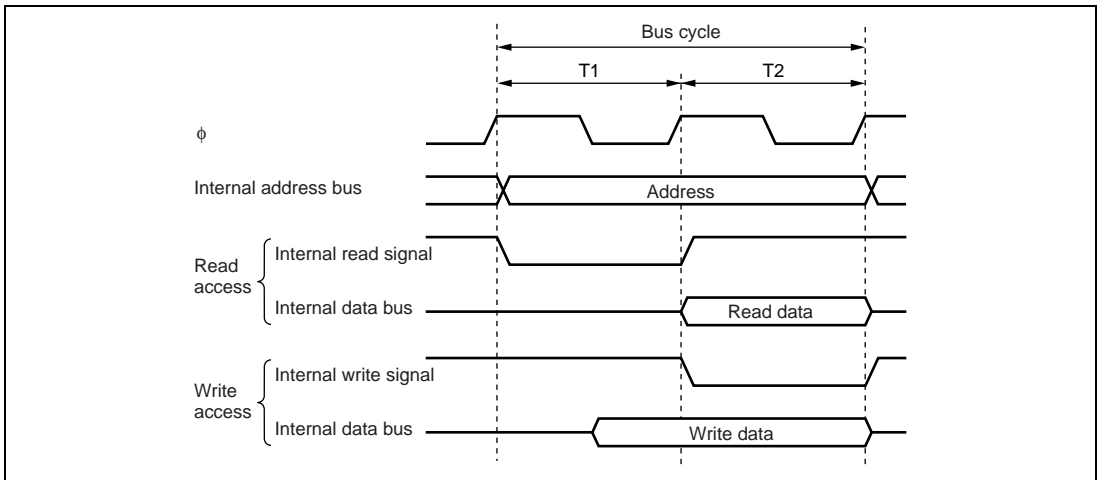


Figure 7.2 On-Chip Peripheral Module Access Cycle (H'FFFDAC to H'FFFFBF)

7.1.3 On-Chip Peripheral Module Access Timing (H'FFFC30 to H'FFFC A3)

Addresses H'FFFC30 to H'FFFC A3 on the on-chip peripheral modules and registers are accessed in four states. The data bus is either 8 bits or 16 bits wide, depending on the particular internal I/O register being accessed. For details, refer to section 25, List of Registers. Figure 7.3 shows access timing for the on-chip peripheral modules (H'FFFC30 to H'FFFC A3).

The on-chip module of which address is between H'FFFC30 to H'FFFC A3 includes LCD, DTMF^{*1}, TMR4^{*1}, port H to L and ports M^{*1} and N^{*1}. The registers are WKP register, module stop control register D and system clock control register 2^{*2}.

Notes: 1. Supported only by the H8S/2268 Series.

2. Supported only by the H8S/2264 Series.

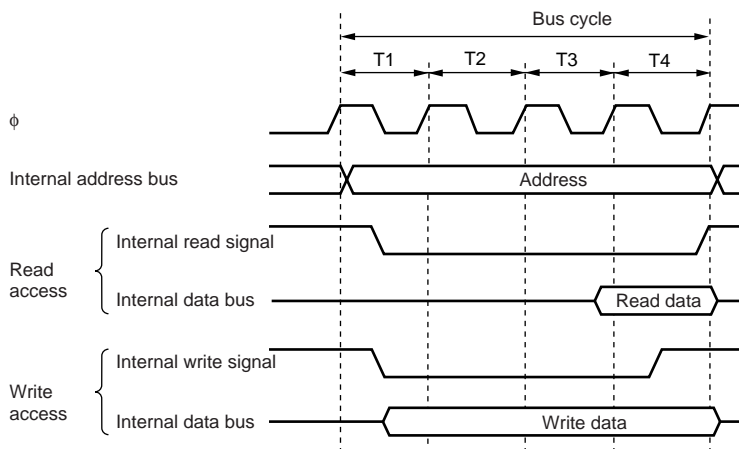


Figure 7.3 On-Chip Peripheral Module Access Cycle (H'FFFC30 to H'FFFC A3)

7.2 Bus Arbitration (H8S/2268 Series Only)

The Bus Controller has a bus arbiter that arbitrates bus master operations.

There are two bus masters, the CPU and DTC, which perform read/write operations when they control the bus.

7.2.1 Order of Priority of the Bus Masters

Each bus master requests the bus by means of a bus request signal. The bus arbiter detects the bus masters' bus request signals, and if the bus is requested, sends a bus request acknowledge signal to the bus master making the request. If there are bus requests from more than one bus master, the bus request acknowledge signal is sent to the one with the highest priority. When a bus master receives the bus request acknowledge signal, it takes possession of the bus until that signal is canceled.

The order of priority of the bus masters is as follows:

(High) DTC > CPU (Low)

7.2.2 Bus Transfer Timing

Even if a bus request is received from a bus master with a higher priority than that of the bus master that has acquired the bus and is currently operating, the bus is not necessarily transferred immediately. The CPU is the lowest-priority bus master, and if a bus request is received from the DTC, the bus arbiter transfers the bus to the bus master that issued the request. The timing for transfer of the bus is as follows:

- The bus is transferred at a break between bus cycles. However, if a bus cycle is executed in discrete operations, as in the case of a longword-size access, the bus is not transferred between such operations. For details, refer to section 2.7, Bus States During Instruction Execution, in the H8S/2600 Series, H8S/2000 Series Programming Manual.
- If the CPU is in sleep mode, it transfers the bus immediately.

The DTC sends the bus arbiter a request for the bus when an activation request is generated.

7.2.3 Resets and the Bus Controller

In a reset, the H8S/2268, including the bus controller, enters the reset state at that point, and an executing bus cycle is discontinued.

Section 8 Data Transfer Controller (DTC)

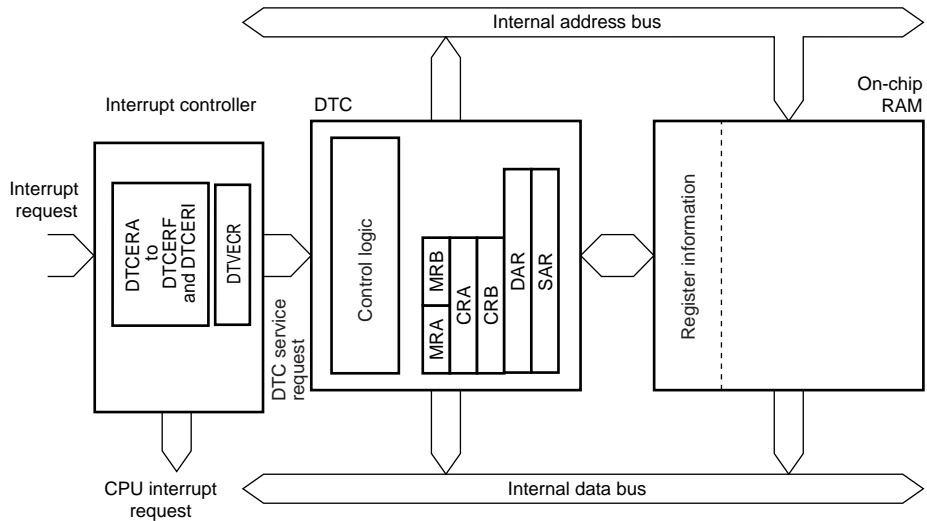
The H8S/2268 Series includes a data transfer controller (DTC), while the H8S/2264 Series does not. The DTC can be activated by an interrupt or software, to transfer data.

Figure 8.1 shows a block diagram of the DTC.

The DTC's register information is stored in the on-chip RAM. When the DTC is used, the RAME bit in SYSCR must be set to 1. A 32-bit bus connects the DTC to the on-chip RAM (1 kbyte), enabling 32-bit/1-state reading and writing of the DTC register information.

8.1 Features

- Transfer is possible over any number of channels
- Three transfer modes
 - Normal, repeat, and block transfer modes are available
- One activation source can trigger a number of data transfers (chain transfer)
- The direct specification of 16-Mbyte address space is 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 stop mode can be set



Legend

MRA, MRB	: DTC mode registers A and B
CRA, CRB	: DTC transfer count registers A and B
SAR	: DTC source address register
DAR	: DTC destination address register
DTCERA to DTCERF and DTCERI	: DTC enable registers A to F and I
DTVECR	: DTC vector register

Figure 8.1 Block Diagram of DTC

8.2 Register Descriptions

The 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)

These six registers cannot be directly accessed from the CPU.

When activated, the DTC reads a set of register information that is stored in on-chip RAM to the corresponding DTC registers and transfers data. After the data transfer, it writes a set of updated register information back to the RAM.

- DTC enable registers (DTCER)
- DTC vector register (DTVECR)

8.2.1 DTC Mode Register A (MRA)

MRA selects the DTC operating mode.

Bit	Bit Name	Initial Value	R/W	Description
7	SM1	Undefined	—	Source Address Mode 1 and 0
6	SM0	Undefined	—	<p>These bits specify an SAR operation after a data transfer.</p> <p>0X: SAR is fixed</p> <p>10: SAR is incremented after a transfer (by +1 when Sz = 0; by +2 when Sz = 1)</p> <p>11: SAR is decremented after a transfer (by –1 when Sz = 0; by –2 when Sz = 1)</p>
5	DM1	Undefined	—	Destination Address Mode 1 and 0
4	DM0	Undefined	—	<p>These bits specify a DAR operation after a data transfer.</p> <p>0X: DAR is fixed</p> <p>10: DAR is incremented after a transfer (by +1 when Sz = 0; by +2 when Sz = 1)</p> <p>11: DAR is decremented after a transfer (by –1 when Sz = 0; by –2 when Sz = 1)</p>
3	MD1	Undefined	—	DTC Mode 1 and 0
2	MD0	Undefined	—	<p>These bits specify the DTC transfer mode.</p> <p>00: Normal mode</p> <p>01: Repeat mode</p> <p>10: Block transfer mode</p> <p>11: Setting prohibited</p>
1	DTS	Undefined	—	<p>DTC Transfer Mode Select</p> <p>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.</p> <p>0: Destination side is repeat area or block area</p> <p>1: Source side is repeat area or block area</p>
0	Sz	Undefined	—	<p>DTC Data Transfer Size</p> <p>Specifies the size of data to be transferred.</p> <p>0: Byte-size transfer</p> <p>1: Word-size transfer</p>

Legend

X: Don't care

8.2.2 DTC Mode Register B (MRB)

MRB is an 8-bit register that selects the DTC operating mode.

Bit	Bit Name	Initial Value	R/W	Description
7	CHNE	Undefined	—	<p>DTC Chain Transfer Enable</p> <p>This bit specifies a chain transfer. For details, refer to 8.5.4, Chain Transfer.</p> <p>In data transfer with CHNE set to 1, determination of the end of the specified number of transfers, clearing of the interrupt source flag, and clearing of DTCER, are not performed.</p> <p>0: DTC data transfer completed (waiting for start)</p> <p>1: DTC data transfer (reads new register information and transfers data)</p>
6	DISEL	Undefined	—	<p>DTC Interrupt Select</p> <p>This bit specifies whether CPU interrupt is disabled or enabled after a data transfer.</p> <p>0: Interrupt request is issued to the CPU when the specified data transfer is completed.</p> <p>1: DTC issues interrupt request to the CPU in every data transfer (DTC does not clear the interrupt request flag that is a cause of the activation).</p>
5 to 0	—	Undefined	—	<p>Reserved</p> <p>These bits have no effect on DTC operation. The write value should always be 0.</p>

8.2.3 DTC Source Address Register (SAR)

SAR is a 24-bit register that designates the source address of data to be transferred by the DTC. For word-size transfer, specify an even source address.

8.2.4 DTC Destination Address Register (DAR)

DAR is a 24-bit register that designates the destination address of data to be transferred by the DTC. For word-size transfer, specify an even destination address.

8.2.5 DTC Transfer Count Register A (CRA)

CRA is a 16-bit register that designates the number of times data is to be transferred by the DTC.

In normal mode, the entire CRA functions as a 16-bit transfer counter (1 to 65536). 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). CRAH holds the number of transfers while CRAL functions as an 8-bit transfer counter (1 to 256). CRAL is decremented by 1 every time data is transferred, and the contents of CRAH are sent when the count reaches H'00.

8.2.6 DTC Transfer Count Register B (CRB)

CRB is a 16-bit register that designates the number of times data is to be transferred by the DTC in block transfer mode. It functions as a 16-bit transfer counter (1 to 65536) that is decremented by 1 every time data is transferred, and transfer ends when the count reaches H'0000.

8.2.7 DTC Enable Register (DTCER)

DTCER is comprised of seven registers; DTCERA to DTCERF and DTCERI, and is a register that specifies DTC activation interrupt sources. The correspondence between interrupt sources and DTCE bits is shown in table 8.1. For DTCE bit setting, use bit manipulation instructions such as BSET and BCLR for reading and writing. 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.

Bit	Bit Name	Initial Value	R/W	Description
7	DTCE7	0	R/W	DTC Activation Enable
6	DTCE6	0	R/W	Setting this bit to 1 specifies a relevant interrupt source as a DTC activation source.
5	DTCE5	0	R/W	[Clearing conditions]
4	DTCE4	0	R/W	When the DISEL bit is 1 and the data transfer has ended
3	DTCE3	0	R/W	When the specified number of transfers have ended
2	DTCE2	0	R/W	When the specified number of transfers have ended
1	DTCE1	0	R/W	These bits are not cleared when the DISEL bit is 0
0	DTCE0	0	R/W	and the specified number of transfers have not been completed

8.2.8 DTC Vector Register (DTVECR)

DTVECR is an 8-bit readable/writable register that enables or disables DTC activation by software, and sets a vector number for the software activation interrupt.

Bit	Bit Name	Initial Value	R/W	Description
7	SWDTE	0	R/W	<p>DTC Software Activation Enable</p> <p>Setting this bit to 1 activates DTC. Only a 1 can be written to this bit.</p> <p>[Clearing conditions]</p> <p>When the DISEL bit is 0 and the specified number of transfers have not ended</p> <p>When 0 s written to the DISEL bit after a software-activated data transfer end interrupt (SWDTEND) request has been sent to the CPU.</p> <p>When the DISEL bit is 1 and data transfer has ended, the specified number of transfers have ended, or software-activated data transfer is in process, this bit will not be cleared.</p>
6	DTVEC6	0	R/W	DTC Software Activation Vectors 0 to 6
5	DTVEC5	0	R/W	<p>These bits specify a vector number for DTC software activation.</p> <p>The vector address is expressed as $H'0400 + (\text{vector number} \times 2)$. For example, when DTVEC6 to DTVEC0 = H'10, the vector address is H'0420.</p> <p>These bits are writable when SWDTE=0.</p>
4	DTVEC4	0	R/W	
3	DTVEC3	0	R/W	
2	DTVEC2	0	R/W	
1	DTVEC1	0	R/W	
0	DTVEC0	0	R/W	

8.3 Activation Sources

The DTC operates when activated by an interrupt or by a write to DTVECR by software. An interrupt request can be directed to the CPU or DTC, as designated by the corresponding DTCER bit. At the end of a data transfer (or the last consecutive transfer in the case of chain transfer), the activation source or corresponding DTCER bit is cleared. The activation source flag, in the case of RXI0, for example, is the RDRF flag of SCI_0.

When an interrupt has been designated a DTC activation source, the 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.

Figure 8.2 shows a block diagram of activation source control. For details, see section 5, Interrupt Controller.

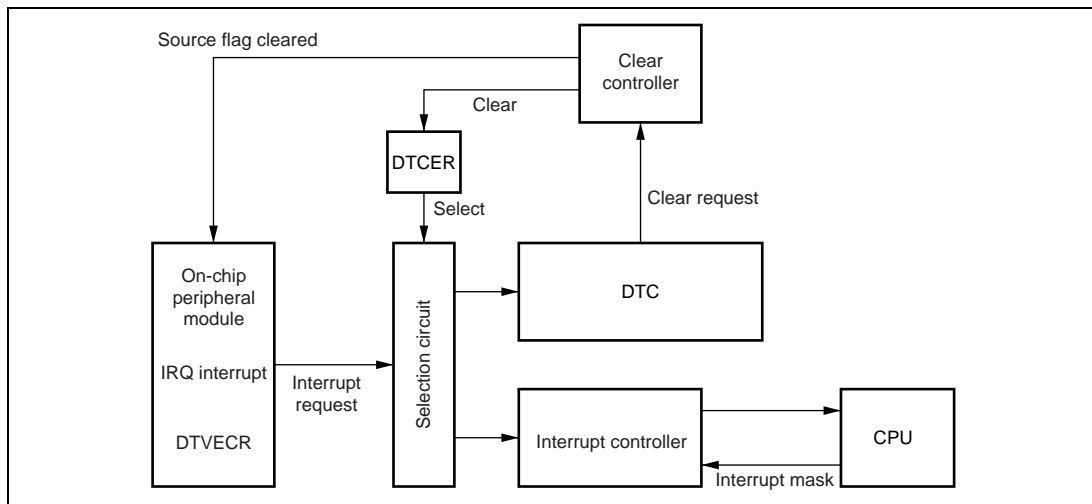


Figure 8.2 Block Diagram of DTC Activation Source Control

8.4 Location of Register Information and DTC Vector Table

Locate the register information in the on-chip RAM (addresses: H'FFEB0 to H'FFEFBF). Register information should be located at an address that is a multiple of four within the range. Locating the register information in address space is shown in figure 8.3. 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 8.3, and the register information start address should be located at the vector address corresponding to the interrupt source. Figure 8.4 shows the correspondence between 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: $H'0400 + (DTVECR[6:0] \times 2)$. For example, if DTVECR is H'10, the vector address is H'0420.

The configuration of the vector address is the same in both normal* and advanced modes, a 2-byte unit being used in both cases. These two bytes specify the lower bits of the register information start address.

Note: Normal mode cannot be used in this LSI.

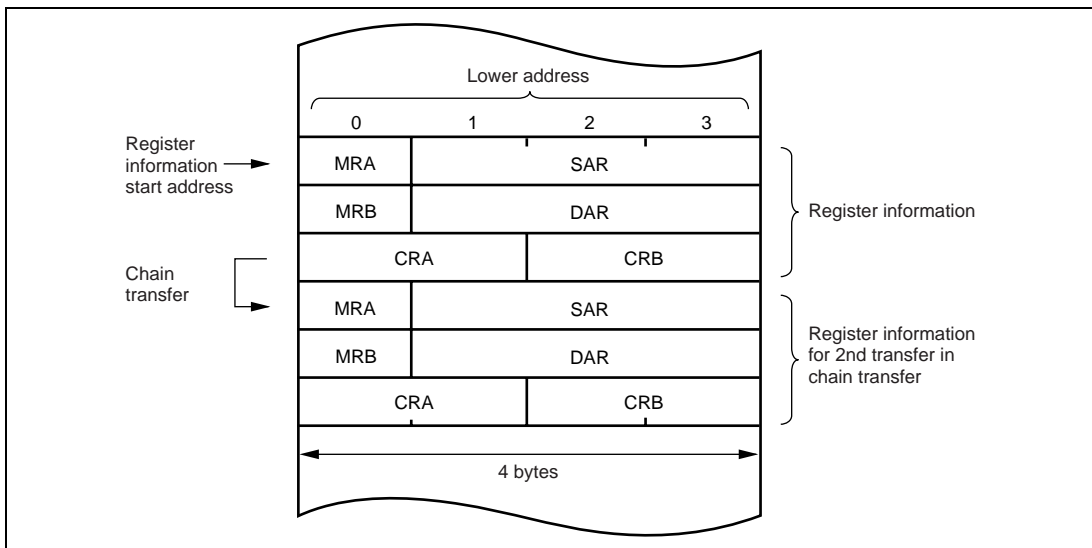


Figure 8.3 The Location of the DTC Register Information in the Address Space

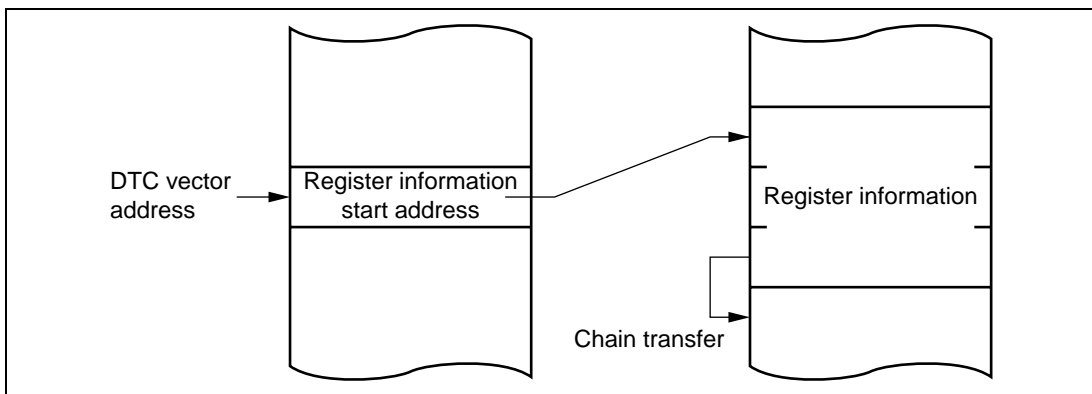


Figure 8.4 Correspondence between DTC Vector Address and Register Information

Table 8.1 Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs

Interrupt Source	Origin of Interrupt Source	Vector Number	DTC Vector Address	DTCE*	Priority
Software	Write to DTVECR	DTVECR	H'0400 + vector number×2	—	High
External pin	IRQ0	16	H'0420	DTCEA7	↑
	IRQ1	17	H'0422	DTCEA6	
	IRQ3	19	H'0426	DTCEA4	
	IRQ4	20	H'0428	DTCEA3	
	IRQ5	21	H'042A	DTCEA2	
A/D	ADI (A/D conversion end)	28	H'0438	DTCEB6	
TPU Channel 0	TGI0A	32	H'0440	DTCEB5	
	TGI0B	33	H'0442	DTCEB4	
	TGI0C	34	H'0444	DTCEB3	
	TGI0D	35	H'0446	DTCEB2	
TPU Channel 1	TGI1A	40	H'0450	DTCEB1	
	TGI1B	41	H'0452	DTCEB0	
TPU Channel 2	TGI2A	44	H'0458	DTCEC7	
	TGI2B	45	H'045A	DTCEC6	
8-bit timer channel 0	CMIA0	64	H'0480	DTCED3	
	CMIB0	65	H'0482	DTCED2	
8-bit timer channel 1	CMIA1	68	H'0488	DTCED1	
	CMIB1	69	H'048A	DTCED0	
SCI channel 0	RXI0	81	H'04A2	DTCEE3	
	TXI0	82	H'04A4	DTCEE2	
SCI channel 1	RXI1	85	H'04AA	DTCEE1	
	TXI1	86	H'04AC	DTCEE0	
8-bit timer channel 2	CMIA2	92	H'04B8	DTCEF5	
	CMIB2	93	H'04BA	DTCEF4	
8-bit timer channel 3	CMIA3	96	H'04C0	DTCEF3	
	CMIB3	97	H'04C2	DTCEF2	Low

Interrupt Source	Origin of Interrupt Source	Vector Number	DTC Vector Address	DTCE*	Priority
IIC channel 0 (optional)	IIC10	100	H'04C8	DTCEF1	High
IIC channel 1 (optional)	IIC11	102	H'04CC	DTCEF0	↑
SCI channel 2	RXI2	121	H'04F2	DTCEI7	
	TXI2	122	H'04F4	DTCEI6	Low

Note: * DTCE bits with no corresponding interrupt are reserved, and should be written with 0.

8.5 Operation

Register information is stored in on-chip RAM. When activated, the DTC reads register information in on-chip RAM and transfers data. After the data transfer, the DTC writes updated register information back to the memory.

The pre-storage of register information in memory makes it possible to transfer data over any required number of channels. The transfer mode can be specified as normal, repeat, and block transfer mode. Setting the CHNE bit in MRB to 1 makes it possible to perform a number of transfers with a single activation source (chain transfer).

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 depending on its register information.

Figure 8.5 shows the flowchart of DTC operation.

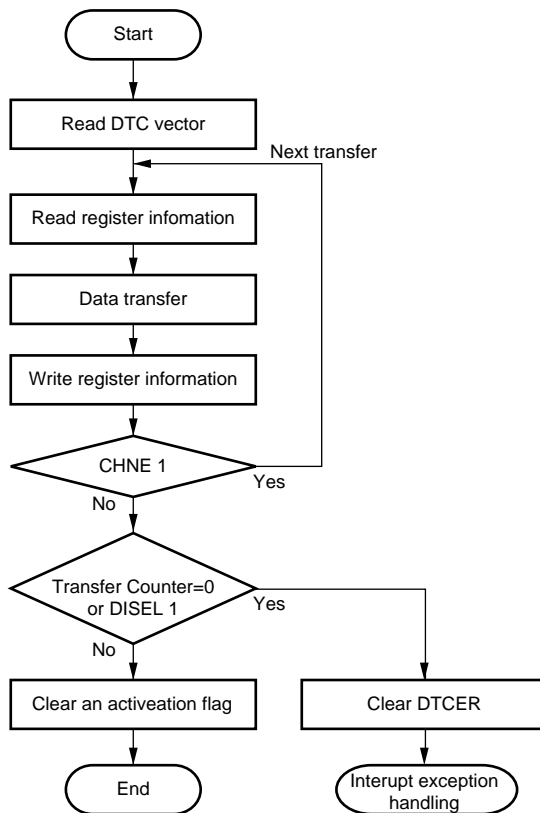


Figure 8.5 Flowchart of DTC Operation

8.5.1 Normal Mode

In normal mode, one operation transfers one byte or one word of data.

From 1 to 65,536 transfers can be specified. Once the specified number of transfers have been completed, a CPU interrupt can be requested.

Table 8.2 lists the register information in normal mode. Figure 8.6 shows the memory mapping in normal mode.

Table 8.2 Register Information in Normal Mode

Name	Abbreviation	Function
DTC source address register	SAR	Designates source address
DTC destination address register	DAR	Designates destination address
DTC transfer count register A	CRA	Designates transfer count
DTC transfer count register B	CRB	Not used

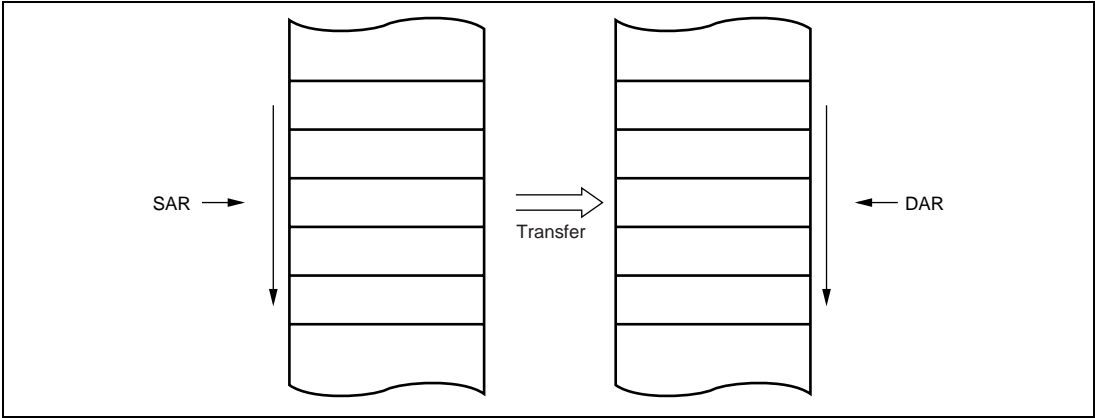


Figure 8.6 Memory Mapping in Normal Mode

8.5.2 Repeat Mode

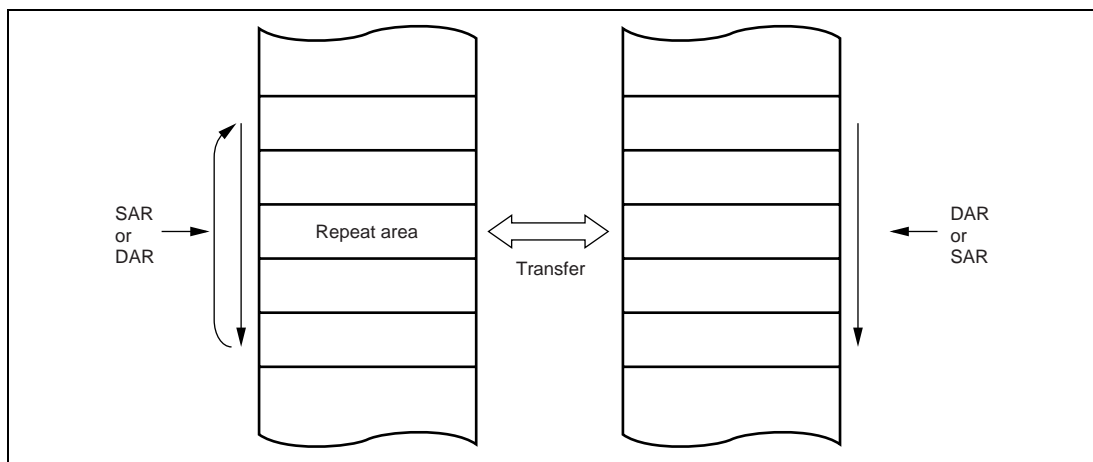
In repeat mode, one operation transfers one byte or one word of data.

From 1 to 256 transfers can be specified. Once the specified number of transfers have 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, and therefore CPU interrupts cannot be requested when DISEL = 0.

Table 8.3 lists the register information in repeat mode. Figure 8.7 shows the memory mapping in repeat mode.

Table 8.3 Register Information in Repeat 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 number of transfers
DTC transfer count register AL	CRAL	Designates transfer count
DTC transfer count register B	CRB	Not used

**Figure 8.7 Memory Mapping in Repeat Mode**

8.5.3 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.

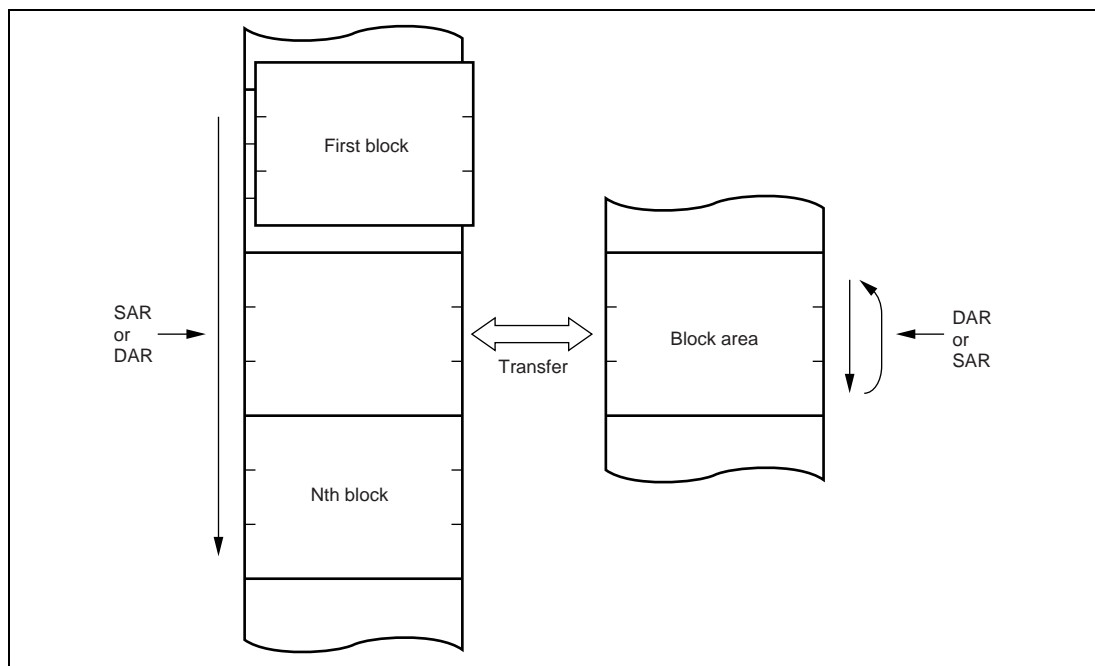
The block size can be between 1 to 256. When the transfer of one block ends, the initial state of the block size counter and the address register specified as the block area is restored. The other address register is then incremented, decremented, or left fixed.

From 1 to 65,536 transfers can be specified. Once the specified number of transfers have been completed, a CPU interrupt is requested.

Table 8.4 lists the register information in block transfer mode. Figure 8.8 shows the memory mapping in block transfer mode.

Table 8.4 Register Information 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	Transfer count

**Figure 8.8 Memory Mapping in Block Transfer Mode**

8.5.4 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, which define data transfers, can be set independently.

Figure 8.9 shows the memory map for 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. After the data transfer, the CHNE bit will be tested. When it has been set to 1, DTC reads the next register information located in a

consecutive area and performs the data transfer. These sequences are repeated until the CHNE bit is cleared to 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.

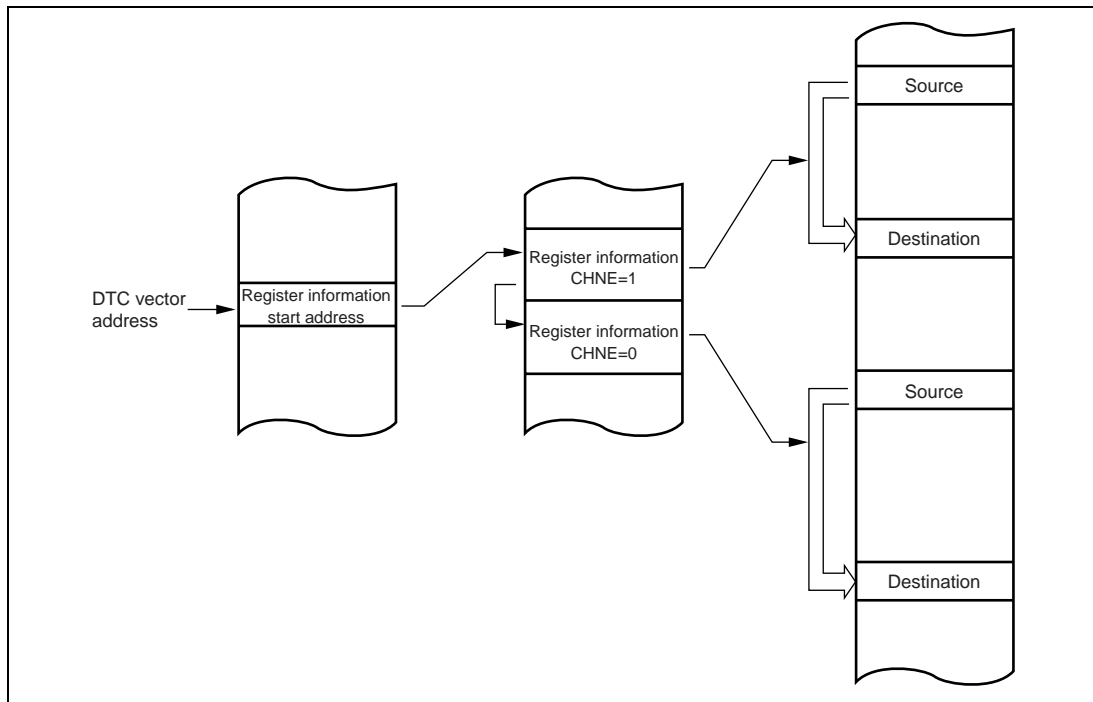


Figure 8.9 Chain Transfer Operation

8.5.5 Interrupts

An interrupt request is issued to the CPU when the DTC has completed the specified number of data transfers, or 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 software activation, a software-activated data transfer end interrupt (SWDTEND) is generated.

When the DISEL bit is 1 and one data transfer has been completed, or the specified number of transfers have been completed, after data transfer ends the SWDTE bit is held at 1 and an SWDTEND interrupt is generated. The interrupt handling routine will then 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.

8.5.6 Operation Timing

Figure 8.10 to 8.12 show the DTC operation timings.

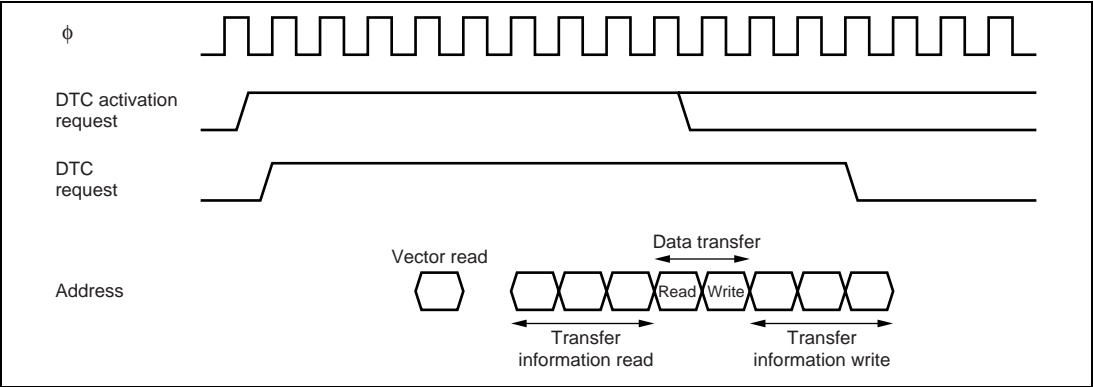


Figure 8.10 DTC Operation Timing (Example in Normal Mode or Repeat Mode)

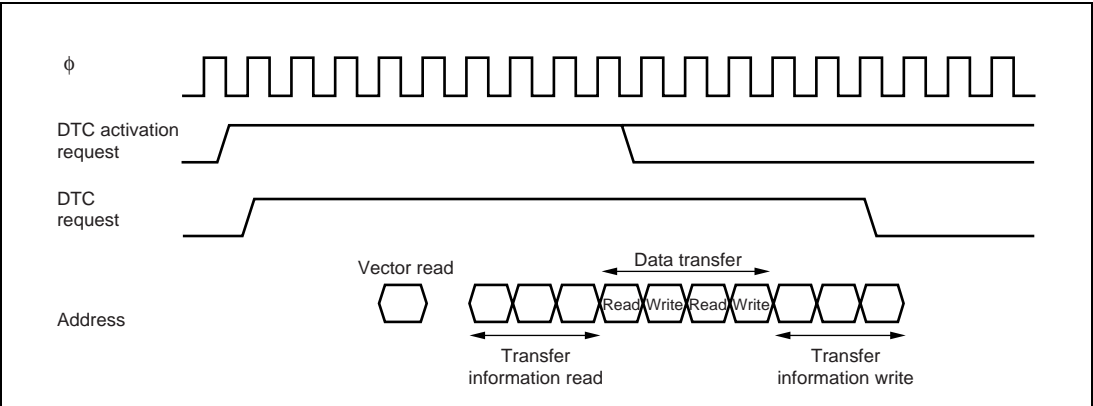


Figure 8.11 DTC Operation Timing (Example of Block Transfer Mode, with Block Size of 2)

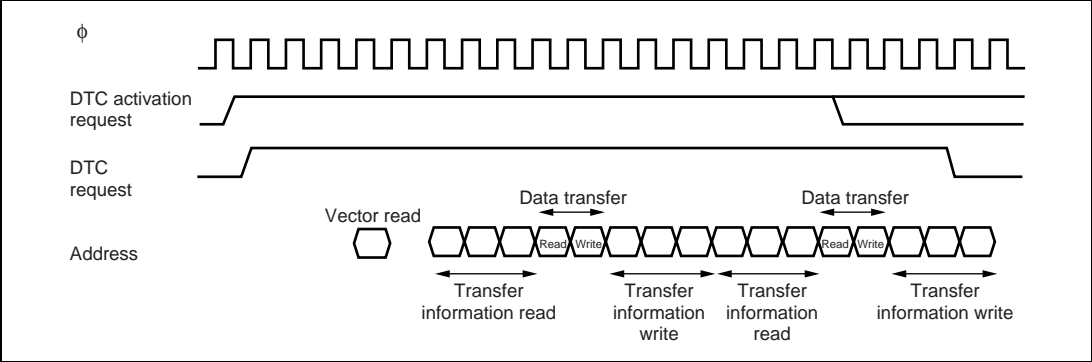


Figure 8.12 DTC Operation Timing (Example of Chain Transfer)

8.5.7 Number of DTC Execution States

Table 8.5 lists execution status for a single DTC data transfer, and table 8.6 shows the number of states required for each execution status.

Table 8.5 DTC Execution Status

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 of CRAH and CRAL)

Table 8.6 Number of States Required for Each Execution Status

Object to be Accessed		On-Chip RAM	On-Chip ROM	Internal I/O Registers		External Devices*		
Bus width		32	16	8	16	8	16	
Access states		1	1	2	2	2	3	2 3
Execution Status	Vector read S_i	—	1	—	—	4	6 + 2m	2 3 + m
	Register information read/write S_j	1	—	—	—	—	—	—
	Byte data read S_k	1	1	2	2	2	3 + m	2 3 + m
	Word data read S_k	1	1	4	2	4	6 + 2m	2 3 + m
	Byte data write S_L	1	1	2	2	2	3 + m	2 3 + m
	Word data write S_L	1	1	4	2	4	6 + 2m	2 3 + m
	Internal operation S_M	1						

Legend:

m: The number of wait states for accessing external devices.

Note: * Cannot be used in this LSI.

The number of execution states is calculated from using the formula below. Note that Σ is the sum of all transfers activated by one activation event (the number in which the CHNE bit is set to 1, plus 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 the on-chip ROM, normal mode is set, and data is transferred from on-chip ROM to an internal I/O register, then the time required for the DTC operation is 13 states. The time from activation to the end of the data write is 10 states.

8.6 Procedures for Using DTC

8.6.1 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 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 one data transfer has been completed, or after the specified number of data transfers have been completed, 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.

8.6.2 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 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 SWDTE bit and the vector number to DTVECR.
5. Check the vector number written to DTVECR.
6. After one data transfer has been completed, 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 have been completed, the SWDTE bit is held at 1 and a CPU interrupt is requested.

8.7 Examples of Use of the DTC

8.7.1 Normal Mode

An example is shown in which the DTC is used to receive 128 bytes of data via the SCI.

1. Set MRA to a 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 SCI RDR address in SAR, the start address of the RAM area where the data will be received 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 SCI 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 the reception of one byte of data has been completed on the SCI, 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 been completed, 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 will perform wrap-up processing.

8.7.2 Software Activation

An example is shown in which the DTC is used to transfer a block of 128 bytes of data by means of 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 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 it is set to the vector number (H'60). If it is not, this indicates that the write failed. This is presumably 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.

8.8 Usage Notes

8.8.1 Module Stop Mode Setting

DTC operation can be disabled or enabled using the module stop control register. The initial setting is for DTC operation to be enabled. Register access is disabled by setting module stop mode. Module stop mode cannot be set during DTC operation. For details, refer to section 22, Power-Down Modes.

8.8.2 On-Chip RAM

The MRA, MRB, SAR, DAR, CRA, and CRB registers are all located in on-chip RAM.

8.8.3 DTCE Bit Setting

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.

Section 9 I/O Ports

The H8S/2268 Series has ten I/O ports (ports 1, 3, 7, F, H, and J to N), and two input-only port (ports 4 and 9). The H8S/2264 Series has eight I/O ports (ports 1, 3, 7, F, H, and J to L), and two input-only port (ports 4 and 9).

Table 9.1 summarizes the port functions. The pins of each port also have other functions such as input/output or interrupt input pins of on-chip peripheral modules.

Each I/O port includes a data direction register (DDR) that controls input/output, a data register (DR) that stores output data, and a port register (PORT) used to read the pin states. The input-only ports do not have DDR and DR registers.

Port J has a built-in input pull-up MOS function and an input pull-up MOS control register (PCR) to control the on/off state of input pull-up MOS.

Port 3 includes an open-drain control register (ODR) that controls the on/off state of the output buffer PMOS.

All the I/O ports can drive a single TTL load and a 30 pF capacitive load.

The P34 and P35 pins on port 3 are NMOS push pull outputs.

Pins $\overline{\text{IRQ}}$ and $\overline{\text{WKP}}$ are Schmitt-trigger inputs. Pins PH0 to PH3 and ports J to N in the H8S/2268 Series and pins PH0 to PH3 and ports J to L in the H8S/2264 Series are shared as LCD segment pins and common pins. They can be selected on an 8-bit basis in the H8S/2268 Series and on a 4-bit basis in the H8S/2264 Series.

Table 9.1 H8S/2268 Series Port Functions (1)

Port	Description	Port and Other Functions Name	Input/Output and Output Type
Port 1	General I/O port also functioning as TPU I/O pins and interrupt input pins	P17/TIOCB2/TCLKD	
		P16/TIOCA2/ $\overline{\text{IRQ1}}$	
		P15/TIOCB1/TCLKC	
		P14/TIOCA1/ $\overline{\text{IRQ0}}$	
		P13/TIOCD0/TCLKB	
		P12/TIOCC0/TCLKA	
		P11/TIOCB0	
		P10/TIOCA0	
Port 3	General I/O port also functioning as SCI_0 and SCI_1 I/O pins, I ² C bus interface I/O pins, and interrupt input pins	P35/SCK1/SCL0/ $\overline{\text{IRQ5}}$	Specifiable of open drain output
		P34/RxD1/SDA0	
		P33/TxD1/SDA0	
		P32/SCK0/SDA1/ $\overline{\text{IRQ4}}$	
		P31/RxD0	
		P30/TxD0	
Port 4	General input port also functioning as A/D converter analog input pins	P47/AN7	
		P46/AN6	
		P45/AN5	
		P44/AN4	
		P43/AN3	
		P42/AN2	
		P41/AN1	
		P40/AN0	
Port 7	General I/O port also functioning as SCI_2 I/O pins and 8-bit timer I/O pins	P77/TxD2	
		P76/RxD2	
		P75/TMO3/SCK2	
		P74/TMO2	
		P73/TMO1	
		P72/TMO0	
		P71/TMRI23/TMCi23	
		P70/TMRI01/TMCi01	

Port	Description	Port and Other Functions Name	Input/Output and Output Type
Port 9	General input port also functioning as A/D converter analog input and D/A converter analog output pins	P97/AN9/DA1	
		P96/AN8/DA0	
Port F	General I/O port also functioning as interrupt input pins and an A/D converter input pins	PF3/ADTRG/IRQ3	
Port H	General input port also functioning as DTMF generation circuit pins, 8-bit reload timer input pins General I/O port also functioning as LCD common output pins	PH7/TONED/TMCI4	
		PH3/COM4	
		PH2/COM3	
		PH1/COM2	
		PH0/COM1	
Port J	General I/O port also functioning as wakeup input pins and LCD segment output pins	PJ7/WKP7/SEG8	Built-in input pull-up MOS
		PJ6/WKP6/SEG7	
		PJ5/WKP5/SEG6	
		PJ4/WKP4/SEG5	
		PJ3/WKP3/SEG4	
		PJ2/WKP2/SEG3	
		PJ1/WKP1/SEG2	
Port K	General I/O port also functioning as LCD segment output pins	PJ0/WKP0/SEG1	
		PK7/SEG16	
		PK6/SEG15	
		PK5/SEG14	
		PK4/SEG13	
		PK3/SEG12	
		PK2/SEG11	
		PK1/SEG10	
		PK0/SEG9	

Port	Description	Port and Other Functions Name	Input/Output and Output Type
Port L	General I/O port also functioning as LCD segment output pins	PL7/SEG24	
		PL6/SEG23	
		PL5/SEG22	
		PL4/SEG21	
		PL3/SEG20	
		PL2/SEG19	
		PL1/SEG18	
		PL0/SEG17	
Port M	General I/O port also functioning as LCD segment output pins	PM7/SEG32	
		PM6/SEG31	
		PM5/SEG30	
		PM4/SEG29	
		PM3/SEG28	
		PM2/SEG27	
		PM1/SEG26	
		PM0/SEG25	
Port N	General I/O port also functioning as LCD segment output pins	PN7/SEG40	
		PN6/SEG39	
		PN5/SEG38	
		PN4/SEG37	
		PN3/SEG36	
		PN2/SEG35	
		PN1/SEG34	
		PN0/SEG33	

Table 9.1 H8S/2264 Series Port Functions (2)

Port	Description	Port and Other Functions Name	Input/Output and Output Type
Port 1	General I/O port also functioning as TPU I/O pins and interrupt input pins	P17/TIOCB2	
		P16/TIOCA2/ $\overline{\text{IRQ1}}$	
		P15/TIOCB1/TCLKC	
		P14/TIOCA1/ $\overline{\text{IRQ0}}$	
		P13/TCLKB	
		P12/TCLKA	
		P11	
		P10	
Port 3	General I/O port also functioning as SCI_0 and SCI_1 I/O pins, I ² C bus interface I/O pins, and interrupt input pins	P35/SCK1/SCL0	Specifiable of open drain output
		P34/RxD1/SDA0	
		P33/TxD1	
		P32/SCK0/ $\overline{\text{IRQ4}}$	
		P31/RxD0	
		P30/TxD0	
Port 4	General input port also functioning as A/D converter analog input pins	P47/AN7	
		P46/AN6	
		P45/AN5	
		P44/AN4	
		P43/AN3	
		P42/AN2	
		P41/AN1	
		P40/AN0	
Port 7	General I/O port also functioning as SCI_2 I/O pins and 8-bit timer I/O pins	P77/TxD2	
		P76/RxD2	
		P75/SCK2	
		P74	
		P73/TMO1	
		P72/TMO0	
		P71	
		P70/TMRI01/TMCI01	

Port	Description	Port and Other Functions Name	Input/Output and Output Type
Port 9	General input port also functioning as A/D converter analog inputs	P97/AN9 P96/AN8	
Port F	General I/O port also functioning as interrupt input pins and an A/D converter input pins	PF3/ADTRG/IRQ3	
Port H	General input port General I/O port also functioning as ϕ output pin and LCD common output pins	PH7 PH5 PH4/ ϕ PH3/COM4 PH2/COM3 PH1/COM2 PH0/COM1	
Port J	General I/O port also functioning as wakeup input pins and LCD segment output pins	PJ7/ $\overline{\text{WKP7}}$ /SEG8 PJ6/ $\overline{\text{WKP6}}$ /SEG7 PJ5/ $\overline{\text{WKP5}}$ /SEG6 PJ4/ $\overline{\text{WKP4}}$ /SEG5 PJ3/ $\overline{\text{WKP3}}$ /SEG4 PJ2/ $\overline{\text{WKP2}}$ /SEG3 PJ1/ $\overline{\text{WKP1}}$ /SEG2 PJ0/ $\overline{\text{WKP0}}$ /SEG1	Built-in input pull-up MOS
Port K	General I/O port also functioning as LCD segment output pins	PK7/SEG16 PK6/SEG15 PK5/SEG14 PK4/SEG13 PK3/SEG12 PK2/SEG11 PK1/SEG10 PK0/SEG9	

Port	Description	Port and Other Functions Name	Input/Output and Output Type
Port L	General I/O port also functioning as LCD segment output pins	PL7/SEG24	
		PL6/SEG23	
		PL5/SEG22	
		PL4/SEG21	
		PL3/SEG20	
		PL2/SEG19	
		PL1/SEG18	
		PL0/SEG17	

9.1 Port 1

Port 1 is an 8-bit I/O port and has the following registers.

- Port 1 data direction register (P1DDR)
- Port 1 data register (P1DR)
- Port 1 register (PORT1)

9.1.1 Port 1 Data Direction Register (P1DDR)

P1DDR specifies input or output of the port 1 pins using the individual bits. P1DDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	P17DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port 1 pin an output pin. Clearing this bit to 0 makes the pin an input pin.
6	P16DDR	0	W	
5	P15DDR	0	W	
4	P14DDR	0	W	
3	P13DDR	0	W	
2	P12DDR	0	W	
1	P11DDR	0	W	
0	P10DDR	0	W	

9.1.2 Port 1 Data Register (P1DR)

P1DR stores output data for port 1 pins.

Bit	Bit Name	Initial Value	R/W	Description
7	P17DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	P16DR	0	R/W	
5	P15DR	0	R/W	
4	P14DR	0	R/W	
3	P13DR	0	R/W	
2	P12DR	0	R/W	
1	P11DR	0	R/W	
0	P10DR	0	R/W	

9.1.3 Port 1 Register (PORT1)

PORT1 shows the pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	P17	—*	R	If a port 1 read is performed while P1DDR bits are set to 1, the P1DR values are read. If a port 1 read is performed while P1DDR bits are cleared to 0, the pin states are read.
6	P16	—*	R	
5	P15	—*	R	
4	P14	—*	R	
3	P13	—*	R	
2	P12	—*	R	
1	P11	—*	R	
0	P10	—*	R	

Note: * Determined by the states of pins P17 to P10.

9.1.4 Pin Functions

Port 1 pins also function as TPU I/O pins (TCLKA, TCLKB, TCLKC, TCLKD*, TIOCA0*, TIOCB0*, TIOCC0*, TIOCD0*, TIOCA1, TIOCB1, TIOCA2, and TIOCB2) and external interrupt input pins ($\overline{\text{IRQ0}}$ and $\overline{\text{IRQ1}}$). Port 1 pin functions are shown below.

Note: * Supported only by the H8S/2268 Series.

- P17/TIOCB2/TCLKD*³

The pin function is switched as shown below according to the combination of the TPU channel 2 setting, TPSC2 to TPS0 bits in TCR0*, and the P17DDR bit.

TPU Channel 2 Setting**	Output	Input or Initial Value	
P17DDR	—	0	1
Pin function	TIOCB2 output	P17 input	P17 output
		TIOCB2 input* ¹	
		TCLKD input* ² * ³	

- Notes
1. This pin functions as TIOCB2 input when TPU channel 2 timer operating mode is set to normal operation or phase counting mode*³ and IOB3 in TIOR_2 is set to 1.
 2. In the H8S/2268 Series, this pin functions as TCLKD input when TPSC2 to TPSC0 in TCR0 are set to 111 or when channel 2 is set to phase counting mode*³.
 3. Supported only by the H8S/2268 Series.

- P16/TIOCA2/ $\overline{\text{IRQ1}}$

The pin function is switched as shown below according to the combination of the TPU channel 2 setting and the P16DDR bit.

TPU Channel 2 Setting**	Output	Input or Initial Value	
P16DDR	—	0	1
Pin function	TIOCA2 output	P16 input	P16 output
		TIOCA2 input* ¹	
		$\overline{\text{IRQ1}}$ input* ²	

- Notes
1. This pin functions as TIOCA2 input when TPU channel 2 timer operating mode is set to normal operation or phase counting mode*³ and IOA3 in TIOR_2 is 1.
 2. When this pin is used as an external interrupt pin, do not specify other functions.
 3. Supported only by the H8S/2268 Series.

- P15/TIOCB1/TCLKC

The pin function is switched as shown below according to the combination of the TPU channel 1 setting, TPSC2 to TPSC0 bits in TCR0*³ and TCR2, and the P15DDR bit.

TPU Channel 1 Setting**	Output	Input or Initial Value	
P15DDR	—	0	1
Pin function	TIOCB1 output	P15 input	P15 output
		TIOCB1 input* ¹	
	TCLKC input* ²		

- Notes
1. This pin functions as TIOCB1 input when TPU channel 1 timer operating mode is set to normal operation or phase counting mode*³ and IOB3 to IOB0 in TIOR_1 are set to 10xx.
 2. This pin functions as TCLKC inputs when TPSC2 to TPSC0 in TCR0*³ or TCR2 are set to 110 or TCLKC input when channel 2 is set to phase counting mode*³.
 3. Supported only by the H8S/2268 Series.

- P14/TIOCA1/ $\overline{\text{IRQ0}}$

The pin function is switched as shown below according to the combination of the TPU channel 1 setting and the P14DDR bit.

TPU Channel 1 Setting**	Output	Input or Initial Value	
P14DDR	—	0	1
Pin function	TIOCA1 output	P14 input	P14 output
		TIOCA1 input* ¹	
	IRQ0 input* ²		

- Notes:
1. This pin functions as TIOCA1 input when TPU channel 1 timer operating mode is set to normal operation or phase counting mode*³ and IOA3 to IOA0 in TIOR_1 are set to 10xx.
 2. When this pin is used as an external interrupt pin, do not specify other functions.
 3. Supported only by the H8S/2268 Series.

- P13/TIOCD0^{*3}/TCLKB

The pin function is switched as shown below according to the combination of the TPU channel 0^{*3} setting, TPSC2 to TPSC0 bits in TCR0^{*3}, TCR1 and TCR2, and the P13DDR bit.

TPU Channel 0 Setting** * ³	Output	Input or Initial Value	
P13DDR	—	0	1
Pin function	TIOCD0 output* ³	P13 input	P13 output
		TIOCD0 input* ¹ * ³	
	TCLKB input* ²		

- Notes: 1. In the H8S/2268 Series, this pin functions as TIOCD0 input when TPU channel 0 timer operating mode is set to normal operation and IOD3 to IOD0 in TIORL_0 are set to 10xx.
2. This pin functions as TCLKB input when TPSC2 to TPSC0 are set to 101 in any of TCR0^{*3}, TCR1 and TCR2. TCLKB input, or when channel 1 is set to phase counting mode*³.
3. Supported only by the H8S/2268 Series.

- P12/TIOCC0^{*3}/TCLKA

The pin function is switched as shown below according to the combination of the TPU channel 0^{*3} setting, TPSC2 to TPSC0 bits in TCR2, TCR1 and TCR0^{*3}, and the P12DDR bit.

TPU Channel 0 Setting** * ³	Output	Input or Initial Value	
P12DDR	—	0	1
Pin function	TIOCC0 output* ³	P12 input	P12 output
		TIOCC0 input* ¹ * ³	
	TCLKA input* ²		

- Notes: 1. In the H8S/2268 Series, TIOCC0 input when TPU channel 0 timer operating mode is set to normal operation and IOC3 to IOC0 in TIORL_0 are set to 10xx.
2. This functions as TCLKA input when TPSC2 to TPSC0 are set to 100 in any of TCR2, TCR1 and TCR0^{*3} or when channel 1 is set to phase counting mode*³.
3. Supported only by the H8S/2268 Series.

- P11/TIOCB0*²

The pin function is switched as shown below according to the combination of the TPU channel 0*² setting and the P11DDR bit.

TPU Channel 0 Setting** * ²	Output	Input or Initial Value	
P11DDR	—	0	1
Pin function	TIOCB0 output* ²	P11 input	P11 output
		TIOCB0 input* ¹ * ²	

- Notes: 1. In the H8S/2268 Series, this pin functions as TIOCB0 input when TPU channel 0 timer operating mode is set to normal operation and IOB3 to IOB0 in TIORH_0 are set to 10xx.
2. Supported only by the H8S/2268 Series.

- P10/TIOCA0*²

The pin function is switched as shown below according to the combination of the TPU channel 0*² setting and the P10DDR bit.

TPU Channel 0 Setting** * ²	Output	Input or Initial Value	
P10DDR	—	0	1
Pin function	TIOCA0 output* ²	P10 input	P10 output
		TIOCA0 input* ¹ * ²	

- Notes: 1. In the H8S/2268 Series, this pin functions as TIOCA0 input when TPU channel 0 timer operating mode is set to normal operation and IOA3 to IOA0 in TIORH_0 are set to 10xx.
2. Supported only by the H8S/2268 Series.

**:

For the setting of the TPU channel, see section 10, 16-Bit Timer Pulse Unit (TPU).

9.2 Port 3

Port 3 is a 6-bit I/O port and has the following registers.

- Port 3 data direction register (P3DDR)
- Port 3 data register (P3DR)
- Port 3 register (PORT3)
- Port 3 open drain control register (P3ODR)

9.2.1 Port 3 Data Direction Register (P3DDR)

P3DDR specifies input or output of the port 3 pins using the individual bits.

P3DDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
5	P35DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port 3 pin an output port. Clearing this bit to 0 makes the pin an input port.
4	P34DDR	0	W	
3	P33DDR	0	W	
2	P32DDR	0	W	
1	P31DDR	0	W	
0	P30DDR	0	W	

9.2.2 Port 3 Data Register (P3DR)

P3DR stores output data for port 3 pins.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
5	P35DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
4	P34DR	0	R/W	
3	P33DR	0	R/W	
2	P32DR	0	R/W	
1	P31DR	0	R/W	
0	P30DR	0	R/W	

9.2.3 Port 3 Register (PORT3)

PORT3 shows the pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
5	P35	—*	R	If a port 3 read is performed while P3DDR bits are set to 1, the P3DR values are read. If a port 3 read is performed while P3DDR bits are cleared to 0, the pin states are read.
4	P34	—*	R	
3	P33	—*	R	
2	P32	—*	R	
1	P31	—*	R	
0	P30	—*	R	

Note: * Determined by the states of pins P35 to P30.

9.2.4 Port 3 Open Drain Control Register (P3ODR)

P3ODR controls on/off state of the PMOS for port 3 pins.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
5	P35ODR	0	R/W	When each of P33ODR to P30ODR bits is set to 1, the corresponding pins P33 to P30 function as NMOS open drain outputs. When cleared to 0, the corresponding pins function as CMOS outputs. When each of P35ODR and P34ODR bits is set to 1, the corresponding pins P35 and P34 function as NMOS open drain outputs. When they are cleared to 0, the corresponding pins function as NMOS push pull outputs.
4	P34ODR	0	R/W	
3	P33ODR	0	R/W	
2	P32ODR	0	R/W	
1	P31ODR	0	R/W	
0	P30ODR	0	R/W	

9.2.5 Pin Functions

The port 3 pins also function as SCI I/O input pins (TxD0, RxD0, SCK0, TxD1, RxD1, and SCK1), I2C bus interface I/O pins (SCL0, SDA0, SCL1*, and SDA1*), and as external interrupt input pins ($\overline{\text{IRQ4}}$ and $\overline{\text{IRQ5}}$).

As shown in figure 9.1, when the pins P34, P35, SCL0 or SDA0 type open drain output is used, a bus line is not affected even if the power supply for this LSI fails. Use (a) type open drain output when using a bus line having a state in which the power is not supplied to this LSI.

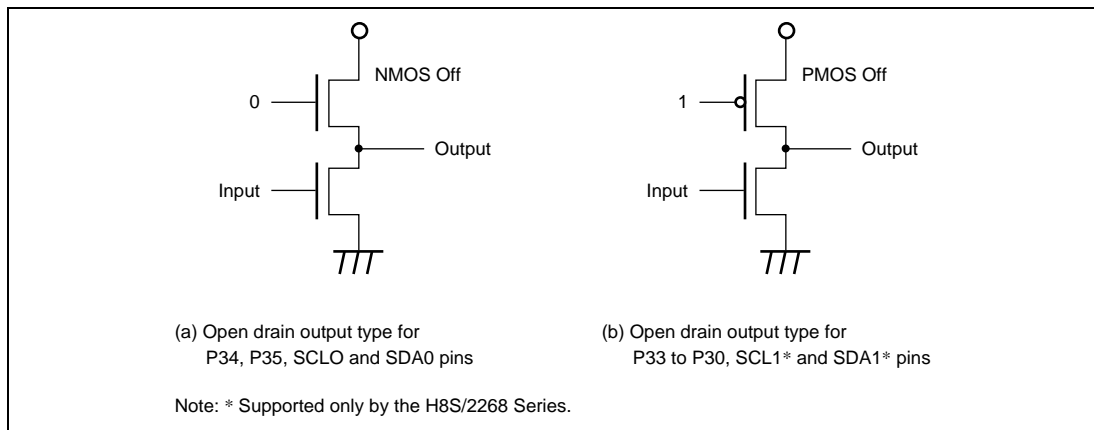


Figure 9.1 Types of Open Drain Outputs

Note: * Supported only by the H8S/2268 Series.

The functions of port 3 pins are shown below.

- P35/SCK1/SCL0/ $\overline{\text{IRQ5}}$ *²

The pin function is switched as shown below according to the combination of the ICE bit in ICCR_0 of IIC_0, C/ $\overline{\text{A}}$ bit in SMR of SCI_1, CKE0 and CKE1 bits in SCR and the P35DDR bit.

ICE	0					1
CKE1	0			1		0
C/ $\overline{\text{A}}$	0			1	—	0
CKE0	0		1	—	—	0
P35DDR	0	1	—	—	—	—
Pin functions	P35 input pin	P35 output pin	SCK1 output pin	SCK1 output pin	SCK1 input pin	SCL0 I/O pin
	$\overline{\text{IRQ5}}$ Input * ¹ * ²					

Notes: 1. When this pin is used as an external interrupt pin, do not specify other functions.
2. Supported only by the H8S/2268 Series.

- P34/RxD1/SDA0

The pin function is switched as shown below according to the combination of the ICE bit in ICCR_0 of IIC_0, RXD1S bit in SCKCR2*, RE bit in SCR of SCI_1 and the P34DDR bit.

ICE	0					1
RXD1S*	0			1		—
RE	0		1	—		—
P34DDR	0	1	—	0	1	—
Pin functions	P34 input pin	P34 output pin	RxD1 input pin	P34 input pin	P34 output pin	SDA0 I/O pin

Note: * Supported only by the H8S/2264 Series.

- P33/TxD1/SCL1*

The pin function is switched as shown below according to the combination of the ICE bit* in ICCR_1 of IIC_1, TE bit in SCR of SCI_1 and the P33DDR bit.

ICE*	0				1
TE	0			1	—
P33DDR	0	1	—	—	—
Pin functions	P33 input pin	P33 output pin	TxD1 output pin	SCL1 I/O pin*	

Note: * Supported only by the H8S/2268 Series.

- P32/SCK0/SDA1^{*2}/ $\overline{\text{IRQ4}}$

The pin function is switched as shown below according to the combination of the ICE bit^{*2} in ICCR_1 of IIC_1, C/ $\overline{\text{A}}$ bit in SMR of SCI_0, CKE0 and CKE1 bits in SCR and the P32DDR bit.

ICE ^{*2}	0					1
CKE1	0			1		0
C/ $\overline{\text{A}}$	0		1	—	—	0
CKE0	0		1	—	—	0
P32DDR	0	1	—	—	—	—
Pin functions	P32 input pin	P32 output pin	SCK0 output pin	SCK0 output pin	SCK0 input pin	SDA1 I/O pin ^{*2}
	$\overline{\text{IRQ4}}$ Input ^{*1}					

Notes: 1. When this pin is used as an external interrupt pin, do not specify other functions.
2. Supported only by the H8S/2268 Series.

- P31/RxD0

The pin function is switched as shown below according to the combination of the RE bit in SCR of SCI_0 and the P31DDR bit.

RE	0		1
P31DDR	0	1	—
Pin functions	P31 input pin	P31 output pin	RxD0 input pin

- P30/TxD0

The pin function is switched as shown below according to the combination of the TE bit in SCR of SCI_0 and the P30DDR bit.

TE	0		1
P30DDR	0	1	—
Pin functions	P30 input pin	P30 output pin	TxD0 output pin

9.3 Port 4

Port 4 is an 8-bit input-only port and has the following register.

- Port 4 register (PORT4)

9.3.1 Port 4 Register (PORT4)

PORT4 shows port 4 pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	P47	—*	R	The pin states are always read when a port 4 read is performed.
6	P46	—*	R	
5	P45	—*	R	
4	P44	—*	R	
3	P43	—*	R	
2	P42	—*	R	
1	P41	—*	R	
0	P40	—*	R	

Note: * Determined by the states of pins P47 to P40.

9.3.2 Pin Functions

Port 4 pins also function as A/D converter analog input pins (AN0 to AN7).

9.4 Port 7

Port 7 is an 8-bit I/O port and has the following registers.

- Port 7 data direction register (P7DDR)
- Port 7 data register (P7DR)
- Port 7 register (PORT7)

9.4.1 Port 7 Data Direction Register (P7DDR)

P7DDR specifies input or output of the port 7 pins using the individual bits. P7DDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	P77DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port 7 pin an output pin. Clearing this bit to 0 makes the pin an input pin.
6	P76DDR	0	W	
5	P75DDR	0	W	
4	P74DDR	0	W	
3	P73DDR	0	W	
2	P72DDR	0	W	
1	P71DDR	0	W	
0	P70DDR	0	W	

9.4.2 Port 7 Data Register (P7DR)

P7DR stores output data for port 7 pins.

Bit	Bit Name	Initial Value	R/W	Description
7	P77DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	P76DR	0	R/W	
5	P75DR	0	R/W	
4	P74DR	0	R/W	
3	P73DR	0	R/W	
2	P72DR	0	R/W	
1	P71DR	0	R/W	
0	P70DR	0	R/W	

9.4.3 Port 7 Register (PORT7)

PORT7 shows the pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	P77	—*	R	If a port 1 read is performed while P7DDR bits are set to 1, the P7DR values are read. If a port 1 read is performed while P7DDR bits are cleared to 0, the pin states are read.
6	P76	—*	R	
5	P75	—*	R	
4	P74	—*	R	
3	P73	—*	R	
2	P72	—*	R	
1	P71	—*	R	
0	P70	—*	R	

Note: * Determined by the states of pins P77 to P70.

9.4.4 Pin Functions

Port 7 pins also function as the 8-bit timer I/O pins (TMRI01, TMCI01, TMRI23*, TMCI23*, TMO0, TMO1, TMO2*, and TMO3*) and SCI I/O pins (SCK2, Rx2D and Tx2D). Port 7 pin functions are shown below.

Note: * Supported only by the H8S/2268 Series.

- P77/TxD2

The pin function is switched as shown below according to the combination of the TE bit in SCR of SCI_2 and the P77DDR bit.

TE	0		1
P77DDR	0	1	—
Pin functions	P77 input pin	P77 output pin	TxD2 output pin

- P76/RxD2

The pin function is switched as shown below according to the combination of the RE bit in SCR of SCI_2 and the P76DDR bit.

RE	0		1
P76DDR	0	1	—
Pin functions	P76 input pin	P76 output pin	RxD2 Input pin

- P75/TMO3*/SCK2

The pin function is switched as shown below according to the combination of the OS3 to OS0 bits in TCSR_3* of the 8-bit timer, the C/A bit in SMR of SCI_2, the CKE0 and CKE1 bits in SCR and the P75DDR bit.

OS3 to OS0*	All bits are 0					Any bit is 1
CKE1	0			1		—
C/ \bar{A}	0			1	—	—
CKE0	0		1	—	—	—
P75DDR	0	1	—	—	—	—
Pin functions	P75 input pin	P75 output pin	SCK2 output pin	SCK2 output pin	SCK2 input pin	TMO3 output pin*

Note: * Supported only by the H8S/2268 Series.

- P74/TMO2*

The pin function is switched as shown below according to the combination of the OS3 to OS0 bits in TCSR_2* of the 8-bit timer and the P74DDR bit.

OS3 to OS0*	All bits are 0		Any bit is 1
P74DDR	0	1	—
Pin functions	P74 input pin	P74 output pin	TMO2 output pin*

Note: * Supported only by the H8S/2268 Series.

- P73/TMO1

The pin function is switched as shown below according to the combination of the OS3 to OS0 bits in TCSR_1 of the 8-bit timer and the P73DDR bit.

OS3 to OS0	All bits are 0		Any bit is 1
P73DDR	0	1	—
Pin functions	P73 input pin	P73 output pin	TMO1 output pin

- P72/TMO0

The pin function is switched as shown below according to the combination of the OS3 to OS0 bits in TCSR_0 of the 8-bit timer and the P72DDR bit.

OS3 to OS0	All bits are 0		Any bit is 1
P72DDR	0	1	—
Pin functions	P72 input pin	P72 output pin	TMO0 output pin

- P71/TMRI23*/TMCI23*

The pin function is switched as shown below according to the P71DDR bit.

P71DDR	0	1
Pin functions	P71 input pin	P71 output pin
	TMRI23/TMCI23 input pin*	

Note: * Supported only by the H8S/2268 Series.

- P70/TMRI01/TMCI01

The pin function is switched as shown below according to the P70DDR bit.

P70DDR	0	1
Pin functions	P70 input pin	P70 output pin
	TMRI01/TMCI01 input pin	

9.5 Port 9

Port 9 is a 2-bit input-only port and has the following register.

- Port 9 register (PORT9)

9.5.1 Port 9 Register (PORT9)

PORT9 shows port 9 pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	P97	—*	R	The pin states are always read when these bits are read.
6	P96	—*	R	
5 to 0	—	Undefined	R	Reserved These bits are always read as undefined value and cannot be modified.

Note: * Determined by the states of pins P97 and P96.

9.5.2 Pin Functions

Port 9 pins also function as A/D converter analog input pins (AN8 and AN9) and D/A converter analog output pins (DA0 and DA1)*.

Note: * Supported only by the H8S/2268 Series.

9.6 Port F

Port F is a 1-bit I/O port and has the following register.

- Port F data direction register (PFDDR)
- Port F data register (PFDR)
- Port F register (PORTF)

9.6.1 Port F Data Direction Register (PFDDR)

PFDDR specifies input or output the port F pins using the individual bits. PFDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
3	PF3DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port F pin an output pin. Clearing this bit to 0 makes the pin an input pin.
2 to 0	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.

9.6.2 Port F Data Register (PFDR)

PFDR stores output data for port F pins.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
3	PF3DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
2 to 0	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.

9.6.3 Port F Register (PORTF)

PORTF shows the pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
3	PF3	—*	R	If this bit is read while PFDDR is set to 1, the PFDR value is read. If this bit is read while PFDDR is cleared, the PF3 pin states are read.
2 to 0	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.

Note: * Determined by the states of PF3 pin.

9.6.4 Pin Functions

Port F pins also function as an external interrupt input pin ($\overline{\text{IRQ3}}$) and A/D trigger output pin ($\overline{\text{ADTRG}}$). Port F pin functions are shown below.

- PF3/ $\overline{\text{ADTRG}}$ / $\overline{\text{IRQ3}}$

The pin function is switched as shown below according to the combination of the TRGS1 and TRGS0 bits of ADCR of the A/D converter and the PF3DDR bit.

PF3DDR	0	1
Pin functions	PF3 input pin	PF3 output pin
	$\overline{\text{ADTRG}}$ Input pin* ¹	
	$\overline{\text{IRQ3}}$ input pin* ²	

Notes: 1. When TRGS0 = TRGS1 = 1, port F is used as the $\overline{\text{ADTRG}}$ input pin.

2. When this port is used as an external interrupt pin, do not specify other functions.

9.7 Port H

Port H for the H8S/2268 Series is a 1-bit input and 4-bit I/O port, and that for the H8S/2264 Series is a 1-bit input and 6-bit I/O port. Port H has the following registers.

- Port H data direction register (PHDDR)
- Port H data register (PHDR)
- Port H register (PORTH)

9.7.1 Port H Data Direction Register (PHDDR)

PHDDR specifies input or output the port H pins using the individual bits. PHDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
5	PH5DDR	0* ¹	W* ²	H8S/2268 Series:
4	PH4DDR	0* ¹	W* ²	Reserved These bits are always read as undefined value and cannot be modified. H8S/2264 Series: When a pin is specified as a general purpose I/O port, setting the bit to 1 makes the corresponding port H pin an output pin. Clearing the bit to 0 makes the pin an input pin.
3	PH3DDR	0	W	When a pin is specified as a general purpose I/O port, setting these bits to 1 makes the corresponding port H pin an output pin. Clearing this bit to 0 makes the pin an input pin.
2	PH2DDR	0	W	
1	PH1DDR	0	W	
0	PH0DDR	0	W	

Notes: 1. Undefined in the H8S/2268 Series.

2. This bit cannot be modified in the H8S/2268 Series.

9.7.2 Port H Data Register (PHDR)

PHDR stores output data for port H pins (H8S/2268 Series: PH3 to PH0; H8S/2264 Series: PH5 to PH0).

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	Undefined	—	Reserved These bits are always read as undefined value and cannot be modified.
5	PH5DR	0* ¹	R/W* ²	H8S/2268 Series:
4	PH4DR	0* ¹	R/W* ²	Reserved These bits are always read as undefined value and cannot be modified. H8S/2264 Series: Output data for a pin is stored when the pin is specified as a general purpose output port.
3	PH3DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
2	PH2DR	0	R/W	
1	PH1DR	0	R/W	
0	PH0DR	0	R/W	

Notes: 1. Undefined in the H8S/2268 Series.

2. This bit cannot be modified in the H8S/2268 Series.

9.7.3 Port H Register (PORTH)

PORTH shows the pin states and cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PH7	—* ¹	R	When this bit is read, PH7 pin status is always read.
6	—	Undefined	—	Reserved This bit is always read as undefined value and cannot be modified.
5	PH5	—* ¹ * ²	R	H8S/2268 Series:
4	PH4	—* ¹ * ²	R	Reserved These bits are always read as undefined value and cannot be modified. H8S/2264 Series: If these bits are read while the corresponding PHDDR bits are set to 1, the PHDR value is read. If these bits are read while PHDDR bits are cleared to 0, the pin states are read.
3	PH3	—* ¹	R	If these bits are read while the corresponding PHDDR
2	PH2	—* ¹	R	bits are set to 1, the PHDR value is read. If these bits
1	PH1	—* ¹	R	are read while PHDDR bits are cleared to 0, the pin
0	PH0	—* ¹	R	states are read.

Notes: 1. In the H8S/2268 Series, determined by the states of pins PH7 and PH3 to PH0. In the H8S/2264 Series, determined by the states of pins PH7 and PH5 to PH0
2. Undefined in the H8S/2264 Series only.

9.7.4 Pin Functions

Port H pins also function as a DTMF generation circuit analog output pin (TONED)*¹, 8-bit reload timer input pin (TMCI4)*¹, SCI input pin (RxD1)*², clock (φ) output pin*² and LCD driver common output pins (COM4 to COM1). Port H pin functions are shown below.

Notes: 1. Supported only by the H8S/2268 Series.
2. Supported only by the H8S/2264 Series.

- PH7/TONED^{*3}/TMCI4^{*3}

The pin function is switched as shown below according to the combination of the CLOE and RWOE bits in DTCR of the DTMF generation circuit^{*3}.

CLOE, RWOE ^{*3}	All bits are 0	Any bit is 1
Pin functions	PH7 input pin ^{*1}	TONED output pin ^{*3}
	TMCI4 input pin ^{*1*2*3}	

Notes: 1. Voltage applied to PH7 and TMCI4^{*3} should be within the range of $V_{SS} \leq (PH7, TMCI4) \leq V_{SS}$.

2. When this port is used as TMCI4 input pin^{*3}, do not specify other functions.

3. Supported only by the H8S/2268 Series.

- PH5/RxD1 (H8S/2264 Series Only)

The pin function is switched as shown below according to the combination of the RXD1S bit in SCKCR2 and the RE bit in SCI_1, and the PH5DDR bit.

RXD1S, RE	Other than B'11		B'11
PH5DDR	0	1	—
Pin functions	PH5 input pin	PH5 output pin	RxD1 input pin

- PH4/φ (H8S/2264 Series Only)

The pin function is switched as shown below according to the combination of the PHOE bit in SCKCR2 and the PH4DDR bit.

PHOE	0		1
PH4DDR	0	1	—
Pin functions	PH4 input pin	PH4 output pin	φ output pin

- PH3/COM4

The pin function is switched as shown below according to the combination of the DTS1, DTS0, CMX, and SGS3 to SGS0 bits of LPCR, the SUPS* bit of LCR2 of the LCD controller/driver and the PH3DDR bit.

SGS3 to SGS0	B'0000		H8S/2268 Series: B'0001, B'001X, or B'010X H8S/2264 Series: B'X01X, B'010X, or B'1100							
DTS1, DTS0	B'XX		B'0X			B'10			B'11	
CMX	—		0	1	—	0	1	—	0	1
SUPS*	—		—			0	1	—	0	1
PH3DDR	0	1	0	1	—	0	1	—	0	1
Pin functions	PH3 input pin	PH3 output pin	PH3 input pin	PH3 output pin	COM4 output pin	PH3 input pin	PH3 output pin	Setting prohibited	COM4 output pin	COM4 output pin

Legend

X: Don't care

Note: * Supported only by the H8S/2268 Series.

- PH2/COM3

The pin function is switched as shown below according to the combination of the DTS1, DTS0, CMX, SGS3 to SGS0 bits of LPCR of the LCD controller/driver, and PH2DDR bit.

SGS3 to SGS0	B'0000		H8S/2268 Series: B'0001, B'001X or B'010X H8S/2264 Series: B'X01X, B'010X, or B'1100			
DTS1, DTS0	B'XX		B'0X			B'1X
CMX	—		0			1
PH2DDR	0	1	0	1	—	
Pin functions	PH2 input pin	PH2 output pin	PH2 input pin	PH2 output pin	COM3 output pin	

Legend

X: Don't care

- PH1/COM2

The pin function is switched as shown below according to the combination of the DTS1, DTS0, CMX, SGS3 to SGS0 bits of LPCR of the LCD controller/driver, and PH2DDR bit.

SGS3 to SGS0	B'0000		H8S/2268 Series: B'0001, B'001X or B'010X H8S/2264 Series: B'X01X, B'010X, or B'1100		
DTS1, DTS0	B'XX		B'00		Other than B'00X
CMX	—		0	1	—
PH1DDR	0	1	0	1	—
Pin functions	PH1 input pin	PH1 output pin	PH1 input pin	PH1 output pin	COM2 output pin

Legend

X: Don't care

- PH0/COM1

The pin function is switched as shown below according to the combination of the SGS3 to SGS0 bits in LPCR of the LCD controller/driver and the PH0DDR bit.

SGS3 to SGS0	B'0000		H8S/2268 Series: B'0001, B'001X or B'010X H8S/2264 Series: B'X01X, B'010X, or B'1100
PH0DDR	0	1	—
Pin functions	PH0 input pin	PH0 output pin	COM1 output pin

Legend

X: Don't care

9.8 Port J

Port J is an 8-bit I/O port and has the following registers.

- Port J data direction register (PJDDR)
- Port J data register (PJDR)
- Port J register (PORTJ)
- Port J pull-up MOS control register (PJPCR)
- Wakeup control register (WPCR)

9.8.1 Port J Data Direction Register (PJDDR)

PJDDR specifies input or output the port J pins using the individual bits. PJDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	PJ7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port J pin an output pin. Clearing this bit to 0 makes the pin an input pin.
6	PJ6DDR	0	W	
5	PJ5DDR	0	W	
4	PJ4DDR	0	W	
3	PJ3DDR	0	W	
2	PJ2DDR	0	W	
1	PJ1DDR	0	W	
0	PJ0DDR	0	W	

9.8.2 Port J Data Register (PJDR)

PJDR stores output data for port J pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PJ7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	PJ6DR	0	R/W	
5	PJ5DR	0	R/W	
4	PJ4DR	0	R/W	
3	PJ3DR	0	R/W	
2	PJ2DR	0	R/W	
1	PJ1DR	0	R/W	
0	PJ0DR	0	R/W	

9.8.3 Port J Register (PORTJ)

PORTJ shows port J pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PJ7	—*	R	If a port J read is performed while PJDDR bits are set to 1, the PJDR values are read. If a port J read is performed while PADDR bits are cleared to 0, the pin states are read.
6	PJ6	—*	R	
5	PJ5	—*	R	
4	PJ4	—*	R	
3	PJ3	—*	R	
2	PJ2	—*	R	
1	PJ1	—*	R	
0	PJ0	—*	R	

Note: * Determined by the states of pins PJ7 to PJ0.

9.8.4 Port J Pull-Up MOS Control Register (PJPCR)

PJPCR controls the input pull-up MOS function for each bit.

Bit	Bit Name	Initial Value	R/W	Description
7	PJ7PCR	0	R/W	When a pin is specified as an input port, setting the corresponding bit to 1 turns on the input pull-up MOS for that pin.
6	PJ6PCR	0	R/W	
5	PJ5PCR	0	R/W	
4	PJ4PCR	0	R/W	
3	PJ3PCR	0	R/W	
2	PJ2PCR	0	R/W	
1	PJ1PCR	0	R/W	
0	PJ0PCR	0	R/W	

9.8.5 Wakeup Control Register (WPCR)

WPCR controls switching of port J pin functions. For details on interrupt request flags, refer to 5.3.6, Wakeup Interrupt Request Register (IWPR).

Bit	Bit Name	Initial Value	R/W	Description
7	WPC7	0	R/W	When these bits are set to 1, the corresponding PJn/ \overline{WKPn} pin becomes the \overline{WKPn} input pin. When cleared, they become the PJn input/output pin. (n = 7 to 0)
6	WPC6	0	R/W	
5	WPC5	0	R/W	
4	WPC4	0	R/W	
3	WPC3	0	R/W	
2	WPC2	0	R/W	
1	WPC1	0	R/W	
0	WPC0	0	R/W	

9.8.6 Pin Functions

Port J pins also function as wakeup input pins ($\overline{WKP7}$ to $\overline{WKP0}$) and LCD driver segment output pins (SEG8 to SEG1). Port J pin functions are shown below.

- PJn/ \overline{WKPn} /SEGn+1

The pin function is switched as shown below according to the combination of the SGS3 to SGS0 bits in LPCR of the LCD driver/controller, $\overline{WKP7}$ to $\overline{WKP0}$ bits in WPCR, and PJnDDR bit.

H8S/2268 Series:

SGS3 to SGS0	B'00XX or B'0100			B'0101
WPCn	0		1	—
PJnDDR	0	1	—	—
Pin functions	PJn input pin	PJn output pin	\overline{WKPn} input pin	SEGn+1 output pin

Legend

X: Don't care

Note: n = 7 to 0

SGS3 to SGS0	B'0000, B'X01X or B'0100			B'0101
WPCn	0		1	—
PJnDDR	0	1	—	—
Pin functions	PJn input pin	PJn output pin	\overline{WKPn} input pin	SEGn + 1 output pin

SGS3 to SGS0	B'0000, B'X01X or B'0100			B'0101
WPCm	0		1	—
PJmDDR	0	1	—	—
Pin functions	PJm input pin	PJm output pin	\overline{WKPm} input pin	SEGm + 1 output pin

Legend

X: Don't care

Note: n = 7 to 4, m = 3 to 0

9.8.7 Input Pull-Up MOS Function

Port J has a built-in input pull-up MOS function that can be controlled by software. Input pull-up MOS can be specified as on or off on an individual bit basis.

When port J is set to port input and wakeup input, PJDDR is cleared to 0, and then PJPCR is set to 1, the input pull-up MOS is turned on.

The input pull-up MOS function is in the off state after a reset, and in hardware standby mode. The prior state is retained in software standby mode.

Table 9.2 summarizes the input pull-up MOS states in port J.

Table 9.2 Input Pull-Up MOS States (Port J)

Pin States	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
Segment output and port output	OFF	OFF	OFF	OFF
Port input and wakeup input			ON/OFF	ON/OFF

Legend:

OFF : Input pull-up MOS is always off.

ON/OFF : On when PJDDR = 0 and PJPCR = 1; otherwise off.

9.9 Port K

Port K is an 8-bit I/O port and has the following registers.

- Port K data direction register (PKDDR)
- Port K data register (PKDR)
- Port K register (PORTK)

9.9.1 Port K Data Direction Register (PKDDR)

PKDDR specifies input or output the port K pins using the individual bits. PKDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	PK7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port K pin an output port. Clearing this bit to 0 makes the pin an input port.
6	PK6DDR	0	W	
5	PK5DDR	0	W	
4	PK4DDR	0	W	
3	PK3DDR	0	W	
2	PK2DDR	0	W	
1	PK1DDR	0	W	
0	PK0DDR	0	W	

9.9.2 Port K Data Register (PKDR)

PKDR stores output data for port K pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PK7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	PK6DR	0	R/W	
5	PK5DR	0	R/W	
4	PK4DR	0	R/W	
3	PK3DR	0	R/W	
2	PK2DR	0	R/W	
1	PK1DR	0	R/W	
0	PK0DR	0	R/W	

9.9.3 Port K Register (PORTK)

PORTK shows port K pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PK7	—*	R	If a port K read is performed while PKDDR bits are set to 1, the PKDR values are read. If a port K read is performed while PKDDR bits are cleared to 0, the pin states are read.
6	PK6	—*	R	
5	PK5	—*	R	
4	PK4	—*	R	
3	PK3	—*	R	
2	PK2	—*	R	
1	PK1	—*	R	
0	PK0	—*	R	

Note: * Determined by the states of pins PK7 to PK0.

9.9.4 Pin Functions

Port K pins also function as LCD driver segment output pins (SEG16 to SEG9). Port K pin functions are shown below.

- PKn/SEGn+9

The pin function is switched as shown below according to the combination of the SGS3 to SGS0 bits in LPCR of the LCD driver/controller and PKnDDR bit.

H8S/2268 Series:

SGS3 to SGS0	B'00XX		B'010X
PKnDDR	0	1	—
Pin functions	PKn input pin	PKn output pin	SEGn+9 output pin

Legend

X: Don't care

Note: n = 7 to 0

H8S/2264 Series:

SGS3 to SGS0	B'0000, B'X010 or B'0011		B'0101, B'X010 or B'1011
PKnDDR	0	1	—
Pin functions	PKn input pin	PKn output pin	SEGn+9 output pin

SGS3 to SGS0	B'0000 or B'X01X		B'0101 or B'X100
PKmDDR	0	1	—
Pin functions	PKm input pin	PKm output pin	SEGm+9 output pin

Legend

X: Don't care

Note: n = 7 to 4, m = 3 to 0

9.10 Port L

Port L is an 8-bit I/O port and has the following registers.

- Port L data direction register (PLDDR)
- Port L data register (PLDR)
- Port L register (PORTL)

9.10.1 Port L Data Direction Register (PLDDR)

PLDDR specifies input or output of the port L pins using the individual bits. PLDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	PL7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port L pin an output port. Clearing this bit to 0 makes the pin an input port.
6	PL6DDR	0	W	
5	PL5DDR	0	W	
4	PL4DDR	0	W	
3	PL3DDR	0	W	
2	PL2DDR	0	W	
1	PL1DDR	0	W	
0	PL0DDR	0	W	

9.10.2 Port L Data Register (PLDR)

PLDR stores output data for port L pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PL7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	PL6DR	0	R/W	
5	PL5DR	0	R/W	
4	PL4DR	0	R/W	
3	PL3DR	0	R/W	
2	PL2DR	0	R/W	
1	PL1DR	0	R/W	
0	PL0DR	0	R/W	

9.10.3 Port L Register (PORTL)

PORTL shows port L pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PL7	—*	R	If a port L read is performed while PLDDR bits are set to 1, the PLDR values are read. If a port L read is performed while PLDDR bits are cleared to 0, the pin states are read.
6	PL6	—*	R	
5	PL5	—*	R	
4	PL4	—*	R	
3	PL3	—*	R	
2	PL2	—*	R	
1	PL1	—*	R	
0	PL0	—*	R	

Note: * Determined by the states of pins PL7 to PL0.

9.10.4 Pin Functions

Port L pins also function as LCD driver segment output pins (SEG24 to SEG17). Port L pin functions are shown below.

- P_L_n/SEG_n+17

The pin function is switched as shown below according to the combination of the SGS3 to SGS0 bits in LPCR of the LCD driver/controller and P_L_nDDR bit.

H8S/2268 Series:

SGS3 to SGS0	B'000X or B'0010		B'0011, or B'010X
PLnDDR	0	1	—
Pin functions	PLn input pin	PLn output pin	SEGn+17 output pin

Legend

X: Don't care

Note: n = 7 to 0

H8S/2264 Series:

SGS3 to SGS0	B'00X0		B'0101, B'X100, B'X011 or B'1010
PLnDDR	0	1	—
Pin functions	PLn input pin	PLn output pin	SEGn+17 output pin

SGS3 to SGS0	B'0000 or B'X010		B'0101, B'X100 or B'X011
PLmDDR	0	1	—
Pin functions	PLm input pin	PLm output pin	SEGm+17 output pin

Legend

X: Don't care

Note: n = 7 to 4, m = 3 to 0

9.11 Port M (H8S/2268 Series Only)

Port M is an 8-bit I/O port and has the following registers.

- Port M data direction register (PMDDR)
- Port M data register (PMDR)
- Port M register (PORTM)

9.11.1 Port M Data Direction Register (PMDDR)

PMDDR specifies input or output of the port M pins using the individual bits. PMDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	PM7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port M pin an output port. Clearing this bit to 0 makes the pin an input port.
6	PM6DDR	0	W	
5	PM5DDR	0	W	
4	PM4DDR	0	W	
3	PM3DDR	0	W	
2	PM2DDR	0	W	
1	PM1DDR	0	W	
0	PM0DDR	0	W	

9.11.2 Port M Data Register (PMDR)

PMDR stores output data for port M pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PM7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	PM6DR	0	R/W	
5	PM5DR	0	R/W	
4	PM4DR	0	R/W	
3	PM3DR	0	R/W	
2	PM2DR	0	R/W	
1	PM1DR	0	R/W	
0	PM0DR	0	R/W	

9.11.3 Port M Register (PORTM)

PORTM shows port M pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PM7	—*	R	If a port M read is performed while PMDDR bits are set to 1, the PMDR values are read. If a port M read is performed while PMDDR bits are cleared to 0, the pin states are read.
6	PM6	—*	R	
5	PM5	—*	R	
4	PM4	—*	R	
3	PM3	—*	R	
2	PM2	—*	R	
1	PM1	—*	R	
0	PM0	—*	R	

Note: * Determined by the states of pins PM7 to PM0.

9.11.4 Pin Functions

Port M pins also function as LCD driver segment output pins (SEG32 to SEG25). Port M pin functions are shown below.

- PMn/SEGn+25

The pin function is switched as shown below according to the combination of the SGS3 to SGS0 bits in LPCR of the LCD driver/controller and PMnDDR bit.

SGS3 to SGS0	B'000X		B'001X, or B'010X
PMnDDR	0	1	—
Pin functions	PMn input pin	PMn output pin	SEGn+25 output pin

Legend

X: Don't care

Note: n = 7 to 0

9.12 Port N (H8S/2268 Series Only)

Port N is an 8-bit I/O port and has the following registers.

- Port N data direction register (PNDDR)
- Port N data register (PNDR)
- Port N register (PORTN)

9.12.1 Port N Data Direction Register (PNDDR)

PNDDR specifies input or output of the port N pins using the individual bits. PNDDR cannot be read; if it is, an undefined value will be read.

Bit	Bit Name	Initial Value	R/W	Description
7	PN7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port N pin an output port. Clearing this bit to 0 makes the pin an input port.
6	PN6DDR	0	W	
5	PN5DDR	0	W	
4	PN4DDR	0	W	
3	PN3DDR	0	W	
2	PN2DDR	0	W	
1	PN1DDR	0	W	
0	PN0DDR	0	W	

9.12.2 Port N Data Register (PNDR)

PNDR stores output data for port N pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PN7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose output port.
6	PN6DR	0	R/W	
5	PN5DR	0	R/W	
4	PN4DR	0	R/W	
3	PN3DR	0	R/W	
2	PN2DR	0	R/W	
1	PN1DR	0	R/W	
0	PN0DR	0	R/W	

9.12.3 Port N Register (PORTN)

PORTN shows port N pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PN7	—*	R	If a port N read is performed while PNDDR bits are set to 1, the PNDR values are read. If a port N read is performed while PNDDR bits are cleared to 0, the pin states are read.
6	PN6	—*	R	
5	PN5	—*	R	
4	PN4	—*	R	
3	PN3	—*	R	
2	PN2	—*	R	
1	PN1	—*	R	
0	PN0	—*	R	

Note: * Determined by the states of pins PN7 to PN0.

9.12.4 Pin Functions

Port N pins also function as LCD driver segment output pins (SEG40 to SEG33). Port N pin functions are shown below.

- P_Nn/SEG_n+33

The pin function is switched as shown below according to the combination of the SGS3 to SGS0 bits in LPCR of the LCD driver/controller and P_NnDDR bit.

SGS3 to SGS0	B'0000		B'0001, B'001X, or B'010X
P _N nDDR	0	1	—
Pin functions	P _N n input pin	P _N n output pin	SEG _n +33 output pin

Legend

X: Don't care

Note: n = 7 to 0

Section 10 16-Bit Timer Pulse Unit (TPU)

The H8S/2268 Series has an on-chip 16-bit timer pulse unit (TPU) comprised of three 16-bit timer channels, and the H8S/2264 Series has the TPU comprised of two 16-bit timer channels. The function list of the TPU is shown in table 10.1. A block diagram of the TPU for the H8S/2268 Series and that for the H8S/2264 Series are shown figures 10.1 and 10.2, respectively.

10.1 Features

- Maximum 8-pulse input/output (H8S/2268 Series)
- Maximum 4-pulse input/output (H8S/2264 Series)
- Selection of 7 or 8 counter input clocks for each channel
- The following operations can be set for each channel:
 - Waveform output at compare match
 - Input capture function
 - Counter clear operation
 - Synchronous operation:
 - Multiple timer counters (TCNT) can be written to simultaneously
 - Simultaneous clearing by compare match and input capture is possible
 - Register simultaneous input/output is possible by synchronous counter operation
 - PWM output with any duty level is possible
 - A maximum 7-phase (H8S/2268 Series)/3-phase (H8S/2264 Series) PWM output is possible in combination with synchronous operation
- Buffer operation settable for channel 0 (H8S/2268 Series only)
- Phase counting mode settable independently for each of channels 1 and 2 (H8S/2268 Series only)
- Operation with Cascaded Connection (H8S/2264 Series only)
- Fast access via internal 16-bit bus
- 13-type interrupt sources (H8S/2268 Series)
- 6-type interrupt sources (H8S/2264 Series)
- Register data can be transmitted automatically
- A/D converter conversion start trigger can be generated
- Module stop mode can be set

Table 10.1 TPU Functions

Item	Channel 0* ¹	Channel 1	Channel 2
Count clock	$\phi/1$ $\phi/4$ $\phi/16$ $\phi/64$ TCLKA TCLKB TCLKC TCLKD	$\phi/1$ $\phi/4$ $\phi/16$ $\phi/64$ $\phi/256$ TCLKA TCLKB	$\phi/1$ $\phi/4$ $\phi/16$ $\phi/64$ $\phi/1024$ TCLKA TCLKB TCLKC
General registers (TGR)	TGRA_0 TGRB_0	TGRA_1 TGRB_1	TGRA_2 TGRB_2
General registers/ buffer registers* ¹	TGRC_0 TGRD_0	—	—
I/O pins	TIOCA0 TIOCB0 TIOCC0 TIOCD0	TIOCA1 TIOCB1	TIOCA2 TIOCB2
Counter clear function	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
Compare match output	0 output ○ 1 output ○ Toggle output ○	○ ○ ○	○ ○ ○
Input capture function	○	○	○
Synchronous operation	○	○	○
PWM mode	○	○	○
Phase counting mode* ¹	—	○	○
Buffer operation* ¹	○	—	—

Item	Channel 0* ¹	Channel 1	Channel 2
DTC activation* ¹	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
A/D converter trigger	TGRA_0 compare match or input capture	TGRA_1 compare match or input capture	TGRA_2 compare match or input capture
Interrupt sources	5 sources	4 sources* ¹ 3 sources* ²	4 sources* ¹ 3 sources* ²
	<ul style="list-style-type: none"> • Compare match or input capture 0A • Compare match or input capture 0B • Compare match or input capture 0C • Compare match or input capture 0D • Overflow 	<ul style="list-style-type: none"> • Compare match or input capture 1A • Compare match or input capture 1B • Overflow • Underflow*¹ 	<ul style="list-style-type: none"> • Compare match or input capture 2A • Compare match or input capture 2B • Overflow • Underflow*¹

Legend

○ : Possible

— : Not possible

Notes: 1. Supported only by the H8S/2268 Series.

2. Supported only by the H8S/2264 Series.

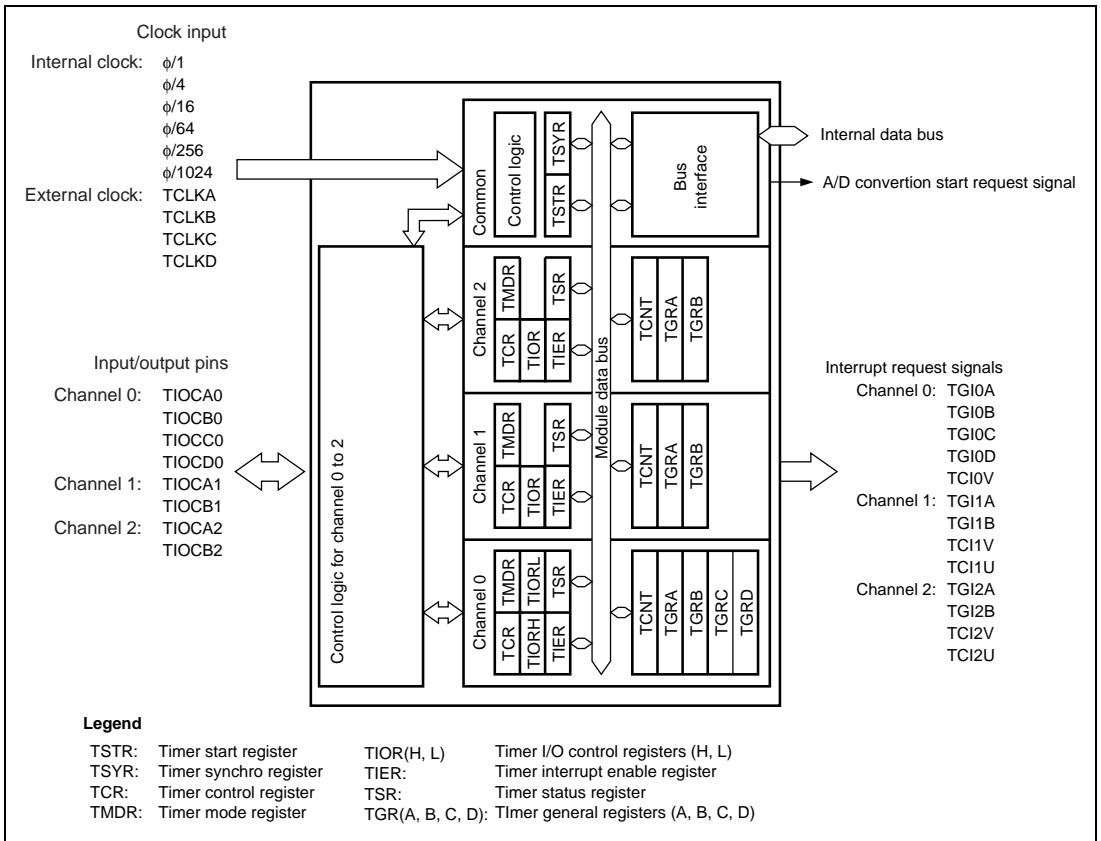


Figure 10.1 Block Diagram of TPU for H8S/2268 Series

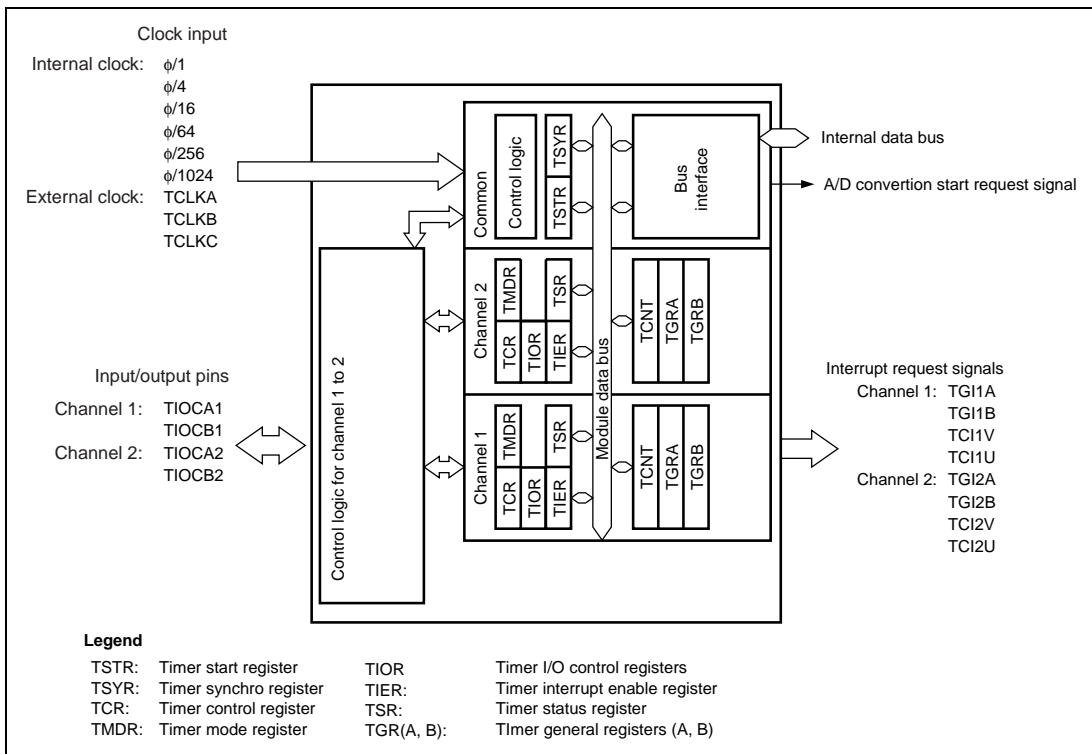


Figure 10.2 Block Diagram of TPU for H8S/2264 Series

10.2 Input/Output Pins

Table 10.2 TPU Pins

Channel	Symbol	I/O	Function
All	TCLKA	Input	External clock A input pin (Channel 1 phase counting mode A phase input*)
	TCLKB	Input	External clock B input pin (Channel 1 phase counting mode B phase input*)
	TCLKC	Input	External clock C input pin (Channel 2 phase counting mode A phase input*)
	TCLKD*	Input	External clock D input pin (Channel 2 phase counting mode B phase input*)
0*	TIOCA0	I/O	TGRA_0 input capture input/output compare output/PWM output pin
	TIOCB0	I/O	TGRB_0 input capture input/output compare output/PWM output pin
	TIOCC0	I/O	TGRC_0 input capture input/output compare output/PWM output pin
	TIOCD0	I/O	TGRD_0 input capture input/output compare output/PWM output pin
1	TIOCA1	I/O	TGRA_1 input capture input/output compare output/PWM output pin
	TIOCB1	I/O	TGRB_1 input capture input/output compare output/PWM output pin
2	TIOCA2	I/O	TGRA_2 input capture input/output compare output/PWM output pin
	TIOCB2	I/O	TGRB_2 input capture input/output compare output/PWM output pin

Note: * Supported only by the H8S/2268 Series.

10.3 Register Descriptions

The TPU has the following registers. To distinguish registers in each channel, an underscore and the channel number are added as a suffix to the register name; TCR for channel 0 is expressed as TCR_0.

- Timer control register_0 (TCR_0)*
- Timer mode register_0 (TMDR_0)*
- Timer I/O control register H_0 (TIORH_0)*
- Timer I/O control register L_0 (TIORL_0)*
- Timer interrupt enable register_0 (TIER_0)*
- Timer status register_0 (TSR_0)*
- Timer counter_0 (TCNT_0)*
- Timer general register A_0 (TGRA_0)*
- Timer general register B_0 (TGRB_0)*
- Timer general register C_0 (TGRC_0)*
- Timer general register D_0 (TGRD_0)*
- Timer control register_1 (TCR_1)
- Timer mode register_1 (TMDR_1)
- Timer I/O control register_1 (TIOR_1)
- Timer interrupt enable register_1 (TIER_1)
- Timer status register_1 (TSR_1)
- Timer counter_1 (TCNT_1)
- Timer general register A_1 (TGRA_1)
- Timer general register B_1 (TGRB_1)
- Timer control register_2 (TCR_2)
- Timer mode register_2 (TMDR_2)
- Timer I/O control register_2 (TIOR_2)
- Timer interrupt enable register_2 (TIER_2)
- Timer status register_2 (TSR_2)
- Timer counter_2 (TCNT_2)
- Timer general register A_2 (TGRA_2)
- Timer general register B_2 (TGRB_2)

Common Registers

- Timer start register (TSTR)
- Timer synchro register (TSYR)

Note: * Supported only by the H8S/2268 Series.

10.3.1 Timer Control Register (TCR)

The TCR registers control the TCNT operation for each channel. The H8S/2268 Series TPU has a total of three TCR registers and the H8S/2264 Series TPU has a total of two TCR registers, one for each channel (channels 0 to 2, or 1 and 2). TCR register settings should be conducted only when TCNT operation is stopped.

Bit	Bit Name	Initial value	R/W	Description
7	CCLR2	0	R/W	Counter Clear 0 to 2
6	CCLR1	0	R/W	These bits select the TCNT counter clearing source. See tables 10.3 and 10.4 for details.
5	CCLR0	0	R/W	
4	CKEG1	0	R/W	Clock Edge 0 and 1
3	CKEG0	0	R/W	These bits select the input clock edge. When the input clock is counted using both edges, the input clock period is halved (e.g. $\phi/4$ both edges = $\phi/2$ rising edge). Internal clock edge selection is valid when the input clock is $\phi/4$ or slower. If the input clock is $\phi/1$, this setting is ignored and count at rising edge is selected. In the H8S/2268 Series, if phase counting mode is used on channels 1 and 2, this setting is ignored and the phase counting mode setting has priority. 00: Count at rising edge 01: Count at falling edge 1X: Count at both edges Legend X: Don't care
2	TPSC2	0	R/W	Time Prescaler 0 to 2
1	TPSC1	0	R/W	These bits select the TCNT counter clock. The clock source can be selected independently for each channel. See tables 10.5 to 10.7 for details.
0	TPSC0	0	R/W	

Table 10.3 CCLR0 to CCLR2 (channel 0) (H8S/2268 Series Only)

Channel	Bit 7 CCLR2	Bit 6 CCLR1	Bit 5 CCLR0	Description
0	0	0	0	TCNT clearing disabled
			1	TCNT cleared by TGRA compare match/input capture
		1	0	TCNT cleared by TGRB compare match/input capture
			1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation* ¹
	1	0	0	TCNT clearing disabled
			1	TCNT cleared by TGRC compare match/input capture* ²
		1	0	TCNT cleared by TGRD compare match/input capture* ²
			1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation* ¹

Notes: 1. Synchronous operation is set by setting the SYNC bit in TSYR to 1.
2. When TGRC or TGRD is used as a buffer register, TCNT is not cleared because the buffer register setting has priority, and compare match/input capture does not occur.

Table 10.4 CCLR0 to CCLR2 (channels 1 and 2)

Channel	Bit 7 Reserved* ²	Bit 6 CCLR1	Bit 5 CCLR0	Description
1, 2	0	0	0	TCNT clearing disabled
			1	TCNT cleared by TGRA compare match/input capture
		1	0	TCNT cleared by TGRB compare match/input capture
			1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation* ¹

Notes: 1. Synchronous operation is selected by setting the SYNC bit in TSYR to 1.
2. Bit 7 is reserved in channels 1 and 2. It is always read as 0 and cannot be modified.

Table 10.5 TPSC0 to TPSC2 (channel 0) (H8S/2268 Series Only)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
0	0	0	0	Internal clock: counts on $\phi/1$
			1	Internal clock: counts on $\phi/4$
		1	0	Internal clock: counts on $\phi/16$
			1	Internal clock: counts on $\phi/64$
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKB pin input
		1	0	External clock: counts on TCLKC pin input
			1	External clock: counts on TCLKD pin input

Table 10.6 TPSC0 to TPSC2 (channel 1)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
1	0	0	0	Internal clock: counts on $\phi/1$
			1	Internal clock: counts on $\phi/4$
		1	0	Internal clock: counts on $\phi/16$
			1	Internal clock: counts on $\phi/64$
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKB pin input
		1	0	Internal clock: counts on $\phi/256$
			1	Counts on TCNT_2 overflow. (H8S/2268 Series: Setting disabled)

Note: * This setting is ignored when channel 1 is in phase counting mode (H8S/2268 Series only).

Table 10.7 TPSC0 to TPSC2 (channels 2)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
2	0	0	0	Internal clock: counts on $\phi/1$
			1	Internal clock: counts on $\phi/4$
		1	0	Internal clock: counts on $\phi/16$
			1	Internal clock: counts on $\phi/64$
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKB pin input
		1	0	External clock: counts on TCLKC pin input
			1	Internal clock: counts on $\phi/1024$

Note: * This setting is ignored when channel 2 is in phase counting mode (H8S/2268 Series only).

10.3.2 Timer Mode Register (TMDR)

The TMDR registers are used to set the operating mode of each channel. The H8S/2268 Series TPU has three TMDR registers and the H8S/2264 Series TPU has two TMDR registers, one for each channel (channels 0 to 2, or 1 and 2). TMDR register settings should be changed only when TCNT operation is stopped.

Bit	Bit Name	Initial value	R/W	Description
7, 6	—	All 1	—	Reserved These bits are always read as 1 and cannot be modified.
5	BFB	0	R/W	H8S/2268 Series: Buffer Operation B Specifies whether TGRB is to operate in the normal way, or TGRB and TGRD are to be used together for buffer operation. When TGRD is used as a buffer register, TGRD input capture/output compare is not generated. In channels 1 and 2, which have no TGRD, bit 5 is reserved. It is always read as 0 and cannot be modified. 0: TGRB operates normally 1: TGRB and TGRD used together for buffer operation H8S/2264 Series: Reserved These bits are always read as 0 and cannot be modified.

Bit	Bit Name	Initial value	R/W	Description
4	BFA	0	R/W	<p>H8S/2268 Series:</p> <p>Buffer Operation A</p> <p>Specifies whether TGRA is to operate in the normal way, or TGRA and TGRC are to be used together for buffer operation. When TGRC is used as a buffer register, TGRC input capture/output compare is not generated.</p> <p>In channels 1 and 2, which have no TGRC, bit 4 is reserved. It is always read as 0 and cannot be modified.</p> <p>0: TGRA operates normally</p> <p>1: TGRA and TGRC used together for buffer operation</p> <p>H8S/2264 Series:</p> <p>Reserved</p> <p>These bits are always read as 0 and cannot be modified.</p>
3	MD3	0	R/W	Modes 0 to 3
2	MD2	0	R/W	These bits are used to set the timer operating mode.
1	MD1	0	R/W	MD3 is a reserved bit. In a write, it should always be written with 0. See table 10.8 for details.
0	MD0	0	R/W	

Table 10.8 MD0 to MD3

Bit 3 MD3* ¹	Bit 2 MD2* ²	Bit 1 MD1	Bit 0 MD0	Description
0	0	0	0	Normal operation
			1	Reserved
		1	0	PWM mode 1
			1	PWM mode 2
	1	0	0	Phase counting mode 1
			1	Phase counting mode 2
		1	0	Phase counting mode 3
			1	Phase counting mode 4
1	X	X	X	—

Legend

X: Don't care

Notes: 1. MD3 is a reserved bit. In a write, it should always be written with 0.

2. Phase counting mode cannot be set in the H8S/2264 Series or for channels 0 in the H8S/2268 Series. In this case, 0 should always be written to MD2.

10.3.3 Timer I/O Control Register (TIOR)

The TIOR registers control the TGR registers. The H8S/2268 Series TPU has four TIOR registers and the H8S/2264 Series TPU has two TIOR registers, two for channel 0, and one each for channels 1 and 2.

Care is required as TIOR is affected by the TMDR setting. The initial output specified by TIOR is valid when the counter is stopped (the CST bit in TSTR is cleared to 0). Note also that, in PWM mode 2, the output at the point at which the counter is cleared to 0 is specified.

In the H8S/2268 Series, when TGRC or TGRD is designated for buffer operation, this setting is invalid and the register operates as a buffer register.

- TIORH_0 (H8S/2268 Series only), TIOR_1, TIOR_2

Bit	Bit Name	Initial value	R/W	Description
7	IOB3	All 0	R/W	I/O Control B0 to B3
6	IOB2			Specify the function of TGRB.
5	IOB1			For details, refer to table 10.9, 10.11, and 10.12.
4	IOB0			
3	IOA3	All 0	R/W	I/O Control A0 to A3
2	IOA2			Specify the function of TGRA.
1	IOA1			For details, refer to table 10.13, 10.15, and 10.16.
0	IOA0			

- TIORL_0 (H8S/2268 Series only)

Bit	Bit Name	Initial value	R/W	Description
7	IOD3	All 0	R/W	I/O Control D0 to D3
6	IOD2			Specify the function of TGRD.
5	IOD1			For details, refer to table 10.10.
4	IOD0			
3	IOC3	All 0	R/W	I/O Control C0 to C3
2	IOC2			Specify the function of TGRC.
1	IOC1			For details, refer to table 10.14.
0	IOC0			

Table 10.9 TIORH_0 (Channel 0) (H8S/2268 Series Only)

				Description	
Bit 7 IOB3	Bit 6 IOB2	Bit 5 IOB1	Bit 4 IOB0	TGRB_0 Function	TIOCB0 Pin Function
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 0 output at compare match
			0		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled
			1		Initial output is 1 0 output at compare match
			0		Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
		1	0		Output disabled
			1		Initial output is 1 0 output at compare match
			0		Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCB0 pin Input capture at rising edge
			1		Capture input source is TIOCB0 pin Input capture at falling edge
			X		Capture input source is TIOCB0 pin Input capture at both edges
			X		Setting disabled
		1	X		
			X		

Legend

X: Don't care

Table 10.10 TIORL_0 (Channel 0) (H8S/2268 Series Only)

				Description	
Bit 7 IOD3	Bit 6 IOD2	Bit 5 IOD1	Bit 4 IOD0	TGRD_0 Function	TIOCD0 Pin Function
0	0	0	0	Output compare register*	Output disabled
			1		Initial output is 0 0 output at compare match
			0		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled
			1		Initial output is 1 0 output at compare match
			0		Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
		1	0		Capture input source is TIOCD0 pin Input capture at rising edge
			1		Capture input source is TIOCD0 pin Input capture at falling edge
			X		Capture input source is TIOCD0 pin Input capture at both edges
			X		Setting disabled

Legend

X: Don't care

Note: * When the BFB bit in TMDR_0 is set to 1 and TGRD_0 is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 10.11 TIOR_1 (Channel 1)

				Description	
Bit 7 IOB3	Bit 6 IOB2	Bit 5 IOB1	Bit 4 IOB0	TGRB_1 Function	TIOCB1 Pin Function
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 0 output at compare match
			0		Initial output is 0 1 output at compare match
		1	0		Initial output is 0 Toggle output at compare match
			1		Initial output is 0 Toggle output at compare match
			1		Initial output is 0 Toggle output at compare match
	1	0	0	Input capture register	Output disabled
			1		Initial output is 1 0 output at compare match
			0		Initial output is 1 1 output at compare match
		1	0		Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
			1		Initial output is 1 Toggle output at compare match
1	0	0	Input capture register	Capture input source is TIOCB1 pin Input capture at rising edge	
		1		Capture input source is TIOCB1 pin Input capture at falling edge	
		X		Capture input source is TIOCB1 pin Input capture at both edges	
	1	X		X	Setting disabled

Legend

X: Don't care

Table 10.12 TIOR_2 (Channel 2)

				Description	
Bit 7 IOB3	Bit 6 IOB2	Bit 5 IOB1	Bit 4 IOB0	TGRB_2 Function	TIOCB2 Pin Function
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 0 output at compare match
		1	0		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled
			1		Initial output is 1 0 output at compare match
	1	0	0	Input capture register	Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
		1	0		Capture input source is TIOCB2 pin Input capture at rising edge
			1		Capture input source is TIOCB2 pin Input capture at falling edge
		1	X		Capture input source is TIOCB2 pin Input capture at both edges

Legend

X: Don't care

Table 10.13 TIORH_0 (Channel 0) (H8S/2268 Series Only)

				Description	
Bit 3 IOA3	Bit 2 IOA2	Bit 1 IOA1	Bit 0 IOA0	TGRA_0 Function	TIOCA0 Pin Function
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 0 output at compare match
			1		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled
			1		Initial output is 1 0 output at compare match
			1		Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
	1	0	0	Input capture register	Capture input source is TIOCA0 pin Input capture at rising edge
			1		Capture input source is TIOCA0 pin Input capture at falling edge
			X		Capture input source is TIOCA0 pin Input capture at both edges
			X		Setting disabled

Legend

X: Don't care

Table 10.14 TIORL_0 (Channel 0) (H8S/2268 Series Only)

				Description	
Bit 3 IOC3	Bit 2 IOC2	Bit 1 IOC1	Bit 0 IOC0	TGRC_0 Function	TIOCC0 Pin Function
0	0	0	0	Output compare register*	Output disabled
			1		Initial output is 0 0 output at compare match
		1	0		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled Initial output is 1 0 output at compare match
			1		Initial output is 1 1 output at compare match Initial output is 1 Toggle output at compare match
	1	0	0	Input capture register*	Capture input source is TIOCC0 pin Input capture at rising edge
			1		Capture input source is TIOCC0 pin Input capture at falling edge
		1	X		Capture input source is TIOCC0 pin Input capture at both edges
			X		Setting disabled

Legend

X: Don't care

Note: * When the BFA bit in TMDR_0 is set to 1 and TGRC_0 is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

Table 10.15 TIOR_1 (Channel 1)

				Description	
Bit 3 IOA3	Bit 2 IOA2	Bit 1 IOA1	Bit 0 IOA0	TGRA_1 Function	TIOCA1 Pin Function
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 0 output at compare match
		1	0		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled Initial output is 1 0 output at compare match
			1		Initial output is 1 1 output at compare match Initial output is 1 Toggle output at compare match
	1	0	0	Input capture register	Capture input source is TIOCA1 pin Input capture at rising edge
			1		Capture input source is TIOCA1 pin Input capture at falling edge
		1	X		Capture input source is TIOCA1 pin Input capture at both edges
			X		Setting disabled

Legend

X: Don't care

Table 10.16 TIOR_2 (Channel 2)

				Description	
Bit 3 IOA3	Bit 2 IOA2	Bit 1 IOA1	Bit 0 IOA0	TGRA_2 Function	TIOCA2 Pin Function
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 0 output at compare match
		1	0		Initial output is 0 1 output at compare match
			1		Initial output is 0 Toggle output at compare match
		1	0		Output disabled
			1		Initial output is 1 0 output at compare match
	1	0	0	Input capture register	Initial output is 1 1 output at compare match
			1		Initial output is 1 Toggle output at compare match
		1	0		Capture input source is TIOCA2 pin Input capture at rising edge
			1		Capture input source is TIOCA2 pin Input capture at falling edge
		1	X		Capture input source is TIOCA2 pin Input capture at both edges

Legend

X: Don't care

10.3.4 Timer Interrupt Enable Register (TIER)

The TIER registers control enabling or disabling of interrupt requests for each channel. The H8S/2268 Series TPU has three TIER registers and the H8S/2264 Series TPU has two TIER registers, one for each channel (channels 0 to 2, or 1 and 2).

Bit	Bit Name	Initial value	R/W	Description
7	TTGE	0	R/W	<p>A/D Conversion Start Request Enable</p> <p>Enables or disables generation of A/D conversion start requests by TGRA input capture/compare match.</p> <p>0: A/D conversion start request generation disabled</p> <p>1: A/D conversion start request generation enabled</p>
6	—	1	—	<p>Reserved</p> <p>This bit is always read as 1 and cannot be modified.</p>
5	TCIEU	0	R/W	<p>H8S/2268 Series:</p> <p>Underflow Interrupt Enable</p> <p>Enables or disables interrupt requests (TCIU) by the TCFU flag when the TCFU flag in TSR is set to 1 in channels 1 and 2.</p> <p>In channel 0, bit 5 is reserved. It is always read as 0 and cannot be modified.</p> <p>0: Interrupt requests (TCIU) by TCFU disabled</p> <p>1: Interrupt requests (TCIU) by TCFU enabled</p> <p>H8S/2264 Series:</p> <p>The write value should always be 0.</p>
4	TCIEV	0	R/W	<p>Overflow Interrupt Enable</p> <p>Enables or disables interrupt requests (TCIV) by the TCFV flag when the TCFV flag in TSR is set to 1.</p> <p>0: Interrupt requests (TCIV) by TCFV disabled</p> <p>1: Interrupt requests (TCIV) by TCFV enabled</p>
3	TGIED	0	R/W	<p>TGR Interrupt Enable D</p> <p>Enables or disables interrupt requests (TGID) by the TGFD bit when the TGFD bit in TSR is set to 1 in channel 0.</p> <p>In channels 1 and 2, bit 3 is reserved. It is always read as 0 and cannot be modified.</p> <p>0: Interrupt requests (TGID) by TGFD bit disabled</p> <p>1: Interrupt requests (TGID) by TGFD bit enabled</p>
2	TGIEC	0	R/W	<p>TGR Interrupt Enable C</p> <p>Enables or disables interrupt requests (TGIC) by the TGFC bit when the TGFC bit in TSR is set to 1 in channel 0.</p> <p>In channels 1 and 2, bit 2 is reserved. It is always read as 0 and cannot be modified.</p> <p>0: Interrupt requests (TGIC) by TGFC bit disabled</p> <p>1: Interrupt requests (TGIC) by TGFC bit enabled</p>

Bit	Bit Name	Initial value	R/W	Description
1	TGIEB	0	R/W	TGR Interrupt Enable B Enables or disables interrupt requests (TGIB) by the TGFB bit when the TGFB bit in TSR is set to 1. 0: Interrupt requests (TGIB) by TGFB bit disabled 1: Interrupt requests (TGIB) by TGFB bit enabled
0	TGIEA	0	R/W	TGR Interrupt Enable A Enables or disables interrupt requests (TGIA) by the TGFA bit when the TGFA bit in TSR is set to 1. 0: Interrupt requests (TGIA) by TGFA bit disabled 1: Interrupt requests (TGIA) by TGFA bit enabled

10.3.5 Timer Status Register (TSR)

The TSR registers indicate the status of each channel. The H8S/2268 Series TPU has three TSR registers and the H8S/2264 Series TPU has two TSR registers, one for each channel (channels 0 to 2, or 1 and 2).

Bit	Bit Name	Initial value	R/W	Description
7	TCFD	1	R	H8S/2268 Series: Count Direction Flag Status flag that shows the direction in which TCNT counts in channels 1 and 2. In channel 0, bit 7 is reserved. It is always read as 1 and cannot be modified. 0: TCNT counts down 1: TCNT counts up H8S/2264 Series: Reserved This bit is always read as 1 and cannot be modified.
6	—	1	—	Reserved This bit is always read as 1 and cannot be modified.

Bit	Bit Name	Initial value	R/W	Description
5	TCFU	0	R/(W) * ¹	<p>H8S/2268 Series:</p> <p>Underflow Flag</p> <p>Status flag that indicates that TCNT underflow has occurred when channels 1 and 2 are set to phase counting mode. Only 0 can be written, for flag clearing.</p> <p>In channel 0, bit 5 is reserved. It is always read as 0 and cannot be modified.</p> <p>[Setting condition]</p> <p>When the TCNT value underflows (changes from H'0000 to H'FFFF)</p> <p>[Clearing condition]</p> <p>When 0 is written to TCFU after reading TCFU = 1</p> <p>H8S/2264 Series:</p> <p>Reserved</p> <p>This bit is always read as 0 and cannot be modified.</p>
4	TCFV	0	R/(W) * ¹	<p>Overflow Flag</p> <p>Status flag that indicates that TCNT overflow has occurred. Only 0 can be written, for flag clearing.</p> <p>[Setting condition]</p> <p>When the TCNT value overflows (changes from H'FFFF to H'0000)</p> <p>[Clearing condition]</p> <p>When 0 is written to TCFV after reading TCFV = 1</p>

Bit	Bit Name	Initial value	R/W	Description
3	TGFD	0	R/(W) * ¹	<p>H8S/2268 Series:</p> <p>Input Capture/Output Compare Flag D</p> <p>Status flag that indicates the occurrence of TGRD input capture or compare match in channel 0. Only 0 can be written, for flag clearing. In channels 1 and 2, bit 3 is reserved. It is always read as 0 and cannot be modified.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRD and TGRD is functioning as output compare register When TCNT value is transferred to TGRD by input capture signal and TGRD is functioning as input capture register <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When DTC is activated by TGID interrupt and the DISEL bit of MRB in DTC is 0 When 0 is written to TGFD after reading TGFD = 1 <p>H8S/2264 Series:</p> <p>Reserved</p> <p>This bit is always read as 0 and cannot be modified.</p>

Bit	Bit Name	Initial value	R/W	Description
2	TGFC	0	R/(W) * ¹	<p>H8S/2268 Series:</p> <p>Input Capture/Output Compare Flag C</p> <p>Status flag that indicates the occurrence of TGRC input capture or compare match in channel 0. Only 0 can be written, for flag clearing. In channels 1 and 2, bit 2 is reserved. It is always read as 0 and cannot be modified.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> • When TCNT = TGRC and TGRC is functioning as output compare register • When TCNT value is transferred to TGRC by input capture signal and TGRC is functioning as input capture register <p>[Clearing conditions]</p> <ul style="list-style-type: none"> • When DTC is activated by TGIC interrupt and the DISEL bit of MRB in DTC is 0 • When 0 is written to TGFC after reading TGFC = 1 <p>H8S/2264 Series:</p> <p>Reserved</p> <p>This bit is always read as 0 and cannot be modified.</p>

Bit	Bit Name	Initial value	R/W	Description
1	TGFB	0	R/(W) * ¹	<p>Input Capture/Output Compare Flag B</p> <p>Status flag that indicates the occurrence of TGRB input capture or compare match. Only 0 can be written, for flag clearing.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRB and TGRB is functioning as output compare register When TCNT value is transferred to TGRB by input capture signal and TGRB is functioning as input capture register <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When DTC*² is activated by TGIB interrupt and the DISEL bit of MRB in DTC*² is 0 When 0 is written to TGFB after reading TGFB = 1
0	TGFA	0	R/(W) * ¹	<p>Input Capture/Output Compare Flag A</p> <p>Status flag that indicates the occurrence of TGRA input capture or compare match. Only 0 can be written, for flag clearing.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRA and TGRA is functioning as output compare register When TCNT value is transferred to TGRA by input capture signal and TGRA is functioning as input capture register <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When DTC*² is activated by TGIA interrupt and the DISEL bit of MRB in DTC*² is 0 When 0 is written to TGFA after reading TGFA = 1

Notes: 1. Only 0 can be written to this bit to clear the flag.
2. Supported only by the H8S/2268 Series.

10.3.6 Timer Counter (TCNT)

The TCNT registers are 16-bit readable/writable counters. The H8S/2268 Series TPU has three TCNT counters and the H8S/2264 Series TPU has two TCNT counters, one for each channel (channels 0 to 2, or 1 and 2).

The TCNT counters are initialized to H'0000 by a reset, or in hardware standby mode.

The TCNT counters cannot be accessed in 8-bit units; they must always be accessed as a 16-bit unit.

10.3.7 Timer General Register (TGR)

The TGR registers are dual function 16-bit readable/writable registers, functioning as either output compare or input capture registers. The H8S/2268 Series TPU has eight TGR registers and the H8S/2264 Series TPU has four TGR registers, four for channel 0 and two each for channels 1 and 2. TGR is initialized to H'FFFF at reset or in hardware standby mode. The TGR registers cannot be accessed in 8-bit units; they must always be accessed as a 16-bit unit. In the H8S/2268 Series, TGRC and TGRD for channel 0 can also be designated for operation as buffer registers. TGR buffer register combinations are TGRA—TGRC and TGRB—TGRD.

10.3.8 Timer Start Register (TSTR)

TSTR selects operation/stoppage for channels 0 to 2 in the H8S/2268 Series and for channels 1 and 2 in the H8S/2264 Series. When setting the operating mode in TMDR or setting the count clock in TCR, first stop the TCNT counter.

Bit	Bit Name	Initial value	R/W	Description
7 to 3	—	All 0	—	Reserved The write value should always be 0.
2	CST2	0	R/W	Counter Start 0 to 2 (CST0 to CST2)
1	CST1	0	R/W	These bits select operation or stoppage for TCNT.
0	CST0*	0	R/W	If 0 is written to the CST bit during operation with the TIOC pin designated for output, the counter stops but the TIOC pin output compare output level is retained. If TIOR is written to when the CST bit is cleared to 0, the pin output level will be changed to the set initial output value. 0: TCNT_n count operation is stopped 1: TCNT_n performs count operation (n = 0 to 2)

Note: * In the H8S/2264 Series, this bit is reserved. The write value should always be 0.

10.3.9 Timer Synchro Register (TSYR)

TSYR selects independent operation or synchronous operation of the TCNT counters for channels 0 to 2 in the H8S/2268 Series and for channels 1 and 2 in the H8S/2264 Series. A channel performs synchronous operation when the corresponding bit in TSYR is set to 1.

Bit	Bit Name	Initial value	R/W	Description
7 to 3	—	0	—	Reserved The write value should always be 0.
2	SYNC2	0	R/W	Timer Synchro 0 to 2
1	SYNC1	0	R/W	These bits are used to select whether operation is independent of or synchronized with other channels. When synchronous operation is selected, the TCNT synchronous presetting of multiple channels, and synchronous clearing by counter clearing on another channel, are possible. To set synchronous operation, the SYNC bits for at least two channels must be set to 1. To set synchronous clearing, in addition to the SYNC bit, the TCNT clearing source must also be set by means of bits CCLR0 to CCLR2 in TCR. 0: TCNT_n operates independently (TCNT presetting/clearing is unrelated to other channels) 1: TCNT_n performs synchronous operation TCNT synchronous presetting/synchronous clearing is possible
0	SYNC0*	0	R/W	

(n = 0 to 2)

Note: * In the H8S/2264 Series, this bit is reserved. The write value should always be 0.

10.4 Interface to Bus Master

10.4.1 16-Bit Registers

TCNT and TGR are 16-bit registers. As the data bus to the master is 16 bits wide, these registers can be read or written to in 8-bit units; 16-bit access must always be used.

An example of 16-bit register access operation is shown in figure 10.3.

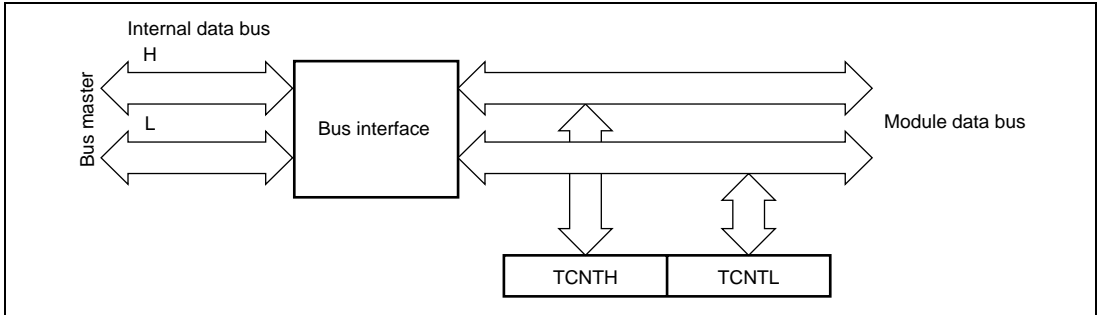


Figure 10.3 16-Bit Register Access Operation [Bus Master ↔ TCNT (16 Bits)]

10.4.2 8-Bit Registers

Registers other than TCNT and TGR are 8-bit. As the data bus to the CPU is 16 bits wide, these registers can be read and written to in 16-bit units. They can also be read and written to in 8-bit units.

Examples of 8-bit register access operation are shown in figure 10.4, 10.5, and 10.6.

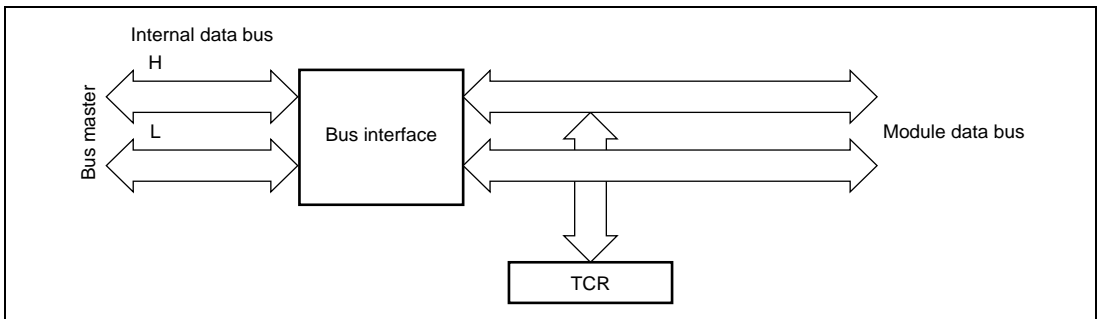


Figure 10.4 8-Bit Register Access Operation [Bus Master ↔ TCR (Upper 8 Bits)]

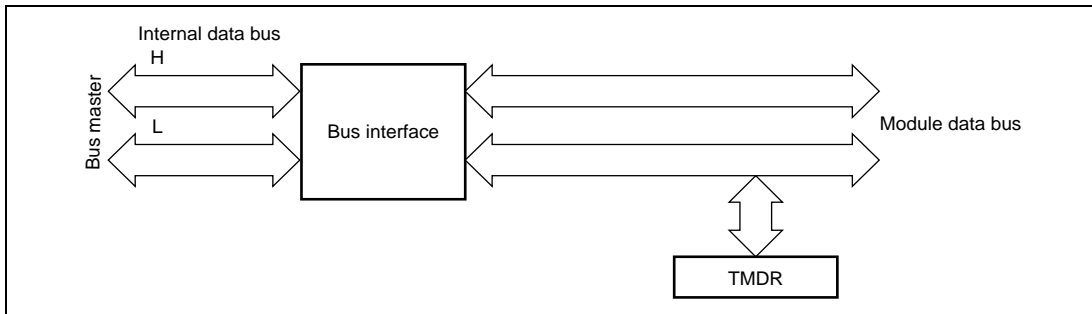


Figure 10.5 8-Bit Register Access Operation [Bus Master ↔ TMDR (Lower 8 Bits)]

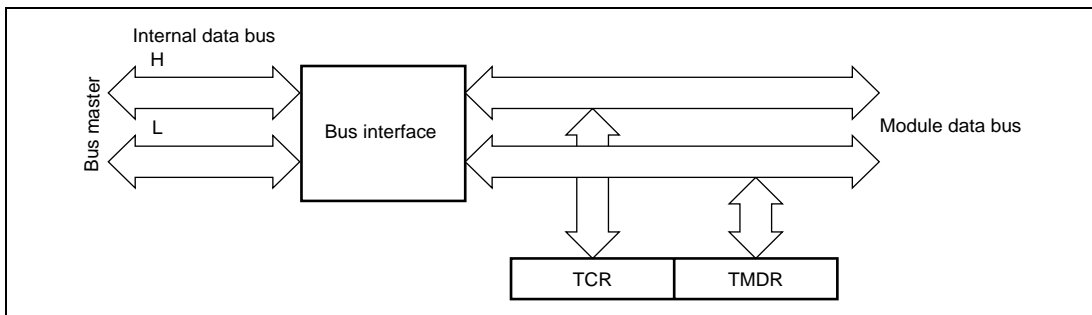


Figure 10.6 8-Bit Register Access Operation [Bus Master ↔ TCR and TMDR (16 Bits)]

10.5 Operation

10.5.1 Basic Functions

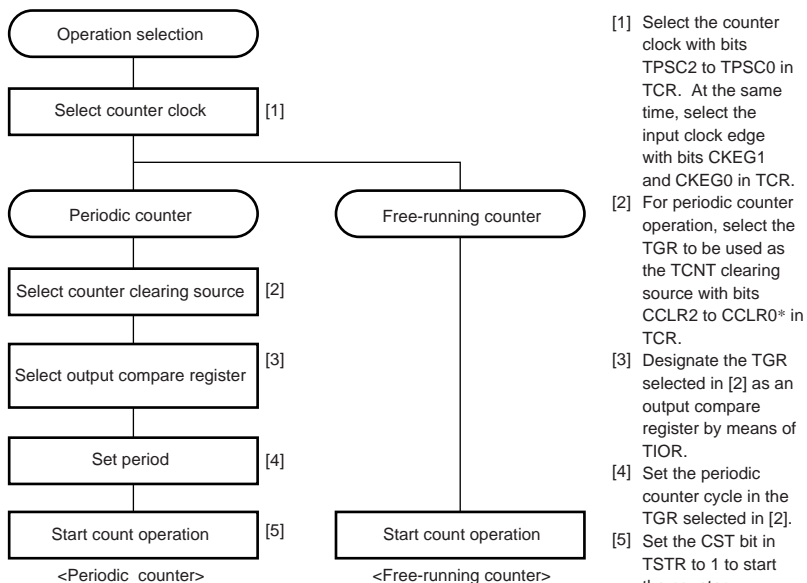
Each channel has a TCNT and TGR register. TCNT performs up-counting, and is also capable of free-running operation, synchronous counting, and external event counting.

Each TGR can be used as an input capture register or output compare register.

Counter Operation: When one of bits CST0 to CST2 in the H8S/2268 Series or one of bits CST1 and CST2 in the H8S/2264 Series is set to 1 in TSTR, the TCNT counter for the corresponding channel begins counting. TCNT can operate as a free-running counter, periodic counter, for example.

1. Example of count operation setting procedure

Figure 10.7 shows an example of the count operation setting procedure.



- [1] Select the counter clock with bits TPSC2 to TPSC0 in TCR. At the same time, select the input clock edge with bits CKEG1 and CKEG0 in TCR.
- [2] For periodic counter operation, select the TGR to be used as the TCNT clearing source with bits CCLR2 to CCLR0* in TCR.
- [3] Designate the TGR selected in [2] as an output compare register by means of TIOR.
- [4] Set the periodic counter cycle in the TGR selected in [2].
- [5] Set the CST bit in TSTR to 1 to start the counter operation.

Note: * In the H8S/2264 Series, bits CCLR1 and CCLR0 in TCR.

Figure 10.7 Example of Counter Operation Setting Procedure

2. Free-running count operation and periodic count operation

Immediately after a reset, the TPU's TCNT counters are all designated as free-running counters. When the relevant bit in TSTR is set to 1 the corresponding TCNT counter starts up-count operation as a free-running counter. When TCNT overflows (from H'FFFF to H'0000), the TCFV bit in TSR is set to 1. If the value of the corresponding TCIEV bit in TIER is 1 at this point, the TPU requests an interrupt. After overflow, TCNT starts counting up again from H'0000.

Figure 10.8 illustrates free-running counter operation.

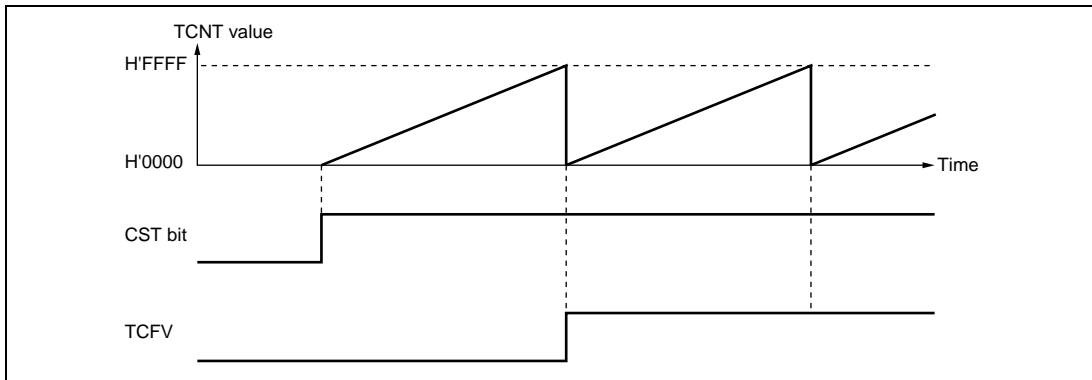


Figure 10.8 Free-Running Counter Operation

When compare match is selected as the TCNT clearing source, the TCNT counter for the relevant channel performs periodic count operation. The TGR register for setting the period is designated as an output compare register, and counter clearing by compare match is selected by means of bits CCLR0 to CCLR2 in the H8S/2268 Series TCR or bits CCLR0 and CCLR1 in the H8S/2264 Series TCR. After the settings have been made, TCNT starts up-count operation as a periodic counter when the corresponding bit in TSTR is set to 1. When the count value matches the value in TGR, the TGF bit in TSR is set to 1 and TCNT is cleared to H'0000.

If the value of the corresponding TGIE bit in TIER is 1 at this point, the TPU requests an interrupt. After a compare match, TCNT starts counting up again from H'0000.

Figure 10.9 illustrates periodic counter operation.

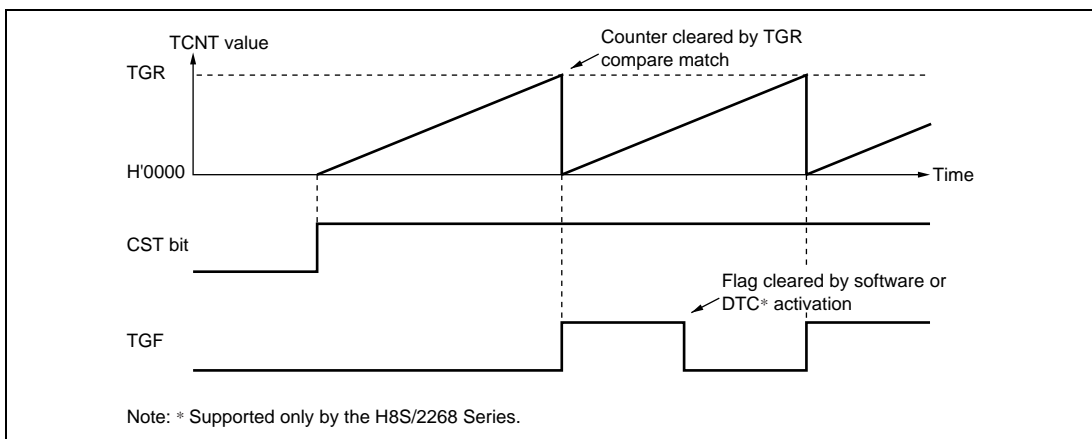


Figure 10.9 Periodic Counter Operation

Waveform Output by Compare Match: The TPU can perform 0, 1, or toggle output from the corresponding output pin using compare match.

1. Example of setting procedure for waveform output by compare match

Figure 10.10 shows an example of the setting procedure for waveform output by compare match.

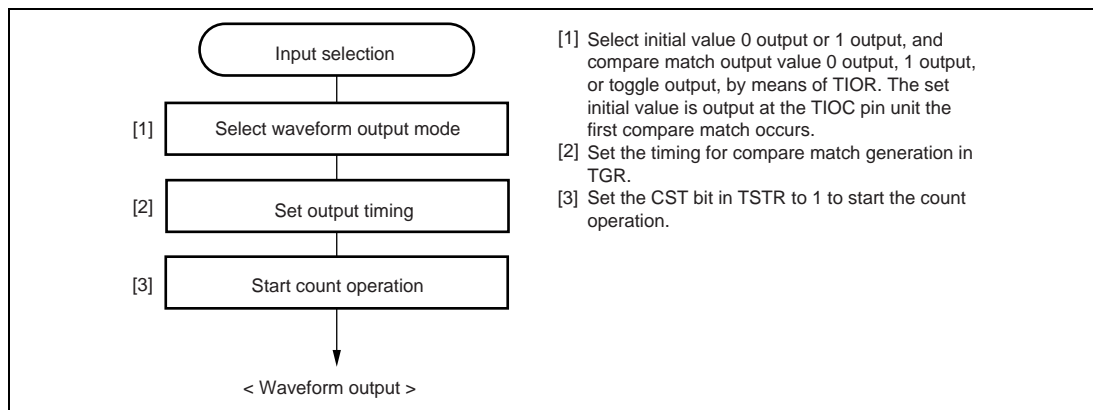


Figure 10.10 Example of Setting Procedure for Waveform Output by Compare Match

2. Examples of waveform output operation

Figure 10.11 shows an example of 0 output/1 output.

In this example TCNT has been designated as a free-running counter, and settings have been made such that 1 is output by compare match A, and 0 is output by compare match B. When the set level and the pin level coincide, the pin level does not change.

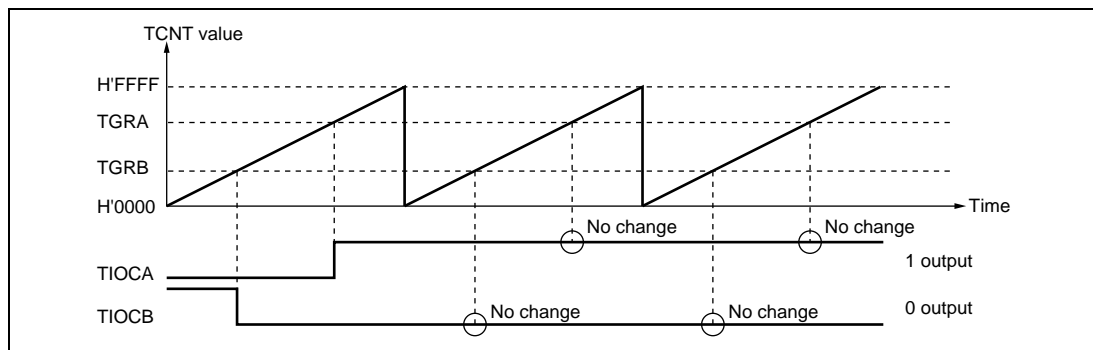


Figure 10.11 Example of 0 Output/1 Output Operation

Figure 10.12 shows an example of toggle output.

In this example, TCNT 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.

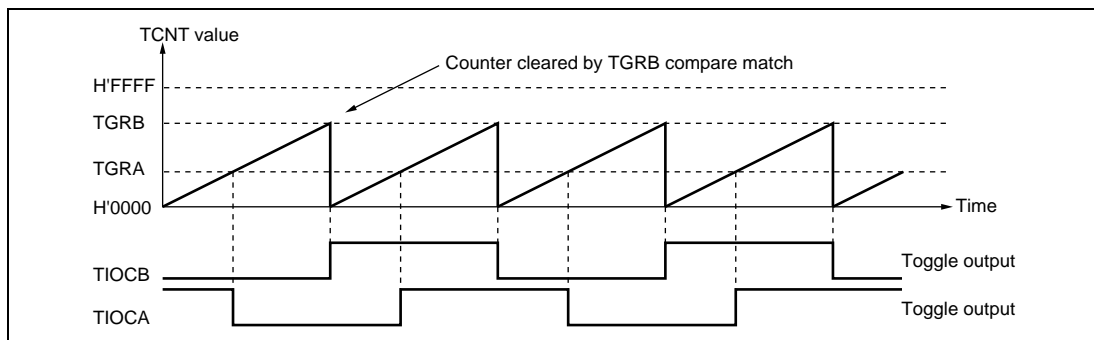


Figure 10.12 Example of Toggle Output Operation

Input Capture Function: The TCNT value can be transferred to TGR on detection of the TIOC pin input edge.

Rising edge, falling edge, or both edges can be selected as the detected edge.

1. Example of input capture operation setting procedure

Figure 10.13 shows an example of the input capture operation setting procedure.

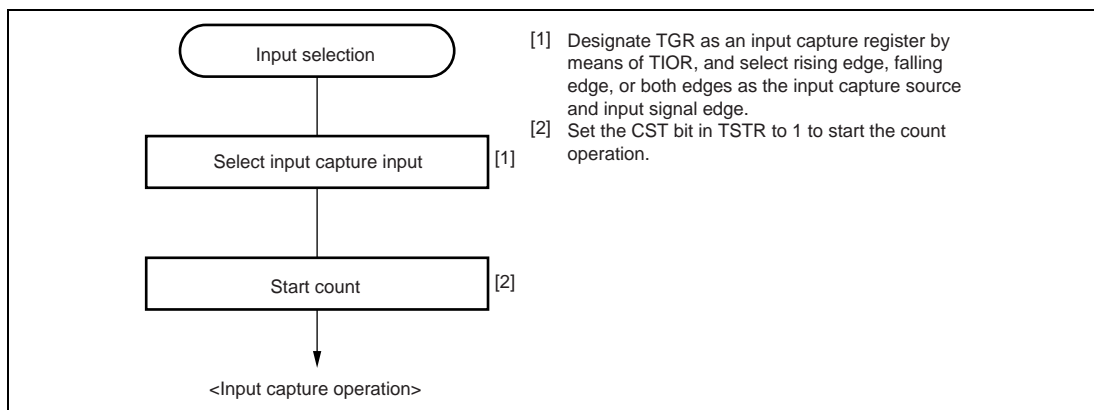


Figure 10.13 Example of Input Capture Operation Setting Procedure

2. Example of input capture operation

Figure 10.14 shows an example of input capture operation.

In this example both rising and falling edges have been selected as the TIOCA pin input capture input edge, the falling edge has been selected as the TIOCB pin input capture input edge, and counter clearing by TGRB input capture has been designated for TCNT.

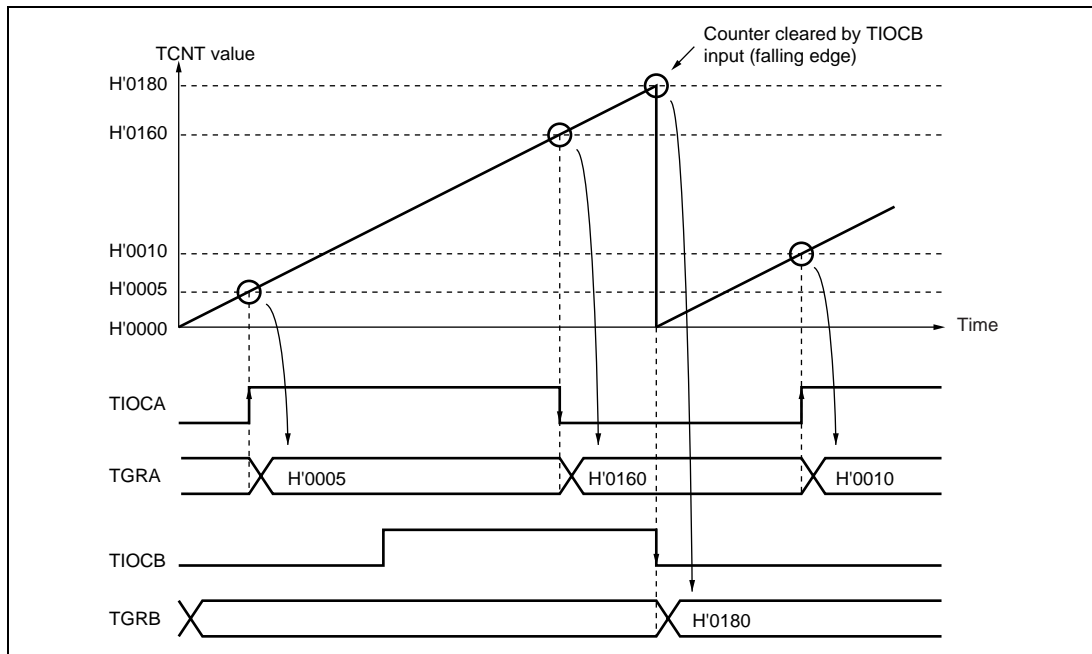


Figure 10.14 Example of Input Capture Operation

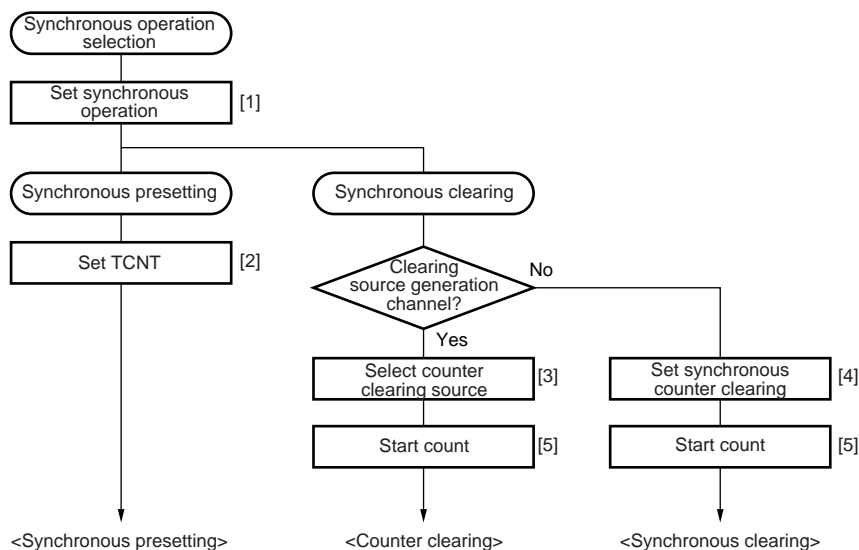
10.5.2 Synchronous Operation

In synchronous operation, the values in a number of TCNT counters can be rewritten simultaneously (synchronous presetting). Also, a number of TCNT counters can be cleared simultaneously by making the appropriate setting in TCR (synchronous clearing).

Synchronous operation enables TGR to be incremented with respect to a single time base.

Channels 0 to 2 in the H8S/2268 Series or channels 1 and 2 in the H8S/2264 Series can all be designated for synchronous operation.

Example of Synchronous Operation Setting Procedure: Figure 10.15 shows an example of the synchronous operation setting procedure.



- [1] Set to 1 the SYNC bits in TSYSR corresponding to the channels to be designated for synchronous operation.
- [2] When the TCNT counter of any of the channels designated for synchronous operation is written to, the same value is simultaneously written to the other TCNT counters.
- [3] Use bits CCLR2 to CCLR0* in TCR to specify TCNT clearing by input capture/output compare, etc.
- [4] Use bits CCLR2 to CCLR0* in TCR to designate synchronous clearing for the counter clearing source.
- [5] Set to 1 the CST bits in TSTR for the relevant channels, to start the count operation.

Note: * In the H8S/2264 Series, bits CCRL1 and CCLR0 in TCR.

Figure 10.15 Example of Synchronous Operation Setting Procedure

Example of Synchronous Operation: Figure 10.16 shows an example of synchronous operation.

In this example, synchronous operation and PWM mode 1 have been designated for channels 0 to 2 in the H8S/2268 Series, TGRB_0 compare match has been set as the channel 0 counter clearing source, and synchronous clearing has been set for the channel 1 and 2 counter clearing source.

Three-phase PWM waveforms are output from pins TIOC0A, TIOC1A, and TIOC2A. At this time, synchronous presetting, and synchronous clearing by TGRB_0 compare match, are performed for channel 0 to 2 TCNT counters, and the data set in TGRB_0 is used as the PWM cycle.

For details of PWM modes, see section 10.5.5, PWM Modes.

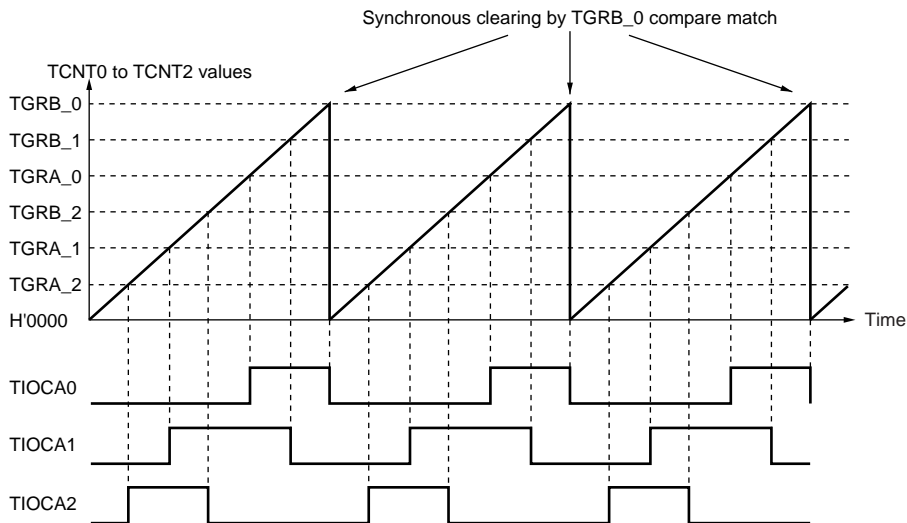


Figure 10.16 Example of Synchronous Operation

10.5.3 Buffer Operation (H8S/2268 Series Only)

Buffer operation, provided for channel 0, enables TGRB_0 and TGRD_0 to be used as buffer registers.

Buffer operation differs depending on whether TGR has been designated as an input capture register or as a compare match register.

Table 10.17 shows the register combinations used in buffer operation.

Table 10.17 Register Combinations in Buffer Operation

Channel	Timer General Register	Buffer Register
0	TGRA_0	TGRC_0
	TGRB_0	TGRD_0

- When TGR is an output compare register

When a compare match occurs, the value in the buffer register for the corresponding channel is transferred to the timer general register.

This operation is illustrated in figure 10.17.

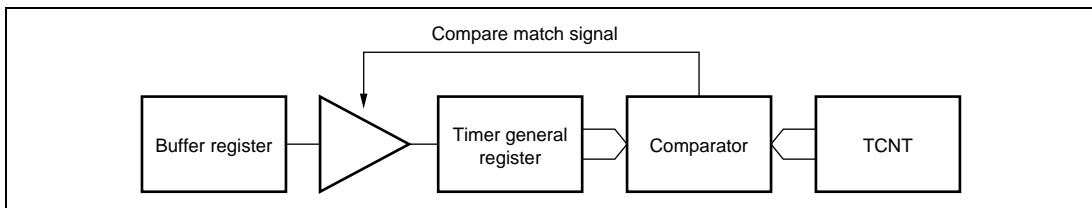


Figure 10.17 Compare Match Buffer Operation

- When TGR is an input capture register

When input capture occurs, the value in TCNT is transferred to TGR and the value previously held in the timer general register is transferred to the buffer register.

This operation is illustrated in figure 10.18.

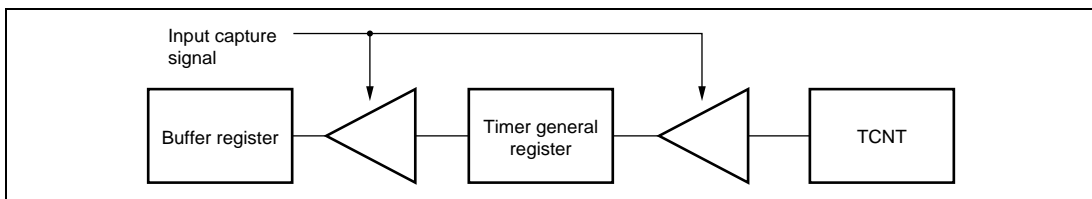


Figure 10.18 Input Capture Buffer Operation

Example of Buffer Operation Setting Procedure: Figure 10.19 shows an example of the buffer operation setting procedure.

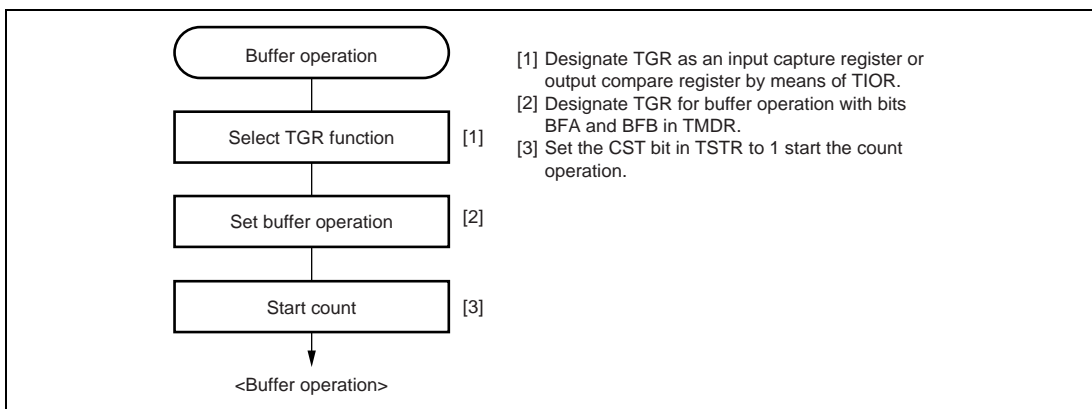


Figure 10.19 Example of Buffer Operation Setting Procedure

Examples of Buffer Operation:

1. When TGR is an output compare register

Figure 10.20 shows an operation example in which PWM mode 1 has been designated for channel 0, and buffer operation has been designated for TGRA and TGRC. The settings used in this example are TCNT clearing by compare match B, 1 output at compare match A, and 0 output at compare match B.

As buffer operation has been set, when compare match A occurs the output changes and the value in buffer register TGRC is simultaneously transferred to timer general register TGRA. This operation is repeated each time that compare match A occurs.

For details of PWM modes, see section 10.5.5, PWM Modes.

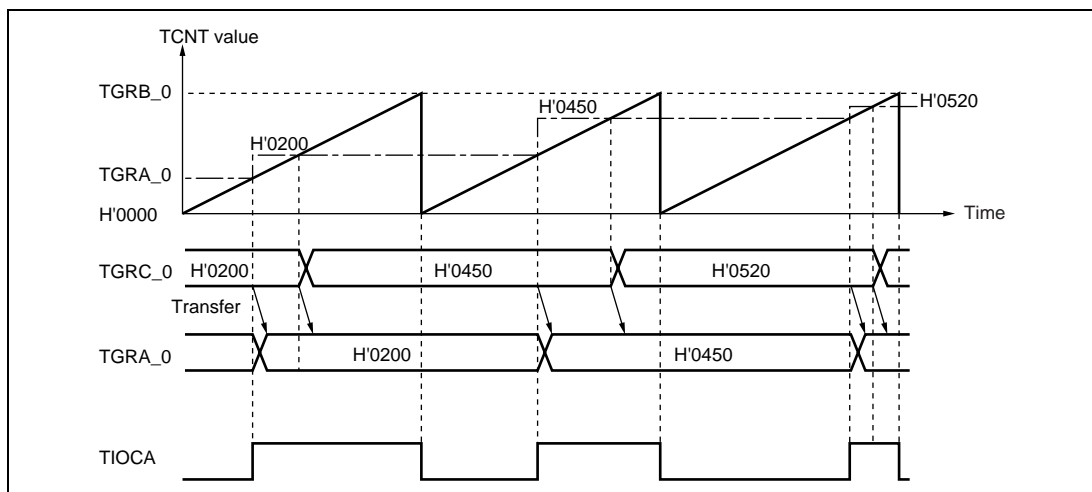


Figure 10.20 Example of Buffer Operation (1)

2. When TGR is an input capture register

Figure 10.21 shows an operation example in which TGRA has been designated as an input capture register, and buffer operation has been designated for TGRA and TGRC.

Counter clearing by TGRA input capture has been set for TCNT, and both rising and falling edges have been selected as the TIOCA pin input capture input edge.

As buffer operation has been set, when the TCNT value is stored in TGRA upon the occurrence of input capture A, the value previously stored in TGRA is simultaneously transferred to TGRC.

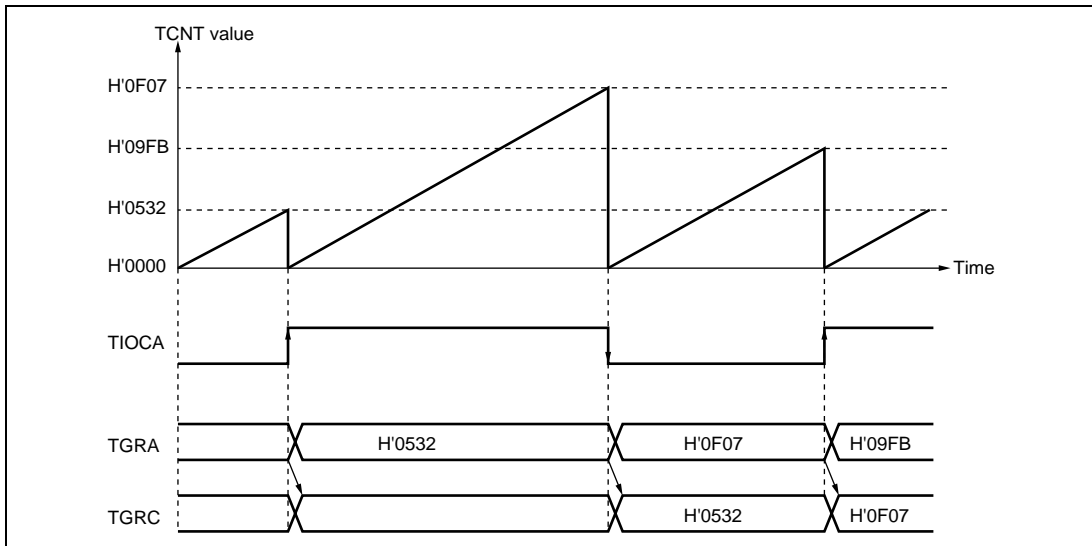


Figure 10.21 Example of Buffer Operation (2)

10.5.4 Operation with Cascaded Connection (H8S/2264 Series Only)

Operation as a 32-bit timer can be performed by cascading two 16-bit counter channels.

This function is enabled when the TPSC2 to TPSC0 bits in TCR are set to count on TCNT2 overflow for the channel 1 counter clock. Table 10.18 shows the counter combination used in operation with the cascaded connection.

Table 10.18 Counter Combination in Operation with Cascaded Connection

Combination	Upper 16 bits	Lower 16 bits
Channel 1 and channel 2	TCNT1	TCNT2

Setting Procedure for Operation with Cascaded Connection: Figure 10.22 shows the cascaded connection operation setting procedure.

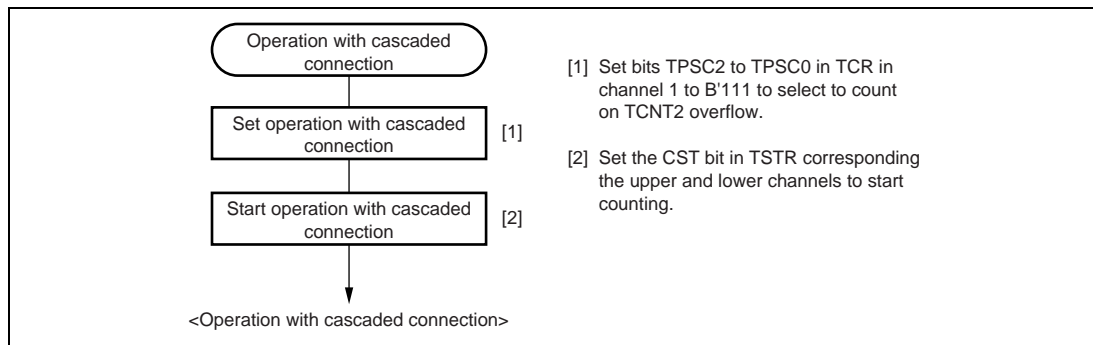


Figure 10.22 Setting Procedure for Operation with Cascaded Operation

Example of Operation with Cascaded Connection: Figure 10.23 shows an example of operation with cascaded connection, where TCNT1 is set to count TCNT2 overflow, TCRA_1 and TCRA_2 are set to be input capture registers, and the TIOC pin rising edge is selected.

If rising edges are input simultaneously to the TIOCA1 and TIOCA2 pins, the upper 16 bits of 32-bit data are transferred to TGRA_1 and the lower 16 bits are transferred to TGRA_2.

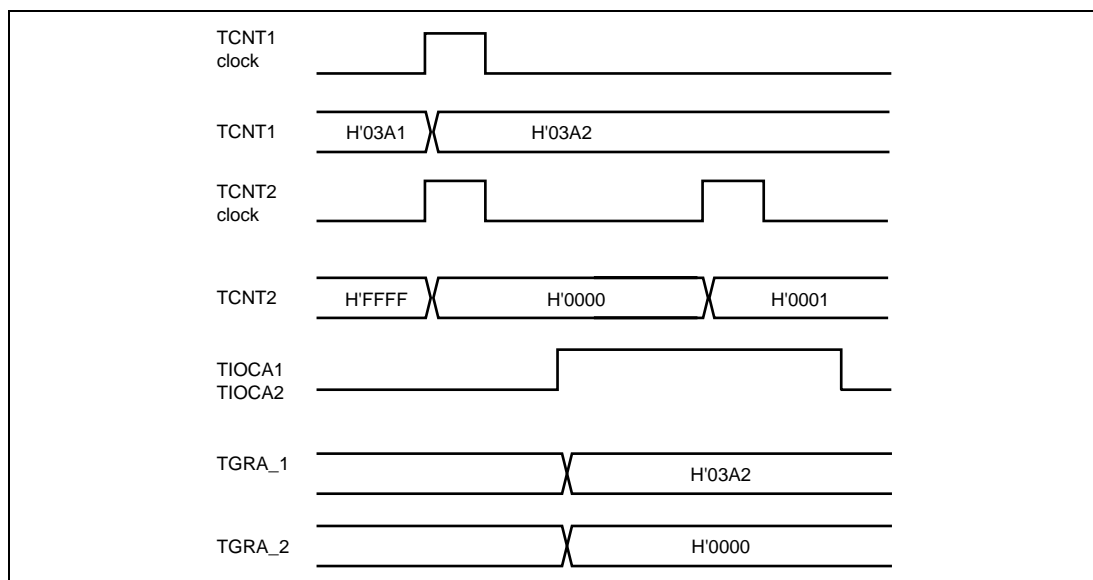


Figure 10.23 Example of Operation with Cascaded Connection

10.5.5 PWM Modes

In PWM mode, PWM waveforms are output from the output pins. The output level can be selected as 0, 1, or toggle output in response to a compare match of each TGR.

Designating TGR compare match as the counter clearing source enables the period to be set in that register. All channels can be designated for PWM mode independently. Synchronous operation is also possible.

There are two PWM modes, as described below.

- PWM mode 1

H8S/2268 Series:

PWM output is generated from the TIOCA and TIOCC pins by pairing TGRA with TGRB and TGRC with TGRD. The output specified by bits IOA0 to IOA3 and IOC0 to IOC3 in TIOR is output from the TIOCA and TIOCC pins at compare matches A and C, and the output specified by bits IOB0 to IOB3 and IOD0 to IOD3 in TIOR is output at compare matches B and D. The initial output value is the value set in TGRA or TGRC. If the set values of paired TGRs are identical, the output value does not change when a compare match occurs.

In PWM mode 1, PWM output is enable up to 4 phases.

H8S/2264 Series:

PWM output is generated from the TIOCA pin by pairing TGRA with TGRB. The output specified by bits IOA0 to IOA3 in TIOR is output from the TIOCA pin at compare match A, and the output specified by bits IOB0 to IOB3 in TIOR is output at compare match B. The initial output value is the value set in TGRA. If the set values of paired TGRs are identical, the output value does not change when a compare match occurs.

In PWM mode 1, PWM output is enable up to 2 phases.

- PWM mode 2

PWM output is generated using one TGR as the cycle register and the others as duty registers. The output specified in TIOR is performed by means of compare matches. Upon counter clearing by a synchronization register compare match, the output value of each pin is the initial value set in TIOR. If the set values of the cycle and duty registers are identical, the output value does not change when a compare match occurs.

In PWM mode 2, PWM output is enabled up to 7 phases in the H8S/2268 Series or 3 phases in the H8S/2264 Series by using also synchronous operation.

The correspondence between PWM output pins and registers is shown in table 10.19.

Table 10.19 PWM Output Registers and Output Pins

Channel	Registers	Output Pins	
		PWM Mode 1	PWM Mode 2 ^{*2}
0 ^{*1}	TGRA_0	TIOCA0	TIOCA0
	TGRB_0		TIOCB0
	TGRC_0	TIOCC0	TIOCC0
	TGRD_0		TIOCD0
1	TGRA_1	TIOCA1	TIOCA1
	TGRB_1		TIOCB1
2	TGRA_2	TIOCA2	TIOCA2
	TGRB_2		TIOCB2

Notes: 1. Supported only by the H8S/2268 Series.
2. In PWM mode 2, PWM output is not possible for the TGR register in which the period is set.

Example of PWM Mode Setting Procedure: Figure 10.24 shows an example of the PWM mode setting procedure.

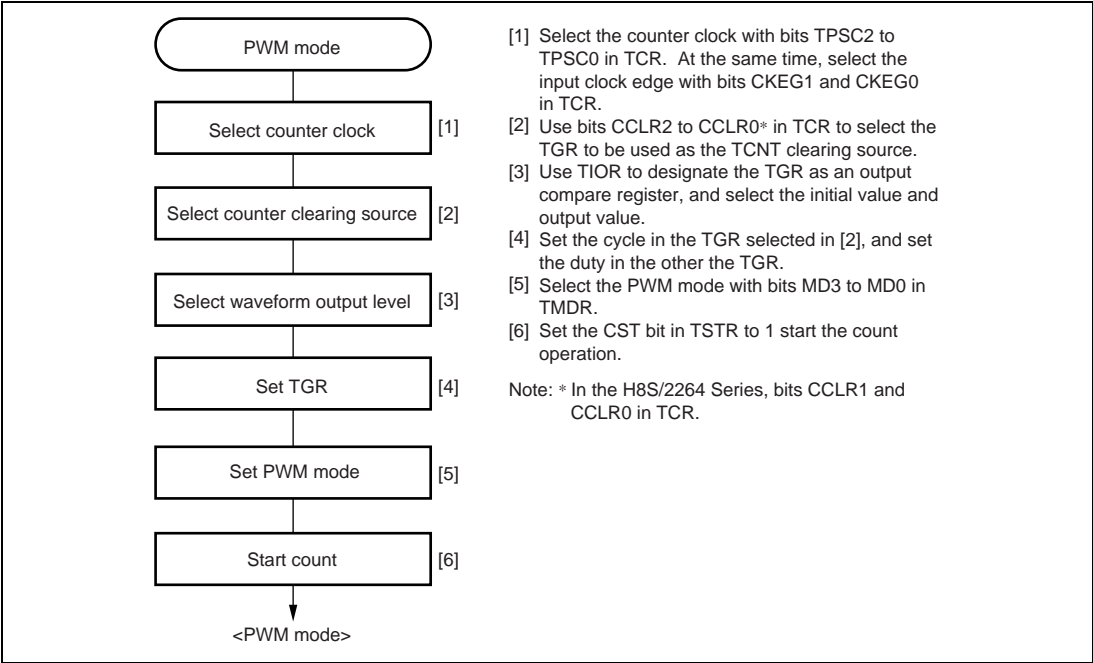


Figure 10.24 Example of PWM Mode Setting Procedure

Examples of PWM Mode Operation: Figure 10.25 shows an example of PWM mode 1 operation.

In this example, TGRA compare match is set as the TCNT clearing source, 0 is set for the TGRA initial output value and output value, and 1 is set as the TGRB output value.

In this case, the value set in TGRA is used as the period, and the values set in the TGRB registers are used as the duty levels.

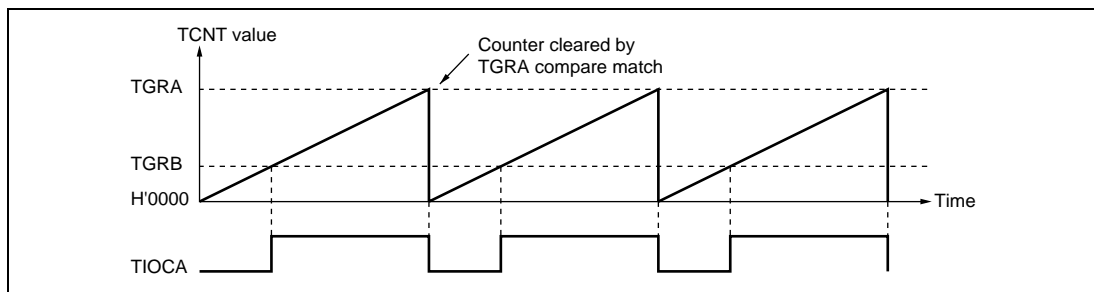


Figure 10.25 Example of PWM Mode Operation (1)

Figure 10.26 shows an example of PWM mode 2 operation.

In this example, synchronous operation is designated for channels 0 and 1, TGRB_1 compare match is set as the TCNT clearing source, and 0 is set for the initial output value and 1 for the output value of the other TGR registers (TGRA_0 to TGRD_0, TGRA_1), outputting a 5-phase PWM waveform, in the H8S/2268 Series.

In this case, the value set in TGRB_1 is used as the cycle, and the values set in the other TGRs are used as the duty levels.

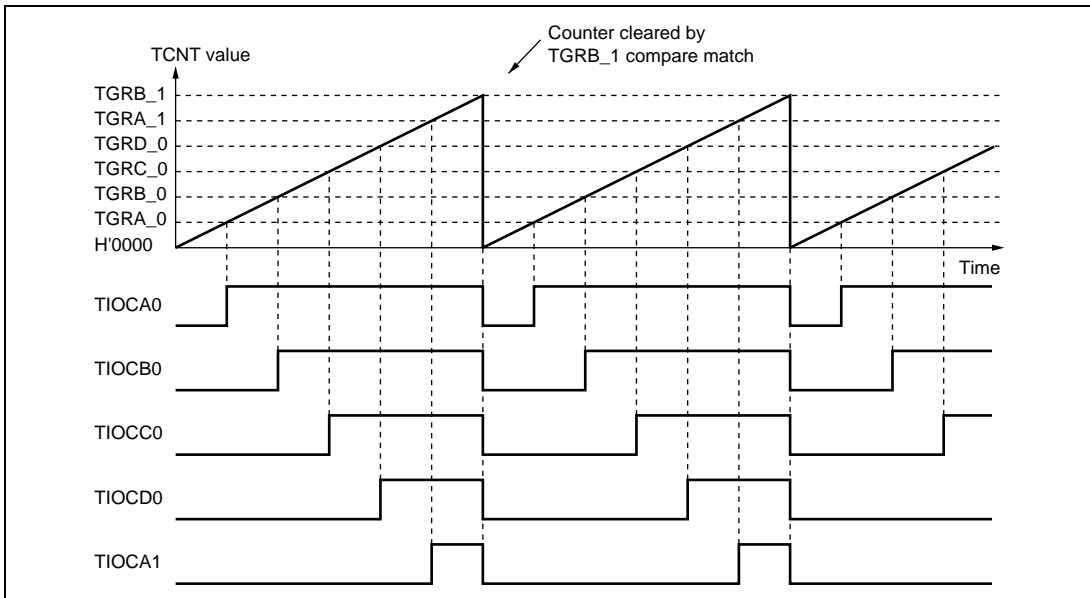


Figure 10.26 Example of PWM Mode Operation (2)

Figure 10.27 shows examples of PWM waveform output with 0% duty and 100% duty in PWM mode.

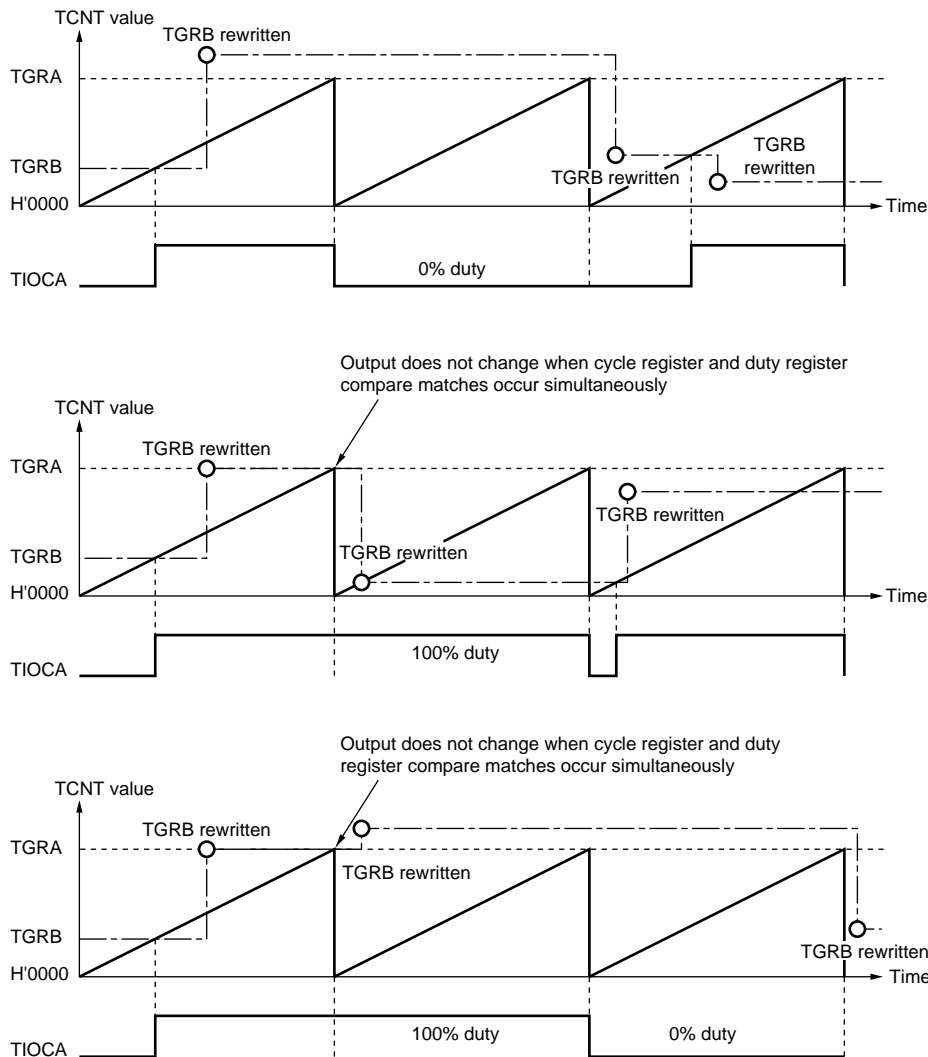


Figure 10.27 Example of PWM Mode Operation (3)

10.5.6 Phase Counting Mode (H8S/2268 Series Only)

In phase counting mode, the phase difference between two external clock inputs is detected and TCNT is incremented/decremented accordingly. This mode can be set for channels 1 and 2.

When phase counting mode is set, an external clock is selected as the counter input clock and TCNT operates as an up/down-counter regardless of the setting of bits TPSC0 to TPSC2 and bits CKEG0 and CKEG1 in TCR. However, the functions of bits CCLR0 and CCLR1 in TCR, and of TIOR, TIER, and TGR, are valid, and input capture/compare match and interrupt functions can be used.

If overflow occurs when TCNT is counting up, the TCFV flag in TSR is set; if underflow occurs when TCNT is counting down, the TCFU flag is set.

The TCFD bit in TSR is the count direction flag. Reading the TCFD flag reveals whether TCNT is counting up or down.

Table 10.20 shows the correspondence between external clock pins and channels.

Table 10.20 Phase Counting Mode Clock Input Pins

Channels	External Clock Pins	
	A-Phase	B-Phase
When channel 1 is set to phase counting mode	TCLKA	TCLKB
When channel 2 is set to phase counting mode	TCLKC	TCLKD

Example of Phase Counting Mode Setting Procedure: Figure 10.28 shows an example of the phase counting mode setting procedure.

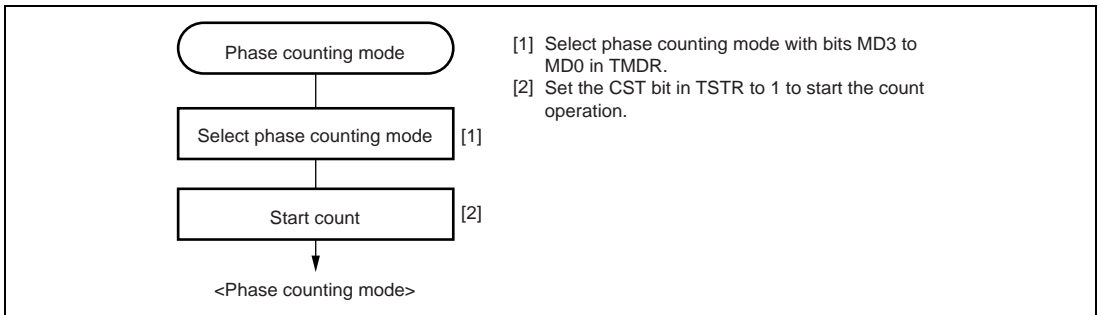


Figure 10.28 Example of Phase Counting Mode Setting Procedure

Examples of Phase Counting Mode Operation: In phase counting mode, TCNT counts up or down according to the phase difference between two external clocks. There are four modes, according to the count conditions.

1. Phase counting mode 1

Figure 10.29 shows an example of phase counting mode 1 operation, and table 10.21 summarizes the TCNT up/down-count conditions.

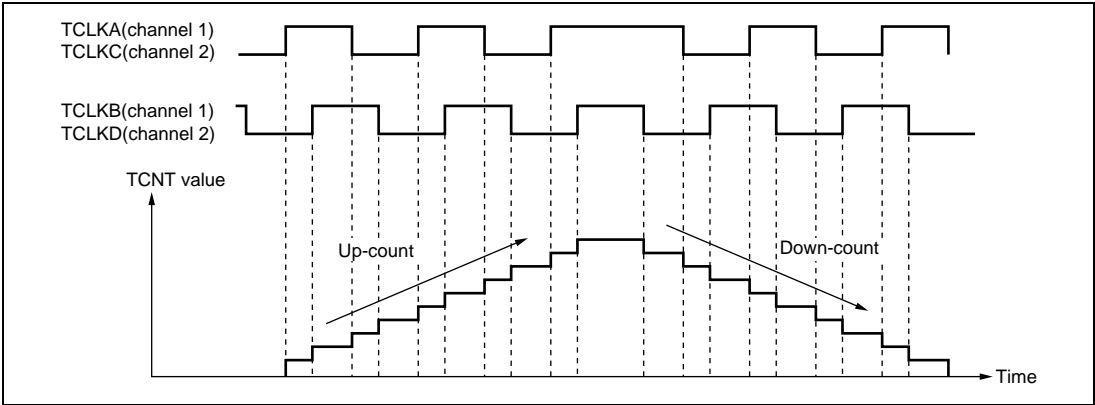












Figure 10.29 Example of Phase Counting Mode 1 Operation

Table 10.21 Up/Down-Count Conditions in Phase Counting Mode 1

TCLKA (Channel 1) TCLKC (Channel 2)	TCLKB (Channel 1) TCLKD (Channel 2)	Operation
High level		Up-count
Low level		
	Low level	
	High level	
High level		Down-count
Low level		
	High level	
	Low level	

Legend

-  : Rising edge
-  : Falling edge

2. Phase counting mode 2

Figure 10.30 shows an example of phase counting mode 2 operation, and table 10.22 summarizes the TCNT up/down-count conditions.

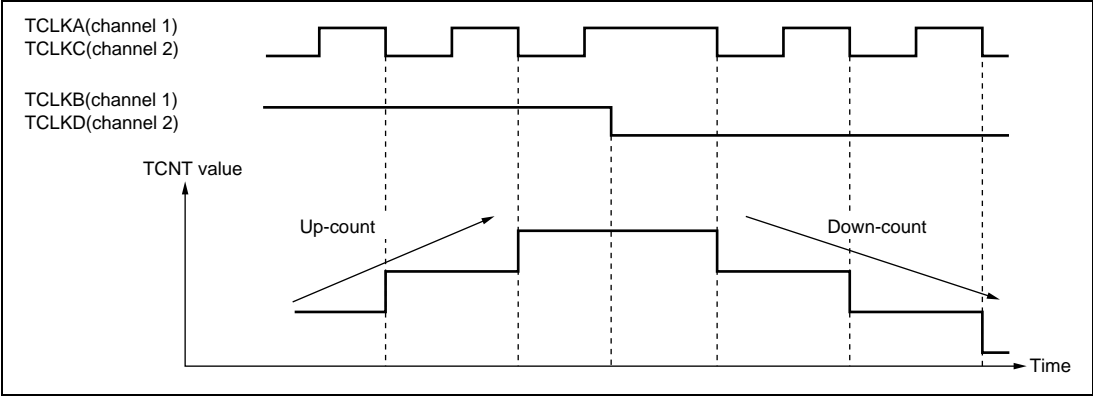


Figure 10.30 Example of Phase Counting Mode 2 Operation

Table 10.22 Up/Down-Count Conditions in Phase Counting Mode 2

TCLKA (Channel 1) TCLKC (Channel 2)	TCLKB (Channel 1) TCLKD (Channel 2)	Operation
High level	⏏	Don't care
Low level	⏏	Don't care
⏏	Low level	Don't care
⏏	High level	Up-count
High level	⏏	Don't care
Low level	⏏	Don't care
⏏	High level	Don't care
⏏	Low level	Down-count

Legend

- ⏏ : Rising edge
- ⏏ : Falling edge

3. Phase counting mode 3

Figure 10.31 shows an example of phase counting mode 3 operation, and table 10.23 summarizes the TCNT up/down-count conditions.

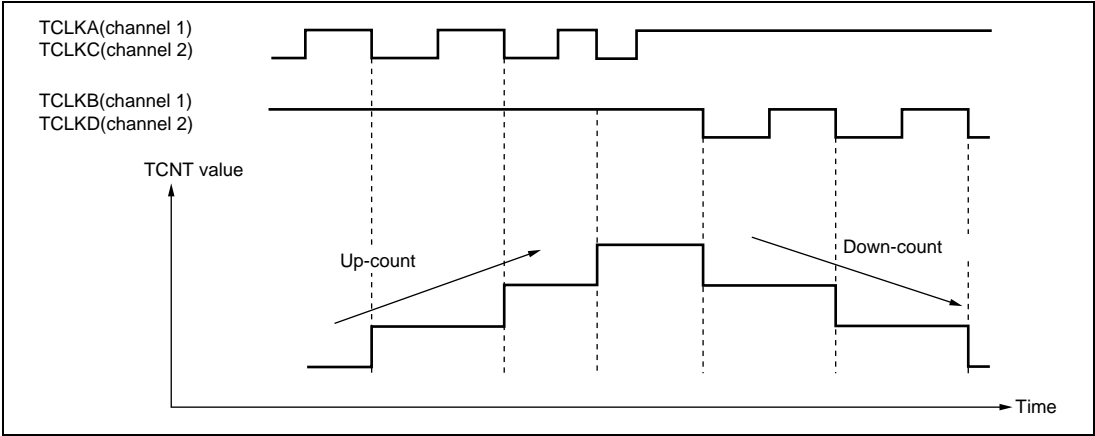


Figure 10.31 Example of Phase Counting Mode 3 Operation

Table 10.23 Up/Down-Count Conditions in Phase Counting Mode 3

TCLKA (Channel 1) TCLKC (Channel 2)	TCLKB (Channel 1) TCLKD (Channel 2)	Operation
High level	⌈	Don't care
Low level	⌋	Don't care
⌈	Low level	Don't care
⌋	High level	Up-count
High level	⌋	Down-count
Low level	⌈	Don't care
⌈	High level	Don't care
⌋	Low level	Don't care

Legend

- ⌈ : Rising edge
- ⌋ : Falling edge

4. Phase counting mode 4

Figure 10.32 shows an example of phase counting mode 4 operation, and table 10.24 summarizes the TCNT up/down-count conditions.

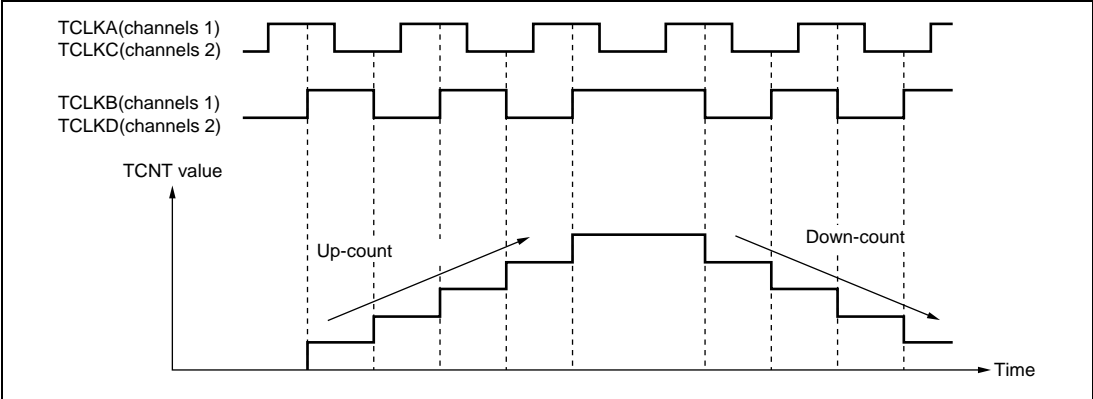












Figure 10.32 Example of Phase Counting Mode 4 Operation

Table 10.24 Up/Down-Count Conditions in Phase Counting Mode 4

TCLKA (Channel 1) TCLKC (Channel 2)	TCLKB (Channel 1) TCLKD (Channel 2)	Operation
High level		Up-count
Low level		
	Low level	Don't care
	High level	
High level		Down-count
Low level		
	High level	Don't care
	Low level	

Legend

-  : Rising edge
-  : Falling edge

10.6 Interrupt Sources

There are three kinds of TPU interrupt source for the H8S/2268 Series; TGR input capture/compare match, TCNT overflow, and TCNT underflow. There are two kinds of TPU interrupt source for the H8S/2264 Series; TGR input capture/compare match and TCNT overflow. Each interrupt source has its own status flag and enable/disable bit, allowing the generation of interrupt request signals to be enabled or disabled individually.

When an interrupt request is generated, the corresponding status flag in TSR is set to 1. If the corresponding enable/disable bit in TIER is set to 1 at this time, an interrupt is requested. The interrupt request is cleared by clearing the status flag to 0.

In the H8S/2268 Series, relative channel priorities can be changed by the interrupt controller, however the priority order within a channel is fixed. For details, see section 5, Interrupt Controller.

Table 10.25 lists the TPU interrupt sources.

Table 10.25 TPU Interrupts

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation*	Priority Level
0*	TGI0A	TGRA_0 input capture/compare match	TGFA_0	Possible	High ↑
	TGI0B	TGRB_0 input capture/compare match	TGFB_0	Possible	
	TGI0C	TGRC_0 input capture/compare match	TGFC_0	Possible	
	TGI0D	TGRD_0 input capture/compare match	TGFD_0	Possible	
	TCI0V	TCNT_0 overflow	TCFV_0	Not possible	
1	TGI1A	TGRA_1 input capture/compare match	TGFA_1	Possible	↑
	TGI1B	TGRB_1 input capture/compare match	TGFB_1	Possible	
	TCI1V	TCNT_1 overflow	TCFV_1	Not possible	
	TCI1U*	TCNT_1 underflow	TCFU_1	Not possible	
2	TGI2A	TGRA_2 input capture/compare match	TGFA_2	Possible	
	TGI2B	TGRB_2 input capture/compare match	TGFB_2	Possible	
	TCI2V	TCNT_2 overflow	TCFV_2	Not possible	
	TCI2U*	TCNT_2 underflow	TCFU_2	Not possible	Low

Note: * Supported only by the H8S/2268 Series.

Input Capture/Compare Match Interrupt: An interrupt is requested if the TGIE bit in TIER is set to 1 when the TGF flag in TSR is set to 1 by the occurrence of a TGR input capture/compare match on a particular channel. The interrupt request is cleared by clearing the TGF flag to 0. The H8S/2268 Series TPU has eight input capture/compare match interrupts and the H8S/2264 Series TPU has four input capture/compare match interrupts, four for channel 0, and two each for channels 1 and 2.

Overflow Interrupt: An interrupt is requested if the TCIEV bit in TIER is set to 1 when the TCFV flag in TSR is set to 1 by the occurrence of TCNT overflow on a channel. The interrupt request is cleared by clearing the TCFV flag to 0. The H8S/2268 Series TPU has three overflow interrupts and the H8S/2264 Series TPU has two overflow interrupts, one for each channel (channels 0 to 2, or 1 and 2).

Underflow Interrupt (H8S/2268 Series Only): An interrupt is requested if the TCIEU bit in TIER is set to 1 when the TCFU flag in TSR is set to 1 by the occurrence of TCNT underflow on a channel. The interrupt request is cleared by clearing the TCFU flag to 0. The TPU has two underflow interrupts, one each for channels 1 and 2.

10.7 DTC Activation (H8S/2268 Series Only)

The DTC can be activated by the TGR input capture/compare match interrupt for a channel. For details, see section 8, Data Transfer Controller (DTC).

A total of eight TPU input capture/compare match interrupts can be used as DTC activation sources, four for channel 0, and two each for channels 1 and 2.

10.8 A/D Converter Activation

The A/D converter can be activated by the TGRA input capture/compare match for a channel.

If the TTGE bit in TIER is set to 1 when the TGFA flag in TSR is set to 1 by the occurrence of a TGRA input capture/compare match on a particular channel, a request to begin A/D conversion is sent to the A/D converter. If the TPU conversion start trigger has been selected on the A/D converter side at this time, A/D conversion is begun.

In the H8S/2268 Series TPU, a total of three TGRA input capture/compare match interrupts can be used as A/D converter conversion start sources, one for each channel (channels 0 to 2). While in the H8S/2264 Series TPU, a total of two TGRA input capture/compare match interrupts can be used, one for each channel (channels 1 and 2).

10.9 Operation Timing

10.9.1 Input/Output Timing

TCNT Count Timing: Figure 10.33 shows TCNT count timing in internal clock operation, and figure 10.34 shows TCNT count timing in external clock operation.

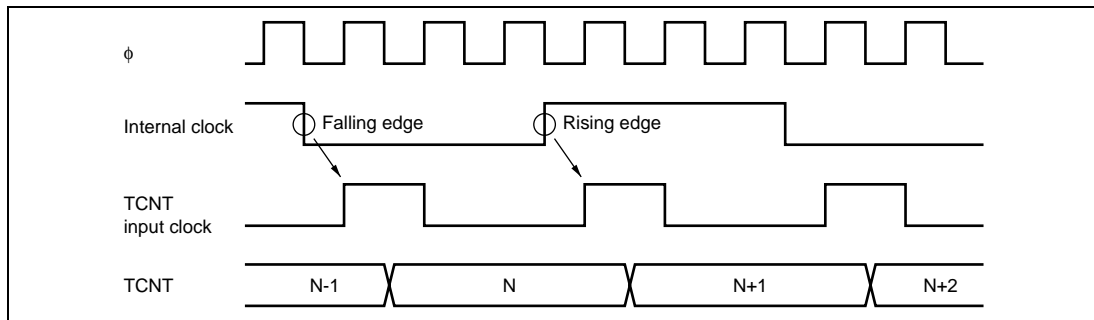


Figure 10.33 Count Timing in Internal Clock Operation

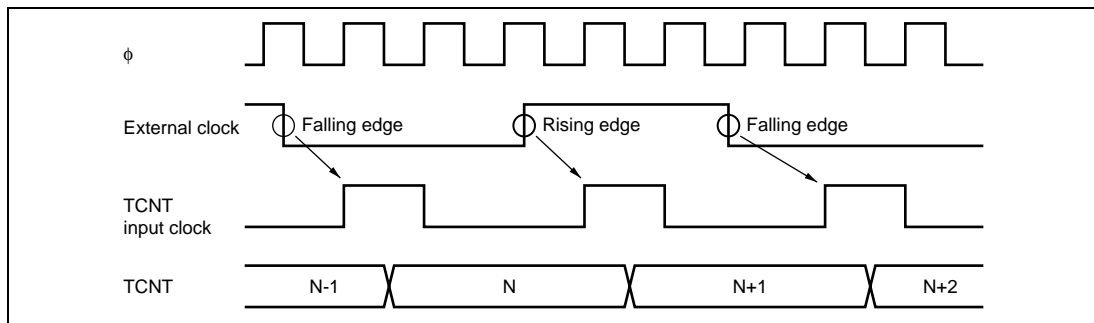


Figure 10.34 Count Timing in External Clock Operation

Output Compare Output Timing: A compare match signal is generated in the final state in which TCNT and TGR match (the point at which the count value matched by TCNT is updated). When a compare match signal is generated, the output value set in TIOR is output at the output compare output pin. After a match between TCNT and TGR, the compare match signal is not generated until the TCNT input clock is generated.

Figure 10.35 shows output compare output timing.

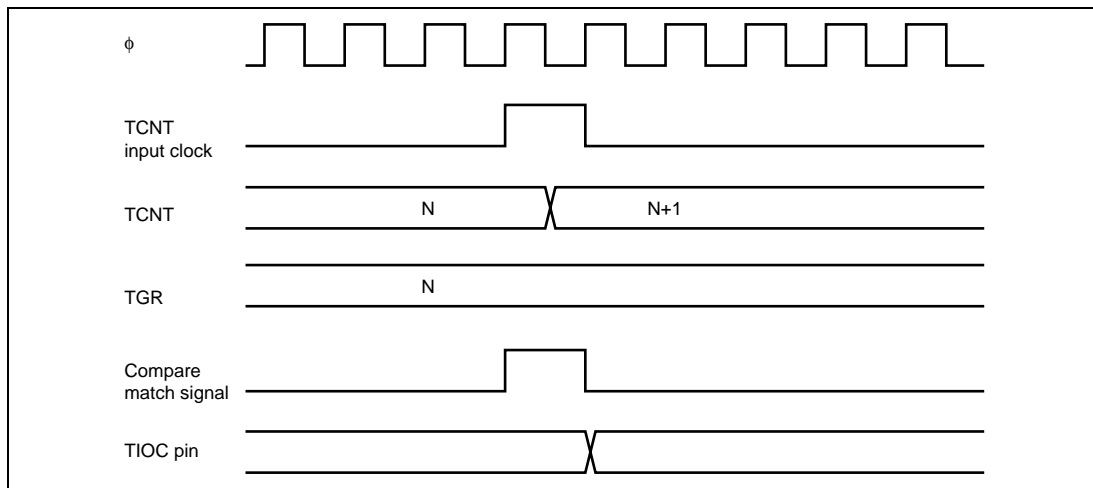


Figure 10.35 Output Compare Output Timing

Input Capture Signal Timing: Figure 10.36 shows input capture signal timing.

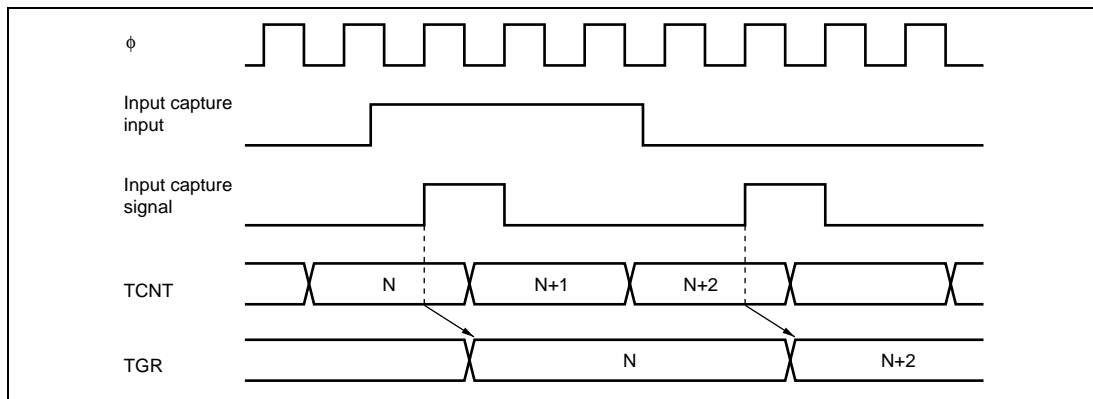


Figure 10.36 Input Capture Input Signal Timing

Timing for Counter Clearing by Compare Match/Input Capture: Figure 10.37 shows the timing when counter clearing on compare match is specified, and figure 10.38 shows the timing when counter clearing on input capture is specified.

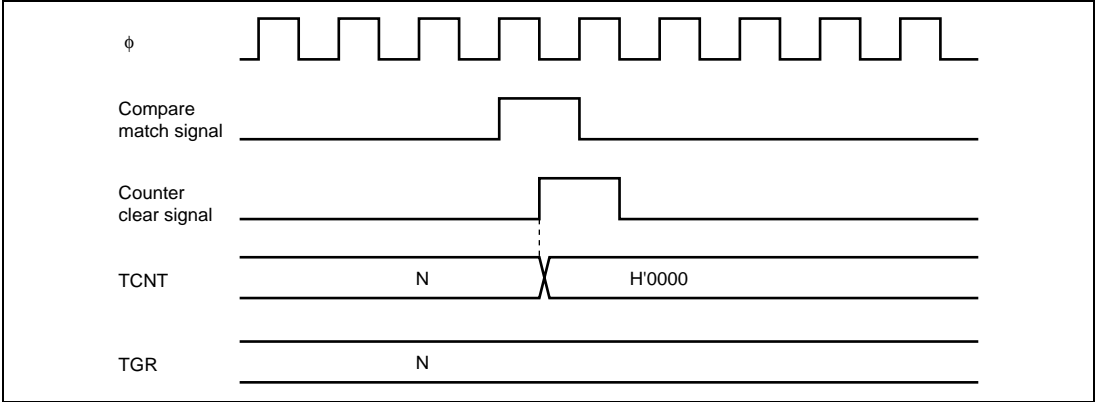


Figure 10.37 Counter Clear Timing (Compare Match)

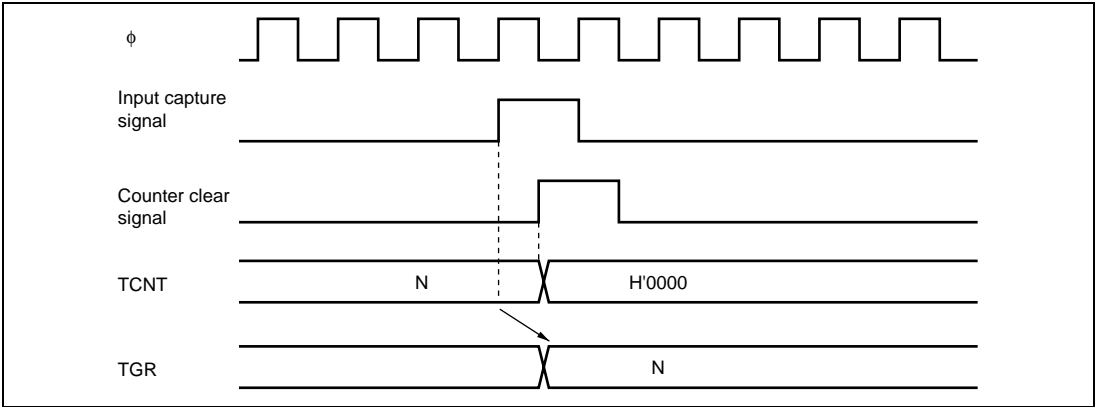


Figure 10.38 Counter Clear Timing (Input Capture)

Buffer Operation Timing (H8S/2268 Series Only): Figures 10.39 and 10.40 show the timing in buffer operation.

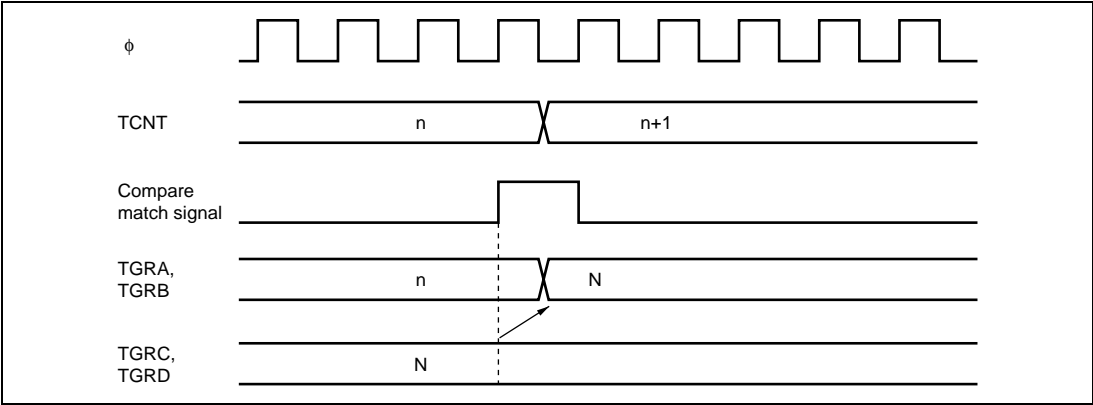


Figure 10.39 Buffer Operation Timing (Compare Match)

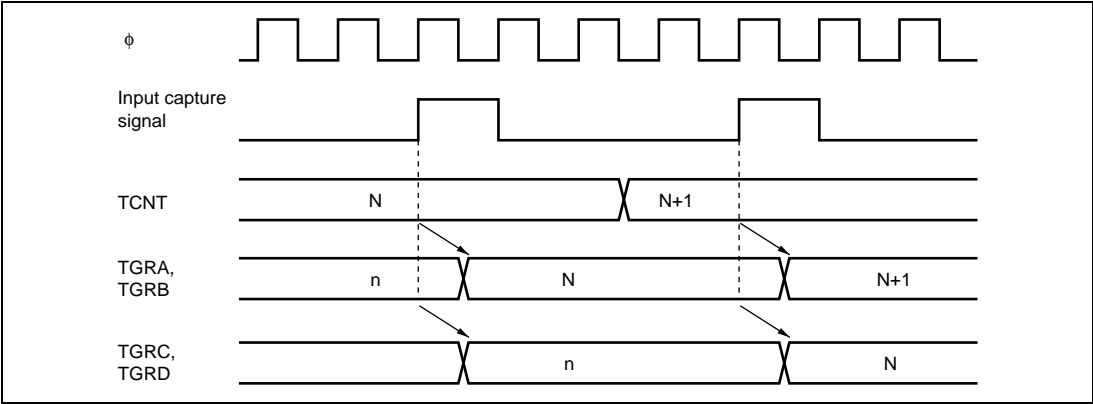


Figure 10.40 Buffer Operation Timing (Input Capture)

10.9.2 Interrupt Signal Timing

TGF Flag Setting Timing in Case of Compare Match: Figure 10.41 shows the timing for setting of the TGF flag in TSR on compare match, and TGI interrupt request signal timing.

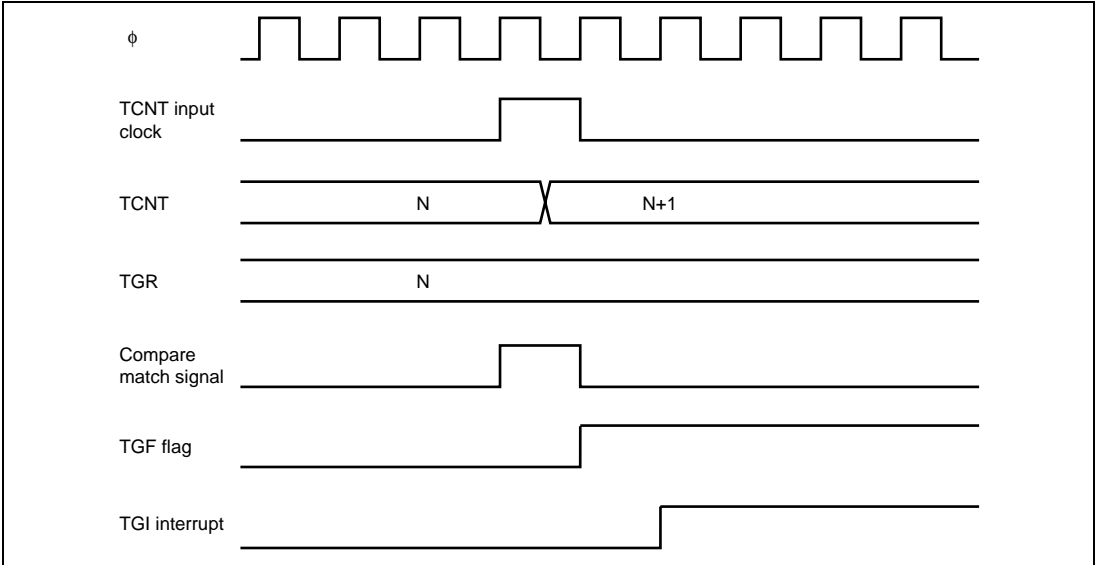


Figure 10.41 TGI Interrupt Timing (Compare Match)

TGF Flag Setting Timing in Case of Input Capture: Figure 10.42 shows the timing for setting of the TGF flag in TSR on input capture, and TGI interrupt request signal timing.

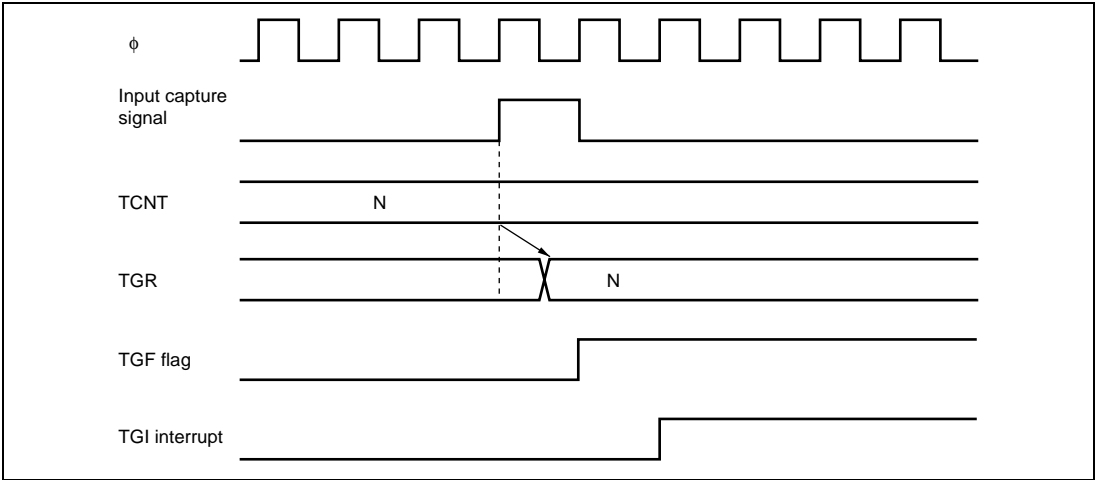


Figure 10.42 TGI Interrupt Timing (Input Capture)

TCFV Flag/TCFU Flag Setting Timing: Figure 10.43 shows the timing for setting of the TCFV flag in TSR on overflow, and TCIV interrupt request signal timing.

Figure 10.44 shows the timing for setting of the TCFU flag in TSR on underflow, and TCIU interrupt request signal timing in the H8S/2268 Series.

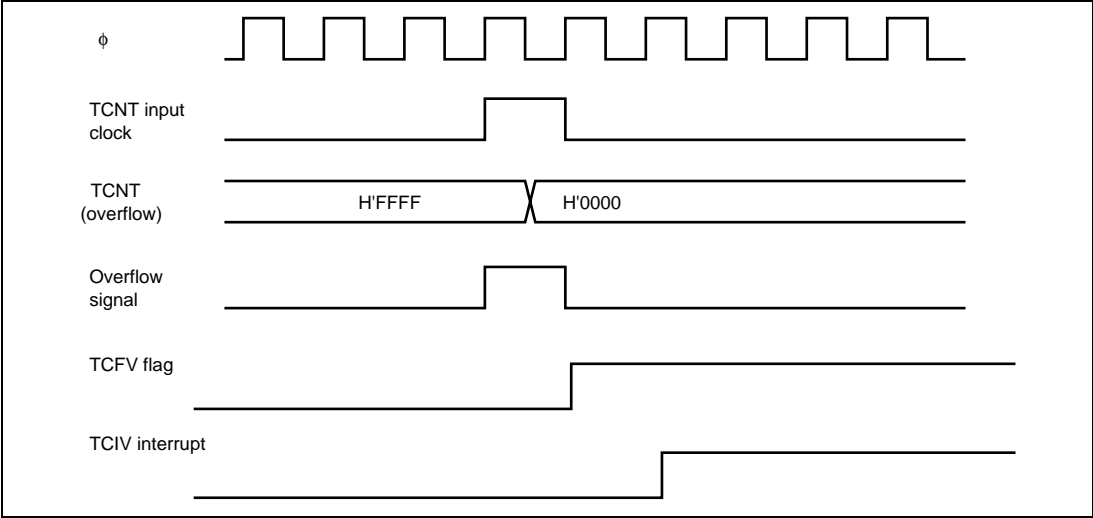


Figure 10.43 TCIV Interrupt Setting Timing

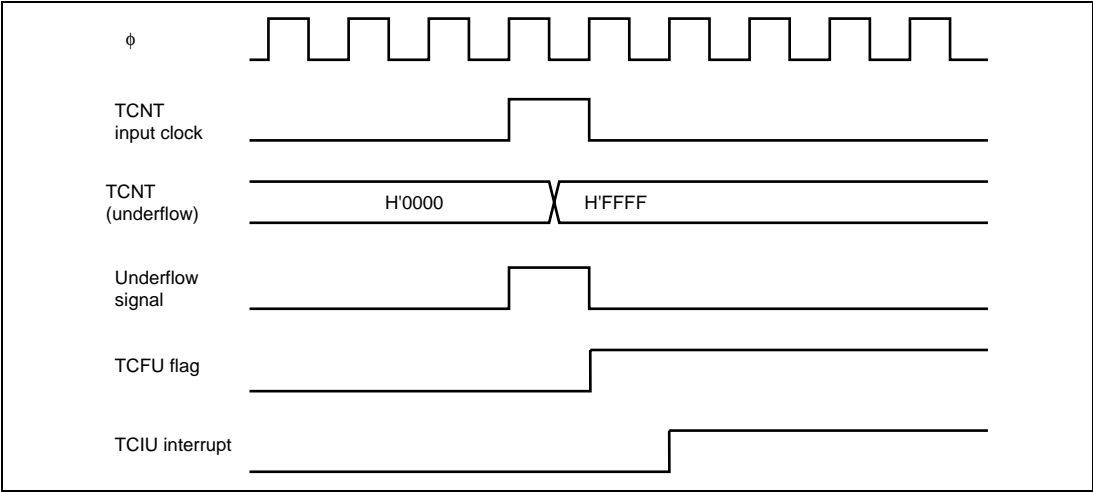


Figure 10.44 TCIU Interrupt Setting Timing (H8S/2268 Series Only)

Status Flag Clearing Timing: After a status flag is read as 1 by the CPU, it is cleared by writing 0 to it. When the DTC is activated in the H8S/2268 Series, the flag is cleared automatically. Figure 10.45 shows the timing for status flag clearing by the CPU, and figure 10.46 shows the timing for status flag clearing by the DTC.

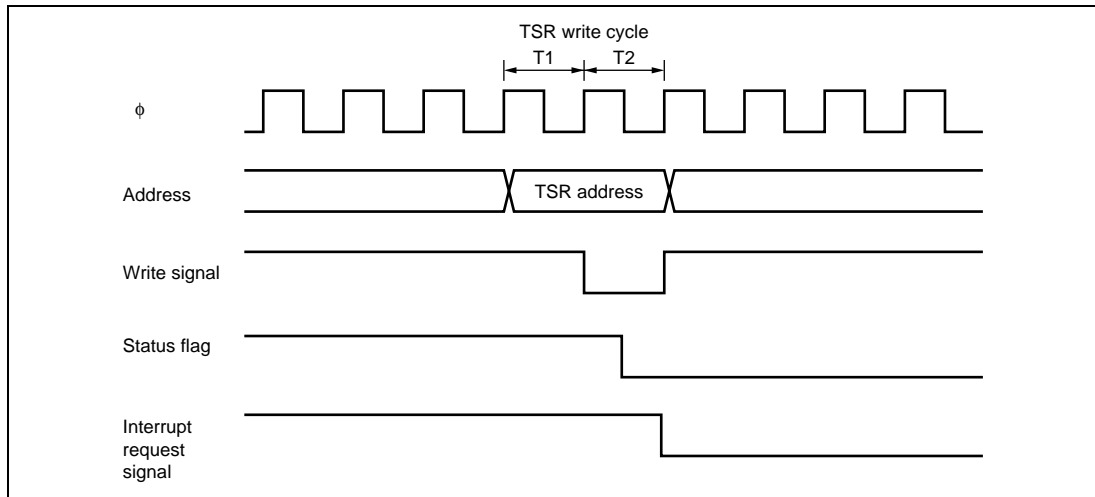


Figure 10.45 Timing for Status Flag Clearing by CPU

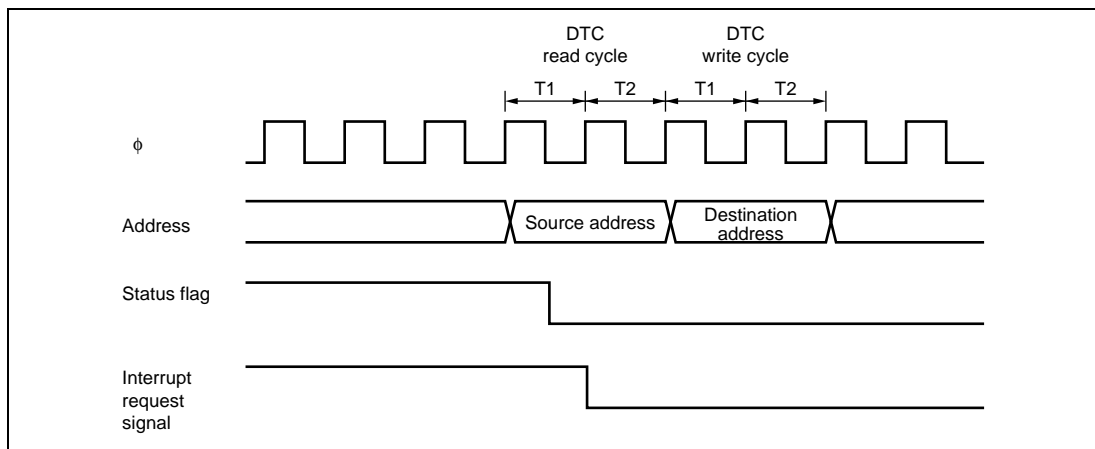


Figure 10.46 Timing for Status Flag Clearing by DTC Activation (H8S/2268 Series Only)

10.10 Usage Notes

10.10.1 Module Stop Mode Setting

TPU operation can be disabled or enabled using the module stop control register. The initial setting is for TPU operation to be halted. Register access is enabled by clearing module stop mode. For details, refer to section 22, Power-Down Modes.

10.10.2 Input Clock Restrictions

The input clock pulse width must be at least 1.5 states in the case of single-edge detection, and at least 2.5 states in the case of both-edge detection. The TPU will not operate properly at narrower pulse widths.

In the H8S/2268 Series phase counting mode, the phase difference and overlap between the two input clocks must be at least 1.5 states, and the pulse width must be at least 2.5 states. Figure 10.47 shows the input clock conditions in phase counting mode.

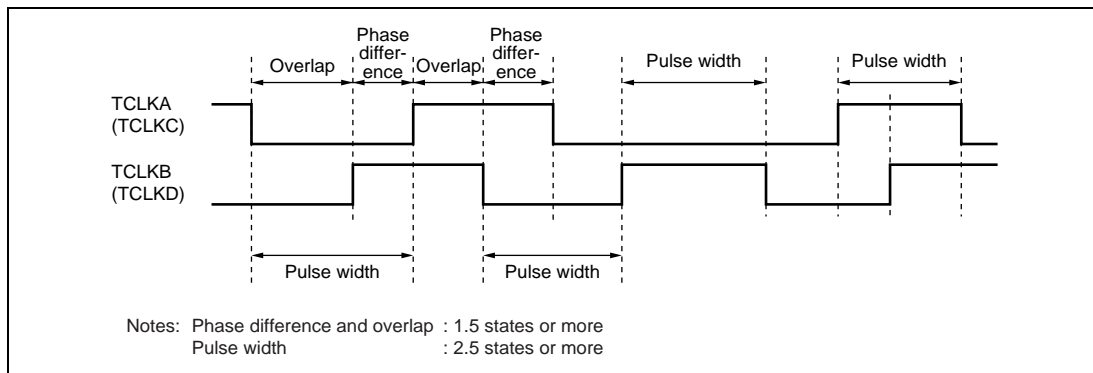


Figure 10.47 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode (H8S/2268 Series Only)

10.10.3 Caution on Period Setting

When counter clearing on compare match is set, TCNT is cleared in the final state in which it matches the TGR value (the point at which the count value matched by TCNT is updated). Consequently, the actual counter frequency is given by the following formula:

$$f = \frac{\phi}{(N + 1)}$$

Where f : Counter frequency
 ϕ : Operating frequency
 N : TGR set value

10.10.4 Contention between TCNT Write and Clear Operations

If the counter clear signal is generated in the T2 state of a TCNT write cycle, TCNT clearing takes precedence and the TCNT write is not performed.

Figure 10.48 shows the timing in this case.

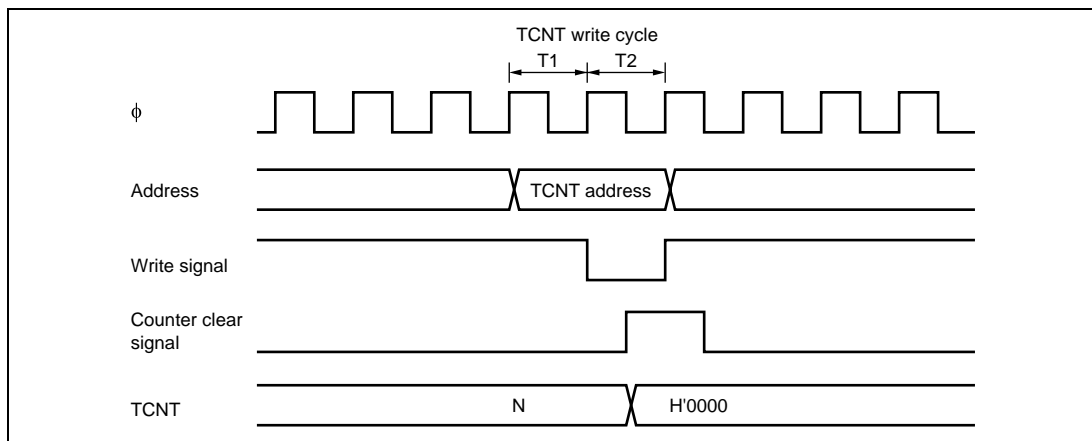


Figure 10.48 Contention between TCNT Write and Clear Operations

10.10.5 Contention between TCNT Write and Increment Operations

If incrementing occurs in the T2 state of a TCNT write cycle, the TCNT write takes precedence and TCNT is not incremented.

Figure 10.49 shows the timing in this case.

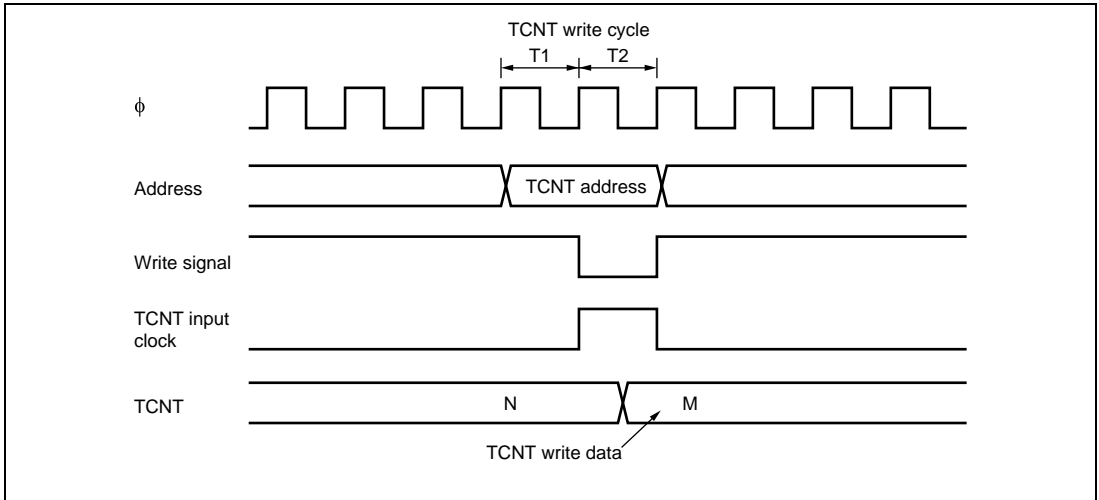


Figure 10.49 Contention between TCNT Write and Increment Operations

10.10.6 Contention between TGR Write and Compare Match

If a compare match occurs in the T2 state of a TGR write cycle, the TGR write takes precedence and the compare match signal is inhibited. A compare match does not occur even if the previous value is written.

Figure 10.50 shows the timing in this case.

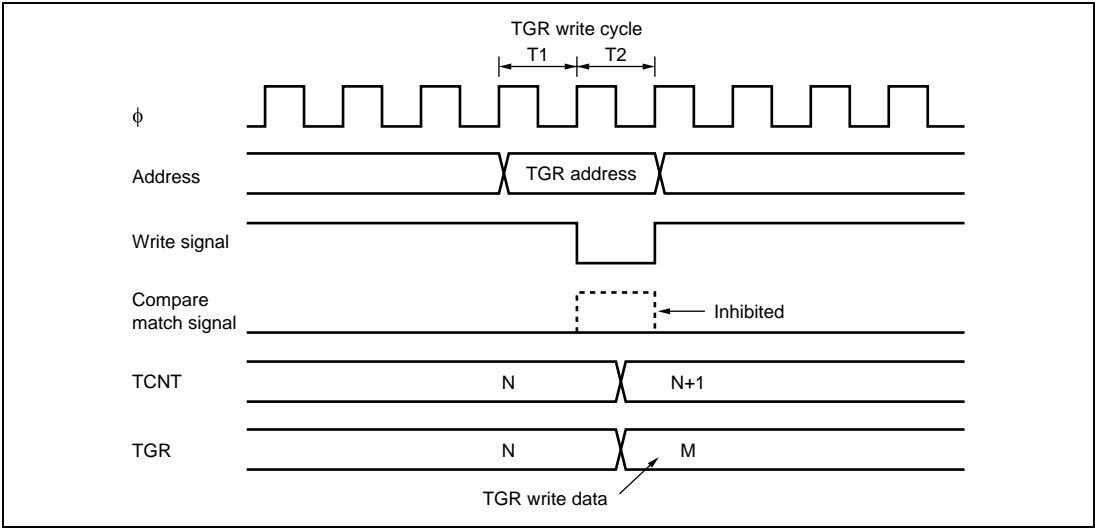


Figure 10.50 Contention between TGR Write and Compare Match

10.10.7 Contention between Buffer Register Write and Compare Match (H8S/2268 Series Only)

If a compare match occurs in the T2 state of a TGR write cycle, the data that is transferred to TGR by the buffer operation will be that in the buffer prior to the write.

Figure 10.51 shows the timing in this case.

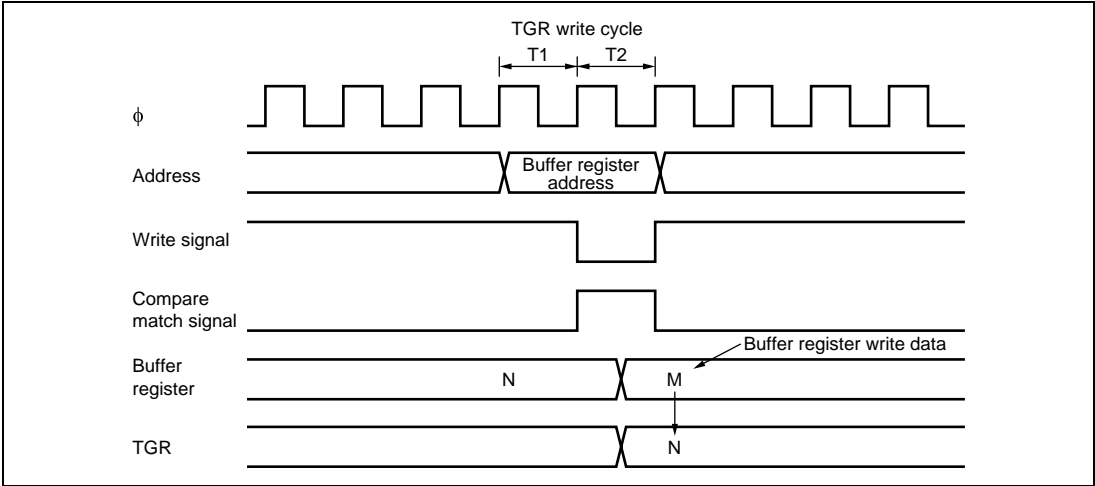


Figure 10.51 Contention between Buffer Register Write and Compare Match

10.10.8 Contention between TGR Read and Input Capture

If an input capture signal is generated in the T1 state of a TGR read cycle, the data that is read will be that in the buffer after input capture transfer.

Figure 10.52 shows the timing in this case.

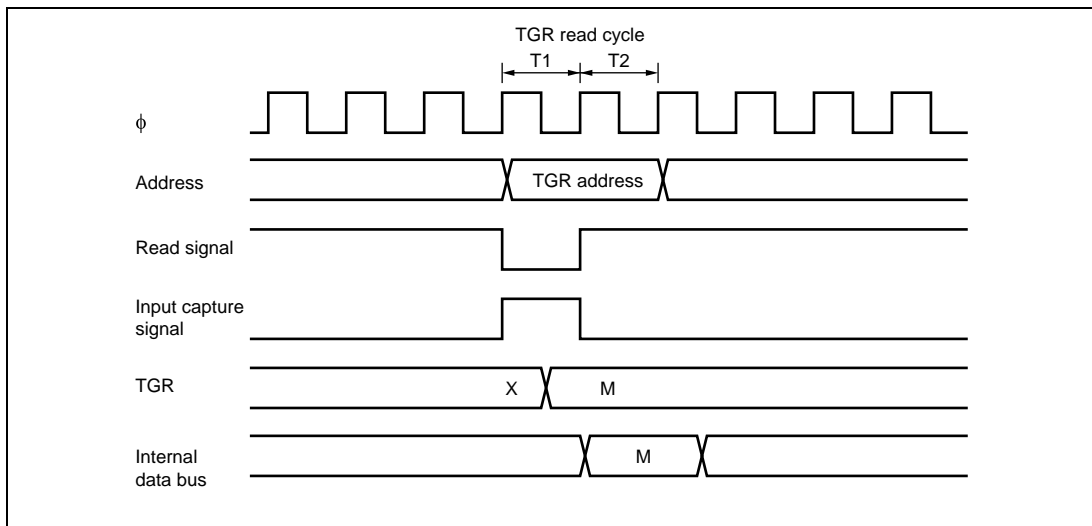


Figure 10.52 Contention between TGR Read and Input Capture

10.10.9 Contention between TGR Write and Input Capture

If an input capture signal is generated in the T2 state of a TGR write cycle, the input capture operation takes precedence and the write to TGR is not performed.

Figure 10.53 shows the timing in this case.

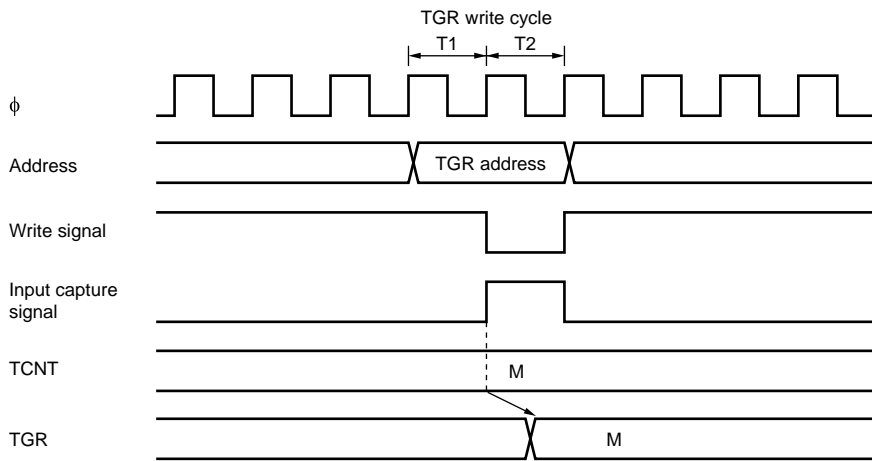


Figure 10.53 Contention between TGR Write and Input Capture

10.10.10 Contention between Buffer Register Write and Input Capture (H8S/2268 Series Only)

If an input capture signal is generated in the T2 state of a buffer register write cycle, the buffer operation takes precedence and the write to the buffer register is not performed.

Figure 10.54 shows the timing in this case.

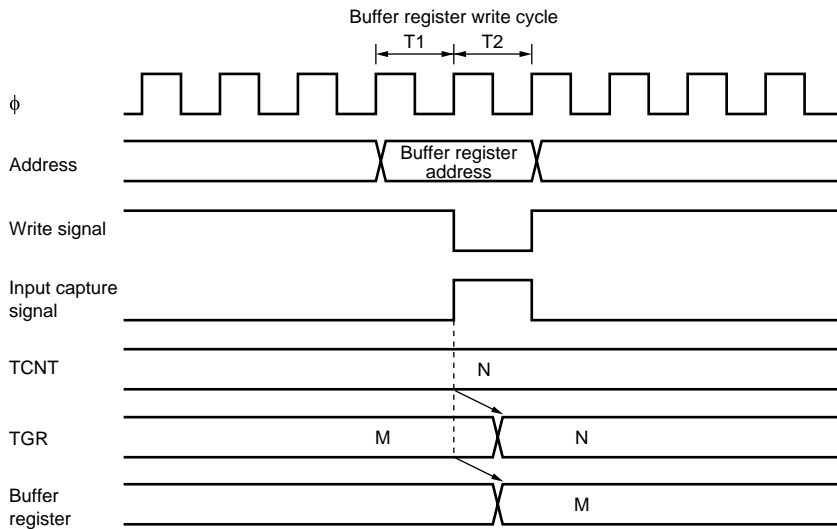


Figure 10.54 Contention between Buffer Register Write and Input Capture

10.10.11 Contention between Overflow/Underflow and Counter Clearing

In the H8S/2268 Series, if overflow/underflow and counter clearing occur simultaneously, the TCFV/TCFU flag in TSR is not set and TCNT clearing takes precedence.

In the H8S/2264 Series, if overflow and counter clearing occur simultaneously, the TCFV flag in TSR is not set and TCNT clearing takes precedence.

Figure 10.55 shows the operation timing when a TGR compare match is specified as the clearing source, and when H'FFFF is set in TGR.

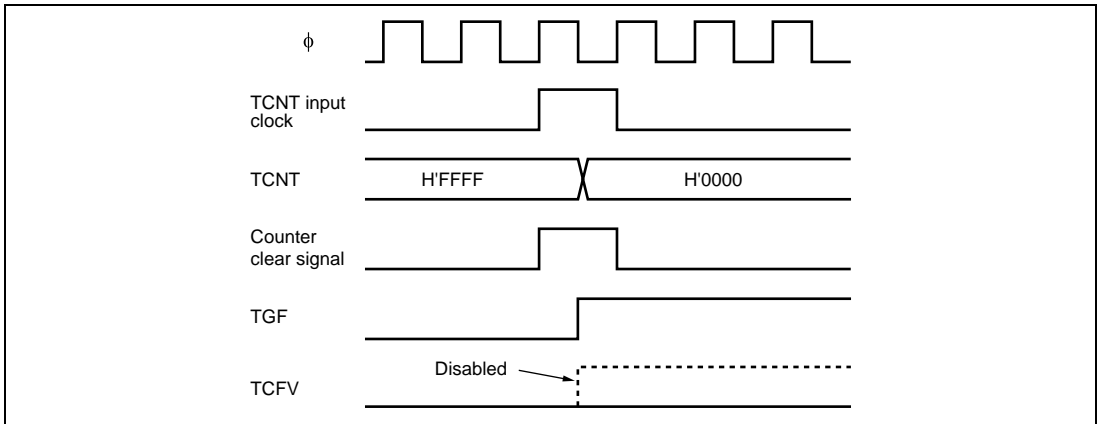


Figure 10.55 Contention between Overflow and Counter Clearing

10.10.12 Contention between TCNT Write and Overflow/Underflow

In the H8S/2268 Series, if there is an up-count or down-count in the T2 state of a TCNT write cycle and overflow/underflow occurs, the TCNT write takes precedence and the TCFV/TCFU flag in TSR is not set.

In the H8S/2264 Series, if there is an up-count in the T2 state of a TCNT write cycle and overflow occurs, the TCNT write takes precedence and the TCFV flag in TSR is not set.

Figure 10.56 shows the operation timing when there is contention between TCNT write and overflow.

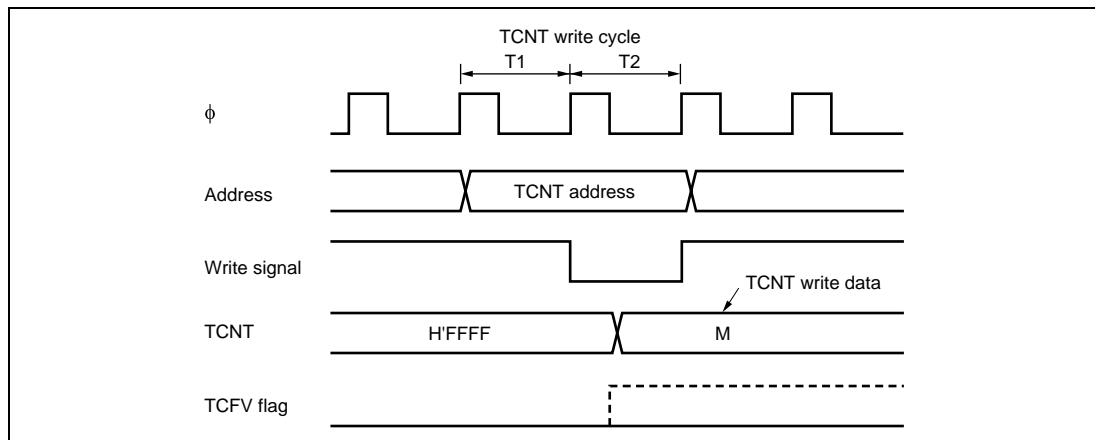


Figure 10.56 Contention between TCNT Write and Overflow

10.10.13 Multiplexing of I/O Pins

In the H8S/2268 Series, the TCLKA input pin is multiplexed with the TIOCC0 I/O pin, the TCLKB input pin with the TIOCD0 I/O pin, the TCLKC input pin with the TIOCB1 I/O pin, and the TCLKD input pin with the TIOCB2 I/O pin. In the H8S/2264 Series, the TCLKC input pin is multiplexed with the TIOCB1 I/O pin. When an external clock is input, compare match output should not be performed from a multiplexed pin.

10.10.14 Interrupts in Module Stop Mode

If module stop mode is entered when an interrupt has been requested, it will not be possible to clear the CPU interrupt source, or the DTC activation source (the H8S/2268 Series only). Interrupts should therefore be disabled before entering module stop mode.

Section 11 8-Bit Timers

The H8S/2268 Series has an on-chip 8-bit timer module with four channels (TMR_0, TMR_1, TMR_2 and TMR_3) operating on the basis of an 8-bit counter and an 8-bit reload timer with four channels (TMR_4). The H8S/2264 Series has an on-chip 8-bit timer module with two channels (TMR_0 and TMR_1) operating on the basis of an 8-bit counter.

11.1 8-Bit Timer Module (TMR_0, TMR_1, TMR_2 and TMR_3)

The 8-bit timer module can be used to count external events and be used as a multifunction timer in a variety of applications, such as generation of counter reset, interrupt requests, and pulse output with an arbitrary duty cycle using a compare-match signal with two registers.

11.1.1 Features

- Selection of clock sources
Selected from three internal clocks ($\phi/8$, $\phi/64$, and $\phi/8192$) and an external clock.
- Selection of three ways to clear the counters
The counters can be cleared on compare-match A or B, or by an external reset signal.
- Timer output controlled by two compare-match signals
The timer output signal in each channel is controlled by two independent compare-match signals, enabling the timer to be used for various applications, such as the generation of pulse output or PWM output with an arbitrary duty cycle.
- Cascading of the two channels
The module can operate as a 16-bit timer using channel 0 (channel 2*) as the upper half and channel 1 (channel 3*) as the lower half (16-bit count mode).
Channel 1 (channel 3*) can be used to count channel 0 (channel 2*) compare-match occurrences (compare-match count mode).
- Multiple interrupt sources for each channel
Two compare-match interrupts and one overflow interrupt can be requested independently.
- Generation of A/D conversion start trigger
Channel 0 compare-match signal can be used as the A/D conversion start trigger.
- Module stop mode can be set
At initialization, the 8-bit timer operation is halted. Register access is enabled by canceling the module stop mode.

Note: * Supported only by the H8S/2268 Series.

Figure 11.1 shows a block diagram of the 8-bit timer module (TMR_0 and TMR_1).

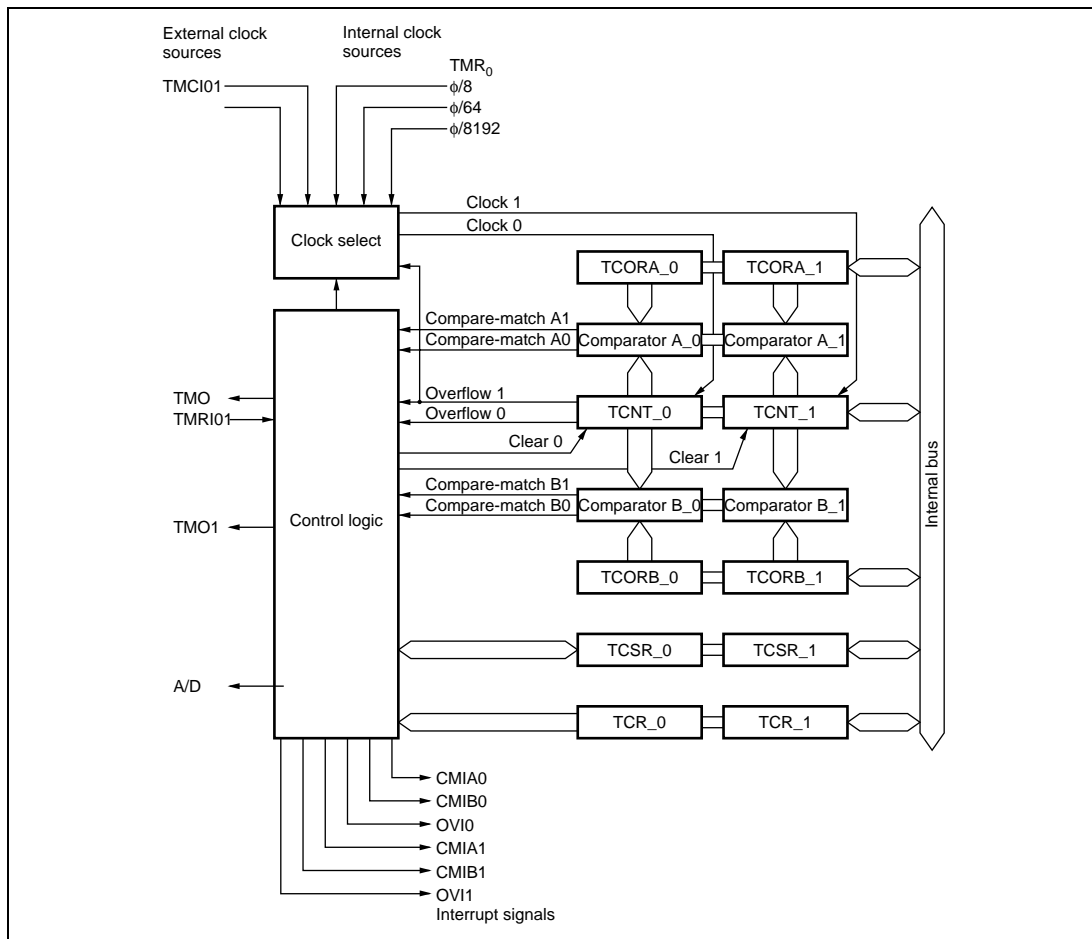


Figure 11.1 Block Diagram of 8-Bit Timer Module

Legend

TCORA_0: Time constant register A_0
 TCORB_0: Time constant register B_0
 TCNT_0: Timer counter_0
 TCSR_0: Timer control/status register_0
 TCR_0: Timer control register_0
 TCORA_1: Time constant register A_1
 TCORB_1: Time constant register B_1
 TCNT_1: Timer counter_1
 TCSR_1: Timer control/status register_1
 TCR_1: Timer control register_1

11.2 Input/Output Pins

Table 11.1 summarizes the input and output pins of the 8-bit timer module.

Table 11.1 Pin Configuration

Channel	Name	Symbol	I/O	Function
0	Timer output	TMO0	Output	Output controlled by compare-match
1	Timer output	TMO1	Output	Output controlled by compare-match
Common to 0 and 1	Timer clock input	TMC101	Input	External clock input for the counter
	Timer reset input	TMRI01	Input	External reset input for the counter
2*	Timer output	TMO2	Output	Output controlled by compare-match
3*	Timer output	TMO3	Output	Output controlled by compare-match
Common to 2 and 3*	Timer clock input	TMC123	Input	External clock input for the counter
	Timer reset input	TMRI23	Input	External reset input for the counter

Note: * Supported only by the H8S/2268 Series.

11.3 Register Descriptions

The 8-bit timer has the following registers. For details on the module stop register, refer to section 22.1.2, Module Stop Registers A to D (MSTPCRA to MSTPCRD).

- Timer counter_0 (TCNT_0)
- Time constant register A_0 (TCORA_0)
- Time constant register B_0 (TCORB_0)
- Timer control register_0 (TCR_0)
- Timer control/status register_0 (TCSR_0)
- Timer counter_1 (TCNT_1)
- Time constant register A_1 (TCORA_1)
- Time constant register B_1 (TCORB_1)
- Timer control register_1 (TCR_1)
- Timer control/status register_1 (TCSR_1)
- Timer counter_2 (TCNT_2)*
- Time constant register A_2 (TCORA_2)*
- Time constant register B_2 (TCORB_2)*
- Timer control register_2 (TCR_2)*
- Timer control/status register_2 (TCSR_2)*
- Timer counter_3 (TCNT_3)*
- Time constant register A_3 (TCORA_3)*

- Time constant register B_3 (TCORB_3)*
- Timer control register_3 (TCR_3)*
- Timer control/status register_3 (TCSR_3)*

Note: * Supported only by the H8S/2268 Series.

11.3.1 Timer Counter (TCNT)

Each TCNT is an 8-bit up-counter. TCNT_0 and TCNT_1 (TCNT_2 and TCNT_3) comprise a single 16-bit register, so they can be accessed together by word access.

TCNT increments on pulses generated from an internal or external clock source. This clock source is selected by clock select bits CKS2 to CKS0 in TCR. TCNT can be cleared by an external reset input signal or compare-match signals A and B. Counter clear bits CCLR1 and CCLR0 in TCR select the method of clearing.

When TCNT overflows from H'FF to H'00, the overflow flag (OVF) in TCSR is set to 1.

11.3.2 Time Constant Register A (TCORA)

TCORA is an 8-bit readable/writable register. TCORA_0 and TCORA_1 (TCORA_2 and TCORA_3) comprise a single 16-bit register, so they can be accessed together by word access.

TCORA is continually compared with the value in TCNT. When a match is detected, the corresponding compare-match flag A (CMFA) in TCSR is set. Note, however, that comparison is disabled during the T2 state of a TCORA write cycle.

The timer output from the TMO pin can be freely controlled by the compare-match signal A and the settings of output select bits OS1 and OS0 in TCSR.

The initial value of TCORA is H'FF.

11.3.3 Time Constant Register B (TCORB)

TCORB is an 8-bit readable/writable register. TCORB_0 and TCORB_1 (TCORB_2 and TCORB_3) comprise a single 16-bit register, so they can be accessed together by word access.

TCORB is continually compared with the value in TCNT. When a match is detected, the corresponding compare-match flag B (CMFB) in TCSR is set. Note, however, that comparison is disabled during the T2 state of a TCORB write cycle.

The timer output from the TMO pin can be freely controlled by the compare-match signal B and the settings of output select bits OS1 and OS0 in TCSR.

The initial value of TCORB is H'FF.

11.3.4 Timer Control Register (TCR)

TCR selects the TCNT clock source and the time at which TCNT is cleared, and controls interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	CMIEB	0	R/W	Compare-Match Interrupt Enable B Selects whether the CMFB interrupt request (CMIB) is enabled or disabled when the CMFB flag in TCSR is set to 1. 0: CMFB interrupt request (CMIB) is disabled 1: CMFB interrupt request (CMIB) is enabled
6	CMIEA	0	R/W	Compare-Match Interrupt Enable A Selects whether the CMFA interrupt request (CMIA) is enabled or disabled when the CMFA flag in TCSR is set to 1. 0: CMFA interrupt request (CMIA) is disabled 1: CMFA interrupt request (CMIA) is enabled
5	OVIE	0	R/W	Timer Overflow Interrupt Enable Selects whether the OVF interrupt request (OVI) is enabled or disabled when the OVF flag in TCSR is set to 1. 0: OVF interrupt request (OVI) is disabled 1: OVF interrupt request (OVI) is enabled
4	CCLR1	0	R/W	Counter Clear 1 and 0
3	CCLR0	0	R/W	These bits select the method by which TCNT is cleared 00: Clearing is disabled 01: Cleared on compare-match A 10: Cleared on compare-match B 11: Cleared on rising edge of external reset input

Bit	Bit Name	Initial Value	R/W	Description
2 to 0	CKS2	0	R/W	Clock Select 2 to 0
	CKS1	0	R/W	<p>The input clock can be selected from three clocks divided from the system clock (ϕ). When use of an external clock is selected, three types of count can be selected: at the rising edge, the falling edge, and both rising and falling edges.</p> <p>000: Clock input disabled</p> <p>001: $\phi/8$ internal clock source, counted on the falling edge</p> <p>010: $\phi/64$ internal clock source, counted on the falling edge</p> <p>011: $\phi/8192$ internal clock source, counted on the falling edge</p> <p>100: For channel 0: Counted on TCNT1 overflow signal*</p> <p>For channel 1: Counted on TCNT0 compare-matchA signal*</p> <p>For channel 2: Counted on TCNT3 overflow signal*</p> <p>For channel 3: Counted on TCNT2 compare-matchA signal*</p> <p>101: External clock source, counted at rising edge</p> <p>110: External clock source, counted at falling edge</p> <p>111: External clock source, counted at both rising and falling edges</p>
	CKS0	0	R/W	

Note: * If the count input of channel 0 (channel 2) is the TCNT1 (TCNT3) overflow signal and that of channel 1 (channel 3) is the TCNT0 (TCNT2) compare-match signal, no incrementing clock will be generated. Do not use this setting.

11.3.5 Timer Control/Status Register (TCSR)

TCSR indicates status flags and controls compare-match output.

- TCSR_0

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W)* ¹	Compare-Match Flag B [Setting condition] When TCNT = TCORB [Clearing condition] Read CMFB when CMFB = 1, then write 0 in CMFB. The DTC* ² is activated by the CMIB interrupt and the DISEL bit = 0 in MRB of the DTC* ² .
6	CMFA	0	R/(W)* ¹	Compare-match Flag A [Setting condition] When TCNT = TCORA [Clearing condition] Read CMFA when CMFA = 1, then write 0 in CMFA. The DTC* ² is activated by the CMIA interrupt and DISEL bit = 0 in MRB of the DTC* ² .
5	OVF	0	R/(W)* ¹	Timer Overflow Flag [Setting condition] When TCNT overflows from H'FF to H'00 [Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
4	ADTE	0	R/W	A/D Trigger Enable Enables or disables A/D converter start requests by compare-match A. 0: A/D converter start requests by compare-match A are disabled 1: A/D converter start requests by compare-match A are enabled

Bit	Bit Name	Initial Value	R/W	Description
3	OS3	0	R/W	Output Select 3 and 2
2	OS2	0	R/W	<p>These bits specify how the timer output level is to be changed by a compare-match B of TCORB and TCNT.</p> <p>00: No change when compare-match B occurs</p> <p>01: 0 is output when compare-match B occurs</p> <p>10: 1 is output when compare-match B occurs</p> <p>11: Output is inverted when compare-match B occurs (toggle output)</p>
1	OS1	0	R/W	Output Select 1 and 0
0	OS0	0	R/W	<p>These bits specify how the timer output level is to be changed by a compare-match A of TCORA and TCNT.</p> <p>00: No change when compare-match A occurs</p> <p>01: 0 is output when compare-match A occurs</p> <p>10: 1 is output when compare-match A occurs</p> <p>11: Output is inverted when compare-match A occurs (toggle output)</p>

Notes: 1. Only 0 can be written to this bit, to clear the flag.
2. Supported only by the H8S/2268 Series.

- TCSR_1 and TCSR_3

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W) * ¹	Compare-Match Flag B [Setting condition] When TCNT = TCORB [Clearing condition] Read CMFB when CMFB = 1, then write 0 in CMFB The DTC* ² is activated by the CMIB interrupt and the DISEL Bit = 0 in MRB of the DTC* ² .
6	CMFA	0	R/(W) * ¹	Compare-match Flag A [Setting condition] When TCNT = TCORA [Clearing condition] Read CMFA when CMFA = 1, then write 0 in CMFA The DTC* ² is activated by the CMIA interrupt and the DISEL Bit = 0 in MRB of the DTC* ² .
5	OVF	0	R/(W) * ¹	Timer Overflow Flag [Setting condition] When TCNT overflows from H'FF to H'00 [Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
4	—	1	—	Reserved This bit is always read as 1 and cannot be modified.
3	OS3	0	R/W	Output Select 3 and 2
2	OS2	0	R/W	These bits specify how the timer output level is to be changed by a compare-match B of TCORB and TCNT. 00: No change when compare-match B occurs 01: 0 is output when compare-match B occurs 10: 1 is output when compare-match B occurs 11: Output is inverted when compare-match B occurs (toggle output)

Bit	Bit Name	Initial Value	R/W	Description
1	OS1	0	R/W	Output Select 1 and 0
0	OS0	0	R/W	<p>These bits specify how the timer output level is to be changed by a compare-match A of TCORA and TCNT.</p> <p>00: No change when compare-match A occurs</p> <p>01: 0 is output when compare-match A occurs</p> <p>10: 1 is output when compare-match A occurs</p> <p>11: Output is inverted when compare-match A occurs (toggle output)</p>

Notes: 1. Only 0 can be written to this bit, to clear the flag.
2. Supported only by the H8S/2268 Series.

- TCSR_2

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W) * ¹	<p>Compare-Match Flag B</p> <p>[Setting condition]</p> <p>When TCNT = TCORB</p> <p>[Clearing condition]</p> <p>Read CMFB when CMFB = 1, then write 0 in CMFB</p> <p>The DTC*² is activated by the CMIB interrupt and the DISEL Bit = 0 in MRB of the DTC*².</p>
6	CMFA	0	R/(W) * ¹	<p>Compare-match Flag A</p> <p>[Setting condition]</p> <p>When TCNT = TCORA</p> <p>[Clearing condition]</p> <p>Read CMFA when CMFA = 1, then write 0 in CMFA</p> <p>The DTC*² is activated by the CMIA interrupt and the DISEL Bit = 0 in MRB of the DTC*².</p>
5	OVF	0	R/(W) * ¹	<p>Timer Overflow Flag</p> <p>[Setting condition]</p> <p>When TCNT overflows from H'FF to H'00</p> <p>[Clearing condition]</p> <p>Read OVF when OVF = 1, then write 0 in OVF</p>

Bit	Bit Name	Initial Value	R/W	Description
4	—	0	R/W	Reserved This bit is a readable/writable bit, but the write value should always be 0.
3	OS3	0	R/W	Output Select 3 and 2
2	OS2	0	R/W	These bits specify how the timer output level is to be changed by a compare-match B of TCORB and TCNT. 00: No change when compare-match B occurs 01: 0 is output when compare-match B occurs 10: 1 is output when compare-match B occurs 11: Output is inverted when compare-match B occurs (toggle output)
1	OS1	0	R/W	Output Select 1 and 0
0	OS0	0	R/W	These bits specify how the timer output level is to be changed by a compare-match A of TCORA and TCNT. 00: No change when compare-match A occurs 01: 0 is output when compare-match A occurs 10: 1 is output when compare-match A occurs 11: Output is inverted when compare-match A occurs (toggle output)

Notes: 1. Only 0 can be written to this bit, to clear the flag.
2. Supported only by the H8S/2268 Series.

11.4 Operation

11.4.1 Pulse Output

Figure 11.2 shows an example of arbitrary duty pulse output.

1. Set TCR in CCR1 to 0 and CCLR0 to 1 to clear TCNT by a TCORA compare-match.
2. Set OS3 to OS0 bits in TCSR to B'0110 to output 1 by a TCORA compare-match and 0 by a TCORB compare-match.

By the above settings, waveforms with the cycle of TCORA and the pulse width of TCORB can be output without software intervention.

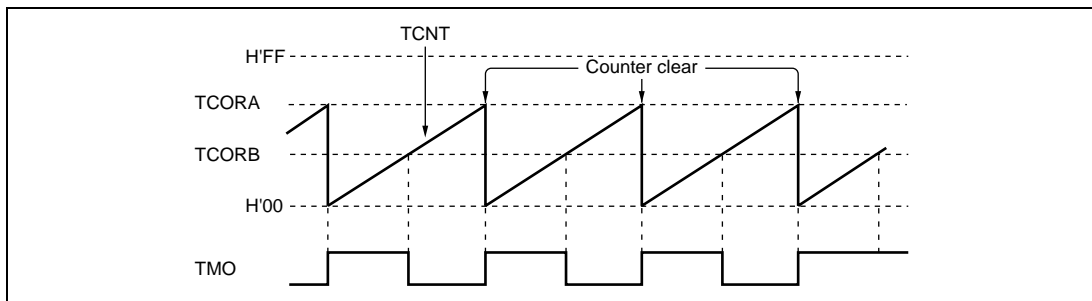


Figure 11.2 Example of Pulse Output

11.5 Operation Timing

11.5.1 TCNT Incrementation Timing

Figure 11.3 shows the TCNT count timing with internal clock source. Figure 11.4 shows the TCNT incrementation timing with external clock source. The pulse width of the external clock for incrementation at single edge must be at least 1.5 status, and at least 2.5 states for incrementation at both edges. The counter will not increment correctly if the pulse width is less than these values.

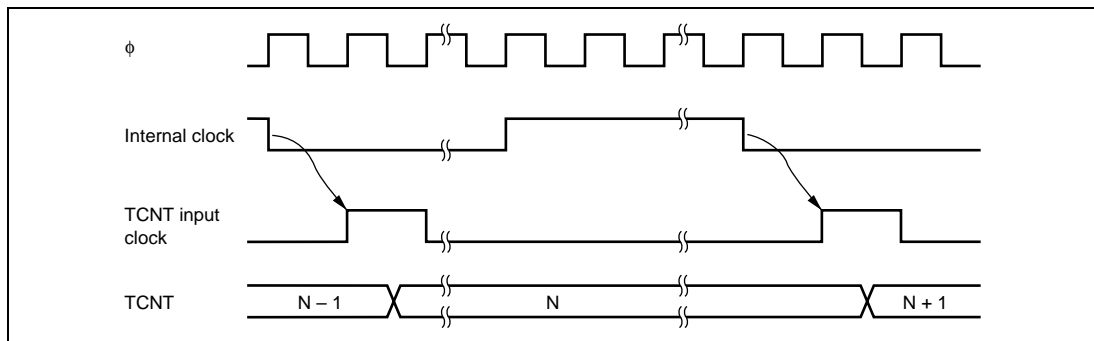


Figure 11.3 Count Timing for Internal Clock Input

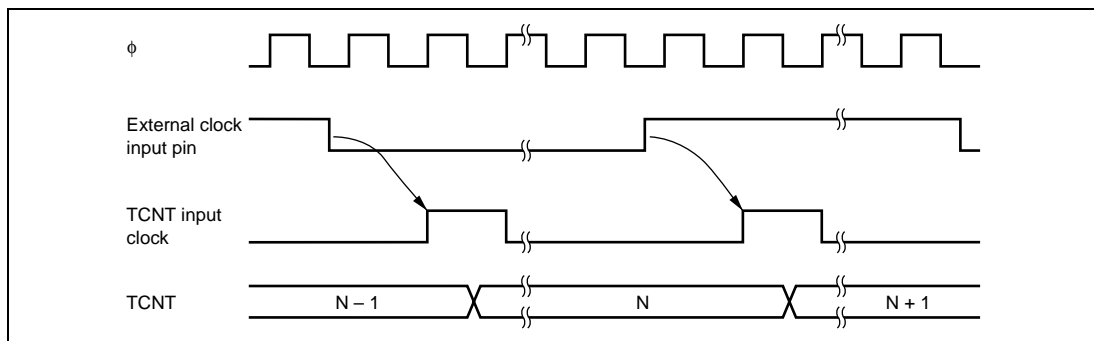


Figure 11.4 Count Timing for External Clock Input

11.5.2 Timing of CMFA and CMFB Setting When a Compare-Match Occurs

The CMFA and CMFB flags in TCSR are set to 1 by a compare-match signal generated when the TCOR and TCNT values match. The compare-match signal is generated at the last state in which the match is true, just before the timer counter is updated. Therefore, when TCOR and TCNT match, the compare-match signal is not generated until the next incrementation clock input. Figure 11.5 shows the timing of CMF flag setting.

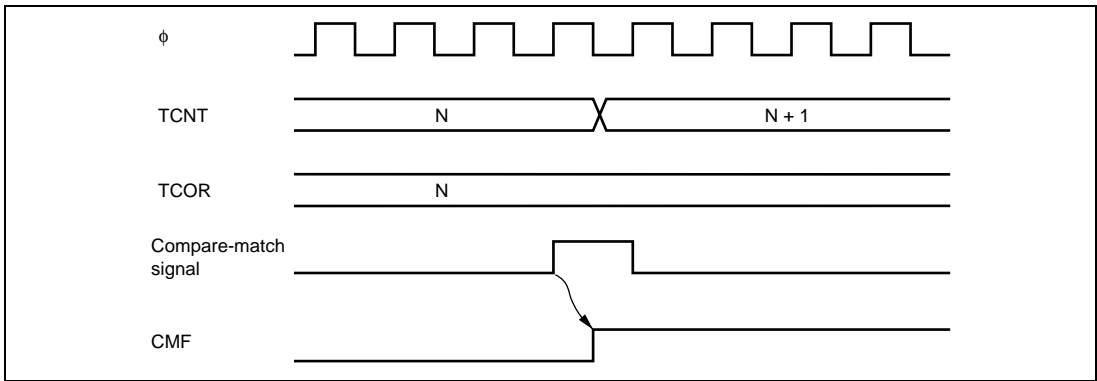


Figure 11.5 Timing of CMF Setting

11.5.3 Timing of Timer Output When a Compare-Match Occurs

When a compare-match occurs, the timer output changes as specified by the output select bits (OS3 to OS0) in TCSR. Figure 11.6 shows the timing when the output is set to toggle at compare-match A.

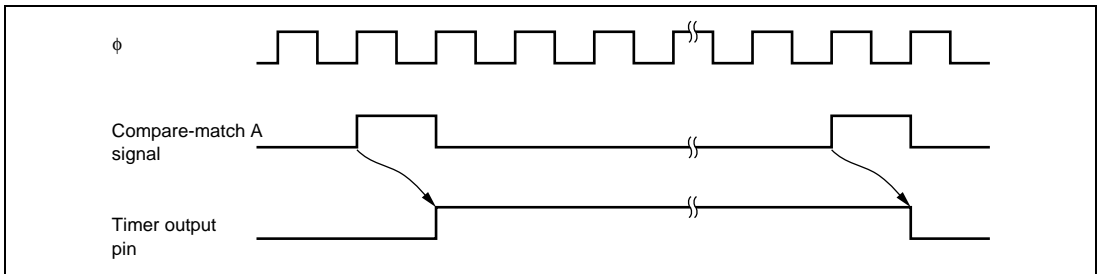


Figure 11.6 Timing of Timer Output

11.5.4 Timing of Compare-Match Clear When a Compare-Match Occurs

TCNT is cleared when compare-match A or B occurs, depending on the setting of the CCLR1 and CCLR0 bits in TCR. Figure 11.7 shows the timing of this operation.

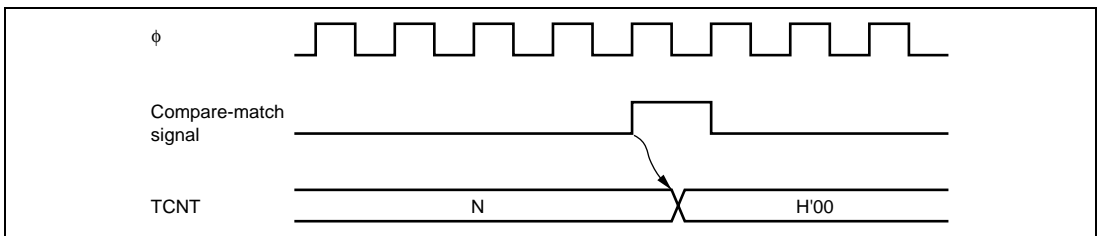


Figure 11.7 Timing of Compare-Match Clear

11.5.5 TCNT External Reset Timing

TCNT is cleared at the rising edge of an external reset input, depending on the settings of the CCLR1 and CCLR0 bits in TCR. The width of the clearing pulse must be at least 1.5 states. Figure 11.8 shows the timing of this operation.

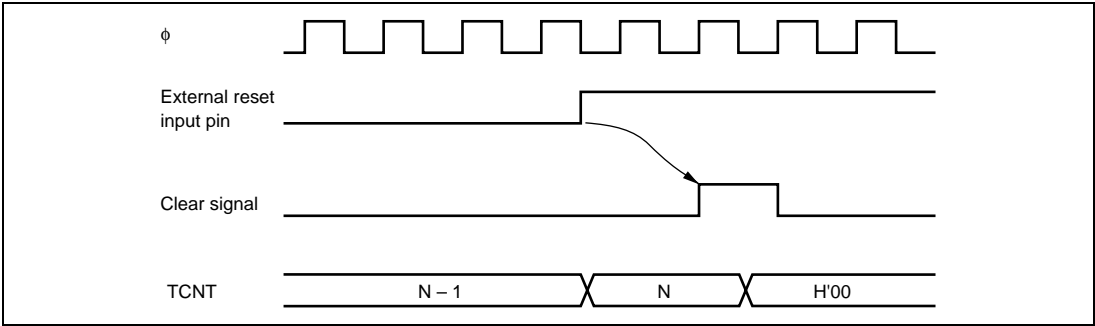


Figure 11.8 Timing of Clearing by External Reset Input

11.5.6 Timing of Overflow Flag (OVF) Setting

OVF in TCSR is set to 1 when the timer count overflows (changes from $H'FF$ to $H'00$). Figure 11.9 shows the timing of this operation.

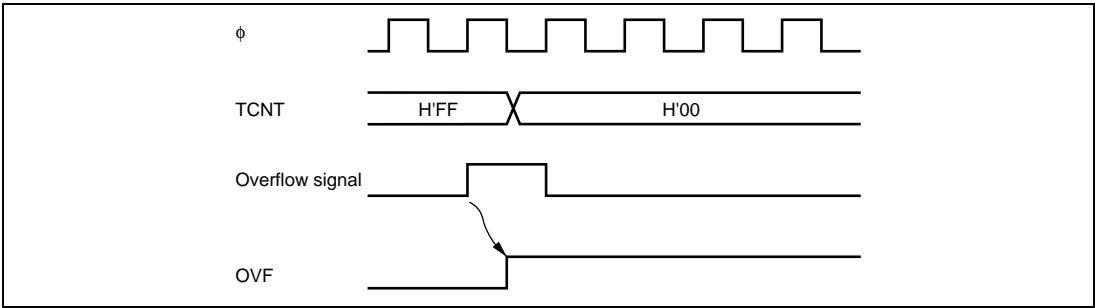


Figure 11.9 Timing of OVF Setting

11.6 Operation with Cascaded Connection

If bits CKS2 to CKS0 in one of TCR_0 and TCR_1 (TCR_2 and TCR_3) are set to B'100, the 8-bit timers of the two channels are cascaded. With this configuration, a single 16-bit timer can be used (16-bit timer mode) or compare-matches of 8-bit channel 0 (channel 2) can be counted by the timer of channel 1 (channel 3) (compare-match count mode). In the case that channel 0 is connected to channel 1 in cascade, the timer operates as described below.

11.6.1 16-Bit Count Mode

When bits CKS2 to CKS0 in TCR_0 are set to B'100, the timer functions as a single 16-bit timer with channel 0 occupying the upper 8 bits and channel 1 occupying the lower 8 bits.

- Setting of compare-match flags
 - The CMF flag in TCSR_0 is set to 1 when a 16-bit compare-match occurs.
 - The CMF flag in TCSR_1 is set to 1 when a lower 8-bit compare-match occurs.
- Counter clear specification
 - If the CCLR1 and CCLR0 bits in TCR_0 have been set for counter clear at compare-match, the 16-bit counter (TCNT_0 and TCNT_1 together) is cleared when a 16-bit compare-match occurs. The 16-bit counter (TCNT_0 and TCNT_1 together) is cleared even if counter clear by the TMRI01 pin has also been set.
 - The settings of the CCLR1 and CCLR0 bits in TCR_1 are ignored. The lower 8 bits cannot be cleared independently.
- Pin output
 - Control of output from the TMO0 pin by bits OS3 to OS0 in TCSR_0 is in accordance with the 16-bit compare-match conditions.
 - Control of output from the TMO1 pin by bits OS3 to OS0 in TCSR_1 is in accordance with the lower 8-bit compare-match conditions.

11.6.2 Compare-Match Count Mode

When bits CKS2 to CKS0 in TCR_1 are B'100, TCNT_1 counts compare-match A for channel 0. Channels 0 and 1 are controlled independently. Conditions such as setting of the CMF flag, generation of interrupts, output from the TMO pin, and counter clearing are in accordance with the settings for each channel.

11.7 Interrupt Sources

11.7.1 Interrupt Sources and DTC Activation

The 8-bit timer can generate three types of interrupt: CMIA, CMIB, and OVI. Table 11.2 shows the interrupt sources and priority. Each interrupt source can be enabled or disabled independently by interrupt enable bits in TCR. Independent signals are sent to the interrupt controller for each interrupt. In the H8S/2268 Series, it is also possible to activate the DTC by means of CMIA and CMIB interrupts.

Table 11.2 8-Bit Timer Interrupt Sources

Interrupt source Description		Flag	DTC Activation*	Interrupt Priority
CMIA0	TCORA_0 compare-match	CMFA	Possible	High
CMIB0	TCORB_0 compare-match	CMFB	Possible	↑
OVI0	TCNT_0 overflow	OVF	Not possible	Low
CMIA1	TCORA_1 compare-match	CMFA	Possible	High
CMIB1	TCORB_1 compare-match	CMFB	Possible	↑
OVI1	TCNT_1 overflow	OVF	Not possible	Low
CMIA2*	TCORA_2 compare-match	CMFA	Possible	High
CMIB2*	TCORB_2 compare-match	CMFB	Possible	↑
OVI2*	TCNT_2 overflow	OVF	Not possible	Low
CMIA3*	TCORA_3 compare-match	CMFA	Possible	High
CMIB3*	TCORB_3 compare-match	CMFB	Possible	↑
OVI3*	TCNT_3 overflow	OVF	Not possible	Low

Note: * Supported only by the H8S/2268 Series.

11.7.2 A/D Converter Activation

The A/D converter can be activated only by channel 0 compare match A.

If the ADTE bit in TCSR0 is set to 1 when the CMFA flag is set to 1 by the occurrence of channel 0 compare match A, a request to start A/D conversion is sent to the A/D converter. If the 8-bit timer conversion start trigger has been selected on the A/D converter side at this time, A/D conversion is started.

11.8 Usage Notes

11.8.1 Contention between TCNT Write and Clear

If a timer counter clock pulse is generated during the T2 state of a TCNT write cycle, the clear takes priority, so that the counter is cleared and the write is not performed. Figure 11.10 shows this operation.

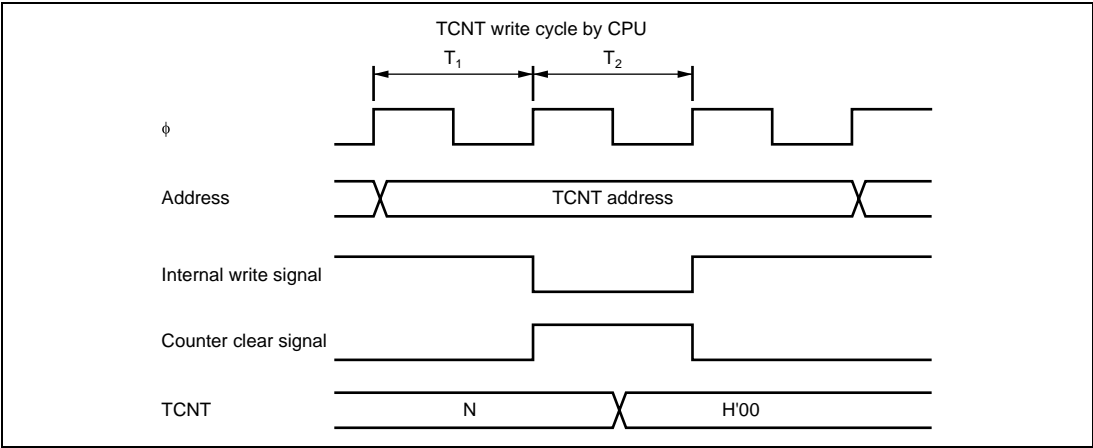


Figure 11.10 Contention between TCNT Write and Clear

11.8.2 Contention between TCNT Write and Increment

If a timer counter clock pulse is generated during the T2 state of a TCNT write cycle, the write takes priority and the counter is not incremented. Figure 11.11 shows this operation.

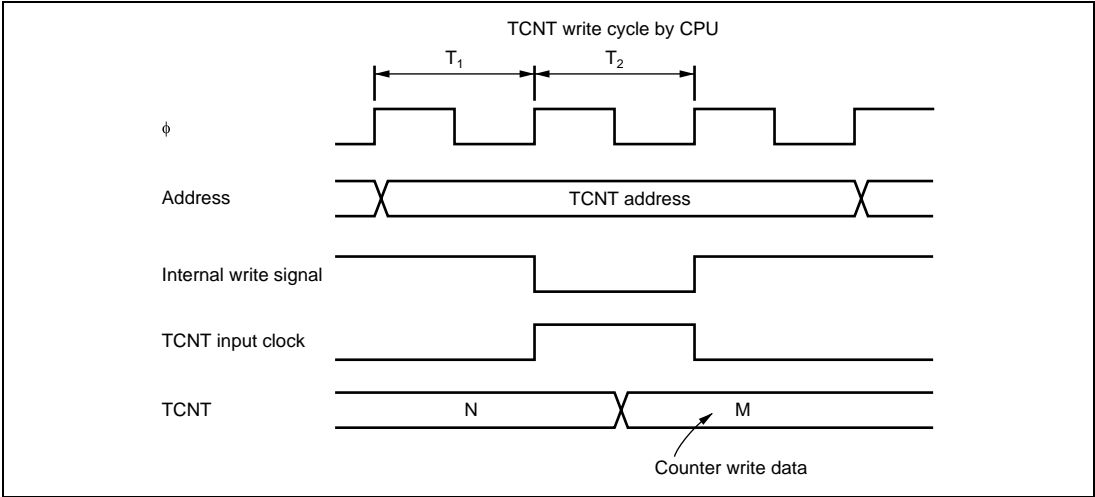


Figure 11.11 Contention between TCNT Write and Increment

11.8.3 Contention between TCOR Write and Compare-Match

During the T2 state of a TCOR write cycle, the TCOR write has priority even if a compare-match occurs and the compare-match signal is disabled. Figure 11.12 shows this operation.

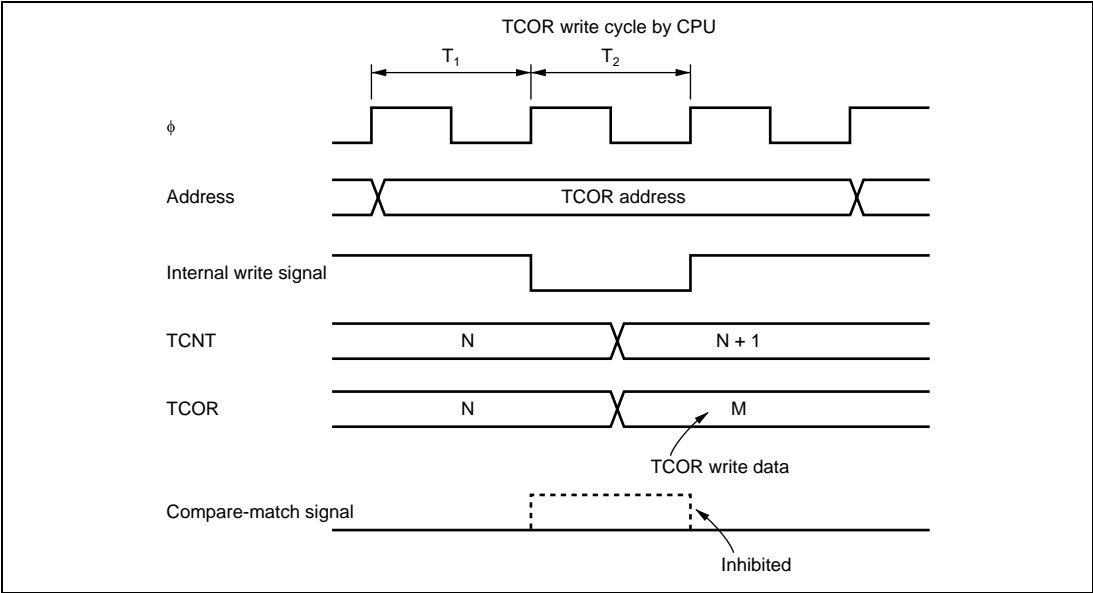


Figure 11.12 Contention between TCOR Write and Compare-Match

11.8.4 Contention between Compare-Matches A and B

If compare-matches A and B occur at the same time, the 8-bit timer operates in accordance with the priorities for the output states set for compare-match A and compare-match B, as shown in table 11.3.

Table 11.3 Timer Output Priorities

Output Setting	Priority
Toggle output	High
1 output	<div>↑</div>
0 output	
No change	
	Low

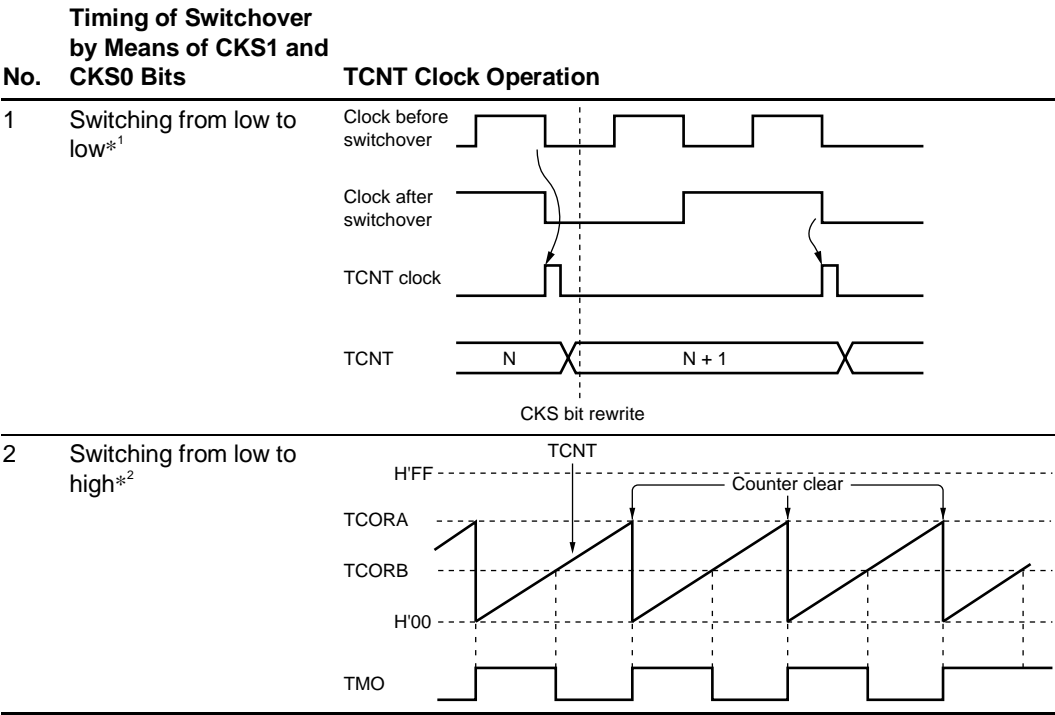
11.8.5 Switching of Internal Clocks and TCNT Operation

TCNT may increment erroneously when the internal clock is switched over. Table 11.4 shows the relationship between the timing at which the internal clock is switched (by writing to the CKS1 and CKS0 bits) and the TCNT operation

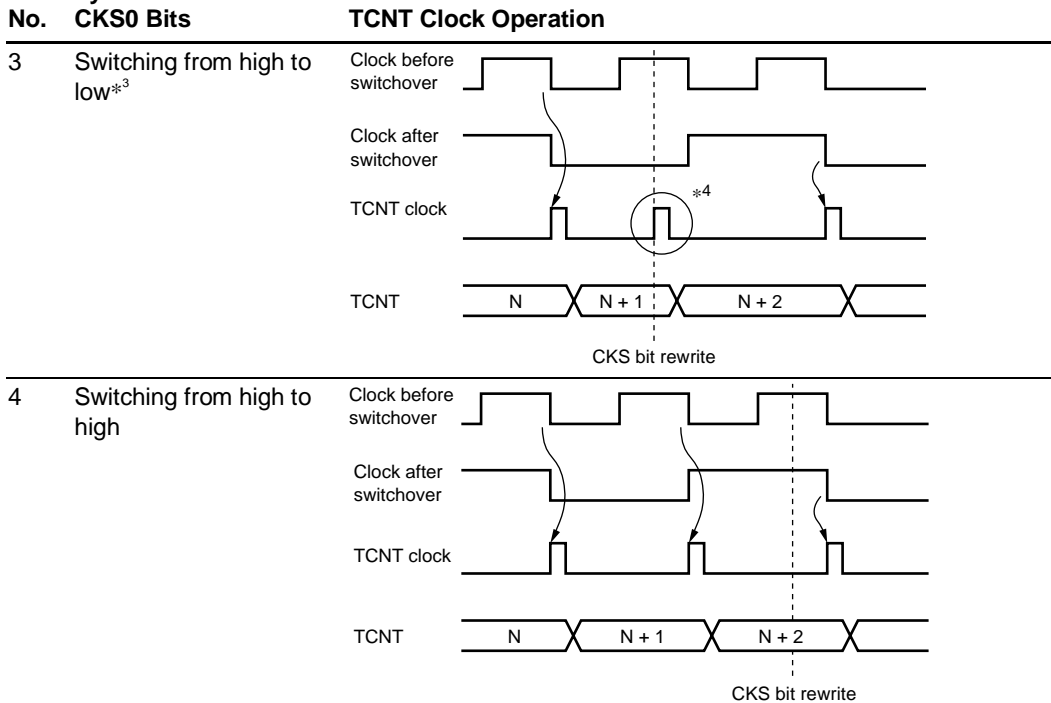
When the TCNT clock is generated from an internal clock, the falling edge of the internal clock pulse is detected. If clock switching causes a change from high to low level, as shown in no. 3 in table 11.4, a TCNT clock pulse is generated on the assumption that the switchover is a falling edge. This increments TCNT.

Erroneous incrementation can also happen when switching between internal and external clocks.

Table 11.4 Switching of Internal Clock and TCNT Operation



Timing of Switchover by Means of CKS1 and CKS0 Bits



- Notes:
1. Includes switching from low to stop, and from stop to low.
 2. Includes switching from stop to high.
 3. Includes switching from high to stop.
 4. Generated on the assumption that the switchover is a falling edge; TCNT is incremented.

11.8.6 Contention between Interrupts and Module Stop Mode

If module stop mode is entered when an interrupt has been requested, it will not be possible to clear the CPU interrupt source or the DTC activation source. Interrupts should therefore be disabled before entering module stop mode.

11.9 8-Bit Reload Timer (TMR_4) (H8S/2268 Series Only)

The 8-bit reload timer comprises an 8-bit up-counter with four channels, and has two functions, the interval function and automatic reload function.

11.9.1 Features

- Selection of clock sources
 - Selected from 14 internal clocks ($\phi/32768$, $\phi/8192$, $\phi/2048$, $\phi/512$, $\phi/128$, $\phi/32$, $\phi/8$, $\phi/2$, $\phi_{\text{SUB}}/256$, $\phi_{\text{SUB}}/128$, $\phi_{\text{SUB}}/64$, $\phi_{\text{SUB}}/32$, $\phi_{\text{SUB}}/8$ and $\phi_{\text{SUB}}/2$) and an external clock.
- Interrupts requested by counter overflow
- Operation with cascaded connection (the lower the channel number, the higher the bit in the connected timer)
 - Connecting two timers (channels 4 and 5, channels 5 and 6, or channels 6 and 7): The module operates as a 16-bit timer
 - Connecting three timers (channels 4 to 6 or channels 5 to 7): The module operates as a 24-bit timer
 - Connecting four timers (channels 4 to 7): The module operates as a 32-bit timer
- Module stop mode can be set
 - At initialization, the 8-bit reload timer is halted. Register access is enabled by canceling the module stop mode.

Figure 11.13 shows a block diagram of the 8-bit reload timer.

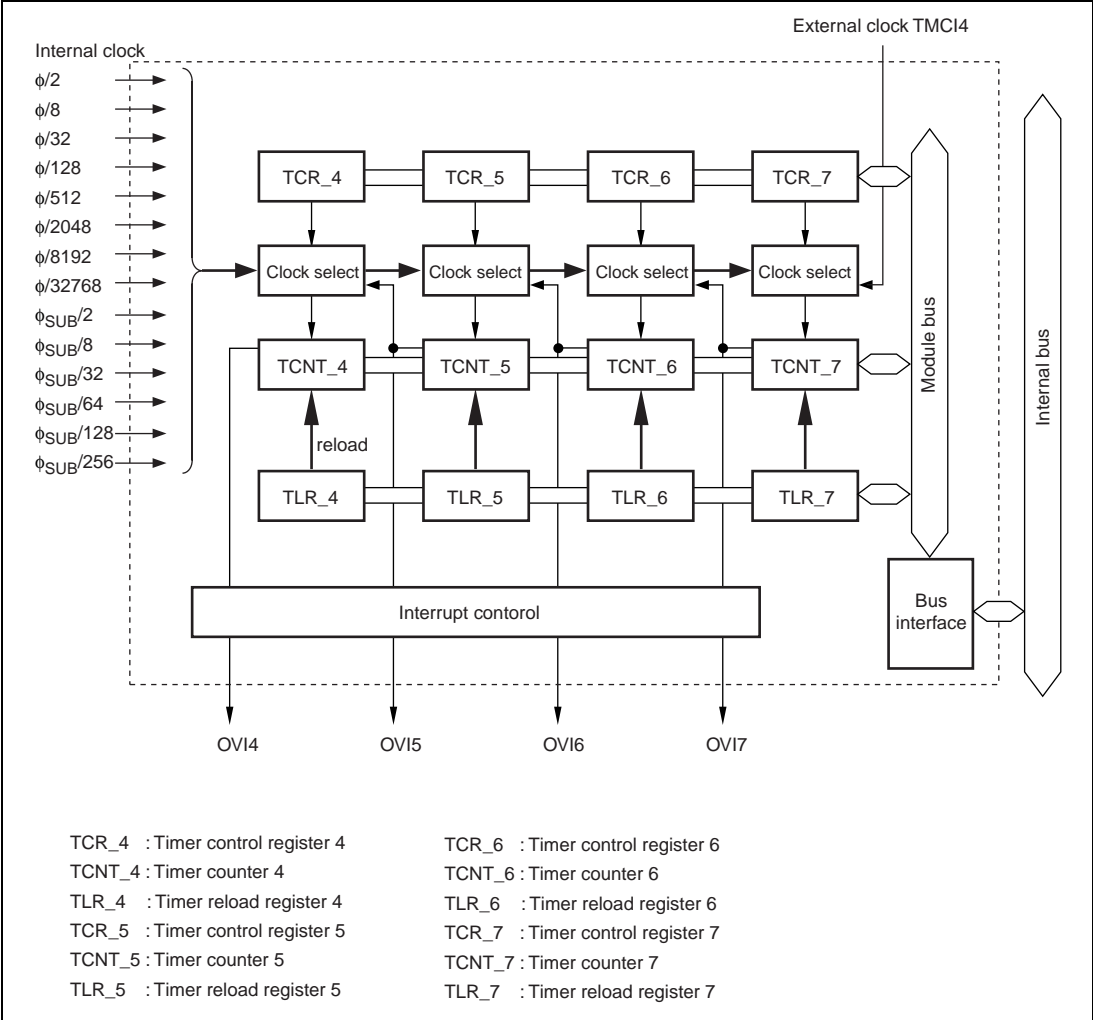


Figure 11.13 Block Diagram of 8-Bit Reload Timer

11.9.2 Input/Output Pins

The following table shows the pin configuration for the 8-bit timer module.

Name	Symbol	I/O	Function
Timer clock input pin	TMC14	Input	External clock input for the counter

Note: Voltage applied to the TMC14 input pin should be within the range, $AV_{ss} \leq TMC14 \leq AV_{cc}$.

11.10 Register Descriptions

The 8-bit reload timer has the following registers. For details on the module stop control register, refer to section 22.1.2, Module Stop Control Registers A to D (MSTPCRA to MSTPCRD).

- Timer control register (TCR)
- Timer Counter (TCNT)
- Timer reload register (TLR)

TCNT or TLR can operate as a 16-bit timer using TCNT_4 or TLR_4 (TCNT_6 or TLR_6) as the upper half and TCNT_5 or TLR_5 (TCNT_7 or TLR_7) as the lower half.

11.10.1 Timer Control Registers 4 to 7 (TCR_4 to TCR_7)

TCR selects the automatic reload function and TCNT clock source, and controls interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	ARSL	0	R/W	Automatic Reload Function Select Selects the automatic reload function 0: The interval function is selected 1: The automatic reload function is selected
6	OVF	0	R/(W)*	Timer Overflow Flag Indicates that TCNT overflows from H'FF to H'00. 0: [Clearing condition] Read OVF when OVF = 1, then write 0 in OVF 1: [Setting condition] When TCNT overflows from H'FF to H'00
5	OVIE	0	R/W	Timer Overflow Interrupt Enable Selects whether the OVF interrupt request (OVI) is enabled or disabled when the OVF flag in TCSR is set to 1. 0: OVF interrupt request (OVI) is disabled 1: OVF interrupt request (OVI) is enabled
4, 3	—	All 1	—	Reserved These bits are always read as 1 and cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
2 to 0	CKS2	0	R/W	Clock Select 2 to 0
	CKS1	0	R/W	The input clock can be selected from internal clocks and an external clock, which are divided from the system clock (ϕ) or subclock (ϕ_{SUB}).
	CKS0	0	R/W	
				Channel4 Channel5 Channel6 Channel7
	000:	$\phi/32768$	$\phi/8192$	$\phi/32768$ $\phi/8192$
	001:	$\phi/2048$	$\phi/512$	$\phi/2048$ $\phi/512$
	010:	$\phi/128$	$\phi/32$	$\phi/128$ $\phi/32$
	011:	$\phi/8$	$\phi/2$	$\phi/8$ $\phi/2$
	100:	$\phi_{SUB}/256$	$\phi_{SUB}/128$	$\phi_{SUB}/256$ $\phi_{SUB}/128$
	101:	$\phi_{SUB}/64$	$\phi_{SUB}/32$	$\phi_{SUB}/64$ $\phi_{SUB}/32$
	110:	$\phi_{SUB}/8$	$\phi_{SUB}/2$	$\phi_{SUB}/8$ $\phi_{SUB}/2$
	111:	TCNT_5 overflow	TCNT_6 overflow	TCNT_7 overflow Count of the rising clock of the external clock.

Note: * Only a 0 can be written to this bit, to clear the flag.

11.10.2 Timer Counters 4 to 7 (TCNT4 to TCNT7)

Each TCNT is an 8-bit readable up-counter and increments on clock pulses generated from an internal or external clock source. This clock source is selected by clock select bits CKS2 to CKS0 in TCR.

TCNT_4 and TCNT_5, or TCNT_6 and TCNT_7 comprise a single 16-bit register, and can be accessed simultaneously by word access.

When TCNT overflows from H'FF to H'00, the overflow flag (OVF) in TCR is set to 1.

TCNT is initialized to H'00 by a reset or in hardware standby mode.

11.10.3 Time Reload Registers 4 to 7 (TLR_4 to TLR_7)

Each TLR is an 8-bit writable register and sets a reload value for TCNT. When a reload value is set to TLR, the value is simultaneously load to TCNT and incrementation starts from the value. When TCNT overflows during automatic reload operation, the TLR value is written to TCNT. Therefore, the overflow cycle can be set within the range from 1 to 256 input clock cycles.

TLR_4 and TLR_5, or TLR_6 and TLR_7 comprise a single 16-bit register, and can be accessed simultaneously by word access.

TLR is initialized to H'00 by a reset or in hardware standby mode.

11.11 Operation

11.11.1 Interval Timer Operation

When the ARSL bit in TCR is set to 0, the timer operates as an interval timer.

After a module stop mode is canceled, the timer continues incrementation as an interval timer without stopping because TCNT is initialized to H'00 and TLR is cleared to 0 by a reset. The input clock source can be selected from 14 internal clocks output from the prescaler unit and an external clock from the TMC14 input pin, using the CKS2 to CKS0 bits in TCR.

When a clock is input after the TCNT value has been H'FF, the timer overflows and OVF in TCR is set to 1. At this time, if OVIE in TCR is 1, an interrupt is generated.

When an overflow occurs, the TCNT count value is cleared to H'00 and TCNT restarts incrementation. If a value is set to TLR during interval timer operation, the value is also written to TCNT.

This operation timing is shown in figure 11.14.

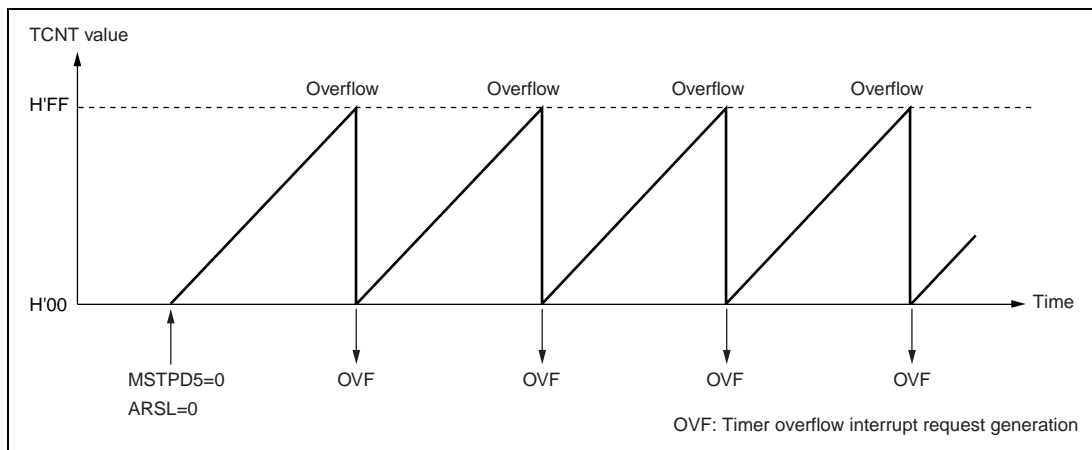


Figure 11.14 Operation in Interval Timer Mode

11.11.2 Automatic Reload Timer Operation

When the ARSL bit in TCR is set to 1, the timer operates as an automatic reload timer.

When a reload value is set to TLR, the value is also loaded to TCNT simultaneously, and TCNT starts incrementation from the value.

If a clock is input after the TCNT count value reaches H'FF, the timer overflows, the TLR value is written to TCNT, and incrementation is continued from the value. Therefore, the overflow cycle can be set within the range from 1 to 256, using a TLR value.

Clock sources and interrupts in automatic reload operation are the same as those in interval operation. If TLR is re-set during automatic reload operation, the value is also set to TCNT.

This operation timing is shown in figure 11.15.

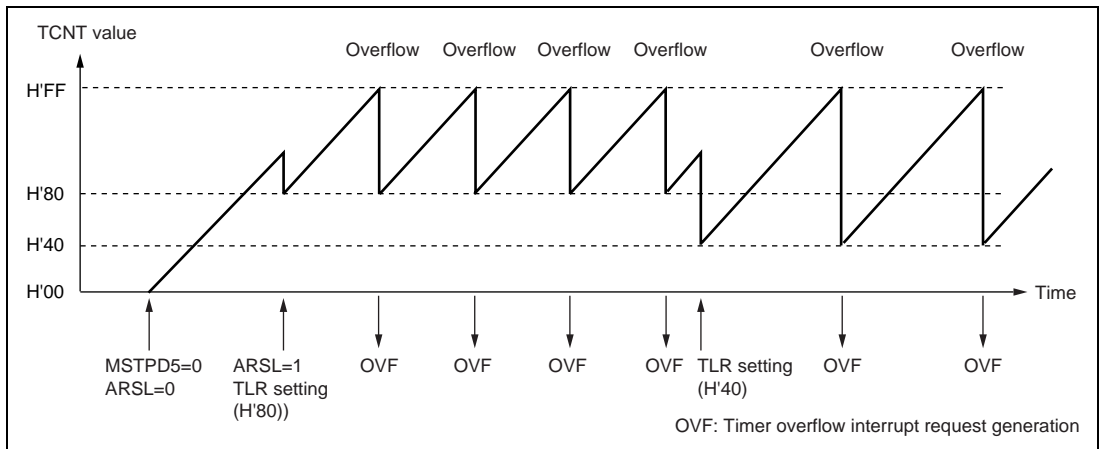


Figure 11.15 Operation in Automatic Reload Timer Mode

11.11.3 Cascaded Connection

- Read of TCNT

The channel relationship for cascaded connection is shown in figure 11.16.

When accessing beyond the word area, for example, when a cascaded connection including channels 5 and 6 is created as shown in (3), and (6) to (8) in the figure, the counter value of the lower channel is read when TCNT5 is read, and the data is stored in the TCNT register.

For case (7) where channels 5 to 7 are cascaded, the counter values of channels 6 and 7 are read when TCNT5 is read, and the data is stored in TCNT6/7 registers. Accordingly, when reading cascaded TCNT, read from the upper channel.

For a word connection, access in word units.

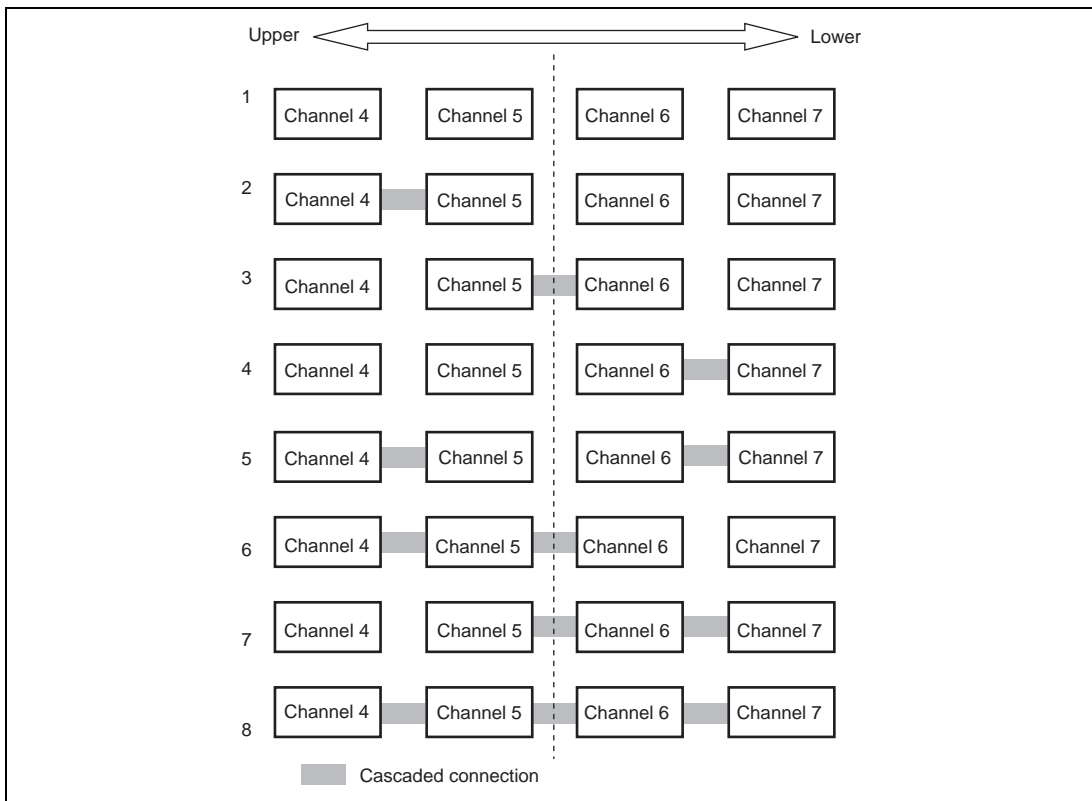


Figure 11.16 Channel Relationship of Cascaded Connection

- **Write to TLR**

When writing to the cascaded TLR, even if a single channel of TLR is written, the system regards that the entire channels of the cascaded TLR are rewritten. At this point in time, the value in the entire cascaded TLR is loaded into the corresponding TCNT. The timer operation starts at the TLR value that is most-recently written in TLR access cycles.

- **Operation Clock**

Although each channel usually operates on an individual clock, a cascaded channel operates on the same clock. The operation clock for the lowest cascaded channel is used as a common clock of each channel.

In this case, the setting for the clocks of the channels other than the lowest channel is disabled.

- **Automatic Reload Function Select and Operation Timing**

Although the automatic reload function is usually set and implemented in individual channel, a cascaded channel operates according to the setting for the automatic reload function of the highest channel.

In this case, the automatic reload function settings for the channels other than the highest channel are disabled. When the automatic reload function is enabled for cascaded channel, the TLR setting value of each channel is automatically reloaded simultaneously in the reload timing of the highest channel.

- **Timer Overflow Flag (OVF)**

Although an OVF is usually set to an individual channel independently, an OVF is set to the highest channel of a cascaded channel. In this case, OVFs of the channels other than that of the highest channel is disabled.

11.12 Usage Notes

11.12.1 Conflict between Write to TLR and Count up/Automatic Reload

Even if a count up occurs in the T2 state during TLR write cycles, the counter is not incremented and TLR write (load to TCNT) is carried out instead (as in Figure 11.11).

Likewise, if an automatic reload occurs during write cycles, TLR write (load to TCNT) is carried out instead.

11.12.2 Switchover of the Internal Clock and TCNT Operation

Depending on the timing which the internal clock is switched, TCNT may be incremented (see table 11.4). Likewise, when the clock pulse is changed (ϕ and ϕ_{SUB}), TCNT may be incremented, and may not in some cases. Therefore, when the internal clock is changed, resume timer operation by resetting TLR (Write H'00 to TLR when the interval timer is in operation).

11.12.3 Interrupt during Module Stop

When module stop mode is entered with an interrupt being requested, the cause of an interrupt to the CPU cannot be cleared. Enter module stop mode after, for example, disabling an interrupt request.

Section 12 Watchdog Timer

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.

When this watchdog function is not needed, the WDT can be used as an interval timer. In interval timer operation, an interval timer interrupt is generated each time the counter overflows.

The block diagram of the WDT is shown in figures 12.1 to 12.3.

12.1 Features

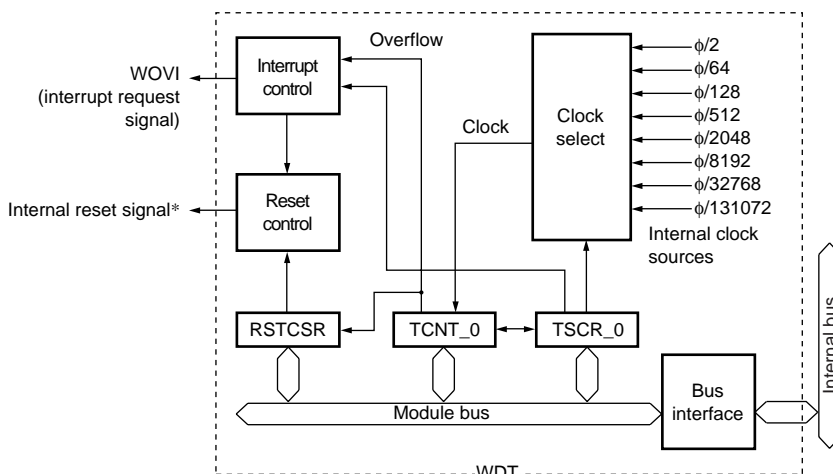
- Selectable from eight counter input clocks for WDT_0
Selectable from 16 counter input clocks for WDT_1 in the H8S/2268 Series
Selectable from 26 counter input clocks for WDT_1 in the H8S/2264 Series
- Switchable between watchdog timer mode and interval timer mode

In watchdog timer mode

- If the counter in WDT_0 overflows, it is possible to select whether this LSI is internally reset or not.
- If the counter in WDT_1 overflows, it is possible to select whether this LSI is internally reset or the internal NMI interrupt is generated.

In interval timer mode

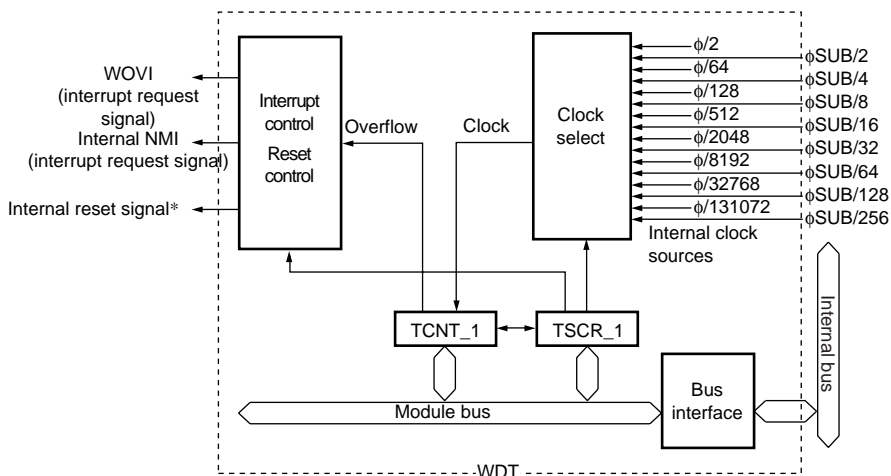
- If the counter overflows, the WDT generates an interval timer interrupt (WOVI).



Legend
TCSR_0 : Timer control/status register0
TCNT_0 : Timer counter0
RSTCSR : Reset control/status register

Note: * The type of internal reset signal depends on a register setting.

Figure 12.1 Block Diagram of WDT_0



Legend
TCSR_1 : Timer control/status register1
TCNT_1 : Timer counter1

Note: * The type of internal reset signal depends on a register setting.

Figure 12.2 Block Diagram of WDT_1 for H8S/2268 Series

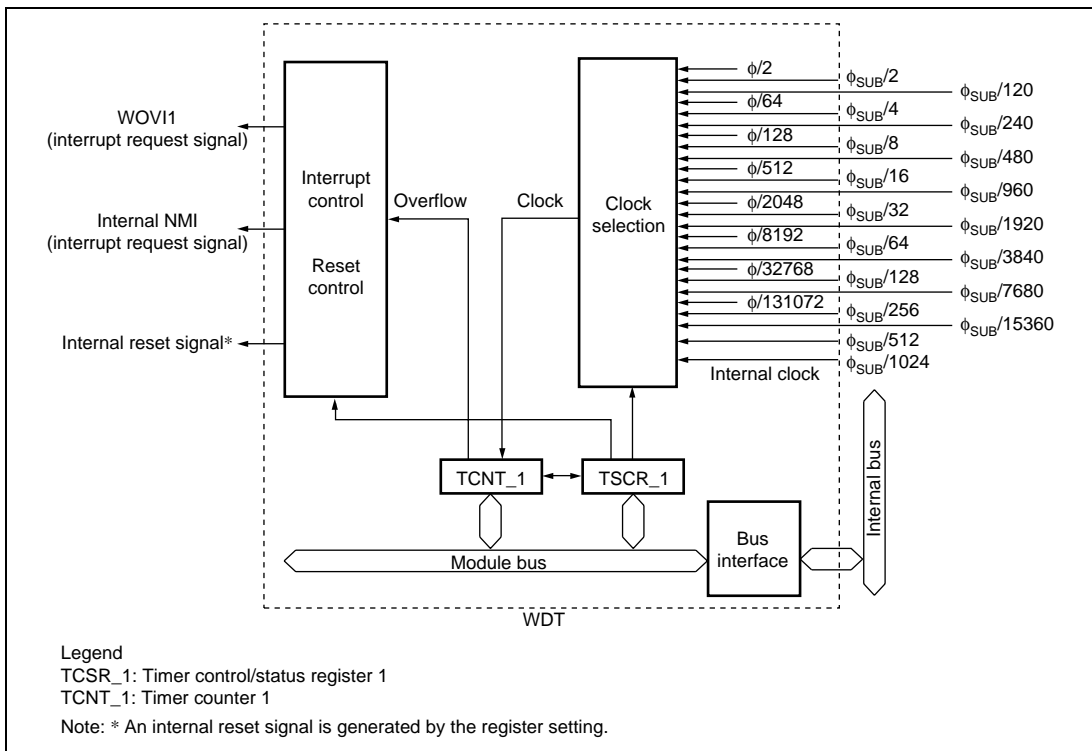


Figure 12.3 Block Diagram of WDT_1 for H8S/2264 Series

12.2 Register Descriptions

The WDT has the following three registers. To prevent accidental overwriting, TCSR, TCNT, and RSTCSR have to be written to by a different method to normal registers. For details, refer to section 12.5.1, Notes on Register Access. For detained description on the system control register, refer to section 5.3.1, System Control Register (SYSCR).

- Timer counter (TCNT)
- Timer control/status register (TCSR)
- Reset control/status register (RSTCSR)

12.2.1 Timer Counter (TCNT)

TCNT is an 8-bit readable/writable up-counter. TCNT is initialized to H'00 when the TME bit in TCSR is cleared to 0.

12.2.2 Timer Control/Status Register (TCSR)

TCSR functions include selecting the clock source to be input to TCNT and the timer mode.

- TCSR_0

Bit	Bit Name	Initial Value	R/W	Description
7	OVF	0	R/(W)* ¹	<p>Overflow Flag</p> <p>Indicates that TCNT has overflowed. Only a 0 can be written to this bit, to clear the flag.</p> <p>[Setting condition]</p> <p>When TCNT overflows (changes from H'FF to H'00)</p> <p>When internal reset request generation is selected in watchdog timer mode, OVF is cleared automatically by the internal reset.</p> <p>[Clearing conditions]</p> <p>Cleared by reading TCSR*² when OVF = 1, then writing 0 to OVF</p>
6	WT/ $\overline{\text{IT}}$	0	R/W	<p>Timer Mode Select</p> <p>Selects whether the WDT is used as a watchdog timer or interval timer.</p> <p>0: Interval timer mode</p> <p>1: Watchdog timer mode</p>
5	TME	0	R/W	<p>Timer Enable</p> <p>When this bit is set to 1, TCNT starts counting. When this bit is cleared, TCNT stops counting and is initialized to H'00.</p>
4, 3	—	All 1	—	<p>Reserved</p> <p>These bits are always read as 1 and cannot be modified.</p>

Bit	Bit Name	Initial Value	R/W	Description
2	CKS2	0	R/W	Clock Select 0 to 2
1	CKS1	0	R/W	Selects the clock source to be input to TCNT. The overflow frequency* ³ for ϕ = 20 MHz is enclosed in parentheses. 000: Clock $\phi/2$ (frequency: 25.6 μ s) 001: Clock $\phi/64$ (frequency: 819.2 μ s) 010: Clock $\phi/128$ (frequency: 1.6 ms) 011: Clock $\phi/512$ (frequency: 6.6 ms) 100: Clock $\phi/2048$ (frequency: 26.2 ms) 101: Clock $\phi/8192$ (frequency: 104.9 ms) 110: Clock $\phi/32768$ (frequency: 419.4 ms) 111: Clock $\phi/131072$ (frequency: 1.68 s)
0	CKS0	0	R/W	

- Notes:
1. Only 0 can be written, for flag clearing.
 2. When the OVF flag is polled with the interval timer interrupt disabled, read the OVF bit while it is 1 at least twice.
 3. The overflow period is the time from when TCNT starts counting up from H'00 until overflow occurs.

- TCSR_1

Bit	Bit Name	Initial Value	R/W	Description
7	OVF	0	R/(W) * ¹	Overflow Flag Indicates that TCNT has overflowed. Only a 0 can be written to this bit, to clear the flag. [Setting condition] When TCNT overflows (changes from H'FF to H'00) When internal reset request generation is selected in watchdog timer mode, OVF is cleared automatically by the internal reset. [Clearing conditions] Cleared by reading TCSR* ² when OVF = 1, then writing 0 to OVF
6	WT/IT	0	R/W	Timer Mode Select Selects whether the WDT is used as a watchdog timer or interval timer. 0: Interval timer mode 1: Watchdog timer mode

Bit	Bit Name	Initial Value	R/W	Description
5	TME	0	R/W	<p>Timer Enable</p> <p>When this bit is set to 1, TCNT starts counting. When this bit is cleared, TCNT stops counting and is initialized to H'00.</p>
4	PSS	0	R/W	<p>Prescaler Select</p> <p>Selects the clock source input to TCNT of WDT_1</p> <p>0: TCNT counts divided clock of ϕ-base prescaler (PSM).</p> <p>1: TCNT counts divided clock of ϕ_{SUB}-base prescaler (PSS)</p>
3	RST/ $\overline{\text{NMI}}$	0	R/W	<p>Reset or NMI (REST/$\overline{\text{NMI}}$)</p> <p>0: An NMI interrupt is requested.</p> <p>1: reset is requested.</p>
2	CKS2	0	R/W	Clock Select 0 to 2
1	CKS1	0	R/W	<p>Selects the clock source to be input to TCNT. The overflow frequency*³ for $\phi = 20$ MHz is enclosed in parentheses.</p> <p>When PSS = 0:</p> <p>000: Clock $\phi/2$ (frequency: 25.6 μs)</p> <p>001: Clock $\phi/64$ (frequency: 819.2 μs)</p> <p>010: Clock $\phi/128$ (frequency: 1.6 ms)</p> <p>011: Clock $\phi/512$ (frequency: 6.6 ms)</p> <p>100: Clock $\phi/2048$ (frequency: 26.2 ms)</p> <p>101: Clock $\phi/8192$ (frequency: 104.9 ms)</p> <p>110: Clock $\phi/32768$ (frequency: 419.4 ms)</p> <p>111: Clock $\phi/131072$ (frequency: 1.68 s)</p> <p>When PSS = 1:</p> <p>See table 12.1, Clock Selection When PSS = 1.</p>
0	CKS0	0	R/W	

- Notes:
1. Only 0 can be written, for flag clearing.
 2. When the OVF flag is polled with the interval timer interrupt disabled, read the OVF bit while it is 1 at least twice
 3. The overflow period is the time from when TCNT starts counting up from H'00 until overflow occurs.

Table 12.1 Clock Selection When PSS = 1.

H8S/2268 Series	H8S/2264 Series
When PSS = 1:	Clock selection differs according to the combination of the SUBCKS1 and SUBCKS0 bits in SCKCR2 and the PSS bit.
000: Clock $\phi_{SUB}/2$ (frequency: 15.6 ms)	When PSS = 1, SUBCKS1=0, SUBCKS0=0,
001: Clock $\phi_{SUB}/4$ (frequency: 31.3 ms)	000: Clock $\phi_{SUB}/2$ (frequency: 15.6 ms)
010: Clock $\phi_{SUB}/8$ (frequency: 62.5 ms)	001: Clock $\phi_{SUB}/4$ (frequency: 31.3 ms)
011: Clock $\phi_{SUB}/16$ (frequency: 125 ms)	010: Clock $\phi_{SUB}/8$ (frequency: 62.5 ms)
100: Clock $\phi_{SUB}/32$ (frequency: 250 ms)	011: Clock $\phi_{SUB}/16$ (frequency: 125 ms)
101: Clock $\phi_{SUB}/64$ (frequency: 500 ms)	100: Clock $\phi_{SUB}/32$ (frequency: 250 ms)
110: Clock $\phi_{SUB}/128$ (frequency: 1 s)	101: Clock $\phi_{SUB}/64$ (frequency: 500 ms)
111: Clock $\phi_{SUB}/256$ (frequency: 2 s)	110: Clock $\phi_{SUB}/128$ (frequency: 1 s)
	111: Clock $\phi_{SUB}/256$ (frequency: 2 s)
	When PSS = 1, SUBCKS1=0, SUBCKS0=1,
	000: Clock $\phi_{SUB}/8$ (frequency: 62.5 ms)
	001: Clock $\phi_{SUB}/16$ (frequency: 125 ms)
	010: Clock $\phi_{SUB}/32$ (frequency: 250 ms)
	011: Clock $\phi_{SUB}/64$ (frequency: 500 ms)
	100: Clock $\phi_{SUB}/128$ (frequency: 1 s)
	101: Clock $\phi_{SUB}/256$ (frequency: 2 s)
	110: Clock $\phi_{SUB}/512$ (frequency: 4 s)
	111: Clock $\phi_{SUB}/1024$ (frequency: 8 s)
	When PSS = 1, SUBCKS1=1, SUBCKS0=0,
	000: Clock $\phi_{SUB}/120$ (frequency: 938 ms)
	001: Clock $\phi_{SUB}/240$ (frequency: 1.9 s)
	010: Clock $\phi_{SUB}/480$ (frequency: 3.8 s)
	011: Clock $\phi_{SUB}/960$ (frequency: 7.5 s)
	100: Clock $\phi_{SUB}/1920$ (frequency: 15 s)
	101: Clock $\phi_{SUB}/3840$ (frequency: 30 s)
	110: Clock $\phi_{SUB}/7680$ (frequency: 1 min)
	111: Clock $\phi_{SUB}/15360$ (frequency: 2 min)

Note: * A value in parentheses represents an overflow period when $\phi_{SUB} = 32.768$ kHz. The overflow period is the time from when TCNT starts counting up from H'00 until overflow occurs.

12.2.3 Reset Control/Status Register (RSTCSR) (only WDT_0)

RSTCSR controls the generation of the internal reset signal when TCNT overflows, and selects the type of internal reset signal. RSTCSR is initialized to H'1F by a reset signal from the $\overline{\text{RES}}$ pin, and not by the WDT internal reset signal caused by overflows.

Bit	Bit Name	Initial Value	R/W	Description
7	WOVF	0	R/(W)*	<p>Watchdog Overflow Flag</p> <p>This bit is set when TCNT overflows in watchdog timer mode. This bit cannot be set in interval timer mode, and only 0 can be written, to clear the flag.</p> <p>[Setting condition]</p> <p>Set when TCNT overflows (changed from H'FF to H'00) in watchdog timer mode</p> <p>[Clearing condition]</p> <p>Cleared by reading RSTCSR when WOVF = 1, and then writing 0 to WOVF</p>
6	RSTE	0	R/W	<p>Reset Enable</p> <p>Specifies whether or not a reset signal is generated in the chip if TCNT overflows during watchdog timer operation.</p> <p>0: Reset signal is not generated even if TCNT overflows (Though this LSI is not reset, TCNT and TCSR in WDT are reset)</p> <p>1: Reset signal is generated if TCNT overflows</p>
5	—	0	R/W	<p>Reserved</p> <p>This bit can be read from and written to. However, the write value should always be 0.</p>
4 to 0	—	1	—	<p>Reserved</p> <p>These bits are always read as 1 and cannot be modified.</p>

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

12.3 Operation

12.3.1 Watchdog Timer Mode

To use the WDT as a watchdog timer, set the $\overline{WT/IT}$ bit in TCSR and the TME bit to 1.

Software must prevent TCNT overflows by rewriting the TCNT value (normally by writing H'00) before overflows occurs. Thus, TCNT does not overflow while the system is operating normally.

When the WDT is used as a watchdog timer and the RSTE bit in RSTCSR of WDT_0 is set to 1, and if TCNT overflows without being rewritten because of a system malfunction or other error, an internal reset signal for this LSI is output for 518 system clocks.

When the $\overline{RST/NMI}$ bit in TCSR of WDT_1 is set to 1, and if TCNT overflows, the internal reset signal is output for 516 system clock periods. When the $\overline{RST/NMI}$ bit is cleared to 0, an NMI interrupt request is generated (for 515 or 516 system clock periods when the clock source is set to ϕ_{SUB} (PSS = 1)).

An internal reset request from the watchdog timer and a reset input from the \overline{RES} pin are both treated as having the same vector. If a WDT internal reset request and the \overline{RES} pin reset occur at the same time, the \overline{RES} pin reset has priority and the WOVF bit in RSTCSR is cleared to 0.

An NMI request from the watchdog timer and an interrupt request from the NMI pin are both treated as having the same vector. So, avoid handling an NMI request from the watchdog timer and an interrupt request from the NMI pin at the same time.

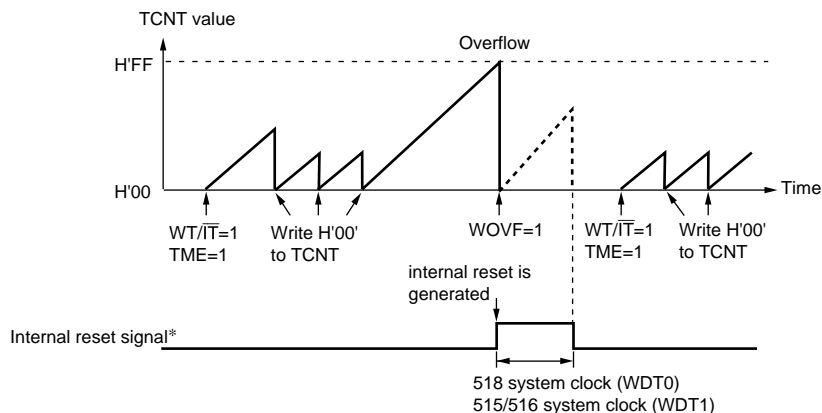


Figure 12.4 Watchdog Timer Mode Operation

12.3.2 Interval Timer Mode

To use the WDT as an interval timer, set the WT/ $\overline{\text{IT}}$ and TME bits in TCSR to 0.

When the WDT is used as an interval timer, an interval timer interrupt (WOVI) is generated each time the TCNT overflows. Therefore, an interrupt can be generated at intervals.

When the TCNT overflows in interval timer mode, an interval timer interrupt (WOVI) is requested at the time the OVF bit of the TCSR is set to 1.

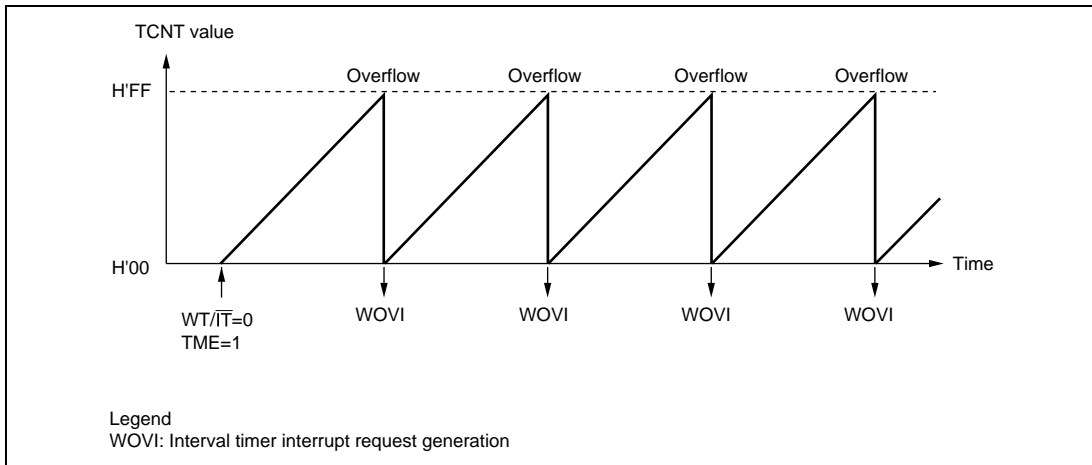


Figure 12.5 Interval Timer Mode Operation

12.3.3 Timing of Setting Overflow Flag (OVF)

The OVF flag is set to 1 if TCNT overflows during interval timer operation. At the same time, an interval timer interrupt (WOVI) is requested. This timing is shown in figure 12.6.

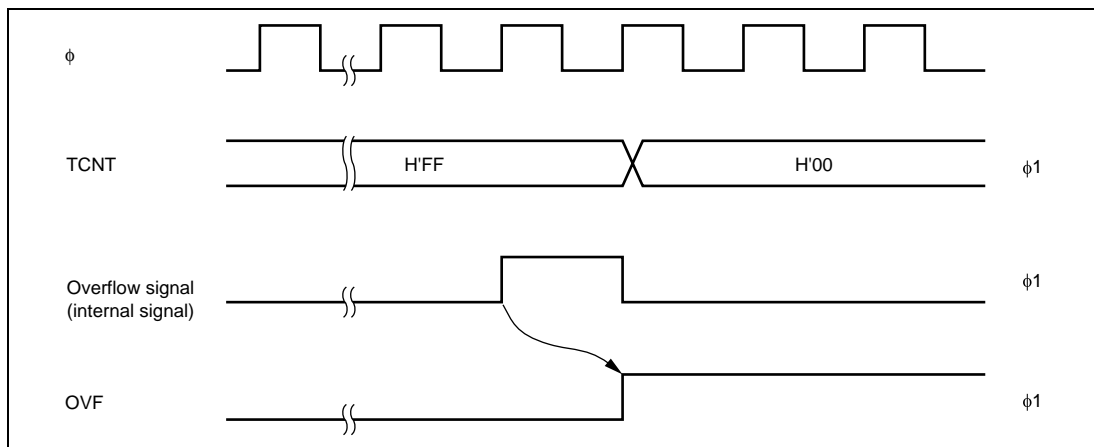


Figure 12.6 Timing of OVF Setting

12.3.4 Timing of Setting Watchdog Timer Overflow Flag (WOVF)

With WDT_0 the WOVF bit in RSTCSR is set to 1 if TCNT overflows in watchdog timer mode. If TCNT overflows while the RSTE bit in RSTCSR is set to 1, an internal is generated for the entire chip. this timing is illustrated in figure 12.7.

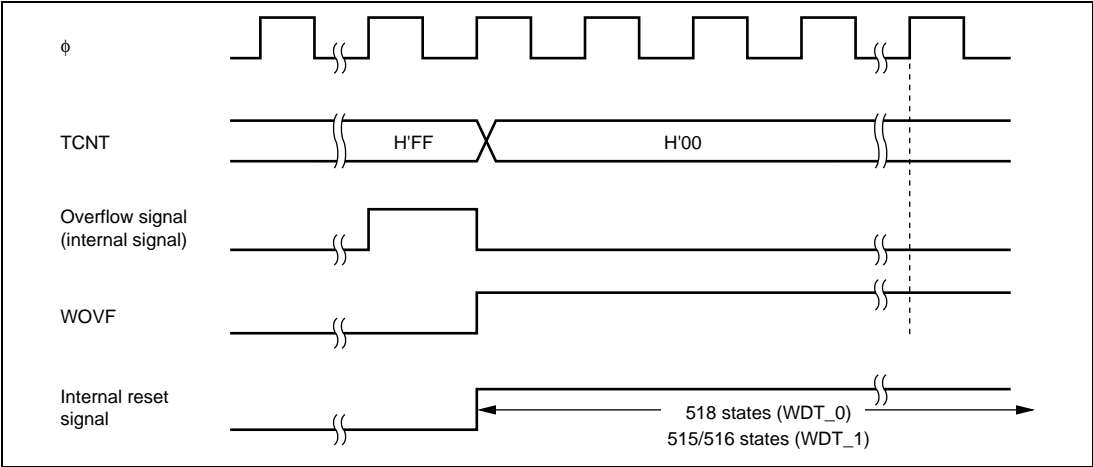


Figure 12.7 Timing of WOVF Setting

12.4 Interrupt Sources

During interval timer mode operation, an overflow generates an interval timer interrupt (WOVI). The interval timer interrupt is requested whenever the OVF flag is set to 1 in TCSR. OVF must be cleared to 0 in the interrupt handling routine.

If an NMI request has been chosen in the watchdog timer mode, an NMI request is generated when a TCNT overflow occurs.

Table 12.2 WDT Interrupt Source

Name	Interrupt Source	Interrupt Flag
WOVI	TCNT overflow (interval timer mode)	OVF
NMI	TCNT overflow (watchdog timer mode)	OVF

12.5 Usage Notes

12.5.1 Notes on Register Access

The watchdog timer’s TCNT and TCSR registers differ from other registers in being more difficult to write to. The procedures for writing to and reading these registers are given below.

Writing to TCNT, TCSR, and RSTCSR

These registers must be written to by a word transfer instruction. They cannot be written to by a byte transfer instruction.

TCNT and TCSR both have the same write address. Therefore, the relative condition shown in figure 12.8 needs to be satisfied in order to write to TCNT or TCSR. The transfer instruction writes the lower byte data to TCNT or TCSR. The upper byte must be H’5A for writing to TCNT, and H’A5 for writing to TCSR.

To write to RSTCSR, execute a word transfer instruction for address H’FF76. A byte transfer instruction cannot write to RSTCSR.

The method of writing 0 to the OVF bit differs from that of writing to the RSTE bit. To write 0 to the WOVF bit, satisfy the condition shown in figure 12.8. If satisfied, the transfer instruction clears the WOVF bit to 0, but has no effect on the RSTE bit. To write to the RSTE and RSTS bits, satisfy the condition shown in figure 12.8. If satisfied, the transfer instruction writes the values in bit 6 of the lower byte into the RSTE bit, but has no effect on the WOVF bit.

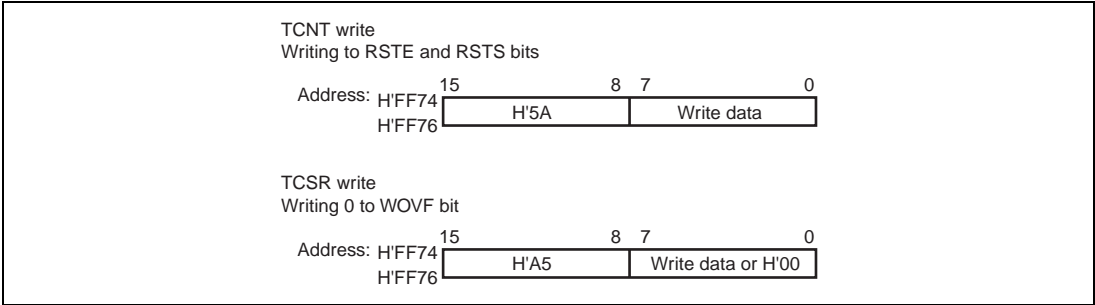


Figure 12.8 Writing to TCNT and TCSR (example for WDT_0)

Reading TCNT, TCSR and RSTCSR (WDT_0)

These registers are read in the same way as other registers. The read addresses are H'FF74 for TCSR and H'FF77 for RSTCSR.

12.5.2 Contention between Timer Counter (TCNT) Write and Increment

If a timer counter clock pulse is generated during the T2 state of a TCNT write cycle, the write takes priority and the timer counter is not incremented. Figure 12.9 shows this operation.

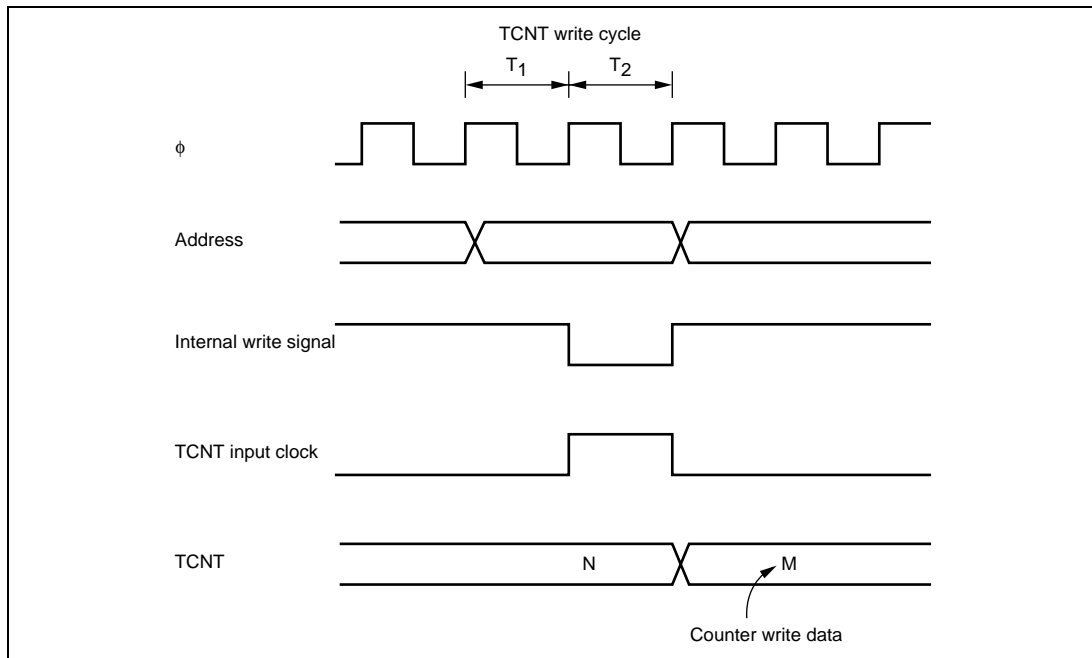


Figure 12.9 Contention between TCNT Write and Increment

12.5.3 Changing Value of CKS2 to CKS0

If bits CKS0 to CKS2 in TCSR are written to while the WDT is operating, errors could occur in the incrementation. Software must be used to stop the watchdog timer (by clearing the TME bit to 0) before changing the value of bits CKS0 to CKS2.

12.5.4 Switching between Watchdog Timer Mode and Interval Timer Mode

If the mode is switched from watchdog timer to interval timer while the WDT is operating, errors could occur in the incrementation. Software must be used to stop the watchdog timer (by clearing the TME bit to 0) before switching the mode.

12.5.5 Internal Reset in Watchdog Timer Mode

This LSI is not reset internally if TCNT overflows while the RSTE bit is cleared to 0 during watchdog timer operation, however TCNT_0 and TCSR_0 of the WDT_0 are reset.

TCNT, TCSR, or RSTCR cannot be written to for 132 states following an overflow. During this period, any attempt to read the WOVF flag is not acknowledged. Accordingly, wait 132 states after overflow to write 0 to the WOVF flag for clearing.

12.5.6 OVF Flag Clearing in Interval Timer Mode

When the OVF flag setting conflicts with the OVF flag reading in interval timer mode, writing 0 to the OVF bit may not clear the flag even though the OVF bit has been read while it is 1. If there is a possibility that the OVF flag setting and reading will conflict, such as when the OVF flag is polled with the interval timer interrupt disabled, read the OVF bit while it is 1 at least twice before writing 0 to the OVF bit to clear the flag.

Section 13 Serial Communication Interface (SCI)

This LSI has three independent serial communication interface (SCI) channels. The SCI can handle both asynchronous and clocked synchronous serial communication. 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). The SCI also supports an IC card (Smart Card) interface conforming to ISO/IEC 7816-3 (Identification Card) as a serial communication interface extension function.

13.1 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 of serial data.

- On-chip baud rate generator allows any bit rate to be selected
External clock can be selected as a transfer clock source (except for in Smart Card interface mode).
- Choice of LSB-first or MSB-first transfer (except in the case of asynchronous mode 7-bit data)
- Four interrupt sources
Transmit-end, transmit-data-empty, receive-data-full, and receive error — that can issue requests.
The transmit-data-empty interrupt and receive data full interrupts can be used to activate the data transfer controller (DTC) (H8S/2268 Series only).
- Module stop mode can be set

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

- Average transfer rate generator (SCI_0): 720 kbps, 460.784 kbps, or 115.196 kbps can be selected at 16 MHz operation.
- Transfer rate clock can be input from the TPU (SCI_0).
- Communications between multi-processors are possible.

Clocked Synchronous mode

- Data length: 8 bits
- Receive error detection: Overrun errors detected

Smart Card Interface

- Automatic transmission of error signal (parity error) in receive mode
- Error signal detection and automatic data retransmission in transmit mode
- Direct convention and inverse convention both supported

Figure 13.1 shows a block diagram of the SCI_0, and figure 13.2 shows that of the SCI1 and SCI_2.

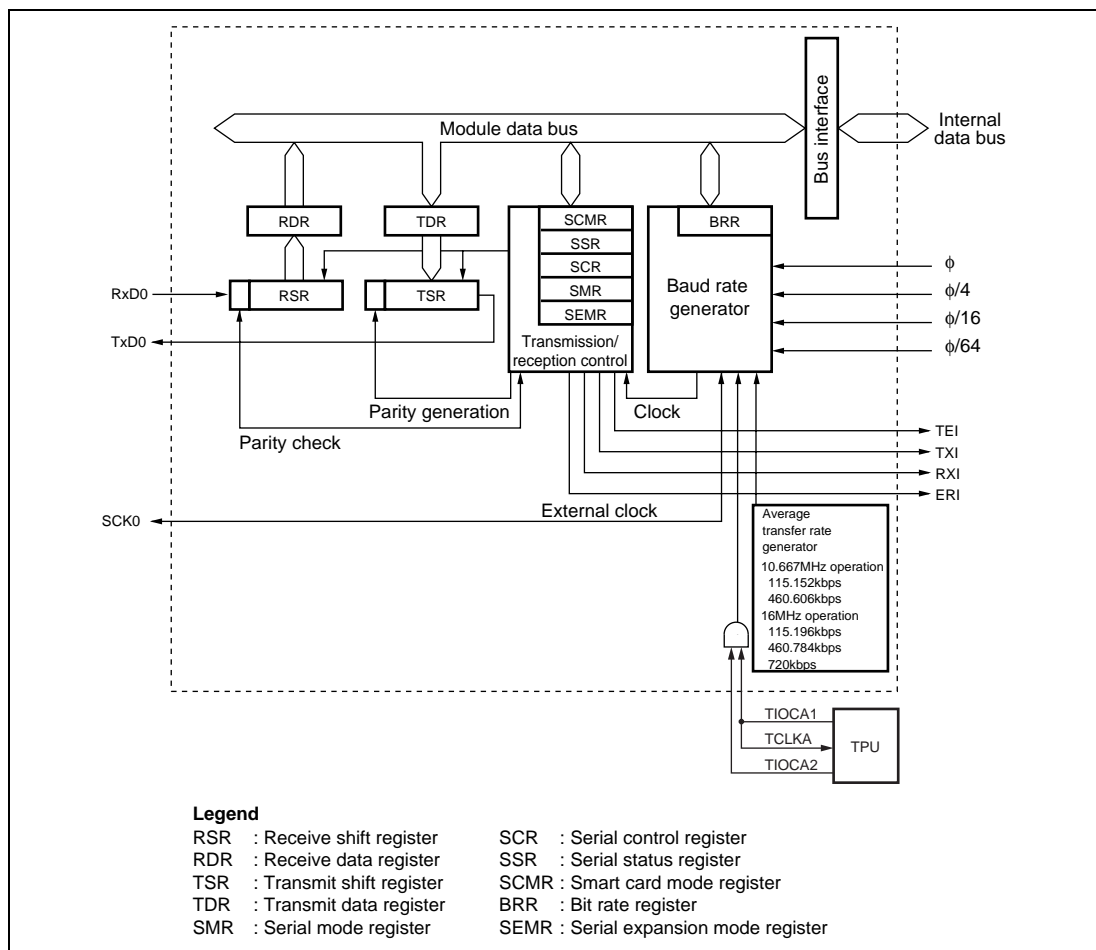


Figure 13.1 Block Diagram of SCI_0

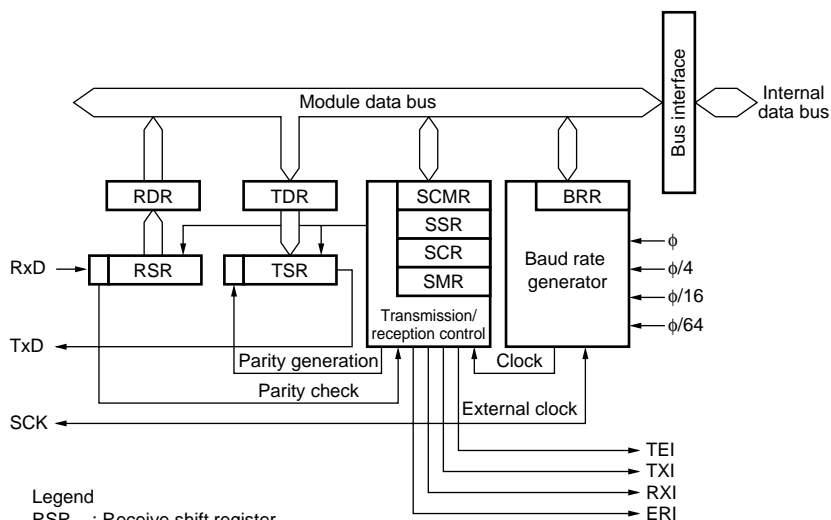


Figure 13.2 Block Diagram of SCI_1 or SCI_2

13.2 Input/Output Pins

Table 13.1 shows the pin configuration for each SCI channel.

Table 13.1 Pin Configuration

Channel	Pin Name*	I/O	Function
0	SCK0	I/O	SCI0 clock input/output
	RxD0	Input	SCI0 receive data input
	TxD0	Output	SCI0 transmit data output
1	SCK1	I/O	SCI1 clock input/output
	RxD1	Input	SCI1 receive data input
	TxD1	Output	SCI1 transmit data output
2	SCK2	I/O	SCI2 clock input/output
	RxD2	Input	SCI2 receive data input
	TxD2	Output	SCI2 transmit data output

Note: * Pin names SCK, RxD, and TxD are used in the text for all channels, omitting the channel designation.

13.3 Register Descriptions

The SCI has the following registers for each channel. For details on register addresses and register states during each process, refer to appendix A, Internal I/O Register. The serial mode register (SMR), serial status register (SSR), and serial control register (SCR) are described separately for normal serial communication interface mode and Smart Card interface mode because their bit functions differ in part.

- Receive Shift Register (RSR)
- Receive Data Register (RDR)
- Transmit Data Register (TDR)
- Transmit Shift Register (TSR)
- Serial Mode Register (SMR)
- Serial Control Register (SCR)
- Serial Status Register (SSR)
- Smart Card Mode Register (SCMR)
- Bit Rate Register (BRR)

Other than the above registers, SCI_0 has the following register.

- Serial Expansion Mode Register (SEMR0)

13.3.1 Receive Shift Register (RSR)

RSR is a shift register that is used to receive serial data input to the RxD pin and convert it into parallel data. When one byte of data has been received, it is transferred to RDR automatically.

RSR cannot be directly accessed by the CPU.

13.3.2 Receive Data Register (RDR)

RDR is an 8-bit register that stores received data. When the SCI has received one byte of serial data, it transfers the received serial 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 by a reset, in standby mode, watch mode, subactive mode, subsleep mode or module stop mode.

13.3.3 Transmit Data Register (TDR)

TDR is an 8-bit register that stores data for transmission. When the SCI 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 serial transmission. If the next transmit data has already been written to TDR during serial transmission, the SCI transfers the written data to TSR to continue transmission. Although TDR can be read or written to by the CPU at all times, 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 by a reset, in standby mode, watch mode, subactive mode, subsleep mode or module stop mode.

13.3.4 Transmit Shift Register (TSR)

TSR is a shift register that transmits serial data. To perform serial data transmission, the SCI first transfers transmit data from TDR to TSR, then sends the data to the TxD pin. TSR cannot be directly accessed by the CPU.

13.3.5 Serial Mode Register (SMR)

SMR is used to set the SCI's serial transfer format and select the baud rate generator clock source.

Some bit functions of SMR differ between normal serial communication interface mode and Smart Card interface mode.

Normal Serial Communication Interface Mode (When SMIF in SCMR is 0)

Bit	Bit Name	Initial Value	R/W	Description
7	C/ \overline{A}	0	R/W	Communication Mode 0: Asynchronous mode 1: Clocked synchronous mode
6	CHR	0	R/W	Character Length (enabled only in asynchronous mode) 0: Selects 8 bits as the data length. 1: Selects 7 bits as the data length. LSB-first is fixed and the MSB (bit 7) of TDR is not transmitted in transmission. In clocked synchronous mode, a fixed data length of 8 bits is used.
5	PE	0	R/W	Parity Enable (enabled only in asynchronous mode) When this bit is set to 1, the parity bit is added to transmit data before transmission, and the parity bit is checked in reception. For a multiprocessor format, parity bit addition and checking are not performed regardless of the PE bit setting.
4	O/ \overline{E}	0	R/W	Parity Mode (enabled only when the PE bit is 1 in asynchronous mode) 0: Selects even parity. When even parity is set, parity bit addition is performed in transmission so that the total number of 1 bits in the transmit character plus the parity bit is even. In reception, a check is performed to see if the total number of 1 bits in the receive character plus parity bit is even. 1: Selects odd parity. When odd parity is set, parity bit addition is performed in transmission so that the total number of 1 bits in the transmit character plus the parity bit is odd. In reception, a check is performed to see if the total number of 1 bits in the receive character plus the parity bit is odd.

Bit	Bit Name	Initial Value	R/W	Description
3	STOP	0	R/W	<p>Stop Bit Length (enabled only in asynchronous mode)</p> <p>Selects the stop bit length in transmission.</p> <p>0: 1 stop bit</p> <p>1: 2 stop bits</p> <p>In reception, only the first stop bit is checked. If the second stop bit is 0, it is treated as the start bit of the next transmit character.</p>
2	MP	0	R/W	<p>Multiprocessor Mode (enabled only in asynchronous mode)</p> <p>When this bit is set to 1, the multiprocessor communication function is enabled. The PE bit and O/\bar{E} bit settings are invalid in multiprocessor mode.</p> <p>For details, see 13.5, Multiprocessor Communication Function.</p>
1	CKS1	0	R/W	Clock Select 0 and 1
0	CKS0	0	R/W	<p>These bits select the clock source for the baud rate generator.</p> <p>00: ϕ clock ($n = 0$)</p> <p>01: $\phi/4$ clock ($n = 1$)</p> <p>10: $\phi/16$ clock ($n = 2$)</p> <p>11: $\phi/64$ clock ($n = 3$)</p> <p>For the relationship between the bit rate register setting and the baud rate, see section 13.3.9, Bit Rate Register (BRR). n is the decimal representation of the value of n in BRR (see section 13.3.9, Bit Rate Register (BRR)).</p>

Bit	Bit Name	Initial Value	R/W	Description
7	GM	0	R/W	<p>GSM Mode</p> <p>When this bit is set to 1, the SCI operates in GSM mode. In GSM mode, the timing of the TEND setting is advanced by 11.0 etu (Elementary Time Unit: the time for transfer of one bit), and clock output control mode addition is performed. For details, refer to section 13.7.8, Clock Output Control.</p>
6	BLK	0	R/W	<p>When this bit is set to 1, the SCI operates in block transfer mode. For details on block transfer mode, refer to section 13.7.3, Block Transfer Mode.</p>
5	PE	0	R/W	<p>Parity Enable (enabled only in asynchronous mode)</p> <p>When this bit is set to 1, the parity bit is added to transmit data in transmission, and the parity bit is checked in reception. In Smart Card interface mode, this bit must be set to 1.</p>
4	O/ \overline{E}	0	R/W	<p>Parity Mode (enabled only when the PE bit is 1 in asynchronous mode)</p> <p>0: Selects even parity. 1: Selects odd parity.</p> <p>For details on setting this bit in Smart Card interface mode, refer to section 13.7.2, Data Format (Except for Block Transfer Mode).</p>
3	BCP1	0	R/W	<p>Basic Clock Pulse 0 and 1</p> <p>These bits specify the number of basic clock periods in a 1-bit transfer interval on the Smart Card interface.</p> <p>00: 32 clock (S = 32) 01: 64 clock (S = 64) 10: 372 clock (S = 372) 11: 256 clock (S = 256)</p> <p>For details, refer to section 13.7.4, Receive Data Sampling Timing and Reception Margin in Smart Card Interface Mode. S stands for the value of S in BRR (see section 13.3.9, Bit Rate Register (BRR)).</p>
2	BCP0	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
1	CKS1	0	R/W	Clock Select 0 and 1
0	CKS0	0	R/W	<p>These bits select the clock source for the baud rate generator.</p> <p>00: ϕ clock ($n = 0$)</p> <p>01: $\phi/4$ clock ($n = 1$)</p> <p>10: $\phi/16$ clock ($n = 2$)</p> <p>11: $\phi/64$ clock ($n = 3$)</p> <p>For the relationship between the bit rate register setting and the baud rate, see section 13.3.9, Bit Rate Register (BRR). n is the decimal representation of the value of n in BRR (see section 13.3.9, Bit Rate Register (BRR)).</p>

Note: t_{etu} (Elementary Time Unit): Abbreviation for the transfer period for one bit.

13.3.6 Serial Control Register (SCR)

SCR is a register that enables or disables SCI transfer operations and interrupt requests, and is also used to selection of the transfer clock source. For details on interrupt requests, refer to section 13.8, Interrupts. Some bit functions of SCR differ between normal serial communication interface mode and Smart Card interface mode.

Normal Serial Communication Interface Mode (When SMIF in SCMR is 0)

Bit	Bit Name	Initial Value	R/W	Description
7	TIE	0	R/W	<p>Transmit Interrupt Enable</p> <p>When this bit is set to 1, the TXI interrupt request is enabled.</p> <p>TXI interrupt request cancellation can be performed by reading 1 from the TDRE flag in SSR, then clearing it to 0, or clearing the TIE bit to 0.</p>
6	RIE	0	R/W	<p>Receive Interrupt Enable</p> <p>When this bit is set to 1, RXI and ERI interrupt requests are enabled.</p> <p>RXI and ERI interrupt request cancellation can be performed by reading 1 from the RDRF, FER, PER, or ORER flag in SSR, then clearing the flag to 0, or clearing the RIE bit to 0.</p>

Bit	Bit Name	Initial Value	R/W	Description
5	TE	0	R/W	<p>Transmit Enable</p> <p>When this bit is set to 1, transmission is enabled.</p> <p>In this state, serial transmission is started when transmit data is written to TDR and the TDRE flag in SSR is cleared to 0.</p> <p>SMR setting must be performed to decide the transfer format before setting the TE bit to 1. When this bit is cleared to 0, the transmission operation is disabled, and the TDRE flag is fixed at 1.</p>
4	RE	0	R/W	<p>Receive Enable</p> <p>When this bit is set to 1, reception is enabled.</p> <p>Serial reception is started in this state when a start bit is detected in asynchronous mode or serial clock input is detected in clocked synchronous mode.</p> <p>SMR setting must be performed to decide the reception format before setting the RE bit to 1.</p> <p>Clearing the RE bit to 0 does not affect the RDRF, FER, PER, and ORER flags, which retain their states.</p>
3	MPIE	0	R/W	<p>Multiprocessor Interrupt Enable (enabled only when the MP bit in SMR is 1 in asynchronous mode)</p> <p>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 ORER status flags in SSR is prohibited. On receiving data in which the multiprocessor bit is 1, this bit is automatically cleared and normal reception is resumed. For details, refer to section 13.5, Multiprocessor Communication Function.</p> <p>When receive data including MPB = 0 is received, receive data transfer from RSR to RDR, receive error detection, and setting of the RERF, FER, and ORER flags in SSR, are not performed.</p> <p>When receive data including MPB = 1 is received, the MPB bit in SSR is set to 1, the MPIE bit is cleared to 0 automatically, and generation of RXI and ERI interrupts (when the TIE and RIE bits in SCR are set to 1) and FER and ORER flag setting are enabled.</p>

Bit	Bit Name	Initial Value	R/W	Description
2	TEIE	0	R/W	<p>Transmit End Interrupt Enable</p> <p>This bit is set to 1, TEI interrupt request is enabled. TEI cancellation can be performed by reading 1 from the TDRE flag in SSR, then clearing it to 0 and clearing the TEND flag to 0, or clearing the TEIE bit to 0.</p>
1	CKE1	0	R/W	Clock Enable 0 and 1
0	CKE0	0	R/W	<p>Selects the clock source and SCK pin function.</p> <p>Asynchronous mode</p> <p>00: On-chip baud rate generator SCK pin functions as I/O port</p> <p>01: On-chip baud rate generator Outputs a clock of the same frequency as the bit rate from the SCK pin.</p> <p>1X: External clock Inputs a clock with a frequency 16 times the bit rate from the SCK pin.</p> <p>Clocked synchronous mode</p> <p>0X: Internal clock (SCK pin functions as clock output)</p> <p>1X: External clock (SCK pin functions as clock input)</p>

Legend

X: Don't care

Bit	Bit Name	Initial Value	R/W	Description
7	TIE	0	R/W	<p>Transmit Interrupt Enable</p> <p>When this bit is set to 1, TXI interrupt request is enabled.</p> <p>TXI interrupt request cancellation can be performed by reading 1 from the TDRE flag in SSR, then clearing it to 0, or clearing the TIE bit to 0.</p>
6	RIE	0	R/W	<p>Receive Interrupt Enable</p> <p>When this bit is set to 1, RXI and ERI interrupt requests are enabled.</p> <p>RXI and ERI interrupt request cancellation can be performed by reading 1 from the RDRF, FER, PER, or ORER flag in SSR, then clearing the flag to 0, or clearing the RIE bit to 0.</p>
5	TE	0	R/W	<p>Transmit Enable</p> <p>When this bit is set to 1, transmission is enabled.</p> <p>In this state, serial transmission is started when transmit data is written to TDR and the TDRE flag in SSR is cleared to 0.</p> <p>SMR setting must be performed to decide the transfer format before setting the TE bit to 1. When this bit is cleared to 0, the transmission operation is disabled, and the TDRE flag is fixed at 1.</p>
4	RE	0	R/W	<p>Receive Enable</p> <p>When this bit is set to 1, reception is enabled.</p> <p>Serial reception is started in this state when a start bit is detected in asynchronous mode or serial clock input is detected in clocked synchronous mode.</p> <p>SMR setting must be performed to decide the reception format before setting the RE bit to 1.</p> <p>Clearing the RE bit to 0 does not affect the RDRF, FER, PER, and ORER flags, which retain their states.</p>

Bit	Bit Name	Initial Value	R/W	Description
3	MPIE	0	R/W	<p>Multiprocessor Interrupt Enable (enabled only when the MP bit in SMR is 1 in asynchronous mode)</p> <p>Write 0 to this bit in Smart Card interface mode.</p> <p>When receive data including MPB = 0 is received, receive data transfer from RSR to RDR, receive error detection, and setting of the RERF, FER, and ORER flags in SSR, are not performed.</p> <p>When receive data including MPB = 1 is received, the MPB bit in SSR is set to 1, the MPIE bit is cleared to 0 automatically, and generation of RXI and ERI interrupts (when the TIE and RIE bits in SCR are set to 1) and FER and ORER flag setting are enabled.</p>
2	TEIE	0	R/W	<p>Transmit End Interrupt Enable</p> <p>Write 0 to this bit in Smart Card interface mode.</p> <p>TEI cancellation can be performed by reading 1 from the TDRE flag in SSR, then clearing it to 0 and clearing the TEND flag to 0, or clearing the TEIE bit to 0.</p>
1	CKE1	0	R/W	Clock Enable 0 and 1
0	CKE0	0		<p>Enables or disables clock output from the SCK pin. The clock output can be dynamically switched in GSM mode. For details, refer to section 13.7.8, Clock Output Control.</p> <p>When the GM bit in SMR is 0:</p> <p>00: Output disabled (SCK pin can be used as an I/O port pin)</p> <p>01: Clock output</p> <p>1X: Reserved</p> <p>When the GM bit in SMR is 1:</p> <p>00: Output fixed low</p> <p>01: Clock output</p> <p>10: Output fixed high</p> <p>11: Clock output</p>

Legend

X: Don't care

13.3.7 Serial Status Register (SSR)

SSR is a register containing status flags of the SCI and multiprocessor bits for transfer. 1 cannot be written to flags TDRE, RDRF, ORER, PER, and FER; they can only be cleared. Some bit functions of SSR differ between normal serial communication interface mode and Smart Card interface mode.

Normal Serial Communication Interface Mode (When SMIF in SCMR is 0)

Bit	Bit Name	Initial Value	R/W	Description
7	TDRE	1	R/(W)*	<p>Transmit Data Register Empty</p> <p>Displays whether TDR contains transmit data.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none">• When the TE bit in SCR is 0• When data is transferred from TDR to TSR and data can be written to TDR <p>[Clearing conditions]</p> <ul style="list-style-type: none">• When 0 is written to TDRE after reading TDRE = 1• When the DTC is activated by a TXI interrupt request and writes data to TDR (H8S/2268 Series only)
6	RDRF	0	R/(W)*	<p>Receive Data Register Full</p> <p>Indicates that the received data is stored in RDR.</p> <p>[Setting condition]</p> <ul style="list-style-type: none">• When serial reception ends normally and receive data is transferred from RSR to RDR <p>[Clearing conditions]</p> <ul style="list-style-type: none">• When 0 is written to RDRF after reading RDRF = 1• When the DTC is activated by an RXI interrupt and transferred data from RDR (H8S/2268 Series only) <p>The RDRF flag is not affected and retains their previous values when the RE bit in SCR is cleared to 0.</p> <p>If reception of the next data is completed while the RDRF flag is still set to 1, an overrun error will occur and the receive data will be lost.</p>

Bit	Bit Name	Initial Value	R/W	Description
5	ORER	0	R/(W)*	<p>Overrun Error</p> <p>Indicates that an overrun error occurred during reception, causing abnormal termination.</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> When the next serial reception is completed while RDRF = 1 <p>The receive data prior to the overrun error is retained in RDR, and the data received subsequently is lost. Also, subsequent serial reception cannot be continued while the ORER flag is set to 1. In clocked synchronous mode, serial transmission cannot be continued either.</p> <p>[Clearing condition]</p> <ul style="list-style-type: none"> When 0 is written to ORER after reading ORER = 1 <p>The ORER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.</p>
4	FER	0	R/(W)*	<p>Framing Error</p> <p>Indicates that a framing error occurred during reception in asynchronous mode, causing abnormal termination.</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> When the stop bit is 0 <p>In 2 stop bit mode, only the first stop bit is checked for a value to 1; the second stop bit is not checked. If a framing error occurs, the receive data is transferred to RDR but the RDRF flag is not set. Also, subsequent serial reception cannot be continued while the FER flag is set to 1. In clocked synchronous mode, serial transmission cannot be continued, either.</p> <p>[Clearing condition]</p> <ul style="list-style-type: none"> When 0 is written to FER after reading FER = 1 <p>In 2-stop-bit mode, only the first stop bit is checked.</p> <p>The FER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.</p>

Bit	Bit Name	Initial Value	R/W	Description
3	PER	0	R/(W)*	<p>Parity Error</p> <p>Indicates that a parity error occurred during reception using parity addition in asynchronous mode, causing abnormal termination.</p> <p>[Setting condition.]</p> <ul style="list-style-type: none"> When a parity error is detected during reception <p>If a parity error occurs, the receive data is transferred to RDR but the RDRF flag is not set. Also, subsequent serial reception cannot be continued while the PER flag is set to 1. In clocked synchronous mode, serial transmission cannot be continued, either.</p> <p>[Clearing condition]</p> <ul style="list-style-type: none"> When 0 is written to PER after reading PER = 1 <p>The PER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.</p>
2	TEND	1	R	<p>Transmit End</p> <p>Indicates that transmission has been ended.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> When the TE bit in SCR is 0 When TDRE = 1 at transmission of the last bit of a 1-byte serial transmit character <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written to TDRE after reading TDRE = 1 When the DTC is activated by a TXI interrupt request and transfer transmission data to TDR (H8S/2268 Series only)
1	MPB	0	R	<p>Multiprocessor Bit</p> <p>MPB stores the multiprocessor bit in the receive data. When the RE bit in SCR is cleared to 0 its previous state is retained.</p>
0	MPBT	0	R/W	<p>Multiprocessor Bit Transfer</p> <p>MPBT stores the multiprocessor bit to be added to the transmit data.</p>

Note: * Only a 0 can be written to this bit, to clear the flag.

Bit	Bit Name	Initial Value	R/W	Description
7	TDRE	1	R/(W)*	<p>Transmit Data Register Empty</p> <p>Indicates whether TDR contains transmit data.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR <p>[Clearing conditions]</p> <ul style="list-style-type: none"> • When 0 is written to TDRE after reading TDRE = 1 • When the DTC is activated by a TXI interrupt request and writes data to TDR (H8S/2268 Series only)
6	RDRF	0	R/(W)*	<p>Receive Data Register Full</p> <p>Indicates that the received data is stored in RDR.</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> • When serial reception ends normally and receive data is transferred from RSR to RDR <p>[Clearing conditions]</p> <ul style="list-style-type: none"> • When 0 is written to RDRF after reading RDRF = 1 • When the DTC is activated by an RXI interrupt and transferred data from RDR (H8S/2268 Series only) <p>The RDRF flag is not affected and retains their previous values when the RE bit in SCR is cleared to 0.</p> <p>If reception of the next data is completed while the RDRF flag is still set to 1, an overrun error will occur and the receive data will be lost.</p>

Bit	Bit Name	Initial Value	R/W	Description
5	ORER	0	R/(W)*	<p>Overrun Error</p> <p>Indicates that an overrun error occurred during reception, causing abnormal termination.</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> When the next serial reception is completed while RDRF = 1 <p>The receive data prior to the overrun error is retained in RDR, and the data received subsequently is lost. Also, subsequent serial cannot be continued while the ORER flag is set to 1. In clocked synchronous mode, serial transmission cannot be continued, either.</p> <p>[Clearing condition]</p> <ul style="list-style-type: none"> When 0 is written to ORER after reading ORER = 1 <p>The ORER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.</p>
4	ERS	0	R/(W)*	<p>Error Signal Status</p> <p>Indicates that the status of an error, signal 1 returned from the reception side at reception</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> When the low level of the error signal is sampled <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written to ERS after reading ERS = 1 <p>The ERS flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.</p>

Bit	Bit Name	Initial Value	R/W	Description
3	PER	0	R/(W)*	<p>Parity Error</p> <p>Indicates that a parity error occurred during reception using parity addition in asynchronous mode, causing abnormal termination.</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> When a parity error is detected during reception <p>If a parity error occurs, the receive data is transferred to RDR but the RDRF flag is not set. Also, subsequent serial reception cannot be continued while the PER flag is set to 1. In clocked synchronous mode, serial transmission cannot be continued, either.</p> <p>[Clearing condition]</p> <ul style="list-style-type: none"> When 0 is written to PER after reading PER = 1 <p>The PER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.</p>

Bit	Bit Name	Initial Value	R/W	Description
2	TEND	1	R	<p>Transmit End</p> <p>This bit is set to 1 when no error signal has been sent back from the receiving end and the next transmit data is ready to be transferred to TDR.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> When the TE bit in SCR is 0 and the ERS bit is also 0 <p>When the ESR bit is 0 and the TDRE bit is 1 after the specified interval following transmission of 1-byte data.</p> <p>The timing of bit setting differs according to the register setting as follows:</p> <p>When GM = 0 and BLK = 0, 2.5 etu after transmission starts</p> <p>When GM = 0 and BLK = 1, 1.0 etu after transmission starts</p> <p>When GM = 1 and BLK = 0, 1.5 etu after transmission starts</p> <p>When GM = 1 and BLK = 1, 1.0 etu after transmission starts</p> <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written to TDRE after reading TDRE = 1 When the DTC is activated by a TXI interrupt and transfers transmission data to TDR (H8S/2268 Series only)
1	MPB	0	R	<p>Multiprocessor Bit</p> <p>This bit is not used in Smart Card interface mode.</p>
0	MPBT	0	R/W	<p>Multiprocessor Bit Transfer</p> <p>Write 0 to this bit in Smart Card interface mode.</p>

Note: Only 0 can be written to this bit, to clear the flag.

13.3.8 Smart Card Mode Register (SCMR)

SCMR is a register that selects Smart Card interface mode and its format.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 1	—	Reserved These bits are always read as 1, and cannot be modified.
3	SDIR	0	R/W	Smart Card Data Transfer Direction Selects the serial/parallel conversion format. 0: LSB-first in transfer 1: MSB-first in transfer The bit setting is valid only when the transfer data format is 8 bits. For 7-bit data, LSB-first is fixed.
2	SINV	0	R/W	Smart Card Data Invert Specifies inversion of the data logic level. The SINV bit does not affect the logic level of the parity bit. To invert the parity bit, invert the O/E bit in SMR. 0: TDR contents are transmitted as they are. Receive data is stored as it is in RDR 1: TDR contents are inverted before being transmitted. Receive data is stored in inverted form in RDR
1	—	1	—	Reserved This bit is always read as 1, and cannot be modified.
0	SMIF	0	R/W	Smart Card Interface Mode Select This bit is set to 1 to make the SCI operate in Smart Card interface mode. 0: Normal asynchronous mode or clocked synchronous mode 1: Smart card interface mode

13.3.9 Bit Rate Register (BRR)

BRR is an 8-bit register that adjusts the bit rate. As the SCI performs baud rate generator control independently for each channel, different bit rates can be set for each channel. Table 13.2 shows the relationships between the N setting in BRR and bit rate B for normal asynchronous mode, clocked synchronous mode, and Smart Card interface mode. The initial value of BRR is H'FF, and it can be read or written to by the CPU at all times.

Table 13.2 The Relationships between The N Setting in BRR and Bit Rate B

Communication Mode	ABCS bit	Bit Rate	Error
Asynchronous Mode	0	$B = \frac{\phi \times 10^6}{64 \times 2^{2n-1} \times (N + 1)}$	$\text{Error (\%)} = \left\{ \frac{\phi \times 10^6}{B \times 64 \times 2^{2n-1} \times (N + 1)} - 1 \right\} \times 100$
	1	$B = \frac{\phi \times 10^6}{32 \times 2^{2n-1} \times (N + 1)}$	$\text{Error (\%)} = \left\{ \frac{\phi \times 10^6}{B \times 32 \times 2^{2n-1} \times (N + 1)} - 1 \right\} \times 100$
Clocked Synchronous Mode	—	$B = \frac{\phi \times 10^6}{8 \times 2^{2n-1} \times (N + 1)}$	—
Smart Card Interface Mode	—	$B = \frac{\phi \times 10^6}{S \times 2^{2n+1} \times (N + 1)}$	$\text{Error (\%)} = \left\{ \frac{\phi \times 10^6}{B \times S \times 2^{2n+1} \times (N + 1)} - 1 \right\} \times 100$

Note: B: Bit rate (bit/s)

N: BRR setting for baud rate generator ($0 \leq N \leq 255$)

ϕ : Operating frequency (MHz)

n and S: Determined by the SMR settings shown in the following tables.

SMR Setting		Clock Source	n
CKS1	CKS0		
0	0	ϕ	0
0	1	$\phi/4$	1
1	0	$\phi/16$	2
1	1	$\phi/64$	3

SMR Setting		
BCP1	BCP0	S
0	0	32
0	1	64
1	0	372
1	1	256

Table 13.3 shows sample N settings in BRR in normal asynchronous mode. Table 13.4 shows the maximum bit rate for each frequency in normal asynchronous mode. Table 13.6 shows sample N settings in BRR in clocked synchronous mode. Table 13.8 shows sample N settings in BRR in Smart Card interface mode. In Smart Card interface mode, S (the number of basic clock periods in a 1-bit transfer interval) can be selected. For details, refer to section 13.7.4, Receive Data Sampling Timing and Reception Margin. Tables 13.5 and 13.7 show the maximum bit rates with external clock input.

When the ABCS bit in SEMR_0 of SCI_0 is set to 1 in asynchronous mode, the maximum bit rate is twice the value shown in tables 13.4 and 13.5.

Table 13.3 BRR Settings for Various Bit Rates (Asynchronous Mode) (1)

Operating Frequency ϕ (MHz)												
2				2.097152			2.4576			3		
Bit Rate (bps)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	1	141	0.03	1	148	-0.04	1	174	-0.26	1	212	0.33
150	1	103	0.16	1	108	0.21	1	127	0.00	1	155	0.16
300	0	207	0.16	0	217	0.21	0	255	0.00	1	77	0.16
600	0	103	0.16	0	108	0.21	0	127	0.00	0	155	0.16
1200	0	51	0.16	0	54	-0.70	0	63	0.00	0	77	0.16
2400	0	25	0.16	0	26	1.14	0	31	0.00	0	38	0.16
4800	0	12	0.16	0	13	-2.48	0	15	0.00	0	19	-2.34
9600	—	—	—	0	6	-2.48	0	7	0.00	0	9	-2.34
19200	—	—	—	—	—	—	0	3	0.00	0	4	-2.34
31250	0	1	0.00	—	—	—	—	—	—	0	2	0.00
38400	—	—	—	—	—	—	0	1	0.00	—	—	—

Table 13.3 BRR Settings for Various Bit Rates (Asynchronous Mode) (2)

Operating Frequency ϕ (MHz)												
3.6864				4			4.9152			5		
Bit Rate (bps)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	64	0.70	2	70	0.33	2	86	0.31	2	88	-0.25
150	1	191	0.00	1	207	0.16	2	255	0.00	2	64	0.16
300	1	95	0.00	1	103	0.16	1	127	0.00	1	129	0.16
600	0	191	0.00	0	207	0.16	1	255	0.00	1	64	0.16
1200	0	95	0.00	0	103	0.16	0	127	0.00	0	129	0.16
2400	0	47	0.00	0	51	0.16	0	63	0.00	0	64	0.16
4800	0	23	0.00	0	25	0.16	0	31	0.00	0	32	-1.36
9600	0	11	0.00	0	12	0.16	0	15	0.00	0	15	1.73
19200	0	5	0.00	—	—	—	0	7	0.00	0	7	1.73
31250	—	—	—	0	3	0.00	0	4	-1.70	0	4	0.00
38400	0	2	0.00	—	—	—	0	3	0.00	0	3	1.73

Operating Frequency ϕ (MHz)												
6				6.144			7.3728			8		
Bit Rate (bps)	N	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	106	-0.44	2	108	0.08	2	130	-0.07	2	141	0.03
150	2	77	0.16	2	79	0.00	2	95	0.00	2	103	0.16
300	1	155	0.16	1	159	0.00	1	191	0.00	1	207	0.16
600	1	77	0.16	1	79	0.00	1	95	0.00	1	103	0.16
1200	0	155	0.16	0	159	0.00	0	191	0.00	0	207	0.16
2400	0	77	0.16	0	79	0.00	0	95	0.00	0	103	0.16
4800	0	38	0.16	0	39	0.00	0	47	0.00	0	51	0.16
9600	0	19	-2.34	0	19	0.00	0	23	0.00	0	25	0.16
19200	0	9	-2.34	0	9	0.00	0	11	0.00	0	12	0.16
31250	0	5	0.00	0	5	2.40	—	—	—	0	7	0.00
38400	0	4	-2.34	0	4	0.00	0	5	0.00	—	—	—

Table 13.3 BRR Settings for Various Bit Rates (Asynchronous Mode) (3)

Operating Frequency ϕ (MHz)												
9.8304				10			12			12.288		
Bit Rate (bps)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	174	-0.26	2	177	-0.25	2	212	0.03	2	217	0.08
150	2	127	0.00	2	129	0.16	2	155	0.16	2	159	0.00
300	1	255	0.00	2	64	0.16	2	77	0.16	2	79	0.00
600	1	127	0.00	1	129	0.16	1	155	0.16	1	159	0.00
1200	0	255	0.00	1	64	0.16	1	77	0.16	1	79	0.00
2400	0	127	0.00	0	129	0.16	0	155	0.16	0	159	0.00
4800	0	63	0.00	0	64	0.16	0	77	0.16	0	79	0.00
9600	0	31	0.00	0	32	-1.36	0	38	0.16	0	39	0.00
19200	0	15	0.00	0	15	1.73	0	19	-2.34	0	19	0.00
31250	0	9	-1.70	0	9	0.00	0	11	0.00	0	11	2.40
38400	0	7	0.00	0	7	1.73	0	9	-2.34	0	9	0.00

Operating Frequency ϕ (MHz)												
14				14.7456			16			17.2032		
Bit Rate (bps)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	248	-0.17	3	64	0.70	3	70	0.03	3	75	0.48
150	2	181	0.16	2	191	0.00	2	207	0.16	2	223	0.00
300	2	90	0.16	2	95	0.00	2	103	0.16	2	111	0.00
600	1	181	0.16	1	191	0.00	1	207	0.16	1	223	0.00
1200	1	90	0.16	1	95	0.00	1	103	0.16	1	111	0.00
2400	0	181	0.16	0	191	0.00	0	207	0.16	0	223	0.00
4800	0	90	0.16	0	95	0.00	0	103	0.16	0	111	0.00
9600	0	45	-0.93	0	47	0.00	0	51	0.16	0	55	0.00
19200	0	22	-0.93	0	23	0.00	0	25	0.16	0	27	0.00
31250	0	13	0.00	0	14	-1.70	0	15	0.00	0	16	1.20
38400	—	—	—	—	11	0.00	0	12	0.16	0	13	0.00

Table 13.3 BRR Settings for Various Bit Rates (Asynchronous Mode) (4)

	Operating Frequency ϕ (MHz)								
	18			19.6608			20		
Bit Rate (bps)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	79	-0.12	3	86	0.31	3	88	-0.25
150	2	233	0.16	2	255	0.00	2	64	0.16
300	2	116	0.16	2	127	0.00	2	129	0.16
600	1	233	0.16	1	255	0.00	1	64	0.16
1200	1	116	0.16	1	127	0.00	1	129	0.16
2400	0	233	0.16	0	255	0.00	0	64	0.16
4800	0	116	0.16	0	127	0.00	0	129	0.16
9600	0	58	-0.69	0	63	0.00	0	64	0.16
19200	0	28	1.02	0	31	0.00	0	32	-1.36
31250	0	17	0.00	0	19	-1.70	0	19	0.00
38400	0	14	-2.34	0	15	0.00	0	15	1.73

Table 13.4 Maximum Bit Rate for Each Frequency (Asynchronous Mode)

ϕ (MHz)	Maximum Bit Rate (kbps)	n	N	ϕ (MHz)	Maximum Bit Rate (kbps)	n	N
2	62.5	0	0	9.8304	307.2	0	0
2.097152	65.536	0	0	10	312.5	0	0
2.4576	76.8	0	0	12	375.0	0	0
3	93.75	0	0	12.288	384.0	0	0
3.6864	115.2	0	0	14	437.5	0	0
4	125.0	0	0	14.7456	460.8	0	0
4.9152	153.6	0	0	16	500.0	0	0
5	156.25	0	0	17.2032	537.6	0	0
6	187.5	0	0	18	562.5	0	0
6.144	192.0	0	0	19.6608	614.4	0	0
7.3728	230.4	0	0	20	625.0	0	0
8	250.0	0	0				

Table 13.5 Maximum Bit Rate with External Clock Input (Asynchronous Mode)

ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (kbps)	ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (kbps)
2	0.5000	31.25	9.8304	2.4576	153.6
2.097152	0.5243	327.68	10	2.5000	156.25
2.4576	0.6144	38.4	12	3.0000	187.5
3	0.7500	46.875	12.288	3.0720	192.0
3.6864	0.9216	57.6	14	3.5000	218.75
4	1.0000	62.5	14.7456	3.6864	230.4
4.9152	1.2288	76.8	16	4.0000	250.0
5	1.2500	78.125	17.2032	4.3008	268.8
6	1.5000	93.75	18	4.5000	281.25
6.144	1.5360	96.0	19.6608	4.9152	307.2
7.3728	1.8432	115.2	20	5.0000	312.5
8	2.0000	125.0			

Table 13.6 BRR Settings for Various Bit Rates (Clocked Synchronous Mode)

Bit Rate (bps)	Operating Frequency ϕ (MHz)											
	2		4		8		10		16		20	
	n	N	n	N	n	N	n	N	n	N	n	N
110	3	70	—	—								
250	2	124	2	249	3	124	—	—	3	249		
500	1	249	2	124	2	249	—	—	3	124	—	—
1k	1	124	1	249	2	124	—	—	2	249	—	—
2.5k	0	199	1	99	1	199	1	249	2	99	2	124
5k	0	99	0	199	1	99	1	124	1	199	1	249
10k	0	49	0	99	0	199	0	249	1	99	1	124
25k	0	19	0	39	0	79	0	99	0	159	0	199
50k	0	9	0	19	0	39	0	49	0	79	0	99
100k	0	4	0	9	0	19	0	24	0	39	0	49
250k	0	1	0	3	0	7	0	9	0	15	0	19
500k	0	0*	0	1	0	3	0	4	0	7	0	9
1M			0	0*	0	1			0	3	0	4
2.5M							0	0*			0	1
5M											0	0*

Legend

Blank : Cannot be set.

— : Can be set, but there will be a degree of error.

* : Continuous transfer is not possible.

Table 13.7 Maximum Bit Rate with External Clock Input (Clocked Synchronous Mode)

ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)	ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
2	0.3333	0.333	12	2.0000	2.000
4	0.6667	0.667	14	2.6667	2.667
6	1.0000	1.000	16	3.0000	3.000
8	1.3333	1.333	20	3.3333	3.333
10	1.6667	1.667			

Table 13.8 Examples of Bit Rate for Various BRR Settings (Smart Card Interface Mode)
(When $n = 0$ and $S = 372$)

Bit Rate (bps)	Operating Frequency ϕ (MHz)									
	5.00		7.00		7.1424		10.00		10.7136	
	N	Error (%)	N	Error (%)	N	Error (%)	N	Error (%)	N	Error (%)
6720	0	0.00	1	30	1	28.75	1	0.01	1	7.14
9600						0.00	1	30	1	25

Bit Rate (bps)	Operating Frequency ϕ (MHz)									
	13.00		14.2848		16.00		18.00		20.00	
	N	Error (%)	N	Error (%)	N	Error (%)	N	Error (%)	N	Error (%)
6720	2	13.33	2	4.76	2	6.67	2	20.01	2	33.34
9600	1	8.99	1	0.00	1	12.01	2	15.99	2	6.66

Table 13.9 Maximum Bit Rate at Various Frequencies (Smart Card Interface Mode)
(when $S = 372$)

ϕ (MHz)	Maximum Bit Rate (bps)	n	N
5.00	6720	0	0
7.00	9409	0	0
7.1424	9600	0	0
10.00	13441	0	0
10.7136	14400	0	0
13.00	17473	0	0
14.2848	19200	0	0
16.00	21505	0	0
18.00	24194	0	0
20.00	26882	0	0

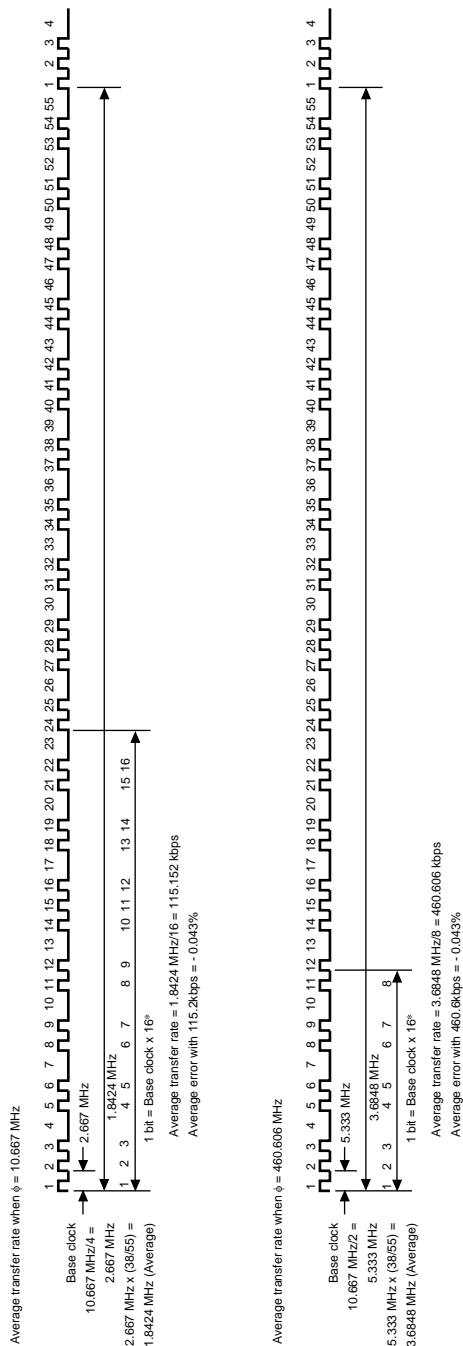
13.3.10 Serial Expansion Mode Register (SEMR_0)

SEMR_0 is an 8-bit register that expands SCI_0 functions; such as setting of the basic clock, selecting of the clock source, and automatic setting of the transfer rate.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved This is a readable/writable bit, but the write value should always be 0.
6 to 4	—	All 0	—	Reserved The write value should always be 0.
3	ABCS	0	R/W	Asynchronous Basic Clock Select Selects the 1-bit-interval base clock in asynchronous mode. The ABCS setting is valid in asynchronous mode (C/\bar{A} in SMR = 0). 0: Operates on a basic clock with a frequency of 16-times the transfer rate. 1: Operates on a basic clock with a frequency of 8-times the transfer rate.

Bit	Bit Name	Initial Value	R/W	Description
2	ACS2	0	R/W	Asynchronous Clock Source Select
1	ACS1	0	R/W	When an average transfer rate is selected, the base clock is set automatically regardless of the ABCS value. Note that average transfer rates are not supported for operating frequencies other than 10.667 MHz and 16 MHz. The ACS0 to ACS0 settings are valid when the external clock input is selected (CKE1 in SCR = 1) in asynchronous mode (C/ \bar{A} in SMR = 0). 000: External clock input 001: Selects the average transfer rate 115.152 kbps only for ϕ = 10.667MHz (operates on a basic clock with a frequency of 16-times the transfer rate). 001: Selects the average transfer rate 460.606 kbps only for ϕ = 10.667MHz (operates on a basic clock with a frequency of 8-times the transfer rate). 011: Reserved 100: TPU clock input (logical ANDs TIOCA1 and TIOCA2) 101: 115.196 kbps average transfer rate (for ϕ = 6 MHz only) is selected (SCI0 operates on base clock with frequency of 16 times transfer rate) 110: 460.784 kbps average transfer rate (for ϕ = 6 MHz only) is selected (SCI0 operates on base clock with frequency of 16 times transfer rate) 111: 720 kbps average transfer rate (for ϕ = 6 MHz only) is selected (SCI0 operates on base clock with frequency of 8 times transfer rate)
0	ACS0	0	R/W	

Figure 13.3 and 13.4 shows an example of the internal base clock when the average transfer rate is selected.



Note: The 1-bit length changes according to the base clock synchronization.

Figure 13.3 Example of the Internal Base Clock When the Average Transfer Rate is Selected (1)

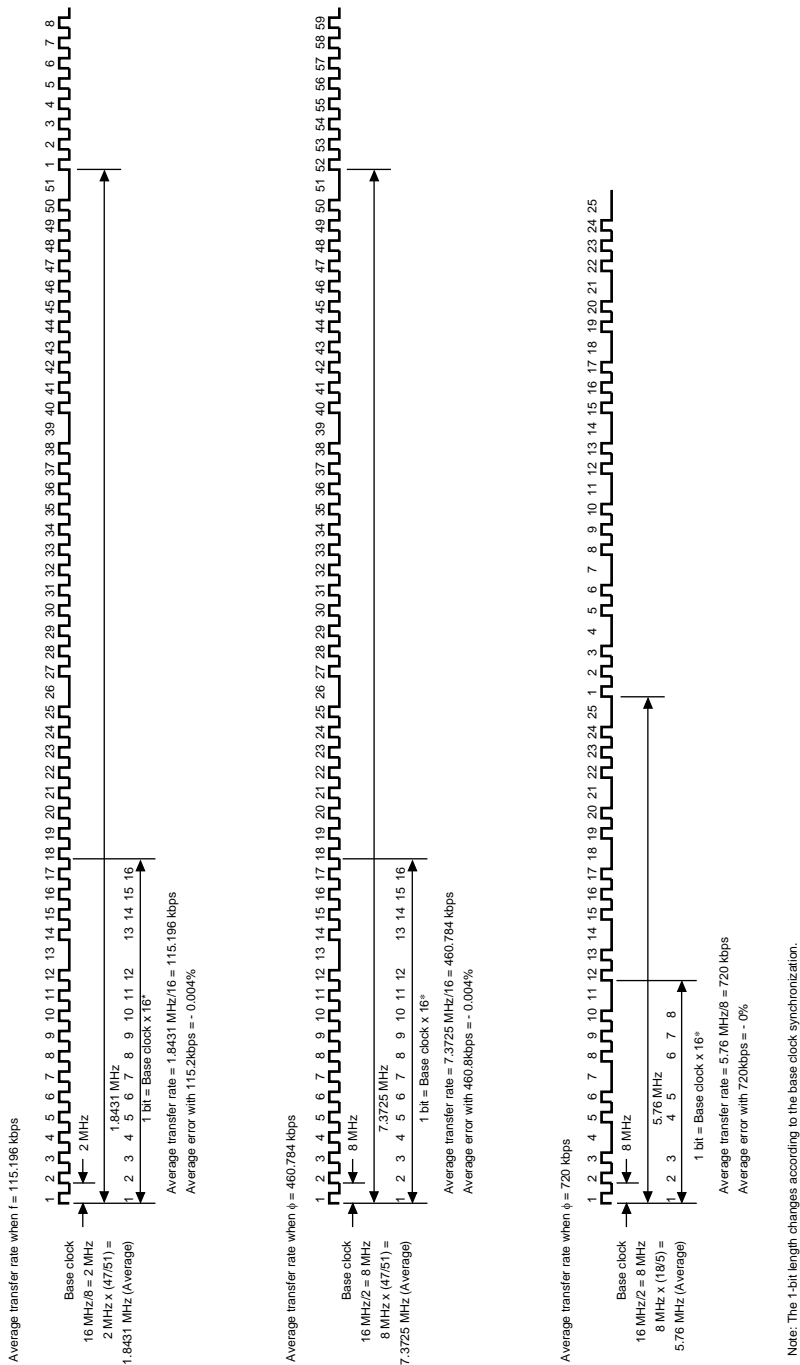


Figure 13.4 Example of the Internal Base Clock When the Average Transfer Rate is Selected (2)

13.4 Operation in Asynchronous Mode

Figure 13.5 shows the general format for asynchronous serial communication. One frame consists of a start bit (low level), followed by data, a parity bit, and finally stop bits (high level). In asynchronous serial communication, the transmission line is usually held in the mark state (high level). The SCI monitors the transmission line, and when it goes to the space state (low level), recognizes a start bit and starts serial communication. Inside the SCI, the transmitter and receiver are independent units, enabling full-duplex communication. Both the transmitter and the receiver also have a double-buffered structure, so that data can be read or written during transmission or reception, enabling continuous data transfer. In asynchronous mode, the SCI performs synchronization at the falling edge of the start bit in reception. The SCI samples the data on the 8th pulse of a clock with a frequency of 16 times the length of one bit, so that the transfer data is latched at the center of each bit.

The SCI_0 samples the data on the 4th pulse of a clock with a frequency of 8 times the length of one bit when the ABCS bit in SEMR_0 is 1.

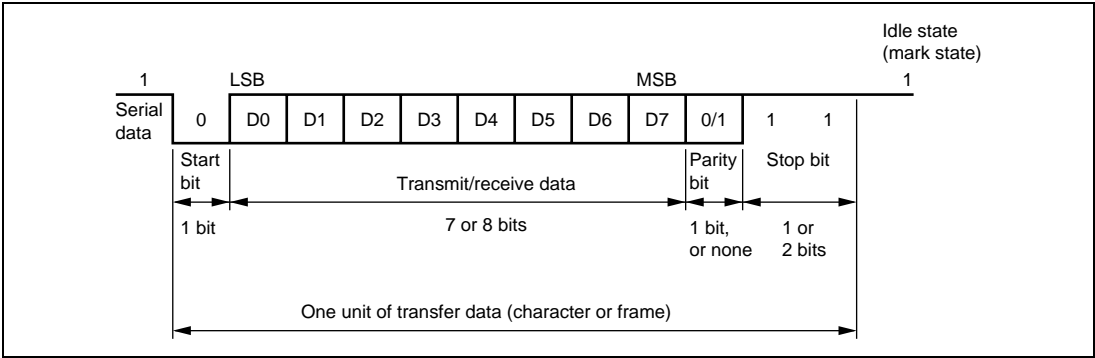


Figure 13.5 Data Format in Asynchronous Communication
(Example with 8-Bit Data, Parity, Two Stop Bits)

13.4.1 Data Transfer Format

Table 13.10 shows the data transfer formats that can be used in asynchronous mode. Any of 12 transfer formats can be selected according to the SMR setting. For details on the multiprocessor bit, refer to section 13.5, Multiprocessor Communication Function.

Table 13.10 Serial Transfer Formats (Asynchronous Mode)

SMR Settings				Serial Transfer Format and Frame Length											
CHR	PE	MP	STOP	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	S	8-bit data								STOP		
0	0	0	1	S	8-bit data								STOP	STOP	
0	1	0	0	S	8-bit data								P	STOP	
0	1	0	1	S	8-bit data								P	STOP	STOP
1	0	0	0	S	7-bit data							STOP			
1	0	0	1	S	7-bit data							STOP	STOP		
1	1	0	0	S	7-bit data							P	STOP		
1	1	0	1	S	7-bit data							P	STOP	STOP	
0	—	1	0	S	8-bit data								MPB	STOP	
0	—	1	1	S	8-bit data								MPB	STOP	STOP
1	—	1	0	S	7-bit data							MPB	STOP		
1	—	1	1	S	7-bit data							MPB	STOP	STOP	

Legend

S : Start bit

STOP : Stop bit

P : Parity bit

MPB : Multiprocessor bit

13.4.2 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI operates on a basic clock with a frequency of 16 times the transfer rate. In reception, the SCI 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 13.6. Thus, the reception margin in asynchronous mode is given by formula (1) below.

$$M = \left\{ \left(0.5 - \frac{1}{2N} \right) - \frac{D - 0.5}{N} - (L - 0.5) F \right\} \times 100 [\%]$$

... Formula (1)

Where 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, D (clock duty) = 0.5, and N (ratio of bit rate to clock) = 16 in formula (1), the reception margin can be given by the formula.

$$M = \left\{ 0.5 - 1/(2 \times 16) \right\} \times 100 [\%] = 46.875\%$$

However, this is only the computed value, and a margin of 20% to 30% should be allowed for in system design.

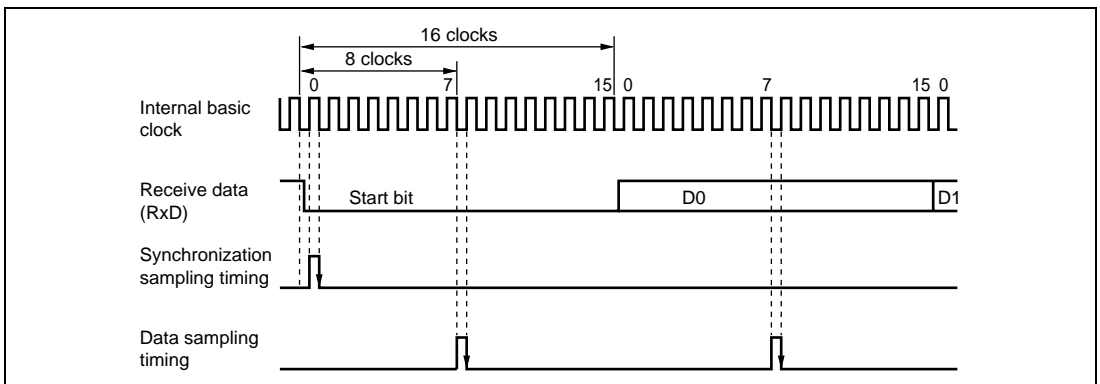


Figure 13.6 Receive Data Sampling Timing in Asynchronous Mode

13.4.3 Clock

Either an internal clock generated by the on-chip baud rate generator or an external clock input at the SCK pin can be selected as the SCI's serial clock, according to the setting of the C/\overline{A} bit in SMR and the CKE0 and CKE1 bits in SCR. When an external clock is input at the SCK pin, the clock frequency should be 16 times the bit rate used. When an external clock is selected, a base clock with an average transfer rate can be selected by setting bits ACS2 to ACS0 in SEMR_0.

When the SCI is operated on an internal clock, the clock can be output from the SCK pin when setting CKE1 = 0 and CKE0 = 1. 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 13.7.

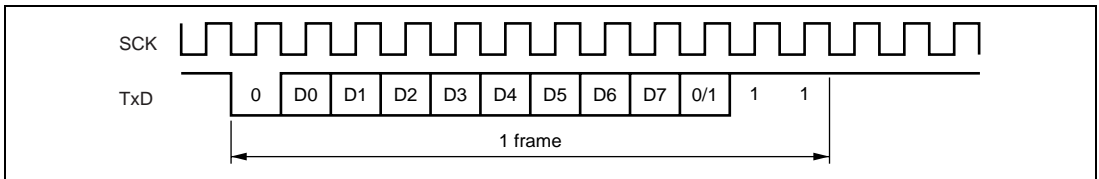


Figure 13.7 Relationship between Output Clock and Transfer Data Phase (Asynchronous Mode)

13.4.4 SCI Initialization (Asynchronous Mode)

Before transmitting and receiving data, you should first clear the TE and RE bits in SCR to 0, then initialize the SCI as described below. 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 initialize the contents of the RDRF, PER, FER, and ORER flags, or the contents of RDR. When the external clock is used in asynchronous mode, the clock must be supplied even during initialization.

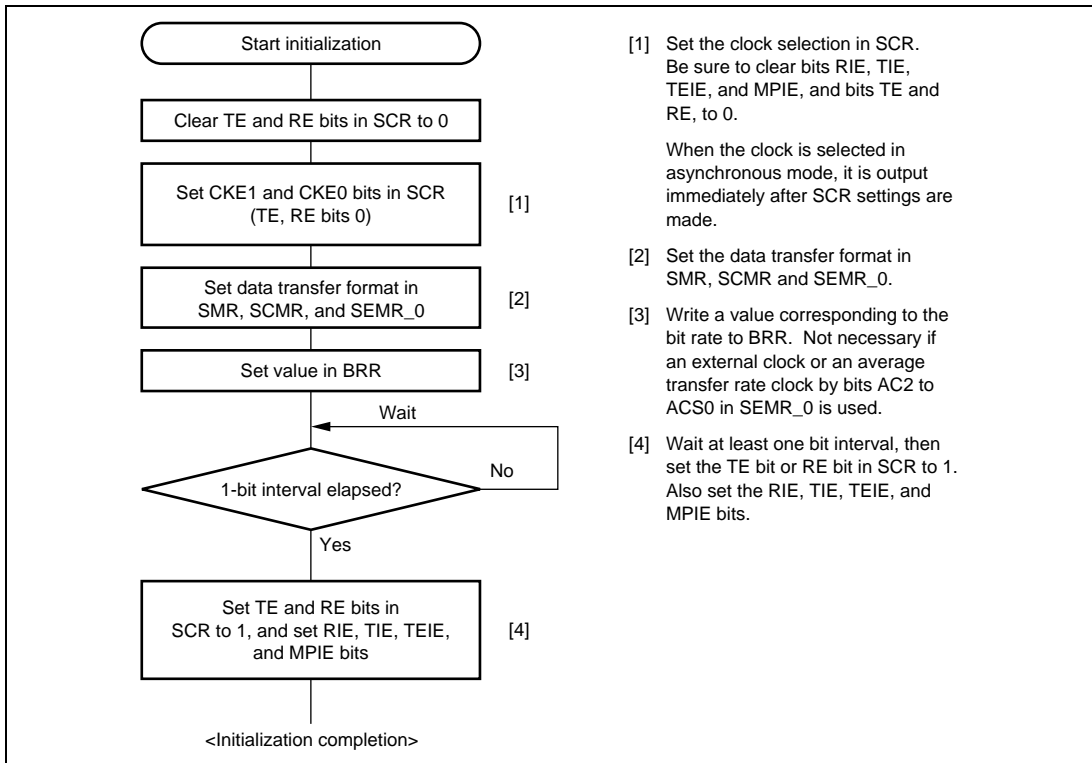


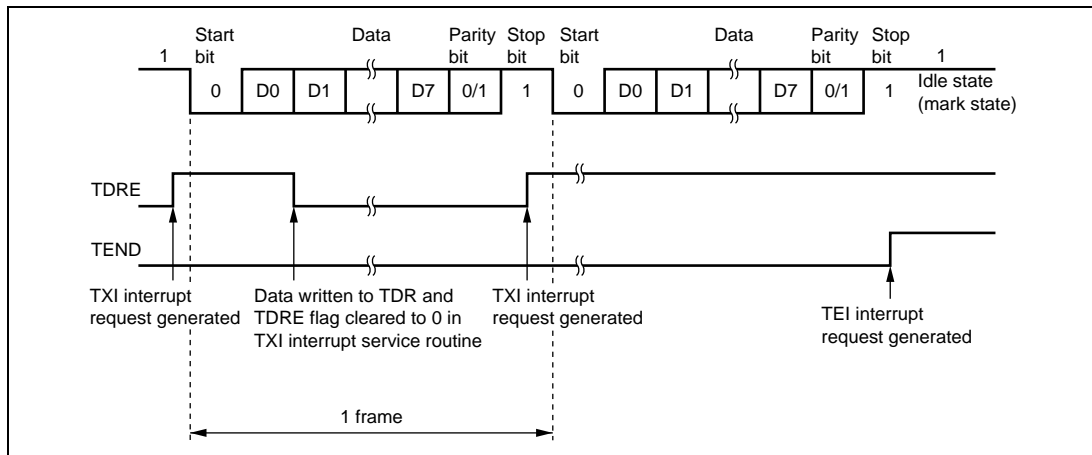
Figure 13.8 Sample SCI Initialization Flowchart

13.4.5 Serial Data Transmission (Asynchronous Mode)

Figure 13.9 shows an example of operation for transmission in asynchronous mode. In transmission, the SCI operates as described below.

1. The SCI monitors the TDRE flag in SSR. If the flag is cleared to 0, the SCI recognizes that data has been written to TDR, and transfers the data from TDR to TSR.
2. After transferring data from TDR to TSR, the SCI sets the TDRE flag to 1 and starts transmission. If the TIE bit is set to 1 at this time, a transmit data empty interrupt request (TXI) 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. Data is sent from the TxD pin in the following order: start bit, transmit data, parity bit or multiprocessor bit (may be omitted depending on the format), and stop bit.
4. The SCI checks the TDRE flag at the timing for sending the stop bit.
5. If the TDRE flag is 0, the data is transferred from TDR to TSR, the stop bit is sent, and then serial transmission of the next frame is started.

6. 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 SCR is set to 1 at this time, a TEI interrupt request is generated.



**Figure 13.9 Example of Operation in Transmission in Asynchronous Mode
(Example with 8-Bit Data, Parity, One Stop Bit)**

Figure 13.10 shows a sample flowchart for data transmission.

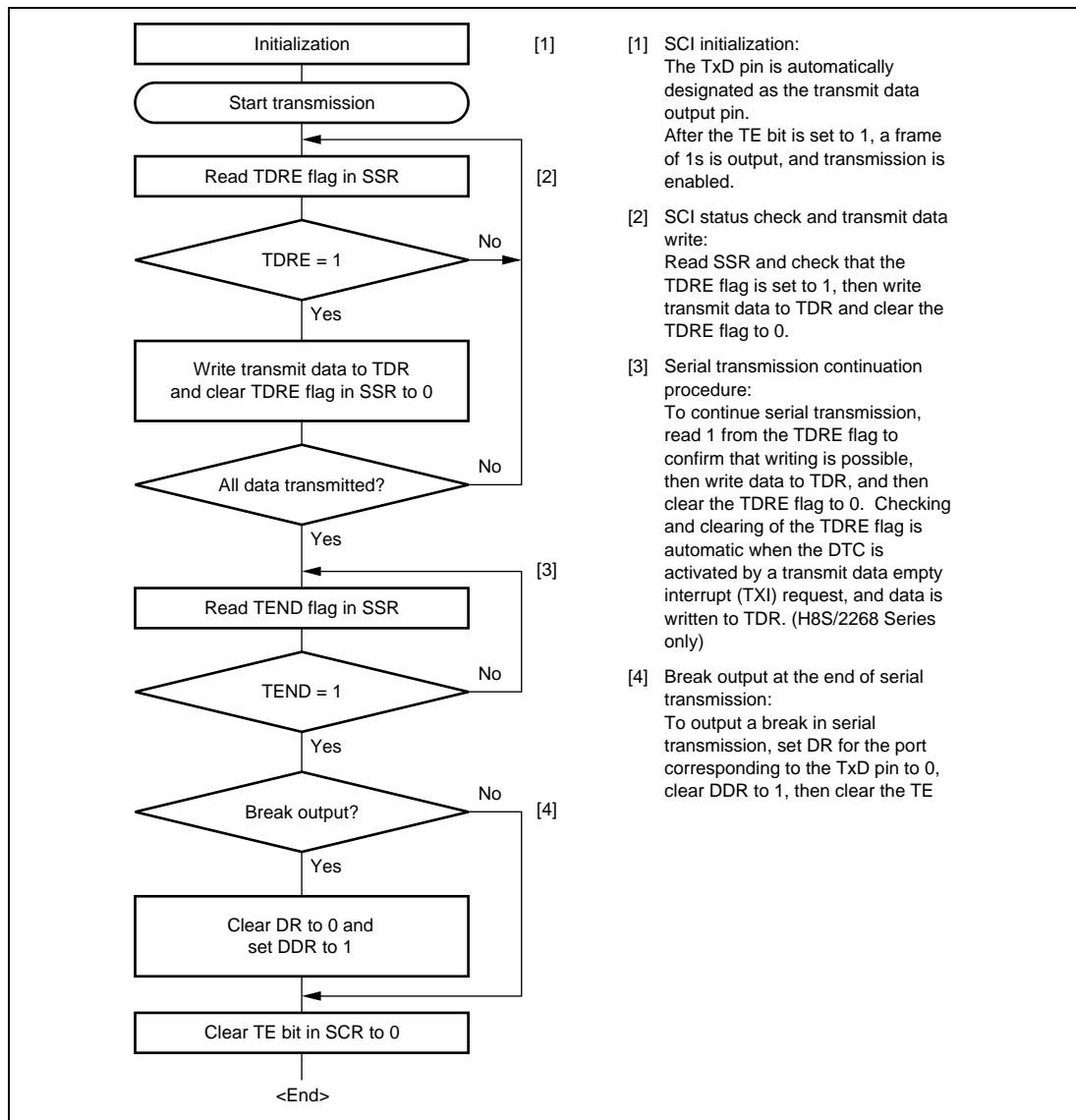


Figure 13.10 Sample Serial Transmission Flowchart

13.4.6 Serial Data Reception (Asynchronous Mode)

Figure 13.11 shows an example of operation for reception in asynchronous mode. In serial reception, the SCI operates as described below.

1. The SCI monitors the communication line. If a start bit is detected, the SCI 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 ORE bit in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR. The RDRF flag remains to be set to 1.
3. If a parity error is detected, the PER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated.
4. If a framing error 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 SCR 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 SCR 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.

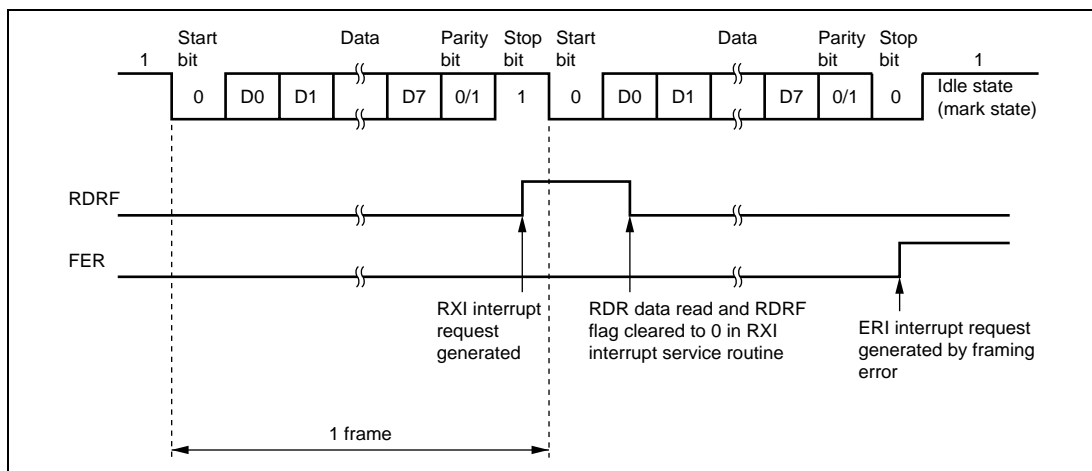


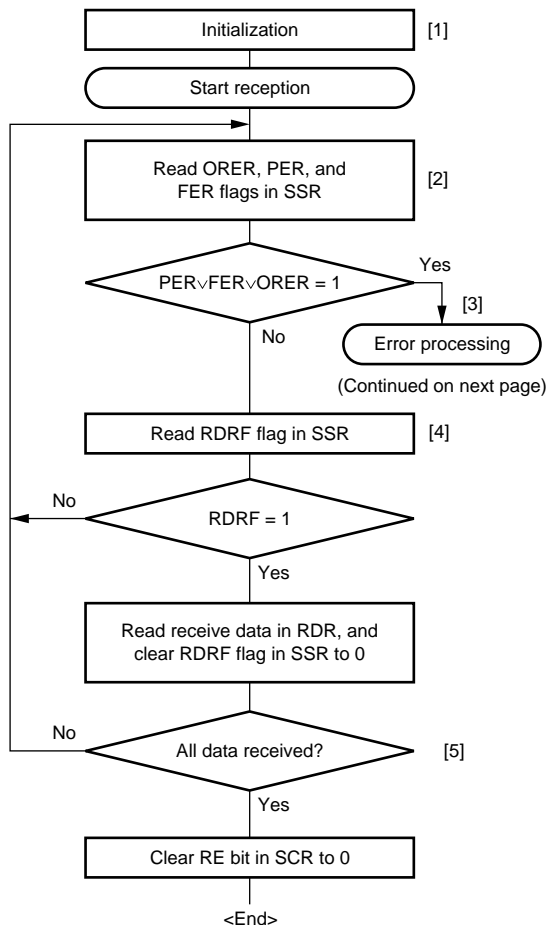
Figure 13.11 Example of SCI Operation in Reception
(Example with 8-Bit Data, Parity, One Stop Bit)

Table 13.11 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 ORER, FER, PER, and RDRF bits to 0 before resuming reception. Figure 13.12 shows a sample flow chart for serial data reception.

Table 13.11 SSR Status Flags and Receive Data Handling

SSR Status Flag				Receive Data	Receive Error Type
RDRF*	ORER	FER	PER		
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] SCI initialization:
The Rx/D pin is automatically designated as the receive data input pin.
- [2] [3] Receive error processing and break detection:
If a receive error occurs, read the ORER, PER, and FER flags in SSR to identify the error. After performing the appropriate error processing, ensure that the ORER, 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 input port corresponding to the Rx/D pin.
- [4] SCI status check and receive data read:
Read SSR and check that RDRF = 1, then read the receive data in RDR and clear the RDRF flag to 0. Transition of the RDRF flag from 0 to 1 can also be identified by an RXI interrupt.
- [5] Serial reception continuation procedure:
To continue serial reception, before the stop bit for the current frame is received, read the RDRF flag, read RDR, and clear the RDRF flag to 0. The RDRF flag is cleared automatically when DTC is activated by an RXI interrupt and the RDR value is read. (H8S/2268 Series only)

Figure 13.12 Sample Serial Reception Data Flowchart (1)

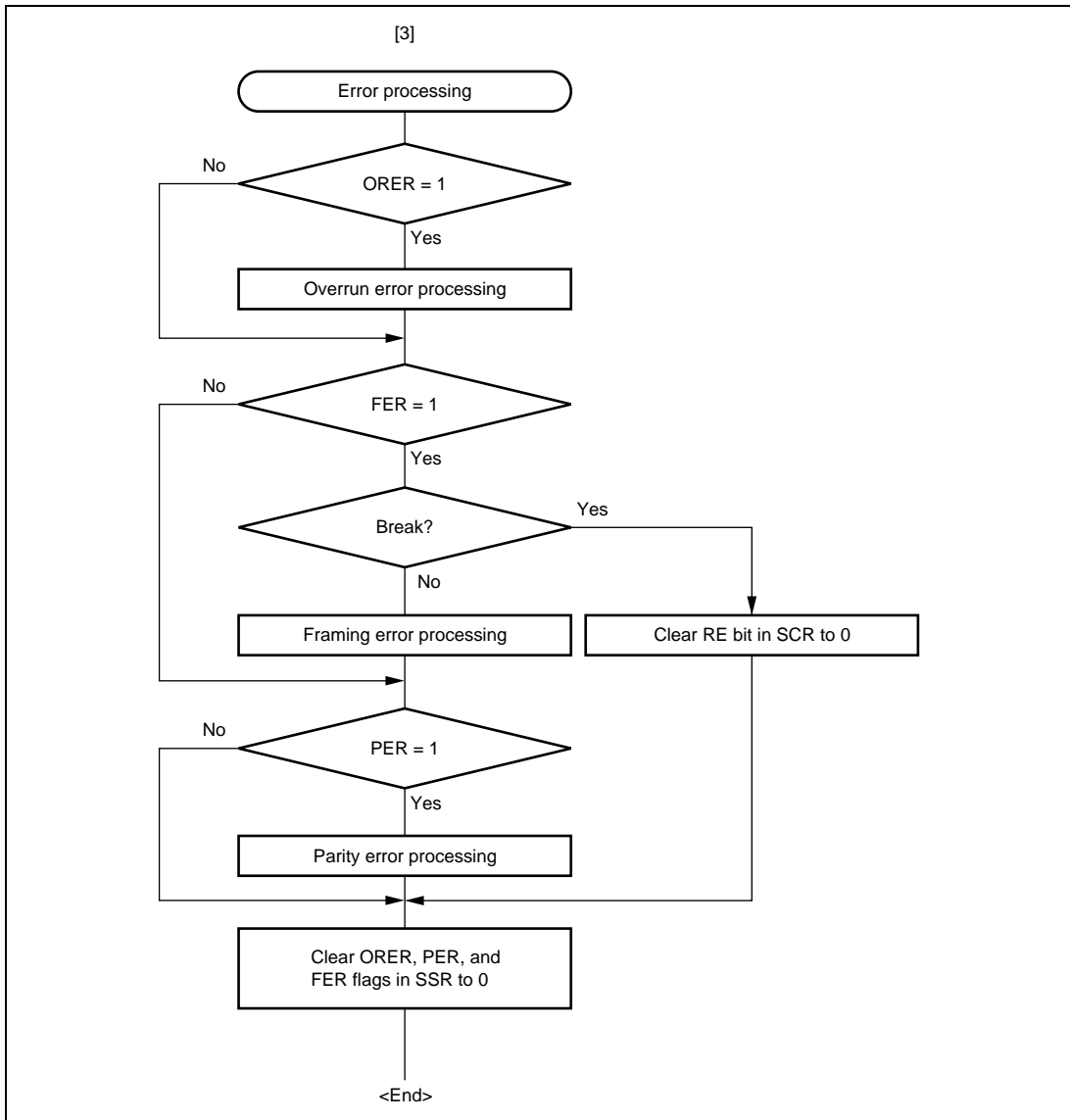


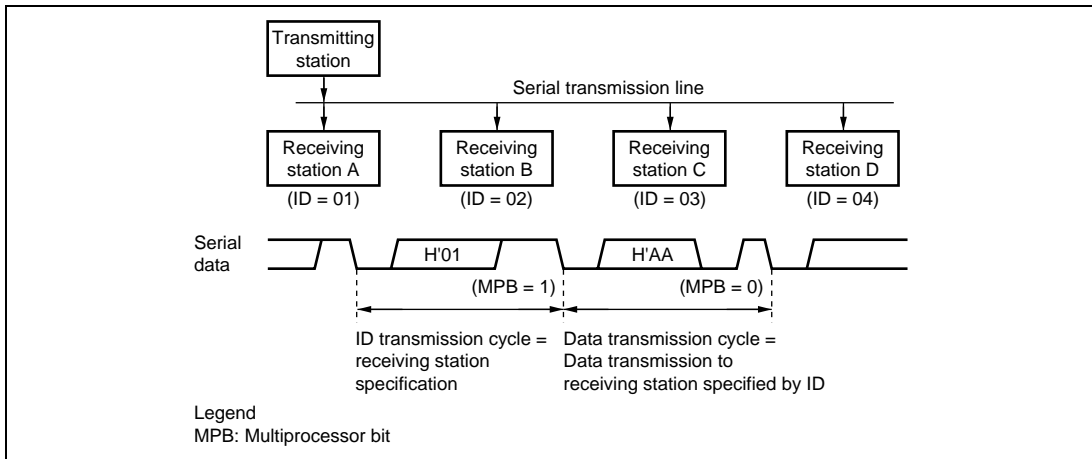
Figure 13.12 Sample Serial Reception Data Flowchart (2)

13.5 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 13.13 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 SCI uses the MPIE bit in SCR 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 ORER 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 MPB bit in SSR is set to 1 and the MPIE bit is automatically cleared, thus normal reception is resumed. If the RIE bit in SCR is set to 1 at this time, an RXI interrupt is generated.

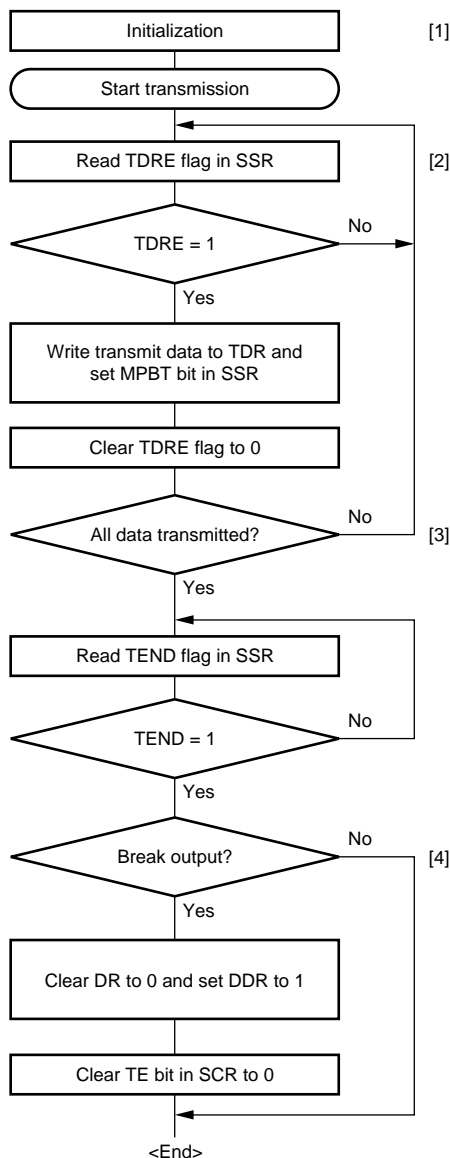
When the multiprocessor format is selected, the parity bit setting is rendered invalid. All other bit settings are the same as those in normal asynchronous mode. The clock used for multiprocessor communication is the same as that in normal asynchronous mode.



**Figure 13.13 Example of Communication Using Multiprocessor Format
(Transmission of Data H'AA to Receiving Station A)**

13.5.1 Multiprocessor Serial Data Transmission

Figure 13.14 shows a sample flowchart for multiprocessor serial 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 SCI operations are the same as those in asynchronous mode.

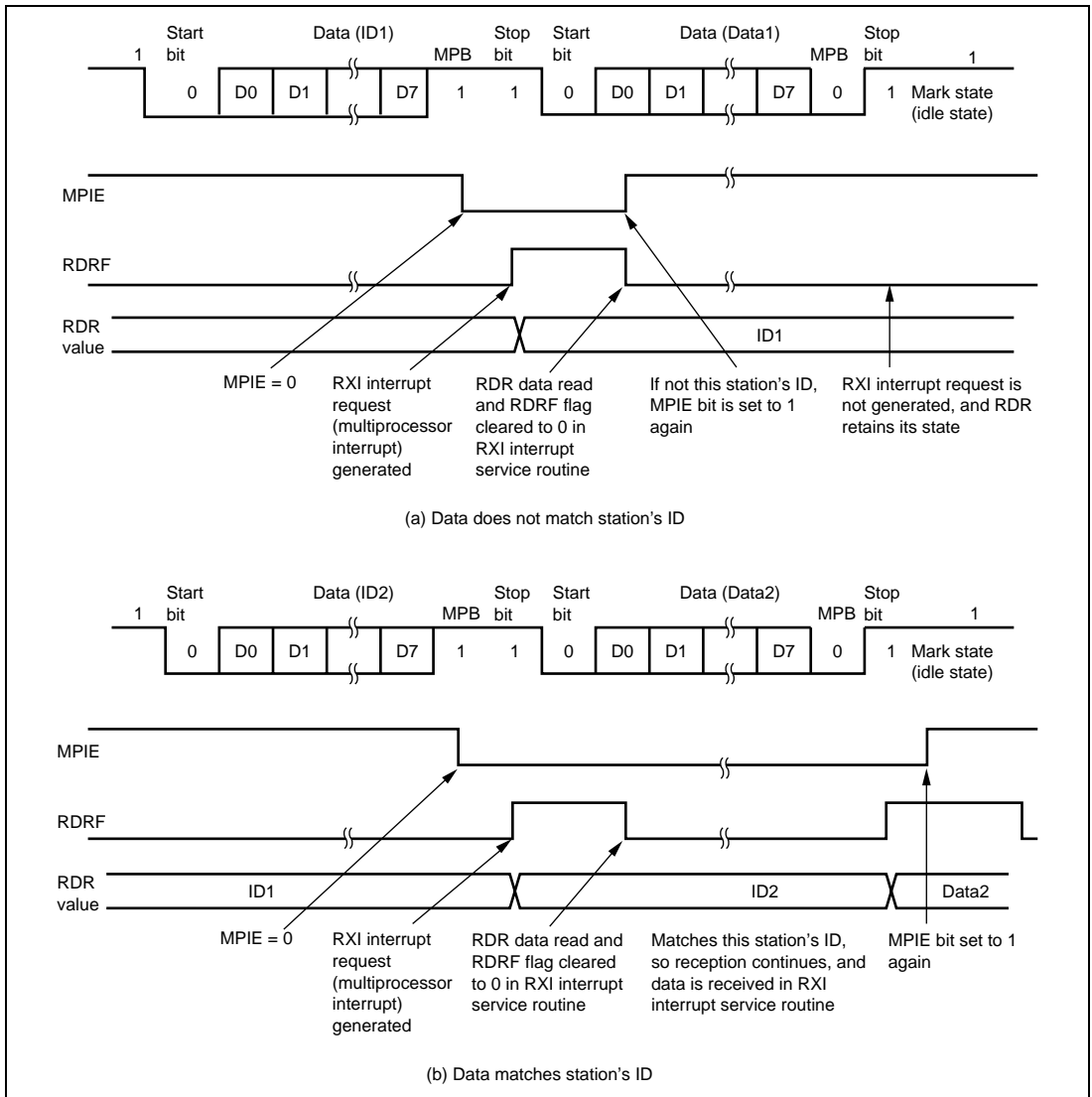


- [1] SCI initialization:
The TxD pin is automatically designated as the transmit data output pin.
After the TE bit is set to 1, a frame of 1s is output, and transmission is enabled.
- [2] SCI status check and transmit data write:
Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR. Set the MPBT bit in SSR to 0 or 1.
Finally, clear the TDRE flag to 0.
- [3] Serial transmission continuation procedure:
To continue serial transmission, be sure to read 1 from the TDRE flag to confirm that writing is possible, then write data to TDR, and then clear the TDRE flag to 0. Checking and clearing of the TDRE flag is automatic when the DTC is activated by a transmit data empty interrupt (TXI) request, and data is written to TDR. (H8S/2268 Series only)
- [4] Break output at the end of serial transmission:
To output a break in serial transmission, set the port DR to 0, clear DDR to 1, then clear the TE bit in SCR to 0.

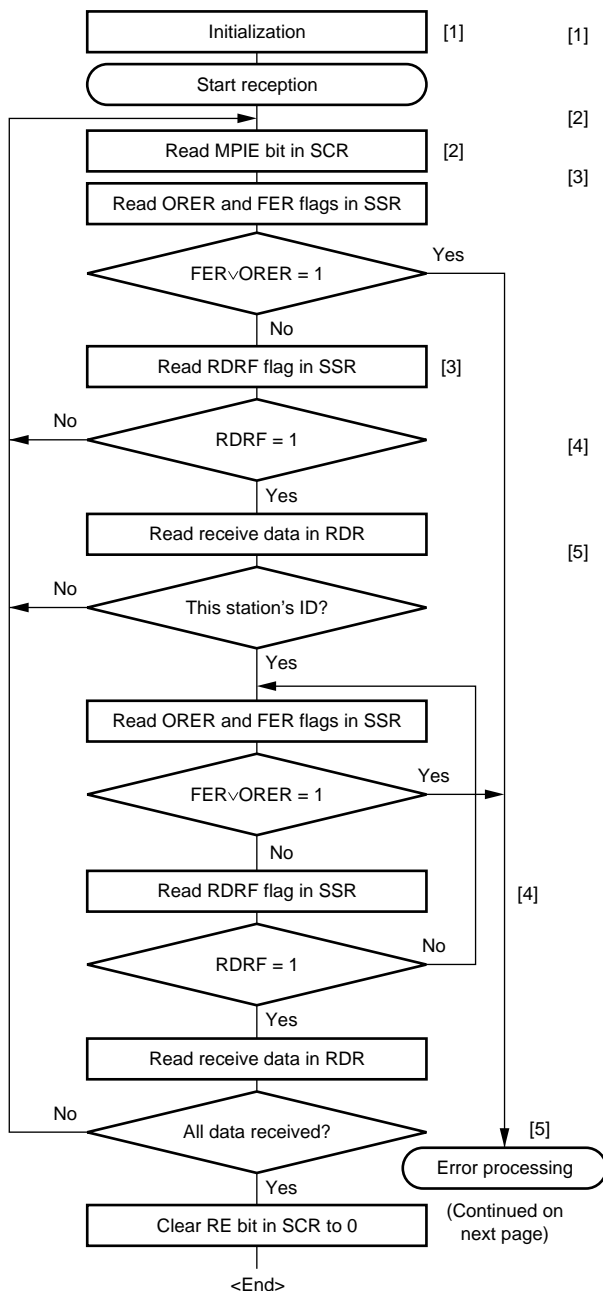
Figure 13.14 Sample Multiprocessor Serial Transmission Flowchart

13.5.2 Multiprocessor Serial Data Reception

Figure 13.16 shows a sample flowchart for multiprocessor serial data reception. If the MPIE bit in SCR 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 SCI operations are the same as in asynchronous mode. Figure 13.15 shows an example of SCI operation for multiprocessor format reception.



**Figure 13.15 Example of SCI Operation in Reception
(Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)**



- [1] SCI initialization:
The Rx/D pin is automatically designated as the receive data input pin.
- [2] ID reception cycle:
Set the MPIE bit in SCR to 1.
- [3] SCI status check, ID reception and comparison:
Read SSR and check that the RDRF flag is set to 1, then read the receive data in RDR and compare it with this station's ID.
If the data is not this station's ID, set the MPIE bit to 1 again, and clear the RDRF flag to 0.
If the data is this station's ID, clear the RDRF flag to 0.
- [4] SCI status check and data reception:
Read SSR and check that the RDRF flag is set to 1, then read the data in RDR.
- [5] Receive error processing and break detection:
If a receive error occurs, read the ORER and FER flags in SSR to identify the error. After performing the appropriate error processing, ensure that the ORER and FER flags are all cleared to 0. Reception cannot be resumed if either of these flags is set to 1.
In the case of a framing error, a break can be detected by reading the Rx/D pin value.

Figure 13.16 Sample Multiprocessor Serial Reception Flowchart (1)

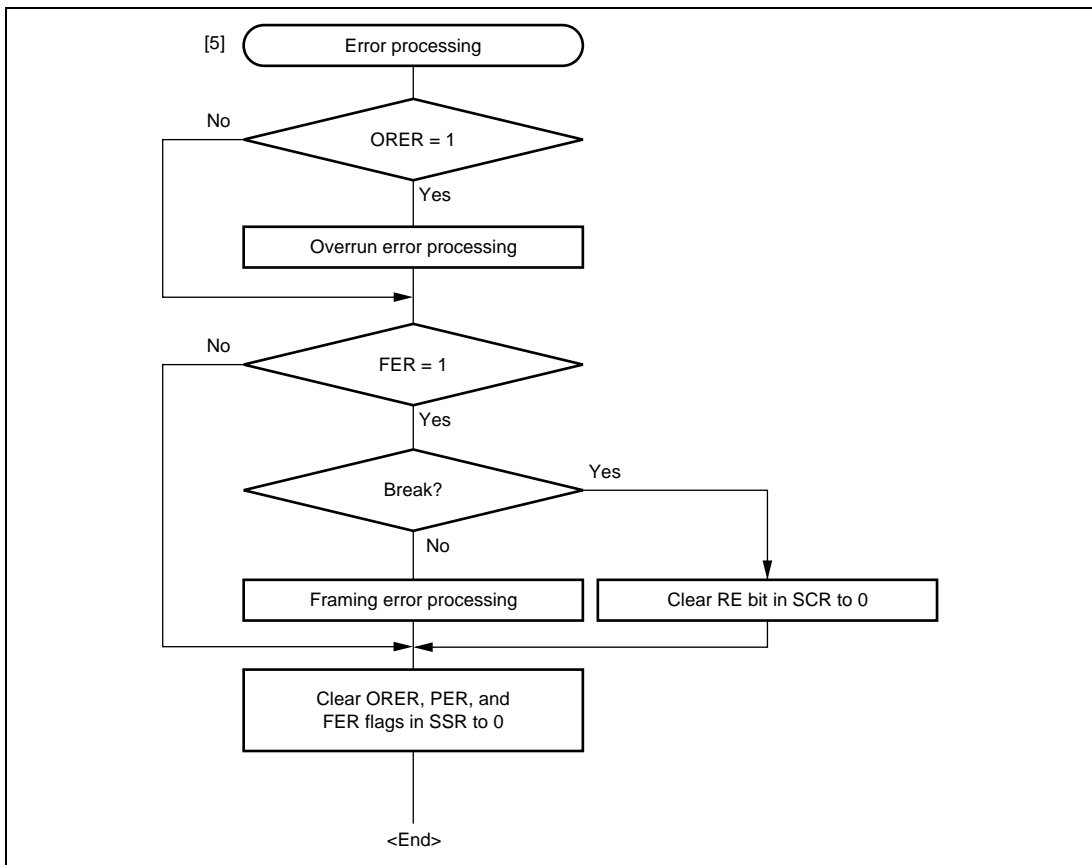


Figure 13.16 Sample Multiprocessor Serial Reception Flowchart (2)

13.6 Operation in Clocked Synchronous Mode

Figure 13.17 shows the general format for clocked synchronous communication. In clocked synchronous mode, data is transmitted or received synchronous with clock pulses. In clocked synchronous serial communication, data on the transmission line is output from one falling edge of the serial clock to the next. In clocked synchronous mode, the SCI receives data in synchronous with the rising edge of the serial 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 SCI, 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.

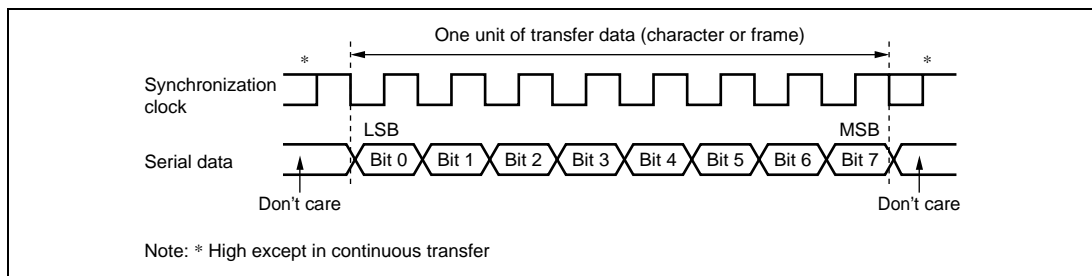


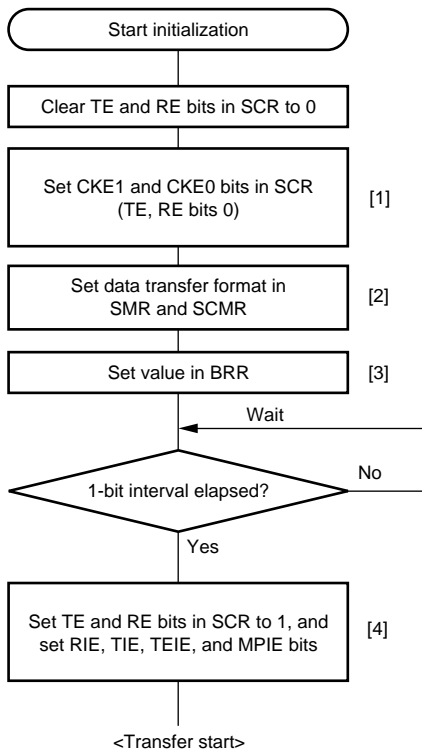
Figure 13.17 Data Format in Synchronous Communication (For LSB-First)

13.6.1 Clock

Either an internal clock generated by the on-chip baud rate generator or an external synchronization clock input at the SCK pin can be selected, according to the setting of CKE0 and CKE1 bits in SCR. When the SCI is operated on an internal clock, the serial clock is output from the SCK pin. Eight serial clock pulses are output in the transfer of one character, and when no transfer is performed the clock is fixed high.

13.6.2 SCI Initialization (Clocked Synchronous Mode)

Before transmitting and receiving data, the TE and RE bits in SCR should be cleared to 0, then the SCI should be initialized as described in a sample flowchart in figure 13.18. 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, PER, FER, and ORER flags, or the contents of RDR.



- [1] Set the clock selection in SCR. Be sure to clear bits RIE, TIE, TEIE, and MPIE, TE and RE, to 0.
- [2] Set the data transfer format in SMR and SCMR.
- [3] Write a 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 SCR to 1. Also set the RIE, TIE, TEIE, and MPIE bits. Setting the TE and RE bits enables the TxD and RxD pins to be used.

Note: In simultaneous transmit and receive operations, the TE and RE bits should both be cleared to 0 or set to 1 simultaneously.

Figure 13.18 Sample SCI Initialization Flowchart

13.6.3 Serial Data Transmission (Clocked Synchronous Mode)

Figure 13.19 shows an example of SCI operation for transmission in clocked synchronous mode. In serial transmission, the SCI operates as described below.

1. The SCI monitors the TDRE flag in SSR, and if the flag is 0, the SCI recognizes that data has been written to TDR, and transfers the data from TDR to TSR.
2. After transferring data from TDR to TSR, the SCI sets the TDRE flag to 1 and starts transmission. If the TIE bit in SCR is set to 1 at this time, a transmit data empty interrupt (TXI) is generated. Continuous transmission is possible because the TXI interrupt routine writes the next transmit data to TDR before transmission of the current transmit data has been completed.
3. 8-bit data is sent from the TxD pin synchronized with the output clock when output clock mode has been specified, and synchronized with the input clock when use of an external clock has been specified.
4. The SCI 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 serial 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 last bit. If the TEIE bit in SCR is set to 1 at this time, a TEI interrupt request is generated. The SCK pin is fixed high.

Figure 13.20 shows a sample flow chart for serial data transmission. Even if the TDRE flag is cleared to 0, transmission will not start while a receive error flag (ORER, FER, or PER) is set to 1. Make sure that the receive error flags are cleared to 0 before starting transmission. Note that clearing the RE bit to 0 does not clear the receive error flags.

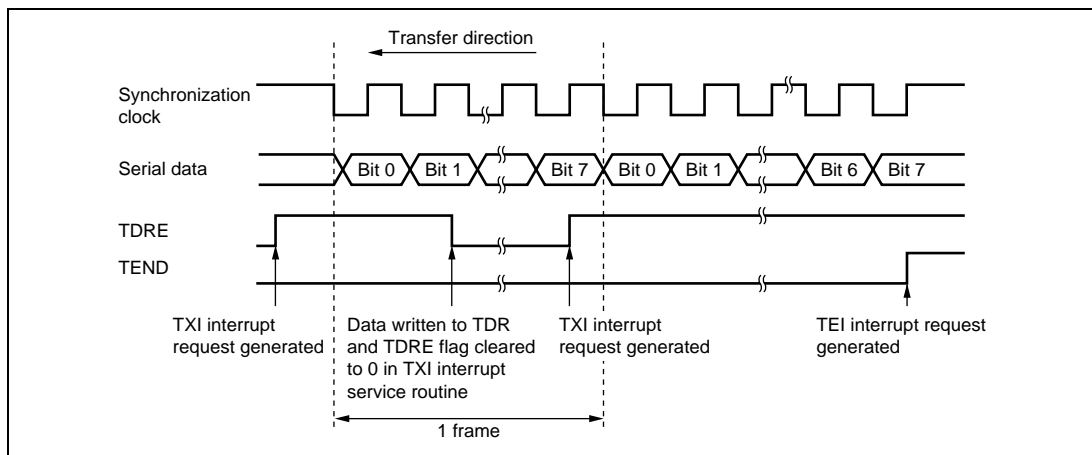
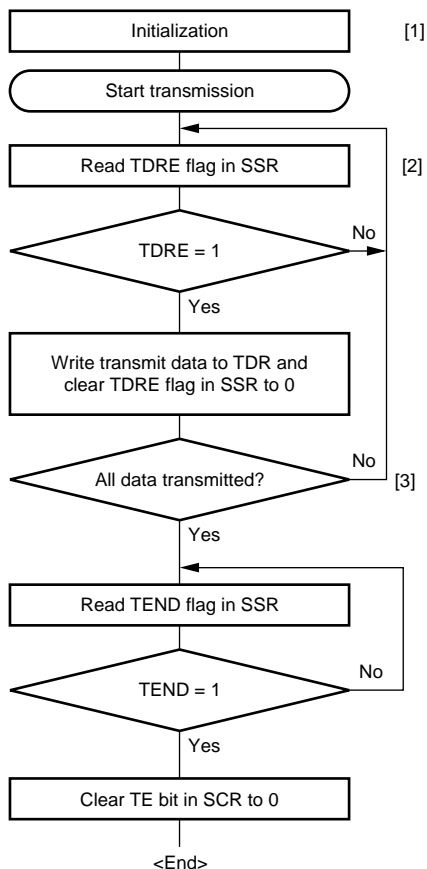


Figure 13.19 Sample SCI Transmission Operation in Clocked Synchronous Mode



- [1] SCI initialization:
The TxD pin is automatically designated as the transmit data output pin.
- [2] SCI status check and transmit data write:
Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR and clear the TDRE flag to 0.
- [3] Serial transmission continuation procedure:
To continue serial transmission, be sure to read 1 from the TDRE flag to confirm that writing is possible, then write data to TDR, and then clear the TDRE flag to 0.
Checking and clearing of the TDRE flag is automatic when the DTC is activated by a transmit data empty interrupt (TXI) request and data is written to TDR. (H8S/2268 Series only)

Figure 13.20 Sample Serial Transmission Flowchart

13.6.4 Serial Data Reception (Clocked Synchronous Mode)

Figure 13.21 shows an example of SCI operation for reception in clocked synchronous mode. In serial reception, the SCI operates as described below.

1. The SCI performs internal initialization synchronous with a synchronous clock input or output, starts receiving data, and stores the received data in RSR.
2. 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 ORER bit in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated, receive data is not transferred to RDR, and the RDRF flag remains to be set to 1.
3. 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 SCR 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 finished.

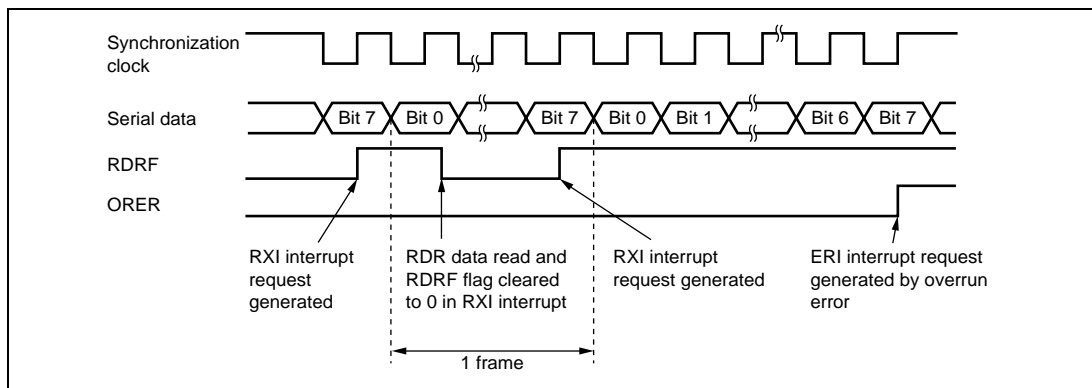


Figure 13.21 Example of SCI Operation in Reception

Reception cannot be resumed while a receive error flag is set to 1. Accordingly, clear the ORER, FER, PER, and RDRF bits to 0 before resuming reception. Figure 13.22 shows a sample flow chart for serial data reception.

An overrun error occurs or synchronous clocks are output until the RE bit is cleared to 0 when an internal clock is selected and only receive operation is possible. When a transmission and reception will be carried out in a unit of one frame, be sure to carry out a dummy transmission with only one frame by the simultaneous transmit and receive operations at the same time.

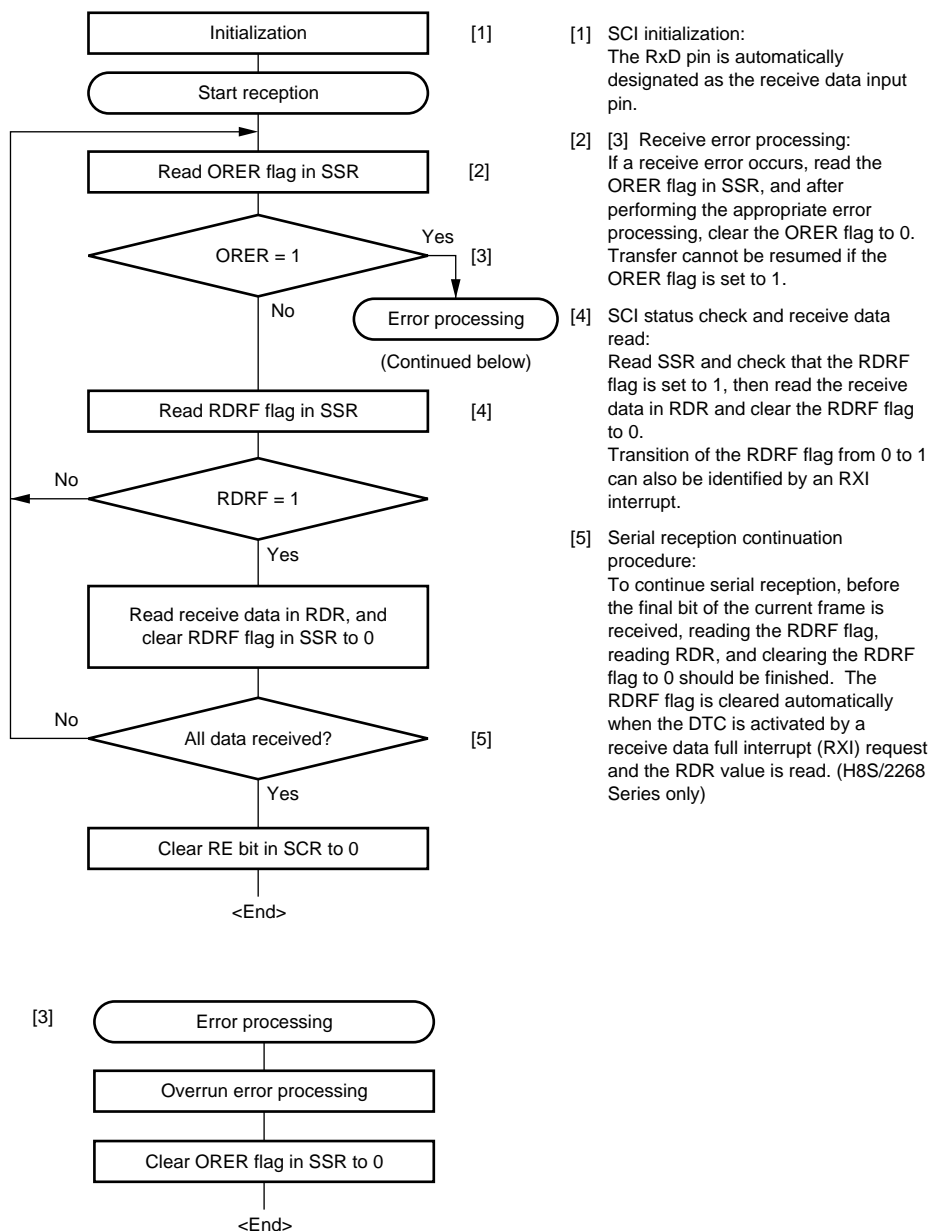
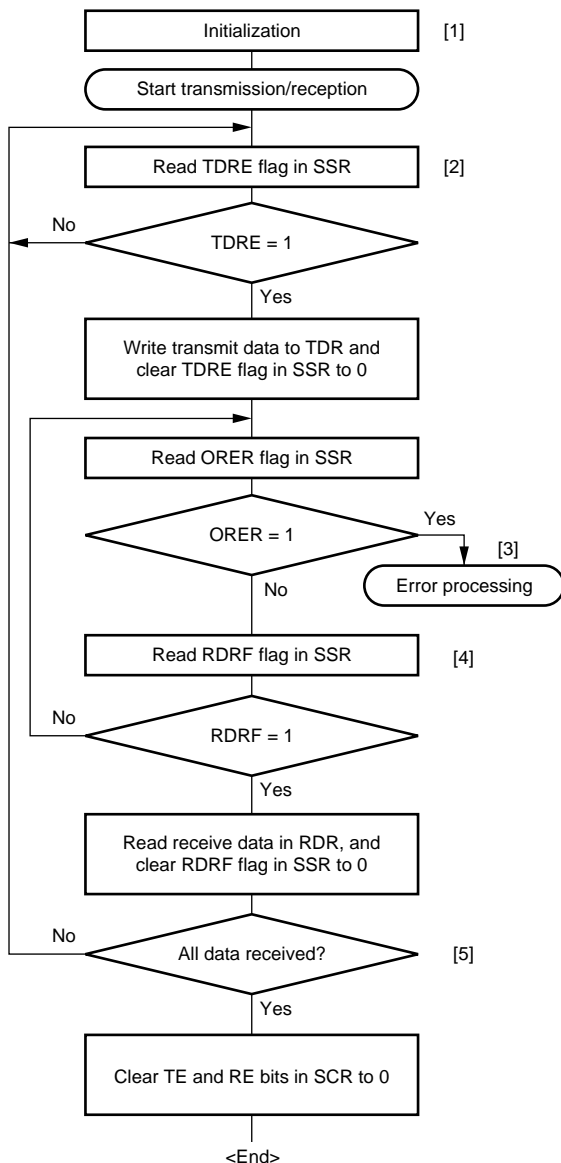


Figure 13.22 Sample Serial Reception Flowchart

13.6.5 Simultaneous Serial Data Transmission and Reception (Clocked Synchronous Mode)

Figure 13.23 shows a sample flowchart for simultaneous serial transmit and receive operations. The following procedure should be used for simultaneous serial data transmit and receive operations. To switch from transmit mode to simultaneous transmit and receive mode, after checking that the SCI 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 SCI has finished reception, clear RE to 0. Then after checking that the RDRF and receive error flags (ORER, FER, and PER) are cleared to 0, simultaneously set TE and RE to 1 with a single instruction.



- [1] SCI initialization:
The TxD pin is designated as the transmit data output pin, and the RxD pin is designated as the receive data input pin, enabling simultaneous transmit and receive operations.
- [2] SCI status check and transmit data write:
Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR and clear the TDRE flag to 0. Transition of the TDRE flag from 0 to 1 can also be identified by a TXI interrupt.
- [3] Receive error processing:
If a receive error occurs, read the ORER flag in SSR, and after performing the appropriate error processing, clear the ORER flag to 0. Transmission/reception cannot be resumed if the ORER flag is set to 1.
- [4] SCI status check and receive data read:
Read SSR and check that the RDRF flag is set to 1, then read the receive data in RDR and clear the RDRF flag to 0. Transition of the RDRF flag from 0 to 1 can also be identified by an RXI interrupt.
- [5] Serial transmission/reception continuation procedure:
To continue serial transmission/reception, before the final bit of the current frame is received, finish reading the RDRF flag, reading RDR, and clearing the RDRF flag to 0. Also, before the final bit of the current frame is transmitted, read 1 from the TDRE flag to confirm that writing is possible. Then write data to TDR and clear the TDRE flag to 0. Checking and clearing of the TDRE flag is automatic when the DTC is activated by a transmit data empty interrupt (TXI) request and data is written to TDR. Also, the RDRF flag is cleared automatically when the DTC is activated by a receive data full interrupt (RXI) request and the RDR value is read. (H8S/2268 Series only)

Note: When switching from transmit or receive operation to simultaneous transmit and receive operations, first clear the TE bit and RE bit to 0, then set both these bits to 1 by one instruction simultaneously.

Figure 13.23 Sample Flowchart of Simultaneous Serial Transmit and Receive Operations

13.7 Operation in Smart Card Interface

The SCI supports an IC card (Smart Card) interface that conforms to ISO/IEC 7816-3 (Identification Card) as a serial communication interface extension function. Switching between the normal serial communication interface and the Smart Card interface mode is carried out by means of a register setting.

13.7.1 Pin Connection Example

Figure 13.24 shows an example of connection with the Smart Card. In communication with an IC card, as both transmission and reception are carried out on a single data transmission line, the Tx/D pin and Rx/D pin should be connected to the LSI pin. The data transmission line should be pulled up to the V_{CC} power supply with a resistor. If an IC card is not connected, and the TE and RE bits are both set to 1, closed transmission/reception is possible, enabling self-diagnosis to be carried out. When the clock generated on the Smart Card interface is used by an IC card, the SCK pin output is input to the CLK pin of the IC card. This LSI port output is used as the reset signal.

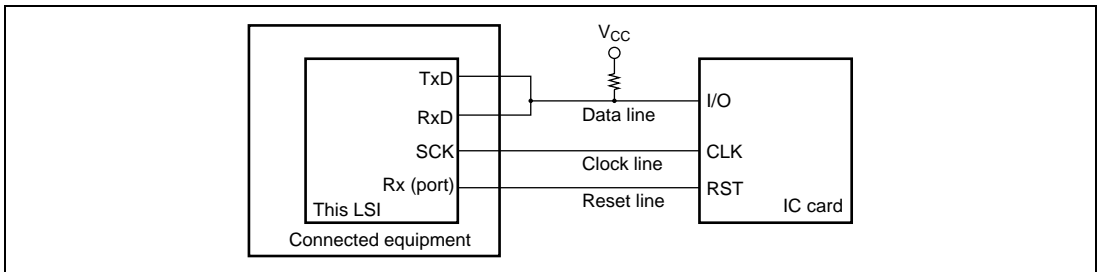


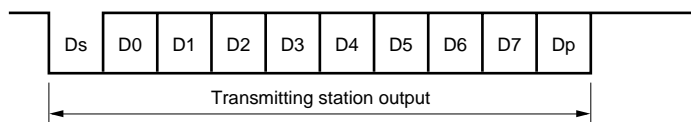
Figure 13.24 Schematic Diagram of Smart Card Interface Pin Connections

13.7.2 Data Format (Except for Block Transfer Mode)

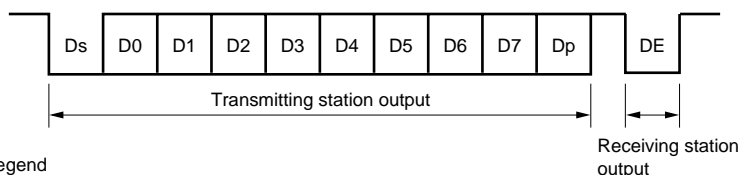
Figure 13.25 shows the transfer data format in Smart Card interface mode.

- One frame consists of 8-bit data plus a parity bit in asynchronous mode.
- In transmission, a guard time of at least 2 etu (Elementary Time Unit: the time for transfer of one bit) is left between the end of the parity bit and the start of the next frame.
- If a parity error is detected during reception, a low error signal level is output for one etu period, 10.5 etu after the start bit.
- If an error signal is sampled during transmission, the same data is retransmitted automatically after a delay of 2 etu or longer.

When there is no parity error



When a parity error occurs



Legend

DS : Start bit
D0 to D7 : Data bits
Dp : Parity bit
DE : Error signal

Figure 13.25 Normal Smart Card Interface Data Format

Data transfer with other types of IC cards (direct convention and inverse convention) are performed as described in the following.

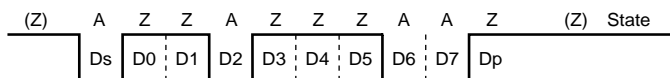


Figure 13.26 Direct Convention ($SDIR = SINV = \overline{O/E} = 0$)

With the direction convention type IC and the above sample start character, the logic 1 level corresponds to state Z and the logic 0 level to state A, and transfer is performed in LSB-first order. The start character data above is H'3B. For the direct convention type, clear the SDIR and SINV bits in SCMR to 0. According to Smart Card regulations, clear the $\overline{O/E}$ bit in SMR to 0 to select even parity mode.

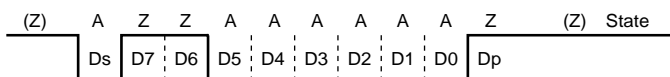


Figure 13.27 Inverse Convention ($SDIR = SINV = \overline{O/E} = 1$)

With the inverse convention type, the logic 1 level corresponds to state A and the logic 0 level to state Z, and transfer is performed in MSB-first order. The start character data for the above is H'3F. For the inverse convention type, set the SDIR and SINV bits in SCMR to 1. According to Smart Card regulations, even parity mode is the logic 0 level of the parity bit, and corresponds to state Z. In this LSI, the SINV bit inverts only data bits D0 to D7. Therefore, set the $\overline{O/E}$ bit in SMR to 1 to invert the parity bit for both transmission and reception.

13.7.3 Block Transfer Mode

Operation in block transfer mode is the same as that in the normal Smart Card interface mode, except for the following points.

- In reception, though the parity check is performed, no error signal is output even if an error is detected. However, the PER bit in SSR is set to 1 and must be cleared before receiving the parity bit of the next frame.
- In transmission, a guard time of at least 1 etu is left between the end of the parity bit and the start of the next frame.
- In transmission, because retransmission is not performed, the TEND flag is set to 1, 11.5 etu after transmission start.
- As with the normal Smart Card interface, the ERS flag indicates the error signal status, but since error signal transfer is not performed, this flag is always cleared to 0.

13.7.4 Receive Data Sampling Timing and Reception Margin

In Smart Card interface mode an internal clock generated by the on-chip baud rate generator can only be used as a transmission/reception clock. In this mode, the SCI operates on a basic clock with a frequency of 32, 64, 372, or 256 times the transfer rate (fixed to 16 times in normal asynchronous mode) as determined by bits BCP1 and BCP0. In reception, the SCI samples the falling edge of the start bit using the basic clock, and performs internal synchronization. As shown in figure 13.28, by sampling receive data at the rising-edge of the 16th, 32nd, 186th, or 128th pulse of the basic clock, data can be latched at the middle of the bit. The reception margin is given by the following formula.

$$M = \left| \left(0.5 - \frac{1}{2N} \right) - (L - 0.5) F - \frac{|D - 0.5|}{N} (1 + F) \right| \times 100\%$$

Where M: Reception margin (%)

N: Ratio of bit rate to clock (N = 32, 64, 372, and 256)

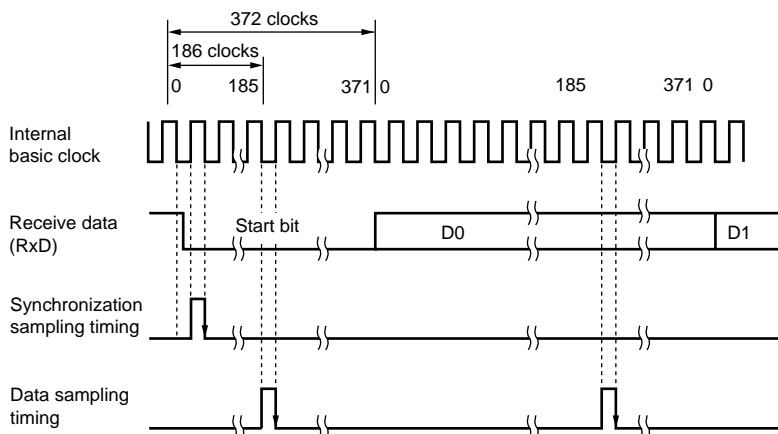
D: Clock duty (D = 0 to 1.0)

L: Frame length (L = 10)

F: Absolute value of clock frequency deviation

Assuming values of F = 0, D = 0.5 and N = 372 in the above formula, the reception margin formula is as follows.

$$\begin{aligned} M &= (0.5 - 1/2 \times 372) \times 100\% \\ &= 49.866\% \end{aligned}$$



**Figure 13.28 Receive Data Sampling Timing in Smart Card Mode
(Using Clock of 372 Times the Transfer Rate)**

13.7.5 Initialization

Before transmitting and receiving data, initialize the SCI as described below. Initialization is also necessary when switching from transmit mode to receive mode, or vice versa.

1. Clear the TE and RE bits in SCR to 0.
2. Clear the error flags ERS, PER, and ORER in SSR to 0.
3. Set the GM, BLK, O/ \bar{E} , BCP0, BCP1, CKS0, CKS1 bits in SMR. Set the PE bit to 1.
4. Set the SMIF, SDIR, and SINV bits in SCMR.

When the SMIF bit is set to 1, the TxD and RxD pins are both switched from ports to SCI pins, and are placed in the high-impedance state.

5. Set the value corresponding to the bit rate in BRR.
6. Set the CKE0 and CKE1 bits in SCR. Clear the TIE, RIE, TE, RE, MPiE, and TEiE bits to 0.

If the CKE0 bit is set to 1, the clock is output from the SCK pin.

7. Wait at least one bit interval, then set the TIE, RIE, TE, and RE bits in SCR. Do not set the TE bit and RE bit at the same time, except for self-diagnosis.

To switch from receive mode to transmit mode, after checking that the SCI has finished reception, initialize the SCI, and set RE to 0 and TE to 1. Whether SCI has finished reception or not can be checked with the RDRF, PER, or ORER flags. To switch from transmit mode to receive mode, after checking that the SCI has finished transmission, initialize the SCI, and set TE to 0 and RE to 1. Whether SCI has finished transmission or not can be checked with the TEND flag.

13.7.6 Serial Data Transmission (Except for Block Transfer Mode)

As data transmission in Smart Card interface mode involves error signal sampling and retransmission processing, the operations are different from those in normal serial communication interface mode (except for block transfer mode). Figure 13.29 illustrates the retransfer operation when the SCI is in transmit mode.

1. If an error signal is sent back from the receiving end after transmission of one frame is complete, the ERS bit in SSR is set to 1. If the RIE bit in SCR is enabled at this time, an ERI interrupt request is generated. The ERS bit in SSR should be cleared to 0 by the time the next parity bit is sampled.
2. The TEND bit in SSR is not set for a frame in which an error signal indicating an abnormality is received. Data is retransferred from TDR to TSR, and retransmitted automatically.
3. If an error signal is not sent back from the receiving end, the ERS bit in SSR is not set. Transmission of one frame, including a retransfer, is judged to have been completed, and the TEND bit in SSR is set to 1. If the TIE bit in SCR is enabled at this time, a TXI interrupt request is generated. Writing transmit data to TDR transfers the next transmit data.

Figure 13.31 shows a flowchart for transmission. In the H8S/2268 Series, a sequence of transmit operations can be performed automatically by specifying the DTC to be activated with a TXI interrupt source. In a transmit operation, the TDRE flag is set to 1 at the same time as the TEND flag in SSR is set, and a TXI interrupt will be generated if the TIE bit in SCR has been set to 1. If the TXI request is designated beforehand as a DTC activation source, the DTC will be activated by the TXI request, and transfer of the transmit data will be carried out. The TDRE and TEND flags are automatically cleared to 0 when data is transferred by the DTC. In the event of an error, the SCI retransmits the same data automatically. During this period, the TEND flag remains cleared to 0 and the DTC is not activated. Therefore, the SCI and DTC will automatically transmit the specified number of bytes in the event of an error, including retransmission. However, the ERS flag is not cleared automatically when an error occurs, and so the RIE bit should be set to 1 beforehand so that an ERI request will be generated in the event of an error, and the ERS flag will be cleared.

When performing transfer using the DTC, it is essential to set and enable the DTC before carrying out SCI setting. For details of the DTC setting procedures, refer to section 8, Data Transfer Controller (DTC).

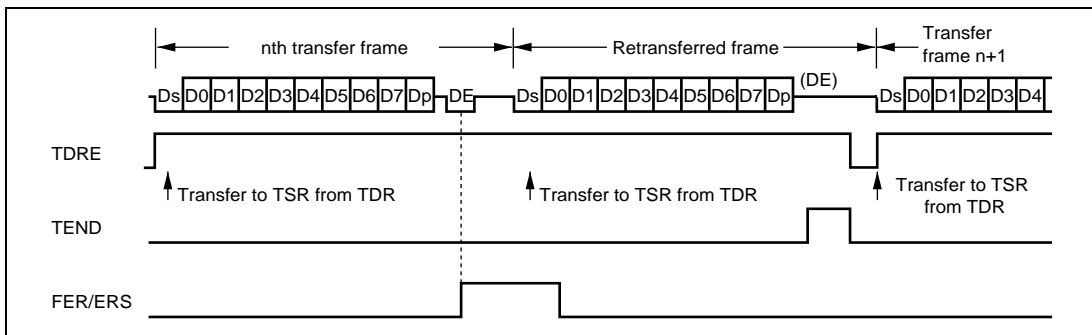


Figure 13.29 Retransfer Operation in SCI Transmit Mode

The timing for setting the TEND flag depends on the value of the GM bit in SMR. The TEND flag set timing is shown in figure 13.30.

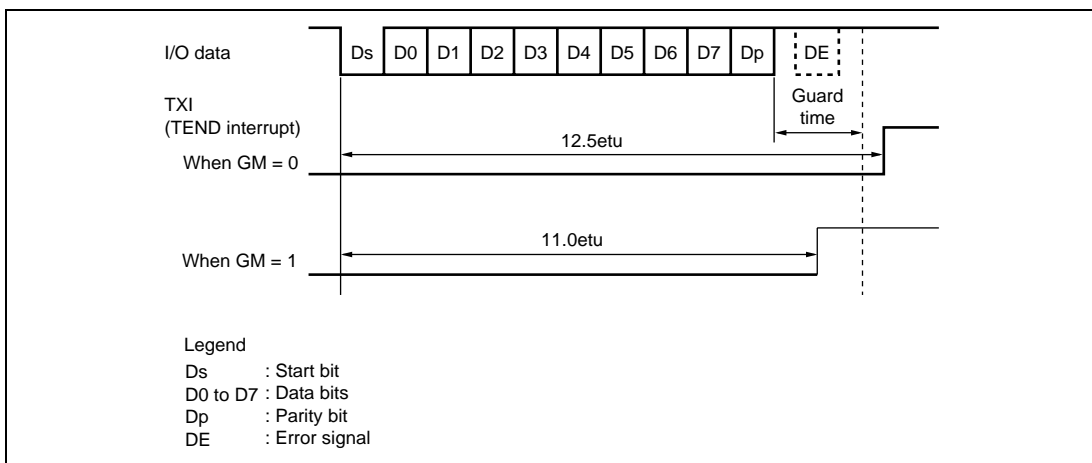


Figure 13.30 TEND Flag Generation Timing in Transmission Operation

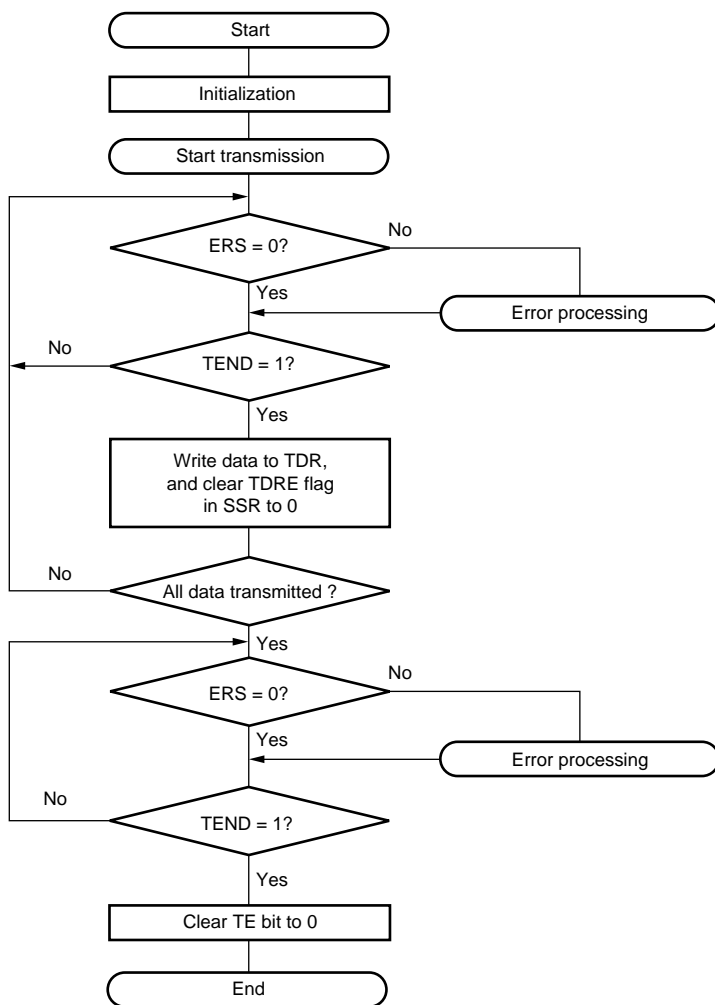


Figure 13.31 Example of Transmission Processing Flow

13.7.7 Serial Data Reception (Except for Block Transfer Mode)

Data reception in Smart Card interface mode uses the same operation procedure as for normal serial communication interface mode. Figure 13.32 illustrates the retransfer operation when the SCI is in receive mode.

1. If an error is found when the received parity bit is checked, the PER bit in SSR is automatically set to 1. If the RIE bit in SCR is set at this time, an ERI interrupt request is generated. The PER bit in SSR should be kept cleared to 0 until the next parity bit is sampled.
2. The RDRF bit in SSR is not set for a frame in which an error has occurred.
3. If no error is found when the received parity bit is checked, the PER bit in SSR is not set to 1, the receive operation is judged to have been completed normally, and the RDRF flag in SSR is automatically set to 1. If the RIE bit in SCR is enabled at this time, an RXI interrupt request is generated.

Figure 13.33 shows a flowchart for reception. In the H8S/2268 Series, a sequence of receive operations can be performed automatically by specifying the DTC to be activated using an RXI interrupt source. In a receive operation, an RXI interrupt request is generated when the RDRF flag in SSR is set to 1. If the RXI request is designated beforehand as a DTC activation source, the DTC will be activated by the RXI request, and the receive data will be transferred. The RDRF flag is cleared to 0 automatically when data is transferred by the DTC. If an error occurs in receive mode and the ORER or PER flag is set to 1, a transfer error interrupt (ERI) request will be generated. Hence, so the error flag must be cleared to 0. In the event of an error, the DTC is not activated and receive data is skipped. Therefore, receive data is transferred for only the specified number of bytes in the event of an error. Even when a parity error occurs in receive mode and the PER flag is set to 1, the data that has been received is transferred to RDR and can be read from there.

Note: For details on receive operations in block transfer mode, refer to section 13.4, Operation in Asynchronous Mode.

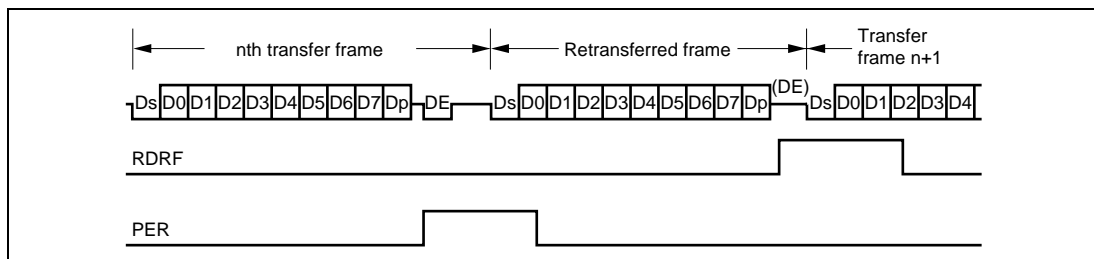


Figure 13.32 Retransfer Operation in SCI Receive Mode

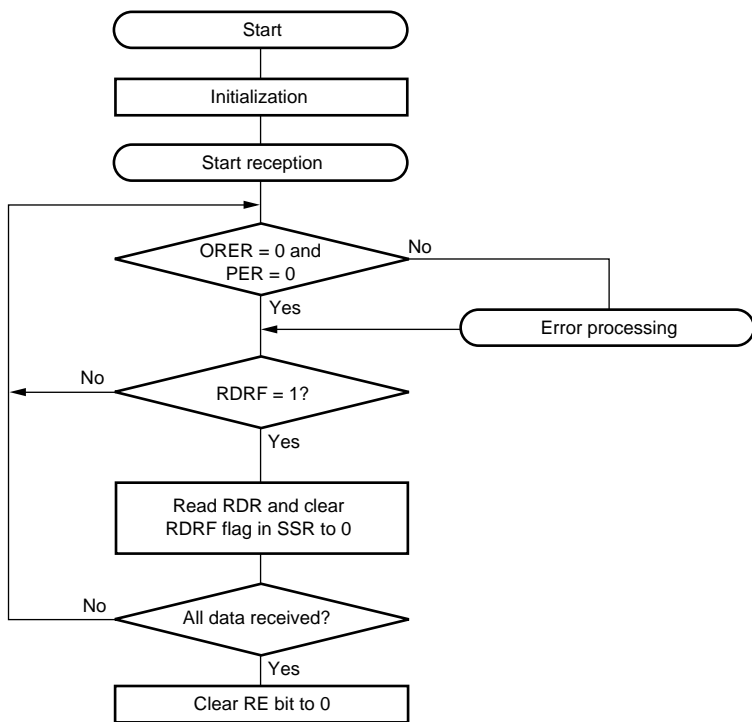


Figure 13.33 Example of Reception Processing Flow

13.7.8 Clock Output Control

When the GM bit in SMR is set to 1, the clock output level can be fixed with bits CKE0 and CKE1 in SCR. At this time, the minimum clock pulse width can be made the specified width. Figure 13.34 shows the timing for fixing the clock output level. In this example, GM is set to 1, CKE1 is cleared to 0, and the CKE0 bit is controlled.

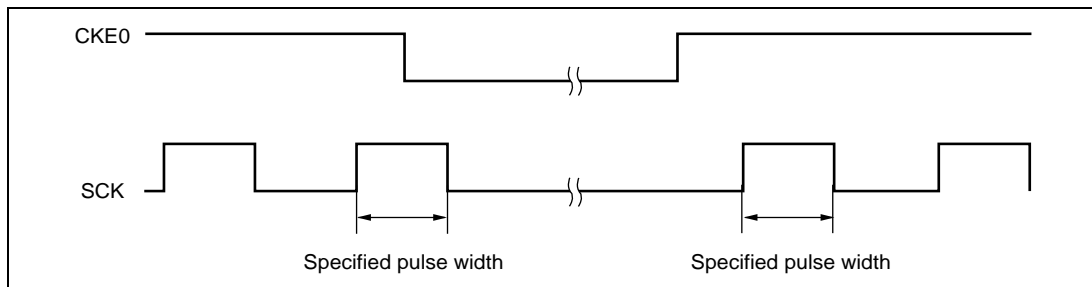


Figure 13.34 Timing for Fixing Clock Output Level

When turning on the power or switching between Smart Card interface mode and software standby mode, the following procedures should be followed in order to maintain the clock duty.

Powering On: To secure clock duty from power-on, the following switching procedure should be followed.

1. The initial state is port input and high impedance. Use a pull-up resistor or pull-down resistor to fix the potential.
2. Fix the SCK pin to the specified output level with the CKE1 bit in SCR.
3. Set SMR and SCMR, and switch to smart card mode operation.
4. Set the CKE0 bit in SCR to 1 to start clock output.

When changing from smart card interface mode to software standby mode:

1. Set the data register (DR) and data direction register (DDR) corresponding to the SCK pin to the value for the fixed output state in software standby mode.
2. Write 0 to the TE bit and RE bit in the serial control register (SCR) to halt transmit/receive operation. At the same time, set the CKE1 bit to the value for the fixed output state in software standby mode.
3. Write 0 to the CKE0 bit in SCR to halt the clock.
4. Wait for one serial clock period.

During this interval, clock output is fixed at the specified level, with the duty preserved.

5. Make the transition to the software standby state.

When returning to smart card interface mode from software standby mode:

1. Exit the software standby state.
2. Write 1 to the CKE0 bit in SCR and output the clock. Signal generation is started with the normal duty.

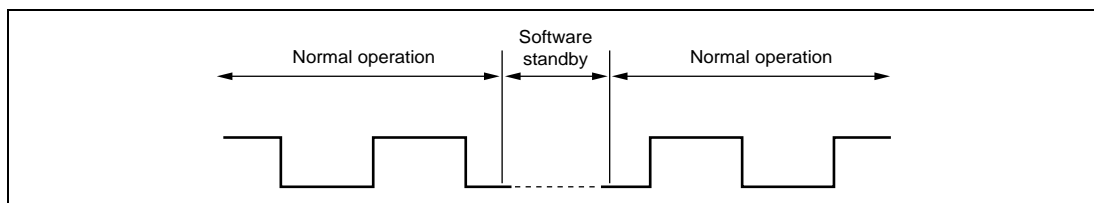


Figure 13.35 Clock Halt and Restart Procedure

13.8 Interrupt Sources

13.8.1 Interrupts in Normal Serial Communication Interface Mode

Table 13.12 shows the interrupt sources in normal serial communication interface mode. A different interrupt vector is assigned to each interrupt source, and individual interrupt sources can be enabled or disabled using the enable bits in SCR.

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.

A TXI interrupt can activate the DTC to perform data transfer. The TDRE flag is cleared to 0 automatically when data is transferred by the DTC. (H8S/2268 Series only)

When the RDRF flag in SSR is set to 1, an RXI interrupt request is generated. When the ORER, PER, or FER flag in SSR is set to 1, an ERI interrupt request is generated.

An RXI interrupt request can activate the DTC to transfer data. The RDRF flag is cleared to 0 automatically when data is transferred by the DTC. (H8S/2268 Series only)

A TEI interrupt is requested when the TEND flag is set to 1 and the TEIE bit is set to 1. If a TEI interrupt and a TXI interrupt are requested simultaneously, the TXI interrupt has priority for acceptance. However, if the TDRE and TEND flags are cleared simultaneously by the TXI interrupt routine, the SCI cannot branch to the TEI interrupt routine later.

Table 13.12 Interrupt Sources of Serial Communication Interface Mode

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation* ²	Priority* ¹
0	ERI0	Receive Error	ORER, FER, PER	Not possible	High
	RXI0	Receive Data Full	RDRF	Possible	↑
	TXI0	Transmit Data Empty	TDRE	Possible	
	TEI0	Transmission End	TEND	Not possible	
1	ERI1	Receive Error	ORER, FER, PER	Not possible	
	RXI1	Receive Data Full	RDRF	Possible	
	TXI1	Transmit Data Empty	TDRE	Possible	
	TEI1	Transmission End	TEND	Not possible	
2	ERI2	Receive Error	ORER, FER, PER	Not possible	
	RXI2	Receive Data Full	RDRF	Possible	
	TXI2	Transmit Data Empty	TDRE	Possible	
	TEI2	Transmission End	TEND	Not possible	Low

Notes: 1. Indicates the initial state immediately after a reset.

Priorities in channels can be changed by the interrupt controller. (H8S/2268 Series only)

2. Supported only by the H8S/2268 Series.

13.8.2 Interrupts in Smart Card Interface Mode

Table 13.13 shows the interrupt sources in Smart Card interface mode. The transmit end interrupt (TEI) request cannot be used in this mode.

Note: In case of block transfer mode, see 13.8.1, Interrupts in Nomal Serial Communication Interface Mode.

Table 13.13 Interrupt Sources in Smart Card Interface Mode

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation*2	Priority*1
0	ERI0	Receive Error, detection	ORER, PER, ERS	Not possible	High ↑ Low
	RXI0	Receive Data Full	RDRF	Possible	
	TXI0	Transmit Data Empty	TEND	Possible	
1	ERI1	Receive Error, detection	ORER, PER, ERS	Not possible	
	RXI1	Receive Data Full	RDRF	Possible	
	TXI1	Transmit Data Empty	TEND	Possible	
2	ERI2	Receive Error, detection	ORER, PER, ERS	Not possible	
	RXI2	Receive Data Full	RDRF	Possible	
	TXI2	Transmit Data Empty	TEND	Possible	

Notes: 1. Indicates the initial state immediately after a reset.

Priorities in channels can be changed by the interrupt controller. (H8S/2268 Series only)

2. Supported only by the H8S/2268 Series.

13.9 Usage Notes

13.9.1 Module Stop Mode Setting

SCI operation can be disabled or enabled using the module stop control register. The initial setting is for SCI operation to be halted. Register access is enabled by clearing module stop mode. For details, refer to section 22, Power-Down Modes.

13.9.2 Break Detection and Processing (Asynchronous mode only)

When framing error (FER) 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 SCI continues the receive operation after receiving a break, even if the FER flag is cleared to 0, it will be set to 1 again.

13.9.3 Mark State and Break Detection (Asynchronous mode only)

When TE is 0, the TxD pin is used as an I/O port whose direction (input or output) and level are determined by DDR. This can be used to set the TxD pin to mark state (high level) or send a break during serial data transmission. To maintain the communication line at mark state until TE is set to 1, set both DDR and DR to 1. As TE 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 serial transmission, first set PDR to 1 and DR to 0, and then clear TE to 0. When TE 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.

13.9.4 Receive Error Flags and Transmit Operations (Clocked Synchronous Mode Only)

Transmission cannot be started when a receive error flag (ORER, 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.

13.9.5 Restrictions on Use of DTC (H8S/2268 Series Only)

- When an external clock source is used as the serial clock, the transmit clock should not be input until at least 5 ϕ clock cycles after TDR is updated by the DTC. Misoperation may occur if the transmit clock is input within 4 ϕ clocks after TDR is updated. (Figure 13.36)
- When RDR is read by the DTC, be sure to set the activation source to the relevant SCI reception data full interrupt (RXI).

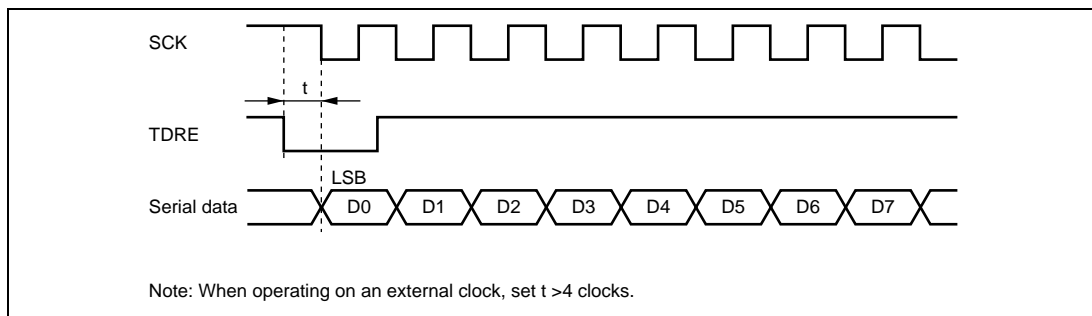


Figure 13.36 Example of Clocked Synchronous Transmission by DTC

13.9.6 Operation in Case of Mode Transition

- Transmission

Operation should be stopped (by clearing TE, TIE, and TEIE to 0) before making a module stop mode, software standby mode, watch mode, subactive mode, or subsleep mode transition. TSR, TDR, and SSR are reset. The output pin states in module stop mode, software standby mode, watch mode, subactive mode, or subsleep mode depend on the port settings, and becomes high-level output after the relevant mode is cleared. If a transition is made during transmission, the data being transmitted will be undefined. When transmitting without changing the transmit mode after the relevant mode is cleared, transmission can be started by setting TE to 1 again, and performing the following sequence: SSR read -> TDR write -> TDRE clearance. To transmit with a different transmit mode after clearing the relevant mode, the procedure must be started again from initialization. Figure 13.37 shows a sample flowchart for mode transition during transmission. Port pin states are shown in figures 13.38 and 13.39.

Operation should also be stopped (by clearing TE, TIE, and TEIE to 0) before making a transition from transmission by DTC transfer to module stop mode, software standby mode, watch mode, subactive mode, or subsleep mode transition. To perform transmission with the DTC after the relevant mode is cleared, setting TE and TIE to 1 will set the TXI flag and start DTC transmission. (H8S/2268 Series only)

- Reception

Receive operation should be stopped (by clearing RE to 0) before making a module stop mode, software standby mode, watch mode, subactive mode, or subsleep mode transition. RSR, RDR, and SSR are reset. If a transition is made without stopping operation, the data being received will be invalid.

To continue receiving without changing the reception mode after the relevant mode is cleared, set RE to 1 before starting reception. To receive with a different receive mode, the procedure must be started again from initialization.

Figure 13.40 shows a sample flowchart for mode transition during reception.

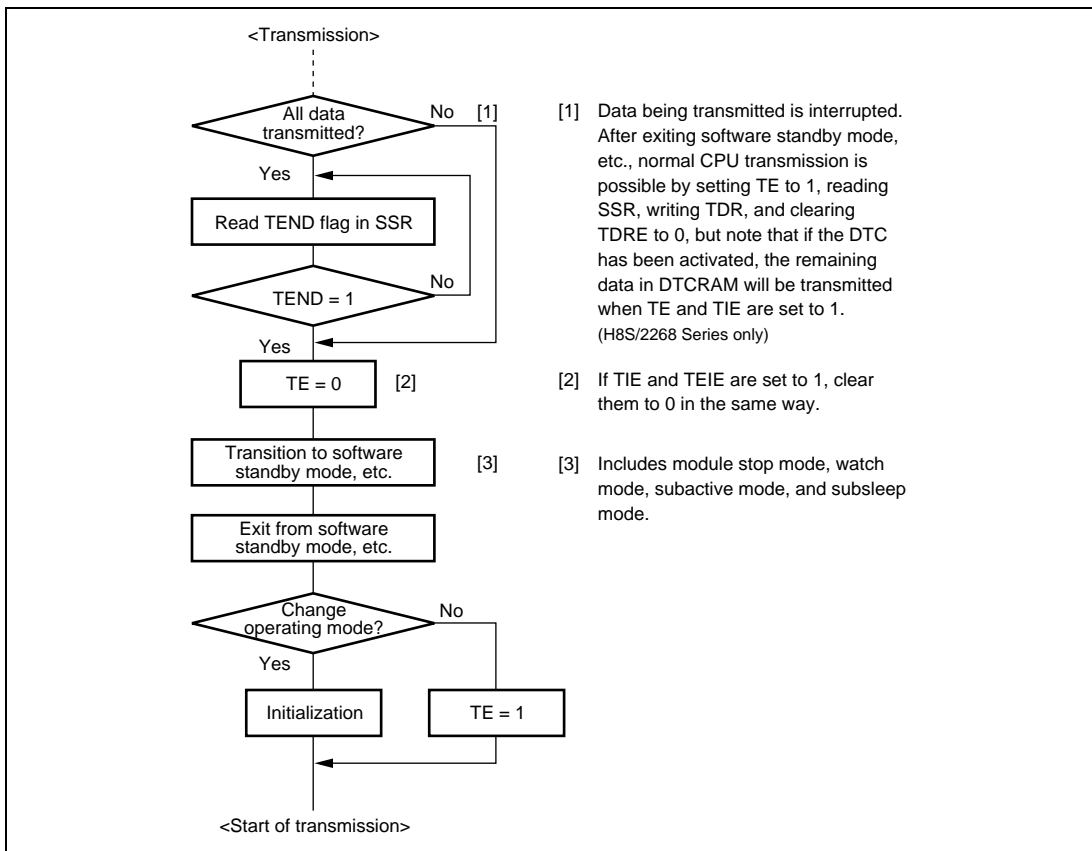


Figure 13.37 Sample Flowchart for Mode Transition during Transmission

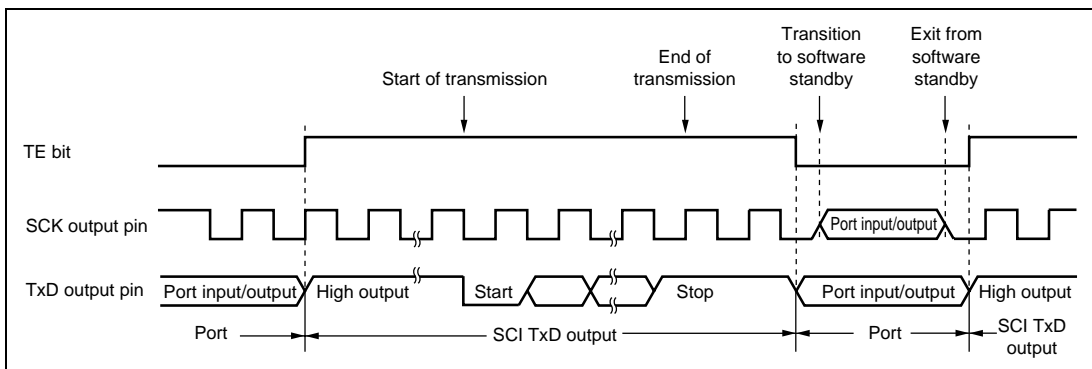


Figure 13.38 Asynchronous Transmission Using Internal Clock

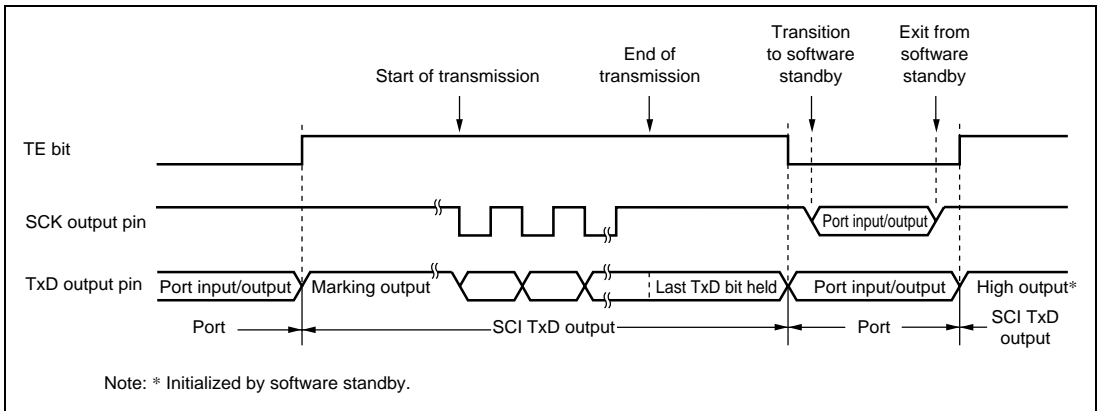


Figure 13.39 Synchronous Transmission Using Internal Clock

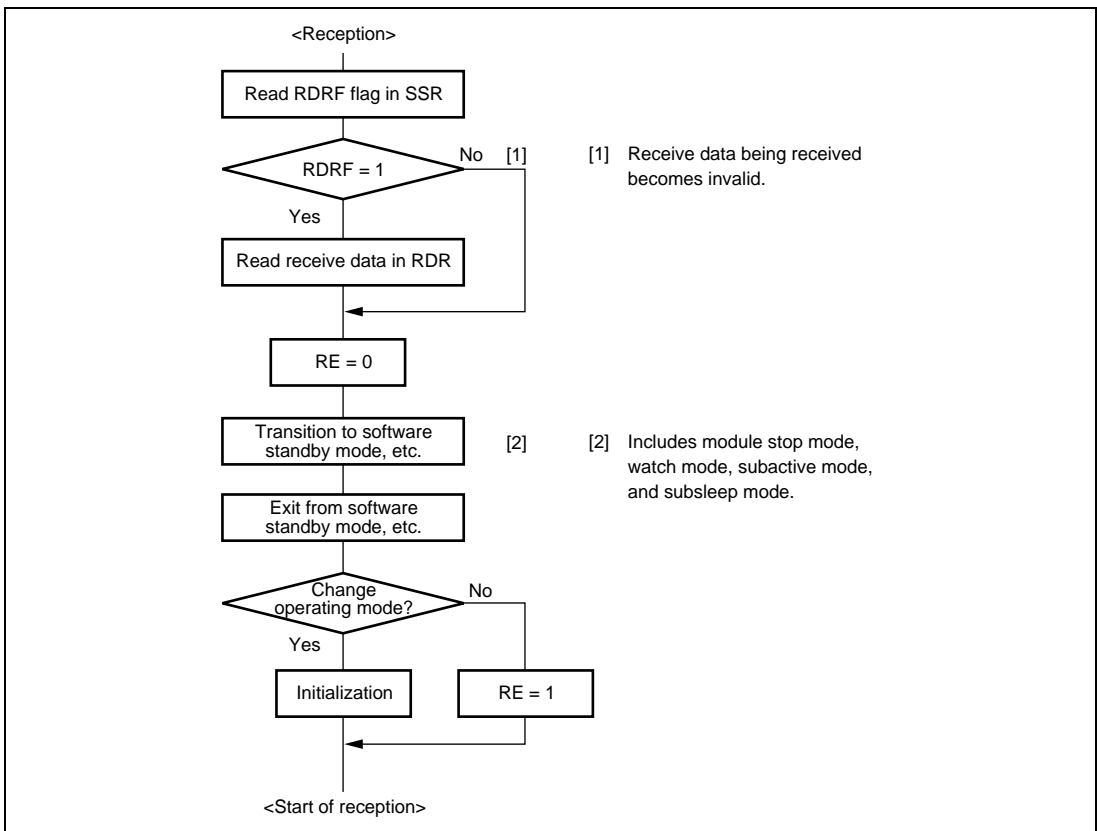


Figure 13.40 Sample Flowchart for Mode Transition during Reception

13.9.7 Switching from SCK Pin Function to Port Pin Function:

- Problem in Operation: When switching the SCK pin function to the output port function (high-level output) by making the following settings while $\text{DDR} = 1$, $\text{DR} = 1$, $\text{C}/\overline{\text{A}} = 1$, $\text{CKE1} = 0$, $\text{CKE0} = 0$, and $\text{TE} = 1$ (synchronous mode), low-level output occurs for one half-cycle.
- End of serial data transmission
 - $\text{TE} \text{ bit} = 0$
 - $\text{C}/\overline{\text{A}} \text{ bit} = 0 \dots$ switchover to port output
 - Occurrence of low-level output (see figure 13.41)

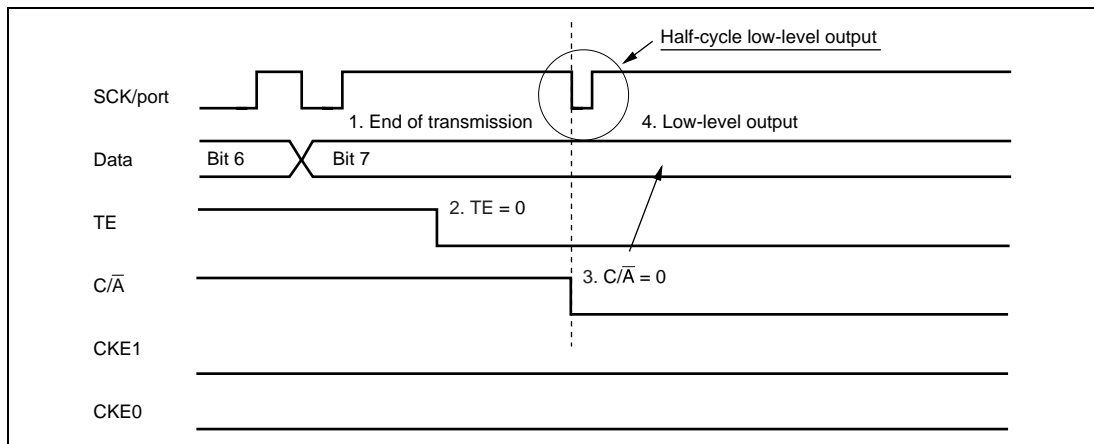
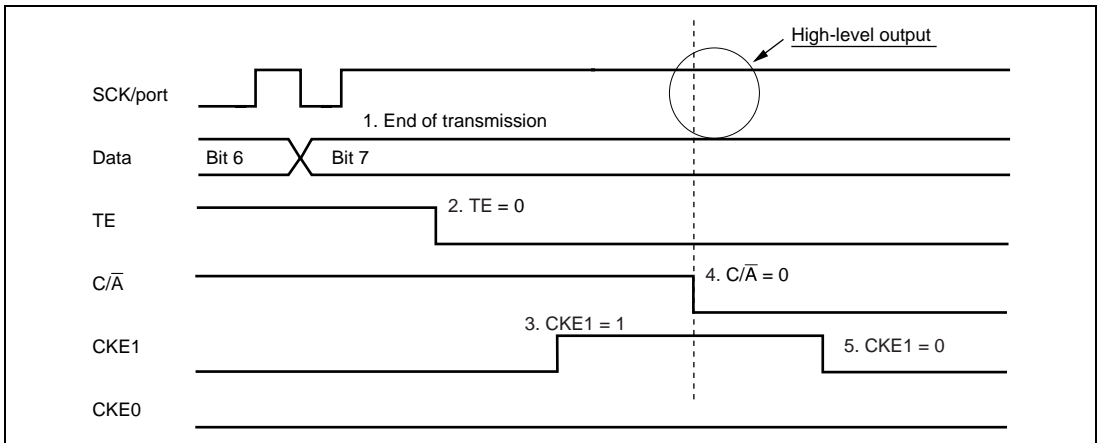


Figure 13.41 Operation when Switching from SCK Pin Function to Port Pin Function

- Sample Procedure for Avoiding Low-Level Output: As this sample procedure temporarily places the SCK pin in the input state, the SCK/port pin should be pulled up beforehand with an external circuit.

With $\text{DDR} = 1$, $\text{DR} = 1$, $\text{C}/\overline{\text{A}} = 1$, $\text{CKE1} = 0$, $\text{CKE0} = 0$, and $\text{TE} = 1$, make the following settings in the order shown.

- End of serial data transmission
- $\text{TE} \text{ bit} = 0$
- $\text{CKE1} \text{ bit} = 1$
- $\text{C}/\overline{\text{A}} \text{ bit} = 0 \dots$ switchover to port output
- $\text{CKE1} \text{ bit} = 0$



**Figure 13.42 Operation when Switching from SCK Pin Function to Port Pin Function
(Example of Preventing Low-Level Output)**

13.9.8 Assignment and Selection of Registers

Some serial communication interface registers are assigned to the same address as other registers. Register selection is performed by means of the IICE bit in the serial control register (SCRX). For details on register addresses, see section 25, List of Registers.

Section 14 I²C Bus Interface (IIC) (Option)

An I²C bus interface is available as an option. Observe the following notes when using this option.

1. For mask-ROM versions, a W is added to the part number in products in which this optional function is used.

Examples: HD6432268WTE

2. The product number is identical for F-ZTAT versions. However, be sure to inform your Hitachi sales representative if you will be using this option.

The H8S/2268 Series has an internal I²C bus interface of two channels, while the H8S/2264 Series has that of one channel.

The I²C bus interface 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.

The I²C bus interface data transfer is performed using a data line (SDA) and a clock line (SCL) for each channel, which allows efficient use of connectors and the area of the PCB.

14.1 Features

- Selection of I²C format or clocked synchronous serial format
 - I²C bus format: addressing format with acknowledge bit, for master/slave operation
 - Clocked synchronous serial format: non-addressing format without acknowledge bit, for master operation only

I²C bus format

- Two ways of setting slave address
- Start and stop conditions generated automatically in master mode
- Selection of acknowledge output levels when receiving
- Automatic loading of acknowledge bit when transmitting
- Wait function in master mode

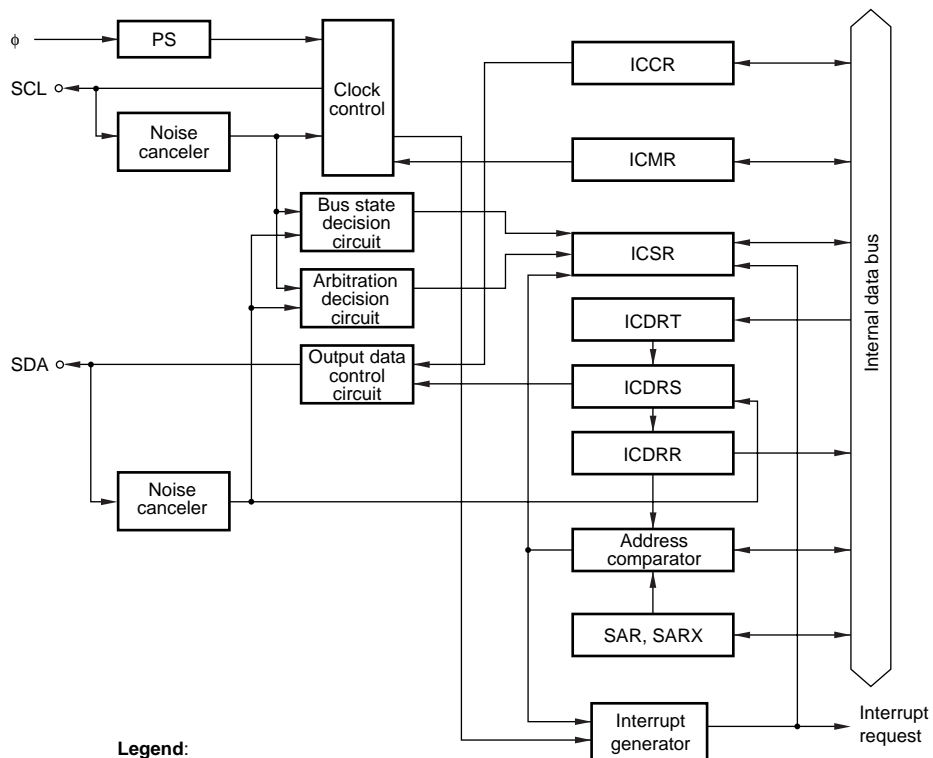
A wait can be inserted by driving the SCL pin low after data transfer, excluding acknowledgement. The wait can be cleared by clearing the interrupt flag.

- Wait function in slave mode

A wait request can be generated by driving the SCL pin low after data transfer, excluding acknowledgement. The wait request is cleared when the next transfer becomes possible.

- Three interrupt sources
 - Data transfer end (including transmission mode transition with I2C bus format and address reception after loss of master arbitration)
 - Address match: when any slave address matches or the general call address is received in slave receive mode
 - Stop condition detection
- Selection of 16 internal clocks (in master mode)
- Direct bus drive
 - Two pins, P35/SCL0 and P34/SDA0, function as NMOS open-drain outputs when the bus drive function is selected.
 - Two pins – P33/SCL1 and P32/SDA1 – function as NMOS-only outputs when the bus drive function is selected. (H8S/2268 Series only)

Figure 14.1 shows a block diagram of the I²C bus interface. Figure 14.2 shows an example of I/O pin connections to external circuits. Channel I/O pins are NMOS open drains, and it is possible to apply voltages in excess of the power supply (V_{cc}) voltage for this LSI. Set the upper limit of voltage applied to the power supply (V_{cc}) power supply range +0.3V, i.e.5.8.V. Channel 1 (H8S/2268 Series only) I/O pins are driven solely by NMOS, so in terms of appearance they carry out the same operations as an NMOS open drain. However, the voltage which can be applied to the I/O pins depends on the voltage of the power supply (V_{cc}) of this LSI.



Legend:

ICCR: I²C bus control register
 ICMR: I²C bus mode register
 ICSR: I²C bus status register
 ICDR: I²C bus data register
 SAR: Slave address register
 SARX: Slave address register X
 PS: Prescaler

Figure 14.1 Block Diagram of I²C Bus Interface

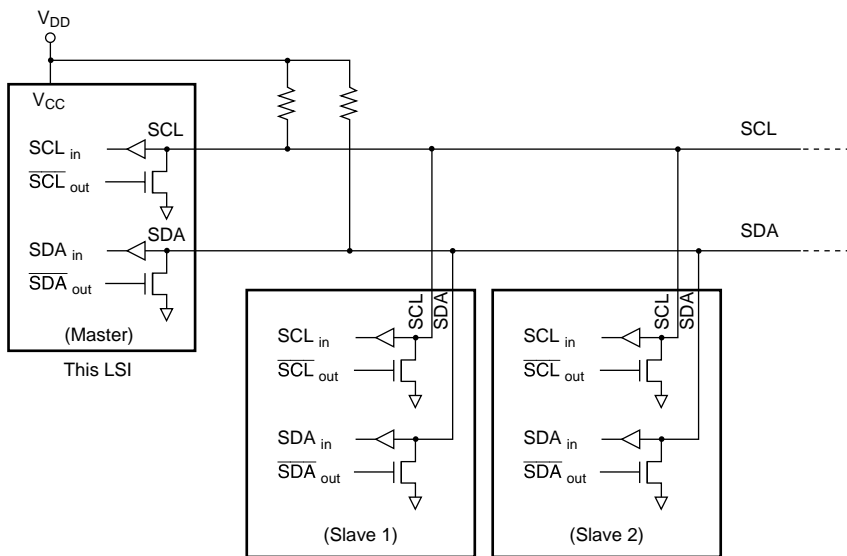


Figure 14.2 I²C Bus Interface Connections (Example: This LSI as Master)

14.2 Input/Output Pins

Table 14.1 shows the pin configuration for the I²C bus interface.

Table 14.1 Pin Configuration

Name	Abbreviation* ¹	I/O	Function
Serial clock	SCL0	I/O	IIC_0 serial clock input/output
Serial data	SDA0	I/O	IIC_0 serial data input/output
Serial clock* ²	SCL1	I/O	IIC_1 serial clock input/output
Serial data* ²	SDA1	I/O	IIC_1 serial data input/output

Notes: 1. In the text, the channel subscript is omitted, and only SCL and SDA are used.

2. Supported only by the H8S/2268 Series.

14.3 Register Descriptions

The I²C bus interface has the following registers. Registers ICDR and SARX and registers ICMR and SAR are allocated to the same addresses. Accessible addresses differ depending on the ICE bit in ICCR. SAR and SARX are accessed when ICE is 0, and ICMR and ICDR are accessed when ICE is 1. For details on the module stop control register, refer to section 22.1.2, Module Stop Control Registers A to D (MSTPCRA to MSTPCRD).

- I²C bus data register_0 (ICDR_0)
- Slave address register_0 (SAR_0)
- Second slave address register_0 (SARX_0)
- I²C bus mode register_0 (ICMR_0)
- I²C bus control register_0 (ICCR_0)
- I²C bus status register_0 (ICSR_0)
- I²C bus data register_1 (ICDR_1)*
- Slave address register_1 (SAR_1)*
- Second slave address register_1 (SARX_1)*
- I²C bus mode register_1 (ICMR_1)*
- I²C bus control register_1 (ICCR_1)*
- I²C bus status register_1 (ICSR_1)*
- DDC switch register (DDCSWR)
- Serial control register (SCRX)

Note: * Supported only by the H8S/2268 Series.

14.3.1 I²C Bus Data Register (ICDR)

ICDR is an 8-bit readable/writable register that is used as a transmit data register when transmitting and a receive data register when receiving. ICDR is divided internally into a shift register (ICDRS), receive buffer (ICDRR), and transmit buffer (ICDRT). Data transfers among the three registers are performed automatically in coordination with changes in the bus state, and affect the status of internal flags such as TDRE and RDRF. When TDRE is 1 and the transmit buffer is empty, TDRE shows that the next transmit data can be written from the CPU. When RDRF is 1, it shows that the valid receive data is stored in the receive buffer.

If I²C is in transmit mode and the next data is in ICDRT (the TDRE flag is 0) following transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRT to ICDRS. If I²C is in receive mode and no previous data remains in ICDRR (the RDRF flag is 0) following transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRS to ICDRR.

If the number of bits in a frame, excluding the acknowledge bit, is less than 8, transmit data and receive data are stored differently. Transmit data should be written justified toward the MSB side when MLS = 0, and toward the LSB side when MLS = 1. Receive data bits read from the LSB side should be treated as valid when MLS = 0, and bits read from the MSB side when MLS = 1.

ICDR can be written and read only when the ICE bit is set to 1 in ICCR. The value of ICDR is undefined after a reset.

The TDRE and RDRF flags are set and cleared under the conditions shown below. Setting the TDRE and RDRF flags affects the status of the interrupt flags.

Bit	Bit Name	Initial Value	R/W	Description
—	TDRE	—	—	Transmit Data Register Empty [Setting conditions] <ul style="list-style-type: none"> • In transmit mode, when a start condition is detected in the bus line state after a start condition is issued in master mode with the I²C bus format or serial format selected • When data is transferred from ICDRT to ICDRS • When a switch is made from receive mode to transmit mode after detection of a start condition [Clearing conditions] <ul style="list-style-type: none"> • When transmit data is written in ICDR in transmit mode • When a stop condition is detected in the bus line state after a stop condition is issued with the I²C bus format or serial format selected • When a stop condition is detected with the I²C bus format selected • In receive mode
—	RDRF	—	—	Receive Data Register Full [Setting condition] When data is transferred from ICDRS to ICDRR [Clearing condition] When ICDR (ICDRR) receive data is read in receive mode

14.3.2 Slave Address Register (SAR)

SAR selects the slave address and selects the transfer format. SAR can be written and read only when the ICE bit is cleared to 0 in ICCR.

Bit	Bit Name	Initial Value	R/W	Description
7	SVA6	0	R/W	Slave Address 6 to 0
6	SVA5	0	R/W	Sets a slave address
5	SVA4	0	R/W	
4	SVA3	0	R/W	
3	SVA2	0	R/W	
2	SVA1	0	R/W	
1	SVA0	0	R/W	
0	FS	0	R/W	Selects the transfer format together with the FSX bit in SARX. Refer to table 14.2.

14.3.3 Second Slave Address Register (SARX)

SARX stores the second slave address and selects the transfer format. SARX can be written and read only when the ICE bit is cleared to 0 in ICCR.

Bit	Bit Name	Initial Value	R/W	Description
7	SVAX6	0	R/W	Slave Address 6 to 0
6	SVAX5	0	R/W	Sets the second slave address
5	SVAX4	0	R/W	
4	SVAX3	0	R/W	
3	SVAX2	0	R/W	
2	SVAX1	0	R/W	
1	SVAX0	0	R/W	
0	FSX	1	R/W	Selects the transfer format together with the FS bit in SAR. Refer to table 14.2.

Table 14.2 Transfer Format

SAR	SARX	
FS	FSX	I²C Transfer Format
0	0	SAR and SARX are used as the slave addresses with the I ² C bus format.
0	1	Only SAR is used as the slave address with the I ² C bus format.
1	0	Only SARX is used as the slave address with the I ² C bus format.
1	1	Clock synchronous serial format (SAR and SARX are invalid)

14.3.4 I²C Bus Mode Register (ICMR)

ICMR sets the transfer format and transfer rate. It can only be accessed when the ICE bit in ICCR is 1.

Bit	Bit Name	Initial Value	R/W	Description
7	MLS	0	R/W	MSB-First/LSB-First Select 0: MSB-first 1: LSB-first Set this bit to 0 when the I ² C bus format is used.
6	WAIT	0	R/W	Wait Insertion Bit This bit is valid only in master mode with the I ² C bus format. When WAIT is set to 1, after the fall of the clock for the final data bit, the IRIC flag is set to 1 in ICCR, and a wait state begins (with SCL at the low level). When the IRIC flag is cleared to 0 in ICCR, the wait ends and the acknowledge bit is transferred. If WAIT is cleared to 0, data and acknowledge bits are transferred consecutively with no wait inserted. The IRIC flag in ICCR is set to 1 on completion of the acknowledge bit transfer, regardless of the WAIT setting.
5	CKS2	0	R/W	Serial Clock Select 2 to 0
4	CKS1	0	R/W	This bit is valid only in master mode.
3	CKS0	0	R/W	These bits select the required transfer rate, together with the IICX 1 and IICX0 bit in SCRX. Refer table 14.3.

Bit	Bit Name	Initial Value	R/W	Description
2	BC2	0	R/W	Bit Counter 2 to 0
1	BC1	0	R/W	These bits specify the number of bits to be transferred next. With the I ² C bus format, the data is transferred with one addition acknowledge bit. Bit BC2 to BC0 settings should be made 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 line is low. The value returns to 000 at the end of a data transfer, including the acknowledge bit.
0	BC0	0	R/W	
				I ² C Bus Format Clocked Synchronous Mode
				000: 9 bit 000: 8 bit
				001: 2 bit 001: 1 bit
				010: 3 bit 010: 2 bit
				011: 4 bit 011: 3 bit
				100: 5 bit 100: 4 bit
				101: 6 bit 101: 5 bit
				110: 7 bit 110: 6 bit
				111: 8 bit 111: 7 bit

Table 14.3 I²C Transfer Rate

SCRX		ICMR			Clock	Transfer Rate				
Bit 5 or 6	Bit 5	Bit 4	Bit 3	$\phi = 5 \text{ MHz}$		$\phi = 8 \text{ MHz}$	$\phi = 10 \text{ MHz}$	$\phi = 16 \text{ MHz}$	$\phi = 20 \text{ MHz}$	
IICX	CKS2	CKS1	CKS0							
0	0	0	0	$\phi/28$	179MHz	286kHz	357kHz	571kHz*	714kHz*	
0	0	0	1	$\phi/40$	125kHz	200kHz	250kHz	400kHz	500kHz*	
0	0	1	0	$\phi/48$	104kHz	167kHz	208kHz	333kHz	417kHz	
0	0	1	1	$\phi/64$	78.1kHz	125kHz	156kHz	250kHz	313kHz	
0	1	0	0	$\phi/80$	62.5kHz	100kHz	125kHz	200kHz	250kHz	
0	1	0	1	$\phi/100$	50.0kHz	80.0kHz	100kHz	160kHz	200kHz	
0	1	1	0	$\phi/112$	44.6kHz	71.4kHz	89.3kHz	143kHz	179kHz	
0	1	1	1	$\phi/128$	39.1kHz	62.5kHz	78.1kHz	125kHz	156kHz	
1	0	0	0	$\phi/56$	89.3kHz	143kHz	179kHz	286kHz	357kHz	
1	0	0	1	$\phi/80$	62.5kHz	100kHz	125kHz	200kHz	250kHz	
1	0	1	0	$\phi/96$	52.1kHz	83.3kHz	104kHz	167kHz	208kHz	
1	0	1	1	$\phi/128$	39.1kHz	62.5kHz	78.1kHz	125kHz	156kHz	
1	1	0	0	$\phi/160$	31.3kHz	50.0kHz	62.5kHz	100kHz	125kHz	
1	1	0	1	$\phi/200$	25.0kHz	40.0kHz	50.0kHz	80.0kHz	100kHz	
1	1	1	0	$\phi/224$	22.3kHz	35.7kHz	44.6kHz	71.4kHz	89.3kHz	
1	1	1	1	$\phi/256$	19.5kHz	31.3kHz	39.1kHz	62.5kHz	78.1kHz	

Note: * Out of the range of the I2C bus interface specification (normal mode: 100kHz in max. and high-speed mode: 400kHz in max)

14.3.5 Serial Control Register (SCRX)

SCRX controls the IIC operating modes.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved The initial value should not be changed.
6	IICX1*	0	R/W	I ² C Transfer Rate Select 1 and 0
5	IICX0	0	R/W	Selects the transfer rate in master mode, together with bits CKS2 to CKS0 in ICMR. Refer to table 14.3. Note:* In the H8S/2264 Series, this bit is reserved.
4	IICE	0	R/W	I ² C Master Enable Controls CPU access to the IIC data register and control registers (ICCR, ICSR, ICDR/SARX, and ICMR/SAR). 0: CPU access to the IIC data register and control registers is disabled. 1: CPU access to the IIC data register and control registers is enabled.
3	FLSHE	0	R/W	For details on this bit, refer to section 20.5.7, Serial Control Register X (SCRX).
2 to 0	—	All 0	R/W	Reserved The initial value should not be changed.

14.3.6 I²C Bus Control Register (ICCR)

I²C bus control register (ICCR) consists of the control bits and interrupt request flags of I²C bus interface.

Bit	Bit Name	Initial Value	R/W	Description
7	ICE	0	R/W	<p>I²C Bus Interface Enable</p> <p>When this bit is set to 1, the I²C bus interface module is enabled to send/receive data and drive the bus since it is connected to the SCL and SDA pins. ICMR and ICDR can be accessed.</p> <p>When this bit is cleared, the module is halted and separated from the SCL and SDA pins. SAR and SARX can be accessed.</p>
6	IEIC	0	R/W	<p>I²C Bus Interface Interrupt Enable</p> <p>When this bit is 1, interrupts are enabled by IRIC.</p>
5	MST	0	R/W	Master/Slave Select
4	TRS	0		<p>Transmit/Receive Select</p> <p>00: Slave receive mode</p> <p>01: Slave transmit mode</p> <p>10: Master receive mode</p> <p>11: Master transmit mode</p> <p>Both these bits will be cleared by hardware when they lose in a bus contention in master mode of the I²C bus format. In slave receive mode, the R/W bit in the first frame immediately after the start automatically sets these bits in receive mode or transmit mode by using hardware. The settings can be made again for the bits that were set/cleared by hardware, by reading these bits. When the TRS bit is intended to change during a transfer, the bit will not be switched until the frame transfer is completed, including acknowledgement.</p>

Bit	Bit Name	Initial Value	R/W	Description
3	ACKE	0	R/W	<p>Acknowledge Bit Judgement Selection</p> <p>0: The value of the acknowledge bit is ignored, and continuous transfer is performed. The value of the received acknowledge bit is not indicated by the ACKB bit, which is always 0.</p> <p>1: If the acknowledge bit is 1, continuous transfer is interrupted.</p> <p>In the H8S/2268 Series, the DTC* can be used to perform continuous transfer. The DTC* is activated when the IRTR interrupt flag is set to 1 (IRTR us one of two interrupt flags, the other being IRIC). When the ACKE bit is 0, the TDRE, IRIC, and IRTR flags are set on completion of data transmission, regardless of the acknowledge bit. When the ACKE bit is 1, the TDRE, IRIC, and IRTR flags are set on completion of data transmission when the acknowledge bit is 0, and the IRIC flag alone is set on completion of data transmission when the acknowledge bit is 1.</p> <p>When the DTC* is activated, the TDRE, IRIC, and IRTR flags are cleared to 0 after the specified number of data transfers have been executed. Consequently, interrupts are not generated during continuous data transfer, but if data transmission is completed with a 1 acknowledge bit when the ACKE bit is set to 1, the DTC* is not activated and an interrupt is generated, if enabled.</p> <p>Depending on the receiving device, the acknowledge bit may be significant, in indicating completion of processing of the received data, for instance, or may be fixed at 1 and have no significance.</p> <p>Note:* Supported only by the H8S/2268 Series.</p>
2	BBSY	0	R/W	<p>Bus Busy</p> <p>In slave mode, reading the BBSY flag enables to confirm whether the I²C bus is occupied or released. The BBSY flag is set to 0 when the SDA level changes from high to low under the condition of SCL = high, assuming that the start condition has been issued. The BBSY flag is cleared to 0 when the SDA level changes from low to high under the condition of SCL = high, assuming that the start condition has been issued. Writing to the BBSY flag in slave mode is disabled.</p> <p>In master mode, the BBSY flag is used to issue start and stop conditions. Write 1 to BBSY and 0 to SCP to issue a start condition. Follow this procedure when also re-transmitting a start condition. To issue a start/stop condition, use the MOV instruction. The I²C bus interface must be set in master transmit mode before the issue of a start condition.</p>

Bit	Bit Name	Initial Value	R/W	Description
1	IRIC	0	R/W	<p>I²C Bus Interface Interrupt Request Flag</p> <p>Also see table 14.4.</p> <p>[Setting conditions]</p> <p>In I²C bus format master mode</p> <ul style="list-style-type: none"> When a start condition is detected in the bus line state after a start condition is issued (when the TDRE flag is set to 1 because of first frame transmission) When a wait is inserted between the data and acknowledge bit when WAIT = 1 At the end of data transfer (when the TDRE or RDRF flag is set to 1) When a slave address is received after bus arbitration is lost (when the AL flag is set to 1) When 1 is received as the acknowledge bit when the ACKE bit is 1 (when the ACKB bit is set to 1) <p>In I²C bus format slave mode</p> <ul style="list-style-type: none"> When the slave address (SVA, SVAX) matches (when the AAS and AASX flags are set to 1) and at the end of data transfer up to the subsequent retransmission start condition or stop condition detection (when the TDRE or RDRF flag is set to 1) When the general call address is detected (when the ADZ flag is set to 1) and at the end of data transfer up to the subsequent retransmission start condition or stop condition detection (when the TDRE or RDRF flag is set to 1) When 1 is received as the acknowledge bit when the ACKE bit is 1 (when the ACKB bit is set to 1) When a stop condition is detected (when the STOP or ESTP flag is set to 1) <p>With clocked synchronous serial format</p> <ul style="list-style-type: none"> At the end of data transfer (when the TDRE or RDRF flag is set to 1) When a start condition is detected with serial format selected <p>When a condition occurs in which internal flag of TDRE and RDRF is set to 1 except for the above</p> <p>[Clearing condition]</p> <p>When 0 is written in IRIC after reading IRIC = 1</p> <ul style="list-style-type: none"> When ICDR is read/written by DTC (H8S/2268 Series only) <p>(When TDRE or RDRF flag is cleared to 0)</p> <p>(AS it might not be a condition to clear, for details, see description of DTC operation below)</p>

Bit	Bit Name	Initial Value	R/W	Description
0	SCP	1	R/W	<p>Start Condition/Stop Condition Prohibit bit</p> <p>The SCP bit controls the issue of start/stop conditions in master mode.</p> <p>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.</p>

When, with the I²C bus format selected, IRIC is set to 1 and an interrupt is generated, other flags must be checked in order to identify the source that set IRIC to 1. Although each source has a corresponding flag, caution is needed at the end of a transfer.

When the TDRE or RDRF internal flag is set, the readable IRTR flag may or may not be set. In the H8S/2268 Series, even when data transfer is complete, the DTC activation request flag, IRTR, is not set until a retransmission start condition or stop condition is detected after a slave address (SVA) or general call address matched in the I²C bus format slave mode.

Even when the IRIC flag and IRTR flag are set, the TDRE or RDRF internal flag may not be set. For a continuous transfer using the DTC in the H8S/2268 Series, the IRIC or IRTR flag is not cleared at the completion of the specified number of times of transfers. On the other hand, the TDRE and RDRF flags are cleared because the specified number of times of read/write operations have been complete.

Table 14.4 shows the relationship between the flags and the transfer states.

Table 14.4 Flags and Transfer States

MST	TRS	BBSY	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	State
1/0	1/0	0	0	0	0	0	0	0	0	0	Idle state (flag clearing required)
1	1	0	0	0	0	0	0	0	0	0	Start condition issuance
1	1	1	0	0	1	0	0	0	0	0	Start condition established
1	1/0	1	0	0	0	0	0	0	0	0/1	Master mode wait
1	1/0	1	0	0	1	0	0	0	0	0/1	Master mode transmit/receive end
0	0	1	0	0	0	1/0	1	1/0	1/0	0	Arbitration lost
0	0	1	0	0	0	0	0	1	0	0	SAR match by first frame in slave mode
0	0	1	0	0	0	0	0	1	1	0	General call address match
0	0	1	0	0	0	1	0	0	0	0	SARX match
0	1/0	1	0	0	0	0	0	0	0	0/1	Slave mode transmit/receive end(except after SARX match)
0	1/0	1	0	0	1	1	0	0	0	0	Slave mode transmit/receive end(after SARX match)
0	1	1	0	0	0	1	0	0	0	1	
0	1/0	0	1/0	1/0	0	0	0	0	0	0/1	Stop condition detected

14.3.7 I²C Bus Status Register (ICSR)

ICSR consists of status flags.

Bit	Bit Name	Initial Value	R/W	Description
7	ESTP	0	R/(W)*	Error Stop Condition Detection Flag This bit is valid in I ² C bus format slave mode. [Setting condition] When a stop condition is detected during frame transfer. [Clearing condition] <ul style="list-style-type: none"> When 0 is written in ESTP after reading the state of 1 When the IRIC flag is cleared to 0
6	STOP	0	R/(W)*	Normal Stop Condition Detection Flag This bit is valid in I ² C bus format slave mode. [Setting condition] When a stop condition is detected during frame transfer. [Clearing condition] <ul style="list-style-type: none"> When 0 is written in STOP after reading STOP = 1 When the IRIC flag is cleared to 0

Bit	Bit Name	Initial Value	R/W	Description
5	IRTR	0	R/(W)*	<p>I²C Bus Interface Continuous Transmission/Reception Interrupt Request Flag</p> <p>[Setting conditions]</p> <p>In I²C bus interface slave mode</p> <ul style="list-style-type: none"> When the TDRE or RDRF flag is set to 1 when AASX = 1 <p>In I²C bus interface other modes</p> <ul style="list-style-type: none"> When the TDRE or RDRF flag is set to 1 <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written in IRTR after reading IRTR = 1 When the IRIC flag is cleared to 0
4	AASX	0	R/(W)*	<p>Second Slave Address Recognition Flag</p> <p>[Setting condition]</p> <p>When the second slave address is detected in slave receive mode and FSX = 0</p> <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written in AASX after reading AASX = 1 When a start condition is detected In master mode
3	AL	0	R/(W)*	<p>Arbitration Lost Flag</p> <p>Indicates that bus arbitration was lost in master mode.</p> <p>[Setting condition]</p> <ul style="list-style-type: none"> When the internal SDA and SDA pin do not match at the rise of SCL. When the internal SCL is high at the fall of SCL. <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written in AL after reading AL = 1 When ICDR data is written (transmit mode) or read (receive mode)

Bit	Bit Name	Initial Value	R/W	Description
2	AAS	0	R/(W)*	<p>Slave Address Recognition Flag</p> <p>[Setting condition]</p> <p>When the slave address or general call address is detected in slave receive mode and FS = 0.</p> <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When ICDR data is written (transmit mode) or read (receive mode) When 0 is written in AAS after reading AAS = 1 In master mode
1	ADZ	0	R/(W)*	<p>General Call Address Recognition Flag</p> <p>This bit is valid in I²C bus format slave receive mode.</p> <p>[Setting condition]</p> <p>When the general call address is detected in slave receive mode and FSX = 0 or FS = 0.</p> <p>[Clearing conditions]</p> <ul style="list-style-type: none"> When ICDR data is written (transmit mode) or read (receive mode) When 0 is written in ADZ after reading ADZ = 1 In master mode
0	ACKB	0	R/(W)*	<p>Acknowledge Bit</p> <p>Stores acknowledge bit.</p> <p>0: At reception, outputs 0 in the acknowledge output timing. At transmission, indicates that acknowledge was sent (0) from the receive device.</p> <p>1: At reception, outputs 1 in the acknowledge output timing. At transmission, indicates that acknowledge was not sent (1) from the receive device.</p>

Note: Only a 0 can be written to this bit, to clear the flag.

14.3.8 DDC Switch Register (DDCSWR)

DDCSWR controls the I²C bus interface format automatic switching function and internal latch clear.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 0	R/(W) * ¹	Reserved The write value should always be 0.
3	CLR3	1	W	I ² C Bus Interface Clear 3 to 0:
2	CLR2	1	W	When bits CLR3 to CLR0 are set, a clear signal is generated for the I ² C bus interface internal latch circuit, and the internal state is initialized. The write data for these bits is not retained. To perform I ² C clearance, bits CLR3 to CLR0 must be written to simultaneously using an MOV instruction. Do not use a bit manipulation instruction such as BCLR. 00XX: Setting prohibited 0100: Setting prohibited 0101: IIC_0 Internal latch cleared 0110: IIC_1* ² Internal latch cleared 0111: IIC_0, IIC_1* ² Internal latch cleared 1XXX: Invalid setting
1	CLR1	1	W	
0	CLR0	1	W	

Legend

X: Don't care

Notes: 1. Only 0 can be written to these bits, to clear the flag.

2. Supported only by the H8S/2268 Series.

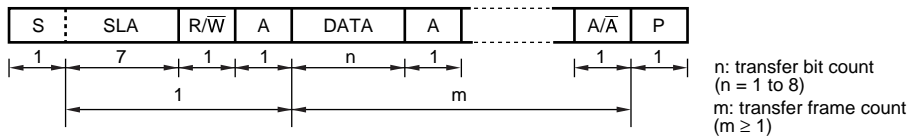
14.4 Operation

The I²C bus interface has serial and I²C bus formats.

14.4.1 I²C Bus Data Format

The I²C bus formats are addressing formats and an acknowledge bit is inserted. The first frame following a start condition always consists of 8 bits. The I²C bus format is shown in figure 14.3. The serial format is a non-addressing format with no acknowledge bit. This is shown in figure 14.4. Figure 14.5 shows the I²C bus timing.

(a) I²C bus format (FS = 0 or FSX = 0)



(b) I²C bus format (start condition retransmission, FS = 0 or FSX = 0)

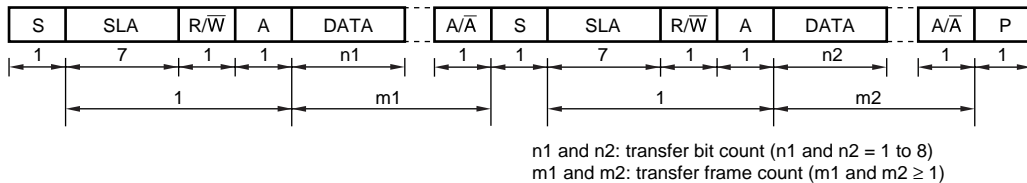


Figure 14.3 I²C Bus Data Formats (I²C Bus Formats)

FS = 1 and FSX = 1

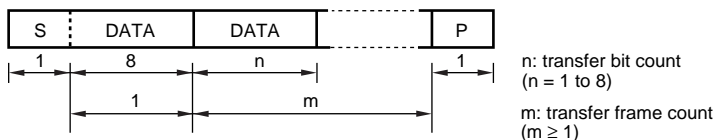


Figure 14.4 I²C Bus Data Format (Serial Format)

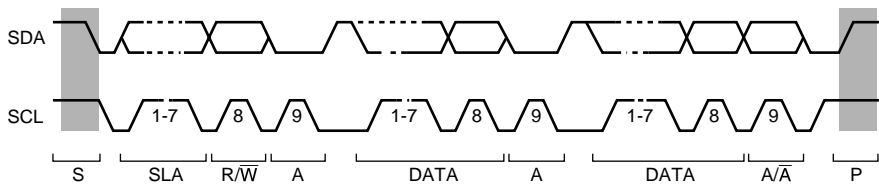


Figure 14.5 I²C Bus Timing

Legend

S: Start condition. The master device drives SDA from high to low while SCL is high

SLA: Slave address

R/W: Indicates the direction of data transfer: from the slave device to the master device when R/W is 1, or from the master device to the slave device when R/W is 0

A: Acknowledge. The receiving device drives SDA

DATA: Transferred data

P: Stop condition. The master device drives SDA from low to high while SCL is high

14.4.2 Master Transmit Operation

In I²C bus format master transmit mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal. The transmission procedure and operations synchronized with the ICDR writing are described below.

1. Set the ICE bit in ICCR to 1. Set bits MLS, WAIT, and CKS2 to CKS0 in ICMR, and bit IICX in SCRX, according to the operating mode.
2. Read the BBSY flag in ICCR to confirm that the bus is free.
3. Set bits MST and TRS to 1 in ICCR to select master transmit mode.
4. Write 1 to BBSY and 0 to SCP. This changes SDA from high to low when SCL is high, and generates the start condition.
5. Then IRIC and IRTR flags are set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU.
6. Write the data (slave address + R/\overline{W}) to ICDR. With the I²C bus format (when the FS bit in SAR or the FSX bit in SARX is 0), the first frame data following the start condition indicates the 7-bit slave address and transmit/receive direction. As indicating the end of the transfer, and so the IRIC flag is cleared to 0. After writing ICDR, clear IRIC continuously not to execute other interrupt handling routine. If one frame of data has been transmitted before the IRIC clearing, it can not be determine the end of transmission. The master device sequentially sends the transmission clock and the data written to ICDR using the timing shown in figure 14.6. The selected slave device (i.e. the slave device with the matching slave address) drives SDA low at the 9th transmit clock pulse and returns an acknowledge signal.
7. When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of the 9th transmit clock pulse. After one frame has been transmitted SCL is automatically fixed low in synchronization with the internal clock until the next transmit data is written.
8. Read the ACKB bit in ICSR to confirm that ACKB is cleared to 0. When the slave device has not acknowledged (ACKB bit is 1), operate the step [12] to end transmission, and retry the transmit operation.
9. Write the transmit data to ICDR. As indicating the end of the transfer, and so the IRIC flag is cleared to 0. Perform the ICDR write and the IRIC flag clearing sequentially, just as in point 6 in this flowchart. Transmission of the next frame is performed in synchronization with the internal clock.
10. When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of the 9th transmit clock pulse. After one frame has been transmitted SCL is automatically fixed low in synchronization with the internal clock until the next transmit data is written.
11. Read the ACKB bit in ICSR. Confirm that the slave device has been acknowledged (ACKB bit is 0). When there is data to be transmitted, go to the step [9] to continue next transmission. When the slave device has not acknowledged (ACKB bit is set to 1), operate the step [12] to end transmission.

12. Clear the IRIC flag to 0. And write 0 to BBSY and SCP in ICCR. This changes SDA from low to high when SCL is high, and generates the stop condition.

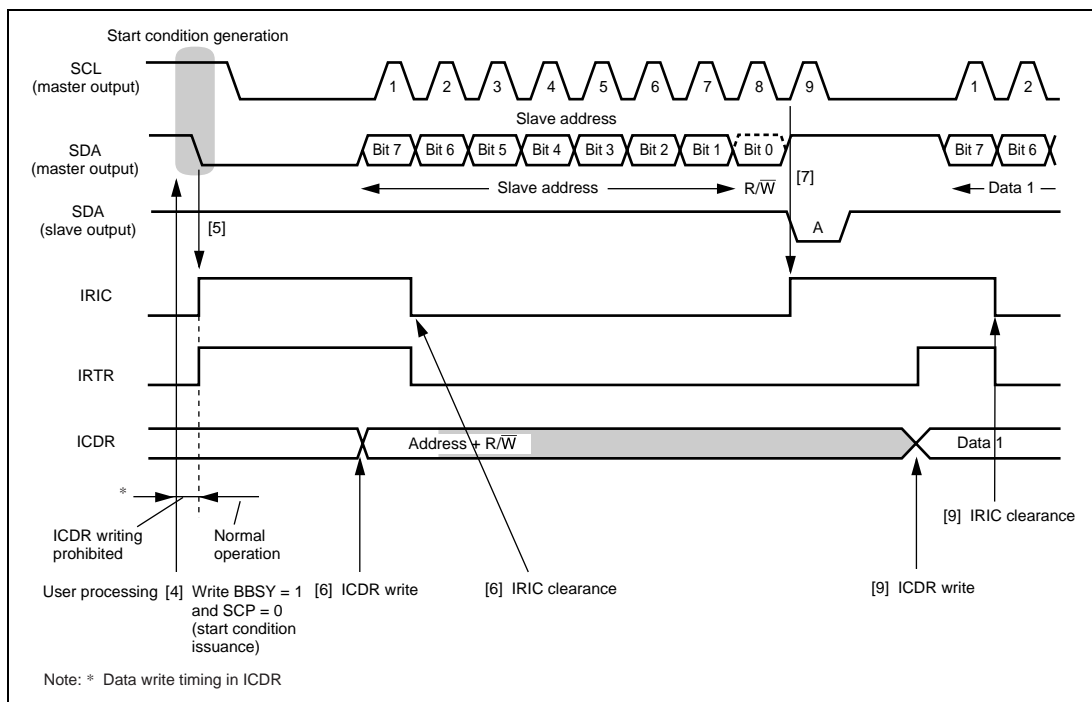


Figure 14.6 Master Transmit Mode Operation Timing Example (MLS = WAIT = 0)

14.4.3 Master Receive Operation

In master receive mode, the master device outputs the receive clock, receives data, and returns an acknowledge signal. The slave device transmits data. The reception procedure and operations with the wait function synchronized with the ICDR read operation to receive data in sequence are shown below.

1. Clear the TRS bit in ICCR to 0 to switch from transmit mode to receive mode, and set the WAIT bit in ICMR to 1. Also clear the bit in ICSR to ACKB 0 (acknowledge data setting).
2. When ICDR is read (dummy data read), reception is started, and the receive clock is output, and data received, in synchronization with the internal clock. In order to detect wait operation, set the IRIC flag in ICCR must be cleared to 0. After reading ICDR, clear IRIC continuously not to execute other interrupt handling routine. If one frame of data has been received before the IRIC clearing, it cannot be determine the end of reception.

3. The IRIC flag is set to 1 at the fall of the 8th receive clock pulse. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag clearing. If the first frame is the last receive data, execute step [10] to halt reception.
4. Clear the IRIC flag to release from the Wait State. The master device outputs the 9th clock and drives SDA at the 9th receive clock pulse to return an acknowledge signal.
5. When one frame of data has been received, the IRIC flag in ICCR and the IRTR flag in ICSR are set to 1 at the rise of the 9th receive clock pulse. The master device outputs SCL clock to receive next data.
6. Read ICDR.
7. Clear the IRIC flag to detect next wait operation. Data reception process from [5] to [7] should be executed during one byte reception period after IRIC flag clearing in [4] or [9] to release wait status.
8. The IRIC flags set to 1 at the fall of 8th receive clock pulse. SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag clearing. If this frame is the last receive data, execute step [10] to halt reception.
9. Clear the IRIC flag in ICCR to cancel wait operation. The master device drives SDA low at the 9th receive clock pulse and returns an acknowledge signal.
10. Data can be received continuously by repeating step [5] to [9].
11. Set the ACKB bit in ICSR to 1 so as to return “No acknowledge” data. Also set the TRS bit in ICCR to 1 to switch from receive mode to transmit mode.
12. Clear IRIC flag to 0 to release from the Wait State.
13. When one frame of data has been received, the IRIC flag is set to 1 at the rise of the 9th receive clock pulse.
14. Clear the WAIT bit to 0 to switch from wait mode to no wait mode. Read ICDR and clear the IRIC flag to 0. Clearing of the IRIC flag should be after the WAIT = 0. If the WAIT bit is cleared to 0 after clearing the IRIC flag and then an instruction to issue a stop condition is executed, the stop condition cannot be issued because the output level of the SDA line is fixed as low.
15. Clear the BBSY bit and SCP bit to 0. This changes SDA from low to high when SCL is high, and generates the stop condition.

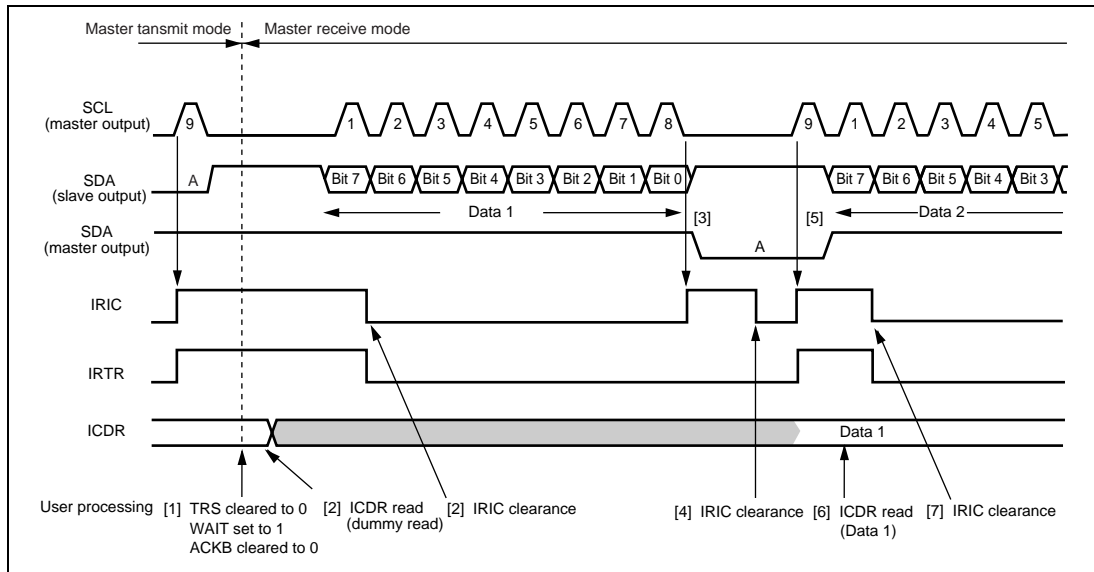


Figure 14.7 (1) Master Receive Mode Operation Timing Example
(MLS = ACKB = 0, WAIT = 1)

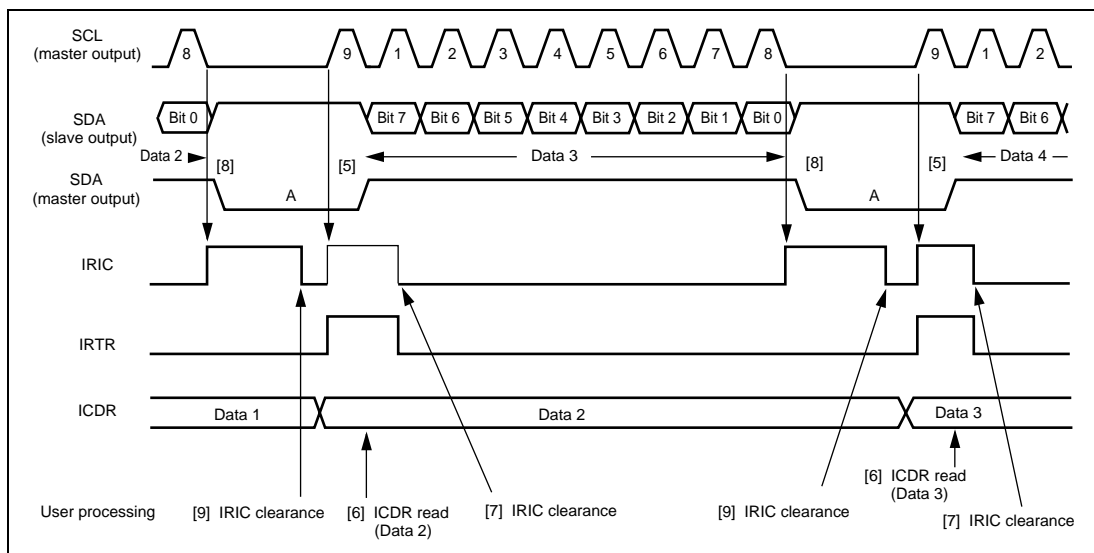


Figure 14.7 (2) Master Receive Mode Operation Timing Example
(MLS = ACKB = 0, WAIT = 1)

14.4.4 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. The reception procedure and operations in slave receive mode are described below.

1. Set the ICE bit in ICCR to 1. Set the MLS bit in ICMR and the MST and TRS bits in ICCR according to the operating mode.
2. When the start condition output by the master device is detected, the BBSY flag in ICCR is set to 1.
3. When the slave address matches in the first frame following the start condition, the device operates as the slave device specified by the master device. If the 8th data bit (R/\overline{W}) is 0, the TRS bit in ICCR remains cleared to 0, and slave receive operation is performed.
4. At the 9th clock pulse of the receive frame, the slave device drives SDA low and returns an acknowledge signal. At the same time, the IRIC flag in ICCR is set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. If the RDRF internal flag has been cleared to 0, it is set to 1, and the receive operation continues. If the RDRF internal flag has been set to 1, the slave device drives SCL low from the fall of the receive clock until data is read into ICDR.
5. Read ICDR and clear the IRIC flag in ICCR to 0. The RDRF flag is cleared to 0.

Receive operations can be performed continuously by repeating steps [4] and [5]. When SDA is changed from low to high when SCL is high, and the stop condition is detected, the BBSY flag in ICCR is cleared to 0.

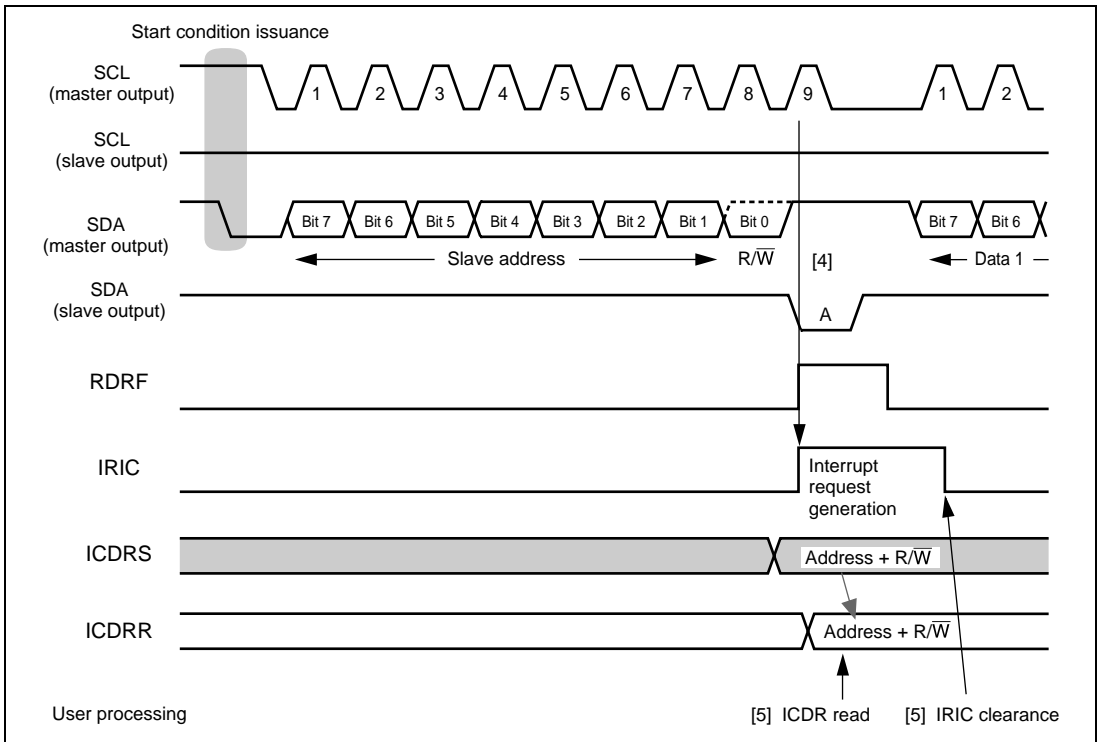


Figure 14.8 Example of Slave Receive Mode Operation Timing (1)
($MLS = ACKB = 0$)

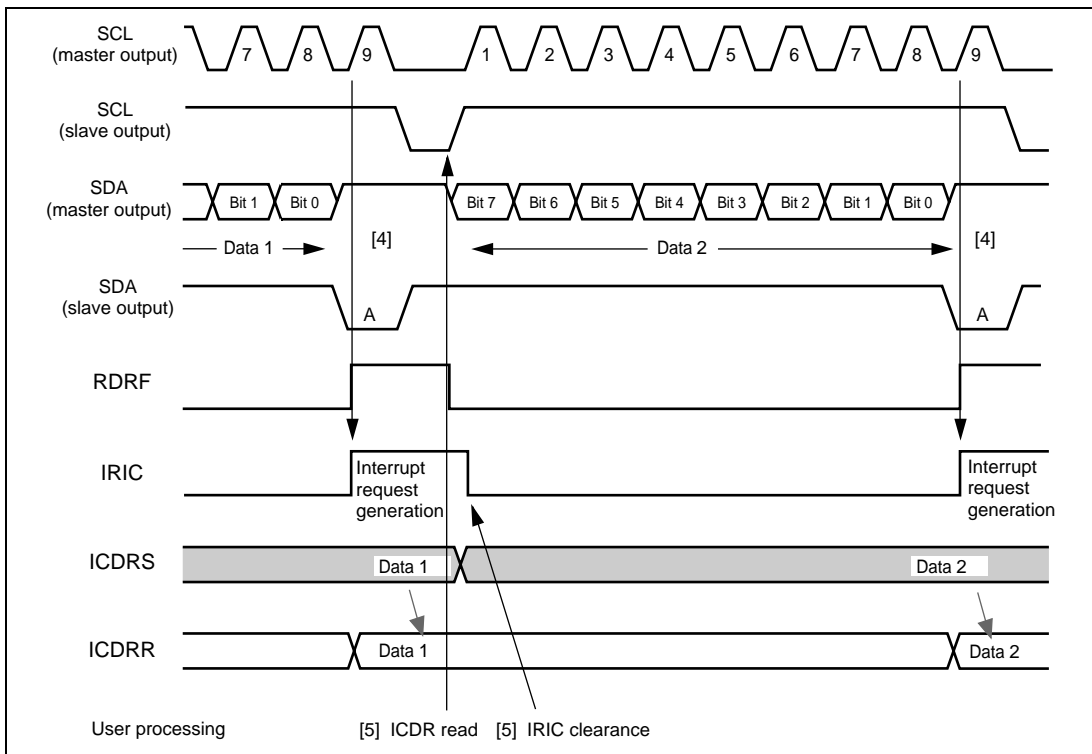


Figure 14.9 Example of Slave Receive Mode Operation Timing (2)
($MLS = ACKB = 0$)

14.4.5 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. The transmission procedure and operations in slave transmit mode are described below.

1. Set the ICE bit in ICCR to 1. Set the MLS bit in ICMR and the MST and TRS bits in ICCR according to the operating mode.
2. When the slave address matches in the first frame following detection of the start condition, the slave device drives SDA low at the 9th clock pulse and returns an acknowledge signal. At the same time, the IRIC flag in ICCR is set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. If the 8th data bit (R/\overline{W}) is 1, the TRS bit in ICCR is set to 1, and the mode changes to slave transmit mode automatically. The TDRE internal flag is set to 1. The slave device drives SCL low from the fall of the transmit clock until ICDR data is written.

3. After clearing the IRIC flag to 0, write data to ICDR. The TDRE internal flag is cleared to 0. The written data is transferred to ICDRS, and the TDRE internal flag and the IRIC and IRTR flags are set to 1 again. After clearing the IRIC flag to 0, write the next data to ICDR. The slave device sequentially sends the data written into ICDR in accordance with the clock output by the master device at the timing shown in figure 14.10.
4. When one frame of data has been transmitted, the IRIC flag in ICCR is set to 1 at the rise of the 9th transmit clock pulse. If the TDRE internal flag has been set to 1, this slave device drives SCL low from the fall of the transmit clock until data is written to ICDR. The master device drives SDA low at the 9th clock pulse, and returns an acknowledge signal. As this acknowledge signal is stored in the ACKB bit in ICSR, this bit can be used to determine whether the transfer operation was performed normally. When the TDRE internal flag is 0, the data written into ICDR is transferred to ICDRS, transmission is started, and the TDRE internal flag and the IRIC and IRTR flags are set to 1 again.
5. To continue transmission, clear the IRIC flag to 0, then write the next data to be transmitted into ICDR. The TDRE flag is cleared to 0.

Transmit operations can be performed continuously by repeating steps [4] and [5]. To end transmission, write H'FF to ICDR. When SDA is changed from low to high when SCL is high, and the stop condition is detected, the BBSY flag in ICCR is cleared to 0.

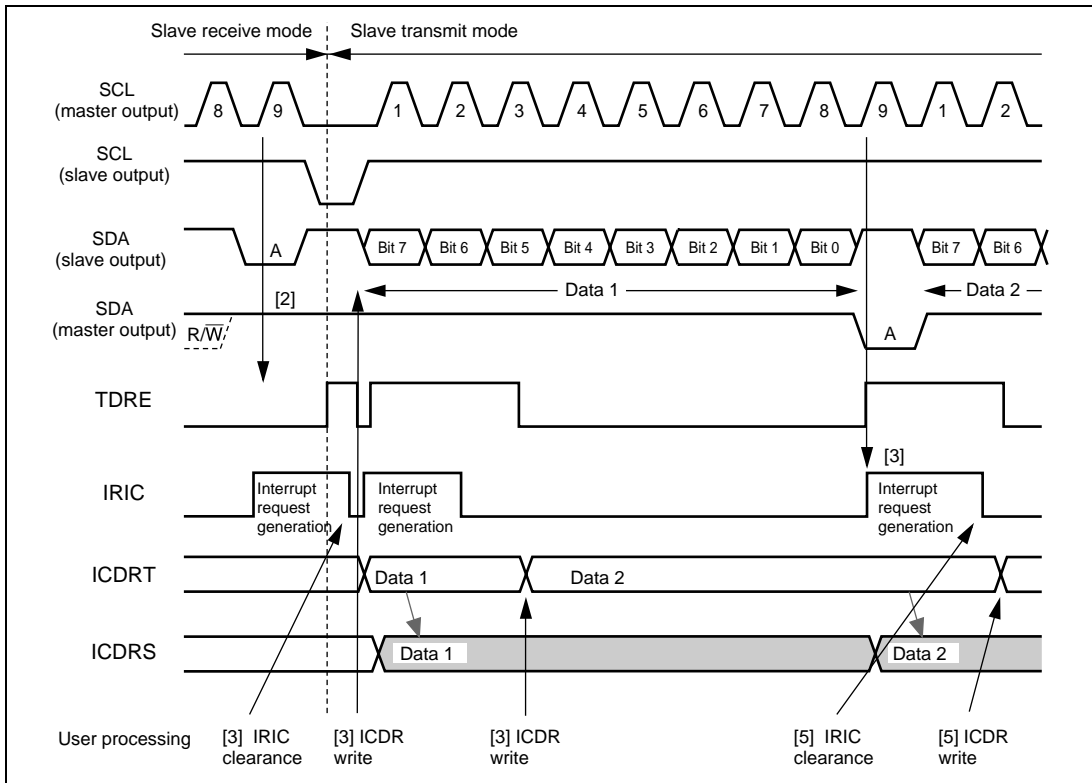


Figure 14.10 Example of Slave Transmit Mode Operation Timing (MLS = 0)

14.4.6 IRIC Setting Timing and SCL Control

The interrupt request flag (IRIC) is set at different times depending on the WAIT bit in ICMR, the FS bit in SAR, and the FSX bit in SARX. If the TDRE or RDRF internal flag is set to 1, SCL is automatically held low after one frame has been transferred; this timing is synchronized with the internal clock. Figure 14.11 shows the IRIC set timing and SCL control.

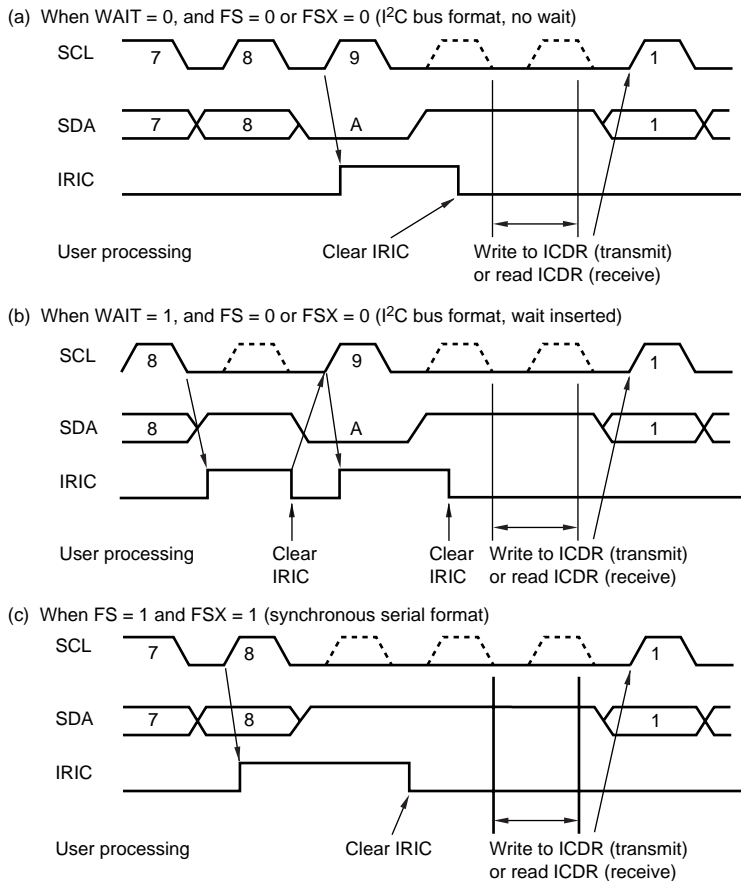


Figure 14.11 IRIC Setting Timing and SCL Control

14.4.7 Operation Using the DTC (H8S/2268 Series Only)

The I²C bus format provides for selection of the slave device and transfer direction by means of the slave address and the $\overline{R/\overline{W}}$ bit, confirmation of reception with acknowledge bit, indication of the last frame, and so on. Therefore, continuous data transfer using the DTC must be carried out in conjunction CPU processing by means of interrupts.

Table 14.5 shows some example of processing using the DTC. These examples assume that the number of transfer data bytes is know in slave mode.

Table 14.5 Flags and Transfer States

Item	Master Transmit Mode	Master Receive Mode	Slave Transmit Mode	Slave Receive Mode
Slave address + R/W bit	Transmission by DTC (ICDR rite)	Transmission by DTC (ICDR rite)	Reception by CPU (ICDR read)	Reception by CPU (ICDR read)
Transmission/ reception				
Dummy data read	—	Processing by DTC (ICDR read)	—	—
Actual data transmission/rec option	Transmission by DTC (ICDR write)	Reception by CPU (ICDR read)	Transmission by DTC (ICDR write)	Reception by CPU (ICDR read)
Dummy data (H'FF) write	—	—	Processing by DTC (ICDR write)	—
Last frame processing	Not necessary	Reception by CPU (ICDR read)	Not necessary	Reception by CPU (ICDR read)
Transfer request processing after last frame processing	1st time: Clearing by CPU 2nd time: End condition issuance by CPU	Not necessary	Automatic clearing on detection of end condition during transmission of dummy data (H'FF)	Not necessary
Setting of number of DTC transfer data frames	Transmission: Actual data count + 1 (+ 1 equivalent to slave address + $\overline{R/\overline{W}}$ bits)	Reception: Actual data count	Transmission: Actual data count + 1 (+ 1 equivalent to dummy data (H'FF))	Reception: Actual data count

14.4.8 Noise Chanceller

The logic levels at the SCL and SDA pins are routed through noise chancellors before being latched internally. Figure 14.12 shows a block diagram of the noise cancelled circuit.

The noise chanceller consists of two cascaded latches and a match detector. The SCL (or SDA) input signal is sampled on the system clock, but is not passed forward to the next circuit unless the outputs of both latches agree. If they do not agree, the previous value is held.

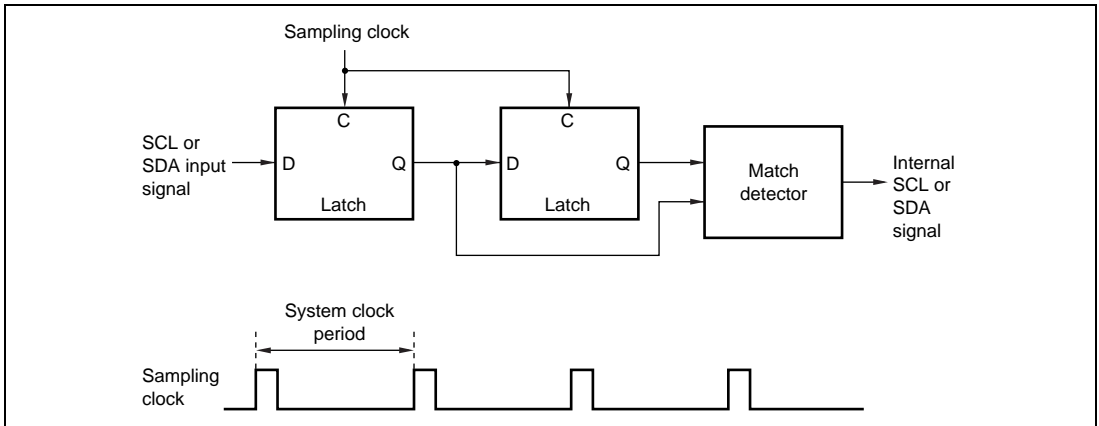


Figure 14.12 Block Diagram of Noise Chanceller

14.4.9 Sample Flowcharts

Figures 14.13 to 14.16 show sample flowcharts for using the I²C bus interface in each mode.

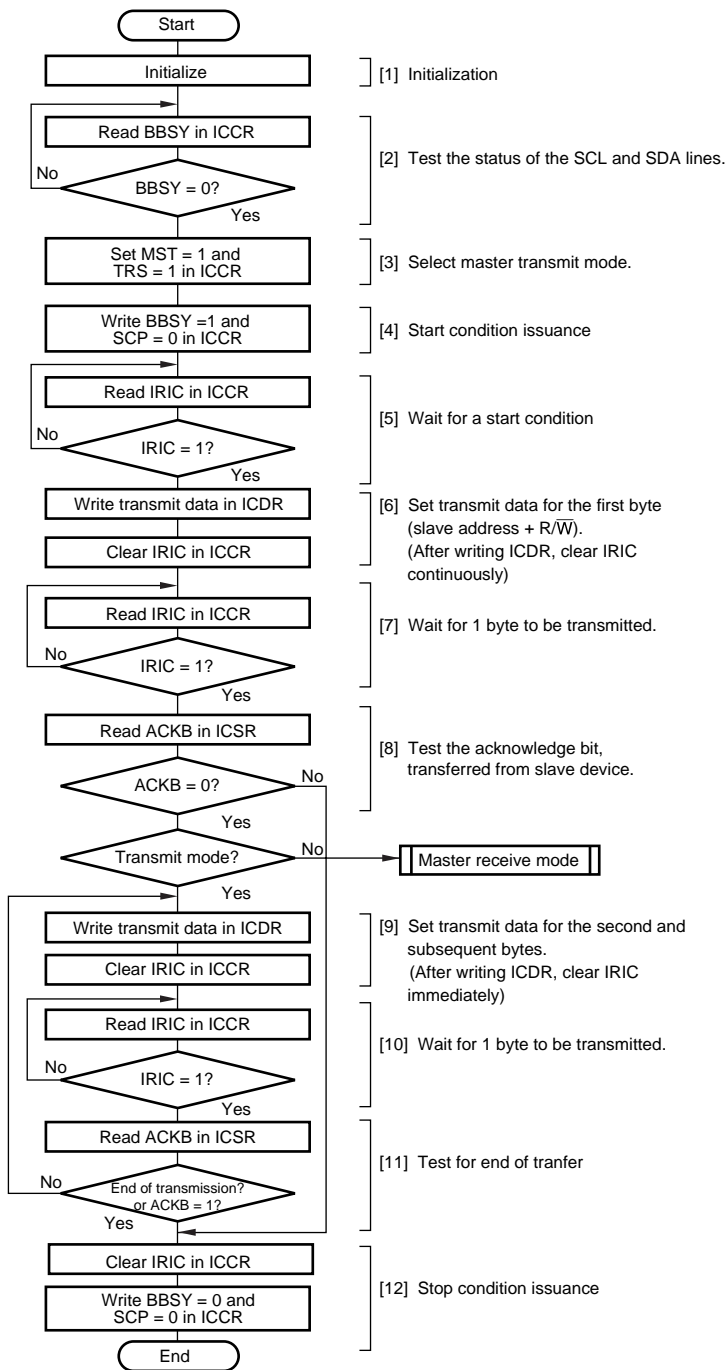


Figure 14.13 Sample Flowchart for Master Transmit Mode

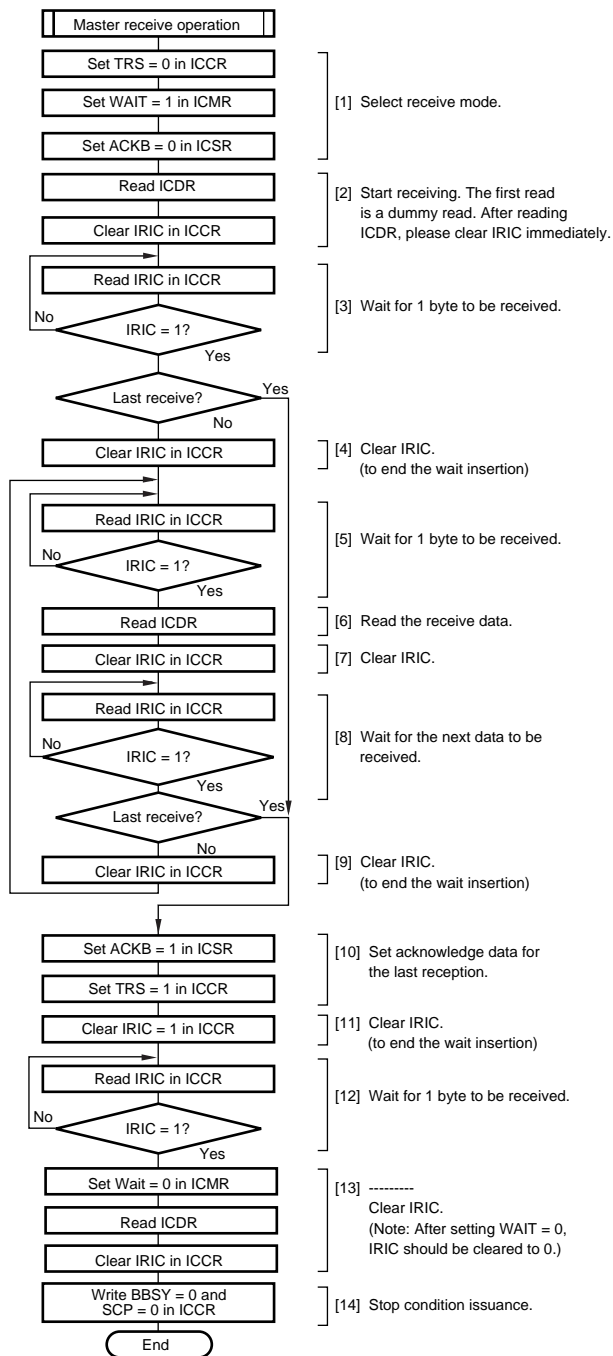
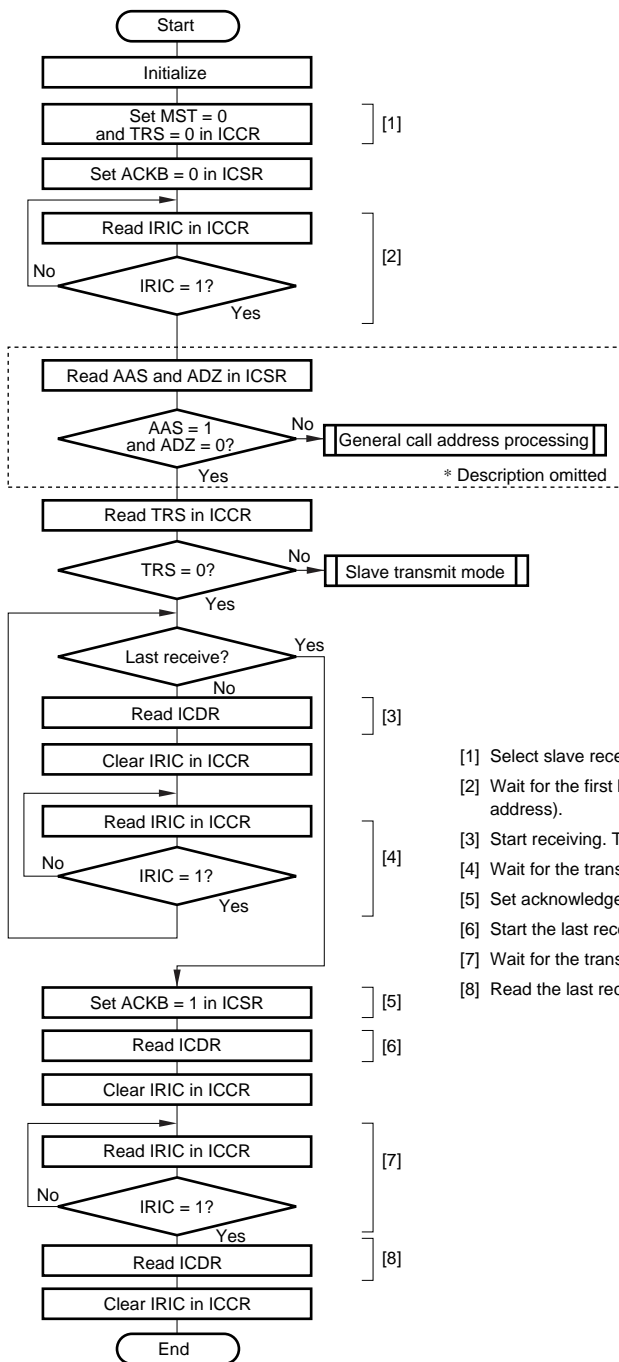


Figure 14.14 Sample Flowchart for Master Receive Mode



- [1] Select slave receive mode.
- [2] Wait for the first byte to be received (slave address).
- [3] Start receiving. The first read is a dummy read.
- [4] Wait for the transfer to end.
- [5] Set acknowledge data for the last reception.
- [6] Start the last reception.
- [7] Wait for the transfer to end.
- [8] Read the last receive data.

Figure 14.15 Sample Flowchart for Slave Receive Mode

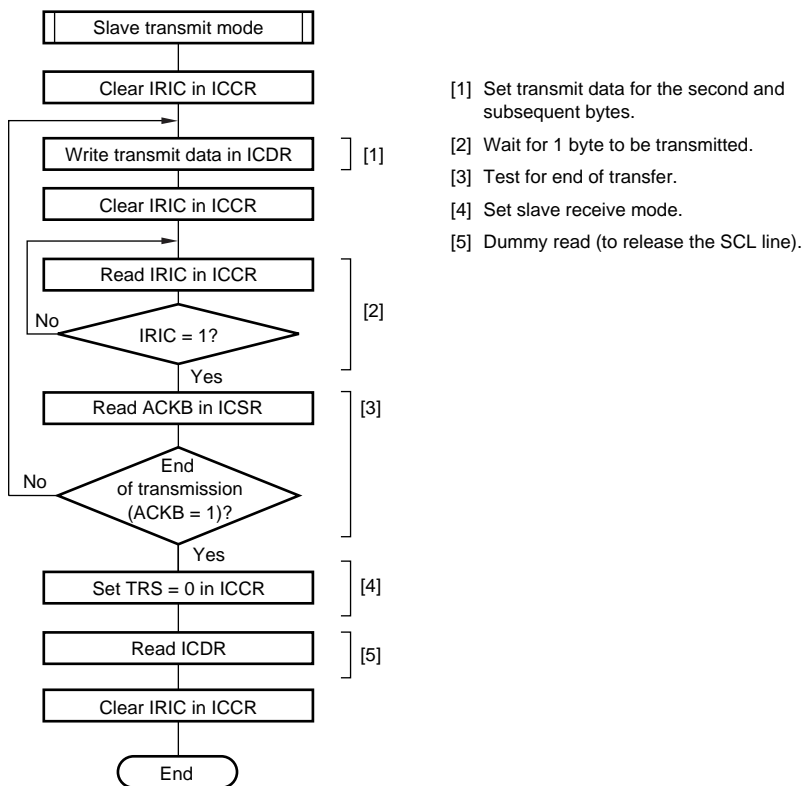


Figure 14.16 Sample Flowchart for Slave Transmit Mode

14.5 Usage Notes

1. In master mode, if an instruction to generate a start condition is immediately followed by an instruction to generate a stop condition, neither condition will be output correctly. To output consecutive start and stop conditions, after issuing the instruction that generates the start condition, read the relevant ports, check that SCL and SDA are both low, then issue the instruction that generates the stop condition. Note that SCL may not yet have gone low when BBSY is cleared to 0.
2. Either of the following two conditions will start the next transfer. Pay attention to these conditions when reading or writing to ICDR.
 - Write access to ICDR when ICE = 1 and TRS = 1 (including automatic transfer from ICDRT to ICDRS)
 - Read access to ICDR when ICE = 1 and TRS = 0 (including automatic transfer from ICDRS to ICDRR)
3. Table 14.6 shows the timing of SCL and SDA output in synchronization with the internal clock. Timings on the bus are determined by the rise and fall times of signals affected by the bus load capacitance, Series resistance, and parallel resistance.

Table 14.6 I²C Bus Timing (SCL and SDA Output)

Item	Symbol	Output Timing	Unit	Notes
SCL output cycle time	t_{SCLO}	$28t_{\text{cyc}}$ to $256t_{\text{cyc}}$	ns	
SCL output high pulse width	t_{SCLHO}	$0.5t_{\text{SCLO}}$	ns	
SCL output low pulse width	t_{SCLLO}	$0.5t_{\text{SCLO}}$	ns	
SDA output bus free time	t_{BUFO}	$0.5t_{\text{SCLO}} - 1t_{\text{cyc}}$	ns	
Start condition output hold time	t_{STAHO}	$0.5t_{\text{SCLO}} - 1t_{\text{cyc}}$	ns	
Retransmission start condition output setup time	t_{STASO}	$1t_{\text{SCLO}}$	ns	
Stop condition output setup time	t_{STOSO}	$0.5t_{\text{SCLO}} + 2t_{\text{cyc}}$	ns	
Data output setup time (master)	t_{SDASO}	$1t_{\text{SCLLO}} - 3t_{\text{cyc}}$	ns	
Data output setup time (slave)		$1t_{\text{SCLL}} - 3t_{\text{cyc}}$	ns	
Data output hold time	t_{SDAHO}	$3t_{\text{cyc}}$	ns	

4. SCL and SDA inputs are sampled in synchronization with the internal clock. The AC timing therefore depends on the system clock cycle t_{cyc} , as shown in table 26.8 in section 26, Electrical Characteristics. Note that the I²C bus interface AC timing specifications will not be met with a system clock frequency of less than 5 MHz.

5. The I²C bus interface specification for the SCL rise time t_{sr} is under 1000 ns (300 ns for high-speed mode). In master mode, the I²C bus interface monitors the SCL line and synchronizes one bit at a time during communication. If t_{sr} (the time for SCL to go from low to V_{IH}) exceeds the time determined by the input clock of the I²C bus interface, the high period of SCL is extended. The SCL rise time is determined by the pull-up resistance and load capacitance of the SCL line. To insure proper operation at the set transfer rate, adjust the pull-up resistance and load capacitance so that the SCL rise time does not exceed the values given in the table in table 14.7.

Table 14.7 Permissible SCL Rise Time (t_{sr}) Values

			Time Indication					
			I ² C Bus Specification (Max.)	ϕ = 5 MHz	ϕ = 8 MHz	ϕ = 10 MHz	ϕ = 16 MHz	ϕ = 20 MHz
IICX	t _{cyc} Indication							
0	7.5t _{cyc}	Normal mode	1000 ns	1000 ns	937 ns	750 ns	468 ns	375 ns
		High-speed mode	300 ns	300 ns	300 ns	300 ns	300 ns	300 ns
1	17.5t _{cyc}	Normal mode	1000 ns	1000 ns	1000 ns	1000 ns	1000 ns	875 ns
		High-speed mode	300 ns	300 ns	300 ns	300 ns	300 ns	300 ns

6. The I²C bus interface specifications for the SCL and SDA rise and fall times are under 1000 ns and 300 ns. The I²C bus interface SCL and SDA output timing is prescribed by t_{scyc} and t_{cyc} , as shown in table 14.6. However, because of the rise and fall times, the I²C bus interface specifications may not be satisfied at the maximum transfer rate. Table 14.8 shows output timing calculations for different operating frequencies, including the worst-case influence of rise and fall times. The values in the above table will vary depending on the settings of the IICX bit and bits CKS0 to CKS2. Depending on the frequency it may not be possible to achieve the maximum transfer rate; therefore, whether or not the I²C bus interface specifications are met must be determined in accordance with the actual setting conditions. t_{BUFO} fails to meet the I²C bus interface specifications at any frequency. The solution is either (a) to provide coding to secure the necessary interval (approximately 1 μ s) between issuance of a stop condition and issuance of a start condition, or (b) to select devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

t_{SCLLO} in high-speed mode and t_{STASO} in standard mode fail to satisfy the I²C bus interface specifications for worst-case calculations of t_{sr}/t_{sf} . Possible solutions that should be investigated include (a) adjusting the rise and fall times by means of a pull-up resistor and capacitive load, (b) reducing the transfer rate to meet the specifications, or (c) selecting devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

Table 14.8 I²C Bus Timing (with Maximum Influence of t_{sr}/t_{sf})

Item	t_{cyc} Indication		Time Indication (at Maximum Transfer Rate) [ns]						
			t_{sr}/t_{sf} Influence (Max.)	I ² C Bus Specifi- cation (Min.)	$\phi =$ 5 MHz	$\phi =$ 8 MHz	$\phi =$ 10 MHz	$\phi =$ 16 MHz	$\phi =$ 20 MHz
t_{SCLHO}	$0.5t_{SCLO} - (-t_{sr})$	Standard mode	-1000	4000	4000	4000	4000	4000	4000
		High-speed mode	-300	600	950	950	950	950	950
t_{SCLLO}	$0.5t_{SCLO} - (-t_{sf})$	Standard mode	-250	4700	4750	4750	4750	4750	4750
		High-speed mode	-250	1300	1000* ¹	1000* ¹	1000* ¹	1000* ¹	1000* ¹
t_{BUFO}	$0.5t_{SCLO} - 1t_{cyc}$ ($-t_{sf}$)	Standard mode	-1000	4700	3800* ¹	3875* ¹	3900* ¹	3938* ¹	3950* ¹
		High-speed mode	-300	1300	750* ¹	825* ¹	850* ¹	888* ¹	900* ¹
t_{STAHO}	$0.5t_{SCLO} - 1t_{cyc}$ ($-t_{sf}$)	Standard mode	-250	4000	4550	4625	4650	4688	4700
		High-speed mode	-250	600	800	875	900	938	950
t_{STASO}	$1t_{SCLO} - (-t_{sr})$	Standard mode	-1000	4700	9000	9000	9000	9000	9000
		High-speed mode	-300	600	2200	2200	2200	2200	2200
t_{STOSO}	$0.5t_{SCLO} + 2t_{cyc}$ ($-t_{sr}$)	Standard mode	-1000	4000	4400	4250	4200	4125	4100
		High-speed mode	-300	600	1350	1200	1150	1075	1050
t_{SDASO} (master)	$1t_{SCLLO}^{*2} - 3t_{cyc}$ ($-t_{sr}$)	Standard mode	-1000	250	3100	3325	3400	3513	3550
		High-speed mode	-300	100	400	625	700	813	850
t_{SDASO} (slave)	$1t_{SCLL}^{*2} - 3t_{cyc}^{*2}$ ($-t_{sr}$)	Standard mode	-1000	250	3100	3325	3400	3513	3550
		High-speed mode	-300	100	400	625	700	813	850
t_{SDAHO}	$3t_{cyc}$	Standard mode	0	0	600	375	300	188	150
		High-speed mode	0	0	600	375	300	188	150

- Notes: 1. Does not meet the I²C bus interface specification. Remedial action such as the following is necessary: (a) secure a start/stop condition issuance interval; (b) adjust the rise and fall times by means of a pull-up resistor and capacitive load; (c) reduce the transfer rate; (d) select slave devices whose input timing permits this output timing.
The values in the above table will vary depending on the settings of the IICX bit and bits CKS0 to CKS2. Depending on the frequency it may not be possible to achieve the maximum transfer rate; therefore, whether or not the I²C bus interface specifications are met must be determined in accordance with the actual setting conditions.
2. Calculated using the I²C bus specification values (standard mode: 4700 ns min.; high-speed mode: 1300 ns min.).

7. Note on ICDR Read at End of Master Reception

To halt reception after completion of a receive operation in master receive mode, set the TRS bit to 1 and write 0 to BBSY and SCP in ICCR. This changes the SDA pin from low to high when the SCL pin is high, and generates the stop condition. After this, receive data can be read by means of an ICDR read, but if data remains in the buffer the ICDRS receive data will not be transferred to ICDR, and so it will not be possible to read the second byte of data. If it is necessary to read the second byte of data, issue the stop condition in master receive mode (i.e. with the TRS bit cleared to 0). When reading the receive data, first confirm that the BBSY bit in ICCR is cleared to 0, the stop condition has been generated, and the bus has been released, then read ICDR with TRS cleared to 0. Note that if the receive data (ICDR data) is read in the interval between execution of the instruction for issuance of the stop condition (writing of 0 to BBSY and SCP in ICCR) and the actual generation of the stop condition, the clock may not be output correctly in subsequent master transmission.

Clearing of the MST bit after completion of master transmission/reception, or other modifications of IIC control bits to change the transmit/receive operating mode or settings, must be carried out during interval (a) in figure 14.17 (after confirming that the BBSY bit has been cleared to 0 in the ICCR register).

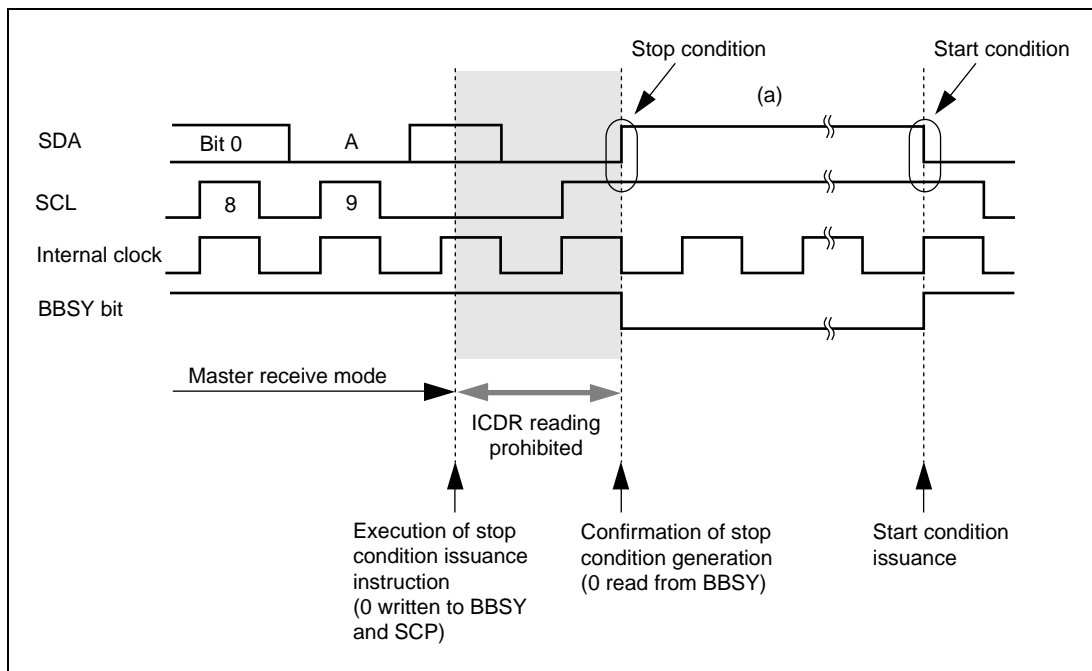
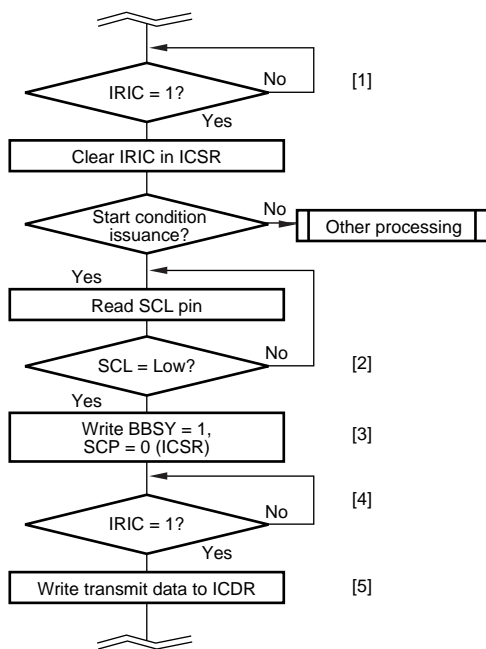


Figure 14.17 Points for Attention Concerning Reading of Master Receive Data

8. Notes on Start Condition Issuance for Retransmission

Depending on the timing combination with the start condition issuance and the subsequently writing data to ICDR, it may not be possible to issue the retransmission and the data transmission after retransmission condition issuance.

After start condition issuance is done and determined the start condition, write the transmit data to ICDR, as shown below. Figure 14.18 shows the timing of start condition issuance for retransmission, and the timing for subsequently writing data to ICDR, together with the corresponding flowchart.



[1] Wait for end of 1-byte transfer

[2] Determine whether SCL0 is low

[3] Issue restart condition instruction for transmission

[4] Determine whether start condition is generated or not

[5] Set transmit data (slave address + R/W)

Note: Program so that processing from [3] to [5] is executed continuously.

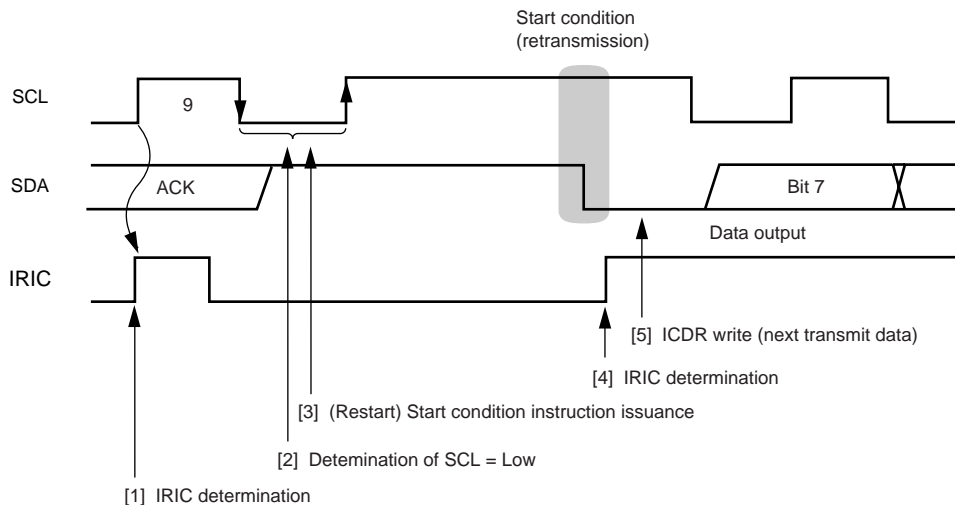


Figure 14.18 Flowchart and Timing of Start Condition Instruction Issuance for Retransmission

9. Notes on I²C Bus Interface Stop Condition Instruction Issuance

If the rise time of the 9th SCL clock exceeds the specification because the bus load capacitance is large, or if there is a slave device of the type that drives SCL low to effect a wait, after rising of the 9th SCL clock, issue the stop condition after reading SCL and determining it to be low, as shown below.

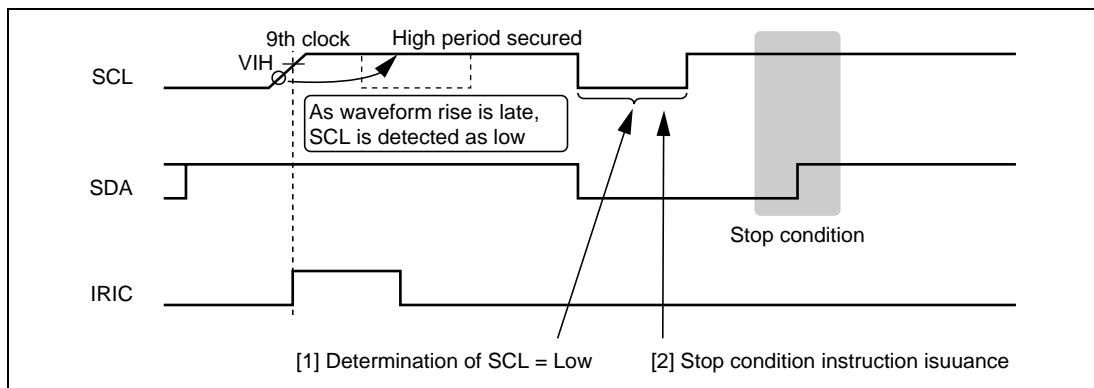


Figure 14.19 Timing of Stop Condition Issuance

10. Notes on Initialization of Internal State

The I²C has a function for forcible initialization of its internal state if a deadlock occurs during communication.

Initialization is executed by (1) setting bits CLR3 to CLR0 in the DDCCSWR register. For details see section 14.3.8 DDC Switch Register (DDCCSWR).

- Scope of Initialization: The initialization executed by function covers the following items:
 - TDRE and RDRF internal flags
 - Transmit/receive sequencer and internal operating clock counter
 - Internal latches for retaining the output state of the SCL and SDA pins (wait, clock, data output, etc.)
- The following items are not initialized:
 - Actual register values (ICDR, SAR, SARX, ICMR, ICCR, ICSR, DDCCSWR, STCR)
 - Internal latches used to retain register read information setting/clearing flags in the ICMR, ICCR, ICSR, and DDCCSWR registers
 - The value of the ICMR register bit counter (BC2 to BC0)
 - Generated interrupt sources (interrupt sources transferred to the interrupt controller)

- Notes on Initialization:

Interrupt flags and interrupt sources are not cleared, and so flag clearing measures must be taken as necessary. Basically, other register flags are not cleared either, and so flag clearing measures must be taken as necessary.

When initialization is executed by the DDCSWR register, the write data for bits CLR3 to CLR0 is not retained. To perform IIC clearance, bits CLR3 to CLR0 must be written to simultaneously using an MOV instruction. Do not use a bit manipulation instruction such as BCLR. Similarly, when clearing is required again, all the bits must be written to simultaneously in accordance with the setting.

If a flag clearing setting is made during transmission/reception, the IIC module will stop transmitting/receiving at that point and the SCL and SDA pins will be released. When transmission/reception is started again, register initialization, etc., must be carried out as necessary to enable correct communication as a system.

The value of the BBSY bit cannot be modified directly by this module clear function, but since the stop condition pin waveform is generated according to the state and release timing of the SCL and SDA pins, the BBSY bit may be cleared as a result. Similarly, state switching of other bits and flags may also have an effect.

To prevent problems caused by these factors, the following procedure should be used when initializing the IIC state.

Execute initialization of the internal state according to the setting of bits CLR3 to CLR0.

Execute a stop condition issuance instruction (write 0 to BBSY and SCP) to clear the BBSY bit to 0, and wait for two transfer rate clock cycles.

Re-execute initialization of the internal state according to the setting of bits CLR3 to CLR0.

Initialize (re-set) the IIC registers.

11. Interrupt during Module Stop Mode

When the module is stopped in the state that an interrupt is requested, the interrupt source of the CPU or activation source of the DTC* is not cleared. Be sure to enter module stop mode by disabling the interrupt beforehand.

Note: * Supported only by the H8S/2268 Series.

12. Assignment and Selection of Register Addresses

Some I²C bus interface registers are assigned to the same address as other registers. Register selection is performed by means of the ICE bit in the serial control register X (SCRX). For details on register addresses, see section 25, List of Registers.

Section 15 A/D Converter

This LSI includes a successive approximation type 10-bit A/D converter that allows up to ten analog input channels to be selected. A block diagram of the A/D converter is shown in figure 15.1.

15.1 Features

- 10-bit resolution
- Ten input channels
- Conversion time: 6.3 μ s per channel (at 20.5 MHz operation)
- Two operating modes
 - Single mode: Single-channel A/D conversion
 - Scan mode: Continuous A/D conversion on 1 to 4 channels
- Four data registers
 - Conversion results are held in a 16-bit data register for each channel
- Sample and hold function
- Three methods conversion start
 - Software
 - 16-bit timer pulse unit (TPU or TMR) conversion start trigger
 - External trigger signal
- Interrupt request
 - An A/D conversion end interrupt request (ADI) can be generated
- Module stop mode can be set

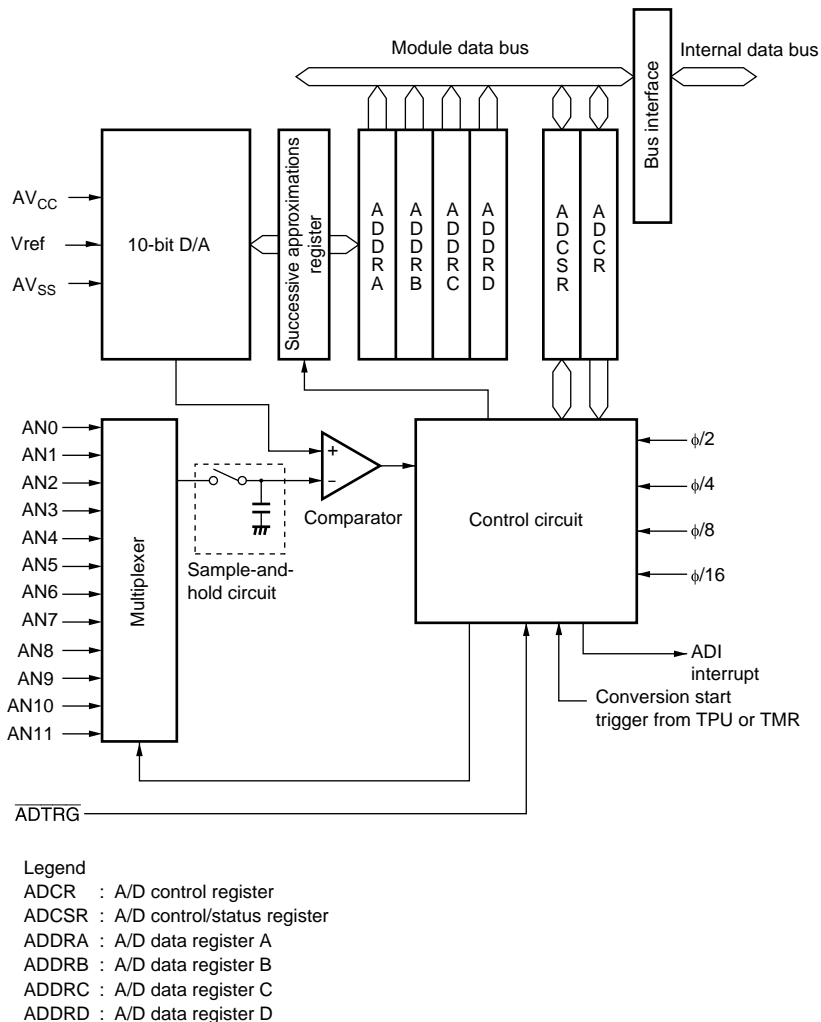


Figure 15.1 Block Diagram of A/D Converter

15.2 Input/Output Pins

Table 15.1 summarizes the input pins used by the A/D converter. The eight analog input pins are divided into two groups each of which consists of four channels; analog input pins 0 to 3 (AN0 to AN3) comprising group 0 and analog input pins 4 to 7 (AN4 to AN7) comprising group 1. The AVcc and AVss pins are the power supply pins for the analog block in the A/D converter. The Vref pin is the A/D conversion reference voltage pin.

Table 15.1 Pin Configuration

Pin Name	Symbol	I/O	Function
Analog power supply pin	AV _{cc}	Input	Analog block power supply and reference voltage
Analog ground pin	AV _{ss}	Input	Analog block ground and reference voltage
Reference voltage pin	Vref	Input	Reference voltage for A/D conversion
Analog input pin 0	AN0	Input	Group 0 analog input pins
Analog input pin 1	AN1	Input	
Analog input pin 2	AN2	Input	
Analog input pin 3	AN3	Input	
Analog input pin 4	AN4	Input	Group 1 analog input pins
Analog input pin 5	AN5	Input	
Analog input pin 6	AN6	Input	
Analog input pin 7	AN7	Input	
Analog input pin 8	AN8	Input	Analog input pins
Analog input pin 9	AN9	Input	
A/D external trigger input pin	ADTRG	Input	External trigger input pin for starting A/D conversion

15.3 Register Descriptions

The A/D converter has the following registers. For details on the module stop control register, refer to section 22.1.2, Module Stop Control Registers A to D (MSTPCRA to MSTPCRD).

- A/D data register A (ADDRA)
- A/D data register B (ADDRB)
- A/D data register C (ADDRC)
- A/D data register D (ADDRD)
- A/D control/status register (ADCSR)
- A/D control register (ADCR)

15.3.1 A/D Data Registers A to D (ADDRA to ADDRD)

There are four 16-bit read-only ADDR registers; ADDRA to ADDRD, used to store the results of A/D conversion. The ADDR registers, which store a conversion result for each channel, are shown in table 15.2.

The converted 10-bit data is stored in bits 6 to 15. The lower 6 bits are always read as 0.

The data bus between the CPU and the A/D converter is 8 bits wide. The upper byte can be read directly from the CPU, however the lower byte should be read via a temporary register. Therefore, when reading the ADDR, read only the upper byte, or read in word unit.

Table 15.2 Analog Input Channels and Corresponding ADDR Registers

Analog Input Channel				A/D Data Register to Be Stored the Results of A/D Conversion
CH3 = 0		CH3 = 1		
Group 0 (CH2 = 0)	Group 1 (CH2 = 1)	— (CH2 = 0)	— (CH2 = 1)	
AN0	AN4	Setting prohibited	Setting prohibited	ADDRA
AN1	AN5	Setting prohibited	Setting prohibited	ADDRB
AN2	AN6	Setting prohibited	AN8	ADDRC
AN3	AN7	Setting prohibited	AN9	ADDRD

15.3.2 A/D Control/Status Register (ADCSR)

ADCSR controls A/D conversion operations.

Bit	Bit Name	Initial Value	R/W	Description
7	ADF	0	R/(W)* ¹	<p>A/D End Flag</p> <p>A status flag that indicates the end of A/D conversion.</p> <p>[Setting conditions]</p> <ul style="list-style-type: none">• When A/D conversion ends in single mode• When A/D conversion ends on all specified channels in scan mode <p>[Clearing conditions]</p> <ul style="list-style-type: none">• When 0 is written after reading ADF = 1• When the DTC is activated by an ADI interrupt and ADDR is read*²
6	ADIE	0	R/W	<p>A/D Interrupt Enable</p> <p>A/D conversion end interrupt (ADI) request enabled when 1 is set</p>
5	ADST	0	R/W	<p>A/D Start</p> <p>Clearing this bit to 0 stops A/D conversion, and the A/D converter enters the wait state.</p> <p>Setting this bit to 1 starts A/D conversion. In single mode, this bit is cleared to 0 automatically when conversion on the specified channel is complete. In scan mode, conversion continues sequentially on the specified channels until this bit is cleared to 0 by software, a reset, or a transition to power-down mode in which the A/D converter is halted, shown in table 22.1.</p> <p>The ADST bit can be set to 1 by software, a timer conversion start trigger, or the A/D external trigger input pin (ADTRG).</p>

Bit	Bit Name	Initial Value	R/W	Description
4	SCAN	0	R/W	Scan Mode Selects single mode or scan mode as the A/D conversion operating mode. Only set the SCAN bit while conversion is stopped (ADST = 0). 0: Single mode 1: Scan mode
3	CH3	0	R/W	Channel Select 0 to 3
2	CH2	0	R/W	Select analog input channels.
1	CH1	0	R/W	When SCAN = 0
0	CH0	0	R/W	When SCAN = 1
				0000: AN0
				0001: AN1
				0010: AN2
				0011: AN3
				0100: AN4
				0101: AN5
				0110: AN6
				0111: AN7
				1000: Setting prohibited
				1001: Setting prohibited
				1010: Setting prohibited
				1011: Setting prohibited
				1100: Setting prohibited
				1101: Setting prohibited
				1110: AN8
				1111: AN9

Notes: 1. Only 0 can be written to bit 7, to clear this bit.
 2. Supported only by the H8S/2268 Series.

15.3.3 A/D Control Register (ADCR)

The ADCR enables A/D conversion started by an external trigger signal.

Bit	Bit Name	Initial Value	R/W	Description
7	TRGS1	0	R/W	Timer Trigger Select 0 and 1
6	TRGS0	0	R/W	Enables the start of A/D conversion by a trigger signal. Only set bits TRGS0 and TRGS1 while conversion is stopped (ADST = 0). 00: A/D conversion start by software is enabled 01: A/D conversion start by TPU conversion start trigger is enabled 10: A/D conversion start by 8-bit timer conversion start trigger is enabled 11: A/D conversion start by external trigger pin (ADTRG) is enabled
5	—	1	—	Reserved
4	—	1	—	These bits are always read as 1 and cannot be modified.
3	CKS1	0	R/W	Clock Select 0 and 1
2	CKS0	0	R/W	These bits specify the A/D conversion time. The conversion time should be changed only when ADST = 0. Specify a setting that gives a value within the range shown in table 26.9 or 26.22 in section 26, Electrical Characteristics. 00: Conversion time = 530 states (max.) 01: Conversion time = 266 states (max.) 10: Conversion time = 134 states (max.) 11: Conversion time = 68 states (max.)
1, 0	—	All 1	—	Reserved These bits are always read as 1 and cannot be modified.

15.4 Operation

The A/D converter operates by successive approximation with 10-bit resolution. It has two operating modes; single mode and scan mode. When changing the operating mode or analog input channel, in order to prevent incorrect operation, first clear the bit ADST to 0 in ADCSR. The ADST bit can be set at the same time as the operating mode or analog input channel is changed.

15.4.1 Single Mode

In single mode, A/D conversion is to be performed only once on the specified single channel. The operations are as follows.

1. A/D conversion is started when the ADST bit is set to 1, according to software, timer conversion start trigger, or external trigger input.
2. When A/D conversion is completed, the result is transferred to the corresponding A/D data register 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. When A/D conversion ends, the ADST bit is automatically cleared to 0 and the A/D converter enters the wait state.

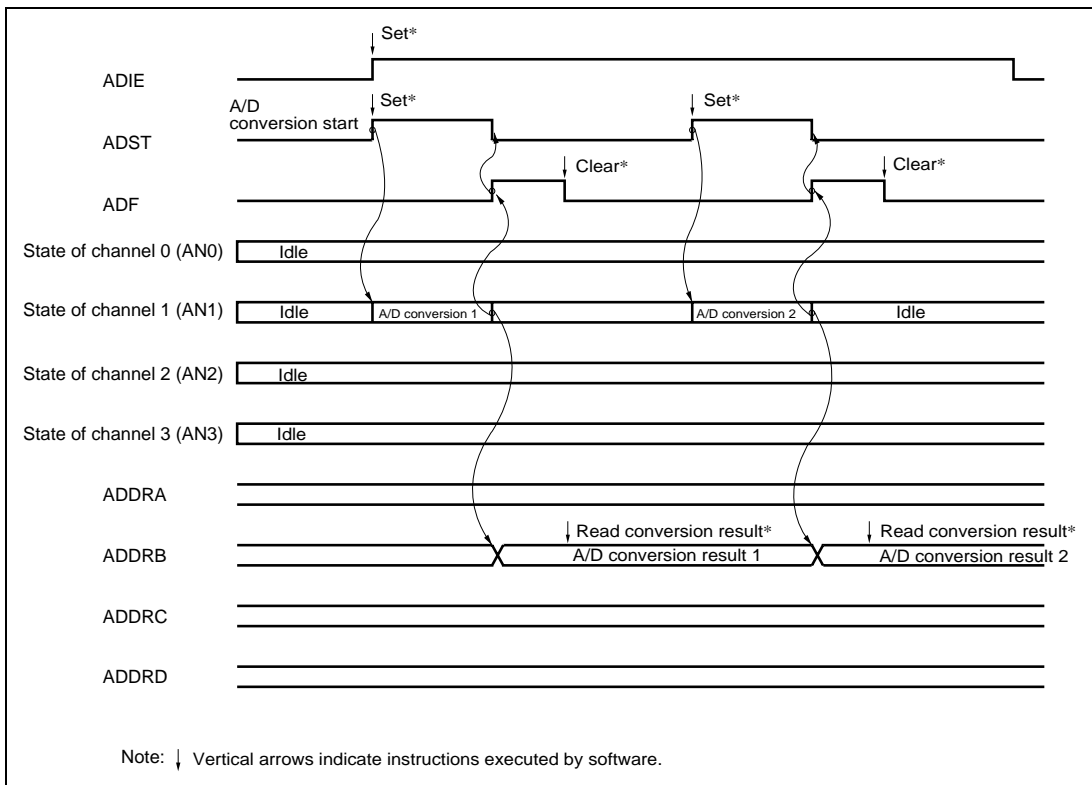


Figure 15.2 Example of A/D converter Operation (Single Mode, Channel 1 Selected)

15.4.2 Scan Mode

In scan mode, A/D conversion is to be performed sequentially on the specified channels (four channels maximum). The operations are as follows.

1. When the ADST bit is set to 1 by software, TPU, timer conversion start trigger, or external trigger, input, A/D conversion starts on the first channel in the group (AN0 when CH3 and CH2 = 00, AN4 when CH3 and CH2 = 01, or AN8 when CH3 and CH2 = 10).
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 flag is set to 1. If the ADIE bit is set to 1 at this time, an ADI interrupt is requested after A/D conversion ends. Conversion of the first channel in the group starts again.
4. 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 the wait state.

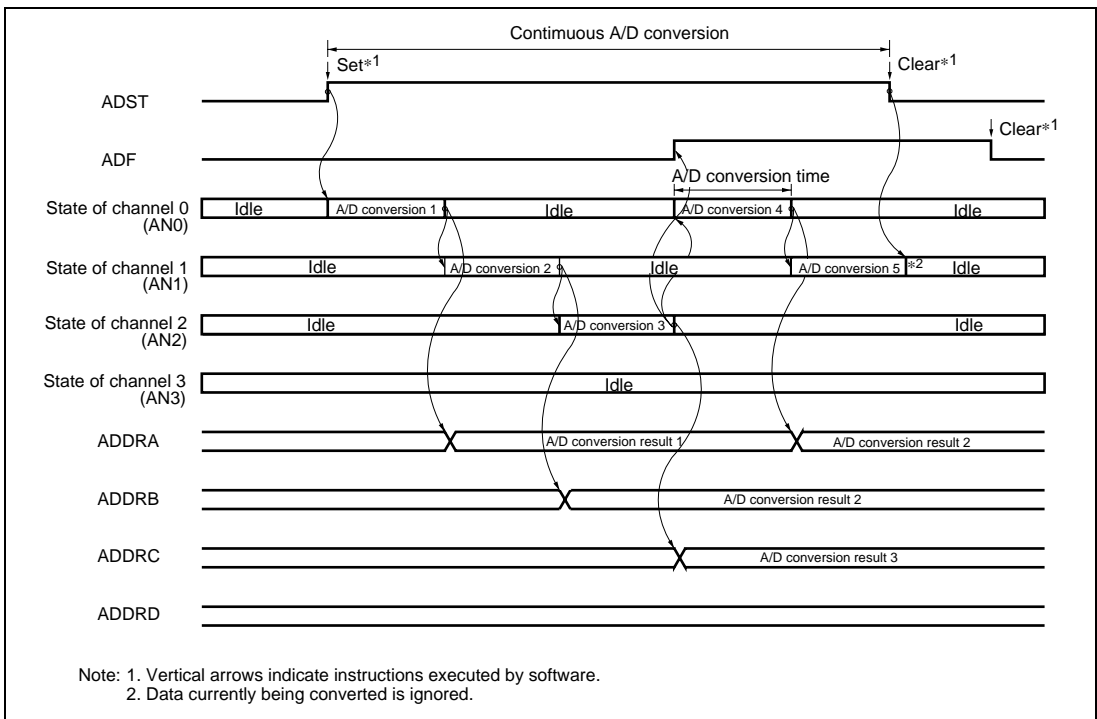


Figure 15.3 Example of A/D Converter Operation (Scan Mode, Channels AN0 to AN2 Selected)

15.4.3 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 the A/D conversion start delay time (t_d) has passed after the ADST bit is set to 1, then starts conversion. Figure 15.2 shows the A/D conversion timing. Table 15.3 shows the A/D conversion time.

As indicated in figure 15.4, 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 table 15.3.

In scan mode, the values given in table 15.3 apply to the first conversion time. The values given in table 15.4 apply to the second and subsequent conversions.

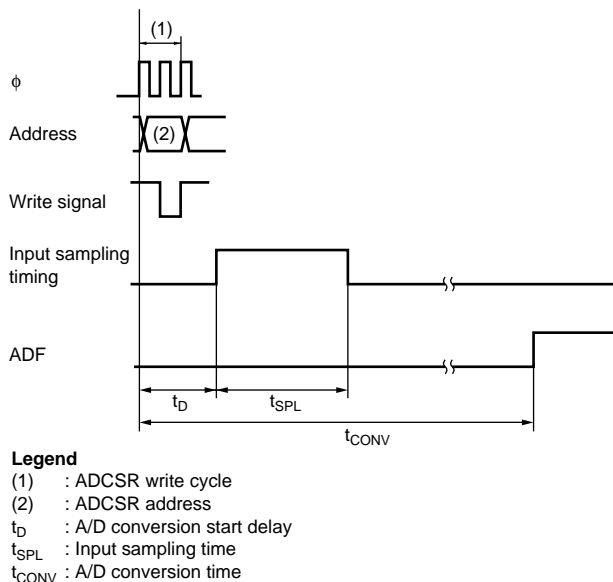


Figure 15.4 A/D Conversion Timing

Table 15.3 A/D Conversion Time (Single Mode)

Item	Symbol	CKS1 = 0						CKS1 = 1					
		CKS0 = 0			CKS0 = 1			CKS0 = 0			CKS0 = 1		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
A/D conversion start delay	t_D	18	—	33	10	—	17	6	—	9	4	—	5
Input sampling time	t_{SPL}	—	127	—	—	63	—	—	31	—	—	15	—
A/D conversion time	t_{CONV}	515	—	530	259	—	266	131	—	134	67	—	68

Note: * All values represent the number of states.

Table 15.4 A/D Conversion Time (Scan Mode)

CKS1	CKS0	Conversion Time (State)
0	0	512 (Fixed)
	1	256 (Fixed)
1	0	128 (Fixed)
	1	64 (Fixed)

15.4.4 External Trigger Input Timing

A/D conversion can be externally triggered. When the TRGS0 and TRGS1 bits are set to 11 in ADCR, external trigger input is enabled at the $\overline{\text{ADTRG}}$ pin. A falling edge at the $\overline{\text{ADTRG}}$ pin sets the ADST bit to 1 in ADCSR, 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 15.5 shows the timing.

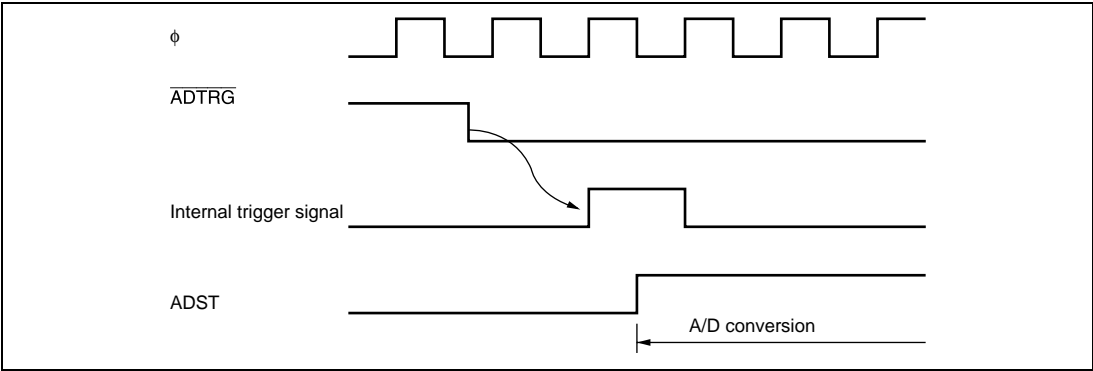


Figure 15.5 External Trigger Input Timing

15.5 Interrupt Source

The A/D converter generates an A/D conversion end interrupt (ADI) at the end of A/D conversion. Setting the ADIE bit to 1 enables ADI interrupt requests while the bit ADF in ADCSR is set to 1 after A/D conversion is completed. In the H8S/2268 Series, the DTC* can be activated by an ADI interrupt. Having the converted data read by the DTC* in response to an ADI interrupt enables continuous conversion without imposing a load on software.

Table 15.5 A/D Converter Interrupt Source

Name	Interrupt Source	Interrupt Source Flag	DTC Activation*
ADI	A/D conversion completed	ADF	Possible

Note: * Supported only by the H8S/2268 Series.

15.6 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 15.6).
- 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'000000000 (H'000) to B'000000001 (H'001) (see figure 15.7).
- 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'111111110 (H'3FE) to B'111111111 (H'3FF) (see figure 15.7).

- Nonlinearity error

The error with respect to the ideal A/D conversion characteristic between zero voltage and full-scale voltage. Does not include offset error, full-scale error, or quantization error (see figure 15.7).

- Absolute accuracy
The deviation between the digital value and the analog input value. Includes offset error, full-scale error, quantization error, and nonlinearity error.

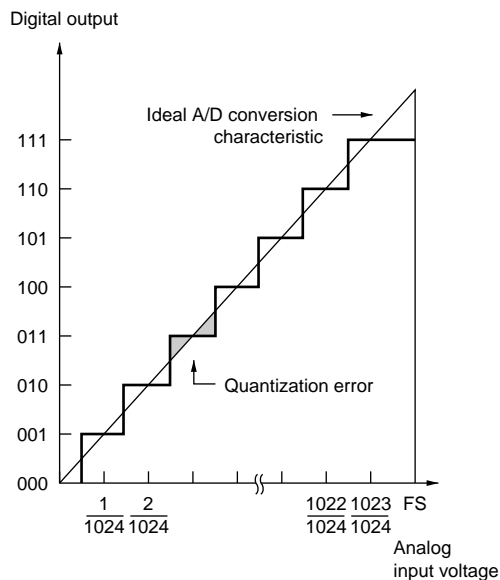


Figure 15.6 A/D Conversion Accuracy Definitions (1)

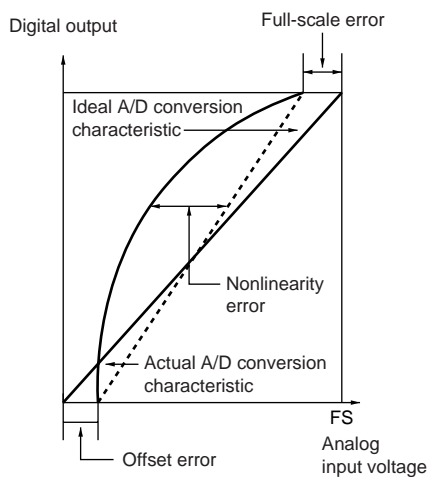


Figure 15.7 A/D Conversion Accuracy Definitions (2)

15.7 Usage Notes

15.7.1 Module Stop Mode Setting

Operation of the A/D converter can be disabled or enabled using the module stop control register. The initial setting is for operation of the A/D converter to be halted. Register access is enabled by clearing module stop mode. For details, refer to section 22, Power-Down Modes.

15.7.2 Permissible Signal Source Impedance

This LSI's analog input is designed such that conversion accuracy is guaranteed for an input signal for which the signal source impedance is $5\text{ k}\Omega$ 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 $5\text{ k}\Omega$, charging may be insufficient and it may not be possible to guarantee A/D conversion accuracy. However, for A/D conversion in single mode with a large capacitance provided externally, the input load will essentially comprise only the internal input resistance of $10\text{ k}\Omega$, and the signal source impedance is ignored. However, as 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., $5\text{ mV}/\mu\text{s}$ or greater) (see figure 15.8). When converting a high-speed analog signal, a low-impedance buffer should be inserted.

15.7.3 Influences on Absolute Accuracy

Adding capacitance results in coupling with GND, and therefore noise in GND may adversely affect absolute accuracy. 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 (i.e., acting as antennas).

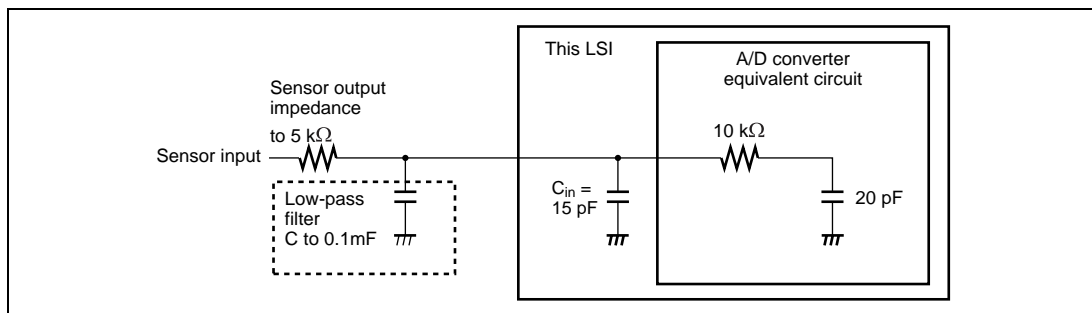


Figure 15.8 Example of Analog Input Circuit

15.7.4 Range of Analog Power Supply and Other Pin Settings

If the conditions 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 $AV_{ss} \leq ANn \leq AV_{cc}$.

- Relationship between AV_{cc} , AV_{ss} and V_{cc} , V_{ss}

Set $AV_{ss} = V_{ss}$ as the relationship between AV_{cc} , AV_{ss} and V_{cc} , V_{ss} . If the A/D converter is not used, the AV_{cc} and AV_{ss} pins must not be left open.

- V_{ref} range

The reference voltage input from the V_{ref} pin should be set to AV_{cc} or less.

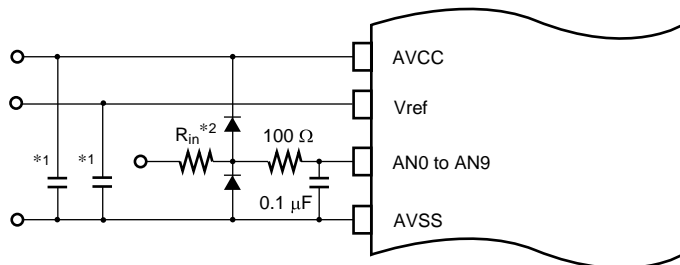
15.7.5 Notes on Board Design

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 AN9), and analog power supply (AV_{cc}) by the analog ground (AV_{ss}). Also, the analog ground (AV_{ss}) should be connected at one point to a stable digital ground (V_{ss}) on the board.

15.7.6 Notes on Noise Countermeasures

A protection circuit should be connected in order to prevent damage due to abnormal voltage, such as an excessive surge at the analog input pins (AN0 to AN9), between AV_{cc} and AV_{ss} , as shown in figure 15.9. Also, the bypass capacitors connected to AV_{cc} and the filter capacitor connected to AN0 to AN9 must be connected to AV_{ss} .

If a filter capacitor is connected, the input currents at the analog input pins (AN0 to AN9) 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 circuit constants.



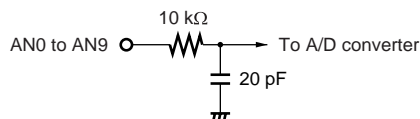
Notes: Values are reference values.

- 1.
2. R_{in} : Input impedance

Figure 15.9 Example of Analog Input Protection Circuit

Table 15.6 Analog Pin Specifications

Item	Min	Max	Unit
Analog input capacitance	—	20	pF
Permissible signal source impedance	—	5	kΩ



Note: Values are reference values.

Figure 15.10 Analog Input Pin Equivalent Circuit

Section 16 D/A Converter

The H8S/2268 Series includes a D/A converter, while the H8S/2264 Series does not.

16.1 Features

- 8-bit resolution
- Two output channels
- Conversion time: 10 μ s, maximum (when load capacitance is 20 pF)
- Output voltage: 0 V to Vref
- D/A output retaining function in software standby mode
- Module stop mode can be set

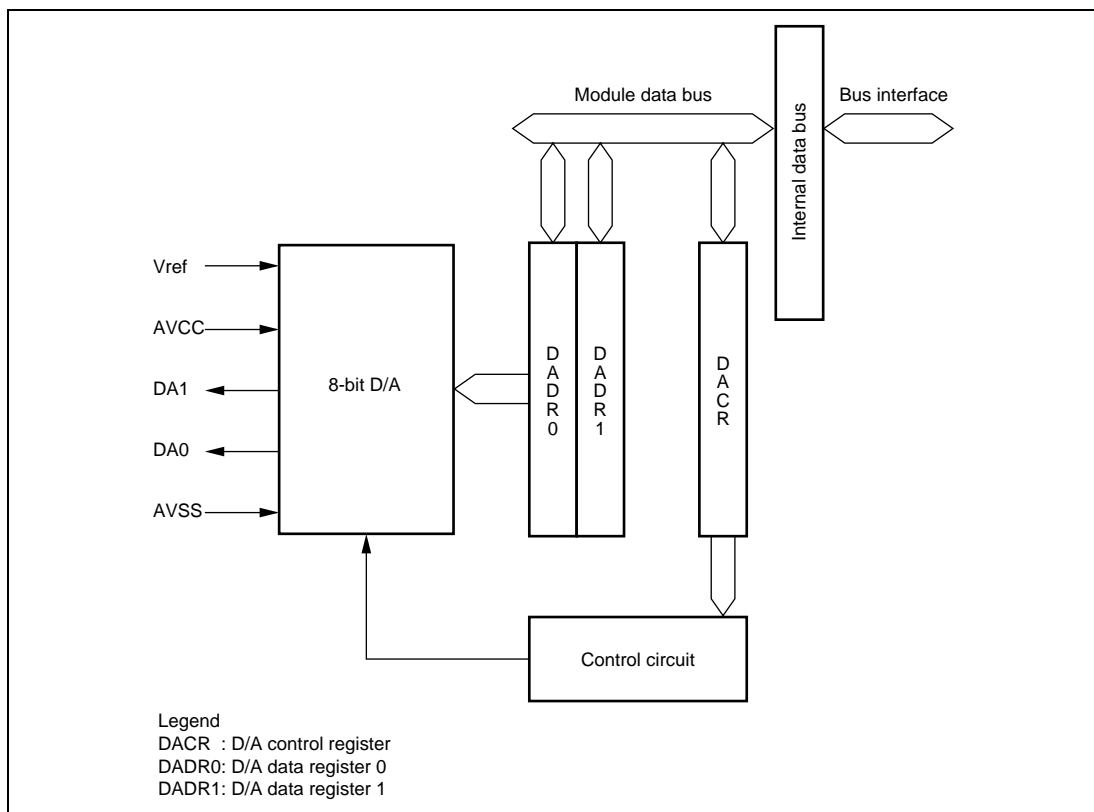


Figure 16.1 Block Diagram of D/A Converter

16.2 Input/Output Pins

Table 16.1 shows the pin configuration for the D/A converter.

Table 16.1 Pin Configuration

Pin Name	Symbol	I/O	Function
Analog power supply pin	AV_{CC}	Input	Analog block power supply
Analog ground pin	AV_{SS}	Input	Analog block ground and reference voltage
Analog output pin 0	DA0	Output	Channel 0 analog output pin
Analog output pin 1	DA1	Output	Channel 1 analog output pin
Reference voltage pin	Vref	Input	Reference voltage for analog block

16.3 Register Description

The D/A converter has the following registers. For details on the module stop control register, refer to section 22.1.2, Module Stop Control Registers A to D (MSTPCRA to MSTPCRD).

- D/A data register 0 (DADR0)
- D/A data register 1 (DADR1)
- D/A control register (DACR)

16.3.1 D/A Data Registers 0 and 1 (DADR0 and DADR1)

DADR0 and DADR1 are 8-bit readable/writable registers that store data for D/A conversion. When analog output is permitted, D/A data register contents are converted and output to analog output pins.

16.3.2 D/A Control Register (DACR)

DACR controls D/A converter operation.

Bit	Bit Name	Initial Value	R/W	Description
7	DAOE1	0	R/W	D/A Output Enable 1 Controls D/A conversion and analog output 0: Analog output DA1 is disabled 1: D/A conversion for channel 1 and analog output DA1 are enabled
6	DAOE0	0	R/W	D/A Output Enable 0 Controls D/A conversion and analog output 0: Analog output DA0 is disabled 1: D/A conversion for channel 0 and analog output DA0 are enabled
5	DAE	0	R/W	D/A Enable Controls D/A conversion in conjunction with the DAOE0 and DAOE1 bits. When the DAE bit is cleared to 0, D/A conversion for channels 0 and 1 are controlled individually. When DAE is set to 1, D/A conversion for channels 0 and 1 are controlled as one. Conversion result output is controlled by the DAOE0 and DAOE1 bits. For details, see table 16.2.
4 to 0	—	All 1	—	Reserved These bits are always read as 1 and cannot be modified.

Table 16.2 D/A Conversion Control

Bit 5	Bit 7	Bit 6	
DAE	DAOE1	DAOE0	Description
0	0	0	Disables D/A Conversion
		1	Enables D/A Conversion for channel 0
	1	0	Enables D/A Conversion for channel 1
		1	Enables D/A Conversion for channels 0 and 1
1	0	0	Disables D/A Conversion
		1	Enables D/A Conversion for channels 0 and 1
	1	0	
		1	

16.4 Operation

Two channels of the D/A converter can perform conversion individually.

When the DAOE bit in DACR is set to 1, D/A conversion is enabled and the conversion results are output.

An example of D/A conversion of channel 0 is shown below. The operation timing is shown in figure 16.2.

1. Write conversion data to DADR0.
2. When the DAOE0 bit in DACR is set to 1, D/A conversion starts. After the interval of t_{DCONV} , the conversion results are output from the analog output pin DA0. The conversion results are output continuously until DADR0 is modified or DAOE0 bit is cleared to 0. The output value is calculated by the following formula:

$$(\text{DADR contents})/256 \times V_{\text{ref}}$$

3. Conversion starts immediately after DADR0 is modified. After the interval of t_{DCONV} , conversion results are output.
4. When the DAOE bit is cleared to 0, analog output is disabled.

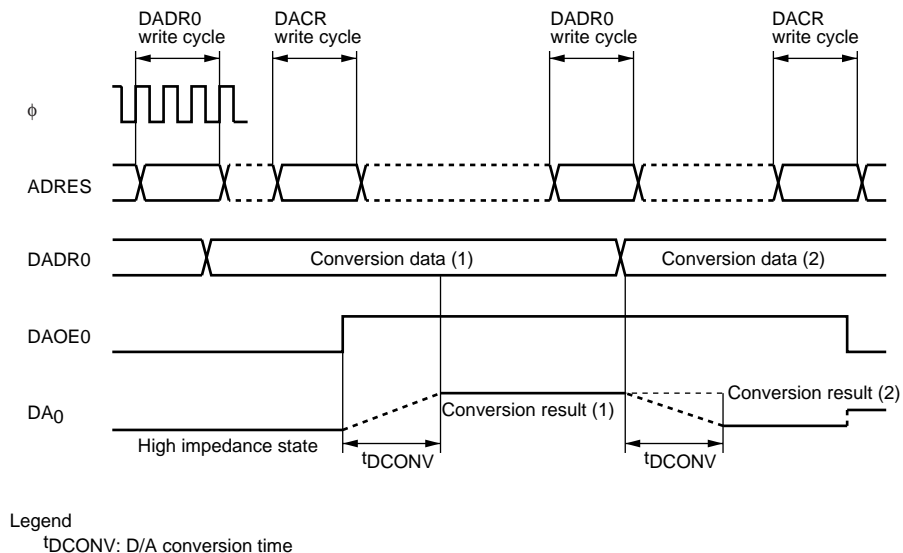


Figure 16.2 D/A Converter Operation Example

16.5 Usage notes

16.5.1 Analog Power Supply Current in Software Standby Mode

If this LSI enters software standby mode while D/A conversion is enabled, D/A output is retained and the analog power supply current is equivalent to that during D/A conversion. To reduce analog power supply current in software standby mode, clear the DAOE0, DAOE1 and DAE bits to 0 to disable D/A output.

16.5.2 Setting for Module Stop Mode

It is possible to enable/disable the D/A converter operation using the module stop control register, the D/A converter does not operate by the initial value of the register. The register can be accessed by releasing the module stop mode. For more details, see section 22, Power-Down Modes.

Section 17 LCD Controller/Driver

The H8S/2268 has an on-chip segment type LCD control circuit, LCD driver, and power supply circuit, enabling it to directly drive an LCD panel.

17.1 Overview

Features of the LCD controller/driver are given below.

- Display capacity

Duty Cycle	Internal Driver
Static	40 SEG
1/2	40 SEG
1/3	40 SEG
1/4	40 SEG

- LCD RAM capacity
8 bits \times 20 bytes (160 bits)
Byte or word access to LCD RAM
- The segment output pins can be used as ports.
H8S/2268 series: SEG40 to SEG1 pins can be used as ports in groups of eight.
H8S/2264 series: SEG24 to SEG1 pins can be used as ports in groups of four.
- Common output pins not used because of the duty cycle can be used for common double-buffering (parallel connection).
With 1/2 duty, parallel connection of COM1 to COM2, and of COM3 to COM4, can be used
In static mode, parallel connection of COM1 to COM2, COM3, and COM4 can be used
- Choice of 11 frame frequencies
- A or B waveform selectable by software
- Built-in power supply split-resistance
- Display possible in operating modes other than standby mode and module stop mode
- Display possible during low-voltage operation by built-in triple step-up voltage circuit (supported only by the H8S/2268 Series)
- Module stop mode
As the initial setting, LCD operation is halted. Access to registers and LCD RAM is enabled by clearing module stop mode.

Figure 17.1 shows a block diagram of the LCD controller/driver.

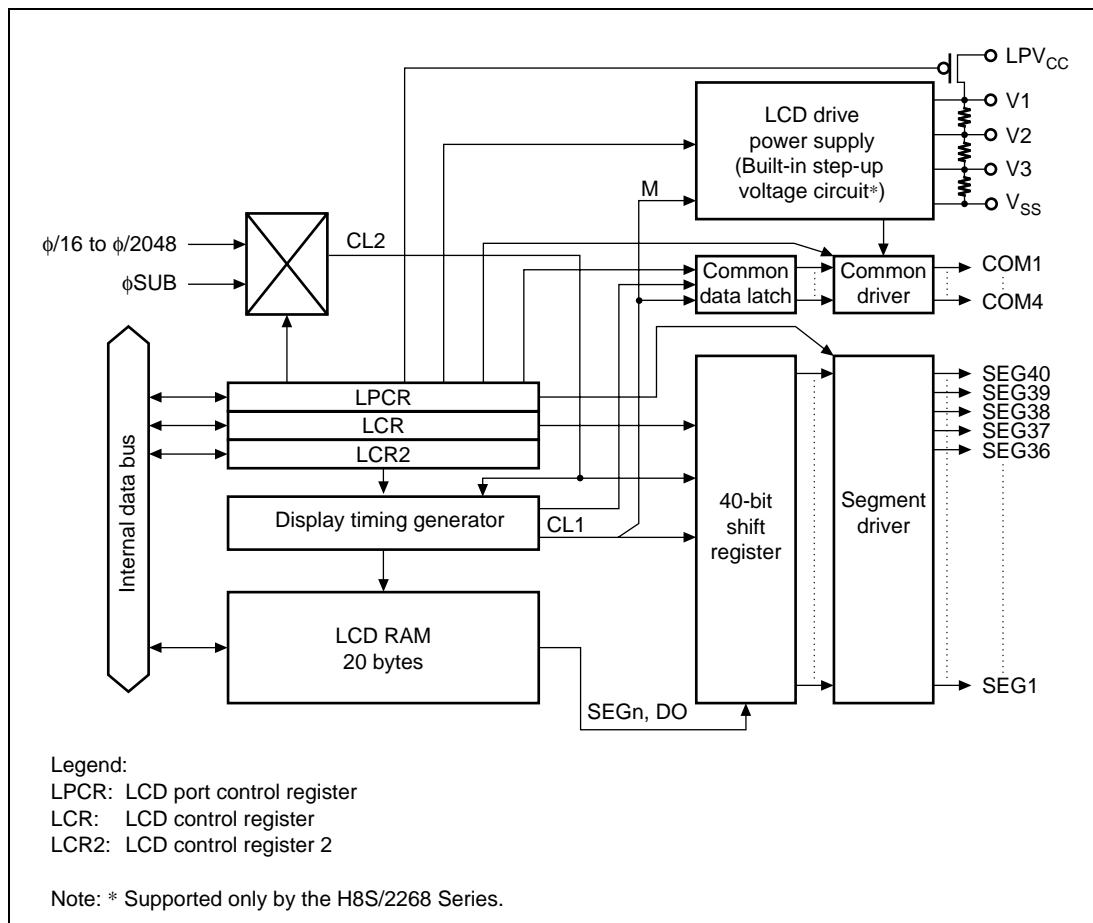


Figure 17.1 Block Diagram of LCD Controller/Driver

17.2 Input/Output Pins

Table 17.1 shows the LCD controller/driver pin configuration.

Table 17.1 Pin Configuration

Name	Abbreviation	I/O	Function
Segment output pins	SEG40 to SEG1	Output	LCD segment drive pins (H8S/2268 Series) All pins are multiplexed as port pins (setting programmable) (H8S/2264 Series) SEG24 to SEG1 pins are multiplexed as port pins (setting programmable)
Common output pins	COM4 to COM1	Output	LCD common drive pins Pins can be used in parallel with static or 1/2 duty
LCD power supply pins	V1, V2, V3	—	Used when a bypass capacitor is connected externally, and when an external power supply circuit is used V3 pin is LCD input reference power supply when triple step-up voltage circuit is used*.
Capacitance pins for LCD step-up voltage*	C1, C2	—	Capacitance pins for step-up voltage LCD drive power supply

Note:* Supported only by the H8S/2268 Series.

17.3 Register Descriptions

The LCD controller/driver has the following registers.

- LCD port control register (LPCR)
- LCD control register (LCR)
- LCD control register 2 (LCR2)
- LCDRAM

17.3.1 LCD Port Control Register (LPCR)

LPCR selects the duty cycle, LCD driver, and pin functions.

Bit	Bit Name	Initial Value	R/W	Description
7	DTS1	0	R/W	Duty Cycle Select 1 and 0
6	DTS0	0	R/W	Common Function Select
5	CMX	0	R/W	The combination of DTS1 and DTS0 selects static, 1/2, 1/3, or 1/4 duty. CMX specifies whether or not the same waveform is to be output from multiple pins to increase the common drive power when not all common pins are used because of the duty setting.
4	—	0	—	Reserved This bit is always read as 0 and should only be written with 0.
3	SGS3	0	R/W	Segment Driver Select 3 to 0
2	SGS2	0	R/W	Bits 3 to 0 select the segment drivers to be used.
1	SGS1	0	R/W	For details, see tables 17.3 and 17.4.
0	SGS0	0	R/W	

Table 17.2 Duty Cycle and Common Function Selection

Bit 7: DTS1	Bit 6: DTS0	Bit 5: CMX	Duty Cycle	Common Drivers	Notes
0	0	0	Static	COM1	COM4, COM3, and COM2 can be used as ports (Initial value)
		1		COM4 to COM1	COM4, COM3, and COM2 output the same waveform as COM1
	1	0	1/2 duty	COM2 to COM1	COM4 and COM3 can be used as ports
		1		COM4 to COM1	COM4 outputs the same waveform as COM3, and COM2 outputs the same waveform as COM1
1	0	0	1/3 duty	COM3 to COM1	COM4 can be used as a port*
		1		COM4 to COM1	Do not use COM4
	1	X	1/4 duty	COM4 to COM1	—

Legend

X: Don't care

Note: COM4 to COM1 function as ports when the setting of SGS3 to SGS0 is 0000.

* Cannot be used as a port when the SUPS bit in LCR2 is 1 in the H8S/2268 Series. Set the SUPS bit to 0 when using as a port.

Table 17.3 Segment Driver Selection (1) (H8S/2268 Series)

				Function of Pins SEG40 to SEG1				
Bit 3: SGS3	Bit 2: SGS2	Bit 1: SGS1	Bit 0: SGS0	SEG40to SEG33	SEG32to SEG25	SEG24to SEG17	SEG16to SEG9	SEG8to SEG1
0	0	0	0	Port	Port	Port	Port	Port
			1	SEG	Port	Port	Port	Port
		1	0	SEG	SEG	Port	Port	Port
			1	SEG	SEG	SEG	Port	Port
	1	0	0	SEG	SEG	SEG	SEG	Port
			1	SEG	SEG	SEG	SEG	SEG
1	X	X	1	X	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited
			X	X	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited

Legend

X: Don't care

Note:* COM4 to COM1 also function as ports when the setting of SGS3 to SGS0 is 0000.

Table 17.4 Segment Driver Selection (2) (H8S/2264 Series)

				Function of Pins SEG40 to SEG1						
Bit 3: SGS3	Bit 2: SGS2	Bit 1: SGS1	Bit 0: SGS0	SEG40 to SEG25	SEG24 to SEG21	SEG20 to SEG17	SEG16 to SEG13	SEG12 to SEG9	SEG8 to SEG5	SEG4 to SEG1
0	0	0	0	—	Port	Port	Port	Port	Port	Port
			1	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited
		1	0	SEG	Port	Port	Port	Port	Port	Port
			1	SEG	SEG	SEG	Port	Port	Port	Port
	1	0	0	SEG	SEG	SEG	SEG	SEG	Port	Port
			1	SEG	SEG	SEG	SEG	SEG	SEG	SEG
		1	X	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited
1	0	0	X	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited
		1	0	SEG	SEG	Port	Port	Port	Port	Port
			1	SEG	SEG	SEG	SEG	Port	Port	Port
	1	0	0	SEG	SEG	SEG	SEG	SEG	SEG	Port
			1	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited
		1	X	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited	Setting prohibited

Legend

X: Don't care

Note:* COM4 to COM1 also function as ports when the setting of SGS3 to SGS0 is 0000.

17.3.2 LCD Control Register (LCR)

LCR performs LCD power supply split-resistance connection control and display data control, and selects the frame frequency.

Bit	Bit Name	Initial Value	R/W	Description
7	—	1	R/W	LCD Disable Bit This bit is always read as 1. The write value should always be 0.
6	PSW	0	R/W	LCD Power Supply Split-Resistance Connection Control Bit 6 can be used to disconnect the LCD power supply split-resistance from V_{cc} when LCD display is not required in a power-down mode, or when an external power supply is used. When the ACT bit is cleared to 0, and also in standby mode, the LCD power supply split-resistance is disconnected from V_{cc} regardless of the setting of this bit. 0: LCD power supply split-resistance is disconnected from V_{cc} 1: LCD power supply split-resistance is connected to V_{cc}
5	ACT	0	R/W	Display Function Activate Bit 5 specifies whether or not the LCD controller/driver is used. Clearing this bit to 0 halts operation of the LCD controller/driver. The LCD drive power supply ladder resistance is also turned off, regardless of the setting of the PSW bit. However, register contents are retained. 0: LCD controller/driver operation halted 1: LCD controller/driver operation enabled
4	DISP	0	R/W	Display Data Control Bit 4 specifies whether the LCD RAM contents are displayed or blank data is displayed regardless of the LCD RAM contents. 0: Blank data is displayed 1: LCD RAM data is displayed

Bit	Bit Name	Initial Value	R/W	Description
3	CKS3	0	R/W	Frame Frequency Select 3 to 0
2	CKS2	0	R/W	Bits 3 to 0 select the operating clock and the frame frequency. In subactive mode, watch mode, and subsleep mode, the system clock (ϕ) is halted, and therefore display operations are not performed if one of the clocks from $\phi/16$ to $\phi/2048$ is selected. If LCD display is required in these modes, ϕ_{SUB} , $\phi_{\text{SUB}}/2$, or $\phi_{\text{SUB}}/4$ must be selected as the operating clock. For details, see table 17.5.
1	CKS1	0	R/W	
0	CKS0	0	R/W	

Note:* 0 should be written to bit 7 after the other bits have been set.

Table 17.5 Frame Frequency Selection

Bit 3: CKS3	Bit 2: CKS2	Bit 1: CKS1	Bit 0: CKS0	Operating Clock	Frame Frequency* ¹	
					$\phi = 20 \text{ MHz}$	$\phi = 2 \text{ MHz}$
0	X	0	0	ϕ_{SUB}	128 Hz* ²	128 Hz* ²
			1	$\phi_{\text{SUB}}/2$	64 Hz* ²	64 Hz* ²
			1	$\phi_{\text{SUB}}/4$	32 Hz* ²	32 Hz* ²
1	0	0	0	$\phi/16$	—	488 Hz
			1	$\phi/32$	—	244 Hz
		1	0	$\phi/64$	—	122 Hz
			1	$\phi/128$	610 Hz	61 Hz
	1	0	0	$\phi/256$	305 Hz	30.5 Hz
			1	$\phi/512$	152.6 Hz	—
		1	0	$\phi/1024$	76.3 Hz	—
			1	$\phi/2048$	38.1 Hz	—

Legend

X: Don't care

Notes: 1. When 1/3 duty is selected, the frame frequency is 4/3 times the value shown.

2. This is the frame frequency when $\phi_{\text{SUB}} = 32.768 \text{ kHz}$.

17.3.3 LCD Control Register 2 (LCR2)

LCR2 controls switching between the A waveform and B waveform, selects clock for step-up voltage circuit, selects power supply, and selects the duty ratio for charge/discharge pulse that controls to separate power supply divider resistance from power supply circuit.

Bit	Bit Name	Initial Value	R/W	Description
7	LCDAB	0	R/W	<p>A Waveform/B Waveform Switching Control</p> <p>Bit 7 specifies whether the A waveform or B waveform is used as the LCD drive waveform.</p> <p>0: Drive using A waveform</p> <p>1: Drive using B waveform</p>
6	—	1	—	<p>Reserved</p> <p>These bits are always read as 1 and cannot be modified.</p>
5	HCKS	0	R/W	<p>(H8S/2268 Series)</p> <p>Triple Step-Up Voltage Circuit Clock Select</p> <p>This bit selects a clock used for triple step-up voltage circuit. This bit selects a clock which divides a clock specified by the LCD operating control register (LCR) by 4 or 8 as step-up voltage circuit clock.</p> <p>0: A clock, which divides a LCD operating clock by 4, is selected as step-up voltage circuit clock</p> <p>1: A clock, which divides a LCD operating clock by 8, is selected as step-up voltage circuit clock</p> <p>(H8S/2264 Series)</p> <p>Reserved</p> <p>0 should be written to this bit.</p>
4	SUPS	0	R/W	<p>(H8S/2268 Series)</p> <p>Drive Power Select</p> <p>Triple Step-up Voltage Circuit Control</p> <p>The triple step-up voltage circuit stops operation when V_{CC} is selected as drive power. The triple step-up voltage circuit starts operation when LCD input reference voltage (V_{LCD3}) is selected as drive power.</p> <p>0: Drive power is V_{CC}, triple step-up voltage circuit halts</p> <p>1: Drive power is triple step-up voltage of the LCD input reference voltage (V_{LCD3}), triple step-up voltage circuit operates</p> <p>(H8S/2264 Series)</p> <p>Reserved</p> <p>0 should be written to this bit.</p>

Bit	Bit Name	Initial Value	R/W	Description
3	CDS3	0	R/W	Selection of Duty Ratio for Charge/Discharge Pulse
2	CDS2	0	R/W	Duty ratio is selected during the power supply divider resistance is connected to power supply circuit. When the duty ratio of 0 is selected, the power supply divider resistance is fixed to the state that the resistance is separated from the power supply circuit. Therefore, supply the power to pins V_1 , V_2 , and V_3 from the external circuit.
1	CDS1	0	R/W	
0	CDS0	0	R/W	

The charge/discharge pulses have the waveform shown in figure 17.2. The duty ratio is represented by T_c/T_w .

0000: duty ratio = 1 (stack at high)

0001: duty ratio = 1/8

0010: duty ratio = 2/8

0011: duty ratio = 3/8

0100: duty ratio = 4/8

0101: duty ratio = 5/8

0110: duty ratio = 6/8

0111: duty ratio = 0 (stack at low)

10XX: duty ratio = 1/16

11XX: duty ratio = 1/32

Legend

X: Don't care

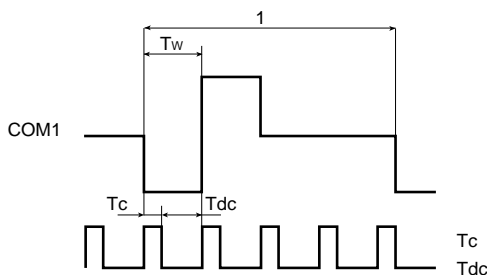


Figure 17.2 A waveform 1/2 duty 1/2 bias

The relationships between the LCD operating clock and step-up voltage clock, and between bits CKS3 to CKS0 in LCD control register (LCR) and bit HCKS in LCD control register 2 (LCR2) are shown below.

LCR						Step-up Voltage Circuit clock*	Frame frequency		Step-Up Voltage Circuit clock frequency*	
Bit 3	Bit 2	Bit 1	Bit 0	LCR2 Bit 5 HCKS*	LCD clock		$\phi = 20$ MHz	$\phi = 2$ MHz	$\phi = 20$ MHz	$\phi = 2$ MHz
0	X	0	0	0	ϕ_{SUB}	$\phi_{SUB}/4$	128 Hz		8192 Hz	
				1		$\phi_{SUB}/8$			4096 Hz	
0	X	0	1	0	$\phi_{SUB}/2$		64 Hz			
				1		$\phi_{SUB}/16$			2048 Hz	
0	X	1	X	0	$\phi_{SUB}/4$		32 Hz			
				1		$\phi_{SUB}/32$			1024 Hz	
1	0	0	0	0	$\phi/16$	$\phi 64$	—	488 Hz	—	
				1		$\phi 128$			—	
1	0	0	1	0	$\phi/32$		—	244 Hz		
				1		$\phi 256$			—	
1	0	1	0	0	$\phi/64$		—	122 Hz		
				1		$\phi 512$			—	
1	0	1	1	0	$\phi/128$		610 Hz	61 Hz	39.1 kHz	
				1		$\phi 1024$			19.5 kHz	1.95 kHz
1	1	0	0	0	$\phi/256$		305 Hz	30.5 Hz		
				1		$\phi 2048$			9.77 kHz	977 kHz
1	1	0	1	0	$\phi/512$		152.6 Hz	—	—	
				1		$\phi 4096$			4.88 kHz	—
1	1	1	0	0	$\phi/1024$		76.3 Hz	—		
				1		$\phi 8192$			2.44 kHz	—
1	1	1	1	0	$\phi/2048$		38.1 Hz	—		
				1		$\phi 16384$			1.22 kHz	—

Legend

X: Don't care

Note:* Supported only by the H8S/2268 Series.

17.4 Operation

17.4.1 Settings up to LCD Display

To perform LCD display, the hardware and software related items described below must first be determined.

1. Hardware Settings

A. Using 1/2 duty

When 1/2 duty is used, interconnect pins V_2 and V_3 as shown in figure 17.3.

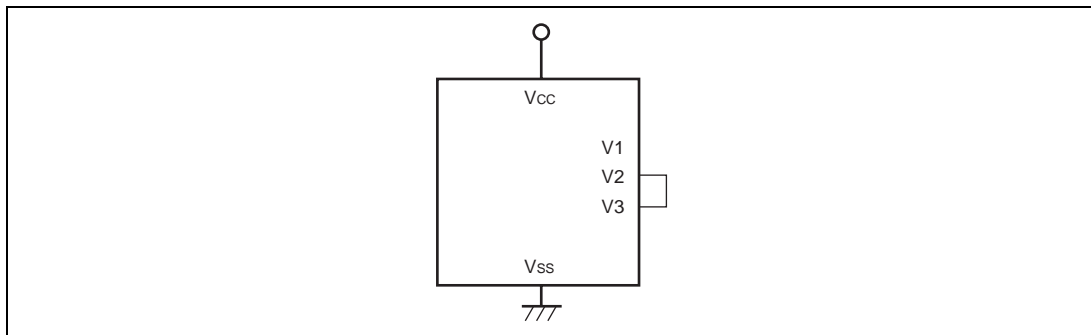


Figure 17.3 Handling of LCD Drive Power Supply when Using 1/2 Duty

B. Large-panel display

As the impedance of the built-in power supply split-resistance is large, it may not be suitable for driving a large panel. If the display lacks sharpness when using a large panel, refer to section 17.4.6, Boosting the LCD Drive Power Supply. When static or 1/2 duty is selected, the common output drive capability can be increased. Set CMX to 1 when selecting the duty cycle. In this mode, with a static duty cycle pins COM4 to COM1 output the same waveform, and with 1/2 duty the COM1 waveform is output from pins COM2 and COM1, and the COM2 waveform is output from pins COM4 and COM3.

C. LCD drive power supply setting

With the H8S/2268 and 2264, there are two ways of providing LCD power: by using the on-chip power supply circuit, or by using an external power supply circuit.

When an external power supply circuit is used for the LCD drive power supply, connect the external power supply to the V1 pin.

2. Software Settings

A. Duty selection

Any of four duty cycles—static, 1/2 duty, 1/3 duty, or 1/4 duty—can be selected with bits DTS1 and DTS0.

B. Segment selection

The segment drivers to be used can be selected with bits SGS3 to SGS0.

3. Frame frequency selection

The frame frequency can be selected by setting bits CKS3 to CKS0. The frame frequency should be selected in accordance with the LCD panel specification. For the clock selection method in watch mode, subactive mode, and subsleep mode, see section 17.4.4, Operation in Power-Down Modes.

A. A or B waveform selection

Either the A or B waveform can be selected as the LCD waveform to be used by means of LCDAB.

B. LCD drive power supply selection

When an external power supply circuit is used, turn the LCD drive power supply off with the PSW bit.

17.4.2 Relationship between LCD RAM and Display

The relationship between the LCD RAM and the display segments differs according to the duty cycle. LCD RAM maps for the different duty cycles are shown in figures 17.4 to 17.7.

After setting the registers required for display, data is written to the part corresponding to the duty using the same kind of instruction as for ordinary RAM, and display is started automatically when turned on. Word- or byte-access instructions can be used for RAM setting.

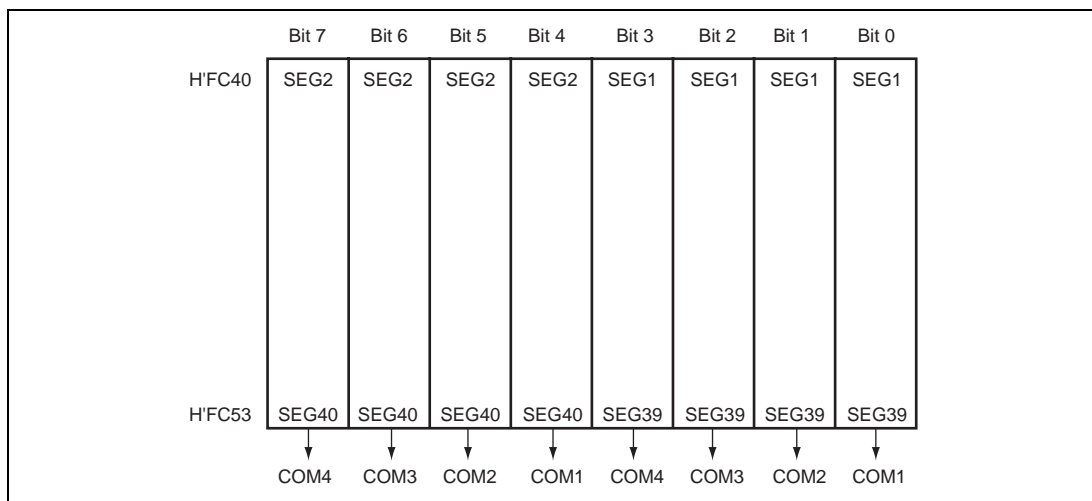


Figure 17.4 LCD RAM Map (1/4 Duty)

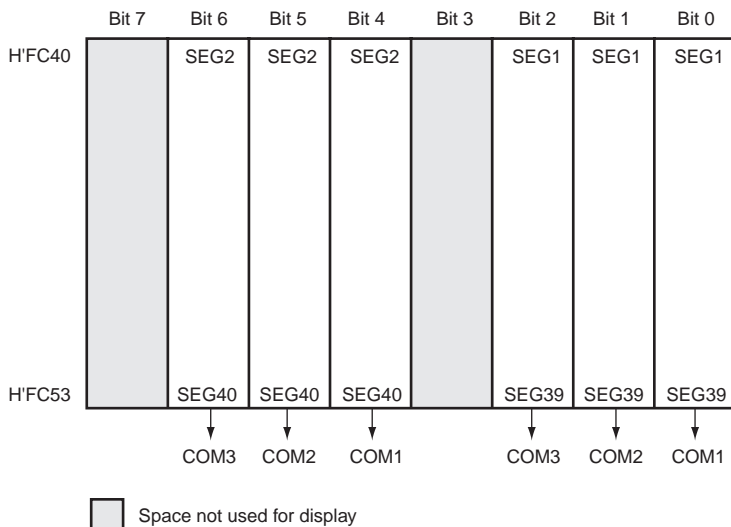


Figure 17.5 LCD RAM Map (1/3 Duty)

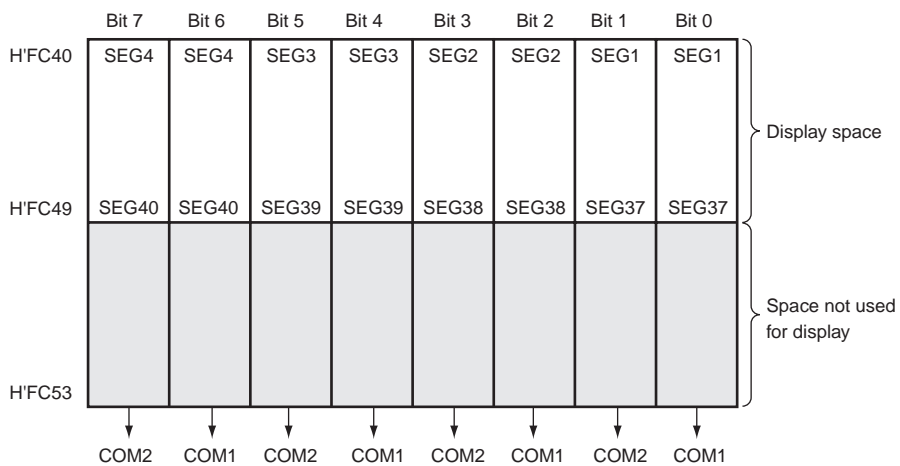


Figure 17.6 LCD RAM Map (1/2 Duty)

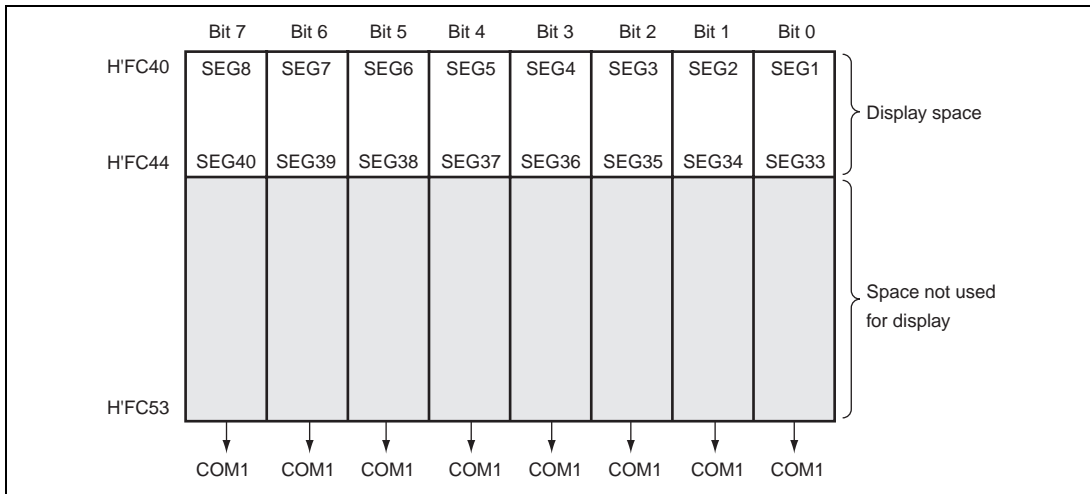
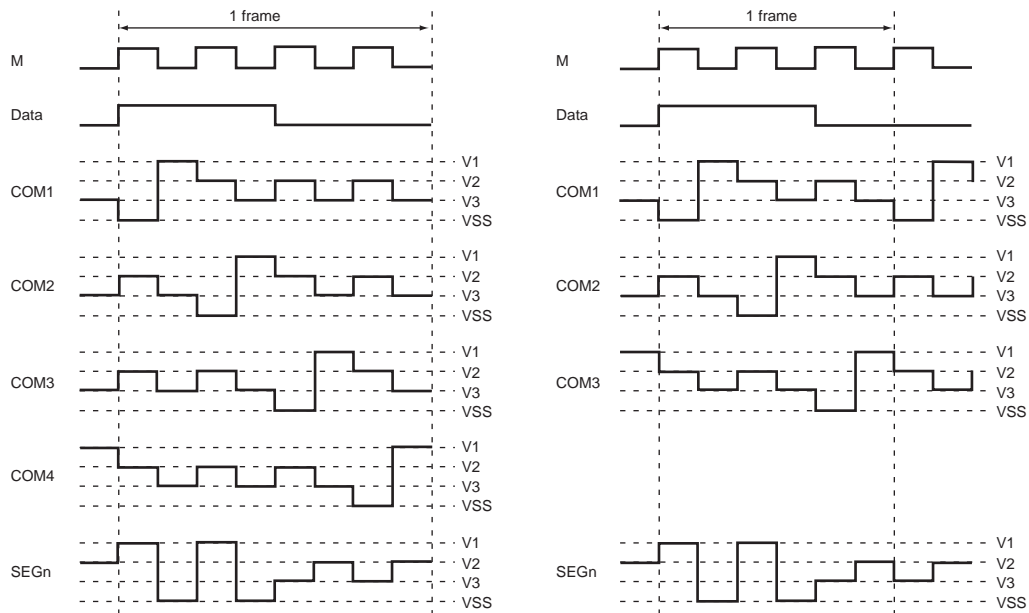
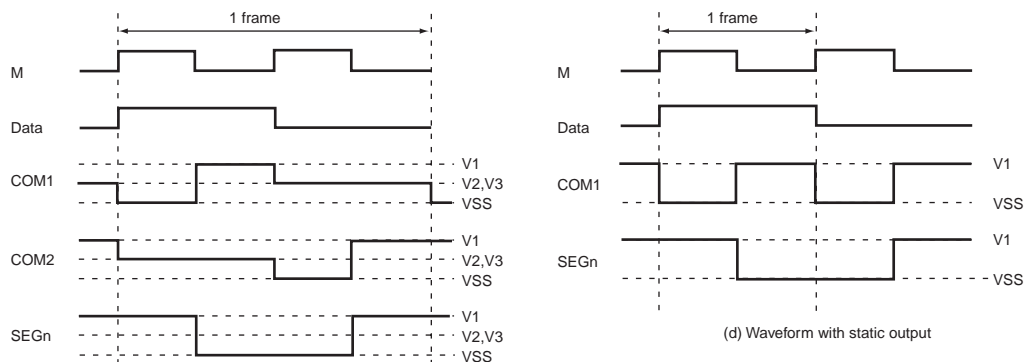


Figure 17.7 LCD RAM Map (Static Mode)



(a) Waveform with 1/4 duty

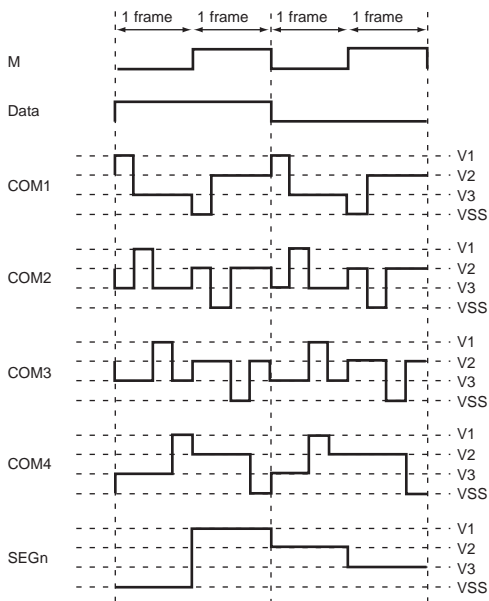
(b) Waveform with 1/3 duty



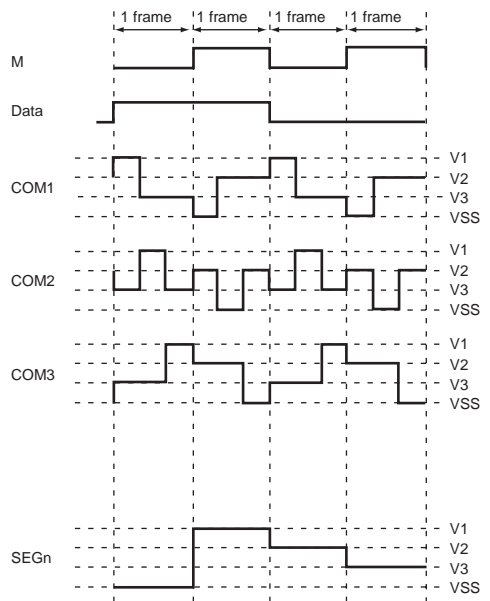
(c) Waveform with 1/2 duty

(d) Waveform with static output

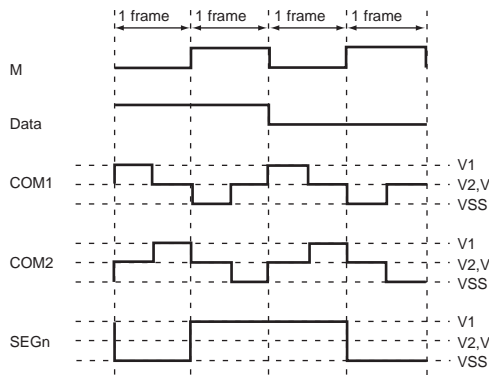
Figure 17.8 Output Waveforms for Each Duty Cycle (A Waveform)



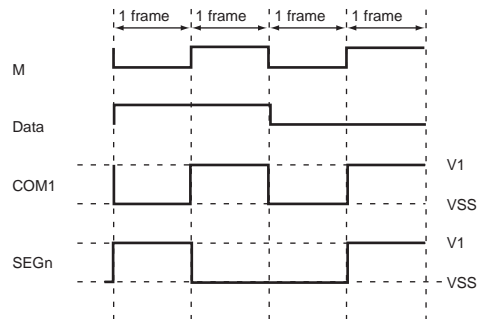
(a) Waveform with 1/4 duty



(b) Waveform with 1/3 duty



(c) Waveform with 1/2 duty



(d) Waveform with static output

Figure 17.9 Output Waveforms for Each Duty Cycle (B Waveform)

Table 17.6 Output Levels

Data		0	0	1	1
M		0	1	0	1
Static	Common output	V1	V _{SS}	V1	V _{SS}
	Segment output	V1	V _{SS}	V _{SS}	V1
1/2 duty	Common output	V2, V3	V2, V3	V1	V _{SS}
	Segment output	V1	V _{SS}	V _{SS}	V1
1/3 duty	Common output	V3	V2	V1	V _{SS}
	Segment output	V2	V3	V _{SS}	V1
1/4 duty	Common output	V3	V2	V1	V _{SS}
	Segment output	V2	V3	V _{SS}	V1

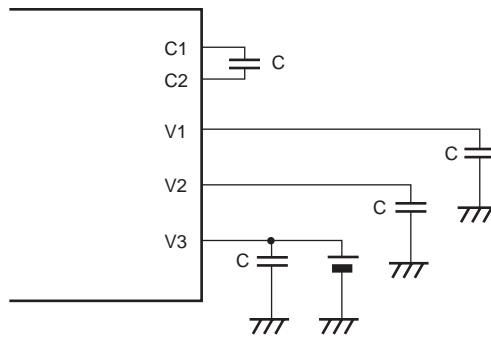
17.4.3 Triple Step-Up Voltage Circuit (Supported Only by the H8S/2268 Series)

The H8S/2268 Series incorporates a triple step-up voltage circuit. Triple voltage of liquid crystal input reference voltage (V_{LCD3}) input from V3 pin can be used for the LCD driver.

Before enabling the step-up voltage circuit, duty cycle (1/3 duty or 1/4 duty), LCD driver or I/O pin function, and display data and frame frequency should be selected. Around 0.1- μ F capacitor should be connected between C1 and C2, and voltage specified in section 26.2.6, LCD Characteristics should be applied to V3 pin.

After above settings, by selecting the step-up voltage circuit clock in LCD control register 2 (LCR2) and setting SUPS to 1, the triple step-up voltage circuit operates, voltage double of V_{LCD3} is generated for V2 pin, and voltage triple of V_{LCD3} is generated for V1 pin.

- Notes:
1. The triple step-up voltage circuit should only be used as LCD drive power of the H8S/2268 Series. To drive large panel, power supply capacitance may be insufficient. In this case, Vcc should be used as power supply or external power supply circuit should be used.
 2. When the triple step-up voltage circuit is used, do not specify static or 1/2 duty as duty cycle.
 3. Do not use capacitance with polarity such as electrolytic capacitor as capacitance to be connected between C1 and C2.



Note: C: 0.1 μ F (typ.) (0.05 to 0.2 μ F)

**Figure 17.10 Connection when Triple Step-Up Voltage Circuit Used
(Supported Only by the H8S/2268 Series)**

17.4.4 Operation in Power-Down Modes

In the H8S/2268 and 2264, the LCD controller/driver can be operated even in the power-down modes. The operating state of the LCD controller/driver in the power-down modes is summarized in table 17.7.

In subactive mode, watch mode, and subsleep mode, the system clock oscillator stops, and therefore, unless ϕ_{SUB} , $\phi_{SUB}/2$, or $\phi_{SUB}/4$ has been selected by bits CKS3 to CKS0, the clock will not be supplied and display will halt. Since there is a possibility that a direct current will be applied to the LCD panel in this case, it is essential to ensure that ϕ_{SUB} , $\phi_{SUB}/2$, or $\phi_{SUB}/4$ is selected.

In the software standby mode the segment output and common output pins switch to I/O port status. In this case if a port's DDR or PCR bit is set to 1, a DC voltage could be applied to the LCD panel. Therefore, DDR and PCR must never be set to 1 for ports being used for segment output or common output.

Table 17.7 Power-Down Modes and Display Operation

Mode		Reset	Active	Sleep	Watch	Subactive	Subsleep	Software Standby	Hardware standby	Module Stop
Clock	ϕ	Runs	Runs	Runs	Stops	Stops	Stops	Stops	Stops	Stops* ⁴
	ϕ_w	Runs	Runs	Runs	Runs	Runs	Runs	Stops* ¹	Stops	Stops* ⁴
Display operation	ACT = 0	Stops	Stops	Stops	Stops	Stops	Stops	Stops* ²	Stops* ²	Stops
	ACT = 1	Stops	Functions	Functions	Functions* ³	Functions* ³	Functions* ³	Stops* ²	Stops* ²	Stops

- Notes:
1. The subclock oscillator does not stop, but clock supply is halted.
 2. The LCD drive power supply is turned off regardless of the setting of the PSW bit.
 3. Display operation is performed only if ϕ_{SUB} , $\phi_{SUB}/2$, or $\phi_{SUB}/4$ is selected as the operating clock.
 4. The clock supplied to the LCD stops.

17.4.5 Low-Power LCD Drive

The simplest way to achieve low-power operation for an LCD power supply circuit is to use an internal division resistor. However, since the values of the internal resistors are fixed, a constant current continually flows from Vcc to Vss of the internal resistor. Since the quantity of the current is independent of the dissipation current of an LCD panel, power is wasted in using a low-power LCD. This LSI incorporates a function that eliminates wastage of power. By using this function, a power supply circuit that is most suitable for the power of a given LCD panel can be obtained.

- Principle
 - As shown in figure 17.11, external capacitors are connected to V1, V2, and V3 of the LCD power supply terminals.
 - The capacitors connected to V1, V2, and V3 are repeatedly charged and discharged to retain required voltage levels in the cycles shown in figure 17.11.
 - In this case, the charged voltages are equivalent to V1, V2, and V3, respectively. (In 1/3 bias operation, for example, the V2 voltage is two thirds of the V1 voltage and the V3 voltage is one third of the V1 voltage.)
 - Power is supplied to the LCD panel by the electric charges that are accumulated in these capacitors.
 - The capacitances of the capacitors and the charge-discharge period are determined by the quantity of power which the LCD panel requires.
 - The charge-discharge period can be determined by software.
- Example of Operation (1/3 bias operation)

- During charging period T_c in figure 17.11, the voltages that are divided by the internal division resistors are applied to the V1, V2, and V3 terminals (the V2 voltage is two thirds of the V1 voltage and the V3 voltage is one third of the V1 voltage), and these voltages charge external capacitors C1, C2, and C3. Even during this period, the LCD panel is being driven.
- In the subsequent discharge period T_{dc} , the charge operation stops. The LCD panel is now driven by discharge of the charges accumulated in the respective capacitors.
- At this point in time, the respective voltages fall slightly as the capacitors are discharged. Attention must be paid so that the operation of the LCD panel is not affected, by selecting the proper charging period and the capacitance of the capacitors.
- The capacitors connected to the V1, V2, and V3 terminals are repeatedly charged and discharged in the cycles shown in figure 17.11 and retain required voltages, keeping the LCD panel in operation.
- The capacitance of the capacitors and a charge-discharge period is determined by the quantity of power in which the LCD panel requires. In addition, the charge-discharge period can be selected by CDS3 to 0.
- In actuality, the capacitance of the capacitors and the charge-discharge period must be determined through experiment, on the basis of the power dissipation specifications of the LCD panel. This method, however, permits the most proper current value to be selected, compared with a case in which a DC current continually flows in the internal resistors.

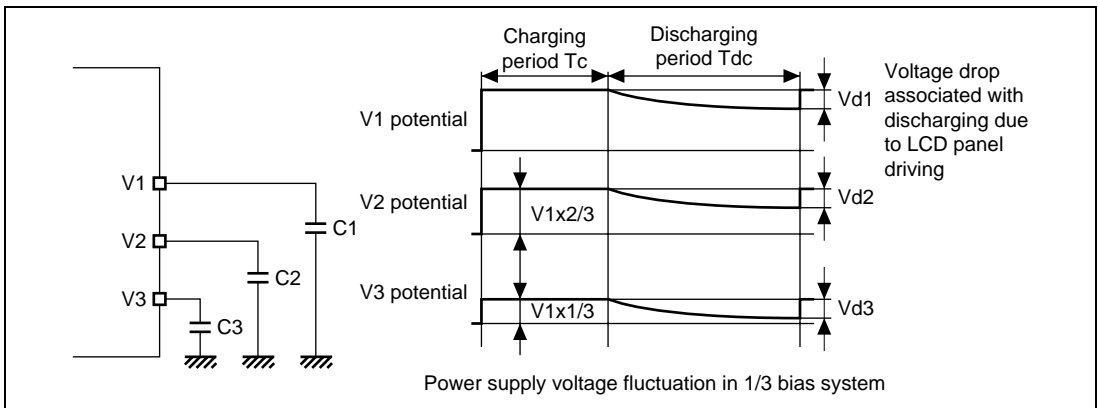


Figure 17.11 Example of Low-Power-Consumption LCD Drive Operation

17.4.6 Boosting the LCD Drive Power Supply

When a large panel is driven, the on-chip power supply capacity may be insufficient. In this case, the power supply impedance must be reduced. This can be done by connecting bypass capacitors of around 0.1 to 0.3 μF to pins V1 to V3, as shown in figure 17.12, or by adding a split-resistance externally.

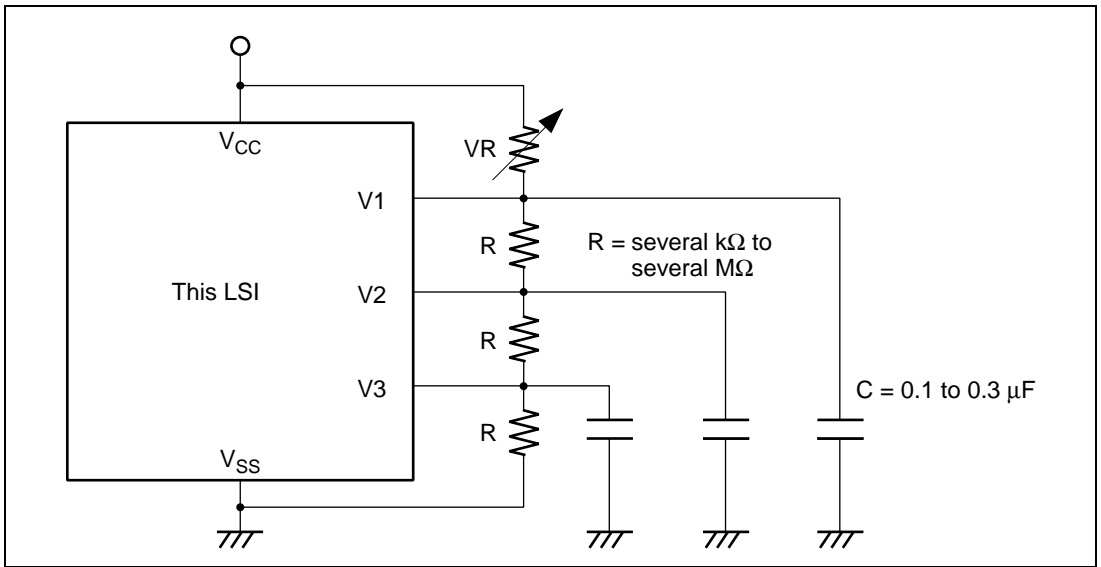


Figure 17.12 Connection of External Split-Resistance

Section 18 DTMF Generation Circuit

The H8S/2268 Series contains a Dual-Tone Multi-Frequency generation circuit to generate DTMF signals. It is not contained in the H8S/2264 Series.

The DTMF signal consists of two types of sine waveforms and is used to access a switch device. The function of the DTMF signal is shown in the frequency matrix in figure 18.1. The DTMF generation circuit produces the frequencies corresponding to the numbers and symbols in the figure.

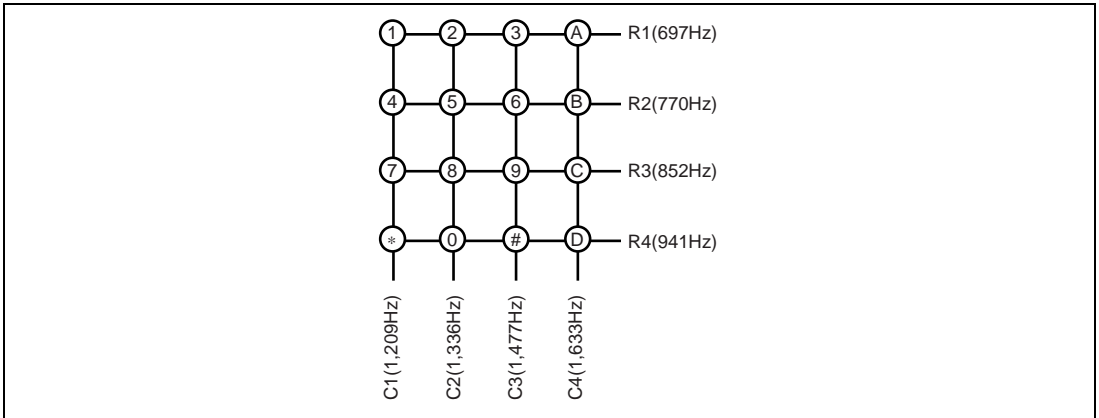


Figure 18.1 DTMF Frequencies

18.1 Features

- Generating DTMF frequency sine waveform from the system clock (ϕ)
The system clock (2.0 to 20.4 MHz, with 400 kHz stops) is divided to produce a 400-kHz clock signal. This clock signal is then supplied to the feedback loop, comprised of a variant program divider and sine waveform counter to generate a DTMF frequency sine waveform.
- Producing low distortion, stable sine waveforms
Sine waveforms signals are output from the high-precision resistor rudder-type D/A converter. In addition, one cycle is divided into 32, resulting in low-distortion stable signal waveforms.
- Synthesis or single waveform output selectable
Synthesized row and column output, row output, or column output are selectable.
- Module stop mode can be set.

Figure 18.2 shows the block diagram for the DTMF generation circuit.

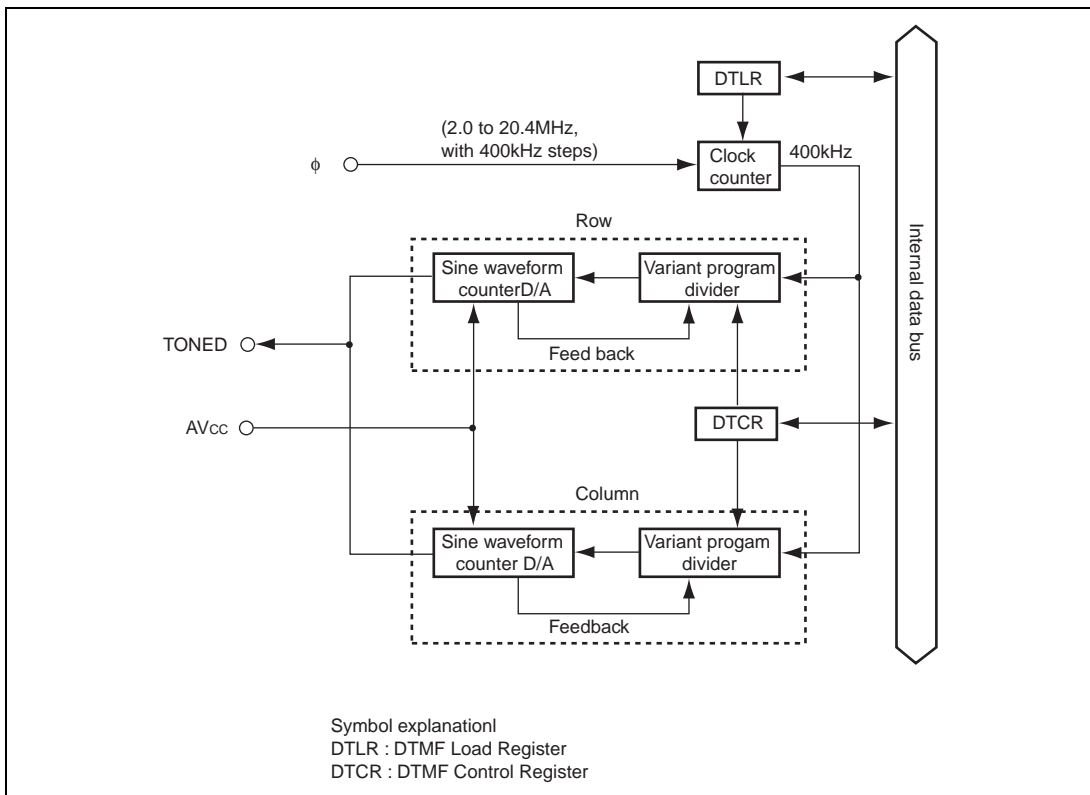


Figure 18.2 DTMF Generation Circuit Diagram

18.2 Input/Output Pins

Table 18.1 shows the pin configuration of the DTMF generation circuit.

Table 18.1 Pin Configuration

Name	Abbreviation	Input/Output	Function
Analog power supply pin	AVcc	Input	Power supply of analog section
DTMF signal output	TONED	Output	DTMF signal output pin

18.3 Register Descriptions

The DTMF generation circuit contains the following registers:

- DTMF control register (DTCR)
- DTMF load register (DTLR)

18.3.1 DTMF Control Register (DTCR)

The DTCR controls the DTMF generation circuit operation, column and row outputs, and selects the output frequency.

Bit	Bit Name	Initial Value	R/W	Description
7	DTEN	0	R/W	This bit controls DTMF generation 0: Halts the DTMF generation circuit. 1: Operates DTMF generation circuit.
6	—	1	—	Reserved This bit is always read as 1 and cannot be modified.
5	CLOE	0	R/W	This bit controls Column section outputs 0: Inhibits DTMF signal output on Column section (hi-impedance) 1: Enables DTMF signal output on Column section.
4	RWOE	0	R/W	This bit controls Column section outputs 0: Inhibits DTMF signal output on Row section (hi-impedance) 1: Enables DTMF signal output on Row section.
3	CLF1	0	R/W	DTMF signal output frequency on Column section 1 and 0 Selects Column DTMF signal frequency from C1 to C4. 00: Column DTMF signal output frequency: 1209 Hz (C1) 01: Column DTMF signal output frequency: 1336 Hz (C2) 10: Column DTMF signal output frequency: 1447 Hz (C3) 11: Column DTMF signal output frequency: 1633 Hz (C4)
2	CLF0	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
1	RWF1	0	R/W	DTMF signal output frequency on Row section: 1, 0
0	RWF0	0	R/W	Selects Column DTMF signal frequency from R1 to R4. 00: Row DTMF signal output frequency: 697 Hz (R1) 01: Row DTMF signal output frequency: 770 Hz (R2) 10: Row DTMF signal output frequency: 852 Hz (R3) 11: Row DTMF signal output frequency: 941 Hz (R4)

18.3.2 DTMF Load Register (DTLR)

The DTLR sets the system clock division ratio for the DTMF generation circuit.

Bit	Bit Name	Initial Value	R/W	Description
7 to 6	—	1	—	Reserved This bit is always read as 1 and cannot be modified.
5	DTL5	0	R/W	Main clock division ratio 5 to 0
4	DTL4	0	R/W	These bits set the system clock division ratio to produce 400-kHz clock signals to be supplied to the DTMF generation circuit. The division ratio determines the counter value of 6b'000101 to 6b'110011(D'5 to D'51) according to the range 2.0 to 20.4 MHz. 000000: Setting prohibited 000001: Setting prohibited 000010: Setting prohibited 000011: Setting prohibited 000100: Setting prohibited 000101: Division ratio (5) main clock frequency (2.0 MHz) 000110: Division ratio (6) main clock frequency (2.4 MHz) 000111: Division ratio (7) main clock frequency (2.8 MHz) : : 110001: Division ratio (49) main clock frequency (19.6 MHz) 110010: Division ratio (50) main clock frequency (20.0 MHz) 110011: Division ratio (51) main clock frequency (20.4 MHz) 110100: Setting prohibited : : 111111: Setting prohibited
3	DTL3	0	R/W	
2	DTL2	0	R/W	
1	DTL1	0	R/W	
0	DTL0	0	R/W	

Note: The correct values should be set in DTL0 to DTL5. If these bit settings do not match the system clock, correct DTMF signal output frequency cannot be obtained. Additionally, correct operation is not guaranteed if the DTL0 to DTL5 settings are other than 5 to 51 (division ratio 5 to 51).

18.4 Operation

18.4.1 Output Waveform

The DTMF generation circuit provides synthesized row and column groups output waveforms or sine waveforms (DTCR signal) of row or column group from TONED pin. These signals are produced in the high-precision resistor rudder-type D/A converter. The output frequency is set in DTCR.

Figure 18.3 shows the TONED pin output equivalent circuit. Figure 18.4 shows a single output waveform of column or row group alone. One cycle of the output waveform is divided into 32, resulting in low-distortion stable signal waveforms.

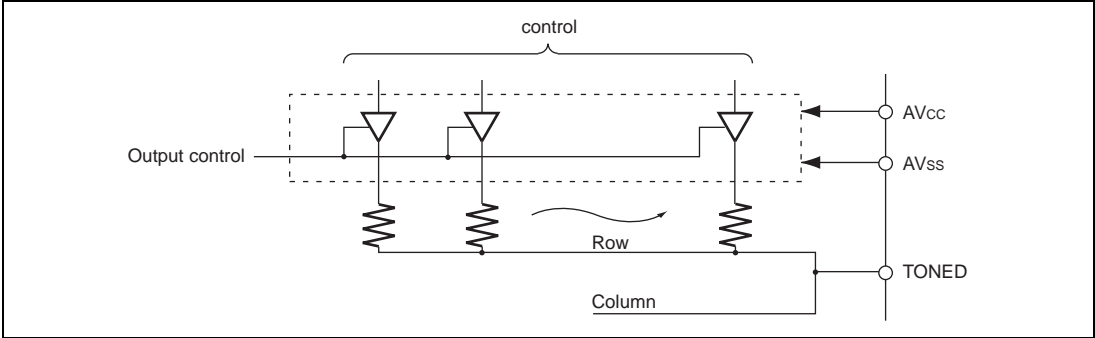


Figure 18.3 TONED Pin Output Equivalent Circuit

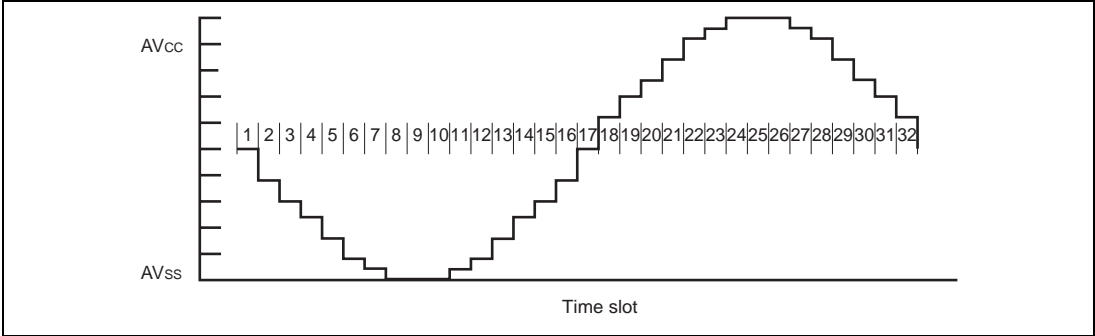


Figure 18.4 TONED Pin Output Waveform (Row or Column Group Alone)

Table 18.2 shows DTMF generation circuit output signal and typical signal frequencies, and frequency deviation between the two.

Table 18.2 Frequency Deviation Between DTMF Output Signals And Typical Signals

Symbol	Typical Signal (Hz)	DTMF Signal Output (Hz)	Frequency Deviation (%)
R1	697	694.44	-0.37
R2	770	769.23	-0.10
R3	852	851.06	-0.11
R4	941	938.97	-0.22
C1	1209	1212.12	0.26
C2	1336	1333.33	-0.20
C3	1477	1481.48	0.30
C4	1633	1639.34	0.39

18.4.2 Operation Flow

The operating procedure for the DTMF generation circuit is as follows:

1. Set the system clock division ratio for the DTLR based on the frequency of the connected system clock. (2.0 to 20.4 MHz, with 400 kHz stops)
2. Set the frequencies of the Row (R1 to R4) and Column (C1 to C4) sections based on CLF0, CLF1, RWF0 and RWF1 of the DTCR.
3. Select the outputs of the Row and Column based on CLOE and RWOE of the DTCR, and set DTEN to 1 to operate the DTMF generation circuit.

With the above setting, the set DTMF signal is output from the TONED pin.

18.5 Application Circuit Example

An application example of the DTMF generation circuit is shown in figure 18.5.

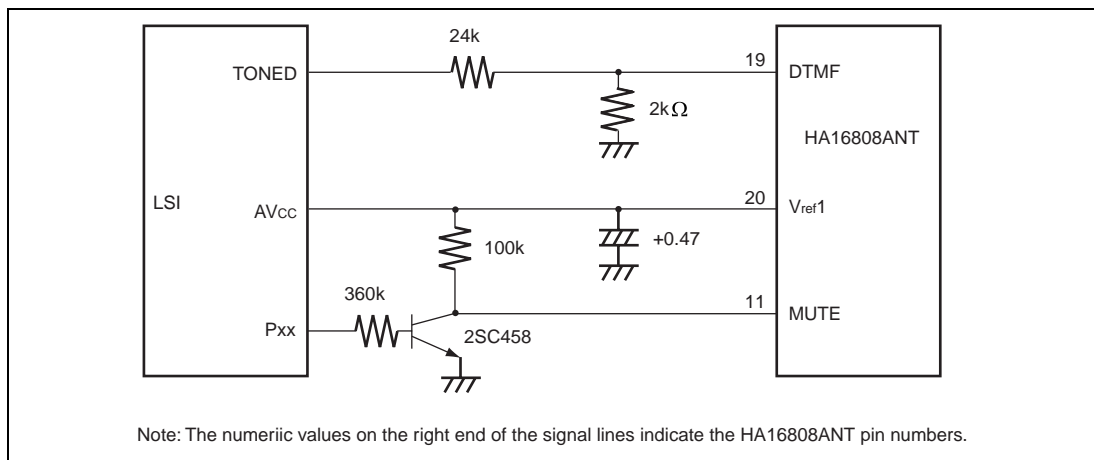


Figure 18.5 Example of HA16808ANT Connection

18.6 Usage Notes

1. Setting the module stop mode

It is possible to enable/disable the DTMF operation using the module stop control register. The DTMF does not operate by the initial value of the register. The register can be accessed by releasing the module stop mode. For more details, see section 22, Power-Down Modes.

2. DTLR setting and system clock

When using the DTMF generation circuit, note the following: The DTLR must be set so as to accommodate the system clock. If the DTLR setting does not match the system clock, correct DTMF signal output frequency cannot be obtained.

3. Relationship between AVcc, AVss and Vcc, Vss

Set AVss = Vss as the relationship between AVcc, AVss and Vcc, Vss. If the DTMF generation circuit is not used, the AVcc and AVss pins must not be left open.

Note: If the conditions above are not met, the reliability of the device may be adversely affected.

Section 19 RAM

In the H8S/2268 Series, the H8S/2268 has 16 kbytes of on-chip high-speed static RAM, the H8S/2266 has 8 kbytes of on-chip high-speed static RAM, and the H8S/2265 has 4 kbytes of on-chip high-speed static RAM. In the H8S/2264 Series, the H8S/2264 and H8S/2264R have 4 kbytes of on-chip high-speed static RAM, and the H8S/2262 and H8S/2262R have 2 kbytes of on-chip high-speed static RAM. The RAM is connected to the CPU by a 16-bit data bus, enabling one-state access by the CPU to both byte data and word data.

Section 20 ROM

The features of the flash memory are summarized below.

The block diagram of the flash memory is shown in figure 20.1.

20.1 Features

- Capacity

H8S/2268 Series: 256 kbytes (H8S/2268)

128 kbytes (H8S/2266, H8S/2265)

H8S/2264 Series: 128 kbytes (H8S/2264, H8S/2264R)

- Programming/erase methods

The flash memory is programmed 128 bytes at a time. Erase is performed in single-block units. The flash memory of the H8S/2268 is configured as follows: 64 kbytes \times 3 blocks, 32 kbytes \times 1 block, and 4 kbytes \times 8 blocks. The flash memory of the H8S/2266 and H8S/2265 is configured as follows: 64 kbytes \times 1 block, 32 kbytes \times 1 block, and 4 kbytes \times 8 blocks. The flash memory of the H8S/2264 and H8S/2264R is configured as follows: 32 kbytes \times 2 blocks, 28 kbytes \times 1 block, 16 kbytes \times 1 block, 8 kbytes \times 2 blocks, and 1 kbyte \times 4 blocks. To erase the entire flash memory, each block must be erased in turn.

- Reprogramming capability

The flash memory can be reprogrammed for 100 times.

- Two programming modes

Boot mode

User program mode

On-board programming/erasing can be done in boot mode, in which the boot program built into the chip is started to erase or program of the entire flash memory. In normal user program mode, individual blocks can be erased or programmed.

- Automatic bit rate adjustment

For data transfer in boot mode, this LSI's bit rate can be automatically adjusted to match the transfer bit rate of the host.

- Programming/erasing protection

There are three protect modes, hardware, software, and error protect, which allow protected status to be designated for flash memory program/erase operations.

- Programmer mode

Flash memory can be programmed/erased in programmer mode using a PROM programmer, as well as in on-board programming mode.

- Emulation function for flash memory in RAM

The real-time emulation for programming of flash memory is possible by overlapping the flash memory to a part of RAM.

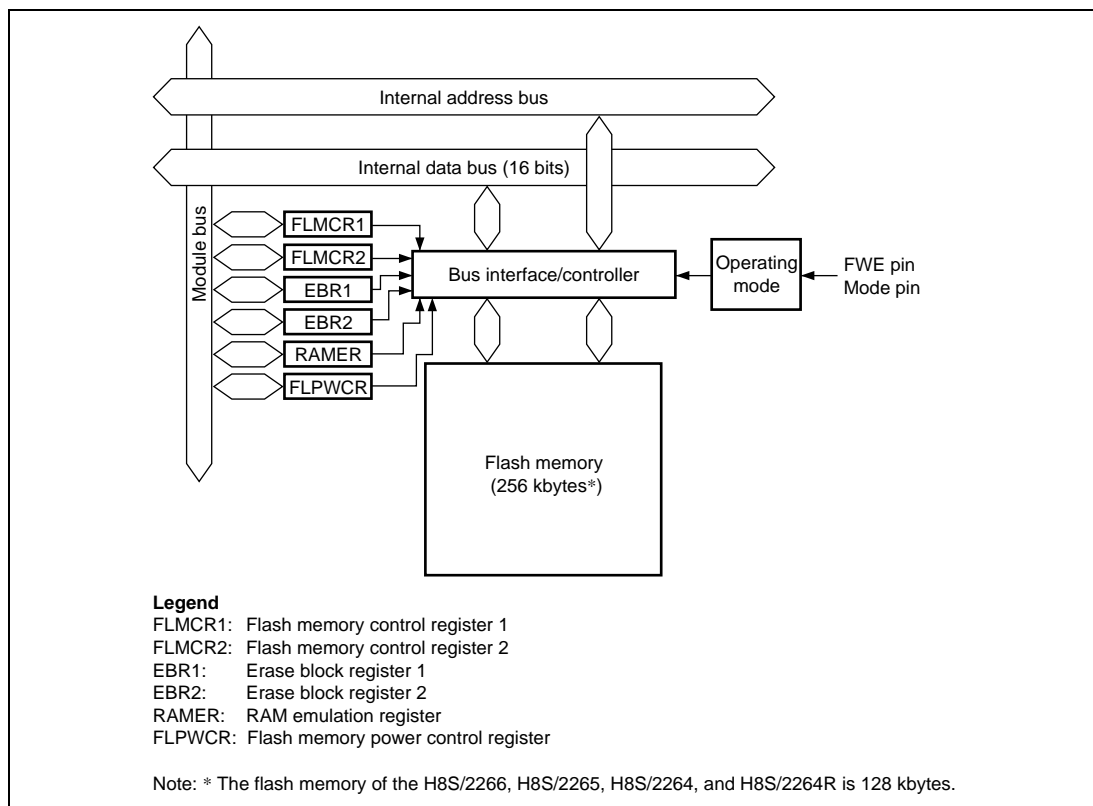


Figure 20.1 Block Diagram of Flash Memory

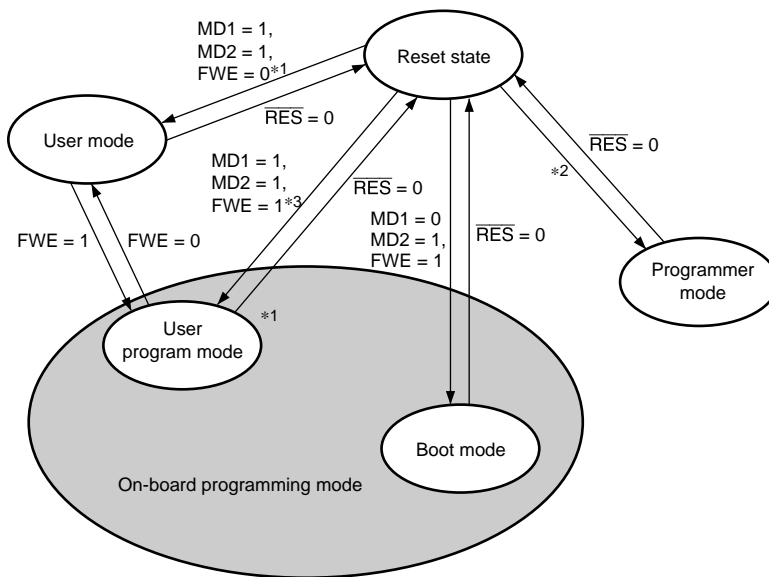
20.2 Mode Transitions

When the mode pins and the FWE pin are set in the reset state and a reset-start is executed, this LSI enters an operating mode as in figure 20.2. In user mode, flash memory can be read but not programmed or erased.

The boot, user program and programmer modes are provided as modes to write and erase the flash memory.

The differences between boot mode and user program mode are shown in table 20.1.

Figure 20.3 shows the operation flow for boot mode and figure 20.4 shows that for user program mode.



Notes: Only make a transition between user mode and user program mode when the CPU is not accessing the flash memory.

1. RAM emulation possible
2. MD1 = 0, MD2 = 0, P14 = 0, P16 = 0, P70 = 1
3. In the H8S/2264 Series, reset state should be cancelled when the P76 pin is driven high by pulling the pin up on the board.

Figure 20.2 Flash Memory State Transitions

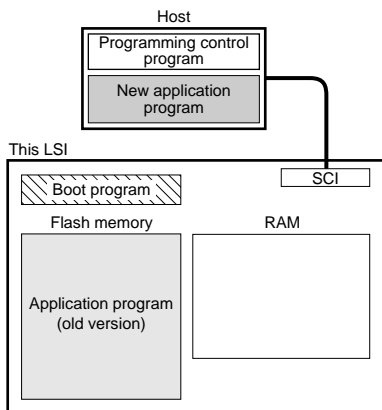
Table 20.1 Differences between Boot Mode and User Program Mode

	Boot Mode	User Program Mode
Total erase	Yes	Yes
Block erase	No	Yes
Programming control program*	Program/program-verify	Program/program-verify/erase/ erase-verify/emulation

Note: * To be provided by the user, in accordance with the recommended algorithm.

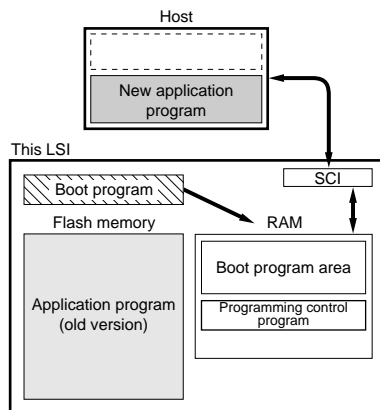
1. Initial state

The old program version or data remains written in the flash memory. The user should prepare the programming control program and new application program beforehand in the host.



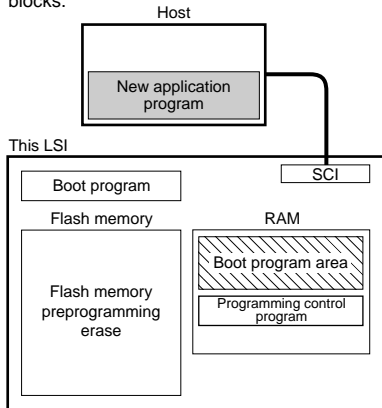
2. Programming control program transfer

When boot mode is entered, the boot program in this LSI (originally incorporated in the chip) is started and the programming control program in the host is transferred to RAM via SCI communication. The boot program required for flash memory erasing is automatically transferred to the RAM boot program area.



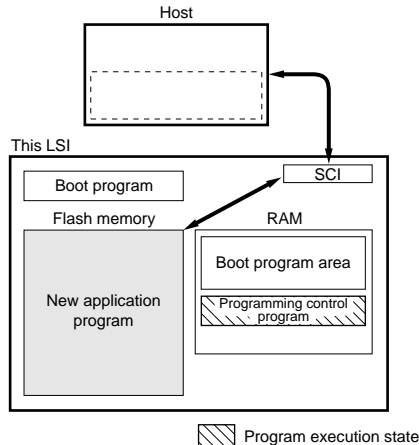
3. Flash memory initialization

The erase program in the boot program area (in RAM) is executed, and the flash memory is initialized (to H'FF). In boot mode, total flash memory erasure is performed, without regard to blocks.



4. Writing new application program

The programming control program transferred from the host to RAM is executed, and the new application program in the host is written into the flash memory.

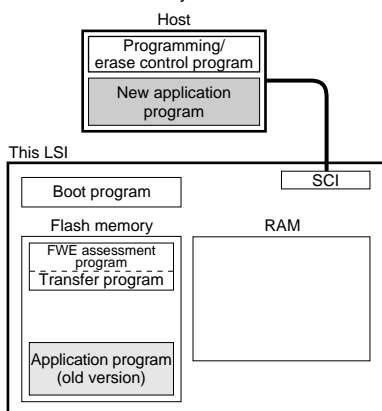


Program execution state

Figure 20.3 Boot Mode

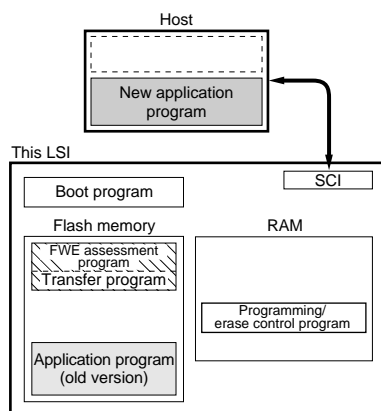
1. Initial state

The FWE assessment program that confirms that user program mode has been entered, and the program that will transfer the programming/erase control program from flash memory to on-chip RAM should be written into the flash memory by the user beforehand. The programming/erase control program should be prepared in the host or in the flash memory.



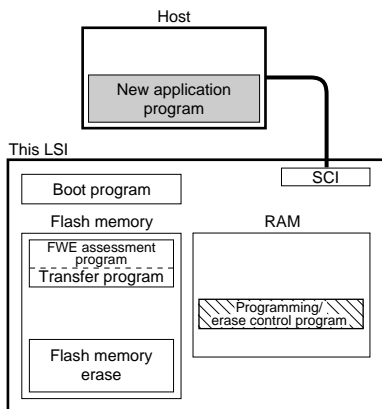
2. Programming/erase control program transfer

When user program mode is entered, user software confirms this fact, executes transfer program in the flash memory, and transfers the programming/erase control program to RAM.



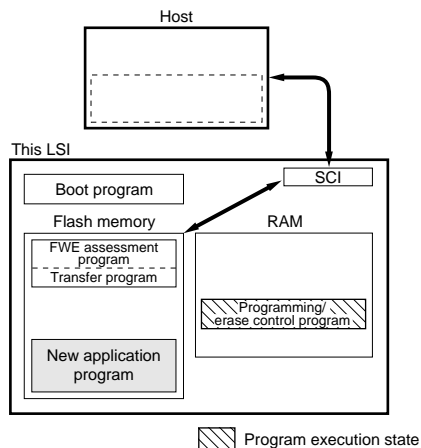
3. Flash memory initialization

The programming/erase program in RAM is executed, and the flash memory is initialized (to H'FF). Erasing can be performed in block units, but not in byte units.



4. Writing new application program

Next, the new application program in the host is written into the erased flash memory blocks. Do not write to unerased blocks.




 Program execution state

Figure 20.4 User Program Mode (Example)

20.3 Block Configuration

Figure 20.5 shows the block configuration of 256-kbyte flash memory of the H8S/2268. Figure 20.6 shows the block configuration of 128-kbyte flash memory of the H8S/2266 and H8S/2265. Figure 20.7 shows the block configuration of 128-kbyte flash memory of the H8S/2264 and H8S/2264R. The thick lines indicate erasing units, the narrow lines indicate programming units, and the values are addresses. The flash memory of the H8S/2268 is divided into 4 kbytes (8 blocks), 32 kbytes (1 block), and 64 kbytes (3 blocks). The flash memory of the H8S/2266 and H8S/2265 is divided into 4 kbytes (8 blocks), 32 kbytes (1 block), and 64 kbytes (1 block). The flash memory of the H8S/2264 and H8S/2264R is divided into 1 kbyte (4 blocks), 28 kbytes (1 block), 16 kbytes (1 block), 8 kbytes (2 blocks), and 32 kbytes (2 blocks). Erasing is performed in these units. Programming is performed in 128-byte units starting from an address with lower eight bits H'00 or H'80.

EB0 Erase unit 4 kbytes	H'000000	H'000001	H'000002	← Programming unit: 128 bytes →	H'00007F
					H'000FFF
EB1 Erase unit 4 kbytes	H'001000	H'001001	H'001002	← Programming unit: 128 bytes →	H'00107F
					H'001FFF
EB2 Erase unit 4 kbytes	H'002000	H'002001	H'002002	← Programming unit: 128 bytes →	H'00207F
					H'002FFF
EB3 Erase unit 4 kbytes	H'003000	H'003001	H'003002	← Programming unit: 128 bytes →	H'00307F
					H'003FFF
EB4 Erase unit 4 kbytes	H'004000	H'004001	H'004002	← Programming unit: 128 bytes →	H'00407F
					H'004FFF
EB5 Erase unit 4 kbytes	H'005000	H'005001	H'005002	← Programming unit: 128 bytes →	H'00507F
					H'005FFF
EB6 Erase unit 4 kbytes	H'006000	H'006001	H'006002	← Programming unit: 128 bytes →	H'00607F
					H'006FFF
EB7 Erase unit 4 kbytes	H'007000	H'007001	H'007002	← Programming unit: 128 bytes →	H'00707F
					H'007FFF
EB8 Erase unit 32 kbytes	H'008000	H'008001	H'008002	← Programming unit: 128 bytes →	H'00807F
					H'00FFFF
EB9 Erase unit 64 kbytes	H'010000	H'010001	H'010002	← Programming unit: 128 bytes →	H'01007F
					H'01FFFF
EB10 Erase unit 64 kbytes	H'020000	H'020001	H'020002	← Programming unit: 128 bytes →	H'02007F
					H'02FFFF
EB11 Erase unit 64 kbytes	H'030000	H'030001	H'030002	← Programming unit: 128 bytes →	H'03007F
					H'03FFFF

Figure 20.5 Flash Memory Block Configuration (H8S/2268)

EB0 Erase unit 4 kbytes	H'000000	H'000001	H'000002	← Programming unit: 128 bytes →	H'00007F
					H'000FFF
EB1 Erase unit 4 kbytes	H'001000	H'001001	H'001002	← Programming unit: 128 bytes →	H'00107F
					H'001FFF
EB2 Erase unit 4 kbytes	H'002000	H'002001	H'002002	← Programming unit: 128 bytes →	H'00207F
					H'002FFF
EB3 Erase unit 4 kbytes	H'003000	H'003001	H'003002	← Programming unit: 128 bytes →	H'00307F
					H'003FFF
EB4 Erase unit 4 kbytes	H'004000	H'004001	H'004002	← Programming unit: 128 bytes →	H'00407F
					H'004FFF
EB5 Erase unit 4 kbytes	H'005000	H'005001	H'005002	← Programming unit: 128 bytes →	H'00507F
					H'005FFF
EB6 Erase unit 4 kbytes	H'006000	H'006001	H'006002	← Programming unit: 128 bytes →	H'00607F
					H'006FFF
EB7 Erase unit 4 kbytes	H'007000	H'007001	H'007002	← Programming unit: 128 bytes →	H'00707F
					H'007FFF
EB8 Erase unit 32 kbytes	H'008000	H'008001	H'008002	← Programming unit: 128 bytes →	H'00807F
					H'00FFFF
EB9 Erase unit 64 kbytes	H'010000	H'010001	H'010002	← Programming unit: 128 bytes →	H'01007F
					H'01FFFF

Figure 20.6 Flash Memory Block Configuration (H8S/2266 and H8S/2265)

EB0 Erase unit 1 kbyte	H'000000	H'000001	H'000002	← Programming unit: 128 bytes →	H'00007F
	H'000380	H'000381	H'000382		H'0003FF
EB1 Erase unit 1 kbyte	H'000400	H'000401	H'000402	← Programming unit: 128 bytes →	H'00047F
	H'000780	H'000781	H'000782		H'0007FF
EB2 Erase unit 1 kbyte	H'000800	H'000801	H'000802	← Programming unit: 128 bytes →	H'00087F
	H'000B80	H'000B81	H'000B82		H'000BFF
EB3 Erase unit 1 kbyte	H'000C00	H'000C01	H'000C02	← Programming unit: 128 bytes →	H'000C7F
	H'000F80	H'000F81	H'000F82		H'000FFF
EB4 Erase unit 28 kbytes	H'001000	H'001001	H'001002	← Programming unit: 128 bytes →	H'00107F
	H'007F80	H'007F81	H'007F82		H'007FFF
EB5 Erase unit 16 kbytes	H'008000	H'008001	H'008002	← Programming unit: 128 bytes →	H'00807F
	H'00BF80	H'00BF81	H'00BF82		H'00BFFF
EB6 Erase unit 8 kbytes	H'00C000	H'00C001	H'00C002	← Programming unit: 128 bytes →	H'00C07F
	H'00DF80	H'00DF81	H'00DF82		H'00DFFF
EB7 Erase unit 8 kbytes	H'00E000	H'00E001	H'00E002	← Programming unit: 128 bytes →	H'00E07F
	H'00FF80	H'00FF81	H'00FF82		H'00FFFF
EB8 Erase unit 32 kbytes	H'010000	H'010001	H'010002	← Programming unit: 128 bytes →	H'01007F
	H'017F80	H'017F81	H'017F82		H'017FFF
EB9 Erase unit 32 kbytes	H'018000	H'018001	H'018002	← Programming unit: 128 bytes →	H'01807F
	H'01FF80	H'01FF81	H'01FF82		H'01FFFF

Figure 20.7 Flash Memory Block Configuration (H8S/2264 and H8S/2264R)

20.4 Input/Output Pins

The flash memory is controlled by means of the pins shown in table 20.2.

Table 20.2 Pin Configuration

Pin Name	I/O	Function
$\overline{\text{RES}}$	Input	Reset
FWE	Input	Flash program/erase protection by hardware
MD2	Input	Sets this LSI's operating mode
MD1	Input	Sets this LSI's operating mode
P70	Input	Sets MCU operating mode in programmer mode
P16	Input	Sets MCU operating mode in programmer mode
P14	Input	Sets MCU operating mode in programmer mode
TxD0	Output	Serial transmit data output
RxD0	Input	Serial receive data input

20.5 Register Descriptions

The flash memory has the following registers.

- Flash memory control register 1 (FLMCR1)
- Flash memory control register 2 (FLMCR2)
- Erase block register 1 (EBR1)
- Erase block register 2 (EBR2)
- RAM emulation register (RAMER)
- Flash memory power control register (FLPWCR)
- Serial control register X (SCRX)

The registers described above are not present in the masked ROM version. If a register described above is read in the masked ROM version, an undefined value will be returned.

20.5.1 Flash Memory Control Register 1 (FLMCR1)

FLMCR1 is a register that makes the flash memory change to program mode, program-verify mode, erase mode, or erase-verify mode. For details on register setting, refer to section 20.8, Flash Memory Programming/Erasing.

Bit	Bit Name	Initial Value	R/W	Description
7	FWE	—	R	Flash Write Enable Bit Reflects the input level at the FWE pin. It is set to 1 when a low level is input to the FWE pin, and cleared to 0 when a high level is input. When this bit is cleared to 0, the flash memory changes to hardware protect mode.
6	SWE1	0	R/W	Software Write Enable Bit When this bit is set to 1, flash memory programming/erasing is enabled. When this bit is cleared to 0, bits 5 to 0 in FLMCR1 register and all EBR1 and EBR2 bits cannot be set. [Setting condition] When FWE = 1.
5	ESU1	0	R/W	Erase Setup Bit When this bit is set to 1, the flash memory changes to the erase setup state. When it is cleared to 0, the erase setup state is cancelled. Set this bit to 1 before setting the E1 bit in FLMCR1. [Setting condition] When FWE = 1 and SWE1 = 1
4	PSU1	0	R/W	Program Setup Bit When this bit is set to 1, the flash memory changes to the program setup state. When it is cleared to 0, the program setup state is cancelled. Set this bit to 1 before setting the P1 bit in FLMCR1. [Setting condition] When FWE = 1 and SWE1 = 1
3	EV1	0	R/W	Erase-Verify When this bit is set to 1, the flash memory changes to erase-verify mode. When it is cleared to 0, erase-verify mode is cancelled. [Setting condition] When FWE = 1 and SWE1 = 1

Bit	Bit Name	Initial Value	R/W	Description
2	PV1	0	R/W	Program-Verify When this bit is set to 1, the flash memory changes to program-verify mode. When it is cleared to 0, program-verify mode is cancelled. [Setting condition] When FWE = 1 and SWE1 = 1
1	E1	0	R/W	Erase When this bit is set to 1, and while the SWE1 and ESU1 bits are 1, the flash memory changes to erase mode. When it is cleared to 0, erase mode is cancelled. [Setting condition] When FWE = 1, SWE1 = 1, and ESU1 = 1
0	P1	0	R/W	Program When this bit is set to 1, and while the SWE1 and PSU1 bits are 1, the flash memory changes to program mode. When it is cleared to 0, program mode is cancelled. When FWE = 1, SWE1 = 1, and PSU1 = 1

20.5.2 Flash Memory Control Register 2 (FLMCR2)

FLMCR2 is a register that displays the state of flash memory programming/erasing. FLMCR2 is a read-only register, and should not be written to.

Bit	Bit Name	Initial Value	R/W	Description
7	FLER	0	R	Indicates that an error has occurred during an operation on flash memory (programming or erasing). When FLER is set to 1, flash memory goes to the error-protection state. See section 20.9.3, Error Protection, for details.
6 to 0	—	All 0	R	Reserved These bits are always read as 0.

20.5.3 Erase Block Register 1 (EBR1)

EBR1 specifies the flash memory erase area block. EBR1 is initialized to H'00 when the SWE1 bit in FLMCR1 is 0. Do not set more than one bit at a time, as this will cause all the bits in EBR1 and EBR2 to be automatically cleared to 0.

- H8S/2268 Series

Bit	Bit Name	Initial Value	R/W	Description
7	EB7	0	R/W	When this bit is set to 1, 4 kbytes of EB7 (H'007000 to H'007FFF) will be erased.
6	EB6	0	R/W	When this bit is set to 1, 4 kbytes of EB6 (H'006000 to H'006FFF) will be erased.
5	EB5	0	R/W	When this bit is set to 1, 4 kbytes of EB5 (H'005000 to H'005FFF) will be erased.
4	EB4	0	R/W	When this bit is set to 1, 4 kbytes of EB4 (H'004000 to H'004FFF) will be erased.
3	EB3	0	R/W	When this bit is set to 1, 4 kbytes of EB3 (H'003000 to H'003FFF) will be erased.
2	EB2	0	R/W	When this bit is set to 1, 4 kbytes of EB2 (H'002000 to H'002FFF) will be erased.
1	EB1	0	R/W	When this bit is set to 1, 4 kbytes of EB1 (H'001000 to H'001FFF) will be erased.
0	EB0	0	R/W	When this bit is set to 1, 4 kbytes of EB0 (H'000000 to H'000FFF) will be erased.

- H8S/2264 Series

Bit	Bit Name	Initial Value	R/W	Description
7	EB7	0	R/W	When this bit is set to 1, 8 kbytes of EB7 (H'00E000 to H'00FFFF) will be erased.
6	EB6	0	R/W	When this bit is set to 1, 8 kbytes of EB6 (H'00C000 to H'00DFFF) will be erased.
5	EB5	0	R/W	When this bit is set to 1, 16 kbytes of EB5 (H'008000 to H'00BFFF) will be erased.
4	EB4	0	R/W	When this bit is set to 1, 28 kbytes of EB4 (H'001000 to H'007FFF) will be erased.
3	EB3	0	R/W	When this bit is set to 1, 1 kbyte of EB3 (H'000C00 to H'000FFF) will be erased.
2	EB2	0	R/W	When this bit is set to 1, 1 kbyte of EB2 (H'000800 to H'000BFF) will be erased.
1	EB1	0	R/W	When this bit is set to 1, 1 kbyte of EB1 (H'000400 to H'0007FF) will be erased.
0	EB0	0	R/W	When this bit is set to 1, 1 kbyte of EB0 (H'000000 to H'0003FF) will be erased.

20.5.4 Erase Block Register 2 (EBR2)

EBR2 specifies the flash memory erase area block. EBR2 is initialized to H'00 when the SWE1 bit in FLMCR1 is 0. Do not set more than one bit at a time, as this will cause all the bits in EBR1 and EBR2 to be automatically cleared to 0.

- H8S/2268 Series

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 0	R/W	Reserved These bits are always read as 0. Only 0 should be written to these bits.
3	EB11*	0	R/W	When this bit is set to 1, 64 kbytes of EB11 (H'030000 to H'03FFFF) will be erased.
2	EB10*	0	R/W	When this bit is set to 1, 64 kbytes of EB10 (H'020000 to H'02FFFF) will be erased.
1	EB9	0	R/W	When this bit is set to 1, 64 kbytes of EB9 (H'010000 to H'01FFFF) will be erased.
0	EB8	0	R/W	When this bit is set to 1, 32 kbytes of EB8 (H'008000 to H'00FFFF) will be erased.

Note:* These bits are reserved bits in the H8S/2266 and H8S/2265. Only 0 should be written to these bits.

- H8S/2264 Series

Bit	Bit Name	Initial Value	R/W	Description
7 to 2	—	All 0	R/W	Reserved These bits are always read as 0. Only 0 should be written to these bits.
1	EB9	0	R/W	When this bit is set to 1, 32 kbytes of EB9 (H'018000 to H'01FFFF) will be erased.
0	EB8	0	R/W	When this bit is set to 1, 32 kbytes of EB8 (H'010000 to H'017FFF) will be erased.

20.5.5 RAM Emulation Register (RAMER)

RAMER specifies the area of flash memory to be overlapped with part of RAM when emulating real-time flash memory programming. RAMER settings should be made in user mode or user program mode. To ensure correct operation of the emulation function, the ROM for which RAM emulation is performed should not be accessed immediately after this register has been modified. Normal execution of an access immediately after register modification is not guaranteed.

- H8S/2268 Series

Bit	Bit Name	Initial Value	R/W	Description
7 to 5	—	All 0	R	Reserved These bits are always read as 0.
4	—	0	R/W	Reserved Only 0 should be written to this bit.
3	RAMS	0	R/W	RAM Select Specifies selection or non-selection of flash memory emulation in RAM. When RAMS = 1, the flash memory is overlapped with part of RAM, and all flash memory block are program/erase-protected.
2	RAM2	0	R/W	Flash Memory Area Selection
1	RAM1	0	R/W	When the RAMS bit is set to 1, one of the following flash memory areas is selected to overlap the RAM area. The areas correspond with 4-kbyte erase blocks. 000: H'000000 to H'000FFF (EB0) 001: H'001000 to H'001FFF (EB1) 010: H'002000 to H'002FFF (EB2) 011: H'003000 to H'003FFF (EB3) 100: H'004000 to H'004FFF (EB4) 101: H'005000 to H'005FFF (EB5) 110: H'006000 to H'006FFF (EB6) 111: H'007000 to H'007FFF (EB7)
0	RAM0	0	R/W	

- H8S/2264 Series

Bit	Bit Name	Initial Value	R/W	Description
7 to 5	—	All 0	R	Reserved These bits are always read as 0.
4	—	0	R/W	Reserved Only 0 should be written to this bit.
3	RAMS	0	R/W	RAM Select Specifies selection or non-selection of flash memory emulation in RAM. When RAMS = 1, the flash memory is overlapped with part of RAM, and all flash memory block are program/erase-protected.

Bit	Bit Name	Initial Value	R/W	Description
2	—	0	R/W	Reserved Only 0 should be written to this bit.
1	RAM1	0	R/W	Flash Memory Area Selection
0	RAM0	0	R/W	When the RAMS bit is set to 1, one of the following flash memory areas is selected to overlap the RAM area. The areas correspond with 1-kbyte erase block. 00: H'000000 to H'0003FF (EB0) 01: H'000400 to H'0007FF (EB1) 10: H'000800 to H'00BFFF (EB2) 11: H'000C00 to H'000FFF (EB3)

20.5.6 Flash Memory Power Control Register (FLPWCR)

FLPWCR enables/disables transition to power-down modes for the flash memory when this LSI enters sub-active mode.

Bit	Bit Name	Initial Value	R/W	Description
7	PDWND	0	R/W	Power Down Disable Enables/disables transition to power-down modes for the flash memory when this LSI enters sub-active mode. 0: Transition to power-down modes for the flash memory enabled. 1: Transition to power-down modes for the flash memory disabled.
6 to 0	—	All 0	R	Reserved These bits are always read as 0.

20.5.7 Serial Control Register X (SCRX)

SCRX performs register access control.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved Only 0 should be written to this bit.
6	IICX1	0	R/W	I ² C Transfer Select 1, 0
5	IICX0	0	R/W	For details, see section 14.3.5, Serial Control Register X (SCRX).
4	IICE	0	R/W	I ² C Master Enable For details, see section 14.3.5, Serial Control Register X (SCRX).
3	FLSHE	0	R/W	Flash Memory Control Register Enable Controls for the CPU accessing to the control registers (FLMCR1, FLMCR2, EBR1, EBR2) of the flash memory. When this bit is set to 1, the flash memory control registers can be read/written to. When this bit is cleared to 0, the flash memory control registers are not selected. At this time, the contents of the flash memory control registers are retained. 0: Area at H'FFFA8 to H'FFFFAC not selected for the flash memory control registers. 1: Area at H'FFFA8 to H'FFFFAC selected for the flash memory control registers.
2 to 0	—	All 0	R/W	Reserved Only 0 should be written to these bits.

20.6 On-Board Programming Modes

When pins are set to on-board programming mode, program/erase/verify operations can be performed on the on-chip flash memory. There are two on-board programming modes: boot mode and user program mode. The pin settings for transition to each of these modes are shown in table 20.3. For a diagram of the transitions to the various flash memory modes, see figure 20.2.

Table 20.3 Setting On-Board Programming Modes

FWE	MD2	MD1	Mode Setting
1	1	0	Boot Mode
1	1	1	User program mode*
0	1	1	User mode

Note: * To set user program mode in the H8S/2264 Series, reset state should be cancelled when the P76 pin is driven high by pulling the pin up on the board.

20.6.1 Boot Mode

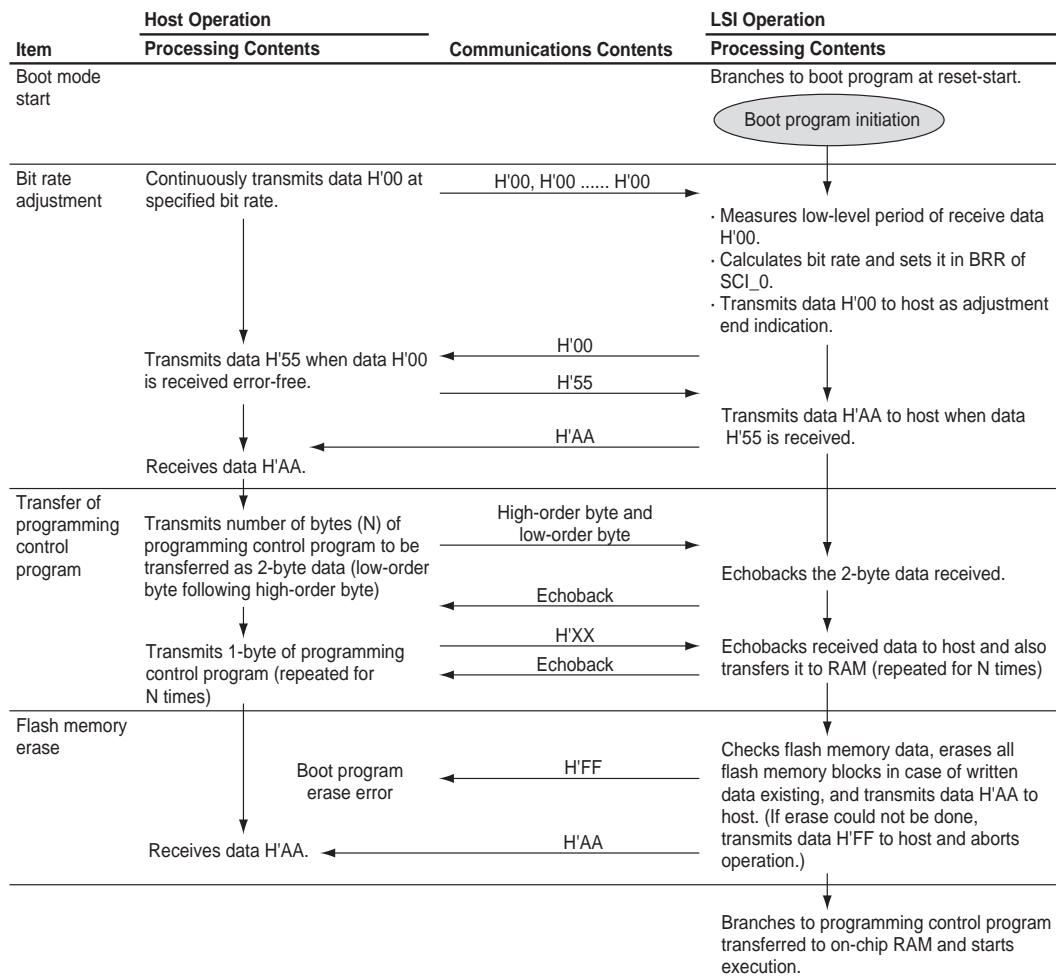
Table 20.4 shows the boot mode operations between reset end and branching to the programming control program.

1. When boot mode is used, the flash memory programming control program must be prepared in the host beforehand. Prepare a programming control program in accordance with the description in section 20.8, Flash Memory Programming/Erasing.
In boot mode, if any data has been programmed into the flash memory (if all data is not 1), all flash memory blocks are erased. Boot mode is for use when user program mode is unavailable, such as the first time on-board programming is performed, or if the program activated in user program mode is accidentally erased.
2. SCI_0 should be set to asynchronous mode, and the transfer format as follows: 8-bit data, 1 stop bit, and no parity.
3. When the boot program is initiated, the chip measures the low-level period of asynchronous SCI communication data (H'00) transmitted continuously from the host. The chip then calculates the bit rate of transmission from the host, and adjusts the SCI_0 bit rate to match that of the host. The reset should end with the Rx/D pin high. The Rx/D and Tx/D pins should be pulled up on the board if necessary. After the reset is complete, it takes approximately 100 states before the chip is ready to measure the low-level period.
4. After matching the bit rates, the chip transmits one H'00 byte to the host to indicate the completion of bit rate adjustment. The host should confirm that this adjustment end indication (H'00) has been received normally, and transmit one H'55 byte to the chip. If reception could not be performed normally, initiate boot mode again by a reset. Depending on the host's transfer bit rate and system clock frequency of this LSI, there will be a discrepancy between

the bit rates of the host and the chip. To operate the SCI properly, set the host's transfer bit rate and system clock frequency of this LSI within the ranges listed in table 20.5.

5. In boot mode, a part of the on-chip RAM area is used by the boot program. The area H'FFC000 to H'FFDFFF is the area to which the programming control program is transferred from the host in the H8S/2268 Series. In the H8S/2266 and H8S/2265, the RAM in this area is enabled only in boot mode. The area H'FFE000 to H'FFE7FF is the area to which the programming control program is transferred from the host in the H8S/2264 Series. The boot program area cannot be used until the execution state in boot mode switches to the programming control program.
6. Before branching to the programming control program, the chip terminates transfer operations by SCI_0 (by clearing the RE and TE bits in SCR to 0), however the adjusted bit rate value remains set in BRR. Therefore, the programming control program can still use it for transfer of write data or verify data with the host. The TxD pin is high. The contents of the CPU general registers are undefined immediately after branching to the programming control program. These registers must be initialized at the beginning of the programming control program, as the stack pointer (SP), in particular, is used implicitly in subroutine calls, etc.
7. Boot mode can be cleared by driving the reset pin low, waiting at least 20 states, then setting the FWE pin and mode pins, and executing reset release*. Boot mode is also cleared when a WDT overflow occurs.
8. All interrupts are disabled during programming or erasing of the flash memory.

Note: The input signals on the FWE and mode pins must satisfy the mode programming setup time ($t_{MDS} = 200 \text{ ns}$) at the reset release timing. In the H8S/2264 Series, reset state should be cancelled when the P76 pin is driven high by pulling the pin up.

Table 20.4 Boot Mode Operation

Table 20.5 System Clock Frequencies for which Automatic Adjustment of LSI Bit Rate is Possible

Host Bit Rate	System Clock Frequency Range of this LSI
19,200 bps	8 to 20.5 MHz
9,600 bps	4 to 20.5 MHz
4,800 bps	2 to 20.5 MHz

20.6.2 Programming/Erasing in User Program Mode

On-board programming/erasing of an individual flash memory block can also be performed in user program mode by branching to a user program/erase control program. The user must prepare on-board means for controlling FWE, on-board means of supplying programming data, and branching conditions. The flash memory must contain the user program/erase control program or a program that provides the user program/erase control program from external memory. As the flash memory itself cannot be read during programming/erasing, transfer the user program/erase control program to on-chip RAM, as in boot mode. Figure 20.8 shows a sample procedure for programming/erasing in user program mode. Prepare a user program/erase control program in accordance with the description in section 20.8, Flash Memory Programming/Erasing.

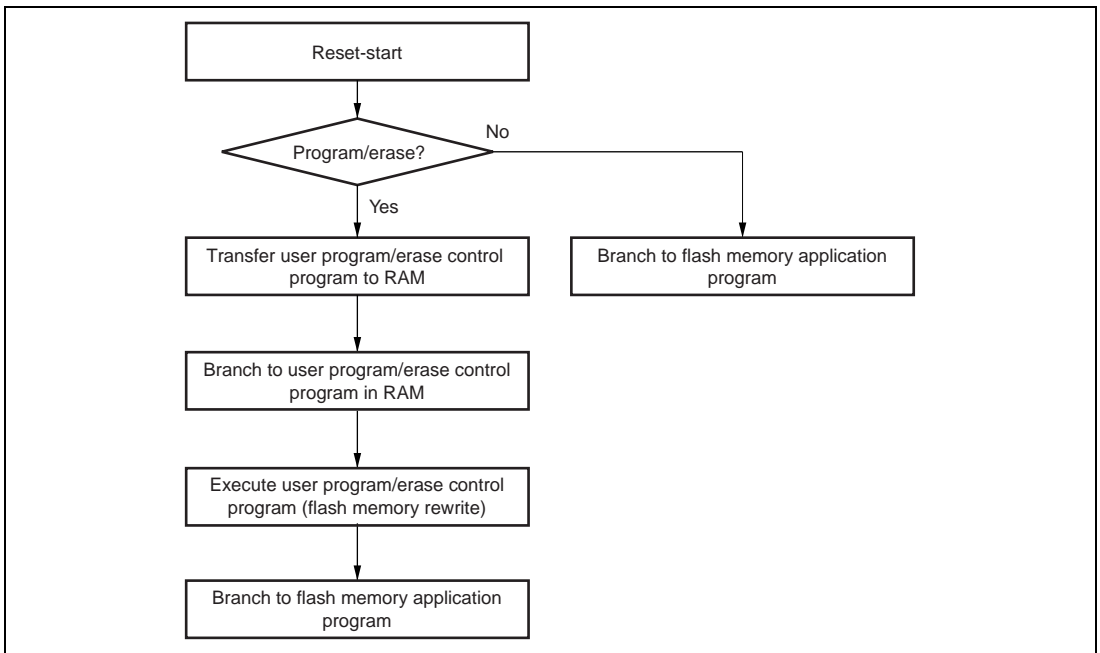


Figure 20.8 Programming/Erasing Flowchart Example in User Program Mode

20.7 Flash Memory Emulation in RAM

A setting in the RAM emulation register (RAMER) enables part of RAM to be overlapped onto the flash memory area so that data to be written to flash memory can be emulated in RAM in real time. Emulation can be performed in user mode or user program mode. Figure 20.9 shows an example of emulation of real-time flash memory programming.

1. Set RAMER to overlap part of RAM onto the area for which real-time programming is required.
2. Emulation is performed using the overlapping RAM.
3. After the program data has been confirmed, the RAMS bit is cleared, thus releasing the RAM overlap.
4. The data written in the overlapping RAM is written into the flash memory space.

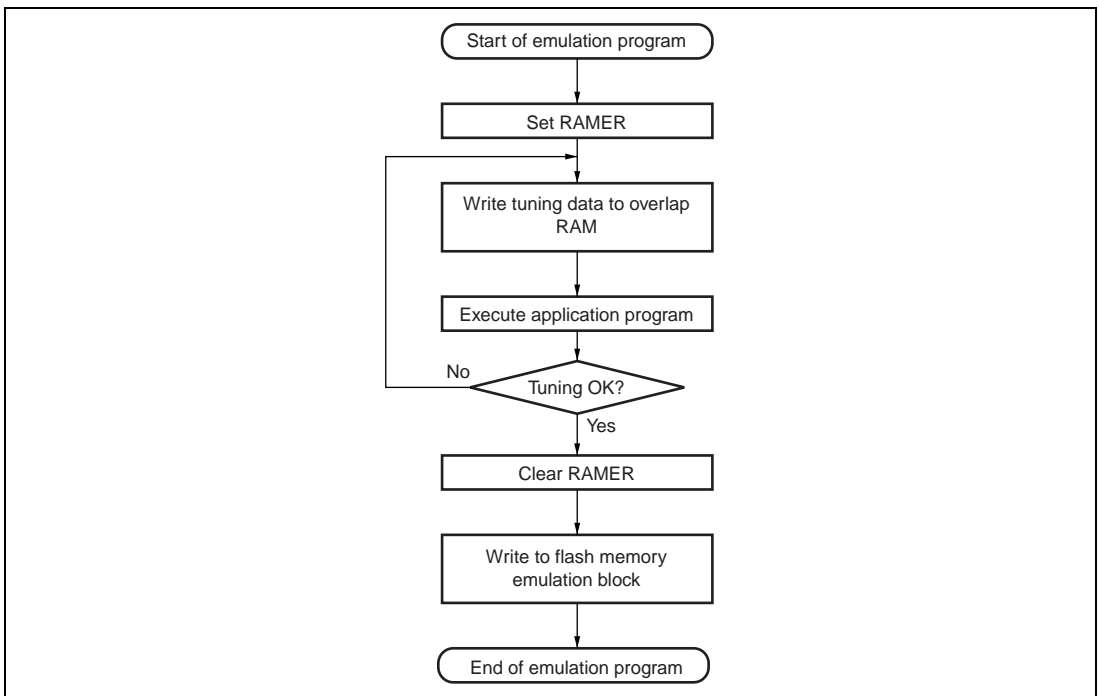


Figure 20.9 Flowchart for Flash Memory Emulation in RAM

An example in which flash memory block area EB0 is overlapped is shown in figures 20.10 and 20.11.

1. The RAM area to be overlapped is fixed at a 4-kbyte area in the range H'FFD000 to H'FFDFFF in the H8S/2268 Series. In the H8S/2265, the RAM in this area is enabled only in RAM emulation mode. The RAM area to be overlapped is fixed at a 1-kbyte area in the range H'FFE000 to H'FFE3FF in the H8S/2264 Series.
2. The flash memory area to be overlapped is selected by RAMER from a 4-kbyte area of the EB0 to EB7 blocks in the H8S/2268 Series. The flash memory area to be overlapped is selected by RAMER from a 1-kbyte area of the EB0 to EB3 blocks in the H8S/2264 Series.
3. The overlapped RAM area can be accessed from both the flash memory addresses and RAM addresses.
4. When the RAMS bit in RAMER is set to 1, program/erase protection is enabled for all flash memory blocks (emulation protection). In this state, setting the P1 or E1 bit in FLMCR1 to 1 does not cause a transition to program mode or erase mode.
5. A RAM area cannot be erased by execution of software in accordance with the erase algorithm.
6. Block area EB0 contains the vector table. When performing RAM emulation, the vector table is needed in the overlap RAM.

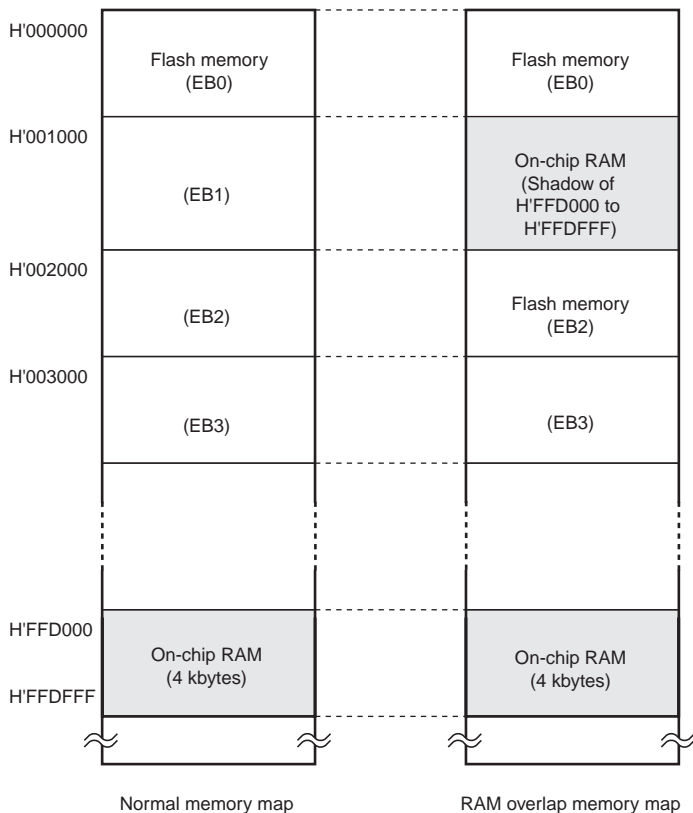


Figure 20.10 Example of RAM Overlap Operation (H8S/2268 Series)

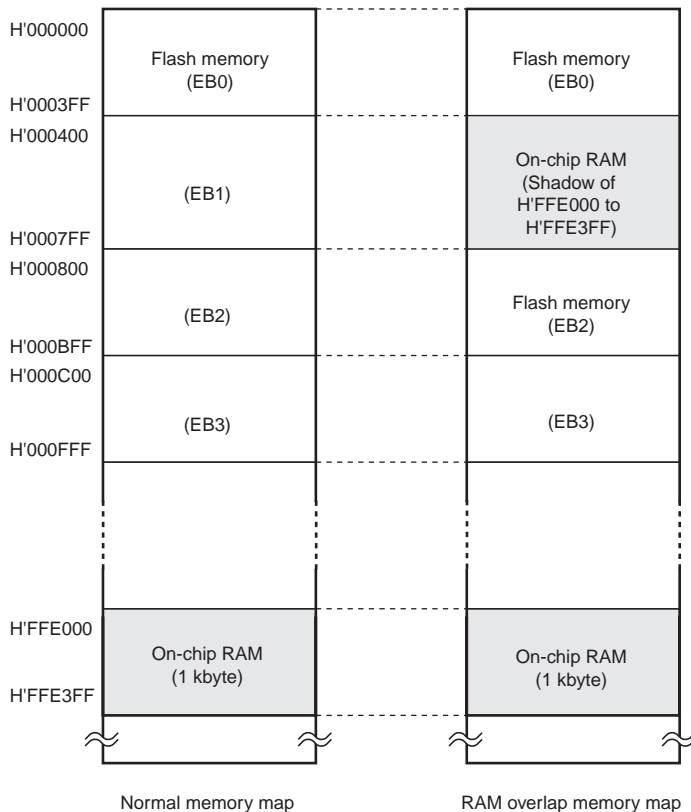


Figure 20.11 Example of RAM Overlap Operation (H8S/2264 Series)

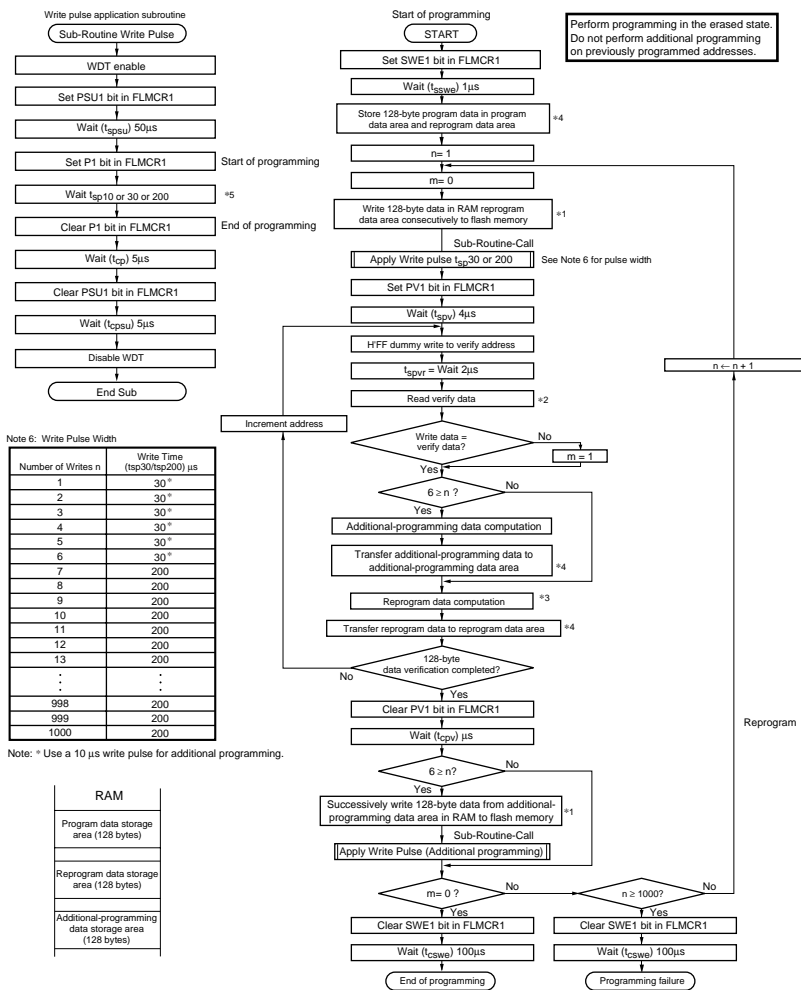
20.8 Flash Memory Programming/Erasing

A software method using the CPU is employed to program and erase flash memory in the on-board programming modes. Depending on the FLMCR1 setting, the flash memory operates in one of the following four modes: Program mode, program-verify mode, erase mode, and erase-verify mode. The programming control program in boot mode and the user program/erase control program in user program mode use these operating modes in combination to perform programming/erasing. Flash memory programming and erasing should be performed in accordance with the descriptions in section 20.8.1, Program/Program-Verify and section 20.8.2, Erase/Erase-Verify, respectively.

20.8.1 Program/Program-Verify

When writing data or programs to the flash memory, the program/program-verify flowchart shown in figure 20.12 should be followed. Performing programming operations according to this flowchart will enable data or programs to be written to the flash memory without subjecting the chip to voltage stress or sacrificing program data reliability.

1. Programming must be done to an empty address. Do not reprogram an address to which programming has already been performed.
2. Programming should be carried out 128 bytes at a time. A 128-byte data transfer must be performed even if writing fewer than 128 bytes. In this case, H'FF data must be written to the extra addresses.
3. Prepare the following data storage areas in RAM: A 128-byte programming data area, a 128-byte reprogramming data area, and a 128-byte additional-programming data area. Perform reprogramming data computation and additional programming data computation according to Figure 20.12.
4. Consecutively transfer 128 bytes of data in byte units from the reprogramming data area or additional-programming data area to the flash memory. The program address and 128-byte data are latched in the flash memory. The lower 8 bits of the start address in the flash memory destination area must be H'00 or H'80.
5. The time during which the P1 bit is set to 1 is the programming time. Figure 20.12 shows the allowable programming times.
6. The watchdog timer (WDT) is set to prevent overprogramming due to program runaway, etc. Set a value greater than $(t_{psu} + t_{sp200} + t_{cp} + t_{cpsu}) \mu s$ as the WDT overflow period.
7. For a dummy write to a verify address, write 1-byte data H'FF to an address whose lower 2 bits are b'00. Verify data can be read in words from the address to which a dummy write was performed.
8. The maximum number of repetitions of the program/program-verify sequence of the same bit is (N).



- Notes:
1. Data transfer is performed by byte transfer. The lower 8 bits of the first address written to must be H00 or H80.
A 128-byte data transfer must be performed even if writing fewer than 128 bytes; in this case, HFF data must be written to the extra addresses.
 2. Verify data is read in 16-bit (word) units.
 3. Reprogram data is determined by the operation shown in the table below (comparison between the data stored in the program data area and the verify data). Bits for which the reprogram data is 0 are programmed in the next reprogramming loop. Therefore, even bits for which programming has been completed will be subjected to programming once again if the result of the subsequent verify operation is NG.
 4. A 128-byte area for storing program data, a 128-byte area for storing reprogram data, and a 128-byte area for storing additional data must be provided in RAM. The contents of the reprogram data area and additional data area are modified as programming proceeds.
 5. A write pulse of 30 μs or 200 μs is applied according to the progress of the programming operation. See Note 6 for details of the pulse widths. When writing of additional-programming data is executed, a 10 μs write pulse should be applied. Reprogram data X means reprogram data when the write pulse is applied.

Reprogram Data Computation Table

Original Data (D)	Verify Data (V)	Reprogram Data (X)	Comments
0	0	1	Programming completed
0	1	0	Programming incomplete; reprogram
1	0	1	
1	1	1	Still in erased state; no action

Additional-Programming Data Computation Table

Reprogram Data (X)	Verify Data (V)	Additional-Programming Data (Y)	Comments
0	0	0	Additional programming to be executed
0	1	1	Additional programming not to be executed
1	0	1	Additional programming not to be executed
1	1	1	Additional programming not to be executed

Figure 20.12 Program/Program-Verify Flowchart

20.8.2 Erase/Erase-Verify

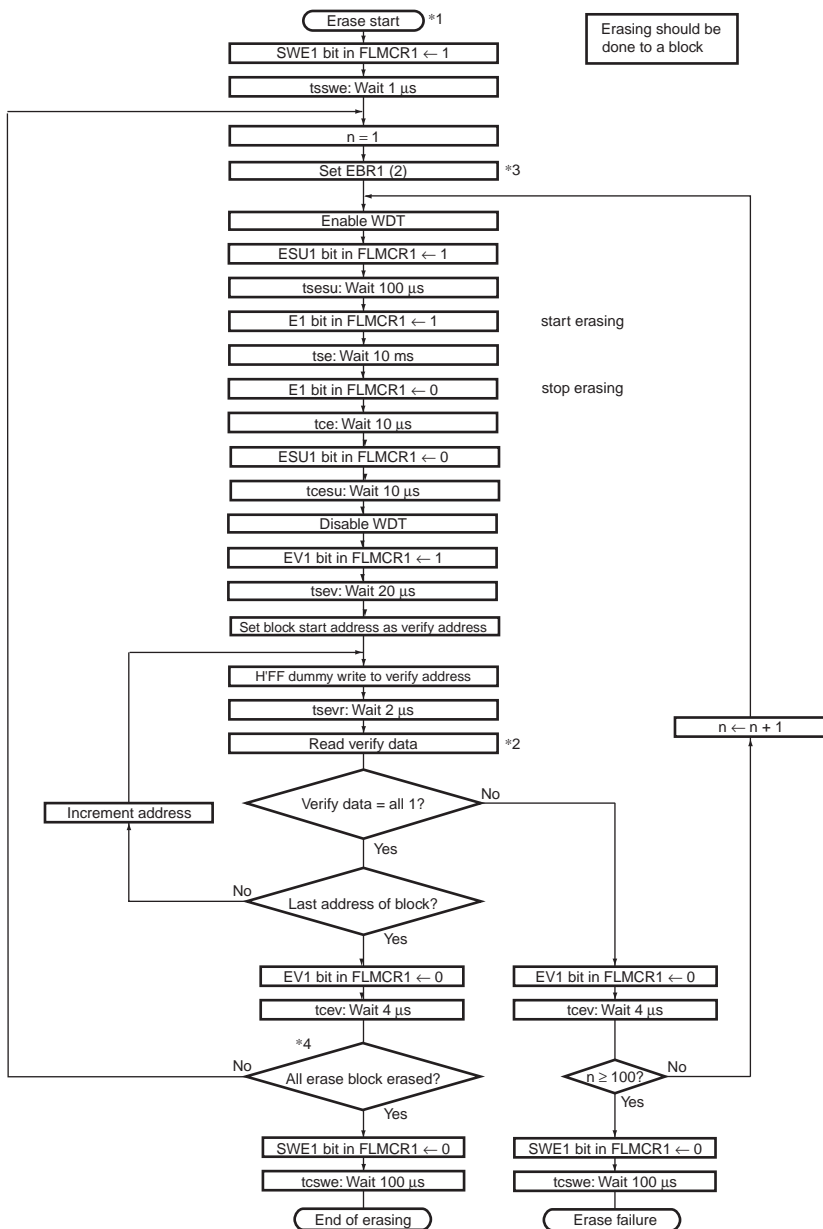
When erasing flash memory, the erase/erase-verify flowchart shown in figure 20.13 should be followed.

1. Prewriting (setting erase block data to all 0) is not necessary.
2. Erasing is performed in block units. Make only a single-bit specification in the erase block register 1 and 2 (EBR1 and EBR2). To erase multiple blocks, each block must be erased in turn.
3. The time during which the E1 bit is set to 1 is the flash memory erase time.
4. The watchdog timer (WDT) is set to prevent overprogramming due to program runaway, etc. Set a value greater than $(t_{\text{sesu}} + t_{\text{se}} + t_{\text{ce}} + t_{\text{cesu}})$ ms as the WDT overflow period.
5. For a dummy write to a verify address, write 1-byte data H'FF to an address whose lower two bits are b'00. Verify data can be read in words from the address to which a dummy write was performed.
6. If the read data is not erased successfully, set erase mode again, and repeat the erase/erase-verify sequence as before. The maximum number of repetitions of the erase/erase-verify sequence is (N).

20.8.3 Interrupt Handling when Programming/Erasing Flash Memory

All interrupts, including the $\overline{\text{NMI}}$ interrupt, are disabled while flash memory is being programmed or erased, or while the boot program is executing, for the following three reasons:

1. Interrupt during programming/erasing may cause a violation of the programming or erasing algorithm, with the result that normal operation cannot be assured.
2. If interrupt exception handling starts before the vector address is written or during programming/erasing, a correct vector cannot be fetched and the CPU malfunctions.
3. If an interrupt occurs during boot program execution, normal boot mode sequence cannot be carried out.



- Notes: 1. Pre-writing (all erase block data are cleared to 0) is not necessary.
 2. Verify data is read out in 16 bit size (word access).
 3. Erasing block register (EBR) can be set about 1 bit at a time.
 Do not specify 2 bits or more.
 4. Erasing is performed block by block. when multiple blocks must be erased,
 erase each lock one by one.

Figure 20.13 Erase/Eraser-Verify Flowchart

20.9 Program/Erase Protection

There are three kinds of flash memory program/erase protection; hardware protection, software protection, and error protection.

20.9.1 Hardware Protection

Hardware protection refers to a state in which programming/erasing of flash memory is forcibly disabled or aborted because of a transition to reset or standby mode. Flash memory control register 1 (FLMCR1), flash memory control register 2 (FLMCR2), erase block register 1 (EBR1), and erase block register 2 (EBR2) are initialized. In a reset via the $\overline{\text{RES}}$ pin, the reset state is not entered unless the $\overline{\text{RES}}$ pin is held low until oscillation stabilizes after powering on. In the case of a reset during operation, hold the $\overline{\text{RES}}$ pin low for the $\overline{\text{RES}}$ pulse width specified in the AC Characteristics section.

20.9.2 Software Protection

Software protection can be implemented against programming/erasing of all flash memory blocks by clearing the SWE1 bit in FLMCR1. When software protection is in effect, setting the P1 or E1 bit in FLMCR1 does not cause a transition to program mode or erase mode. By setting the erase block register 1 and 2 (EBR1 and EBR2), erase protection can be set for individual blocks. When EBR1 and EBR2 are set to H'00, erase protection is set for all blocks. By setting bit RAMS in RAMER, programming/erase protection is set for all blocks.

20.9.3 Error Protection

In error protection, an error is detected when CPU runaway occurs during flash memory programming/erasing, or operation is not performed in accordance with the program/erase algorithm, and the program/erase operation is aborted. Aborting the program/erase operation prevents damage to the flash memory due to overprogramming or overerasing.

When the following errors are detected during programming/erasing of flash memory, the FLER bit in FLMCR2 is set to 1, and the error protection state is entered.

- When the flash memory of the relevant address area is read during programming/erasing (including vector read and instruction fetch)
- Immediately after exception handling (excluding a reset) during programming/erasing
- When a SLEEP instruction is executed during programming/erasing
- When the CPU loses the bus during programming/erasing (supported only by the H8S/2268 Series)

The FLMCR1, FLMCR2, EBR1, and EBR2 settings are retained, however program mode or erase mode is aborted at the point at which the error occurred. Program mode or erase mode cannot be

re-entered by re-setting the P1 or E1 bit. However, PV1 and EV1 bit setting is enabled, and a transition can be made to verify mode. Error protection can be cleared only by a reset or in hardware standby.

20.10 Interrupt Handling when Programming/Erasing Flash Memory

All interrupts, including NMI input, are disabled when flash memory is being programmed or erased (when the P1 or E1 bit is set in FLMCR1), and while the boot program is executing in boot mode*¹, to give priority to the program or erase operation. There are three reasons for this:

1. Interrupt during programming or erasing might cause a violation of the programming or erasing algorithm, with the result that normal operation could not be assured.
2. In the interrupt exception handling sequence during programming or erasing, the vector would not be read correctly*², possibly resulting in CPU runaway.
3. If an interrupt occurred during boot program execution, it would not be possible to execute the normal boot mode sequence.

Notes: 1. Interrupt requests must be disabled inside and outside the CPU until the programming control program has completed programming.

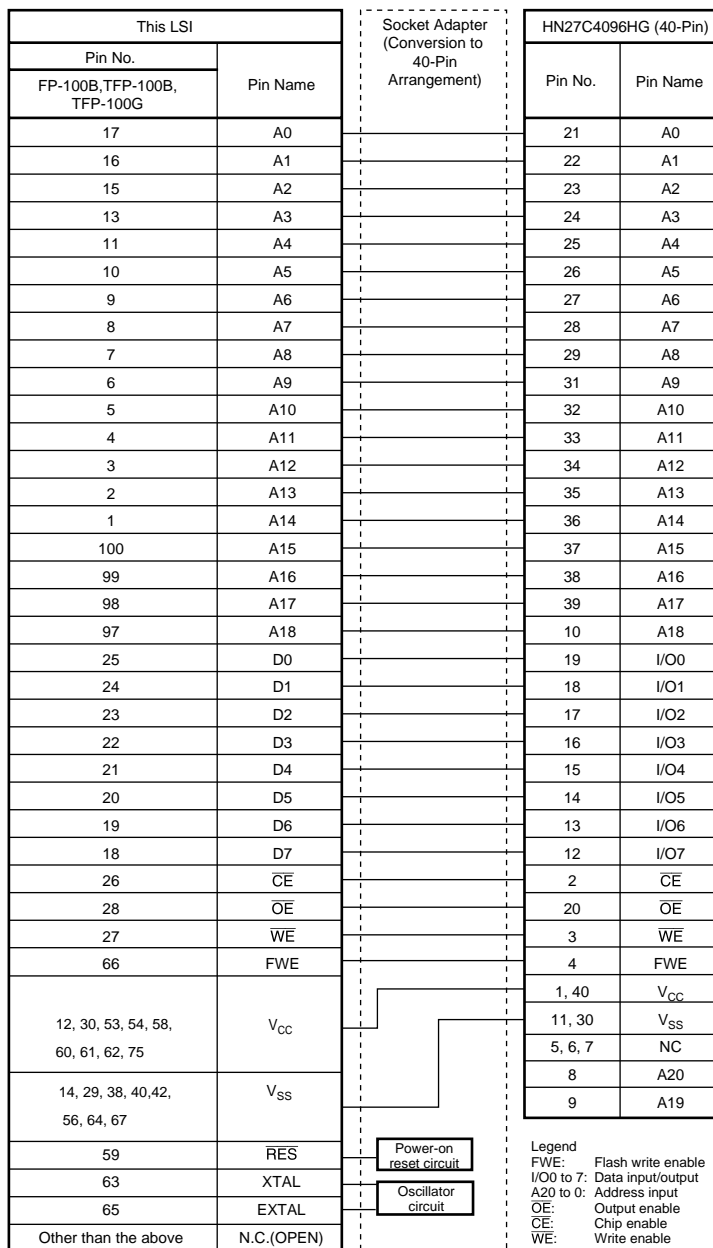
2. The vector may not be read correctly in this case for the following two reasons:

- If flash memory is read while being programmed or erased (while the P1 or E1 bit is set in FLMCR1), correct read data will not be obtained (undetermined values will be returned).
- If the interrupt entry in the vector table has not been programmed yet, interrupt exception handling will not be executed correctly.

20.11 Programmer Mode

In programmer mode, a PROM programmer can be used to perform programming/erasing via a socket adapter, just as for a discrete flash memory. Use a PROM programmer which supports the Hitachi 256-kbyte flash memory on-chip microcomputer device type (FZTAT256V3A) and the Hitachi 128-kbyte flash memory on-chip microcomputer device type (FZTAT128V3A).

The socket adapter pin correspondence diagram is shown in figure 20.14.



Note: This drawing indicates pin correspondences and does not show the entire circuitry of the socket adapter.

Figure 20.14 Socket Adapter Pin Correspondence Diagram

20.12 Power-Down States for Flash Memory

In user mode, the flash memory will operate in either of the following states:

- Normal operating mode
The flash memory can be read and written to at high speed.
- Power-down state
The flash memory can be read when part of the power circuit is halted and the LSI operates by subclocks.
- Standby mode
All flash memory circuits are halted.

Table 20.6 shows the correspondence between the operating modes of the H8S/2268 series and the flash memory. When the flash memory returns to its normal operating state from standby mode, a period to stabilize the power supply circuits that were stopped is needed. When the flash memory returns to its normal operating state, bits STS2 to STS0 in SBYCR must be set to provide a wait time of at least 100 μ s (at least TBD μ s for the H8S/2264R), even when the external clock is being used.

Table 20.6 Flash Memory Operating States

LSI Operating State	Flash Memory Operating State
Active mode	Normal operating mode
Sleep mode	Normal operating mode
Watch mode	Standby mode
Standby mode	
Sub-active mode	PDWND = 0: Power-down mode (read only)
Sub-sleep mode	PDWND = 1: Normal operating mode (read only)

20.13 Flash Memory Programming and Erasing Precautions

Precautions concerning the use of on-board programming mode, the RAM emulation function, and programmer mode are summarized below.

Use the specified voltages and timing for programming and erasing: Applied voltages in excess of the rating can permanently damage the device. Use a PROM programmer that supports the Hitachi 256-kbyte flash memory on-chip microcomputer device type (FZTAT256V3A and the Hitachi 128-kbyte flash memory on-chip microcomputer device type (FZTAT128V3A).

Do not select the HN27C4096, HN27C101, and HN28F101 setting for the PROM programmer, and only use the specified socket adapter. Failure to observe these points may result in damage to the device.

Powering on and off (see figures 20.15 to 20.17): Do not apply a high level to the FWE pin until VCC has stabilized. Also, drive the FWE pin low before turning off VCC.

When applying or disconnecting VCC power, fix the FWE pin low and place the flash memory in the hardware protection state.

The power-on and power-off timing requirements should also be satisfied in the event of a power failure and subsequent recovery.

FWE application/disconnection (see figures 20.15 to 20.17): FWE application should be carried out when MCU operation is in a stable condition. If MCU operation is not stable, fix the FWE pin low and set the protection state.

The following points must be observed concerning FWE application and disconnection to prevent unintentional programming or erasing of flash memory:

- Apply FWE when the VCC voltage has stabilized within its rated voltage range.
- In boot mode, apply and disconnect FWE during a reset.
- In user program mode, FWE can be switched between high and low level regardless of the reset state. FWE input can also be switched during execution of a program in flash memory.
- Do not apply FWE if program runaway has occurred.
- Disconnect FWE only when the SWE1, ESU1, PSU1, EV1, PV1, P1, and E1 bits in FLMCR1 are cleared.

Make sure that the SWE1, ESU1, PSU1, EV1, PV1, P1, and E1 bits are not set by mistake when applying or disconnecting FWE.

Do not apply a constant high level to the FWE pin: Apply a high level to the FWE pin only when programming or erasing flash memory. A system configuration in which a high level is constantly applied to the FWE pin should be avoided. Also, while a high level is applied to the FWE pin, the watchdog timer should be activated to prevent overprogramming or overerasing due to program runaway, etc.

Use the recommended algorithm when programming and erasing flash memory: The recommended algorithm enables programming and erasing to be carried out without subjecting the device to voltage stress or sacrificing program data reliability. When setting the P1 or E1 bit in FLMCR1, the watchdog timer should be set beforehand as a precaution against program runaway, etc.

Do not set or clear the SWE1 bit during execution of a program in flash memory: Wait for at least 100 μ s after clearing the SWE1 bit before executing a program or reading data in flash memory.

When the SWE1 bit is set, data in flash memory can be rewritten. Access flash memory only for verify operations (verification during programming/erasing). Also, do not clear the SWE1 bit during programming, erasing, or verifying. Similarly, when using the RAM emulation function while a high level is being input to the FWE pin, the SWE1 bit must be cleared before executing a program or reading data in flash memory.

However, the RAM area overlapping flash memory space can be read and written to regardless of whether the SWE1 bit is set or cleared.

Do not use interrupts while flash memory is being programmed or erased: All interrupt requests, including NMI, should be disabled during FWE application to give priority to program/erase operations.

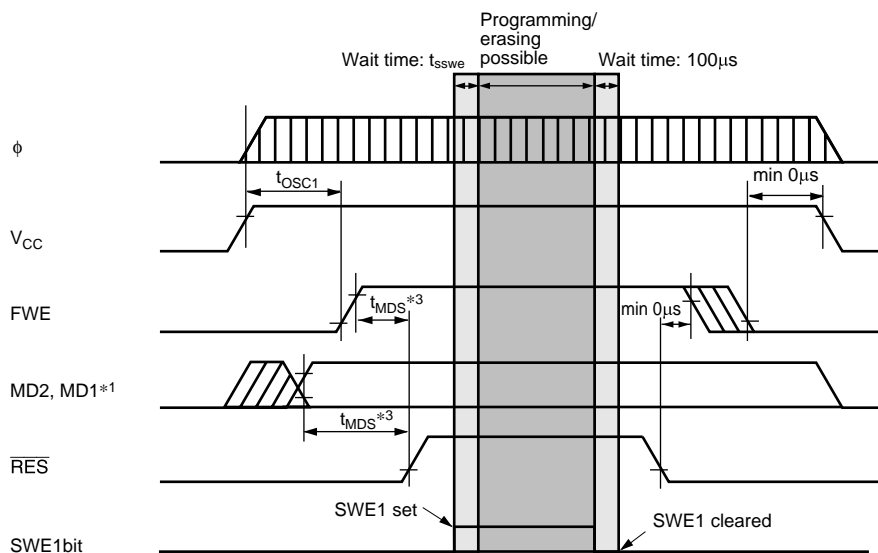
Do not perform additional programming. Erase the memory before reprogramming: In on-board programming, perform only one programming operation on a 128-byte programming unit block. In programmer mode, too, perform only one programming operation on a 128-byte programming unit block. Programming should be carried out with the entire programming unit block erased.

Before programming, check that the chip is correctly mounted in the PROM programmer: Overcurrent damage to the device can result if the index marks on the PROM programmer socket, socket adapter, and chip are not correctly aligned.

Do not touch the socket adapter or chip during programming: Touching either of these can cause contact faults and write errors.

Reset the flash memory before turning on the power: To reset the flash memory during oscillation stabilization period, the reset signal must be input for at least 100 μ s (at least TBD μ s for the H8S/2264R).

Apply the reset signal while SWE1 is low to reset the flash memory during its operation: The reset signal is applied at least 100 μs after the SWE1 bit has been cleared.



Period during which flash memory access is prohibited
(t_{SSWE} : Wait time after setting SWE1 bit)*2

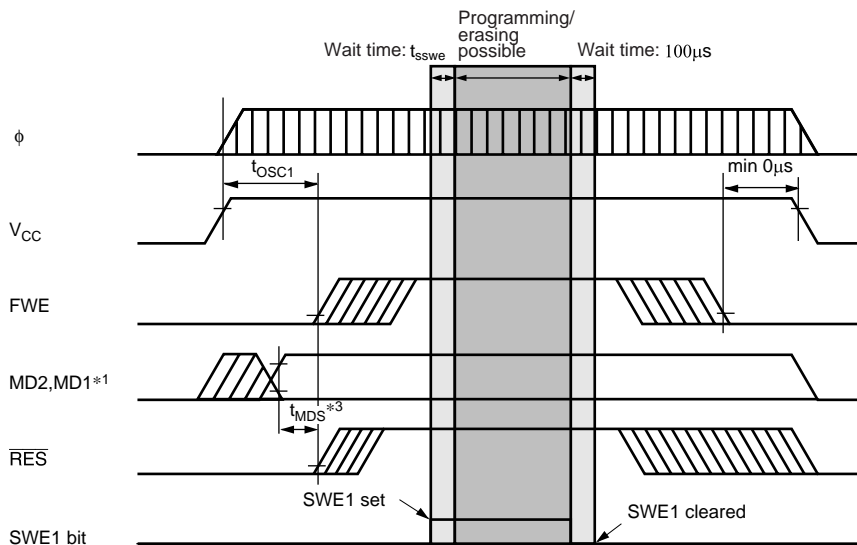
Period during which flash memory can be programmed
(Execution of program in flash memory prohibited, and data reads other than verify operations prohibited)

Notes: 1 Except when switching modes, the level of the mode pins (MD2, MD1) must be fixed until power-off by pulling the pins up or down. In the H8S/2264 Series, the level of the P76 pin must be fixed by pulling the pin up.

2 See sections 26.2.8 and 26.3.6, Flash Memory Characteristics.

3 Mode programming setup time t_{MDS} (min) = 200ns.

Figure 20.15 Power-On/Off Timing (Boot Mode)



Period during which flash memory access is prohibited
(t_{ssw1} : Wait time after setting $SWE1$ bit)*2

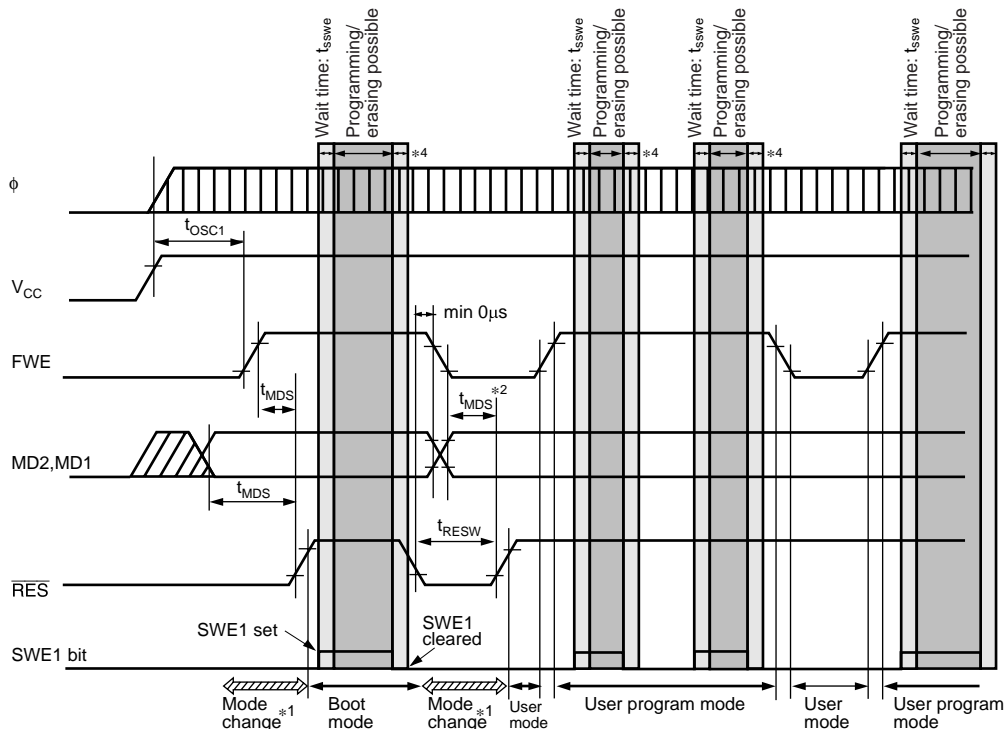
Period during which flash memory can be programmed
(Execution of program in flash memory prohibited, and data reads other than verify operations prohibited)

Notes: 1 Except when switching modes, the level of the mode pins ($MD2, MD1$) must be fixed until power-off by pulling the pins up or down. In the H8S/2264 Series, the level of the P76 pin must be fixed by pulling the pin up.

2 See sections 26.2.8 and 26.3.6, Flash Memory Characteristics.

3 Mode programming setup time t_{MDS} (min) = 200ns.

Figure 20.16 Power-On/Off Timing (User Program Mode)



Period during which flash memory access is prohibited
(t_{sswe} : Wait time after setting SWE1 bit)*3

Period during which flash memory can be programmed
(Execution of program in flash memory prohibited, and data reads other than verify operations prohibited)

Notes: 1 When entering boot mode or making a transition from boot mode to another mode, mode switching must be carried out by means of \overline{RES} input. In the H8S/2264 Series, the level of the P76 pin must be fixed by pulling the pin up when mode switching is carried out by means of \overline{RES} input.

2 When making a transition from boot mode to another mode, a mode programming setup time t_{MDS} (min) of 200 ns is necessary with respect to \overline{RES} clearance timing.

3 See sections 26.2.8 and 26.3.6, Flash Memory Characteristics.

4 Wait time: 100µs.

Figure 20.17 Mode Transition Timing
(Example: Boot Mode → User Mode ↔ User Program Mode)

20.14 Note on Switching from F-ZTAT Version to Masked ROM Version

The masked ROM version does not have the internal registers for flash memory control that are provided in the F-ZTAT version. Table 20.7 lists the registers that are present in the F-ZTAT version but not in the masked ROM version. If a register listed in table 20.7 is read in the masked ROM version, an undefined value will be returned. Therefore, if application software developed on the F-ZTAT version is switched to a masked ROM version product, it must be modified to ensure that the registers in table 20.7 have no effect.

Table 20.7 Registers Present in F-ZTAT Version but Absent in Masked ROM Version

Register	Abbreviation	Address
Flash memory control register 1	FLMCR1	H'FFA8
Flash memory control register 2	FLMCR2	H'FFA9
Erase block register 1	EBR1	H'FFAA
Erase block register 2	EBR2	H'FFAB
RAM emulation register	RAMER	H'FEDB
Flash memory power control register	FLPWCR	H'FFAC
Serial control register X (Only bit 3)	SCRX	H'FDB4

Section 21 Clock Pulse Generator

This LSI has an on-chip clock pulse generator that generates the system clock (ϕ), the bus master clock, and internal clocks. The clock pulse generator consists of an oscillator, duty adjustment circuit, clock selection circuit, medium-speed clock divider, bus master clock selection circuit, subclock oscillator, and wave formation circuit. A block diagram of the clock pulse generator of the H8S/2268 Series is shown in figure 21.1. A block diagram of the clock pulse generator of the H8S/2264 Series is shown in figure 21.2.

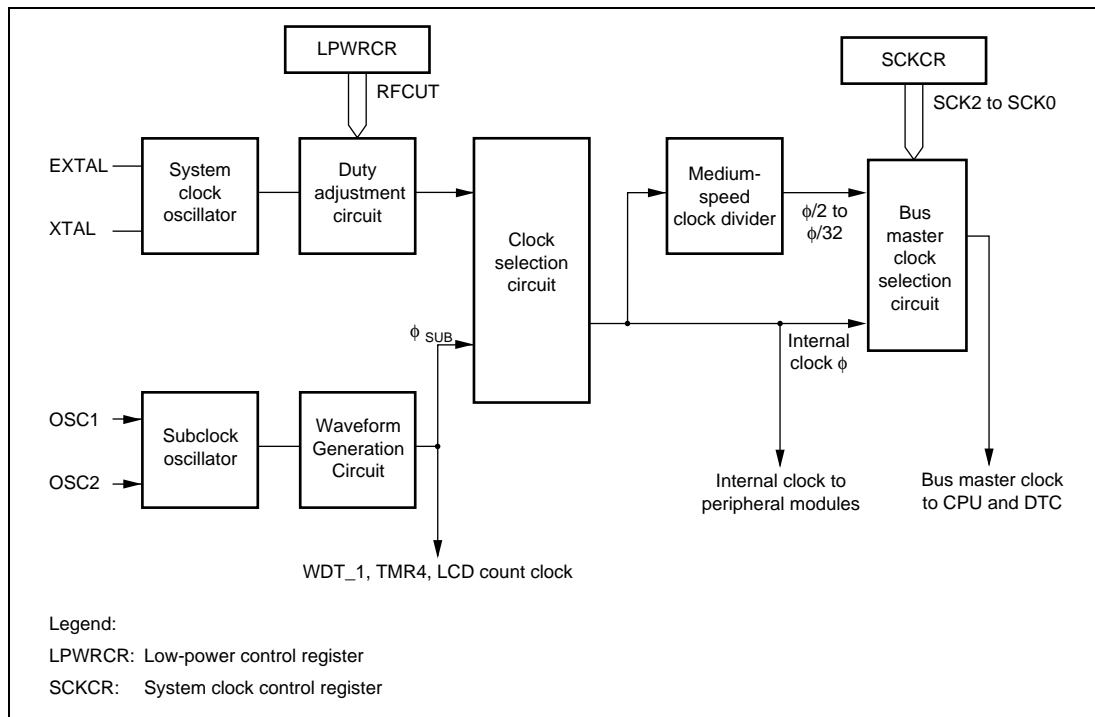


Figure 21.1 Block Diagram of Clock Pulse Generator (H8S/2268 Series)

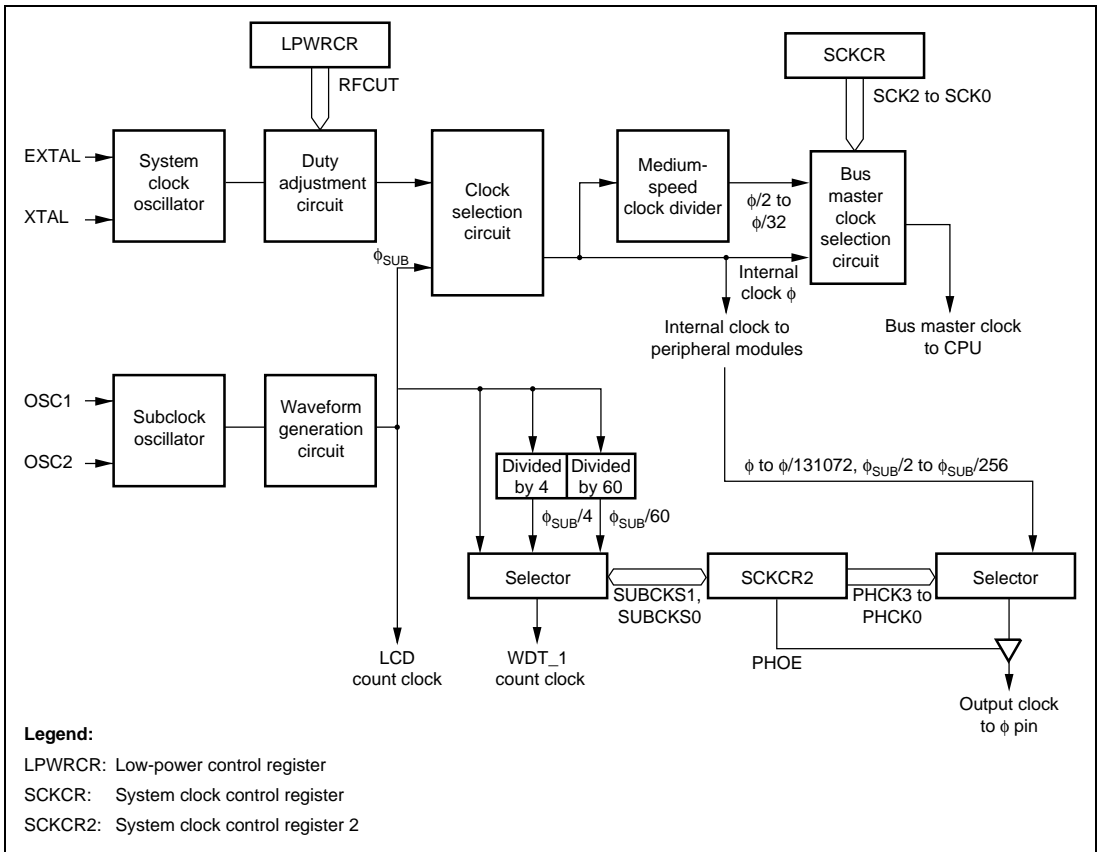


Figure 21.2 Block Diagram of Clock Pulse Generator (H8S/2264 Series)

Frequency changes are performed by software by settings in the low-power control register (LPWRCR) and system clock control register (SCKCR).

21.1 Register Descriptions

The on-chip clock pulse generator has the following registers.

- System clock control register (SCKCR)
- System clock control register 2 (SCKCR2) (supported only by the H8S/2264 Series)
- Low-power control register (LPWRCR)

21.1.1 System Clock Control Register (SCKCR)

SCKCR performs medium-speed mode control.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved
6	—	0	R/W	These are readable/writable bits, but the write value should always be 0.
5	—	0	—	Reserved
4	—	0	—	These bits are always read as 0. Writing is invalid.
3	—	0	R/W	Reserved This is a readable/writable bit, but the write value should always be 0.
2	SCK2	0	R/W	System Clock Select 2 to 0
1	SCK1	0	R/W	These bits select the bus master clock.
0	SCK0	0	R/W	000: High-speed mode 001: Medium-speed clock is $\phi/2$ 010: Medium-speed clock is $\phi/4$ 011: Medium-speed clock is $\phi/8$ 100: Medium-speed clock is $\phi/16$ 101: Medium-speed clock is $\phi/32$ 11X: Setting prohibited

Legend

X: Don't care

21.1.2 System Clock Control Register 2 (SCKCR2) (Supported only by the H8S/2264 Series)

SCKCR2 controls output clock ϕ , selects RxD1 input pin, and TCNT_1 input subclock of WDT_1.

Bit	Bit Name	Initial Value	R/W	Description
7	PHOE	0	R/W	ϕ Clock Output Enable Controls ϕ clock output from the PH4 selected by the bits PHCK3 to PHCK0. For details, see table 21.1.
6	RxD1S	0	R/W	RxD1 Select Selects the RxD1 input pin. 0: The RxD1 signal is input from the P34. 1: The RxD1 signal is input from the PH5.
5	SUBCKS1	0	R/W	Prescaler Subclock Select 1, 0
4	SUBCKS0	0	R/W	These bits select the TCNT_1 input subclock source of WDT_1. 00: Clock ϕ_{SUB} 01: Clock $\phi_{SUB}/4$ 10: Clock $\phi_{SUB}/60$ 11: Setting prohibited
3	PHCK3	0	R/W	ϕ Clock Select 3 to 0
2	PHCK2	0	R/W	These bits select the ϕ clock output from the PH4. For details, see table 21.2.
1	PHCK1	0	R/W	
0	PHCK0	0	R/W	

Note:* To change the ϕ clock output selection, bits PHCK3 to PHCK0 must be set after clock output is halted by wiring 0 to the PHOE bit.

Table 21.1 ϕ Clock Output Control

PHOE	0	1
PHCK3	—	0 1
Subactive mode, subsleap mode, watch mode	PH4 I/O	Fixed to high ϕ output
High-speed mode, medium-speed mode, sleep mode	PH4 I/O	ϕ output
Software standby mode, direct transition	PH4 I/O	Fixed to high
Hardware standby mode	High impedance	High impedance

Table 21.2 ϕ Clock Selection

TCSR_1		SCKCR2									
Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	PH4 Output Clock	Main Clock Frequency		Subclock Frequency			
PSS	PHCK 3	PHCK 2	PHCK 1	PHCK 0		2 MHz	20 MHz	32.768 kHz			
								ϕ_{SUB}^{*2}	$\phi_{SUB}/4^{*2}$	$\phi_{SUB}/60^{*2}$	
X	0	0	0	0	$\phi/1$	2 MHz	20 MHz	—	—	—	
				1	$\phi/2$	1 MHz	10 MHz	—	—	—	
			1	0	$\phi/8$	250 kHz	2.5 MHz	—	—	—	
				1	$\phi/64$	31 kHz	313 kHz	—	—	—	
		1	0	0	$\phi/512$	3.9 Hz	39 kHz	—	—	—	
				1	$\phi/2048$	1.0 kHz	10 kHz	—	—	—	
			1	0	$\phi/8192$	244 Hz	2.4 kHz	—	—	—	
				1	$\phi/131072$	15 Hz	153 Hz	—	—	—	
1* ¹	1	0	0	0	$\phi_{SUB}/2$	—	—	16.38 kHz	4.096 kHz	273 Hz	
				1	$\phi_{SUB}/4$	—	—	8.192 kHz	2.048 kHz	137 Hz	
				1	0	$\phi_{SUB}/8$	—	—	4.096 kHz	1.024 kHz	68 Hz
					1	$\phi_{SUB}/16$	—	—	2.048 kHz	512 Hz	34 Hz
		1		0	0	$\phi_{SUB}/32$	—	—	1.024 kHz	256 Hz	17 Hz
					1	$\phi_{SUB}/64$	—	—	512 Hz	128 Hz	8.5 Hz
			1	0	$\phi_{SUB}/128$	—	—	256 Hz	64 Hz	4.3 Hz	
				1	$\phi_{SUB}/256$	—	—	128 Hz	32 Hz	2.1 Hz	

Legend

X: Don't care

Notes:

1. To output $\phi_{SUB}/2$ to $\phi_{SUB}/256$, the PSS bit in TCSR_1 of WDT_1 must be set to 1.
2. The subclock frequencies of ϕ_{SUB} , $\phi_{SUB}/4$, and $\phi_{SUB}/60$ are set by the SUBCKS1 and SUBCKS0 bits in SCKCR2.

21.1.3 Low-Power Control Register (LPWRCR)

LPWRCR performs down-mode control, selects sampling frequency for eliminating noise, performs subclock generation control, and specifies multiplication factor.

Bit	Bit Name	Initial Value	R/W	Description
7	DTON	0	R/W	<p>Direct Transition ON Flag</p> <p>0: When the SLEEP instruction is executed in high-speed mode or medium-speed mode, operation shifts to sleep mode, software standby mode, or watch mode.</p> <p>When the SLEEP instruction is executed in sub-active mode, operation shifts to sub-sleep mode or watch mode.</p> <p>1: When the SLEEP instruction is executed in high-speed mode or medium-speed mode, operation shifts directly to sub-active mode, or shifts to sleep mode or software standby mode.</p> <p>When the SLEEP instruction is executed in sub-active mode, operation shifts directly to high-speed mode, or shifts to sub-sleep mode.</p>
6	LSON	0	R/W	<p>Low Speed ON Flag</p> <p>0: When the SLEEP instruction is executed in high-speed mode or medium-speed mode, operation shifts to sleep mode, software standby mode, or watch mode*.</p> <p>When the SLEEP instruction is executed in sub-active mode, operation shifts to watch mode* or shifts directly to high-speed mode.</p> <p>Operation shifts to high-speed mode when watch mode is cancelled.</p> <p>1: When the SLEEP instruction is executed in high-speed mode, operation shifts to watch mode or sub-active mode.</p> <p>When the SLEEP instruction is executed in sub-active mode, operation shifts to sub-sleep mode or watch mode.</p> <p>Operation shifts to sub-active mode when watch mode is cancelled.</p>

Bit	Bit Name	Initial Value	R/W	Description
5	NESEL	0	R/W	<p>Noise Elimination Sampling Frequency Select</p> <p>This bit selects the sampling frequency of the subclock (ϕ_{SUB}) generated by the subclock oscillator is sampled by the clock (ϕ) generated by the system clock oscillator</p> <p>Set 0 when ϕ is 5 MHz or higher. Set 1 when ϕ is 2.1 MHz or lower. Any value can be set when ϕ is 2.1 to 5 MHz.</p> <p>0: Sampling using $1/32 \times \phi$</p> <p>1: Sampling using $1/4 \times \phi$</p>
4	SUBSTP	0	R/W	<p>Subclock Enable</p> <p>This bit enables/disables subclock generation. This bit should be set to 1 when subclock is not used.</p> <p>0: Enables subclock generation.</p> <p>1: Disables subclock generation.</p>
3	RFCUT	0	R/W	<p>(H8S/2268, H8S/2266, H8S/2265, H8S/2264, and H8S/2262)</p> <p>Oscillation Circuit Feedback Resistance Control Bit</p> <p>Selects whether or not built-in feedback resistance and duty adjustment circuit of the system clock generator are used when an external clock is input. Do not access when the crystal resonator is used.</p> <p>After setting this bit in the external clock input state, enter software standby mode, watch mode, or subactive mode. When software standby mode, watch mode, or subactive mode is entered, switch whether or not built-in feedback resistance and duty adjustment circuit are used.</p> <p>0: Built-in feedback resistance and duty adjustment circuit of the system clock generator used.</p> <p>1: Built-in feedback resistance and duty adjustment circuit of the system clock generator not used.</p> <p>(H8S/2264R and H8S/2262R)</p> <p>Reserved</p> <p>This is a readable/writable bit, but the write value should always be 0.</p>
2	—	0	R/W	<p>Reserved</p> <p>This is a readable/writable bit, but the write value should always be 0.</p>

Bit	Bit Name	Initial Value	R/W	Description
1	STC1	0	R/W	Multiplication factor setting
0	STC0	0	R/W	Specifies multiplication factor of the PLL circuit built in the evaluation chip. The specified multiplication factor becomes valid software standby mode, watch mode, or subactive mode is entered. These bits should be set to 11 in this LSI. Since the value becomes STC1 = STC0 = 0 after a reset, set STC1 = STC0 = 1. 00: x 1 01: x 2 (setting prohibited) 10: x 4 (setting prohibited) 11: PLL is bypass

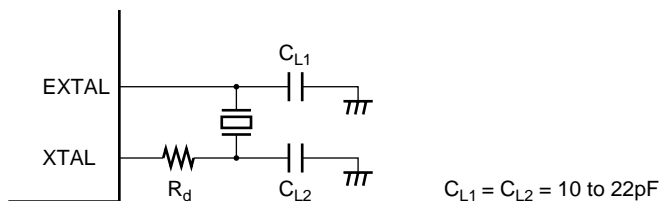
Note: * When watch mode or subactive mode is entered, set high-speed mode.

21.2 System Clock Oscillator

System clock pulses can be supplied by connecting a crystal resonator, or by input of an external clock.

21.2.1 Connecting a Crystal Resonator

A crystal resonator can be connected as shown in the example in figure 21.3. Select the damping resistance R_d according to table 21.3. An AT-cut parallel-resonance crystal should be used.



Note: C_{L1} and C_{L2} are reference values including the floating capacitance of the board.

Figure 21.3 Connection of Crystal Resonator (Example)

Table 21.3 Damping Resistance Value

Frequency (MHz)	2	4	6	8	10	12	16	20
R_d (Ω)	1 k	500	300	200	100	0	0	0

Figure 21.4 shows the equivalent circuit of the crystal resonator. Use a crystal resonator that has the characteristics shown in table 21.4.

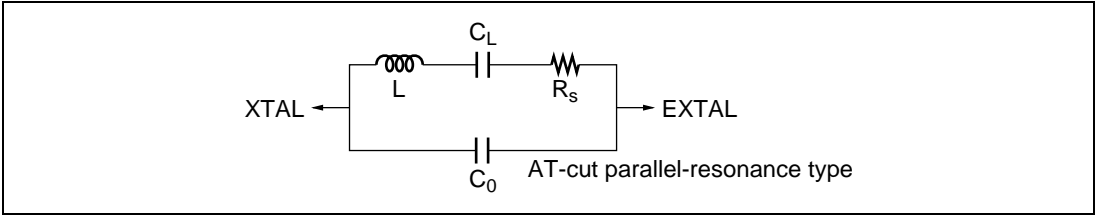


Figure 21.4 Crystal Resonator Equivalent Circuit

Table 21.4 Crystal Resonator Characteristics

Frequency (MHz)	2	4	6	8	10	12	16	20
R_s max (Ω)	500	120	100	80	60	60	50	40
C_0 max (pF)	7	7	7	7	7	7	7	7

21.2.2 Connecting a Ceramic Resonator

A ceramic resonator can be connected in the H8S/2264R and H8S/2262R as shown in the example in figure 21.5.

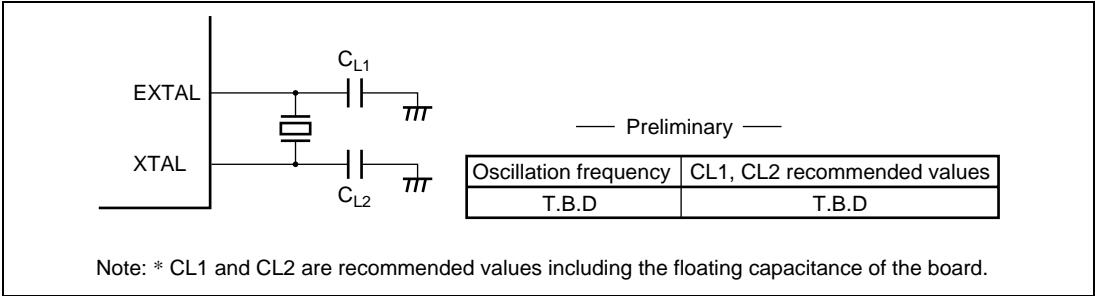


Figure 21.5 Connection of Ceramic Resonator (Example)

21.2.3 External Clock Input

External clock input is supported by the H8S/2268, H8S/2266, H8S/2265, H8S/2264, and H8S/2262. An external clock signal can be input as shown in the examples in figure 21.6. If the XTAL pin is left open, ensure that stray capacitance does not exceed 10 pF. When complementary clock is input to the XTAL pin, the external clock input should be fixed high in standby mode, subactive mode, subsleep mode, or watch mode.

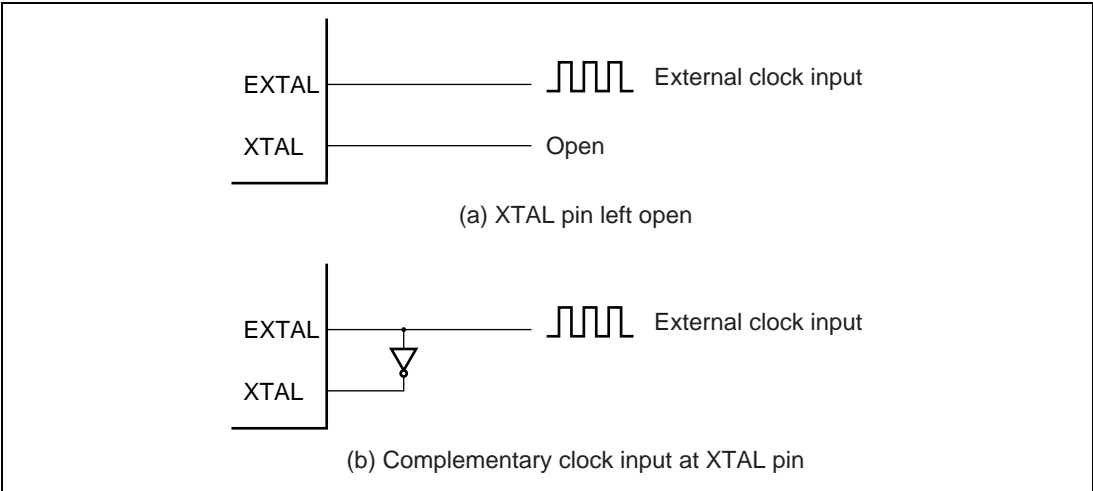


Figure 21.6 External Clock Input (Examples)

Table 21.5 shows the input conditions for the external clock. Table 21.6 shows the input conditions for the external clock when duty adjustment circuit is not used.

Table 21.5 External Clock Input Conditions

		V _{cc} = 2.7 V to 5.0 V		V _{cc} = 4.0 V to 5.5 V		Unit	Test Conditions
Item	Symbol	Min	Max	Min	Max		
External clock input low pulse width	t _{EXL}	30	—	20	—	ns	Figure 21.7
External clock input high pulse width	t _{EXH}	30	—	20	—	ns	
External clock rise time	t _{EXr}	—	7	—	5	ns	
External clock fall time	t _{EXf}	—	7	—	5	ns	

Table 21.6 External Clock Input Conditions (Duty Adjustment Circuit not used)

Item	Symbol	$V_{CC}=2.7\text{ V to }5.0\text{ V}$		$V_{CC}=4.0\text{ V to }5.5\text{ V}$		Unit	Test Conditions
		Min	Max	Min	Max		
External clock input low pulse width	t_{EXL}	37	—	25	—	ns	Figure 21.7
External clock input high pulse width	t_{EXH}	37	—	25	—	ns	
External clock rise time	t_{EXr}	—	7	—	5	ns	
External clock fall time	t_{EXf}	—	7	—	5	ns	

Note: When duty adjustment circuit is not used, maximum operating frequency is lowered according to the input waveform.

(Example: When $t_{EXL} = t_{EXH} = 50\text{ ns}$, $t_{EXr} = t_{EXf} = 10\text{ ns}$, clock cycle time = 120 ns, and maximum operating frequency = 8.3 MHz)

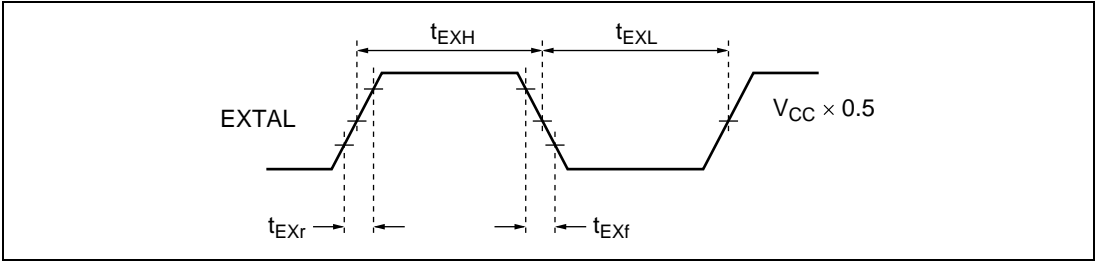


Figure 21.7 External Clock Input Timing

21.2.4 Notes on Switching External Clock

When two or more external clocks (e.g.: 10 MHz and 2 MHz) are used as the system clock, input clock should be switched in software standby mode.

An example of external clock switching circuit is shown in figure 21.8. An example of external clock switching timing is shown in figure 21.9.

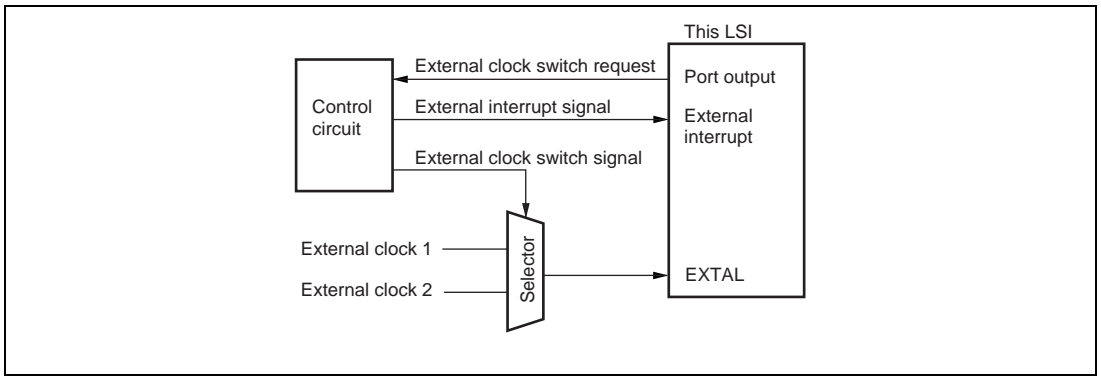


Figure 21.8 External Clock Switching Circuit (Examples)

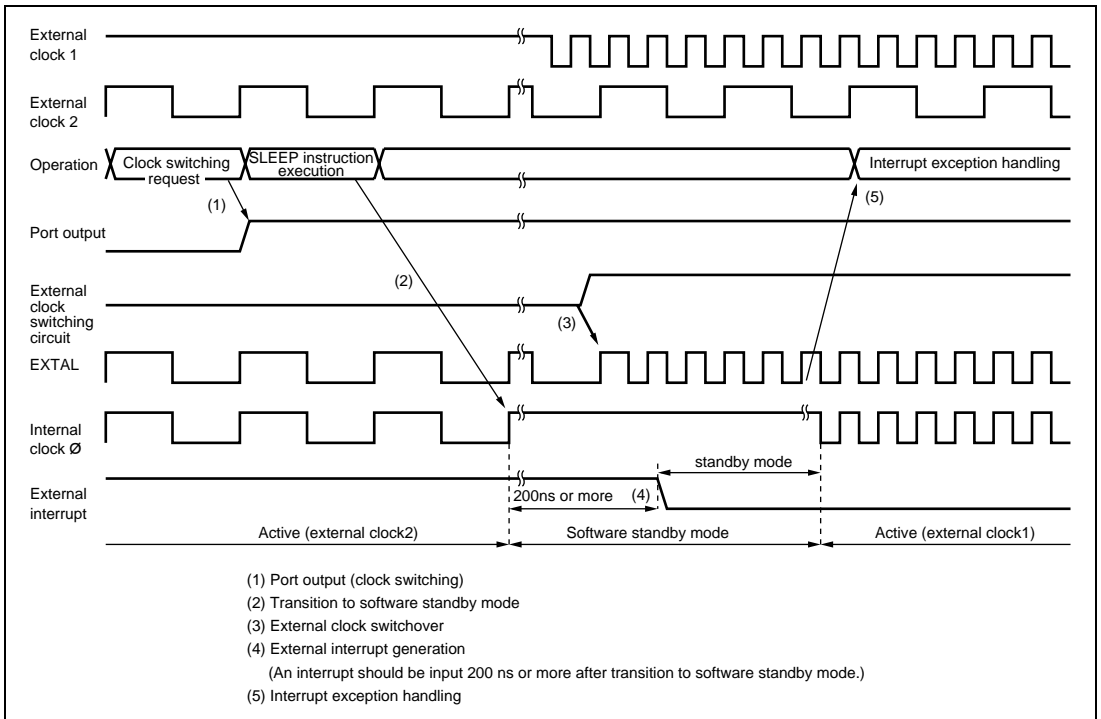


Figure 21.9 External Clock Switching Timing (Examples)

21.3 Duty Adjustment Circuit

The duty adjustment circuit is valid when oscillation frequency is more than 5 MHz. The duty adjustment circuit adjusts clock output fr/m the system clock oscillator to generate the system clock (ϕ).

21.4 Medium-Speed Clock Divider

The medium-speed clock divider divides the system clock to generate $\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, and $\phi/32$.

21.5 Bus Master Clock Selection Circuit

The bus master clock selection circuit selects the clock supplied to the bus master by setting the bits SCK2 to SCK0 in SCKCR. The bus master clock can be selected from system clock (ϕ), or medium-speed clocks ($\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, $\phi/32$).

21.6 Subclock Oscillator

21.6.1 Connecting 32.768kHz Crystal Resonator

To supply a clock to the subclock divider, connect a 32.768kHz crystal resonator, as shown in Figure 21.10. Figure 21.11 shows the equivalence circuit for a 32.768kHz oscillator.

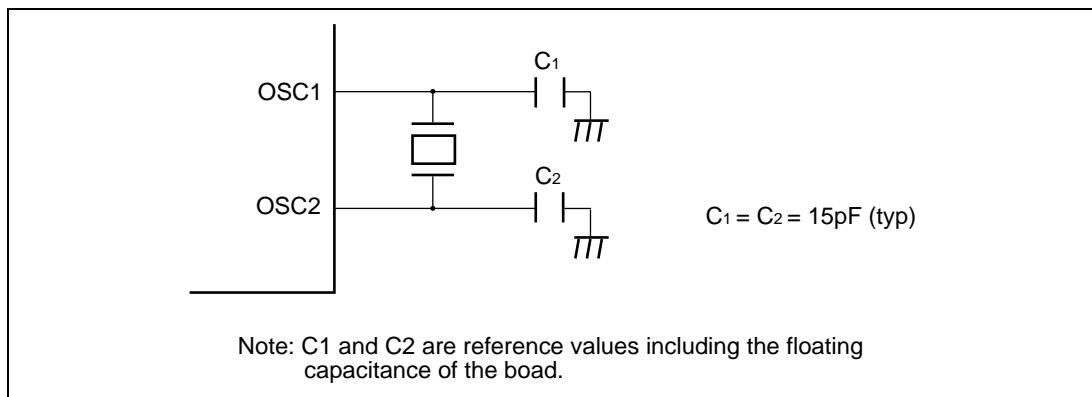


Figure 21.10 Example Connection of 32.768kHz Quartz Oscillator

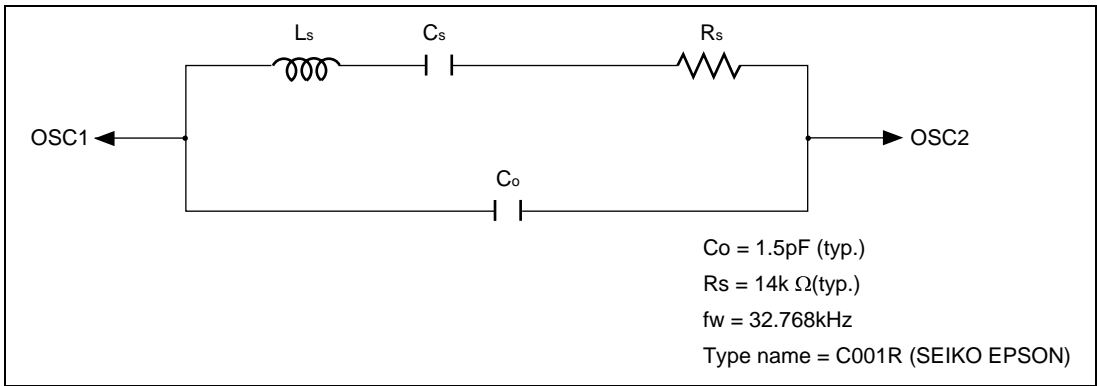


Figure 21.11 Equivalence Circuit for 32.768kHz Oscillator

21.6.2 Handling Pins When Subclock Not Required

If no subclock is required, connect the OSC1 pin to Vss and leave OSC2 open, as shown in figure 21.12. Set the SUBSTP bit of LPWRCR to 1.

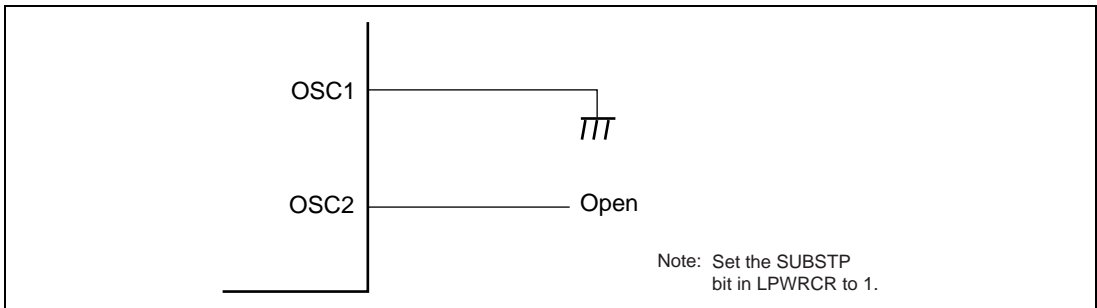


Figure 21.12 Pin Handling When Subclock Not Required

21.7 Subclock Waveform Generation Circuit

To eliminate noise from the subclock input to OSC1, the subclock is sampled using the dividing clock ϕ . The sampling frequency is set using the NESEL bit of LPWRCR. For details, see Section 21.1.3, Low Power Control Register (LPWRCR).

No sampling is performed in sub-active mode, sub-sleep mode, or watch mode.

21.8 Usage Notes

21.8.1 Note on Crystal Resonator

As various characteristics related to the crystal resonator are closely linked to the user's board design, thorough evaluation is necessary on the user's part, using the resonator connection examples shown in this section as a guide. As the resonator circuit ratings will depend on the floating capacitance of the resonator and the mounting circuit, the ratings should be determined in consultation with the resonator manufacturer. The design must ensure that a voltage exceeding the maximum rating is not applied to the oscillator pin.

21.8.2 Note on Board Design

When designing the board, place the crystal resonator (ceramic resonator) and its load capacitors as close as possible to the XTAL and EXTAL pins. Make wires as short as possible. Other signal lines should be routed away from the oscillator circuit, as shown in figure 21.13. This is to prevent induction from interfering with correct oscillation.

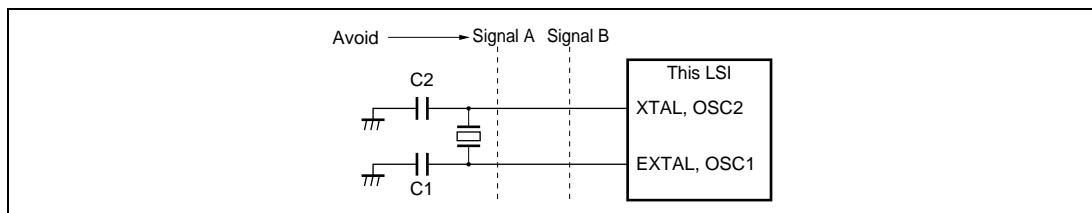


Figure 21.13 Note on Board Design of Oscillator Circuit

21.8.3 Note on Using a Crystal Resonator (Except for a Ceramic Resonator)

When a microcomputer runs, internal power supply potential will fluctuate synchronized with the system clock. In addition, according to the individual characteristics of crystal resonator, there is a case where the amplitude of the oscillation waveform will not be grown sufficiently immediately after oscillation stabilization period, thus the oscillation waveform is easily affected by the

fluctuation of the power supply voltage. In this condition, oscillation waveform will be unstable, resulting in the system clock instability and malfunction of the microcomputer.

If a malfunction occurs, the setting of the standby timer select 2 to 0 (STS2 to STS0) bits in the standby control register (SBYCR) must be set so as for the standby time to be longer.

For example, if a malfunction occurs when the standby time is set to 8192 states, the operation should be confirmed by setting the standby time to 16384 states or longer.

In addition, if a malfunction similar to at state transition occurs at reset, the $\overline{\text{RES}}$ pin hold time must be set longer.

Section 22 Power-Down Modes

In addition to the normal program execution state, the H8S/2268 series and the H8S/2264 series have nine power-down modes in which operation of the CPU and oscillator is halted and power dissipation is reduced. Low-power operation can be achieved by individually controlling the CPU, on-chip peripheral modules, and so on.

The H8S/2268 series and the H8S/2264 series operating modes are as follows:

1. High-speed mode
2. Medium-speed mode
3. Subactive mode
4. Sleep mode
5. Subsleep mode
6. Watch mode
7. Module stop mode
8. Software standby mode
9. Hardware standby mode

2. to 9. are low power dissipation states. Sleep mode and sub-sleep mode are CPU states, medium-speed mode is a CPU and bus master state, sub-active mode is a CPU and bus master and internal peripheral function state, and module stop mode is an internal peripheral function (including bus masters other than the CPU) state. Some of these states can be combined.

After a reset, the LSI is in high-speed mode with modules other than the DTC in module stop mode.

Table 22.1 shows the internal state of the LSI in the respective modes. Table 22.2 shows the conditions for shifting between the low power dissipation modes.

Figure 22.1 is a mode transition diagram.

Table 22.1 LSI Internal States in Each Mode

Function	High-Speed	Medium-Speed	Sleep	Module Stop	Watch	Sub-active	Subsleep	Software Standby	Hardware Standby
System clock pulse generator	Function-ing	Function-ing	Function-ing	Function-ing	Halted	Halted	Halted	Halted	Halted
Subclock pulse generator	Function-ing/halted	Function-ing/halted	Function-ing/halted	Function-ing/halted	Function-ing	Function-ing	Function-ing	Function-ing/halted	Halted

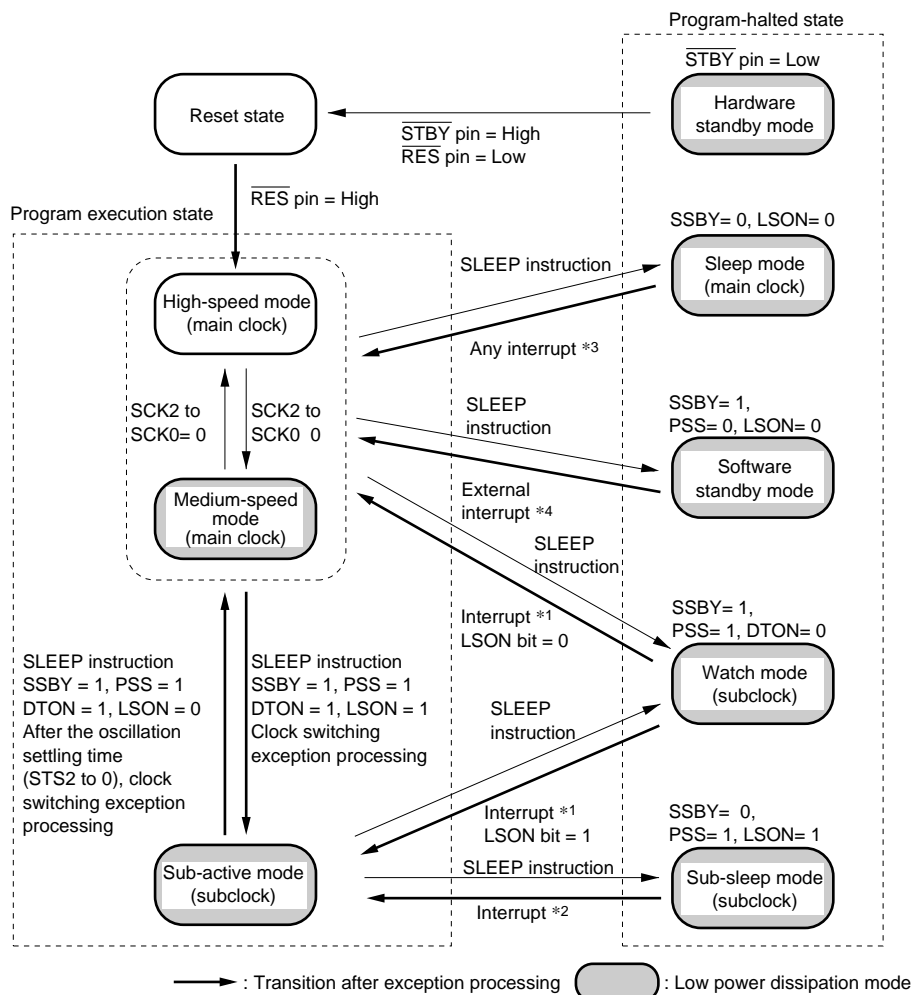
Function		High-Speed	Medium-Speed	Sleep	Module Stop	Watch	Sub-active	Subsleep	Software Standby	Hardware Standby
CPU	Instructions	Functioning	Medium-speed operation	Halted	Functioning	Halted	Subclock operation	Halted	Halted	Halted
	Registers			Retained		Retained		Retained	Retained	Undefined
RAM		Functioning	Functioning	Functioning (DTC) *2	Functioning	Retained	Functioning	Retained	Retained	Retained
I/O		Functioning	Functioning	Functioning	Functioning	Retained	Functioning	Functioning	Halted	High impedance
External interrupts	NMI IRQn WKPn	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Halted
Peripheral functions	PBC*2	Functioning	Medium-speed operation	Functioning	Functioning/halted (retained)	Halted (retained)	Subclock operation	Halted (retained)	Halted (retained)	Halted (reset)
	DTC*2	Functioning	Medium-speed operation	Functioning	Functioning/halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (reset)
	TMR_4*2	Functioning	Functioning	Functioning	Functioning/halted (retained)	Subclock operation *1	Subclock operation *1	Subclock operation *1	Halted (retained)	Halted (reset)
	LCD									
	WDT_1	Functioning	Functioning	Functioning	Functioning	Subclock operation *1	Subclock operation *1	Subclock operation *1	Halted (retained)	Halted (reset)
	WDT_0	Functioning	Functioning	Functioning	Functioning	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	TMR_0 TMR_1 TMR_2*2 TMR_3*2	Functioning	Functioning	Functioning	Functioning/halted (retained)	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	TPU SCI IIC DTMF*2 D/A*2	Functioning	Functioning	Functioning	Functioning/halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (reset)
	A/D	Functioning	Functioning	Functioning	Functioning/halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)

Notes: “Halted (retained)” means that internal register values are retained. The internal state is “operation suspended.”

“Halted (reset)” means that internal register values and internal states are initialized.

In module stop mode, only modules for which a stop setting has been made are halted (reset or retained).

1. When the TMR_4*2, WDT_1, or LCD is operated in watch, subactive, or subsleep mode, select the subclock as the clock to be used.
2. Supported only by the H8S/2268 Series.



- Notes:
1. H8S/2268 Series: NMI, IRQ0, IRQ1, IRQ3 to IRQ5, WKP0 to WKP7, WDT1 interrupt, and TMR4 interrupt
H8S/2264 Series: NMI, IRQ0, IRQ1, IRQ3, IRQ4, WKP0 to WKP7, and WDT1 interrupt
 2. H8S/2268 Series: NMI, IRQ0, IRQ1, IRQ3 to IRQ5, WKP0 to WKP7, WDT0 interrupt, WDT1 interrupt, and TMR0 to TMR4 interrupts
H8S/2264 Series: NMI, IRQ0, IRQ1, IRQ3, IRQ4, WKP0 to WKP7, WDT0 interrupt, WDT1 interrupt, TMR0 interrupt, and TMR1 interrupt
 3. All interrupts
 4. H8S/2268 series: NMI, IRQ0, IRQ1, IRQ3 to IRQ5, WKP0 to WKP7
H8S/2264 series: NMI, IRQ0, IRQ1, IRQ3, IRQ4, WKP0 to WKP7
 - When a transition is made between modes by means of an interrupt, the transition cannot be made on interrupt source generation alone. Ensure that interrupt handling is performed after accepting the interrupt request.
 - From any state except hardware standby mode, a transition to the reset state occurs when $\overline{\text{RES}}$ is driven Low.
 - From any state, a transition to hardware standby mode occurs when $\overline{\text{STBY}}$ is driven low.
 - Always select high-speed mode before making a transition to watch mode or sub-active mode.

Figure 22.1 Mode Transition Diagram

Table 22.2 Low Power Dissipation Mode Transition Conditions

Pre-Transition State	Status of Control Bit at Transition				State After Transition Invoked by SLEEP Instruction	State After Transition Back from Low Power Mode Invoked by Interrupt
	SSBY	PSS	LSON	DTON		
High-speed/ Medium-speed	0	X	0	X	Sleep	High-speed/Medium-speed
	0	X	1	X	—	—
	1	0	0	X	Software standby	High-speed/Medium-speed
	1	0	1	X	—	—
	1	1	0	0	Watch	High-speed
	1	1	1	0	Watch	Sub-active
	1	1	0	1	—	—
	1	1	1	1	Sub-active	—
Sub-active	0	0	X	X	—	—
	0	1	0	X	—	—
	0	1	1	X	Sub-sleep	Sub-active
	1	0	X	X	—	—
	1	1	0	0	Watch	High-speed
	1	1	1	0	Watch	Sub-active
	1	1	0	1	High-speed	—
	1	1	1	1	—	—

Legend

X : Don't care

—: Do not set.

22.1 Register Description

The following registers relates to the power-down modes. For details on system clock control register (SCKCR), refer to section 21.1.1, System Clock Control Register (SCKCR). For details on low power control register (LPWRCR), refer to section 21.1.3, Low Power Control Register (LPWRCR). For details on timer control status register (TCSR), refer to section 12.2.2, Timer Control Status Register (TCSR).

- Standby control register (SBYCR)
- Module stop control register A (MSTPCRA)
- Module stop control register B (MSTPCRB)
- Module stop control register C (MSTPCRC)
- Module stop control register D (MSTPCRD)

- Low power control register (LPWRCR)
- System clock control register (SCKCR)
- Timer control status register (TCSR)

22.1.1 Standby Control Register (SBYCR)

SBYCR performs power-down mode control.

Bit	Bit Name	Initial Value	R/W	Description
7	SSBY	0	R/W	<p>Software Standby</p> <p>Specifies transition destination when the SLEEP instruction is executed.</p> <p>0: Shifts to sleep mode when the SLEEP instruction is executed in high-speed mode or medium-speed mode. Shifts to sub-sleep mode when the SLEEP instruction is executed in sub-active mode.</p> <p>1: Shifts to software standby mode, sub-active mode, and watch mode when the SLEEP instruction is executed in high-speed mode or medium-speed mode. Shifts to watch mode or high-speed mode when the SLEEP instruction is executed in sub-active mode.</p> <p>Note that the value of the SSBY bit does not change even when software standby mode is canceled and making normal operation mode transition by executing an external interrupt. To clear this bit, 0 should be written to.</p>

Bit	Bit Name	Initial Value	R/W	Description
6	STS2	0	R/W	Standby Timer Select 2 to 0
5	STS1	0	R/W	These bits select the MCU wait time for clock settling to cancel software standby mode, watch mode, or sub-active mode.
4	STS0	0	R/W	<p>(Normal oscillation: H8S/2268, H8S/2266, H8S/2265, H8S/2264, and H8S/2262)</p> <p>With a crystal resonator (Table 22.3), select a wait time of 8 ms (oscillation settling time) or more, depending on the operating frequency. With an external clock, there are no specific wait requirements.</p> <p>000: Standby time = 8192 states 001: Standby time = 16384 states 010: Standby time = 32768 states 011: Standby time = 65536 states 100: Standby time = 131072 states 101: Standby time = 262144 states 110: Standby time = 2048 states 111: Standby time = 16 states*</p> <p>(Oscillation settling time shortened: H8S/2264R and H8S/2262R)</p> <p>With a crystal resonator or ceramic resonator, refer to tables 22.4 and 22.5 and select a wait time of TBD μs (oscillation settling time) or more, depending on the operating frequency. An external clock cannot be used.</p> <p>000: Standby time = 8192 states 001: Standby time = 16384 states 010: Standby time = 256 states 011: Standby time = 512 states 100: Standby time = 1024 states 101: Standby time = 4096 states 110: Standby time = 2048 states 111: Reserved</p>
3	—	1	R/W	<p>Reserved</p> <p>This is a readable/writable bit, but the write value should always be 1.</p>

Bit	Bit Name	Initial Value	R/W	Description
2 to 0	—	All 0	—	Reserved
				These bits are always read as 0 and cannot be modified.

Note: *Do not set 16 states for standby time in the version with built-in flash memory. 2048 states or more should be set.

22.1.2 Module Stop Control Registers A to D (MSTPCRA to MSTPCRD)

MSTPCR performs module stop mode control. When bits in MSTPCR registers are set to 1, module stop mode is set. When cleared to 0, module stop mode is cleared.

MSTPCRA

Bit	Bit Name	Initial Value	R/W	Target Module
7	MSTPA7* ¹	0	R/W	
6	MSTPA6* ²	0	R/W	Data transfer controller (DTC)
5	MSTPA5	1	R/W	16-bit timer pulse unit (TPU)
4	MSTPA4	1	R/W	8-bit timer (TMR_0, TMR_1)
3	MSTPA3* ¹	1	R/W	
2	MSTPA2* ¹	1	R/W	
1	MSTPA1	1	R/W	A/D converter
0	MSTPA0* ²	1	R/W	8-bit timer (TMR_2, TMR_3)

MSTPCRB

Bit	Bit Name	Initial Value	R/W	Target Module
7	MSTPB7	1	R/W	Serial communication interface 0 (SCI_0)
6	MSTPB6	1	R/W	Serial communication interface 1 (SCI_1)
5	MSTPB5* ¹	1	R/W	
4	MSTPB4	1	R/W	I ² C bus interface 0 (I ² C_0) (optional)
3	MSTPB3* ²	1	R/W	I ² C bus interface 1 (I ² C_1) (optional)
2	MSTPB2* ¹	1	R/W	
1	MSTPB1* ¹	1	R/W	
0	MSTPB0* ¹	1	R/W	

MSTPCRC

Bit	Bit Name	Initial Value	R/W	Target Module
7	MSTPC7	1	R/W	Serial communication interface 2 (SCI_2)
6	MSTPC6* ¹	1	R/W	
5	MSTPC5* ²	1	R/W	D/A converter
4	MSTPC4* ²	1	R/W	PC break controller (PBC)
3	MSTPC3* ¹	1	R/W	
2	MSTPC2* ²	1	R/W	DTMF generation circuit
1	MSTPC1* ¹	1	R/W	
0	MSTPC0* ¹	1	R/W	

MSTPCRD

Bit	Bit Name	Initial Value	R/W	Target Module
7	MSTPD7* ¹	1	R/W	
6	MSTPD6	1	R/W	LCD controller/driver
5	MSTPD5* ²	1	R/W	8-bit reload timer (TMR_4)
4	MSTPD4* ¹	1	R/W	
3	MSTPD3* ¹	1	R/W	
2	MSTPD2* ¹	1	R/W	
1	MSTPD1* ¹	1	R/W	
0	MSTPD0* ¹	1	R/W	

- Notes: 1. Bit MSTPA7 can be read/written to. This bit is initialized to 0. Only 1 should be written to. Bits MSTPA3, MSTPA2, MSTPB5, MSTPB2 to MSTPB0, MSTPC6, MSTPC3, MSTPC1, MSTPC0, MSTPD7, MSTPD4 to MSTPD0 can be read/written to. These bits are initialized to 1. Only 1 should be written to.
2. With the H8S/2264 Series, only 1 should be written to.

22.2 Medium-Speed Mode

In high-speed mode, when the SCK2 to SCK0 bits in SCKCR are set to 1, the operating mode changes to medium-speed mode as soon as the current bus cycle ends. In medium-speed mode, the CPU operates on the operating clock ($\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, or $\phi/32$) specified by the SCK2 to SCK0 bits. The bus masters other than the CPU (DTC*) also operate in medium-speed mode.

On-chip peripheral modules other than the bus masters always operate on the high-speed clock (ϕ).

In medium-speed mode, a bus access is executed in the specified number of states with respect to the bus master operating clock. For example, if $\phi/4$ is selected as the operating clock, on-chip memory is accessed in 4 states, and internal I/O registers in 8 states.

Medium-speed mode is cleared by clearing all of bits SCK2 to SCK0 to 0. A transition is made to high-speed mode and medium-speed mode is cleared at the end of the current bus cycle.

If a SLEEP instruction is executed when the SSBY bit in SBYCR is cleared to 0, and LSON bit in LPWRCR is cleared to 0, a transition is made to sleep mode. When sleep mode is cleared by an interrupt, medium-speed mode is restored.

When the SLEEP instruction is executed with the SSBY bit = 1, LPWRCR LSON bit = 0, and TCSR (WDT_1) PSS bit = 0, operation shifts to the software standby mode. When software standby mode is cleared by an external interrupt, medium-speed mode is restored.

When the $\overline{\text{RES}}$ pin is set low and medium-speed mode is cancelled, operation shifts to the reset state. The same applies in the case of a reset caused by overflow of the watchdog timer.

When the $\overline{\text{STBY}}$ pin is driven low, a transition is made to hardware standby mode.

Figure 22.2 shows the timing for transition to and clearance of medium-speed mode.

Note: Supported only by the H8S/2268 Series.

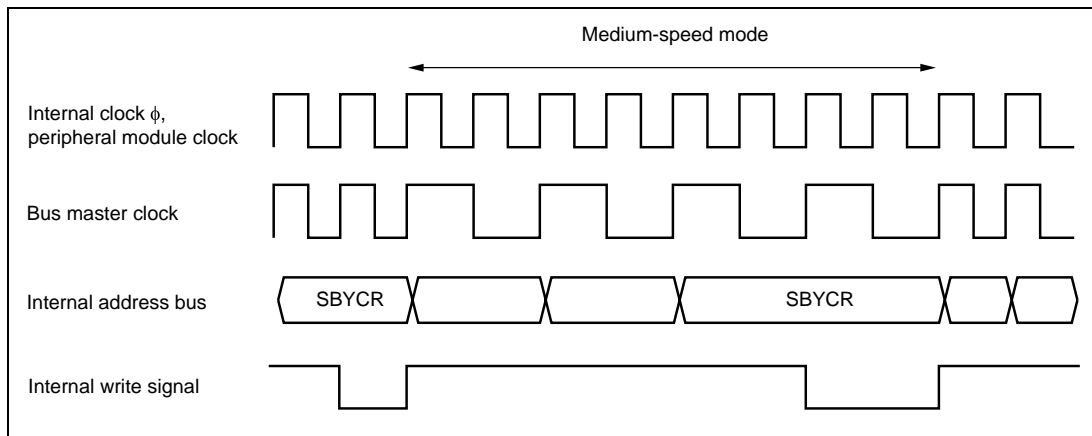


Figure 22.2 Medium-Speed Mode Transition and Clearance Timing

22.3 Sleep Mode

22.3.1 Sleep Mode

When the SLEEP instruction is executed while the SBYCR SSBY bit = 0 and the LPWRCR LSON bit = 0, the CPU enters the sleep mode. In sleep mode, CPU operation stops but the contents of the CPU's internal registers are retained. Other peripheral modules do not stop.

22.3.2 Exiting Sleep Mode

Sleep mode is exited by any interrupt, or signals at the $\overline{\text{RES}}$, or $\overline{\text{STBY}}$ pins.

- **Exiting Sleep Mode by Interrupts**
When an interrupt occurs, sleep mode is exited and interrupt exception processing starts. Sleep mode is not exited if the interrupt is disabled, or interrupts other than NMI are masked by the CPU.
- **Exiting Sleep Mode by $\overline{\text{RES}}$ pin**
Setting the $\overline{\text{RES}}$ pin level low selects the reset state. After the stipulated reset input duration, driving the $\overline{\text{RES}}$ pin high starts the CPU performing reset exception processing.
- **Exiting Sleep Mode by $\overline{\text{STBY}}$ Pin**
When the $\overline{\text{STBY}}$ pin level is driven low, a transition is made to hardware standby mode.

22.4 Software Standby Mode

22.4.1 Software Standby Mode

A transition is made to software standby mode when the SLEEP instruction is executed while the SBYCR SSBY bit = 1 and the LPWRCR LSON bit = 0, and the TCSR (WDT_1) PSS bit = 0. In this mode, the CPU, on-chip peripheral modules, and oscillator all stop. However, the contents of the CPU's internal registers, RAM data, and the states of on-chip peripheral modules other than the A/D converter, and the states of I/O ports are retained. In this mode the oscillator stops, and therefore power dissipation is significantly reduced.

22.4.2 Clearing Software Standby Mode

Software standby mode is cleared by an external interrupt (NMI pin, or pins $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$), or by means of the $\overline{\text{RES}}$ pin or STBY pin.

- Clearing with an interrupt

When an NMI, or $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, or $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$ interrupt request signal is input, clock oscillation starts, and after the elapse of the time set in bits STS2 to STS0 in SYSCR, stable clocks are supplied to the entire chip, software standby mode is cleared, and interrupt exception handling is started.

When clearing software standby mode with an $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, or $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$ interrupt, set the corresponding enable bit/pin function switching bit to 1 and ensure that no interrupt with a higher priority than interrupts $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, or $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$ is generated. Software standby mode cannot be cleared if the interrupt has been masked on the CPU side or has been designated as a DTC activation source.

- Clearing with the $\overline{\text{RES}}$ pin

When the $\overline{\text{RES}}$ pin is driven low, clock oscillation is started. At the same time as clock oscillation starts, clocks are supplied to the entire chip. Note that the $\overline{\text{RES}}$ pin must be held low until clock oscillation settles. When the $\overline{\text{RES}}$ pin goes high, the CPU begins reset exception handling.

- Clearing with the $\overline{\text{STBY}}$ pin

When the $\overline{\text{STBY}}$ pin is driven low, a transition is made to hardware standby mode.

Note: Supported only by the H8S/2268 Series.

22.4.3 Oscillation Settling Time after Clearing Software Standby Mode

Bits STS2 to STS0 in SBYCR should be set as described below.

Normal Oscillation (H8S/2268, H8S/2266, H8S/2265, H8S/2264, and H8S/2262):

- Using a Crystal Oscillator
Set bits STS2 to STS0 so that the standby time is at least 8 ms (the oscillation settling time). Table 22.3 shows the standby times for different operating frequencies and settings of bits STS2 to STS0.
- Using an External Clock
Any value can be set. Normally, minimum time is recommended.

Note: Do not set 16 states for standby time in the version with built-in flash memory. 2048 states or more should be set.

Table 22.3 Oscillation Settling Time Settings (Normal Oscillation)

STS2	STS1	STS0	Standby Time	20 MHz	16 MHz	13 MHz	10 MHz	8 MHz	6 MHz	4 MHz	2 MHz	Unit
0	0	0	8192 states	0.41	0.51	0.63	0.82	1.0	1.4	2.0	4.1	ms
		1	16384 states	0.82	1.0	1.3	1.6	2.0	2.7	4.1	8.2	
	1	0	32768 states	1.6	2.0	2.5	3.3	4.1	5.5	8.2	16.4	
		1	65536 states	3.3	4.1	5.0	6.6	8.2	10.9	16.4	32.8	
1	0	0	131072 states	6.6	8.2	10.1	13.1	16.4	21.8	32.8	65.5	
		1	262144 states	13.1	16.4	20.2	26.2	32.8	43.7	65.5	131.1	
	1	0	2048 states	0.10	0.13	0.16	0.20	0.26	0.34	0.51	1.0	
		1	16 states	0.8	1.0	1.2	1.6	2.0	2.7	4.0	8.0	

Shading: Recommended time setting

Oscillation Settling Time Shortened (H8S/2264R and H8S/2262R) — Preliminary —:

- Using a Crystal Oscillator
Set bits STS2 to STS0 so that the standby time is at least TBD μ s (the oscillation settling time). Table 22.4 shows the standby times for different operating frequencies and settings of bits STS2 to STS0.
- Using a Ceramic Oscillator
Table 22.5 shows the standby times for different operating frequencies and settings of bits STS2 to STS0.

Note: An external clock cannot be used in the H8S/2264R and H8S/2262R.

Table 22.4 Oscillation Settling Time Settings (Oscillation Settling Time Shortened: Crystal Oscillator)

STS2	STS1	STS0	Standby Time	20 MHz	16 MHz	13 MHz	10 MHz	8 MHz	6 MHz	4 MHz	2 MHz	Unit
0	1	0	256 states	12.8	16.0	19.7	25.6	32.0	42.7	64.0	128	μs
0	1	1	512 states	25.6	32.0	39.4	51.2	64.0	85.3	128	256	
1	0	0	1024 states	51.2	64.0	78.8	102	128	171	256	512	
1	1	0	2048 states	102	128	158	205	256	341	512	1024	
1	0	1	4096 states	205	256	315	410	512	683	1024	2048	
0	0	0	8192 states	410	512	630	819	1024	1365	2048	4096	
0	0	1	16384 states	819	1024	1260	1638	2048	2731	4096	8192	
1	1	1	Reserved	—	—	—	—	—	—	—	—	—

Table 22.5 Oscillation Settling Time Settings (Oscillation Settling Time Shortened: Ceramic Oscillator)

STS2	STS1	STS0	Standby Time	20 MHz	16 MHz	13 MHz	10 MHz	8 MHz	6 MHz	4 MHz	2 MHz	Unit
0	1	0	256 states	12.8	16.0	19.7	25.6	32.0	42.7	64.0	128	μs
0	1	1	512 states	25.6	32.0	39.4	51.2	64.0	85.3	128	256	
1	0	0	1024 states	51.2	64.0	78.8	102	128	171	256	512	
1	1	0	2048 states	102	128	158	205	256	341	512	1024	
1	0	1	4096 states	205	256	315	410	512	683	1024	2048	
0	0	0	8192 states	410	512	630	819	1024	1365	2048	4096	
0	0	1	16384 states	819	1024	1260	1638	2048	2731	4096	8192	
1	1	1	Reserved	—	—	—	—	—	—	—	—	—

Shading: Recommended time setting

22.4.4 Software Standby Mode Application Example

Figure 22.3 shows an example in which a transition is made to software standby mode at the falling edge on the NMI pin, and software standby mode is cleared at the rising edge on the NMI pin.

In this example, an NMI interrupt is accepted with the NMIEG bit in SYSCR cleared to 0 (falling edge specification), then the NMIEG bit is set to 1 (rising edge specification), the SSBY bit is set to 1, and a SLEEP instruction is executed, causing a transition to software standby mode.

Software standby mode is then cleared at the rising edge on the NMI pin.

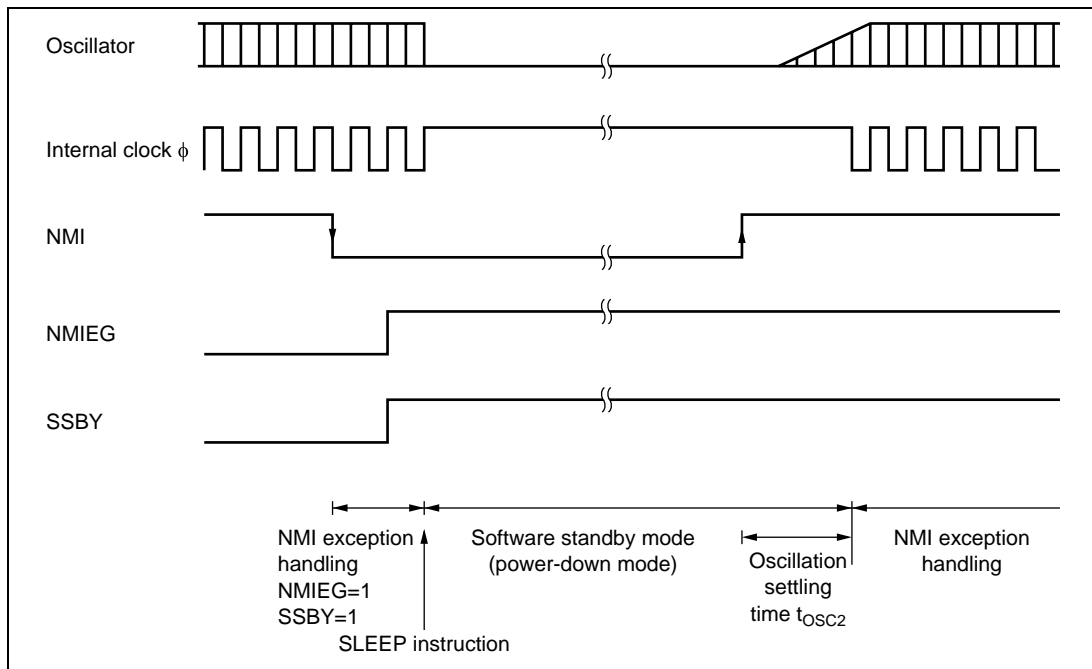


Figure 22.3 Software Standby Mode Application Example

22.5 Hardware Standby Mode

22.5.1 Hardware Standby Mode

When the $\overline{\text{STBY}}$ pin is driven low, a transition is made to hardware standby mode from any mode.

In hardware standby mode, all functions enter the reset state and stop operation, resulting in a significant reduction in power dissipation. As long as the prescribed voltage is supplied, on-chip RAM data is retained. I/O ports are set to the high-impedance state.

Do not change the state of the mode pins (MD2, MD1) during hardware standby mode.

22.5.2 Clearing Hardware Standby Mode

Hardware standby mode is cleared by means of the $\overline{\text{STBY}}$ pin and the $\overline{\text{RES}}$ pin. When the $\overline{\text{STBY}}$ pin is driven high while the $\overline{\text{RES}}$ pin is low, the reset state is set and clock oscillation is started. Ensure that the $\overline{\text{RES}}$ pin is held low until the clock oscillator settles (at least t_{osc1} ms—the oscillation settling time—when using a crystal/ceramic oscillator). When the $\overline{\text{RES}}$ pin is subsequently driven high, a transition is made to the program execution state via the reset exception handling state.

22.5.3 Hardware Standby Mode Timing

Figure 22.4 shows an example of hardware standby mode timing.

When the $\overline{\text{STBY}}$ pin is driven low after the $\overline{\text{RES}}$ pin has been driven low, a transition is made to hardware standby mode. Hardware standby mode is cleared by driving the $\overline{\text{STBY}}$ pin high, waiting for the oscillation settling time, then changing the $\overline{\text{RES}}$ pin from low to high.

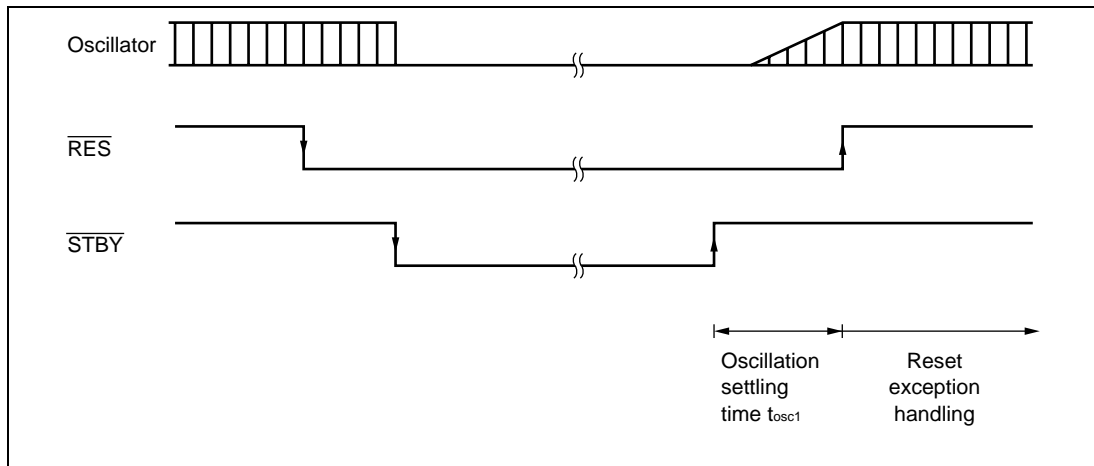


Figure 22.4 Hardware Standby Mode Timing

22.6 Module Stop Mode

Module stop mode can be set for individual on-chip peripheral modules.

When the corresponding MSTP bit in MSTPCR is set to 1, module operation stops at the end of the bus cycle and a transition is made to module stop mode. The CPU continues operating independently.

When the corresponding MSTP bit is cleared to 0, module stop mode is cleared and the module starts operating at the end of the bus cycle. In module stop mode, the internal states of modules other than the A/D converter are retained.

After reset clearance, all modules other than DTC* are in module stop mode.

When an on-chip peripheral module is in module stop mode, read/write access to its registers is disabled.

Since the operations of the bus controller and I/O port are stopped when sleep mode is entered at the all-module stop state (MSTPCR=H'FFFFFFF), power consumption can further be reduced.

Note: Supported only by the H8S/2268 Series.

22.7 Watch Mode

22.7.1 Transition to Watch Mode

CPU operation makes a transition to watch mode when the SLEEP instruction is executed in high-speed mode or sub-active mode with SBYCR SSBY=1, LPWRCR DTON = 0, and TCSR (WDT_1) PSS = 1.

In watch mode, the CPU is stopped and peripheral modules other than WDT_1, TMR_4*, and LCD are also stopped. The contents of the CPU's internal registers, the data in internal RAM, and the statuses of the internal peripheral modules (excluding the A/D converter) and I/O ports are retained. To make a transition to watch mode, bits SCK2 to SCK0 in SCKCR must be set to 0.

Note: Supported only by the H8S/2268 Series.

22.7.2 Exiting Watch Mode

Watch mode is exited by any interrupt (WOVI1 interrupt, OVI4 to OVI7 interrupts*, NMI pin, or $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, or $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$), or signals at the $\overline{\text{RES}}$, or $\overline{\text{STBY}}$ pins.

- Exiting Watch Mode by Interrupts

When an interrupt occurs, watch mode is exited and a transition is made to high-speed mode or medium-speed mode when the LPWRCR LSON bit = 0 or to sub-active mode when the LSON bit = 1. When a transition is made to high-speed mode, a stable clock is supplied to all LSI circuits and interrupt exception processing starts after the time set in SBYCR STS2 to STS0 has elapsed. In the case of $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, and $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$ interrupts, no transition is made from watch mode if the corresponding enable bit/pin function switching bit has been cleared to 0, and, in the case of interrupts from the internal peripheral modules, the interrupt enable register has been set to disable the reception of that interrupt, or is masked by the CPU.

See section 22.4.3, Oscillation Settling Time after Clearing Software Standby Mode, for how to set the oscillation settling time when making a transition from watch mode to high-speed mode.

- Exiting Watch Mode by $\overline{\text{RES}}$ pins

For exiting watch mode by the $\overline{\text{RES}}$ pins, see section 22.4.2, Clearing Software Standby Mode.

- Exiting Watch Mode by $\overline{\text{STBY}}$ pin

When the $\overline{\text{STBY}}$ pin level is driven low, a transition is made to hardware standby mode.

Note: Supported only by the H8S/2268 Series.

22.8 Sub-Sleep Mode

22.8.1 Transition to Sub-Sleep Mode

When the SLEEP instruction is executed with the SBYCR SSBY bit = 0, LPWRCR LSON bit = 1, and TCSR (WDT_1) PSS bit = 1, CPU operation shifts to sub-sleep mode.

In sub-sleep mode, the CPU is stopped. Peripheral modules other than TMR_0, TMR1, TMR2 to TMR_4*, WDT_0, WDT_1, and LCD are also stopped. The contents of the CPU's internal registers, the data in internal RAM, and the statuses of the internal peripheral modules (excluding the A/D converter) and I/O ports are retained.

Note: Supported only by the H8S/2268 Series.

22.8.2 Exiting Sub-Sleep Mode

Sub-sleep mode is exited by an interrupt (interrupts from internal peripheral modules, NMI pin, or $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, or $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$), or signals at the $\overline{\text{RES}}$ or $\overline{\text{STBY}}$ pins.

- Exiting Sub-Sleep Mode by Interrupts

When an interrupt occurs, sub-sleep mode is exited and interrupt exception processing starts.

In the case of $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ3}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ5}}$ *, and $\overline{\text{WKP0}}$ to $\overline{\text{WKP7}}$ interrupts, sub-sleep mode is not cancelled if the corresponding enable bit/pin function switching bit has been cleared to 0, and, in the case of interrupts from the internal peripheral modules, the interrupt enable register has been set to disable the reception of that interrupt, or is masked by the CPU.

- Exiting Sub-Sleep Mode by $\overline{\text{RES}}$

For exiting sub-sleep mode by the $\overline{\text{RES}}$ pins, see section 22.4.2, Clearing Software Standby Mode.

- Exiting Sub-Sleep Mode by $\overline{\text{STBY}}$ Pin

When the $\overline{\text{STBY}}$ pin level is driven low, a transition is made to hardware standby mode.

Note: Supported only by the H8S/2268 Series.

22.9 Sub-Active Mode

22.9.1 Transition to Sub-Active Mode

When the SLEEP instruction is executed in high-speed mode with the SBYCR SSBY bit = 1, LPWRCR DTON bit = 1, LSON bit = 1, and TCSR (WDT_1) PSS bit = 1, CPU operation shifts to sub-active mode. When an interrupt occurs in watch mode, and if the LSON bit of LPWRCR is 1, a transition is made to sub-active mode. And if an interrupt occurs in sub-sleep mode, a transition is made to sub-active mode.

In sub-active mode, the CPU operates at low speed on the subclock, and the program is executed step by step. Peripheral modules other than PBC*, TMR_0, TMR_1, TMR_2 to TMR_4*, WDT_0, WDT_1, and LCD are also stopped.

When operating the CPU in sub-active mode, the SCKCR SCK2 to SCK0 bits must be set to 0.

Note: Supported only by the H8S/2268 Series.

22.9.2 Exiting Sub-Active Mode

Sub-active mode is exited by the SLEEP instruction or the $\overline{\text{RES}}$ or $\overline{\text{STBY}}$ pins.

- Exiting Sub-Active Mode by SLEEP Instruction

When the SLEEP instruction is executed with the SBYCR SSBY bit = 1, LPWRCR DTON bit = 0, and TCSR (WDT_1) PSS bit = 1, the CPU exits sub-active mode and a transition is made to watch mode. When the SLEEP instruction is executed with the SBYCR SSBY bit = 0, LPWRCR LSON bit = 1, and TCSR (WDT_1) PSS bit = 1, a transition is made to sub-sleep mode. Finally, when the SLEEP instruction is executed with the SBYCR SSBY bit = 1, LPWRCR DTON bit = 1, LSON bit = 0, and TCSR (WDT_1) PSS bit = 1, a direct transition is made to high-speed mode (SCK0 to SCK2 all 0).

- Exiting Sub-Active Mode by $\overline{\text{RES}}$ Pins

For exiting sub-active mode by the $\overline{\text{RES}}$ pins, see section 22.4.2, Clearing Software Standby Mode.

- Exiting Sub-Active Mode by $\overline{\text{STBY}}$ Pin

When the $\overline{\text{STBY}}$ pin level is driven low, a transition is made to hardware standby mode.

22.10 Direct Transitions

There are three modes, high-speed, medium-speed, and sub-active, in which the CPU executes programs. When a direct transition is made, there is no interruption of program execution when shifting between high-speed and sub-active modes. Direct transitions are enabled by setting the LPWRCR DTON bit to 1, then executing the SLEEP instruction. After a transition, direct transition interrupt exception processing starts.

22.10.1 Direct Transitions from High-Speed Mode to Sub-Active Mode

Execute the SLEEP instruction in high-speed mode when the SBYCR SSBY bit = 1, LPWRCR LSON bit = 1, and DTON bit = 1, and TSCR (WDT_1) PSS bit = 1 to make a transition to sub-active mode.

22.10.2 Direct Transitions from Sub-Active Mode to High-Speed Mode

Execute the SLEEP instruction in sub-active mode when the SBYCR SSBY bit = 1, LPWRCR LSON bit = 0, and DTON bit = 1, and TSCR (WDT_1) PSS bit = 1 to make a direct transition to high-speed mode after the time set in SBYCR STS2 to STS0 has elapsed.

22.11 Usage Notes

22.11.1 I/O Port Status

In software standby mode and watch mode, I/O port states are retained. Therefore, there is no reduction in current dissipation for the output current when a high-level signal is output.

22.11.2 Current Dissipation during Oscillation Settling Wait Period

Current dissipation increases during the oscillation settling wait period.

22.11.3 DTC Module Stop (Supported only by the H8S/2268 Series)

Depending on the operating status of the DTC, the MSTPA6 bit may not be set to 1. Setting of the DTC module stop mode should be carried out only when the respective module is not activated.

For details, refer to section 8, Data Transfer Controller (DTC).

22.11.4 On-Chip Peripheral Module Interrupt

- Module stop mode

Relevant interrupt operations cannot be performed in module stop mode. Consequently, if module stop mode is entered when an interrupt has been requested, it will not be possible to clear the CPU interrupt source or the DTC* activation source. Interrupts should therefore be disabled before entering module stop mode.

Note: Supported only by the H8S/2268 Series.

- Subactive mode / Watch mode

On-chip peripheral modules (DTC*, TPU, IIC) that stop operation in subactive mode cannot clear interrupts in subactive mode. Therefore, if subactive mode is entered when an interrupt is requested, CPU interrupt factors cannot be cleared.

Interrupts should therefore be cleared before executing the SLEEP instruction and entering subactive or watch mode.

Note: Supported only by the H8S/2268 Series.

22.11.5 Writing to MSTPCR

MSTPCR should only be written to by the CPU.

22.11.6 Entering Subactive / Watch mode and DTC Module Stop (Supported only by the H8S/2268 Series)

To enter subactive or watch mode, set DTC to module stop (write 1 to the MSTPA6 bit) and reading the MSTPA6 bit as 1 before transiting mode. After transiting from subactive mode to active mode, clear module stop.

When DTC activation factor occurs in subactive mode, DTC is activated when module stop is cleared after active mode is entered.

Section 23 Power-On Reset Circuit

The H8S/2264 Series has a power-on reset circuit. The H8S/2268 Series does not have a power-on reset circuit.

Block diagram of the power-on reset circuit is shown in figure 23.1.

23.1 Features

- Power-on reset circuit

The power-on reset circuit can be enabled or disabled according to the mode pin settings (enabled when MD2 = 0 and MD1 = 1).

An internal reset signal is generated at turning the power on by externally connecting a capacitor.

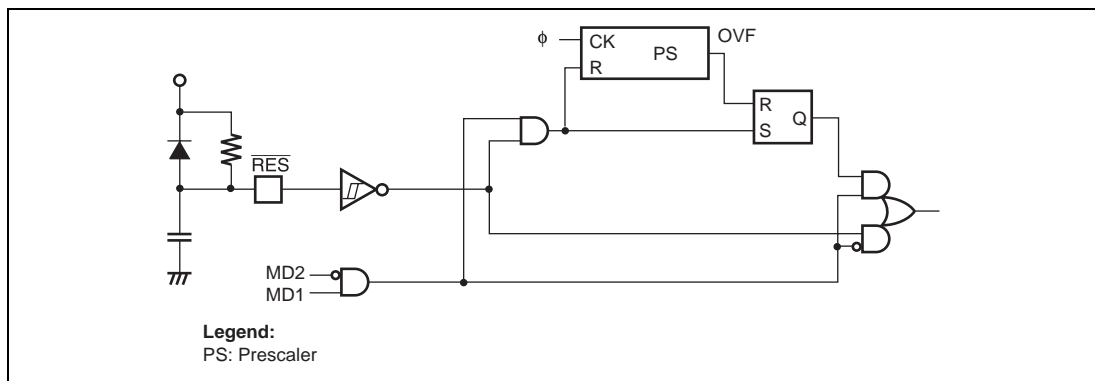


Figure 23.1 Power-On Reset Circuit

23.2 Operation

23.2.1 Power-On Reset Circuit

The power-on reset circuit is enabled by setting the mode pins MD2 and MD1 to B'01. The operation timing of the power-on reset circuit is shown in figure 23.2. As the power supply voltage rises, the capacitor is gradually charged through the pull-up resistor, which is connected to the $\overline{\text{RES}}$ pin. The low level of the $\overline{\text{RES}}$ pin is sent to the chip and resets the prescaler and the whole chip. When the level of the $\overline{\text{RES}}$ pin reaches to the predetermined level, reset state of the prescaler is cancelled and count-up operation starts. When the prescaler counts ϕ for 131,072 times, an OVF signal is generated and an internal reset signal is cancelled.

Note that the power-supply circuit must be designed so that the power supply voltage reaches an appropriate level within the stipulated time. In addition, when the capacitance of the capacitor which is externally connected is determined, the rising time of the power supply voltage level must be taken into consideration.

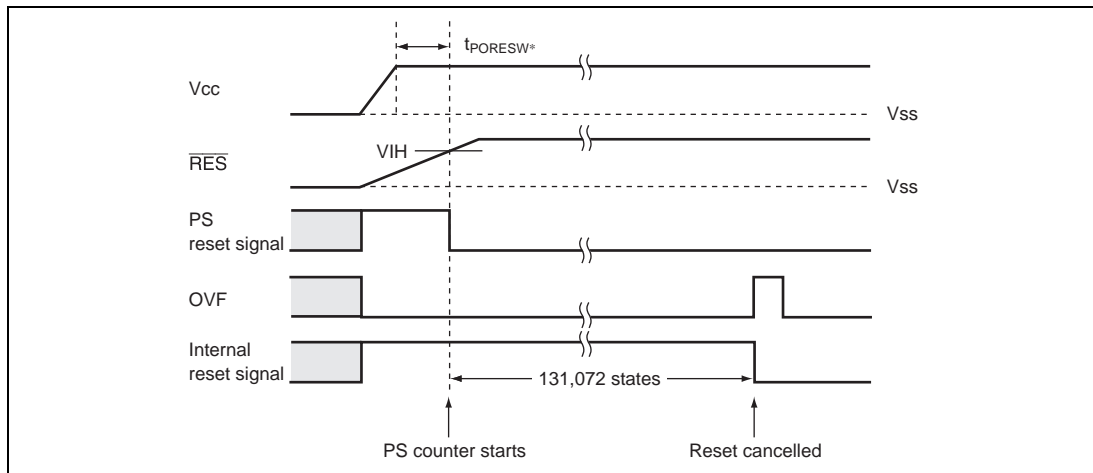


Figure 23.2 Power-On Reset Circuit Operation Timing

Note: *

In case of $t_{OSCI} \leq 131,072$ states

$$t_{PORESW} \geq t_{RESW}$$

In case of $t_{OSCI} > 131,072$ states

$$t_{PORESW} \geq t_{RESW} + t_{OSCI} - 131,072 \text{ states}$$

Section 24 Power Supply Circuit

This LSI has an internal power step-down circuit built into it. Using this circuit allows the internal power supply to be fixed at approximately 3.0 V without relying on the power supply voltage connected to the external Vcc terminal. This means that, when used at an external power supply higher than 3.0 V, the current consumption value can be suppressed to largely the same value as that when used at approximately 3.0 V. If the external voltage is 3.0 V or less, the internal voltage will be largely consistent with the external voltage.

24.1 When the internal power step-down circuit is used

As shown in figure 24.1, an external power supply should be connected to the Vcc terminal, using the shortest possible wiring, with a capacitance of approximately 0.1 μF between CVcc and Vss. Adding this external circuit makes the internal step-down circuit valid. Applying a power supply exceeding the absolute maximum rated value of 4.3 V to the CVcc terminal can permanently damage the LSI, so the power supply should not be connected to the CVcc terminal. The external power supply voltage connected to Vcc and the GND potential connected to Vss serve as the references for the input/output levels of the external circuit. For example, a “High” port input/output level will be the Vcc reference, and a “Low” level will be the Vss reference. The analog power supplies of the A/D converter, D/A converter*, and DTMF generation circuit* do not affect the internal step-down circuit.

Note: * Supported only by the H8S/2268 Series.

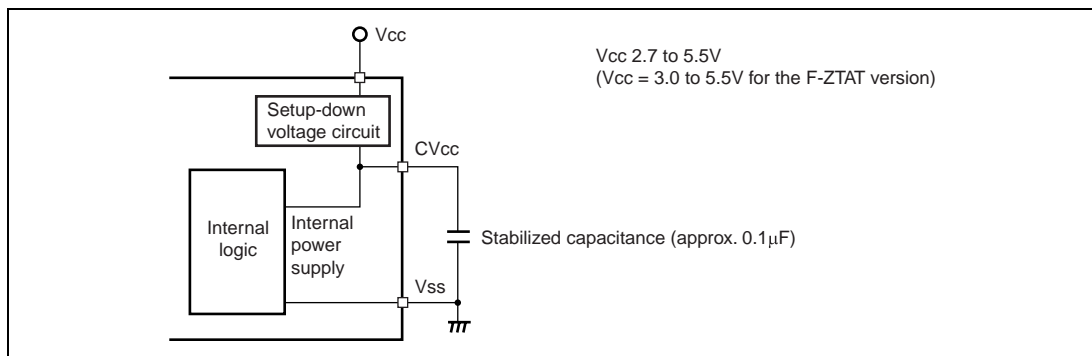


Figure 24.1 Power Supply Connections when an Internal Power Supply Step-Down Circuit is Used

Section 25 List of Registers

This section gives information on the on-chip I/O registers and is configured as described below.

1. Register Addresses (by functional module, in address order)
 - Descriptions by functional module, in ascending order of addresses
 - When registers consist of 16 bits, the addresses of the MSBs are given.
 - Data bus width is given.
 - The number of access states are given.
2. Register Bits
 - Bit configurations of the registers are described in the same order as the Register Addresses (by functional module, in ascending order of addresses).
 - Reserved bits are indicated by — in the bit name.
 - When registers consist of 16 or 32 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 (by functional module, in ascending order of addresses).
 - The register states described are for the basic operating modes. If there is a specific reset for an on-chip module, refer to the section on that on-chip module.

25.1 Register Addresses (by function module, in address order)

The data bus width indicates the numbers of bits by which the register is accessed.

The number of access states indicates the number of states based on the specified reference clock.

Register Name	Abbrevia- tion	Bit No.	Address* ¹	Module	Data Width	Access State
DTC mode register A* ⁴	MRA	8	H'EBC0 to	DTC	16/32* ²	1
DTC source address register* ⁴	SAR	24	H'EFBF	DTC	16/32* ²	1
DTC mode register B* ⁴	MRB	8		DTC	16/32* ²	1
DTC destination address register* ⁴	DAR	24		DTC	16/32* ²	1
DTC transfer count register A* ⁴	CRA	16		DTC	16/32* ²	1
DTC transfer count register B* ⁴	CRB	16		DTC	16/32* ²	1
LCD port control register	LPCR	8	H'FC30	LCD	8/16	4
LCD control register	LCR	8	H'FC31	LCD	8/16	4
LCD control register 2	LCR2	8	H'FC32	LCD	8/16	4
LCD RAM	—	8	H'FC40 to H'FC53	LCD	8/16	4
Module stop control register D	MSTPCRD	8	H'FC60	SYSTEM	8	4
System clock control register 2* ⁵	SCKCR2	8	H'FC61	SYSTEM	8	4
DTMF control register* ⁴	DTCR	8	H'FC68	DTMF	8	4
DTMF load register* ⁴	DTLR	8	H'FC69	DTMF	8	4
Timer control register_4* ⁴	TCR_4	8	H'FC70	TMR_4	8/16	4
Timer control register_5* ⁴	TCR_5	8	H'FC71	TMR_4	8/16	4
Timer control register_6* ⁴	TCR_6	8	H'FC72	TMR_4	8/16	4
Timer control register_7* ⁴	TCR_7	8	H'FC73	TMR_4	8/16	4
Timer counter 4/Timer reload register 4* ⁴	TCNT_4(R)/ TLR_4(W)	8	H'FC74	TMR_4	8/16	4
Timer counter 5/Timer reload register 5* ⁴	TCNT_5(R)/ TLR_5(W)	8	H'FC75	TMR_4	8/16	4
Timer counter 6/Timer reload register 6* ⁴	TCNT_6(R)/ TLR_6(W)	8	H'FC76	TMR_4	8/16	4
Timer counter 7/Timer reload register 7* ⁴	TCNT_7(R)/ TLR_7(W)	8	H'FC77	TMR_4	8/16	4
Port H data direction register	PHDDR	8	H'FC80	PORT	8	4

Register Name	Abbrevia- tion	Bit No.	Address* ¹	Module	Data Width	Access State
Port J data direction register	PJDDR	8	H'FC81	PORT	8	4
Port K data direction register	PKDDR	8	H'FC82	PORT	8	4
Port L data direction register	PLDDR	8	H'FC83	PORT	8	4
Port M data direction register* ⁴	PMDDR	8	H'FC84	PORT	8	4
Port N data direction register* ⁴	PNDDR	8	H'FC85	PORT	8	4
Port H data register	PHDR	8	H'FC88	PORT	8	4
Port J data register	PJDR	8	H'FC89	PORT	8	4
Port K data register	PKDR	8	H'FC8A	PORT	8	4
Port L data register	PLDR	8	H'FC8B	PORT	8	4
Port M data register* ⁴	PMDR	8	H'FC8C	PORT	8	4
Port N data register* ⁴	PNDR	8	H'FC8D	PORT	8	4
Port H register	PORTH	8	H'FC90	PORT	8	4
Port J register	PORTJ	8	H'FC91	PORT	8	4
Port K register	PORTK	8	H'FC92	PORT	8	4
Port L register	PORTL	8	H'FC93	PORT	8	4
Port M register* ⁴	PORTM	8	H'FC94	PORT	8	4
Port N register* ⁴	PORTN	8	H'FC95	PORT	8	4
Port J pull-up MOS control register	PJPCR	8	H'FC99	PORT	8	4
Wakeup control register	WPCR	8	H'FC9F	PORT	8	4
Wakeup interrupt request register	IWPR	8	H'FCA0	INT	8	4
Interrupt enable register	IENR1	8	H'FCA1	INT	8	4
D/A data register_0* ⁴	DADR_0	8	H'FDAC	D/A	8	2
D/A data register_1* ⁴	DADR_1	8	H'FDAD	D/A	8	2
D/A control register* ⁴	DACR	8	H'FDAE	D/A	8	2
Serial control register X	SCRX	8	H'FDB4	IIC, FLASH	8	2
DDC switch register	DDCSWR	8	H'FDB5	IIC	8	2
Timer control register_2* ⁴	TCR_2	8	H'FDC0	TMR_2	8	2
Timer control register_3* ⁴	TCR_3	8	H'FDC1	TMR_3	8	2
Timer control/status register_2* ⁴	TCSR_2	8	H'FDC2	TMR_2	8	2
Timer control/status register_3* ⁴	TCSR_3	8	H'FDC3	TMR_3	8	2
Time constant register A_2* ⁴	TCORA_2	8	H'FDC4	TMR_2	8/16	2
Time constant register A_3* ⁴	TCORA_3	8	H'FDC5	TMR_3	8/16	2

Register Name	Abbrevia- tion	Bit No.	Address* ¹	Module	Data Width	Access State
Time constant register B_2* ⁴	TCORB_2	8	H'FDC6	TMR_2	8/16	2
Time constant register B_3* ⁴	TCORB_3	8	H'FDC7	TMR_3	8/16	2
Timer counter_2* ⁴	TCNT_2	8	H'FDC8	TMR_2	8/16	2
Timer counter_3* ⁴	TCNT_3	8	H'FDC9	TMR_3	8/16	2
Serial mode register_2	SMR_2	8	H'FDD0	SCI_2	8	2
Bit rate register_2	BRR_2	8	H'FDD1	SCI_2	8	2
Serial control register_2	SCR_2	8	H'FDD2	SCI_2	8	2
Transmit data register_2	TDR_2	8	H'FDD3	SCI_2	8	2
Serial status register_2	SSR_2	8	H'FDD4	SCI_2	8	2
Receive data register_2	RDR_2	8	H'FDD5	SCI_2	8	2
Smart card mode register_2	SCMR_2	8	H'FDD6	SCI_2	8	2
Standby control register	SBYCR	8	H'FDE4	SYSTEM	8	2
System control register	SYSCR	8	H'FDE5	SYSTEM	8	2
System clock control register	SCKCR	8	H'FDE6	SYSTEM	8	2
Mode control register	MDCR	8	H'FDE7	SYSTEM	8	2
Module stop control register A	MSTPCRA	8	H'FDE8	SYSTEM	8	2
Module stop control register B	MSTPCRB	8	H'FDE9	SYSTEM	8	2
Module stop control register C	MSTPCRC	8	H'FDEA	SYSTEM	8	2
Low power control register	LPWRCR	8	H'FDEC	SYSTEM	8	2
Serial expansion mode register_0	SEMR_0	8	H'FDF8	SCI_0	8	2
Break address register A* ⁴	BARA	32	H'FE00	PBC	8/16	2
Break address register B* ⁴	BARB	32	H'FE04	PBC	8/16	2
Break control register A* ⁴	BCRA	8	H'FE08	PBC	8/16	2
Break control register B* ⁴	BCRB	8	H'FE09	PBC	8/16	2
IRQ sense control register H	ISCRH	8	H'FE12	INT	8	2
IRQ sense control register L	ISCRL	8	H'FE13	INT	8	2
IRQ enable register	IER	8	H'FE14	INT	8	2
IRQ status register	ISR	8	H'FE15	INT	8	2
DTC enable register* ⁴	DT CER	8	H'FE16 to H'FE1B, H'FE1E	DTC	8	2
DTC vector register* ⁴	DTVECR	8	H'FE1F	DTC	8	2
Port 1 data direction register	P1DDR	8	H'FE30	PORT	8	2
Port 3 data direction register	P3DDR	8	H'FE32	PORT	8	2

Register Name	Abbrevia- tion	Bit No.	Address* ¹	Module	Data Width	Access State
Port 7 data direction register	P7DDR	8	H'FE36	PORT	8	2
Port F data direction register	PFDDR	8	H'FE3E	PORT	8	2
Port 3 open drain control register	P3ODR	8	H'FE46	PORT	8	2
Timer start register	TSTR	8	H'FEB0	TPU	8	2
Timer synchro register	TSYR	8	H'FEB1	TPU	8	2
Interrupt priority register A* ⁴	IPRA	8	H'FEC0	INT	8	2
Interrupt priority register B* ⁴	IPRB	8	H'FEC1	INT	8	2
Interrupt priority register C* ⁴	IPRC	8	H'FEC2	INT	8	2
Interrupt priority register D* ⁴	IPRD	8	H'FEC3	INT	8	2
Interrupt priority register E* ⁴	IPRE	8	H'FEC4	INT	8	2
Interrupt priority register F* ⁴	IPRF	8	H'FEC5	INT	8	2
Interrupt priority register G* ⁴	IPRG	8	H'FEC6	INT	8	2
Interrupt priority register I* ⁴	IPRI	8	H'FEC8	INT	8	2
Interrupt priority register J* ⁴	IPRJ	8	H'FEC9	INT	8	2
Interrupt priority register K* ⁴	IPRK	8	H'FECA	INT	8	2
Interrupt priority register L* ⁴	IPRL	8	H'FECB	INT	8	2
Interrupt priority register M* ⁴	IPRM	8	H'FECC	INT	8	2
Interrupt priority register O* ⁴	IPRO	8	H'FECE	INT	8	2
RAM emulation register	RAMER	8	H'FEDB	FLASH	8	2
Port 1 data register	P1DR	8	H'FF00	PORT	8	2
Port 3 data register	P3DR	8	H'FF02	PORT	8	2
Port 7 data register	P7DR	8	H'FF06	PORT	8	2
Port F data register	PFDR	8	H'FF0E	PORT	8	2
Timer control register_0* ⁴	TCR_0	8	H'FF10	TPU_0	8	2
Timer mode register_0* ⁴	TMDR_0	8	H'FF11	TPU_0	8	2
Timer I/O control register H_0* ⁴	TIORH_0	8	H'FF12	TPU_0	8	2
Timer I/O control register L_0* ⁴	TIORL_0	8	H'FF13	TPU_0	8	2
Timer interrupt enable register_0* ⁴	TIER_0	8	H'FF14	TPU_0	8	2
Timer status register_0* ⁴	TSR_0	8	H'FF15	TPU_0	8	2
Timer counter_0* ⁴	TCNT_0	16	H'FF16	TPU_0	16	2
Timer general register A_0* ⁴	TGRA_0	16	H'FF18	TPU_0	16	2
Timer general register B_0* ⁴	TGRB_0	16	H'FF1A	TPU_0	16	2
Timer general register C_0* ⁴	TGRC_0	16	H'FF1C	TPU_0	16	2

Register Name	Abbrevia- tion	Bit No.	Address*1	Module	Data Width	Access State
Timer general register D_0*4	TGRD_0	16	H'FF1E	TPU_0	16	2
Timer control register_1	TCR_1	8	H'FF20	TPU_1	8	2
Timer mode register_1	TMDR_1	8	H'FF21	TPU_1	8	2
Timer I/O control register_1	TIOR_1	8	H'FF22	TPU_1	8	2
Timer interrupt enable register_1	TIER_1	8	H'FF24	TPU_1	8	2
Timer status register_1	TSR_1	8	H'FF25	TPU_1	8	2
Timer counter_1	TCNT_1	16	H'FF26	TPU_1	16	2
Timer general register A_1	TGRA_1	16	H'FF28	TPU_1	16	2
Timer general register B_1	TGRB_1	16	H'FF2A	TPU_1	16	2
Timer control register_2	TCR_2	8	H'FF30	TPU_2	8	2
Timer mode register_2	TMDR_2	8	H'FF31	TPU_2	8	2
Timer I/O control register_2	TIOR_2	8	H'FF32	TPU_2	8	2
Timer interrupt enable register_2	TIER_2	8	H'FF34	TPU_2	8	2
Timer status register_2	TSR_2	8	H'FF35	TPU_2	8	2
Timer counter_2	TCNT_2	16	H'FF36	TPU_2	16	2
Timer general register A_2	TGRA_2	16	H'FF38	TPU_2	16	2
Timer general register B_2	TGRB_2	16	H'FF3A	TPU_2	16	2
Timer control register_0	TCR_0	8	H'FF68	TMR_0	8	2
Timer control register_1	TCR_1	8	H'FF69	TMR_1	8	2
Timer control/status register_0	TCSR_0	8	H'FF6A	TMR_0	8	2
Timer control/status register_1	TCSR_1	8	H'FF6B	TMR_1	8	2
Time constant register A_0	TCORA_0	8	H'FF6C	TMR_0	8/16	2
Time constant register A_1	TCORA_1	8	H'FF6D	TMR_1	8/16	2
Time constant register B_0	TCORB_0	8	H'FF6E	TMR_0	8/16	2
Time constant register B_1	TCORB_1	8	H'FF6F	TMR_1	8/16	2
Timer counter_0	TCNT_0	8	H'FF70	TMR_0	8/16	2
Timer counter_1	TCNT_1	8	H'FF71	TMR_1	8/16	2
Timer control/status register_0	TCSR_0	8	H'FF74(W) H'FF74(R)	WDT_0	16	2
Timer counter_0	TCNT_0	8	H'FF74(W) H'FF75(R)	WDT_0	16	2

Register Name	Abbrevia- tion	Bit No.	Address* ¹	Module	Data Width	Access State
Reset control/status register	RSTCSR	8	H'FF76(W) H'FF77(R)	WDT_0	16	2
Serial mode register_0	SMR_0	8	H'FF78* ³	SCI_0	8	2
I ² C bus control register_0	ICCR_0	8	H'FF78* ³	IIC_0	8	2
Bit rate register_0	BRR_0	8	H'FF79* ³	SCI_0	8	2
I ² C bus status register_0	ICSR_0	8	H'FF79* ³	IIC_0	8	2
Serial control register_0	SCR_0	8	H'FF7A	SCI_0	8	2
Transmit data register_0	TDR_0	8	H'FF7B	SCI_0	8	2
Serial status register_0	SSR_0	8	H'FF7C	SCI_0	8	2
Receive data register_0	RDR_0	8	H'FF7D	SCI_0	8	2
Smart card mode register_0	SCMR_0	8	H'FF7E* ³	SCI_0	8	2
I ² C bus data register_0/Second slave address register_0	ICDR_0 /SARX_0	8	H'FF7E* ³	IIC_0	8	2
I ² C bus mode register_0/Slave address register_0	ICMR_0 /SAR_0	8	H'FF7F	IIC_0	8	2
Serial mode register_1	SMR_1	8	H'FF80* ³	SCI_1	8	2
I ² C bus control register_1* ⁴	ICCR_1	8	H'FF80* ³	IIC_1	8	2
Bit rate register_1	BRR_1	8	H'FF81* ³	SCI_1	8	2
I ² C bus status register_1* ⁴	ICSR_1	8	H'FF81* ³	IIC_1	8	2
Serial control register_1	SCR_1	8	H'FF82	SCI_1	8	2
Transmit data register_1	TDR_1	8	H'FF83	SCI_1	8	2
Serial status register_1	SSR_1	8	H'FF84	SCI_1	8	2
Receive data register_1	RDR_1	8	H'FF85	SCI_1	8	2
Smart card mode register_1	SCMR_1	8	H'FF86* ³	SCI_1	8	2
I ² C bus data register_1/Second slave address register_1* ⁴	ICDR_1 /SARX_1	8	H'FF86* ³	IIC_1	8	2
I ² C bus mode register_1/Slave address register_1* ⁴	ICMR_1 /SAR_1	8	H'FF87	IIC_1	8	2
A/D data register AH	ADDRAH	8	H'FF90	A/D	8	2
A/D data register AL	ADDRAL	8	H'FF91	A/D	8	2
A/D data register BH	ADDRBH	8	H'FF92	A/D	8	2
A/D data register BL	ADDRBL	8	H'FF93	A/D	8	2
A/D data register CH	ADDRCH	8	H'FF94	A/D	8	2
A/D data register CL	ADDRCL	8	H'FF95	A/D	8	2

Register Name	Abbrevia- tion	Bit No.	Address* ¹	Module	Data Width	Access State
A/D data register DH	ADDRDH	8	H'FF96	A/D	8	2
A/D data register DL	ADDRDL	8	H'FF97	A/D	8	2
A/D control/status register	ADCSR	8	H'FF98	A/D	8	2
A/D control register	ADCR	8	H'FF99	A/D	8	2
Timer control/status register_1	TCSR_1	8	H'FFA2(W) H'FFA2(R)	WDT_1	16	2
Timer counter_1	TCNT_1	8	H'FFA2(W) H'FFA3(R)	WDT_1	16	2
Flash memory control register 1	FLMCR1	8	H'FFA8	FLASH	8	2
Flash memory control register 2	FLMCR2	8	H'FFA9	FLASH	8	2
Erase block register 1	EBR1	8	H'FFAA	FLASH	8	2
Erase block register 2	EBR2	8	H'FFAB	FLASH	8	2
Flash memory power control register	FLPWCR	8	H'FFAC	FLASH	8	2
Port 1 register	PORT1	8	H'FFB0	PORT	8	2
Port 3 register	PORT3	8	H'FFB2	PORT	8	2
Port 4 register	PORT4	8	H'FFB3	PORT	8	2
Port 7 register	PORT7	8	H'FFB6	PORT	8	2
Port 9 register	PORT9	8	H'FFB8	PORT	8	2
Port F register	PORTF	8	H'FFBE	PORT	8	2

Notes: 1. Lower 16 bits of the address.

2. Allocated on the on-chip RAM. 32-bit bus when DTC accesses as register information, and 16-bit in other cases.

3. Part of registers SCI_0 and SCI_1 and part of registers IIC_0 and IIC_1*⁴ are allocated to the same address. Use the IICE bit of the serial control register X (SCRX) to select the register.

4. Supported only by the H8S/2268 Series.

5. Supported only by the H8S/2264 Series.

25.2 Register Bits

Register

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
MRA* ¹	SM1	SM0	DM1	DM0	MD1	MD0	DTS	Sz	DTC
SAR* ¹									
MRB* ¹	CHNE	DISEL	–	–	–	–	–	–	
DAR* ¹									
CRA* ¹									
CRB* ¹									
LPCR	DTS1	DTS0	CMX	–	SGS3	SGS2	SGS1	SGS0	LCD
LCR	–	PSW	ACT	DISP	CKS3	CKS2	CKS1	CKS0	
LCR2	LCDAB	–	HCKS* ⁴	SUPS* ⁴	CDS3	CDS2	CDS1	CDS0	
LCD RAM	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
MSTPCRD	MSTPD7	MSTPD6	MSTPD5	MSTPD4	MSTPD3	MSTPD2	MSTPD1	MSTPD0	SYSTEM
SCKCR2* ²	PHOE	RXD1S	SUBCKS1	SUBCKS0	PHCK3	PHCK2	PHCK1	PHCK0	
DTCR* ¹	DTEN	–	CLOE	RWOE	CLF1	CLF0	RWF1	RWF0	DTMF
DTLR* ¹	–	–	DTL5	DTL4	DTL3	DTL2	DTL1	DTL0	
TCR_4* ¹	ARSL	OVF	OVIE	–	–	CKS2	CKS1	CKS0	TMR_4
TCR_5* ¹	ARSL	OVF	OVIE	–	–	CKS2	CKS1	CKS0	
TCR_6* ¹	ARSL	OVF	OVIE	–	–	CKS2	CKS1	CKS0	
TCR_7* ¹	ARSL	OVF	OVIE	–	–	CKS2	CKS1	CKS0	
TCNT_4(R) /TLR_4(W)* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TCNT_5(R) /TLR_5(W)* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TCNT_6(R) /TLR_6(W)* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TCNT_7(R) /TLR_7(W)* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	

Register

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PHDDR	–	–	PH5DDR* ³	PH4DDR* ³	PH3DDR	PH2DDR	PH1DDR	PH0DDR	PORT
PJDDR	PJ7DDR	PJ6DDR	PJ5DDR	PJ4DDR	PJ3DDR	PJ2DDR	PJ1DDR	PJ0DDR	
PKDDR	PK7DDR	PK6DDR	PK5DDR	PK4DDR	PK3DDR	PK2DDR	PK1DDR	PK0DDR	
PLDDR	PL7DDR	PL6DDR	PL5DDR	PL4DDR	PL3DDR	PL2DDR	PL1DDR	PL0DDR	
PMDDR* ¹	PM7DDR	PM6DDR	PM5DDR	PM4DDR	PM3DDR	PM2DDR	PM1DDR	PM0DDR	
PNDDR* ¹	PN7DDR	PN6DDR	PN5DDR	PN4DDR	PN3DDR	PN2DDR	PN1DDR	PN0DDR	
PHDR	–	–	PHD5R* ³	PH4DR* ³	PH3DR	PH2DR	PH1DR	PH0DR	
PJDR	PJ7DR	PJ6DR	PJ5DR	PJ4DR	PJ3DR	PJ2DR	PJ1DR	PJ0DR	
PKDR	PK7DR	PK6DR	PK5DR	PK4DR	PK3DR	PK2DR	PK1DR	PK0DR	
PLDR	PL7DR	PL6DR	PL5DR	PL4DR	PL3DR	PL2DR	PL1DR	PL0DR	
PMDR* ¹	PM7DR	PM6DR	PM5DR	PM4DR	PM3DR	PM2DR	PM1DR	PM0DR	
PNDR* ¹	PN7DR	PN6DR	PN5DR	PN4DR	PN3DR	PN2DR	PN1DR	PN0DR	
PORTH	PH7	–	PH5* ³	PH4* ³	PH3	PH2	PH1	PH0	
PORTJ	PJ7	PJ6	PJ5	PJ4	PJ3	PJ2	PJ1	PJ0	
PORTK	PK7	PK6	PK5	PK4	PK3	PK2	PK1	PK0	
PORTL	PL7	PL6	PL5	PL4	PL3	PL2	PL1	PL0	
PORTM* ¹	PM7	PM6	PM5	PM4	PM3	PM2	PM1	PM0	
PORTN* ¹	PN7	PN6	PN5	PN4	PN3	PN2	PN1	PN0	
PJPCR	PJ7PCR	PJ6PCR	PJ5PCR	PJ4PCR	PJ3PCR	PJ2PCR	PJ1PCR	PJ0PCR	
WPCR	WPC7	WPC6	WPC5	WPC4	WPC3	WPC2	WPC1	WPC0	
IWPR	IWPF7	IWPF6	IWPF5	IWPF4	IWPF3	IWPF2	IWPF1	IWPF0	INT
IENR1	IENWP	–	–	–	–	–	–	–	
DADR_0* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	D/A
DADR_1* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
DACR* ¹	DAOE1	DAOE0	DAE	–	–	–	–	–	
SCRX	–	IICX1* ⁴	IICX0	IICE	FLSHE	–	–	–	IIC, FLASH
DDCSWR	–	–	–	–	CLR3	CLR2	CLR1	CLR0	IIC
TCR_2* ¹	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_2
TCR_3* ¹	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_3
TCSR_2* ¹	CMFB	CMFA	OVF	–	OS3	OS2	OS1	OS0	TMR_2
TCSR_3* ¹	CMFB	CMFA	OVF	–	OS3	OS2	OS1	OS0	TMR_3
TCORA_2* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_2
TCORA_3* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_3

Register

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCORB_2* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_2
TCORB_3* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_3
TCNT_2* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_2
TCNT_3* ¹	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_3
SMR_2	C / \bar{A}	CHR	PE	O / \bar{E}	STOP	MP	CKS1	CKS0	SCI_2
SMR_2	GM	BLK	PE	O / \bar{E}	BCP1	BCP0	CKS1	CKS0	
BRR_2	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SCR_2	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	
TDR_2	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SSR_2	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT	
SSR_2	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT	
RDR_2	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SCMR_2	–	–	–	–	SDIR	SINV	–	SMIF	
SBYCR	SSBY	STS2	STS1	STS0	–	–	–	–	SYSTEM
SYSCR	–	–	INTM1	INTM0	NMIEG	–	–	–	
SCKCR	–	–	–	–	–	SCK2	SCK1	SCK0	
MDCR	–	–	–	–	–	MDS2	MDS1	–	
MSTPCRA	MSTPA7	MSTPA6	MSTPA5	MSTPA4	MSTPA3	MSTPA2	MSTPA1	MSTPA0	
MSTPCRB	MSTPB7	MSTPB6	MSTPB5	MSTPB4	MSTPB3	MSTPB2	MSTPB1	MSTPB0	
MSTPCRC	MSTPC7	MSTPC6	MSTPC5	MSTPC4	MSTPC3	MSTPC2	MSTPC1	MSTPC0	
LPWRCR	DTON	LSON	NESEL	SUBSTP	RFCUT	–	STC1	STC0	
SEMR0	–	–	–	–	ABCS	ACS2	ACS1	ACS0	SCI_0
BARA* ¹	–	–	–	–	–	–	–	–	PBC
	BAA23	BAA22	BAA21	BAA20	BAA19	BAA18	BAA17	BAA16	
	BAA15	BAA14	BAA13	BAA12	BAA11	BAA10	BAA9	BAA8	
	BAA7	BAA6	BAA5	BAA4	BAA3	BAA2	BAA1	BAA0	
BARB* ¹	–	–	–	–	–	–	–	–	
	BAB23	BAB22	BAB21	BAB20	BAB19	BAB18	BAB17	BAB16	
	BAB15	BAB14	BAB13	BAB12	BAB11	BAB10	BAB9	BAB8	
	BAB7	BAB6	BAB5	BAB4	BAB3	BAB2	BAB1	BAB0	
BCRA* ¹	CMFA	CDA	BAMRA2	BAMRA1	BAMRA0	CSELA1	CSELA0	BIEA	
BCRB* ¹	CMFB	CDB	BAMRB2	BAMRB1	BAMRB0	CSELB1	CSELB0	BIEB	

Register

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
ISCRH	–	–	–	–	IRQ5SCB* ⁴	IRQ5SCA* ⁴	IRQ4SCB	IRQ4SCA	INT
ISCR L	IRQ3SCB	IRQ3SCA	–	–	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0SCA	
IER	–	–	IRQ5E* ⁴	IRQ4E	IRQ3E	–	IRQ1E	IRQ0E	
ISR	–	–	IRQ5F* ⁴	IRQ4F	IRQ3F	–	IRQ1F	IRQ0F	
DT CER* ¹	DTCE7	DTCE6	DTCE5	DTCE4	DTCE3	DTCE2	DTCE1	DTCE0	DTC
DTVECR* ¹	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0	
P1DDR	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR	PORT
P3DDR	–	–	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR	P30DDR	
P7DDR	P77DDR	P76DDR	P75DDR	P74DDR	P73DDR	P72DDR	P71DDR	P70DDR	
PFDDR	–	–	–	–	PF3DDR	–	–	–	
P3ODR	–	–	P35ODR	P34ODR	P33ODR	P32ODR	P31ODR	P30ODR	
TSTR	–	–	–	–	–	CST2	CST1	CST0* ⁴	
TSYR	–	–	–	–	–	SYNC2	SYNC1	SYNC0* ⁴	TPU
IPRA* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRB* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	INT
IPRC* ¹	–	–	–	–	–	IPR2	IPR1	IPR0	
IPRD* ¹	–	IPR6	IPR5	IPR4	–	–	–	–	
IPRE* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRF* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRG* ¹	–	IPR6	IPR5	IPR4	–	–	–	–	
IPRI* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRJ* ¹	–	–	–	–	–	IPR2	IPR1	IPR0	
IPRK* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRL* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRM* ¹	–	IPR6	IPR5	IPR4	–	IPR2	IPR1	IPR0	
IPRO* ¹	–	IPR6	IPR5	IPR4	–	–	–	–	
RAMER	–	–	–	–	RAMS	RAM2* ⁴	RAM1	RAM0	FLASH
P1DR	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR	PORT
P3DR	–	–	P35DR	P34DR	P33DR	P32DR	P31DR	P30DR	
P7DR	P77DR	P76DR	P75DR	P74DR	P73DR	P72DR	P71DR	P70DR	
PFDR	–	–	–	–	PF3DR	–	–	–	

Register

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCR_0* ¹	CCLR2	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_0
TMDR_0* ¹	–	–	BFB	BFA	MD3	MD2	MD1	MD0	
TIORH_0* ¹	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIORL_0* ¹	IOD3	IOD2	IOD1	IOD0	IOC3	IOC2	IOC1	IOC0	
TIER_0* ¹	TTGE	–	–	TCIEV	TGIED	TGIEC	TGIEB	TGIEA	
TSR_0* ¹	–	–	–	TCFV	TGFD	TGFC	TGFB	TGFA	
TCNT_0* ¹	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRA_0* ¹	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRB_0* ¹	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRC_0* ¹	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRD_0* ¹	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TCR_1	–	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_1
TMDR_1	–	–	–	–	MD3	MD2	MD1	MD0	
TIOR_1	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIER_1	TTGE	–	TCIEU* ⁴	TCIEV	–	–	TGIEB	TGIEA	
TSR_1	TCFD* ⁴	–	TCFU* ⁴	TCFV	–	–	TGFB	TGFA	
TCNT_1	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRA_1	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRB_1	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TCR_2	–	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_2
TMDR_2	–	–	–	–	MD3	MD2	MD1	MD0	
TIOR_2	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIER_2	TTGE	–	TCIEU* ⁴	TCIEV	–	–	TGIEB	TGIEA	
TSR_2	TCFD* ⁴	–	TCFU* ⁴	TCFV	–	–	TGFB	TGFA	

Register

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCNT_2	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	TPU_2
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRA_2	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TGRB_2	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	
	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
TCR_0	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_0
TCR_1	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_1
TCSR_0	CMFB	CMFA	OVF	ADTE	OS3	OS2	OS1	OS0	TMR_0
TCSR_1	CMFB	CMFA	OVF	–	OS3	OS2	OS1	OS0	TMR_1
TCORA_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_0
TCORA_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_1
TCORB_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_0
TCORB_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_1
TCNT_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_0
TCNT_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	TMR_1
TCSR_0	OVF	WT / \overline{IT}	TME	–	–	CKS2	CKS1	CKS0	WDT_0
TCNT_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
RSTCSR	WOVF	RSTE	–	–	–	–	–	–	
SMR_0	C / \overline{A}	CHR	PE	O / \overline{E}	STOP	MP	CKS1	CKS0	SCI_0
SMR_0	GM	BLK	PE	O / \overline{E}	BCP1	BCP0	CKS1	CKS0	
ICCR_0	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP	IIC_0
BRR_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	SCI_0
ICSR_0	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	IIC_0
SCR_0	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	SCI_0
TDR_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SSR_0	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT	
SSR_0	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT	
RDR_0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SCMR_0	–	–	–	–	SDIR	SINV	–	SMIF	
ICDR_0 / SARX_0	ICDR7 / SVAX6	ICDR6 / SVAX5	ICDR5 / SVAX4	ICDR4 / SVAX3	ICDR3 / SVAX2	ICDR2 / SVAX1	ICDR1 / SVAX0	ICDR0 / FSX	IIC_0
ICMR_0 / SAR_0	MLS / SVA6	WAIT / SVA5	CKS2 / SVA4	CKS1 / SVA3	CKS0 / SVA2	BC2 / SVA1	BC1 / SVA0	BC0 / FS	

Register

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
SMR_1	C / \bar{A}	CHR	PE	O / \bar{E}	STOP	MP	CKS1	CKS0	SCL_1
SMR_1	GM	BLK	PE	O / \bar{E}	BCP1	BCP0	CKS1	CKS0	
ICCR_1* ¹	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP	IIC_1
BRR_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	SCL_1
ICSR_1* ¹	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	IIC_1
SCR_1	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	SCL_1
TDR_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SSR_1	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT	
SSR_1	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT	
RDR_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
SCMR_1	–	–	–	–	SDIR	SINV	–	SMIF	
ICDR_1 / SARX_1* ¹	ICDR7 / SVAX6	ICDR6 / SVAX5	ICDR5 / SVAX4	ICDR4 / SVAX3	ICDR3 / SVAX2	ICDR2 / SVAX1	ICDR1 / SVAX0	ICDR0 / FSX	IIC_1
ICMR_1 / SAR_1* ¹	MLS / SVA6	WAIT / SVA5	CKS2 / SVA4	CKS1 / SVA3	CKS0 / SVA2	BC2 / SVA1	BC1 / SVA0	BC0 / FS	
ADDDRAH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	A/D
ADDRAL	AD1	AD0	–	–	–	–	–	–	
ADDRBH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	
ADDRBL	AD1	AD0	–	–	–	–	–	–	
ADDRCH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	
ADDRCL	AD1	AD0	–	–	–	–	–	–	
ADDRDH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	
ADDRDL	AD1	AD0	–	–	–	–	–	–	
ADCSR	ADF	ADIE	ADST	SCAN	CH3	CH2	CH1	CH0	
ADCR	TRGS1	TRGS0	–	–	CKS1	CKS0	–	–	
TCSR_1	OVF	WT / \bar{IT}	TME	PSS	RST / \bar{NMI}	CKS2	CKS1	CKS0	WDT_1
TCNT_1	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
FLMCR1	FWE	SWE1	ESU1	PSU1	EV1	PV1	E1	P1	FLASH
FLMCR2	FLER	–	–	–	–	–	–	–	
EBR1	EB7	EB6	EB5	EB4	EB3	EB2	EB1	EB0	
EBR2	–	–	–	–	EB11* ⁴	EB10* ⁴	EB9	EB8	
FLPWCR	PDWND	–	–	–	–	–	–	–	

Register

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PORT1	P17	P16	P15	P14	P13	P12	P11	P10	PORT
PORT3	–	–	P35	P34	P33	P32	P31	P30	
PORT4	P47	P46	P45	P44	P43	P42	P41	P40	
PORT7	P77	P76	P75	P74	P73	P72	P71	P70	
PORT9	P97	P96	–	–	–	–	–	–	
PORTF	–	–	–	–	PF3	–	–	–	

Notes: 1. Supported only by the H8S/2268 Series.

2. Supported only by the H8S/2264 Series.

3. Reserved in the H8S/2268 Series.

4. Reserved in the H8S/2264 Series.

25.3 Register States in Each Operating Mode

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
MRA* ¹	–	–	–	–	–	–	–	–	–	–	DTC
SAR* ¹	–	–	–	–	–	–	–	–	–	–	
MRB* ¹	–	–	–	–	–	–	–	–	–	–	
DAR* ¹	–	–	–	–	–	–	–	–	–	–	
CRA* ¹	–	–	–	–	–	–	–	–	–	–	
CRB* ¹	–	–	–	–	–	–	–	–	–	–	
LPCR	Initialized	–	–	–	–	–	–	–	–	Initialized	LCD
LCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
LCR2	Initialized	–	–	–	–	–	–	–	–	Initialized	
LCD RAM	–	–	–	–	–	–	–	–	–	–	
MSTPCRD	Initialized	–	–	–	–	–	–	–	–	Initialized	SYSTEM
SCKCR2* ²	Initialized	–	–	–	–	–	–	–	–	Initialized	
DTCR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	DTMF
DTLR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCR_4* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_4
TCR_5* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCR_6* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCR_7* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCNT_4/ TLR_4* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCNT_5/ TLR_5* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCNT_6/ TLR_6* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCNT_7/ TLR_7* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	PORT
PHDDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PJDDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PKDDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PLDDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PMDDR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
PNDDR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
PHDR	Initialized	–	–	–	–	–	–	–	–	Initialized	

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
PJDR	Initialized	–	–	–	–	–	–	–	–	Initialized	PORT
PKDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PLDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PMDR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
PNDR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORTH	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORTJ	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORTK	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORTL	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORTM* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	INT
PORTN* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
PJPCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
WPCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
IWPR	Initialized	–	–	–	–	–	–	–	–	Initialized	
IENR1	Initialized	–	–	–	–	–	–	–	–	Initialized	
DADR_0* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	D/A
DADR_1* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
DACR	Initialized	–	–	–	–	–	–	–	–	Initialized	
SCRX	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC, FLASH
DDCSWR	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCR_2* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_2
TCR_3* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_3
TCSR_2* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_2
TCSR_3* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_3
TCORA_2* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_2
TCORA_3* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_3
TCORB_2* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_2
TCORB_3* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_3
TCNT_2* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_2
TCNT_3* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_3
SMR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_2
BRR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
SCR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
TDR_2	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_2
SSR_2	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_2	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
SBYCR	Initialized	–	–	–	–	–	–	–	–	Initialized	SYSTEM
SYSCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
SCKCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
MDCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
MSTPCRA	Initialized	–	–	–	–	–	–	–	–	Initialized	
MSTPCRB	Initialized	–	–	–	–	–	–	–	–	Initialized	
MSTPCRC	Initialized	–	–	–	–	–	–	–	–	Initialized	
LPWRCR	Initialized	–	–	–	–	–	–	–	–	Initialized	
SEMR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_0
BARA* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	PBC
BARB* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
BCRA* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
BCRB* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
ISCRH	Initialized	–	–	–	–	–	–	–	–	Initialized	INT
ISCR L	Initialized	–	–	–	–	–	–	–	–	Initialized	
IER	Initialized	–	–	–	–	–	–	–	–	Initialized	
ISR	Initialized	–	–	–	–	–	–	–	–	Initialized	DTC
DTCER* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
DTVECR* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
P1DDR	Initialized	–	–	–	–	–	–	–	–	Initialized	PORT
P3DDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
P7DDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
PFDDR	Initialized	–	–	–	–	–	–	–	–	Initialized	
P3ODR	Initialized	–	–	–	–	–	–	–	–	Initialized	TPU
TSTR	Initialized	–	–	–	–	–	–	–	–	Initialized	
TSYR	Initialized	–	–	–	–	–	–	–	–	Initialized	
IPRA* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	INT
IPRB* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
IPRC* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
IPRD* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
IPRE* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	INT
IPRF* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRG* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRI* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRJ* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRK* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRL* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRM* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRO* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
RAMER	Initialized	—	—	—	—	—	—	—	—	Initialized	FLASH
P1DR	Initialized	—	—	—	—	—	—	—	—	Initialized	
P3DR	Initialized	—	—	—	—	—	—	—	—	Initialized	
P7DR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PFDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCR_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_0
TMDR_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIORH_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIORL_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRC_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_1
TGRD_0* ¹	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TMDR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIOR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_1	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_2
TCR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
TMDR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	TPU_2
TIOR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
TIER_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
TSR_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCNT_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
TGRA_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
TGRB_2	Initialized	–	–	–	–	–	–	–	–	Initialized	
TCR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_0
TCR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_1
TCSR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_0
TCSR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_1
TCORA_0	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_0
TCORA_1	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_1
TCORB_0	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_0
TCORB_1	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_1
TCNT_0	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_0
TCNT_1	Initialized	–	–	–	–	–	–	–	–	Initialized	TMR_1
TCSR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	WDT_0
TCNT_0	Initialized	–	–	–	–	–	–	–	–	Initialized	
RSTCSR	Initialized	–	–	–	–	–	–	–	–	Initialized	
SMR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_0
ICCR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC_0
BRR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_0
ICSR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC_0
SCR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_0
TDR_0	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SSR_0	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_0	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	
ICDR_0/ SARX_0	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC_0
ICMR_0/ SAR_0	Initialized	–	–	–	–	–	–	–	–	Initialized	

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
SMR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_1
ICCR_1* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC_1
BRR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_1
ICSR_1* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC_1
SCR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	SCI_1
TDR_1	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SSR_1	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_1	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	
ICDR_1/ SARX_1* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	IIC_1
ICMR_1/ SAR_1* ¹	Initialized	–	–	–	–	–	–	–	–	Initialized	
ADDDRAH	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	A/D
ADDRAL	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADDRBH	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADDRBL	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADDRCH	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADDRCL	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADDRDH	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADDRDL	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADCSR	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
ADCR	Initialized	–	–	–	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
TCSR_1	Initialized	–	–	–	–	–	–	–	–	Initialized	WDT_1
TCNT_1	Initialized	–	–	–	–	–	–	–	–	Initialized	
FLMCR1	Initialized	–	–	–	–	–	–	–	Initialized	Initialized	FLASH
FLMCR2	Initialized	–	–	–	–	–	–	–	Initialized	Initialized	
EBR1	Initialized	–	–	–	–	–	–	–	Initialized	Initialized	
EBR2	Initialized	–	–	–	–	–	–	–	Initialized	Initialized	
FLPWCR	Initialized	–	–	–	–	–	–	–	Initialized	Initialized	
PORT1	Initialized	–	–	–	–	–	–	–	–	Initialized	PORT
PORT3	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORT4	Initialized	–	–	–	–	–	–	–	–	Initialized	

Register Name	Reset	High-speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
PORT7	Initialized	–	–	–	–	–	–	–	–	Initialized	PORT
PORT9	Initialized	–	–	–	–	–	–	–	–	Initialized	
PORTF	Initialized	–	–	–	–	–	–	–	–	Initialized	

Notes: – is not initialized.

1. Supported only by the H8S/2268 Series.
2. Supported only by the H8S/2264 Series.

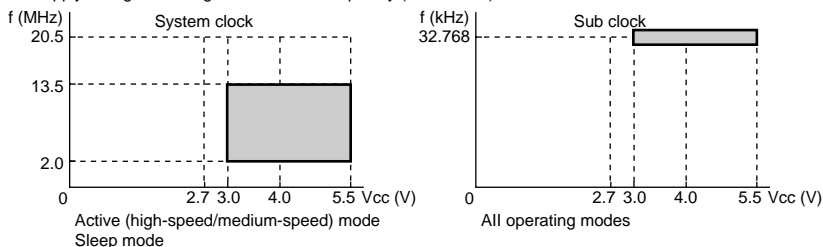
Section 26 Electrical Characteristics

26.1 Power Supply Voltage and Operating Frequency Range

Power supply voltage and operating frequency ranges (shaded areas) are shown in figure 26.1.

Condition A (F-ZTAT version)	: $V_{CC} = 3.0$ to $5.5V$, $AV_{CC} = 2.7$ to $5.5V$, $V_{ref} = 2.7V$ to AV_{CC} , $V_{SS} = AV_{SS} = 0V$, $\phi = 32.768kHz$, 2 to $13.5MHz$, $T_a = -20$ to $+75$ (regular specification), $T_a = -40$ to $+85$ (wide range specification)
Condition B (mask ROM version)	: $V_{CC} = 2.7$ to $5.5V$, $AV_{CC} = 2.7$ to $5.5V$, $V_{ref} = 2.7V$ to AV_{CC} , $V_{SS} = AV_{SS} = 0V$, $\phi = 32.768kHz$, 2 to $13.5MHz$, $T_a = -20$ to $+75$ (regular specification), $T_a = -40$ to $+85$ (wide range specification)
Condition C (F-ZTAT version)	: $V_{CC} = 4.0$ to $5.5V$, $AV_{CC} = 4.0$ to $5.5V$, $V_{ref} = 4.0V$ to AV_{CC} , $V_{SS} = AV_{SS} = 0V$, $\phi = 32.768kHz$, 10 to $20.5MHz$, $T_a = -20$ to $+75$ (regular specification), $T_a = -40$ to $+85$ (wide range specification)
Condition D (mask ROM version)	: $V_{CC} = 4.0$ to $5.5V$, $AV_{CC} = 4.0$ to $5.5V$, $V_{ref} = 4.0V$ to AV_{CC} , $V_{SS} = AV_{SS} = 0V$, $\phi = 32.768kHz$, 10 to $20.5MHz$, $T_a = -20$ to $+75$ (regular specification), $T_a = -40$ to $+85$ (wide range specification)

(1) Power supply voltage and range of oscillation frequency (condition A)



(2) Power supply voltage and range of oscillation frequency (condition B)

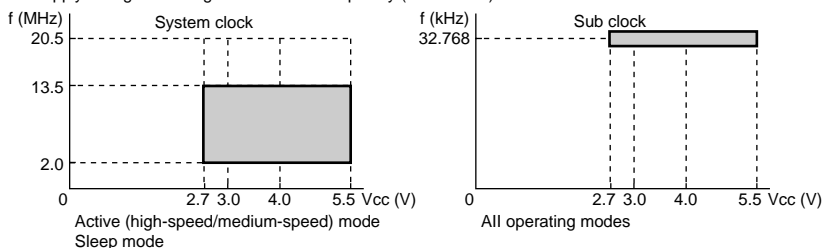
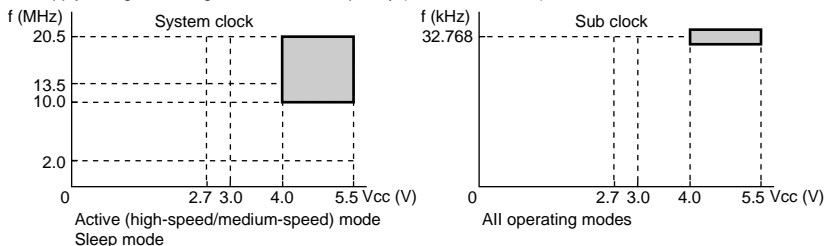
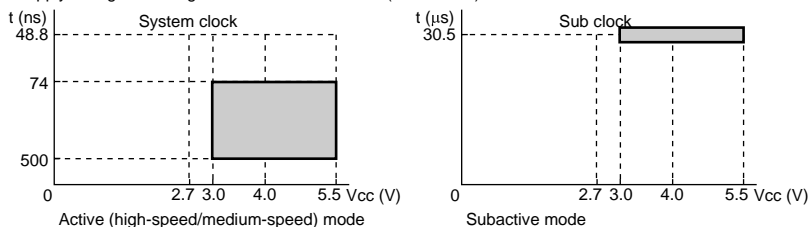


Figure 26.1 Power Supply Voltage and Operating Ranges (1)

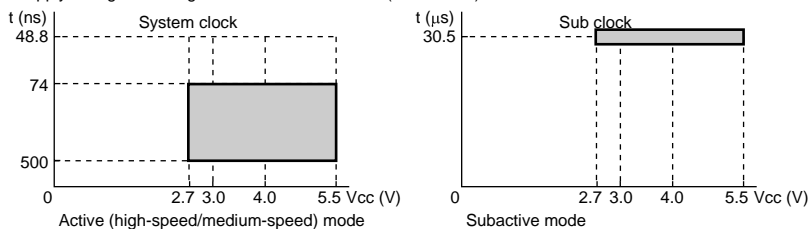
(3) Power supply voltage and range of oscillation frequency (condition C and D)



(4) Power supply voltage and range of instruction execution (condition A)



(5) Power supply voltage and range of instruction execution (condition B)



(6) Power supply voltage and range of instruction execution (condition C and D)

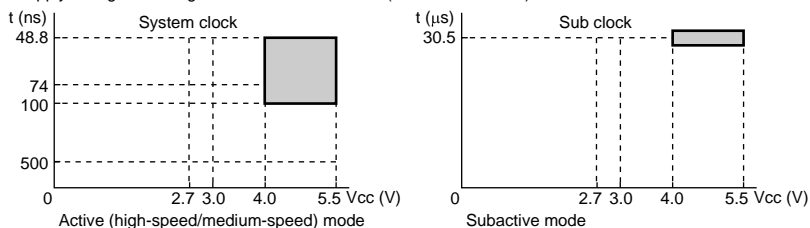


Figure 26.1 Power Supply Voltage and Operating Ranges (2)

26.2 Electrical Characteristics of the H8S/2268 Series

26.2.1 Absolute Maximum Ratings

Table 26.1 lists the absolute maximum ratings.

Table 26.1 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	−0.3 to +7.0	V
	CV_{CC}	−0.3 to +4.3	V
Input voltage (except port 4, 9, PH7)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (port 4, 9, PH7)	V_{in}	−0.3 to $AV_{CC} + 0.3$	V
Reference voltage	V_{ref}	−0.3 to $AV_{CC} + 0.3$	V
Analog power supply voltage	AV_{CC}	−0.3 to +7.0	V
Analog input voltage	V_{AN}	−0.3 to $AV_{CC} + 0.3$	V
Operating temperature	T_{opr}	Regular specifications: −20 to +75*	°C
		Wide-range specifications: −40 to +85*	°C
Storage temperature	T_{stg}	−55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum rating are exceeded.

Note: * Operating temperature range for flash memory programming/erasing is $T_a = -20$ to +75°C.

26.2.2 DC Characteristics

Table 26.2 lists the DC characteristics. Table 26.3 lists the permissible output currents. Table 26.4 lists the bus drive characteristics.

Table 26.2 DC Characteristics (1)

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	$\overline{IRQ0}$, $\overline{IRQ1}$,	VT^-	$V_{CC} \times 0.2$	—	—	V
	$\overline{IRQ3}$ to $\overline{IRQ5}$,	VT^+	—	—	$V_{CC} \times 0.8$	V
	$\overline{WKP0}$ to $\overline{WKP7}$	$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	—	V $V_{CC} = 4.0\text{ to }5.5\text{ V}$
			$V_{CC} \times 0.04$	—	—	V $V_{CC} = 2.7\text{ to }4.0\text{ V}$
Input high voltage	\overline{RES} , \overline{STBY} , NMI, FWE, MD2, MD1	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
	EXTAL, Port 1, 3, 7, F, J to N, PH0 to PH3		$V_{CC} \times 0.8$	—	$V_{CC} + 0.3$	V
	Port 4, 9, PH7		$V_{CC} \times 0.8$	—	$AV_{CC} + 0.3$	V
Input low voltage	\overline{RES} , \overline{STBY} , FWE, MD2, MD1	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V
	NMI, EXTAL, Port 1, 3, 4, 7, 9, F, H, J to N		-0.3	—	$V_{CC} \times 0.2$	V

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Output high voltage	All output pins except P34 and P35, PH0 to PH3, and Port J to N	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = - 200\ \mu A$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = - 1\ mA$
	P34 and P35* ²		$V_{CC} - 2.7$	—	—	V	$I_{OH} = - 100\ \mu A$ $V_{CC} = 4.0\ to\ 5.5\ V$
	PH0 to PH3, Port J to N		$V_{CC} - 0.5$	—	—	V	$I_{OH} = - 200\ \mu A$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = - 1\ mA$ $V_{CC} = 4.0\ to\ 5.5\ V$
Output low voltage	All output pins* ³	V_{OL}	—	—	0.4	V	$I_{OL} = - 0.8\ mA$
	Port 7		—	—	1.0	V	$I_{OL} = 5\ mA$
							$I_{OL} = 10\ mA,$ $V_{CC} = 4.0\ to\ 5.5\ V$
Input leakage current	\overline{RES}	$ I_{in} $	—	—	1.0	μA	$V_{in} = 0.5\ to\ V_{CC} - 0.5\ V$
	\overline{STBY} , NMI, FWE, MD2, MD1		—	—	1.0	μA	
	Port 4, 9		—	—	1.0	μA	$V_{in} = 0.5\ to\ AV_{CC} - 0.5\ V$
	PH7		—	—	1.0	μA	$V_{in} = 0.5\ to\ AV_{CC} - 0.5\ V$
Three-state leakage current (off state)	Port 1, 3, 7, Port F, J to N, PH0 to PH3	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5\ to\ AV_{CC} - 0.5\ V$
Input pull-up MOS current	Port J	$-I_p$	10	—	300	μA	$V_{in} = 0\ V$

- Notes: 1. If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 2.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
2. P35/SCK1/SCL0 and P34/SDA0 are NMOS push/pull outputs.
To output high level signal from SCL0 and SDA0 (ICE = 1), pull-up resistance must be connected externally.
P35/SCK1 and P34 (ICE = 0) are driven high by NMOS. To output high when $V_{CC} = 4.0V$ or less, pull-up resistance should be connected externally.
3. When ICE = 0. To output low when bus drive function is selected is determined in table 26.4, Bus Drive Characteristics.

Table 26.2 DC Characteristics (2)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)*¹

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	$\overline{IRQ0}$, $\overline{IRQ1}$,	VT	$V_{CC} \times 0.2$	—	—	V	
	$\overline{IRQ3}$ to $\overline{IRQ5}$,	VT ⁺	—	—	$V_{CC} \times 0.8$	V	
	WKP0 to WKP7	VT ⁺ - VT	$V_{CC} \times 0.05$	—	—	V	
Input high voltage	\overline{RES} , \overline{STBY} , NMI, FWE, MD2, MD1	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V	
	EXTAL, Port 1, 3, 7, F, J to N, PH0 to PH3		$V_{CC} \times 0.8$	—	$V_{CC} + 0.3$	V	
	Port 4, 9, PH7		$V_{CC} \times 0.8$	—	$V_{CC} + 0.3$	V	
Input low voltage	\overline{RES} , \overline{STBY} , FWE, MD2, MD1	V_{IL}	- 0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, Port 1, 3, 4, 7, 9, F, H, J to N		- 0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins except P34 and P35, PH0 to PH3, and Port J to N	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = - 200\text{ }\mu\text{A}$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = - 1\text{ mA}$
	P34 and P35* ²		$V_{CC} - 2.7$	—	—	V	$I_{OH} = - 100\text{ }\mu\text{A}$
	PH0 to PH3, Port J to N		$V_{CC} - 0.5$	—	—	V	$I_{OH} = - 200\text{ }\mu\text{A}$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = - 1\text{ mA}$

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Output low voltage	All output pins*3	V_{OL}	—	—	0.4	V	$I_{OL} = 0.8 \text{ mA}$
	Port 7		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
Input leakage current	\overline{RES}	$ I_{in} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	\overline{STBY} , NMI, FWE, MD2, MD1		—	—	1.0	μA	V
	Port 4, 9		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
	PH7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
Three-state leakage current (off state)	Port 1, 3, 7, Port F, J to N, PH0 to PH3	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
Input pull-up MOS current	Port J	$-I_p$	50	—	300	μA	$V_{in} = 0 \text{ V}$

- Notes:
1. If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 4.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
 2. P35/SCK1/SCL0 and P34/SDA0 are NMOS push/pull outputs.
To output high level signal from SCL0 and SDA0 ($ICE = 1$), pull-up resistance must be connected externally.
P35/SCK1 and P34 ($ICE = 0$) are driven high by NMOS.
 3. When $ICE = 0$. To output low when bus drive function is selected is determined in table 26.4, Bus Drive Characteristics.

Table 26.2 DC Characteristics (3)

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	–	–	30	pF	$V_{in} = 0\text{ V}$
	NMI		–	–	30	pF	$f = 1\text{ MHz}$
	P32 to P35		–	–	20	pF	$T_a = 25^{\circ}\text{C}$
	All input pins except \overline{RES} , NMI, P32 to P35		–	–	15	pF	
Current consumption* ²	Normal operation	I_{CC} * ⁴	–	18 $V_{CC} = 3.0\text{ V}$	30 $V_{CC} = 5.5\text{ V}$	mA	$f = 13.5\text{ MHz}$
	Sleep mode		–	13 $V_{CC} = 3.0\text{ V}$	22 $V_{CC} = 5.5\text{ V}$	mA	$f = 13.5\text{ MHz}$
	All modules stopped		–	10	–	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Medium-speed mode ($\phi/32$)		–	12	–	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Subactive mode		–	60	110	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD lighting)
	Subsleep mode		–	50	90	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD lighting)
	Watch mode		–	4	25	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD and TMR4 not used, WDT_1 operates)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption* ²	Standby mode* ³	I_{CC} * ⁴	—	0.5	10	μA	$T_a \leq 50^\circ\text{C}$
				$V_{CC} = 3.0\text{ V}$	$V_{CC} = 5.5\text{ V}$		32.768 kHz not used
				—	50		$50^\circ\text{C} < T_a$
					$V_{CC} = 5.5\text{ V}$		32.768 kHz not used
Analog power supply current	During A/D conversion, D/A conversion, DTMF output	AI_{CC}	—	1.0	2.4	mA	
	Waiting for A/D conversion, D/A conversion, DTMF stopped		—	0.01	5.0	μA	
Reference current	During A/D conversion, D/A conversion	AI_{CC}	—	1.0	2.2	mA	
	Waiting for A/D conversion, D/A conversion		—	0.01	5.0	μA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

- Notes: 1. If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 2.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC1} for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2\text{ V}$, V_{IL} max. = 0.2 V with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 3.0\text{ V}$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = 0.2 V .
4. I_{CC} depends on V_{CC} and f as follows (reference):
 I_{CC} max. = $4.0\text{ (mA)} + 0.64\text{ (mA/V)} \times V_{CC} + 0.75\text{ (mA/MHz)} \times f + 0.15\text{ (mA/(MHz} \bullet \text{V))} \times V_{CC} \times f$ (normal operation)
 I_{CC} max. = $3.0\text{ (mA)} + 0.60\text{ (mA/V)} \times V_{CC} + 0.60\text{ (mA/MHz)} \times f + 0.10\text{ (mA/(MHz} \bullet \text{V))} \times V_{CC} \times f$ (sleep mode)

Table 26.2 DC Characteristics (4)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	–	–	30	pF	$V_{in} = 0\text{ V}$
	NMI		–	–	30	pF	$f = 1\text{ MHz}$
	P32 to P35		–	–	20	pF	$T_a = 25^{\circ}\text{C}$
	All input pins except \overline{RES} , NMI, P32 to P35		–	–	15	pF	
Current consumption* ²	Normal operation	I_{CC} ^{*4}	–	TBD $V_{CC} = 3.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 13.5\text{ MHz}$
	Sleep mode		–	TBD $V_{CC} = 3.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 13.5\text{ MHz}$
	All modules stopped		–	TBD	–	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Medium-speed mode ($\phi/32$)		–	TBD	–	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Subactive mode		–	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD lighting)
	Subsleep mode		–	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD lighting)
	Watch mode		–	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD and TMR4 not used, WDT_1 operates)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption* ²	Standby mode* ³	I_{CC}^{*4}	—	TBD	TBD	μA	$T_a \leq 50^{\circ}C$
				$V_{CC} = 3.0 V$	$V_{CC} = 5.5 V$		32.768 kHz not used
				—	TBD		$50^{\circ}C < T_a$
					$V_{CC} = 5.5 V$		32.768 kHz not used
Analog power supply current	During A/D conversion, D/A conversion, DTMF output	AI_{CC}	—	TBD	TBD	mA	
	Waiting for A/D conversion, D/A conversion, DTMF stopped		—	TBD	TBD	μA	
Reference current	During A/D conversion, D/A conversion	AI_{CC}	—	TBD	TBD	mA	
	Waiting for A/D conversion, D/A conversion		—	TBD	TBD	μA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

- Notes: 1. If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 2.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC1} for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2 V$, V_{IL} max. = 0.2 V with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7 V$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = 0.2 V.
4. I_{CC} depends on V_{CC} and f as follows (reference):
- $$I_{CC} \text{ max.} = \text{TBD (mA)} + \text{TBD (mA/V)} \times V_{CC} + \text{TBD (mA/MHz)} \times f + \text{TBD (mA/(MHz} \bullet V)) \times V_{CC} \times f \text{ (normal operation)}$$
- $$I_{CC} \text{ max.} = \text{TBD (mA)} + \text{TBD (mA/V)} \times V_{CC} + \text{TBD (mA/MHz)} \times f + \text{TBD (mA/(MHz} \bullet V)) \times V_{CC} \times f \text{ (sleep mode)}$$

Table 26.2 DC Characteristics (5)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$
(wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	–	–	30	pF	$V_{in} = 0\text{ V}$
	NMI		–	–	30	pF	$f = 1\text{ MHz}$
	P32 to P35		–	–	20	pF	$T_a = 25^\circ\text{C}$
	All input pins except \overline{RES} , NMI, P32 to P35		–	–	15	pF	
Current consumption* ²	Normal operation	I_{CC} ^{*4}	–	30 $V_{CC} = 5.0\text{ V}$	40 $V_{CC} = 5.5\text{ V}$	mA	$f = 20.5\text{ MHz}$
	Sleep mode		–	22 $V_{CC} = 5.0\text{ V}$	30 $V_{CC} = 5.5\text{ V}$	mA	$f = 20.5\text{ MHz}$
	All modules stopped		–	15	–	mA	$f = 20.5\text{ MHz}$, $V_{CC} = 5.0\text{ V}$ (reference values)
	Medium-speed mode ($\phi/32$)		–	19	–	mA	$f = 20.5\text{ MHz}$, $V_{CC} = 5.0\text{ V}$ (reference values)
	Subactive mode		–	70	120	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{ V}$ (LCD lighting)
	Subsleep mode		–	60	100	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{ V}$ (LCD lighting)
	Watch mode		–	5	30	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{ V}$ (LCD and TMR4 not used, WDT_1 operates)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption*2	Standby mode*3	I_{CC}^{*4}	—	1.0	10	μA	$T_a \leq 50^\circ\text{C}$
				$V_{CC} = 5.0\text{ V}$	$V_{CC} = 5.5\text{ V}$		32.768 kHz not used
				—	50		$50^\circ\text{C} < T_a$
					$V_{CC} = 5.5\text{ V}$		32.768 kHz not used
Analog power supply current	During A/D conversion, D/A conversion, DTMF output	AI_{CC}	—	1.5	2.5	mA	
	Waiting for A/D conversion, D/A conversion, DTMF stopped		—	0.01	5.0	μA	
Reference current	During A/D conversion, D/A conversion	AI_{CC}	—	1.5	2.2	mA	
	Waiting for A/D conversion, D/A conversion		—	0.01	5.0	μA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

- Notes: 1. If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 4.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC1} for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2\text{ V}$, V_{IL} max. = 0.2 V with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 4.0\text{ V}$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = 0.2 V .
4. I_{CC} depends on V_{CC} and f as follows (reference):
 I_{CC} max. = $4.0\text{ (mA)} + 0.64\text{ (mA/V)} \times V_{CC} + 0.75\text{ (mA/MHz)} \times f + 0.15\text{ (mA/(MHz} \cdot \text{V))} \times V_{CC} \times f$ (normal operation)
 I_{CC} max. = $3.0\text{ (mA)} + 0.60\text{ (mA/V)} \times V_{CC} + 0.60\text{ (mA/MHz)} \times f + 0.10\text{ (mA/(MHz} \cdot \text{V))} \times V_{CC} \times f$ (sleep mode)

Table 26.2 DC Characteristics (6) — Preliminary —

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V}$ to 5.5V , $AV_{CC} = 4.0\text{V}$ to 5.5V , $V_{ref} = 4.0\text{V}$ to AV_{CC} , $V_{SS} = AV_{SS} = 0\text{V}$, $T_a = -20^\circ\text{C}$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C}$ to $+85^\circ\text{C}$ (wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	—	—	30	pF	$V_{in} = 0\text{V}$
	NMI		—	—	30	pF	$f = 1\text{MHz}$
	P32 to P35		—	—	20	pF	$T_a = 25^\circ\text{C}$
	All input pins except \overline{RES} , NMI, P32 to P35		—	—	15	pF	
Current consumption* ²	Normal operation	I_{CC}^{*4}	—	TBD $V_{CC} = 5.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 20.5\text{MHz}$
	Sleep mode		—	TBD $V_{CC} = 5.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 20.5\text{MHz}$
	All modules stopped		—	TBD	—	mA	$f = 20.5\text{MHz}$, $V_{CC} = 5.0\text{V}$ (reference values)
	Medium-speed mode ($\phi/32$)		—	TBD	—	mA	$f = 20.5\text{MHz}$, $V_{CC} = 5.0\text{V}$ (reference values)
	Subactive mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD lighting)
	Subsleep mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD lighting)
	Watch mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD and TMR4 not used, WDT_1 operates)

Table 26.3 Permissible Output Currents

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Item		Symbol	Min.	Typ.	Max.	Unit
Permissible output low current (per pin)	Port 7	I_{OL}	—	—	10	mA
	SCL1, SCL0, SDA1, SDA0		—	—	10	mA
	Output pins except port 7, SCL1, SCL0, SDA1, SDA0		—	—	1.0	mA
Permissible output low current (total)	Total of port 7	ΣI_{OL}	—	—	30	mA
	Total of all output pins including port 7		—	—	60	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	1.0	mA
Permissible output high current (total)	Total of all output pins	$-\Sigma I_{OH}$	—	—	30	mA

Note: To protect chip reliability, do not exceed the output current values in table 26.3.

Table 26.4 Bus Drive Characteristics (1)

Condition A (F-ZTAT version): $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{ref} = 2.7 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)*¹, Target pins: SCL1, SCL0, SDA1, SDA0

Condition B (Masked-ROM version): $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{ref} = 2.7 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)*¹, Target pins: SCL1, SCL0, SDA1, SDA0

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	VT	$V_{CC} \times 0.3$	—	—	V	
	VT ⁺	—	—	$V_{CC} \times 0.7$		
	VT ⁺ - VT	0.4	—	—		$V_{CC} = 4.0 \text{ to } 5.5 \text{ V}$
		$V_{CC} \times 0.05$	—	—		$V_{CC} = 2.7 \text{ to } 4.0 \text{ V}$
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$	V	
Output low voltage	V_{OL}	—	—	0.5	V	$I_{OL} = 8 \text{ mA}$, $V_{CC} = 4.0 \text{ to } 5.5 \text{ V}$
		—	—	0.4		$I_{OL} = 3 \text{ mA}$
Input capacitance	C_{IN}	—	—	20	pF	$V_{IN} = 0 \text{ V}$, $f = 1 \text{ MHz}$, $T_a = 25^\circ\text{C}$
Three-state leakage current (off state)	$ I_{ST} $	—	—	1.0	μA	$V_{IN} = 0.5 \text{ to } V_{CC} - 0.5$
SDL, SDA output fall time	t_{of}	$20 + 0.1Cb$	—	250	ns	

Note: If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 2.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$

Table 26.4 Bus Drive Characteristics (2)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$
(wide-range specifications)*¹, Target pins: SCL1, SCL0, SDA1, SDA0

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$
(wide-range specifications)*¹, Target pins: SCL1, SCL0, SDA1, SDA0

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	V_T	$V_{CC} \times 0.3$	—	—	V	
	V_T^+	—	—	$V_{CC} \times 0.7$		
	$V_T^+ - V_T$	0.4	—	—		
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$	V	
Output low voltage	V_{OL}	—	—	0.5	V	$I_{OL} = 8\text{ mA}$
		—	—	0.4		$I_{OL} = 3\text{ mA}$
Input capacitance	C_{in}	—	—	20	pF	$V_{IN} = 0\text{ V}$, $f = 1\text{ MHz}$, $T_a = 25^\circ\text{C}$
Three-state leakage current (off state)	$ I_{STT} $	—	—	1.0	μA	$V_{IN} = 0.5\text{ to } V_{CC} - 0.5$
SDL, SDA output fall time	t_{Of}	$20 + 0.1Cb$	—	250	ns	

Note: If the A/D and D/A converters and DTMF generation circuit are not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 4.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$

26.2.3 AC Characteristics

Figure 26.2 show, the test conditions for the AC characteristics.

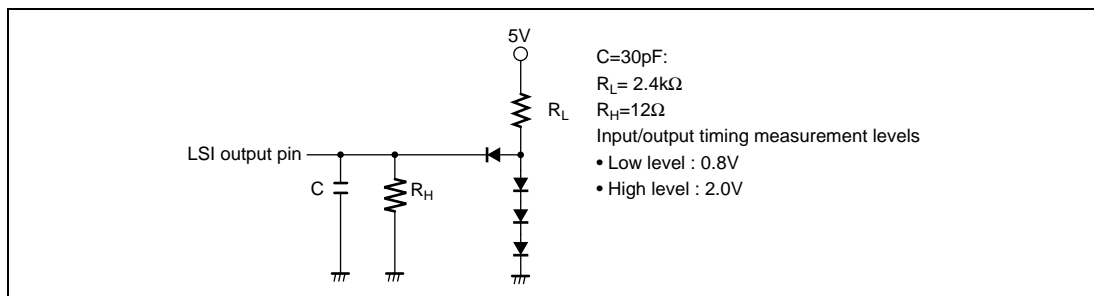


Figure 26.2 Output Load Circuit

Clock Timing: Table 26.5 lists the clock timing.

Table 26.5 Clock Timing

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{ref} = 4.0\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{ref} = 4.0\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A and B			Condition C and D			Unit	Test Conditions
		Min.	Typ.	Max.	Min.	Typ.	Max.		
Clock cycle time	t _{cyc}	74	—	500	48.8	—	100	ns	
Clock oscillator settling time at reset (crystal)	t _{OSC1}	20	—	—	10	—	—	ms	Figure 26.5
Clock oscillator settling time in software standby (crystal)	t _{OSC2}	8	—	—	8	—	—	ms	Figure 26.3
External clock settling delay time	t _{DEXT}	500	—	—	500	—	—	μs	Figure 26.5
Sub clock oscillator settling time	t _{OSC3}	—	—	2	—	—	2	s	
Sub clock oscillator frequency	f _{SUB}	—	32.768	—	—	32.768	—	kHz	
Sub clock (ϕ _{SUB}) cycle time	t _{SUB}	—	30.5	—	—	30.5	—	μs	

Control Signal Timing: Table 26.6 lists the control signal timing.

Table 26.6 Control Signal Timing

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Min.	Max.	Unit	Test Conditions
\overline{RES} pulse width	t_{RESW}	20	—	t_{cyc}	Figure 26.6
NMI pulse width (exiting software standby mode)	t_{NMW}	200	—	ns	Figure 26.7
\overline{IRQ} pulse width (exiting software standby mode)	t_{IRW}	200	—	ns	

Timing of On-Chip Peripheral Modules: Table 26.7 lists the timing of on-chip peripheral modules. Table 26.8 lists the I²C bus timing.

Table 26.7 Timing of On-Chip Peripheral Modules

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

			Condition A, B Condition C, D						
Item		Symbol	Min.	Max.	Min.	Max.	Unit	Test Conditions	
TPU	Timer clock pulse width	Single edge	t_{TCKWH}	1.5	—	1.5	—	t_{cyC}	Figure 26.8
		Both edges	t_{TCKWL}	2.5	—	2.5	—		
TMR_0 to TMR_3	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	1.5	—	t_{cyC}	Figure 26.9
		Both edges	t_{TMCWL}	2.5	—	2.5	—		
TMR_4	Timer clock pulse width	t_{TMCWH} t_{TMCWL}	1.5	—	1.5	—	t_{cyC}		
SCI	Input clock cycle	Asynchronous	t_{SCYC}	—	4	—	t_{cyC}	Figure 26.10	
		Synchronous		—	6	—			
	Input clock pulse width	t_{SCKW}	0.4	0.6	0.4	0.6	t_{SoyC}		
	Input clock rise time	t_{SCKI}	—	1.5	—	1.5	t_{cyC}		
	Input clock fall time	t_{SCKI}	—	1.5	—	1.5			
	Transmit data delay time	t_{TXD}	—	75	—	50	ns	Figure 26.11	
	Receive data setup time (synchronous)	t_{RXS}	75	—	50	—	ns		
	Receive data hold time (synchronous)	t_{RXH}	75	—	50	—	ns		

Table 26.8 I²C Bus Timing

Conditions: $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 5 \text{ MHz}$ to maximum operating frequency
 $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +80^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions	Remarks
SCL input cycle time	t_{SCL}	$12t_{cyc}$	—	—	ns		Figure 26.12
SCL input high pulse width	t_{SCLH}	$3t_{cyc}$	—	—	ns		
SCL input low pulse width	t_{SCLL}	$5t_{cyc}$	—	—	ns		
SCL, SDA input rise time	t_{Sr}	—	—	$7.5t_{cyc}^*$	ns		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse elimination time	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		
Retransmission 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}	$0.5t_{cyc}$	—	—	ns		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA load capacitance	C_b	—	—	400	pF		

Note: * t_{Sr} can be set to $7.5 t_{cyc}$ or $17.5 t_{cyc}$ according to the clock used for the I²C module. For details, see section 14.5 Usage Notes.

26.2.4 A/D Conversion Characteristics

Table 26.9 lists the A/D conversion characteristics.

Table 26.9 A/D Conversion Characteristics

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Condition A, B			Condition C, D			Unit
	13.5MHz			20.5 MHz			
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Resolution	10	10	10	10	10	10	bits
Conversion time	9.6	—	—	6.3	—	—	μs
Analog input capacitance	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	5	kΩ
Nonlinearity error	—	—	±6.0	—	—	±3.0	LSB
Offset error	—	—	±4.0	—	—	±2.0	LSB
Full-scale error	—	—	±4.0	—	—	±2.0	LSB
Quantization error	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±4.0	LSB

26.2.5 D/A Conversion Characteristics

Table 26.10 lists the D/A conversion characteristics.

Table 26.10 D/A Conversion Characteristics

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Condition A, B, C, D				Test Conditions
	Min.	Typ.	Max.	Unit	
Resolution	8	8	8	bits	
Conversion time	—	—	10	μs	Load capacitance: 20 pF
Absolute accuracy	—	± 2.0	± 3.0	LSB	Load resistance: 2 M Ω
	—	—	± 2.0	LSB	Load resistance: 4 M Ω

26.2.6 LCD Characteristics

Table 26.11 lists the LCD characteristics.

Table 26.11 LCD Characteristics

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Applicable Pins	Test Conditions	Condition A, B			Condition C, D			Unit	Notes
				Standard Value			Standard Value				
				Min.	Typ.	Max.	Min.	Typ.	Max.		
Segment driver step-down voltage	V _{DS}	SEG1 to SEG40	ID = 2μA	—	—	0.6	—	—	0.6	V	* ¹
Common driver step-down voltage	V _{DC}	COM1 to COM4	ID = 2μA	—	—	0.3	—	—	0.3	V	* ¹
LCD power supply division resistor	R _{LCD}		Between V1 and V _{SS}	40	360	1000	40	360	1000	kΩ	
LCD voltage (step-up voltage circuit not used)	V _{LCD}	V1		3.0* ⁴	—	V _{CC}	4.0	—	V _{CC}	V	* ²
LCD input reference voltage (using step-up voltage circuit)* ³	V _{LCD3}	V3		1.0	1.67	1.83	—	—	—	V	
LCD voltage (using step-up voltage circuit)* ³	V _{LCD2}	V2	No load	—	2× V _{LCD3}	—	—	—	—	V	Reference value
	V _{LCD1}	V1		—	3× V _{LCD3}	—	—	—	—		

Item	Symbol	Pins	Applicable Test Conditions	Condition A, B			Condition C, D			Unit	Notes
				Standard Value			Standard Value				
				Min.	Typ.	Max.	Min.	Typ.	Max.		
LCD input reference power supply current (using step-up voltage circuit)*3	I _{LCD3}	V3	No load, frame frequency: 64 Hz, V _{LCD3} = 1.67 V	—	2.0	—	—	—	—	μA	Reference value

- Notes:
1. Voltage step-down between power supply pins V1, V2, V3, and V_{SS} and segment pins.
 2. If the LCD voltage is provided by an external power supply, the following relationship must be maintained: $V_{CC} \geq V1 \geq V2 \geq V3 \geq V_{SS}$.
 3. The step-up voltage circuit should be used with 1/3 duty or 1/4 duty.
 4. When the step-up voltage circuit is not used, the lowest value of V_{CC} is $VCC = V1 = 3.0\text{V}$. Use the step-up voltage circuit when $VCC < 3.0\text{V}$.

26.2.7 DTMF Characteristics

Table 26.12 lists the DTMF characteristics.

Table 26.12 DTMF Characteristics

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.2\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.2\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V}^{*1}\text{ to }5.5\text{V}$, $V_{ref} = 2.7\text{ V}^{*1}\text{ to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.4\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V}^{*1}\text{ to }5.5\text{V}$, $V_{ref} = 2.7\text{ V}^{*1}\text{ to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.4\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Applicable Pins	Test Conditions	Standard Value			Unit	Notes
				Min.	Typ.	Max.		
DTMF output voltage (Row side)	V_{OR}	TONED	$AV_{CC} -$ GND=2.7V $R_L=100\text{k}\Omega$	750	924	—	mVrms	Figure 26.13* ²
DTMF output voltage (Column side)	V_{OC}	TONED	$AV_{CC} -$ GND=2.7V $R_L=100\text{k}\Omega$	770	945	—	mVrms	Figure 26.13* ²
DTMF output distortion	% DISDT	TONED	$AV_{CC} -$ GND=2.7V $R_L=100\text{k}\Omega$	—	3	7	%	Figure 26.13
DTMF output ratio	dB_{CR}	TONED	$AV_{CC} -$ GND=2.7V $R_L=100\text{k}\Omega$	—	2.5	—	dB	Figure 26.13

Notes: 1. When $AV_{CC} = 2.7\text{ to }4.0\text{ V}$, and $V_{ref} = 2.7\text{ to }4.0\text{ V}$, DTMF is only available.

2. V_{OR} and V_{OC} are output voltages when a single waveform is output.

26.2.8 Flash Memory Characteristics

Table 26.13 shows the flash memory characteristics.

Table 26.13 Flash Memory Characteristics

Conditions: $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$,
 $T_a = -25^{\circ}\text{C to }+75^{\circ}\text{C}$ (Programming/erasing operating temperature range: regular specification)

Item	Symbol	Min.	Typ.	Max.	Unit	Test Condition
Programming time* ¹ * ² * ⁴	t_p	—	30	200	ms/ 128 bytes	
Erase time* ¹ * ³ * ⁵	t_E	—	100	1200	ms/block	
Count of rewriting	N_{WEC}	100* ⁶	10000* ⁷	—	Times	
Data retention time	T_{DRP} * ⁸	10	—	—	Year	
Programming	Wait time after SWE1 bit setting* ¹	t_{sswe}	1	1	—	μs
	Wait time after PSU1 bit setting* ¹	t_{spsu}	50	50	—	μs
	Wait time after P1 bit setting* ¹ * ⁴	t_{sp10}	8	10	12	μs
		t_{sp30}	28	30	32	μs $6 \geq n \geq 1$
		t_{sp200}	198	200	202	μs $1000 \geq n \geq 7$
	Wait time after P1 bit clear* ¹	t_{cp}	5	5	—	μs
	Wait time after PSU1 bit clear* ¹	t_{cpsu}	4	4	—	μs
	Wait time after PV1 bit setting* ¹	t_{spv}	2	2	—	μs
	Wait time after H'FF dummy write* ¹	t_{spvr}	2	2	—	μs
	Wait time after PV1 bit clear* ¹	t_{cpv}	100	100	—	μs
	Wait time after SWE1 bit clear	t_{cswe}	—	—	—	μs
	Maximum programming count* ¹ * ⁴	N1	—	—	6* ⁴	Times
		N2	—	—	994* ⁴	Times
Erase	Wait time after SWE1 bit setting* ¹	t_{sswe}	1	1	—	μs
	Wait time after ESU1 bit setting* ¹	t_{sesu}	100	100	—	μs
	Wait time after E1 bit setting* ¹ * ⁵	t_{se}	10	10	100	ms
	Wait time after E1 bit clear* ¹	t_{ce}	10	10	—	μs
	Wait time after ESU1 bit clear* ¹	t_{cesu}	10	10	—	μs
	Wait time after EV1 bit setting* ¹	t_{sevr}	20	20	—	μs
	Wait time after H'FF dummy write* ¹	t_{sevr}	2	2	—	μs
	Wait time after EV1 bit clear* ¹	t_{cev}	4	4	—	μs
	Wait time after SWE1 bit clear	t_{cswe}	100	100	—	μs
	Maximum erase count* ¹ * ⁵	N	—	—	100	Times

- Notes:
1. Make each time setting in accordance with the program or erase algorithm.
 2. Programming time per 128 bytes (Shows the total period for which the P1 bit in the flash memory control register (FLMCR1) is set. It does not include the programming verification time.)
 3. Block erase time (Shows the total period for which the E1 bit in FLMCR1 is set. It does not include the erase verification time.)
 4. The maximum programming time value ($t_p(\text{max.})$):

$$t_p(\text{max.}) = \text{Wait time after P1 bit setting } (t_{sp}) \times \text{maximum programming count (N)}$$

$$(t_{sp30} + t_{sp10}) \times 6 + (t_{sp200}) \times 994$$
 5. For the maximum erase time ($t_e(\text{max.})$), the following relationship applies between the wait time after E1 bit setting (t_{se}) and the maximum erase count (N):

$$t_e(\text{max.}) = \text{Wait time after E1 bit setting } (t_{se}) \times \text{maximum erase count (N)}$$
 6. The minimum times that all characteristics after rewriting are guaranteed. (A range between 1 and minimum value is guaranteed.)
 7. The reference value at 25°C. (Normally, it is a reference that rewriting is enabled up to this value.)
 8. Data hold characteristics when rewriting is performed within the range of specifications including minimum value.

26.3 Electrical Characteristics of the H8S/2264 Series

26.3.1 Absolute Maximum Ratings

Table 26.14 lists the absolute maximum ratings.

Table 26.14 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	-0.3 to +7.0	V
	CV_{CC}	-0.3 to +4.3	V
Input voltage (except port 4, 9, PH7)	V_{in}	-0.3 to $V_{CC} + 0.3$	V
Input voltage (port 4, 9, PH7)	V_{in}	-0.3 to $AV_{CC} + 0.3$	V
Reference voltage	V_{ref}	-0.3 to $AV_{CC} + 0.3$	V
Analog power supply voltage	AV_{CC}	-0.3 to +7.0	V
Analog input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$	V
Operating temperature	T_{opr}	Regular specifications: -20 to +75*	°C
		Wide-range specifications: -40 to +85*	°C
Storage temperature	T_{stg}	-55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum rating are exceeded.

Note: * Operating temperature range for flash memory programming/erasing is $T_a = -20$ to +75°C.

26.3.2 DC Characteristics

Table 26.15 lists the DC characteristics. Table 26.16 lists the permissible output currents. Table 26.17 lists the bus drive characteristics.

Table 26.15 DC Characteristics (1) — Preliminary —

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	$\overline{IRQ0}$, $\overline{IRQ1}$, $\overline{IRQ3}$, $\overline{IRQ4}$, $\overline{WKP0}$ to $\overline{WKP7}$	VT^-	$V_{CC} \times 0.2$	—	V	
		VT^+	—	$V_{CC} \times 0.8$	V	
		$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	V	$V_{CC} = 4.0\text{ to }5.5\text{ V}$
			$V_{CC} \times 0.04$	—	V	$V_{CC} = 2.7\text{ to }4.0\text{ V}$
Input high voltage	\overline{RES} , \overline{STBY} , NMI, FWE, MD2, MD1	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
	EXTAL* ⁴ , Port 1, 3, 7, F, J to L, PH0 to PH5		$V_{CC} \times 0.8$	—	$V_{CC} + 0.3$	V
	Port 4, 9, PH7		$V_{CC} \times 0.8$	—	$AV_{CC} + 0.3$	V
Input low voltage	\overline{RES} , \overline{STBY} , FWE, MD2, MD1	V_{IL}	- 0.3	—	$V_{CC} \times 0.1$	V
	NMI, EXTAL* ⁴ , Port 1, 3, 4, 7, 9, F, H, J to L		- 0.3	—	$V_{CC} \times 0.2$	V
Output high voltage	All output pins except P34 and P35	V_{OH}	$V_{CC} - 0.5$	—	V	$I_{OH} = - 200\text{ }\mu\text{A}$
			$V_{CC} - 1.0$	—	V	$I_{OH} = - 1\text{ mA}$
	P34 and P35* ²		$V_{CC} - 2.7$	—	V	$I_{OH} = - 100\text{ }\mu\text{A}$ $V_{CC} = 4.0\text{ to }5.5\text{ V}$
Output low voltage	All output pins* ³	V_{OL}	—	—	0.4	V $I_{OL} = - 0.8\text{ mA}$
	Port 7		—	—	1.0	V $I_{OL} = 5\text{ mA}$
						$I_{OL} = 10\text{ mA}$, $V_{CC} = 4.0\text{ to }5.5\text{ V}$

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input leakage current	\overline{RES}	$ I_{in} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	STBY, NMI, FWE, MD2, MD1		—	—	1.0	μA	
	Port 4, 9		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
	PH7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
Three-state leakage current (off state)	Port 1, 3, 7, Port F, J to N, PH0 to PH5	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
Input pull-up MOS current	Port J	$-I_p$	10	—	300	μA	$V_{in} = 0 \text{ V}$

- Notes:
1. If the A/D converter is not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 2.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
 2. P35/SCK1/SCL0 and P34/SDA0 are NMOS push/pull outputs.
To output high level signal from SCL0 and SDA0 (ICE = 1), pull-up resistors must be connected externally.
P35/SCK1 and P34 (ICE = 0) are driven high by NMOS. To output high when $V_{CC} = 4.0\text{V}$ or less, pull-up resistors should be connected externally.
 3. When ICE = 0. The output low level when bus drive function is selected is indicated in table 26.17, Bus Drive Characteristics.
 4. Supported only by the H8S/2264 and H8S/2262. In the H8S/2264R and H8S/2262R, an external clock is disabled.

Table 26.15 DC Characteristics (2)**— Preliminary —**

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V}$ to 5.5V , $AV_{CC} = 4.0\text{V}$ to 5.5V , $V_{ref} = 4.0\text{V}$ to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0\text{V}$, $T_a = -20^\circ\text{C}$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C}$ to $+85^\circ\text{C}$
(wide-range specifications)*¹

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V}$ to 5.5V , $AV_{CC} = 4.0\text{V}$ to 5.5V , $V_{ref} = 4.0\text{V}$ to
 AV_{CC} , $V_{SS} = AV_{SS} = 0\text{V}$, $T_a = -20^\circ\text{C}$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C}$ to
 $+85^\circ\text{C}$ (wide-range specifications)*¹

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	$\overline{IRQ0}, \overline{IRQ1},$	V_T	$V_{CC} \times 0.2$	—	—	V
	$\overline{IRQ3}, \overline{IRQ4},$	V_T^+	—	—	$V_{CC} \times 0.8$	V
	$\overline{WKP0}$ to $\overline{WKP7}$	$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	V
Input high voltage	$\overline{RES}, \overline{STBY},$ NMI, FWE, MD2, MD1	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
	EXTAL* ⁴ , Port 1, 3, 7, F, J to L, PH0 to PH5		$V_{CC} \times 0.8$	—	$V_{CC} + 0.3$	V
	Port 4, 9, PH7		$V_{CC} \times 0.8$	—	$AV_{CC} + 0.3$	V
Input low voltage	$\overline{RES}, \overline{STBY},$ FWE, MD2, MD1	V_{IL}	- 0.3	—	$V_{CC} \times 0.1$	V
	NMI, EXTAL* ⁴ , Port 1, 3, 4, 7, 9, F, H, J to L		- 0.3	—	$V_{CC} \times 0.2$	V
Output high voltage	All output pins except P34 and P35	V_{OH}	$V_{CC} - 0.5$	—	—	V $I_{OH} = - 200\text{ }\mu\text{A}$
			$V_{CC} - 1.0$	—	—	V $I_{OH} = - 1\text{ mA}$
	P34 and P35* ²		$V_{CC} - 2.7$	—	—	V $I_{OH} = - 100\text{ }\mu\text{A}$
Output low voltage	All output pins* ³	V_{OL}	—	—	0.4	V $I_{OL} = 0.8\text{ mA}$
	Port 7		—	—	1.0	V $I_{OL} = 10\text{ mA}$
Input leakage current	\overline{RES}	$ I_{in} $	—	—	1.0	μA $V_{in} = 0.5$ to $V_{CC} - 0.5\text{ V}$
	\overline{STBY} , NMI, FWE, MD2, MD1		—	—	1.0	μA
	Port 4, 9		—	—	1.0	μA $V_{in} = 0.5$ to $AV_{CC} - 0.5\text{ V}$
	PH7		—	—	1.0	μA $V_{in} = 0.5$ to $AV_{CC} - 0.5\text{ V}$

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Three-state leakage current (off state)	Port 1, 3, 7, Port F, J to L, PH0 to PH5	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
Input pull-up MOS current	Port J	$-I_p$	50	—	300	μA	$V_{in} = 0 \text{ V}$

- Notes:
1. If the A/D converter is not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 4.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
 2. P35/SCK1/SCL0 and P34/SDA0 are NMOS push/pull outputs.
To output high level signal from SCL0 and SDA0 (ICE = 1), pull-up resistors must be connected externally.
P35/SCK1 and P34 (ICE = 0) are driven high by NMOS.
 3. When ICE = 0. The output low level when bus drive function is selected is indicated in table 26.17, Bus Drive Characteristics.
 4. Supported only by the H8S/2264 and H8S/2262. In the H8S/2264R and H8S/2262R, an external clock is disabled.

Table 26.15 DC Characteristics (3) — Preliminary —

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$
(wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	—	—	30	pF	$V_{in} = 0\text{ V}$
	NMI		—	—	30	pF	$f = 1\text{ MHz}$
	P34 and P35		—	—	20	pF	$T_a = 25^{\circ}\text{C}$
	All input pins except \overline{RES} , NMI, P34, and P35		—	—	15	pF	
Current consumption* ²	Normal operation	I_{CC} * ⁴	—	TBD $V_{CC} = 3.0\text{ V}$	TBD $V_{CC} = 5.5\text{ V}$	mA	$f = 13.5\text{ MHz}$
	Sleep mode		—	TBD $V_{CC} = 3.0\text{ V}$	TBD $V_{CC} = 5.5\text{ V}$	mA	$f = 13.5\text{ MHz}$
	All modules stopped		—	TBD	—	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Medium-speed mode ($\phi/32$)		—	TBD	—	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Subactive mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD lighting)
	Subsleep mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD lighting)
Current consumption* ²	Watch mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0\text{ V}$ (LCD not used, WDT_1 operates)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption*2	Watch mode	I_{CC}^{*4}	–	TBD	–	μA	Using 32.768 kHz crystal resonator $V_{CC} = 3.0 V$ (LCD not used, WDT_1 operates) WDT_1 overflow cycle 2 min selected (reference value)
	Standby mode*3		–	TBD	TBD	μA	$T_a \leq 50^{\circ}C$ 32.768 kHz not used
				$V_{CC} = 3.0 V$	$V_{CC} = 5.5 V$		
			–	–	TBD $V_{CC} = 5.5 V$		$50^{\circ}C < T_a$ 32.768 kHz not used
Analog power supply current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
Reference current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
RAM standby voltage		V_{RAM}	2.0	–	–	V	

- Notes: 1. If the A/D converter is not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 2.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2 V$, V_{IL} max. = $0.2 V$ with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 3.0 V$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = $0.2 V$.
4. I_{CC} depends on V_{CC} and f as follows (reference):
 I_{CC} max. = TBD (mA) + TBD (mA/V) x V_{CC} + TBD (mA/MHz) x f + TBD (mA/(MHz • V)) x V_{CC} x f (normal operation)
 I_{CC} max. = TBD (mA) + TBD (mA/V) x V_{CC} + TBD (mA/MHz) x f + TBD (mA/(MHz • V)) x V_{CC} x f (sleep mode)

Table 26.15 DC Characteristics (4) — Preliminary —

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V}$ to 5.5 V , $AV_{CC} = 2.7\text{ V}$ to 5.5 V , $V_{ref} = 2.7\text{ V}$ to AV_{CC} , $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C}$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C}$ to $+85^\circ\text{C}$ (wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	—	—	30	pF	$V_{in} = 0\text{ V}$
	NMI		—	—	30	pF	$f = 1\text{ MHz}$
	P34 and P35		—	—	20	pF	$T_a = 25^\circ\text{C}$
	All input pins except \overline{RES} , NMI, P34, and P35		—	—	15	pF	
Current consumption* ²	Normal operation	I_{CC} * ⁴	—	TBD $V_{CC} = 3.0\text{ V}$	TBD $V_{CC} = 5.5\text{ V}$	mA	$f = 13.5\text{ MHz}$
	Sleep mode		—	TBD $V_{CC} = 3.0\text{ V}$	TBD $V_{CC} = 5.5\text{ V}$	mA	$f = 13.5\text{ MHz}$
	All modules stopped		—	TBD	—	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Medium-speed mode ($\phi/32$)		—	TBD	—	mA	$f = 13.5\text{ MHz}$, $V_{CC} = 3.0\text{ V}$ (reference values)
	Subactive mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 2.7\text{ V}$ (LCD lighting)
	Subsleep mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 2.7\text{ V}$ (LCD lighting)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption*2	Watch mode	I_{CC}^{**}	–	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 2.7 V$ (LCD not used, WDT_1 operates)
			–	TBD	–	μA	Using 32.768 kHz crystal resonator $V_{CC} = 2.7 V$ (LCD not used, WDT_1 operates) WDT_1 overflow cycle 2 min selected (reference value)
	Standby mode*3		–	TBD	TBD	μA	$T_a \leq 50^\circ C$ 32.768 kHz not used
			–	–	TBD		$50^\circ C < T_a$ 32.768 kHz not used
Analog power supply current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
Reference current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
RAM standby voltage		V_{RAM}	2.0	–	–	V	

- Notes: 1. If the A/D converter is not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 2.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2 V$, V_{IL} max. = $0.2 V$ with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7 V$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = $0.2 V$.
4. I_{CC} depends on V_{CC} and f as follows (reference):
 I_{CC} max. = TBD (mA) + TBD (mA/V) $\times V_{CC}$ + TBD (mA/MHz) $\times f$ + TBD (mA/(MHz \bullet V)) $\times V_{CC} \times f$ (normal operation)
 I_{CC} max. = TBD (mA) + TBD (mA/V) $\times V_{CC}$ + TBD (mA/MHz) $\times f$ + TBD (mA/(MHz \bullet V)) $\times V_{CC} \times f$ (sleep mode)

Table 26.15 DC Characteristics (5) — Preliminary —

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V}$ to 5.5V , $AV_{CC} = 4.0\text{V}$ to 5.5V , $V_{ref} = 4.0\text{V}$ to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0\text{V}$, $T_a = -20^\circ\text{C}$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C}$ to $+85^\circ\text{C}$
(wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	—	—	30	pF	$V_{in} = 0\text{V}$
	NMI		—	—	30	pF	$f = 1\text{MHz}$
	P34 and P35		—	—	20	pF	$T_a = 25^\circ\text{C}$
	All input pins except \overline{RES} , NMI, P34, and P35		—	—	15	pF	
Current consumption* ²	Normal operation	I_{CC}^{*4}	—	TBD $V_{CC} = 5.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 20.5\text{MHz}$
	Sleep mode		—	TBD $V_{CC} = 5.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 20.5\text{MHz}$
	All modules stopped		—	TBD	—	mA	$f = 20.5\text{MHz}$, $V_{CC} = 5.0\text{V}$ (reference values)
	Medium-speed mode ($\phi/32$)		—	TBD	—	mA	$f = 20.5\text{MHz}$, $V_{CC} = 5.0\text{V}$ (reference values)
	Subactive mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD lighting)
	Subsleep mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD lighting)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption*2	Watch mode	I_{CC}^{**}	–	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0 V$ (LCD not used, WDT_1 operates)
			–	TBD	–	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0 V$ (LCD not used, WDT_1 operates), WDT_1 overflow cycle 2 min selected (reference value)
	Standby mode*3	I_{CC}^{**}	–	TBD	TBD	μA	$T_a \leq 50^\circ C$ 32.768 kHz not used
			–	–	TBD		$50^\circ C < T_a$ 32.768 kHz not used
Analog power supply current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
Reference current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
RAM standby voltage		V_{RAM}	2.0	–	–	V	

- Notes: 1. If the A/D converter is not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 4.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2 V$, V_{IL} max. = $0.2 V$ with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 4.0 V$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = $0.2 V$.
4. I_{CC} depends on V_{CC} and f as follows (reference):
 I_{CC} max. = TBD (mA) + TBD (mA/V) $\times V_{CC}$ + TBD (mA/MHz) $\times f$ + TBD (mA/(MHz \bullet V)) $\times V_{CC} \times f$ (normal operation)
 I_{CC} max. = TBD (mA) + TBD (mA/V) $\times V_{CC}$ + TBD (mA/MHz) $\times f$ + TBD (mA/(MHz \bullet V)) $\times V_{CC} \times f$ (sleep mode)

Table 26.15 DC Characteristics (6) — Preliminary —

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V}$ to 5.5V , $AV_{CC} = 4.0\text{V}$ to 5.5V , $V_{ref} = 4.0\text{V}$ to AV_{CC} , $V_{SS} = AV_{SS} = 0\text{V}$, $T_a = -20^\circ\text{C}$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C}$ to $+85^\circ\text{C}$ (wide-range specifications)*¹

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Input capacitance	\overline{RES}	C_{in}	—	—	30	pF	$V_{in} = 0\text{V}$
	NMI		—	—	30	pF	$f = 1\text{MHz}$
	P34 and P35		—	—	20	pF	$T_a = 25^\circ\text{C}$
	All input pins except \overline{RES} , NMI, P34, and P35		—	—	15	pF	
Current consumption* ²	Normal operation	I_{CC} * ⁴	—	TBD $V_{CC} = 5.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 20.5\text{MHz}$
	Sleep mode		—	TBD $V_{CC} = 5.0\text{V}$	TBD $V_{CC} = 5.5\text{V}$	mA	$f = 20.5\text{MHz}$
	All modules stopped		—	TBD	—	mA	$f = 20.5\text{MHz}$, $V_{CC} = 5.0\text{V}$ (reference values)
	Medium-speed mode ($\phi/32$)		—	TBD	—	mA	$f = 20.5\text{MHz}$, $V_{CC} = 5.0\text{V}$ (reference values)
	Subactive mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD lighting)
	Subsleep mode		—	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0\text{V}$ (LCD lighting)

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Current consumption* ²	Watch mode	I_{CC}^{**}	–	TBD	TBD	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0 V$ (LCD not used, WDT_1 operates)
			–	TBD	–	μA	Using 32.768 kHz crystal resonator $V_{CC} = 5.0 V$ (LCD not used, WDT_1 operates), WDT_1 overflow cycle 2 min selected (reference value)
	Standby mode* ³		–	TBD	TBD	μA	$T_a \leq 50^\circ C$ 32.768 kHz not used
			–	–	TBD		$50^\circ C < T_a$ 32.768 kHz not used
Analog power supply current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
Reference current	During A/D conversion	AI_{CC}	–	TBD	TBD	mA	
	Waiting for A/D conversion		–	TBD	TBD	μA	
RAM standby voltage		V_{RAM}	2.0	–	–	V	

- Notes: 1. If the A/D converter is not used, do not leave the AVCC, Vref, and AVSS pins open. Apply a voltage 4.0 to 5.5 V to the AVCC and Vref pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.
2. Current consumption values are for V_{IH} min. = $V_{CC} - 0.2 V$, V_{IL} max. = $0.2 V$ with all output pins unloaded and the on-chip pull-up resistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 4.0 V$, V_{IH} min. = $V_{CC} - 0.2$, and V_{IL} max. = $0.2 V$.
4. I_{CC} depends on V_{CC} and f as follows (reference):
 I_{CC} max. = TBD (mA) + TBD (mA/V) $\times V_{CC}$ + TBD (mA/MHz) $\times f$ + TBD (mA/(MHz \bullet V)) $\times V_{CC} \times f$ (normal operation)
 I_{CC} max. = TBD (mA) + TBD (mA/V) $\times V_{CC}$ + TBD (mA/MHz) $\times f$ + TBD (mA/(MHz \bullet V)) $\times V_{CC} \times f$ (sleep mode)

Table 26.16 Permissible Output Currents

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Item		Symbol	Min.	Typ.	Max.	Unit
Permissible output low current (per pin)	Port 7	I_{OL}	—	—	10	mA
	SCL0, SDA0		—	—	10	mA
	Output pins except port 7, SCL0, SDA0		—	—	1.0	mA
Permissible output low current (total)	Total of port 7	ΣI_{OL}	—	—	30	mA
	Total of all output pins including port 7		—	—	60	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	1.0	mA
Permissible output high current (total)	Total of all output pins	$-\Sigma I_{OH}$	—	—	30	mA

Note: To protect chip reliability, do not exceed the output current values in table 26.16.

Table 26.17 Bus Drive Characteristics (1)

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹, Target pins: SCL0, SDA0

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)*¹, Target pins: SCL0, SDA0

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	VT	$V_{CC} \times 0.3$	—	—	V	
	VT ⁺	—	—	$V_{CC} \times 0.7$		
	VT ⁺ - VT	0.4	—	—		$V_{CC} = 4.0\text{ to }5.5\text{ V}$
		$V_{CC} \times 0.05$	—	—		$V_{CC} = 2.7\text{ to }4.0\text{ V}$
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$	V	
Output low voltage	V_{OL}	—	—	0.5	V	$I_{OL} = 8\text{ mA}$, $V_{CC} = 4.0\text{ to }5.5\text{ V}$
		—	—	0.4		$I_{OL} = 3\text{ mA}$
Input capacitance	C_{IN}	—	—	20	pF	$V_{IN} = 0\text{ V}$, $f = 1\text{ MHz}$, $T_a = 25^{\circ}\text{C}$
Three-state leakage current (off state)	$ I_{STT} $	—	—	1.0	μA	$V_{IN} = 0.5\text{ to }V_{CC} - 0.5$
SDL, SDA output fall time	t_{of}	$20 + 0.1Cb$	—	250	ns	

Note: If the A/D converter is not used, do not leave the AV_{CC} , V_{ref} , and AV_{SS} pins open. Apply a voltage 4.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC} , for instance. Set $V_{ref} \leq AV_{CC}$.

Table 26.17 Bus Drive Characteristics (2)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$
 (wide-range specifications)*¹, Target pins: SCL0, SDA0

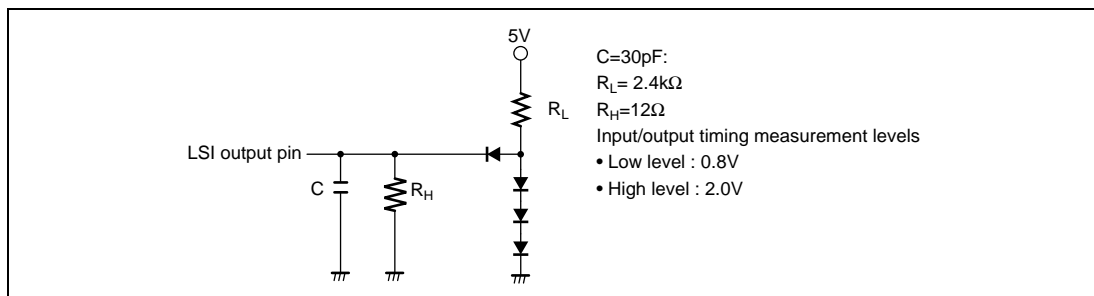
Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to } 5.5\text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$
 (wide-range specifications)*¹, Target pins: SCL0, SDA0

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Schmitt trigger input voltage	VT	$V_{CC} \times 0.3$	—	—	V	
	VT ⁺	—	—	$V_{CC} \times 0.7$		
	VT ⁺ - VT	0.4	—	—		
Input high voltage	V _{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	
Input low voltage	V _{IL}	-0.5	—	$V_{CC} \times 0.3$	V	
Output low voltage	V _{OL}	—	—	0.5	V	I _{OL} =8mA
		—	—	0.4		I _{OL} =3mA
Input capacitance	C _{in}	—	—	20	pF	V _{IN} =0 V, f=1 MHz, T _a =25°C
Three-state leakage current (off state)	I _{sn}	—	—	1.0	μA	V _{IN} =0.5 to V _{CC} -0.5
SDL, SDA output fall time	t _{of}	20 + 0.1Cb	—	250	ns	

Note: If the A/D converter is not used, do not leave the AV_{CC}, V_{ref}, and AV_{SS} pins open. Apply a voltage 4.0 V to 5.5 V to the AV_{CC} and V_{ref} pins by connecting them to V_{CC}, for instance. Set V_{ref} ≤ AV_{CC}.

26.3.3 AC Characteristics

Figure 26.3 shows the test conditions for the AC characteristics.

**Figure 26.3 Output Load Circuit**

Clock Timing: Table 26.18 lists the clock timing.

Table 26.18 Clock Timing — Preliminary —

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{kHz}$, 2 to 13.5MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition B (Mask-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{kHz}$, 2 to 13.5MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{kHz}$, 10 to 20.5 MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition D (Mask-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{kHz}$, 10 to 20.5 MHz, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

		Condition A and B			Condition C and D				
		13.5MHz			20.5 MHz				
Item	Symbol	Min.	Typ.	Max.	Min.	Typ.	Max.	Unit	Test Conditions
Clock cycle time	t _{cyc}	74	—	500	48.8	—	100	ns	
Output clock high width	t _{OCH}	25	—	—	16	—	—	ns	Figure 26.4
Output clock low width	t _{OCL}	25	—	—	16	—	—		
Output clock rising time	t _{OGr}	—	—	10	—	—	8		
Output clock falling time	t _{OCf}	—	—	10	—	—	8		
Clock oscillator settling time at reset (crystal)	t _{OSC1}	20	—	—	10	—	—	ms	Figure 26.5 H8S/2264, H8S/2262
Clock oscillator settling time in software standby (crystal)	t _{OSC2}	8	—	—	8	—	—	ms	Figure 22.3 H8S/2264, H8S/2262
Clock oscillator settling time at reset or in software standby (ceramic)	t _{OSC1}	—	TBD	TBD	—	TBD	TBD	μs	Figure 26.5 H8S/2264R, H8S/2262R
Clock oscillator settling time at reset or in software standby (crystal)	t _{OSC1}	—	TBD (ϕ = 2 to (ϕ = 2 4 MHz) to 4 MHz)	TBD	—	TBD	TBD	μs	Figure 26.5 H8S/2264R, H8S/2262R
			TBD	TBD					

Item	Symbol	Condition A and B			Condition C and D			Unit	Test Conditions
		Min.	Typ.	Max.	Min.	Typ.	Max.		
External clock settling time*	t _{DEXT}	500	—	—	500	—	—	μs	Figure 26.5
Sub clock oscillator settling time	t _{OSC3}	—	—	2	—	—	2	s	
Sub clock oscillator frequency	f _{SUB}	—	32.768	—	—	32.768	—	kHz	
Sub clock (ϕ _{SUB}) cycle time	t _{SUB}	—	30.5	—	—	30.5	—	μs	

Note: * Supported only by the H8S/2264 and H8S/2262. In the H8S/2264R and H8S/2262R, an external clock input is disabled.

Control Signal Timing: Table 26.19 lists the control signal timing.

Table 26.19 Control Signal Timing

Condition A (F-ZTAT version): $V_{\text{CC}} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{\text{CC}} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{\text{ref}} = 2.7 \text{ V to } AV_{\text{CC}}$, $V_{\text{SS}} = AV_{\text{SS}} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{\text{CC}} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{\text{CC}} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{\text{ref}} = 2.7 \text{ V to } AV_{\text{CC}}$, $V_{\text{SS}} = AV_{\text{SS}} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{\text{CC}} = 4.0\text{V to } 5.5 \text{ V}$, $AV_{\text{CC}} = 4.0\text{V to } 5.5\text{V}$, $V_{\text{ref}} = 4.0\text{V to } AV_{\text{CC}}$, $V_{\text{SS}} = AV_{\text{SS}} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{\text{CC}} = 4.0\text{V to } 5.5 \text{ V}$, $AV_{\text{CC}} = 4.0\text{V to } 5.5\text{V}$, $V_{\text{ref}} = 4.0\text{V to } AV_{\text{CC}}$, $V_{\text{SS}} = AV_{\text{SS}} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Min.	Max.	Unit	Test Conditions
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	t_{cyc}	Figure 26.6
NMI pulse width (exiting software standby mode)	t_{NMW}	200	—	ns	Figure 26.7
$\overline{\text{IRQ}}$ pulse width (exiting software standby mode)	t_{IRQW}	200	—	ns	

Timing of On-Chip Peripheral Modules: Table 26.20 lists the timing of on-chip peripheral modules. Table 26.21 lists the I²C bus timing.

Table 26.20 Timing of On-Chip Peripheral Modules

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz, }2\text{ to }13.5\text{ MHz}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz, }2\text{ to }13.5\text{ MHz}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz, }10\text{ to }20.5\text{ MHz}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz, }10\text{ to }20.5\text{ MHz}$, $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+85^{\circ}\text{C}$ (wide-range specifications)

Condition A, B Condition C, D

Item			Symbol	Min.	Max.	Min.	Max.	Unit	Test Conditions
TPU	Timer clock pulse width	Single edge	t_{TCWH}	1.5	—	1.5	—	t_{cyC}	Figure 26.8
		Both edges	t_{TCWL}	2.5	—	2.5	—		
TMR_0, TMR_1	Timer clock pulse width	Single edge	t_{TCWH}	1.5	—	1.5	—	t_{cyC}	Figure 26.9
		Both edges	t_{TCWL}	2.5	—	2.5	—		
SCI	Input clock cycle	Asynchronous	t_{scyC}	4	—	4	—	t_{cyC}	Figure 26.10
		Synchronous		6	—	6	—		
	Input clock pulse width		t_{SCKW}	0.4	0.6	0.4	0.6	t_{scyC}	
	Input clock rise time		t_{SCKI}	—	1.5	—	1.5	t_{cyC}	
	Input clock fall time		t_{SCKI}	—	1.5	—	1.5		
	Transmit data delay time		t_{TXD}	—	75	—	50	ns	Figure 26.11
	Receive data setup time (synchronous)		t_{RXS}	75	—	50	—	ns	
	Receive data hold time (synchronous)		t_{RXH}	75	—	50	—	ns	

Table 26.21 I²C Bus Timing

Conditions: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 5\text{ MHz}$ to maximum operating frequency,
 $T_a = -20^{\circ}\text{C to }+75^{\circ}\text{C}$ (regular specifications), $T_a = -40^{\circ}\text{C to }+80^{\circ}\text{C}$ (wide-range specifications)

Item	Symbol	Min.	Typ.	Max.	Unit	Test Conditions	Remarks
SCL input cycle time	t_{SCL}	$12t_{cyc}$	—	—	ns		Figure 26.12
SCL input high pulse width	t_{SCLH}	$3t_{cyc}$	—	—	ns		
SCL input low pulse width	t_{SCLL}	$5t_{cyc}$	—	—	ns		
SCL, SDA input rise time	t_{Sr}	—	—	$7.5t_{cyc}^*$	ns		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse elimination time	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		
Retransmission 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}	$0.5t_{cyc}$	—	—	ns		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA load capacitance	C_b	—	—	400	pF		

Note: * t_{Sr} can be set to $7.5 t_{cyc}$ or $17.5 t_{cyc}$ according to the clock used for the I²C module. For details, see section 14.5 Usage Notes.

26.3.4 A/D Conversion Characteristics

Table 26.22 lists the A/D conversion characteristics.

Table 26.22 A/D Conversion Characteristics — Preliminary —

Condition A (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }13.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{V to }5.5\text{V}$, $V_{ref} = 4.0\text{V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 10\text{ to }20.5\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Condition A, B			Condition C, D			Unit
	13.5MHz			20.5 MHz			
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Resolution	10	10	10	10	10	10	bits
Conversion time	9.6	—	—	6.3	—	—	μs
Analog input capacitance	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	5	kΩ
Nonlinearity error	—	—	±6.0	—	—	±3.0	LSB
Offset error	—	—	±4.0	—	—	±2.0	LSB
Full-scale error	—	—	±4.0	—	—	±2.0	LSB
Quantization error	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±4.0	LSB

26.3.5 LCD Characteristics

Table 26.23 lists the LCD characteristics.

Table 26.23 LCD Characteristics

Condition A (F-ZTAT version): $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{ref} = 2.7 \text{ V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Condition B (Masked-ROM version): $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{ref} = 2.7 \text{ V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 to 13.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Condition C (F-ZTAT version): $V_{CC} = 4.0\text{V to } 5.5 \text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Condition D (Masked-ROM version): $V_{CC} = 4.0\text{V to } 5.5 \text{ V}$, $AV_{CC} = 4.0\text{V to } 5.5\text{V}$, $V_{ref} = 4.0\text{V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 10 to 20.5 MHz, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Applicable Pins	Test Conditions	Condition A, B			Condition C, D			Unit	Notes
				Standard Value			Standard Value				
				Min.	Typ.	Max.	Min.	Typ.	Max.		
Segment driver step-down voltage	V _{DS}	SEG1 to SEG40	ID = 2μA	—	—	0.6	—	—	0.6	V	*1
Common driver step-down voltage	V _{DC}	COM1 to COM4	ID = 2μA	—	—	0.3	—	—	0.3	V	*1
LCD power supply division resistor	R _{LCD}		Between V1 and V _{SS}	40	360	1000	40	360	1000	kΩ	
LCD voltage	V _{LCD}	V1		3.0	—	V _{CC}	4.0	—	V _{CC}	V	*2

Notes: 1. Voltage step-down between power supply pins V1, V2, V3, and V_{SS} and segment pins.
2. If the LCD voltage is provided by an external power supply, the following relationship must be maintained: $V_{CC} \geq V1 \geq V2 \geq V3 \geq V_{SS}$.

26.3.6 Flash Memory Characteristics

Table 26.24 shows the flash memory characteristics.

Table 26.24 Flash Memory Characteristics — Preliminary —

Conditions: $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{ref} = 2.7 \text{ V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$,
 $T_a = -25^{\circ}\text{C to } +75^{\circ}\text{C}$ (Programming/erasing operating temperature range: regular specification)

Item	Symbol	Min.	Typ.	Max.	Unit	Test Condition
Programming time* ¹ * ² * ⁴	t_p	—	10	200	ms/ 128 bytes	
Erase time* ¹ * ³ * ⁵	t_E	—	100	1200	ms/block	
Count of rewriting	N_{WEC}	100* ⁶	10000* ⁷	—	Times	
Data retention time	t_{DRP} * ⁸	10	—	—	Year	
Programming	Wait time after SWE1 bit setting* ¹	t_{sswe}	1	1	—	μs
	Wait time after PSU1 bit setting* ¹	t_{spsu}	50	50	—	μs
	Wait time after P1 bit setting* ¹ * ⁴	t_{sp10}	8	10	12	μs
		t_{sp30}	28	30	32	μs $6 \geq n \geq 1$
		t_{sp200}	198	200	202	μs $1000 \geq n \geq 7$
	Wait time after P1 bit clear* ¹	t_{cp}	5	5	—	μs
	Wait time after PSU1 bit clear* ¹	t_{cpsu}	4	4	—	μs
	Wait time after PV1 bit setting* ¹	t_{spv}	2	2	—	μs
	Wait time after H'FF dummy write* ¹	t_{spvr}	2	2	—	μs
	Wait time after PV1 bit clear* ¹	t_{cpv}	100	100	—	μs
	Wait time after SWE1 bit clear	t_{cswe}	—	—	—	μs
	Maximum programming count* ¹ * ⁴	N1	—	—	6* ⁴	Times
		N2	—	—	994* ⁴	Times
Erase	Wait time after SWE1 bit setting* ¹	t_{sswe}	1	1	—	μs
	Wait time after ESU1 bit setting* ¹	t_{sesu}	100	100	—	μs
	Wait time after E1 bit setting* ¹ * ⁵	t_{se}	10	10	100	ms
	Wait time after E1 bit clear* ¹	t_{ce}	10	10	—	μs
	Wait time after ESU1 bit clear* ¹	t_{cesu}	10	10	—	μs
	Wait time after EV1 bit setting* ¹	t_{sev}	20	20	—	μs

Item		Symbol	Min.	Typ.	Max.	Unit	Test Condition
Erase	Wait time after H'FF dummy write* ¹	t_{sevr}	2	2	—	μs	
	Wait time after EV1 bit clear* ¹	t_{cdev}	4	4	—	μs	
	Wait time after SWE1 bit clear	t_{cswe}	100	100	—	μs	
	Maximum erase count* ^{1,3,5}	N	—	—	100	Times	

- Notes:
1. Make each time setting in accordance with the program or erase algorithm.
 2. Programming time per 128 bytes (Shows the total period for which the P1 bit in the flash memory control register (FLMCR1) is set. It does not include the programming verification time.)
 3. Block erase time (Shows the total period for which the E1 bit in FLMCR1 is set. It does not include the erase verification time.)
 4. The maximum programming time value ($t_p(\text{max.})$):

$$t_p(\text{max.}) = \text{Wait time after P1 bit setting } (t_{sp}) \times \text{maximum programming count (N)}$$

$$(t_{sp30} + t_{sp10}) \times 6 + (t_{sp200}) \times 994$$
 5. For the maximum erase time ($t_e(\text{max.})$), the following relationship applies between the wait time after E1 bit setting (t_{se}) and the maximum erase count (N):

$$t_e(\text{max.}) = \text{Wait time after E1 bit setting } (t_{se}) \times \text{maximum erase count (N)}$$
 6. The minimum times that all characteristics after rewriting are guaranteed. (A range between 1 and minimum value is guaranteed.)
 7. The reference value at 25°C. (Normally, it is a reference that rewriting is enabled up to this value.)
 8. Data retention characteristics when rewriting is performed within the range of specifications including minimum value.

26.4 Operation Timing

Operation timings are shown below.

26.4.1 Clock Timing

Clock timing is shown below.

Output Clock Timing (Supported only by the H8S/2264 Series): Figure 26.4 shows the output clock timing.

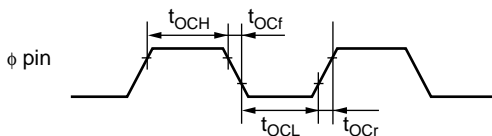


Figure 26.4 Output Clock Timing

Oscillator Settling Timing: Figure 26.5 shows the oscillator settling timing.

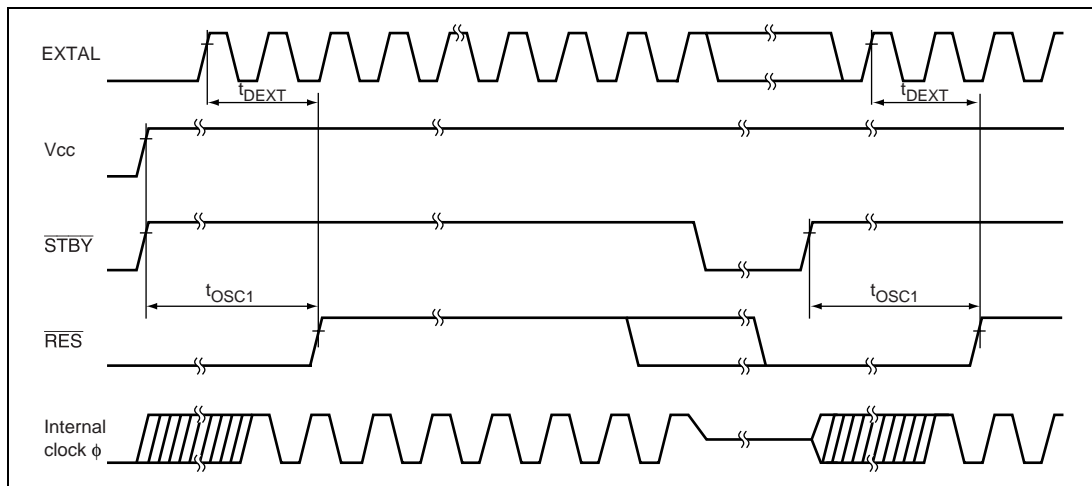


Figure 26.5 Oscillator Settling Timing

26.4.2 Control Signal Timings

Control signal timings are shown below.

- Reset Input Timing

Figure 26.6 shows the reset input timing.

- Interrupt Input Timing

Figure 26.7 shows the NMI, $\overline{\text{IRQ}}$ interrupt reset input timing.

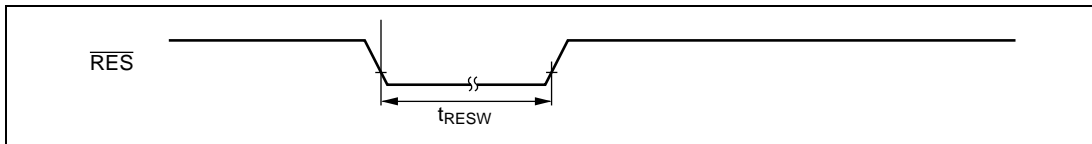


Figure 26.6 Reset Input Timing

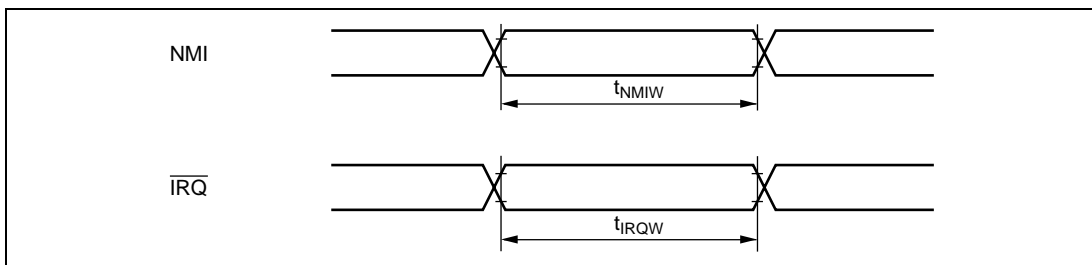


Figure 26.7 Interrupt Input Timing

26.4.3 Timing of On-Chip Peripheral Modules

Figures 26.8 to 26.12 show timing of on-chip peripheral modules.

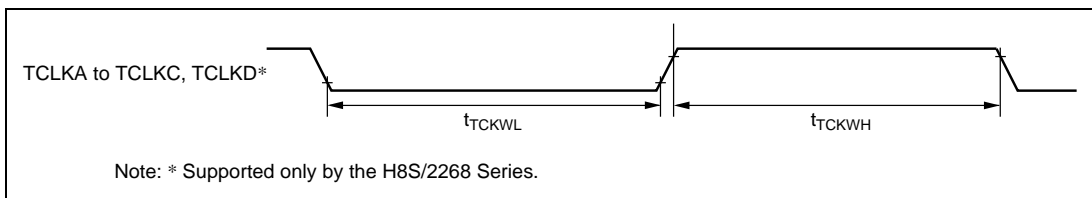


Figure 26.8 TPU Clock Input Timing

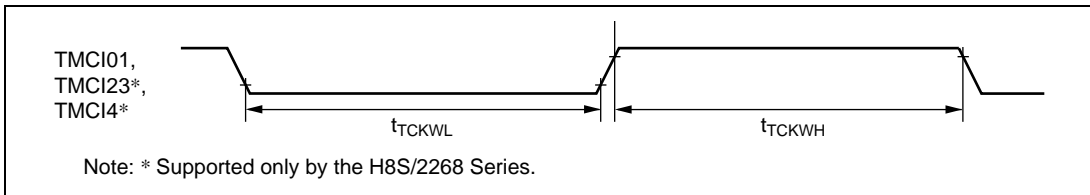


Figure 26.9 8-Bit Timer Clock Input Timing

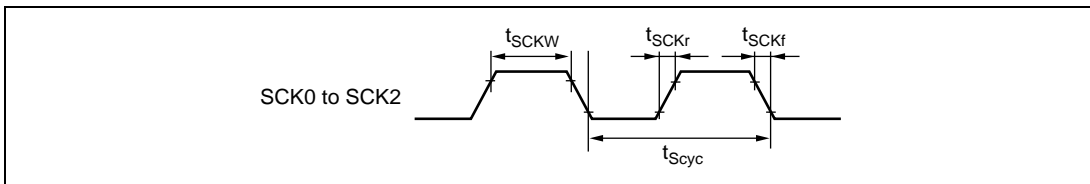


Figure 26.10 SCK Clock Input Timing

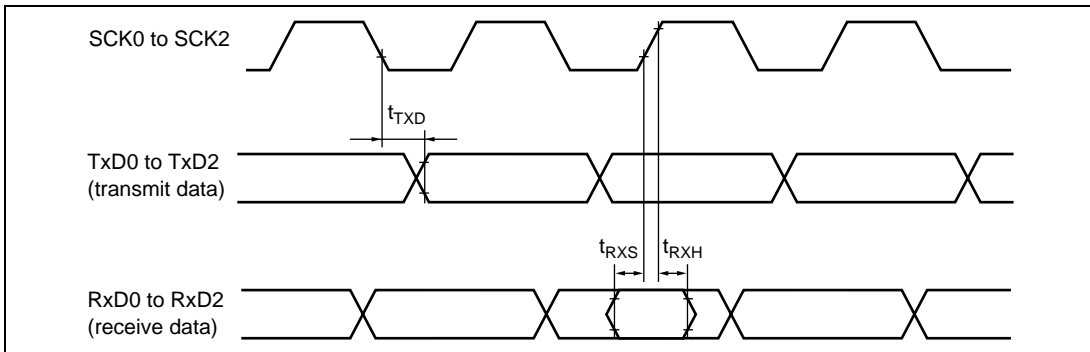


Figure 26.11 SCI Input/Output Timing (Clock Synchronous Mode)

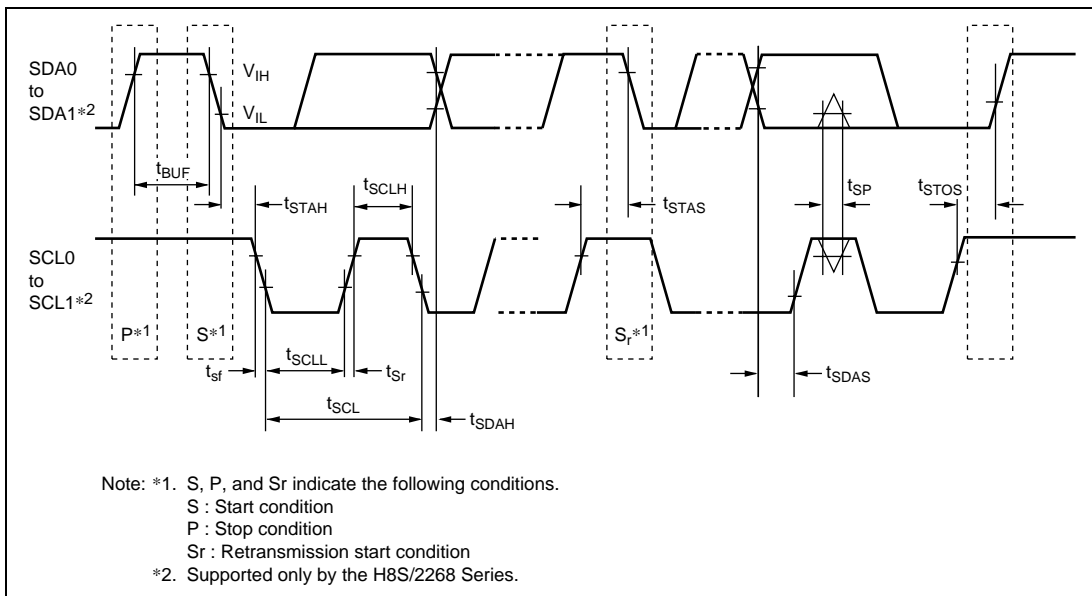


Figure 26.12 I²C Bus Interface Input/Output Timing (Option)

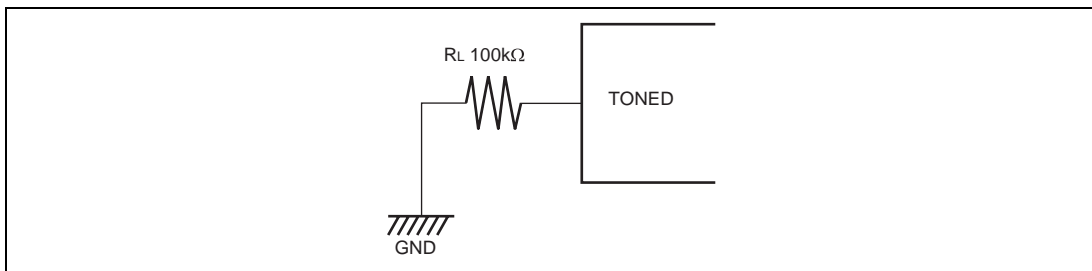


Figure 26.13 TONED Load Circuit (Supported only by the H8S/2268 Series)

26.5 Usage Note

The F-ZTAT and masked ROM versions both satisfy the electrical characteristics shown in this manual, but actual electrical characteristic values, operating margins, noise margins, and other properties may vary due to differences in manufacturing process, on-chip ROM, layout patterns, and so on.

When system evaluation testing is carried out using the F-ZTAT version, the same evaluation testing should also be conducted for the masked ROM version when changing over to that version.

Appendix A I/O Port States in Each Pin State

A.1 I/O Port State in Each Pin State of the H8S/2268 Series

Port Name	Reset	Hardware Standby Mode	Software Standby Mode	Watch Mode	Program Execution State Sleep Mode Subsleep Mode
Port 1	T	T	Keep	Keep	I/O port
Port 3	T	T	Keep	Keep	I/O port
Port 4	T	T	T	T	I/O port
Port 7	T	T	Keep	Keep	I/O port
P97/DA1 P96/DA0	T	T	[DAOEn = 1] Keep [DAOEn = 0] T	[DAOEn = 1] Keep [DAOEn = 0] T	Input port
Port F	T	T	Keep	Keep	I/O port
PH7	T	T	T	T	Input port
PH3 to PH0	T	T	[Common output] Port [Otherwise] Keep	[Common output] COM4 to COM1 [Otherwise] Keep	[Common output] COM4 to COM1 [Otherwise] I/O port
Port J	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG8 to SEG1 [Otherwise] Keep	[Segment output] SEG8 to SEG1 [Otherwise] I/O port
Port K	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG16 to SEG9 [Otherwise] Keep	[Segment output] SEG16 to SEG9 [Otherwise] I/O port
Port L	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG24 to SEG17 [Otherwise] Keep	[Segment output] SEG24 to SEG17 [Otherwise] I/O port
Port M	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG32 to SEG25 [Otherwise] Keep	[Segment output] SEG32 to SEG25 [Otherwise] I/O port

Port Name	Reset	Hardware Standby Mode	Software Standby Mode	Watch Mode	Program Execution State Sleep Mode
Port N	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG40 to SEG33 [Otherwise] Keep	[Segment output] SEG40 to SEG33 [Otherwise] I/O port

A.2 I/O Port State in Each Pin State of the H8S/2264 Series

Port Name	Reset	Hardware Standby Mode	Software Standby Mode	Watch Mode	Program Execution State Sleep Mode Subsleep Mode
Port 1	T	T	Keep	Keep	I/O port
Port 3	T	T	Keep	Keep	I/O port
Port 4	T	T	T	T	Input port
Port 7	T	T	Keep	Keep	I/O port
Port 9	T	T	T	T	Input port
Port F	T	T	Keep	Keep	I/O port
PH7	T	T	T	T	Input port
PH5	T	T	Keep	Keep	I/O port
PH4	T	T	[Clock output] H [Otherwise] Keep	[Clock output] ϕ [Otherwise] Keep	[Clock output] ϕ * [Otherwise] I/O port
PH3 to PH0	T	T	[Common output] Port [Otherwise] Keep	[Common output] COM4 to COM1 [Otherwise] Keep	[Common output] COM4 to COM1 [Otherwise] I/O port
Port J	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG8 to SEG1 [Otherwise] Keep	[Segment output] SEG8 to SEG1 [Otherwise] I/O port
Port K	T	T	[Segment output] Port [Otherwise] Keep	[Segment output] SEG16 to SEG9 [Otherwise] Keep	[Segment output] SEG16 to SEG9 [Otherwise] I/O port

Port Name	Reset	Hardware Standby Mode	Software Standby Mode	Watch Mode	Program Execution
					State Sleep Mode Subsleep Mode
Port L	T	T	[Segment output]	[Segment output]	[Segment output]
			Port	SEG24 to SEG17	SEG24 to SEG17
			[Otherwise]	[Otherwise]	[Otherwise]
			Keep	Keep	I/O port
SEG40 to SEG25	T	T	T	[Segment output]	[Segment output]
				SEG40 to SEG25	SEG40 to SEG25
				[Otherwise]	[Otherwise]
				T	T

Legend

H: High level

T: High-impedance

Keep: Input port becomes high-impedance, output port retains state

Port: Determined by port setting (input is high-impedance)

Note: * The I/O port state at the clock output is high, if the operation shifts to sleep mode while all modules are stopped (MSTPCR = H"FFFFFFF").

Appendix B Product Codes

- H8S/2268 Series

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2268 (regular oscillation)	Masked-ROM version	Standard product	HD6432268	HD6432268(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432268(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432268(A**)FA	100-pin QFP (FP-100B)	
				HD6432268(F**)TE	100-pin TQFP (TFP-100B)	
				HD6432268(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432268(F**)FA	100-pin QFP (FP-100B)	
	Version with on-chip I ² C bus interface	HD6432268W		HD6432268W(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432268W(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432268W(A**)FA	100-pin QFP (FP-100B)	
				HD6432268W(F**)TE	100-pin TQFP (TFP-100B)	
				HD6432268W(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432268W(F**)FA	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2268 (regular oscillation)	F-ZTAT version	Standard product	HD64F2268	HD64F2268TE13	100-pin TQFP (TFP-100B)	3.0 V to 5.5 V
				HD64F2268TF13	100-pin TQFP (TFP-100G)	
				HD64F2268FA13	100-pin QFP (FP-100B)	
				HD64F2268TE20	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD64F2268TF20	100-pin TQFP (TFP-100G)	
				HD64F2268FA20	100-pin QFP (FP-100B)	
H8S/2266 (regular oscillation)	Masked- ROM version	Standard product	HD6432266	HD6432266(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432266(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432266(A**)FA	100-pin QFP (FP-100B)	
				HD6432266(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432266(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432266(F**)FA	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2266 (regular oscillation)	Masked-ROM version	Version with on-chip I ² C bus interface	HD6432266W	HD6432266W(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432266W(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432266W(A**)FA	100-pin QFP (FP-100B)	
				HD6432266W(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432266W(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432266W(F**)FA	100-pin QFP (FP-100B)	
F-ZTAT version	Standard product	HD64F2266	HD64F2266TE13	HD64F2266TE13	100-pin TQFP (TFP-100B)	3.0 V to 5.5 V
				HD64F2266TF13	100-pin TQFP (TFP-100G)	
				HD64F2266FA13	100-pin QFP (FP-100B)	
				HD64F2266TE20	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD64F2266TF20	100-pin TQFP (TFP-100G)	
				HD64F2266FA20	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2265 (regular oscillation)	Masked-ROM version	Standard product	HD6432265	HD6432265(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432265(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432265(A**)FA	100-pin QFP (FP-100B)	
				HD6432265(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432265(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432265(F**)FA	100-pin QFP (FP-100B)	
	Version with on-chip I ² C bus interface		HD6432265W	HD6432265W(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432265W(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432265W(A**)FA	100-pin QFP (FP-100B)	
				HD6432265W(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432265W(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432265W(F**)FA	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2265 (regular oscillation)	F-ZTAT version	Standard product	HD64F2265	HD64F2265TE13	100-pin TQFP (TFP-100B)	3.0 V to 5.5 V
				HD64F2265TF13	100-pin TQFP (TFP-100G)	
				HD64F2265FA13	100-pin QFP (FP-100B)	
				HD64F2265TE20	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD64F2265TF20	100-pin TQFP (TFP-100G)	
				HD64F2265FA20	100-pin QFP (FP-100B)	

Legend

(A**), (F**): ROM code

Note: Some products above are in the developing or planning stage. Please contact Hitachi agency to conform the present state of each product.

- H8S/2264 Series

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2264 (regular oscillation)	Masked-ROM version	Standard product	HD6432264	HD6432264(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432264(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432264(A**)FA	100-pin QFP (FP-100B)	
				HD6432264(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432264(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432264(F**)FA	100-pin QFP (FP-100B)	
	Version with on-chip I ² C bus interface		HD6432264 W	HD6432264W(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432264W(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432264W(A**)FA	100-pin QFP (FP-100B)	
				HD6432264W(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432264W(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432264W(F**)FA	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2264 (regular oscillation)	F-ZTAT version	Standard product	HD64F2264	HD64F2264TE13	100-pin TQFP (TFP-100B)	3.0 V to 5.5 V
				HD64F2264TF13	100-pin TQFP (TFP-100G)	
				HD64F2264FA13	100-pin QFP (FP-100B)	
				HD64F2264TE20	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD64F2264TF20	100-pin TQFP (TFP-100G)	
				HD64F2264FA20	100-pin QFP (FP-100B)	
H8S/2264R (oscillation stabilization time shortened)	Masked-ROM version	Standard product	HD6432264 R	HD6432264R(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432264R(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432264R(A**)FA	100-pin QFP (FP-100B)	
				HD6432264R(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432264R(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432264R(F**)FA	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2264R (oscillation stabilization time shortened)	Masked-ROM version	Version with on-chip I ² C bus interface	HD6432264 RW	HD6432264RW(A**)T E	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432264RW(A**)T F	100-pin TQFP (TFP-100G)	
				HD6432264RW(A**)F A	100-pin QFP (FP-100B)	
				HD6432264RW(F**)T E	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432264RW(F**)T F	100-pin TQFP (TFP-100G)	
				HD6432264RW(F**)F A	100-pin QFP (FP-100B)	
F-ZTAT version	Standard product		HD64F2264 R	HD64F2264RTE13	100-pin TQFP (TFP-100B)	3.0 V to 5.5 V
				HD64F2264RTF13	100-pin TQFP (TFP-100G)	
				HD64F2264RFA13	100-pin QFP (FP-100B)	
				HD64F2264RTE20	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD64F2264RTF20	100-pin TQFP (TFP-100G)	
				HD64F2264RFA20	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2264R (regular oscillation)	Masked-ROM version	Version with on-chip I ² C bus interface	HD6432262W	HD6432262W(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432262W(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432262W(A**)FA	100-pin QFP (FP-100B)	
				HD6432262W(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432262W(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432262W(F**)FA	100-pin QFP (FP-100B)	
H8S/2262R (oscillation stabilization time shortened)	Masked-ROM version	Standard product	HD6432262R	HD6432262R(A**)TE	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432262R(A**)TF	100-pin TQFP (TFP-100G)	
				HD6432262R(A**)FA	100-pin QFP (FP-100B)	
				HD6432262R(F**)TE	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432262R(F**)TF	100-pin TQFP (TFP-100G)	
				HD6432262R(F**)FA	100-pin QFP (FP-100B)	

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)	Operating Voltage
H8S/2262R (oscillation stabilization time shortened)	Masked-ROM version	Version with on-chip I ² C bus interface	HD6432262 RW	HD6432262RW(A**)T E	100-pin TQFP (TFP-100B)	2.7 V to 5.5 V
				HD6432262RW(A**)T F	100-pin TQFP (TFP-100G)	
				HD6432262RW(A**)F A	100-pin QFP (FP-100B)	
				HD6432262RW(F**)T E	100-pin TQFP (TFP-100B)	4.0 V to 5.5 V
				HD6432262RW(F**)T F	100-pin TQFP (TFP-100G)	
				HD6432262RW(F**)F A	100-pin QFP (FP-100B)	

Legend

(A**), (F**): ROM code

Note: Some products above are in the developing or planning stage. Please contact Hitachi agency to conform the present state of each product.

Appendix C Package Dimensions

Figures C.1, C.2, and C.3 show the package dimensions of the H8S/2268 Series and H8S/2264 Series.

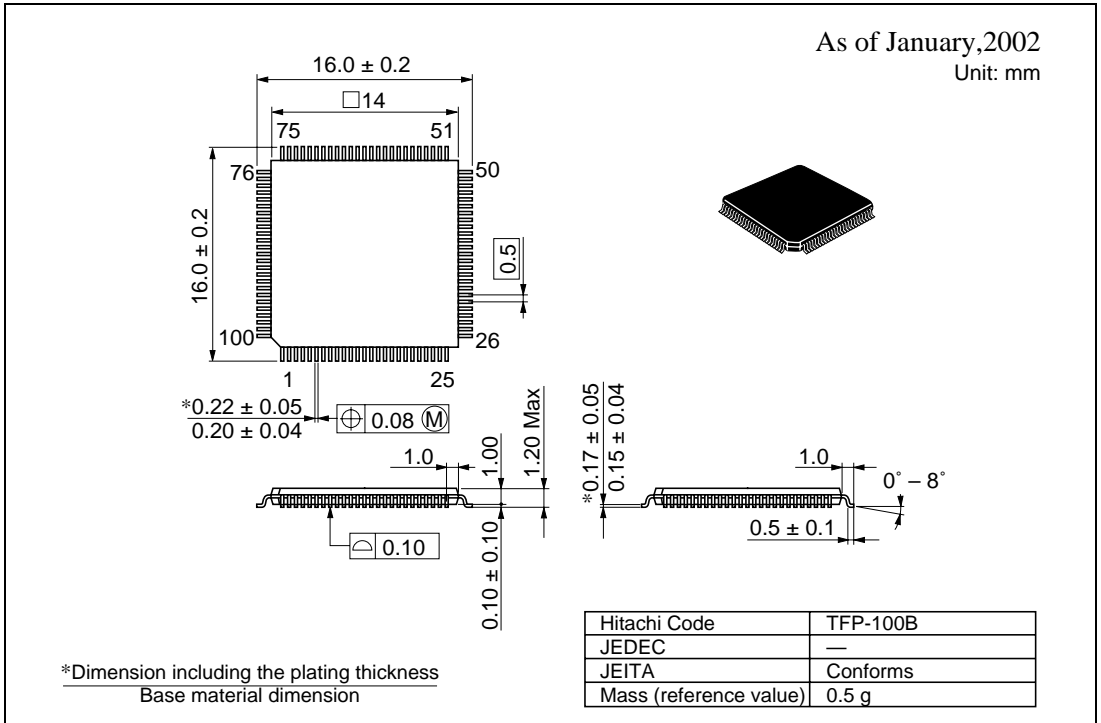
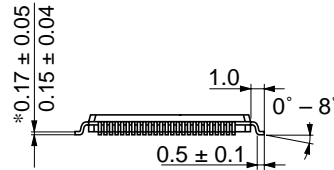
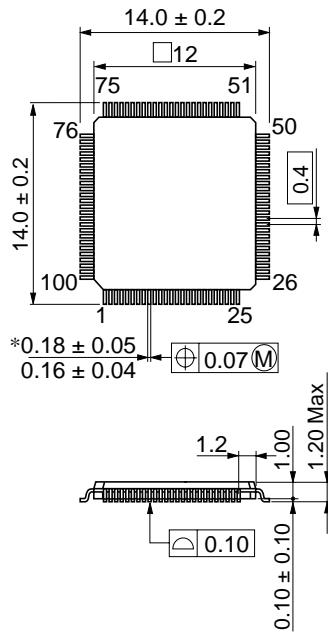


Figure C.1 TFP-100B Package Dimensions

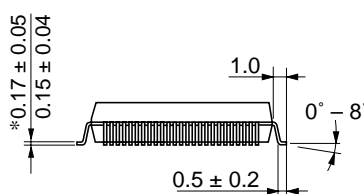
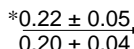


*Dimension including the plating thickness
Base material dimension

Hitachi Code	TFP-100G
JEDEC	—
JEITA	Conforms
Mass (reference value)	0.4 g

Figure C.2 TFP-100G Package Dimensions

Unit: mm


$$\frac{\text{*Dimension including the plating thickness}}{\text{Base material dimension}}$$

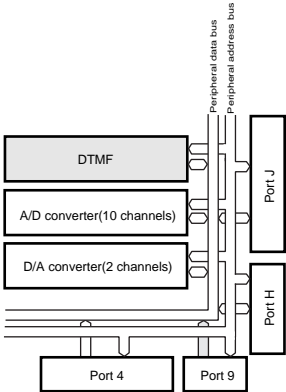
Hitachi Code	FP-100B
JEDEC	—
JEITA	Conforms
Mass (reference value)	1.2 g

Figure C.3 FP-100B Package Dimensions

Main Revisions and Additions in this Edition

Item	Page	Revisions (See Manual for Details)																																																															
	All	In this version, descriptions of the H8S/2264 Series are added. Therefore, notes indicating the series name are added if there are differences in the specifications between the H8S/2268 Series and H8S/2264 Series. The added notes are as follows: (H8S/2268), (H8S/2268 Series), (H8S/2268 Series only), supported only by the H8S/2268 Series, (H8S/2264), (H8S/2264 Series), (H8S/2264 Series only), or supported only by the H8S/2264 Series.																																																															
Section 1 Overview	(Error)	(Correction)																																																															
1.1 Overview		H8S/2268 Series:																																																															
• On-chip memory	<table><tr><th>Model</th><th>ROM</th><th>RAM</th></tr><tr><td>HD64F2268</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD6432268</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD6432268W</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD6432268D</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD6432266</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD6432266W</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD6432266D</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD6432265</td><td>128 kbytes</td><td>4 kbytes</td></tr><tr><td>HD6432265W</td><td>128 kbytes</td><td>4 kbytes</td></tr><tr><td>HD6432265D</td><td>128 kbytes</td><td>4 kbytes</td></tr></table>	Model	ROM	RAM	HD64F2268	256 kbytes	16 kbytes	HD6432268	256 kbytes	16 kbytes	HD6432268W	256 kbytes	16 kbytes	HD6432268D	256 kbytes	16 kbytes	HD6432266	128 kbytes	8 kbytes	HD6432266W	128 kbytes	8 kbytes	HD6432266D	128 kbytes	8 kbytes	HD6432265	128 kbytes	4 kbytes	HD6432265W	128 kbytes	4 kbytes	HD6432265D	128 kbytes	4 kbytes	<table><tr><th>Model</th><th>ROM</th><th>RAM</th></tr><tr><td>HD64F2268</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD64F2266</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD64F2265</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD6432268</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD6432268W</td><td>256 kbytes</td><td>16 kbytes</td></tr><tr><td>HD6432266</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD6432266W</td><td>128 kbytes</td><td>8 kbytes</td></tr><tr><td>HD6432265</td><td>128 kbytes</td><td>4 kbytes</td></tr><tr><td>HD6432265W</td><td>128 kbytes</td><td>4 kbytes</td></tr></table>	Model	ROM	RAM	HD64F2268	256 kbytes	16 kbytes	HD64F2266	128 kbytes	8 kbytes	HD64F2265	128 kbytes	8 kbytes	HD6432268	256 kbytes	16 kbytes	HD6432268W	256 kbytes	16 kbytes	HD6432266	128 kbytes	8 kbytes	HD6432266W	128 kbytes	8 kbytes	HD6432265	128 kbytes	4 kbytes	HD6432265W	128 kbytes	4 kbytes
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HD6432265W	128 kbytes	4 kbytes																																																															

Figure 1.1 Internal Block Diagram of H8S/2268	Amended. Description of (option) in DTMF deleted. Bus line of port 9 amended.
---	---



Item

Page

Revisions (See Manual for Details)

9.1.4 Pin Functions

P15/TIOCB1/TCLKC

Amended.

(Error)

Notes: 2. This pin functions as TCLKD inputs when TPSC2 to TPSC0 in TCR0 or TCR2 are set to 110.

(Correction)

Notes: 2. This pin functions as TCLKC inputs when TPSC2 to TPSC0 in TCR0 or TCR2 are set to 110.

9.2.4 Port 3 Open Drain Control Register (P3ODR)

Description of bits 5 to 0 amended.

(Error)

When each of P35DDR and P34DDR bits is set to 1, the corresponding pins P35 and P34 function as open drain outputs.

(Correction)

When each of P35ODR and P34ODR bits is set to 1, the corresponding pins P35 and P34 function as open drain outputs.

9.7.4 Pin Functions

Amended.

PH3/COM4

X is amended to — in table.

1 is amended to 0 in table.

CMX			0	1	0	1	
SUPS*					0	1	
PH3DDR	0	1	0	1		0	1

PH2/COM3 and PH1/COM2

X is amended to — in table.

CMX			0	1	
PH2DDR	0	1	0	1	

Table 10.6 TPSC0 to TPSC2 (channel 1)

Amended.

1

1

1

Counts on TCNT_2 overflow.

(H8S/2268 Series: Setting disabled)

Item	Page	Revisions (See Manual for Details)
Table 10.13 TIORH_0 (channel 0) (H8S/2268 Series only)		<p>Amended.</p> <hr/> <p>Input capture register Capture input source is TIOCA0 pin</p> <hr/> <p>Input capture at rising edge</p> <hr/> <p>Capture input source is TIOCA0 pin</p> <hr/> <p>Input capture at falling edge</p> <hr/>
10.3.6 Timer Counter (TCNT)		<p>Amended.</p> <p>The TCNT counters are initialized to H'0000 by a reset, or in hardware standby mode.</p>
11.9.2 Input/Output Pins		<p>Name in table amended.</p> <p>(Error) Timer clock input pin 4</p> <p>(Correction) Timer clock input pin</p>
13.3.10 Serial Expansion Mode Register (SEMR_0)		<p>Description of bits 6 to 4 amended.</p> <p>(Error) These bits are always read as 0 and cannot be modified.</p> <p>(Correction) The write value should always be 0.</p> <hr/> <p>Description of bits 2 to 0 amended.</p> <p>The ACS0 to ACS0 settings are valid when the external clock input is selected (CKE1 in SCR = 1) in asynchronous mode (C/\bar{A} in SMR = 0).</p> <p>000: External clock input</p> <p>:</p> <p>111: 720 kbps average transfer rate (for ϕ = 6 MHz only) is selected (SCI0 operates on base clock with frequency of 8 times transfer rate)</p>
15.1 Features		<p>Amended.</p> <ul style="list-style-type: none"> Conversion time: 6.3 μs per channel (at 20.5 MHz operation)
15.3.2 A/D Control/Status Register (ADCSR)		<p>Description of bit 5 amended.</p> <p>A/D Start</p> <p>... In scan mode, conversion continues sequentially on the specified channels until this bit is cleared to 0 by software, a reset, or a transition to power-down mode in which the A/D converter is halted, shown in table 22.1.</p>
Figure 17.1 Block Diagram of LCD Controller/Driver		<p>Amended.</p> <p>Description of $\phi/8$ to $\phi/1024$ is amended to $\phi/16$ to $\phi/2048$.</p>

Item	Page	Revisions (See Manual for Details)
17.3.2 LCD Control Register (LCR)		Description of bits 7 and 3 amended.
		Bit 7
	R/W	LCD Disable Bit This bit is always read as 1. The write value should always be 0.
		Bit 3
	R/W	Frame Frequency Select 3 to 0
	R/W	... In subactive mode, watch mode, and subsleep mode, the system clock (ϕ) is halted, and therefore display operations are not performed if one of the clocks from $\phi/16$ to $\phi/2048$ is selected. ...
Table 17.5 Frame Frequency Selection		Values of Operating Clock and Frame Frequency amended.
17.3.3 LCD Control Register 2 (LCR2)		Description of bit 5 amended.
		(H8S/2268 Series)
		Triple Step-Up Voltage Circuit Clock Select
		This bit selects a clock used for triple step-up voltage circuit. This bit selects a clock which divides a clock specified by the LCD operating control register (LCR) by 4 or 8 as step-up voltage circuit clock.
		0: A clock, which divides a LCD operating clock by 4, is selected as step-up voltage circuit clock
		1: A clock, which divides a LCD operating clock by 8, is selected as step-up voltage circuit clock
		Relationships between LCD operating clock and step-up voltage clock, and between bits CKS3 to CKS0 and bit HCKS
		Values of LCD clock, step-up voltage circuit clock, frame frequency, and step-up voltage circuit clock frequency amended.
		Symbol of * is amended to X.
18.1 Features		Amended.
		<ul style="list-style-type: none"> Generating DTMF frequency sine waveform from the system clock (ϕ)
		The system clock (2.0 to 20.4 MHz, with 400 kHz stops)
Figure 18.2 DTMF Generation Circuit Diagram		Amended.
		Description of 2.0 to 20.0 MHz is amended to 2.0 to 20.4 MHz.

Item	Page	Revisions (See Manual for Details)
18.3.2 DTMF Load Register (DTLR)		<p>Description of bits 5 to 0 amended.</p> <p>Main clock division ratio 5 to 0</p> <p>These bits set the system clock division ratio to produce 400-kHz clock signals to be supplied to the DTMF generation circuit. The division ratio determines the counter value of 6b'000101 to 6b'110011(D'5 to D'51) according to the range 2.0 to 20.4 MHz.</p> <p>000000: Setting prohibited</p> <p>: :</p> <p>110010: Division ratio (50) main clock frequency (20.0 MHz)</p> <p>110011: Division ratio (51) main clock frequency (20.4 MHz)</p> <p>110100: Setting prohibited</p> <p>: :</p> <hr/> <p>Note amended.</p> <p>Additionally, correct operation is not guaranteed if the DTL0 to DTL5 settings are other than 5 to 51 (division ratio 5 to 51).</p>
18.4.2 Operation Flow		<p>Amended.</p> <p>1. Set the system clock division ratio for the DTLR based on the frequency of the connected system clock. (2.0 to 20.4 MHz, with 400 kHz stops)</p>
Table 20.5 System Clock Frequencies for which Automatic Adjustment of LSI Bit Rate is Possible		<p>Amended.</p> <hr/> <p>8 to 20.5 MHz</p> <hr/> <p>4 to 20.5 MHz</p> <hr/> <p>2 to 20.5 MHz</p> <hr/>
20.11 Programmer Mode		Description amended.
20.13 Flash Memory Programming and Erasing Precautions		Description of Use the specified voltages and timing for programming and erasing amended.
22.1.1 Standby Control Register (SBYCR)		<p>Description of bits 6 to 4 amended.</p> <p>000: Standby time = 8192 states</p> <p>: :</p> <p>101: Standby time = 262144 states</p> <p>110: Standby time = 2048 states</p> <p>111: Standby time = 16 states*</p>

Item	Page	Revisions (See Manual for Details)
Figure 22.2 Medium-Speed Mode Transition and Clearance Timing		Amended. Description of ϕ is amended to internal clock ϕ .
25.1 Register Addresses (In Address Order)		Amended. Number of access states is amended from 2 to 1 in MRA, SAR, MRB, DAR, CRA, and CRB.
		Added. System clock control register 2 added.
25.3 Register States in Each Operating Mode		Amended. States of MRA, SAR, MRB, DAR, CRA, and CRB are amended from initialized to --- .
Figure 26.1 Power Supply Voltage and Operating Ranges (1)		Amended. Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz. Values of f (MHz) in graphs (1) and (2) are amended from 20.0 to 20.5.
Figure 26.1 Power Supply Voltage and Operating Ranges (2)		Amended. Value of f (MHz) in graph (3) is amended from 20.0 to 20.5 and value of 10.0 is added. Values of t (ns) in graphs (4) and (5) are amended from 50 to 48.8. Value of t (ns) in graph (6) is amended from 50 to 48.8 and value of 100 is added.
Table 26.2 DC Characteristics (1)		Amended. Description of $\text{--- Preliminary ---}$ deleted. Values of output high voltage, output low voltage, and input leakage current amended.
Table 26.2 DC Characteristics (2)		Amended. Description of $\text{--- Preliminary ---}$ deleted. Values of output high voltage, output low voltage, and input leakage current amended.
Table 26.2 DC Characteristics (3)		Amended. Description of $\text{--- Preliminary ---}$ deleted. Values of current dissipation and analog power supply current amended. Values of reference current amended. Notes 3 and 4 amended.

Item	Page	Revisions (See Manual for Details)
Table 26.2 DC Characteristics (4) – Preliminary –		Amended. Notes 3 and 4 amended.
Table 26.2 DC Characteristics (5)		Amended. Description of – Preliminary – deleted. Values of current dissipation, analog power supply current, and reference current amended.
		Notes 3 and 4 amended.
Table 26.2 DC Characteristics (6) – Preliminary –		Amended. Test condition of current dissipation is amended from $f = 20$ MHz to $f = 20.5$ MHz.
		Notes 3 and 4 amended.
Table 26.3 Permissible Output Currents		Amended. Value of total of port 7, 8 is amended from TBD to 30.
Table 26.5 Clock Timing		Amended. Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz. Description of 20 MHz in condition C and D in table is amended to 20.5 MHz.
		Values of condition C and D in clock cycle time are amended from min. 50 and max. 500 to min. 48.8 and max. 100.
Table 26.6 Control Signal Timing		Amended. Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz.
Table 26.7 Timing of On-Chip Peripheral Modules		Amended. Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz.
		Item of transmit data delay time t_{XD} is added to SCI.
Table 26.8 I ² C Bus Timing		Added. Conditions of (regular specifications), $T_a = -40^{\circ}\text{C}$ to $+80^{\circ}\text{C}$ (wide-range specifications) added.

Item	Page	Revisions (See Manual for Details)
Table 26.9 A/D Conversion Characteristics		<p>Amended.</p> <p>Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz.</p> <p>Description of 20 MHz in condition C and D in table is amended to 20.5 MHz.</p> <hr/> <p>In table:</p> <p>Value of condition C and D in conversion time is amended from min. 6.5 to min. 6.3.</p> <p>Value of condition C and D in nonlinearity error is amended from max. ± 6.0 to max. ± 3.0.</p> <p>Value of condition C and D in offset error is amended from max. ± 4.0 to max. ± 2.0.</p> <p>Value of condition C and D in full-scale error is amended from max. ± 4.0 to max. ± 2.0.</p> <p>Value of condition C and D in absolute accuracy is amended from max. ± 8.0 to max. ± 4.0.</p>
Table 26.10 D/A Conversion Characteristics		<p>Amended.</p> <p>Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz.</p>
Table 26.11 LCD Characteristics		<p>Amended.</p> <p>Description of 2 to 20 MHz in conditions C and D is amended to 10 to 20.5 MHz.</p> <hr/> <p>Values of LCD power supply division resistor, LCD input reference voltage, LCD voltage, and LCD input reference power supply current amended.</p>
Table 26.12 DTMF Characteristics		<p>Amended.</p> <p>Conditions C and D</p> <p>Description of $AV_{cc} = 4.0\text{ V}$ to 5.5 V, $V_{ref} = 4.0\text{ V}$ to AV_{cc}, $V_{ss} = AV_{ss} = 0\text{ V}$, $\phi = 2$ to 20 MHz is amended to $AV_{cc} = 2.7\text{ V}$ to 5.5 V, $V_{ref} = 2.7\text{ V}$ to AV_{cc}, $V_{ss} = AV_{ss} = 0\text{ V}$, $\phi = 10$ to 20.4 MHz.</p> <hr/> <p>Values of DTMF output voltage (row side) and DTMF output voltage (column side) amended.</p> <p>Note amended.</p>

Item	Page	Revisions (See Manual for Details)
Table 26.13 Flash Memory Characteristics		Amended. Values of programming time, erase time, and count of rewriting amended. Item of data hold time added.
Figure 26.5 Oscillator Settling Timing		Amended. Description of ϕ is amended to internal clock ϕ .
Figure 26.10 SCK Clock Input Timing		Amended. Arrow which indicates range of t_{SCKW} amended.

Index

16-Bit Timer Pulse Unit (TPU).....	171	Program-Counter Relative.....	42
Buffer Operation	210	Register Direct.....	41
Buffer Operation Timing	230	Register Indirect	41
Counter Operation	203	Register Indirect with Displacement.....	41
Free-running count operation	204	Register indirect with post-increment ...	41
Input Capture Function	207	Register indirect with pre-decrement	41
Input Capture Signal Timing.....	228		
Output Compare Output Timing	227	Bcc.....	37
periodic count operation	204	break address.....	93
Phase Counting Mode	220	Break Condition	95
PWM Modes	215	Bus Arbitration.....	103
Synchronous Operation	208	bus cycle	101
TCNT Count Timing	227	Bus Masters.....	103
toggle output	206		
Waveform Output by Compare Match	206	Clock Pulse Generator	507
		Condition Field	39
8-Bit Reload Timer.....	265	Condition-Code Register	24
Automatic Reload Timer Operation ...	270		
Interval Timer Operation	269	D/A Converter.....	429
8-Bit Timers.....	243	data direction register (DDR)	127
16-Bit Count Mode.....	258	data register (DR).....	127
Cascaded Connection	258	Data Transfer Controller.....	105
Compare-Match Count Mode.....	258	activated by software	121
Pulse Output.....	254	block transfer mode	118
TCNT Incrementation Timing.....	255	chain transfer.....	119
Toggle output.....	262	DTC Vector Table	112
		normal mode.....	116
A/D Converter.....	411	register information	112
A/D Converter Activation.....	226	repeat mode.....	117
Analog Input Channel.....	414	software activation.....	120, 125
conversion time	420	vector number for the software activation	
external trigger	422	interrupt.....	111
Scan Mode	419	DTMF Generation Circuit.....	457
single mode	418		
Address Map.....	51	Effective Address	40, 43
Address Space	20	Effective Address Extension	39
Addressing Modes.....	40	Exception Handling	53
Absolute Address	41	Interrupts.....	57
Immediate	42	Reset Exception Handling.....	55
Memory Indirect.....	42		

Stack Status.....	59	TEI.....	359
Traces	57	TGI	225
Trap Instruction.....	58	TXI	359
Exception Vector Table.....	54	WOVI	284
Extended Control Register.....	23	Interrupt Control Modes	82
flash memory	467	Interrupt Controller.....	61
boot mode	484	Interrupt Exception Handling Vector Table	77
emulation	488	Interrupt Mask Bit	24
erase/erase-verify.....	494	LCD Controller/Driver	435
erasing units.....	472	Common Drivers	439
error protection.....	496	Duty Cycle	435
Hardware protection	496	LCD Display	446
program/program-verify	492	LCD RAM	447
Software protection	496	Segment Driver	440
user program mode.....	487	memory cycle.....	101
General Register.....	26	On-Board Programming	484
I ² C Bus Interface.....	367	Operating Mode Selection	49
I ² C bus format	385	Operation Field	39
noise cancelers	398	PC Break Controller	93
serial format	385	Power-Down Modes.....	523
input pull-up MOS function.....	127	Direct Transitions.....	541
Instruction Set.....	29	Hardware Standby Mode.....	536
Arithmetic Operations Instructions	32	medium-speed mode.....	531
Bit Manipulation Instructions	35	Module Stop Mode	537
Block Data Transfer Instructions.....	39	Sleep Mode	532
Branch Instructions.....	37	Software Standby Mode.....	533
Data Transfer Instructions.....	31	Sub-Active Mode.....	540
Logic Operations Instructions	34	Sub-Sleep Mode	539
Shift Instructions	34	Watch Mode.....	538
System Control Instructions.....	38	Power-on Reset Circuit	543
Interrupt		power-on reset circuit	543
ADI.....	422	Program Counter	23
CMIA	259	Program/Erase Protection	496
CMIB.....	259	Programmer Mode.....	497
ERI	359	Register	
NMI.....	284	ADCR.....	417, 554, 561, 568
OVI.....	259	ADCSR.....	415, 554, 561, 568
RXI.....	359		
SWDTEND.....	120		
TCI	225		

ADDR.....	414, 553, 561, 568	P3DR	139, 551, 558, 566
BARA	94, 550, 557, 565	P3ODR.....	140, 551, 558, 565
BARB	94, 550, 557, 565	P7DDR.....	145, 551, 558, 565
BCRA	95, 550, 557, 565	P7DR	145, 551, 558, 566
BCRB	96, 550, 557, 565	PFDDR.....	149, 551, 558, 565
BRR	311, 553, 560, 567	PFDR	149, 551, 558, 566
CRA.....	110, 548, 555, 563	PHDDR.....	151, 548, 556, 563
CRB	110, 548, 555, 563	PHDR.....	152, 549, 556, 563
DACR.....	431, 549, 556, 564	PJDDR	157, 549, 556, 563
DADR.....	430, 549, 556, 564	PJDR.....	157, 549, 556, 564
DAR.....	109, 548, 555, 563	PJPCR.....	158, 549, 556, 564
DDCSWR	385, 549, 556, 564	PKDDR.....	161, 549, 556, 563
DT CER.....	110, 550, 558, 565	PKDR.....	161, 549, 556, 564
DT CR	459, 548, 555, 563	PLDDR	163, 549, 556, 563
DT LR.....	460, 548, 555, 563	PLDR	164, 549, 556, 564
DTVECR.....	111, 550, 558, 565	PMDDR	166, 549, 556, 563
EBR1	478, 554, 561, 568	PMDR.....	166, 549, 556, 564
EBR2	480, 554, 561, 568	PNDDR.....	168, 549, 556, 563
FLMCR1	477, 554, 561, 568	PNDR.....	168, 549, 556, 564
FLMCR2.....	478, 554, 561, 568	PORT1	134, 554, 562, 568
FLPWCRCR	482, 554, 561, 568	PORT3	140, 554, 562, 568
ICCR.....	378, 553, 560, 567	PORT4	144, 554, 562, 568
ICDR	371, 553, 560, 567	PORT7	146, 554, 562, 569
ICMR.....	374, 553, 560, 567	PORT9	148, 554, 562, 569
ICSR	382, 553, 560, 567	PORTF.....	150, 554, 562, 569
IENR1.....	73, 549, 556, 564	PORTH	153, 549, 556, 564
IER	68, 550, 558, 565	PORTJ.....	158, 549, 556, 564
IPR.....	67, 551, 558, 565	PORTK	162, 549, 556, 564
ISCR.....	69, 550, 558, 565	PORTL.....	164, 549, 556, 564
ISR.....	71, 550, 558, 565	PORTM.....	167, 549, 556, 564
IWPR.....	73, 549, 556, 564	PORTN	169, 549, 556, 564
LCD RAM	447, 548, 555, 563	RAMER	480, 551, 558, 566
LCR	441, 548, 555, 563	RDR.....	294, 553, 560, 567
LCR2	442, 548, 555, 563	RSR.....	294
LPCR.....	438, 548, 555, 563	RSTCSR.....	280, 553, 560, 567
LPWRCR.....	512, 550, 557, 565	SAR	109, 548, 555, 563
MDCR	50, 550, 557, 565	SARX.....	373, 553, 560, 567
MRA	107, 548, 555, 563	SBYCR	527, 550, 557, 565
MRB	109, 548, 555, 563	SCKCR	509, 550, 557, 565
MSTPCR.....	529, 557, 563, 565	SCMR	310, 553, 560, 567
P1DDR.....	133, 550, 558, 565	SCR.....	298, 553, 560, 567
P1DR	134, 551, 558, 566	SCRX.....	377, 549, 556, 564
P3DDR.....	139, 550, 558, 565	SEMR	319, 550, 557, 565

SMR	295, 553, 560, 567	Serial Communication Interface (SCI) ...	289
SSR.....	303, 553, 560, 567	Asynchronous Mode.....	323
SYSCR	65, 550, 557, 565	Bit Rate	311
TCNT	199, 246, 268, 275, 551,	Break	361
	552, 559, 560, 566, 567	Clocked Synchronous Mode	340
TCORA.....	246, 552, 560, 567	framing error	330
TCORB.....	246, 552, 560, 567	Mark State.....	361
TCR.....	178, 247, 551, 552,	Multiprocessor Communication Function	
	559, 560, 566, 567	334
TCSR.....	249, 276, 552, 560, 567	overrun error	330
TDR.....	294, 553, 560, 567	parity error	330
TGR.....	199, 551, 559, 566	Smart Card.....	289
TIER.....	192, 551, 559, 566	Smart Card Interface.....	348
TIOR.....	184, 551, 559, 566	stack pointer	22
TMDR	182, 551, 559, 566		
TSR	194, 551, 559, 566	the internal power step-down circuit	545
TSTR.....	199, 551, 558, 565		
TSYR.....	201, 551, 558, 565	Watchdog Timer.....	273
WPCR.....	159, 549, 556, 564	Interval Timer Mode.....	282
Register Field.....	39	Overflow	283
Reset.....	55	Watchdog Timer Mode	281

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