Hitachi 16-Bit Single-Chip Microcomputer

H8S/2239 Series, H8S/2238R Series, H8S/2237 Series, H8S/2227 Series

H8S/2239 HD64F2239, H8S/2239 HD6432239, H8S/2239 HD6432239W

H8S/2238 HD64F2238R, H8S/2238 HD6432238R, H8S/2238 HD6432238RW

H8S/2236 HD6432236R, H8S/2236 HD6432236RW

H8S/2237 HD6472237, H8S/2237 HD6432237

H8S/2235 HD6432235

H8S/2233 HD6432233

H8S/2227 HD64F2227, H8S/2227 HD6432227

H8S/2225 HD6432225

H8S/2224 HD6432224

H8S/2223 HD6432223

Hardware Manual

HITACHI

ADE-602-300

Rev1.0
09/24/02
Hitachi, Ltd.

Shaping intelligence
HITACHI SEMICONDUCTOR

Cautions

1. Hitachi neither warrants nor grants licenses of any rights of Hitachi's or any third party's patent, copyright, trademark, or other intellectual property rights for information contained in this document. Hitachi bears no responsibility for problems that may arise with third party's rights, including intellectual property rights, in connection with use of the information contained in this document.
2. Products and product specifications may be subject to change without notice. Confirm that you have received the latest product standards or specifications before final design, purchase or use.
3. Hitachi makes every attempt to ensure that its products are of high quality and reliability. However, contact Hitachi's sales office before using the product in an application that demands especially high quality and reliability or where its failure or malfunction may directly threaten human life or cause risk of bodily injury, such as aerospace, aeronautics, nuclear power, combustion control, transportation, traffic, safety equipment or medical equipment for life support.
4. Design your application so that the product is used within the ranges guaranteed by Hitachi particularly for maximum rating, operating supply voltage range, heat radiation characteristics, installation conditions and other characteristics. Hitachi bears no responsibility for failure or damage when used beyond the guaranteed ranges. Even within the guaranteed ranges, consider normally foreseeable failure rates or failure modes in semiconductor devices and employ systemic measures such as fail-safes, so that the equipment incorporating Hitachi product does not cause bodily injury, fire or other consequential damage due to operation of the Hitachi product.
5. This product is not designed to be radiation resistant.
6. No one is permitted to reproduce or duplicate, in any form, the whole or part of this document without written approval from Hitachi.
7. Contact Hitachi's sales office for any questions regarding this document or Hitachi semiconductor products.

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 be 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

The H8S/2239 Series, H8S/2238R Series, H8S/2237 Series, and H8S/2227 Series are high-performance microcomputers made up of the internal 32-bit configuration H8S/2000 CPU as their cores, and the peripheral functions required to configure a system.

A single-power flash memory (F-ZTAT™*) version and masked ROM version are available for these LSIs' ROM. These versions provide flexibility as they 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 of which the specifications frequently changeable.

On-chip peripheral functions of each microcomputer are summarized below.

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

List of On-Chip Peripheral Functions

Series Name	H8S/2239 Series	H8S/2238R Series	H8S/2237 Series	H8S/2227 Series
Microcomputer	H8S/2239	H8S/2238R H8S/2236R	H8S/2237 H8S/2235 H8S/2233	H8S/2227 H8S/2225 H8S/2224 H8S/2223
Bus controller (BSC)	O (16 bits)	O (16 bits)	O (16bits)	O (16 bits)
Data transfer controller (DTC)	O	O	O	O
DMA controller (DMAC)	O	—	—	—
PC break controller (PBC)	×2	×2	×2	×2
16-bit timer pulse unit (TPU)	×6	×6	×6	×3
8-bit timer (TMR)	×4	×4	×2	×2
Watch dog timer (WDT)	×2	×2	×2	×2
Serial communication interface (SCI)	×4	×4	×4	×3
I^2C bus interface (IIC)	×2 (option)	×2 (option)	—	—
D/A converter	×2	×2	×2	—
A/D converter Analog input	×8	×8	×8	×8

Target Users: This manual was written for users who will be using the H8S/2239 Series, H8S/2238R Series, H8S/2237 Series, and H8S/2227 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 H8S/2239 Series, H8S/2238R Series, H8S/2237 Series, and H8S/2227 Series hardware functions and electrical characteristics of this LSI 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 descriptions 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 whose name is already 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 24, List of Registers.

Rules:	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.
	Number notation:	Binary is B'xxxx, hexadecimal is H'xxxx, and decimal is xxxx.
	Signal notation:	An overbar is added to a low-active signal: $\overline{\text{xxxx}}$

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. http://www.hitachisemiconductor.com/

H8S/2239 Series, H8S/2238R Series, H8S/2237 Series, H8S/2227 Series manuals:

Manual Title	ADE No.
H8S/2239 Series, H8S/2238R Series, H8S/2237 Series, H8S/2227 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, Optimizing 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

Contents

Section 1 Overview 1
1.1 Features 1
1.2 Internal Block Diagram 3
1.3 Pin Description 7
1.3.1 Pin Arrangement 7
1.3.2 Pin Arrangements in Each Mode 14
1.3.3 Pin Functions 34

Section 2 CPU 45
2.1 Features 45
2.1.1 Differences between H8S/2600 CPU and H8S/2000 CPU 46
2.1.2 Differences from H8/300 CPU 47
2.1.3 Differences from H8/300H CPU 47
2.2 CPU Operating Modes 48
2.2.1 Normal Mode 48
2.2.2 Advanced Mode 49
2.3 Address Space 52
2.4 Register Configuration 53
2.4.1 General Registers 54
2.4.2 Program Counter (PC) 55
2.4.3 Extended Control Register (EXR) 55
2.4.4 Condition-Code Register (CCR) 56
2.4.5 Initial Values of CPU Registers 57
2.5 Data Formats 58
2.5.1 General Register Data Formats 58
2.5.2 Memory Data Formats 60
2.6 Instruction Set 61
2.6.1 Table of Instructions Classified by Function 62
2.6.2 Basic Instruction Formats 71
2.7 Addressing Modes and Effective AddressCalculation 72
2.7.1 Register Direct—Rn 73
2.7.2 Register Indirect—@ERn 73
2.7.3 Register Indirect with Displacement—@(d:16, ERn) or @(d:32, ERn) 73
2.7.4 Register Indirect with Post-Increment —@ERn+ or Register Indirect with Pre-Decrement—@-ERn 73
2.7.5 Absolute Address—@aa:8, @aa:16, @aa:24, or @aa:32 74
2.7.6 Immediate—#xx:8, #xx:16, or #xx:32 74
2.7.7 Program-Counter Relative—@(d:8, PC) or @(d:16, PC) 75
2.7.8 Memory Indirect—@@aa:8 75

2.7.9 Effective Address Calculation 76
2.8 Processing States 78
2.9 Usage Notes 80
2.9.1 TAS Instruction 80
2.9.2 STM/LDM Instruction 80
2.9.3 Bit Manipulation Instructions 80

Section 3 MCU Operating Modes 81
3.1 Operating Mode Selection 81
3.2 Register Descriptions 82
3.2.1 Mode Control Register (MDCR) 82
3.2.2 System Control Register (SYSCR) 83
3.3 Operating Mode Descriptions 84
3.3.1 Mode 4 84
3.3.2 Mode 5 85
3.3.3 Mode 6 85
3.3.4 Mode 7 86
3.3.5 Pin Functions 86
3.4 Memory Map in Each Operating Mode 87

Section 4 Exception Handling 95
4.1 Exception Handling Types and Priority 95
4.2 Exception Sources and Exception Vector Table 96
4.3 Reset 97
4.3.1 Reset Types 97
4.3.2 Reset Exception Handling 98
4.3.3 Interrupts after Reset 99
4.3.4 State of On-Chip Peripheral Modules after Reset Release 99
4.4 Traces 99
4.5 Interrupts 100
4.6 Trap Instruction 100
4.7 Stack Status after Exception Handling 101
4.8 Usage Note 102

Section 5 Interrupt Controller 103
5.1 Features 103
5.2 Input/Output Pins 105
5.3 Register Descriptions 105
5.3.1 Interrupt Priority Registers A to L, and O (IPRA to IPRL, IPRO) 106
5.3.2 IRQ Enable Register (IER) 107
5.3.3 IRQ Sense Control Registers H and L (ISCRH and ISCRL) 107
5.3.4 IRQ Status Register (ISR) 110
5.4 Interrupt Sources 111

5.4.1 External Interrupts 111
5.4.2 Internal Interrupts 112
5.4.3 Interrupt Exception Handling Vector Table 112
5.5 Operation 118
5.5.1 Interrupt Control Modes and Interrupt Operation 118
5.5.2 Interrupt Control Mode 0 121
5.5.3 Interrupt Control Mode 2 123
5.5.4 Interrupt Exception Handling Sequence 124
5.5.5 Interrupt Response Times 126
5.5.6 DTC and DMAC Activation by Interrupt 127
5.6 Usage Notes 127
5.6.1 Contention between Interrupt Generation and Disabling 127
5.6.2 Instructions that Disable Interrupts 128
5.6.3 When Interrupts Are Disabled 128
5.6.4 Interrupts during Execution of EEPMOV Instruction 129

Section 6 PC Break Controller (PBC) 131
6.1 Features 131
6.2 Register Descriptions 132
6.2.1 Break Address Register A (BARA) 132
6.2.2 Break Address Register B (BARB) 133
6.2.3 Break Control Register A (BCRA) 133
6.2.4 Break Control Register B (BCRB) 134
6.3 Operation 134
6.3.1 PC Break Interrupt Due to Instruction Fetch 134
6.3.2 PC Break Interrupt Due to Data Access 135
6.3.3 Notes on PC Break Interrupt Handling 135
6.3.4 Operation in Transitions to Power-Down Modes 135
6.3.5 When Instruction Execution Is Delayed by One State 136
6.4 Usage Notes 137
6.4.1 Module Stop Mode Setting 137
6.4.2 PC Break Interrupts 137
6.4.3 CMFA and CMFB 137
6.4.4 PC Break Interrupt when DTC or DMAC Is Bus Master 137
6.4.5 PC Break Set for Instruction Fetch at Address Following BSR, JSR, JMP, TRAPA, RTE, or RTS Instruction 137
6.4.6 I Bit Set by LDC, ANDC, ORC, or XORC Instruction 138
6.4.7 PC Break Set for Instruction Fetch at Address Following Bcc Instruction 138
6.4.8 PC Break Set for Instruction Fetch at Branch Destination Address of Bcc Instruction 138

Section 7 Bus Controller 139
7.1 Features 139

7.2 Input/Output Pins 141
7.3 Register Descriptions 141
7.3.1 Bus Width Control Register (ABWCR) 142
7.3.2 Access State Control Register (ASTCR) 142
7.3.3 Wait Control Registers H and L (WCRH, WCRL) 143
7.3.4 Bus Control Register H (BCRH) 146
7.3.5 Bus Control Register L (BCRL) 147
7.3.6 Pin Function Control Register (PFCR) 148
7.4 Bus Control 149
7.4.1 Area Divisions 149
7.4.2 Bus Specifications 150
7.4.3 Bus Interface for Each Area 151
7.4.4 Chip Select Signals 152
7.5 Basic Timing 153
7.5.1 On-Chip Memory (ROM, RAM) Access Timing 153
7.5.2 On-Chip Peripheral Module Access Timing 154
7.5.3 External Address Space Access Timing 155
7.6 Basic Bus Interface 156
7.6.1 Data Size and Data Alignment 156
7.6.2 Valid Strobes 157
7.6.3 Basic Timing 158
7.6.4 Wait Control 166
7.7 Burst ROM Interface 168
7.7.1 Basic Timing 168
7.7.2 Wait Control 170
7.8 Idle Cycle 170
7.9 Bus Release 173
7.9.1 Bus Release Usage Note 174
7.10 Bus Arbitration 175
7.10.1 Operation 175
7.10.2 Bus Transfer Timing 176
7.10.3 External Bus Release Usage Note 176
7.11 Resets and the Bus Controller 177

Section 8 DMA Controller (DMAC) 179
8.1 Features 179
8.2 Input/Output Pins 181
8.3 Register Descriptions 181
8.3.1 Memory Address Registers (MARA and MARB) 183
8.3.2 I/O Address Registers (IOARA and IOARB) 183
8.3.3 Execute Transfer Count Registers (ETCRA and ETCRB) 184
8.3.4 DMA Control Registers (DMACRA and DMACRB) 185
8.3.5 DMA Band Control Registers H and L (DMABCRH and DMABCRL) 193

8.3.6 DMA Write Enable Register (DMAWER) 204
8.3.7 DMA Terminal Control Register (DMATCR) 206
8.4 Activation Sources 207
8.4.1 Activation by Internal Interrupt Request 207
8.4.2 Activation by External Request 208
8.4.3 Activation by Auto-Request 208
8.5 Operation 209
8.5.1 Transfer Modes 209
8.5.2 Sequential Mode 211
8.5.3 Idle Mode 214
8.5.4 Repeat Mode 216
8.5.5 Single Address Mode 220
8.5.6 Normal Mode 224
8.5.7 Block Transfer Mode 227
8.5.8 Basic Bus Cycles 232
8.5.9 DMA Transfer (Dual Address Mode) Bus Cycles 233
8.5.10 DMA Transfer (Single Address Mode) Bus Cycles 241
8.5.11 Multi-Channel Operation 247
8.5.12 Relation between DMAC and External Bus Requests, and DTC 248
8.5.13 DMAC and NMI Interrupts 248
8.5.14 Forced Termination of DMAC Operation 250
8.5.15 Clearing Full Address Mode 251
8.6 Interrupt Sources 252
8.7 Usage Notes 253
8.7.1 DMAC Register Access during Operation 253
8.7.2 Module Stop 254
8.7.3 Medium-Speed Mode 254
8.7.4 Activation by Falling Edge on DREQ Pin 255
8.7.5 Activation Source Acceptance 255
8.7.6 Internal Interrupt after End of Transfer 255
8.7.7 Channel Re-Setting 256

Section 9 Data Transfer Controller (DTC) 257
9.1 Features 257
9.2 Register Descriptions 259
9.2.1 DTC Mode Register A (MRA) 260
9.2.2 DTC Mode Register B (MRB) 261
9.2.3 DTC Source Address Register (SAR) 261
9.2.4 DTC Destination Address Register (DAR) 261
9.2.5 DTC Transfer Count Register A (CRA) 262
9.2.6 DTC Transfer Count Register B (CRB) 262
9.2.7 DTC Enable Register (DTCER) 262
9.2.8 DTC Vector Register (DTVECR) 263

9.3 Activation Sources 264
9.4 Location of Register Information and DTC Vector Table 265
9.5 Operation 268
9.5.1 Normal Mode 269
9.5.2 Repeat Mode 270
9.5.3 Block Transfer Mode 271
9.5.4 Chain Transfer 273
9.5.5 Interrupts 274
9.5.6 Operation Timing 274
9.5.7 Number of DTC Execution States 275
9.6 Procedures for Using DTC 277
9.6.1 Activation by Interrupt 277
9.6.2 Activation by Software 277
9.7 Examples of Use of the DTC 278
9.7.1 Normal Mode 278
9.7.2 Software Activation 278
9.8 Usage Notes 279
9.8.1 Module Stop Mode Setting 279
9.8.2 On-Chip RAM 279
9.8.3 DTCE Bit Setting 279

Section 10 I/O Ports 281
10.1 Port 1 285
10.1.1 Port 1 Data Direction Register (P1DDR) 285
10.1.2 Port 1 Data Register (P1DR) 286
10.1.3 Port 1 Register (PORT1) 286
10.1.4 Pin Functions 287
10.2 Port 3 291
10.2.1 Port 3 Data Direction Register (P3DDR) 291
10.2.2 Port 3 Data Register (P3DR) 292
10.2.3 Port 3 Register (PORT3) 292
10.2.4 Port 3 Open Drain Control Register (P3ODR) 293
10.2.5 Pin Functions 293
10.3 Port 4 296
10.3.1 Port 4 Register (PORT4) 296
10.3.2 Pin Functions 296
10.4 Port 7 297
10.4.1 Port 7 Data Direction Register (P7DDR) 297
10.4.2 Port 7 Data Register (P7DR) 297
10.4.3 Port 7 Register (PORT7) 298
10.4.4 Pin Functions 298
10.5 Port 9 301
10.5.1 Port 9 Register (PORT9) 301

10.5.2 Pin Functions 301
10.6 Port A 302
10.6.1 Port A Data Direction Register (PADDR) 302
10.6.2 Port A Data Register (PADR) 302
10.6.3 Port A Register (PORTA) 303
10.6.4 Port A Pull-up MOS Control Register (PAPCR) 303
10.6.5 Port A Open Drain Control Register (PAODR) 303
10.6.6 Pin Functions 304
10.6.7 Input Pull-up MOS States in Port A 306
10.7 Port B 307
10.7.1 Port B Data Direction Register (PBDDR) 307
10.7.2 Port B Data Register (PBDR) 308
10.7.3 Port B Register (PORTB) 308
10.7.4 Port B Pull-up MOS Control Register (PBPCR) 309
10.7.5 Pin Functions 309
10.7.6 Input Pull-up MOS States in Port B 313
10.8 Port C 314
10.8.1 Port C Data Direction Register (PCDDR) 314
10.8.2 Port C Data Register (PCDR) 314
10.8.3 Port C Register (PORTC) 315
10.8.4 Port C Pull-up MOS Control Register (PCPCR) 315
10.8.5 Pin Functions 316
10.8.6 Input Pull-up MOS States in Port C 316
10.9 Port D 317
10.9.1 Port D Data Direction Register (PDDDR) 317
10.9.2 Port D Data Register (PDDR) 317
10.9.3 Port D Register (PORTD) 318
10.9.4 Port D Pull-up MOS Control Register (PDPCR) 318
10.9.5 Pin Functions 319
10.9.6 Input Pull-up MOS States in Port D 319
10.10 Port E 320
10.10.1 Port E Data Direction Register (PEDDR) 320
10.10.2 Port E Data Register (PEDR) 321
10.10.3 Port E Register (PORTE) 321
10.10.4 Port E Pull-up MOS Control Register (PEPCR) 322
10.10.5 Pin Functions 322
10.10.6 Input Pull-up MOS States in Port E 323
10.11 Port F 324
10.11.1 Port F Data Direction Register (PFDDR) 324
10.11.2 Port F Data Register (PFDR) 324
10.11.3 Port F Register (PORTF) 325
10.11.4 Pin Functions 325
10.12 Port G 328

10.12.1 Port G Data Direction Register (PGDDR) 328
10.12.2 Port G Data Register (PGDR) 328
10.12.3 Port G Register (PORTG) 329
10.12.4 Pin Functions 329

Section 11 16-Bit Timer Pulse Unit (TPU) 331
11.1 Features 331
11.2 Input/Output Pins 336
11.3 Register Descriptions 337
11.3.1 Timer Control Register (TCR) 339
11.3.2 Timer Mode Register (TMDR) 344
11.3.3 Timer I/O Control Register (TIOR) 345
11.3.4 Timer Interrupt Enable Register (TIER) 363
11.3.5 Timer Status Register (TSR) 365
11.3.6 Timer Counter (TCNT) 368
11.3.7 Timer General Register (TGR) 368
11.3.8 Timer Start Register (TSTR) 368
11.3.9 Timer Synchronous Register (TSYR) 369
11.4 Operation 370
11.4.1 Basic Functions 370
11.4.2 Synchronous Operation 375
11.4.3 Buffer Operation 377
11.4.4 Cascaded Operation 380
11.4.5 PWM Modes 382
11.4.6 Phase Counting Mode 387
11.5 Interrupt Sources 393
11.6 DTC Activation 395
11.7 DMAC Activation (H8S/2239 Series Only) 395
11.8 A/D Converter Activation 395
11.9 Operation Timing 396
11.9.1 Input/Output Timing 396
11.9.2 Interrupt Signal Timing 400
11.10 Usage Notes 403
11.10.1 Module Stop Mode Setting 403
11.10.2 Input Clock Restrictions 403
11.10.3 Caution on Cycle Setting 404
11.10.4 Contention between TCNT Write and Clear Operations 404
11.10.5 Contention between TCNT Write and Increment Operations 405
11.10.6 Contention between TGR Write and Compare Match 405
11.10.7 Contention between Buffer Register Write and Compare Match 406
11.10.8 Contention between TGR Read and Input Capture 407
11.10.9 Contention between TGR Write and Input Capture 407
11.10.10 Contention between Buffer Register Write and Input Capture 408

11.10.11 Contention between Overflow/Underflow and Counter Clearing 409
11.10.12 Contention between TCNT Write and Overflow/Underflow 409
11.10.13 Multiplexing of I/O Pins 410
11.10.14 Interrupts and Module Stop Mode 410

Section 12 8-Bit Timers 411
12.1 Features 411
12.2 Input/Output Pins 413
12.3 Register Descriptions 413
12.3.1 Timer Counter (TCNT) 414
12.3.2 Time Constant Register A (TCORA) 414
12.3.3 Time Constant Register B (TCORB) 414
12.3.4 Timer Control Register (TCR) 415
12.3.5 Timer Control/Status Register (TCSR) 417
12.4 Operation 421
12.4.1 Pulse Output 421
12.5 Operation Timing 422
12.5.1 TCNT Incrementation Timing 422
12.5.2 Timing of CMFA and CMFB Setting When a Compare-Match Occurs 423
12.5.3 Timing of Timer Output When a Compare-Match Occurs 423
12.5.4 Timing of Compare-Match Clear When a Compare-Match Occurs 424
12.5.5 TCNT External Reset Timing 424
12.5.6 Timing of Overflow Flag (OVF) Setting 425
12.6 Operation with Cascaded Connection 425
12.6.1 16-Bit Count Mode 425
12.6.2 Compare-Match Count Mode 426
12.7 Interrupt Sources 426
12.7.1 Interrupt Sources and DTC Activation 426
12.7.2 A/D Converter Activation 427
12.8 Usage Notes 427
12.8.1 Contention between TCNT Write and Clear 427
12.8.2 Contention between TCNT Write and Increment 428
12.8.3 Contention between TCOR Write and Compare-Match 429
12.8.4 Contention between Compare-Matches A and B 429
12.8.5 Switching of Internal Clocks and TCNT Operation 430
12.8.6 Contention between Interrupts and Module Stop Mode 431
12.8.7 Mode Setting of Cascaded Connection 432

Section 13 Watchdog Timer (WDT) 433
13.1 Features 433
13.2 Input/Output Pins 435
13.3 Register Descriptions 435
13.3.1 Timer Counter (TCNT) 435

13.3.2 Timer Control/Status Register (TCSR) 435
13.3.3 Reset Control/Status Register (RSTCSR) (only WDT_0) 440
13.4 Operation 441
13.4.1 Watchdog Timer Mode 441
13.4.2 Interval Timer Mode 442
13.4.3 Timing of Setting Overflow Flag (OVF) 443
13.4.4 Timing of Setting Watchdog Timer Overflow Flag (WOVF) 444
13.5 Interrupt Sources 444
13.6 Usage Notes 445
13.6.1 Notes on Register Access 445
13.6.2 Contention between Timer Counter (TCNT) Write and Increment 446
13.6.3 Changing Value of CKS2 to CKS0 446
13.6.4 Switching between Watchdog Timer Mode and Interval Timer Mode 446
13.6.5 Internal Reset in Watchdog Timer Mode 446
13.6.6 OVF Flag Clearing in Interval Timer Mode 447

Section 14 Serial Communication Interface (SCI) 449
14.1 Features 449
14.2 Input/Output Pins 453
14.3 Register Descriptions 453
14.3.1 Receive Shift Register (RSR) 454
14.3.2 Receive Data Register (RDR) 454
14.3.3 Transmit Data Register (TDR) 454
14.3.4 Transmit Shift Register (TSR) 454
14.3.5 Serial Mode Register (SMR) 455
14.3.6 Serial Control Register (SCR) 458
14.3.7 Serial Status Register (SSR) 463
14.3.8 Smart Card Mode Register (SCMR) 470
14.3.9 Bit Rate Register (BRR) 471
14.3.10 Serial Expansion Mode Register (SEMR_0) 478
14.4 Operation in Asynchronous Mode 482
14.4.1 Data Transfer Format 482
14.4.2 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode 484
14.4.3 Clock 485
14.4.4 SCI Initialization (Asynchronous Mode) 485
14.4.5 Serial Data Transmission (Asynchronous Mode) 486
14.4.6 Serial Data Reception (Asynchronous Mode) 489
14.5 Multiprocessor Communication Function 493
14.5.1 Multiprocessor Serial Data Transmission 494
14.5.2 Multiprocessor Serial Data Reception 496
14.6 Operation in Clocked Synchronous Mode 499
14.6.1 Clock 499

14.6.2 SCI Initialization (Clocked Synchronous Mode) 499
14.6.3 Serial Data Transmission (Clocked Synchronous Mode) 500
14.6.4 Serial Data Reception (Clocked Synchronous Mode) 503
14.6.5 Simultaneous Serial Data Transmission and Reception (Clocked Synchronous Mode) 505
14.7 Operation in Smart Card Interface 507
14.7.1 Pin Connection Example 507
14.7.2 Data Format (Except for Block Transfer Mode) 507
14.7.3 Block Transfer Mode 509
14.7.4 Receive Data Sampling Timing and Reception Margin 509
14.7.5 Initialization 510
14.7.6 Serial Data Transmission (Except for Block Transfer Mode) 511
14.7.7 Serial Data Reception (Except for Block Transfer Mode) 514
14.7.8 Clock Output Control 515
14.8 SCI Select Function (H8S/2239 Series Only) 517
14.9 Interrupt Sources 519
14.9.1 Interrupts in Normal Serial Communication Interface Mode 519
14.9.2 Interrupts in Smart Card Interface Mode 521
14.10 Usage Notes 522
14.10.1 Module Stop Mode Setting 522
14.10.2 Break Detection and Processing (Asynchronous mode only) 522
14.10.3 Mark State and Break Detection (Asynchronous mode only) 522
14.10.4 Receive Error Flags and Transmit Operations (Clocked Synchronous Mode Only) 522
14.10.5 Restrictions on Use of DMAC or DTC 523
14.10.6 Operation in Case of Mode Transition 523
14.10.7 Switching from SCK Pin Function to Port Pin Function 526
14.10.8 Assignment and Selection of Registers 528

Section 15 I^2C Bus Interface (IIC) (Option) 529
15.1 Features 529
15.2 Input/Output Pins 532
15.3 Register Descriptions 533
15.3.1 I^2C Bus Data Register (ICDR) 533
15.3.2 Slave Address Register (SAR) 535
15.3.3 Second Slave Address Register (SARX) 535
15.3.4 I^2C Bus Mode Register (ICMR) 536
15.3.5 Serial Control RegisterX (SCRX) 539
15.3.6 I^2C Bus Control Register (ICCR) 540
15.3.7 I^2C Bus Status Register (ICSR) 544
15.3.8 DDC Switch Register (DDCSWR) 547
15.4 Operation 547
15.4.1 I^2C Bus Data Format 547

15.4.2 Master Transmit Operation 549
15.4.3 Master Receive Operation 550
15.4.4 Slave Receive Operation 553
15.4.5 Slave Transmit Operation 555
15.4.6 IRIC Setting Timing and SCL Control 558
15.4.7 Operation Using the DTC 558
15.4.8 Noise Chancellor 560
15.4.9 Sample Flowcharts 560
15.5 Usage Notes 565

Section 16 A/D Converter 573
16.1 Features 573
16.2 Input/Output Pins 575
16.3 Register Descriptions 576
16.3.1 A/D Data Registers A to D (ADDRA to ADDRD) 576
16.3.2 A/D Control/Status Register (ADCSR) 577
16.3.3 A/D Control Register (ADCR) 579
16.4 Operation 580
16.4.1 Single Mode 580
16.4.2 Scan Mode 581
16.4.3 Input Sampling and A/D Conversion Time 582
16.4.4 External Trigger Input Timing 584
16.5 Interrupt Source 584
16.6 A/D Conversion Accuracy Definitions 585
16.7 Usage Notes 587
16.7.1 Module Stop Mode Setting 587
16.7.2 Permissible Signal Source Impedance 587
16.7.3 Influences on Absolute Accuracy 587
16.7.4 Range of Analog Power Supply and Other Pin Settings 588
16.7.5 Notes on Board Design 588
16.7.6 Notes on Noise Countermeasures 588

Section 17 D/A Converter 591
17.1 Features 591
17.2 Input/Output Pins 592
17.3 Register Description 592
17.3.1 D/A Data Registers 0 and 1 (DADR0 and DADR1) 592
17.3.2 D/A Control Register (DACR) 593
17.4 Operation 594
17.5 Usage notes 595
17.5.1 Analog Power Supply Current in Software Standby Mode 595
17.5.2 Setting for Module Stop Mode 595

Section 18 RAM 597

Section 19 ROM 599
19.1 Features 599
19.2 Mode Transitions 600
19.3 Block Configuration 604
19.4 Input/Output Pins 608
19.5 Register Descriptions 608
19.5.1 Flash Memory Control Register 1 (FLMCR1) 609
19.5.2 Flash Memory Control Register 2 (FLMCR2) 610
19.5.3 Erase Block Register 1 (EBR1) 610
19.5.4 Erase Block Register 2 (EBR2) 612
19.5.5 RAM Emulation Register (RAMER) 613
19.5.6 Flash Memory Power Control Register (FLPWCR) 615
19.5.7 Serial Control Register X (SCRX) 615
19.6 On-Board Programming Modes 617
19.6.1 Boot Mode 617
19.6.2 Programming/Erasing in User Program Mode 620
19.7 Flash Memory Emulation in RAM 621
19.8 Flash Memory Programming/Erasing 623
19.8.1 Program/Program-Verify 623
19.8.2 Erase/Erase-Verify 625
19.9 Program/Erase Protection 627
19.9.1 Hardware Protection 627
19.9.2 Software Protection 627
19.9.3 Error Protection 627
19.10 Interrupt Handling when Programming/Erasing Flash Memory 628
19.11 Programmer Mode 628
19.12 Power-Down States for Flash Memory 630
19.13 Flash Memory Programming and Erasing Precautions 631
19.14 Note on Switching from F-ZTAT Version to Masked ROM Version 636

Section 20 Masked ROM 637
20.1 Features 637

Section 21 PROM 639
21.1 PROM Mode Setting 639
21.2 Socket Adapter and Memory Map 639
21.3 Programming 643
21.3.1 Programming and Verification 643
21.3.2 Programming Precautions 648
21.3.3 Reliability of Programmed Data 648

Section 22 Clock Pulse Generator 651
22.1 Register Descriptions 652
22.1.1 System Clock Control Register (SCKCR) 652
22.1.2 Low-Power Control Register (LPWRCR) 653
22.2 System Clock Oscillator 656
22.2.1 Connecting a Crystal Resonator 656
22.2.2 External Clock Input 657
22.2.3 Notes on Switching External Clock 660
22.3 Duty Adjustment Circuit 662
22.4 Medium-Speed Clock Divider 662
22.5 Bus Master Clock Selection Circuit 662
22.6 Subclock Oscillator 662
22.6.1 Connecting 32.768kHz Crystal Resonator 662
22.6.2 Handling Pins When Subclock Not Required 663
22.7 Subclock Waveform Generation Circuit 664
22.8 Usage Notes 664
22.8.1 Note on Crystal Resonator 664
22.8.2 Note on Board Design 664

Section 23 Power-Down Modes 665
23.1 Register Description 669
23.1.1 Standby Control Register (SBYCR) 669
23.1.2 Module Stop Control Registers A to C (MSTPCRA to MSTPCRC) 671
23.2 Medium-Speed Mode 672
23.3 Sleep Mode 673
23.3.1 Sleep Mode 673
23.3.2 Exiting Sleep Mode 673
23.4 Software Standby Mode 674
23.4.1 Software Standby Mode 674
23.4.2 Clearing Software Standby Mode 674
23.4.3 Oscillation Settling Time after Clearing Software Standby Mode 675
23.4.4 Software Standby Mode Application Example 675
23.5 Hardware Standby Mode 676
23.5.1 Hardware Standby Mode 676
23.5.2 Clearing Hardware Standby Mode 676
23.5.3 Hardware Standby Mode Timing 677
23.6 Module Stop Mode 677
23.7 Watch Mode 678
23.7.1 Transition to Watch Mode 678
23.7.2 Exiting Watch Mode 678
23.8 Subsleep Mode 679
23.8.1 Transition to Subsleep Mode 679
23.8.2 Exiting Subsleep Mode 679

23.9 Subactive Mode 680
23.9.1 Transition to Subactive Mode 680
23.9.2 Exiting Subactive Mode 680
23.10 Direct Transitions 681
23.10.1 Direct Transitions from High-Speed Mode to Subactive Mode 681
23.10.2 Direct Transitions from Subactive Mode to High-Speed Mode 681
23.11 φ Clock Output Enable 681
23.12 Usage Notes 682
23.12.1 I/O Port Status 682
23.12.2 Current Dissipation during Oscillation Settling Wait Period 682
23.12.3 DTC and DMAC Module Stop 682
23.12.4 On-Chip Peripheral Module Interrupt 683
23.12.5 Writing to MSTPCR 683
23.12.6 Entering Subactive/Watch mode and DMAC and DTC Module Stop 683

Section 24 List of Registers 685
24.1 Register Addresses (in address order) 685
24.2 Register Bits 695
24.3 Register States in Each Operating Mode 706

Section 25 Electrical Characteristics 715
25.1 Power Supply Voltage and Operating Frequency Range 715
25.2 Electrical Characteristics of H8S/2239 Series 718
25.2.1 Absolute Maximum Ratings 718
25.2.2 DC Characteristics 719
25.2.3 AC Characteristics 726
25.2.4 A/D Conversion Characteristics 734
25.2.5 D/A Conversion Characteristics 735
25.2.6 Flash Memory Characteristics 736
25.3 Electrical Characteristics of H8S/2238R Series 738
25.3.1 Absolute Maximum Ratings 738
25.3.2 DC Characteristics 739
25.3.3 AC Characteristics 746
25.2.4 A/D Conversion Characteristics 753
25.3.5 D/A Conversion Characteristics 754
25.3.6 Flash Memory Characteristics 755
25.4 Electrical Characteristics of H8S/2237 Series and H8S/2227 Series 757
25.4.1 Absolute Maximum Ratings 757
25.4.2 DC Characteristics 757
25.4.3 AC Characteristics 766
25.4.4 A/D Conversion Characteristics 772
25.4.5 D/A Conversion Characteristics 773
25.4.6 Flash Memory Characteristics 774

25.5 Operating Timing 776
25.5.1 Clock Timing 776
25.5.2 Control Signal Timing 777
25.5.3 Bus Timing 778
25.5.4 Timing of On-Chip Peripheral Modules 785
25.6 Usage Note 788

Appendix A I/O Port States in Each Pin State 789
A.1 I/O Port State in Each Pin State 789

Appendix B Product Codes 794

Appendix C Package Dimensions 797

Index 803

Figures

Section 1 Overview
Figure 1.1 Internal Block Diagram of H8S/2239 Series 3
Figure 1.2 Internal Block Diagram of H8S/2238R Series 4
Figure 1.3 Internal Block Diagram of H8S/2237 Series 5
Figure 1.4 Internal Block Diagram of H8S/2227 Series 6
Figure 1.5 Pin Arrangement of H8S/2239 Series (TFP-100B, TFP-100G, FP100B: Top View) 7
Figure 1.6 Pin Arrangement of H8S/2238R Series (TFP-100B, TFP-100G, FP100B: Top View) 8
Figure 1.7 Pin Arrangement of H8S/2238R Series (BP-112: Top View, Being Planned) 9
Figure 1.8 Pin Arrangement of H8S/2237 Series (TFP-100B, TFP-100G, FP100B: Top View) 10
Figure 1.9 Pin Arrangement of H8S/2237 Series (FP-100A: Top View) 11
Figure 1.10 Pin Arrangement of H8S/2227 Series (TFP-100B, TFP-100G, FP100B: Top View) 12
Figure 1.11 Pin Arrangement of H8S/2227 Series (FP-100A: Top View) 13

Section 2 CPU
Figure 2.1 Exception Vector Table (Normal Mode) 49
Figure 2.2 Stack Structure in Normal Mode 49
Figure 2.3 Exception Vector Table (Advanced Mode) 50
Figure 2.4 Stack Structure in Advanced Mode 51
Figure 2.5 Memory Map 52
Figure 2.6 CPU Registers 53
Figure 2.7 Usage of General Registers 54
Figure 2.8 Stack Status 55
Figure 2.9 General Register Data Formats (1) 58
Figure 2.9 General Register Data Formats (2) 59
Figure 2.10 Memory Data Formats 60
Figure 2.11 Instruction Formats (Examples) 72
Figure 2.12 Branch Address Specification in Memory Indirect Mode 75
Figure 2.13 State Transitions 79

Section 3 MCU Operating Modes
Figure 3.1 H8S/2239 Memory Map in Each Operating Mode 87
Figure 3.2 H8S/2238R Memory Map in Each Operating Mode 88
Figure 3.3 H8S/2236R Memory Map in Each Operating Mode 89
Figure 3.4 H8S/2237 and H8S/2227 Memory Map in Each Operating Mode 90
Figure 3.5 H8S/2235 and H8S/2225 Memory Map in Each Operating Mode 91
Figure 3.6 H8S/2224 Memory Map in Each Operating Mode 92
Figure 3.7 H8S/2233 and H8S/2223 Memory Map in Each Operating Mode 93

Section 4 Exception Handling
Figure 4.1 Reset Sequence (Mode 4) 98
Figure 4.2 Stack Status after Exception Handling (Advanced Mode) 101
Figure 4.3 Operation when SP Value Is Odd 102

Section 5 Interrupt Controller
Figure 5.1 Block Diagram of Interrupt Controller 104
Figure 5.2 Block Diagram of IRQn Interrupts 111
Figure 5.3 Set Timing for IRQnF 112
Figure 5.4 Block Diagram of Interrupt Control Operation 119
Figure 5.5 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 0 122
Figure 5.6 Flowchart of Procedure Up to Interrupt Acceptance in Control Mode 2 124
Figure 5.7 Interrupt Exception Handling 125
Figure 5.8 Contention between Interrupt Generation and Disabling 128

Section 6 PC Break Controller (PBC)
Figure 6.1 Block Diagram of PC Break Controller 132
Figure 6.2 Operation in Power-Down Mode Transitions 136

Section 7 Bus Controller
Figure 7.1 Block Diagram of Bus Controller 140
Figure 7.2 Overview of Area Divisions 149
Figure 7.3 CSn Signal Output Timing (n = 0 to 7) 152
Figure 7.4 On-Chip Memory Access Cycle 153
Figure 7.5 Pin States during On-Chip Memory Access 154
Figure 7.6 On-Chip Peripheral Module Access Cycle 154
Figure 7.7 Pin States during On-Chip Peripheral Module Access 155
Figure 7.8 Access Sizes and Data Alignment Control (8-Bit Access Space) 156
Figure 7.9 Access Sizes and Data Alignment Control (16-Bit Access Space) 157
Figure 7.10 Bus Timing for 8-Bit 2-State Access Space 158
Figure 7.11 Bus Timing for 8-Bit 3-State Access Space 159
Figure 7.12 Bus Timing for 16-Bit 2-State Access Space (1) (Even Address Byte Access) 160
Figure 7.13 Bus Timing for 16-Bit 2-State Access Space (2) (Odd Address Byte Access) 161
Figure 7.14 Bus Timing for 16-Bit 2-State Access Space (3) (Word Access) 162
Figure 7.15 Bus Timing for 16-Bit 3-State Access Space (1) (Even Address Byte Access) 163
Figure 7.16 Bus Timing for 16-Bit 3-State Access Space (2) (Odd Address Byte Access) 164
Figure 7.17 Bus Timing for 16-Bit 3-State Access Space (3) (Word Access) 165
Figure 7.18 Example of Wait State Insertion Timing 167
Figure 7.19 Example of Burst ROM Access Timing (When AST0 = BRSTS1 = 1) 169
Figure 7.20 Example of Burst ROM Access Timing (When AST0 = BRSTS1 = 0) 169
Figure 7.21 Example of Idle Cycle Operation (1) 170
Figure 7.22 Example of Idle Cycle Operation (2) 171
Figure 7.23 Relationship between Chip Select (CS) and Read (RD) 172
Figure 7.24 Bus-Released State Transition Timing 174

Section 8 DMA Controller (DMAC)

Figure 8.1 Block Diagram of DMAC 180
Figure 8.2 Areas for Register Re-Setting by DTC (Channel 0A) 205
Figure 8.3 Operation in Sequential Mode 212
Figure 8.4 Example of Sequential Mode Setting Procedure 213
Figure 8.5 Operation in Idle Mode 214
Figure 8.6 Example of Idle Mode Setting Procedure 215
Figure 8.7 Operation in Repeat mode 218
Figure 8.8 Example of Repeat Mode Setting Procedure 219
Figure 8.9 Data Bus in Single Address Mode 220
Figure 8.10 Operation in Single Address Mode (When Sequential Mode is Specified) 222
Figure 8.11 Example of Single Address Mode Setting Procedure (When Sequential Mode is Specified) 223
Figure 8.12 Operation in Normal Mode 225
Figure 8.13 Example of Normal Mode Setting Procedure 226
Figure 8.14 Operation in Block Transfer Mode (BLKDIR = 0) 228
Figure 8.15 Operation in Block Transfer Mode (BLKDIR = 1) 229
Figure 8.16 Operation Flow in Block Transfer Mode 230
Figure 8.17 Example of Block Transfer Mode Setting Procedure 231
Figure 8.18 Example of DMA Transfer Bus Timing 232
Figure 8.19 Example of Short Address Mode Transfer 233
Figure 8.20 Example of Full Address Mode Transfer (Cycle Steal) 234
Figure 8.21 Example of Full Address Mode Transfer (Burst Mode) 235
Figure 8.22 Example of Full Address Mode Transfer (Block Transfer Mode) 236
Figure 8.23 Example of DREQ Pin Falling Edge Activated Normal Mode Transfer 237
Figure 8.24 Example of DREQ Pin Falling Edge Activated Block Transfer Mode Transfer 238
Figure 8.25 Example of DREQ Pin Low Level Activated Normal Mode Transfer 239
Figure 8.26 Example of DREQ Pin Low Level Activated Block Transfer Mode Transfer 240
Figure 8.27 Example of Single Address Mode Transfer (Byte Read) 241
Figure 8.28 Example of Single Address Mode (Word Read) Transfer 242
Figure 8.29 Example of Single Address Mode Transfer (Byte Write) 243
Figure 8.30 Example of Single Address Mode Transfer (Word Write) 244
Figure 8.31 Example of DREQ Pin Falling Edge Activated Single Address Mode Transfer 245
Figure 8.32 Example of DREQ Pin Low Level Activated Single Address Mode Transfer 246
Figure 8.33 Example of Multi-Channel Transfer 248
Figure 8.34 Example of Procedure for Continuing Transfer on Channel Interrupted by NMI Interrupt 249
Figure 8.35 Example of Procedure for Forcibly Terminating DMAC Operation 250
Figure 8.36 Example of Procedure for Clearing Full Address Mode 251
Figure 8.37 Block Diagram of Transfer End/Transfer Break Interrupt 252
Figure 8.38 DMAC Register Update Timing 253
Figure 8.39 Contention between DMAC Register Update and CPU Read 254

Section 9 Data Transfer Controller (DTC)
Figure 9.1 Block Diagram of DTC 258
Figure 9.2 Block Diagram of DTC Activation Source Control 264
Figure 9.3 The Location of the DTC Register Information in the Address Space 265
Figure 9.4 Correspondence between DTC Vector Address and Register Information 266
Figure 9.5 Flowchart of DTC Operation 269
Figure 9.6 Memory Mapping in Normal Mode 270
Figure 9.7 Memory Mapping in Repeat Mode 271
Figure 9.8 Memory Mapping in Block Transfer Mode 272
Figure 9.9 Chain Transfer Operation 273
Figure 9.10 DTC Operation Timing (Example in Normal Mode or Repeat Mode) 274
Figure 9.11 DTC Operation Timing (Example of Block Transfer Mode, with Block Size of 2) 275
Figure 9.12 DTC Operation Timing (Example of Chain Transfer) 275

Section 10 I/O Ports
Figure 10.1 Types of Open Drain Outputs 293

Section 11 16-Bit Timer Pulse Unit (TPU)
Figure 11.1 Block Diagram of TPU (H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series) 334
Figure 11.2 Block Diagram of TPU (H8S/2227 Series) 335
Figure 11.3 Example of Counter Operation Setting Procedure 370
Figure 11.4 Free-Running Counter Operation 371
Figure 11.5 Periodic Counter Operation 372
Figure 11.6 Example of Setting Procedure for Waveform Output by Compare Match 372
Figure 11.7 Example of 0 Output/1 Output Operation 373
Figure 11.8 Example of Toggle Output Operation 373
Figure 11.9 Example of Setting Procedure for Input Capture Operation 374
Figure 11.10 Example of Input Capture Operation 375
Figure 11.11 Example of Synchronous Operation Setting Procedure 376
Figure 11.12 Example of Synchronous Operation 377
Figure 11.13 Compare Match Buffer Operation 378
Figure 11.14 Input Capture Buffer Operation 378
Figure 11.15 Example of Buffer Operation Setting Procedure 378
Figure 11.16 Example of Buffer Operation (1) 379
Figure 11.17 Example of Buffer Operation (2) 380
Figure 11.18 Cascaded Operation Setting Procedure 381
Figure 11.19 Example of Cascaded Operation (1) 381
Figure 11.20 Example of Cascaded Operation (2) 382
Figure 11.21 Example of PWM Mode Setting Procedure 384
Figure 11.22 Example of PWM Mode Operation (1) 385
Figure 11.23 Example of PWM Mode Operation (2) 385
Figure 11.24 Example of PWM Mode Operation (3) 386

Figure 11.25 Example of Phase Counting Mode Setting Procedure 387
Figure 11.26 Example of Phase Counting Mode 1 Operation 388
Figure 11.27 Example of Phase Counting Mode 2 Operation 389
Figure 11.28 Example of Phase Counting Mode 3 Operation 390
Figure 11.29 Example of Phase Counting Mode 4 Operation 391
Figure 11.30 Phase Counting Mode Application Example 392
Figure 11.31 Count Timing in Internal Clock Operation 396
Figure 11.32 Count Timing in External Clock Operation 396
Figure 11.33 Output Compare Output Timing 397
Figure 11.34 Input Capture Input Signal Timing 397
Figure 11.35 Counter Clear Timing (Compare Match) 398
Figure 11.36 Counter Clear Timing (Input Capture) 398
Figure 11.37 Buffer Operation Timing (Compare Match) 399
Figure 11.38 Buffer Operation Timing (Input Capture) 399
Figure 11.39 TGI Interrupt Timing (Compare Match) 400
Figure 11.40 TGI Interrupt Timing (Input Capture) 401
Figure 11.41 TCIV Interrupt Setting Timing 401
Figure 11.42 TCIU Interrupt Setting Timing 402
Figure 11.43 Timing for Status Flag Clearing by CPU 402
Figure 11.44 Timing for Status Flag Clearing by DTC/DMAC Activation 403
Figure 11.45 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode 404
Figure 11.46 Contention between TCNT Write and Clear Operations 405
Figure 11.47 Contention between TCNT Write and Increment Operations 405
Figure 11.48 Contention between TGR Write and Compare Match 406
Figure 11.49 Contention between Buffer Register Write and Compare Match 406
Figure 11.50 Contention between TGR Read and Input Capture 407
Figure 11.51 Contention between TGR Write and Input Capture 408
Figure 11.52 Contention between Buffer Register Write and Input Capture 408
Figure 11.53 Contention between Overflow and Counter Clearing 409
Figure 11.54 Contention between TCNT Write and Overflow 410

Section 12 8-Bit Timers

Figure 12.1 Block Diagram of 8-Bit Timer Module 412
Figure 12.2 Example of Pulse Output 422
Figure 12.3 Count Timing for Internal Clock Input 422
Figure 12.4 Count Timing for External Clock Input 423
Figure 12.5 Timing of CMF Setting 423
Figure 12.6 Timing of Timer Output 424
Figure 12.7 Timing of Compare-Match Clear 424
Figure 12.8 Timing of Clearing by External Reset Input 424
Figure 12.9 Timing of OVF Setting 425
Figure 12.10 Contention between TCNT Write and Clear 427
Figure 12.11 Contention between TCNT Write and Increment 428

Figure 12.12 Contention between TCOR Write and Compare-Match 429

Section 13 Watchdog Timer (WDT)

Figure 13.1 Block Diagram of WDT_0 (1) 434
Figure 13.1 Block Diagram of WDT_1 (2) 434
Figure 13.2 Watchdog Timer Mode Operation 442
Figure 13.3 Interval Timer Mode Operation 442
Figure 13.4 Timing of OVF Setting 443
Figure 13.5 Timing of WOVF Setting 444
Figure 13.6 Writing to TCNT and TCSR (example for WDT_0) 445
Figure 13.7 Contention between TCNT Write and Increment 446

Section 14 Serial Communication Interface (SCI)

Figure 14.1 Block Diagram of SCI 451
Figure 14.2 Block Diagram of SCI_0 of H8S/2239 Series 452
Figure 14.3 Example of the Internal Base Clock When the Average Transfer Rate is Selected (1) 480
Figure 14.4 Example of the Internal Base Clock When the Average Transfer Rate is Selected (2) 481
Figure 14.5 Data Format in Asynchronous Communication (Example with 8-Bit Data, Parity, Two Stop Bits) 482
Figure 14.6 Receive Data Sampling Timing in Asynchronous Mode 484
Figure 14.7 Relationship between Output Clock and Transfer Data Phase (Asynchronous Mode) 485
Figure 14.8 Sample SCI Initialization Flowchart 486
Figure 14.9 Example of Operation in Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit) 487
Figure 14.10 Sample Serial Transmission Flowchart 488
Figure 14.11 Example of SCI Operation in Reception (Example with 8-Bit Data, Parity, One Stop Bit) 489
Figure 14.12 Sample Serial Reception Data Flowchart (1) 491
Figure 14.12 Sample Serial Reception Data Flowchart (2) 492
Figure 14.13 Example of Communication Using Multiprocessor Format (Transmission of Data H'AA to Receiving Station A) 494
Figure 14.14 Sample Multiprocessor Serial Transmission Flowchart 495
Figure 14.15 Example of SCI Operation in Reception (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit) 496
Figure 14.16 Sample Multiprocessor Serial Reception Flowchart (1) 497
Figure 14.16 Sample Multiprocessor Serial Reception Flowchart (2) 498
Figure 14.17 Data Format in Synchronous Communication (For LSB-First) 499
Figure 14.18 Sample SCI Initialization Flowchart 500
Figure 14.19 Sample SCI Transmission Operation in Clocked Synchronous Mode 501
Figure 14.20 Sample Serial Transmission Flowchart 502
Figure 14.21 Example of SCI Operation in Reception 503

Figure 14.22 Sample Serial Reception Flowchart....504
Figure 14.23 Sample Flowchart of Simultaneous Serial Transmit and Receive Operations....506
Figure 14.24 Schematic Diagram of Smart Card Interface Pin Connections....507
Figure 14.25 Normal Smart Card Interface Data Format....508
Figure 14.26 Direct Convention (SDIR = SINV = O/E = 0)....508
Figure 14.27 Inverse Convention (SDIR = SINV = O/E = 1)....508
Figure 14.28 Receive Data Sampling Timing in Smart Card Mode (Using Clock of 372 Times the Transfer Rate)....510
Figure 14.29 Retransfer Operation in SCI Transmit Mode....512
Figure 14.30 TEND Flag Generation Timing in Transmission Operation....512
Figure 14.31 Example of Transmission Processing Flow....513
Figure 14.32 Retransfer Operation in SCI Receive Mode....514
Figure 14.33 Example of Reception Processing Flow....515
Figure 14.34 Timing for Fixing Clock Output Level....515
Figure 14.35 Clock Halt and Restart Procedure....516
Figure 14.36 Example of Communication Using SCI Select Function....517
Figure 14.37 Summary of SCI Select Function Operation....518
Figure 14.38 Example of Clocked Synchronous Transmission by DMAC or DTC....523
Figure 14.39 Sample Flowchart for Mode Transition during Transmission....524
Figure 14.40 Asynchronous Transmission Using Internal Clock....525
Figure 14.41 Synchronous Transmission Using Internal Clock....525
Figure 14.42 Sample Flowchart for Mode Transition during Reception....526
Figure 14.43 Operation when Switching from SCK Pin Function to Port Pin Function....527
Figure 14.44 Operation when Switching from SCK Pin Function to Port Pin Function (Example of Preventing Low-Level Output)....527

Section 15 I^2C Bus Interface (IIC) (Option)

Figure 15.1 Block Diagram of I^2C Bus Interface....531
Figure 15.2 I^2C Bus Interface Connections (Example: This LSI as Master)....532
Figure 15.3 I^2C Bus Data Formats (I^2C Bus Formats)....548
Figure 15.4 I^2C Bus Data Format (Serial Format)....548
Figure 15.5 I^2C Bus Timing....548
Figure 15.6 Master Transmit Mode Operation Timing Example (MLS = WAIT = 0)....550
Figure 15.7 (1) Master Receive Mode Operation Timing Example (MLS = ACKB = 0, WAIT = 1)....552
Figure 15.7 (2) Master Receive Mode Operation Timing Example (MLS = ACKB = 0, WAIT = 1)....552
Figure 15.8 Example of Slave Receive Mode Operation Timing (1) (MLS = ACKB = 0)....554
Figure 15.9 Example of Slave Receive Mode Operation Timing (2) (MLS = ACKB = 0)....555
Figure 15.10 Example of Slave Transmit Mode Operation Timing (MLS = 0)....557
Figure 15.11 IRIC Setting Timing and SCL Control....558
Figure 15.12 Block Diagram of Noise Chancellor....560
Figure 15.13 Sample Flowchart for Master Transmit Mode....561

Figure 15.14 Sample Flowchart for Master Receive Mode 562
Figure 15.15 Sample Flowchart for Slave Receive Mode 563
Figure 15.16 Sample Flowchart for Slave Transmit Mode 564
Figure 15.17 Points for Attention Concerning Reading of Master Receive Data 568
Figure 15.18 Flowchart and Timing of Start Condition Instruction Issuance for Retransmission 570
Figure 15.19 Timing of Stop Condition Issuance 571

Section 16 A/D Converter

Figure 16.1 Block Diagram of A/D Converter 574
Figure 16.2 Example of A/D converter Operation (Single Mode, Channel 1 Selected) 581
Figure 16.3 Example of A/D Converter Operation (Scan Mode, Channels AN0 to AN2 Selected) 582
Figure 16.4 A/D Conversion Timing 583
Figure 16.5 External Trigger Input Timing 584
Figure 16.6 A/D Conversion Accuracy Definitions 586
Figure 16.7 A/D Conversion Accuracy Definitions 586
Figure 16.8 Example of Analog Input Circuit 587
Figure 16.9 Example of Analog Input Protection Circuit 589
Figure 16.10 Analog Input Pin Equivalent Circuit 589

Section 17 D/A Converter

Figure 17.1 Block Diagram of D/A Converter 591
Figure 17.2 D/A Converter Operation Example 595

Section 19 ROM

Figure 19.1 Block Diagram of Flash Memory 600
Figure 19.2 Flash Memory State Transitions 601
Figure 19.3 Boot Mode (Example) 602
Figure 19.4 User Program Mode (Example) 603
Figure 19.5 Block Configuration of 384-kbyte Flash Memory 605
Figure 19.6 Block Configuration of 256-kbyte Flash Memory 606
Figure 19.7 Block Configuration of 128-kbyte Flash Memory 607
Figure 19.8 Programming/Erasing Flowchart Example in User Program Mode 620
Figure 19.9 Flowchart for Flash Memory Emulation in RAM 621
Figure 19.10 Example of RAM Overlap Operation 622
Figure 19.11 Program/Program-Verify Flowchart 624
Figure 19.12 Erase/Erase-Verify Flowchart 626
Figure 19.13 Socket Adapter Pin Correspondence Diagram 629
Figure 19.14 Power-On/Off Timing (Boot Mode) 633
Figure 19.15 Power-On/Off Timing (User Program Mode) 634
Figure 19.16 Mode Transition Timing (Example: Boot Mode → User Mode ↔ User Program Mode) 635

Section 20 Masked ROM
Figure 20.1 Block Diagram of On-Chip Masked ROM (384 kbytes) 637

Section 21 PROM
Figure 21.1 HD6472237 Socket Adapter Pin Correspondence Diagram (FP-100B, TFP-100B, TFP-100G) 640
Figure 21.2 HD6472237 Socket Adapter Pin Correspondence Diagram (FP-100A) 641
Figure 21.3 Memory Map in PROM Mode 642
Figure 21.4 High-Speed Programming Flowchart 644
Figure 21.5 PROM Programming/Verification Timing 647
Figure 21.6 Recommended Screening Procedure 648

Section 22 Clock Pulse Generator
Figure 22.1 Block Diagram of Clock Pulse Generator 651
Figure 22.2 Connection of Crystal Resonator (Example) 656
Figure 22.3 Crystal Resonator Equivalent Circuit 657
Figure 22.4 External Clock Input (Examples) 658
Figure 22.5 External Clock Input Timing 660
Figure 22.6 External Clock Switching Circuit (Example) 661
Figure 22.7 External Clock Switching Timing (Example) 661
Figure 22.8 Connection Example of 32.768-kHz Quartz Oscillator 662
Figure 22.9 Equivalence Circuit for 32.768-kHz Oscillator 663
Figure 22.10 Pin Handling When Subclock Not Required 663
Figure 22.11 Note on Board Design of Oscillator Circuit 664

Section 23 Clock Pulse Generator
Figure 23.1 Mode Transition Diagram 667
Figure 23.2 Medium-Speed Mode Transition and Clearance Timing 673
Figure 23.3 Software Standby Mode Application Example 676
Figure 23.4 Hardware Standby Mode Timing 677

Section 25 Electrical Characteristics
Figure 25.1 Power Supply Voltage and Operating Ranges (H8S/2239 Series) 715
Figure 25.2 Power Supply Voltage and Operating Ranges (H8S/2238R Series) 716
Figure 25.3 Power Supply Voltage and Operating Ranges (H8S/2237 Series and H8S/2227 Series) 717
Figure 25.4 Output Load Circuit 726
Figure 25.5 System Clock Timing 776
Figure 25.6 Oscillation Stabilization Timing 776
Figure 25.7 Reset Input Timing 777
Figure 25.8 Interrupt Input Timing 777
Figure 25.9 Basic Bus Timing (Two-State Access) 778
Figure 25.10 Basic Bus Timing (Three-State Access) 779
Figure 25.11 Basic Bus Timing (Three-State Access with One Wait State) 780
Figure 25.12 Burst ROM Access Timing (Two-State Access) 781

Figure 25.13 Burst ROM Access Timing (One-State Access) 782
Figure 25.14 External Bus Release Timing 782
Figure 25.15 DMAC Single Address Transfer Timing (Two-State Access) 783
Figure 25.16 DMAC Single Address Transfer Timing (Three-State Access) 784
Figure 25.17 DMAC TEND Output Timing 784
Figure 25.18 DMAC DREQ Input Timing 785
Figure 25.19 I/O Port Input/Output Timing 785
Figure 25.20 TPU Input/Output Timing 785
Figure 25.21 TPU Clock Input Timing 786
Figure 25.22 8-Bit Timer Output Timing 786
Figure 25.23 8-Bit Timer Clock Input Timing 786
Figure 25.24 8-Bit Timer Reset Input Timing 786
Figure 25.25 WDT_1 Output Timing 787
Figure 25.26 SCK Clock Input Timing 787
Figure 25.27 SCI Input/Output Timing (Clocked Synchronous Mode) 787
Figure 25.28 A/D Converter External Trigger Input Timing 787
Figure 25.29 I^2C Bus Interface Input/Output Timing (Optional) 788

Appendix

Figure C.1 TFP-100B Package Dimensions 797
Figure C.2 TFP-100G Package Dimensions 798
Figure C.3 FP-100A Package Dimensions 799
Figure C.4 FP-100B Package Dimensions 800
Figure C.5 BP-112 Package Dimensions 801

Tables

Section 1 Overview
Table 1.1 Pin Arrangements in Each Mode of H8S/2239 Series 14
Table 1.2 Pin Arrangements in Each Mode of H8S/2238R Series 19
Table 1.3 Pin Arrangements in Each Mode of H8S/2237 Series 24
Table 1.4 Pin Arrangements in Each Mode of H8S/2227 Series 29
Table 1.5 Pin Functions of H8S/2239 Series and H8S/2238R Series 34
Table 1.6 Pin Functions of H8S/2237 Series and H8S/2227 Series 40

Section 2 CPU
Table 2.1 Instruction Classification 61
Table 2.2 Operation Notation 62
Table 2.3 Data Transfer Instructions 63
Table 2.4 Arithmetic Operations Instructions (1) 64
Table 2.4 Arithmetic Operations Instructions (2) 65
Table 2.5 Logic Operations Instructions 66
Table 2.6 Shift Instructions 66
Table 2.7 Bit Manipulation Instructions (1) 67
Table 2.7 Bit Manipulation Instructions (2) 68
Table 2.8 Branch Instructions 69
Table 2.9 System Control Instructions 70
Table 2.10 Block Data Transfer Instructions 71
Table 2.11 Addressing Modes 72
Table 2.12 Absolute Address Access Ranges 74
Table 2.13 Effective Address Calculation (1) 76
Table 2.13 Effective Address Calculation (2) 77

Section 3 MCU Operating Modes
Table 3.1 MCU Operating Mode Selection 81
Table 3.2 Pin Functions in Each Operating Mode 86

Section 4 Exception Handling
Table 4.1 Exception Types and Priority 95
Table 4.2 Exception Handling Vector Table 96
Table 4.3 Reset Types 97
Table 4.4 Status of CCR and EXR after Trace Exception Handling 99
Table 4.5 Status of CCR and EXR after Trap Instruction Exception Handling 101

Section 5 Interrupt Controller
Table 5.1 Pin Configuration 105
Table 5.2 Interrupt Sources, Vector Addresses, and Interrupt Priorities 113
Table 5.3 Interrupt Control Modes 118
Table 5.4 Interrupts Selected in Each Interrupt Control Mode (1) 119

Table 5.5 Interrupts Selected in Each Interrupt Control Mode (2) 120
Table 5.6 Operations and Control Signal Functions in Each Interrupt Control Mode 120
Table 5.7 Interrupt Response Times 126
Table 5.8 Number of States in Interrupt Handling Routine Execution Status 126

Section 7 Bus Controller
Table 7.1 Pin Configuration 141
Table 7.2 Bus Specifications for Each Area (Basic Bus Interface) 151
Table 7.3 Data Buses Used and Valid Strobes 157
Table 7.4 Pin States in Idle Cycle 172
Table 7.5 Pin States in Bus Released State 173

Section 8 DMA Controller (DMAC)
Table 8.1 Pin Configuration 181
Table 8.2 Short Address Mode and Full Address Mode (Channel 0) 182
Table 8.3 DMAC Activation Sources 207
Table 8.4 DMAC Transfer Modes 209
Table 8.5 Register Functions in Sequential Mode 211
Table 8.6 Register Functions in Idle Mode 214
Table 8.7 Register Functions in Repeat Mode 216
Table 8.8 Register Functions in Single Address Mode 221
Table 8.9 Register Functions in Normal Mode 224
Table 8.10 Register Functions in Block Transfer Mode 227
Table 8.11 DMAC Channel Priority Order 247
Table 8.12 Interrupt Sources and Priority Order 252

Section 9 Data Transfer Controller (DTC)
Table 9.1 Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs 266
Table 9.2 Register Information in Normal Mode 270
Table 9.3 Register Information in Repeat Mode 271
Table 9.4 Register Information in Block Transfer Mode 272
Table 9.5 DTC Execution Status 275
Table 9.6 Number of States Required for Each Execution Status 276

Section 10 I/O Ports
Table 10.1 Port Functions 282
Table 10.2 Input Pull-up MOS States in Port A 306
Table 10.3 Input Pull-up MOS States in Port B 313
Table 10.4 Input Pull-up MOS States in Port C 316
Table 10.5 Input Pull-up MOS States in Port D 319
Table 10.6 Input Pull-up MOS States in Port E 323

Section 11 16-Bit Timer Pulse Unit (TPU)
Table 11.1 TPU Functions 332
Table 11.2 Pin Configuration 336
Table 11.3 CCLR2 to CCLR0 (Channels 0 and 3) 340

Table 11.4 CCLR2 to CCLR0 (Channels 1, 2, 4, and 5)....340
Table 11.5 TPSC2 to TPSC0 (Channel 0)....341
Table 11.6 TPSC2 to TPSC0 (Channel 1)....341
Table 11.7 TPSC2 to TPSC0 (Channel 2)....342
Table 11.8 TPSC2 to TPSC0 (Channel 3)....342
Table 11.9 TPSC2 to TPSC0 (Channel 4)....343
Table 11.10 TPSC2 to TPSC0 (Channel 5)....343
Table 11.11 MD3 to MD0....345
Table 11.12 TIORH_0....347
Table 11.13 TIORL_0....348
Table 11.14 TIOR_1....349
Table 11.15 TIOR_2....350
Table 11.16 TIORH_3....351
Table 11.17 TIORL_3....352
Table 11.18 TIOR_4....353
Table 11.19 TIOR_5....354
Table 11.20 TIORH_0....355
Table 11.21 TIORL_0....356
Table 11.22 TIOR_1....357
Table 11.23 TIOR_2....358
Table 11.24 TIORH_3....359
Table 11.25 TIORL_3....360
Table 11.26 TIOR_4....361
Table 11.27 TIOR_5....362
Table 11.28 Register Combinations in Buffer Operation....377
Table 11.29 Cascaded Combinations....380
Table 11.30 PWM Output Registers and Output Pins....383
Table 11.31 Clock Input Pins in Phase Counting Mode....387
Table 11.32 Up/Down-Count Conditions in Phase Counting Mode 1....388
Table 11.33 Up/Down-Count Conditions in Phase Counting Mode 2....389
Table 11.34 Up/Down-Count Conditions in Phase Counting Mode 3....390
Table 11.35 Up/Down-Count Conditions in Phase Counting Mode 4....391
Table 11.36 TPU Interrupts....394

Section 12 8-Bit Timers

Table 12.1 Pin Configuration....413
Table 12.2 8-Bit Timer Interrupt Sources....426
Table 12.3 Timer Output Priorities....429
Table 12.4 Switching of Internal Clock and TCNT Operation....430

Section 13 Watchdog Timer (WDT)

Table 13.1 lists WDT pin....435
Table 13.2 WDT Interrupt Source....444

Section 14 Serial Communication Interface (SCI)
Table 14.1 Pin Configuration....453
Table 14.2 The Relationships between The N Setting in BRR and Bit Rate B....471
Table 14.3 BRR Settings for Various Bit Rates (Asynchronous Mode)....472
Table 14.4 Maximum Bit Rate for Each Frequency (Asynchronous Mode)....475
Table 14.5 Maximum Bit Rate with External Clock Input (Asynchronous Mode)....475
Table 14.6 BRR Settings for Various Bit Rates (Clocked Synchronous Mode)....476
Table 14.7 Maximum Bit Rate with External Clock Input (Clocked Synchronous Mode)....476
Table 14.8 Examples of Bit Rate for Various BRR Settings (Smart Card Interface Mode) (When n = 0 and S = 372)....477
Table 14.9 Maximum Bit Rate at Various Frequencies (Smart Card Interface Mode) (when S = 372)....477
Table 14.10 Serial Transfer Formats (Asynchronous Mode)....483
Table 14.11 SSR Status Flags and Receive Data Handling....490
Table 14.12 Interrupt Sources of Serial Communication Interface Mode....520
Table 14.13 Interrupt Sources in Smart Card Interface Mode....521

Section 15 I^2C Bus Interface (IIC) (Option)
Table 15.1 Pin Configuration....532
Table 15.2 Transfer Format....536
Table 15.3 I^2C Transfer Rate....538
Table 15.4 Flags and Transfer States....544
Table 15.5 Flags and Transfer States....559
Table 15.6 I^2C Bus Timing (SCL and SDA Output)....565
Table 15.7 Permissible SCL Rise Time (t_{sr}) Values....566
Table 15.8 I^2C Bus Timing (with Maximum Influence of t_{Sr}/t_{Sf})....567

Section 16 A/D Converter
Table 16.1 Pin Configuration....575
Table 16.2 Analog Input Channels and Corresponding ADDR Registers....576
Table 16.3 A/D Conversion Time (Single Mode)....583
Table 16.4 A/D Conversion Time (Scan Mode)....583
Table 16.5 A/D Converter Interrupt Source....584
Table 16.6 Analog Pin Specifications....589

Section 17 D/A Converter
Table 17.1 Pin Configuration....592
Table 17.2 D/A Conversion Control....594

Section 19 ROM
Table 19.1 Differences between Boot Mode and User Program Mode....601
Table 19.2 Pin Configuration....608
Table 19.3 Setting On-Board Programming Modes....617
Table 19.4 Boot Mode Operation....619

Table 19.5 System Clock Frequencies for which Automatic Adjustment of LSI Bit Rate is Possible 619
Table 19.6 Flash Memory Operating States 630
Table 19.7 Registers Present in F-ZTAT Version but Absent in Masked ROM Version 636

Section 22 Clock Pulse Generator

Table 22.1 Damping Resistance Value 657
Table 22.2 Crystal Resonator Characteristics 657
Table 22.3 External Clock Input Conditions (1) (H8S/2238R Series, H8S/2237 Series, H8S/2227 Series) 658
Table 22.3 External Clock Input Conditions (2) (H8S/2239 Series) 659
Table 22.4 External Clock Input Conditions (Duty Adjustment Circuit Unused) (1) (H8S/2238R Series, H8S/2237 Series, H8S/2227 Series) 659
Table 22.4 External Clock Input Conditions (Duty Adjustment Circuit Unused) (2) (H8S/2239 Series) 660

Section 23 Power-Down Modes

Table 23.1 LSI Internal States in Each Mode 665
Table 23.2 Low Power Dissipation Mode Transition Conditions 668
Table 23.3 Oscillation Settling Time Settings 675
Table 23.4 ϕ Pin States in Respective Processes 682

Section 25 Electrical Characteristics

Table 25.1 Absolute Maximum Ratings 718
Table 25.2 DC Characteristics (1) 719
Table 25.2 DC Characteristics (2) 720
Table 25.2 DC Characteristics (3) 722
Table 25.3 Permissible Output Currents 725
Table 25.4 Bus Driving Characteristics 726
Table 25.5 Clock Timing 727
Table 25.6 Control Signal Timing 728
Table 25.7 Bus Timing 729
Table 25.8 DMAC Timing 730
Table 25.9 Timing of On-Chip Peripheral Modules 731
Table 25.10 I^2C Bus Timing 733
Table 25.11 A/D Conversion Characteristics 734
Table 25.12 D/A Conversion Characteristics 735
Table 25.13 Flash Memory Characteristics 736
Table 25.14 Absolute Maximum Ratings 738
Table 25.15 DC Characteristics (1) 739
Table 25.15 DC Characteristics (2) 741
Table 25.15 DC Characteristics (3) 743
Table 25.16 Permissible Output Currents 745
Table 25.17 Bus Driving Characteristics 746

Table 25.18 Clock Timing 747
Table 25.19 Control Signal Timing 748
Table 25.20 Bus Timing 749
Table 25.21 Timing of On-Chip Peripheral Modules 750
Table 25.22 I^2C Bus Timing 752
Table 25.23 A/D Conversion Characteristics 753
Table 25.24 D/A Conversion Characteristics 754
Table 25.25 Flash Memory Characteristics 755
Table 25.26 Absolute Maximum Ratings 757
Table 25.27 DC Characteristics (1) 757
Table 25.27 DC Characteristics (2) 759
Table 25.27 DC Characteristics (3) 761
Table 25.27 DC Characteristics (4) 763
Table 25.28 Permissible Output Currents 765
Table 25.29 lists the Clock timing 766
Table 25.30 Control Signal Timing 767
Table 25.31 Bus Timing 768
Table 25.32 Timing of On-Chip Peripheral Modules 770
Table 25.33 A/D Conversion Characteristics 772
Table 25.34 D/A Conversion Characteristics 773
Table 25.35 Flash Memory Characteristics 774

Appendix

Table B.1 Product Codes of H8S/2239 Series 794
Table B.2 Product Codes of H8S/2238R Series 795
Table B.3 Product Codes of H8S/2237 Series and H8S/2227 Series 796

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
  - PC break controller
  - DMA controller (DMAC)
    Supported only by the H8S/2239 Series.
  - Data transfer controller (DTC)
  - 16-bit timer-pulse unit (TPU)
    H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series: Six channels
    H8S/2227 Series: Three channels
  - 8-bit timer (TMR)
    H8S/2239 Series, H8S/2238R Series: Four channels
    H8S/2237 Series, H8S/2227 Series: Two channels
  - Watchdog timer (WDT)
  - Serial communication interface (SCI)
    H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series: Four channels (SCI_0 to SCI_3)
    H8S/2227 Series: Three channels (SCI_0, SCI_1, and SCI_3)
  - I^2C bus interface (IIC)
    Optional function for the H8S/2239 Series and H8S/2238R Series
  - 10-bit A/D converter
  - 8-bit D/A converter
    Not available in the H8S/2227 Series.
- On-chip memory

ROM	Model	ROM	RAM	Remarks
Flash memory version	HD64F2239	384 kbytes	32 kbytes	
	HD64F2238R	256 kbytes	16 kbytes	
	HD64F2227	128 kbytes	16 kbytes	
PROM version	HD6472237	128 kbytes	16 kbytes	
Masked ROM version	HD6432239	384 kbytes	32 kbytes	
	HD6432239W	384 kbytes	32 kbytes	
	HD6432238R	256 kbytes	16 kbytes	
	HD6432238RW	256 kbytes	16 kbytes	
	HD6432236R	128 kbytes	8 kbytes	
	HD6432236RW	128 kbytes	8 kbytes	
	HD6432237	128 kbytes	16 kbytes	
	HD6432235	128 kbytes	4 kbytes	
	HD6432233	64 kbytes	4 kbytes	
	HD6432227	128 kbytes	16 kbytes	
	HD6432225	128 kbytes	4 kbytes	
	HD6432224	96 kbytes	4 kbytes	
	HD6432223	64 kbytes	4 kbytes	

- General I/O ports
  - I/O pins: 72
  - Input-only pins: 10
- 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*[1]	FP-100A	14.0 × 20.0 mm	0.65 mm
QFP-100	FP-100B	14.0 × 14.0 mm	0.5 mm
TFBGA-112*[2]	BP-112	10.0 × 10.0 mm	0.8 mm

Notes: 1. Supported only by the H8S/2237 Series and H8S/2227 Series.
2. Being planned only for the H8S/2238R Series.

1.2 Internal Block Diagram

Figures 1.1, 1.2, 1.3, and 1.4 show the internal block diagrams of the H8S/2239 Series, the H8S/2238R Series, H8S/2237 Series, and the H8S/2227 Series, respectively.

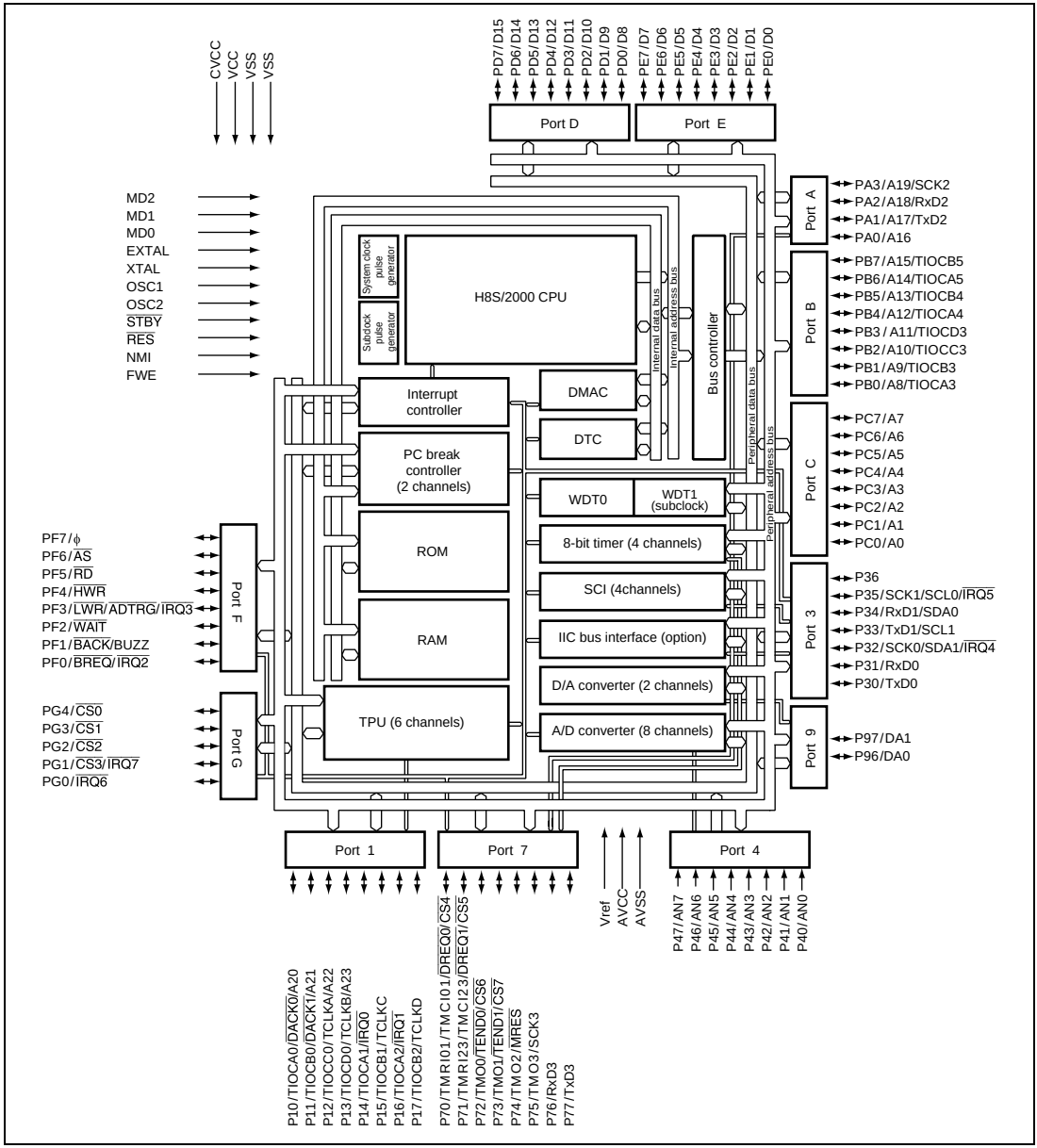


Figure 1.1 Internal Block Diagram of H8S/2239 Series

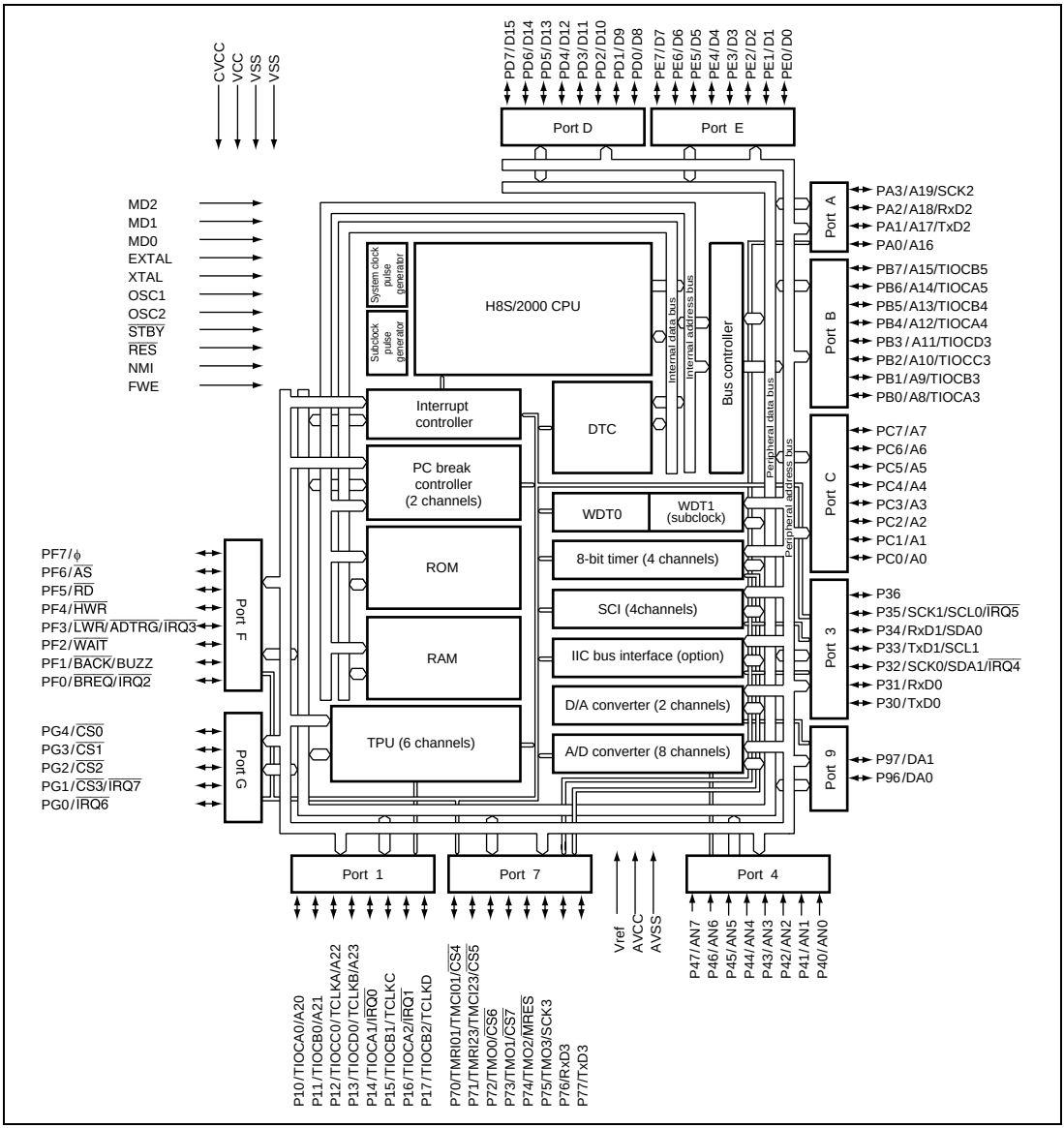


Figure 1.2 Internal Block Diagram of H8S/2238R Series

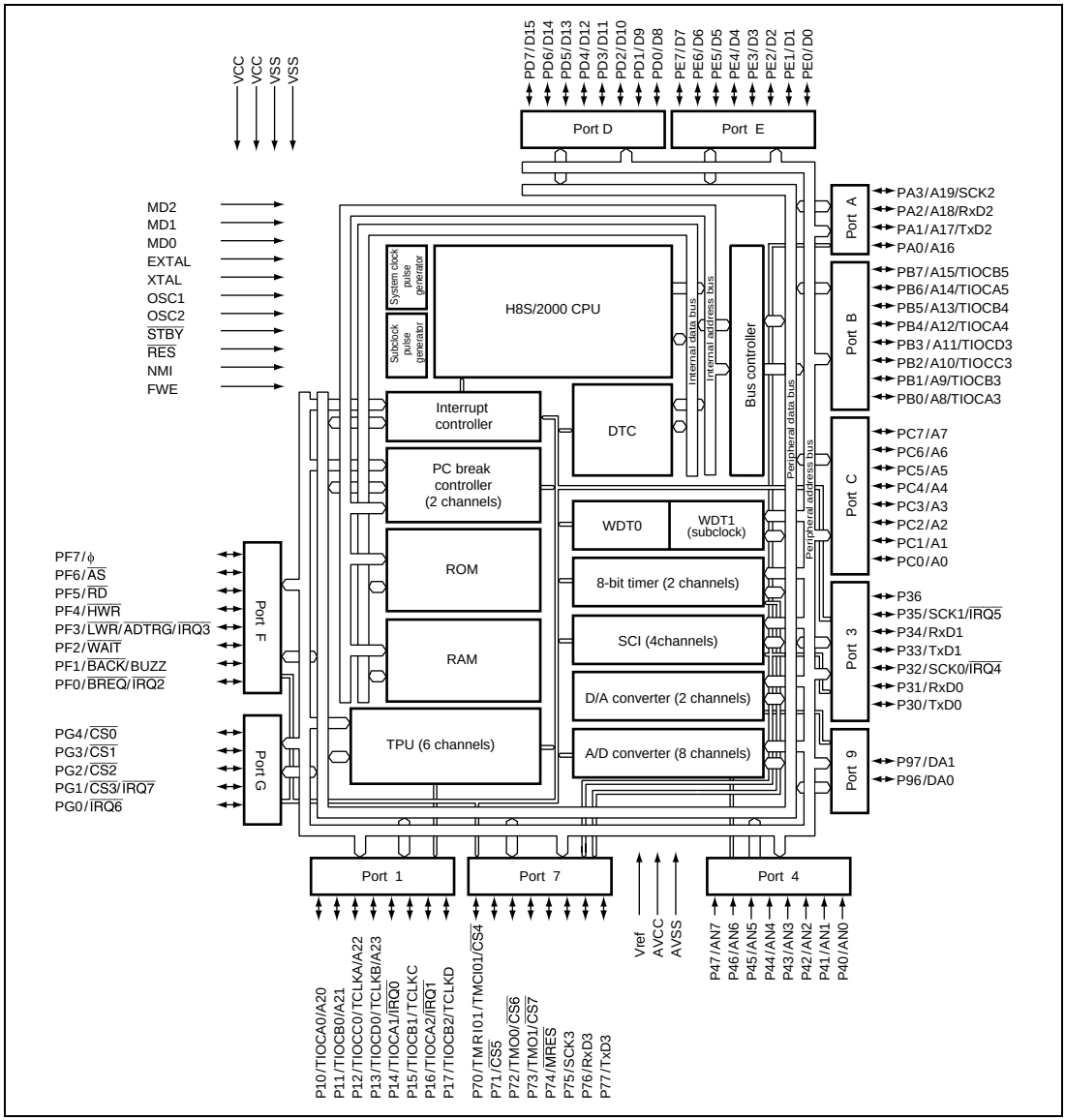


Figure 1.3 Internal Block Diagram of H8S/2237 Series

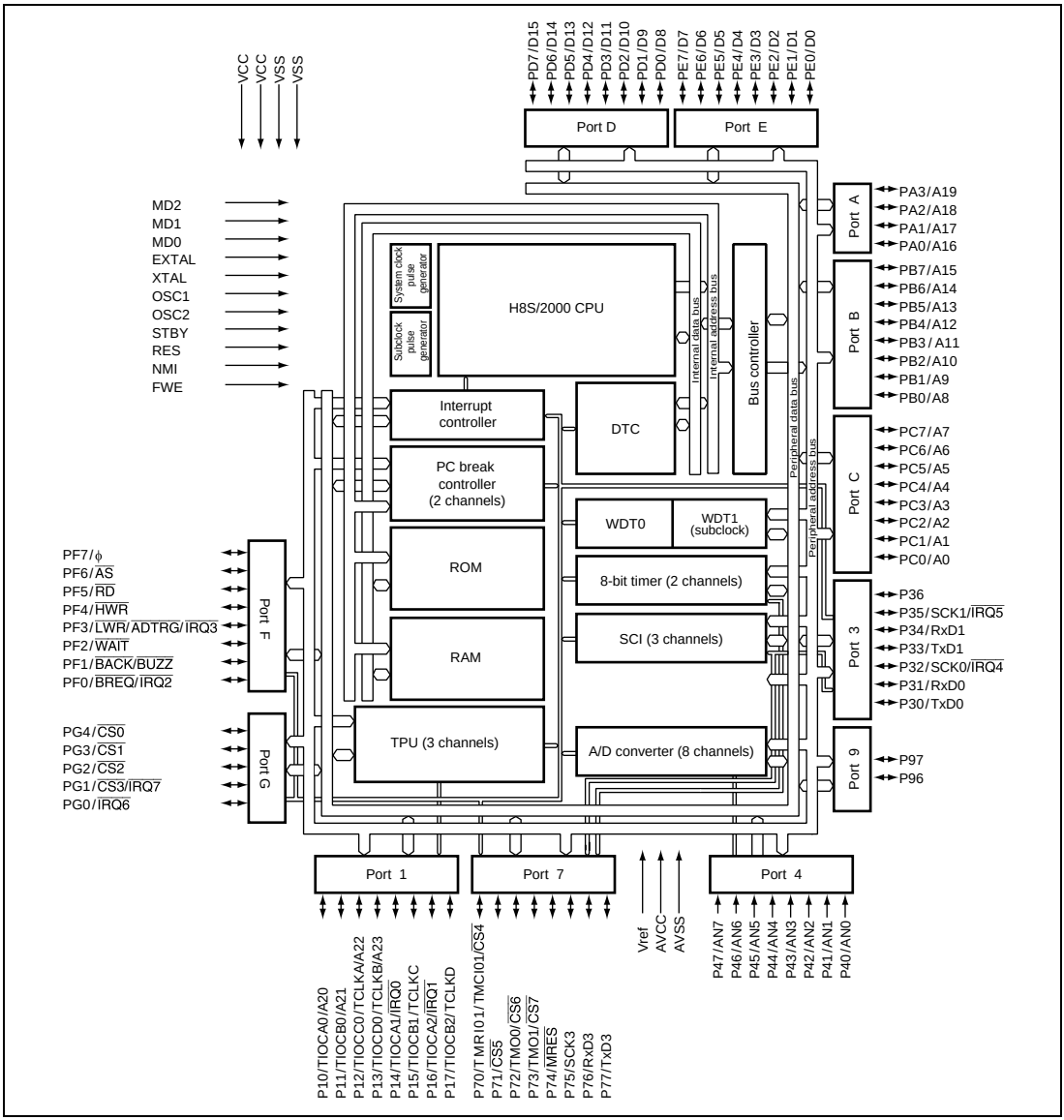


Figure 1.4 Internal Block Diagram of H8S/2227 Series

1.3 Pin Description

1.3.1 Pin Arrangement

(1) Pin Arrangement of H8S/2239 Series

Figure 1.5 shows the pin arrangement of the H8S/2239 Series.

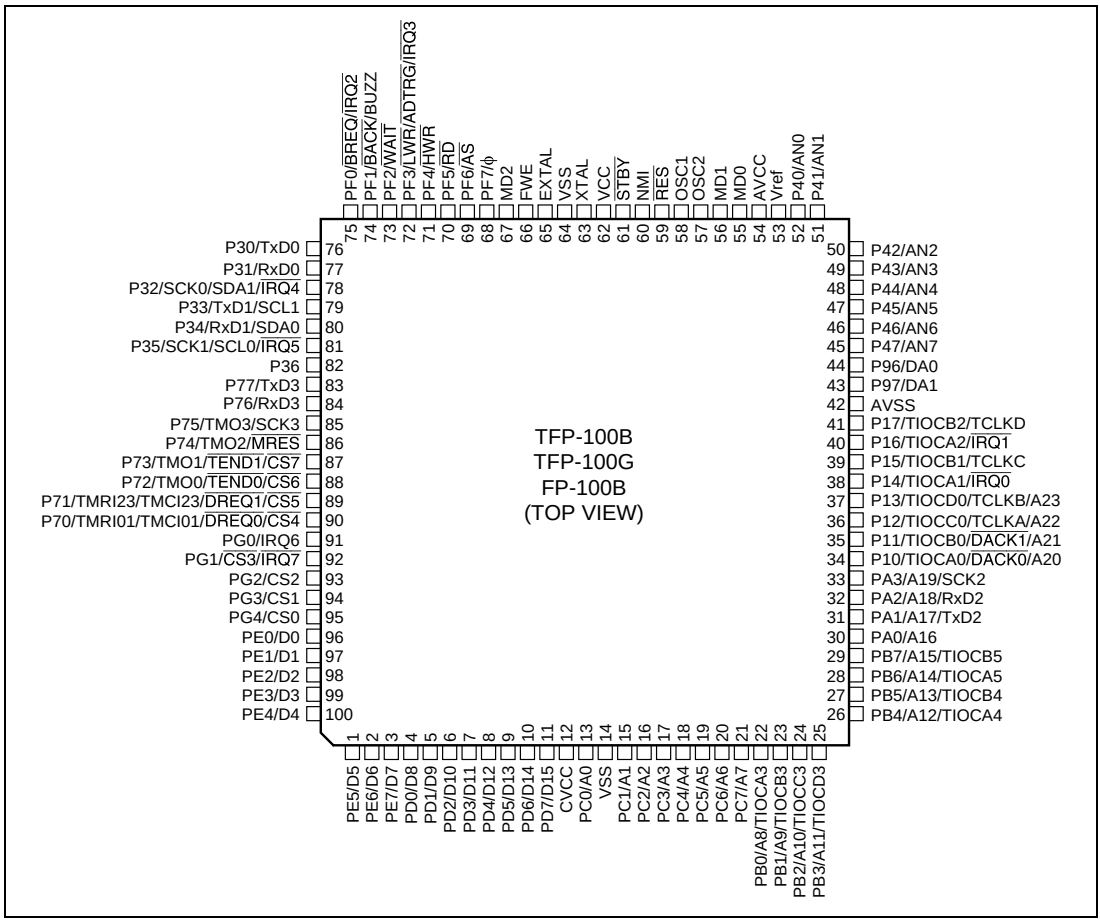


Figure 1.5 Pin Arrangement of H8S/2239 Series (TFP-100B, TFP-100G, FP100B: Top View)

(2) Pin Arrangement of H8S/2238R Series

Figure 1.6 and figure 1.7 show the pin arrangement of the H8S/2238R Series.

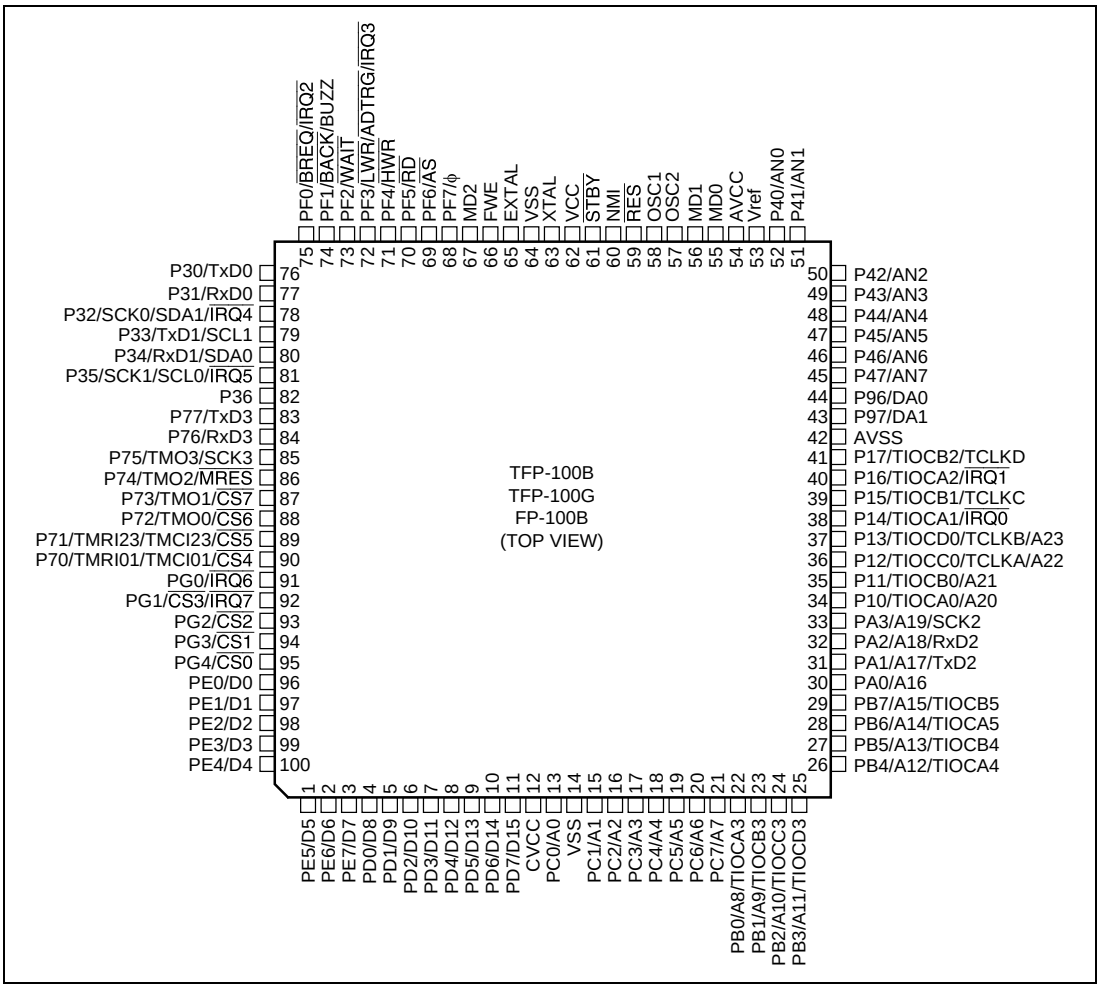
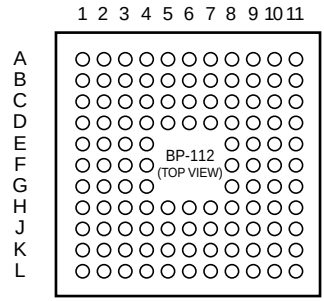


Figure 1.6 Pin Arrangement of H8S/2238R Series
(TFP-100B, TFP-100G, FP100B: Top View)



Pin No.	Pin Name	Pin No.	Pin Name	Pin No.	Pin Name
A1	NC (Reserve)	E1	PD7/D15	J1	PC7/A7
A2	PE4/D4	E2	CVCC	J2	PB1/A9/TIOCB3
A3	PE1/D1	E3	PD6/D14	J3	PB3/A11/TIOCD3
A4	PG3/$\overline{CS1}$	E4	PD5/D13	J4	PA1/A17/TxD2
A5	PG0/$\overline{IRQ6}$	E8	PF6/$\overline{AS}$	J5	P11/TIOCB0/A21
A6	P72/TMO0/$\overline{CS6}$	E9	MD2	J6	P14/TIOCA1/$\overline{IRQ0}$
A7	P75/TMO3/SCK3	E10	FWE	J7	P97/DA1
A8	P36	E11	EXTAL	J8	P44/AN4
A9	P33/TxD1/SCL1			J9	NC (Reserve)
A10	P30/TxD0			J10	AVCC
A11	NC (Reserve)			J11	MD0
B1	PE6/D6	F1	PC0/A0	K1	PB2/A10/TIOCC3
B2	PE5/D5	F2	VSS	K2	PB4/A12/TIOCA4
B3	PE3/D3	F3	CVCC	K3	PB7/A15/TIOCB5
B4	PE0/D0	F4	VSS	K4	PA2/A18/RxD2
B5	PG1/CS3/$\overline{IRQ7}$	F8	VSS	K5	P13/TIOCD0/TCLKB/A23
B6	P71/TMRI23/TMCI23/$\overline{CS5}$	F9	VCC	K6	P16/TIOCA2/$\overline{IRQ1}$
B7	P74/TMO2/$\overline{MRES}$	F10	VSS	K7	AVSS
B8	P35/SCK1/SCL0/$\overline{IRQ5}$	F11	XTAL	K8	P46/AN6
B9	P32/SCK0/SDA1/$\overline{IRQ4}$			K9	P43/AN3
B10	NC (Reserve)			K10	P41/AN1
B11	PF1/$\overline{BACK}$/BUZZ			K11	P40/AN0
C1	PD1/D9	G1	PC1/A1	L1	NC (Reserve)
C2	PD0/D8	G2	PC2/A2	L2	PB5/A13/TIOCB4
C3	NC (Reserve)	G3	PC3/A3	L3	PA0/A16
C4	PE2/D2	G4	PC5/A5	L4	PA3/A19/SCK2
C5	PG2/$\overline{CS2}$	G8	$\overline{RES}$	L5	P12/TIOCC0/TCLKA/A22
C6	P73/TMO1/$\overline{CS7}$	G9	NMI	L6	P15/TIOCB1/TCLKC
C7	P76/RxD3	G10	VCC	L7	AVSS
C8	P34/RxD1/SDA0	G11	$\overline{STBY}$	L8	P96/DA0
C9	PF0/BREQ/$\overline{IRQ2}$			L9	P45/AN5
C10	PF2/$\overline{WAIT}$			L10	P42/AN2
C11	PF4/$\overline{HWR}$			L11	NC (Reserve)
D1	PD4/D12	H1	PC4/A4		
D2	PD3/D11	H2	PC6/A6		
D3	PD2/D10	H3	PB0/A8/TIOCA3		
D4	PE7/D7	H4	PB6/A14/TIOCA5		
D5	PG4/$\overline{CS0}$	H5	P10/TIOCA0/A20		
D6	P70/TMRI01/TMCI01/$\overline{CS4}$	H6	P17/TIOCB2/TCLKD		
D7	P77/TxD3	H7	P47/AN7		
D8	P31/RxD0	H8	Vref		
D9	PF3/LWR/$\overline{ADTRG}$/$\overline{IRQ3}$	H9	MD1		
D10	PF5/$\overline{RD}$	H10	OSC2		
D11	PF7/ϕ	H11	OSC1		

Figure 1.7 Pin Arrangement of H8S/2238R Series
(BP-112: Top View, Being Planned)

(3) Pin Arrangement of H8S/2237 Series

Figure1.8 and figure 1.9 show the pin arrangement of the H8S/2237 Series.

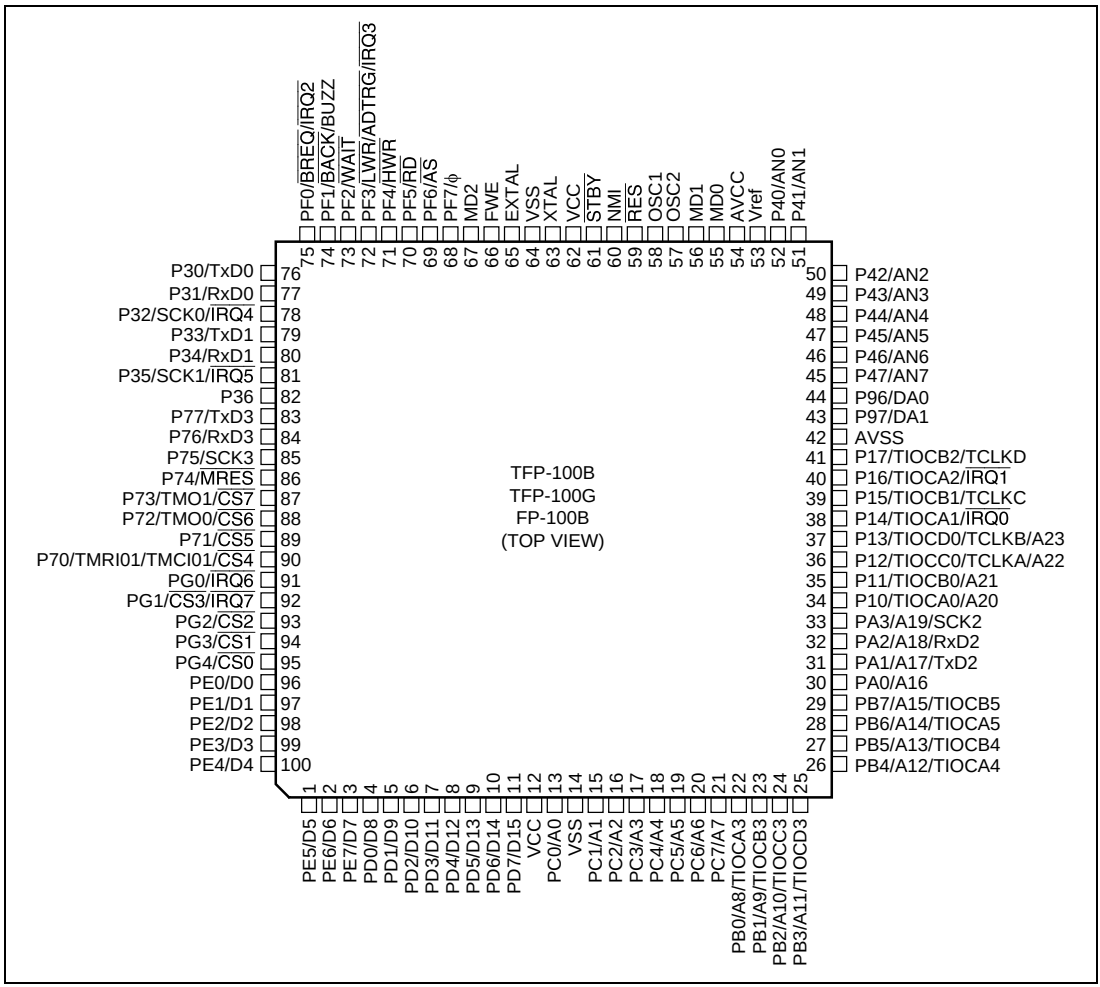


Figure 1.8 Pin Arrangement of H8S/2237 Series
(TFP-100B, TFP-100G, FP100B: Top View)

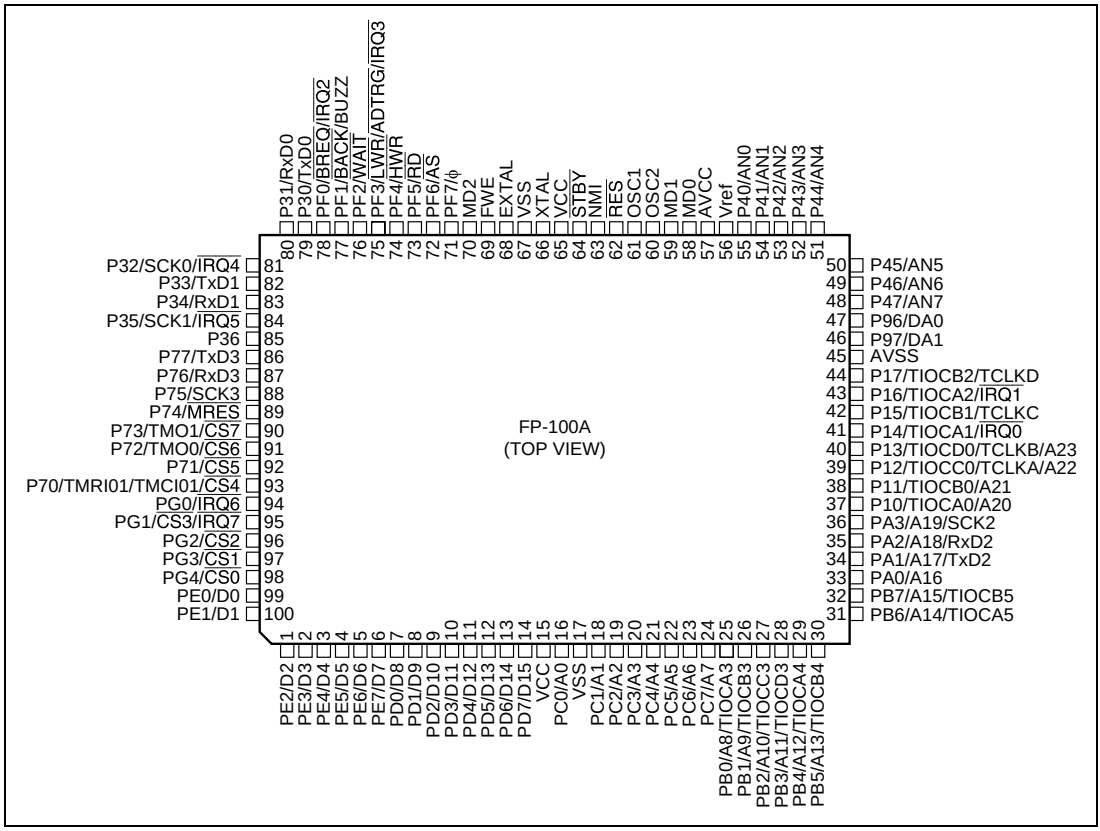


Figure 1.9 Pin Arrangement of H8S/2237 Series (FP-100A: Top View)

(4) Pin Arrangement of H8S/2227 Series

Figure 1.10 and figure 1.11 show the pin arrangement of the H8S/2227 Series.

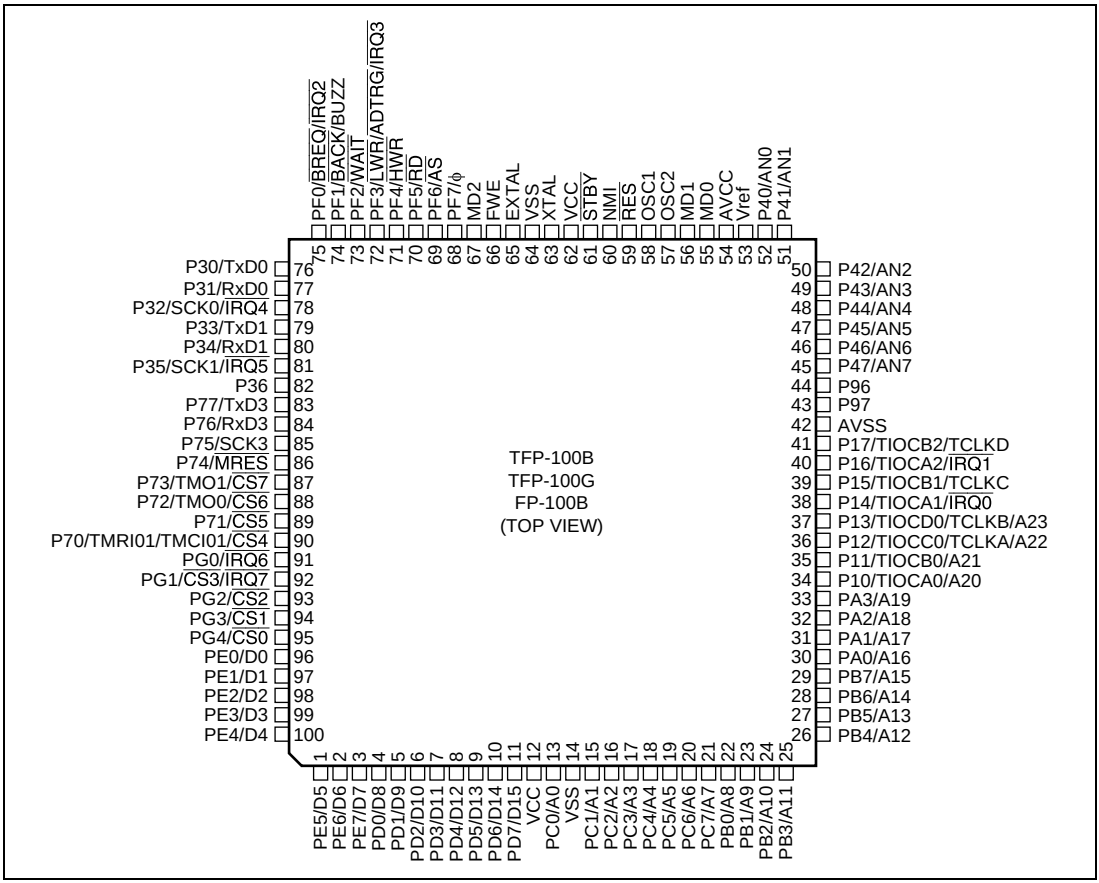


Figure 1.10 Pin Arrangement of H8S/2227 Series (TFP-100B, TFP-100G, FP100B: Top View)

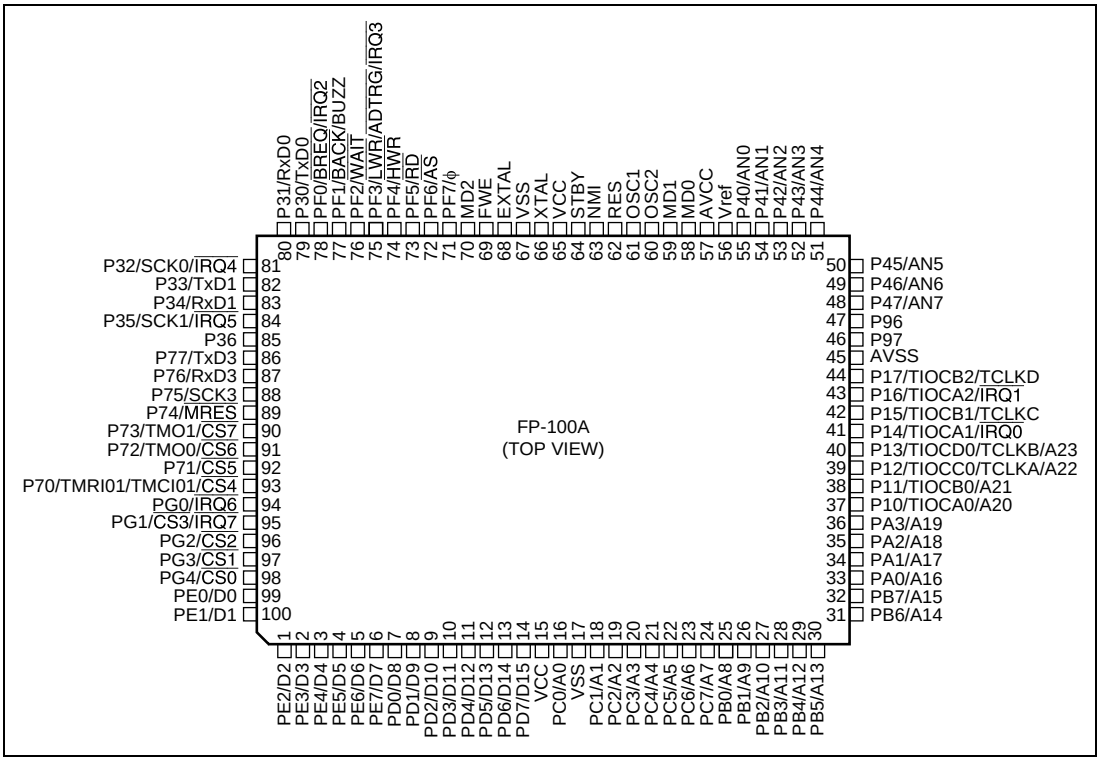


Figure 1.11 Pin Arrangement of H8S/2227 Series (FP-100A: Top View)

1.3.2 Pin Arrangements in Each Mode

Tables 1.1, 1.2, 1.3, and 1.4 list the pin arrangements in each mode of the H8S/2239 Series, the H8S/2238R Series, the H8S/2237 Series, and the H8S/2227 Series, respectively.

Table 1.1 Pin Arrangements in Each Mode of H8S/2239 Series

Pin No.	Pin Name				
TFP-100B TFP-100G FP-100B	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
1	PE5/D5	PE5/D5	PE5/D5	PE5	OE
2	PE6/D6	PE6/D6	PE6/D6	PE6	WE
3	PE7/D7	PE7/D7	PE7/D7	PE7	CE
4	D8	D8	D8	PD0	D0
5	D9	D9	D9	PD1	D1
6	D10	D10	D10	PD2	D2
7	D11	D11	D11	PD3	D3
8	D12	D12	D12	PD4	D4
9	D13	D13	D13	PD5	D5
10	D14	D14	D14	PD6	D6
11	D15	D15	D15	PD7	D7
12	CVCC	CVCC	CVCC	CVCC	VCC
13	A0	A0	PC0/A0	PC0	A0
14	VSS	VSS	VSS	VSS	VSS
15	A1	A1	PC1/A1	PC1	A1
16	A2	A2	PC2/A2	PC2	A2
17	A3	A3	PC3/A3	PC3	A3
18	A4	A4	PC4/A4	PC4	A4
19	A5	A5	PC5/A5	PC5	A5
20	A6	A6	PC6/A6	PC6	A6

Pin No.	Pin Name				
TFP-100B TFP-100G FP-100B	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
21	A7	A7	PC7/A7	PC7	A7
22	PB0/A8/ TIOCA3	PB0/A8/ TIOCA3	PB0/A8/ TIOCA3	PB0/TIOCA3	A8
23	PB1/A9/ TIOCB3	PB1/A9/ TIOCB3	PB1/A9/ TIOCB3	PB1/TIOCB3	A9
24	PB2/A10/ TIOCC3	PB2/A10/ TIOCC3	PB2/A10/ TIOCC3	PB2/TIOCC3	A10
25	PB3/A11/ TIOCD3	PB3/A11/ TIOCD3	PB3/A11/ TIOCD3	PB3/TIOCD3	A11
26	PB4/A12/ TIOCA4	PB4/A12/ TIOCA4	PB4/A12/ TIOCA4	PB4/TIOCA4	A12
27	PB5/A13/ TIOCB4	PB5/A13/ TIOCB4	PB5/A13/ TIOCB4	PB5/TIOCB4	A13
28	PB6/A14/ TIOCA5	PB6/A14/ TIOCA5	PB6/A14/ TIOCA5	PB6/TIOCA5	A14
29	PB7/A15/ TIOCB5	PB7/A15/ TIOCB5	PB7/A15/ TIOCB5	PB7/TIOCB5	A15
30	PA0/A16	PA0/A16	PA0/A16	PA0	A16
31	PA1/A17/TxD 2	PA1/A17/TxD2	PA1/A17/TxD2	PA1/TxD2	A17
32	PA2/A18/RxD 2	PA2/A18/RxD2	PA2/A18/RxD2	PA2/RxD2	A18
33	PA3/A19/ SCK2	PA3/A19/ SCK2	PA3/A19/ SCK2	PA3/SCK2	NC
34	P10/TIOCA0/ DACK0/A20	P10/TIOCA0/ DACK0/A20	P10/TIOCA0/ DACK0/A20	P10/TIOCA0/ DACK0	NC
35	P11/TIOCB0/ DACK1/A21	P11/TIOCB0/ DACK1/A21	P11/TIOCB0/ DACK1/A21	P11/TIOCB0/ DACK1	NC

Pin No.	Pin Name				
TFP-100B TFP-100G FP-100B	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
36	P12/TIOCC0/ TCLKA/A22	P12/TIOCC0/ TCLKA/A22	P12/TIOCC0/ TCLKA/A22	P12/TIOCC0/ TCLKA	NC
37	P13/TIOCD0/ TCLKB/A23	P13/TIOCD0/ TCLKB/A23	P13/TIOCD0/ TCLKB/A23	P13/TIOCD0/ TCLKB	NC
38	P14/TIOCA1/ IRQ0	P14/TIOCA1/ IRQ0	P14/TIOCA1/ IRQ0	P14/TIOCA1/ IRQ0	VSS
39	P15/TIOCB1/ TCLKC	P15/TIOCB1/ TCLKC	P15/TIOCB1/ TCLKC	P15/TIOCB1/ TCLKC	NC
40	P16/TIOCA2/ IRQ1	P16/TIOCA2/ IRQ1	P16/TIOCA2/ IRQ1	P16/TIOCA2/ IRQ1	VSS
41	P17/TIOCB2/ TCLKD	P17/TIOCB2/ TCLKD	P17/TIOCB2/ TCLKD	P17/TIOCB2/ TCLKD	NC
42	AVSS	AVSS	AVSS	AVSS	VSS
43	P97/DA1	P97/DA1	P97/DA1	P97/DA1	NC
44	P96/DA0	P96/DA0	P96/DA0	P96/DA0	NC
45	P47/AN7	P47/AN7	P47/AN7	P47/AN7	NC
46	P46/AN6	P46/AN6	P46/AN6	P46/AN6	NC
47	P45/AN5	P45/AN5	P45/AN5	P45/AN5	NC
48	P44/AN4	P44/AN4	P44/AN4	P44/AN4	NC
49	P43/AN3	P43/AN3	P43/AN3	P43/AN3	NC
50	P42/AN2	P42/AN2	P42/AN2	P42/AN2	NC
51	P41/AN1	P41/AN1	P41/AN1	P41/AN1	NC
52	P40/AN0	P40/AN0	P40/AN0	P40/AN0	NC
53	Vref	Vref	Vref	Vref	VCC
54	AVCC	AVCC	AVCC	AVCC	VCC
55	MD0	MD0	MD0	MD0	VSS
56	MD1	MD1	MD1	MD1	VSS
57	OSC2	OSC2	OSC2	OSC2	NC
58	OSC1	OSC1	OSC1	OSC1	VCC
59	RES	RES	RES	RES	RES
60	NMI	NMI	NMI	NMI	VCC

Pin No.	Pin Name				
TFP-100B TFP-100G FP-100B	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
61	STBY	STBY	STBY	STBY	VCC
62	VCC	VCC	VCC	VCC	VCC
63	XTAL	XTAL	XTAL	XTAL	XTAL
64	VSS	VSS	VSS	VSS	VSS
65	EXTAL	EXTAL	EXTAL	EXTAL	EXTAL
66	FWE	FWE	FWE	FWE	FWE
67	MD2	MD2	MD2	MD2	NC
68	PF7/ϕ	PF7/ϕ	PF7/ϕ	PF7/ϕ	NC
69	AS	AS	AS	PF6	NC
70	RD	RD	RD	PF5	NC
71	HWR	HWR	HWR	PF4	NC
72	PF3/LWR/ ADTRG/IRQ3	PF3/LWR/ ADTRG/IRQ3	PF3/LWR/ ADTRG/IRQ3	PF3/ADTRG/ IRQ3	NC
73	PF2/WAIT	PF2/WAIT	PF2/WAIT	PF2	NC
74	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BUZZ	NC
75	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/IRQ2	VCC
76	P30/TxD0	P30/TxD0	P30/TxD0	P30/TxD0	NC
77	P31/RxD0	P31/RxD0	P31/RxD0	P31/RxD0	NC
78	P32/SCK0/ SDA1/IRQ4	P32/SCK0/ SDA1/IRQ4	P32/SCK0/ SDA1/IRQ4	P32/SCK0/ SDA1/IRQ4	NC
79	P33/TxD1/ SCL1	P33/TxD1/ SCL1	P33/TxD1/ SCL1	P33/TxD1/ SCL1	NC
80	P34/RxD1/ SDA0	P34/RxD1/ SDA0	P34/RxD1/ SDA0	P34/RxD1/ SDA0	NC

Pin No.	Pin Name				
TFP-100B TFP-100G FP-100B	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
81	P35/SCK1/ SCL0/IRQ5	P35/SCK1/ SCL0/IRQ5	P35/SCK1/ SCL0/IRQ5	P35/SCK1/ SCL0/IRQ5	NC
82	P36	P36	P36	P36	NC
83	P77/TxD3	P77/TxD3	P77/TxD3	P77/TxD3	NC
84	P76/RxD3	P76/RxD3	P76/RxD3	P76/RxD3	NC
85	P75/TMO3/ SCK3	P75/TMO3/ SCK3	P75/TMO3/ SCK3	P75/TMO3/ SCK3	NC
86	P74/TMO2/ MRES	P74/TMO2/ MRES	P74/TMO2/ MRES	P74/TMO2/ MRES	NC
87	P73/TMO1/ TEND1/CS7	P73/TMO1/ TEND1/CS7	P73/TMO1/ TEND1/CS7	P73/TMO1/ TEND1	NC
88	P72/TMO0 / TEND0/CS6	P72/TMO0 / TEND0/CS6	P72/TMO0 / TEND0/CS6	P72/TMO0/ TEND0	NC
89	P71/TMRI23/ TMCI23/ DREQ1/CS5	P71/TMRI23/ TMCI23/ DREQ1/CS5	P71/TMRI23/ TMCI23/ DREQ1/CS5	P71/TMRI23/ TMCI23/ DREQ1	NC
90	P70/TMRI01/ TMCI01/ DREQ0/CS4	P70/TMRI01/ TMCI01/ DREQ0/CS4	P70/TMRI01/ TMCI01/ DREQ0/CS4	P70/TMRI01/ TMCI01/ DREQ0	NC
91	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	NC
92	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/IRQ7	NC
93	PG2/CS2	PG2/CS2	PG2/CS2	PG2	NC
94	PG3/CS1	PG3/CS1	PG3/CS1	PG3	NC
95	PG4/CS0	PG4/CS0	PG4/CS0	PG4	NC
96	PE0/D0	PE0/D0	PE0/D0	PE0	NC
97	PE1/D1	PE1/D1	PE1/D1	PE1	NC
98	PE2/D2	PE2/D2	PE2/D2	PE2	NC
99	PE3/D3	PE3/D3	PE3/D3	PE3	VCC
100	PE4/D4	PE4/D4	PE4/D4	PE4	VSS

Table 1.2 Pin Arrangements in Each Mode of H8S/2238R Series

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	BP-112	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
1	B2	PE5/D5	PE5/D5	PE5/D5	PE5	OE
2	B1	PE6/D6	PE6/D6	PE6/D6	PE6	WE
3	D4	PE7/D7	PE7/D7	PE7/D7	PE7	CE
4	C2	D8	D8	D8	PD0	D0
5	C1	D9	D9	D9	PD1	D1
6	D3	D10	D10	D10	PD2	D2
7	D2	D11	D11	D11	PD3	D3
8	D1	D12	D12	D12	PD4	D4
9	E4	D13	D13	D13	PD5	D5
10	E3	D14	D14	D14	PD6	D6
11	E1	D15	D15	D15	PD7	D7
12	E2, F3	CVCC	CVCC	CVCC	CVCC	VCC
13	F1	A0	A0	PC0/A0	PC0	A0
14	F2, F4	VSS	VSS	VSS	VSS	VSS
15	G1	A1	A1	PC1/A1	PC1	A1
16	G2	A2	A2	PC2/A2	PC2	A2
17	G3	A3	A3	PC3/A3	PC3	A3
18	H1	A4	A4	PC4/A4	PC4	A4
19	G4	A5	A5	PC5/A5	PC5	A5
20	H2	A6	A6	PC6/A6	PC6	A6
21	J1	A7	A7	PC7/A7	PC7	A7
22	H3	PB0/A8/ TIOCA3	PB0/A8/ TIOCA3	PB0/A8/ TIOCA3	PB0/ TIOCA3	A8
23	J2	PB1/A9/ TIOCB3	PB1/A9/ TIOCB3	PB1/A9/ TIOCB3	PB1/ TIOCB3	A9
24	K1	PB2/A10/ TIOCC3	PB2/A10/ TIOCC3	PB2/A10/ TIOCC3	PB2/ TIOCC3	A10
25	J3	PB3/A11/ TIOCD3	PB3/A11/ TIOCD3	PB3/A11/ TIOCD3	PB3/ TIOCD3	A11

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	BP-112	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
26	K2	PB4/A12/ TIOCA4	PB4/A12/ TIOCA4	PB4/A12/ TIOCA4	PB4/ TIOCA4	A12
27	L2	PB5/A13/ TIOCB4	PB5/A13/ TIOCB4	PB5/A13/ TIOCB4	PB5/ TIOCB4	A13
28	H4	PB6/A14/ TIOCA5	PB6/A14/ TIOCA5	PB6/A14/ TIOCA5	PB6/ TIOCA5	A14
29	K3	PB7/A15/ TIOCB5	PB7/A15/ TIOCB5	PB7/A15/ TIOCB5	PB7/ TIOCB5	A15
30	L3	PA0/A16	PA0/A16	PA0/A16	PA0	A16
31	J4	PA1/A17/ TxD2	PA1/A17/ TxD2	PA1/A17/ TxD2	PA1/TxD2	A17
32	K4	PA2/A18/ RxD2	PA2/A18/ RxD2	PA2/A18/ RxD2	PA2/ RxD2	A18
33	L4	PA3/A19/ SCK2	PA3/A19/ SCK2	PA3/A19/ SCK2	PA3/ SCK2	NC
34	H5	P10/TIOCA0/ A20	P10/TIOCA0/ A20	P10/TIOCA0/ A20	P10/ TIOCA0	NC
35	J5	P11/ TIOCB0/ A21	P11/ TIOCB0/ A21	P11/ TIOCB0/ A21	P11/ TIOCB0	NC
36	L5	P12/ TIOCC0/ TCLKA/A22	P12/ TIOCC0/ TCLKA/A22	P12/ TIOCC0/ TCLKA/A22	P12/ TIOCC0/ TCLKA	NC
37	K5	P13/ TIOCD0/ TCLKB/A23	P13/ TIOCD0/ TCLKB/A23	P13/ TIOCD0/ TCLKB/A23	P13/ TIOCD0/ TCLKB	NC
38	J6	P14/ TIOCA1/ IRQ0	P14/ TIOCA1/ IRQ0	P14/ TIOCA1/ IRQ0	P14/ TIOCA1/ IRQ0	VSS
39	L6	P15/ TIOCB1/ TCLKC	P15/ TIOCB1/ TCLKC	P15/ TIOCB1/ TCLKC	P15/ TIOCB1/ TCLKC	NC
40	K6	P16/ TIOCA2/ IRQ1	P16/ TIOCA2/ IRQ1	P16/ TIOCA2/ IRQ1	P16/ TIOCA2/ IRQ1	VSS

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	BP-112	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
41	H6	P17/ TIOCB2/ TCLKD	P17/ TIOCB2/ TCLKD	P17/ TIOCB2/ TCLKD	P17/ TIOCB2/ TCLKD	NC
42	K7, L7	AVSS	AVSS	AVSS	AVSS	VSS
43	J7	P97/DA1	P97/DA1	P97/DA1	P97/DA1	NC
44	L8	P96/DA0	P96/DA0	P96/DA0	P96/DA0	NC
45	H7	P47/AN7	P47/AN7	P47/AN7	P47/AN7	NC
46	K8	P46/AN6	P46/AN6	P46/AN6	P46/AN6	NC
47	L9	P45/AN5	P45/AN5	P45/AN5	P45/AN5	NC
48	J8	P44/AN4	P44/AN4	P44/AN4	P44/AN4	NC
49	K9	P43/AN3	P43/AN3	P43/AN3	P43/AN3	NC
50	L10	P42/AN2	P42/AN2	P42/AN2	P42/AN2	NC
51	K10	P41/AN1	P41/AN1	P41/AN1	P41/AN1	NC
52	K11	P40/AN0	P40/AN0	P40/AN0	P40/AN0	NC
53	H8	Vref	Vref	Vref	Vref	VCC
54	J10	AVCC	AVCC	AVCC	AVCC	VCC
55	J11	MD0	MD0	MD0	MD0	VSS
56	H9	MD1	MD1	MD1	MD1	VSS
57	H10	OSC2	OSC2	OSC2	OSC2	NC
58	H11	OSC1	OSC1	OSC1	OSC1	VCC
59	G8	RES	RES	RES	RES	RES
60	G9	NMI	NMI	NMI	NMI	VCC
61	G11	STBY	STBY	STBY	STBY	VCC
62	F9, G10	VCC	VCC	VCC	VCC	VCC
63	F11	XTAL	XTAL	XTAL	XTAL	XTAL
64	F8, F10	VSS	VSS	VSS	VSS	VSS
65	E11	EXTAL	EXTAL	EXTAL	EXTAL	EXTAL
66	E10	FWE	FWE	FWE	FWE	FWE
67	E9	MD2	MD2	MD2	MD2	NC
68	D11	PF7/ϕ	PF7/ϕ	PF7/ϕ	PF7/ϕ	NC
69	E8	AS	AS	AS	PF6	NC
70	D10	RD	RD	RD	PF5	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	BP-112	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
71	C11	HWR	HWR	HWR	PF4	NC
72	D9	PF3/LWR/ ADTRG/ IRQ3	PF3/LWR/ ADTRG/ IRQ3	PF3/LWR/ ADTRG/ IRQ3	PF3/ ADTRG/ IRQ3	NC
73	C10	PF2/WAIT	PF2/WAIT	PF2/WAIT	PF2	NC
74	B11	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/ BUZZ	NC
75	C9	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/IRQ2	VCC
76	A10	P30/TxD0	P30/TxD0	P30/TxD0	P30/TxD0	NC
77	D8	P31/RxD0	P31/RxD0	P31/RxD0	P31/RxD0	NC
78	B9	P32/SCK0/ SDA1/IRQ4	P32/SCK0/ SDA1/IRQ4	P32/SCK0/ SDA1/IRQ4	P32/ SCK0/ SDA1/ IRQ4	NC
79	A9	P33/TxD1/ SCL1	P33/TxD1/ SCL1	P33/TxD1/ SCL1	P33/ TxD1/ SCL1	NC
80	C8	P34/RxD1/ SDA0	P34/RxD1/ SDA0	P34/RxD1/ SDA0	P34/ RxD1/ SDA0	NC
81	B8	P35/SCK1/ SCL0/IRQ5	P35/SCK1/ SCL0/IRQ5	P35/SCK1/ SCL0/IRQ5	P35/ SCK1/ SCL0/ IRQ5	NC
82	A8	P36	P36	P36	P36	NC
83	D7	P77/TxD3	P77/TxD3	P77/TxD3	P77/TxD3	NC
84	C7	P76/RxD3	P76/RxD3	P76/RxD3	P76/RxD3	NC
85	A7	P75/TMO3/ SCK3	P75/TMO3/ SCK3	P75/TMO3/ SCK3	P75/ TMO3/ SCK3	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	BP-112	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
86	B7	P74/TMO2/ MRES	P74/TMO2/ MRES	P74/TMO2/ MRES	P74/ TMO2/ MRES	NC
87	C6	P73/TMO1/ CS7	P73/TMO1/ CS7	P73/TMO1/ CS7	P73/TMO1	NC
88	A6	P72/TMO0/ CS6	P72/TMO0/ CS6	P72/TMO0/ CS6	P72/TMO0	NC
89	B6	P71/TMRI23/ TMCI23/CS5	P71/TMRI23/ TMCI23/CS5	P71/TMRI23/ TMCI23/CS5	P71/ TMRI23/ TMCI23	NC
90	D6	P70/TMRI01/ TMCI01/CS4	P70/TMRI01/ TMCI01/CS4	P70/TMRI01/ TMCI01/CS4	P70/ TMRI01/ TMCI01	NC
91	A5	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	NC
92	B5	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/IRQ7	NC
93	C5	PG2/CS2	PG2/CS2	PG2/CS2	PG2	NC
94	A4	PG3/CS1	PG3/CS1	PG3/CS1	PG3	NC
95	D5	PG4/CS0	PG4/CS0	PG4/CS0	PG4	NC
96	B4	PE0/D0	PE0/D0	PE0/D0	PE0	NC
97	A3	PE1/D1	PE1/D1	PE1/D1	PE1	NC
98	C4	PE2/D2	PE2/D2	PE2/D2	PE2	NC
99	B3	PE3/D3	PE3/D3	PE3/D3	PE3	VCC
100	A2	PE4/D4	PE4/D4	PE4/D4	PE4	VSS

Table 1.3 Pin Arrangements in Each Mode of H8S/2237 Series

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	PROM Mode
1	4	PE5/D5	PE5/D5	PE5/D5	PE5	NC
2	5	PE6/D6	PE6/D6	PE6/D6	PE6	NC
3	6	PE7/D7	PE7/D7	PE7/D7	PE7	NC
4	7	D8	D8	D8	PD0	D0
5	8	D9	D9	D9	PD1	D1
6	9	D10	D10	D10	PD2	D2
7	10	D11	D11	D11	PD3	D3
8	11	D12	D12	D12	PD4	D4
9	12	D13	D13	D13	PD5	D5
10	13	D14	D14	D14	PD6	D6
11	14	D15	D15	D15	PD7	D7
12	15	VCC	VCC	VCC	VCC	VCC
13	16	A0	A0	PC0/A0	PC0	A0
14	17	VSS	VSS	VSS	VSS	VSS
15	18	A1	A1	PC1/A1	PC1	A1
16	19	A2	A2	PC2/A2	PC2	A2
17	20	A3	A3	PC3/A3	PC3	A3
18	21	A4	A4	PC4/A4	PC4	A4
19	22	A5	A5	PC5/A5	PC5	A5
20	23	A6	A6	PC6/A6	PC6	A6
21	24	A7	A7	PC7/A7	PC7	A7
22	25	PB0/A8/ TIOCA3	PB0/A8/ TIOCA3	PB0/A8/ TIOCA3	PB0/TIOCA 3	A8
23	26	PB1/A9/ TIOCB3	PB1/A9/ TIOCB3	PB1/A9/ TIOCB3	PB1/TIOCB 3	OE
24	27	PB2/A10/ TIOCC3	PB2/A10/ TIOCC3	PB2/A10/ TIOCC3	PB2/TIOCC 3	A10
25	28	PB3/A11/ TIOCD3	PB3/A11/ TIOCD3	PB3/A11/ TIOCD3	PB3/TIOCD 3	A11

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	**FP-100A**	**Mode 4**	**Mode 5**	**Mode 6**	**Mode 7**	**PROM Mode**
26	29	PB4/A12/ TIOCA4	PB4/A12/ TIOCA4	PB4/A12/ TIOCA4	PB4/TIOCA 4	A12
27	30	PB5/A13/ TIOCB4	PB5/A13/ TIOCB4	PB5/A13/ TIOCB4	PB5/TIOCB 4	A13
28	31	PB6/A14/ TIOCA5	PB6/A14/ TIOCA5	PB6/A14/ TIOCA5	PB6/TIOCA 5	A14
29	32	PB7/A15/ TIOCB5	PB7/A15/ TIOCB5	PB7/A15/ TIOCB5	PB7/TIOCB 5	A15
30	33	PA0/A16	PA0/A16	PA0/A16	PA0	A16
31	34	PA1/A17/ TxD2	PA1/A17/ TxD2	PA1/A17/ TxD2	PA1/TxD2	VCC
32	35	PA2/A18/ RxD2	PA2/A18/ RxD2	PA2/A18/ RxD2	PA2/RxD2	VCC
33	36	PA3/A19/ SCK2	PA3/A19/ SCK2	PA3/A19/ SCK2	PA3/SCK2	NC
34	37	P10/TIOCA0 /A20	P10/TIOCA0 /A20	P10/TIOCA0 /A20	P10/TIOCA0	NC
35	38	P11/TIOCB0 /A21	P11/TIOCB0 /A21	P11/TIOCB0 /A21	P11/TIOCB0	NC
36	39	P12/TIOCC0/ TCLKA/A22	P12/TIOCC0/ TCLKA/A22	P12/TIOCC0/ TCLKA/A22	P12/TIOCC0/ TCLKA	NC
37	40	P13/TIOCD0/ TCLKB/A23	P13/TIOCD0/ TCLKB/A23	P13/TIOCD0/ TCLKB/A23	P13/TIOCD0/ TCLKB	NC
38	41	P14/TIOCA1 /IRQ0	P14/TIOCA1 /IRQ0	P14/TIOCA1 /IRQ0	P14/TIOCA1 /IRQ0	NC
39	42	P15/TIOCB1/ TCLKC	P15/TIOCB1/ TCLKC	P15/TIOCB1/ TCLKC	P15/TIOCB1/ TCLKC	NC
40	43	P16/TIOCA2 /IRQ1	P16/TIOCA2 /IRQ1	P16/TIOCA2 /IRQ1	P16/TIOCA2 /IRQ1	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	PROM Mode
41	44	P17/TIOCB2/ TCLKD	P17/TIOCB2/ TCLKD	P17/TIOCB2/ TCLKD	P17/TIOCB2/ TCLKD	NC
42	45	AVSS	AVSS	AVSS	AVSS	VSS
43	46	P97/DA1	P97/DA1	P97/DA1	P97/DA1	NC
44	47	P96/DA0	P96/DA0	P96/DA0	P96/DA0	NC
45	48	P47/AN7	P47/AN7	P47/AN7	P47/AN7	NC
46	49	P46/AN6	P46/AN6	P46/AN6	P46/AN6	NC
47	50	P45/AN5	P45/AN5	P45/AN5	P45/AN5	NC
48	51	P44/AN4	P44/AN4	P44/AN4	P44/AN4	NC
49	52	P43/AN3	P43/AN3	P43/AN3	P43/AN3	NC
50	53	P42/AN2	P42/AN2	P42/AN2	P42/AN2	NC
51	54	P41/AN1	P41/AN1	P41/AN1	P41/AN1	NC
52	55	P40/AN0	P40/AN0	P40/AN0	P40/AN0	NC
53	56	Vref	Vref	Vref	Vref	VCC
54	57	AVCC	AVCC	AVCC	AVCC	VCC
55	58	MD0	MD0	MD0	MD0	VSS
56	59	MD1	MD1	MD1	MD1	VSS
57	60	OSC2	OSC2	OSC2	OSC2	NC
58	61	OSC1	OSC1	OSC1	OSC1	NC
59	62	RES	RES	RES	RES	VPP
60	63	NMI	NMI	NMI	NMI	A9
61	64	STBY	STBY	STBY	STBY	VSS
62	65	VCC	VCC	VCC	VCC	VCC
63	66	XTAL	XTAL	XTAL	XTAL	NC
64	67	VSS	VSS	VSS	VSS	VSS
65	68	EXTAL	EXTAL	EXTAL	EXTAL	NC
66	69	FWE	FWE	FWE	FWE	NC
67	70	MD2	MD2	MD2	MD2	VSS
68	71	PF7/ϕ	PF7/ϕ	PF7/ϕ	PF7/ϕ	NC
69	72	AS	AS	AS	PF6	NC
70	73	RD	RD	RD	PF5	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	PROM Mode
71	74	HWR	HWR	HWR	PF4	NC
72	75	PF3/LWR/ ADTRG/ IRQ3	PF3/LWR/ ADTRG/ IRQ3	PF3/LWR/ ADTRG/ IRQ3	PF3/ADTRG /IRQ3	NC
73	76	PF2/WAIT	PF2/WAIT	PF2/WAIT	PF2	CE
74	77	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BUZZ	PGM
75	78	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/IRQ2	NC
76	79	P30/TxD0	P30/TxD0	P30/TxD0	P30/TxD0	NC
77	80	P31/RxD0	P31/RxD0	P31/RxD0	P31/RxD0	NC
78	81	P32/SCK0/ IRQ4	P32/SCK0/ IRQ4	P32/SCK0/ IRQ4	P32/SCK0/ IRQ4	NC
79	82	P33/TxD1	P33/TxD1	P33/TxD1	P33/TxD1	NC
80	83	P34/RxD1	P34/RxD1	P34/RxD1	P34/RxD1	NC
81	84	P35/SCK1/ IRQ5	P35/SCK1/ IRQ5	P35/SCK1/ IRQ5	P35/SCK1/ IRQ5	NC
82	85	P36	P36	P36	P36	NC
83	86	P77/TxD3	P77/TxD3	P77/TxD3	P77/TxD3	NC
84	87	P76/RxD3	P76/RxD3	P76/RxD3	P76/RxD3	NC
85	88	P75/SCK3	P75/SCK3	P75/SCK3	P75/SCK3	NC
86	89	P74/MRES	P74/MRES	P74/MRES	P74/MRES	NC
87	90	P73/TMO1/ CS7	P73/TMO1/ CS7	P73/TMO1/ CS7	P73/TMO1	NC
88	91	P72/TMO0/ CS6	P72/TMO0/ CS6	P72/TMO0/ CS6	P72/TMO0	NC
89	92	P71/CS5	P71/CS5	P71/CS5	P71	NC
90	93	P70/ TMRI01/ TMCI01/ CS4	P70/ TMRI01/ TMCI01/ CS4	P70/ TMRI01/ TMCI01/ CS4	P70/ TMRI01/ TMCI01	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	**FP-100A**	**Mode 4**	**Mode 5**	**Mode 6**	**Mode 7**	**PROM Mode**
91	94	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	NC
92	95	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/IRQ7	NC
93	96	PG2/CS2	PG2/CS2	PG2/CS2	PG2	NC
94	97	PG3/CS1	PG3/CS1	PG3/CS1	PG3	NC
95	98	PG4/CS0	PG4/CS0	PG4/CS0	PG4	NC
96	99	PE0/D0	PE0/D0	PE0/D0	PE0	NC
97	100	PE1/D1	PE1/D1	PE1/D1	PE1	NC
98	1	PE2/D2	PE2/D2	PE2/D2	PE2	NC
99	2	PE3/D3	PE3/D3	PE3/D3	PE3	NC
100	3	PE4/D4	PE4/D4	PE4/D4	PE4	NC

Table 1.4 Pin Arrangements in Each Mode of H8S/2227 Series

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
1	4	PE5/D5	PE5/D5	PE5/D5	PE5	OE
2	5	PE6/D6	PE6/D6	PE6/D6	PE6	WE
3	6	PE7/D7	PE7/D7	PE7/D7	PE7	CE
4	7	D8	D8	D8	PD0	D0
5	8	D9	D9	D9	PD1	D1
6	9	D10	D10	D10	PD2	D2
7	10	D11	D11	D11	PD3	D3
8	11	D12	D12	D12	PD4	D4
9	12	D13	D13	D13	PD5	D5
10	13	D14	D14	D14	PD6	D6
11	14	D15	D15	D15	PD7	D7
12	15	VCC	VCC	VCC	VCC	VCC
13	16	A0	A0	PC0/A0	PC0	A0
14	17	VSS	VSS	VSS	VSS	VSS
15	18	A1	A1	PC1/A1	PC1	A1
16	19	A2	A2	PC2/A2	PC2	A2
17	20	A3	A3	PC3/A3	PC3	A3
18	21	A4	A4	PC4/A4	PC4	A4
19	22	A5	A5	PC5/A5	PC5	A5
20	23	A6	A6	PC6/A6	PC6	A6
21	24	A7	A7	PC7/A7	PC7	A7
22	25	PB0/A8	PB0/A8	PB0/A8	PB0	A8
23	26	PB1/A9	PB1/A9	PB1/A9	PB1	A9
24	27	PB2/A10	PB2/A10	PB2/A10	PB2	A10
25	28	PB3/A11	PB3/A11	PB3/A11	PB3	A11

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
26	29	PB4/A12	PB4/A12	PB4/A12	PB4	A12
27	30	PB5/A13	PB5/A13	PB5/A13	PB5	A13
28	31	PB6/A14	PB6/A14	PB6/A14	PB6	A14
29	32	PB7/A15	PB7/A15	PB7/A15	PB7	A15
30	33	PA0/A16	PA0/A16	PA0/A16	PA0	A16
31	34	PA1/A17	PA1/A17	PA1/A17	PA1	A17
32	35	PA2/A18	PA2/A18	PA2/A18	PA2	A18
33	36	PA3/A19	PA3/A19	PA3/A19	PA3	NC
34	37	P10/ TIOCA0/ A20	P10/ TIOCA0/ A20	P10/ TIOCA0/ A20	P10/ TIOCA0	NC
35	38	P11/TIOCB 0/A21	P11/TIOCB 0/A21	P11/TIOCB 0/A21	P11/TIOCB 0	NC
36	39	P12/ TIOCC0/ TCLKA/A22	P12/ TIOCC0/ TCLKA/A22	P12/ TIOCC0/ TCLKA/A22	P12/ TIOCC0/ TCLKA	NC
37	40	P13/ TIOCD0/ TCLKB/A23	P13/ TIOCD0/ TCLKB/A23	P13/ TIOCD0/ TCLKB/A23	P13/ TIOCD0/TC LKB	NC
38	41	P14/TIOCA 1/IRQ0	P14/TIOCA 1/IRQ0	P14/TIOCA 1/IRQ0	P14/TIOCA 1/IRQ0	VSS
39	42	P15/ TIOCB1/ TCLKC	P15/ TIOCB1/ TCLKC	P15/ TIOCB1/TC LKC	P15/ TIOCB1/ TCLKC	NC
40	43	P16/TIOCA 2/IRQ1	P16/TIOCA 2/IRQ1	P16/TIOCA 2/IRQ1	P16/TIOCA 2/IRQ1	VSS
41	44	P17/ TIOCB2/ TCLKD	P17/ TIOCB2/ TCLKD	P17/ TIOCB2/TC LKD	P17/ TIOCB2/ TCLKD	NC
42	45	AVSS	AVSS	AVSS	AVSS	VSS
43	46	P97	P97	P97	P97	NC
44	47	P96	P96	P96	P96	NC
45	48	P47/AN7	P47/AN7	P47/AN7	P47/AN7	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
46	49	P46/AN6	P46/AN6	P46/AN6	P46/AN6	NC
47	50	P45/AN5	P45/AN5	P45/AN5	P45/AN5	NC
48	51	P44/AN4	P44/AN4	P44/AN4	P44/AN4	NC
49	52	P43/AN3	P43/AN3	P43/AN3	P43/AN3	NC
50	53	P42/AN2	P42/AN2	P42/AN2	P42/AN2	NC
51	54	P41/AN1	P41/AN1	P41/AN1	P41/AN1	NC
52	55	P40/AN0	P40/AN0	P40/AN0	P40/AN0	NC
53	56	Vref	Vref	Vref	Vref	VCC
54	57	AVCC	AVCC	AVCC	AVCC	VCC
55	58	MD0	MD0	MD0	MD0	VSS
56	59	MD1	MD1	MD1	MD1	VSS
57	60	OSC2	OSC2	OSC2	OSC2	NC
58	61	OSC1	OSC1	OSC1	OSC1	VCC
59	62	RES	RES	RES	RES	RES
60	63	NMI	NMI	NMI	NMI	VCC
61	64	STBY	STBY	STBY	STBY	VCC
62	65	VCC	VCC	VCC	VCC	VCC
63	66	XTAL	XTAL	XTAL	XTAL	XTAL
64	67	VSS	VSS	VSS	VSS	VSS
65	68	EXTAL	EXTAL	EXTAL	EXTAL	EXTAL
66	69	FWE	FWE	FWE	FWE	FWE
67	70	MD2	MD2	MD2	MD2	VSS
68	71	PF7/ϕ	PF7/ϕ	PF7/ϕ	PF7/ϕ	NC
69	72	AS	AS	AS	PF6	NC
70	73	RD	RD	RD	PF5	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
71	74	HWR	HWR	HWR	PF4	NC
72	75	PF3/LWR/ ADTRG/ IRQ3	PF3/LWR/ ADTRG/ IRQ3	PF3/LWR/ ADTRG/ IRQ3	PF3/ADTR G/ IRQ3	VCC
73	76	PF2/WAIT	PF2/WAIT	PF2/WAIT	PF2	NC
74	77	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BACK/ BUZZ	PF1/BUZZ	NC
75	78	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/BREQ/ IRQ2	PF0/IRQ2	VCC
76	79	P30/TxD0	P30/TxD0	P30/TxD0	P30/TxD0	NC
77	80	P31/RxD0	P31/RxD0	P31/RxD0	P31/RxD0	NC
78	81	P32/SCK0/ IRQ4	P32/SCK0/ IRQ4	P32/SCK0/ IRQ4	P32/SCK0/ IRQ4	NC
79	82	P33/TxD1	P33/TxD1	P33/TxD1	P33/TxD1	NC
80	83	P34/RxD1	P34/RxD1	P34/RxD1	P34/RxD1	NC
81	84	P35/SCK1/ IRQ5	P35/SCK1/ IRQ5	P35/SCK1/ IRQ5	P35/SCK1/ IRQ5	NC
82	85	P36	P36	P36	P36	NC
83	86	P77/TxD3	P77/TxD3	P77/TxD3	P77/TxD3	NC
84	87	P76/RxD3	P76/RxD3	P76/RxD3	P76/RxD3	NC
85	88	P75/SCK3	P75/SCK3	P75/SCK3	P75/SCK3	NC
86	89	P74/MRES	P74/MRES	P74/MRES	P74/MRES	NC
87	90	P73/TMO1/ CS7	P73/TMO1/ CS7	P73/TMO1/ CS7	P73/TMO1	NC
88	91	P72/TMO0/ CS6	P72/TMO0/ CS6	P72/TMO0/ CS6	P72/TMO0	NC
89	92	P71/CS5	P71/CS5	P71/CS5	P71	NC
90	93	P70/ TMRI01/ TMCI01/ CS4	P70/ TMRI01/ TMCI01/ CS4	P70/ TMRI01/ TMCI01/ CS4	P70/ TMRI01/ TMCI01	NC

Pin No.		Pin Name				
TFP-100B TFP-100G FP-100B	FP-100A	Mode 4	Mode 5	Mode 6	Mode 7	Flash Memory Programmable Mode
91	94	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	PG0/IRQ6	NC
92	95	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/CS3/ IRQ7	PG1/IRQ7	NC
93	96	PG2/CS2	PG2/CS2	PG2/CS2	PG2	NC
94	97	PG3/CS1	PG3/CS1	PG3/CS1	PG3	NC
95	98	PG4/CS0	PG4/CS0	PG4/CS0	PG4	NC
96	99	PE0/D0	PE0/D0	PE0/D0	PE0	NC
97	100	PE1/D1	PE1/D1	PE1/D1	PE1	NC
98	1	PE2/D2	PE2/D2	PE2/D2	PE2	NC
99	2	PE3/D3	PE3/D3	PE3/D3	PE3	VCC
100	3	PE4/D4	PE4/D4	PE4/D4	PE4	VSS

1.3.3 Pin Functions

Table 1.5 lists the pin functions of the H8S/2239 Series and H8S/2238R Series. Table 1.6 lists the pin functions of the H8S/2237 Series and H8S/2227 Series.

Table 1.5 Pin Functions of H8S/2239 Series and H8S/2238R Series

		Pin No.			
		TFP-100B TFP-100G			
Type	Symbol	FP-100B	BP-112*[1]	I/O	Function
Power supply	VCC	62	F9, G10	Input	For connection to the power supply. Connect all VCC pins to the system power supply.
	CVCC	12	E2, F3	Input	Connect to the system power supply.
	VSS	14 64	F2, F3 F8, F10	Input	For connection to the power supply (0 V). Connect all VSS pins to the system power supply (0 V).
Clock	XTAL	63	F11	Input	For connection to a crystal resonator. For examples of crystal resonator connection and external clock input, see section 22, Clock Pulse Generator.
	EXTAL	65	E11	Input	For connection to a crystal resonator. This pin can be also used for external clock input. For examples of crystal resonator connection and external clock input, see section 22, Clock Pulse Generator.
	OSC1	58	H11	Input	Connects to a 32.768 kHz crystal resonator. See section 22, Clock Pulse Generator, for typical connection diagrams for a crystal resonator.
	OSC2	57	H10	Input	Connects to a 32.768 kHz crystal resonator. See section 22, Clock Pulse Generator, for typical connection diagrams for a crystal resonator.
	ϕ	68	D11	Output	Supplies the system clock to external devices.
Operating mode control	MD2 MD1 MD0	67 56 55	E9 H9 J11	Input	Sets the operating mode. Inputs at these pins should not be changed during operation. Except for mode changing, be sure to fix the levels of the mode pins (MD2 to MD0) by pulling them down or pulling them up until the power turns off.

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-112*[1]	I/O	Function
System control	RES	59	G8	Input	Reset input pin. When this pin is low, the chip enters the power-on reset state.
	MRES	86	B7	Input	When this pin is low, the chip enters the manual reset state.
	STBY	61	G11	Input	When this pin is low, a transition is made to hardware standby mode.
	BREQ	75	C9	Input	Used by an external bus master to request the bus mastership to this LSI.
	BACK	74	B11	Output	Indicates that the bus mastership has been granted to an external bus master.
	FWE	66	E10	Input	Enables/disables programming the flash memory.
Interrupts	NMI	60	G9	Input	Nonmaskable interrupt pin. If this pin is not used, it should be fixed high.
	IRQ7 IRQ6 IRQ5 IRQ4 IRQ3 IRQ2 IRQ1 IRQ0	92 91 81 78 72 75 40 38	B5 A5 B8 B9 D9 C9 K6 J6	Input	These pins request a maskable interrupt.
Address bus	A23 to A0	37 to 15, 13	K5, L5, J5, H5, L4, K4, J4, L3, K3, H4, L2, K2, J3, K1, J2, H3, J1, H2, G4, H1, G3, G2, G1, F1	Output	Outputs Address.
Data bus	D15 to D0	11 to 1 100 to 96	E1, E3, E4, D1, D2, D3, C1, C2, D4, B1, B2, A2, B3, C4, A3, B4	Input/output	Used as the bidirectional data bus.

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-112*[1]	I/O	Function
Bus control	CS7 CS6	87	C6	Output	Select signals for areas 7 to 0.
	CS5 CS4	88	A6		
	CS3 CS2	89	B6		
	CS1 CS0	90	D6		
		92	B5		
		93	C5		
		94	A4		
		95	D5		
	AS	69	E8	Output	When this pin is low, it indicates valid address output on the address bus.
	RD	70	D10	Output	When this pin is low, it indicates that the external address space is being read.
	HWR	71	C11	Output	Strobe signal: Writes to the external address bus to indicate valid data on the upper data bus (D15 to D8).
	LWR	72	D9	Output	Strobe signal: Writes to the external bus to indicate valid data on the lower data bus (D7 to D0)
	WAIT	73	C10	Input	Requests insertion of wait states in bus cycle when accesses to the external three-state address.
DMA controller (DMAC)*[2]	DREQ1	89	—	Input	Request DMAC activation. (Supported only by the H8S/2239 Series.)
	DREQ0	90			
	TEND1	87	—	Output	Indicate that the DMAC has ended transmitting data. (Supported only by the H8S/2239 Series.)
	TEND0	88			
	DACK1	35	—	Output	These pins function as single address transmitting acknowledge of DMAC. (Supported only by the H8S/2239 Series.)
	DACK0	34			

		Pin No.			
		TFP-100B TFP-100G			
Type	**Symbol**	**FP-100B**	**BP-112*[1]**	**I/O**	**Function**
16-bit timer-pulse unit (TPU)	TCLKD	41	H6	Input	These pins input an external clock.
	TCLKC	39	L6		
	TCLKB	37	K5		
	TCLKA	36	L5		
	TIOCA0	34	H5	Input/ Output	Pins for the TGRA_0 to TGRD_0 input capture input, output compare output, or PWM output.
	TIOCB0	35	J5		
	TIOCC0	36	L5		
	TIOCD0	37	K5		
	TIOCA1	38	J6	Input/ Output	Pins for the TGRA_1 and TGRB_1 input capture input, output compare output, or PWM output.
	TIOCB1	39	L6		
	TIOCA2	40	K6	Input/ Output	Pins for the TGRA_2 and TGRB_2 input capture input, output compare output, or PWM output.
	TIOCB2	41	H6		
	TIOCA3	22	H3	Input/ Output	Pins for the TGRA_3 to TGRD_3 input capture input, output compare output, or PWM output.
	TIOCB3	23	J2		
	TIOCC3	24	K1		
	TIOCD3	25	J3		
	TIOCA4	26	K2	Input/ Output	Pins for the TGRA_4 and TGRB_4 input capture input, output compare output, or PWM output.
	TIOCB4	27	L2		
	TIOCA5	28	H4	Input/ Output	Pins for the TGRA_5 and TGRB_5 input capture input, output compare output, or PWM output.
	TIOCB5	29	K3		
8-bit timer	TMO3 to TMO0	85 to 88	A7, B7, C6, A6,	Output	Compare-match output pins
	TMCI23	89	B6	Input	Pins for external clock input to the counter
	TMCI01	90	D6		
	TMRI23	89	B6	Input	Counter reset input pins.
	TMRI01	90	D6		
Watchdog timer (WDT)	BUZZ	74	B11	Output	This pin outputs the pulse that is divided by watchdog timer.

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-112*[1]	I/O	Function
Serial communication interface (SCI)	TxD3	83	D7	Output	Data output pins
	TxD2	31	J4		
	TxD1	79	A9		
	TxD0	76	A10		
smart card interface	RxD3	84	C7	Input	Data input pins
	RxD2	32	K4		
	RxD1	80	C8		
	RxD0	77	D8		
	SCK3	85	A7	Input/ Output	Clock input/output pins
	SCK2	33	L4		
	SCK1	81	B8		
	SCK0	78	B9		
I^2C bus interface (IIC) (optional)	SCL1	79	A9	Input/ Output	I^2C clock input/output pins. These pins drive bus. The output of SCL0 is NMOS open drain.
	SCL0	81	B8		
	SDA1	78	B9	Input/ Output	I^2C data input/output pins. These pins drive bus. The output of SDA0 is NMOS open drain.
	SDA0	80	C8		
A/D converter	AN7 to AN0	45 to 52	H7, K8, L9, J8, K9, L10, K10, K11	Input	Analog input pins for the A/D converter
	ADTRG	72	D9	Input	Pin for input of an external trigger to start A/D conversion
D/A converter	DA1	43	J7	Output	Analog output pins for the D/A converter.
	DA0	44	L8		
A/D converter, D/A converter	AVCC	54	J10	Input	Power supply pin for the A/D converter and D/A converter. If none of the A/D converter and D/A converter is used, connect this pin to the system power supply (+3 V).
	AVSS	42	K7, L7	Input	Ground pin for the A/D converter and D/A converter. Connect this pin to the system power supply (0 V).
	Vref	53	H8	Input	Reference voltage input pin for the A/D converter and D/A converter. If neither the A/D converter nor D/A converter is used, connect this pin to the system power supply (+3 V).

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-112*[1]	I/O	Function
I/O ports	P17 to P10	41 to 34	H6, K6, L6, J6, K5, L5, J5, H5	Input/ Output	8-bit I/O pins
	P36 to P30	82 to 76	A8, B8, C8, A9, B9, D8, A10	Input/ Output	7-bit I/O pins P34 and P35 output NMOS push/pull.
	P47 to P40	45 to 52	H7, K8, L9, J8, K9, L10, K10, K11	Input	8-bit input pins
	P77 to P70	83 to 90	D7, C7, A7, B7, C6, A6, B6, D6	Input/ Output	8-bit I/O pins
	P97 P96	43 44	J7 L8	Input	2-bit input pins
	PA3 to PA0	33 to 30	L4, K4, J4, L3	Input/ Output	4-bit I/O pins
	PB7 to PB0	29 to 22	K3, H4, L2, K2, J3, K1, J2, H3	Input/ Output	8-bit I/O pins
	PC7 to PC0	21 to 15, 13	J1, H2, G4, H1, G3, G2, G1, F1	Input/ Output	8-bit I/O pins
	PD7 to PD0	11 to 4	E1, E3, E4, D1, D2, D3, C1, C2	Input/ Output	8-bit I/O pins
	PE7 to PE0	3 to 1, 100 to 96	D4, B1, B2, A2, B3, C4, A3, B4	Input/ Output	8-bit I/O pins
	PF7 to PF0	68 to 75	D11, E8, D10, C11, D9, C10, B11, C9	Input/ Output	8-bit I/O pins
	PG4 to PG0	95 to 91	D5, A4, C5, B5, A5	Input / Output	5-bit I/O pins

Notes: 1. Supported only by the H8S/2238R Series.
2. Supported only by the H8S/2239 Series.

Table 1.6 Pin Functions of H8S/2237 Series and H8S/2227 Series

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-100A	I/O	Function
Power supply	VCC	12 62	15 65	Input	For connection to the power supply. Connect all VCC pins to the system power supply.
	VSS	14 64	17 67	Input	For connection to the power supply (0 V). Connect all VSS pins to the system power supply (0 V).
Clock	XTAL	63	66	Input	For connection to a crystal resonator. For examples of crystal resonator connection and external clock input, see section 22, Clock Pulse Generator.
	EXTAL	65	68	Input	For connection to a crystal resonator. This pin can be also used for external clock input. For examples of crystal resonator connection and external clock input, see section 22, Clock Pulse Generator.
	OSC1	58	61	Input	Connects to a 32.768 kHz crystal resonator. See section 22, Clock Pulse Generator, for typical connection diagrams for a crystal resonator.
	OSC2	57	60	Input	Connects to a 32.768 kHz crystal resonator. See section 22, Clock Pulse Generator, for typical connection diagrams for a crystal resonator.
	ϕ	68	71	Output	Supplies the system clock to external devices.
Operating mode control	MD2 MD1 MD0	67 56 55	70 59 58	Input	Sets the operating mode. Inputs at these pins should not be changed during operation. Except for mode changing, be sure to fix the levels of the mode pins (MD2 to MD0) by pulling them down or pulling them up until the power turns off.
System control	RES	59	62	Input	Reset input pin. When this pin is low, the chip enters in the power-on reset state.
	MRES	86	89	Input	When this pin is low, the chip enters in the manual reset state.
	STBY	61	64	Input	When this pin is low, a transition is made to hardware standby mode.
	BREQ	75	78	Input	Used by an external bus master to request the bus mastership to this LSI.
	BACK	74	77	Output	Indicates that the bus mastership has been granted to an external bus master.
	FWE	66	69	Input	Enables/disables programming the flash memory.

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-100A	I/O	Function
Interrupts	NMI	60	63	Input	Nonmaskable interrupt pin. If this pin is not used, it should be fixed-high.
	IRQ7	92	95	Input	These pins request a maskable interrupt.
	IRQ6	91	94		
	IRQ5	81	84		
	IRQ4	78	81		
	IRQ3	72	75		
	IRQ2	75	78		
	IRQ1	40	43		
	IRQ0	38	41		
Address bus	A23 to A0	37 to 15, 13	40 to 18, 16	Output	Outputs Address.
Data bus	D15 to D0	11 to 1 100 to 96	14 to 1, 100, 99	Input/output	Used as the bidirectional data bus.
Bus control	CS7 CS6 CS5 CS4 CS3 CS2 CS1 CS0	87 88 89 90 92 93 94 95	90 91 92 93 95 96 97 98	Output	Select signals for areas 7 to 0.
	AS	69	72	Output	When this pin is low, it indicates valid address output on the address bus.
	RD	70	73	Output	When this pin is low, it indicates that the external address space is being read.
	HWR	71	74	Output	Strobe signal: Writes to the external address bus to indicate valid data on the upper data bus (D15 to D8).
	LWR	72	75	Output	Strobe signal: Writes to the external bus to indicate valid data on the lower data bus (D7 to D0)
	WAIT	73	76	Input	Requests insertion of wait states in bus cycle when accesses to the external three state address.

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-100A	I/O	Function
16-bit timer-pulse unit (TPU)	TCLKD TCLKC TCLKB TCLKA	41 39 37 36	44 42 40 39	Input	These pins input an external clock.
	TIOCA0 TIOCB0 TIOCC0 TIOCD0	34 35 36 37	37 38 39 40	Input/ Output	Pins for the TGRA_0 to TGRD_0 input capture input, output compare output, or PWM output.
	TIOCA1 TIOCB1	38 39	41 42	Input/ Output	Pins for the TGRA_1 and TGRB_1 input capture input, output compare output, or PWM output.
	TIOCA2 TIOCB2	40 41	43 44	Input/ Output	Pins for the TGRA_2 and TGRB_2 input capture input, output compare output, or PWM output.
	TIOCA3 TIOCB3 TIOCC3 TIOCD3	22 23 24 25	25 26 27 28	Input/ Output	Pins for the TGRA_3 to TGRD_3 input capture input, output compare output, or PWM output. (Not available in the H8S/2227 Series.)
	TIOCA4 TIOCB4	26 27	29 30	Input/ Output	Pins for the TGRA_4 and TGRB_4 input capture input, output compare output, or PWM output. (Not available in the H8S/2227 Series.)
	TIOCA5 TIOCB5	28 29	31 32	Input/ Output	Pins for the TGRA_5 and TGRB_5 input capture input, output compare output, or PWM output. (Not available in the H8S/2227 Series.)
8-bit timer	TMO1 TMO0	87 88	90 91	Output	Compare-match output pins
	TMCI01	90	93	Input	Pin for external clock input to the counter
	TMRI01	90	93	Input	Counter reset input pin
Watchdog timer (WDT)	BUZZ	74	77	Output	This pin outputs the pulse that is divided by watchdog timer.
Serial communi-cation interface (SCI)	TxD3 TxD2 TxD1 TxD0	83 31 79 76	86 34 82 79	Output	Data output pins (TxD2 is not available in the H8S/2227 Series.)
smart card interface	RxD3 RxD2 RxD1 RxD0	84 32 80 77	87 35 83 80	Input	Data input pins (RxD2 is not available in the H8S/2227 Series.)
	SCK3 SCK2 SCK1 SCK0	85 33 81 78	88 36 84 81	Input/ Output	Clock input/output pins (SCK2 is not available in the H8S/2227 Series.)

Type	Symbol	Pin No. TFP-100B TFP-100G FP-100B	Pin No. BP-100A	I/O	Function
A/D converter	AN7 to AN0	45 to 52	48 to 55	Input	Analog input pins for the A/D converter
	ADTRG	72	75	Input	Pin for input of an external trigger to start A/D conversion
D/A converter	DA1 DA0	43 44	46 47	Output	Analog output pins for the D/A converter. (Not available in the H8S/2227 Series.)
A/D converter, D/A converter	AVCC	54	57	Input	Power supply pin for the A/D converter and D/A converter. If none of the A/D converter and D/A converter is used, connect this pin to the system power supply (+3 V).
	AVSS	42	45	Input	Ground pin for the A/D converter and D/A converter. Connect this pin to the system power supply (0 V).
	Vref	53	56	Input	Reference voltage input pin for the A/D converter and D/A converter. If neither the A/D converter nor D/A converter is used, connect this pin to the system power supply (+3 V).
I/O ports	P17 to P10	41 to 34	44 to 37	Input/ Output	8-bit I/O pins
	P36 to P30	82 to 76	85 to 79	Input/ Output	7-bit I/O pins
	P47 to P40	45 to 52	48 to 55	Input	8-bit input pins
	P77 to P70	83 to 90	86 to 93	Input/ Output	8-bit I/O pins
	P97 P96	43 44	46 47	Input	2-bit input pins
	PA3 to PA0	33 to 30	36 to 33	Input/ Output	4-bit I/O pins
	PB7 to PB0	29 to 22	32 to 25	Input/ Output	8-bit I/O pins
	PC7 to PC0	21 to 15, 13	24 to 18, 16	Input/ Output	8-bit I/O pins
	PD7 to PD0	11 to 4	14 to 7	Input/ Output	8-bit I/O pins

		Pin No.			
		TFP-100B TFP-100G			
Type	**Symbol**	**FP-100B**	**BP-100A**	**I/O**	**Function**
I/O ports	PE7 to PE0	3 to 1, 100 to 96	6 to 1, 100, 99	Input/ Output	8-bit I/O pins
	PF7 to PF0	68 to 75	71 to 78	Input/ Output	8-bit I/O pins
	PG4 to PG0	95 to 91	98 to 94	Input/ Output	5-bit I/O pins

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 ÷ 8-bit register-register divide : 12 states
  - 16 × 16-bit register-register multiply : 20 states
  - 32 ÷ 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;

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

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

2.1.2 Differences from H8/300 CPU

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

- More general registers and control registers
  - Eight 16-bit 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

In normal mode, the exception vector table and stack have the same structure as 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

  In normal 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 2.2. 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.

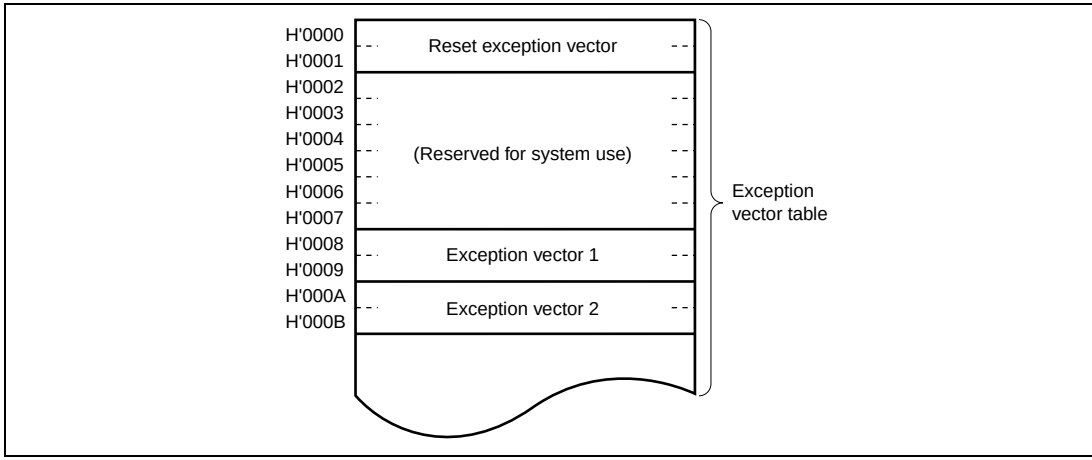


Figure 2.1 Exception Vector Table (Normal Mode)

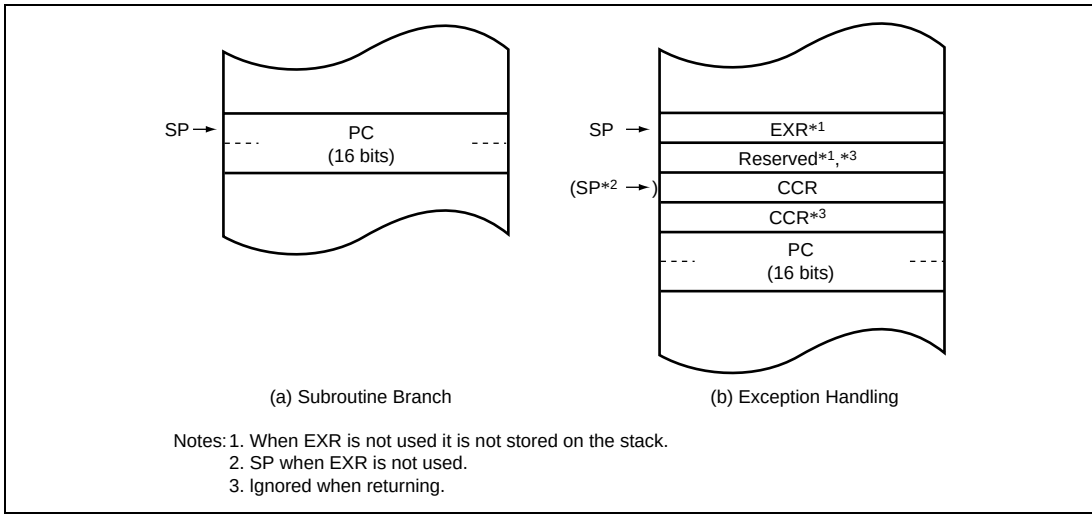


Figure 2.2 Stack Structure in Normal Mode

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.

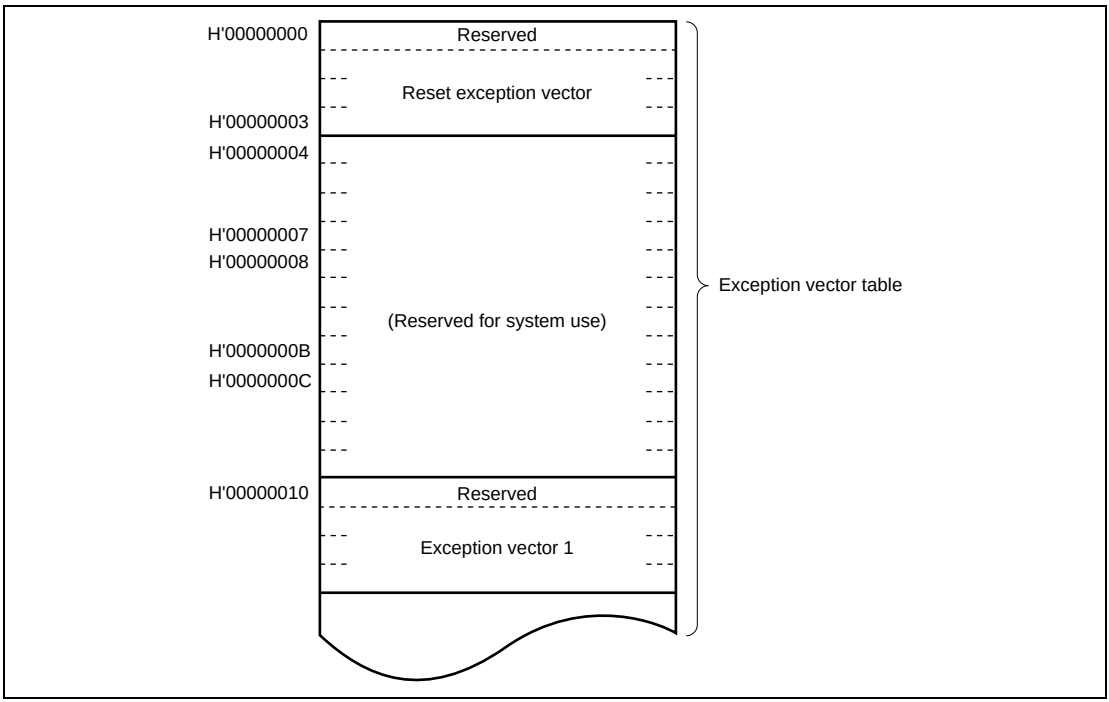
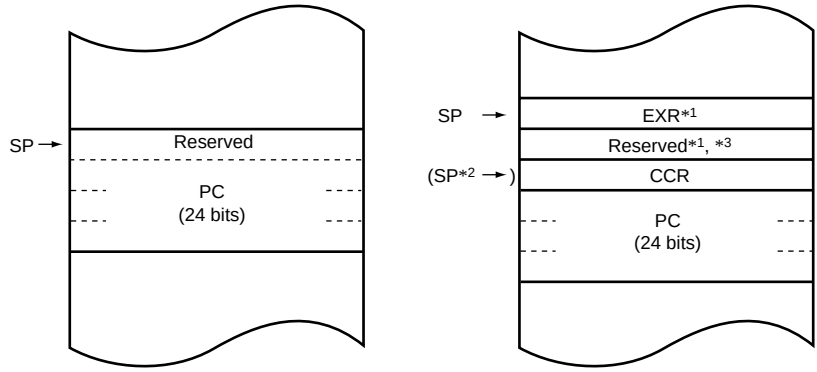


Figure 2.3 Exception Vector Table (Advanced Mode)

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.



(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.
3. Ignored when returning.

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.

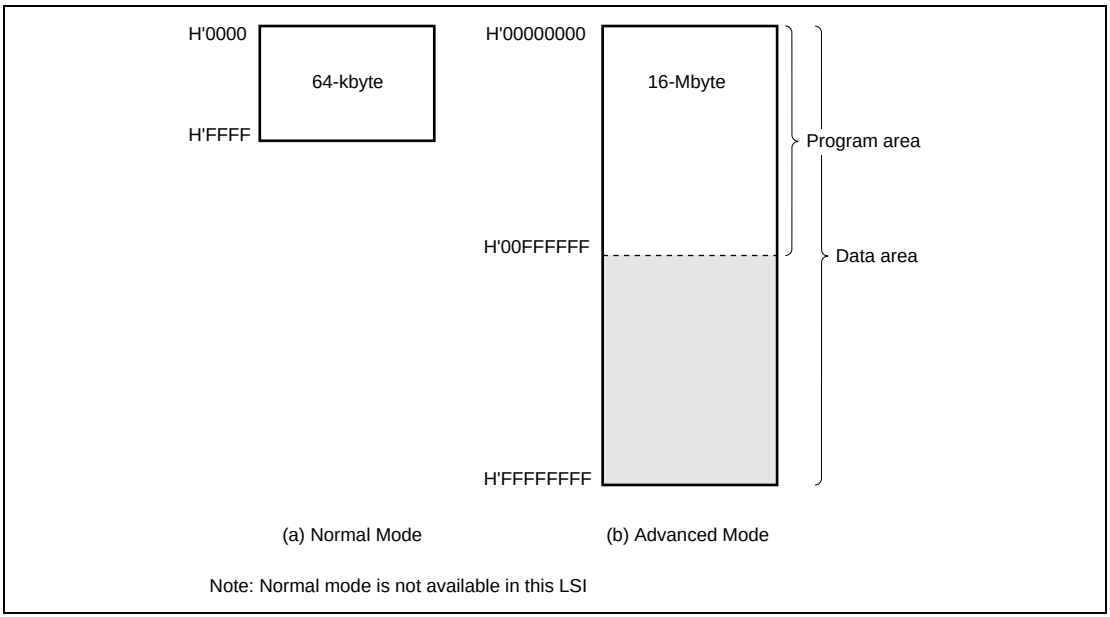


Figure 2.5 Memory Map

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).

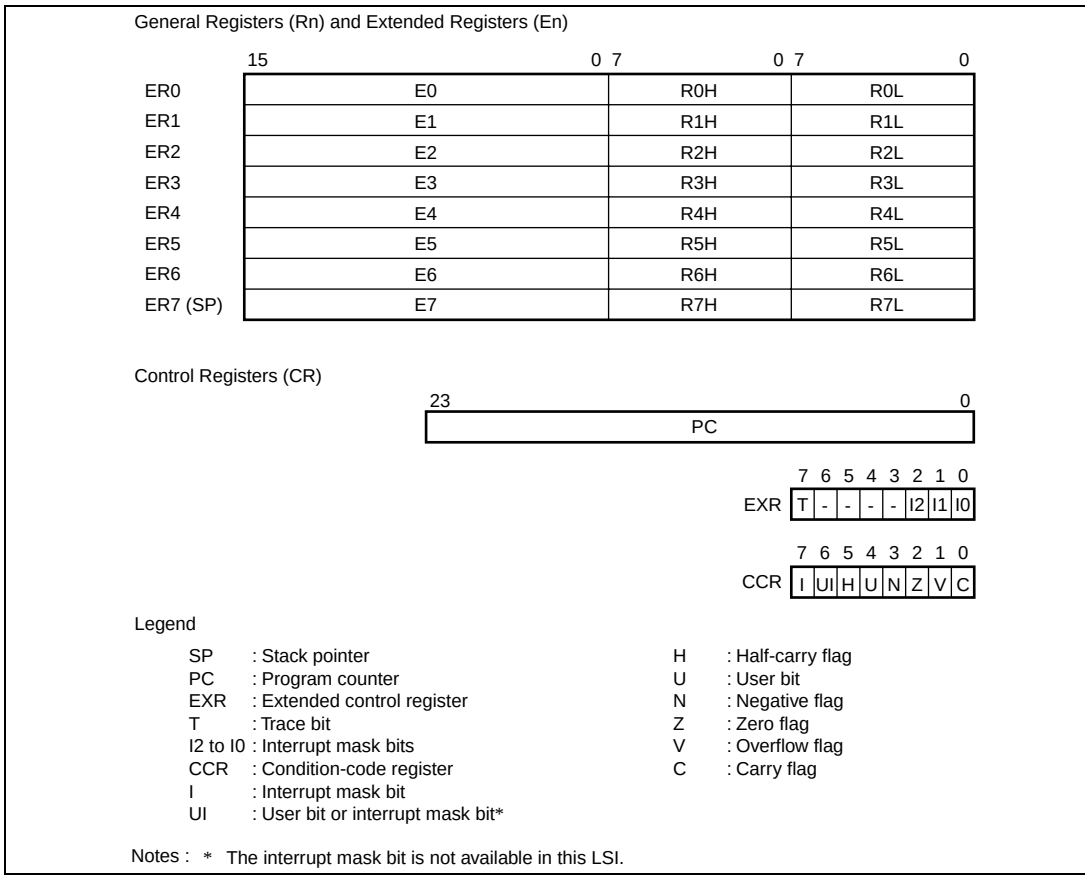


Figure 2.6 CPU Registers

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 2egisters.

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.

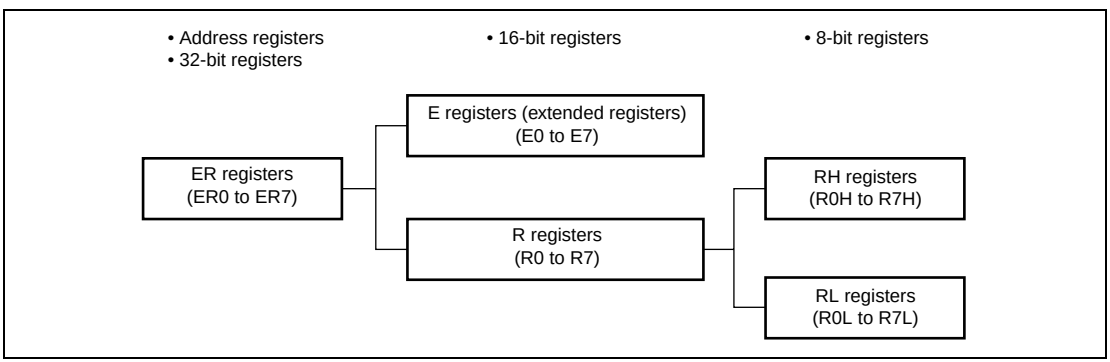


Figure 2.7 Usage of General Registers

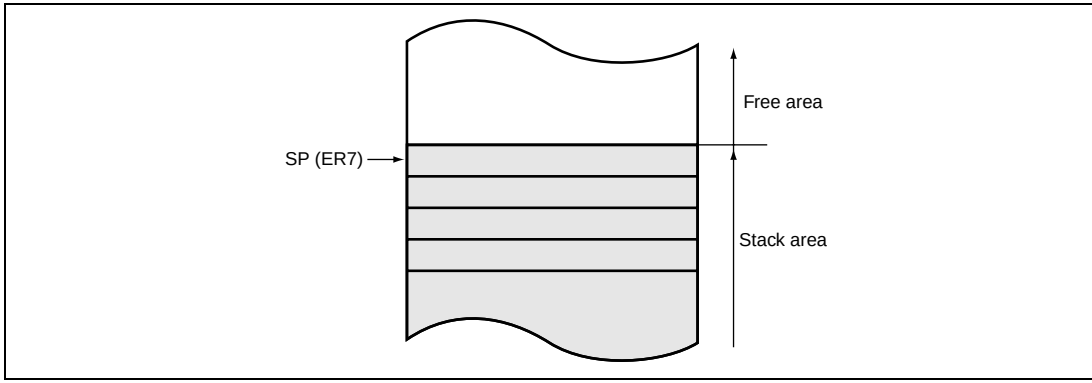


Figure 2.8 Stack Status

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)

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: • 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.

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.

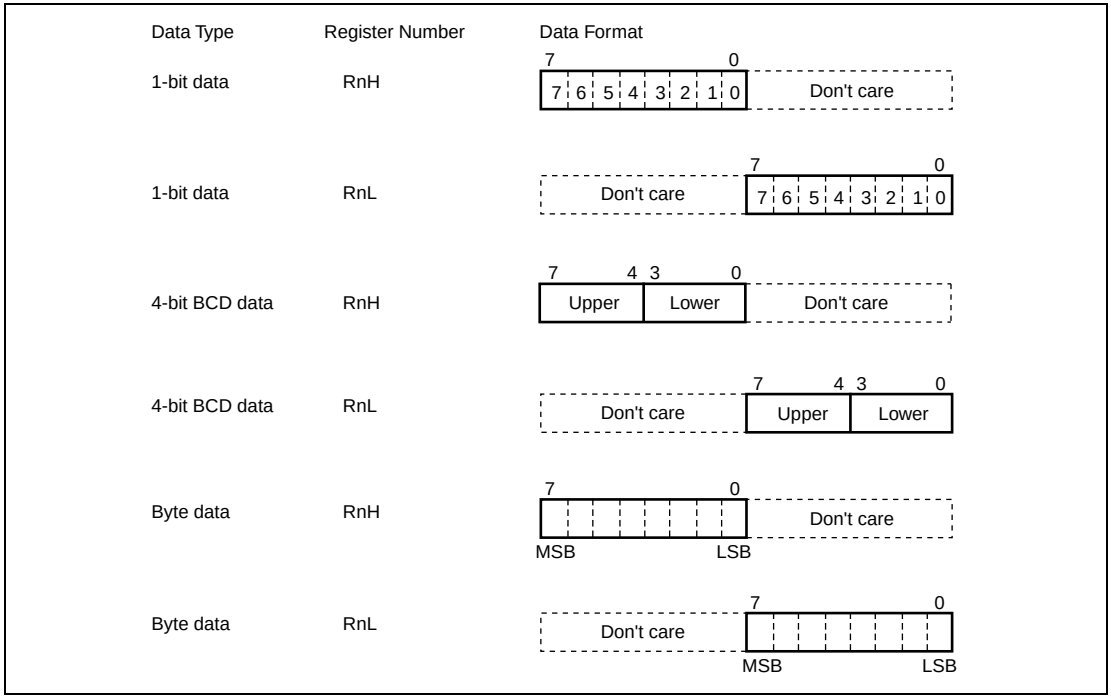


Figure 2.9 General Register Data Formats (1)

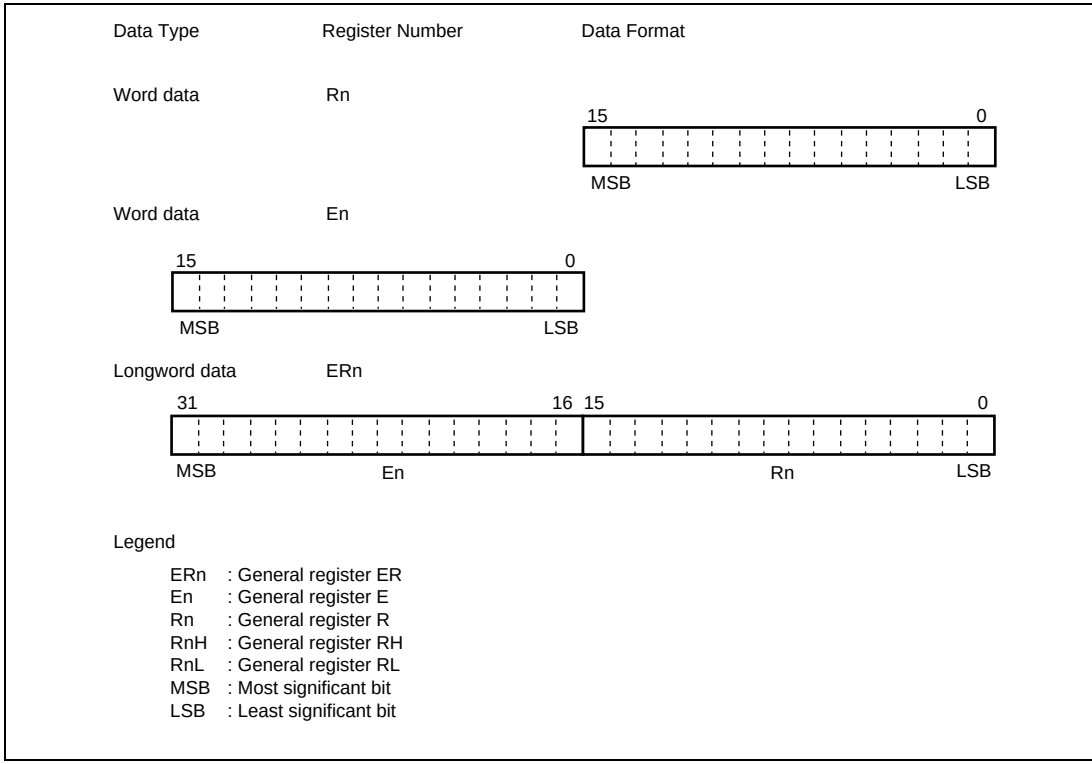


Figure 2.9 General Register Data Formats (2)

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.

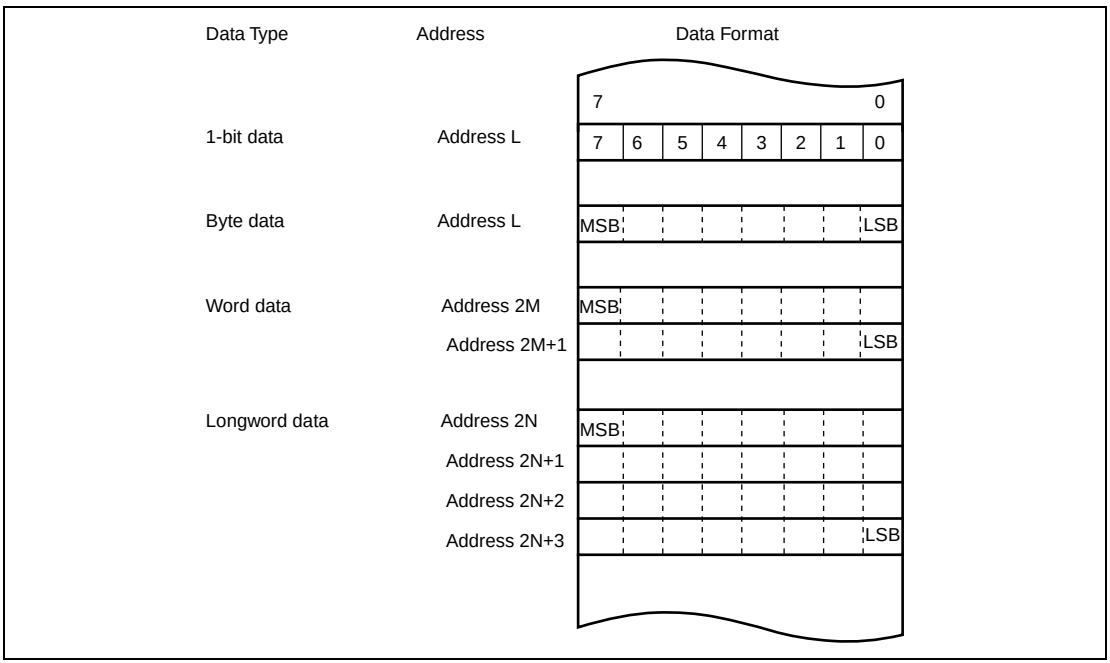


Figure 2.10 Memory Data Formats

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

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

Table 2.3 Data Transfer Instructions

Instruction	Size*	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 ± Rs → Rd, Rd ± #IMM → 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 ± Rs ± C → Rd, Rd ± #IMM ± C → 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 ± 1 → Rd, Rd ± 2 → 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 ± 1 → Rd, Rd ± 2 → Rd, Rd ± 4 → 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 → 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 × Rs → Rd Performs unsigned multiplication on data in two general registers: either 8 bits × 8 bits → 16 bits or 16 bits × 16 bits → 32 bits.
MULXS	B/W	Rd × Rs → Rd Performs signed multiplication on data in two general registers: either 8 bits × 8 bits → 16 bits or 16 bits × 16 bits → 32 bits.
DIVXU	B/W	Rd ÷ Rs → Rd Performs unsigned division on data in two general registers: either 16 bits ÷ 8 bits → 8-bit quotient and 8-bit remainder or 32 bits ÷ 16 bits → 16-bit quotient and 16-bit remainder.

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

Table 2.4 Arithmetic Operations Instructions (2)

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

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

Table 2.5 Logic Operations Instructions

Instruction	Size*	Function
AND	B/W/L	Rd ∧ Rs → Rd, Rd ∧ #IMM → Rd Performs a logical AND operation on a general register and another general register or immediate data.
OR	B/W/L	Rd ∨ Rs → Rd, Rd ∨ #IMM → Rd Performs a logical OR operation on a general register and another general register or immediate data.
XOR	B/W/L	Rd ⊕ Rs → Rd, Rd ⊕ #IMM → Rd Performs a logical exclusive OR operation on a general register and another general register or immediate data.
NOT	B/W/L	¬ (Rd) → (Rd) Takes the one's complement 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 (shift) → Rd Performs an arithmetic shift on general register contents. 1-bit or 2-bit shifts are possible.
SHLL SHLR	B/W/L	Rd (shift) → Rd Performs a logical shift on general register contents. 1-bit or 2-bit shifts are possible.
ROTL ROTR	B/W/L	Rd (rotate) → Rd Rotates general register contents. 1-bit or 2-bit rotations are possible.
ROTXL ROTXR	B/W/L	Rd (rotate) → 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 → (<bit-No.> of <EAd>) Sets a specified bit in a general register or memory operand to 1. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BCLR	B	0 → (<bit-No.> of <EAd>) Clears a specified bit in a general register or memory operand to 0. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BNOT	B	¬ (<bit-No.> of <EAd>) → (<bit-No.> of <EAd>) Inverts a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BTST	B	¬ (<bit-No.> of <EAd>) → Z Tests a specified bit in a general register or memory operand and sets or clears the Z flag accordingly. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BAND	B	C ∧ (<bit-No.> of <EAd>) → C ANDs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIAND	B	C ∧ ¬ (<bit-No.> of <EAd>) → C ANDs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.
BOR	B	C ∨ (<bit-No.> of <EAd>) → C ORs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIOR	B	C ∨ ¬ (<bit-No.> of <EAd>) → C 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 ⊕ (<bit-No.> of <EAd>) → 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 ⊕ ¬ (<bit-No.> of <EAd>) → 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	(<bit-No.> of <EAd>) → C Transfers a specified bit in a general register or memory operand to the carry flag.
BILD	B	¬ (<bit-No.> of <EAd>) → C Transfers the inverse of a specified bit in a general register or memory operand to the carry flag. The bit number is specified by 3-bit immediate data.
BST	B	C → (<bit-No.> of <EAd>) Transfers the carry flag value to a specified bit in a general register or memory operand.
BIST	B	¬ C → (<bit-No.> of <EAd>) Transfers the inverse of the carry flag value to a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data.

Note: * Refers to the operand size.
B: Byte

Table 2.8 Branch Instructions

Instruction	Size	Function
Bcc	—	Branches to a specified address if a specified condition is true. The branching conditions are listed below.

Mnemonic	Description	Condition
BRA(BT)	Always (true)	Always
BRN(BF)	Never (false)	Never
BHI	High	$C \vee Z = 0$
BLS	Low or same	$C \vee Z = 1$
BCC(BHS)	Carry clear (high or same)	$C = 0$
BCS(BLO)	Carry set (low)	$C = 1$
BNE	Not equal	$Z = 0$
BEQ	Equal	$Z = 1$
BVC	Overflow clear	$V = 0$
BVS	Overflow set	$V = 1$
BPL	Plus	$N = 0$
BMI	Minus	$N = 1$
BGE	Greater or equal	$N \oplus V = 0$
BLT	Less than	$N \oplus V = 1$
BGT	Greater than	$Z \vee (N \oplus V) = 0$
BLE	Less or equal	$Z \vee (N \oplus V) = 1$

JMP	—	Branches unconditionally to a specified address.
BSR	—	Branches to a subroutine at a specified address.
JSR	—	Branches to a subroutine at a specified address.
RTS	—	Returns from a subroutine

Table 2.9 System Control Instructions

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

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

Table 2.10 Block Data Transfer Instructions

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

2.6.2 Basic Instruction Formats

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.

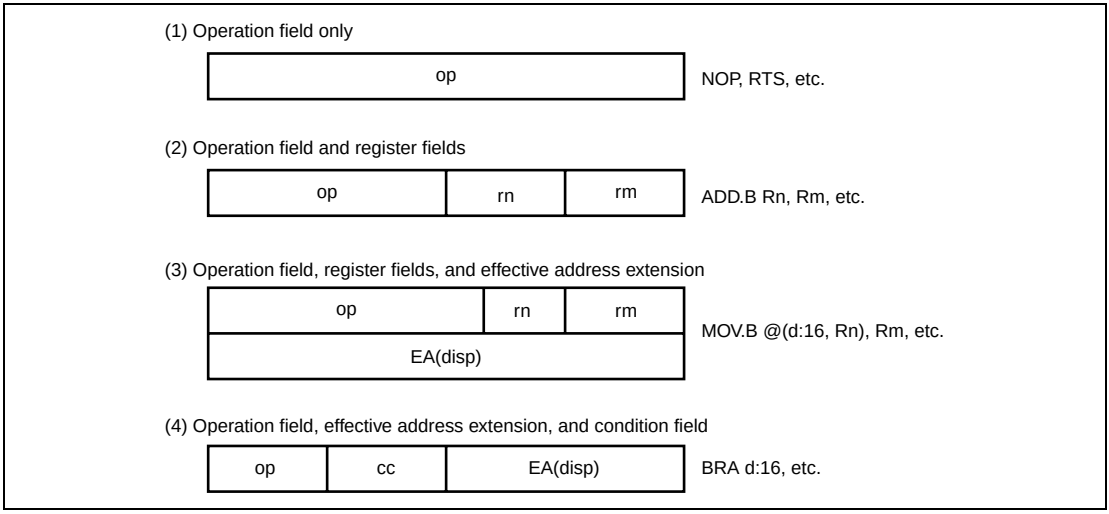


Figure 2.11 Instruction Formats (Examples)

2.7 Addressing Modes and Effective AddressCalculation

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—@ERn+ or Register Indirect with Pre-Decrement—@-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.

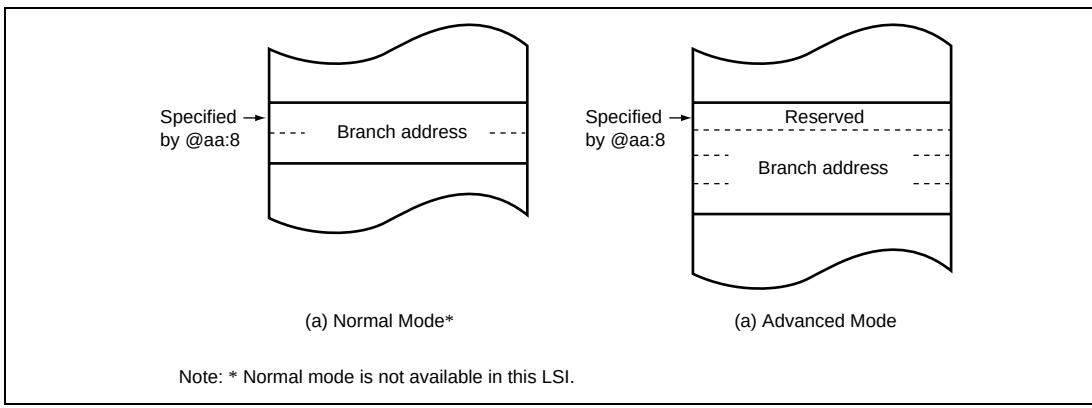


Figure 2.12 Branch Address Specification in Memory Indirect Mode

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)

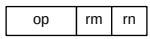
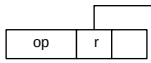
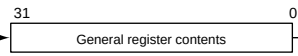
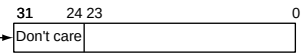
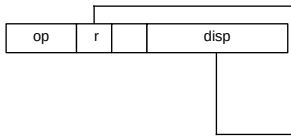
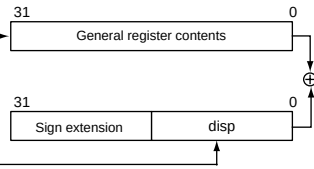
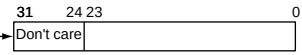
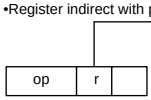
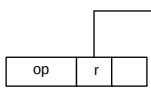
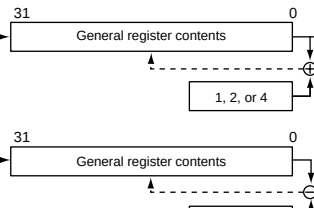
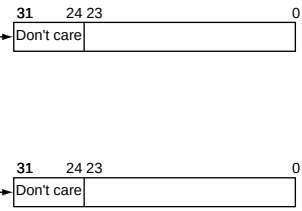
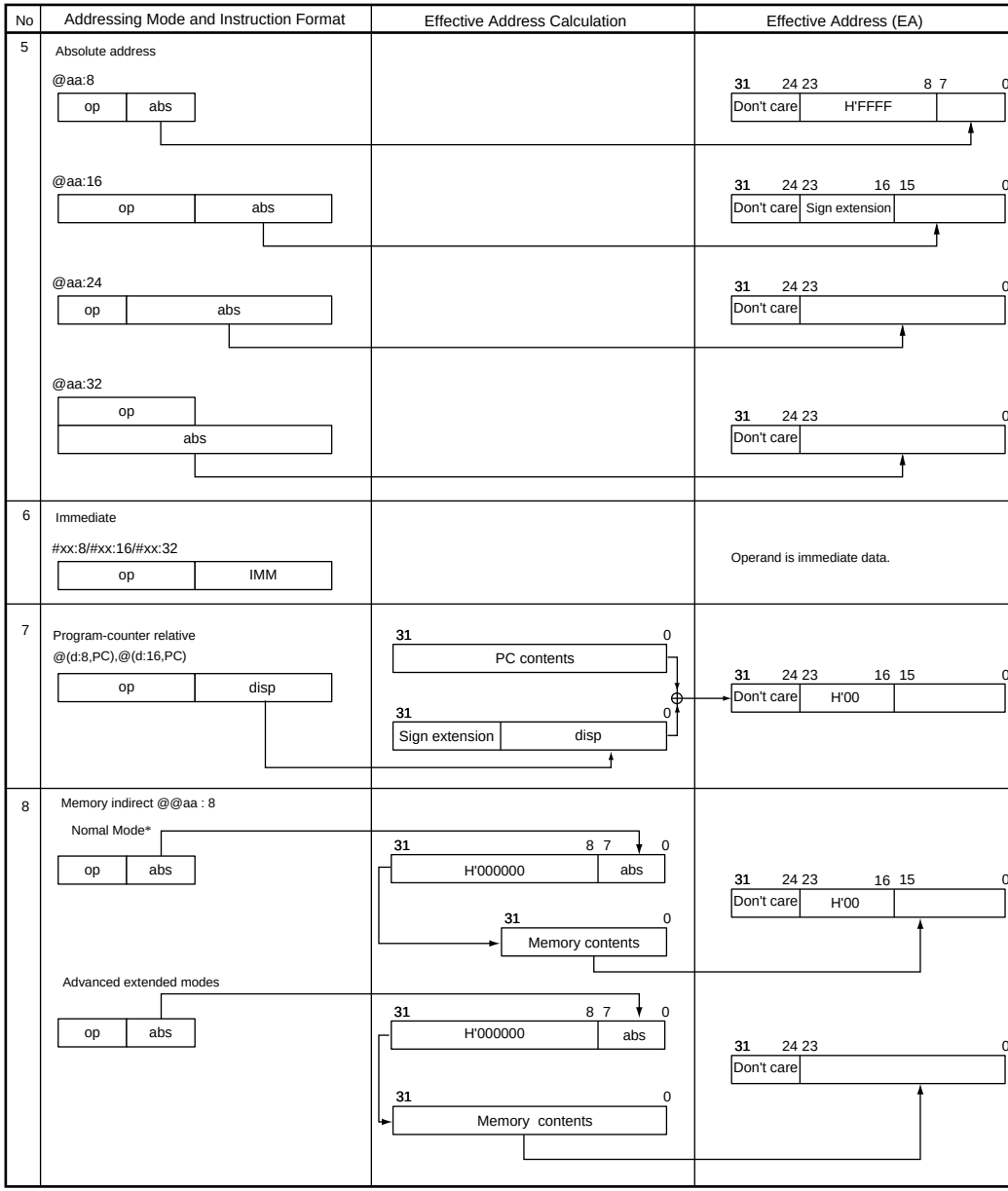
No	Addressing Mode and Instruction Format	Effective Address Calculation	Effective Address (EA)
1	Register direct(Rn) 		Operand is general register contents.
2	Register indirect(@ERn) 		
3	Register indirect with displacement @(d:16,ERn) or @(d:32,ERn) 		
4	Register indirect with post-increment or pre-decrement •Register indirect with post-increment @ERn+  •Register indirect with pre-decrement @-ERn 	 Operand Size / Offset Byte: 1 Word: 2 Longword: 4	

Table 2.13 Effective Address Calculation (2)



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 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 RES signal changes from low to high. For details, refer to section 4, Exception Handling.

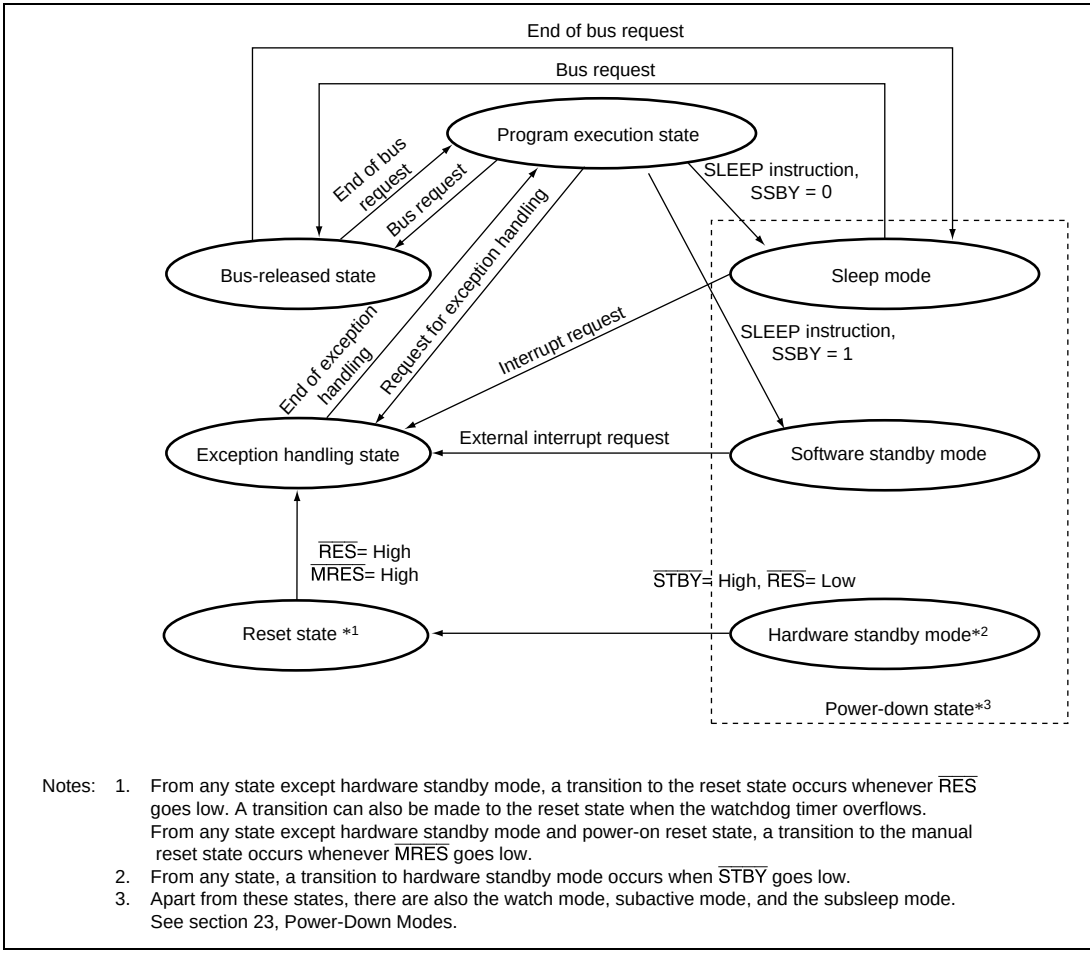
  The reset state can also be entered by a watchdog timer overflow.

- Exception-Handling State
  The exception-handling state is a transient state that occurs when the CPU alters the normal processing flow due to an exception source, such as a reset, trace, interrupt, or trap instruction. The CPU fetches a start address (vector) from the exception vector table and branches to that address. For further details, refer to section 4, Exception Handling.
- Program Execution State
  In this state, the CPU executes program instructions in sequence.
- Bus-Released State
  In a product which has a DMA controller (DMAC)* or 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 23, Power-Down Modes.

Note:* Supported only by the H8S/2239 Series.



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. From any state except hardware standby mode and power-on reset state, a transition to the manual reset state occurs whenever $\overline{MRES}$ goes low.
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 23, Power-Down Modes.

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 four operating modes (modes 4 to 7). These modes enable selection of the CPU operating mode, enabling/disabling of on-chip ROM, and the initial bus width setting, by setting the mode pins (MD2 to MD0) as show in table 3.1. Do not change the mode pin settings during operation.

Table 3.1 MCU Operating Mode Selection

MCU Operating Mode	MD2	MD1	MD0	CPU Operating Mode	Description	On-chip ROM	External Data Bus	
							Initial Value	Maximum Value
4	1	0	0	Advanced mode	On-chip ROM disabled, extended mode	Disabled	16 bits	16 bits
5	1	0	1	Advanced mode	On-chip ROM disabled, extended mode	Disabled	8 bits	16 bits
6	1	1	0	Advanced mode	On-chip ROM enabled, extended mode	Enabled	8 bits	16 bits
7*	1	1	1	Advanced mode	Single-chip mode	Enabled	–	–

3.2 Register Descriptions

The following registers are related to the operating mode.

- Mode control register (MDCR)
- System control register (SYSCR)

3.2.1 Mode Control Register (MDCR)

MDCR is used to monitor the current operating mode of this LSI.

Bit	Bit Name	Initial Value	R/W	Description
7	–	1	–	Reserved This bit is always read as 1 and cannot be modified.
6 to 3	–	0	–	Reserved These bits are always read as 0 and cannot be modified.
2	MDS2	–*	R	Mode Select 2 to 0 These bits indicate the input levels at pins MD2 to MD0 (the current operating mode).Bits MDS2 to MDS0 correspond to MD2 to MD0. MDS2 to MDS0 are read-only bits and they cannot be written to. The mode pin (MD2 to MD0) input levels are latched into these bits when MDCR is read. These latches are canceled by a power-on reset, but maintained at manual reset.
1	MDS1	–*	R	
0	MDS0	–*	R	

Note:* Determined by the MD2 to MD0 pin settings.

3.2.2 System Control Register (SYSCR)

SYSCR is used to select the interrupt control mode and the detected edge for NMI, select the MRES input pin enable or disable, and enables or disables on-chip RAM.

Bit	Bit Name	Initial Value	R/W	Description
7	–	0	R/W	Reserved The write value should always be 0.
6	–	0	–	Reserved These bits are always read as 0 and cannot be modified.
5	INTM1	0	R/W	These bits select the control mode of the interrupt controller. For details of the interrupt control modes, see section 5.5.1, Interrupt Control Modes and Interrupt Operation. 00: Interrupt control mode 0 (Interrupt is controlled by I bit.) 01: Setting prohibited 10: Interrupt control mode 2 (Interrupt is controlled by I2 to I0 bits and IPR.) 11: Setting prohibited
4	INTM0	0	R/W	
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	MRESE	0	R/W	Manual Reset Select Enables or disables the MRES pin input. 0: The MRES pin input (manual reset) is disabled 1: The MRES pin input (manual reset) is enabled The MRES input pin can be used.
1	–	0	–	Reserved These bits are always read as 0 and cannot be modified.
0	RAME	1	R/W	RAM Enable Enables or disables the on-chip RAM. The RAME bit is initialized when the reset status is released. 0: On-chip RAM is disabled 1: On-chip RAM is enabled

3.3 Operating Mode Descriptions

This LSI has four operating modes, mode 4 to mode 7.

Modes 4 to 6 are extended modes in which external memory and external peripheral devices can be accessed. In extended modes, each area can be used as 8-bit or 16-bit address space according to the bus controller settings after program execution. In this case, if an area is specified as 16-bit access space, 16-bit bus mode is employed for all areas; while if an area is specified as 8-bit access space, 8-bit bus mode is employed for all areas.

In mode 7, external addresses cannot be used.

3.3.1 Mode 4

The CPU can access a 16-Mbyte address space in advanced mode. The on-chip ROM is disabled.

Pins P13 to P10, and ports A, B, and C function as an address bus, ports D and E function as a data bus, and part of port F carries bus control signals.

Pins P13 to P11 function as input ports immediately after a reset. Pin 10 and ports A and B function as address (A20 to A8) outputs immediately after a reset. Address (A23 to A21) output can be enabled or disabled by bits AE3 to AE0 in the pin function control register (PFCR) regardless of the corresponding data direction register (DDR) values. Pins for which address output is disabled among pins P13 to P10 and in ports A and B become port outputs when the corresponding DDR bits are set to 1.

Port C always has an address (A7 to A0) output function.

The initial bus mode after a reset is 16 bits, with 16-bit access to all areas. However, note that if 8-bit access is designated by the bus controller for all areas, the bus mode switches to 8 bits.

3.3.2 Mode 5

The CPU can access a 16-Mbyte address space in advanced mode. The on-chip ROM is disabled.

Pins P13 to P10, and ports A, B, and C function as an address bus, ports D and E function as a data bus, and part of port F carries bus control signals.

Pins P13 to P11 function as input ports immediately after a reset. Pin 10 and ports A and B function as address (A20 to A8) outputs immediately after a reset. Address (A23 to A21) output can be enabled or disabled by bits AE3 to AE0 in the pin function control register (PFCR) regardless of the corresponding data direction register (DDR) values. Pins for which address output is disabled among pins P13 to P10 and in ports A and B become port outputs when the corresponding DDR bits are set to 1.

Port C always has an address (A7 to A0) output function.

The initial bus mode after a reset is 8 bits, with 8-bit access to all areas. However, note that if 16-bit access is designated by the bus controller for any area, the bus mode switches to 16 bits and port E becomes a data bus.

3.3.3 Mode 6

The CPU can access a 16-Mbyte address space in advanced mode. The on-chip ROM is enabled.

Pins P13 to P10, and ports A, B and C function as input ports immediately after a reset. Address (A23 to A8) output can be enabled or disabled by bits AE3 to AE0 in the pin function control register (PFCR) regardless of the corresponding data direction register (DDR) values. Pins for which address output is disabled among pins P13 to P10 and in ports A and B become port outputs when the corresponding DDR bits are set to 1.

Port C is an input port immediately after a reset. Addresses A7 to A0 are output by setting the corresponding DDR bits to 1.

Ports D and E function as a data bus, and part of port F carries data bus signals.

The initial bus mode after a reset is 8 bits, with 8-bit access to all areas. However, note that if 16-bit access is designated by the bus controller for any area, the bus mode switches to 16 bits and port E becomes a data bus.

3.3.4 Mode 7

The CPU can access a 16-Mbyte address space in advanced mode. The on-chip ROM is enabled, but external addresses cannot be accessed.

All I/O ports are available for use as input-output ports.

3.3.5 Pin Functions

The pin functions of ports 1, and A to F vary depending on the operating mode. Table 3.2 shows their functions in each operating mode.

Table 3.2 Pin Functions in Each Operating Mode

Port		Mode 4	Mode 5	Mode 6	Mode 7*[1]
Port 1	P13 to P11	P*/A	P*/A	P*/A	P
	P10	P/A*	P/A*	P*/A	P
Port A	PA3 to PA0	P/A*	P/A*	P*/A	P
Port B		P/A*	P/A*	P*/A	P
Port C		A	A	P*/A	P
Port D		D	D	D	P
Port E		P/D*	P*/D	P*/D	P
Port F	PF7	P/C*	P/C*	P/C*	P*/C
	PF6 to PF4	C	C	C	P
	PF3	P/C*	P*/C	P*/C	
	PF2 to PF0	P*/C	P*/C	P*/C	

Legend

P: I/O port
A: Address bus output
D: Data bus I/O
C: Control signals, clock I/O
*: After reset

3.4 Memory Map in Each Operating Mode

Figures 3.1 to 3.7 show the memory map in each operating mode.

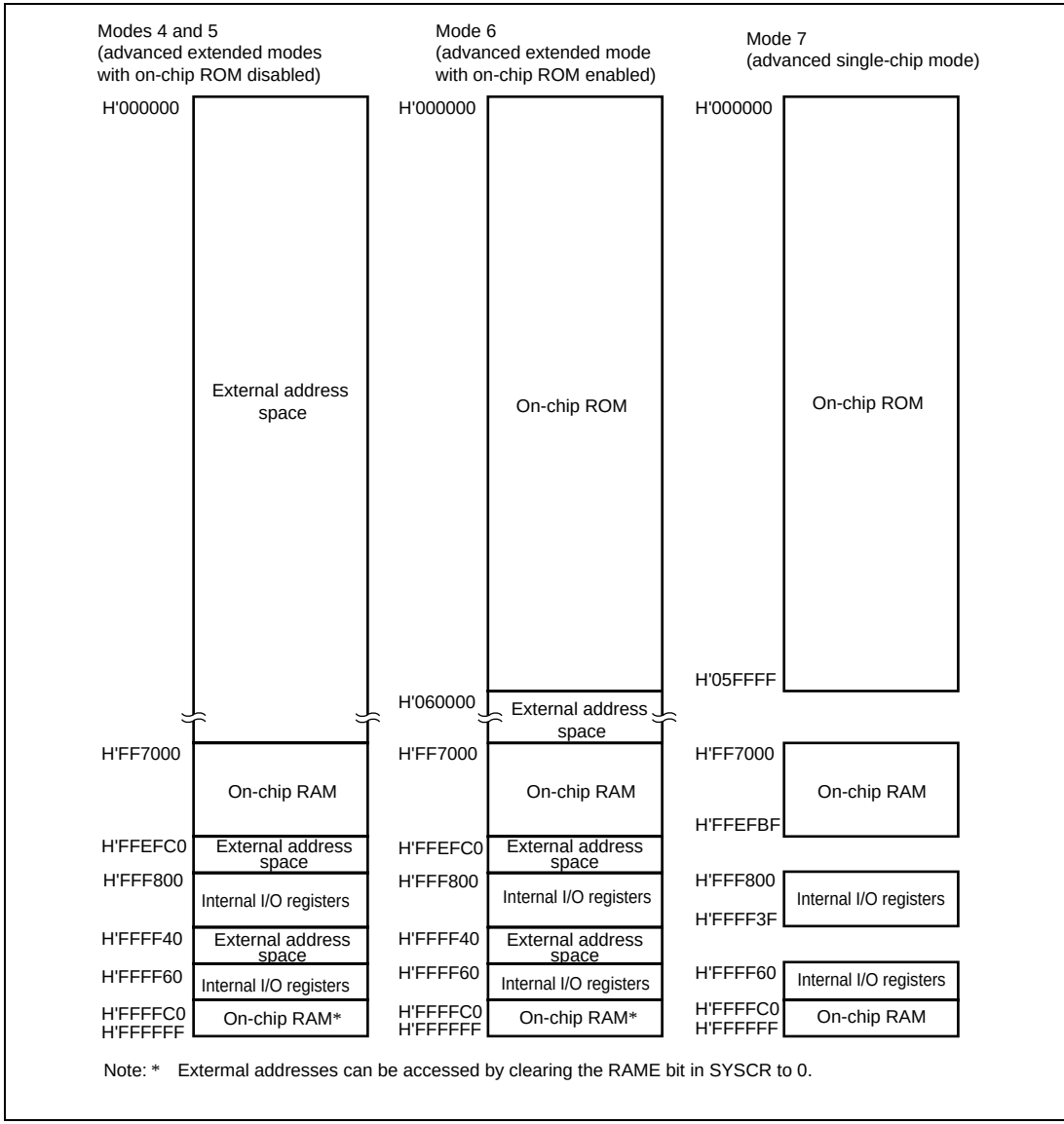


Figure 3.1 H8S/2239 Memory Map in Each Operating Mode

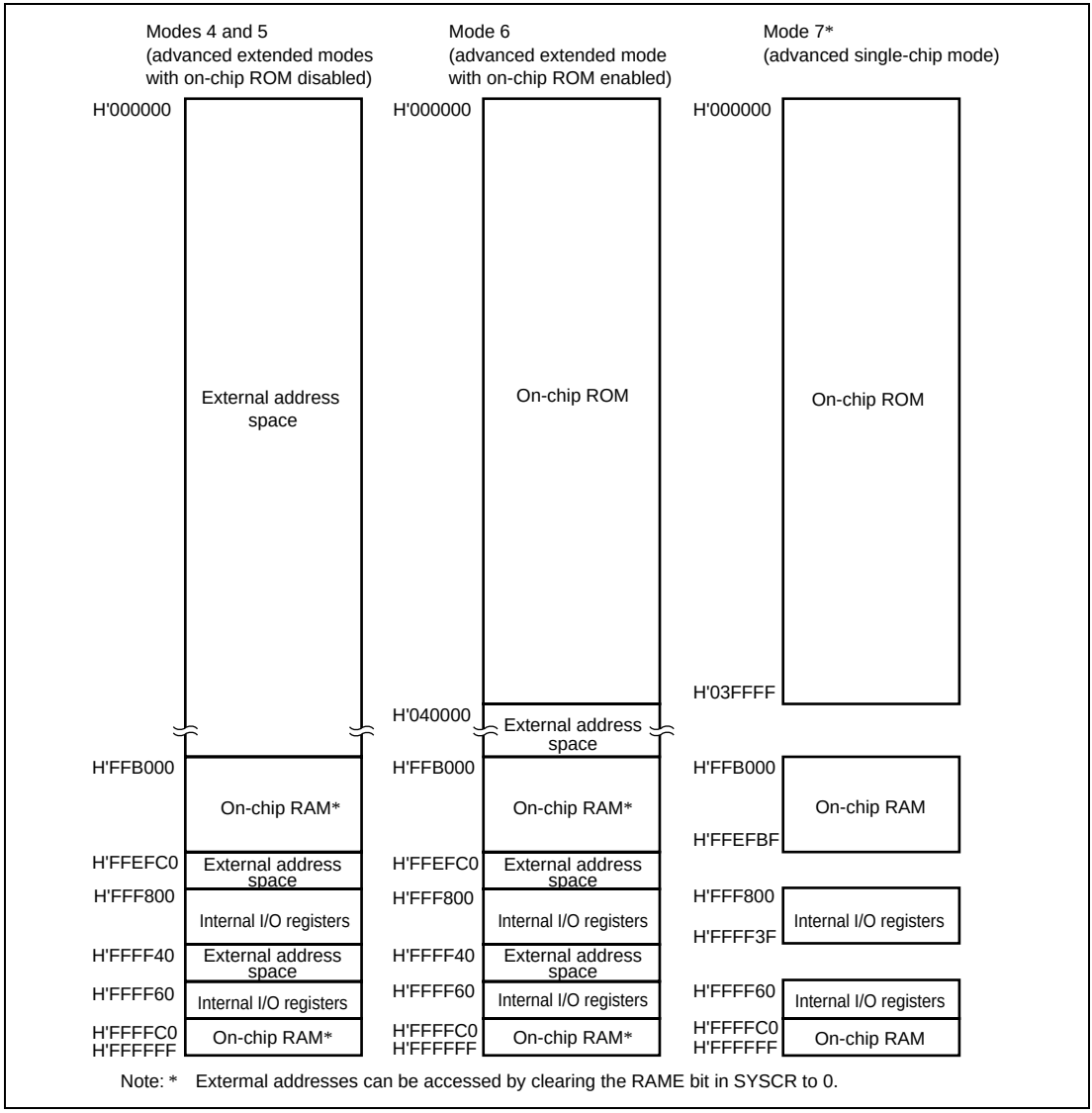


Figure 3.2 H8S/2238R Memory Map in Each Operating Mode

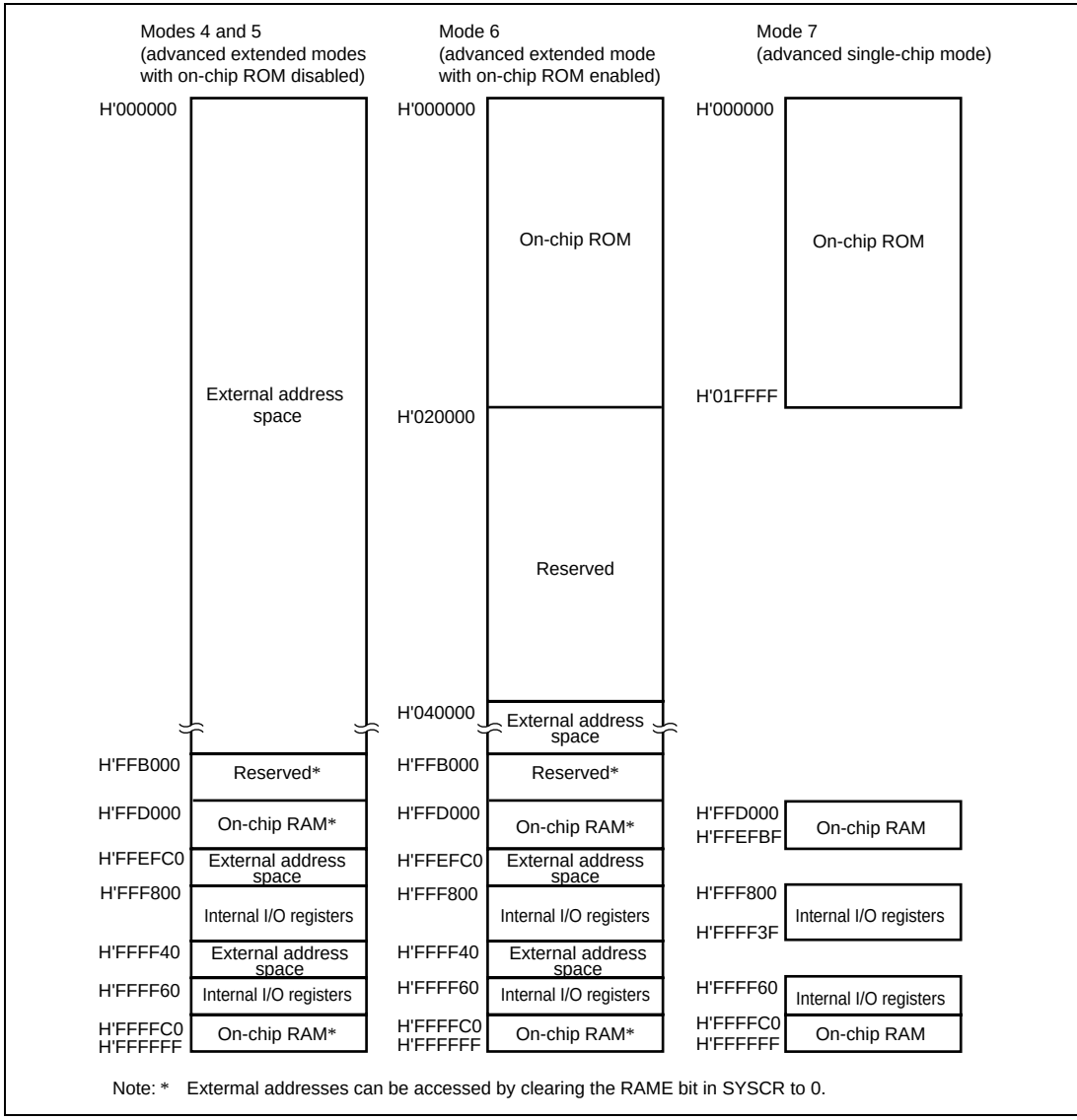
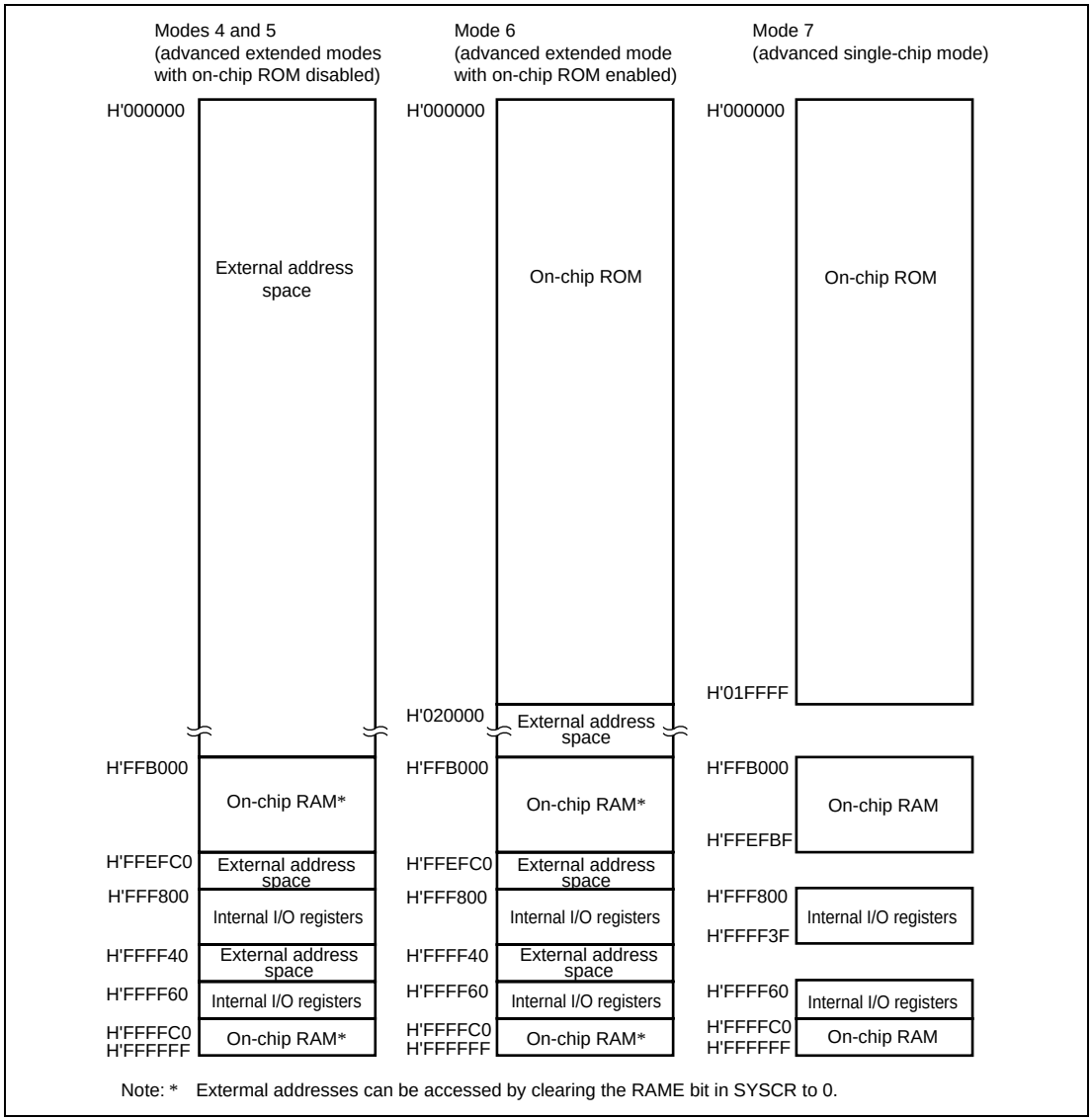


Figure 3.3 H8S/2236R Memory Map in Each Operating Mode



Note: * External addresses can be accessed by clearing the RAME bit in SYSCR to 0.

Figure 3.4 H8S/2237 and H8S/2227 Memory Map in Each Operating Mode

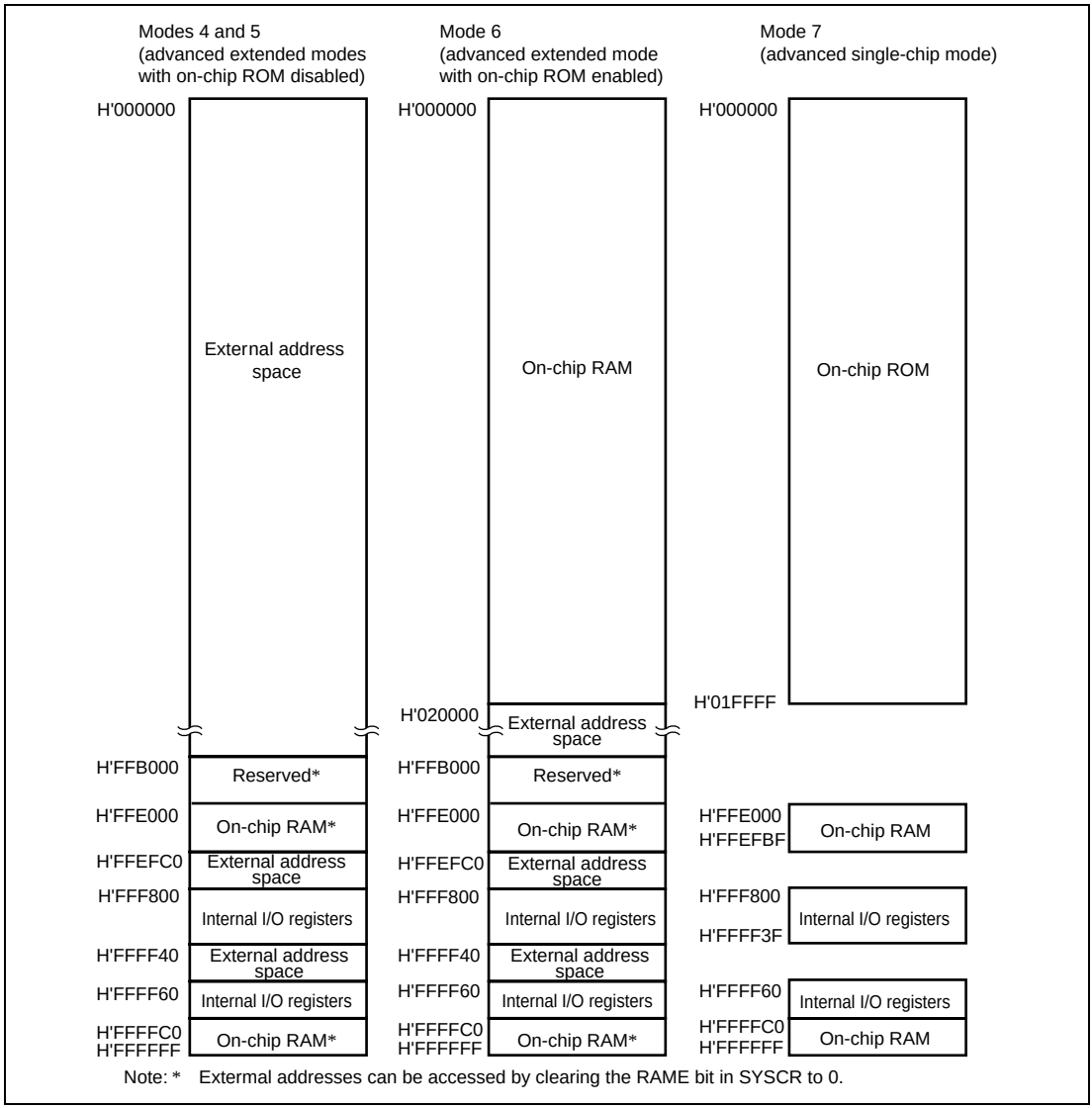


Figure 3.5 H8S/2235 and H8S/2225 Memory Map in Each Operating Mode

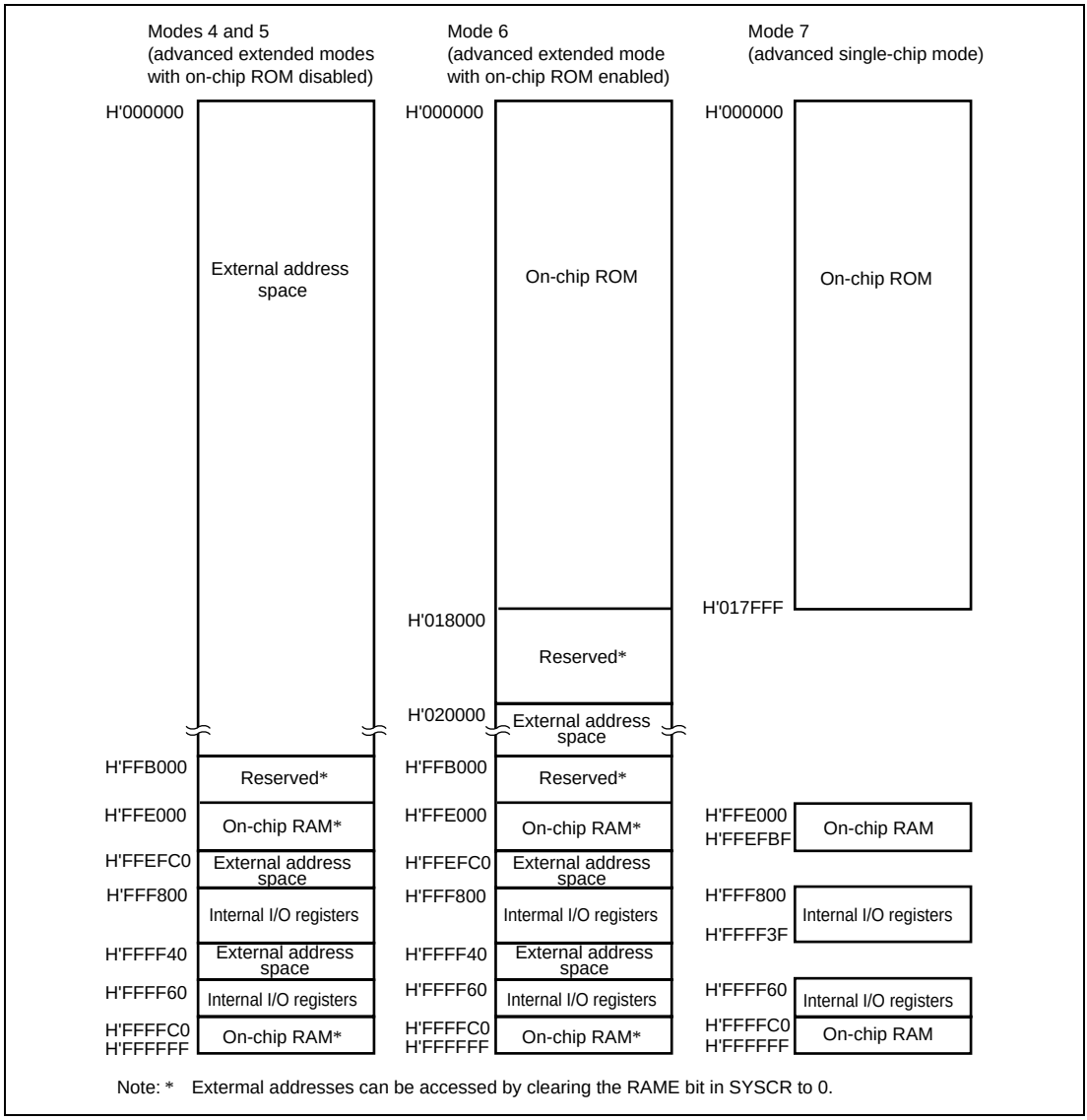


Figure 3.6 H8S/2224 Memory Map in Each Operating Mode

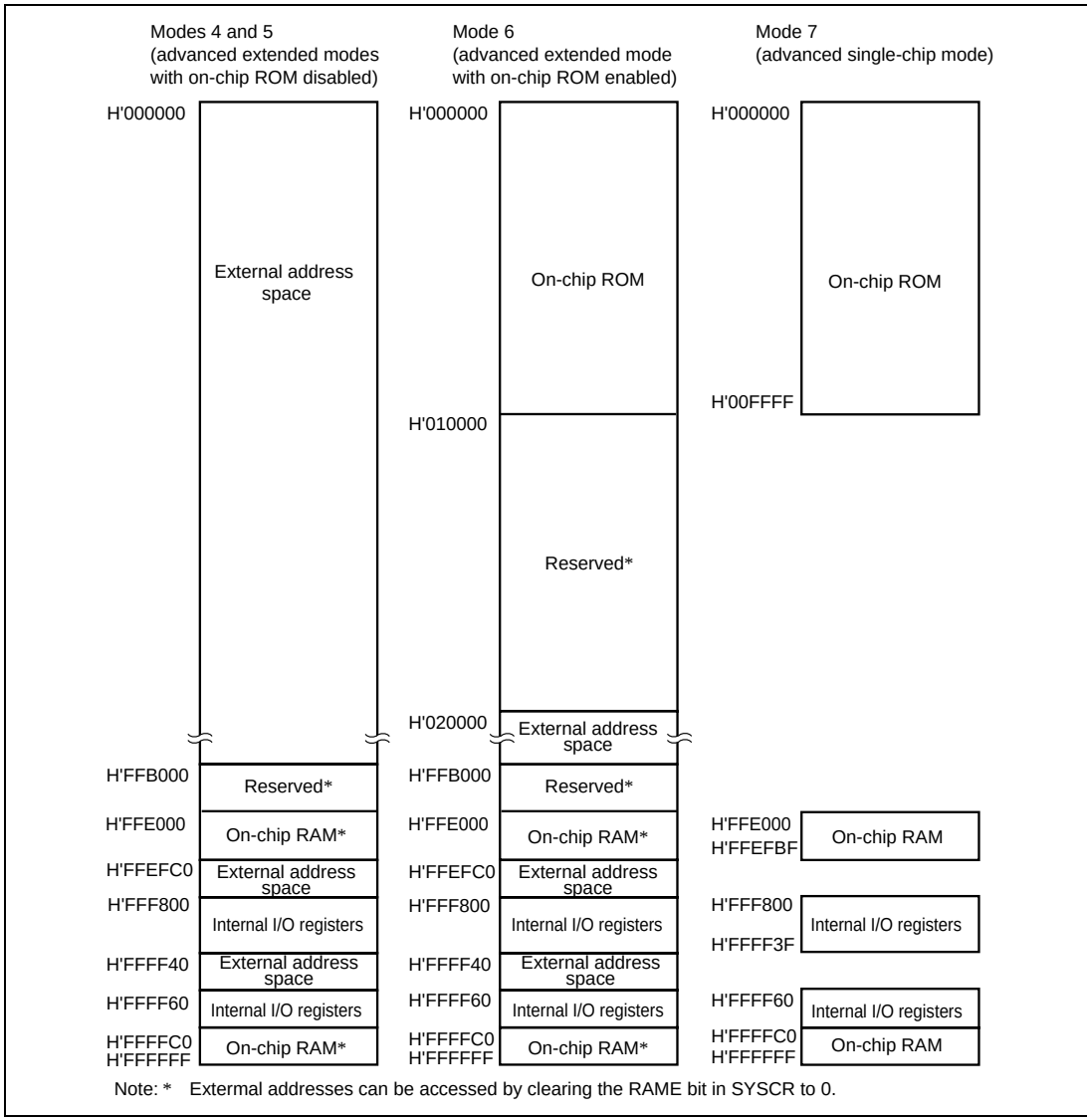


Figure 3.7 H8S/2233 and H8S/2223 Memory Map in Each Operating Mode

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 RES or MRES pin, or when the watchdog timer overflows. The CPU enters the power-on reset state when the RES pin is low. The CPU enters the manual reset state when the MRES 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.
	Trap instruction	Started by execution of a trap instruction (TRAPA). Trap instruction exception handling requests are accepted at all times in program execution state.
Low		

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]
Power-on reset		0	H'0000 to H'0003
Manual reset		1	H'0004 to H'0007
Reserved for system use		2	H'0008 to H'000B
		3	H'000C to H'000F
		4	H'0010 to H'0013
Trace		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
	IRQ2	18	H'0048 to H'004B
	IRQ3	19	H'004C to H'004F
	IRQ4	20	H'0050 to H'0053
	IRQ5	21	H'0054 to H'0057
	IRQ6	22	H'0058 to H'005B
	IRQ7	23	H'005C to H'005F
Internal interrupt*[2]		24 ⎮ 123	H'0060 to H'0063 ⎮ 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 23.10, Direct Transitions.

4.3 Reset

A reset has the highest exception priority.

When the RES or MRES 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 RES or MRES 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 13, Watchdog Timer (WDT).

4.3.1 Reset Types

The power-on reset and the manual reset are available as the reset.

Table 4.3 lists the reset types. When the power is supplied, select the power-on reset.

Both the power-on reset and the manual reset initialize the internal state of the CPU. The power-on reset initializes all registers in on-chip peripheral modules. The manual reset initializes the registers in on-chip peripheral modules except the bus controller and the I/O ports. The state of the bus controller and the I/O ports are maintained.

At the manual reset, the on-chip peripheral modules are initialized. Thus, the ports that are used as I/O pins for the on-chip peripheral modules are changed to the ports controlled by the DDR and the DR.

Table 4.3 Reset Types

	Condition to Enter Reset		Internal State	
Reset	**MRES**	**RES**	**CPU**	**Internal Peripheral Modules**
Power-on reset	*	Low	Initialized	Initialized
Manual reset	Low	High	Initialized	Initialized except the bus controller and the I/O ports

Legend:* Don't care.

The power-on reset and the manual reset are also available for the reset by the watchdog timer.

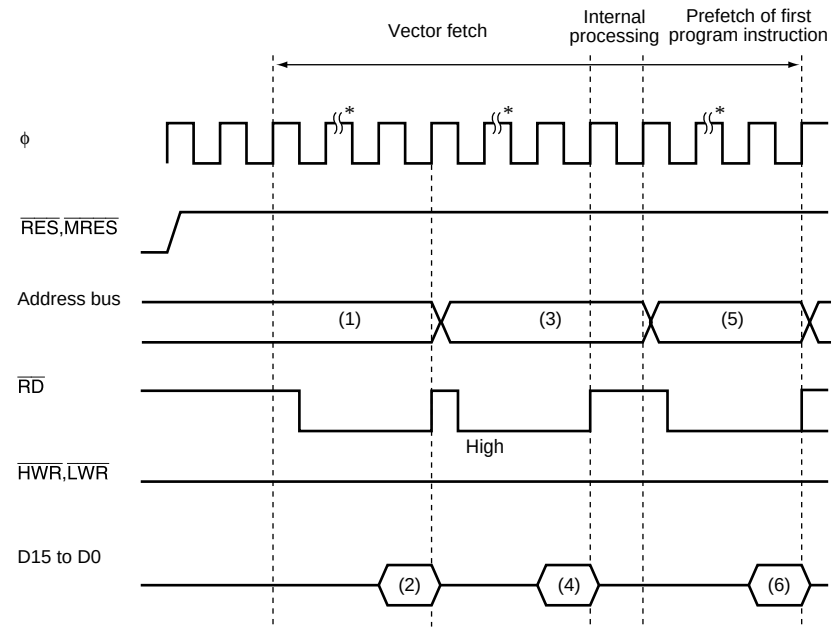
To enable the MRES pin, set the MRESE bit in SYSCR to 1.

4.3.2 Reset Exception Handling

When the RES or MRES pin goes low, this LSI enters the reset. To ensure that this LSI is reset, hold the RES or MRES pin low for at least 20 ms at power-up. To reset the chip during operation, hold the RES or MRES pin low for at least 20 states. When the RES or MRES pin goes high after being held low for the necessary time, this LSI starts reset exception handling as follows.

1. The internal state of the CPU and the registers of the on-chip peripheral modules are initialized, the T bit in EXR is cleared to 0, and the I bits in EXR and CCR are 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.

Figures 4.1 shows an example of the reset sequence.



(1)(3) Reset exception handling vector address (at power on reset, (1)=H'000000, (3)=H'000002, at manual reset, (1)=H'000004, (3)=H'000006)
(2)(4) Start address (contents of reset exception handling vector address)
(5) Start address ((5)=(2)(4))
(6) First program instruction

Note: * Three states are inserted for waiting.

Figure 4.1 Reset Sequence (Mode 4)

4.3.3 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).

4.3.4 State of On-Chip Peripheral Modules after Reset Release

After reset release, MSTPCRA is initialized to H'3F, MSTPCRB and MSTPCRC are initialized to H'FF, and all modules except the DTC* and DTC 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.

Note: * Supported only by the H8S/2239 Series.

4.4 Traces

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 4.4 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 4.4 Status of CCR and EXR after Trace Exception Handling

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

Legend:

1: Set to 1
0: Cleared to 0
—: Retains value prior to execution

4.5 Interrupts

Interrupts are controlled by the interrupt controller. The interrupt control 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.

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 to 0.
3. A vector address corresponding to the interrupt source is generated, the start address is loaded from the vector table to the PC, and program execution starts from that address.

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

Table 4.5 shows the status of CCR and EXR after execution of trap instruction exception handling.

Table 4.5 Status of CCR and EXR after Trap Instruction Exception Handling

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

Legend:

1: Set to 1

0: Cleared to 0

—: Retains value prior to execution

4.7 Stack Status after Exception Handling

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

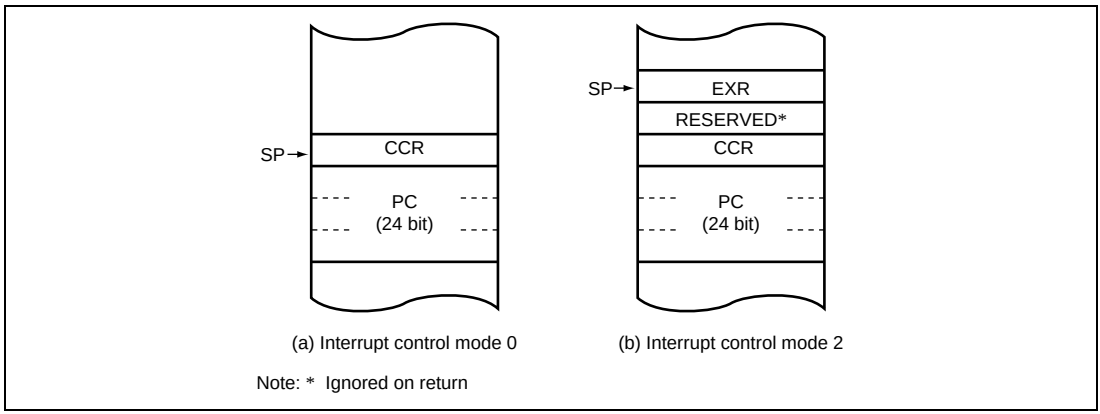


Figure 4.2 Stack Status after Exception Handling (Advanced Mode)

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.

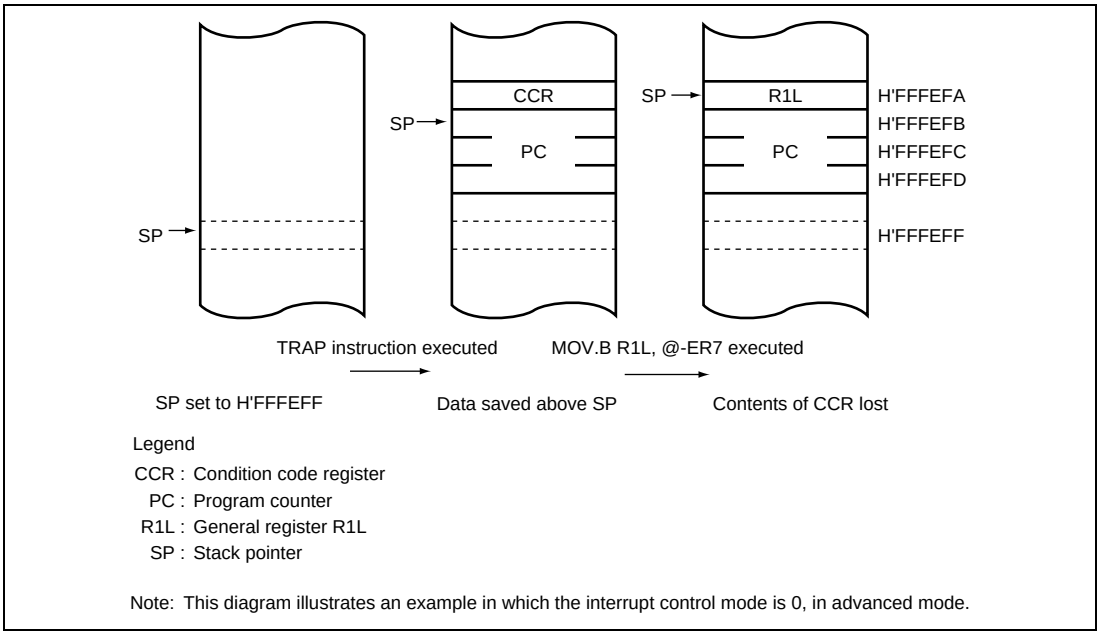


Figure 4.3 Operation when SP Value Is Odd

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
  - 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
  - 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 are assigned independent vector addresses, making it unnecessary for the source to be identified in the interrupt handling routine.
- Nine external interrupts
  - NMI is the highest-priority interrupt, and is accepted at all times. Rising edge or falling edge can be selected for NMI. Falling edge, rising edge, or both edge detection, or level sensing, can be independently selected for IRQ7 to IRQ0.
- DTC and DMAC* control
  - The DTC and DMAC* can be activated by an interrupt request.

Note:* Supported only by the H8S/2239 Series.

A block diagram of the interrupt controller is shown in figure 5.1.

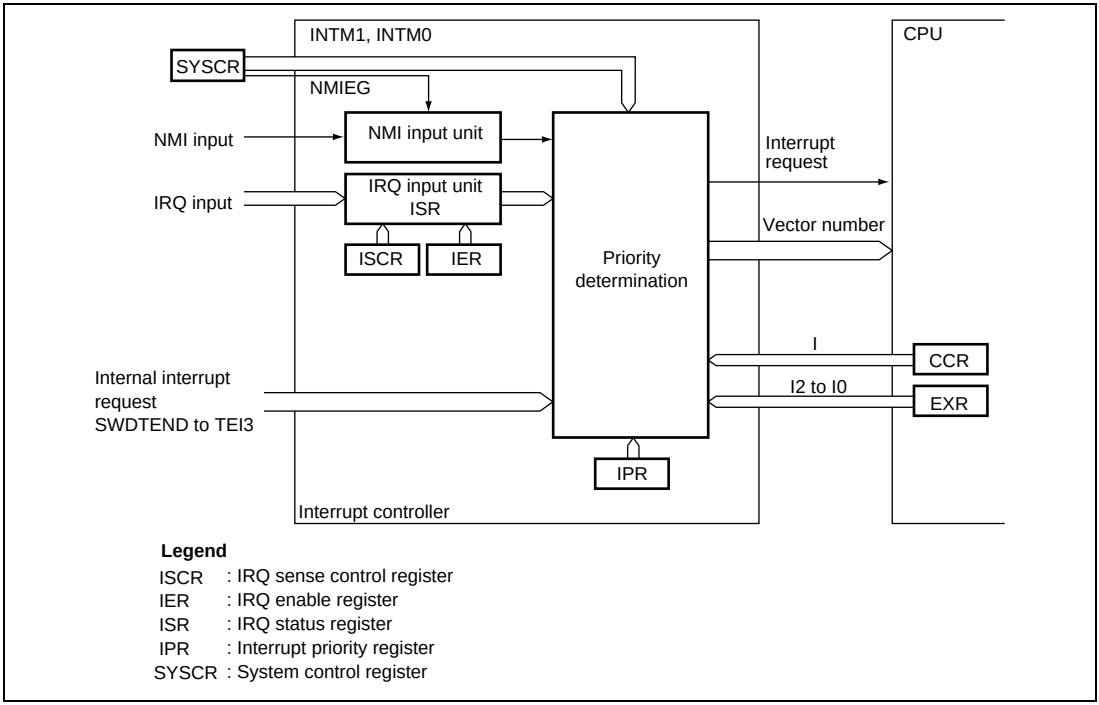


Figure 5.1 Block Diagram of Interrupt Controller

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
IRQ7	Input	Maskable external interrupts Rising, falling, or both edges, or level sensing can be selected
IRQ6	Input	
IRQ5	Input	
IRQ4	Input	
IRQ3	Input	
IRQ2	Input	
IRQ1	Input	
IRQ0	Input	

5.3 Register Descriptions

The interrupt controller has the following registers. For the system control register, see section 3.2.2, System Control Register (SYSCR).

- 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 H (IPRH)
- Interrupt priority register I (IPRI)
- Interrupt priority register J (IPRJ)
- Interrupt priority register K (IPRK)

- Interrupt priority register L (IPRL)
- Interrupt priority register O (IPRO)

5.3.1 Interrupt Priority Registers A to L, and O (IPRA to IPRL, IPRO)

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)

5.3.2 IRQ Enable Register (IER)

IER controls the enabling and disabling of interrupt requests IRQn (n = 7 to 0).

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ7E	0	R/W	IRQ7 Enable The IRQ7 interrupt request is enabled when this bit is 1.
6	IRQ6E	0	R/W	IRQ6 Enable The IRQ6 interrupt request is enabled when this bit is 1.
5	IRQ5E	0	R/W	IRQ5 Enable The IRQ5 interrupt request is enabled when this bit is 1.
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	IRQ2E	0	R/W	IRQ2 Enable The IRQ2 interrupt request is enabled when this bit is 1.
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.

5.3.3 IRQ Sense Control Registers H and L (ISCRH and ISCRL)

The ISCR registers select the source that generates an interrupt request at pins IRQn (n = 7 to 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	IRQ7SCB	0	R/W	IRQ7 Sense Control B
14	IRQ7SCA	0	R/W	IRQ7 Sense Control A 00: Interrupt request generated at IRQ7 input level low 01: Interrupt request generated at falling edge of IRQ7 input 10: Interrupt request generated at rising edge of IRQ7 input 11: Interrupt request generated at both falling and rising edges of IRQ7 input
13	IRQ6SCB	0	R/W	IRQ6 Sense Control B
12	IRQ6SCA	0	R/W	IRQ6 Sense Control A 00: Interrupt request generated at IRQ6 input level low 01: Interrupt request generated at falling edge of IRQ6 input 10: Interrupt request generated at rising edge of IRQ6 input 11: Interrupt request generated at both falling and rising edges of IRQ6 input
11	IRQ5SCB	0	R/W	IRQ5 Sense Control B
10	IRQ5SCA	0	R/W	IRQ5 Sense Control A 00: Interrupt request generated at IRQ5 input level low 01: Interrupt request generated at falling edge of IRQ5 input 10: Interrupt request generated at rising edge of IRQ5 input 11: Interrupt request generated at both falling and rising edges of IRQ5 input
9	IRQ4SCB	0	R/W	IRQ4 Sense Control B
8	IRQ4SCA	0	R/W	IRQ4 Sense Control A 00: Interrupt request generated at IRQ4 input level low 01: Interrupt request generated at falling edge of IRQ4 input 10: Interrupt request generated at rising edge of IRQ4 input 11: Interrupt request generated at both falling and rising edges of IRQ4 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 IRQ3 input level low 01: Interrupt request generated at falling edge of IRQ3 input 10: Interrupt request generated at rising edge of IRQ3 input 11: Interrupt request generated at both falling and rising edges of IRQ3 input
5	IRQ2SCB	0	R/W	IRQ2 Sense Control B
4	IRQ2SCA	0	R/W	IRQ2 Sense Control A 00: Interrupt request generated at IRQ2 input level low 01: Interrupt request generated at falling edge of IRQ2 input 10: Interrupt request generated at rising edge of IRQ2 input 11: Interrupt request generated at both falling and rising edges of IRQ2 input
3	IRQ1SCB	0	R/W	IRQ1 Sense Control B
2	IRQ1SCA	0	R/W	IRQ1 Sense Control A 00: Interrupt request generated at IRQ1 input level low 01: Interrupt request generated at falling edge of IRQ1 input 10: Interrupt request generated at rising edge of IRQ1 input 11: Interrupt request generated at both falling and rising edges of 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 IRQ0 input level low 01: Interrupt request generated at falling edge of IRQ0 input 10: Interrupt request generated at rising edge of IRQ0 input 11: Interrupt request generated at both falling and rising edges of IRQ0 input

5.3.4 IRQ Status Register (ISR)

ISR indicates the status of IRQn (n = 7 to 0) interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ7F	0	R/W*	IRQ7 to IRQ0 Flags
6	IRQ6F	0	R/W*	Indicates the status of IRQ7 to IRQ0 interrupt requests.
5	IRQ5F	0	R/W*	[Setting condition]
4	IRQ4F	0	R/W*	When the interrupt source selected by the ISCRH, or ISCRL occurs
3	IRQ3F	0	R/W*	
2	IRQ2F	0	R/W*	[Clearing conditions]
1	IRQ1F	0	R/W*	Cleared by reading IRQnF flag when IRQnF = 1, then writing 0 to IRQnF flag
0	IRQ0F	0	R/W*	When interrupt exception handling is executed when low-level detection is set and IRQn input is high level
				When IRQn interrupt exception handling is executed when falling, rising, or both-edge detection is set
				When the DTC is activated by an IRQn interrupt, and the DISEL bit in MRB of the DTC is cleared to 0

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

5.4 Interrupt Sources

5.4.1 External Interrupts

There are nine external interrupts: NMI and IRQ7 to IRQ0. 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 (n = 7 to 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.
- 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 5.2.

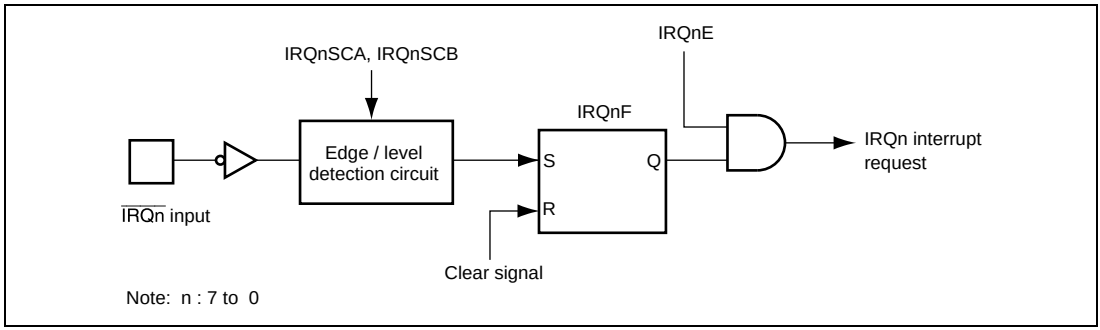


Figure 5.2 Block Diagram of IRQn Interrupts

The set timing for IRQnF is shown in figure 5.3.

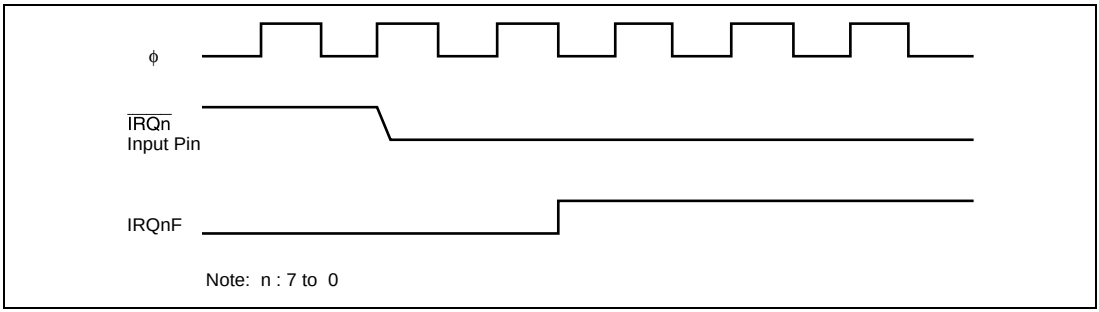


Figure 5.3 Set Timing for IRQnF

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.

5.4.2 Internal Interrupts

Internal interrupts that are requested from the on-chip peripheral modules have the following features.

- For each on-chip peripheral module, there are flags that indicate the interrupt request status, and enable bits that select enabling or disabling of these interrupts, and they are masked independently. If the enable bit is set to 1 for a particular interrupt source, an interrupt request is issued to the interrupt controller.
- The interrupt priority level can be set with IPR.
- TPU and SCI interrupt requests can activate the DMAC* or DTC. When the DMAC* or DTC is activated by the interrupt request, the interrupt control mode and CPU interrupt mask bits are disregarded.

Note: * Supported only by the H8S/2239 Series.

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. 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] Advanced Mode	IPR*[2]	Priority
External Pin	NMI	7	H'001C		High
	IRQ0	16	H'0040	IPRA6 to IPRA4	
	IRQ1	17	H'0044	IPRA2 to IPRA0	
	IRQ2	18	H'0048	IPRB6 to IPRB4	
	IRQ3	19	H'004C		
	IRQ4	20	H'0050	IPRB2 to IPRB0	
	IRQ5	21	H'0054		
	IRQ6	22	H'0058	IPRC6 to IPRC4	
	IRQ7	23	H'005C		
DTC	SWDTEND (completion of software initiation data transfer)	24	H'0060	IPRC2 to IPRC0	
Watchdog timer 0	WOVI0 (interval timer 0)	25	H'0064	IPRD6 to IPRD4	
PC break	PC break	27	H'006C	IPRE6 to IPRE4	
A/D	ADI (completion of A/D conversion)	28	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	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		
					Low

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address*[1] Advanced Mode	IPR*[2]	Priority
	TGI0D (TGR0D input capture/compare-match)	35	H'008C		High
	TCI0V (overflow 0)	36	H'0090		
—	Reserved	37 38 39	H'0094 H'0098 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)	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)	47	H'00BC		
TPU channel 3*[3]	TGI3A (TGR3A input capture/compare-match)	48	H'00C0	IPRG2 to IPRG0	
	TGI3B (TGR3B input capture/compare-match)	49	H'00C4		
	TGI3C (TGR3C input capture/compare-match)	50	H'00C8		
	TGI3D (TGR3D input capture/compare-match)	51	H'00CC		
	TCI3V (overflow 3)	52	H'00D0		Low

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address*[1] Advanced Mode	IPR*[2]	Priority
—	Reserved	53	H'00D4	IPRG2 to IPRG0	High
		54	H'00D8		
		55	H'00DC		
TPU channel 4*[3]	TGI4A (TGR4A input capture/compare-match)	56	H'00E0	IPRH6 to IPRH4	
	TGI4B (TGR4B input capture/compare-match)	57	H'00E4		
	TCI4V (overflow 4)	58	H'00E8		
	TCI4U (underflow 4)	59	H'00EC		
TPU channel 5*[3]	TGI5A (TGR5A input capture/compare-match)	60	H'00F0	IPRH2 to IPRH0	
	TGI5B (TGR5B input capture/compare-match)	61	H'00F4		
	TCI5V (overflow 5)	62	H'00F8		
	TCI5U (underflow 5)	63	H'00FC		
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		
8-bit timer channel 1	CMIA1 (compare-match A1)	68	H'0110	IPRI2 to IPRI0	
	CMIB1 (compare-match B1)	69	H'0114		
	OVI1 (overflow 1)	70	H'0118		
—	Reserved	71	H'011C		Low

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address*[1] Advanced Mode	IPR*[2]	Priority
DMAC*[5]	DEND0A (completion of channel 0/channel 0A transfer)	72	H'0120	IPRJ6 to IPRJ4	High
	DEND0B (completion of channel 0B transfer)	73	H'0124		
	DEND1A (completion of channel 1/channel 1A transfer)	74	H'0128		
	DEND1B (completion of channel 1B transfer)	75	H'012C		
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		
SCI channel 2*[3]	ERI2 (receive error 2)	88	H'0160	IPRK2 to IPRK0	
	RXI2 (receive completion 2)	89	H'0164		
	TXI2 (transmit data empty 2)	90	H'0168		
	TEI2 (transmit end 2)	91	H'016C		
8-bit timer channel 2*[4]	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		Low

Interrupt Source	Origin of Interrupt Source	Vector Number	Vector Address*1 Advanced Mode	IPR*2	Priority
8-bit timer channel 3*4	CMIA3 (compare-match A3)	96	H'0180	IPRL6 to IPRL4	High
	CMIB3 (compare-match B3)	97	H'0184		
	OVI3 (overflow 3)	98	H'0188		
—	Reserved	99	H'018C		
IIC channel 0*4 (option)	IICI0 (1-byte transmission/ reception completion)	100	H'0190	IPRL2 to IPRL0	
	Reserved	101	H'0194		
IIC channel 1*4 (option)	IICI1 (1-byte transmission/ reception completion)	102	H'0198	IPRL2 to IPRL0	
	Reserved	103	H'019C		
SCI channel 3	ERI3 (receive error 3)	120	H'01E0	IPRO6 to IPRO4	
	RXI3 (receive completion 3)	121	H'01E4		
	TXI3 (transmit data empty 3)	122	H'01E8		
	TEI3 (transmit end)	123	H'01EC		Low

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. Not available in the H8S/2227 Series.
4. Not available in the H8S/2237 Series and H8S/2227 Series.
5. Supported only by the H8S/2239 Series.

5.5 Operation

5.5.1 Interrupt Control Modes and Interrupt Operation

Interrupt operations in this LSI 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 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

Figure 5.4 shows the block diagram of the priority decision circuits.

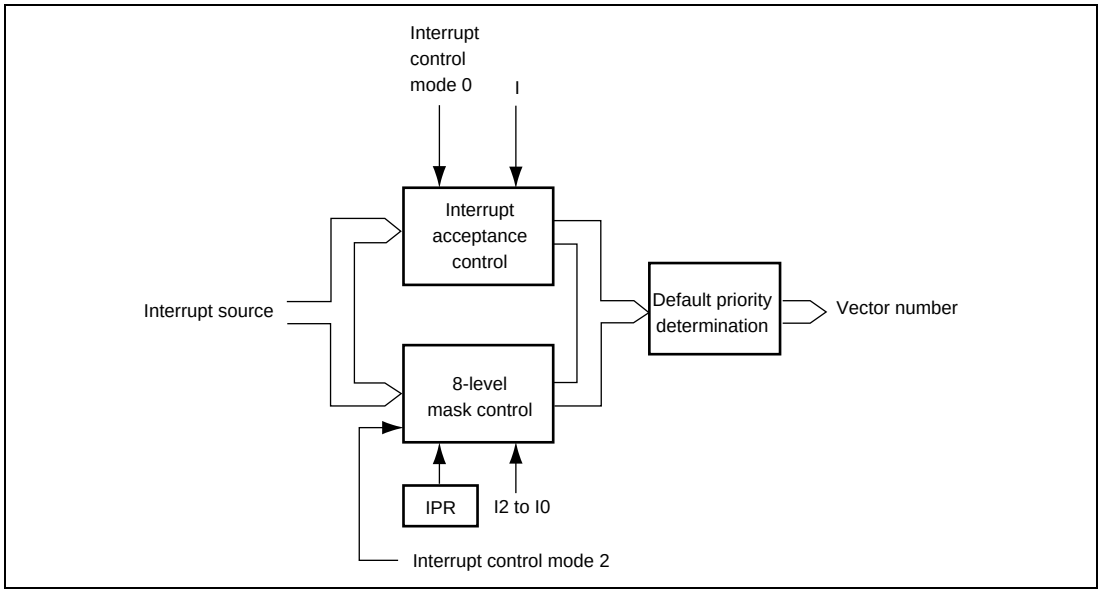


Figure 5.4 Block Diagram of Interrupt Control Operation

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

Legend: X: Don't care

8-Level Control: 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.

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		Default Priority Determination	T (Trace)
	INTM1	INTM0		I		I2 to I0	IPR		
0	0	0	O	IM	X	—	—*[2]	O	—
2	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.

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 5.5 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.

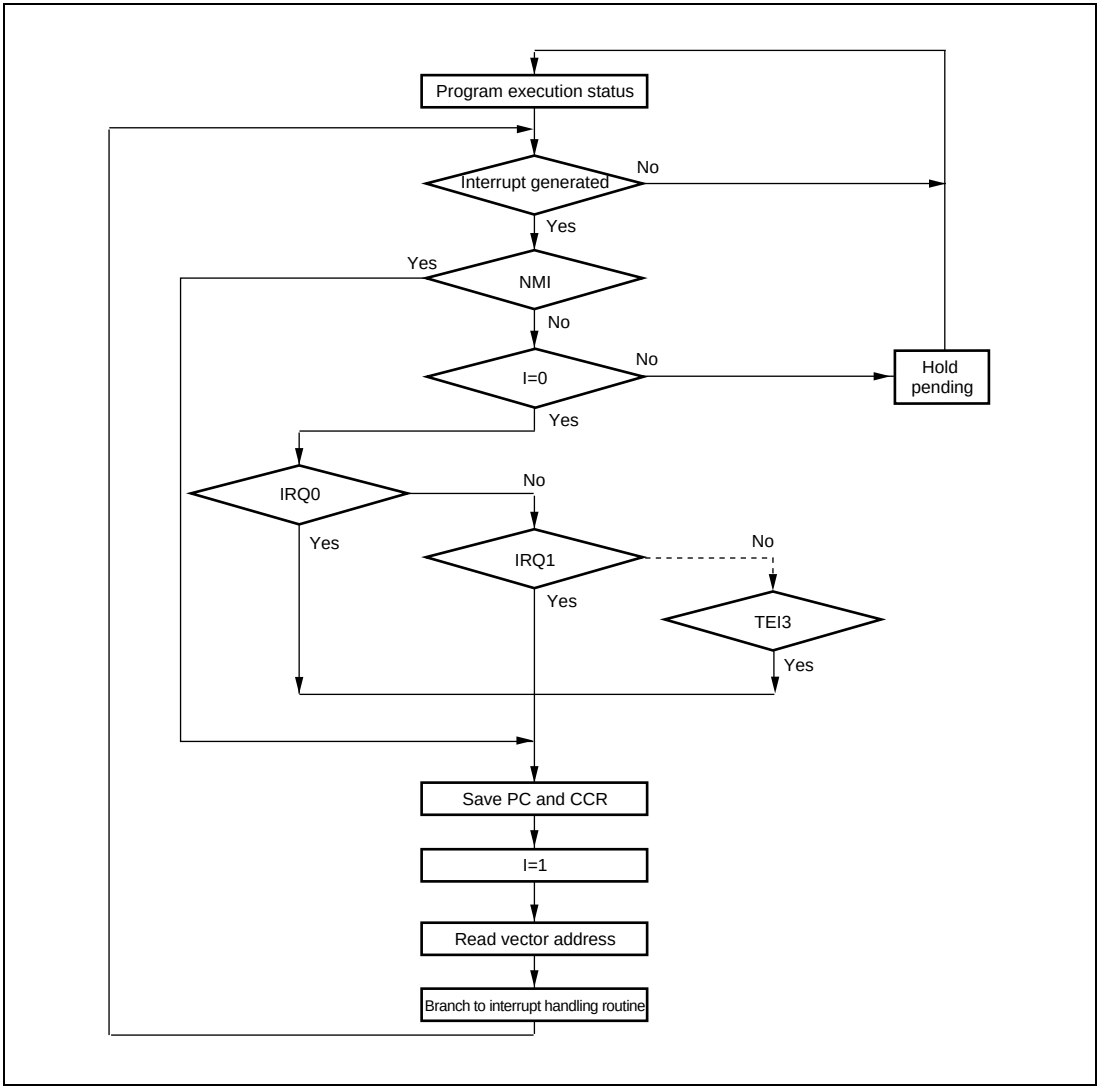


Figure 5.5 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 0

5.5.3 Interrupt Control Mode 2

Eight-level masking is implemented for IRQ 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 5.6 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.

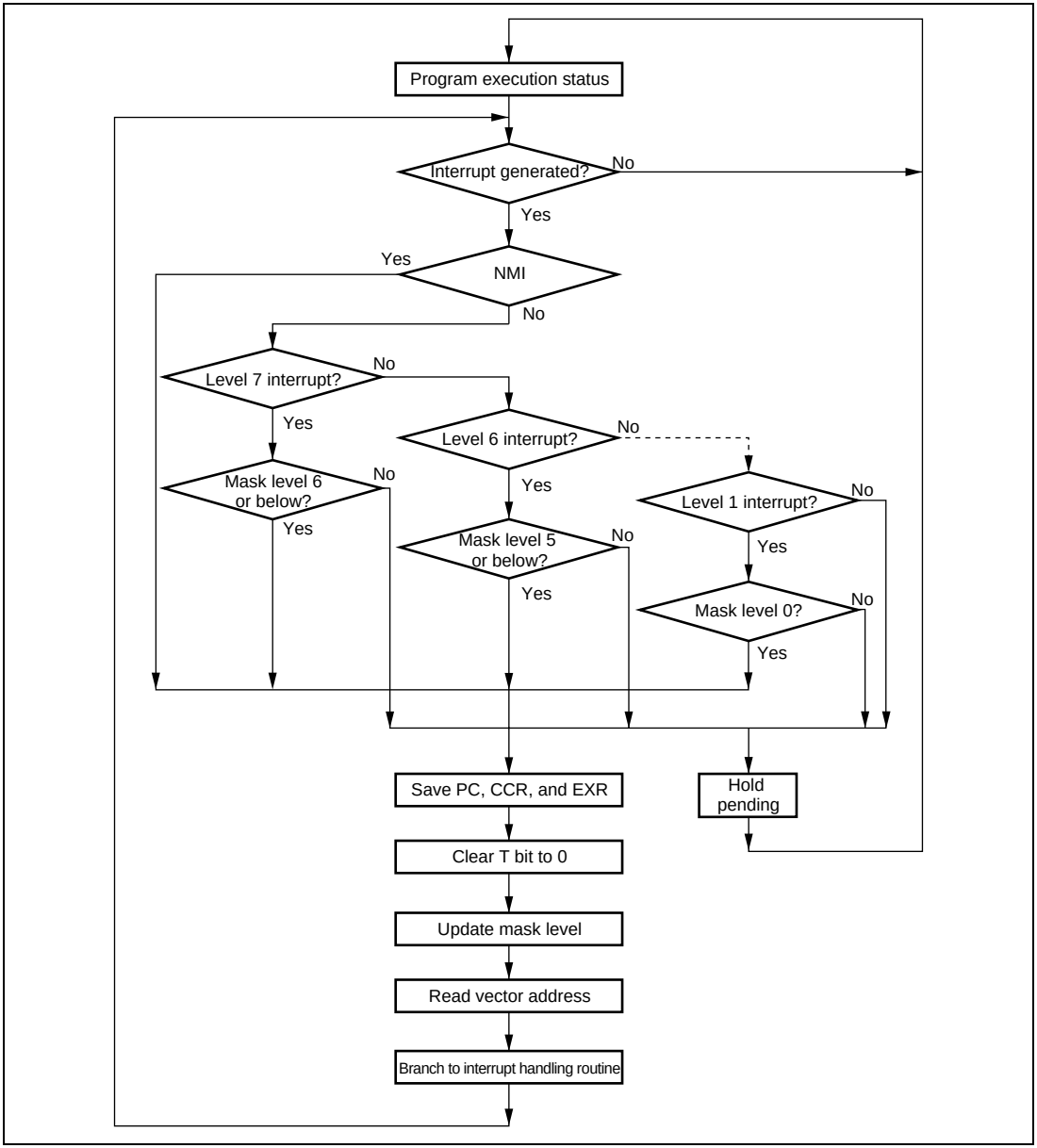


Figure 5.6 Flowchart of Procedure Up to Interrupt Acceptance in Control Mode 2

5.5.4 Interrupt Exception Handling Sequence

Figure 5.7 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.

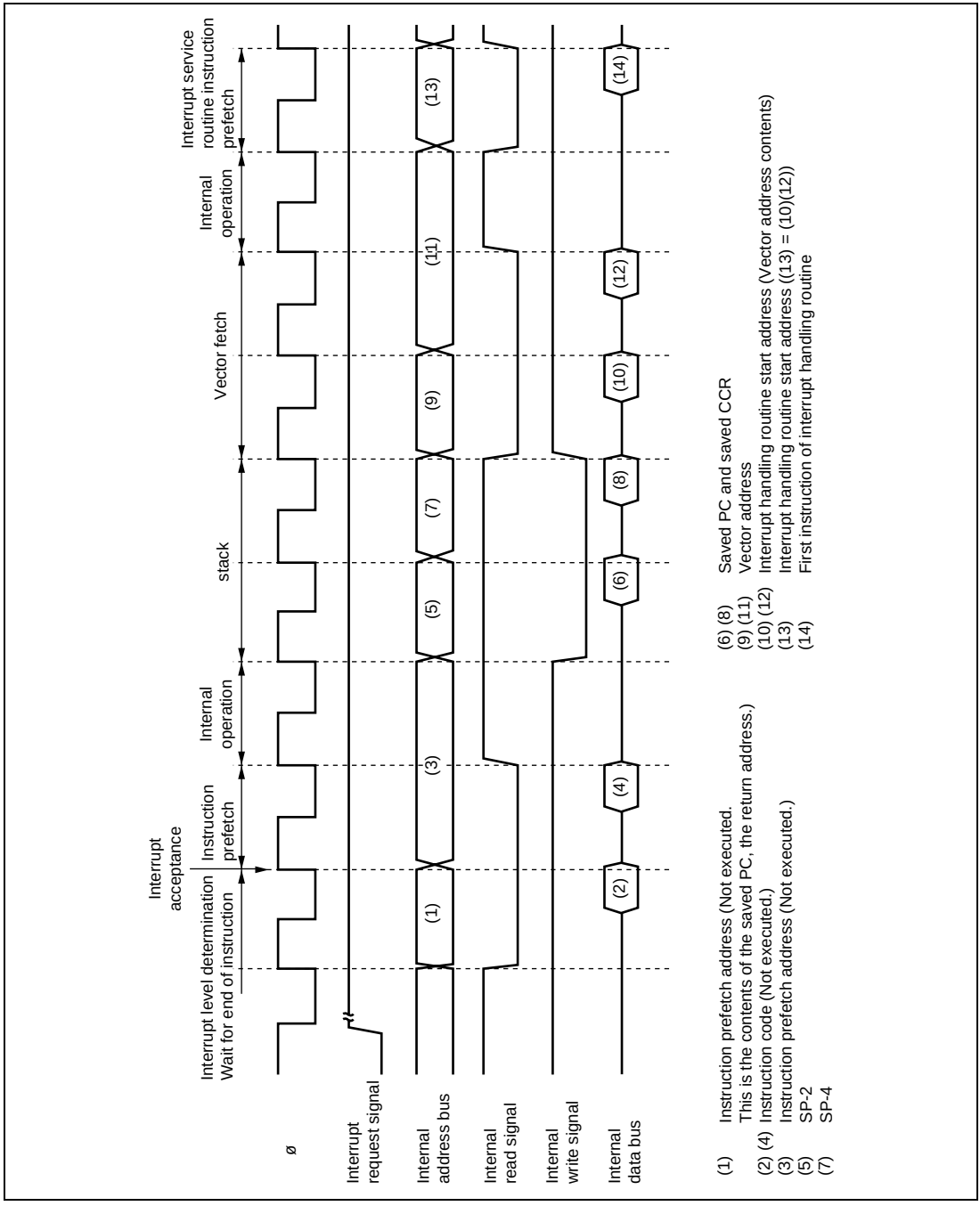


Figure 5.7 Interrupt Exception Handling

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

		Normal Mode*[5]		Advanced Mode	
No.	**Execution Status**	**INTM1 = 0**	**INTM1 = 1**	**INTM1 = 0**	**INTM1 = 1**
1	Interrupt priority determination*[1]	3	3	3	3
2	Number of wait states until executing instruction ends*[2]	1 to 19 + 2·S_I	1 to 19 + 2·S_I	1 to 19 + 2·S_I	1 to 19 + 2·S_I
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

		Object of Access				
			External Device *			
			8 Bit Bus		16 Bit Bus	
Symbol		**Internal Memory**	**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 and DMAC Activation by Interrupt

The DTC and DMAC can be activated by an interrupt. For details, see section 9, Data Transfer Controller (DTC) and section 8, DMA Controller (DMAC).

Note: The DMAC is supported only by the H8S/2239 Series.

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

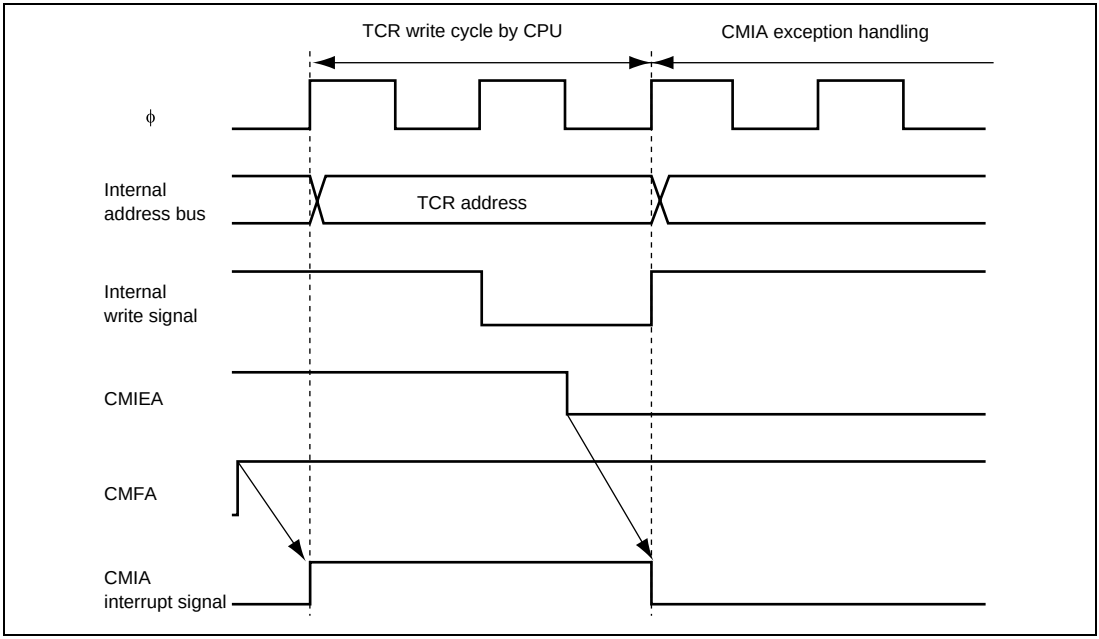


Figure 5.8 Contention between Interrupt Generation and Disabling

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 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

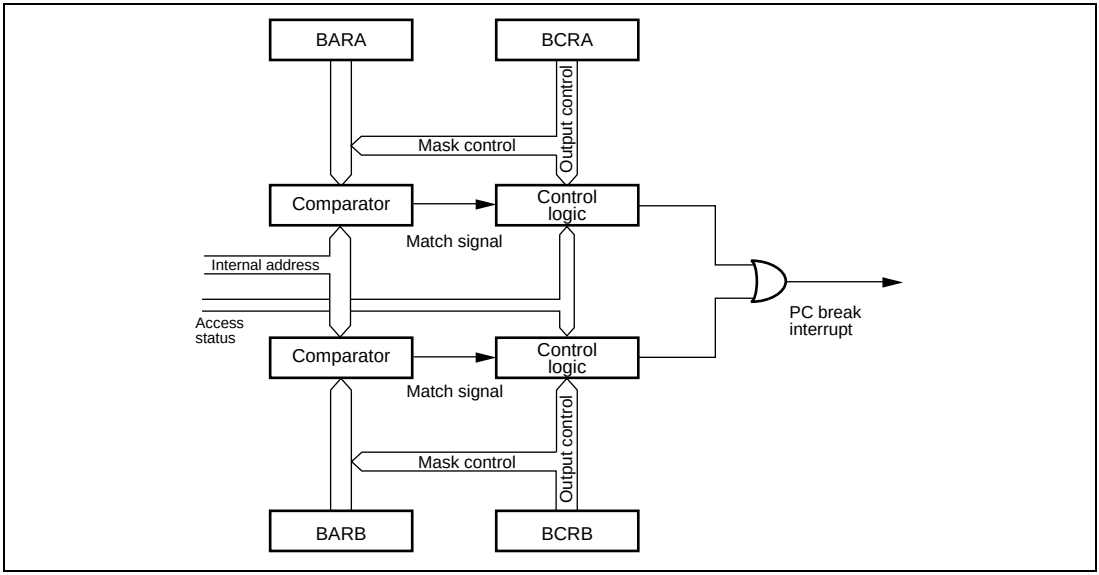


Figure 6.1 Block Diagram of PC Break Controller

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	All 0	R/W	Break Address 23 to 0 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, DTC, or DMAC*[3]
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	Break Condition Select Selects break condition of channel A. 00: Instruction fetch is used as break condition 01: Data read cycle is used as break condition 10: Data write cycle is used as break condition 11: Data read/write cycle is used as break condition
1	CSELA0	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
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.
3. Supported only by the H8S/2239 Series.

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 BCRA.
   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 (BAMRA2 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 (BAMRA2 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)).

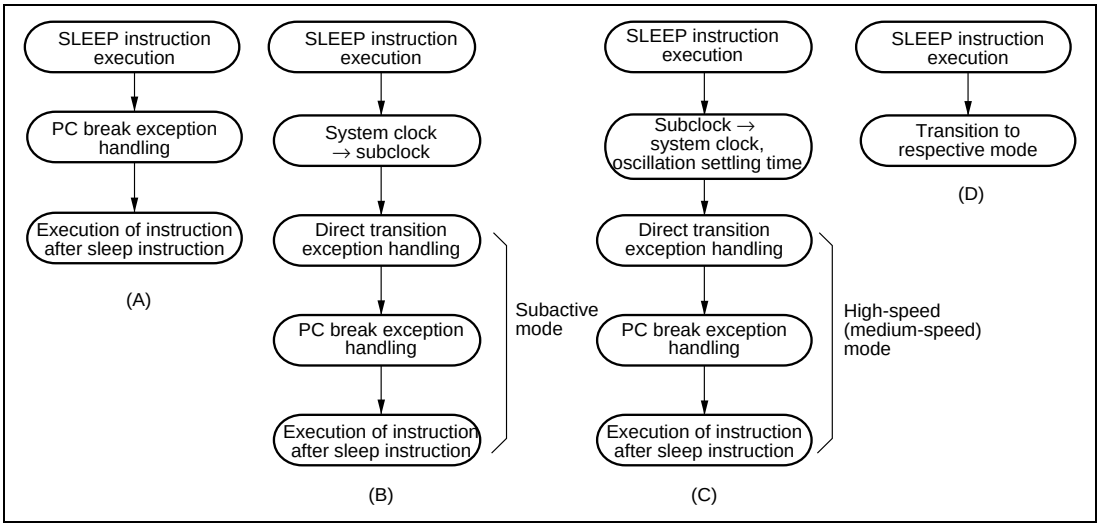


Figure 6.2 Operation in Power-Down Mode Transitions

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 23, 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 or DMAC Is Bus Master

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

Note: * Supported only by the H8S/2239 Series.

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

This LSI has a built-in bus controller (BSC) that manages the external address space divided into eight areas. The bus controller also has a bus arbitration function, and controls the operation of the internal bus masters: the CPU, DMA controller (DMAC), and data transfer controller (DTC).

7.1 Features

- Manages external address space in area units
  - Manages the external space as 8 areas of 2-Mbytes
  - Bus specifications can be set independently for each area
  - Burst ROM interface can be set
- Basic bus interface
  - Chip select ($\overline{CS0}$ to $\overline{CS7}$) can be output for areas 0 to 7
  - 8-bit access or 16-bit access can be selected for each area
  - 2-state access or 3-state access can be selected for each area
  - Program wait states can be inserted for each area
- Burst ROM interface
  - Burst ROM interface can be selected for area 0
  - One or two states can be selected for the burst cycle
- Idle cycle insertion
  - Idle cycle can be inserted between consecutive read accesses to different areas
  - Idle cycle can be inserted before a write access to an external area immediately after a read access to an external area
- Bus arbitration
  - The on-chip bus arbiter arbitrates bus mastership among CPU, DMAC*, and DTC.
- Other features
  - External bus release function

Note: * Supported only by the H8S/2239 Series.

Figure 7.1 shows a block diagram of the bus controller.

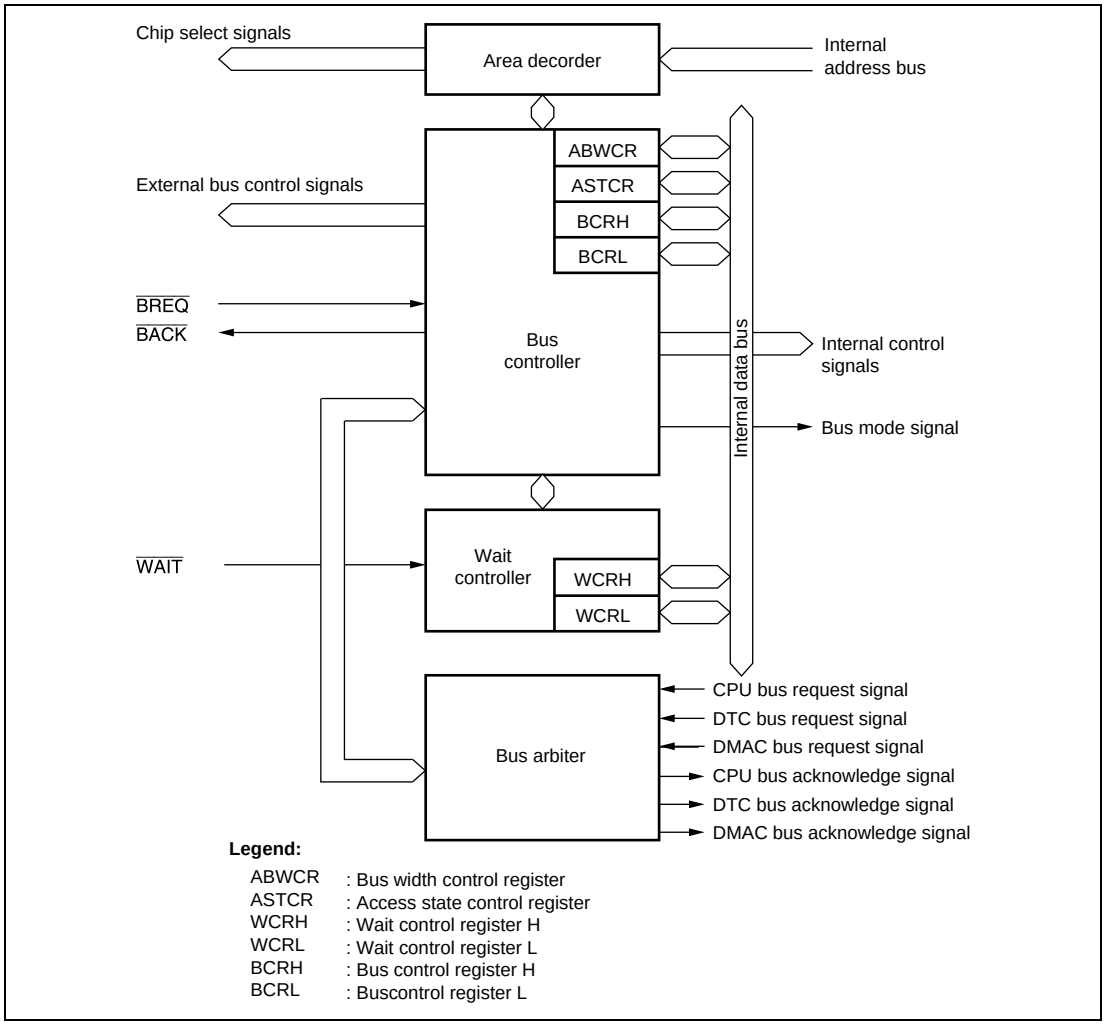


Figure 7.1 Block Diagram of Bus Controller

7.2 Input/Output Pins

Table 7.1 summarizes the pins of the bus controller.

Table 7.1 Pin Configuration

Name	Symbol	I/O	Function
Address strove	AS	Output	Strobe signal indicating that address output on address bus is enabled.
Read	RD	Output	Strobe signal indicating that external space is being read.
High write	HWR	Output	Strobe signal indicating that external space is to be written, and upper half (D15 to D8) of data bus is enabled.
Low write	LWR	Output	Strobe signal indicating that external space is to be written, and lower half (D7 to D0) of data bus is enabled.
Chip select 0 to 7	CS0 to CS7	Output	Strobe signal indicating that areas 0 to 7 are selected.
Wait	WAIT	Input	Wait request signal when accessing external 3-state access space.
Bus request	BREQ	Input	Request signal that releases bus to external device.
Bus request acknowledge	BACK	Output	Acknowledge signal indicating that bus has been released.

7.3 Register Descriptions

The following shows the registers of the bus controller.

- Bus width control register (ABWCR)
- Access state control register (ASTCR)
- Wait control register H (WCRH)
- Wait control register L (WCRL)
- Bus control register H (BCRH)
- Bus control register L (BCRL)
- Pin function control register (PFCR)

7.3.1 Bus Width Control Register (ABWCR)

ABWCR designates each area for either 8-bit access or 16-bit access.

ABWCR sets the data bus width for the external memory space. The bus width for on-chip memory and internal I/O registers is fixed regardless of the settings in ABWCR.

Bit	Bit Name	Initial Value	R/W	Description
7	ABW7	1/0*	R/W	Area 7 to 0 Bus Width Control: These bits select whether the corresponding area is to be designated for 8-bit access or 16-bit access. 0: Area n is designated for 16-bit access 1: Area n is designated for 8-bit access Legend n: 7 to 0
6	ABW6	1/0*	R/W	
5	ABW5	1/0*	R/W	
4	ABW4	1/0*	R/W	
3	ABW3	1/0*	R/W	
2	ABW2	1/0*	R/W	
1	ABW1	1/0*	R/W	
0	ABW0	1/0*	R/W	

Note: * In modes 5 to 7, initial value of each bit is 1. In mode 4, initial value of each bit is 0.

7.3.2 Access State Control Register (ASTCR)

ASTCR designates each area as either a 2-state access space or a 3-state access space.

ASTCR sets the number of access states for the external memory space. The number of access states for on-chip memory and internal I/O registers is fixed regardless of the settings in ASTCR.

Bit	Bit Name	Initial Value	R/W	Description
7	AST7	1	R/W	Area 7 to 0 Access State Control: These bits select whether the corresponding area is to be designated as a 2-state access space or a 3-state access space. Wait state insertion is enabled or disabled at the same time. 0: Area n is designated for 2-state access Wait state insertion in area n external space is disabled 1: Area n is designated for 3-state access Wait state insertion in area n external space is enabled Legend n: 7 to 0
6	AST6	1	R/W	
5	AST5	1	R/W	
4	AST4	1	R/W	
3	AST3	1	R/W	
2	AST2	1	R/W	
1	AST1	1	R/W	
0	AST0	1	R/W	

7.3.3 Wait Control Registers H and L (WCRH, WCRL)

WCRH and WCRL select the number of program wait states for each area.

Program waits are not inserted in the case of on-chip memory or internal I/O registers.

- WCRH

Bit	Bit Name	Initial Value	R/W	Description
7	W71	1	R/W	Area 7 Wait Control 1 and 0:
6	W70	1	R/W	These bits select the number of program wait states when area 7 in external space is accessed while the AST7 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 7 is accessed 01: 1 program wait state inserted when external space area 7 is accessed 10: 2 program wait states inserted when external space area 7 is accessed 11: 3 program wait states inserted when external space area 7 is accessed
5	W61	1	R/W	Area 6 Wait Control 1 and 0:
4	W60	1	R/W	These bits select the number of program wait states when area 6 in external space is accessed while the AST6 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 6 is accessed 01: 1 program wait state inserted when external space area 6 is accessed 10: 2 program wait states inserted when external space area 6 is accessed 11: 3 program wait states inserted when external space area 6 is accessed

Bit	Bit Name	Initial Value	R/W	Description
3	W51	1	R/W	Area 5 Wait Control 1 and 0:
2	W50	1	R/W	These bits select the number of program wait states when area 5 in external space is accessed while the AST5 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 5 is accessed 01: 1 program wait state inserted when external space area 5 is accessed 10: 2 program wait states inserted when external space area 5 is accessed 11: 3 program wait states inserted when external space area 5 is accessed
1	W41	1	R/W	Area 4 Wait Control 1 and 0:
0	W40	1	R/W	These bits select the number of program wait states when area 4 in external space is accessed while the AST4 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 4 is accessed 01: 1 program wait state inserted when external space area 4 is accessed 10: 2 program wait states inserted when external space area 4 is accessed 11: 3 program wait states inserted when external space area 4 is accessed

- WCRL

Bit	Bit Name	Initial Value	R/W	Description
7	W31	1	R/W	Area 3 Wait Control 1 and 0:
6	W30	1	R/W	These bits select the number of program wait states when area 3 in external space is accessed while the AST3 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 3 is accessed 01: 1 program wait state inserted when external space area 3 is accessed 10: 2 program wait states inserted when external space area 3 is accessed 11: 3 program wait states inserted when external space area 3 is accessed

Bit	Bit Name	Initial Value	R/W	Description
5	W21	1	R/W	Area 2 Wait Control 1 and 0:
4	W20	1	R/W	These bits select the number of program wait states when area 2 in external space is accessed while the AST2 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 2 is accessed 01: 1 program wait state inserted when external space area 2 is accessed 10: 2 program wait states inserted when external space area 2 is accessed 11: 3 program wait states inserted when external space area 2 is accessed
3	W11	1	R/W	Area 1 Wait Control 1 and 0:
2	W10	1	R/W	These bits select the number of program wait states when area 1 in external space is accessed while the AST1 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 1 is accessed 01: 1 program wait state inserted when external space area 1 is accessed 10: 2 program wait states inserted when external space area 1 is accessed 11: 3 program wait states inserted when external space area 1 is accessed
1	W01	1	R/W	Area 0 Wait Control 1 and 0:
0	W00	1	R/W	These bits select the number of program wait states when area 0 in external space is accessed while the AST0 bit in ASTCR is set to 1. 00: Program wait not inserted when external space area 0 is accessed 01: 1 program wait state inserted when external space area 0 is accessed 10: 2 program wait states inserted when external space area 0 is accessed 11: 3 program wait states inserted when external space area 0 is accessed

7.3.4 Bus Control Register H (BCRH)

BCRH selects enabling or disabling of idle cycle insertion, and the memory interface for area 0.

Bit	Bit Name	Initial Value	R/W	Description
7	ICIS1	1	R/W	Idle Cycle Insert 1: Selects whether or not one idle cycle state is to be inserted between bus cycles when successive external read cycles are performed in different areas. 0: Idle cycle not inserted in case of successive external read cycles in different areas 1: Idle cycle inserted in case of successive external read cycles in different areas
6	ICIS0	1	R/W	Idle Cycle Insert 0: Selects whether or not one idle cycle state is to be inserted between bus cycles when successive external read and write cycles are performed. 0: Idle cycle not inserted in case of successive external read and write cycles 1: Idle cycle inserted in case of successive external read and write cycles
5	BRSTRM	0	R/W	Burst ROM enable: Selects whether area 0 is used as a burst ROM interface. 0: Area 0 is basic bus interface 1: Area 0 is burst ROM interface
4	BRSTS1	1	R/W	Burst Cycle Select 1: Selects the number of burst cycles for the burst ROM interface. 0: Burst cycle comprises 1 state 1: Burst cycle comprises 2 states
3	BRSTS0	0	R/W	Burst Cycle Select 0: Selects the number of words that can be accessed in a burst ROM interface burst access. 0: Max. 4 words in burst access 1: Max. 8 words in burst access
2 to 0	–	All 0	R/W	Reserved The write value should always be 0.

7.3.5 Bus Control Register L (BCRL)

BCRL performs selection of the external bus-released state protocol, and enabling or disabling of WAIT pin input.

Bit	Bit Name	Initial Value	R/W	Description
7	BRLE	0	R/W	Bus release enable: Enables or disables external bus release. 0: External bus release is disabled. BREQ and BACK can be used as I/O ports. 1: External bus release is enabled.
6	–	0	R/W	Reserved The write value should always be 0.
5	–	0	–	Reserved This bit is always read as 0 and cannot be modified.
4	–	0	R/W	Reserved The write value should always be 0.
3	–	1	R/W	Reserved The write value should always be 1.
2	–	0	R/W	Reserved
1	–	0	R/W	The write value should always be 0.
0	WAITE	0	R/W	WAIT pin enable: Selects enabling or disabling of wait input by the WAIT pin. 0: Wait input by WAIT pin disabled. WAIT pin can be used as I/O port. 1: Wait input by WAIT pin enabled.

7.3.6 Pin Function Control Register (PFCR)

PFCR performs address output control in external extended mode.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved
6	—	0	R/W	The write value should always be 0.
5	BUZZE	0	R/W	BUZZ Output Enable: This bit selects enabling or disabling of BUZZ output from pin PF1. WDT_1 input clock that is selected by PSS, and CKS2 to CKS0 bits is output as BUZZ signal. 0: PF1 input/output pin 1: BUZZ output pin
4	—	0	R/W	Reserved The write value should always be 0.
3	AE3	1/0*	R/W	Address Output Enable 3 to 0: These bits select enabling or disabling of address outputs A8 to A23 in ROMless extended mode and modes with ROM. When a pin is enabled for address output, the address is output regardless of the corresponding DDR setting. When a pin is disabled for address output, it becomes an output port when the corresponding DDR bit is set to 1. 0000: A8 to A23 output disabled 0001: A8 output enabled; A9 to A23 output disabled 0010: A8, A9 output enabled; A10 to A23 output disabled 0011: A8 to A10 output enabled; A11 to A23 output disabled 0100: A8 to A11 output enabled; A12 to A23 output disabled 0101: A8 to A12 output enabled; A13 to A23 output disabled 0110: A8 to A13 output enabled; A14 to A23 output disabled 0111: A8 to A14 output enabled; A15 to A23 output disabled 1000: A8 t o A15 output enabled; A16 to A23 output disabled 1001: A8 to A16 output enabled; A17 to A23 output disabled 1010: A8 to A17 output enabled; A18 to A23 output disabled 1011: A8 to A18 output enabled; A19 to A23 output disabled 1100: A8 to A19 output enabled; A20 to A23 output disabled 1101: A8 to A20 output enabled; A21 to A23 output disabled 1110: A8 to A21 output enabled; A22, A23 output disabled 1111: A8 to A23 output enabled
2	AE2	1/0*	R/W	
1	AE1	0	R/W	
0	AE0	1/0*	R/W	

Note: * In modes 4 and 5, initial value of each bit is 1. In modes 6 and 7, initial value of each bit is 0.

7.4 Bus Control

7.4.1 Area Divisions

In advanced mode, the bus controller partitions the 16 Mbytes address space into eight areas, 0 to 7, in 2-Mbyte units, and performs bus control for external space in area units. In normal mode*, it controls a 64-kbyte address space comprising part of area 0.

Figure 7.2 shows an outline of the memory map.

Chip select signals (CS0 to CS7) can be output for each area.

Note:* Not available in this LSI.

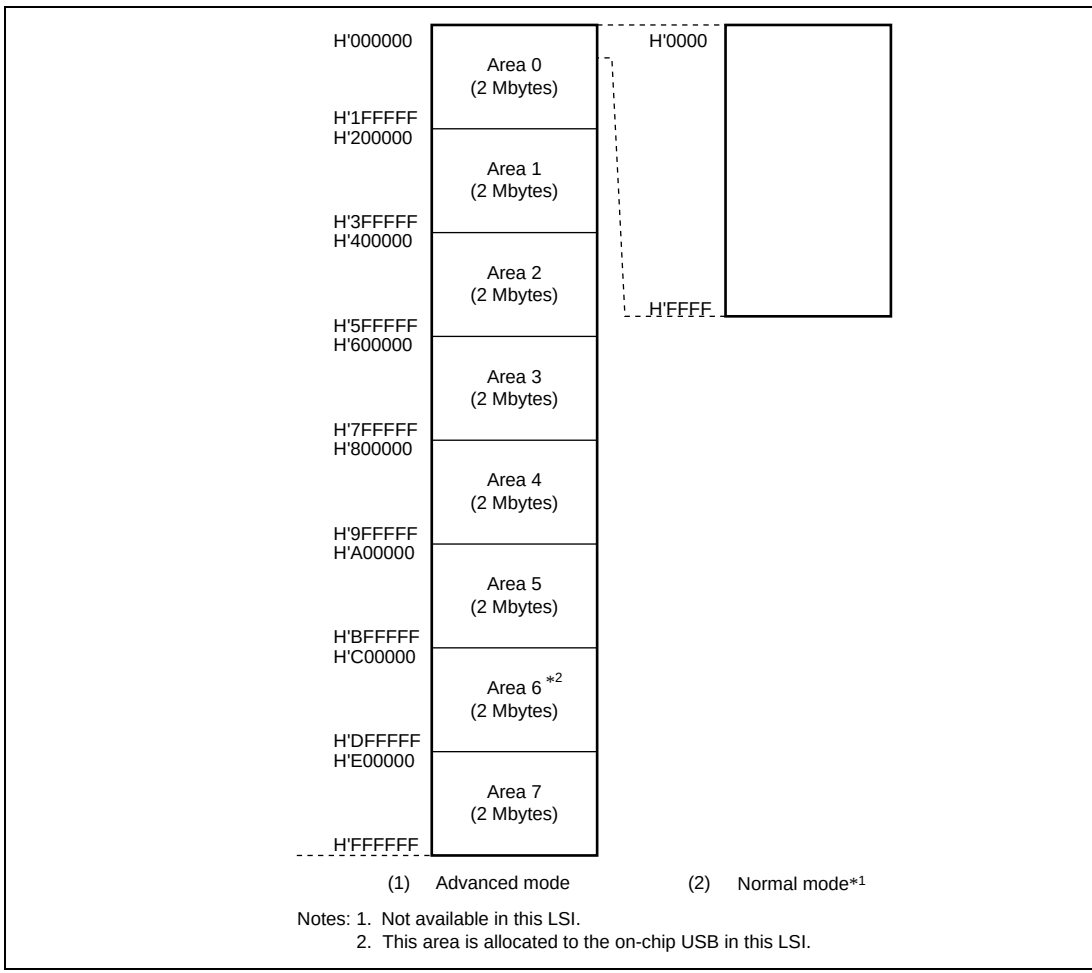


Figure 7.2 Overview of Area Divisions

7.4.2 Bus Specifications

The external space bus specifications consist of three elements: bus width, number of access states, and number of program wait states.

The bus width and number of access states for on-chip memory and internal I/O registers are fixed, and are not affected by the bus controller.

(1) Bus Width: A bus width of 8 or 16 bits can be selected with ABWCR. An area for which an 8-bit bus is selected functions as an 8-bit access space, and an area for which a 16-bit bus is selected functions as a16-bit access space.

If all areas are designated for 8-bit access, 8-bit bus mode is set; if any area is designated for 16-bit access, 16-bit bus mode is set. When the burst ROM interface is designated, 16-bit bus mode is always set.

(2) Number of Access States: Two or three access states can be selected with ASTCR.

An area for which 2-state access is selected functions as a 2-state access space, and an area for which 3-state access is selected functions as a 3-state access space.

With the burst ROM interface, the number of access states may be determined without regard to ASTCR.

When 2-state access space is designated, wait insertion is disabled.

Area 6 should be set to function as a 3-state access space in this LSI.

(3) Number of Program Wait States: When 3-state access space is designated by ASTCR, the number of program wait states to be inserted automatically is selected with WCRH and WCRL.

From 0 to 3 program wait states can be selected.

The number of program wait states in area 6 should be set to 0 in this LSI.

Table 7.2 Bus Specifications for Each Area (Basic Bus Interface)

ABWCR	ASTCR	WCRH, WCRL		Bus Specifications (Basic Bus Interface)		
ABWn	ASTn	Wn1	Wn0	Bus Width	Number of Access States	Number of Program Wait States
0	0	—	—	16	2	0
	1	0	0		3	0
			1			1
		1	0			2
			1			3
1	0	—	—	8	2	0
	1	0	0		3	0
			1			1
		1	0			2
			1			3

7.4.3 Bus Interface for Each Area

The initial state of each area is basic bus interface, 3-state access space. The initial bus width is selected according to the operating mode. The bus specifications described here cover basic items only, and the sections on each memory interface (7.6 and 7.7) should be referred to for further details.

(1) Area 0: Area 0 includes on-chip ROM, and in ROM-disabled extended mode, all of area 0 is external space. In ROM-enabled extended mode, the space excluding on-chip ROM is external space.

When area 0 external space is accessed, the CS0 signal can be output.

Either basic bus interface or burst ROM interface can be selected for area 0.

(2) Areas 1 to 6: In external extended mode, all of areas 1 to 6 is external space. When area 1 to 6 external space is accessed, the CS1 to CS6 pin signals respectively can be output. Only the basic bus interface can be used for areas 1 to 6.

(3) Area 7: Area 7 includes the on-chip RAM and internal l/O registers. In external extended mode, the space excluding the on-chip RAM and internal l/O registers, is external space. The on-chip RAM is enabled when the RAME bit in the system control register (SYSCR) is set to 1; when the RAME bit is cleared to 0, the on-chip RAM is disabled and the corresponding space becomes external space.

When area 7 external space is accessed, the CS7 signal can be output.

Only the basic bus interface can be used for the area 7.

7.4.4 Chip Select Signals

This LSI can output chip select signals (CS0 to CS7) to areas 0 to 7, the signal being driven low when the corresponding external space area is accessed. Figure 7.3 shows an example of CSn (n = 0 to 7) output timing. Enabling or disabling of the CSn signal is performed by setting the data direction register (DDR) for the port corresponding to the particular CSn pin.

In ROM-disabled extended mode, the CS0 pin is placed in the output state after a power-on reset. Pins CS1 to CS7 are placed in the input state after a power-on reset, and so the corresponding DDR should be set to 1 when outputting signals CS1 to CS7 .

In ROM-enabled extended mode, pins CS0 to CS7 are all placed in the input state after a power-on reset, and so the corresponding DDR should be set to 1 when outputting signals CS0 to CS7. For details, see section 10, I/O Ports.

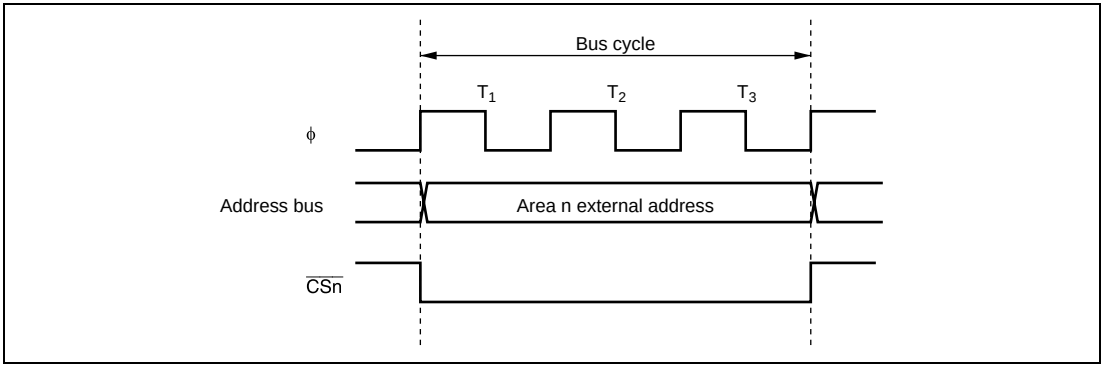


Figure 7.3 CSn Signal Output Timing (n = 0 to 7)

7.5 Basic Timing

The CPU is driven by a system clock (ø), denoted by the symbol ø. The period from one rising edge of ø to the next is referred to as a "state." The memory cycle or bus cycle consists of one, two, or three states. Different methods are used to access on-chip memory, on-chip peripheral modules, and the external address space.

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

On-chip memory is accessed in one state. The data bus is 16 bits wide, permitting both byte and word transfer instruction. Figure 7.4 shows the on-chip memory access cycle. Figure 7.5 shows the pin states.

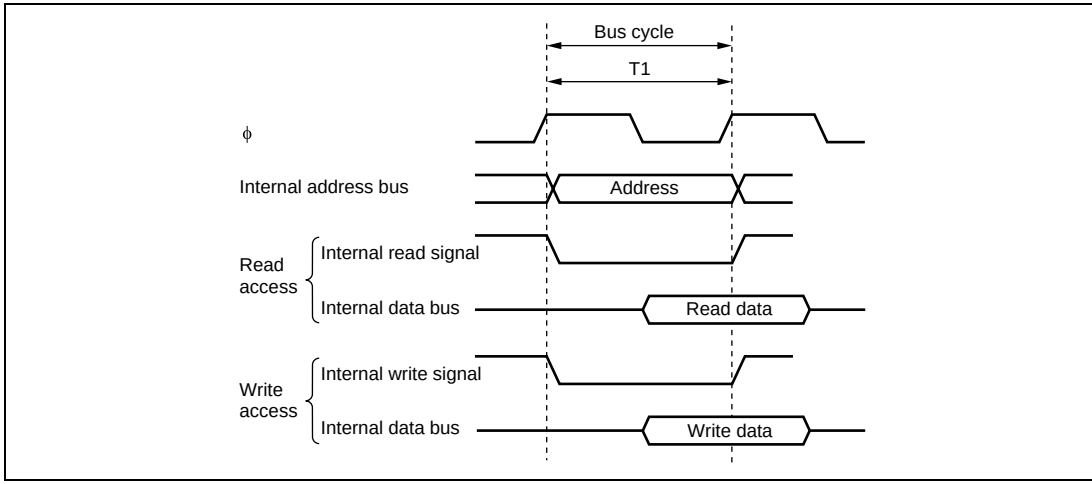


Figure 7.4 On-Chip Memory Access Cycle

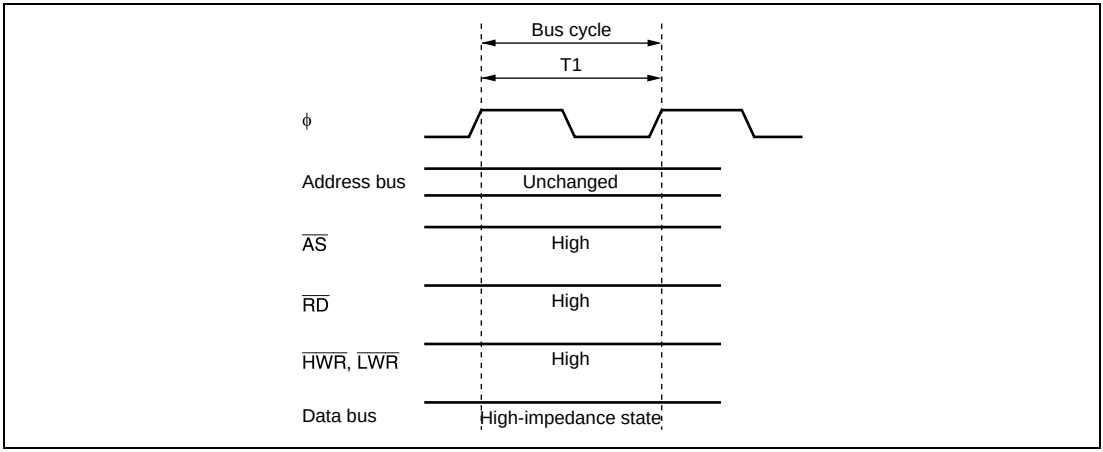


Figure 7.5 Pin States during On-Chip Memory Access

7.5.2 On-Chip Peripheral Module Access Timing

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. Figure 7.6 shows the access timing for the on-chip peripheral modules. Figure 7.7 shows the pin states.

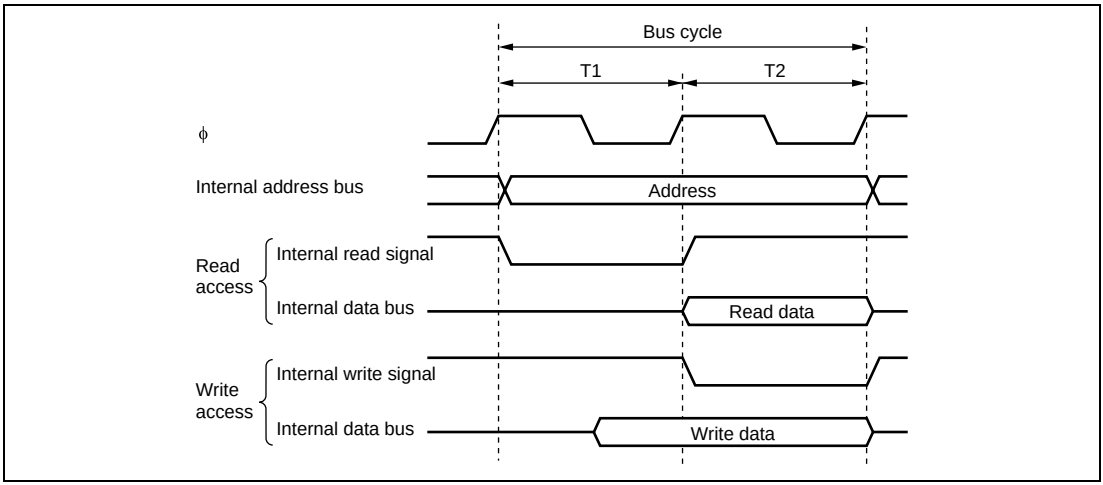


Figure 7.6 On-Chip Peripheral Module Access Cycle

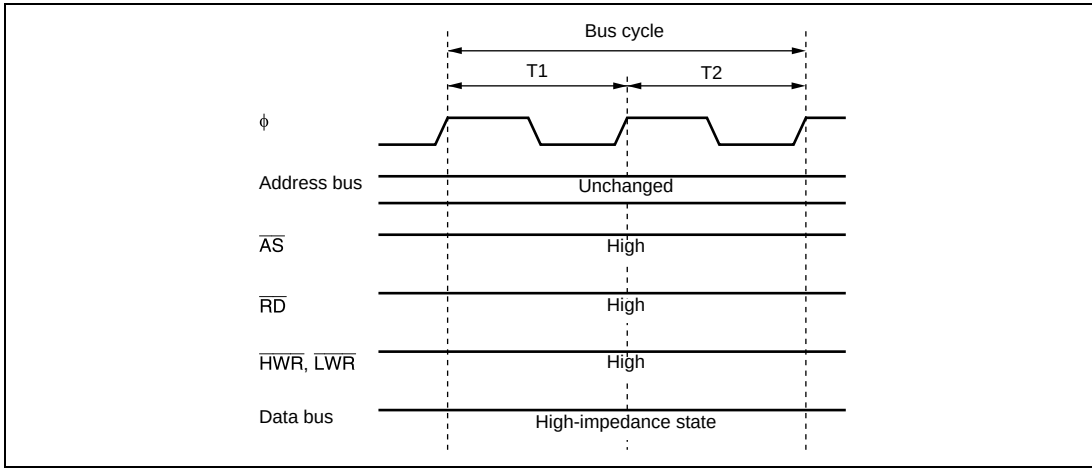


Figure 7.7 Pin States during On-Chip Peripheral Module Access

7.5.3 External Address Space Access Timing

The external address space is accessed with an 8-bit or 16-bit data bus width in a two-state or three-state bus cycleIn three-state access, wait states can be inserted. For further details, refer to section 7.6.3, Basic Timing.

7.6 Basic Bus Interface

The basic bus interface enables direct connection of ROM, SRAM, and so on.

7.6.1 Data Size and Data Alignment

Data sizes for the CPU and other internal bus masters are byte, word, and longword. The bus controller has a data alignment function, and when accessing external space, controls whether the upper data bus (D15 to D8) or lower data bus (D7 to D0) is used according to the bus specifications for the area being accessed (8-bit access space or 16-bit access space) and the data size.

8-Bit Access Space: Figure 7.8 illustrates data alignment control for the 8-bit access space. With the 8-bit access space, the upper data bus (D15 to D8) is always used for accesses. The amount of data that can be accessed at one time is one byte: a word transfer instruction is performed as two-byte accesses, and a longword transfer instruction, as four-byte accesses.

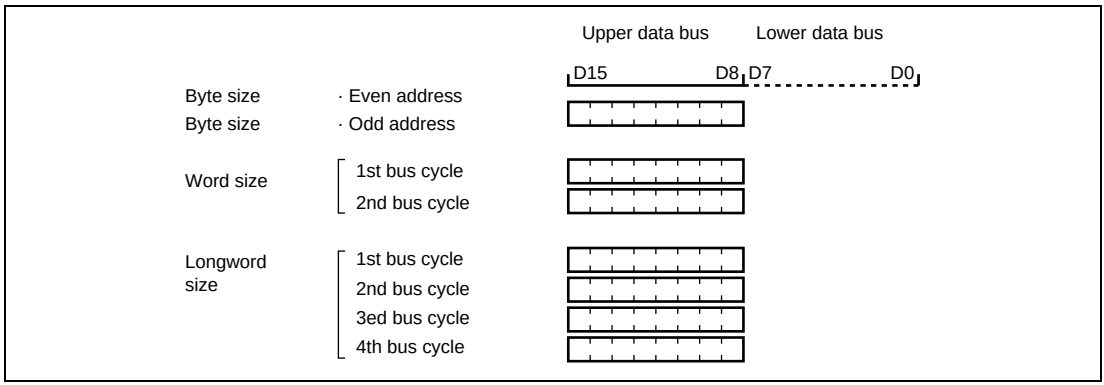


Figure 7.8 Access Sizes and Data Alignment Control (8-Bit Access Space)

16-Bit Access Space: Figure 7.9 illustrates data alignment control for the 16-bit access space. With the 16-bit access space, the upper data bus (D15 to D8) and lower data bus (D7 to D0) are used for accesses. The amount of data that can be accessed at one time is one byte or one word, and a longword transfer instruction is executed as two word transfer instructions.

In byte access, whether the upper or lower data bus is used is determined by whether the address is even or odd. The upper data bus is used for an even address, and the lower data bus for an odd address.

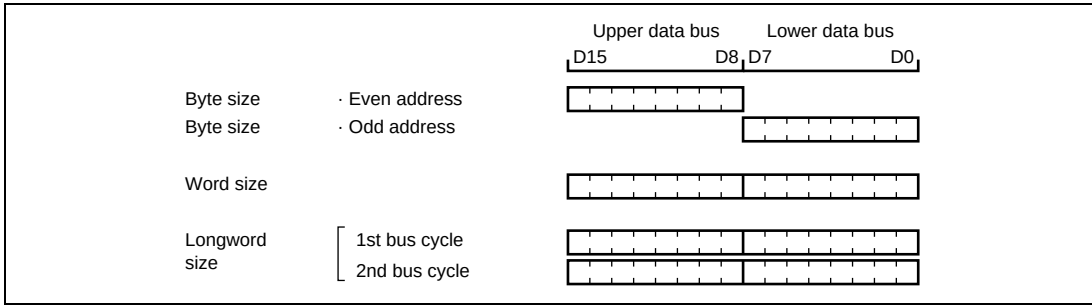


Figure 7.9 Access Sizes and Data Alignment Control (16-Bit Access Space)

7.6.2 Valid Strobes

Table 7.3 shows the data buses used and valid strobes for the access spaces.

In a read, the RD signal is valid without discrimination between the upper and lower halves of the data bus.

In a write, the HWR signal is valid for the upper half of the data bus, and the LWR signal for the lower half.

Table 7.3 Data Buses Used and Valid Strobes

Area	Access Size	Read/ Write	Address	Valid Strobe	Upper Data Bus (D15 to D8)	Lower Data Bus (D7 to D0)
8-bit access space	Byte	Read	–	RD	Valid	Invalid
		Write	–	HWR		Hi-Z
16-bit access space	Byte	Read	Even	RD	Valid	Invalid
			Odd		Invalid	Valid
		Write	Even	HWR	Valid	Hi-Z
			Odd	LWR	Hi-Z	Valid
	Word	Read	–	RD	Valid	Valid
		Write	–	HWR, LWR	Valid	Valid

Note: Hi-Z: High impedance.
Invalid: Input state: input value is ignored.

7.6.3 Basic Timing

8-Bit 2-State Access Space: Figure 7.10 shows the bus timing for an 8-bit 2-state access space. When an 8-bit access space is accessed , the upper half (D15 to D8) of the data bus is used.

Wait states cannot be inserted.

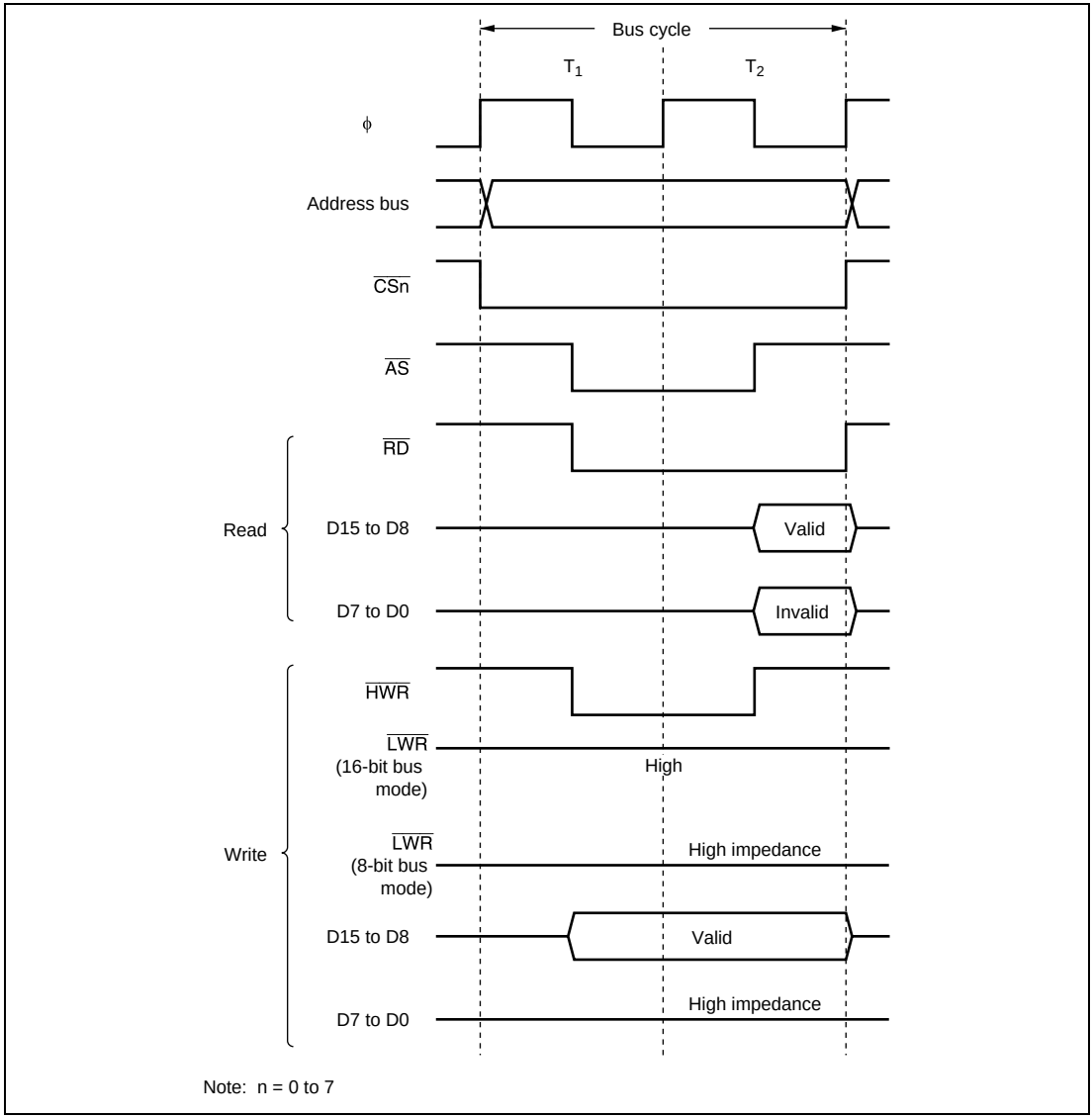


Figure 7.10 Bus Timing for 8-Bit 2-State Access Space

8-Bit 3-State Access Space: Figure 7.11 shows the bus timing for an 8-bit 3-state access space. When an 8-bit access space is accessed, the upper half (D15 to D8) of the data bus is used.

Wait states can be inserted.

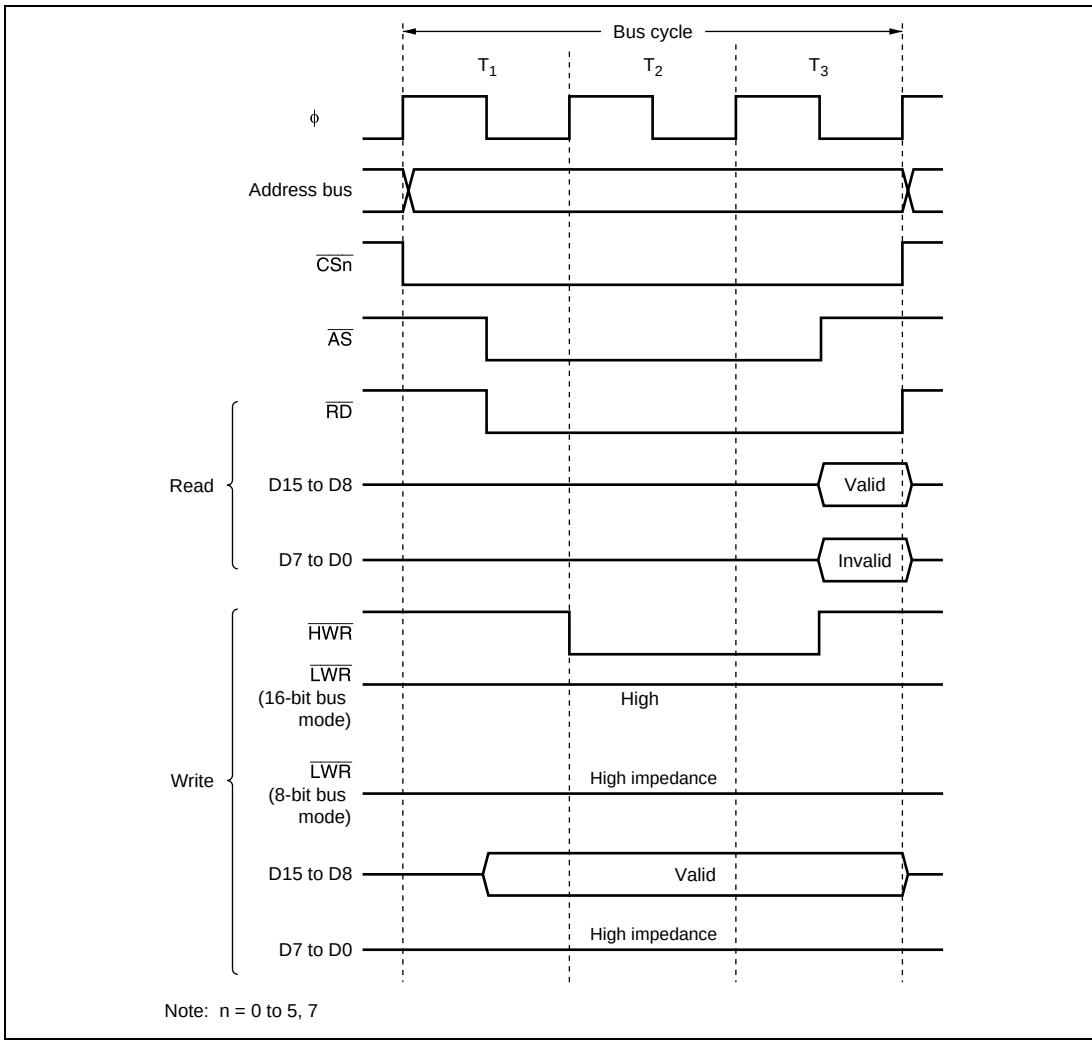


Figure 7.11 Bus Timing for 8-Bit 3-State Access Space

16-Bit 2-State Access Space: Figures 7.12 to 7.14 show bus timings for a 16-bit 2-state access space. When a 16-bit access space is accessed, the upper half (D15 to D8) of the data bus is used for the even address, and the lower half (D7 to D0) for the odd address.

Wait states cannot be inserted.

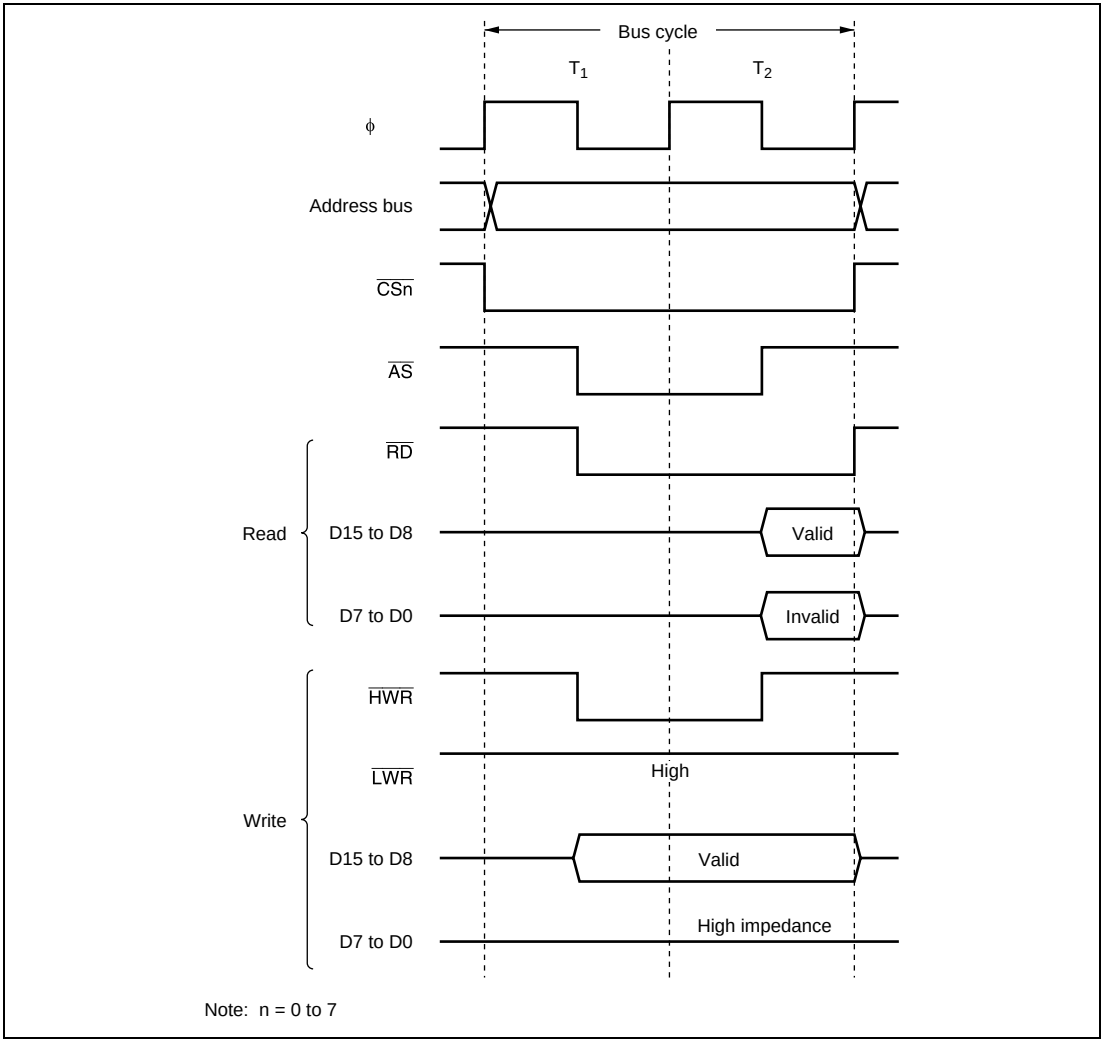


Figure 7.12 Bus Timing for 16-Bit 2-State Access Space (1) (Even Address Byte Access)

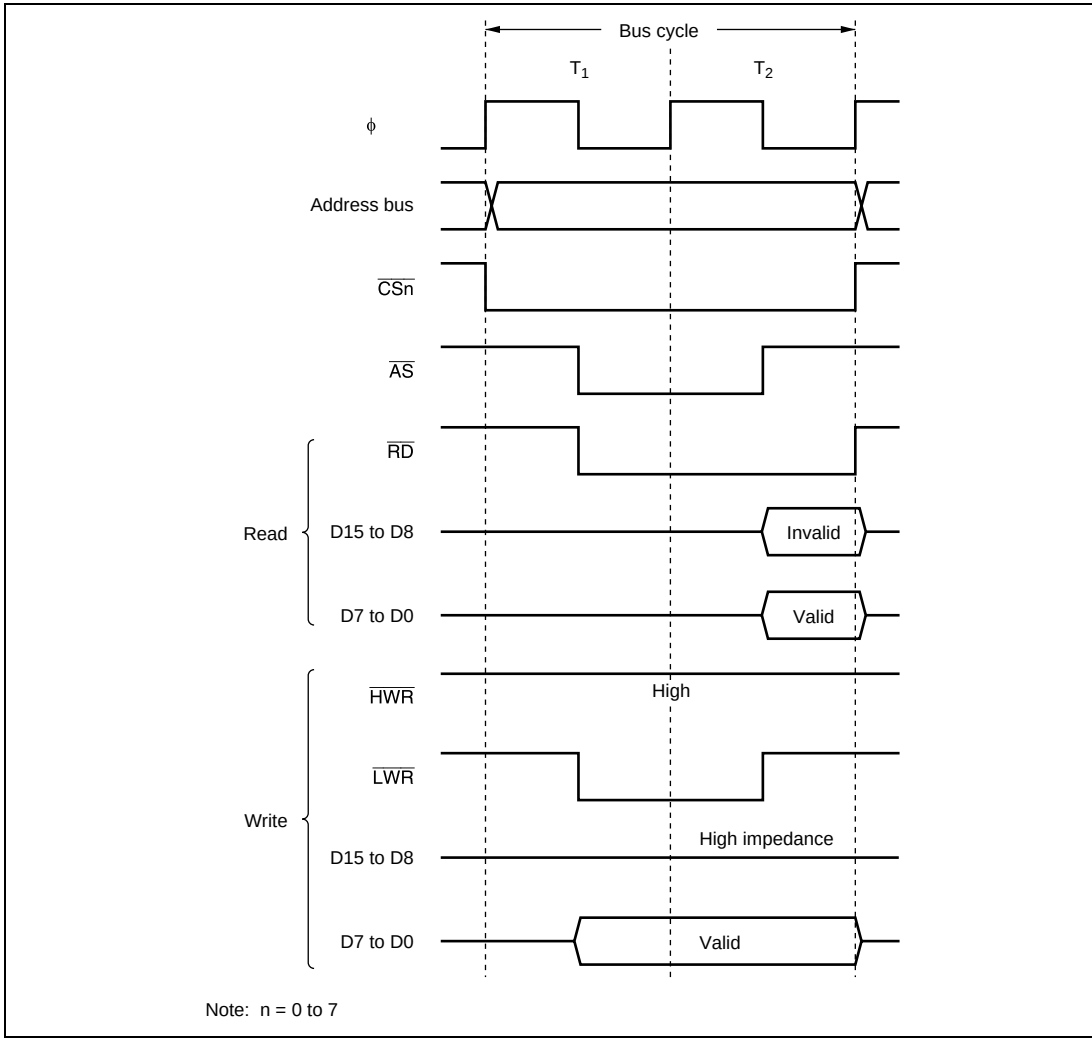


Figure 7.13 Bus Timing for 16-Bit 2-State Access Space (2) (Odd Address Byte Access)

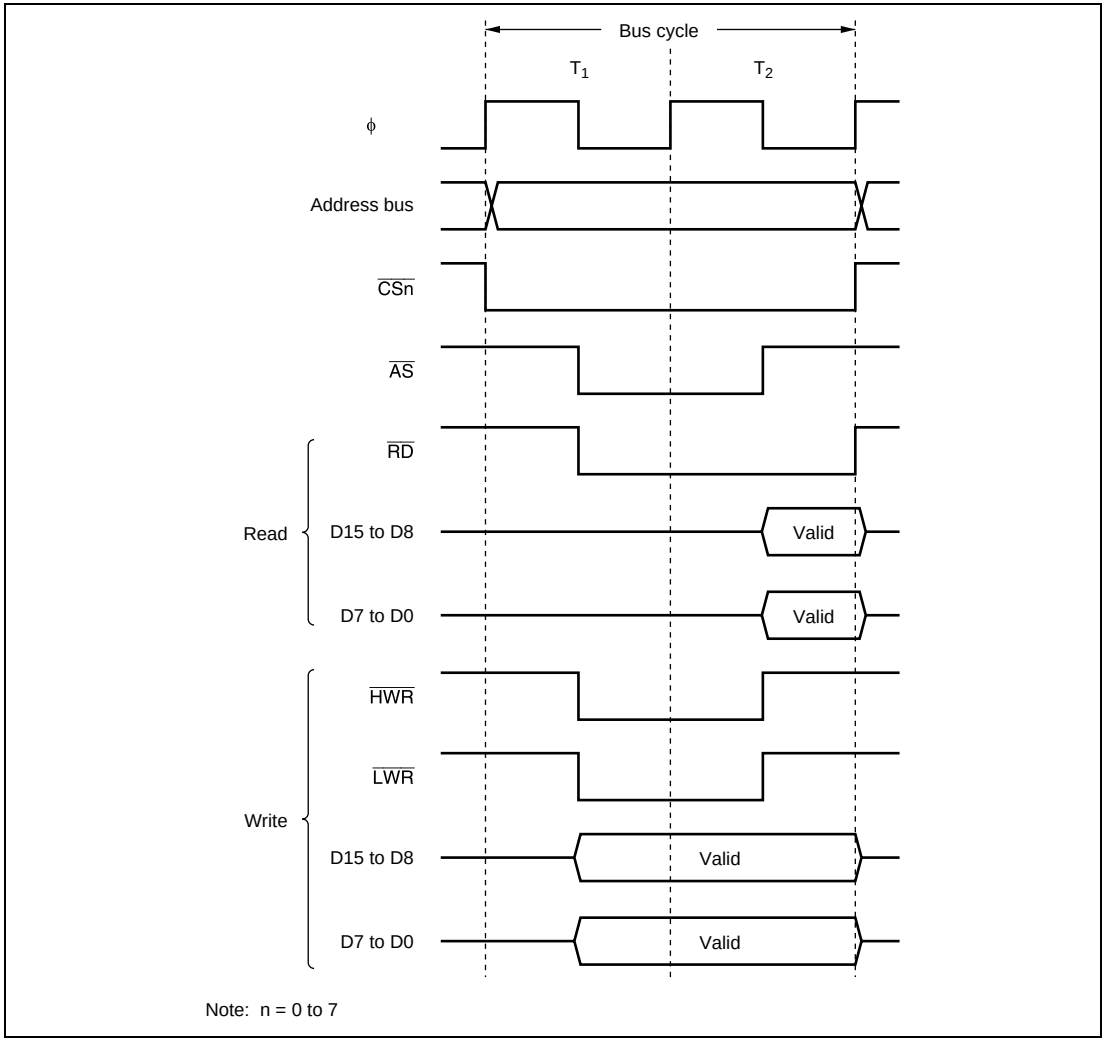


Figure 7.14 Bus Timing for 16-Bit 2-State Access Space (3) (Word Access)

16-Bit 3-State Access Space: Figures 7.15 to 7.17 show bus timings for a 16-bit 3-state access space. When a 16-bit access space is accessed , the upper half (D15 to D8) of the data bus is used for the even address, and the lower half (D7 to D0) for the odd address.

Wait states can be inserted.

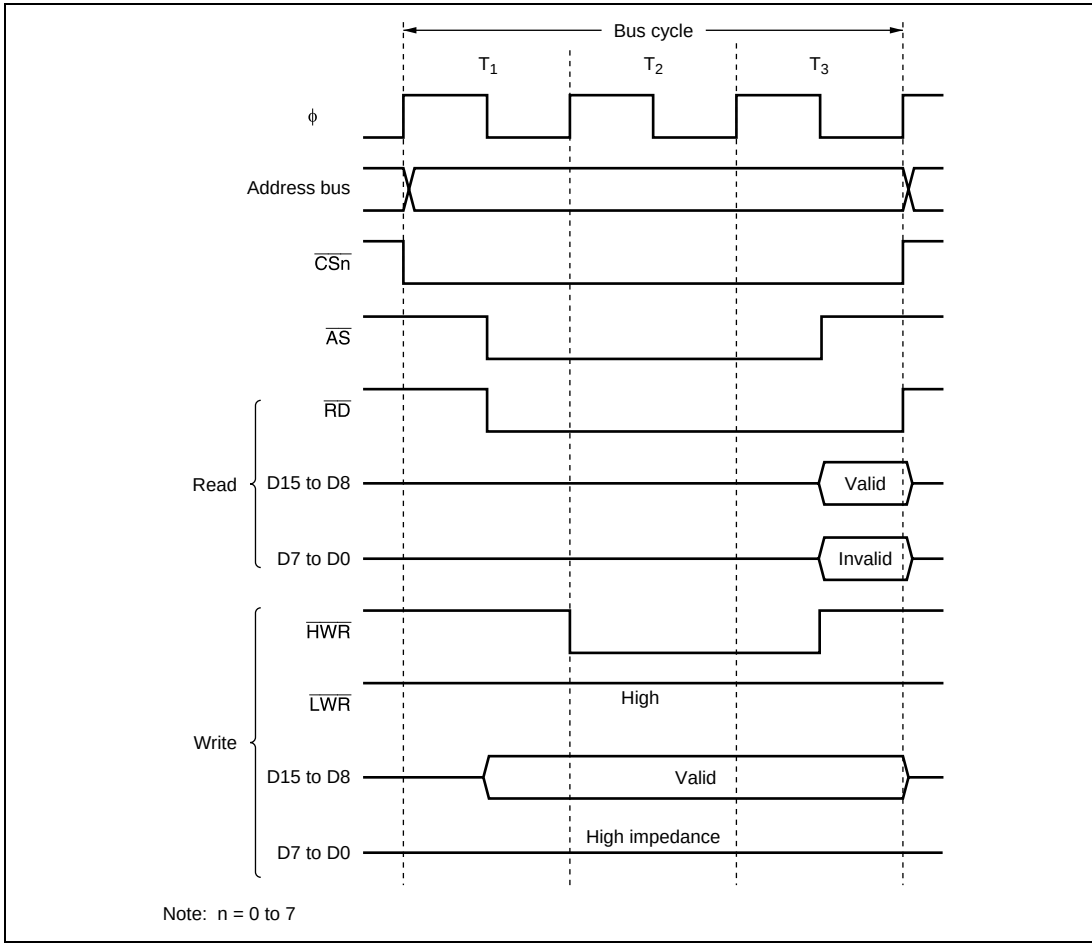


Figure 7.15 Bus Timing for 16-Bit 3-State Access Space (1) (Even Address Byte Access)

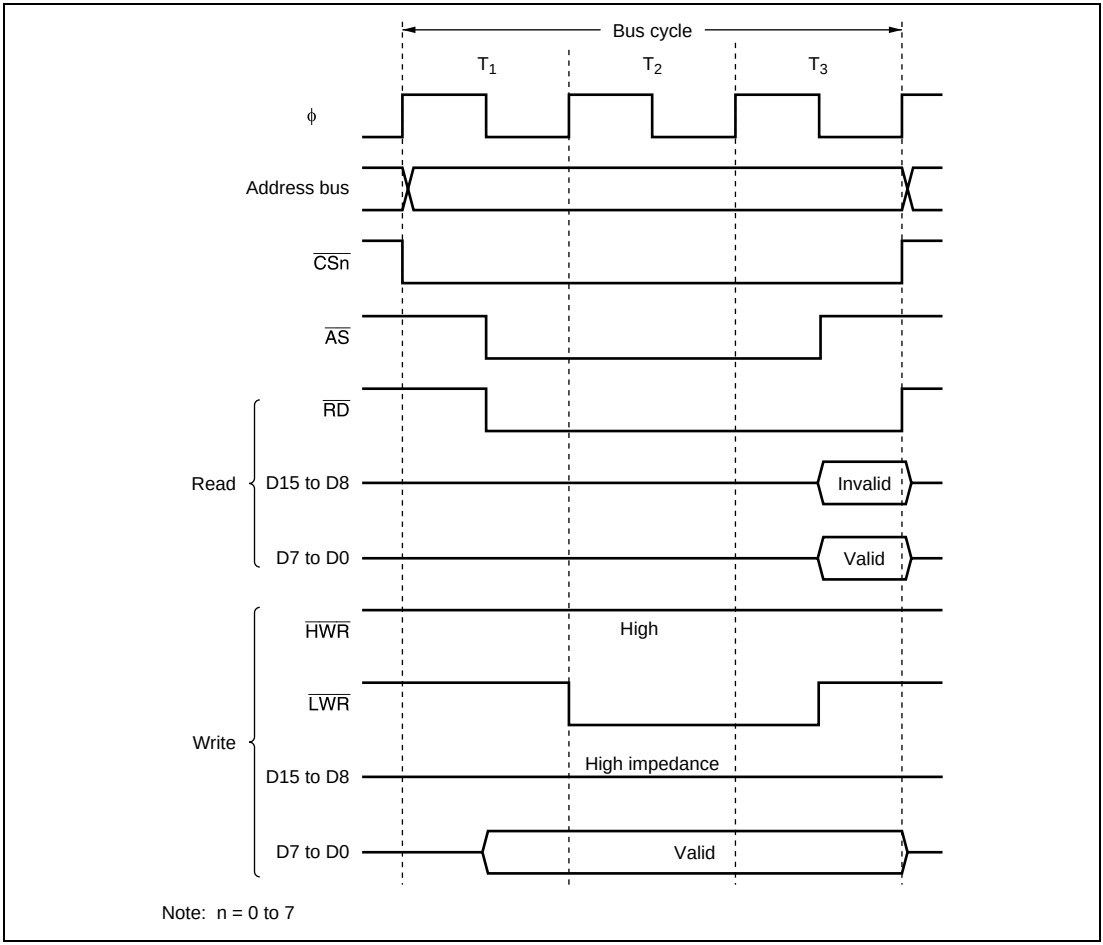


Figure 7.16 Bus Timing for 16-Bit 3-State Access Space (2) (Odd Address Byte Access)

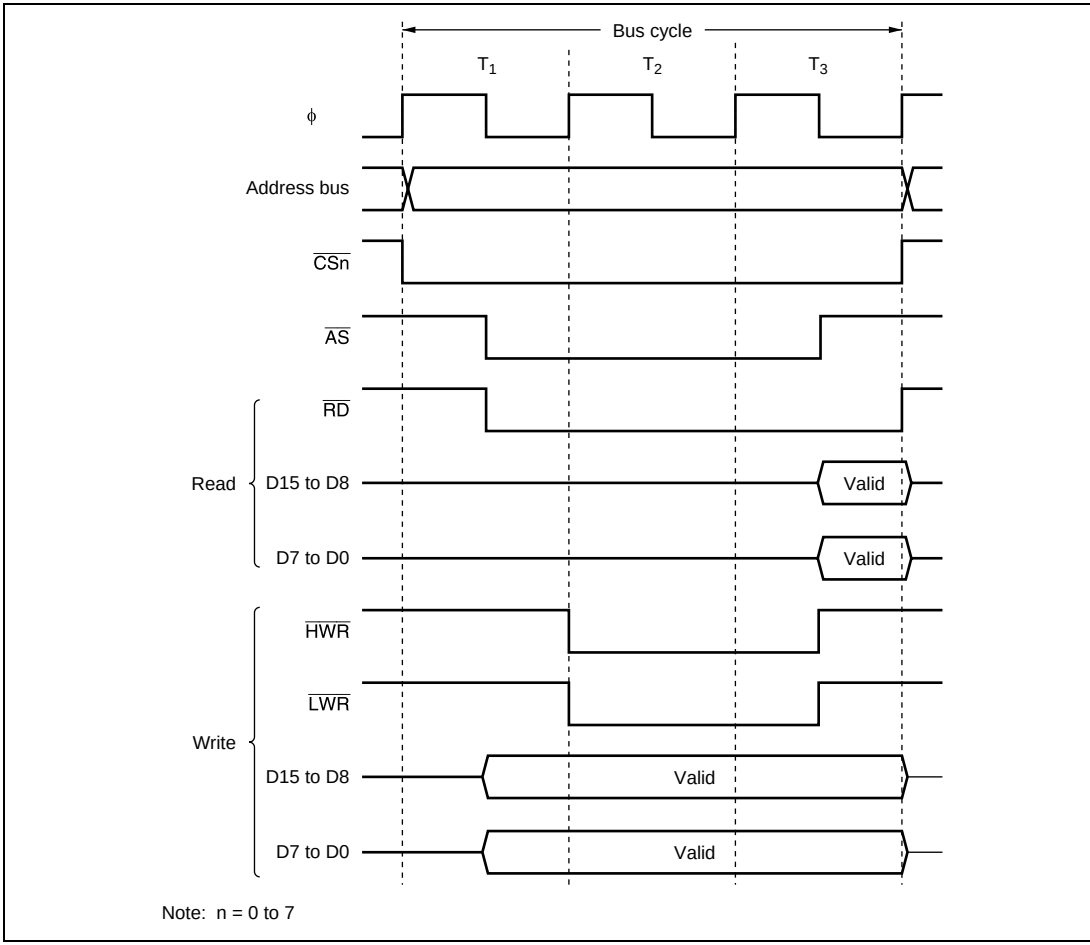


Figure 7.17 Bus Timing for 16-Bit 3-State Access Space (3) (Word Access)

7.6.4 Wait Control

When accessing external space, this LSI can extend the bus cycle by inserting one or more wait states (Tw). There are two ways of inserting wait states: program wait insertion and pin wait insertion using the WAIT pin.

(1) Program Wait Insertion

From 0 to 3 wait states can be inserted automatically between the T_2 state and T_3 state on an individual area basis in 3-state access space, according to the settings of WCRH and WCRL.

(2) Pin Wait Insertion

Setting the WAITE bit in BCRH to 1 enables wait insertion by means of the WAIT pin. When external space is accessed in this state, program wait insertion is first carried out according to the settings in WCRH and WCRL. Then, if the WAIT pin is low at the falling edge of ø in the last T_2 or T_W state, a T_W state is inserted. If the WAIT pin is held low, T_W states are inserted until it goes high.

Figure 7.18 shows an example of wait state insertion timing.

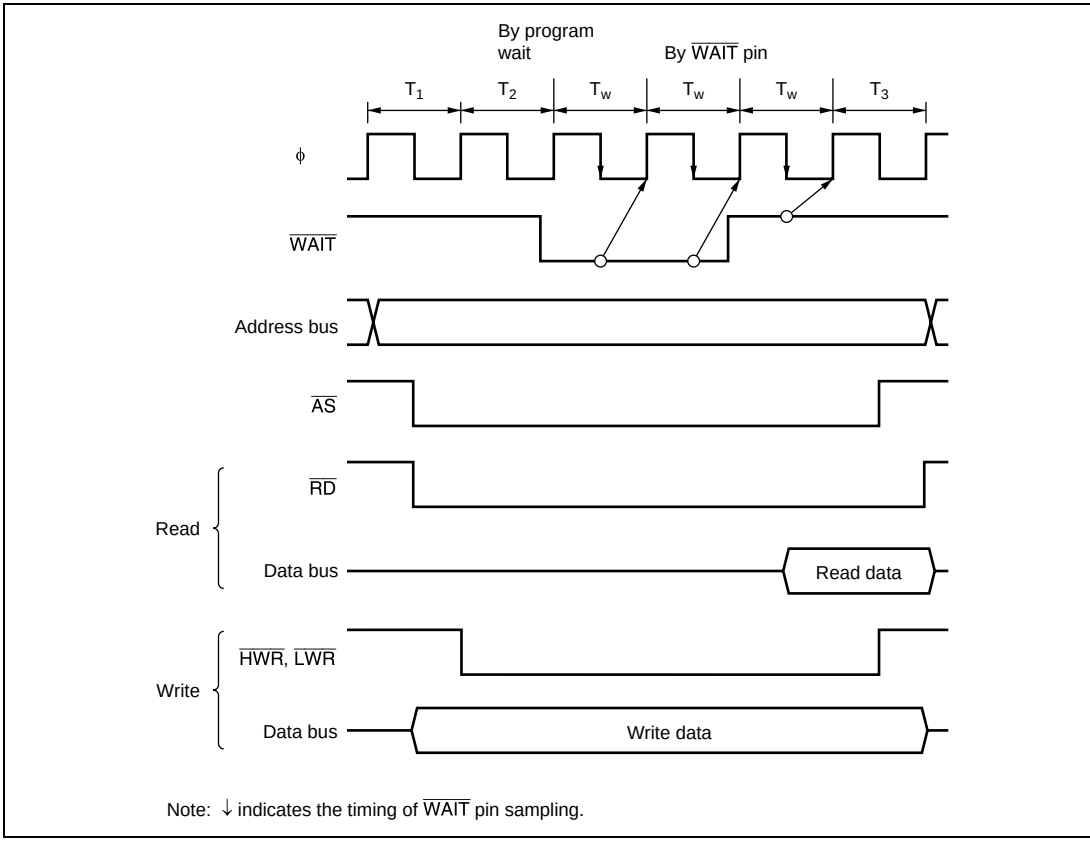


Figure 7.18 Example of Wait State Insertion Timing

7.7 Burst ROM Interface

With this LSI, external space area 0 can be designated as burst ROM space, and burst ROM interfacing can be performed. The burst ROM space interface enables 16-bit configuration ROM with burst access capability to be accessed at high speed.

Area 0 can be designated as burst ROM space by means of the BRSTRM bit in BCRH.

Consecutive burst accesses of a maximum of 4 words or 8 words can be performed for CPU instruction fetches only. One or two states can be selected for burst access.

7.7.1 Basic Timing

The number of states in the initial cycle (full access) of the burst ROM interface is in accordance with the setting of the AST0 bit in ASTCR. Also, when the AST0 bit is set to 1, wait state insertion is possible. One or two states can be selected for the burst cycle, according to the setting of the BRSTS1 bit in BCRH. Wait states cannot be inserted. When area 0 is designated as burst ROM space, it becomes 16-bit access space regardless of the setting of the ABW0 bit in ABWCR.

When the BRSTS0 bit in BCRH is cleared to 0, burst access of up to 4 words is performed; when the BRSTS0 bit is set to 1, burst access of up to 8 words is performed.

The basic access timing for burst ROM space is shown in figures 7.19 and 7.20. The timing shown in figure 7.19 is for the case where the AST0 and BRSTS1 bits are both set to 1, and that in figure 7.20 is for the case where both these bits are cleared to 0.

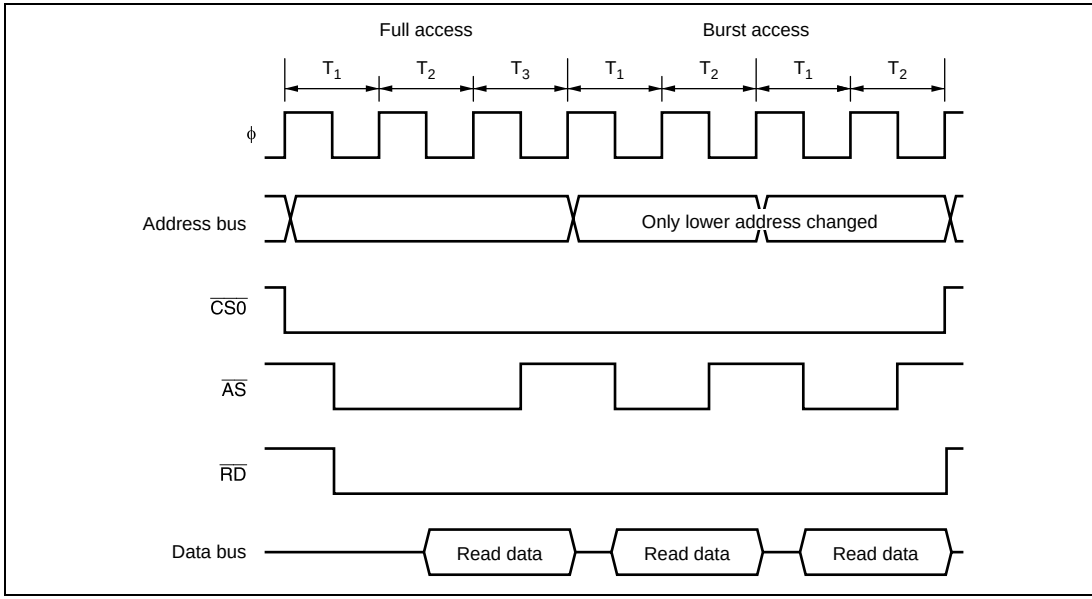


Figure 7.19 Example of Burst ROM Access Timing (When AST0 = BRSTS1 = 1)

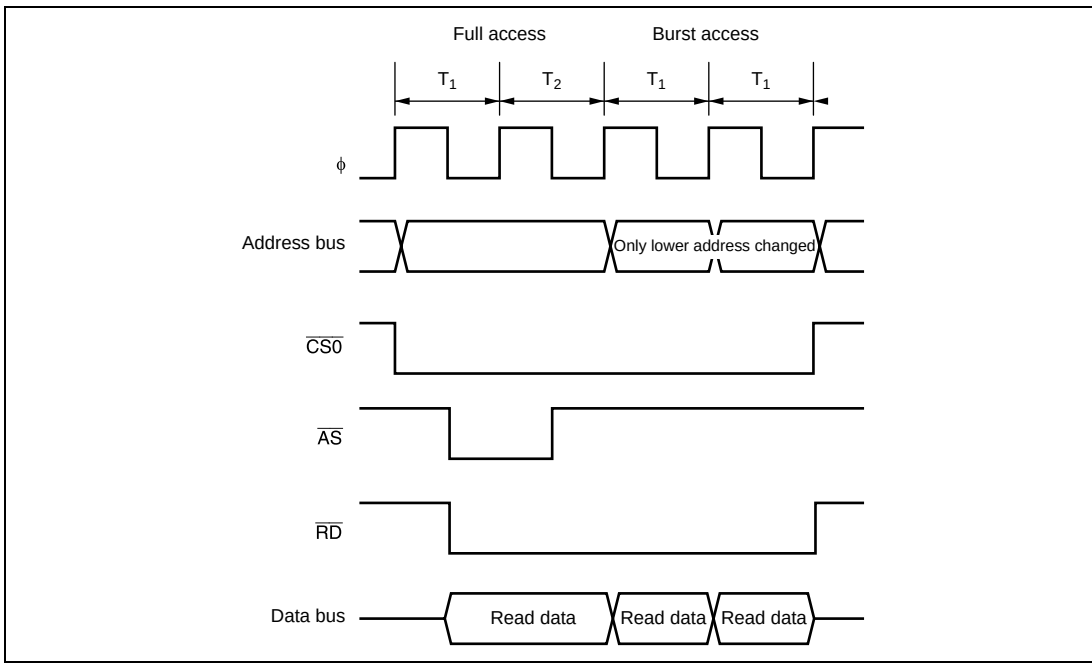


Figure 7.20 Example of Burst ROM Access Timing (When AST0 = BRSTS1 = 0)

7.7.2 Wait Control

As with the basic bus interface, either program wait insertion or pin wait insertion using the WAIT pin can be used in the initial cycle (full access) of the burst ROM interface. See section 7.6.4, Wait Control.

Wait states cannot be inserted in a burst cycle.

7.8 Idle Cycle

When this LSI accesses external space, it can insert a 1-state idle cycle (T_i) between bus cycles in the following two cases: (1) when read accesses between different areas occur consecutively, and (2) when a write cycle occurs immediately after a read cycle. By inserting an idle cycle it is possible, for example, to avoid data collisions between ROM, with a long output floating time, and high-speed memory, I/O interfaces, and so on.

(1) Consecutive Reads between Different Areas

If consecutive reads between different areas occur while the ICIS1 bit in BCRH is set to 1, an idle cycle is inserted at the start of the second read cycle.

Figure 7.21 shows an example of the operation in this case. In this example, bus cycle A is a read cycle from ROM with a long output floating time, and bus cycle B is a read cycle from SRAM, each being located in a different area. In (a), an idle cycle is not inserted, and a collision occurs in cycle B between the read data from ROM and that from SRAM. In (b), an idle cycle is inserted, and a data collision is prevented.

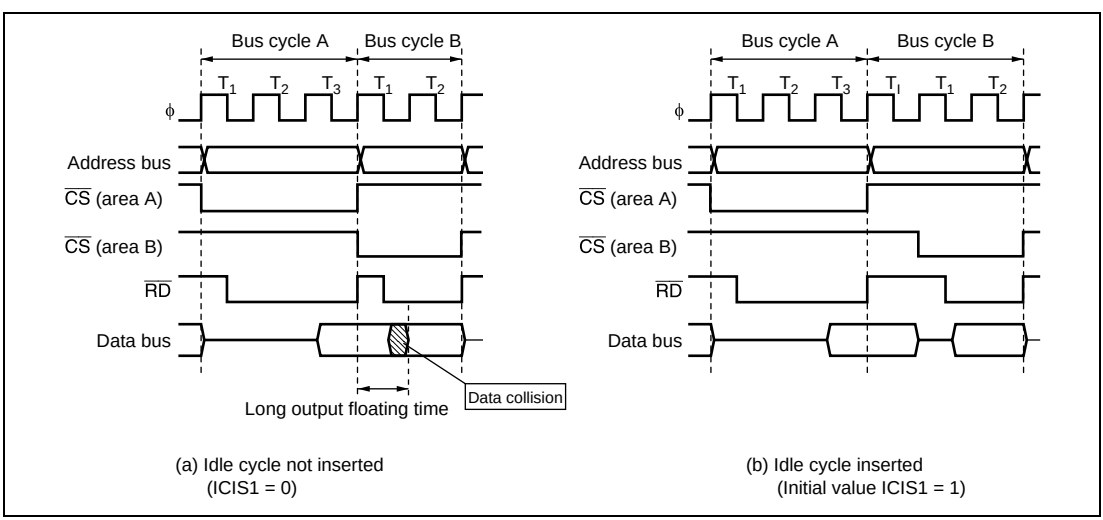


Figure 7.21 Example of Idle Cycle Operation (1)

(2) Write after Read

If an external write occurs after an external read while the ICIS0 bit in BCRH is set to 1, an idle cycle is inserted at the start of the write cycle.

Figure 7.22 shows an example of the operation in this case. In this example, bus cycle A is a read cycle from ROM with a long output floating time, and bus cycle B is a CPU write cycle. In (a), an idle cycle is not inserted, and a collision occurs in cycle B between the read data from ROM and the CPU write data. In (b), an idle cycle is inserted, and a data collision is prevented.

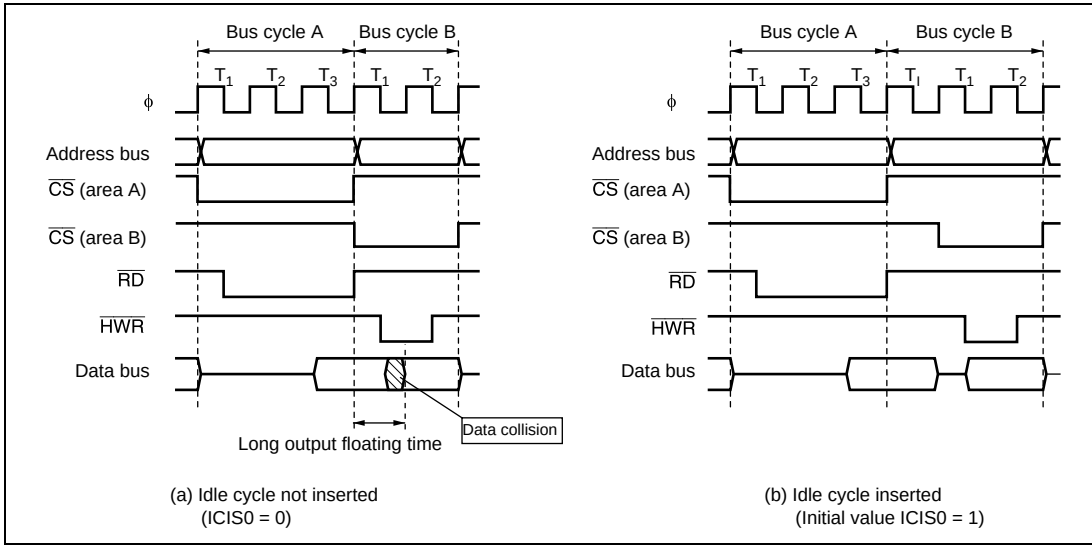


Figure 7.22 Example of Idle Cycle Operation (2)

(3) Relationship between Chip Select (CS) Signal and Read (RD) Signal

Depending on the system's load conditions, the RD signal may lag behind the CS signal. An example is shown in figure 7.23.

In this case, with the setting for no idle cycle insertion (a), there may be a period of overlap between the bus cycle A RD signal and the bus cycle B CS signal.

Setting idle cycle insertion, as in (b), however, will prevent any overlap between the RD and CS signals.

In the initial state after reset release, idle cycle insertion (b) is set.

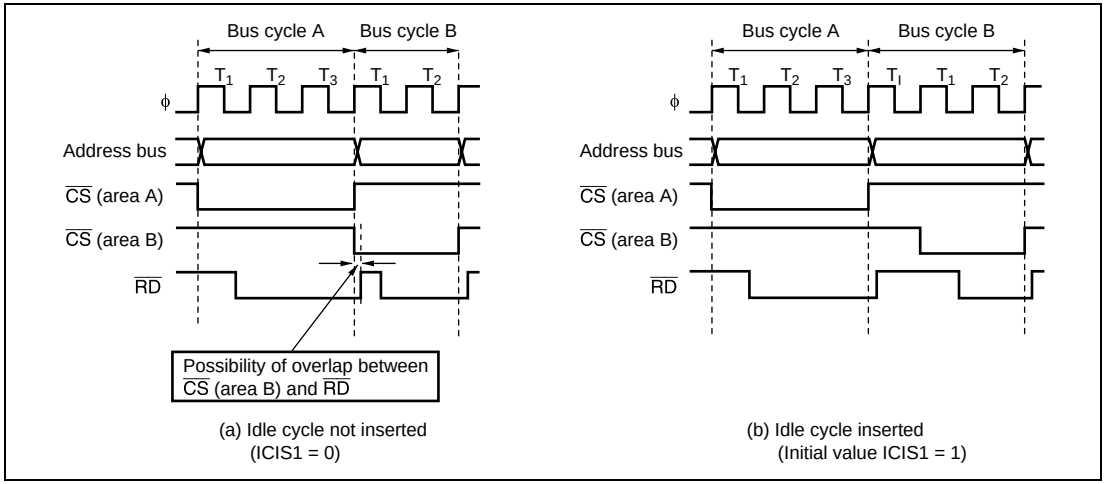


Figure 7.23 Relationship between Chip Select (CS) and Read (RD)

Table 7.4 shows pin states in an idle cycle.

Table 7.4 Pin States in Idle Cycle

Pins	Pin State
A23 to A0	Contents of next bus cycle
D15 to D0	High impedance
CSn	High
AS	High
RD	High
HWR	High
LWR	High

7.9 Bus Release

This LSI can release the external bus in response to a bus request from an external device. In the external bus released state, the internal bus master continues to operate as long as there is no external access.

In external extended mode, the bus can be released to an external device by setting the BRLE bit in BCRL to 1. Driving the BREQ pin low issues an external bus request to this LSI. When the BREQ pin is sampled, at the prescribed timing the BACK pin is driven low, and the address bus, data bus, and bus control signals are placed in the high-impedance state, establishing the external bus-released state.

In the external bus released state, an internal bus master can perform accesses using the internal bus. When an internal bus master wants to make an external access, it temporarily defers activation of the bus cycle, and waits for the bus request from the external bus master to be dropped.

When the BREQ pin is driven high, the BACK pin is driven high at the prescribed timing and the external bus released state is terminated.

In the event of simultaneous external bus release request and external access request generation, the order of priority is as follows:

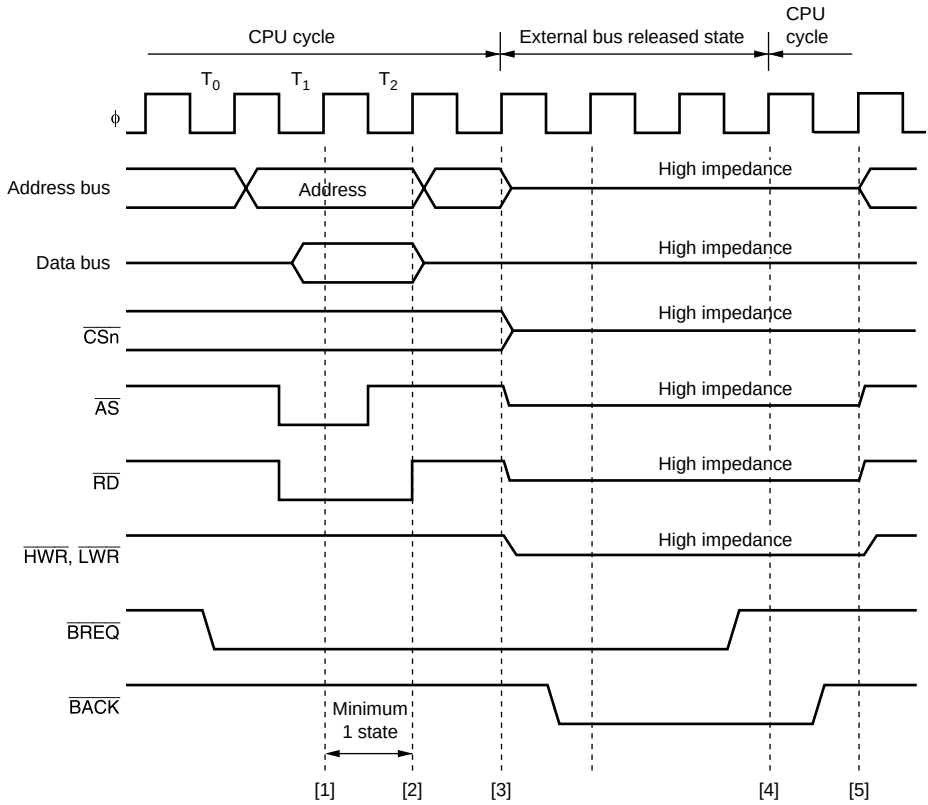
(High) External bus release > Internal bus master external access (Low)

Table 7.5 shows pin states in the external bus released state.

Table 7.5 Pin States in Bus Released State

Pins	Pin State
A23 to A0	High impedance
D15 to D0	High impedance
CSn	High impedance
AS	High impedance
RD	High impedance
HWR	High impedance
LWR	High impedance

Figure 7.24 shows the timing for transition to the bus-released state.



[1] Low level of $\overline{\text{BREQ}}$ pin is sampled at rise of T_2 state.
[2] $\overline{\text{BACK}}$ pin is driven low at end of CPU read cycle, releasing bus to external bus master.
[3] $\overline{\text{BREQ}}$ pin state is still sampled in external bus released state.
[4] High level of $\overline{\text{BREQ}}$ pin is sampled.
[5] $\overline{\text{BACK}}$ pin is driven high, ending bus release cycle.

Note : n = 0 to 7

Figure 7.24 Bus-Released State Transition Timing

7.9.1 Bus Release Usage Note

When MSTPCR is set to H'FFFFFF and transmitted to sleep mode, the external bus release does not function. To activate the external bus release in sleep mode, do not set MSTPCR to H'FFFFFF.

7.10 Bus Arbitration

This LSI has a bus arbiter that arbitrates bus master operations.

There are three bus masters, the CPU, DMAC*, and DTC, which perform read/write operations when they have possession of the bus. Each bus master requests the bus by means of a bus request signal. The bus arbiter determines priorities at the prescribed timing, and permits use of the bus by means of a bus request acknowledge signal. The selected bus master then takes possession of the bus and begins its operation.

Note: * Supported only by the H8S/2239 Series.

7.10.1 Operation

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) DMAC* > DTC > CPU (Low)

An internal bus access by an internal bus master, and external bus release, can be executed in parallel.

In the event of simultaneous external bus release request, and internal bus master external access request generation, the order of priority is as follows:

(High) External bus release > Internal bus master external access (Low)

Note: * Supported only by the H8S/2239 Series.

7.10.2 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. There are specific times at which each bus master can relinquish the bus.

CPU: The CPU is the lowest-priority bus master, and if a bus request is received from the DMAC* and 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 the operations.
- If the CPU is in sleep mode, it transfers the bus immediately.

Note: * Supported only by the H8S/2239 Series.

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

The DTC can release the bus after a vector read, a register information read (3 states), a single data transfer, or a register information write (3 states). It does not release the bus during a register information read (3 states), a single data transfer, or a register information write (3 states).

DMAC (only by the H8S/2239 Series): The DMAC sends the bus arbiter a request for the bus when an activation request is generated.

In the case of an external request in short address mode or normal mode, and in cycle steal mode, the DMAC releases the bus after a single transfer.

In block transfer mode, it releases the bus after transfer of one block, and in burst mode, after completion of the transfer.

7.10.3 External Bus Release Usage Note

External bus release can be performed on completion of an external bus cycle. The $\overline{CS}$ signal remains low until the end of the external bus cycle. Therefore, when external bus release is performed, the $\overline{CS}$ signal may change from the low level to the high-impedance state.

7.11 Resets and the Bus Controller

In a power-on reset, this LSI, including the bus controller, enters the reset state at that point, and an executing bus cycle is discontinued.

In a manual reset, the bus controller's registers and internal state are maintained, and an executing external bus cycle is completed. In this case, WAIT input is ignored and write data is not guaranteed.

When the DMAC* is initialized at the manual reset, DACK and TEND output is disabled. The DMAC* operates as I/O port controlled by DDR and DR.

Note: * Supported only by the H8S/2239 Series.

Section 8 DMA Controller (DMAC)

The H8S/2239 Series has a built-in DMA controller (DMAC) which can carry out data transfer on up to 4 channels.

Note: The DMAC is supported only by the H8S/2239 Series. It is not available in the H8S/2238R Series, H8S/2237 Series, or H8S/2227 Series.

8.1 Features

- Selectable as short address mode or full address mode

  Short address mode

  Maximum of 4 channels can be used

  Dual address mode or single address mode can be selected

  In dual address mode, one of the two addresses, transfer source and transfer destination, is specified as 24 bits and the other as 16 bits

  In single address mode, transfer source or transfer destination address only is specified as 24 bits

  In single address mode, transfer can be performed in one bus cycle

  Choice of sequential mode, idle mode, or repeat mode for dual address mode and single address mode

  Full address mode

  Maximum of 2 channels can be used

  Transfer source and transfer destination addresses as specified as 24 bits

  Choice of normal mode or block transfer mode
- 16-Mbyte address space can be specified directly
- Byte or word can be set as the transfer unit
- Activation sources: internal interrupt, external request, auto-request (depending on transfer mode)

  Six 16-bit timer-pulse unit (TPU) compare match/input capture interrupts

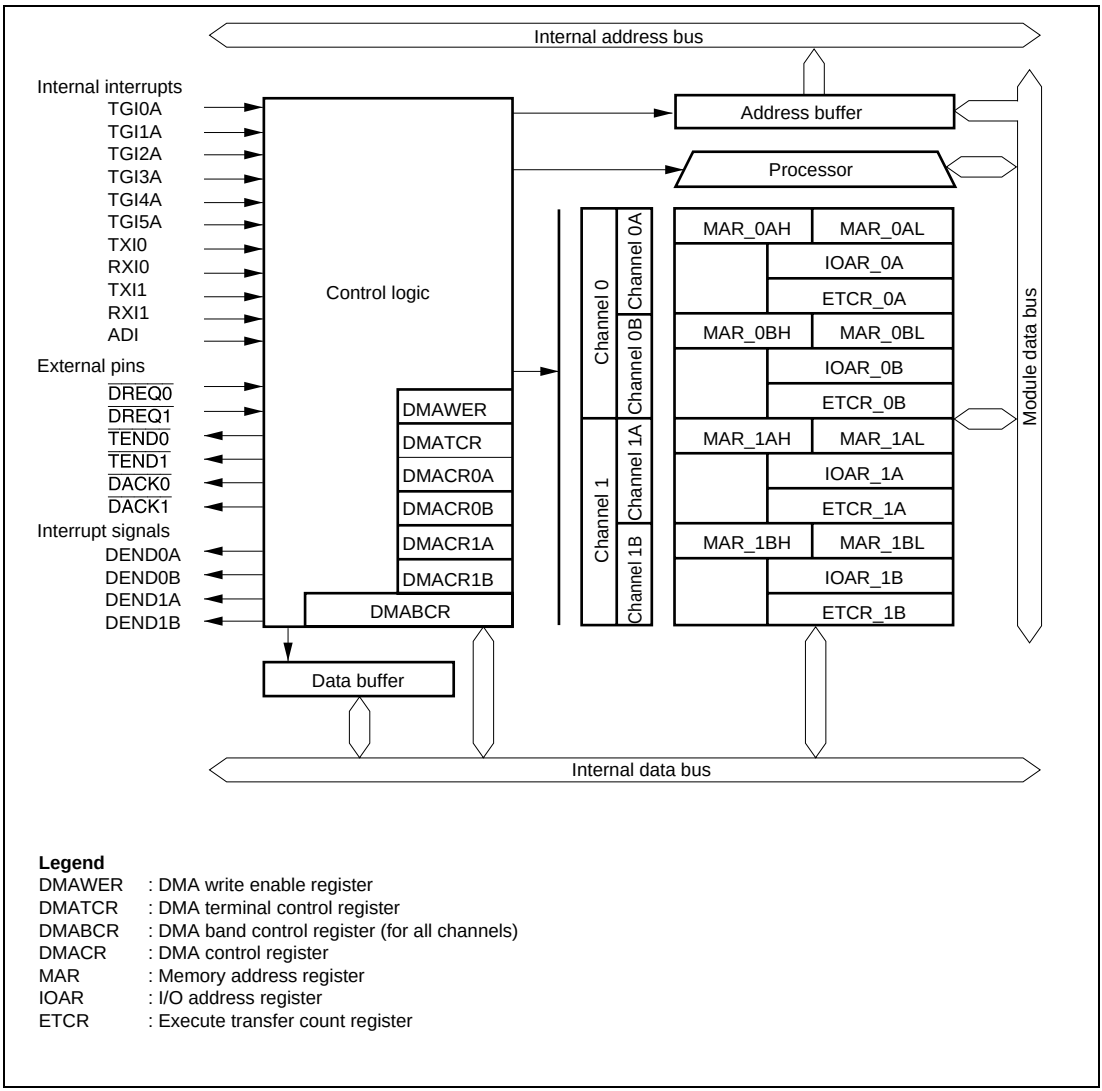
  Serial communication interface (SCI_0, SCI_1) transmit-data-empty interrupt, receive-data-full interrupt

  A/D converter conversion end interrupt

  External request

  Auto-request
- Module stop mode can be set

A block diagram of the DMAC is shown in figure 8.1.



Legend

DMAWER	: DMA write enable register
DMATCR	: DMA terminal control register
DMABCR	: DMA band control register (for all channels)
DMACR	: DMA control register
MAR	: Memory address register
IOAR	: I/O address register
ETCR	: Execute transfer count register

Figure 8.1 Block Diagram of DMAC

8.2 Input/Output Pins

Table 8.1 shows the pin configuration of the interrupt controller.

Table 8.1 Pin Configuration

Channel	Pin Name	Symbol	I/O	Function
0	DMA request 0	DREQ0	Input	Channel 0 external request
	DMA transfer acknowledge 0	DACK0	Output	Channel 0 single address transfer acknowledge
	DMA transfer end 0	TEND0	Output	Channel 0 transfer end
1	DMA request 1	DREQ1	Input	Channel 1 external request
	DMA transfer acknowledge 1	DACK1	Output	Channel 1 single address transfer acknowledge
	DMA transfer end 1	TEND1	Output	Channel 1 transfer end

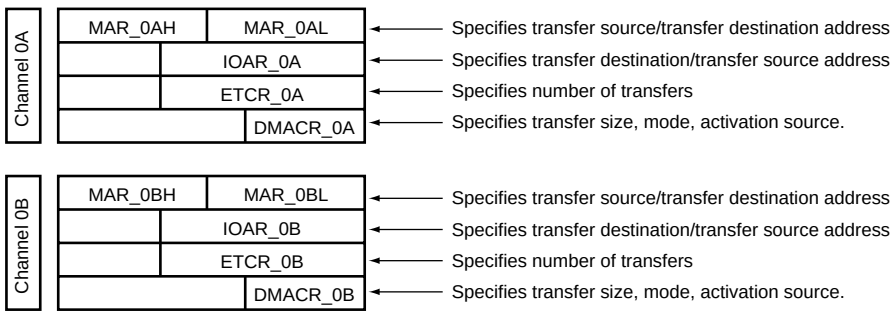
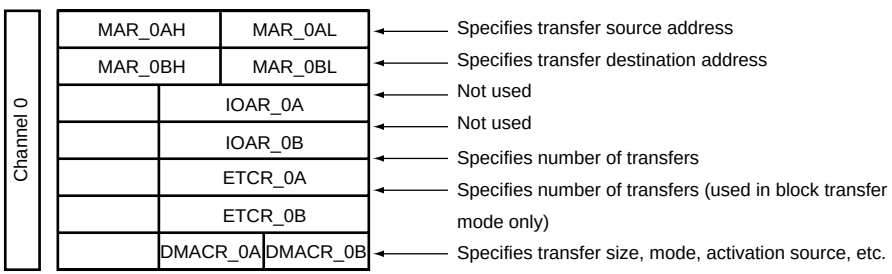
8.3 Register Descriptions

- Memory address register_0AH (MAR_0AH)
- Memory address register_0AL (MAR_0AL)
- I/O address register_0A (IOAR_0A)
- Transfer count register_0A (ECTR_0A)
- Memory address register_0BH (MAR_0BH)
- Memory address register_0BL (MAR_0BL)
- I/O address register_0B (IOAR_0B)
- Transfer count register_0B (ECTR_0B)
- Memory address register_1AH (MAR_1AH)
- Memory address register_1AL (MAR_1AL)
- I/O address register_1A (IOAR_1A)
- Transfer count register_1A (ETCR_1B)
- Memory address register_1BH (MAR_1BH)
- Memory address register_1BL (MAR_1BL)
- I/O address register_1B (IOAR_1B)
- Transfer count register_1B (ETCR_1B)
- DMA control register_0A (DMACR_0A)
- DMA control register_0B (DMACR_0B)
- DMA control register_1A (DMACR_1A)
- DMA control register_1B (DMACR_1B)

- DMA band control register H (DMABCRH)
- DMA band control register L (DMABCRL)
- DMA write enable register (DMAWER)
- DMA terminal control register (DMATCR)

The functions of MAR, IOAR, ETCR, DMACR, and DMABCR differ according to the transfer mode (short address mode or full address mode). The transfer mode can be selected by means of the FAE1 and FAE0 bits in DMABCRH. The register configurations for short address mode and full address mode of channel 0 are shown in table 8.2.

Table 8.2 Short Address Mode and Full Address Mode (Channel 0)

FAE0	Description
0	Short address mode specified (channels 0A and 0B operate independently) 
1	Full address mode specified (channels 0A and 0B operate in combination as channel 0) 

8.3.1 Memory Address Registers (MARA and MARB)

MAR is a 32-bit readable/writable register that specifies the source address (transfer source address) or destination address (transfer destination address). MAR consists of two 16-bit registers MARH and MARL. The upper 8 bits of MARH are reserved: they are always read as 0, and cannot be modified.

The DMA has four MAR registers: MAR_0A in channel 0 (channel 0A), MAR_0B in channel 0 (channel 0B), MAR_1A in channel 1 (channel 1A), and MAR_1B in channel 1 (channel 1B).

MAR is not initialized by a reset or in standby mode.

Short Address Mode: In short address mode, MARA and MARB operate independently. Whether MAR functions as the source address register or as the destination address register can be selected by means of the DTDIR bit in DMACR.

MAR is incremented or decremented each time a byte or word transfer is executed, so that the address specified by MAR is constantly updated.

Full Address Mode: In full address mode, MARA functions as the source address register, and MARB as the destination address register.

MAR is incremented or decremented each time a byte or word transfer is executed, so that the source or destination address is constantly updated.

8.3.2 I/O Address Registers (IOARA and IOARB)

IOAR is a 16-bit readable/writable register that specifies the lower 16 bits of the source address (transfer source address) or destination address (transfer destination address). The upper 8 bits of the transfer address are automatically set to H'FF.

The DMA has four IOAR registers: IOAR_0A in channel 0 (channel 0A), IOAR_0B in channel 0 (channel 0B), IOAR_1A in channel 1 (channel 1A), and IOAR_1B in channel 1 (channel 1B).

Whether IOAR functions as the source address register or as the destination address register can be selected by means of the DTDIR bit in DMACR.

IOAR is not incremented or decremented each time a data transfer is executed, so the address specified by IOAR is fixed.

IOAR is not initialized by a reset or in standby mode.

IOAR can be used in short address mode but not in full address mode.

8.3.3 Execute Transfer Count Registers (ETCRA and ETCRB)

ETCR is a 16-bit readable/writable register that specifies the number of transfers.

The DMA has four ETCR registers: ETCR_0A in channel 0 (channel 0A), ETCR_0B in channel 0 (channel 0B), ETCR_1A in channel 1 (channel 1A), and ETCR_1B in channel 1 (channel 1B).

ETCR is not initialized by a reset or in standby mode.

Short Address Mode: The function of ETCR in sequential mode and idle mode differs from that in repeat mode.

In sequential mode and idle mode, ETCR functions as a 16-bit transfer counter. ETCR is decremented by 1 each time a transfer is performed, and when the count reaches H'00, the DTE bit in DMABCRL is cleared, and transfer ends.

In repeat mode, ETCRL functions as an 8-bit transfer counter and ETCRH functions as a transfer count holding register. ETCRL is decremented by 1 each time a transfer is performed, and when the count reaches H'00, ETCRL is loaded with the value in ETCRH. At this point, MAR is automatically restored to the value it had when the count was started. The DTE bit in DMABCRL is not cleared, and so transfers can be performed repeatedly until the DTE bit is cleared by the user.

Full Address Mode: The function of ETCR in normal mode differs from that in block transfer mode.

In normal mode, ETCRA functions as a 16-bit transfer counter. ETCRA is decremented by 1 each time a data transfer is performed, and transfer ends when the count reaches H'0000. ETCRB is not used in normal mode.

In block transfer mode, ETCRAL functions as an 8-bit block size counter and ETCRAH functions as a block size holding register. ETCRAL is decremented by 1 each time a 1-byte or 1-word transfer is performed, and when the count reaches H'00, ETCRAL is loaded with the value in ETCRAH. So by setting the block size in ETCRAH and ETCRAL, it is possible to repeatedly transfer blocks consisting of any desired number of bytes or words.

In block transfer mode, ETCRB functions as a 16-bit block transfer counter. ETCRB is decremented by 1 each time a block is transferred, and transfer ends when the count reaches H'0000.

8.3.4 DMA Control Registers (DMACRA and DMACRB)

DMACR controls the operation of each DMAC channel.

The DMA has four DMACR registers: DMACR_0A in channel 0 (channel 0A), DMACR_0B in channel 0 (channel 0B), DMACR_1A in channel 1 (channel 1A), and DMACR_1B in channel 1 (channel 1B).

In short address mode, channels A and B operate independently, and in full address mode, channels A and B operate together. The bit functions in the DMACR registers differ according to the transfer mode.

Short Address Mode:

- DMACR_0A, DMACR_0B, DMACR_1A, and DMARC_1B

Bit	Bit Name	Initial Value	R/W	Description
7	DTSZ	0	R/W	Data Transfer Size Selects the size of data to be transferred at one time. 0: Byte-size transfer 1: Word-size transfer
6	DTID	0	R/W	Data Transfer Increment/Decrement Selects incrementing or decrementing of MAR after every data transfer in sequential mode or repeat mode. In idle mode, MAR is neither incremented nor decremented. 0: MAR is incremented after a data transfer (Initial value) • When DTSZ = 0, MAR is incremented by 1 • When DTSZ = 1, MAR is incremented by 2 1: MAR is decremented after a data transfer • When DTSZ = 0, MAR is decremented by 1 • When DTSZ = 1, MAR is decremented by 2

Bit	Bit Name	Initial Value	R/W	Description
5	RPE	0	R/W	Repeat Enable Used in combination with the DTIE bit in DMABCR to select the mode (sequential, idle, or repeat) in which transfer is to be performed. • When DTIE = 0 (no transfer end interrupt) 0: Transfer in sequential mode 1: Transfer in repeat mode • When DTIE = 1 (with transfer end interrupt) 0: Transfer in sequential mode 1: Transfer in idle mode
4	DTDIR	0	R/W	Data Transfer Direction Used in combination with the SAE bit in DMABCR to specify the data transfer direction (source or destination). The function of this bit is therefore different in dual address mode and single address mode. • When SAE = 0 0: Transfer with MAR as source address and IOAR as destination address 1: Transfer with IOAR as source address and MAR as destination address • When SAE = 1 0: Transfer with MAR as source address and DACK pin as write strobe 1: Transfer with DACK pin as read strobe and MAR as destination address

Bit	Bit Name	Initial Value	R/W	Description
3	DTF3	0	R/W	Data Transfer Factor 3 to 0
2	DTF2	0	R/W	These bits select the data transfer factor (activation source). There are some differences in activation sources for channel A and channel B.
1	DTF1	0	R/W	
0	DTF0	0	R/W	

- Channel A

0000: Setting prohibited

0001: Activated by A/D converter conversion end interrupt

0010: Setting prohibited

0011: Setting prohibited

0100: Activated by SCI channel 0 transmit-data-empty interrupt

0101: Activated by SCI channel 0 receive-data-full interrupt

0110: Activated by SCI channel 1 transmit-data-empty interrupt

0111: Activated by SCI channel 1 receive-data-full interrupt

1000: Activated by TPU channel 0 compare match/input capture A interrupt

1001: Activated by TPU channel 1 compare match/input capture A interrupt

1010: Activated by TPU channel 2 compare match/input capture A interrupt

1011: Activated by TPU channel 3 compare match/input capture A interrupt

1100: Activated by TPU channel 4 compare match/input capture A interrupt

1101: Activated by TPU channel 5 compare match/input capture A interrupt

1110: Setting prohibited

1111: Setting prohibited

Bit	Bit Name	Initial Value	R/W	Description
3	DTF3	0	R/W	• Channel B
2	DTF2	0	R/W	0000: Setting prohibited
1	DTF1	0	R/W	0001: Activated by A/D converter conversion end interrupt
0	DTF0	0	R/W	0010: Activated by DREQ pin falling edge input (detected as a low level in the first transfer after transfer is enabled)
				0011: Activated by DREQ pin low-level input
				0100: Activated by SCI channel 0 transmit-data-empty interrupt
				0101: Activated by SCI channel 0 receive-data-full interrupt
				0110: Activated by SCI channel 1 transmit-data-empty interrupt
				0111: Activated by SCI channel 1 receive-data-full interrupt
				1000: Activated by TPU channel 0 compare match/input capture A interrupt
				1001: Activated by TPU channel 1 compare match/input capture A interrupt
				1010: Activated by TPU channel 2 compare match/input capture A interrupt
				1011: Activated by TPU channel 3 compare match/input capture A interrupt
				1100: Activated by TPU channel 4 compare match/input capture A interrupt
				1101: Activated by TPU channel 5 compare match/input capture A interrupt
				1110: Setting prohibited
				1111: Setting prohibited
				The same factor can be selected for more than one channel. In this case, activation starts with the highest-priority channel according to the relative channel priorities. For relative channel priorities, see section 8.5.11 Multi-Channel Operation.

Full Address Mode:

- DMACR_0A and DMACR_1A

Bit	Bit Name	Initial Value	R/W	Description
15	DTSZ	0	R/W	Data Transfer Size Selects the size of data to be transferred at one time. 0: Byte-size transfer 1: Word-size transfer
14	SAID	0	R/W	Source Address Increment/Decrement
13	SAIDE	0	R/W	Source Address Increment/Decrement Enable These bits specify whether source address register MARA is to be incremented, decremented, or left unchanged, when data transfer is performed. 00: MARA is fixed 01: MARA is incremented after a data transfer • When DTSZ = 0, MARA is incremented by 1 • When DTSZ = 1, MARA is incremented by 2 10: MARA is fixed 11: MARA is decremented after a data transfer • When DTSZ = 0, MARA is decremented by 1 • When DTSZ = 1, MARA is decremented by 2
12	BLKDIR	0	R/W	Block Direction
11	BLKE	0	R/W	Block Enable These bits specify whether normal mode or block transfer mode is to be used for data transfer. If block transfer mode is specified, the BLKDIR bit specifies whether the source side or the destination side is to be the block area. x0: Transfer in normal mode 01: Transfer in block transfer mode (destination side is block area) 11: Transfer in block transfer mode (source side is block area)

Bit	Bit Name	Initial Value	R/W	Description
10 to 8	—	All 0	R/W	Reserved These bits can be read from or written to. However, the write value should always be 0.

Legend

x: Don't care

- DMACR_0B and DMACR_1B

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved This bit can be read from or written to. However, the write value should always be 0.
6	DAID	0	R/W	Destination Address Increment/Decrement
5	DAIDE	0	R/W	Destination Address Increment/Decrement Enable These bits specify whether destination address register MARB is to be incremented, decremented, or left unchanged, when data transfer is performed. 00: MARB is fixed 01: MARB is incremented after a data transfer • When DTSZ = 0, MARB is incremented by 1 • When DTSZ = 1, MARB is incremented by 2 10: MARB is fixed 11: MARB is decremented after a data transfer • When DTSZ = 0, MARB is decremented by 1 • When DTSZ = 1, MARB is decremented by 2
4	—	0	R/W	Reserved This bit can be read from or written to. However, the write value should always be 0.

Bit	Bit Name	Initial Value	R/W	Description
3	DTF3	0	R/W	Data Transfer Factor 3 to 0
2	DTF2	0	R/W	These bits select the data transfer factor (activation source). The factors that can be specified differ between normal mode and block transfer mode.
1	DTF1	0	R/W	
0	DTF0	0	R/W	
				• Normal Mode
				0000: Setting prohibited
				0001: Setting prohibited
				0010: Activated by DREQ pin falling edge input (detected as a low level in the first transfer after transfer is enabled)
				0011: Activated by DREQ pin low-level input
				010x: Setting prohibited
				0110: Auto-request (cycle steal)
				0111: Auto-request (burst)
				1xxx: Setting prohibited

Bit	Bit Name	Initial Value	R/W	Description
3	DTF3	0	R/W	• Block Transfer Mode
2	DTF2	0	R/W	0000: Setting prohibited
1	DTF1	0	R/W	0001: Activated by A/D converter conversion end interrupt
0	DTF0	0	R/W	0010: Activated by DREQ pin falling edge input
				0011: Activated by DREQ pin low-level input
				0100: Activated by SCI channel 0 transmit-data-empty interrupt
				0101: Activated by SCI channel 0 receive-data-full interrupt
				0110: Activated by SCI channel 1 transmit-data-empty interrupt
				0111: Activated by SCI channel 1 receive-data-full interrupt
				1000: Activated by TPU channel 0 compare match/input capture A interrupt
				1001: Activated by TPU channel 1 compare match/input capture A interrupt
				1010: Activated by TPU channel 2 compare match/input capture A interrupt
				1011: Activated by TPU channel 3 compare match/input capture A interrupt
				1100:Activated by TPU channel 4 compare match/input capture A interrupt
				1101:Activated by TPU channel 5 compare match/input capture A interrupt
				1110: Setting prohibited
				1111: Setting prohibited
				The same factor can be selected for more than one channel. In this case, activation starts with the highest-priority channel according to the relative channel priorities. For relative channel priorities, see section 8.5.11 Multi-Channel Operation.

Legend

x: Don't care

8.3.5 DMA Band Control Registers H and L (DMABCRH and DMABCRL)

DMABCR controls the operation of each DMAC channel. The bit functions in the DMACR registers differ according to the transfer mode.

Short Address Mode:

- DMABCRH

Bit	Bit Name	Initial Value	R/W	Description
15	FAE1	0	R/W	Full Address Enable 1 Specifies whether channel 1 is to be used in short address mode or full address mode. In short address mode, channels 1A and 1B can be used as independent channels. 0: Short address mode 1: Full address mode
14	FAE0	0	R/W	Full Address Enable 0 Specifies whether channel 0 is to be used in short address mode or full address mode. In short address mode, channels 0A and 0B can be used as independent channels. 0: Short address mode 1: Full address mode
13	SAE1	0	R/W	Single Address Enable 1 Specifies whether channel 1B is to be used for transfer in dual address mode or single address mode. This bit is invalid in full address mode. 0: Dual address mode 1: Single address mode
12	SAE0	0	R/W	Single Address Enable 0 Specifies whether channel 0B is to be used for transfer in dual address mode or single address mode. This bit is invalid in full address mode. 0: Dual address mode 1: Single address mode

Bit	Bit Name	Initial Value	R/W	Description
11	DTA1B	0	R/W	Data Transfer Acknowledge 1B
10	DTA1A	0	R/W	Data Transfer Acknowledge 1A
9	DTA0B	0	R/W	Data Transfer Acknowledge 0B
8	DTA0A	0	R/W	Data Transfer Acknowledge 0A These bits enable or disable clearing when DMA transfer is performed for the internal interrupt source selected by the DTF3 to DTF0 bits in DMACR. It the DTA bit is set to 1 when DTE = 1, the internal interrupt source is cleared automatically by DMA transfer. When DTE = 1 and DTA = 1, the internal interrupt source does not issue an interrupt request to the CPU or DTC. If the DTA bit is cleared to 0 when DTE = 1, the internal interrupt source is not cleared when a transfer is performed, and can issue an interrupt request to the CPU or DTC in parallel. In this case, the interrupt source should be cleared by the CPU or DTC transfer. When DTE = 0, the internal interrupt source issues an interrupt request to the CPU or DTC regardless of the DTA bit setting. 0: Clearing is disabled when DMA transfer is performed for the selected internal interrupt source. 1: Clearing is enabled when DMA transfer is performed for the selected internal interrupt source.

- DMABCRL

Bit	Bit Name	Initial Value	R/W	Description
7	DTE1B	0	R/W	Data Transfer Enable 1B
6	DTE1A	0	R/W	Data Transfer Enable 1A
5	DTE0B	0	R/W	Data Transfer Enable 0B
4	DTE0A	0	R/W	Data Transfer Enable 0A If the DTE bit is cleared to 0 when DTIE = 1, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU or DTC. When DTE = 0, data transfer is disabled and the DMAC ignores the activation source selected by the DTF3 to DTF0 bits in DMACR. When DTE = 1, data transfer is enabled and the DMAC waits for a request by the activation source selected by the DTF3 to DTF0 bits in DMACR. When a request is issued by the activation source, DMA transfer is executed. 0: Data transfer is disabled. 1: Data transfer is enabled. [Clearing conditions] • When initialization is performed • When the specified number of transfers have been completed in a transfer mode other than repeat mode • When 0 is written to the DTE bit to forcibly suspend the transfer, or for a similar reason [Setting condition] When 1 is written to the DTE bit after reading DTE = 0

Bit	Bit Name	Initial Value	R/W	Description
3	DTIE1B	0	R/W	Data Transfer End Interrupt Enable 1B
2	DTIE1A	0	R/W	Data Transfer End Interrupt Enable 1A
1	DTIE0B	0	R/W	Data Transfer End Interrupt Enable 0B
0	DTIE0A	0	R/W	Data Transfer End Interrupt Enable 0A These bits enable or disable an interrupt to the CPU or DTC when transfer ends. If the DTIE bit is set to 1 when DTE = 0, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU or DTC. A transfer end interrupt can be canceled either by clearing the DTIE bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the transfer counter and address register again, and then setting the DTE bit to 1. 0: Transfer end interrupt is disabled. 1: Transfer end interrupt is enabled.

Full Address Mode:

- DMABCRH

Bit	Bit Name	Initial Value	R/W	Description
15	FAE1	0	R/W	Full Address Enable 1 Specifies whether channel 1 is to be used in short address mode or full address mode. In full address mode, channels 1A and 1B are used together as channel 1. 0: Short address mode 1: Full address mode
14	FAE0	0	R/W	Full Address Enable 0 Specifies whether channel 0 is to be used in short address mode or full address mode. In full address mode, channels 0A and 0B are used together as channel 0. 0: Short address mode 1: Full address mode
13	—	0	R/W	Reserved
12	—	0	R/W	These bits can be read from or written to. However, the write value should always be 0.

Bit	Bit Name	Initial Value	R/W	Description
11	DTA1	0	R/W	Data Transfer Acknowledge 1 These bits enable or disable clearing when DMA transfer is performed for the internal interrupt source selected by the DTF3 to DTF0 bits in DMACR of channel 1. It the DTA1 bit is set to 1 when DTE1 = 1, the internal interrupt source is cleared automatically by DMA transfer. When DTE1 = 1 and DTA1 = 1, the internal interrupt source does not issue an interrupt request to the CPU or DTC. It the DTA1 bit is cleared to 0 when DTE1 = 1, the internal interrupt source is not cleared when a transfer is performed, and can issue an interrupt request to the CPU or DTC in parallel. In this case, the interrupt source should be cleared by the CPU or DTC transfer. When DTE1 = 0, the internal interrupt source issues an interrupt request to the CPU or DTC regardless of the DTA1 bit setting. The state of the DTME1 bit does not affect the above operations. 0: Clearing is disabled when DMA transfer is performed for the selected internal interrupt source. 1: Clearing is enabled when DMA transfer is performed for the selected internal interrupt source.
10	—	0	R/W	Reserved This bit can be read from or written to. However, the write value should always be 0.

Bit	Bit Name	Initial Value	R/W	Description
9	DTA0	0	R/W	Data Transfer Acknowledge 0 These bits enable or disable clearing when DMA transfer is performed for the internal interrupt source selected by the DTF3 to DTF0 bits in DMACR of channel 0. It the DTA0 bit is set to 1 when DTE0 = 1, the internal interrupt source is cleared automatically by DMA transfer. When DTE0 = 1 and DTA0 = 1, the internal interrupt source does not issue an interrupt request to the CPU or DTC. It the DTA0 bit is cleared to 0 when DTE0 = 1, the internal interrupt source is not cleared when a transfer is performed, and can issue an interrupt request to the CPU or DTC in parallel. In this case, the interrupt source should be cleared by the CPU or DTC transfer. When DTE0 = 0, the internal interrupt source issues an interrupt request to the CPU or DTC regardless of the DTA0 bit setting. The state of the DTME0 bit does not affect the above operations. 0: Clearing is disabled when DMA transfer is performed for the selected internal interrupt source. 1: Clearing is enabled when DMA transfer is performed for the selected internal interrupt source.
8	—	0	R/W	Reserved This bit can be read from or written to. However, the write value should always be 0.

- DMABCRL

Bit	Bit Name	Initial Value	R/W	Description
7	DTME1	0	R/W	Data Transfer Master Enable 1 Together with the DTE1 bit, this bit controls enabling or disabling of data transfer on channel 1. When both the DTME1 bit and DTE1 bit are set to 1, transfer is enabled for channel 1. If channel 1 is in the middle of a burst mode transfer when an NMI interrupt is generated, the DTME1 bit is cleared, the transfer is interrupted, and bus mastership passes to the CPU. When the DTME1 bit is subsequently set to 1 again, the interrupted transfer is resumed. In block transfer mode, however, the DTME1 bit is not cleared by an NMI interrupt, and transfer is not interrupted. 0: Data transfer is disabled. 1: Data transfer is enabled. [Clearing conditions] • When initialization is performed • When NMI is input in burst mode • When 0 is written to the DTME1 bit [Setting condition] When 1 is written to DTME1 after reading DTME1 = 0

Bit	Bit Name	Initial Value	R/W	Description
6	DTE1	0	R/W	Data Transfer Enable 1 Enables or disables DMA transfer for the activation source selected by the DTF3 to DTF0 bits in DMACR of channel 1. When DTE1 = 0, data transfer is disabled and the activation source is ignored. If the activation source is an internal interrupt, an interrupt request is issued to the CPU or DTC. If the DTE1 bit is cleared to 0 when DTIE1 = 1, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU. When DTE1 = 1 and DTME1 = 1, data transfer is enabled and the DMAC waits for a request by the activation source. When a request is issued by the activation source, DMA transfer is executed. 0: Data transfer is disabled. 1: Data transfer is enabled. [Clearing conditions] • When initialization is performed • When the specified number of transfers have been completed • When 0 is written to the DTE1 bit to forcibly suspend the transfer, or for a similar reason [Setting condition] When 1 is written to the DTE1 bit after reading DTE1 = 0

Bit	Bit Name	Initial Value	R/W	Description
5	DTME0	0	R/W	Data Transfer Master Enable 0 Together with the DTE0 bit, this bit controls enabling or disabling of data transfer on channel 0. When both the DTME0 bit and DTE0 bit are set to 1, transfer is enabled for channel 0. If channel 0 is in the middle of a burst mode transfer when an NMI interrupt is generated, the DTME0 bit is cleared, the transfer is interrupted, and bus mastership passes to the CPU. When the DTME0 bit is subsequently set to 1 again, the interrupted transfer is resumed. In block transfer mode, however, the DTME0 bit is not cleared by an NMI interrupt, and transfer is not interrupted. 0: Data transfer is disabled. 1: Data transfer is enabled. [Clearing conditions] • When initialization is performed • When NMI is input in burst mode • When 0 is written to the DTME0 bit [Setting condition] When 1 is written to DTME0 after reading DTME0 = 0

Bit	Bit Name	Initial Value	R/W	Description
4	DTE0	0	R/W	Data Transfer Enable 0 Enables or disables DMA transfer for the activation source selected by the DTF3 to DTF0 bits in DMACR of channel 0. When DTE0 = 0, data transfer is disabled and the activation source is ignored. If the activation source is an internal interrupt, an interrupt request is issued to the CPU or DTC. If the DTE0 bit is cleared to 0 when DTIE0 = 1, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU. When DTE0 = 1 and DTME0 = 1, data transfer is enabled and the DMAC waits for a request by the activation source. When a request is issued by the activation source, DMA transfer is executed. 0: Data transfer is disabled. 1: Data transfer is enabled. [Clearing conditions] • When initialization is performed • When the specified number of transfers have been completed • When 0 is written to the DTE0 bit to forcibly suspend the transfer, or for a similar reason [Setting condition] When 1 is written to the DTE0 bit after reading DTE0 = 0
3	DTIE1B	0	R/W	Data Transfer Interrupt Enable 1B Enables or disables an interrupt to the CPU or DTC when transfer on channel 1 is interrupted. If the DTME1 bit is cleared to 0 when DTIE1B = 1, the DMAC regards this as indicating a break in the transfer, and issues a transfer break interrupt request to the CPU or DTC. A transfer break interrupt can be canceled either by clearing the DTIE1B bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the DTME1 bit to 1. 0: Data transfer is disabled. 1: Data transfer is enabled.

Bit	Bit Name	Initial Value	R/W	Description
2	DTIE1A	0	R/W	Data Transfer End Interrupt Enable 1A Enables or disables an interrupt to the CPU or DTC when transfer ends. If the DTE1 bit is cleared to 1 when DTIE1A = 1, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU or DTC. A transfer end interrupt can be canceled either by clearing the DTIE1A bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the transfer counter and address register again, and then setting the DTE1 bit to 1. 0: Data transfer is disabled. 1: Data transfer is enabled.
1	DTIE0B	0	R/W	Data Transfer Interrupt Enable 0B Enables or disables an interrupt to the CPU or DTC when transfer on channel 1 is interrupted. If the DTME0 bit is cleared to 0 when DTIE0B = 1, the DMAC regards this as indicating a break in the transfer, and issues a transfer break interrupt request to the CPU or DTC. A transfer break interrupt can be canceled either by clearing the DTIE0B bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the DTME0 bit to 1. 0: Data transfer is disabled. 1: Data transfer is enabled.
0	DTIE0A	0	R/W	Data Transfer End Interrupt Enable 0A Enables or disables an interrupt to the CPU or DTC when transfer ends. If the DTE0 bit is cleared to 0 when DTIE0A = 1, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU or DTC. A transfer end interrupt can be canceled either by clearing the DTIE0A bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the transfer counter and address register again, and then setting the DTE0 bit to 1. 0: Data transfer is disabled. 1: Data transfer is enabled.

8.3.6 DMA Write Enable Register (DMAWER)

The DMAC can activate the DTC with a transfer end interrupt, rewrite the channel on which the transfer ended using a DTC chain transfer, and then reactivate the DTC. DMAWER applies restrictions for changing all bits of DMACR, and specific bits for DMATCR and DMABCR for the specific channel, to prevent inadvertent rewriting of registers other than those for the channel concerned. The restrictions applied by DMAWER are valid for the DTC.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 0	—	Reserved These bits are always read as 0 and cannot be modified.
3	WE1B	0	R/W	Write Enable 1B Enables or disables writes to all bits in DMACR1B, bits 11, 7, and 3 in DMABCR, and bit 5 in DMATCR. 0: Writes are disabled 1: Writes are enabled
2	WE1A	0	R/W	Write Enable 1A Enables or disables writes to all bits in DMACR1A, and bits 10, 6, and 2 in DMABCR. 0: Writes are disabled 1: Writes are enabled
1	WE0B	0	R/W	Write Enable 0B Enables or disables writes to all bits in DMACR0B, bits 9, 5, and 1 in DMABCR, and bit 4 in DMATCR. 0: Writes are disabled 1: Writes are enabled
0	WE0A	0	R/W	Write Enable 0A Enables or disables writes to all bits in DMACR0A, and bits 8, 4, and 0 in DMABCR. 0: Writes are disabled 1: Writes are enabled

Figure 8.2 shows the transfer areas for activating the DTC with a channel 0A transfer end interrupt request, and reactivating channel 0A. The address register and count register areas are set again during the first DTC transfer, then the control register area is set again during the second DTC chain transfer. When re-setting the control register area, perform masking by setting bits in DMAWER to prevent modification of the contents of other channels.

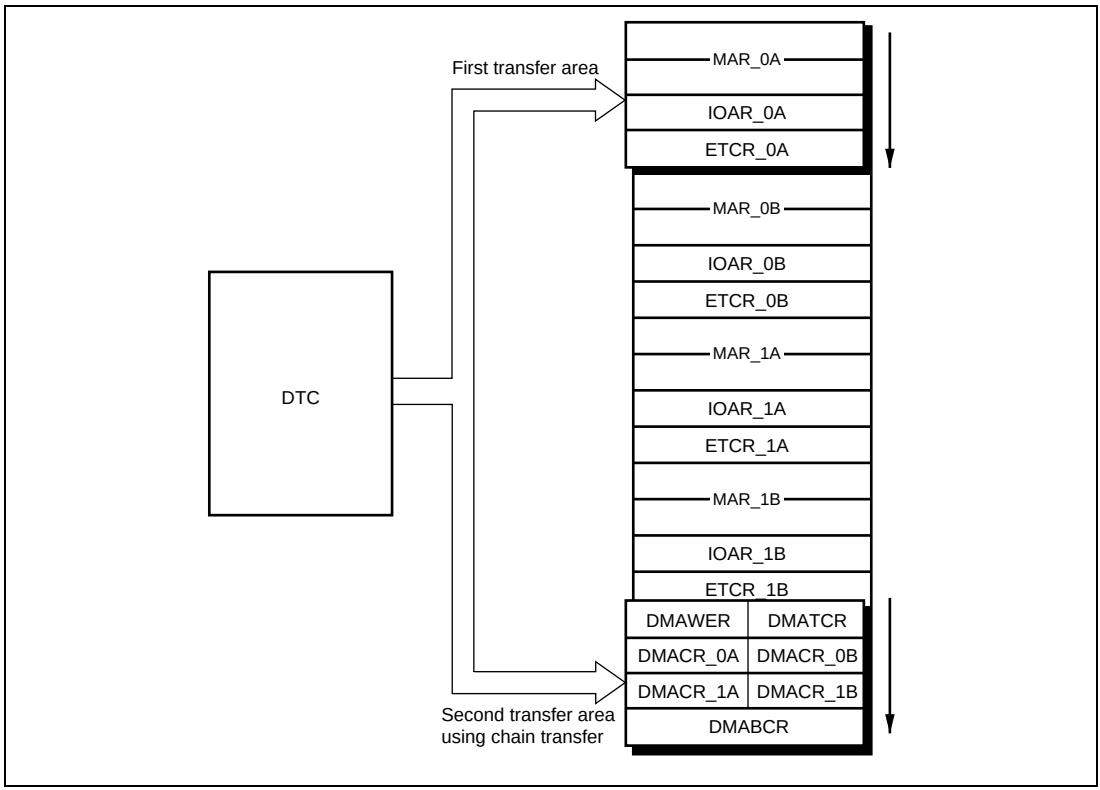


Figure 8.2 Areas for Register Re-Setting by DTC (Channel 0A)

Writes by the DTC to bits 15 to 12 (FAE and SAE) in DMABCR are invalid regardless of the DMAWER settings. These bits should be changed, if necessary, by CPU processing.

In writes by the DTC to bits 7 to 4 (DTE) in DMABCR, 1 can be written without first reading 0. To reactivate a channel set to full address mode, write 1 to both Write Enable A and Write Enable B for the channel to be reactivated.

MAR, IOAR, and ETCR can always be written to regardless of the DMAWER settings. When modifying these registers, the channel to be modified should be halted.

8.3.7 DMA Terminal Control Register (DMATCR)

DMATCR controls enabling or disabling of output from the DMAC transfer end pin. A port can be set for output automatically, and a transfer end signal output, by setting the appropriate bit. The TEND pin is available only for channel B in short address mode. Except for the block transfer mode, a transfer end signal asserts in the transfer cycle in which the transfer counter contents reaches 0 regardless of the activation source. In the block transfer mode, a transfer end signal asserts in the transfer cycle in which the block counter contents reaches 0.

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	—	Reserved
6	—	0	—	These bits are always read as 0 and cannot be modified.
5	TEE1	0	R/W	Transfer End Enable 1 Enables or disables transfer end pin 1 (TEND1) output. 0: TEND1 pin output disabled 1: TEND1 pin output enabled
4	TEE0	0	R/W	Transfer End Enable 0 Enables or disables transfer end pin 0 (TEND0) output. 0: TEND0 pin output disabled 1: TEND0 pin output enabled
3 to 0	—	All 0	—	Reserved These bits are always read as 0 and cannot be modified.

8.4 Activation Sources

DMAC activation sources consist of internal interrupt requests, external requests, and auto-requests. The DMAC activation sources that can be specified depend on the transfer mode and channel, as shown in table 8.3.

Table 8.3 DMAC Activation Sources

		Short Address Mode		Full Address Mode	
Activation Source		**Channels 0A and 1A**	**Channels 0B and 1B**	**Normal Mode**	**Block Transfer Mode**
Internal interrupts	ADI	O	O	X	O
	TXI0	O	O	X	O
	RXI0	O	O	X	O
	TXI1	O	O	X	O
	RXI1	O	O	X	O
	TGI0A	O	O	X	O
	TGI1A	O	O	X	O
	TGI2A	O	O	X	O
	TGI3A	O	O	X	O
	TGI4A	O	O	X	O
	TGI5A	O	O	X	O
External requests	DREQ pin falling edge input	X	O	O	O
	DREQ pin low-level input	X	O	O	O
Auto-request		X	X	O	X

Legend

O: Can be specified

X: Cannot be specified

8.4.1 Activation by Internal Interrupt Request

An interrupt request selected as a DMAC activation source can also simultaneously generate an interrupt request for the CPU or DTC. For details, see section 5, Interrupt Controller.

With activation by an internal interrupt request, the DMAC accepts the interrupt request independently of the interrupt controller. Consequently, interrupt controller priority settings are irrelevant.

If the DMAC is activated by a CPU interrupt source or an interrupt request that is not used as a DTC activation source (DTA = 1), the interrupt request flag is cleared automatically by the DMA transfer. With ADI, TXI, and RXI interrupts, however, the interrupt source flag is not cleared unless the relevant register is accessed in a DMA transfer. If the same interrupt is used as an activation source for more than one channel, the interrupt request flag is cleared when the highest-priority channel is activated. Transfer requests for other channels are held pending in the DMAC, and activation is carried out in order of priority.

When DTE = 0 after completion of a transfer, an interrupt request from the selected activation source is not sent to the DMAC, regardless of the DTA bit setting. In this case, the relevant interrupt request is sent to the CPU or DTC.

When an interrupt request signal for DMAC activation is also used for an interrupt request to the CPU or DTC activation (DTA = 0), the interrupt request flag is not cleared by the DMAC.

8.4.2 Activation by External Request

If an external request (DREQ pin) is specified as a DMAC activation source, the relevant port should be set to input mode in advance. Level sensing or edge sensing can be used for external requests.

External request operation in normal mode of short address mode or full address mode is described below.

When edge sensing is selected, a byte or word is transferred each time a high-to-low transition is detected on the DREQ pin. The next data transfer may not be performed if the next edge is input before data transfer is completed.

When level sensing is selected, the DMAC stands by for a transfer request while the DREQ pin is held high. While the DREQ pin is held low, transfers continue in succession, with the bus being released each time a byte or word is transferred. If the DREQ pin goes high in the middle of a transfer, the transfer is interrupted and the DMAC stands by for a transfer request.

8.4.3 Activation by Auto-Request

Auto-request is activated by register setting only, and transfer continues to the end. With auto-request activation, cycle steal mode or burst mode can be selected.

In cycle steal mode, the DMAC releases the bus to another bus master each time a byte or word is transferred. DMA and CPU cycles are usually repeated alternately. In burst mode, the DMAC keeps possession of the bus until the end of the transfer so that transfer is performed continuously.

8.5 Operation

8.5.1 Transfer Modes

Table 8.4 lists the DMAC transfer modes.

Table 8.4 DMAC Transfer Modes

Transfer Mode		Transfer Source	Remarks
Short address mode	Dual address mode • 1-byte or 1-word transfer for a single transfer request • Specify source and destination addresses to transfer data in two bus cycles. (1) Sequential mode • Memory address incremented or decremented by 1 or 2 • Number of transfers: 1 to 65,536 (2) Idle mode • Memory address fixed • Number of transfers: 1 to 65,536 (3) Repeat mode • Memory address incremented or decremented by 1 or 2 • Continues transfer after sending number of transfers (1 to 256) and restoring the initial value	• TPU channel 0 to 5 compare match/input capture A interrupt • SCI transmit-data-empty interrupt • SCI receive-data-full interrupt • A/D converter conversion end interrupt • External request	• Up to 4 channels can operate independently • External request applies to channel B only • Single address mode applies to channel B only

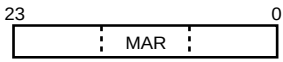
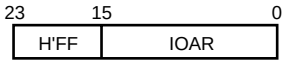
Transfer Mode		Transfer Source	Remarks
	Single address mode • 1-byte or 1-word transfer for a single transfer request • 1-bus cycle transfer by means of DACK pin instead of using address for specifying I/O • Sequential mode, idle mode, or repeat mode can be specified	• External request	
Full address mode	Normal mode (1) Auto-request • Transfer request is internally held • Number of transfers (1 to 65,536) is continuously sent • Burst/cycle steal transfer can be selected	• Auto-request	• Max. 2-channel operation, combining channels A and B
	(2) External request • 1-byte or 1-word transfer for a single transfer request • Number of transfers: 1 to 65,536	• External request	
	Block transfer mode • Transfer of 1-block, size selected for a single transfer request • Number of transfers: 1 to 65,536 • Source or destination can be selected as block area • Block size: 1 to 256 bytes or word	• TPU channel 0 to 5 compare match/input capture A interrupt • SCI transmit-data-empty interrupt • SCI receive-data-full interrupt • A/D converter conversion end interrupt • External request	

8.5.2 Sequential Mode

Sequential mode can be specified by clearing the RPE bit in DMACR to 0. In sequential mode, MAR is updated after each byte or word transfer in response to a single transfer request, and this is executed the number of times specified in ETCR. One address is specified by MAR, and the other by IOAR. The transfer direction can be specified by the DTDIR bit in DMACR.

Table 8.5 summarizes register functions in sequential mode.

Table 8.5 Register Functions in Sequential Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
	Source address register	Destination address register	Start address of transfer destination or transfer source	Incremented/ decremented every transfer
	Destination address register	Source address register	Start address of transfer source or transfer destination	Fixed
	Transfer counter		Number of transfers	Decremented every transfer; transfer ends when count reaches H'0000

MAR specifies the start address of the transfer source or transfer destination as 24 bits. MAR is incremented or decremented by 1 or 2 each time a byte or word is transferred. IOAR specifies the lower 16 bits of the other address. The 8 bits above IOAR have a value of H'FF.

Figure 8.3 illustrates operation in sequential mode.

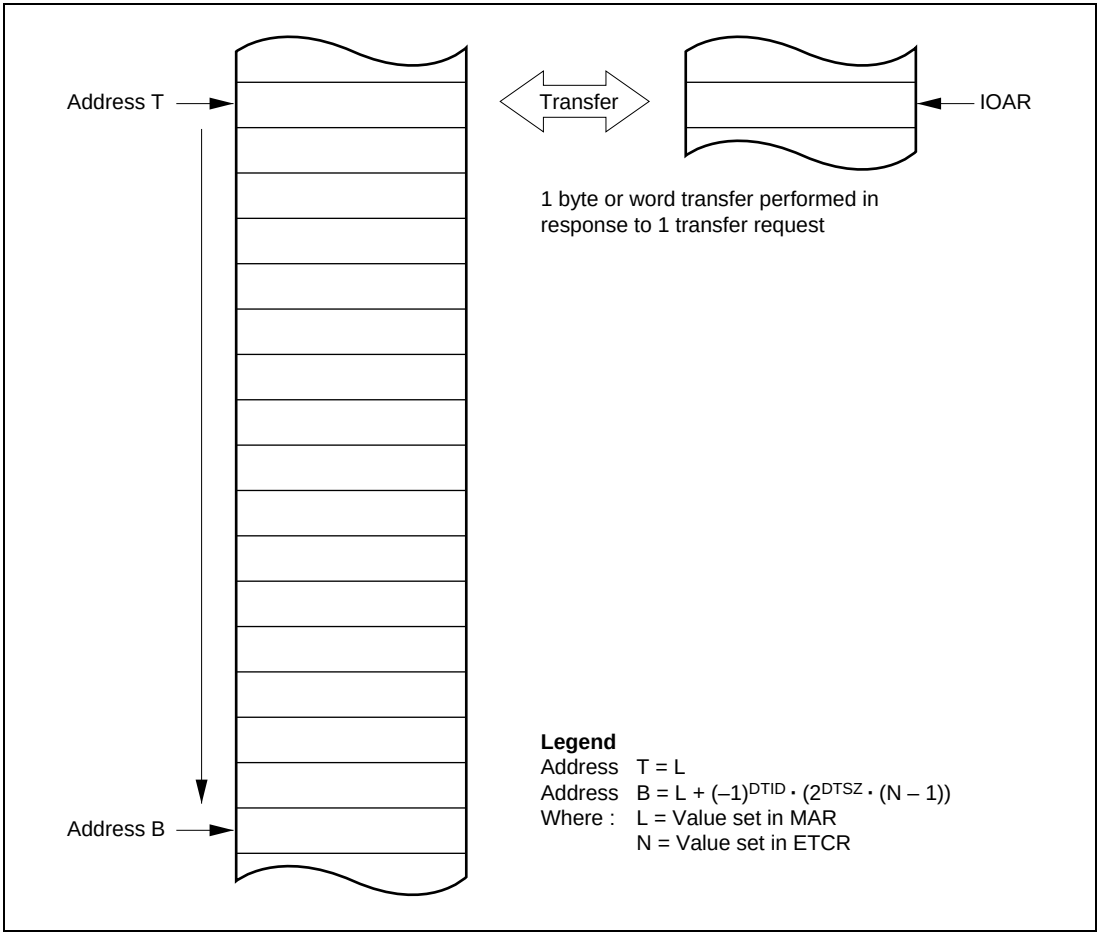
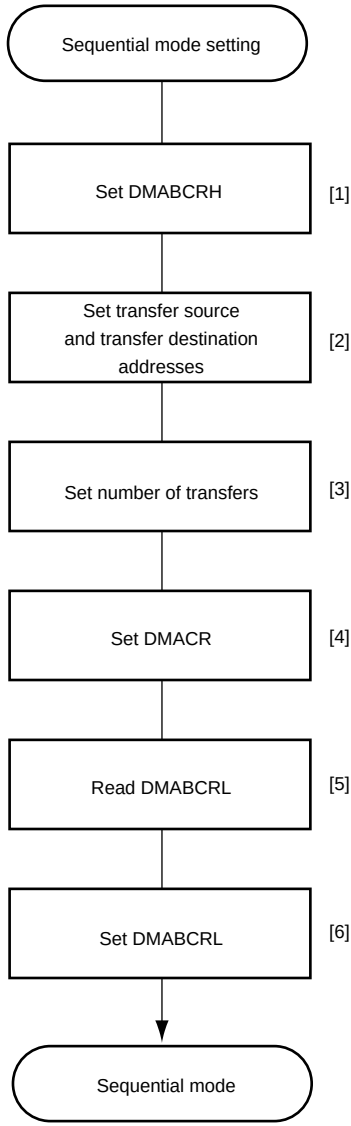


Figure 8.3 Operation in Sequential Mode

The number of transfers is specified as 16 bits in ETCR. ETCR is decremented by 1 each time a data transfer is executed, and when its value reaches H'0000, the DTE bit is cleared and data transfer ends. If the DTIE bit is set to 1 at this time, an interrupt request is sent to the CPU or DTC. The maximum number of transfers, when H'0000 is set in ETCR, is 65,536.

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmit-data-empty and receive-data-full interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts. External requests can only be specified for channel B.

Figure 8.4 shows an example of the setting procedure for sequential mode.



[1] Set each bit in DMABCRH.
- Clear the FAE bit to 0 to select short address mode.
- Specify enabling or disabling of internal interrupt clearing with the DTA bit.

[2] Set the transfer source address and transfer destination address in MAR and IOAR.

[3] Set the number of transfers in ETCR.

[4] Set each bit in DMACR.
- Set the transfer data size with the DTSZ bit.
- Specify whether MAR is to be incremented or decremented with the DTID bit.
- Clear the RPE bit to 0 to select sequential mode.
- Specify the transfer direction with the DTDIR bit.
- Select the activation source with bits DTF3 to DTF0.

[5] Read the DTE bit in DMABCRL as 0.

[6] Set each bit in DMABCRL.
- Specify enabling or disabling of transfer end interrupts with the DTIE bit.
- Set the DTE bit to 1 to enable transfer.

Figure 8.4 Example of Sequential Mode Setting Procedure

8.5.3 Idle Mode

Idle mode can be specified by setting the RPE bit in DMACR and DTIE bit in DMABCRL to 1. In idle mode, one byte or word is transferred in response to a single transfer request, and this is executed the number of times specified in ETCR. One address is specified by MAR, and the other by IOAR. The transfer direction can be specified by the DTDIR bit in DMACR. Table 8.6 summarizes register functions in idle mode.

Table 8.6 Register Functions in Idle Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
23 MAR 0	Source address register	Destination address register	Start address of transfer destination or transfer source	Fixed
23 H'FF 15 IOAR 0	Destination address register	Source address register	Start address of transfer source or transfer destination	Fixed
7 ETCRH 0	Transfer counter		Number of transfers	Decremented every transfer; transfer ends when count reaches H'0000

MAR specifies the start address of the transfer source or transfer destination as 24 bits. MAR is neither incremented nor decremented by a data transfer. IOAR specifies the lower 16 bits of the other address. The upper 8 bits of IOAR have a value of H'FF.

Figure 8.5 illustrates operation in idle mode.

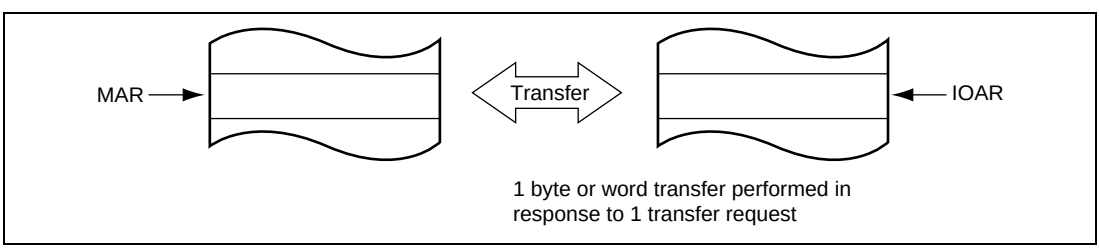
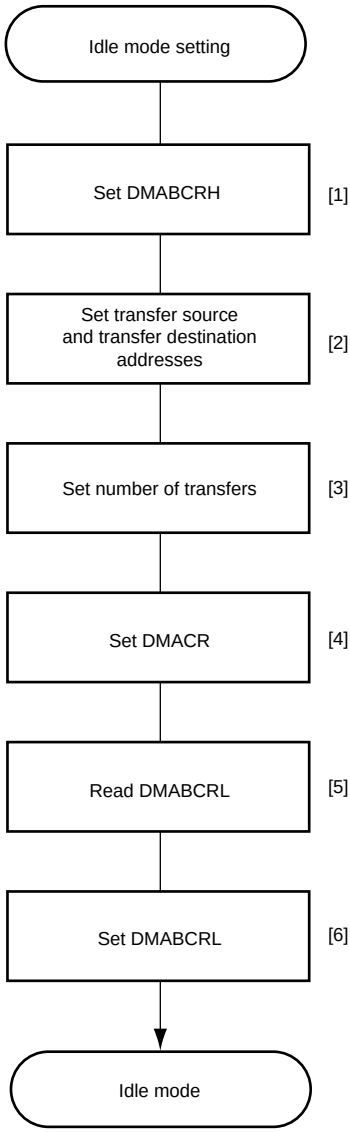


Figure 8.5 Operation in Idle Mode

The number of transfers is specified as 16 bits in ETCR. ETCR is decremented by 1 each time a transfer is executed, and when its value reaches H'0000, the DTE bit is cleared and data transfer ends. If the DTIE bit is set to 1 at this time, an interrupt request is sent to the CPU or DTC. The maximum number of transfers, when H'0000 is set in ETCR, is 65,536.

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmit-data-empty and receive-data-full interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts. External requests can only be specified for channel B.

Figure 8.6 shows an example of the setting procedure for idle mode.



[1] Set each bit in DMABCRH.
- Clear the FAE bit to 0 to select short address mode.
- Specify enabling or disabling of internal interrupt clearing with the DTA bit.

[2] Set the transfer source address and transfer destination address in MAR and IOAR.

[3] Set the number of transfers in ETCR.

[4] Set each bit in DMACR.
- Set the transfer data size with the DTSZ bit.
- Specify whether MAR is to be incremented or decremented with the DTID bit.
- Set the RPE bit to 1.
- Specify the transfer direction with the DTDIR bit.
- Select the activation source with bits DTF3 to DTF0.

[5] Read the DTE bit in DMABCRL as 0.

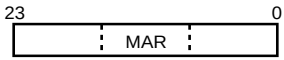
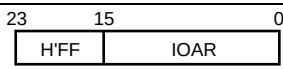
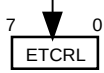
[6] Set each bit in DMABCRL.
- Set the DTIE bit to 1.
- Set the DTE bit to 1 to enable transfer.

Figure 8.6 Example of Idle Mode Setting Procedure

8.5.4 Repeat Mode

Repeat mode can be specified by setting the RPE bit in DMACR to 1, and clearing the DTIE bit in DMABCRL to 0. In repeat mode, MAR is updated after each byte or word transfer in response to a single transfer request, and this is executed the number of times specified in ETCRL. On completion of the specified number of transfers, MAR and ETCRL are automatically restored to their original settings and operation continues. One address is specified by MAR, and the other by IOAR. The transfer direction can be specified by the DTDIR bit in DMACR. Table 8.7 summarizes register functions in repeat mode.

Table 8.7 Register Functions in Repeat Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
	Source address register	Destination address register	Start address of transfer destination or transfer source	Incremented/ decremented every transfer. Initial setting is restored when value reaches H'0000
	Destination address register	Source address register	Start address of transfer source or transfer destination	Fixed
	Holds number of transfers		Number of transfers	Fixed
	Transfer counter		Number of transfers	Decremented every transfer. Loaded with ETCRH value when count reaches H'00

MAR specifies the start address of the transfer source or transfer destination as 24 bits. MAR is incremented or decremented by 1 or 2 each time a byte or word is transferred. IOAR specifies the lower 16 bits of the other address. The upper 8 bits of IOAR have a value of H'FF. The number of transfers is specified as 8 bits by ETCRH and ETCRL. The maximum number of transfers, when H'00 is set in both ETCRH and ETCRL, is 256.

In repeat mode, ETCRL functions as the transfer counter, and ETCRH is used to hold the number of transfers. ETCRL is decremented by 1 each time a data transfer is executed, and when its value reaches H'00, it is loaded with the value in ETCRH. At the same time, the value set in MAR is restored in accordance with the values of the DTSZ and DTID bits in DMACR. The MAR restoration operation is as shown below.

$$MAR = MAR - (-1)^{DTID} \cdot 2^{DTSZ} \cdot ETCRH$$

The same value should be set in ETCRH and ETCRL.

In repeat mode, operation continues until the DTE bit in DMABCRL is cleared. To end the transfer operation, therefore, the DTE bit should be cleared to 0. A transfer end interrupt request is not sent to the CPU or DTC. By setting the DTE bit to 1 again after it has been cleared, the operation can be restarted from the transfer after that terminated when the DTE bit was cleared.

Figure 8.7 illustrates operation in repeat mode.

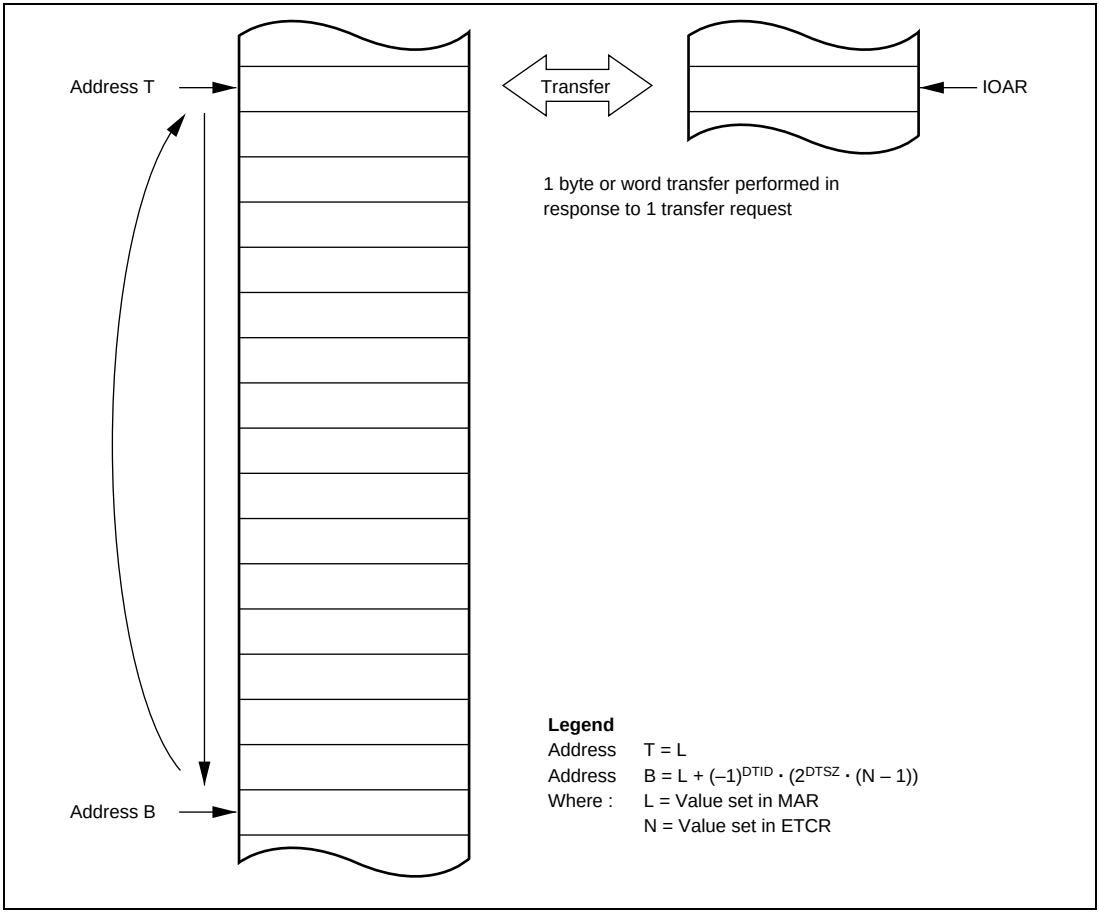
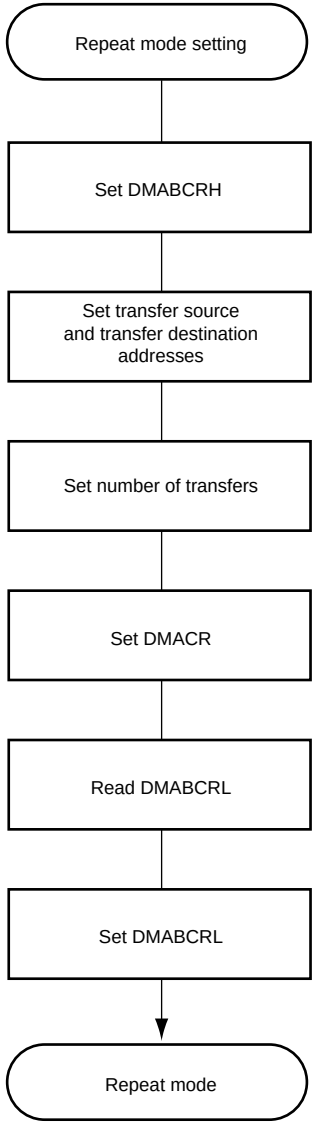


Figure 8.7 Operation in Repeat mode

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmit-data-empty and receive-data-full interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts. External requests can only be specified for channel B.

Figure 8.8 shows an example of the setting procedure for repeat mode.



[1] Set each bit in DMABCRH.
- Clear the FAE bit to 0 to select short address mode.
- Specify enabling or disabling of internal interrupt clearing with the DTA bit.

[2] Set the transfer source address and transfer destination address in MAR and IOAR.

[3] Set the number of transfers in both ETCRH and ETCRL.

[4] Set each bit in DMACR.
- Set the transfer data size with the DTSZ bit.
- Specify whether MAR is to be incremented or decremented with the DTID bit.
- Set the RPE bit to 1.
- Specify the transfer direction with the DTDIR bit.
- Select the activation source with bits DTF3 to DTF0.

[5] Read the DTE bit in DMABCRL as 0.

[6] Set each bit in DMABCRL.
- Clear the DTIE bit to 0.
- Set the DTE bit to 1 to enable transfer.

Figure 8.8 Example of Repeat Mode Setting Procedure

8.5.5 Single Address Mode

DMAC supports the dual address mode, in which two different cycles are used for reading and writing, and the single address mode, in which a single cycle is used for both reading and writing.

In dual address mode, the source address and the destination address are specified respectively for transferring data.

In single address mode, data is transferred between the external space, in which the transfer source or transfer destination is specified by the address, and the external device that is selected by DACK strobe regardless of the address. Figure 8.9 shows the data bus in single address mode.

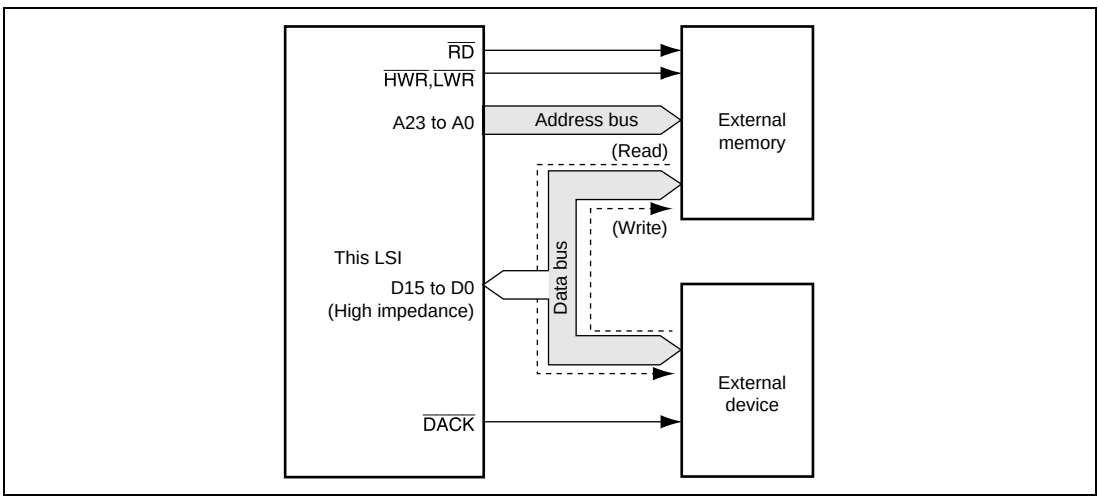


Figure 8.9 Data Bus in Single Address Mode

When the data bus is used for reading in single address mode, data is transferred from the external memory to the external device and the DACK pin functions as the write strobe for the external device. When the data bus is used for writing in single address mode, data is transferred from the external device to the external memory and the DACK pin functions as the read strobe for the external device. Since the direction for the external device cannot be controlled, chose one of directions described above.

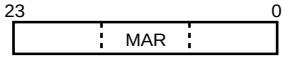
The setting of the bus controller for the external memory area controls the bus cycle in single address mode. To the external device, DACK is output in synchronization with the address strobe. For details on the bus cycle, see section 8.5.10, DMA Transfer (Single Address Mode) Bus Cycles.

In single address mode, do not specify the internal area for the transfer address.

Single address mode can only be specified for channel B. This mode can be specified by setting the SAE bit in DMABCRH to 1 in short address mode.

One address is specified by MAR, and the other is set automatically to the data transfer acknowledge pin (DACK). The transfer direction can be specified by the DTDIR bit in DMACR. Table 8.8 summarizes register functions in single address mode.

Table 8.8 Register Functions in Single Address Mode

	Function			
Register	**DTDIR = 0**	**DTDIR = 1**	**Initial Setting**	**Operation**
	Source address register	Destination address register	Start address of transfer destination or transfer source	See sections 8.5.2, Sequential Mode, 8.5.3, Idle Mode, and 8.5.4, Repeat Mode.
DACK pin	Write strobe	Read strobe	(Set automatically by SAE bit; IOAR is invalid)	Strobe for external device
	Transfer counter		Number of transfers	See sections 8.5.2, Sequential Mode, 8.5.3, Idle Mode, and 8.5.4, Repeat Mode.

MAR specifies the start address of the transfer source or transfer destination as 24 bits. IOAR is invalid; in its place the strobe for external devices (DACK) is output.

Figure 8.10 illustrates operation in single address mode (when sequential mode is specified).

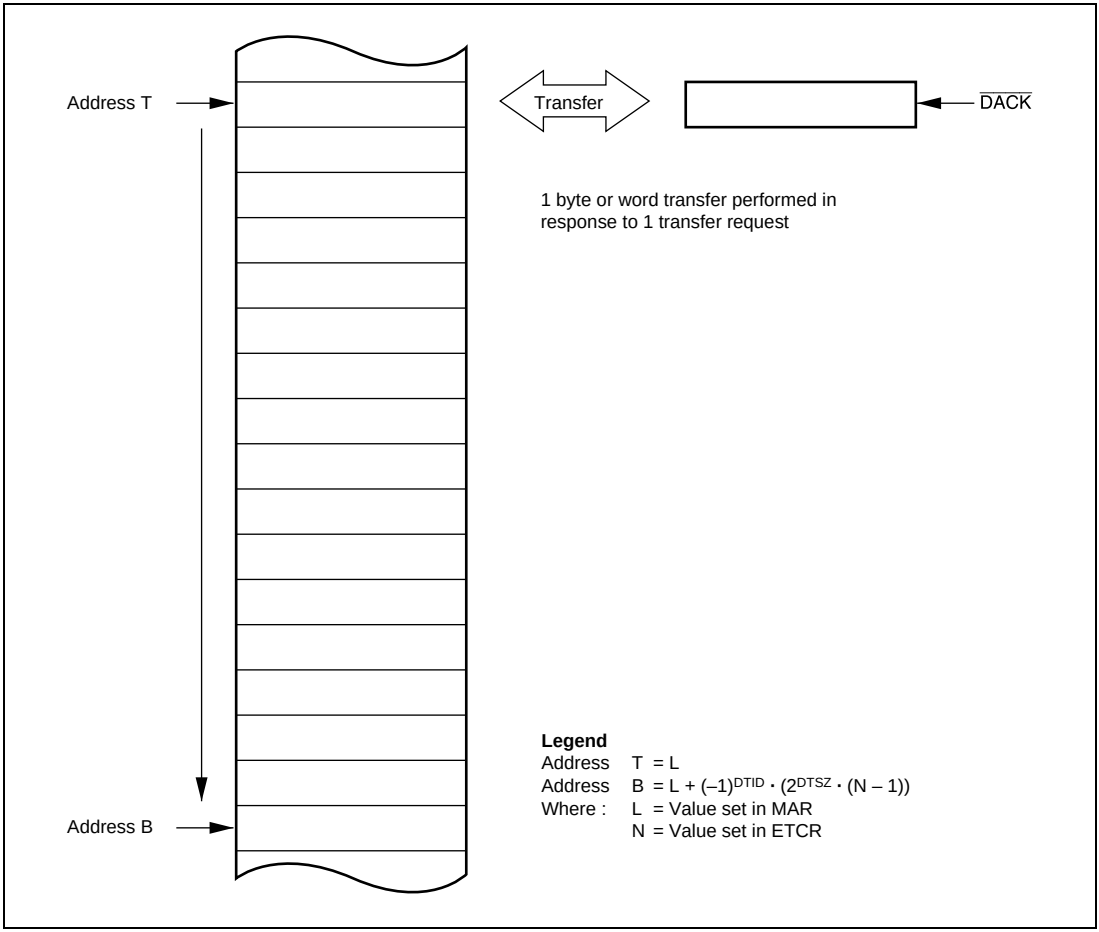
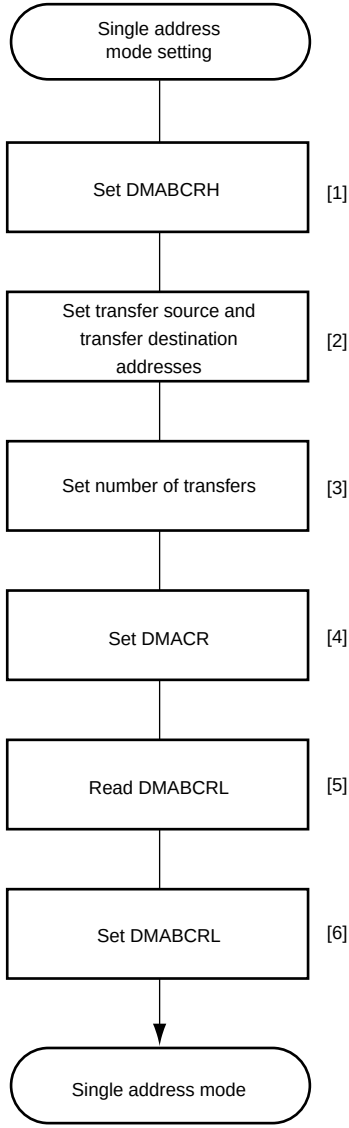


Figure 8.10 Operation in Single Address Mode (When Sequential Mode is Specified)

Figure 8.11 shows an example of the setting procedure for single address mode (when sequential mode is specified).



[1] Set each bit in DMABCRH.
- Clear the FAE bit to 0 to select short address mode.
- Set the SAE bit to 1 to select single address mode.
- Specify enabling or disabling of internal interrupt clearing with the DTA bit.

[2] Set the transfer source address/transfer destination address in MAR.

[3] Set the number of transfers in ETCR.

[4] Set each bit in DMACR.
- Set the transfer data size with the DTSZ bit.
- Specify whether MAR is to be incremented or decremented with the DTID bit.
- Clear the RPE bit to 0 to select sequential mode.
- Specify the transfer direction with the DTDIR bit.
- Select the activation source with bits DTF3 to DTF0.

[5] Read the DTE bit in DMABCRL as 0.

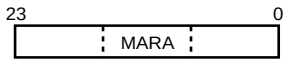
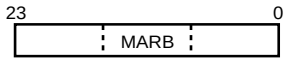
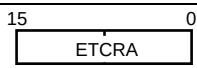
[6] Set each bit in DMABCRL.
- Specify enabling or disabling of transfer end interrupts with the DTIE bit.
- Set the DTE bit to 1 to enable transfer.

Figure 8.11 Example of Single Address Mode Setting Procedure (When Sequential Mode is Specified)

8.5.6 Normal Mode

In normal mode, transfer is performed with channels A and B used in combination. Normal mode can be specified by setting the FAE bit in DMABCRH to 1 and clearing the BLKE bit in DMACRA to 0. In normal mode, MAR is updated after data transfer of a byte or word in response to a single transfer request, and this is executed the number of times specified in ETCRA. The transfer source is specified by MARA, and the transfer destination by MARB. Table 8.9 summarizes register functions in normal mode.

Table 8.9 Register Functions in Normal Mode

Register	Function	Initial Setting	Operation
	Source address register	Start address of transfer source	Incremented/decremented every transfer, or fixed
	Destination address register	Start address of transfer destination	Incremented/decremented every transfer, or fixed
	Transfer counter	Number of transfers	Decremented every transfer; transfer ends when count reaches H′0000

MARA and MARB specify the start addresses of the transfer source and transfer destination, respectively, as 24 bits. MAR can be incremented or decremented by 1 or 2 each time a byte or word is transferred, or can be fixed. Incrementing, decrementing, or holding a fixed value can be set separately for MARA and MARB.

The number of transfers is specified by ETCRA as 16 bits. ETCRA is decremented by 1 each time a transfer is performed, and when its value reaches H'0000 the DTE bit in DMABCRL is cleared and transfer ends. If the DTIE bit in DMABCRL is set to 1 at this time, an interrupt request is sent to the CPU or DTC. The maximum number of transfers, when H′0000 is set in ETCRA, is 65,536.

Figure 8.12 illustrates operation in normal mode.

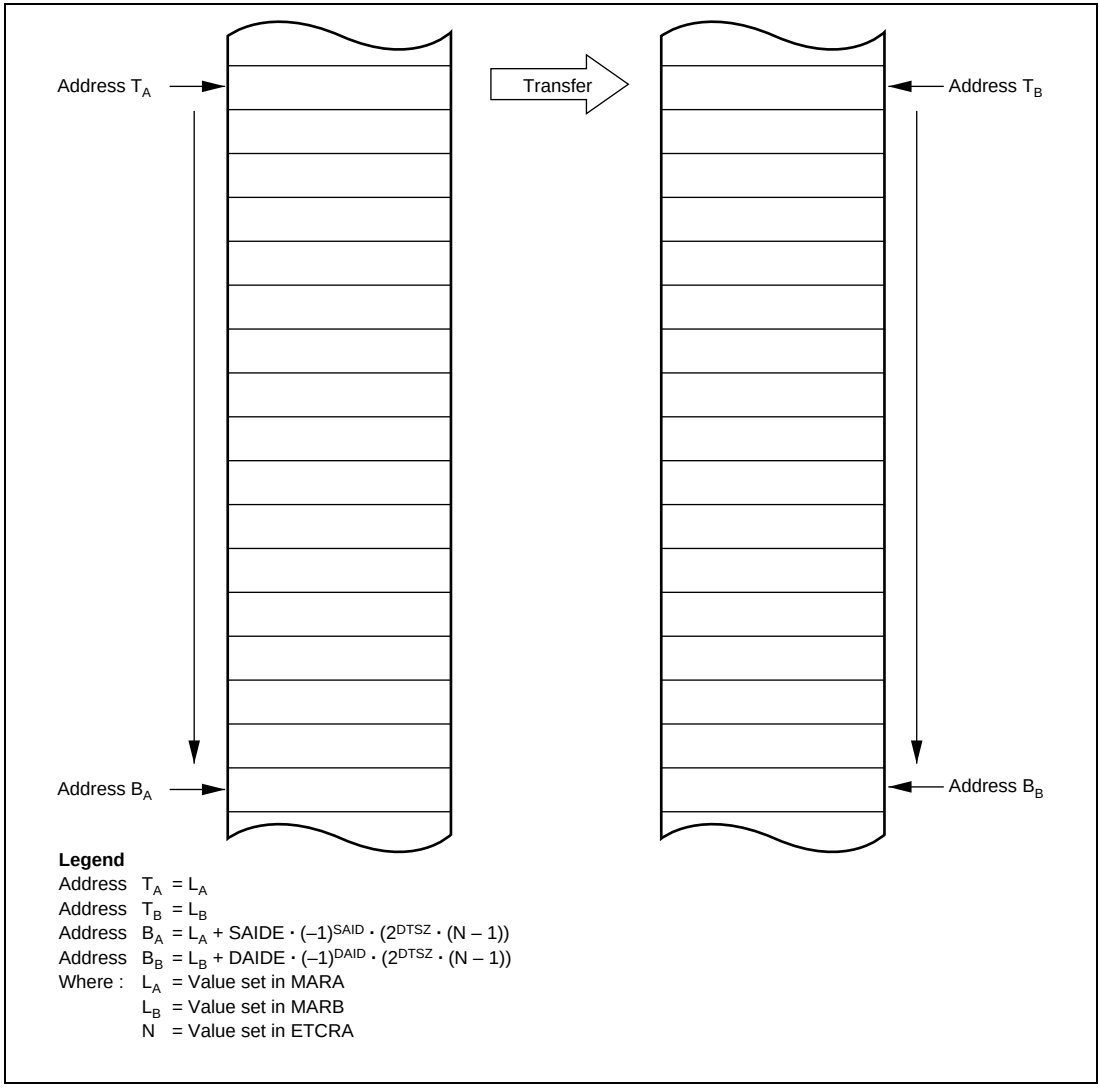
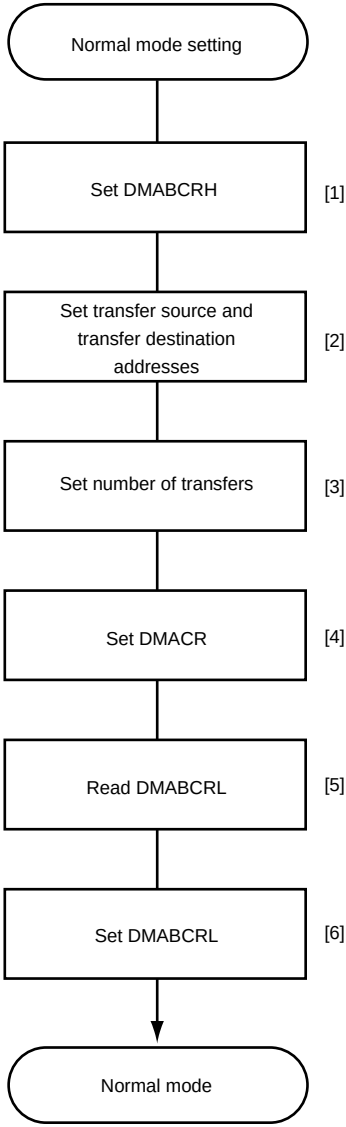


Figure 8.12 Operation in Normal Mode

Transfer requests (activation sources) are external requests and auto-requests. With auto-request, the DMAC is only activated by register setting, and the specified number of transfers are performed automatically. With auto-request, cycle steal mode or burst mode can be selected. In cycle steal mode, the bus is released to another bus master each time a transfer is performed. In burst mode, the bus is held continuously until transfer ends.

Figure 8.13 shows an example of the setting procedure for normal mode.



[1] Set each bit in DMABCRH.
- Set the FAE bit to 1 to select full address mode.
- Specify enabling or disabling of internal interrupt clearing with the DTA bit.

[2] Set the transfer source address in MARA, and the transfer destination address in MARB.

[3] Set the number of transfers in ETCRA.

[4] Set each bit in DMACRA and DMACRB.
- Set the transfer data size with the DTSZ bit.
- Specify whether MARA is to be incremented, decremented, or fixed, with the SAID and SAIDE bits.
- Clear the BLKE bit to 0 to select normal mode.
- Specify whether MARB is to be incremented, decremented, or fixed, with the DAID and DAIDE bits.
- Select the activation source with bits DTF3 to DTF0.

[5] Read DTE = 0 and DTME = 0 in DMABCRL.

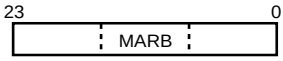
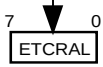
[6] Set each bit in DMABCRL.
- Specify enabling or disabling of transfer end interrupts with the DTIE bit.
- Set both the DTME bit and the DTE bit to 1 to enable transfer.

Figure 8.13 Example of Normal Mode Setting Procedure

8.5.7 Block Transfer Mode

In block transfer mode, data transfer is performed with channels A and B used in combination. Block transfer mode can be specified by setting the FAE bit in DMABCRH and the BLKE bit in DMACRA to 1. In block transfer mode, a data transfer of the specified block size is carried out in response to a single transfer request, and this is executed for the number of times specified in ETCRB. The transfer source is specified by MARA, and the transfer destination by MARB. Either the transfer source or the transfer destination can be selected as a block area (an area composed of a number of bytes or words). Table 8.10 summarizes register functions in block transfer mode.

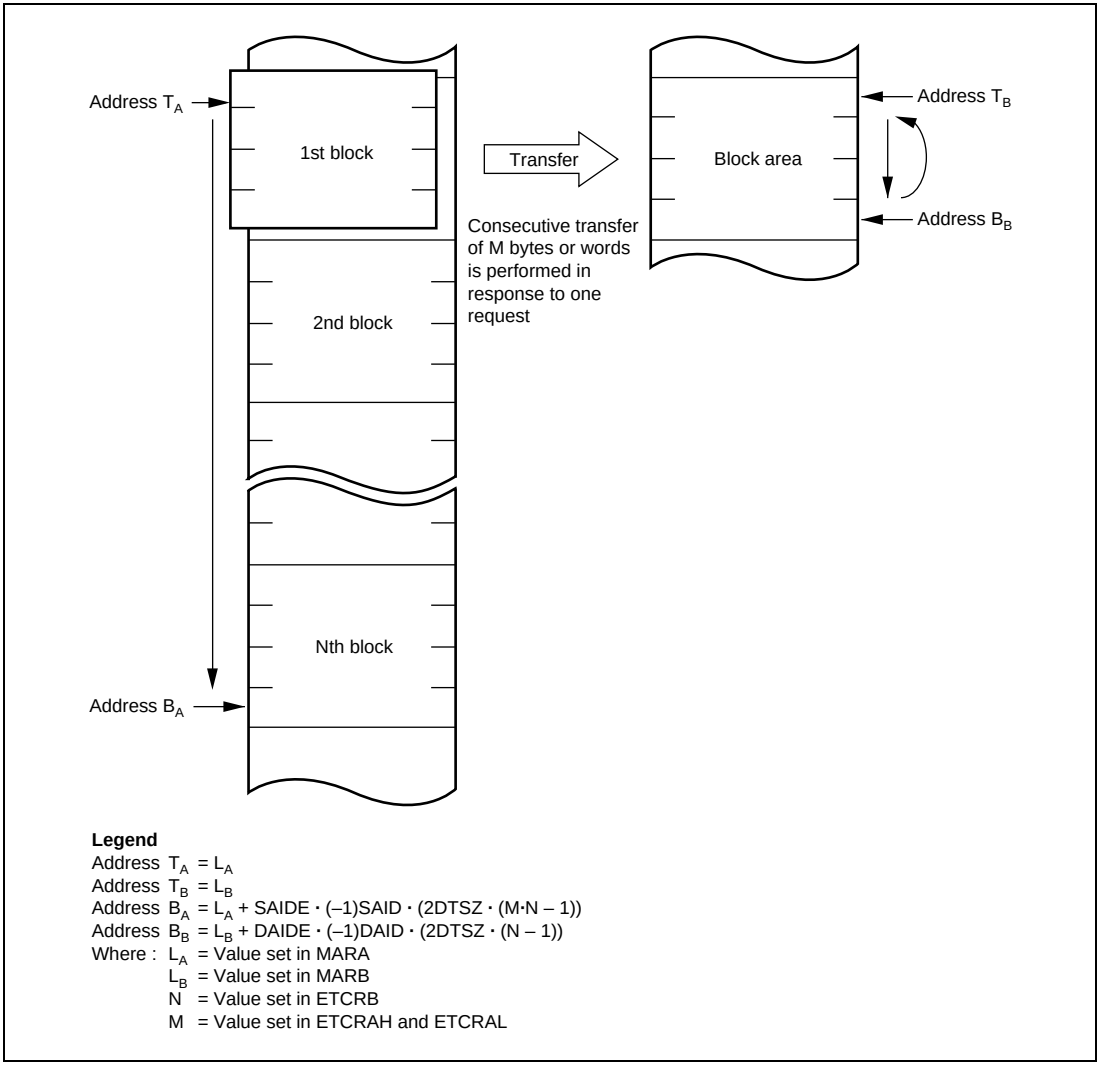
Table 8.10 Register Functions in Block Transfer Mode

Register	Function	Initial Setting	Operation
	Source address register	Start address of transfer source	Incremented/decremented every transfer, or fixed
	Destination address register	Start address of transfer destination	Incremented/decremented every transfer, or fixed
	Holds block size	Block size	Fixed
	Block size counter	Block size	Decremented every transfer; ETCRH value copied when count reaches H'00
	Block transfer counter	Number of block transfers	Decremented every block transfer; transfer ends when count reaches H'0000

MARA and MARB specify the start addresses of the transfer source and transfer destination, respectively, as 24 bits. MAR can be incremented or decremented by 1 or 2 each time a byte or word is transferred, or can be fixed. Incrementing, decrementing, or holding a fixed value can be set separately for MARA and MARB. Whether a block is to be designated for MARA or for MARB is specified by the BLKDIR bit in DMACRA.

To specify the number of transfers, if M is the size of one block (where M = 1 to 256) and N transfers are to be performed (where N = 1 to 65,536), M is set in both ETCRAH and ETCRAL, and N in ETCRB.

Figure 8.14 illustrates operation in block transfer mode when MARB is designated as a block area.



Legend

Address T_A = L_A
Address T_B = L_B
Address B_A = L_A + SAIDE · (–1)SAID · (2DTSZ · (M·N – 1))
Address B_B = L_B + DAIDE · (–1)DAID · (2DTSZ · (N – 1))
Where : L_A = Value set in MARA
L_B = Value set in MARB
N = Value set in ETCRB
M = Value set in ETCRAH and ETCRAL

Figure 8.14 Operation in Block Transfer Mode (BLKDIR = 0)

Figure 8.15 illustrates operation in block transfer mode when MARA is designated as a block area.

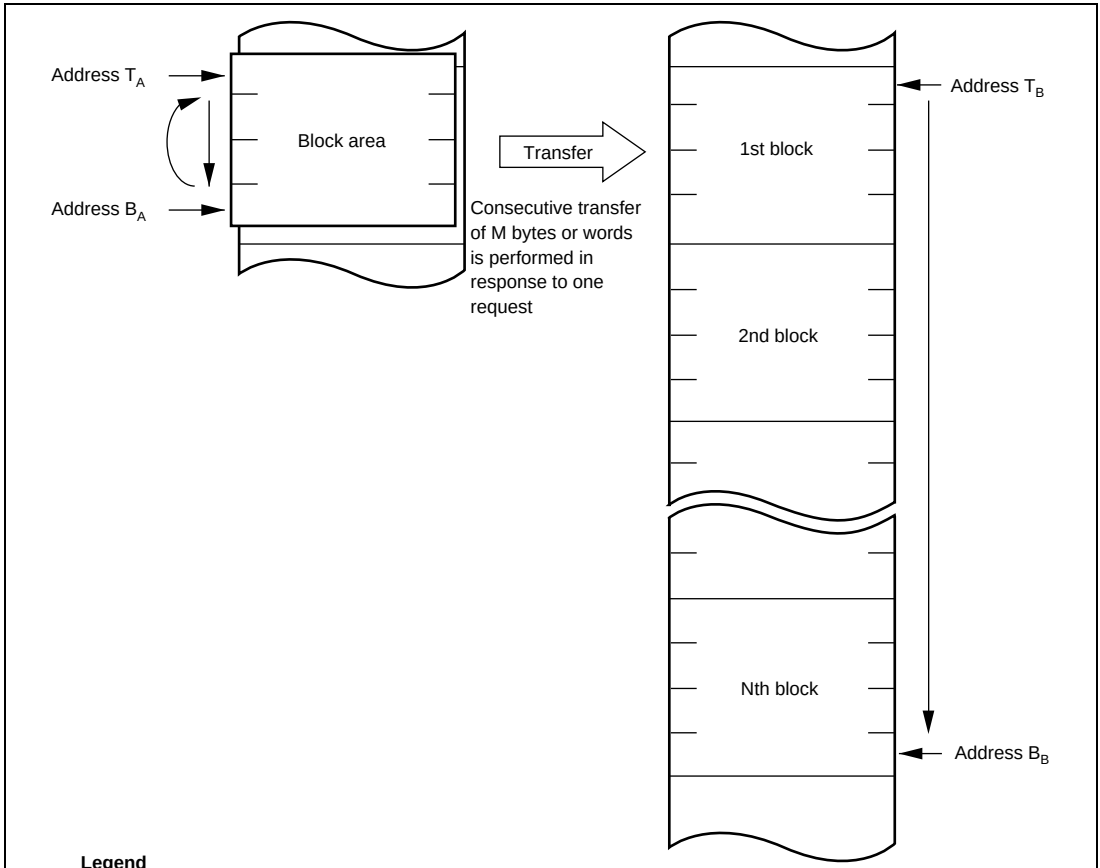


Figure 8.15 Operation in Block Transfer Mode (BLKDIR = 1)

ETCRAL is decremented by 1 each time a byte or word transfer is performed. In response to a single transfer request, burst transfer is performed until the value in ETCRAL reaches H'00. ETCRAL is then loaded with the value in ETCRAH. At this time, the value in the MAR register for which a block designation has been given by the BLKDIR bit in DMACRA is restored in accordance with the DTSZ, SAID/DAID, and SAIDE/DAIDE bits in DMACR.

ETCRB is decremented by 1 after every block transfer, and when the count reaches H'0000 the DTE bit in DMABCRL is cleared and transfer ends. If the DTIE bit in DMABCRL is set to 1 at this point, an interrupt request is sent to the CPU or DTC.

Figure 8.16 shows the operation flow in block transfer mode.

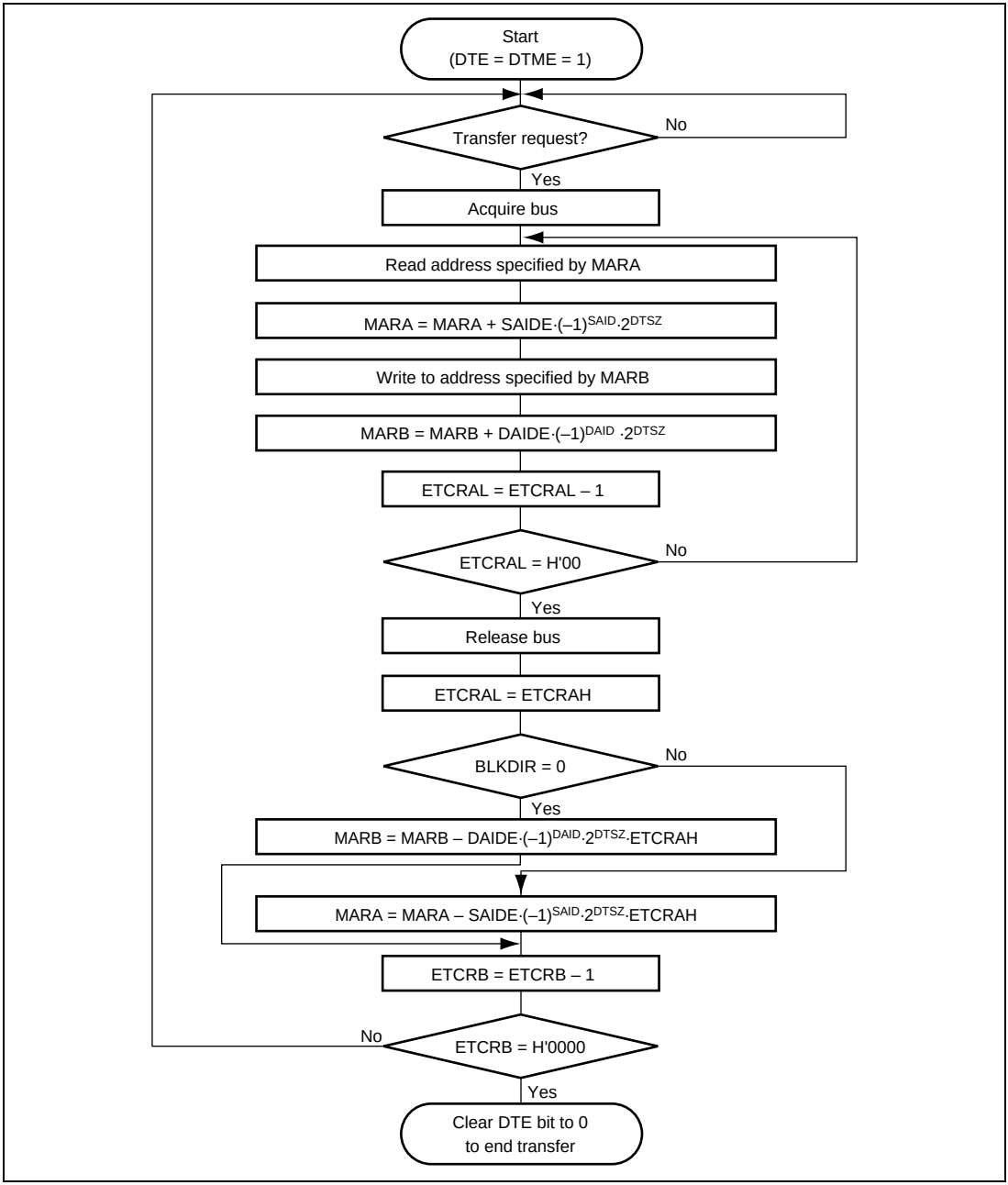
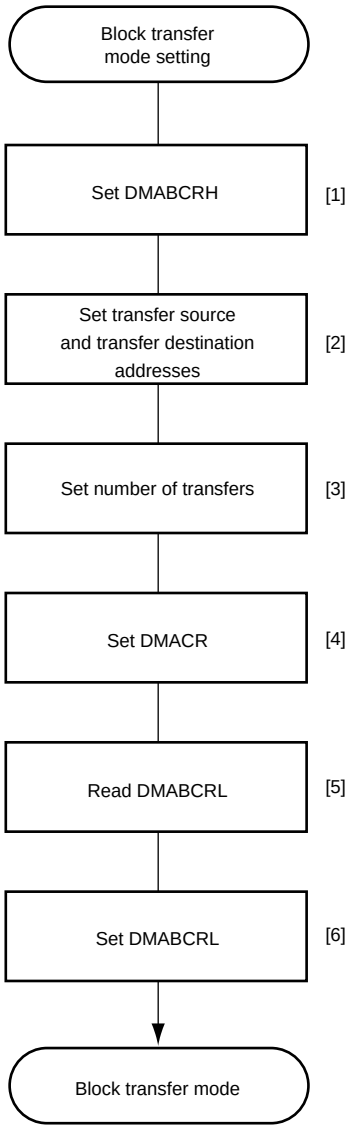


Figure 8.16 Operation Flow in Block Transfer Mode

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmit-data-empty and receive-data-full interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts.

Figure 8.17 shows an example of the setting procedure for block transfer mode.



[1] Set each bit in DMABCRH.
- Set the FAE bit to 1 to select full address mode.
- Specify enabling or disabling of internal interrupt clearing with the DTA bit.

[2] Set the transfer source address in MARA, and the transfer destination address in MARB.

[3] Set the block size in both ETCRAH and ETCRAL. Set the number of transfers in ETCRB.

[4] Set each bit in DMACRA and DMACRB.
- Set the transfer data size with the DTSZ bit.
- Specify whether MARA is to be incremented, decremented, or fixed, with the SAID and SAIDE bits.
- Set the BLKE bit to 1 to select block transfer mode.
- Specify whether the transfer source or the transfer destination is a block area with the BLKDIR bit.
- Specify whether MARB is to be incremented, decremented, or fixed, with the DAID and DAIDE bits.
- Select the activation source with bits DTF3 to DTF0.

[5] Read DTE = 0 and DTME = 0 in DMABCRL.

[6] Set each bit in DMABCRL.
- Specify enabling or disabling of transfer end interrupts to the CPU with the DTIE bit.
- Set both the DTME bit and the DTE bit to 1 to enable transfer.

Figure 8.17 Example of Block Transfer Mode Setting Procedure

8.5.8 Basic Bus Cycles

An example of the basic DMAC bus cycle timing is shown in figure 8.18. In this example, word-size transfer is performed from 16-bit, 2-state access space to 8-bit, 3-state access space. When the bus is transferred from the CPU to the DMAC, a source address read and destination address write are performed. The bus is not released in response to another bus request, etc., between these read and write operations. As like CPU cycles, DMA cycles conform to the bus controller settings.

The address is not output to the external address bus in an access to on-chip memory or an internal I/O register.

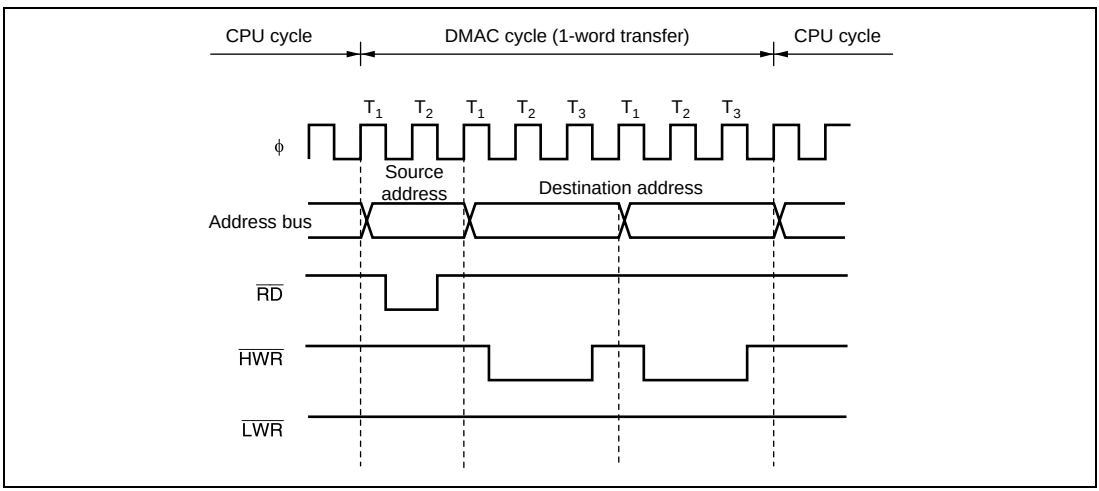


Figure 8.18 Example of DMA Transfer Bus Timing

8.5.9 DMA Transfer (Dual Address Mode) Bus Cycles

Short Address Mode: Figure 8.19 shows a transfer example in which TEND output is enabled and byte-size short address mode transfer (sequential/idle/repeat mode) is performed from external 8-bit, 2-state access space to internal I/O space.

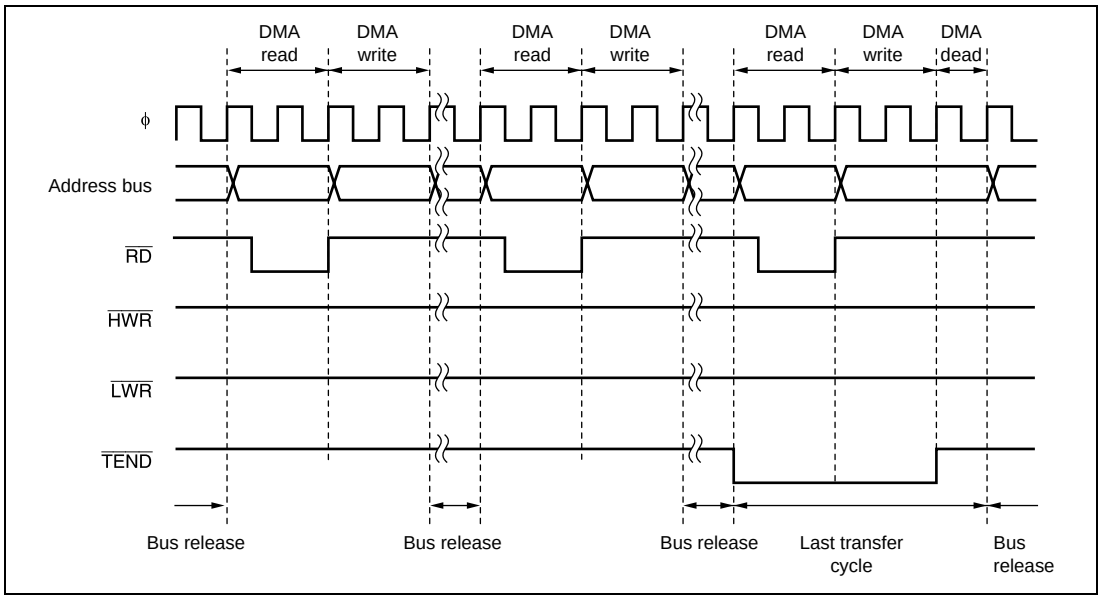


Figure 8.19 Example of Short Address Mode Transfer

A byte or word transfer is performed for a single transfer request, and after the transfer, the bus is released. While the bus is released, one or more bus cycles are executed by the CPU or DTC.

In the transfer end cycle (the cycle in which the transfer counter reaches 0), a one-state DMA dead cycle is inserted after the DMA write cycle.

In repeat mode, when TEND output is enabled, TEND output goes low in the transfer end cycle.

Full Address Mode (Cycle Steal Mode): Figure 8.20 shows a transfer example in which TEND output is enabled and word-size full address mode transfer (cycle steal mode) is performed from external 16-bit, 2-state access space to external 16-bit, 2-state access space.

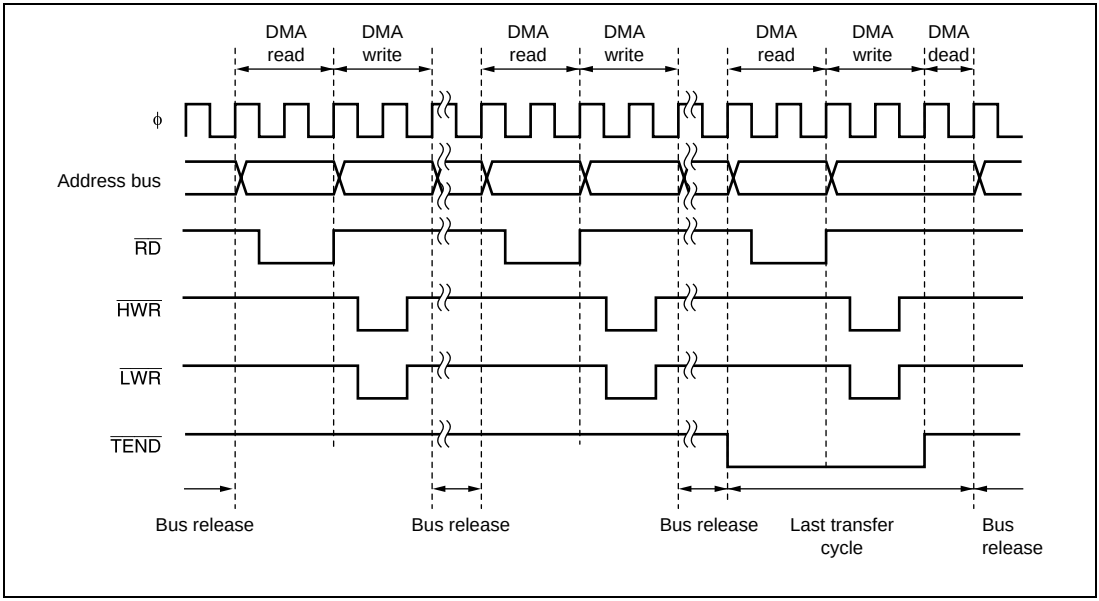


Figure 8.20 Example of Full Address Mode Transfer (Cycle Steal)

A byte or word transfer is performed for a single transfer request, and after the transfer, the bus is released. While the bus is released, one bus cycle is executed by the CPU or DTC.

In the transfer end cycle (the cycle in which the transfer counter reaches 0), a one-state DMA dead cycle is inserted after the DMA write cycle.

Full Address Mode (Burst Mode): Figure 8.21 shows a transfer example in which TEND output is enabled and word-size full address mode transfer (burst mode) is performed from external 16-bit, 2-state access space to external 16-bit, 2-state access space.

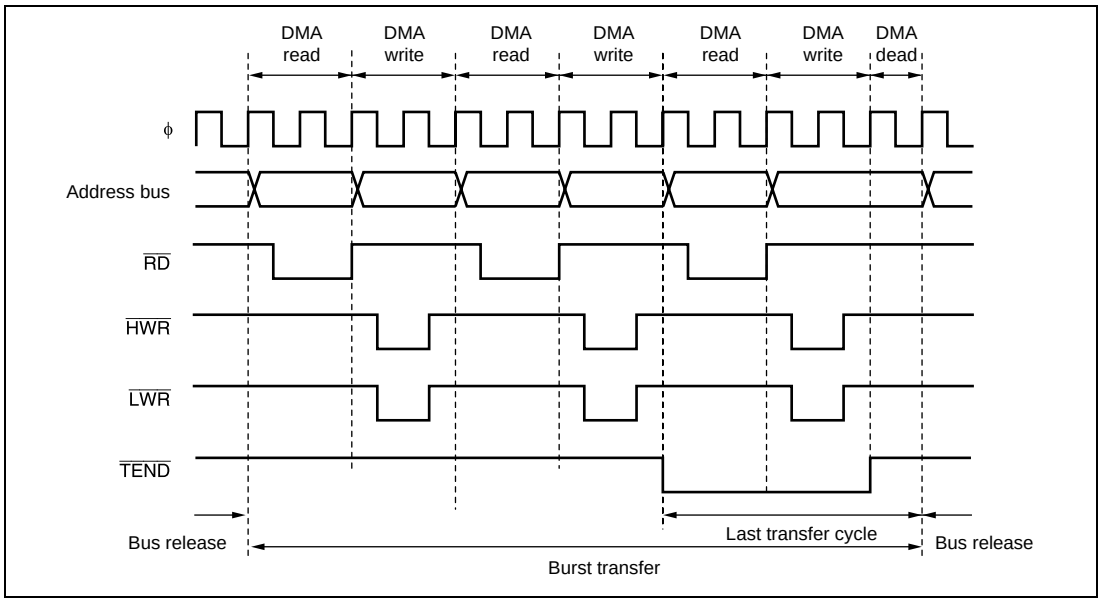


Figure 8.21 Example of Full Address Mode Transfer (Burst Mode)

In burst mode, one-byte or one-word transfers are executed consecutively until transfer ends.

In the transfer end cycle (the cycle in which the transfer counter reaches 0), a one-state DMA dead cycle is inserted after the DMA write cycle.

If a request from another higher-priority channel is generated after burst transfer starts, that channel has to wait until the burst transfer ends.

If an NMI interrupt is generated while a channel designated for burst transfer is in the transfer enabled state, the DTME bit in DMABCRL is cleared and the channel is placed in the transfer disabled state. If burst transfer has already been activated inside the DMAC, the bus is released on completion of a one-byte or one-word transfer within the burst transfer, and burst transfer is suspended. If the last transfer cycle of the burst transfer has already been activated inside the DMAC, execution continues to the end of the transfer even if the DTME bit is cleared.

Full Address Mode (Block Transfer Mode): Figure 8.22 shows a transfer example in which TEND output is enabled and word-size full address mode transfer (block transfer mode) is performed from internal 16-bit, 1-state access space to external 16-bit, 2-state access space.

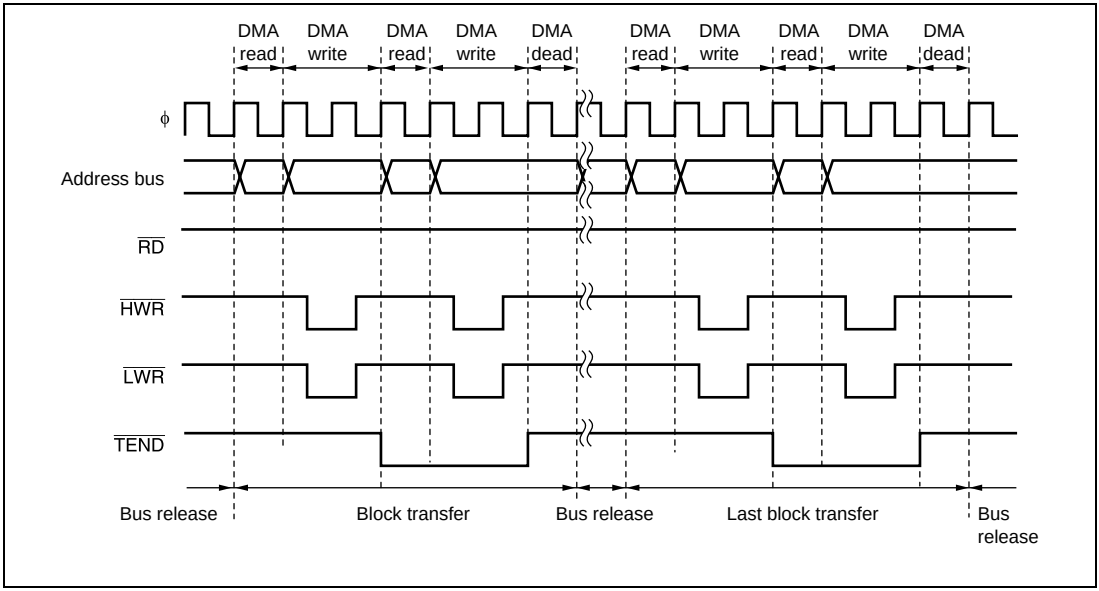


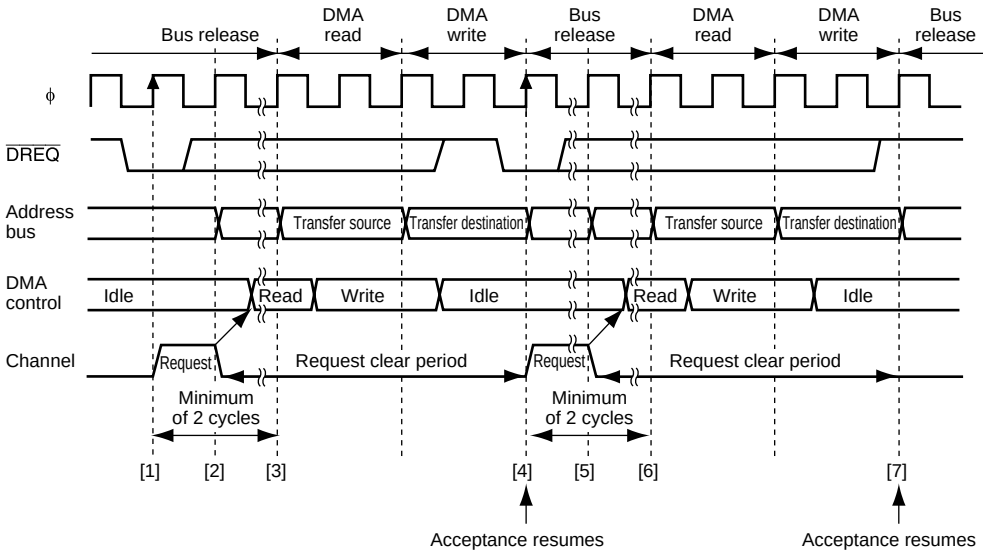
Figure 8.22 Example of Full Address Mode Transfer (Block Transfer Mode)

A one-block transfer is performed for a single transfer request, and after the transfer the bus is released. While the bus is released, one or more bus cycles are executed by the CPU or DTC.

In the transfer end cycle of each block (the cycle in which the transfer counter reaches 0), a one-state DMA dead cycle is inserted after the DMA write cycle. Even if an NMI interrupt is generated during data transfer, block transfer operation is not affected until data transfer for one block has ended.

DREQ Pin Falling Edge Activation Timing: Set the DTA bit in DMABCRH to 1 for the channel for which the DREQ pin is selected.

Figure 8.23 shows an example of normal mode transfer activated by the DREQ pin falling edge.



[1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of φ, and the request is held.

[2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.

[3] [6] Start of DMA cycle; $\overline{\text{DREQ}}$ pin high level sampling on the rising edge of φ starts.

[4] [7] When the $\overline{\text{DREQ}}$ pin high level has been sampled, acceptance is resumed after the write cycle is completed.
(As in [1], the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of φ, and the request is held.)

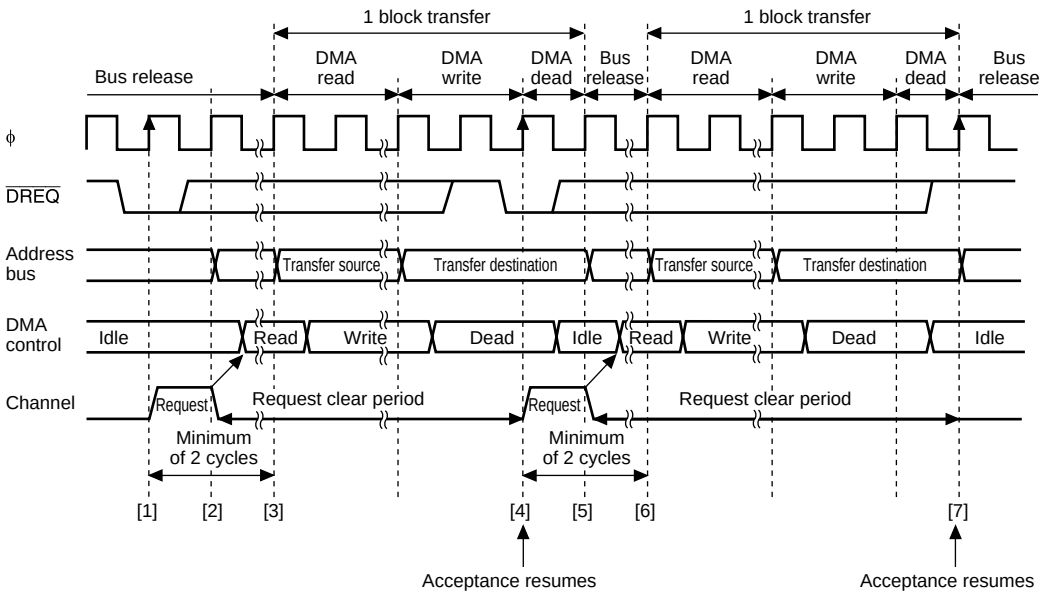
Note: In write data buffer mode, bus breaks from [2] to [7] may be hidden, and not visible.

Figure 8.23 Example of DREQ Pin Falling Edge Activated Normal Mode Transfer

DREQ pin sampling is performed every cycle, with the rising edge of the next ø cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

When the DREQ pin low level is sampled while acceptance by means of the DREQ pin is possible, the request is held in the DMAC. Then, when activation is initiated in the DMAC, the request is cleared, and DREQ pin high level sampling for edge detection is started. If DREQ pin high level sampling has been completed by the time the DMA write cycle ends, acceptance resumes after the end of the write cycle, DREQ pin low level sampling is performed again, and this operation is repeated until the transfer ends.

Figure 8.24 shows an example of block transfer mode transfer activated by the DREQ pin falling edge.



[1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ, and the request is held.
[2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.
[3] [6] Start of DMA cycle; $\overline{\text{DREQ}}$ pin high level sampling on the rising edge of ϕ starts.
[4] [7] When the $\overline{\text{DREQ}}$ pin high level has been sampled, acceptance is resumed after the dead cycle is completed.
(As in [1], the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ, and the request is held.)

Note: In write data buffer mode, bus breaks from [2] to [7] may be hidden, and not visible.

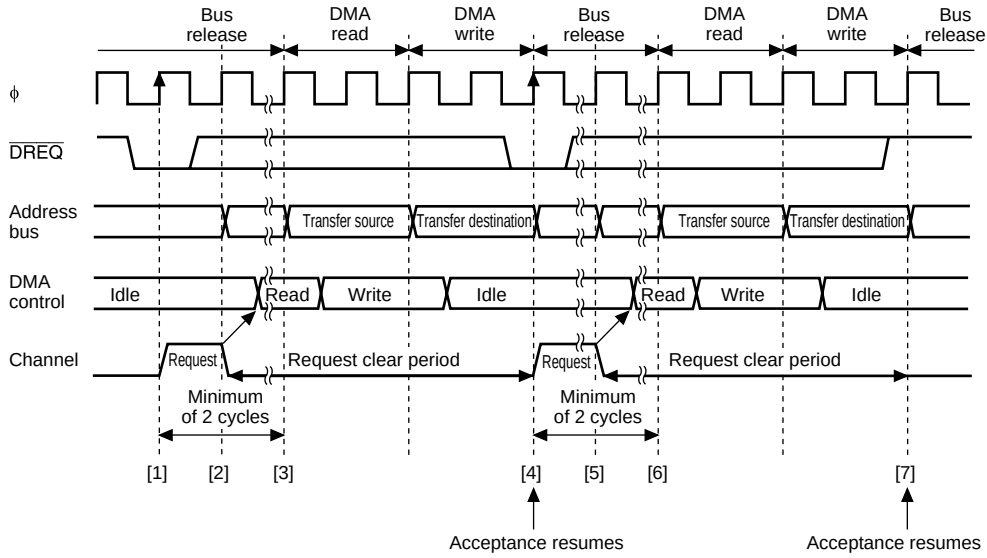
Figure 8.24 Example of DREQ Pin Falling Edge Activated Block Transfer Mode Transfer

DREQ pin sampling is performed every cycle, with the rising edge of the next ø cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

When the DREQ pin low level is sampled while acceptance by means of the DREQ pin is possible, the request is held in the DMAC. Then, when activation is initiated in the DMAC, the request is cleared, and DREQ pin high level sampling for edge detection is started. If DREQ pin high level sampling has been completed by the time the DMA dead cycle ends, acceptance resumes after the end of the dead cycle, DREQ pin low level sampling is performed again, and this operation is repeated until the transfer ends.

DREQ Pin Low Level Activation Timing (Normal Mode): Set the DTA bit in DMABCRH to 1 for the channel for which the DREQ pin is selected.

Figure 8.25 shows an example of normal mode transfer activated by the DREQ pin low level.



[1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ, and the request is held.
[2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.
[3] [6] The DMA cycle is started.
[4] [7] Acceptance is resumed after the write cycle is completed.
(As in [1], the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ, and the request is held.)

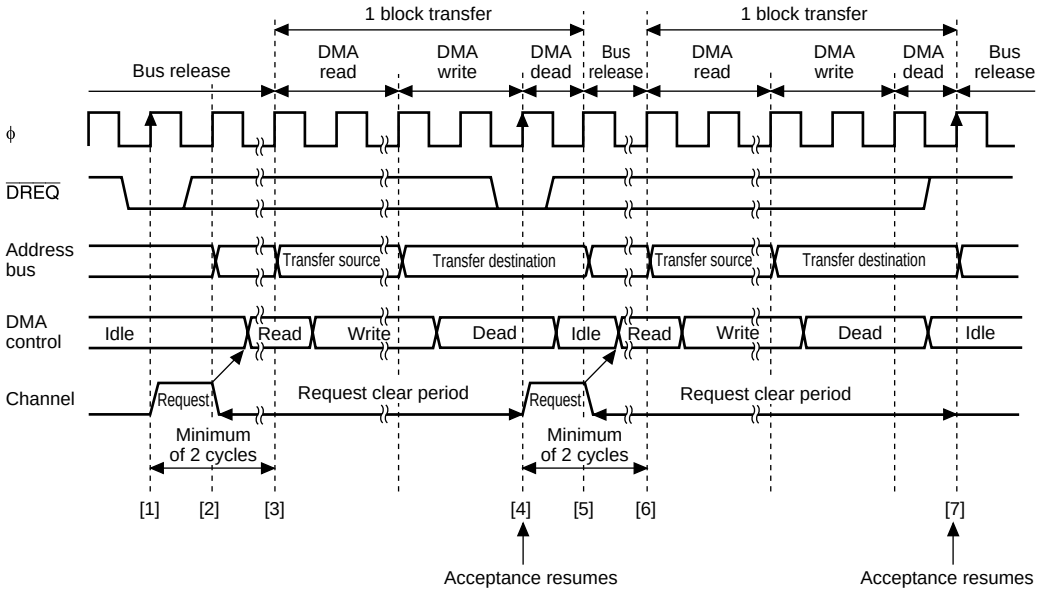
Note: In write data buffer mode, bus breaks from [2] to [7] may be hidden, and not visible.

Figure 8.25 Example of DREQ Pin Low Level Activated Normal Mode Transfer

DREQ pin sampling is performed every cycle, with the rising edge of the next ø cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

When the DREQ pin low level is sampled while acceptance by means of the DREQ pin is possible, the request is held in the DMAC. Then, when activation is initiated in the DMAC, the request is cleared. After the end of the write cycle, acceptance resumes, DREQ pin low level sampling is performed again, and this operation is repeated until the transfer ends.

Figure 8.26 shows an example of block transfer mode transfer activated by DREQ pin low level.



[1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ, and the request is held.

[2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.

[3] [6] The DMA cycle is started.

[4] [7] Acceptance is resumed after the dead cycle is completed.
(As in [1], the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ, and the request is held.)

Note: In write data buffer mode, bus breaks from [2] to [7] may be hidden, and not visible.

Figure 8.26 Example of DREQ Pin Low Level Activated Block Transfer Mode Transfer

DREQ pin sampling is performed every cycle, with the rising edge of the next ø cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

When the DREQ pin low level is sampled while acceptance by means of the DREQ pin is possible, the request is held in the DMAC. Then, when activation is initiated in the DMAC, the request is cleared. After the end of the dead cycle, acceptance resumes, DREQ pin low level sampling is performed again, and this operation is repeated until the transfer ends.

8.5.10 DMA Transfer (Single Address Mode) Bus Cycles

Single Address Mode (Read): Figure 8.27 shows a transfer example in which TEND output is enabled and byte-size single address mode transfer (read) is performed from external 8-bit, 2-state access space to an external device.

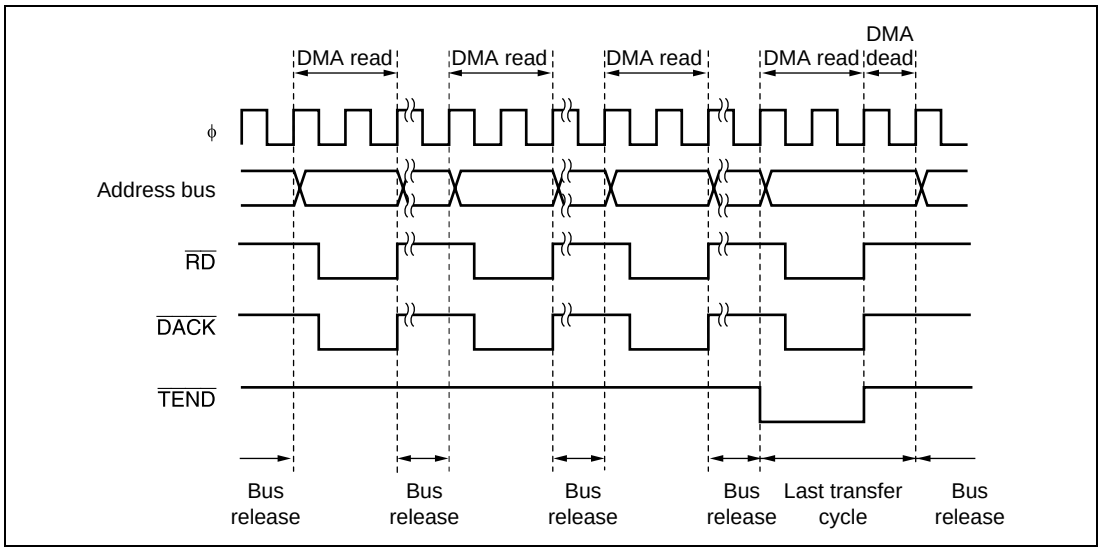


Figure 8.27 Example of Single Address Mode Transfer (Byte Read)

Figure 8.28 shows a transfer example in which TEND output is enabled and word-size single address mode transfer (read) is performed from external 8-bit, 2-state access space to an external device.

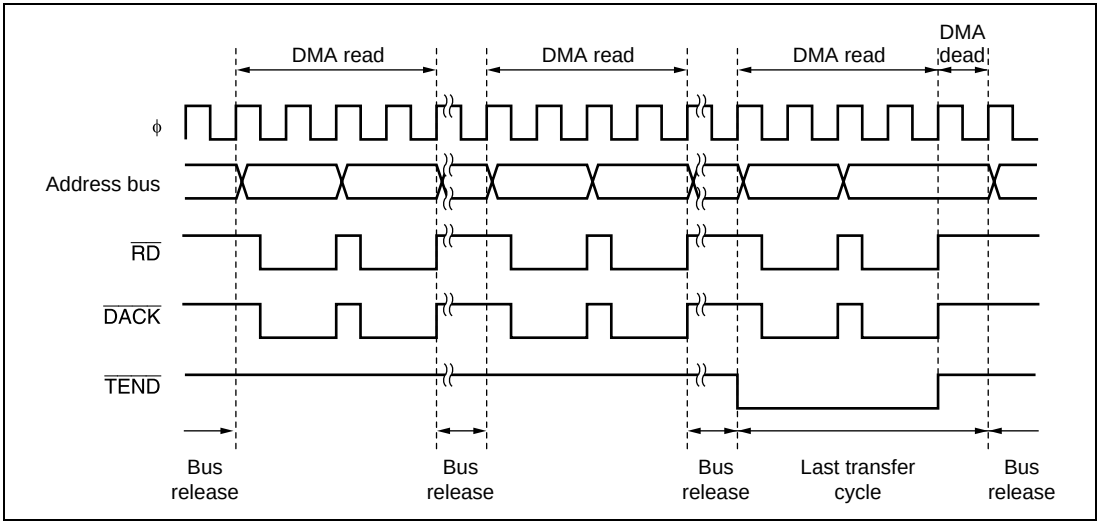


Figure 8.28 Example of Single Address Mode (Word Read) Transfer

A byte or word transfer is performed for a single transfer request, and after the transfer, the bus is released. While the bus is released, one or more bus cycles are executed by the CPU or DTC.

In the transfer end cycle (the cycle in which the transfer counter reaches 0), a one-state DMA dead cycle is inserted after the DMA write cycle.

Single Address Mode (Write): Figure 8.29 shows a transfer example in which TEND output is enabled and byte-size single address mode transfer (write) is performed from an external device to external 8-bit, 2-state access space.

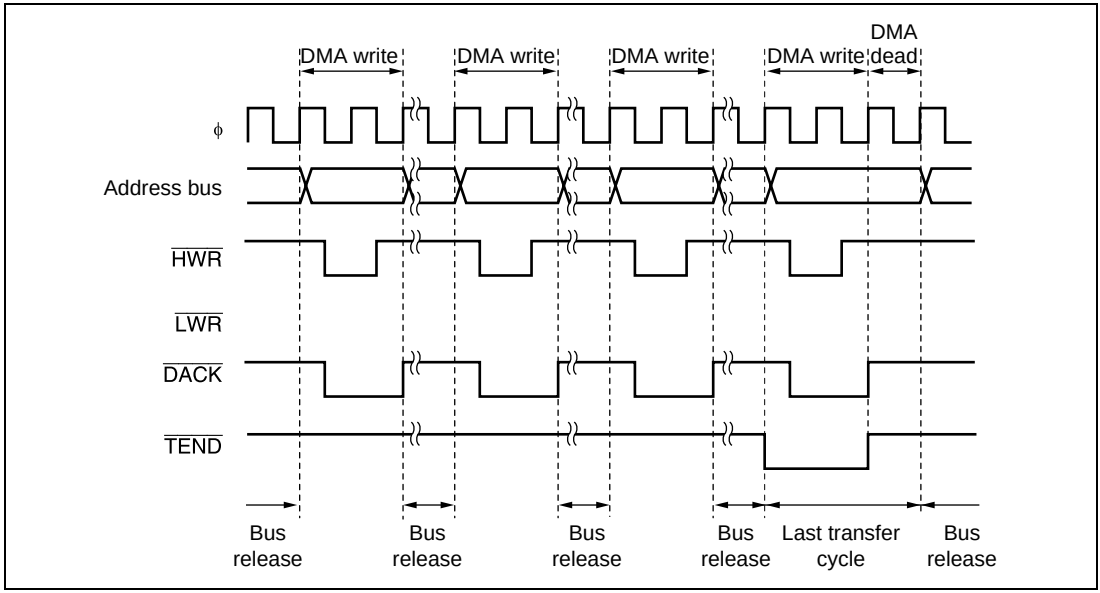


Figure 8.29 Example of Single Address Mode Transfer (Byte Write)

Figure 8.30 shows a transfer example in which TEND output is enabled and word-size single address mode transfer (write) is performed from an external device to external 8-bit, 2-state access space.

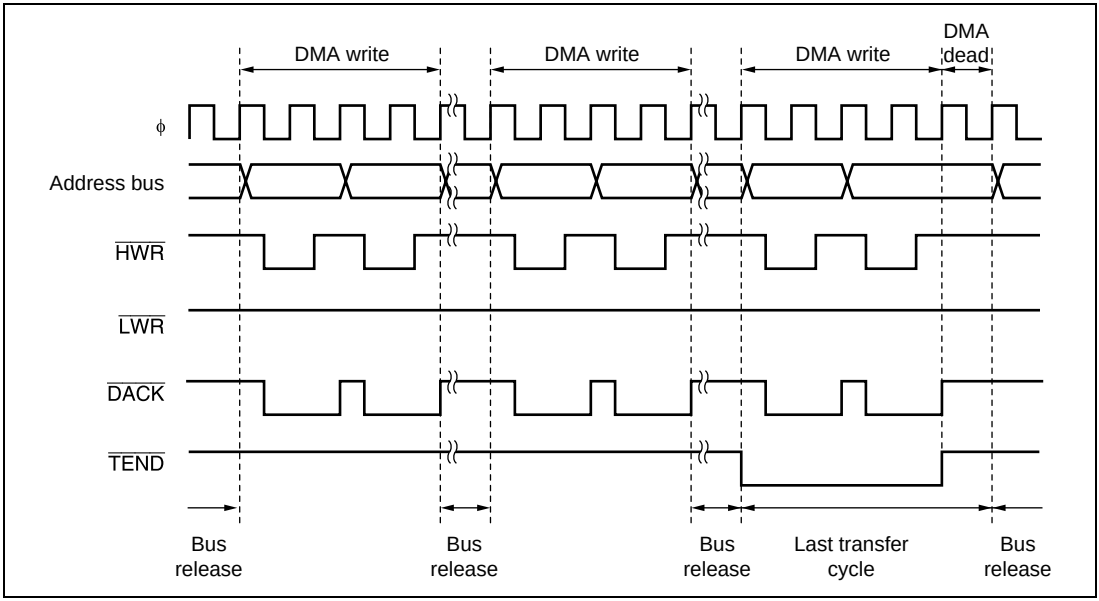


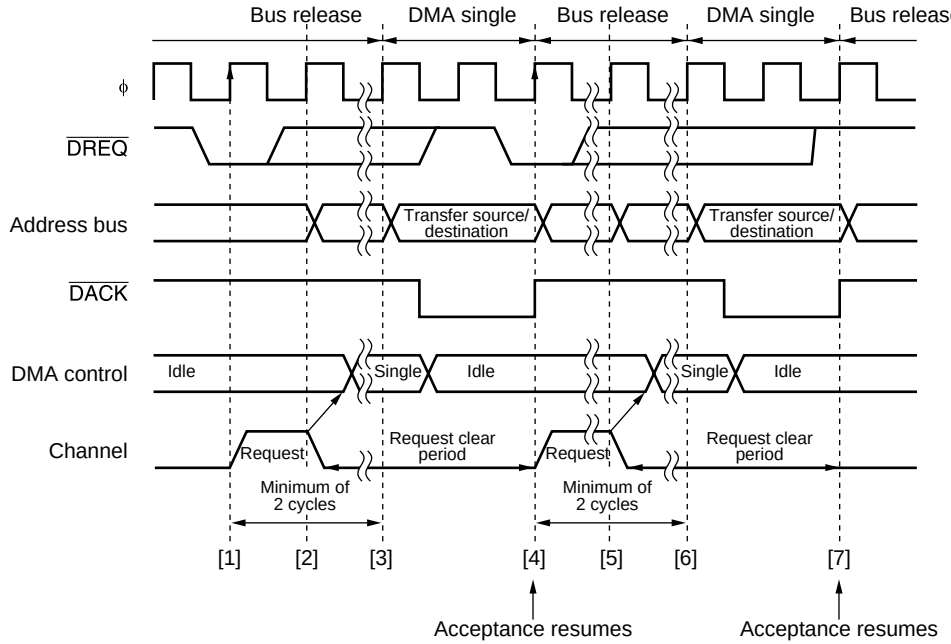
Figure 8.30 Example of Single Address Mode Transfer (Word Write)

A byte or word transfer is performed for a single transfer request, and after the transfer, the bus is released. While the bus is released, one or more bus cycles are executed by the CPU or DTC.

In the transfer end cycle (the cycle in which the transfer counter reaches 0), a one-state DMA dead cycle is inserted after the DMA write cycle.

DREQ Pin Falling Edge Activation Timing: Set the DTA bit in DMABCRH to 1 for the channel for which the DREQ pin is selected.

Figure 8.31 shows an example of single address mode transfer activated by the DREQ pin falling edge.



[1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of φ, and the request is held.

[2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.

[3] [6] Start of DMA cycle; $\overline{\text{DREQ}}$ pin high level sampling on the rising edge of φ starts.

[4] [7] When the $\overline{\text{DREQ}}$ pin high level has been sampled, acceptance is resumed after the single cycle is completed. (As in [1], the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of φ, and the request is held.)

Note: In write data buffer mode, bus breaks from [2] to [7] may be hidden, and not visible.

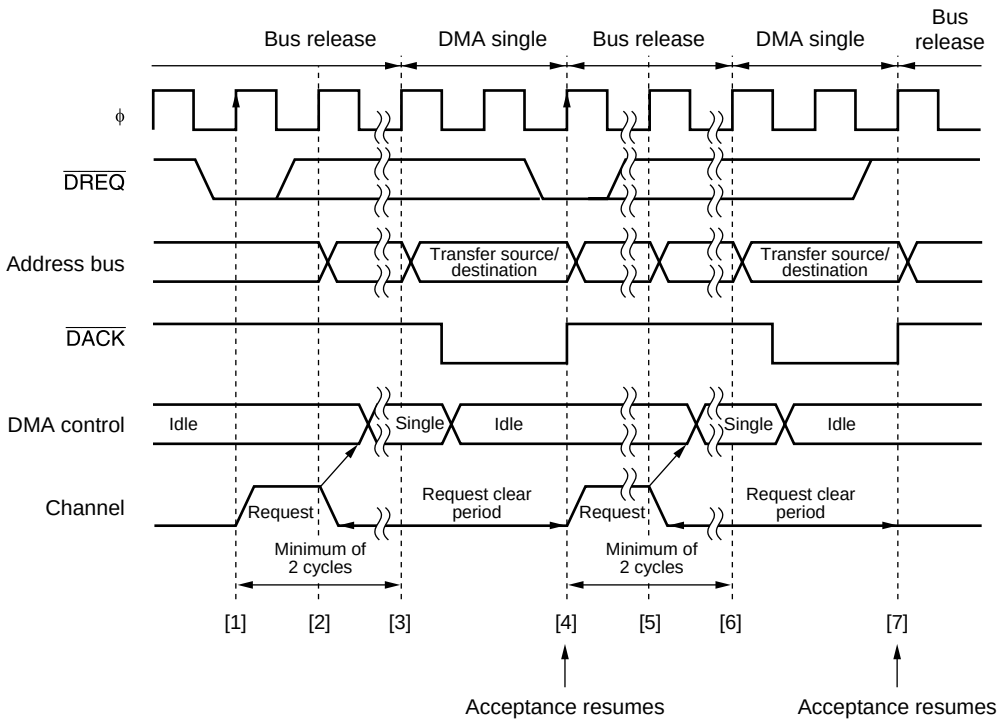
Figure 8.31 Example of DREQ Pin Falling Edge Activated Single Address Mode Transfer

DREQ pin sampling is performed every cycle, with the rising edge of the next ø cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

When the DREQ pin low level is sampled while acceptance by means of the DREQ pin is possible, the request is held in the DMAC. Then, when activation is initiated in the DMAC, the request is cleared, and DREQ pin high level sampling for edge detection is started. If DREQ pin high level sampling has been completed by the time the DMA single cycle ends, acceptance resumes after the end of the single cycle, DREQ pin low level sampling is performed again, and this operation is repeated until the transfer ends.

DREQ Pin Low Level Activation Timing: Set the DTA bit in DMABCRH to 1 for the channel for which the DREQ pin is selected.

Figure 8.32 shows an example of single address mode transfer activated by the DREQ pin low level.



[1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of φ, and the request is held.
[2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.
[3] [6] The DMAC cycle is started.
[4] [7] Acceptance is resumed after the single cycle is completed.
(As in [1], the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of φ, and the request is held.)

Note: In write data buffer mode, bus breaks from [2] to [7] may be hidden, and not visible.

Figure 8.32 Example of DREQ Pin Low Level Activated Single Address Mode Transfer

DREQ pin sampling is performed every cycle, with the rising edge of the next ø cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

When the DREQ pin low level is sampled while acceptance by means of the DREQ pin is possible, the request is held in the DMAC. Then, when activation is initiated in the DMAC, the request is cleared. After the end of the single cycle, acceptance resumes, DREQ pin low level sampling is performed again, and this operation is repeated until the transfer ends.

8.5.11 Multi-Channel Operation

The DMAC channel priority order is: channel 0 > channel 1, and channel A > channel B. Table 8.11 summarizes the priority order for DMAC channels.

Table 8.11 DMAC Channel Priority Order

Short Address Mode	Full Address Mode	Priority
Channel 0A	Channel 0	High
Channel 0B		
Channel 1A	Channel 1	
Channel 1B		Low

If transfer requests are issued simultaneously for more than one channel, or if a transfer request for another channel is issued during a transfer, when the bus is released, the DMAC selects the highest-priority channel from among those issuing a request according to the priority order shown in table 8.11. During burst transfer, or when one block is being transferred in block transfer, the channel will not be changed until the end of the transfer. Figure 8.33 shows a transfer example in which transfer requests are issued simultaneously for channels 0A, 0B, and 1.

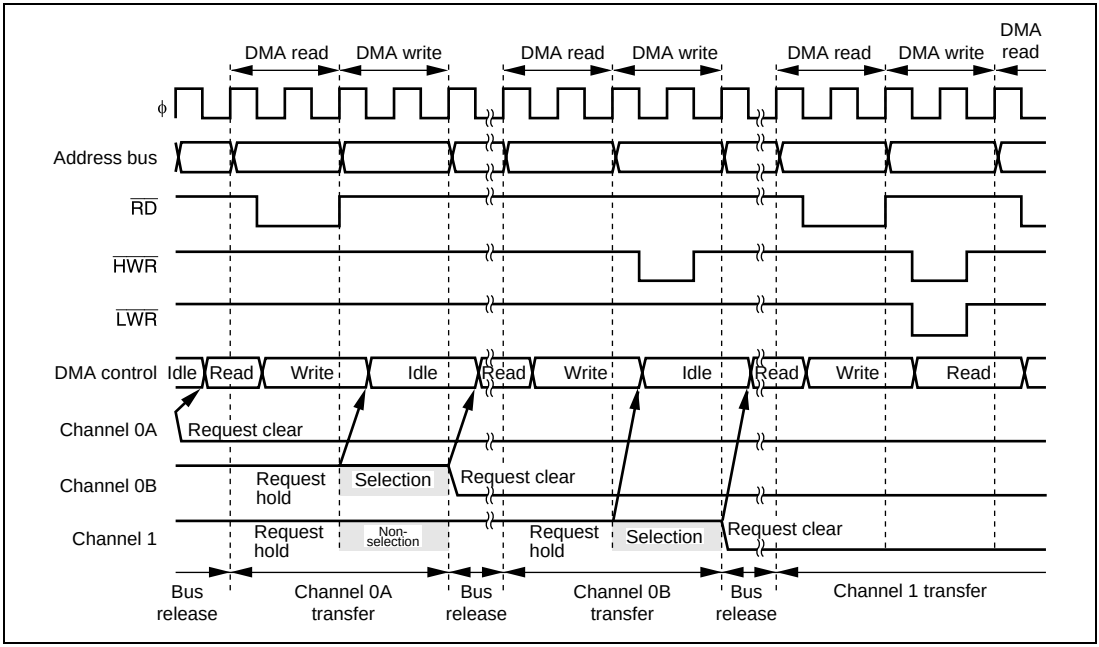


Figure 8.33 Example of Multi-Channel Transfer

8.5.12 Relation between DMAC and External Bus Requests, and DTC

The DMA read cycle and write cycle are inseparable, and so the external bus release cycle and DTC cycle do not arise between the DMA external read cycle and internal write cycle.

When the read cycle and write cycle are set in series as in a burst transfer or block transfer, the external bus release may be inserted after the write cycle. As the DTC has a lower priority than the DMAC, it is not executed until the DMAC releases the bus.

When the DMA read cycle or write cycle accesses the on-chip memory or an internal I/O register, the DMAC cycle or external bus release may be executed at the same time.

8.5.13 DMAC and NMI Interrupts

When an NMI interrupt is requested, burst mode transfer in full address mode is interrupted. An NMI interrupt does not affect the operation of the DMAC in other modes.

In full address mode, transfer is enabled for a channel when both the DTE bit and DTME bit are set to 1. With burst mode setting, the DTME bit is cleared when an NMI interrupt is requested.

If the DTME bit is cleared during burst mode transfer, the DMAC discontinues transfer on completion of the 1-byte or 1-word transfer in progress, then releases the bus, which passes to the CPU.

The channel on which transfer was interrupted can be restarted by setting the DTME bit to 1 again. Figure 8.34 shows the procedure for continuing transfer when it has been interrupted by an NMI interrupt on a channel designated for burst mode transfer.

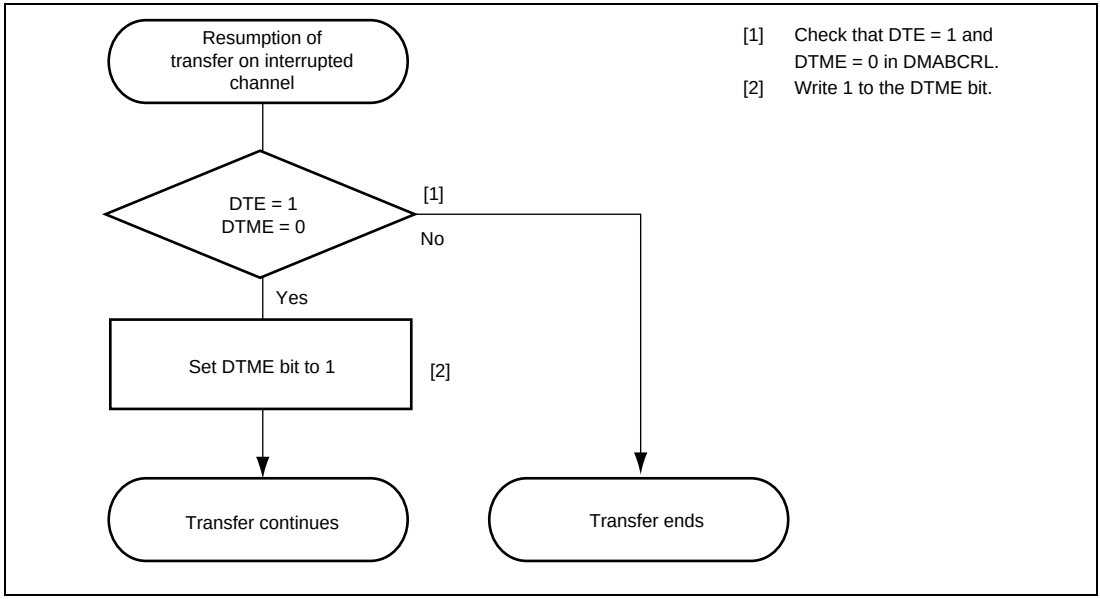


Figure 8.34 Example of Procedure for Continuing Transfer on Channel Interrupted by NMI Interrupt

8.5.14 Forced Termination of DMAC Operation

If the DTE bit in DMABCRL is cleared to 0 for the channel currently operating, the DMAC stops on completion of the 1-byte or 1-word transfer in progress. DMAC operation resumes when the DTE bit is set to 1 again. In full address mode, the same applies to the DTME bit in DMABCRL. Figure 8.35 shows the procedure for forcibly terminating DMAC operation by software.

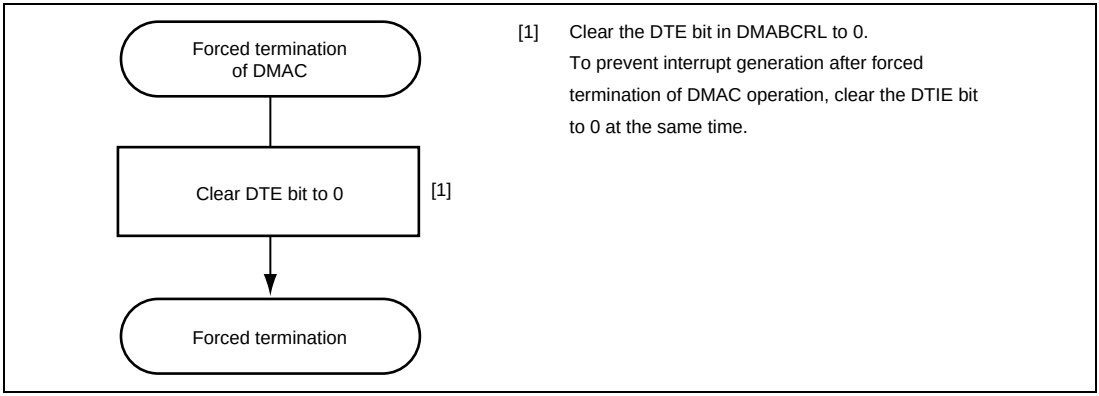


Figure 8.35 Example of Procedure for Forcibly Terminating DMAC Operation

8.5.15 Clearing Full Address Mode

Figure 8.36 shows the procedure for releasing and initializing a channel designated for full address mode. After full address mode has been cleared, the channel can be set to another transfer mode using the appropriate setting procedure.

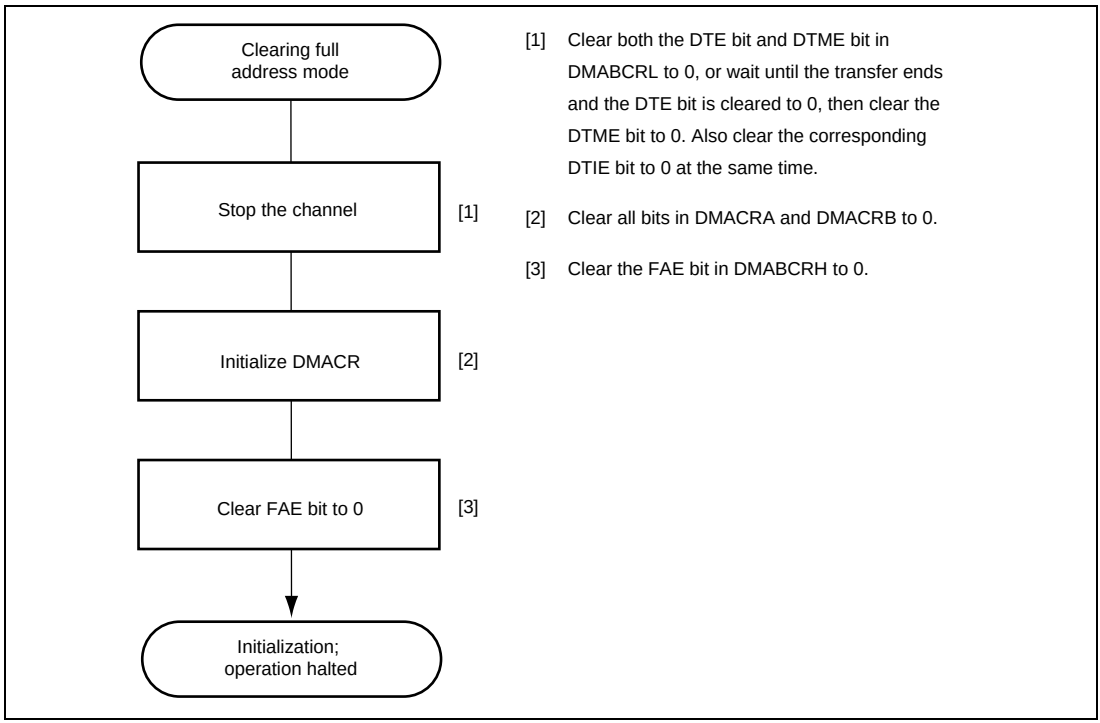


Figure 8.36 Example of Procedure for Clearing Full Address Mode

8.6 Interrupt Sources

The sources of interrupts generated by the DMAC are transfer end and transfer break. Table 8.12 shows the interrupt sources and their priority order.

Table 8.12 Interrupt Sources and Priority Order

Interrupt Name	Interrupt Source		Interrupt Priority Order
	Short Address Mode	Full Address Mode	
DEND0A	Interrupt due to end of transfer on channel 0A	Interrupt due to end of transfer on channel 0	High
DEND0B	Interrupt due to end of transfer on channel 0B	Interrupt due to break in transfer on channel 0	
DEND1A	Interrupt due to end of transfer on channel 1A	Interrupt due to end of transfer on channel 1	
DEND1B	Interrupt due to end of transfer on channel 1B	Interrupt due to break in transfer on channel 1	Low

Enabling or disabling of each interrupt source is set by means of the DTIE bit in DMABCRL for the corresponding channel in DMABCRL, and interrupts from each source are sent to the interrupt controller independently. The priority of transfer end interrupts on each channel is decided by the interrupt controller, as shown in table 8.12.

Figure 8.37 shows a block diagram of a transfer end/transfer break interrupt. An interrupt is always generated when the DTIE bit is set to 1 while the DTE bit in DMABCRL is cleared to 0.

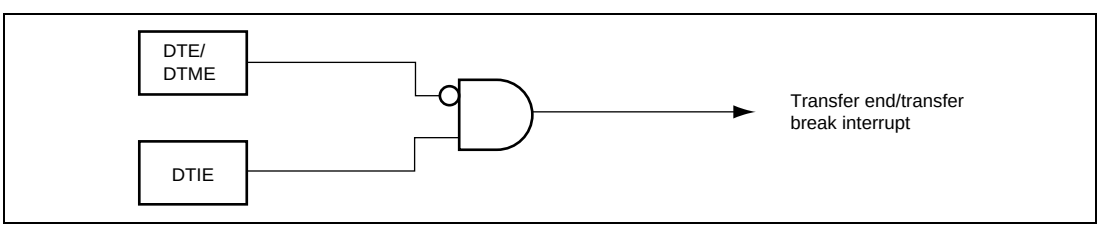


Figure 8.37 Block Diagram of Transfer End/Transfer Break Interrupt

In full address mode, a transfer break interrupt is generated when the DTME bit is cleared to 0 while the DTIEB bit is set to 1. In both short address mode and full address mode, DMABCR should be set so as to prevent the occurrence of a combination that constitutes a condition for interrupt generation during setting.

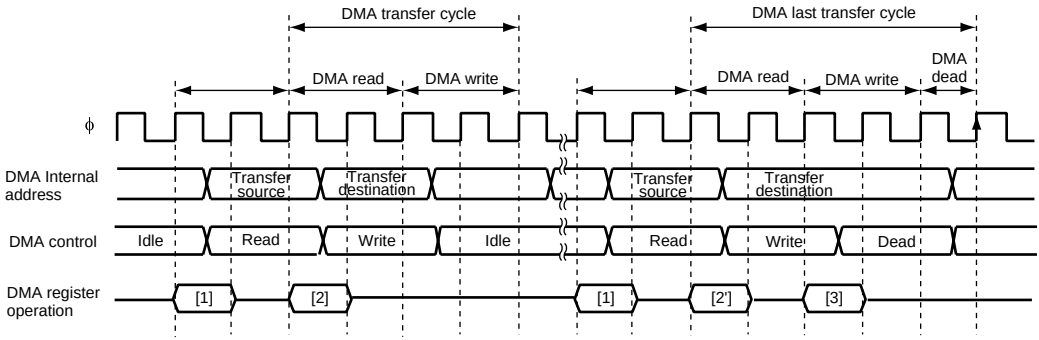
8.7 Usage Notes

8.7.1 DMAC Register Access during Operation

Except for forced termination of the DMAC, the operating (including transfer waiting state) channel setting should not be changed. The operating channel setting should only be changed when transfer is disabled. Also, DMAC registers should not be written to in a DMA transfer.

DMAC register reads during operation (including the transfer waiting state) are described below.

- DMAC control starts one cycle before the bus cycle, with output of the internal address. Consequently, MAR is updated in the bus cycle before DMA transfer. Figure 8.38 shows an example of the update timing for DMAC registers in dual address transfer mode.

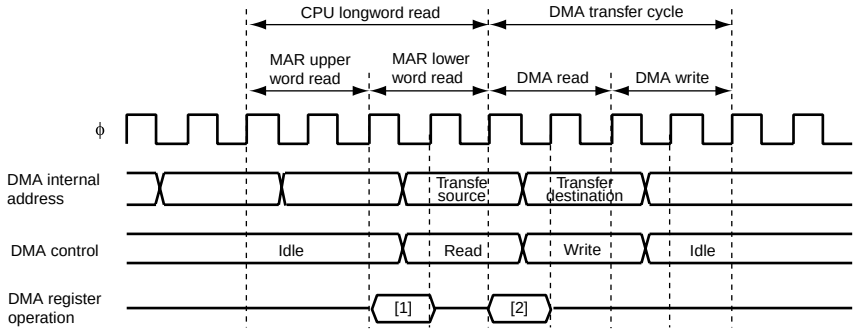


[1] Transfer source address register MAR operation (incremented/decremented/fixed)
Transfer counter ETCR operation (decremented)
Block size counter ETCR operation (decremented in block transfer mode)
[2] Transfer destination address register MAR operation (incremented/decremented/fixed)
[2'] Transfer destination address register MAR operation (incremented/decremented/fixed)
Block transfer counter ETCR operation (decremented, in last transfer cycle of a block in block transfer mode)
[3] Transfer address register MAR restore operation (in block or repeat transfer mode)
Transfer counter ETCR restore (in repeat transfer mode)
Block size counter ETCR restore (in block transfer mode)

Note: In single address transfer mode, the update timing is the same as [1].
The MAR operation is post-incrementing/decrementing of the DMA internal address value.

Figure 8.38 DMAC Register Update Timing

- If a DMAC transfer cycle occurs immediately after a DMAC register read cycle, the DMAC register is read as shown in figure 8.39.



Note: The lower word of MAR is the updated value after the operation in [1].

Figure 8.39 Contention between DMAC Register Update and CPU Read

8.7.2 Module Stop

When the MSTP13 bit in MSTPCRH is set to 1, the DMAC clock stops, and the module stop state is entered. However, 1 cannot be written to the MSTP13 bit if any of the DMAC channels is enabled. This setting should therefore be made when DMAC operation is stopped.

When the DMAC clock stops, DMAC register accesses can no longer be made. Since the following DMAC register settings are valid even in the module stop state, they should be invalidated, if necessary, before a module stop.

- Transfer end/break interrupt (DTE = 0 and DTIE = 1)
- TEND pin enable (TEE = 1)
- DACK pin enable (FAE = 0 and SAE = 1)

8.7.3 Medium-Speed Mode

When the DTA bit is cleared to 0, the internal interrupt signal that is specified for the DMAC transfer source is detected at the edge. In medium-speed mode, the DMAC operates by the medium-speed clock and the internal peripheral module operates by the high-speed clock. Therefore, when the corresponding interruption source is cleared by the CPU, DTC, or other channels of the DMAC and the period until the next interruption is executed is less than one state regarding to the DMAC clock (bus master clock), the signal is not detected at the edge and ignored.

In medium-speed mode, the DREQ pin is sampled at the rising edge of the medium clock.

8.7.4 Activation by Falling Edge on DREQ Pin

DREQ pin falling edge detection is performed in synchronization with DMAC internal operations. The operation is as follows:

[1] Activation request wait state: Waits for detection of a low level on the DREQ pin, and switches to [2].

[2] Transfer wait state: Waits for DMAC data transfer to become possible, and switches to [3].

[3] Activation request disabled state: Waits for detection of a high level on the DREQ pin, and switches to [1].

After DMAC transfer is enabled, a transition is made to [1]. Thus, initial activation after transfer is enabled is performed on detection of a low level.

8.7.5 Activation Source Acceptance

At the start of activation source acceptance, a low level is detected in both DREQ pin falling edge sensing and low level sensing. Similarly, in the case of an internal interrupt, the interrupt request is detected. Therefore, a request is accepted from an internal interrupt or DREQ pin low level that occurs before write to DMABCRL to enable transfer.

When the DMAC is activated, take any necessary steps to prevent an internal interrupt or DREQ pin low level remaining from the end of the previous transfer, etc.

8.7.6 Internal Interrupt after End of Transfer

When the DTE bit in DMABCRL is cleared to 0 at the end of a transfer or by a forcible termination, the selected internal interrupt request will be sent to the CPU or DTC even if the DTA bit in DMABCRH is set to 1.

Also, if internal DMAC activation has already been initiated when operation is forcibly terminated, the transfer is executed but flag clearing is not performed for the selected internal interrupt even if the DTA bit is set to 1.

An internal interrupt request following the end of transfer or a forcible termination should be handled by the CPU as necessary.

8.7.7 Channel Re-Setting

To reactivate a number of channels when multiple channels are enabled, use exclusive handling of transfer end interrupts, and perform DMABCR control bit operations exclusively.

Note, in particular, that in cases where multiple interrupts are generated between reading and writing of DMABCR, and a DMABCR operation is performed during new interrupt handling, the DMABCR write data in the original interrupt handling routine will be incorrect, and the write may invalidate the results of the operations by the multiple interrupts. Ensure that overlapping DMABCR operations are not performed by multiple interrupts, and that there is no separation between read and write operations by the use of a bit-manipulation instruction.

Also, when the DTE and DTME bits are cleared by the DMAC or are written with 0, they must first be read while cleared to 0 before the CPU can write 1 to them.

Section 9 Data Transfer Controller (DTC)

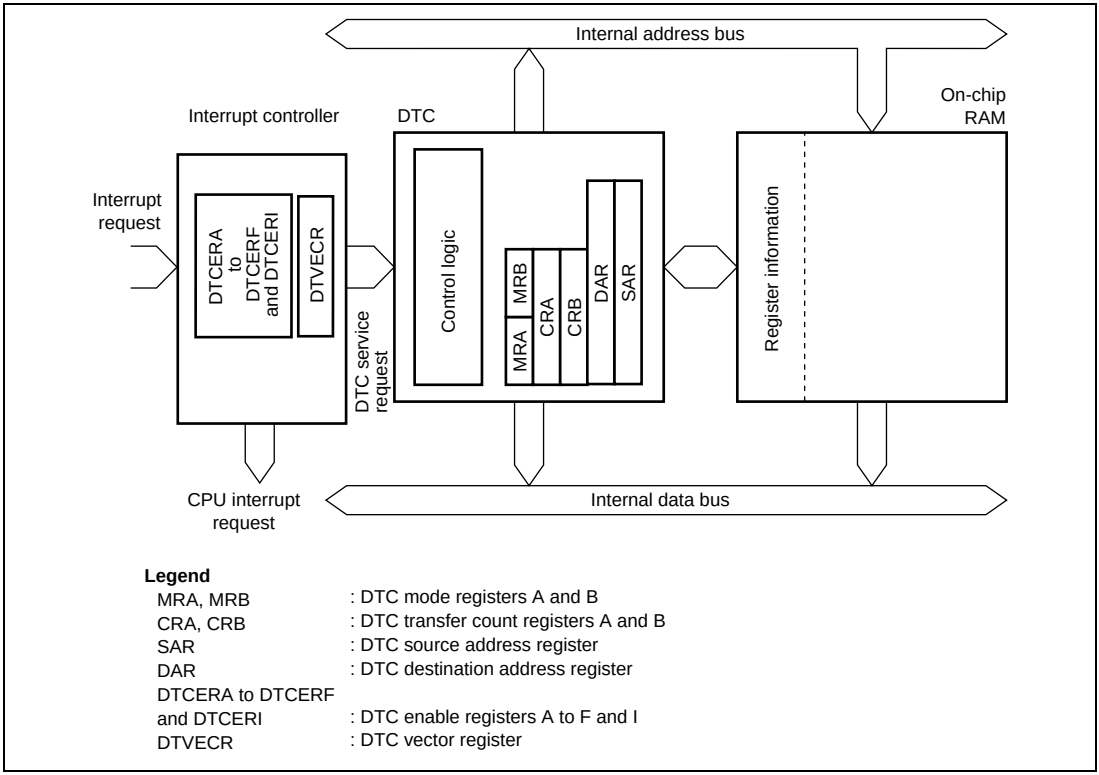
This LSI includes a data transfer controller (DTC). The DTC can be activated by an interrupt or software, to transfer data.

Figure 9.1 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.

9.1 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 9.1 Block Diagram of DTC

9.2 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)

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

Legend: X: Don't care

9.2.2 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	—	DTC Chain Transfer Enable This bit specifies a chain transfer. For details, refer to 9.5.4, Chain Transfer. 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. 0: DTC data transfer completed (waiting for start) 1: DTC data transfer (reads new register information and transfers data)
6	DISEL	Undefined	—	DTC Interrupt Select This bit specifies whether CPU interrupt is disabled or enabled after a data transfer. 0: Interrupt request is issued to the CPU when the specified data transfer is completed. 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).
5 to 0	—	Undefined	—	Reserved These bits have no effect on DTC operation. The write value should always be 0.

9.2.3 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.

9.2.4 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.

9.2.5 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.

9.2.6 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.

9.2.7 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 9.1. 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	
4	DTCE4	0	R/W	[Clearing conditions]
3	DTCE3	0	R/W	When the DISEL bit is 1 and the data transfer has ended
2	DTCE2	0	R/W	
1	DTCE1	0	R/W	When the specified number of transfers have ended
0	DTCE0	0	R/W	These bits are not cleared when the DISEL bit is 0 and the specified number of transfers have not been completed

9.2.8 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	DTC Software Activation Enable Setting this bit to 1 activates DTC. Only a 1 can be written to this bit. [Clearing conditions] When the DISEL bit is 0 and the specified number of transfers have not ended When 0 s written to the DISEL bit after a software-activated data transfer end interrupt (SWDTEND) request has been sent to the CPU. When the DISEL bit is 1 and data transfer has ended, the specified number of transfers have ended, or software-activated data transfer is in process, this bit will not be cleared.
6	DTVEC6	0	R/W	DTC Software Activation Vectors 0 to 6 These bits specify a vector number for DTC software activation. The vector address is expressed as H'0400 + (vector number × 2). For example, when DTVEC6 to DTVEC0 = H'10, the vector address is H'0420. These bits are writable when SWDTE=0.
5	DTVEC5	0	R/W	
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	

9.3 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 9.2 shows a block diagram of activation source control. For details, see section 5, Interrupt Controller.

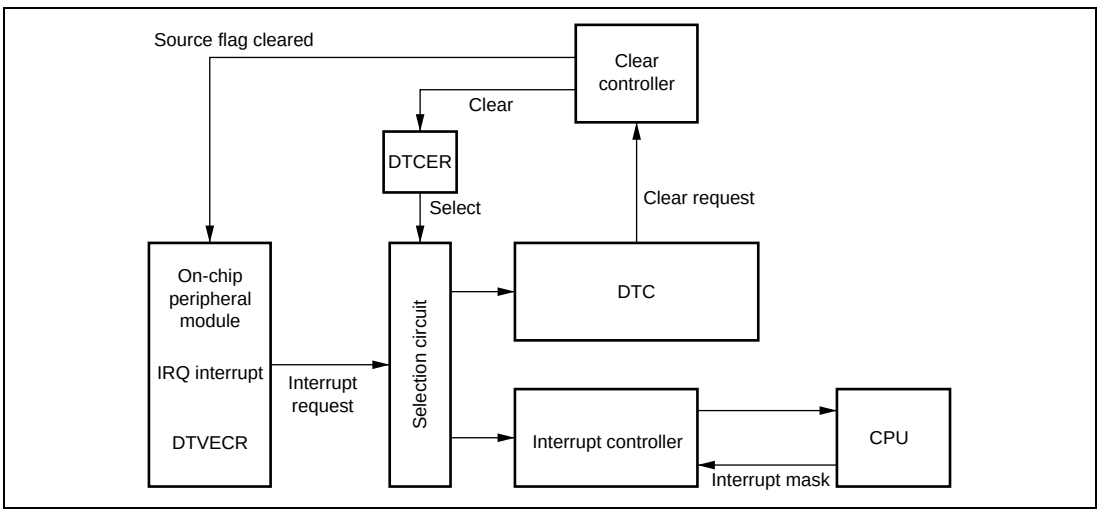


Figure 9.2 Block Diagram of DTC Activation Source Control

9.4 Location of Register Information and DTC Vector Table

Locate the register information in the on-chip RAM (addresses: H'FFEBC0 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 9.3. 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 9.3, and the register information start address should be located at the vector address corresponding to the interrupt source. Figure 9.4 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] × 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.

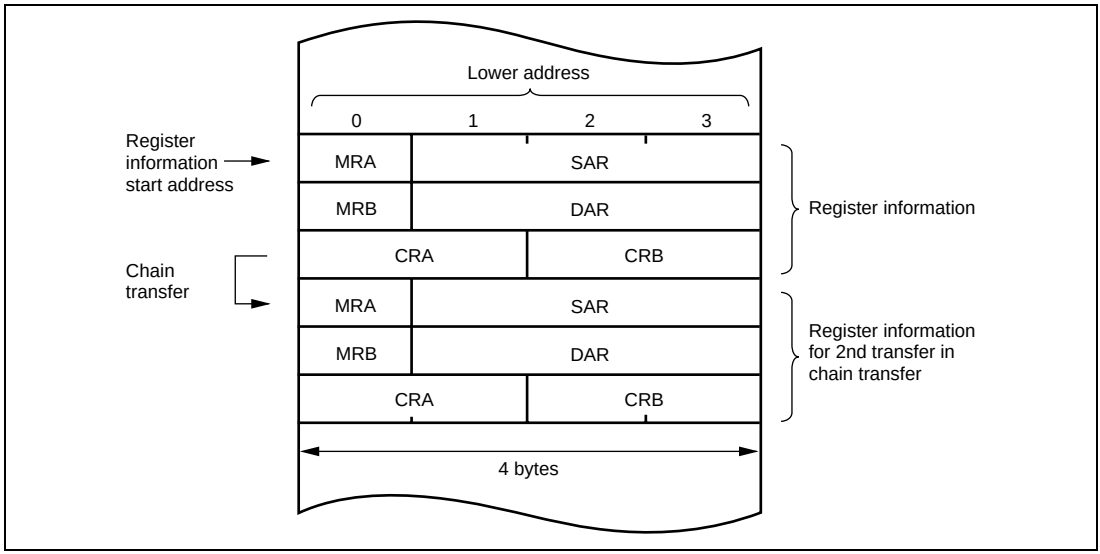


Figure 9.3 The Location of the DTC Register Information in the Address Space

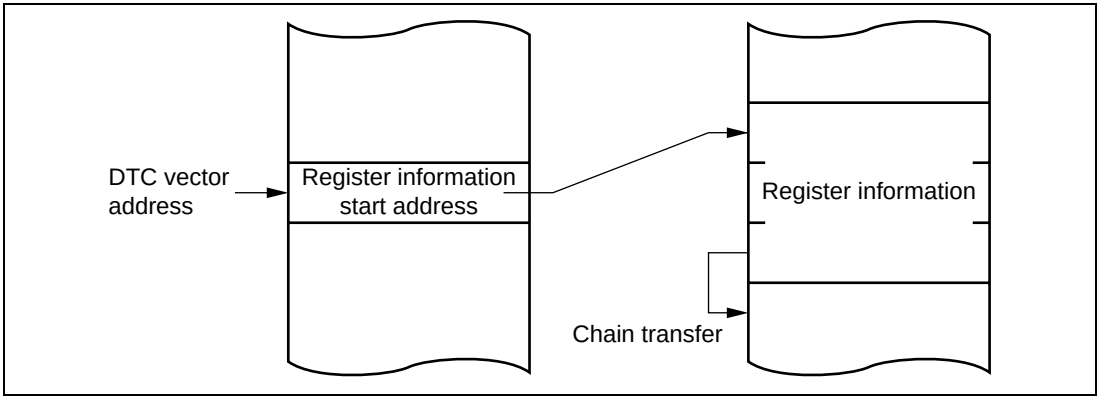


Figure 9.4 Correspondence between DTC Vector Address and Register Information

Table 9.1 Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs

Interrupt Source	Origin of Interrupt Source	Vector Number	DTC Vector Address	DTCE*[1]	Priority
Software	Write to DTVECR	DTVECR	H'0400 + vector number	—	High
External pin	IRQ0	16	H'0420	DTCEA7	
	IRQ1	17	H'0422	DTCEA6	
	IRQ2	18	H'0424	DTCEA5	
	IRQ3	19	H'0426	DTCEA4	
	IRQ4	20	H'0428	DTCEA3	
	IRQ5	21	H'042A	DTCEA2	
	IRQ6	22	H'042A	DTCEA2	
	IRQ7	23	H'042C	DTCEA2	
A/D	ADI (A/D conversion end)	28	H'042E	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	Low

Interrupt Source	Origin of Interrupt Source	Vector Number	DTC Vector Address	DTCE*[1]	Priority
TPU Channel 3*[4]	TGI3A	48	H'0460	DTCEC5	High
	TGI3B	49	H'0462	DTCEC4	
	TGI3C	50	H'0464	DTCEC3	
	TGI3D	51	H'0466	DTCEC2	
TPU Channel 4*[4]	TGI4A	56	H'0470	DTCEC1	
	TGI4B	57	H'0472	DTCEC0	
TPU Channel 5*[4]	TGI5A	60	H'0478	DTCED5	
	TGI5B	61	H'047A	DTCED4	
8-bit timer channel 0	CMIA0	64	H'0480	DTCED3	
	CMIB0	65	H'0482	DTCED2	
8-bot timer channel 1	CMIA1	68	H'0488	DTCED1	
	CMIB1	69	H'048A	DTCED0	
DMAC*[2]	DEND0A	72	H'0490	DTCEE7	
	DEND0A	73	H'0492	DTCEE6	
	DEND1A	74	H'0494	DTCEE5	
	DEND1A	75	H'0496	DTCEE4	
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	
SCI channel 2*[4]	RXI2	89	H'04B2	DTCEF7	
	TXI2	90	H'04B4	DTCEF6	
8-bit timer channel 2*[3]	CMIA2	92	H'04B8	DTCEF5	
	CMIB2	93	H'04BA	DTCEF4	
8-bit timer channel 3*[3]	CMIA3	96	H'04C0	DTCEF3	
	CMIB3	97	H'04C2	DTCEF2	
IIC channel 0 (optional) *[3]	IICI0	100	H'04C8	DTCEF1	
IIC channel 1 (optional) *[3]	IICI1	102	H'04CC	DTCEF0	
SCI channel 3	RXI3	121	H'04F2	DTCEI7	
	TXI3	122	H'04F4	DTCEI6	Low

Notes: 1. DTCE bits with no corresponding interrupt are reserved, and should be written with 0.
2. Supported only by the H8S/2239 Series.
3. These channels are not available in the H8S/2237 Series or H8S/2227 Series.
4. These channels are not available in the H8S/2227 Series.

9.5 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 9.5 shows the flowchart of DTC operation.

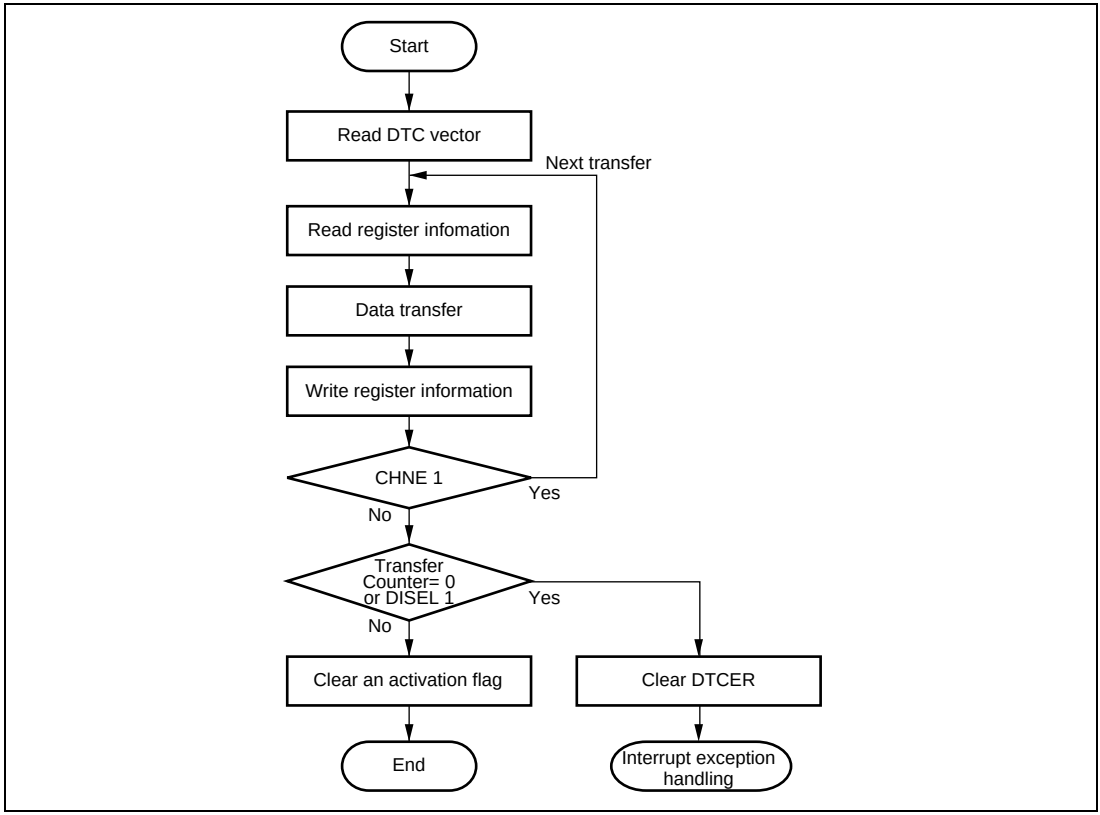


Figure 9.5 Flowchart of DTC Operation

9.5.1 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 9.2 lists the register information in normal mode. Figure 9.6 shows the memory mapping in normal mode.

Table 9.2 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

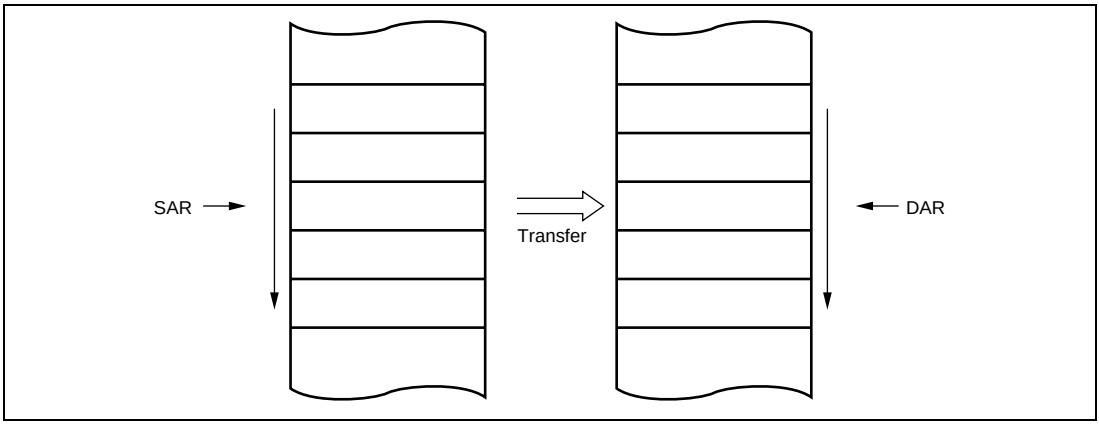


Figure 9.6 Memory Mapping in Normal Mode

9.5.2 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 9.3 lists the register information in repeat mode. Figure 9.7 shows the memory mapping in repeat mode.

Table 9.3 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

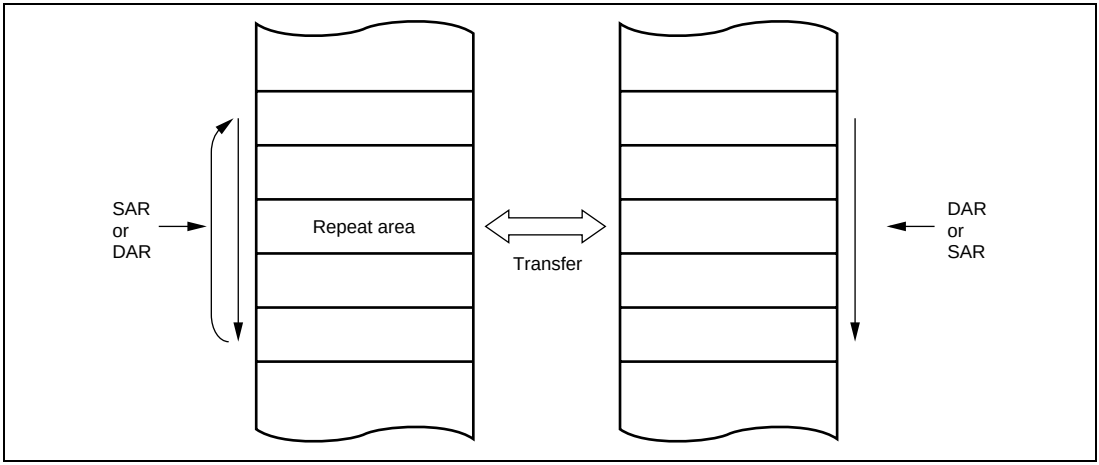


Figure 9.7 Memory Mapping in Repeat Mode

9.5.3 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 9.4 lists the register information in block transfer mode. Figure 9.8 shows the memory mapping in block transfer mode.

Table 9.4 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

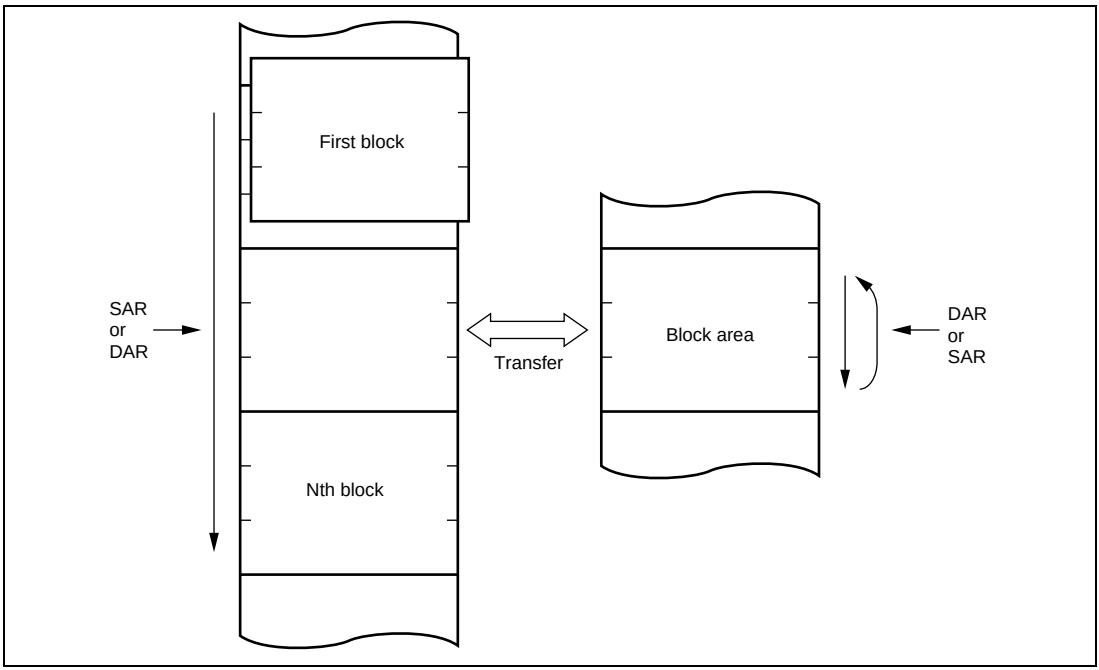


Figure 9.8 Memory Mapping in Block Transfer Mode

9.5.4 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 9.9 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.

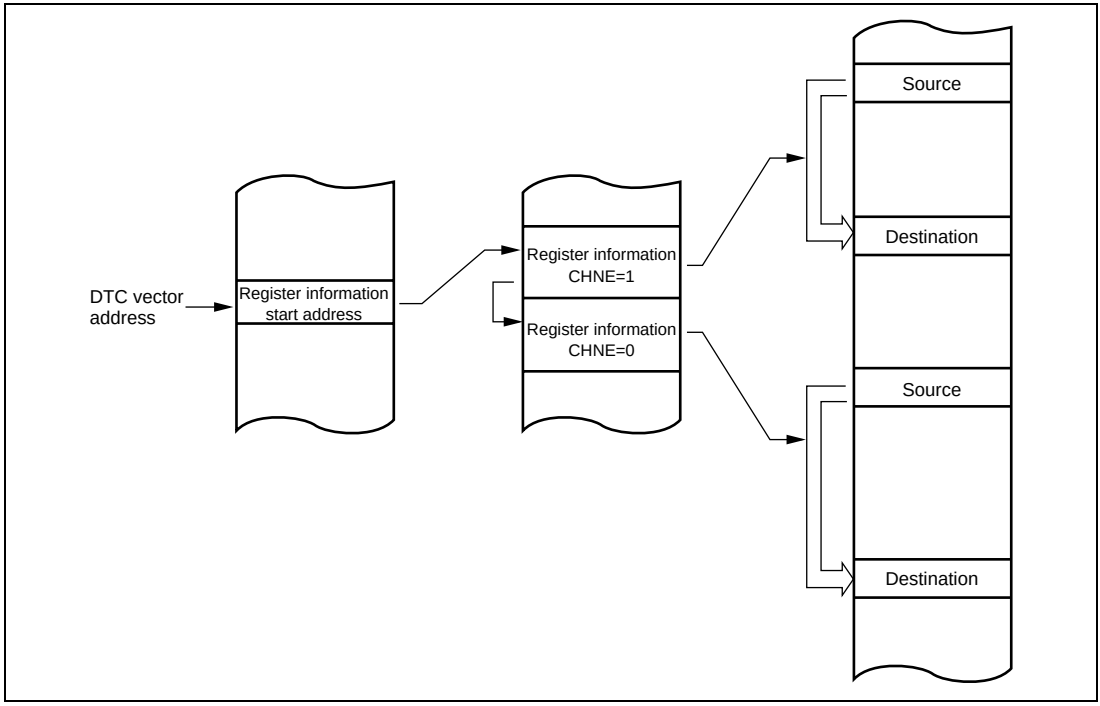


Figure 9.9 Chain Transfer Operation

9.5.5 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.

9.5.6 Operation Timing

Figure 9.10 to 9.12 show the DTC operation timings.

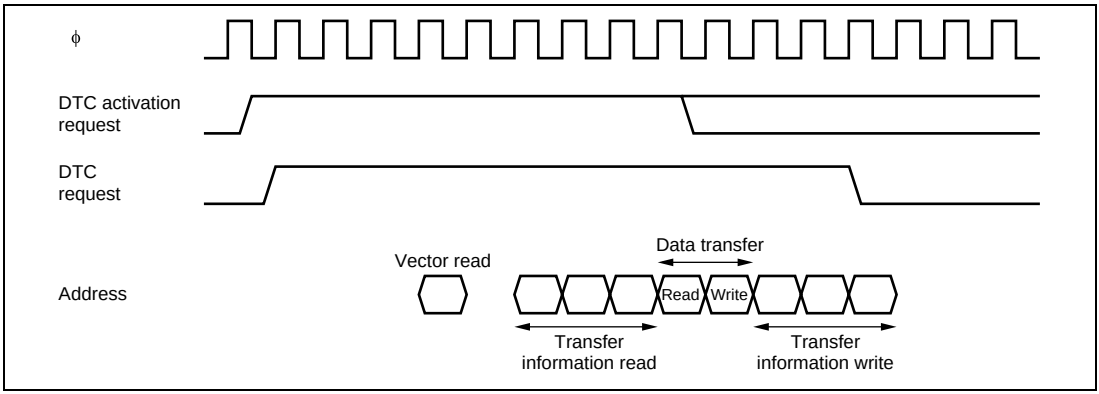


Figure 9.10 DTC Operation Timing (Example in Normal Mode or Repeat Mode)

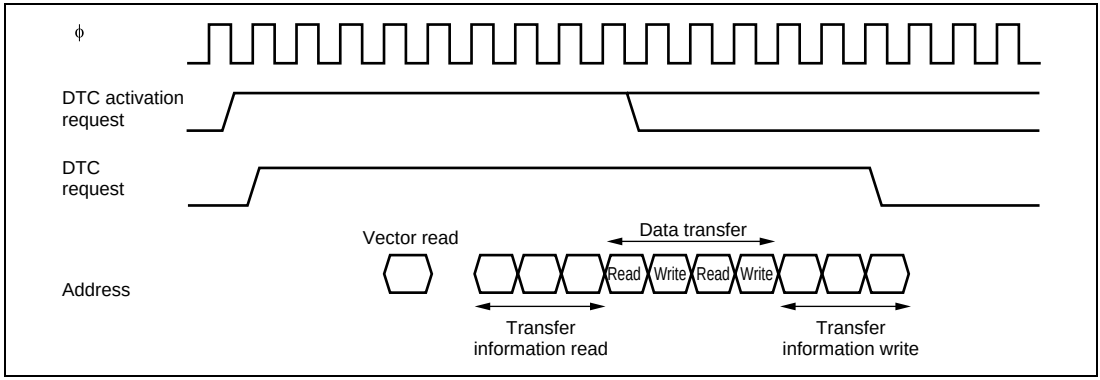


Figure 9.11 DTC Operation Timing (Example of Block Transfer Mode,with Block Size of 2)

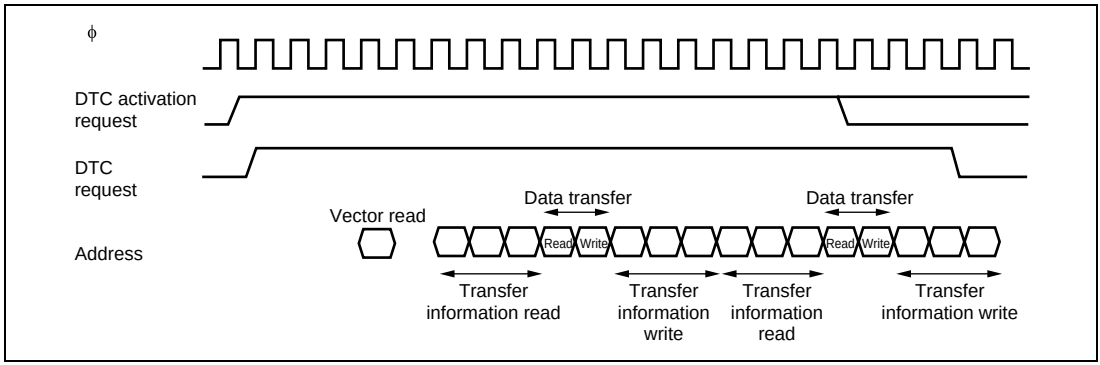


Figure 9.12 DTC Operation Timing (Example of Chain Transfer)

9.5.7 Number of DTC Execution States

Table 9.5 lists execution status for a single DTC data transfer, and table 9.6 shows the number of states required for each execution status.

Table 9.5 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 9.6 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.

9.6 Procedures for Using DTC

9.6.1 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.

9.6.2 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.

9.7 Examples of Use of the DTC

9.7.1 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.

9.7.2 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.

9.8 Usage Notes

9.8.1 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 23, Power-Down Modes.

9.8.2 On-Chip RAM

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

9.8.3 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 10 I/O Ports

Table 10.1 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 DR and DDR registers.

Ports A to E have 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 respectively.

Ports 3 and A include an open-drain control register (ODR) that controls the on/off state of the output buffer PMOS respectively.

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.*

The $\overline{\text{IRQ}}$ pin is Schmitt-trigger input.

Note: * Supported only by the H8S/2239 Series and H8S/2238R Series.

Table 10.1 Port Functions

Port	Description	Mode4	Mode5	Mode 6	Mode 7	Input/Output and Output Type
Port 1	General I/O port also functioning as TPU_2, TPU_1, and TPU_0 I/O pins, interrupt input pins, address output pins, and DMAC output pins	P17/TIOCB2/TCLKD			P17/TIOCB2/TCLKD	Schmitt-trigger input (IRQ0, IRQ1)
		P16/TIOCA2/IRQ1			P16/TIOCA2/IRQ1	
		P15/TIOCB1/TCLKC			P15/TIOCB1/TCLKC	
		P14/TIOCA1/IRQ0			P14/TIOCA1/IRQ0	
		P13/TIOCD0/TCLKB/A23			P13/TIOCD0/TCLKB	
		P12/TIOCC0/TCLKA/A22			P12/TIOCC0/TCLKA	
		P11/TIOCB0/DACK1*3/A21			P11/TIOCB0/DACK1*3	
		P10/TIOCA0/DACK0*3/A20			P10/TIOCA0/DACK0*3	
Port 3	General input port also functioning as I2C bus interface*1 I/O pins, SCI_1 and SCI_0 I/O pins, and interrupt input pins	P36				Specifiable of open drain output Schmitt-trigger input (IRQ4, IRQ5) NMOS push-pull output*1 (SCL0, SDA0)
		P35/SCK1/SCL0*1/IRQ5				
		P34/RxD1/SDA0*1				
		P33/TxD1/SDA0*1				
		P32/SCK0/SDA1*1/IRQ4				
		P31/RxD0				
		P30/TxD0				
Port 4	General input port also functioning as A/D converter analog inputs	P47/AN7				
		P46/AN6				
		P45/AN5				
		P44/AN4				
		P43/AN3				
		P42/AN2				
		P41/AN1				
		P40/AN0				
Port 7	General input port also functioning as SCI_3 I/O pins, TMR_3*1, TMR_2*1, TMR_1, TMR_0 I/O pins, and DMAC I/O pins	P77/TxD3				
		P76/RxD3				
		P75/TMO3*1/SCK3				
		P74/TMO2*1/MRES				
		P73/TMO1/TEND1*3/CS7			P73/TMO1/TEND1*3	
		P72/TMO0/TEND0*3/CS6			P72/TMO0/TEND0*3	
		P71/TMRI23*1/TMCI23*1/DREQ1*3/CS5			P71/TMRI23*1/TMCI23*1/DREQ1*3	
		P70/TMRI01/TMCI01 DREQ0*3/CS4			P70/TMRI01/TMCI01 DREQ0*3	

Port	Description	Mode 4	Mode5	Mode 6	Mode 7	Input/Output and Output Type
Port 9	General input port also functioning as A/D converter*2 analog input pins	P97/DA1*2				
		P96/ DA0*2				
Port A	General I/O port also functioning as SCI_2*2 I/O pins and address output pins	PA3/A19/SCK2*2			PA3/ SCK2*2	Specifiable of built-in input pull-up MOS open drain output
		PA2/A18/RxD2*2			PA2/ RxD2*2	
		PA1/A17/TxD2*2			PA1/ TxD2*2	
		PA0/A16			PA0	
Port B	General I/O port also functioning as TPU_5*2, TPU_4*2, TPU_3*2 I/O pins, and address output pins	PB7/A15/TIOCB5*2			PB7/ TIOCB5*2	Built-in input pull-up MOS
		PB6/A14/TIOCA5*2			PB6/ TIOCA5*2	
		PB5/A13/TIOCB4*2			PB5/ TIOCB4*2	
		PB4/A12/TIOCA4*2			PB4/ TIOCA4*2	
		PB3/A11/TIOCD3*2			PB3/ TIOCD3*2	
		PB2/A10/TIOCC3*2			PB2/ TIOCC3*2	
		PB1/A9/TIOCB3*2			PB1/ TIOCB3*2	
		PB0/A8/TIOCA3*2			PB0/ TIOCA3*2	
Port C	General I/O port also functioning as address output pins	A7		PC7/A7	PC7	Built-in input pull-up MOS
		A6		PC6/A6	PC6	
		A5		PC5/A5	PC5	
		A4		PC4/A4	PC4	
		A3		PC3/A3	PC3	
		A2		PC2/A2	PC2	
		A1		PC1/A1	PC1	
		A0		PC0/A0	PC0	
Port D	General I/O port also functioning as data I/O pins	D15			PD7	Built-in input pull-up MOS
		D14			PD6	
		D13			PD5	
		D12			PD4	
		D11			PD3	
		D10			PD2	
		D9			PD1	
		D8			PD0	

Port	Description	Mode 4	Mode5	Mode 6	Mode 7	Input/Output and Output Type
Port E	General I/O port also functioning as data I/O pins	PE7/D7			PE7	Built-in input pull-up MOS
		PE6/D6			PE6	
		PE5/D5			PE5	
		PE4/D4			PE4	
		PE3/D3			PE3	
		PE2/D2			PE2	
		PE1/D1			PE1	
		PE0/D0			PE0	
Port F	General I/O port also functioning as interrupt input pins, bus control I/O pins, an A/D converter input pins and WDT output pins	PF7/ϕ			PF7/ϕ	Schmit-trigger input (IRQ2, IRQ3)
		AS			PF6	
		RD			PF5	
		HWR			PF4	
		PF3/LWR/ADTRG/IRQ3			PF3/ADTRG/IRQ3	
		PF2/WAIT			PF2	
		PF1/BACK/BUZZ			PF1/BUZZ	
		PF0/BREQ/IRQ2			PF0/IRQ2	
Port G	General I/O port also functioning as interrupt input pins	PG4/CS0			PG4	Schmit-trigger input (IRQ6, IRQ7)
		PG3/CS1			PG3	
		PG2/CS2			PG2	
		PG1/CS3/IRQ7			PG1/IRQ7	
		PG0/IRQ6			PG0/IRQ6	

Notes: 1. Not available in the H8S/2237 Series and H8S/2227 Series.
2. Not available in the H8S/2227 Series.
3. Supported only by the H8S/2239 Series.

10.1 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)

10.1.1 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	

10.1.2 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 I/O 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	

10.1.3 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.

10.1.4 Pin Functions

Port 1 pins also function as TPU I/O pins (TPU_0, TPU_1, and TPU_2), DMAC* output pins, interrupt input pins and address output pins. Values of the register and pin functions are shown below.

Note: * Supported only by the H8S/2239 Series.

- P17/TIOCB2/TCLKD

  The pin functions are switched as shown below according to the combination of the TPU channel 2 setting, TPSC2 to TPS0 bits in TCR_0 and TCR_5, and the P17DDR bit.

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

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCB2 input when TPU channel 2 timer operating mode is set to normal operating or phase counting mode and IOB3 in TIOR_2 is set to 1.
3. This pin functions as TCLKD input when TPSC2 to TPSC0 in TCR_0 or TCR_5 are set to 111 or when channels 2 and 4 are set to phase counting mode.

- P16/TIOCA2/IRQ1

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

TPU Channel 2 Setting*[1]	Output	Input or Initial Value	
P16DDR	—	0	1
Pin functions	TIOCA2 output pin	P16 input pin	P16 output pin
		TIOCA2 input pin*[2]	
	IRQ1 input pin*[3]		

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCA2 input when TPU channel 2 timer operating mode is set to normal operating or phase counting mode and IOA3 in TIOR_2 is 1.
3. When this pin is used as an external interrupt pin, do not specify other functions.

- P15/TIOCB1/TCLKC

  The pin functions are switched as shown below according to the combination of the TPU channel 1 setting, TPSC2 to TPS0 bits in TCR_0, TCR_2, TCR_4, and TCR_5 and the P15DDR bit.

TPU Channel 1 Setting*[1]	Output	Input or Initial Value	
P15DDR	—	0	1
Pin functions	TIOCB1 output pin	P15 input pin	P15 output pin
		TIOCB1 input pin*[2]	
	TCLKC input pin*[3]		

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCB1 input when TPU channel 1 timer operating mode is set to normal operating or phase counting mode and IOB3 to IOB0 in TIOR_1 are set to10xx.
3. This pin functions as TCLKC input when TPSC2 to TPSC0 in TCR_0 or TCR_2 are set to 110 or TPSC2 to TPSC0 in TCR_4 or TCR_0 are 101 or when channels 2 and 4 are set to phase counting mode.

- P14/TIOCA1/IRQ0

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

TPU Channel 1 Setting*[1]	Output	Input or Initial Value	
P14DDR	—	0	1
Pin functions	TIOCA1 output pin	P14 input pin	P14 output pin
		TIOCA1 input pin*[2]	
	IRQ0 input pin*[3]		

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCA1 input when TPU channel 1 timer operating mode is set to normal operating or phase counting mode and IOA3 to IOA0 in TIOR_1 are set to 10xx.
3. When this pin is used as an external interrupt pin, do not specify other functions.

- P13/TIOCD0/TCLKB/A23

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 0 setting, TPSC2 to TPSC0 bits in TCR_0 to TCR_2, AE3 to AE0 bits in PFCR and the P13DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'1111	Other than B'1111			—		
TPU Channel 0 Setting*[1]	—	Output	Input or Initial Value		Output	Input or Initial Value	
P13DDR	—	—	0	1	—	0	1
Pin functions	A23 output pin	TIOCD0 output pin	P13 input pin	P13 output pin	TIOCD0 output pin	P13 input pin	P13 output pin
			TIOCD0 input*[2]			TIOCD0 input pin*[2]	
		TCLKB input pin*[3]			TCLKB input pin*[3]		

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCD0 input when TPU channel 0 timer operating mode is set to normal operating and IOD3 to IOD0 in TIORL_0 are set to 10xx.
3. This pin functions as TCLKB input when TPSC2 to TPSC0 in any of TCR_0 to TCR_2 are set to 101 or when channels 1 and 5 are set to phase counting mode.

- P12/TIOCC0/TCLKA/A22

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 0 setting, TPSC2 to TPSC0 bits in TCR_0 to TCR_5, AE3 to AE0 bits in PFCR, and the P12DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'1111	Other than B'1111			—		
TPU Channel 0 Setting*[1]	—	Output	Input or Initial Value		Output	Input or Initial Value	
P12DDR	—	—	0	1	—	0	1
Pin functions	A22 output pin	TIOCC0 output pin	P12 input pin	P12 output pin	TIOCC0 output pin	P12 input pin	P12 output pin
			TIOCC0 input pin*[2]			TIOCC0 input pin*[2]	
		TCLKA input pin*[3]			TCLKA input pin*[3]		

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCC0 input when TPU channel 0 timer operating mode is set to normal operating and IOC3 to IOC0 in TIORL_0 are set to 10xx.
3. This pin functions as TCLKB input when TPSC2 to TPSC0 in any of TCR_0 to TCR_5 are set to 100 or when channels 1 and 5 are set to phase counting mode.

- P11/TIOCB0/DACK1/A21

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 0 setting, AE3 to AE0 bits in PFCR, the SAE1 bit*[3] in DMABCRH, and the P11DDR bit.

Operating mode	Modes 4 to 6					Mode 7		
AE3 to AE0	B'111x	Other than B'111x				—		
SAE1*[3]	—	0			1	—		
TPU Channel 0 Setting*[1]	—	Output	Input or Initial Value		—	Output	Input or Initial Value	
P11DDR	—	—	0	1	—	—	0	1
Pin functions	A21 output pin	TIOCB0 output pin	P11 input pin	P11 output pin	DACK1 output pin	TIOCB0 output pin	P11 input pin	P11 output pin
			TIOCB0 input pin*[2]				TIOCB0 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCB0 input when TPU channel 0 timer operating mode is set to normal operating and IOB3 to IOB0 in TIORH_0 are set to 10xx.
3. Supported only by the H8S/2239 Series.

- P10/TIOCA0/DACK0/A20

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 0 setting, AE3 to AE0 bits in PFCR, the SAE0 bit*[3] in DMABCRH, and the P10DDR bit.

Operating mode	Modes 4 to 6					Mode 7		
AE3 to AE0	B'1101 or B'111x	Other than (B'1101 or B'111x)				—		
SAE0*[3]	—	0			1	—		
TPU Channel 0 Setting*[1]	—	Output	Input or Initial Value		—	Output	Input or Initial Value	
P10DDR	—	—	0	1	—	—	0	1
Pin functions	A20 output pin	TIOCA0 output pin	P10 input pin	P10 output pin	DACK0 output pin	TIOCA0 output pin	P10 input pin	P10 output pin
			TIOCA0 input pin*[2]				TIOCA0 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCA0 input when TPU channel 0 timer operating mode is set to normal operating and IOA3 to IOA0 in TIORH_0 are set to 10xx.
3. Supported only by the H8S/2239 Series.

10.2 Port 3

Port 3 is a general 7-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)

10.2.1 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	—	Undefined	—	Reserved These bits are always read as undefined value.
6	P36DDR	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.
5	P35DDR	0	W	
4	P34DDR	0	W	
3	P33DDR	0	W	
2	P32DDR	0	W	
1	P31DDR	0	W	
0	P30DDR	0	W	

10.2.2 Port 3 Data Register (P3DR)

P3DR stores output data for port 3 pins.

Bit	Bit Name	Initial Value	R/W	Description
7	—	Undefined	—	Reserved These bits are always read as undefined value.
6	P36DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
5	P35DR	0	R/W	
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	

10.2.3 Port 3 Register (PORT3)

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

Bit	Bit Name	Initial Value	R/W	Description
7	—	Undefined	—	Reserved These bits are always read as undefined value.
6	P36	—*	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.
5	P35	—*	R	
4	P34	—*	R	
3	P33	—*	R	
2	P32	—*	R	
1	P31	—*	R	
0	P30	—*	R	

Note: * Determined by the states of pins P36 to P30.

10.2.4 Port 3 Open Drain Control Register (P3ODR)

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

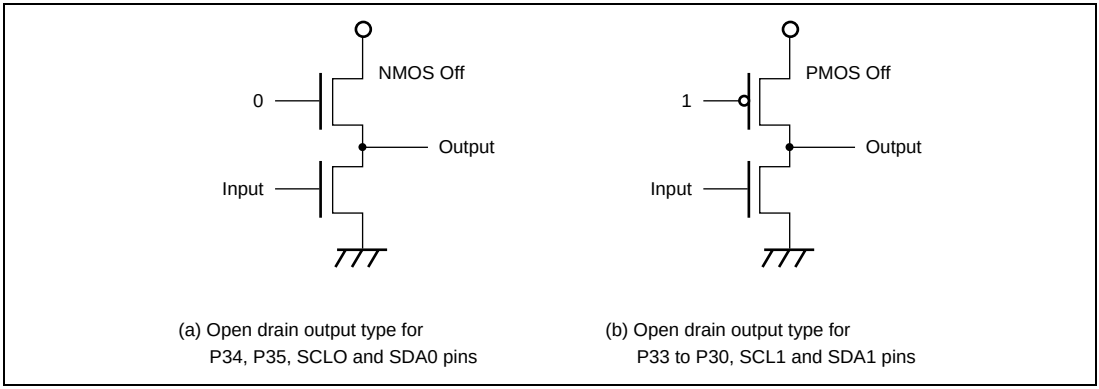
Bit	Bit Name	Initial Value	R/W	Description
7	—	Undefined	—	Reserved These bits are always read as undefined value.
6	P36ODR	0	R/W	When each of P36ODR and P33ODR to P30ODR bits is set to 1, the corresponding pins P36 and P33 to P30 function as NMOS open drain outputs. When cleared to 0, the corresponding pins function as CMOS outputs. When each of P35ODR and P34ODR bits is set to 1, the corresponding pins P35 and P34 function as open drain outputs. When they are cleared to 0, the corresponding pins function as NMOS push pull outputs.
5	P35ODR	0	R/W	
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	

10.2.5 Pin Functions

The port 3 pins also function as SCI I/O input pins, I^2C bus interface* I/O pins, and as external interrupt input pins.

As shown in figure 10.1, 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.

Note: * Not available in the H8S/2237 Series and H8S/2227 Series.



(a) Open drain output type for P34, P35, SCLO and SDA0 pins

(b) Open drain output type for P33 to P30, SCL1 and SDA1 pins

Figure 10.1 Types of Open Drain Outputs

- P36

The pin functions are switched as shown below according to the P36DDR bit condition.

P36DDR	0	1
Pin functions	P36 input pin	P36 output pin*

Note: * When P36ODR is set to 1, functions as NMOS open drain output.

- P35/SCK1/SCL0/IRQ5

The pin functions are switched as shown below according to the combination of the ICE bit*3 in ICCR_0 of IIC_0, the C/A bit in SMR_1 of SCI_1, CKE0 and CKE1 bits in SCR_1 and the P35DDR bit. To use this port as SCL0 I/O pin, clear the C/A bit, CKE0 bit, and CKE1 bit to 0. The SCL0 functions as NMOS open drain output and the pin can drive bus directly. When this pin is specified as the P35 output pin or SCK1 output pin, it functions as NMOS push-pull output.

ICE*3	0					1
CKE1	0				1	0
C/A	0			1	—	0
CKE0	0		1	—	—	0
P35DDR	0	1	—	—	—	—
Pin functions	P35 input pin	P35 output pin*1	SCK1 output pin*1	SCK1 output pin*1	SCK1 I/O pin	SCLO I/O pin
	IRQ5 Input pin*2					

Notes: 1. When the P35ODR is set to 1, it functions as NMOS open drain output.
2. When this pin is used as an external interrupt pin, do not specify other functions.
3. Not available in the H8S/2237 Series and H8S/2227 Series.

- P34/RxD1/SDA0

The pin functions are switched as shown below according to the combination of the ICE bit*2 in ICCR_0 of IIC_0, the RE bit in SCR_1 of SCI_1 and the P34DDR bit. When this pin is specified as P34 output pin, it functions as NMOS push-pull output. The SDA0 also functions as NMOS open drain outputs and can drive bus directly.

ICE*2	0			1
RE	0		1	—
P34DDR	0	1	—	—
Pin functions	P34 input pin	P34 output pin*1	RxD1 input pin	SDA0 I/O pin

Notes: 1. When P34ODR is set to 1, it functions as NMOS open drain output.
2. Not available in theH8S/2237 Series and H8S/2227 Series.

- P33/TxD1/SCL1

  The pin functions are switched as shown below according to the combination of the ICE bit*[2] in ICCR_1 of IIC_1, the TE bit in SCR_1 of SCI_1 and the P33DDR bit. SCL1 functions as NMOS open drain output and can drive bus directly.

ICE*[2]	0			1
TE	0		1	—
P33DDR	0	1	—	—
Pin functions	P33 input pin	P33 output pin*[1]	TxD1 output pin*[1]	SCL1 I/O pin

Notes: 1. When P33ODR is set to 1, it functions as NMOS open drain output.
2. Not available in the H8S/2237 Series and H8S/2227 Series.

- P32/SCK0/SDA1/IRQ4

  The pin functions are switched as shown below according to the combination of the ICE bit*[3] in ICCR_1 of IIC_1, the C/A bit in SMR_0 of SCI_0, CKE0 and CKE1 bits in SCR and the P32DDR bit. To use this port as SDA1 input pin, clear the C/A bit, CKE0 bit, and CKE1 bit to 0. The SDA1 functions as NMOS open drain output and can drive bus directly.

ICE*[3]	0					1
CKE1	0				1	0
C/A	0			1	—	0
CKE0	0		1	—	—	0
P32DDR	0	1	—	—	—	—
Pin functions	P32 input pin	P32 output pin*[1]	SCK0 output pin*[1]	SCK0 output pin*[1]	SCK0 input pin	SDA1 I/O pin
	IRQ4 Input *[2]					

Notes: 1. When P32ODR is set to 1, it functions as NMOS open drain output.
2. When this pin is used as an external interrupt pin, do not specify other functions.
3. Not available in the H8S/2237 Series and H8S/2227 Series.

- P31/RxD0

  The pin functions are switched as shown below according to the combination of the RE bit in SCR_0 of SCI_0 and the P31DDR bit.

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

Note: * When P31ODR is set to 1, it functions as NMOS open drain output.

- P30/TxD0

  The pin functions are switched as shown below according to the combination of the TE bit in SCR_0 of SCI_0 and the P30DDR bit.

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

Note: * When P30ODR is set to 1, it functions as NMOS open drain output.

10.3 Port 4

Port 4 is an 8-bit I/O port and has the following register.

- Port 4 register (PORT4)

10.3.1 Port 4 Register (PORT4)

PORT4 shows port 4 pin states.

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.

10.3.2 Pin Functions

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

10.4 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)

10.4.1 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	

10.4.2 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 I/O 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	

10.4.3 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.

10.4.4 Pin Functions

Port 7 pins also function as TMR I/O pins (TMR_0, TMR_1, TMR_2*[1], and TMR_3*[1]), bus control output pin, SCI I/O pins, and DMAC*[2] I/O pins. Values of the register and pin functions are shown below.

Notes: 1. Not available in the H8S/2237 Series and H8S/2227 Series.
2. Supported only by the H8S/2239 Series.

- P77/TxD3

  The pin functions are switched as shown below according to the combination of the TE bit in SCR_3 of SCI_3 and the P77DDR bit.

TE	0		1
P77DDR	0	1	—
Pin functions	P77 input pin	P77 output pin	TxD3 output

- P76/RxD3

  The pin functions are switched as shown below according to the combination of the RE bit in SCR_3 of SCI_3 and the P76DDR bit.

RE	0		1
P76DDR	0	1	—
Pin functions	P76 input pin	P76 output pin	RxD3 Input

- P75/TMO3/SCK3

  The pin functions are switched as shown below according to the combination of OS3 to OS0 bits in TCSR_3 of TMR_3, CKE1 and CKE0 bits in SCR_3 of SCI_3, the C/A bit in SMR_3, and the P75DDR bit.

OS3 to OS0	All bits are 0					Any bit is 1
CKE1	0				1	—
C/A	0			1	—	—
CKE0	0		1	—	—	—
P75DDR	0	1	—	—	—	—
Pin functions	P75 input pin	P75 output pin	SCK3 output pin	SCK3 output pin	SCK3 input pin	TMO3 output pin

- P74/TMO2/MRES

  The pin functions are switched as shown below according to the combination of OS3 to OS0 bits in TCSR_2 of TMR_2, the MRESE bit in SYSCR, and the P74DDR bit.

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

- P73/TMO1/TEND1/CS7

  The pin functions are switched as shown below according to the combination of operating mode, the TEE1 bit in DMATCR of DMAC, OS3 to OS0 bits in TCSR_1 of TMR_1 and the P73DDR bit.

Operating mode	Modes 4 to 6				Mode 7			
TEE1	0			1	0			1
OS3 to OS0	All bits are 0		Any bit is 1	—	All bits are 0		Any bit is 1	—
P73DDR	0	1	—	—	0	1	—	—
Pin functions	P73 input pin	CS7 output pin	TMO1 output pin	TEND1 output pin	P73 input pin	P73 output pin	TMO1 output pin	TEND1 output pin

- P72/TMO0/ TEND0/CS6

  The pin functions are switched as shown below according to the combination of operating mode the TEE0 bit in DMATCR of DMAC, OS3 to OS0 bits in TCSR_0 of TMR_0, and the P72DDR bit.

Operating mode	Modes 4 to 6				Mode 7			
TEE0	0			1	0			1
OS3 to OS0	All bits are 0		Any bit is 1	—	All bits are 0		Any bit is 1	—
P72DDR	0	1	—	—	—		—	—
Pin functions	P72 input pin	CS6 output pin	TMO0 output pin	TEND0 output pin	P72 input pin	P72 output pin	TMO0 output pin	TEND0 output pin

- P71/TMRI23/TMCI23/DREQ1/CS5

  The pin functions are switched as shown below according to the combination of operating mode and the P71DDR bit.

Operating mode	Modes 4 to 6		Mode 7	
P71DDR	0	1	0	1
Pin functions	P71 input pin	CS5 output pin	P71 input pin	P71 output pin
	TMRI23, TMCI23, DREQ1 input pin	—	TMRI23, TMCI23, DREQ1 input pin	

- P70/TMRI01/TMCI01/DREQ0/CS4

  The pin functions are switched as shown below according to the combination of operating mode and the P70DDR bit.

Operating mode	Modes 4 to 6		Mode 7	
P70DDR	0	1	0	1
Pin functions	P70 input pin	CS4 output pin	P70 input pin	P70 output pin
	TMRI01,TMCI01, DREQ0 input pin	—	TMRI01,TMCI01, DREQ0 input pin	

10.5 Port 9

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

- Port 9 register (PORT9)

10.5.1 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	—	—	R	Reserved These bits are always read as undefined value.

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

10.5.2 Pin Functions

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

Note: * Not available in the H8S/2227 Series.

10.6 Port A

Port A is a 4-bit I/O port and has the following register.

- Port A data direction register (PADDR)
- Port A data register (PADR)
- Port A register (PORTA)
- Port A pull-up MOS control register (PAPCR)
- Port A open drain control register (PAODR)

10.6.1 Port A Data Direction Register (PADDR)

PADDR specifies input or output the port A pins using the individual bits. PADDR 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.
3	PA3DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port A pin an output pin. Clearing this bit to 0 makes the pin an input pin.
2	PA2DDR	0	W	
1	PA1DDR	0	W	
0	PA0DDR	0	W	

10.6.2 Port A Data Register (PADR)

PADR stores output data for port A pins.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	Undefined	—	Reserved These bits are always read as undefined value.
3	PA3DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
2	PA2DR	0	R/W	
1	PA1DR	0	R/W	
0	PA0DR	0	R/W	

10.6.3 Port A Register (PORTA)

PORTA 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.
3	PA3	—*	R	If this bit is read while PADDR is set to 1, the PADR value is read. If this bit is read while PADDR is cleared, the PA3 pin states are read.
2	PA2	—*	R	
1	PA1	—*	R	
0	PA0	—*	R	

Note: * Determined by the states of PA3 to PA0 pins.

10.6.4 Port A Pull-up MOS Control Register (PAPCR)

PAPCR controls the on/off state of port A input pull-up MOS.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	Undefined	—	Reserved These bits are always read as undefined value.
3	PA3PCR	0	R/W	When the pin is specified as an input port, setting the corresponding bit to 1 turns on the input pull-up MOS for that pin.
2	PA2PCR	0	R/W	
1	PA1PCR	0	R/W	
0	PA0PCR	0	R/W	

10.6.5 Port A Open Drain Control Register (PAODR)

PAODR selects output state of port A.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	Undefined	—	Reserved These bits are always read as undefined value.
3	PAODR	0	R/W	When this bit is set to 1, the corresponding port A pin functions as open drain output. When this bit is cleared to 0, the corresponding pin functions as CMOS output.
2	PAODR	0	R/W	
1	PAODR	0	R/W	
0	PAODR	0	R/W	

10.6.6 Pin Functions

Port A pins also function as an address output pin and SCI_2* I/O pins. The relationship between the value of register and pin is shown as below.

Note: * Not available in the H8S/2227 Series.

- PA3/A19/SCK2

  The pin functions are switched as shown below according to the combination of operating mode, AE3 to AE0 bits in PFCR, the C/A in SMR_2 of SCI_2, CKE0 and CKE1 bits in SCR_2, and the PA3DDR bit.

Operating mode	Modes 4 to 6					
AE3 to AE0	B'11xx	Other than B'11xx				
CKE1	—	0				1
C/A	—	0			1	—
CKE0	—	0		1	—	—
PA3DDR	—	0	1	—	—	—
Pin functions	A19 output pin	PA3 input pin	PA3 output pin*	SCK2 output pin*	SCK2 output pin*	SCK2 input pin

Operating mode	Mode 7				
AE3 to AE0	—				
CKE1	0				1
C/A	0			1	—
CKE0	0		1	—	—
PA3DDR	0	1	—	—	—
Pin functions	PA3 input pin	PA3 output pin*	SCK2 output pin*	SCK2 output pin*	SCK2 input pin

Note: * When PA3ODR in PAODR is set to 1, the corresponding pin functions as NMOS open drain output.

- PA2/A18 /RxD2

  The pin functions are switched as shown below according to the combination of operating mode, AE3 to AE0 bits in PFCR, the RE bit in SCR_2 of SCI_2, and the PA2DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'1011 or B'11xx	Other than (B'1011 or B'11xx)			—		
RE	—	0		1	0		1
PA2DDR	—	0	1	—	0	1	—
Pin functions	A18 output pin	PA2 input pin	PA2 output pin*	RxD2 input pin	PA2 input pin	PA2 output pin*	RxD2 input pin

Note: * When PA2ODR in PAODR is set to 1, the corresponding pin functions as NMOS open drain output.

- PA1/A17 /TxD2

  The pin functions are switched as shown below according to the combination of operating mode, AE3 to AE0 bits in PFCR, the TE bit in SCR_2 of SCI_2, and the PA1DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'101x or B'11xx	Other than (B'101x or B'11xx)			—		
TE	—	0		1	0		1
PA1DDR	—	0	1	—	0	1	—
Pin functions	A17 output pin	PA1 input pin	PA1 output pin*	TxD2 output pin*	PA1 input pin	PA1 output pin*	TxD2 output pin*

Note: * When PA1ODR in PAODR is set to 1, the corresponding pin functions as NMOS open drain output.

- PA0/A16

  The pin functions are switched as shown below according to the combination of operating mode, AE3 to AE0 bits in PFCR and the PA0DDR bit.

Operating mode	Modes 4 to 6			Mode 7	
AE3 to AE0	Other than (B'0xxx or B'1000)	B'0xxx or B'1000		—	
PA0DDR	—	0	1	0	1
Pin functions	A16 output pin	PA0 input pin	PA0 output pin*	PA0 input pin	PA0 output pin*

Note: * When PA0ODR in PAODR is set to 1, the corresponding pin functions as NMOS open drain output.

10.6.7 Input Pull-up MOS States in Port A

Port A 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.

Table 10.2 summarizes the input pull-up MOS states.

Table 10.2 Input Pull-up MOS States in Port A

Pin States	Power-on Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
Address output, Port output, SCI output	OFF	OFF	OFF	OFF	OFF
Port input, SCI input			ON/OFF	ON/OFF	ON/OFF

Legend:

OFF : Input pull-up MOS is always off.

ON/OFF : On when PADDR = 0 and PAPCR = 1; otherwise off.

10.7 Port B

Port B is a 8-bit I/O port. Port B has the following registers.

- Port B data direction register (PBDDR)
- Port B data register (PBDR)
- Port B register (PORTB)
- Port B pull-up MOS control register (PBPCR)

10.7.1 Port B Data Direction Register (PBDDR)

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

Bit	Bit Name	Initial Value	R/W	Description
7	PB7DDR	0	W	When a pin is specified as a general purpose I/O port, setting the bit to 1 makes the corresponding port B pin an output pin. Clearing the bit to 0 makes the pin an input pin.
6	PB6DDR	0	W	
5	PB5DDR	0	W	
4	PB4DDR	0	W	
3	PB3DDR	0	W	
2	PB2DDR	0	W	
1	PB1DDR	0	W	
0	PB0DDR	0	W	

10.7.2 Port B Data Register (PBDR)

PBDR stores output data for port B pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PB7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
6	PB6DR	0	R/W	
5	PB5DR	0	R/W	
4	PB4DR	0	R/W	
3	PB3DR	0	R/W	
2	PB2DR	0	R/W	
1	PB1DR	0	R/W	
0	PB0DR	0	R/W	

10.7.3 Port B Register (PORTB)

PORTB shows the pin states and cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PB7	—*	R	If these bits are read while the corresponding PBDDR bits are set to 1, the PBDR value is read. If these bits are read while PBDDR bits are cleared to 0, the pin states are read.
6	PB6	—*	R	
5	PB5	—*	R	
4	PB4	—*	R	
3	PB3	—*	R	
2	PB2	—*	R	
1	PB1	—*	R	
0	PB0	—*	R	

Note: * Determined by the states of pins PB7 to PB0.

10.7.4 Port B Pull-up MOS Control Register (PBPCR)

PBPCR controls the on/off state of port B input pull-up MOS.

Bit	Bit Name	Initial Value	R/W	Description
7	PB7PCR	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	PB6PCR	0	R/W	
5	PB5PCR	0	R/W	
4	PB4PCR	0	R/W	
3	PB3PCR	0	R/W	
2	PB2PCR	0	R/W	
1	PB1PCR	0	R/W	
0	PB0PCR	0	R/W	

10.7.5 Pin Functions

Port B pins also function as TPU I/O pins (TPU_3*, TPU_4*, and TPU_5*) and address output pins. The values of register and pin functions are shown bellow.

Note: * Not available in the H8S/2227 Series.

- PB7/A15/TIOCB5

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 5 setting, AE3 to AE0 bits in PFCR, and the PB7DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'1xxx	Other than B'1xxx			—		
TPU channel 5 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB7DDR	—	—	0	1	—	0	1
Pin functions	A15 output pin	TIOCB5 output pin	PB7 input pin	PB7 output pin	TIOCB5 output pin	PB7 input pin	PB7 output pin
			TIOCB5 input pin*[2]			TIOCB5 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCB5 input when TPU channel 5 timer operating mode is set to normal operating or phase counting mode and IOB3 in TIOR_5 is set to 1.

- PB6/A14/TIOCA5

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 5 setting, AE3 to AE0 bits in PFCR, and the PB6DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'0111 or B'1xxx	Other than (B'0111 or B'1xxx)			—		
TPU channel 5 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB6DDR	—	—	0	1	—	0	1
Pin functions	A14 output pin	TIOCA5 output pin	PB6 input pin	PB6 output pin	TIOCA5 output pin	PB6 input pin	PB6 output pin
			TIOCA5 input pin*[2]			TIOCA5 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCA5 input when TPU channel 5 timer operating mode is set to normal operating or phase counting mode and IOA3 in TIOR_5 is set to 1.

- PB5/A13/TIOCB4

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 4 setting, AE3 to AE0 bits in PFCR, and the PB5DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	B'011x or B'1xxx	Other than (B'011x or B'1xxx)			—		
TPU channel 4 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB5DDR	—	—	0	1	—	0	1
Pin functions	A13 output pin	TIOCB4 output pin	PB5 input pin	PB5 output pin	TIOCB4 output pin	PB5 input pin	PB5 output pin
			TIOCB4 input pin*[2]			TIOCB4 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCB4 input when TPU channel 4 timer operating mode is set to normal operating or phase counting mode and IOB3 to IOB0 in TIOR_4 are set to 10xx.

- PB4/A12/TIOCA4

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 4 setting, AE3 to AE0 bits in PFCR, and the PB4DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	Other than (B'0100 or B'00xx)	B'0100 or B'00xx			—		
TPU channel 4 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB4DDR	—	—	0	1	—	0	1
Pin functions	A12 output pin	TIOCA4 output pin	PB4 input pin	PB4 output pin	TIOCA4 output pin	PB4 input pin	PB4 output pin
			TIOCA4 input pin*[2]			TIOCA4 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCA4 input when TPU channel 4 timer operating mode is set to normal operating or phase counting mode and IOA3 to IOA0 in TIOR_4 are set to 10xx.

- PB3/A11/TIOCD3

  The pin function is switched as shown below according to combination of the operating mode, the TPU channel 3 setting, AE3 to AE0 bits in PFCR, and the PB3DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	Other than B'00xx	B'00xx			—		
TPU channel 3 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB3DDR	—	—	0	1	—	0	1
Pin functions	A11 output pin	TIOCD3 output pin	PB3 input pin	PB3 output pin	TIOCD3 output pin	PB3 input pin	PB3 output pin
			TIOCD3 input pin*[2]			TIOCD3 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCD3 input when TPU channel 3 timer operating mode is set to normal operating and IOD3 to IOD0 in TIORL_3 are set to 10xx.

- PB2/A10/TIOCC3

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 3 setting, AE3 to AE0 bits in PFCR, and the PB2DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	Other than (B'0010 or B'000x)	B'0010 or B'000x			—		
TPU channel 3 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB2DDR	—	—	0	1	—	0	1
Pin functions	A10 output pin	TIOCC3 output pin	PB2 input pin	PB2 output pin	TIOCC3 output pin	PB2 input pin	PB2 output pin
			TIOCC3 input pin*[2]			TIOCC3 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCC3 input when TPU channel 3 timer operating mode is set to normal operating mode and IOC3 to IOC0 in TIORL_3 are set to 10xx.

- PB1/A9/TIOCB3

  The pin functions are switched as shown below according to the combination of operating mode, the TPU channel 3 setting, AE3 to AE0 bits in PFCR, and the PB1DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	Other than B'000x	B'000x			—		
TPU channel 3 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB1DDR	—	—	0	1	—	0	1
Pin functions	A9 output pin	TIOCB3 output pin	PB1 input pin	PB1 output pin	TIOCB3 output pin	PB1 input pin	PB1 output pin
			TIOCB3 input pin*[2]			TIOCB3 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCB3 input when TPU channel 3 timer operating mode is set to normal operating mode and IOB3 to IOB0 in TIORH_3 are set to 10xx.

- PB0/A8/TIOCA3

  The pin functions are switched as shown below according to the combination of the operating mode, TPU channel 3 setting, the AE3 to AE0 bits in PFCR, and the PB0DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
AE3 to AE0	Other than B'0000	B'0000			—		
TPU channel 3 setting*[1]	—	Output	Input or initial value		Output	Input or initial value	
PB0DDR	—	—	0	1	—	0	1
Pin functions	A8 output pin	TIOCA3 output pin	PB0 input pin	PB0 output pin	TIOCA3 output pin	PB0 input pin	PB0 output pin
			TIOCA3 input pin*[2]			TIOCA3 input pin*[2]	

Notes: 1. For the setting of the TPU channel, see section 11, 16-Bit Timer Pulse Unit (TPU).
2. This pin functions as TIOCA3 input when TPU channel 3 timer operating mode is set to normal operating mode and IOA3 to IOA0 in TIORH_3 are set to 10xx.

10.7.6 Input Pull-up MOS States in Port B

Port B 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.

Table 10.3 summarizes the input pull-up MOS states.

Table 10.3 Input Pull-up MOS States in Port B

Pin States	Power-on Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
Address output, Port output, TPU output	OFF	OFF	OFF	OFF	OFF
Port input, TPU input			ON/OFF	ON/OFF	ON/OFF

Legend:
OFF : Input pull-up MOS is always off.
ON/OFF : On when PBDDR = 0 and PBPCR = 1; otherwise off.

10.8 Port C

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

- Port C data direction register (PCDDR)
- Port C data register (PCDR)
- Port C register (PORTC)
- Port C pull-up MOS control register (PCPCR)

10.8.1 Port C Data Direction Register (PCDDR)

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

Bit	Bit Name	Initial Value	R/W	Description
7	PC7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port C pin an output pin. Clearing this bit to 0 makes the pin an input pin.
6	PC6DDR	0	W	
5	PC5DDR	0	W	
4	PC4DDR	0	W	
3	PC3DDR	0	W	
2	PC2DDR	0	W	
1	PC1DDR	0	W	
0	PC0DDR	0	W	

10.8.2 Port C Data Register (PCDR)

PCDR stores output data for port C pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
6	PC6DR	0	R/W	
5	PC5DR	0	R/W	
4	PC4DR	0	R/W	
3	PC3DR	0	R/W	
2	PC2DR	0	R/W	
1	PC1DR	0	R/W	
0	PC0DR	0	R/W	

10.8.3 Port C Register (PORTC)

PORTC shows port C pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7	—*	R	If a port C read is performed while PCDDR bits are set to 1, the PCDR values are read. If a port C read is performed while PCDDR bits are cleared to 0, the pin states are read.
6	PC6	—*	R	
5	PC5	—*	R	
4	PC4	—*	R	
3	PC3	—*	R	
2	PC2	—*	R	
1	PC1	—*	R	
0	PC0	—*	R	

Note: * Determined by the states of pins PC7 to PC0.

10.8.4 Port C Pull-up MOS Control Register (PCPCR)

PCPCR controls the input pull-up MOS specification as on or off for port C.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7PCR	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	PC6PCR	0	R/W	
5	PC5PCR	0	R/W	
4	PC4PCR	0	R/W	
3	PC3PCR	0	R/W	
2	PC2PCR	0	R/W	
1	PC1PCR	0	R/W	
0	PC0PCR	0	R/W	

10.8.5 Pin Functions

Port C pins also function as address output pin. The values of register and pin functions are shown below.

- PC7/A7, PC6/A6, PC5/A5, PC4/A4, PC3/A3, PC2/A2, PC1/A1, PC0/A0

  The pin functions are switched as shown below according to the combination of operating mode and the PCnDDR bit.

Operating mode	Modes 4 and 5	Mode 6		Mode 7	
PCnDDR	—	0	1	0	1
Pin functions	Address output pin	PCn input pin	Address output pin	PCn input pin	PCn output pin

Note: n = 7 to 0

10.8.6 Input Pull-up MOS States in Port C

Port C has a built-in input pull-up MOS function that can be controlled by software. Input pull-up MOS can be used in modes 6 and 7 and specified as on or off on an individual bit basis.

Table 10.4 summarizes the input pull-up MOS states in port C.

Table 10.4 Input Pull-up MOS States in Port C

Pin States	Power-on Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
Address output (modes 4 and 5) and port output (modes 6 and 7)	OFF	OFF	OFF	OFF
Port input (modes 6 and 7)			ON/OFF	ON/OFF

Legend:

OFF : Input pull-up MOS is always off.

ON/OFF : On when PCDDR = 0 and PCPCR = 1; otherwise off.

10.9 Port D

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

- Port D data direction register (PDDDR)
- Port D data register (PDDR)
- Port D register (PORTD)
- Port D pull-up MOS control register (PDPCR)

10.9.1 Port D Data Direction Register (PDDDR)

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

Bit	Bit Name	Initial Value	R/W	Description
7	PD7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port D pin an output port. Clearing this bit to 0 makes the pin an input port.
6	PD6DDR	0	W	
5	PD5DDR	0	W	
4	PD4DDR	0	W	
3	PD3DDR	0	W	
2	PD2DDR	0	W	
1	PD1DDR	0	W	
0	PD0DDR	0	W	

10.9.2 Port D Data Register (PDDR)

PDDR stores output data for port D pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PD7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
6	PD6DR	0	R/W	
5	PD5DR	0	R/W	
4	PD4DR	0	R/W	
3	PD3DR	0	R/W	
2	PD2DR	0	R/W	
1	PD1DR	0	R/W	
0	PD0DR	0	R/W	

10.9.3 Port D Register (PORTD)

PORTD shows port D pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PD7	—*	R	If a port D read is performed while PDDDR bits are set to 1, the PDDR values are read. If a port D read is performed while PDDDR bits are cleared to 0, the pin states are read.
6	PD6	—*	R	
5	PD5	—*	R	
4	PD4	—*	R	
3	PD3	—*	R	
2	PD2	—*	R	
1	PD1	—*	R	
0	PD0	—*	R	

Note: * Determined by the states of pins PD7 to PD0.

10.9.4 Port D Pull-up MOS Control Register (PDPCR)

PDPCR controls the on/off state of port D input pull-up MOS.

Bit	Bit Name	Initial Value	R/W	Description
7	PD7PCR	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	PD6PCR	0	R/W	
5	PD5PCR	0	R/W	
4	PD4PCR	0	R/W	
3	PD3PCR	0	R/W	
2	PD2PCR	0	R/W	
1	PD1PCR	0	R/W	
0	PD0PCR	0	R/W	

10.9.5 Pin Functions

Port D pins also function as data I/O pins. The values of register and pin functions are shown below.

- PD7/D15, PD6/D14, PD5/D13, PD4/D12, PD3/D11, PD2/D10, PD1/D9, PD0/D8

The pin functions are switched as shown below according to the combination of the operating mode and the PDnDDR bit.

Operating mode	Modes 4 to 6	Mode 7	
PDnDDR	—	0	1
Pin functions	Data I/O pin	PDn input pin	PDn output pin

Note: n = 7 to 0

10.9.6 Input Pull-up MOS States in Port D

Port D has a built-in input pull-up MOS function that can be controlled by software. Input pull-up MOS can be used in mode 7 and specified as on or off on an individual bit basis.

Table 10.5 summarizes the input pull-up MOS states in port D.

Table 10.5 Input Pull-up MOS States in Port D

Pin States	Power-on Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
Data I/O (modes 4 and 6) and port output (mode 7)	OFF	OFF	OFF	OFF	OFF
Port input (modes 6 and 7)			ON/OFF	ON/OFF	ON/OFF

Legend:

OFF : Input pull-up MOS is always off.

ON/OFF : On when PDDDR = 0 and PDPCR = 1; otherwise off.

10.10 Port E

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

- Port E data direction register (PEDDR)
- Port E data register (PEDR)
- Port E register (PORTE)
- Port E pull-up MOS control register (PEPCR)

10.10.1 Port E Data Direction Register (PEDDR)

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

Bit	Bit Name	Initial Value	R/W	Description
7	PE7DDR	0	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port E pin an output port. Clearing this bit to 0 makes the pin an input port.
6	PE6DDR	0	W	
5	PE5DDR	0	W	
4	PE4DDR	0	W	
3	PE3DDR	0	W	
2	PE2DDR	0	W	
1	PE1DDR	0	W	
0	PE0DDR	0	W	

10.10.2 Port E Data Register (PEDR)

PEDR stores output data for port E pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
6	PE6DR	0	R/W	
5	PE5DR	0	R/W	
4	PE4DR	0	R/W	
3	PE3DR	0	R/W	
2	PE2DR	0	R/W	
1	PE1DR	0	R/W	
0	PE0DR	0	R/W	

10.10.3 Port E Register (PORTE)

PORTE shows port E pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7	—*	R	If a port E read is performed while PEDDR bits are set to 1, the PEDR values are read. If a port E read is performed while PEDDR bits are cleared to 0, the pin states are read.
6	PE6	—*	R	
5	PE5	—*	R	
4	PE4	—*	R	
3	PE3	—*	R	
2	PE2	—*	R	
1	PE1	—*	R	
0	PE0	—*	R	

Note: * Determined by the states of pins PE7 to PE0.

10.10.4 Port E Pull-up MOS Control Register (PEPCR)

PEPCR controls the on/off state of port E input pull-up MOS.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7PCR	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	PE6PCR	0	R/W	
5	PE5PCR	0	R/W	
4	PE4PCR	0	R/W	
3	PE3PCR	0	R/W	
2	PE2PCR	0	R/W	
1	PE1PCR	0	R/W	
0	PE0PCR	0	R/W	

10.10.5 Pin Functions

Port E pins also function as data I/O pins. The values of register and pin functions are shown below.

- PE7/D7, PE6/D6, PE5/D5, PE4/D4, PE3/D3, PE2/D2, PE1/D1, PE0/D0

The pin functions are switched as shown below according to the combination of the operating mode, bus mode, and the PEnDDR bit.

Operating mode	Modes 4 to 6			Mode 7	
Bus mode	8-bit bus mode		16-bit bus mode	—	
PEnDDR	0	1	—	0	1
Pin functions	PEn input pin	PEn output pin	Data I/O pin	PEn input pin	PEn output pin

Note: n = 7 to 0

10.10.6 Input Pull-up MOS States in Port E

Port E has a built-in input pull-up MOS function that can be controlled by software. Input pull-up MOS can be used in modes 4 to 6 and 8-bit bus mode or in mode 7 and specified as on or off on an individual bit basis.

Table 10.6 summarizes the input pull-up MOS states in port E.

Table 10.6 Input Pull-up MOS States in Port E

Pin States	Power-on Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
Data I/O (16-bit bus in modes 4 to 6) and port output (8-bit bus in modes 4 to 6 and mode 7)	OFF	OFF	OFF	OFF	OFF
Port input (8-bit bus in modes 4 to 6 and mode 7)			ON/OFF	ON/OFF	ON/OFF

Legend:

OFF : Input pull-up MOS is always off.

ON/OFF : On when PEDDR = 0 and PEPCR = 1; otherwise off.

10.11 Port F

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

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

10.11.1 Port F Data Direction Register (PFDDR)

PFDDR specifies input or output of 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	PF7DDR	0/1*	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 port. Clearing this bit to 0 makes the pin an input port.
6	PF6DDR	0	W	
5	PF5DDR	0	W	
4	PF4DDR	0	W	
3	PF3DDR	0	W	
2	PF2DDR	0	W	
1	PF1DDR	0	W	
0	PF0DDR	0	W	

Note: * In modes 4 to 6, initial value is 1. In mode 7, initial value is 0.

10.11.2 Port F Data Register (PFDR)

PFDR stores output data for port F pins.

Bit	Bit Name	Initial Value	R/W	Description
7	PF7DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
6	PF6DR	0	R/W	
5	PF5DR	0	R/W	
4	PF4DR	0	R/W	
3	PF3DR	0	R/W	
2	PF2DR	0	R/W	
1	PF1DR	0	R/W	
0	PF0DR	0	R/W	

10.11.3 Port F Register (PORTF)

PORTF shows port F pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7	PF7	—*	R	If a port F read is performed while PFDDR bits are set to 1, the PFDR values are read. If a port F read is performed while PFDDR bits are cleared to 0, the pin states are read.
6	PF6	—*	R	
5	PF5	—*	R	
4	PF4	—*	R	
3	PF3	—*	R	
2	PF2	—*	R	
1	PF1	—*	R	
0	PF0	—*	R	

Note: * Determined by the states of pins PF7 to PF0.

10.11.4 Pin Functions

Port F pins also function as bus control signal input/output pin, interrupt input pin, system clock output pin, A/D trigger input pin, and BUZZ output pin. The values of register and pin functions are shown below.

- PF7/ϕ

  The pin functions are switched as shown below according to the PF7DDR bit.

PF7DDR	0	1
Pin functions	PF7 input pin	ϕ output pin

- PF6/AS

The pin functions are switched as shown below according to the combination of operating mode and the PF6DDR bit.

Operating mode	Modes 4 to 6	Mode 7	
PF6DDR	—	0	1
Pin functions	AS output pin	PF6 input pin	PF6 output pin

- PF5/RD

The pin functions are switched as shown below according to the combination of operating mode and the PF5DDR bit.

Operating mode	Modes 4 to 6	Mode 7	
PF5DDR	—	0	1
Pin functions	RD output pin	PF5 input pin	PF5 output pin

- PF4/HWR

The pin functions are switched as shown below according to the combination of operating mode and the PF4DDR bit.

Operating mode	Modes 4 to 6	Mode 7	
PF4DDR	—	0	1
Pin functions	HWR output pin	PF4 input pin	PF4 output pin

- PF3/LWR/ADTRG/IRQ3

The pin functions are switched as shown below according to the combination of operating mode and the PF3DDR bit.

Operating mode	Modes 4 to 6			Mode 7	
Bus mode	16-bit bus mode	8-bit bus mode		—	
PF3DDR	—	0	1	0	1
Pin functions	LWR output pin	PF3 input pin	PF3 output pin	PF3 input pin	PF3 output pin
		ADTRG input pin*[1]			
		IRQ3 input pin*[2]			

Notes: 1. When TRGS0 and TRGS1 are set to 1, this pin is ADTRG input.
2. When this pin is used as an external interrupt pin, do not specify other functions.

- PF2/WAIT

The pin functions are switched as shown below according to the combination of operating mode, the WAITE bit, and the PF2DDR bit.

Operating mode	Modes 4 to 6			Mode 7	
WAITE	0		1	—	
PF2DDR	0	1	—	0	1
Pin functions	PF2 input pin	PF2 output pin	WAIT input pin	PF2 input pin	PF2 output pin

- PF1/BACK/BUZZ

The pin functions are switched as shown below according to the combination of operating mode, the BUZZ bit in PFCR, and the PF1DDR bit.

Operating mode	Modes 4 to 6				Mode 7		
BRLE	0			1	—		
BUZZE	0		1	—	0		1
PF1DDR	0	1	—	—	0	1	—
Pin functions	PF1 input pin	PF1 output pin	BUZZ output pin	BACK output pin	PF1 input pin	PF1 output pin	BUZZ output pin

- PF0/BREQ/IRQ2

The pin functions are switched as shown below according to the combination of operating mode, the BRLE bit, and the PF0DDR bit.

Operating mode	Modes 4 to 6			Mode 7	
BRLE	0		1	—	
PF0DDR	0	1	—	0	1
Pin functions	PF0 input pin	PF0 output pin	BREQ input pin	PF0 input pin	PF0 output pin
	IRQ2 input pin*				

Note: * When this pin is used as an external interrupt pin, do not specify other functions.

10.12 Port G

Port G is a 5-bit I/O port and has the following registers.

- Port G data direction register (PGDDR)

- Port G data register (PGDR)
- Port G register (PORTG)

10.12.1 Port G Data Direction Register (PGDDR)

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

Bit	Bit Name	Initial Value	R/W	Description
7 to 5	—	Undefined	—	Reserved These bits are always read as undefined value.
4	PG4DDR	0/1*	W	When a pin is specified as a general purpose I/O port, setting this bit to 1 makes the corresponding port G pin an output port. Clearing this bit to 0 makes the pin an input port.
3	PG3DDR	0	W	
2	PG2DDR	0	W	
1	PG1DDR	0	W	
0	PG0DDR	0	W	

Note: * In modes 4 and 5, initial value is 1. In modes 6 and 7, initial value is 0.

10.12.2 Port G Data Register (PGDR)

PGDR stores output data for port G pins.

Bit	Bit Name	Initial Value	R/W	Description
7 to 5	—	Undefined	—	Reserved These bits are always read as undefined value.
4	PG4DR	0	R/W	Output data for a pin is stored when the pin is specified as a general purpose I/O port.
3	PG3DR	0	R/W	
2	PG2DR	0	R/W	
1	PG1DR	0	R/W	
0	PG0DR	0	R/W	

10.12.3 Port G Register (PORTG)

PORTG shows port G pin states. This register cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
7 to 5	—	Undefined	—	Reserved These bits are always read as undefined value.
4	PG4	—*	R	If a port G read is performed while PGDDR bits are set to 1, the PGDR values are read. If a port G read is performed while PGDDR bits are cleared to 0, the pin states are read.
3	PG3	—*	R	
2	PG2	—*	R	
1	PG1	—*	R	
0	PG0	—*	R	

Note: * Determined by the states of pins PG4 to PG0.

10.12.4 Pin Functions

Port G pins also function as bus control signal input/output pin and interrupt input pin. The values of registers and pin functions are shown below.

- PG4/CS0

  The pin functions are switched as shown below according to the combination of operating mode and the PG4DDR bit.

Operating mode	Modes 4 to 6		Mode 7	
PG4DDR	0	1	0	1
Pin functions	PG4 input pin	CS0 output pin	PG4 input pin	PG4 output pin

- PG3/CS1

  The pin functions are switched as shown below according to the combination of operating mode and the PG3DDR bit.

Operating mode	Modes 4 to 6		Mode 7	
PG3DDR	0	1	0	1
Pin functions	PG3 input pin	CS1 output pin	PG3 input pin	PG3 output pin

- PG2/CS2

  The pin functions are switched as shown below according to the combination of operating mode and the PG2DDR bit.

Operating mode	Modes 4 to 6		Mode 7	
PG2DDR	0	1	0	1
Pin functions	PG2 input pin	CS2 output pin	PG2 input pin	PG2 output pin

- PG1/CS3/IRQ7

  The pin functions are switched as shown below according to the combination of operating mode and the PG1DDR bit.

Operating mode	Modes 4 to 6		Mode 7	
PG1DDR	0	1	0	1
Pin functions	PG1 input pin	CS3 output pin	PG1 input pin	PG1 output pin
	IRQ7 input pin*			

Note: * When this pin is used as an external interrupt pin, do not specify other functions.

- PG0/IRQ6

  The pin functions are switched as shown below according to the PG0DDR bit.

PG0DDR	0	1
Pin functions	PG0 input pin	PG0 output pin
	IRQ6 input pin*	

Note: * When this pin is use as an external interrupt pin, do not specify other functions.

Section 11 16-Bit Timer Pulse Unit (TPU)

This LSI has an on-chip 16-bit timer pulse unit (TPU) that comprises six 16-bit timer channels. The function list of the 16-bit timer unit and its block diagram are shown in table 11.1 and figure 11.1, respectively.

11.1 Features

- The number of channels

  H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series: Six channels (channels 0, 1, 2, 3, 4, and 5)

  H8S/2227 Series: three channels (channels 0, 1, and 2)
- Pulse input/output

  H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series: Maximum of 16-pulse input/output

  H8S/2227 Series: Maximum of eight-pulse input/output
- Selection of 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 operations:

    Multiple timer counters (TCNT) can be written to simultaneously

    Simultaneous clearing by compare match and input capture possible

    Register simultaneous input/output possible by counter synchronous operation

  Maximum of 15-phase PWM output possible by combination with synchronous operation
- Buffer operation settable for channels 0 and 3
- Phase counting mode settable independently for each of channels 1, 2, 4, and 5
- Cascaded operation*
- Fast access via internal 16-bit bus
- 26 interrupt sources
- Automatic transfer of register data
- A/D converter conversion start trigger can be generated
- Module stop mode can be set

Note: * Not available in the H8S/2227 Series.

Table 11.1 TPU Functions

Item		Channel 0	Channel 1	Channel 2	Channel 3*[1]	Channel 4*[1]	Channel 5*[1]
Count clock		φ/1 φ/4 φ/16 φ/64 TCLKA TCLKB TCLKC TCLKD	φ/1 φ/4 φ/16 φ/64 φ/256 TCLKA TCLKB	φ/1 φ/4 φ/16 φ/64 φ/1024 TCLKA TCLKB TCLKC	φ/1 φ/4 φ/16 φ/64 φ/256 φ/1024 φ/4096 TCLKA	φ/1 φ/4 φ/16 φ/64 φ/1024 TCLKA TCLKC	φ/1 φ/4 φ/16 φ/64 φ/256 TCLKA TCLKC TCLKD
General registers (TGR)		TGRA_0 TGRB_0	TGRA_1 TGRB_1	TGRA_2 TGRB_2	TGRA_3 TGRB_3	TGRA_4 TGRB_4	TGRA_5 TGRB_5
General registers/ buffer registers		TGRC_0 TGRD_0	—	—	TGRC_3 TGRD_3	—	—
I/O pins		TIOCA0 TIOCB0 TIOCC0 TIOCD0	TIOCA1 TIOCB1	TIOCA2 TIOCB2	TIOCA3 TIOCB3 TIOCC3 TIOCD3	TIOCA4 TIOCB4	TIOCA5 TIOCB5
Counter clear function		TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
Compare match output	0 output	O	O	O	O	O	O
	1 output	O	O	O	O	O	O
	Toggle output	O	O	O	O	O	O
Input capture function		O	O	O	O	O	O
Synchronous operation		O	O	O	O	O	O
PWM mode		O	O	O	O	O	O
Phase counting mode		—	O	O	—	O	O
Buffer operation		O	—	—		—	—

Item	Channel 0	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
DTC activation	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
DMAC*[2] activation	TGRA_0 compare match or input capture	TGRA_1 compare match or input capture	TGRA_2 compare match or input capture	TGRA_3 compare match or input capture	TGRA_4 compare match or input capture	TGRA_5 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	TGRA_3 compare match or input capture	TGRA_4 compare match or input capture	TGRA_5 compare match or input capture
Interrupt sources	5 sources • Compare match or input capture 0A • Compare match or input capture 0B • Compare match or input capture 0C • Compare match or input capture 0D • Overflow	4 sources • Compare match or input capture 1A • Compare match or input capture 1B • Overflow • Underflow	4 sources • Compare match or input capture 2A • Compare match or input capture 2B • Overflow • Underflow	5 sources • Compare match or input capture 3A • Compare match or input capture 3B • Compare match or input capture 3C • Compare match or input capture 3D • Overflow	4 sources • Compare match or input capture 4A • Compare match or input capture 4B • Overflow • Underflow	4 sources • Compare match or input capture 5A • Compare match or input capture 5B • Overflow • Underflow

Legend

O : Possible

— : Not possible

Notes: 1. Not available in the H8S/2227 Series.

2. Supported only by the H8S/2239 Series.

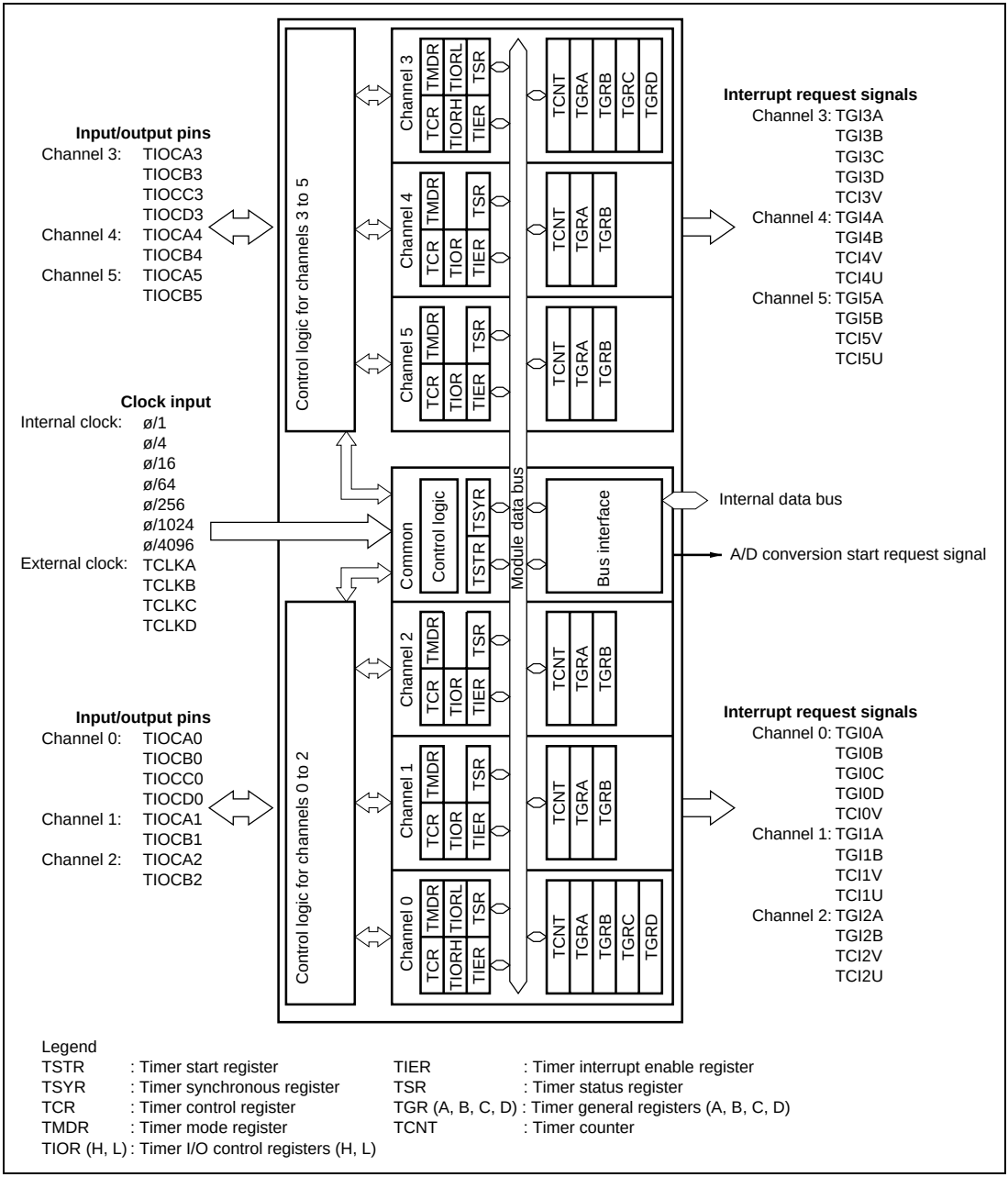


Figure 11.1 Block Diagram of TPU
(H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series)

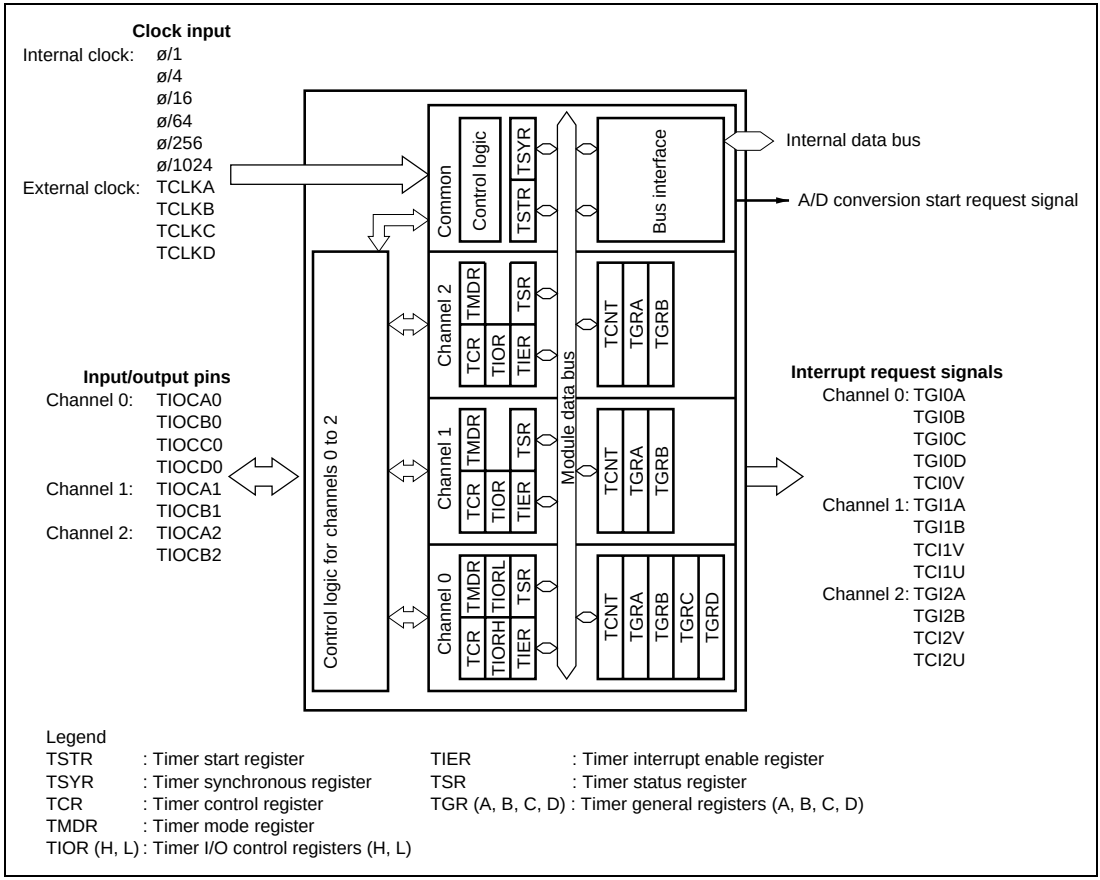


Figure 11.2 Block Diagram of TPU (H8S/2227 Series)

11.2 Input/Output Pins

Table 11.2 Pin Configuration

Channel	Symbol	I/O	Function
All	TCLKA	Input	External clock A input pin (Channel 1 and 5* phase counting mode A phase input)
	TCLKB	Input	External clock B input pin (Channel 1 and 5* phase counting mode B phase input)
	TCLKC	Input	External clock C input pin (Channel 2 and 4* phase counting mode A phase input)
	TCLKD	Input	External clock D input pin (Channel 2 and 4* 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
3*	TIOCA3	I/O	TGRA_3 input capture input/output compare output/PWM output pin
	TIOCB3	I/O	TGRB_3 input capture input/output compare output/PWM output pin
	TIOCC3	I/O	TGRC_3 input capture input/output compare output/PWM output pin
	TIOCD3	I/O	TGRD_3 input capture input/output compare output/PWM output pin
4*	TIOCA4	I/O	TGRA_4 input capture input/output compare output/PWM output pin
	TIOCB4	I/O	TGRB_4 input capture input/output compare output/PWM output pin
5*	TIOCA5	I/O	TGRA_5 input capture input/output compare output/PWM output pin
	TIOCB5	I/O	TGRB_5 input capture input/output compare output/PWM output pin

Note: * Not available in the H8S/2227 Series.

11.3 Register Descriptions

The TPU has the following registers in each channel.

- 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)
- Timer control register_3 (TCR_3) *
- Timer mode register_3 (TMDR_3) *
- Timer I/O control register H_3 (TIORH_3) *
- Timer I/O control register L_3 (TIORL_3) *
- Timer interrupt enable register_3 (TIER_3) *
- Timer status register_3 (TSR_3) *
- Timer counter_3 (TCNT_3) *

- Timer general register A_3 (TGRA_3) *
- Timer general register B_3 (TGRB_3) *
- Timer general register C_3 (TGRC_3) *
- Timer general register D_3 (TGRD_3) *
- Timer control register_4 (TCR_4) *
- Timer mode register_4 (TMDR_4) *
- Timer I/O control register _4 (TIOR_4) *
- Timer interrupt enable register_4 (TIER_4) *
- Timer status register_4 (TSR_4) *
- Timer counter_4 (TCNT_4) *
- Timer general register A_4 (TGRA_4) *
- Timer general register B_4 (TGRB_4) *
- Timer control register_5 (TCR_5) *
- Timer mode register_5 (TMDR_5) *
- Timer I/O control register_5 (TIOR_5) *
- Timer interrupt enable register_5 (TIER_5) *
- Timer status register_5 (TSR_5) *
- Timer counter_5 (TCNT_5) *
- Timer general register A_5 (TGRA_5) *
- Timer general register B_5 (TGRB_5) *

Common Registers

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

Note: * Not available in the H8S/2227 Series.

11.3.1 Timer Control Register (TCR)

The TCR registers control the TCNT operation for each channel. The TPU has a total of six TCR registers, one for each channel. TCR register settings should be made only when TCNT operation is stopped.

Bit	Bit Name	Initial Value	R/W	Description
7 6 5	CCLR2 CCLR1 CCLR0	0 0 0	R/W R/W R/W	Counter Clear 2 to 0 These bits select the TCNT counter clearing source. See tables 11.3 and 11.4 for details.
4 3	CKEG1 CKEG0	0 0	R/W R/W	Clock Edge 1 and 0 These bits select the input clock edge. When the input clock is counted using both edges, the input clock period is halved (e.g. ϕ/4 both edges = ϕ/2 rising edge). If phase counting mode is used on channels 1, 2, 4, and 5, this setting is ignored and the phase counting mode setting has priority. Internal clock edge selection is valid when the input clock is ϕ/4 or slower. This setting is ignored if the input clock is ϕ/1, or when overflow/underflow of another channel is selected. 00: Count at rising edge 01: Count at falling edge 1x: Count at both edges Legend: x: Don't care
2 1 0	TPSC2 TPSC1 TPSC0	0 0 0	R/W R/W R/W	Time Prescaler 2 to 0 These bits select the TCNT counter clock. The clock source can be selected independently for each channel. See tables 11.5 to 11.10 for details.

Table 11.3 CCLR2 to CCLR0 (Channels 0 and 3)

Channel	Bit 7 CCLR2	Bit 6 CCLR1	Bit 5 CCLR0	Description
0, 3	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 setting is performed 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 11.4 CCLR2 to CCLR0 (Channels 1, 2, 4, and 5)

Channel	Bit 7 Reserved*[2]	Bit 6 CCLR1	Bit 5 CCLR0	Description
1, 2, 4, 5	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 setting is performed by setting the SYNC bit in TSYR to 1.
2. Bit 7 is reserved in channels 1, 2, 4, and 5. It is always read as 0 and cannot be modified.

Table 11.5 TPSC2 to TPSC0 (Channel 0)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
0	0	0	0	Internal clock: counts on ϕ/1
			1	Internal clock: counts on ϕ/4
		1	0	Internal clock: counts on ϕ/16
			1	Internal clock: counts on ϕ/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 11.6 TPSC2 to TPSC0 (Channel 1)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
1	0	0	0	Internal clock: counts on ϕ/1
			1	Internal clock: counts on ϕ/4
		1	0	Internal clock: counts on ϕ/16
			1	Internal clock: counts on ϕ/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 ϕ/256
			1	Counts on TCNT2 overflow/underflow
				Setting is prohibited in the H8S/2227 Series.

Note: This setting is ignored when channel 1 is in phase counting mode.

Table 11.7 TPSC2 to TPSC0 (Channel 2)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
2	0	0	0	Internal clock: counts on ϕ/1
			1	Internal clock: counts on ϕ/4
		1	0	Internal clock: counts on ϕ/16
			1	Internal clock: counts on ϕ/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 ϕ/1024

Note: This setting is ignored when channel 2 is in phase counting mode.

Table 11.8 TPSC2 to TPSC0 (Channel 3)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
3*	0	0	0	Internal clock: counts on ϕ/1
			1	Internal clock: counts on ϕ/4
		1	0	Internal clock: counts on ϕ/16
			1	Internal clock: counts on ϕ/64
	1	0	0	External clock: counts on TCLKA pin input
			1	Internal clock: counts on ϕ/1024
		1	0	Internal clock: counts on ϕ/256
			1	Internal clock: counts on ϕ/4096

Note: * Not available in the H8S/2227 Series.

Table 11.9 TPSC2 to TPSC0 (Channel 4)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
4*	0	0	0	Internal clock: counts on ϕ/1
			1	Internal clock: counts on ϕ/4
		1	0	Internal clock: counts on ϕ/16
			1	Internal clock: counts on ϕ/64
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKC pin input
		1	0	Internal clock: counts on ϕ/1024
			1	Counts on TCNT5 overflow/underflow

Notes: This setting is ignored when channel 4 is in phase counting mode.

* Not available in the H8S/2227 Series.

Table 11.10 TPSC2 to TPSC0 (Channel 5)

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
5*	0	0	0	Internal clock: counts on ϕ/1
			1	Internal clock: counts on ϕ/4
		1	0	Internal clock: counts on ϕ/16
			1	Internal clock: counts on ϕ/64
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKC pin input
		1	0	Internal clock: counts on ϕ/256
			1	External clock: counts on TCLKD pin input

Notes: This setting is ignored when channel 5 is in phase counting mode.

* Not available in the H8S/2227 Series.

11.3.2 Timer Mode Register (TMDR)

The TMDR registers are used to set the operating mode for each channel. The TPU has six TMDR registers, one for each channel. TMDR register settings should be made only when TCNT operation is stopped.

Bit	Bit Name	Initial Value	R/W	Description
7	—	1	—	Reserved
6	—	1	—	These bits are always read as 1 and cannot be modified.
5	BFB	0	R/W	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, 2, 4, and 5, 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
4	BFA	0	R/W	Buffer Operation A 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. In channels 1, 2, 4, and 5, which have no TGRC, bit 4 is reserved. It is always read as 0 and cannot be modified. 0: TGRA operates normally 1: TGRA and TGRC used together for buffer operation
3	MD3	0	R/W	Modes 3 to 0 These bits are used to set the timer operating mode. MD3 is a reserved bit. The write value should always be 0. See table 11.11 for details.
2	MD2	0	R/W	
1	MD1	0	R/W	
0	MD0	0	R/W	

Table 11.11 MD3 to MD0

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 for channels 0 and 3. In this case, 0 should always be written to MD2.

11.3.3 Timer I/O Control Register (TIOR)

The TIOR registers control the TGR registers. The TPU has eight TIOR registers, two each for channels 0 and 3, and one each for channels 1, 2, 4, and 5. Care is required since 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.

When TGRC or TGRD is designated for buffer operation, this setting is invalid and the register operates as a buffer register.

TIORH_0, TIOR_1, TIOR_2, TIORH_3, TIOR_4, TIOR_5

Bit	Bit Name	Initial Value	R/W	Description
7	IOB3	0	R/W	I/O Control B3 to B0
6	IOB2	0	R/W	Specify the function of TGRB. For details, see tables 11.12, 11.14, 11.15, 11.16, 11.18, and 11.19.
5	IOB1	0	R/W	
4	IOB0	0	R/W	
3	IOA3	0	R/W	I/O Control A3 to A0
2	IOA2	0	R/W	Specify the function of TGRA. For details, see tables 11.20, 11.22, 11.23, 11.24, 11.26, and 11.27.
1	IOA1	0	R/W	
0	IOA0	0	R/W	

TIORL_0, TIORL_3

Bit	Bit Name	Initial Value	R/W	Description
7	IOD3	0	R/W	I/O Control D3 to D0
6	IOD2	0	R/W	Specify the function of TGRD. For details, see tables 11.13, and 11.17.
5	IOD1	0	R/W	
4	IOD0	0	R/W	
3	IOC3	0	R/W	I/O Control C3 to C0
2	IOC2	0	R/W	Specify the function of TGRC. For details, see tables 11.21, and 11.25
1	IOC1	0	R/W	
0	IOC0	0	R/W	

Table 11.12 TIORH_0

				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 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output 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
		1	x		Capture input source is TIOCB0 pin Input capture at both edges
	1	x	x		Capture input source is channel 1/count clock Input capture at TCNT_1 count- up/count-down*[1]*[2]

Legend: x: Don't care

Notes: 1. When bits TPSC2 to TPSC0 in TCR_1 are set to B'000 and ϕ/1 is used as the TCNT_1 count clock, this setting is invalid and input capture is not generated.

2. Not available in the H8S/2227 Series.

Table 11.13 TIORL_0

				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*[2]	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register*[2]	Capture input source is TIOCD0 pin Input capture at rising edge
			1		Capture input source is TIOCD0 pin Input capture at falling edge
		1	x		Capture input source is TIOCD0 pin Input capture at both edges
	1	x	x		Capture input source is channel 1/count clock Input capture at TCNT_1 count-up/count-down*[1]*[3]

Legend: x: Don't care

Notes: 1. When bits TPSC2 to TPSC0 in TCR_1 are set to B'000 and φ/1 is used as the TCNT_1 count clock, this setting is invalid and input capture is not generated.

2. 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.

3. Not available in the H8S/2227 Series.

Table 11.14 TIOR_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 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	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
		1	x		Capture input source is TIOCB1 pin Input capture at both edges
	1	x	x		TGRC_0 compare match/input capture Input capture at generation of TGRC_0 compare match/input capture*

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.15 TIOR_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 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	x	0	0	Input capture register	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 11.16 TIORH_3

				Description	
Bit 7 IOB3	**Bit 6 IOB2**	**Bit 5 IOB1**	**Bit 4 IOB0**	**TGRB_3 Function*[2]**	**TIOCB3 Pin Function*[2]**
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCB3 pin Input capture at rising edge
			1		Capture input source is TIOCB3 pin Input capture at falling edge
		1	x		Capture input source is TIOCB3 pin Input capture at both edges
	1	x	x		Capture input source is channel 4/count clock Input capture at TCNT_4 count-up/count-down*[1]

Legend: x: Don't care

Notes: 1. When bits TPSC2 to TPSC0 in TCR_4 are set to B'000 and ϕ/1 is used as the TCNT_4 count clock, this setting is invalid and input capture is not generated.

2. Not available in the H8S/2227 Series.

Table 11.17 TIORL_3

				Description	
Bit 7 IOD3	**Bit 6 IOD2**	**Bit 5 IOD1**	**Bit 4 IOD0**	**TGRD_3 Function*[3]**	**TIOCD3 Pin Function*[3]**
0	0	0	0	Output compare register*[2]	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register*[2]	Capture input source is TIOCD3 pin Input capture at rising edge
			1		Capture input source is TIOCD3 pin Input capture at falling edge
		1	x		Capture input source is TIOCD3 pin Input capture at both edges
	1	x	x		Capture input source is channel 4/count clock Input capture at TCNT_4 count-up/count-down*[1]

Legend: x: Don't care

Notes: 1. When bits TPSC2 to TPSC0 in TCR_4 are set to B'000 and φ/1 is used as the TCNT_4 count clock, this setting is invalid and input capture is not generated.

2. When the BFB bit in TMDR_3 is set to 1 and TGRD_3 is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

3. Not available in the H8S/2227 Series.

Table 11.18 TIOR_4

				Description	
Bit 7 IOB3	**Bit 6 IOB2**	**Bit 5 IOB1**	**Bit 4 IOB0**	**TGRB_4 Function***	**TIOCB4 Pin Function***
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCB4 pin Input capture at rising edge
			1		Capture input source is TIOCB4 pin Input capture at falling edge
		1	x		Capture input source is TIOCB4 pin Input capture at both edges
	1	x	x		Capture input source is TGRC_3 compare match/input capture Input capture at generation of TGRC_3 compare match/input capture

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.19 TIOR_5

				Description	
Bit 7 IOB3	**Bit 6 IOB2**	**Bit 5 IOB1**	**Bit 4 IOB0**	**TGRB_5 Function***	**TIOCB5 Pin Function***
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	x	0	0	Input capture register	Capture input source is TIOCB5 pin Input capture at rising edge
			1		Capture input source is TIOCB5 pin Input capture at falling edge
		1	x		Capture input source is TIOCB5 pin Input capture at both edges

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.20 TIORH_0

				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 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	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
		1	x		Capture input source is TIOCA0 pin Input capture at both edges
	1	x	x		Capture input source is channel 1/count clock Input capture at TCNT_1 count-up/count-down*

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.21 TIORL_0

				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*[1]	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register*[1]	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
	1	x	x		Capture input source is channel 1/count clock Input capture at TCNT_1 count-up/count-down*[2]

Legend: x: Don't care

Notes: 1. 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.

2. Not available in the H8S/2227 Series.

Table 11.22 TIOR_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 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	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
	1	x	x		Capture input source is TGRA_0 compare match/input capture Input capture at generation of channel 0/TGRA_0 compare match/input capture*

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.23 TIOR_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 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	x	0	0	Input capture register	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

Table 11.24 TIORH_3

				Description	
Bit 3 IOA3	**Bit 2 IOA2**	**Bit 1 IOA1**	**Bit 0 IOA0**	**TGRA_3 Function***	**TIOCA3 Pin Function***
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCA3 pin Input capture at rising edge
			1		Capture input source is TIOCA3 pin Input capture at falling edge
		1	x		Capture input source is TIOCA3 pin Input capture at both edges
	1	x	x		Capture input source is channel 4/count clock Input capture at TCNT_4 count-up/count-down

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.25 TIORL_3

				Description	
Bit 3 IOC3	**Bit 2 IOC2**	**Bit 1 IOC1**	**Bit 0 IOC0**	**TGRC_3 Function*[2]**	**TIOCC3 Pin Function*[2]**
0	0	0	0	Output compare register*[1]	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register*[1]	Capture input source is TIOCC3 pin Input capture at rising edge
			1		Capture input source is TIOCC3 pin Input capture at falling edge
		1	x		Capture input source is TIOCC3 pin Input capture at both edges
	1	x	x		Capture input source is channel 4/count clock Input capture at TCNT_4 count-up/count-down

Legend: x: Don't care

Notes: 1. When the BFA bit in TMDR_3 is set to 1 and TGRC_3 is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

2. Not available in the H8S/2227 Series.

Table 11.26 TIOR_4

				Description	
Bit 3 IOA3	**Bit 2 IOA2**	**Bit 1 IOA1**	**Bit 0 IOA0**	**TGRA_4 Function***	**TIOCA4 Pin Function***
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	0	0	0	Input capture register	Capture input source is TIOCA4 pin Input capture at rising edge
			1		Capture input source is TIOCA4 pin Input capture at falling edge
		1	x		Capture input source is TIOCA4 pin Input capture at both edges
	1	x	x		Capture input source is TGRA_3 compare match/input capture Input capture at generation of TGRA_3 compare match/input capture

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

Table 11.27 TIOR_5

				Description	
Bit 3 IOA3	**Bit 2 IOA2**	**Bit 1 IOA1**	**Bit 0 IOA0**	**TGRA_5 Function***	**TIOCA5 Pin Function***
0	0	0	0	Output compare register	Output disabled
			1		Initial output is 0 output 0 output at compare match
		1	0		Initial output is 0 output 1 output at compare match
			1		Initial output is 0 output Toggle output at compare match
	1	0	0		Output disabled
			1		Initial output is 1 output 0 output at compare match
		1	0		Initial output is 1 output 1 output at compare match
			1		Initial output is 1 output Toggle output at compare match
1	x	0	0	Input capture register	Input capture source is TIOCA5 pin Input capture at rising edge
			1		Input capture source is TIOCA5 pin Input capture at falling edge
		1	x		Input capture source is TIOCA5 pin Input capture at both edges

Legend: x: Don't care

Note: * Not available in the H8S/2227 Series.

11.3.4 Timer Interrupt Enable Register (TIER)

The TIER registers control enabling or disabling of interrupt requests for each channel. The TPU has six TIER registers, one for each channel.

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

Bit	Bit Name	Initial value	R/W	Description
2	TGIEC	0	R/W	TGR Interrupt Enable C Enables or disables interrupt requests (TGIC) by the TGFC bit when the TGFC bit in TSR is set to 1 in channels 0 and 3. In channels 1, 2, 4, and 5, bit 2 is reserved. It is always read as 0 and cannot be modified. 0: Interrupt requests (TGIC) by TGFC bit disabled 1: Interrupt requests (TGIC) by TGFC bit enabled
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

11.3.5 Timer Status Register (TSR)

The TSR registers indicate the status of each channel. The TPU has six TSR registers, one for each channel.

Bit	Bit Name	Initial value	R/W	Description
7	TCFD	1	R	Count Direction Flag Status flag that shows the direction in which TCNT counts in channels 1, 2, 4, and 5. In channels 0 and 3, bit 7 is reserved. It is always read as 1 and cannot be modified. 0: TCNT counts down 1: TCNT counts up
6	—	1	—	Reserved This bit is always read as 1 and cannot be modified.
5	TCFU	0	R/(W)*[1]	Underflow Flag Status flag that indicates that TCNT underflow has occurred when channels 1, 2, 4, and 5 are set to phase counting mode. In channels 0 and 3, bit 5 is reserved. It is always read as 0 and cannot be modified. [Setting condition] When the TCNT value underflows (changes from H′0000 to H′FFFF) [Clearing condition] When 0 is written to TCFU after reading TCFU = 1
4	TCFV	0	R/(W)*[1]	Overflow Flag Status flag that indicates that TCNT overflow has occurred. [Setting condition] When the TCNT value overflows (changes from H′FFFF to H′0000) [Clearing condition] When 0 is written to TCFV after reading TCFV = 1

Bit	Bit Name	Initial value	R/W	Description
3	TGFD	0	R/(W)*[1]	Input Capture/Output Compare Flag D Status flag that indicates the occurrence of TGRD input capture or compare match in channels 0 and 3. In channels 1, 2, 4, and 5, bit 3 is reserved. It is always read as 0 and cannot be modified. [Setting conditions] • When TCNT = TGRD while TGRD is functioning as output compare register • When TCNT value is transferred to TGRD by input capture signal while TGRD is functioning as input capture register [Clearing conditions] • When DTC is activated by TGID interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFD after reading TGFD = 1
2	TGFC	0	R/(W)*[1]	Input Capture/Output Compare Flag C Status flag that indicates the occurrence of TGRC input capture or compare match in channels 0 and 3. In channels 1, 2, 4, and 5, bit 2 is reserved. It is always read as 0 and cannot be modified. [Setting conditions] • When TCNT = TGRC while TGRC is functioning as output compare register • When TCNT value is transferred to TGRC by input capture signal while TGRC is functioning as input capture register [Clearing conditions] • When DTC is activated by TGIC interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFC after reading TGFC = 1

Bit	Bit Name	Initial value	R/W	Description
1	TGFB	0	R/(W)*[1]	Input Capture/Output Compare Flag B Status flag that indicates the occurrence of TGRB input capture or compare match. [Setting conditions] • When TCNT = TGRB while TGRB is functioning as output compare register • When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register [Clearing conditions] • When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFB after reading TGFB = 1
0	TGFA	0	R/(W)*[1]	Input Capture/Output Compare Flag A Status flag that indicates the occurrence of TGRA input capture or compare match. [Setting conditions] • When TCNT = TGRA while TGRA is functioning as output compare register • When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register [Clearing conditions] • When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 • When DMAC is activated by TGIA interrupt while DTE bit of DMABCR in DMAC is 1*[2] • When 0 is written to TGFA after reading TGFA = 1

Notes: 1. Only 0 can be written, for flag clearing.
2. Supported only by the H8S/2239 Series.

11.3.6 Timer Counter (TCNT)

The TCNT registers are 16-bit readable/writable counters. The TPU has six TCNT counters, one for each channel.

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.

11.3.7 Timer General Register (TGR)

The TGR registers are 16-bit readable/writable registers with a dual function as output compare and input capture registers. The TPU has 16 TGR registers, four each for channels 0 and 3 and two each for channels 1, 2, 4, and 5. TGRC and TGRD for channels 0 and 3 can also be designated for operation as buffer registers. The TGR registers cannot be accessed in 8-bit units; they must always be accessed as a 16-bit unit. TGR buffer register combinations are TGRA–TGRC and TGRB–TGRD.

11.3.8 Timer Start Register (TSTR)

TSTR selects operation/stoppage for channels 0 to 5. 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	—	0	—	Reserved
6	—	0	—	The write value should always be 0.
5	CST5	0	R/W	Counter Start 5 to 0
4	CST4	0	R/W	These bits select operation or stoppage for TCNT.
3	CST3	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.
2	CST2	0	R/W	
1	CST1	0	R/W	
0	CST0	0	R/W	0: TCNT_5 to TCNT_0 count operation is stopped 1: TCNT_5 to TCNT_0 performs count operation

11.3.9 Timer Synchronous Register (TSYR)

TSYR selects independent operation or synchronous operation for the TCNT counters of channels 0 to 5. A channel performs synchronous operation when the corresponding bit in TSYR is set to 1.

Bit	Bit Name	Initial value	R/W	Description
7	–	0	R/W	Reserved
6	–	0	R/W	The write value should always be 0.
5	SYNC5	0	R/W	Timer Synchronization 5 to 0
4	SYNC4	0	R/W	These bits select whether operation is independent of or synchronized with other channels.
3	SYNC3	0	R/W	
2	SYNC2	0	R/W	When synchronous operation is selected, synchronous presetting of multiple channels, and synchronous clearing through counter clearing on another channel are possible.
1	SYNC1	0	R/W	
0	SYNC0	0	R/W	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 CCLR2 to CCLR0 in TCR. 0: TCNT_5 to TCNT_0 operates independently (TCNT presetting /clearing is unrelated to other channels) 1: TCNT_5 to TCNT_0 performs synchronous operation (TCNT synchronous presetting/ synchronous clearing is possible)

11.4 Operation

11.4.1 Basic Functions

Each channel has a TCNT and TGR register. TCNT performs up-counting, and is also capable of free-running operation, periodic 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 CST5 is set to 1 in TSTR, the TCNT counter for the corresponding channel starts counting. TCNT can operate as a free-running counter, periodic counter, and so on.

1. Example of count operation setting procedure
   Figure 11.3 shows an example of the count operation setting procedure.

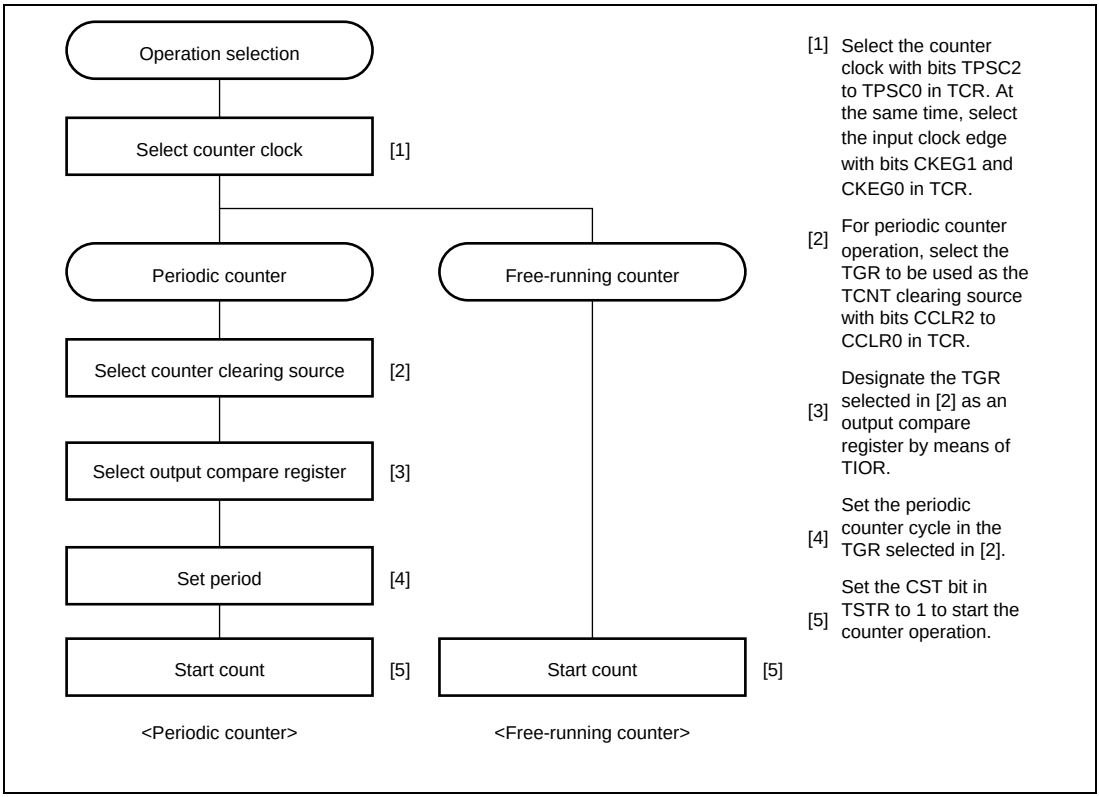


Figure 11.3 Example of Counter Operation Setting Procedure

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 (changes 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 11.4 illustrates free-running counter operation.

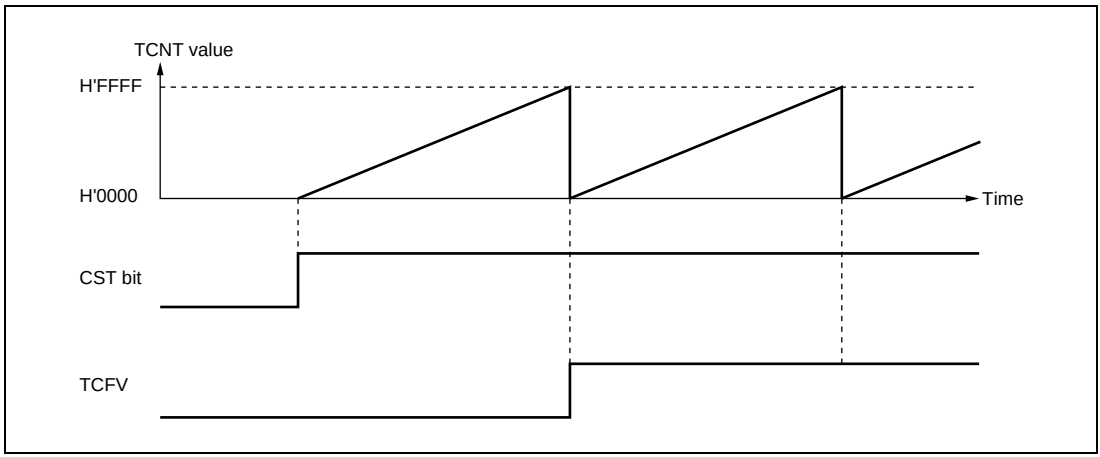


Figure 11.4 Free-Running Counter Operation

When compare match is selected as the TCNT clearing source, the TCNT counter for the relevant channel performs periodic count operation. The 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 CCLR2 to CCLR0 in TCR. After the settings have been made, TCNT starts count-up 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 11.5 illustrates periodic counter operation.

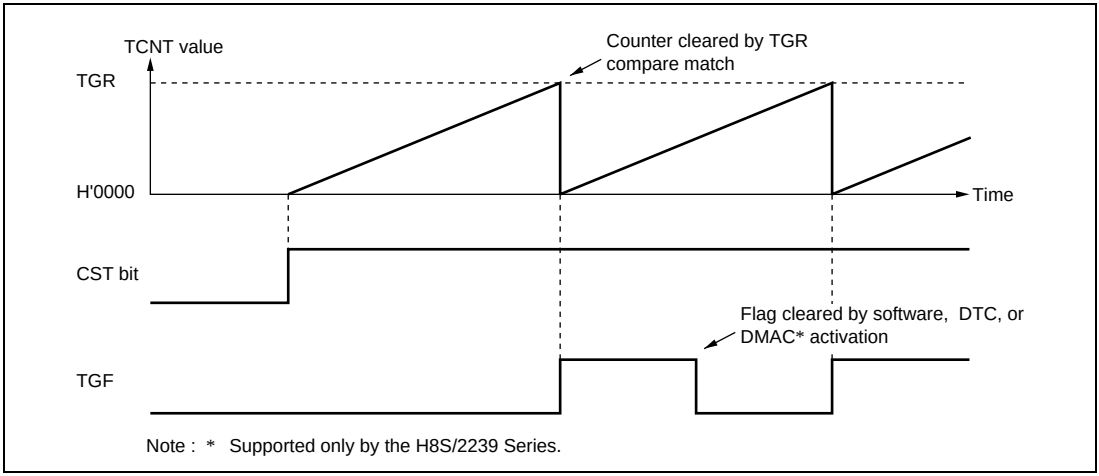


Figure 11.5 Periodic Counter Operation

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

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

   Figure 11.6 shows an example of the setting procedure for waveform output by a compare match.

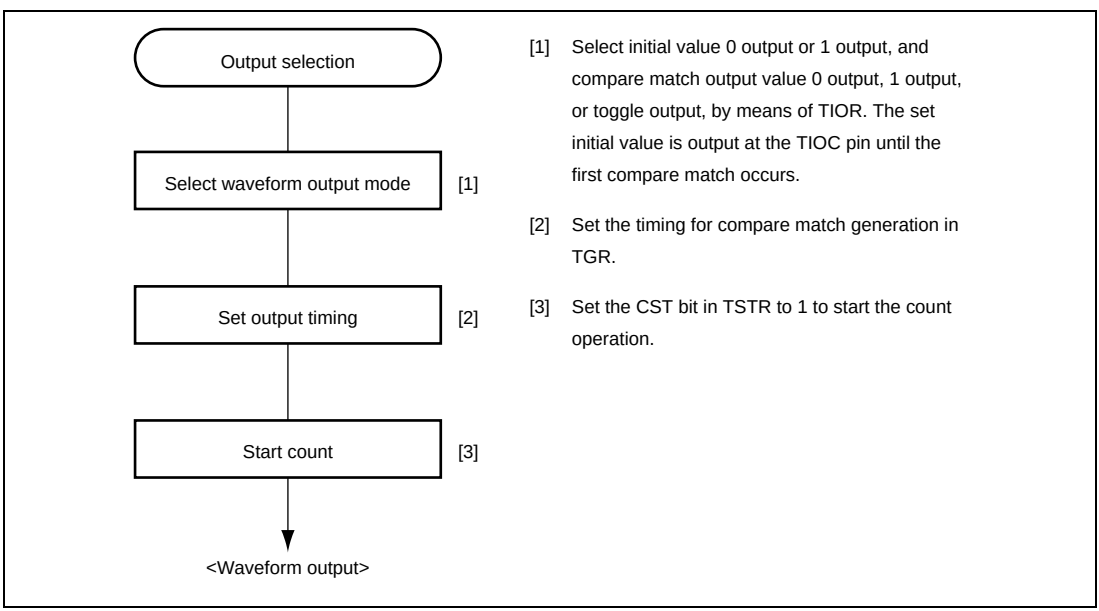


Figure 11.6 Example of Setting Procedure for Waveform Output by Compare Match

2. Examples of waveform output operation

Figure 11.7 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 so that 1 is output by compare match A, and 0 is output by compare match B. When the set level and the pin level match, the pin level does not change.

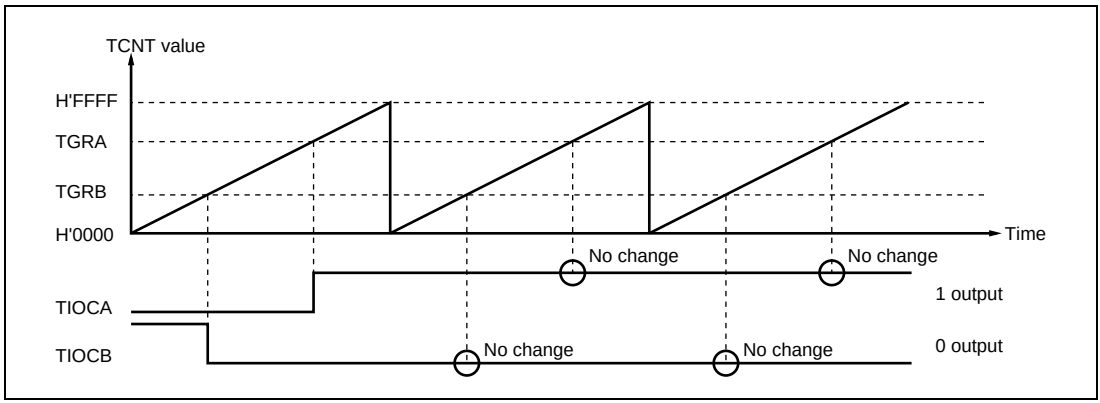


Figure 11.7 Example of 0 Output/1 Output Operation

Figure 11.8 shows an example of toggle output.

In this example TCNT has been designated as a periodic counter (with counter clearing performed by compare match B), and settings have been made so that output is toggled by both compare match A and compare match B.

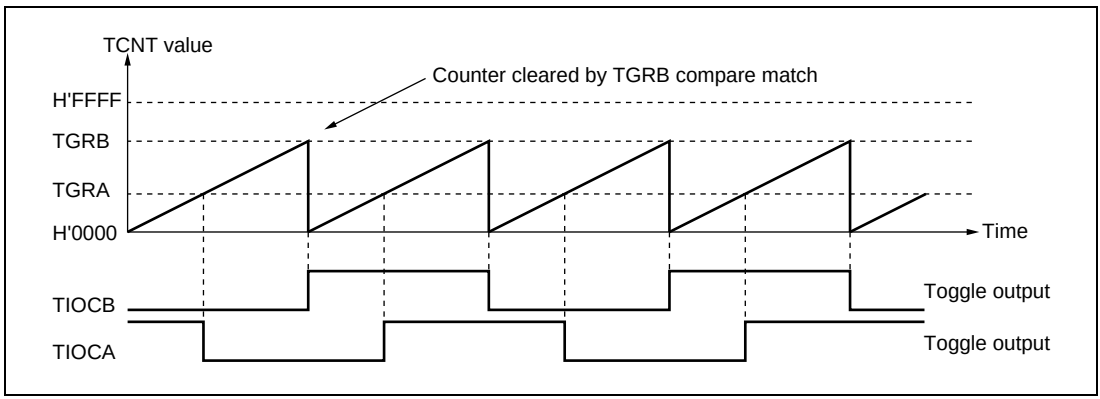


Figure 11.8 Example of Toggle Output Operation

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 detection edge. For channels 0, 1, 3, and 4, it is also possible to specify another channel's counter input clock or compare match signal as the input capture source.

Note: When another channel's counter input clock is used as the input capture input for channels 0 and 3, $\phi/1$ should not be selected as the counter input clock used for input capture input. Input capture will not be generated if $\phi/1$ is selected.

1. Example of setting procedure for input capture operation

   Figure 11.9 shows an example of the setting procedure for input capture operation.

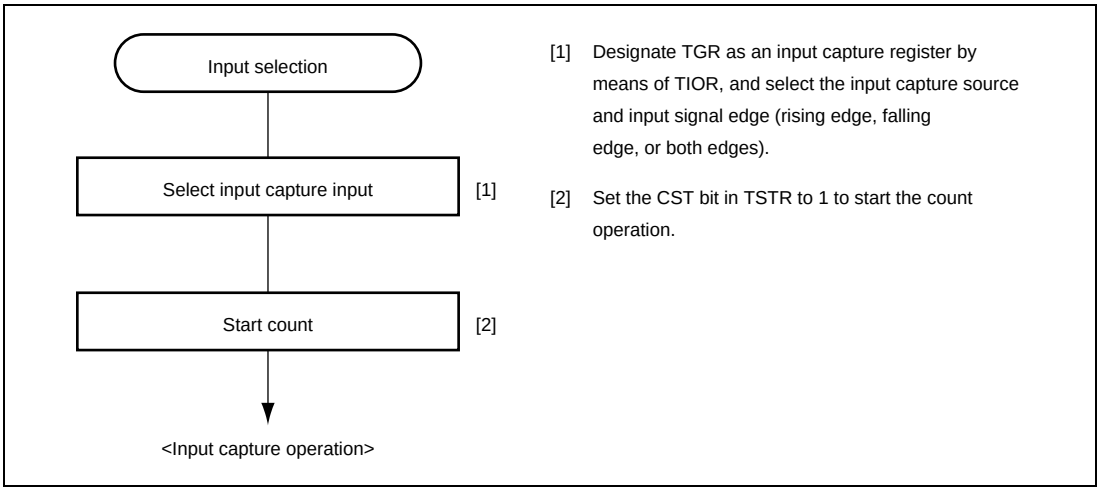


Figure 11.9 Example of Setting Procedure for Input Capture Operation

2. Example of input capture operation

   Figure 11.10 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, 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.

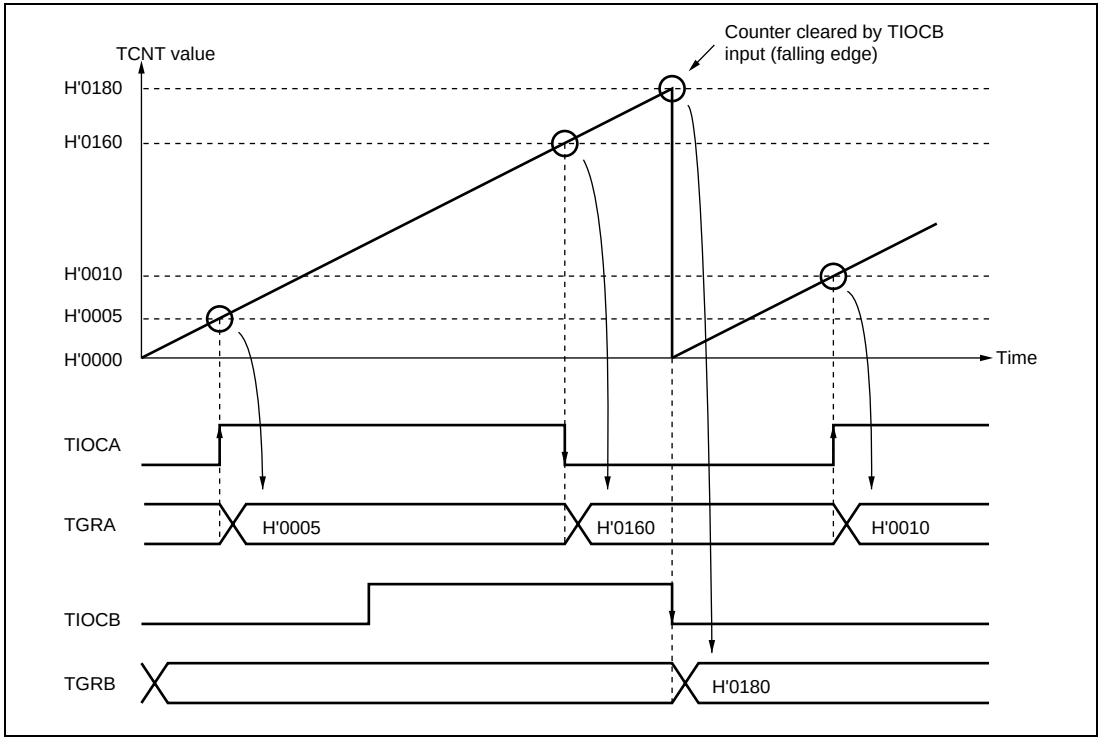


Figure 11.10 Example of Input Capture Operation

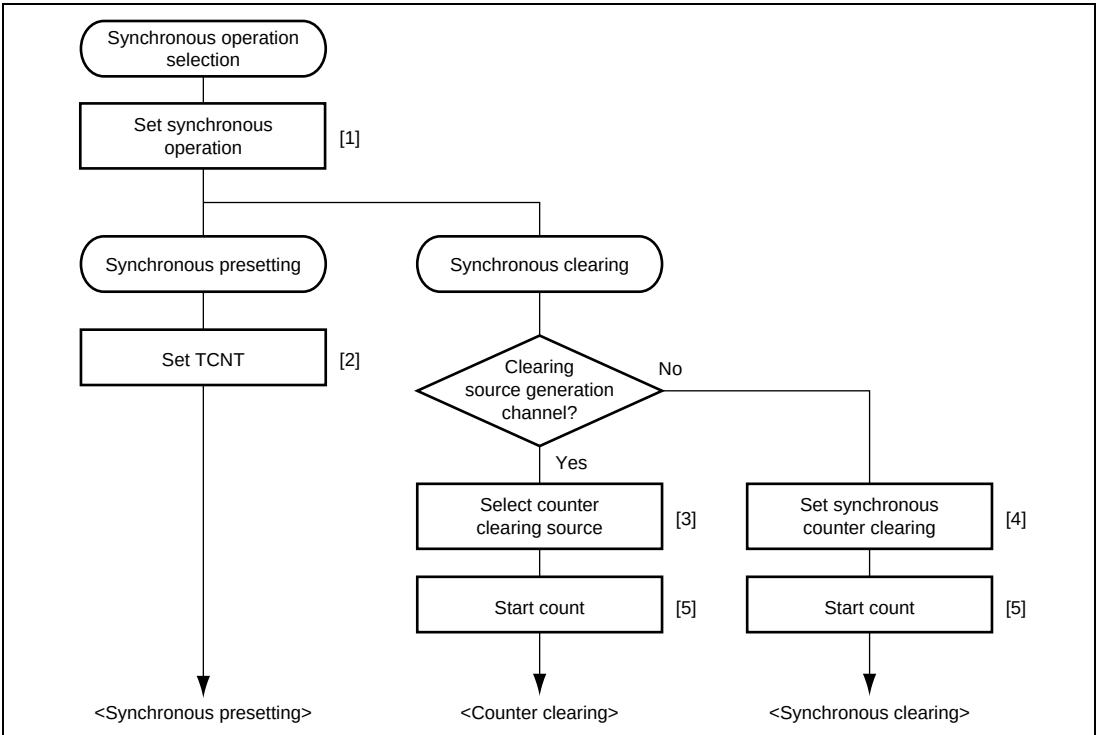
11.4.2 Synchronous Operation

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

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

Channels 0 to 5 can all be designated for synchronous operation.

Example of Synchronous Operation Setting Procedure: Figure 11.11 shows an example of the synchronous operation setting procedure.



[1] Set to 1 the SYNC bits in TSYR 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.

Figure 11.11 Example of Synchronous Operation Setting Procedure

Example of Synchronous Operation: Figure 11.12 shows an example of synchronous operation.

In this example, synchronous operation and PWM mode 1 have been designated for channels 0 to 2, 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 TIOCA0, TIOCA1, and TIOCA2. At this time, synchronous presetting, and synchronous clearing by TGRB_0 compare match, is performed for channel 0 to 2 TCNT counters, and the data set in TGRB_0 is used as the PWM cycle.

For details on PWM modes, see section 11.4.5, PWM Modes.

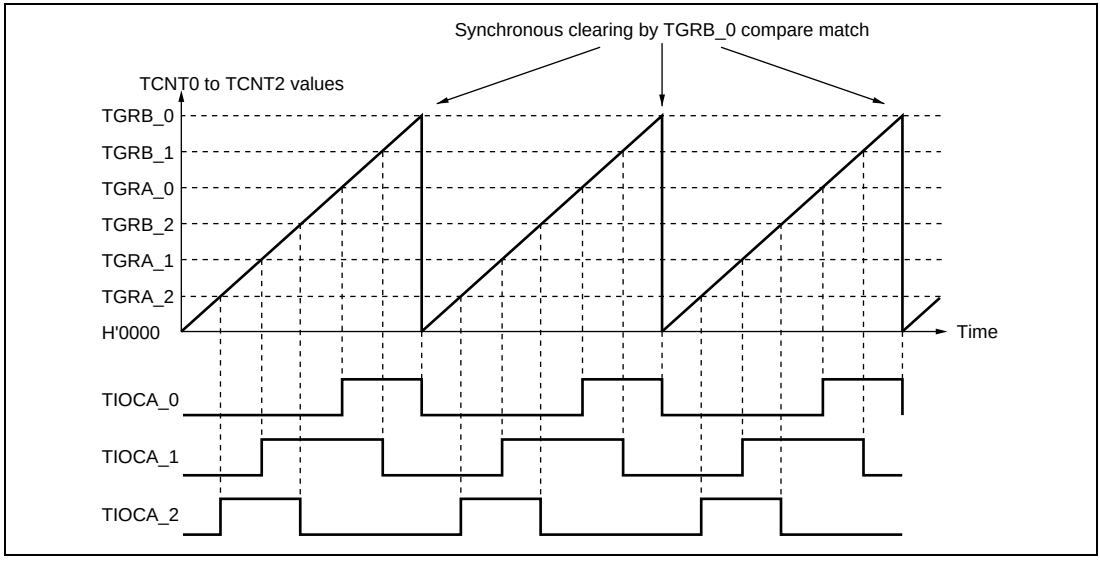


Figure 11.12 Example of Synchronous Operation

11.4.3 Buffer Operation

Buffer operation, provided for channels 0 and 3, enables TGRC and TGRD to be used as buffer registers.

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

Table 11.28 shows the register combinations used in buffer operation.

Table 11.28 Register Combinations in Buffer Operation

Channel	Timer General Register	Buffer Register
0	TGRA_0	TGRC_0
	TGRB_0	TGRD_0
3	TGRA_3	TGRC_3
	TGRB_3	TGRD_3

- 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 11.13.

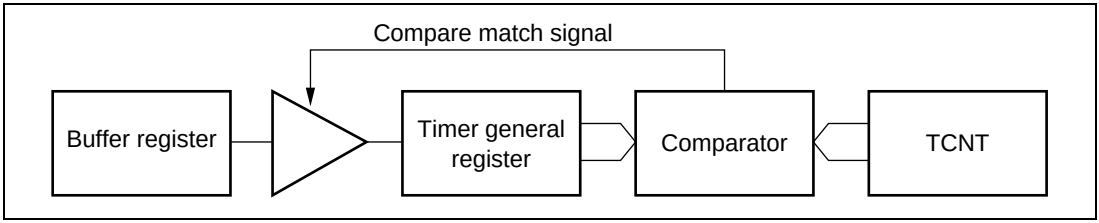


Figure 11.13 Compare Match Buffer Operation

- 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 11.14.

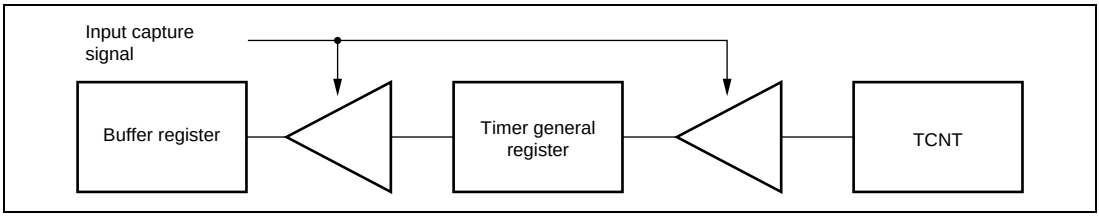


Figure 11.14 Input Capture Buffer Operation

Example of Buffer Operation Setting Procedure: Figure 11.15 shows an example of the buffer operation setting procedure.

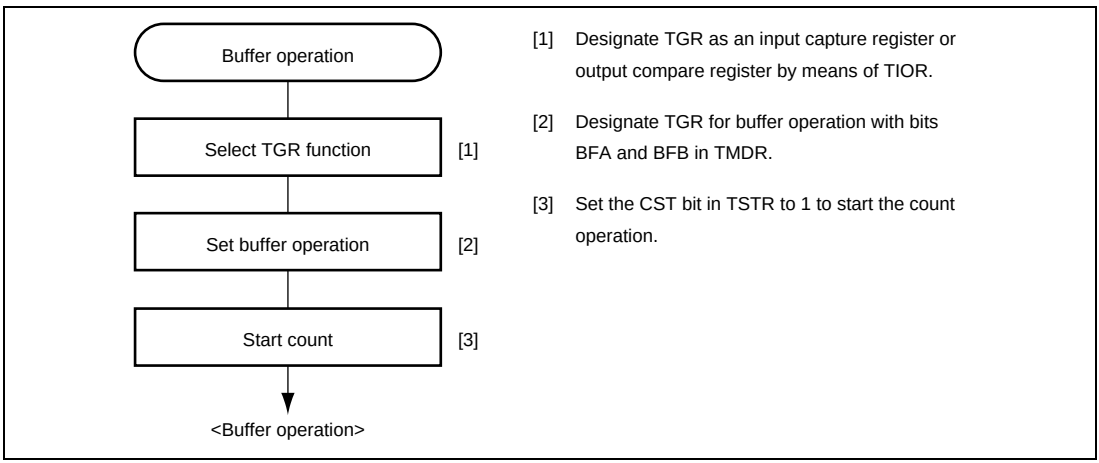


Figure 11.15 Example of Buffer Operation Setting Procedure

Examples of Buffer Operation:

1. When TGR is an output compare register

   Figure 11.16 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 compare match A occurs.

   For details on PWM modes, see section 11.4.5, PWM Modes.

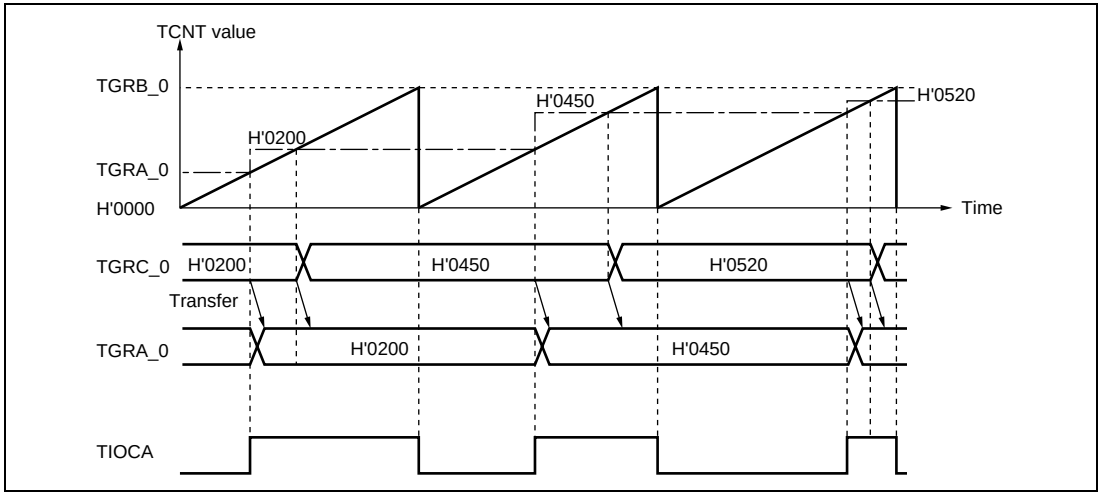


Figure 11.16 Example of Buffer Operation (1)

2. When TGR is an input capture register

   Figure 11.17 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 occurrence of input capture A, the value previously stored in TGRA is simultaneously transferred to TGRC.

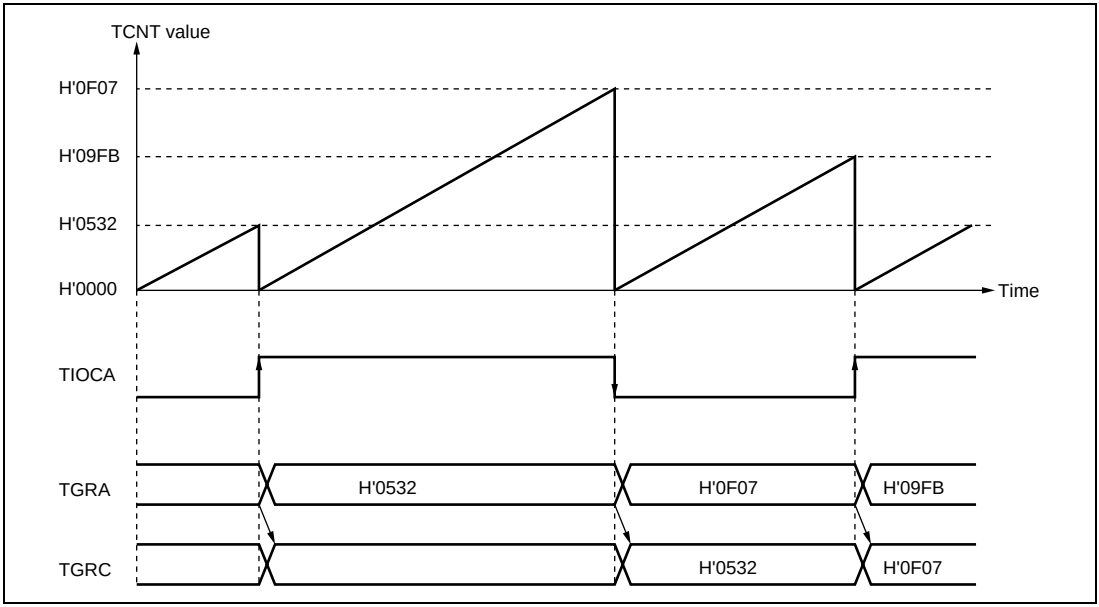


Figure 11.17 Example of Buffer Operation (2)

11.4.4 Cascaded Operation

In cascaded operation*, two 16-bit counters for different channels are used together as a 32-bit counter.

This function works by counting the channel 1 (channel 4) counter clock at overflow/underflow of TCNT_2 (TCNT_5) as set in bits TPSC2 to TPSC0 in TCR.

Underflow occurs only when the lower 16-bit TCNT is in phase-counting mode.

Table 11.29 shows the register combinations used in cascaded operation.

Notes: When phase counting mode is set for channel 1 or 4, the counter clock setting is invalid and the counter operates independently in phase counting mode.

* Not available in the H8S/2227 Series.

Table 11.29 Cascaded Combinations

Combination	Upper 16 Bits	Lower 16 Bits
Channels 1 and 2	TCNT_1	TCNT_2
Channels 4 and 5	TCNT_4	TCNT_5

Example of Cascaded Operation Setting Procedure: Figure 11.18 shows an example of the setting procedure for cascaded operation.

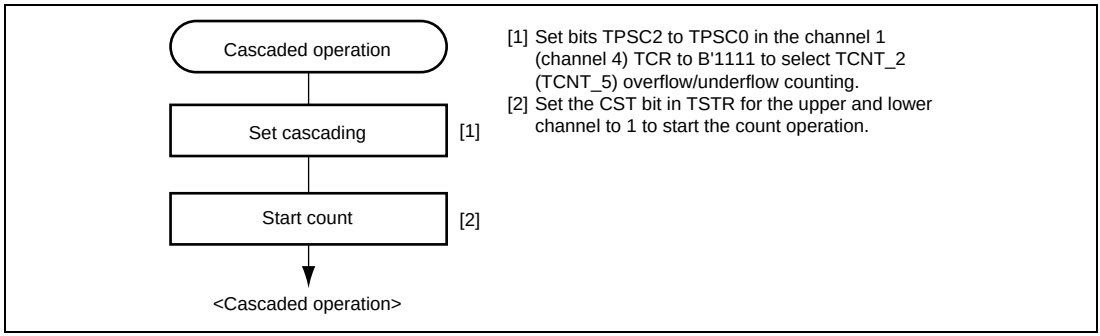


Figure 11.18 Cascaded Operation Setting Procedure

Examples of Cascaded Operation: Figure 11.19 illustrates the operation when counting upon TCNT_2 overflow/underflow has been set for TCNT_1, TGRA_1 and TGRA_2 have been designated as input capture registers, and the TIOC pin rising edge has been selected.

When a rising edge is input to the TIOCA1 and TIOCA2 pins simultaneously, the upper 16 bits of the 32-bit data are transferred to TGRA_1, and the lower 16 bits to TGRA_2.

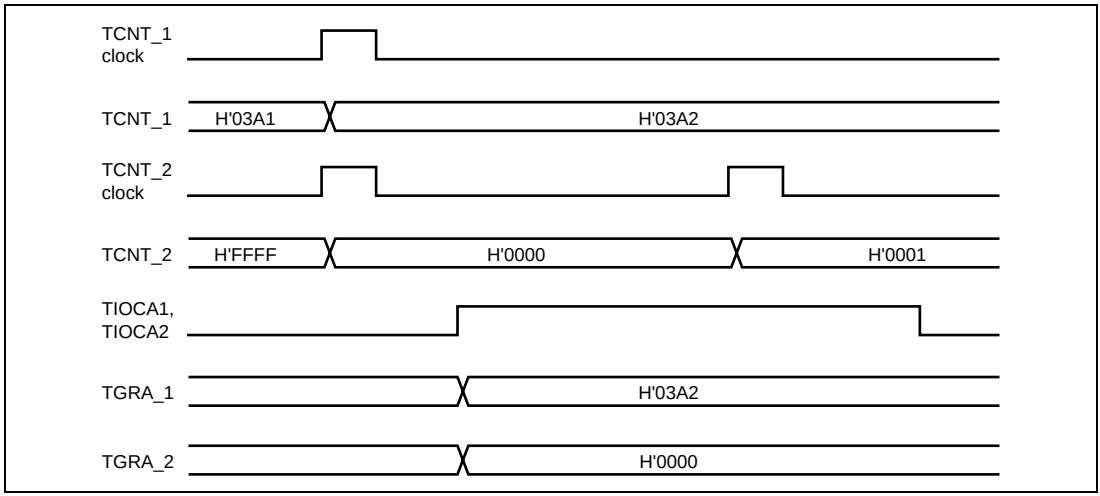


Figure 11.19 Example of Cascaded Operation (1)

Figure 11.20 illustrates the operation when counting upon TCNT_2 overflow/underflow has been set for TCNT_1, and phase counting mode has been designated for channel 2.

TCNT_1 is incremented by TCNT_2 overflow and decremented by TCNT_2 underflow.

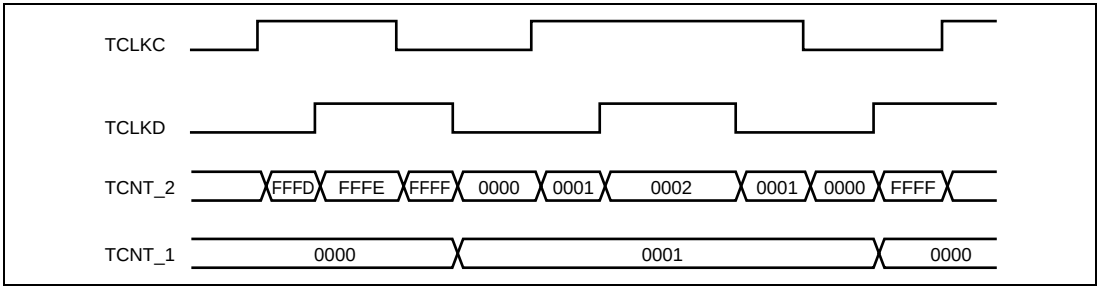


Figure 11.20 Example of Cascaded Operation (2)

11.4.5 PWM Modes

In PWM mode, PWM waveforms are output from the output pins. 0, 1, or toggle output can be selected as the output level in response to compare match of each TGR.

Settings of TGR registers can output a PWM waveform in the range of 0–% to 100–% duty cycle.

Designating TGR compare match as the counter clearing source enables the cycle 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

  PWM output is generated from the TIOCA and TIOCC pins by pairing TGRA with TGRB and TGRC with TGRD. The outputs specified by bits IOA3 to IOA0 and IOC3 to IOC0 in TIOR are output from the TIOCA and TIOCC pins at compare matches A and C, respectively. The outputs specified by bits IOB3 to IOB0 and IOD3 to IOD0 in TIOR are output at compare matches B and D, respectively. The initial output value is the value set in TGRA or TGRC. If the set values of paired TGRs are identical, the output value does not change when a compare match occurs.

  In PWM mode 1, a maximum 8-phase PWM output is possible.

- PWM mode 2

  PWM output is generated using one TGR as the cycle register and the others as duty cycle 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 cycle registers are identical, the output value does not change when a compare match occurs.

  In PWM mode 2, a maximum 15-phase PWM output is possible by combined use with synchronous operation.

The correspondence between PWM output pins and registers is shown in table 11.30.

Table 11.30 PWM Output Registers and Output Pins

		Output Pins	
Channel	**Registers**	**PWM Mode 1**	**PWM Mode 2**
0	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
3*	TGRA_3	TIOCA3	TIOCA3
	TGRB_3		TIOCB3
	TGRC_3	TIOCC3	TIOCC3
	TGRD_3		TIOCD3
4*	TGRA_4	TIOCA4	TIOCA4
	TGRB_4		TIOCB4
5*	TGRA_5	TIOCA5	TIOCA5
	TGRB_5		TIOCB5

Notes: In PWM mode 2, PWM output is not possible for the TGR register in which the cycle is set.

* Not available in the H8S/2227 Series.

Example of PWM Mode Setting Procedure: Figure 11.21 shows an example of the PWM mode setting procedure.

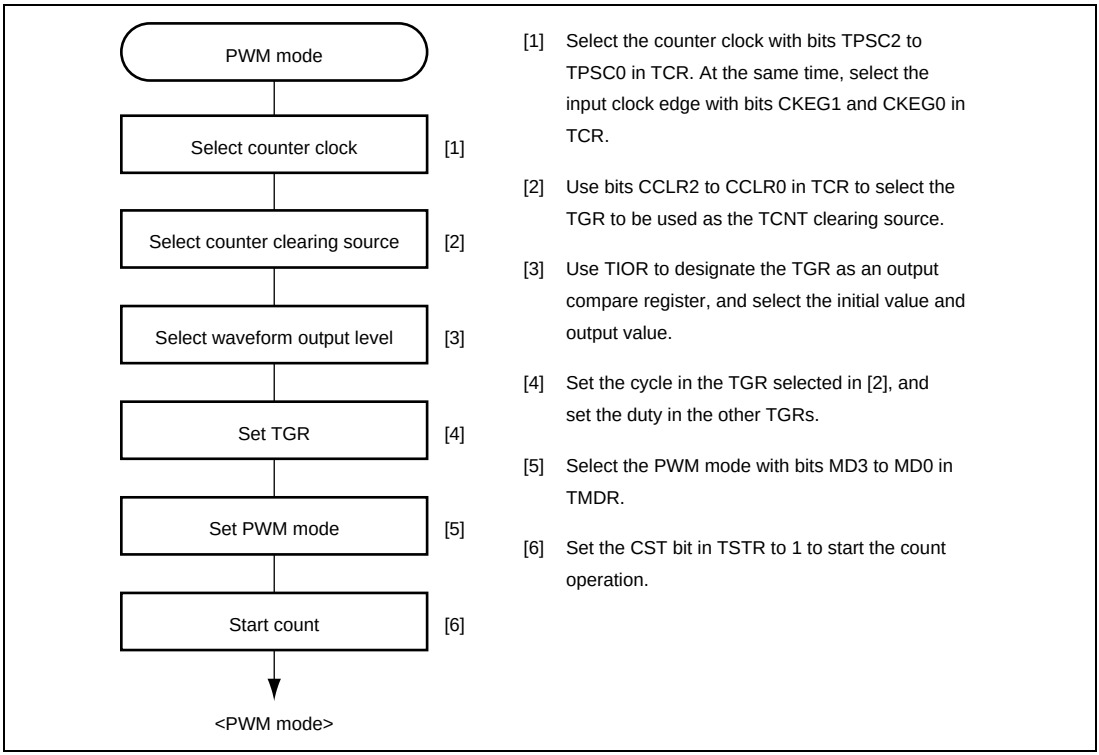


Figure 11.21 Example of PWM Mode Setting Procedure

Examples of PWM Mode Operation: Figure 11.22 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 cycle, and the values set in TGRB registers as the duty cycle.

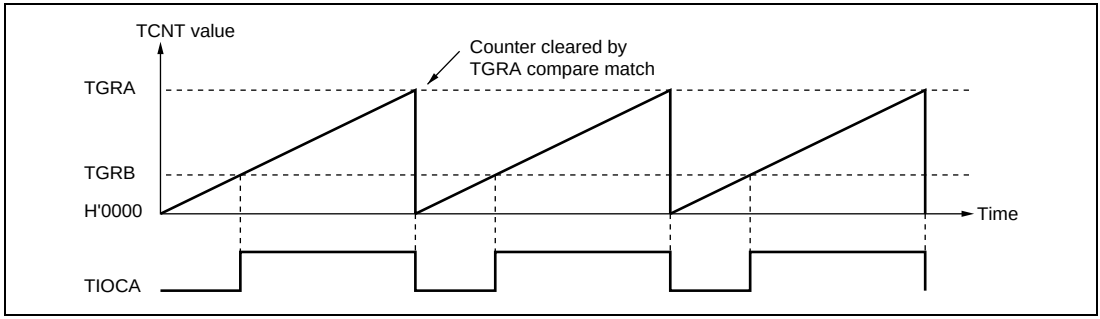


Figure 11.22 Example of PWM Mode Operation (1)

Figure 11.23 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), to output a 5-phase PWM waveform.

In this case, the value set in TGRB_1 is used as the cycle, and the values set in the other TGRs as the duty cycle.

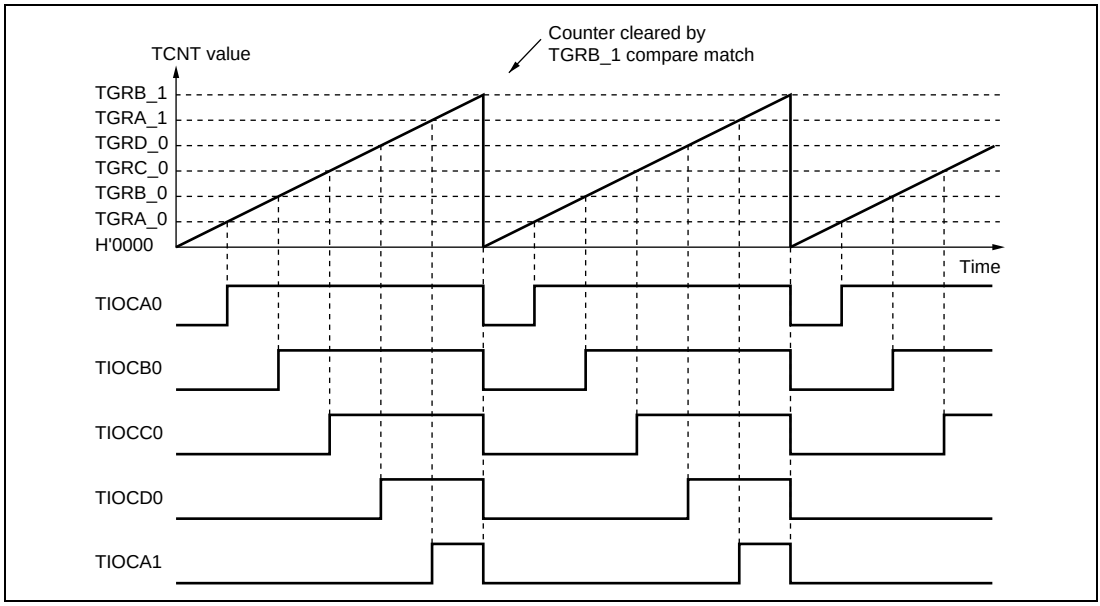


Figure 11.23 Example of PWM Mode Operation (2)

Figure 11.24 shows examples of PWM waveform output with 0% duty cycle and 100% duty cycle in PWM mode.

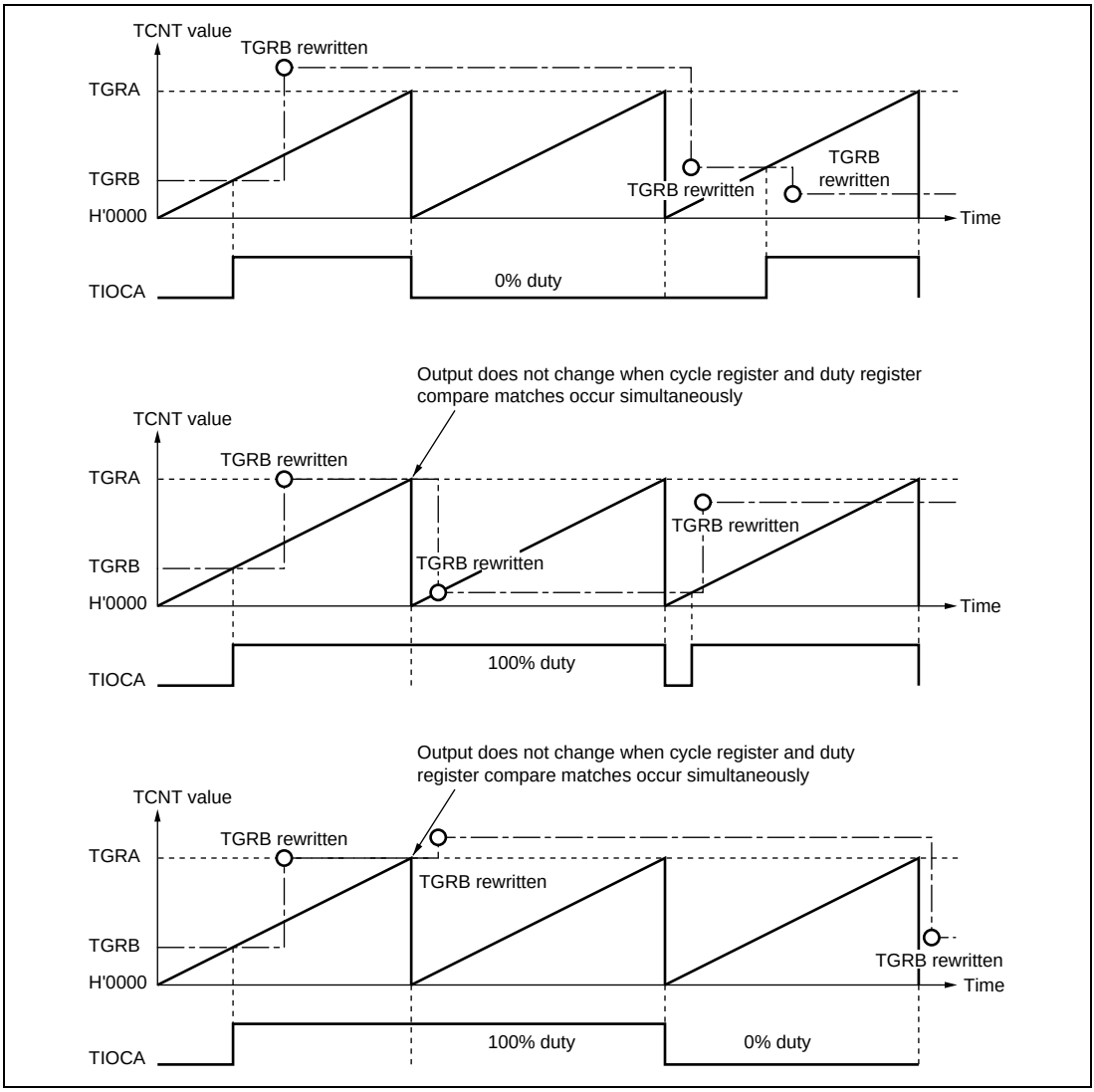


Figure 11.24 Example of PWM Mode Operation (3)

11.4.6 Phase Counting Mode

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, 2, 4, and 5.

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 TPSC2 to TPSC0 and bits CKEG1 and CKEG0 in TCR. However, the functions of bits CCLR1 and CCLR0 in TCR, and of TIOR, TIER, and TGR are valid, and input capture/compare match and interrupt functions can be used.

This can be used for two-phase encoder pulse input.

When overflow occurs while TCNT is counting up, the TCFV flag in TSR is set; when underflow occurs while TCNT is counting down, the TCFU flag is set.

The TCFD bit in TSR is the count direction flag. Reading the TCFD flag provides an indication of whether TCNT is counting up or down.

Table 11.31 shows the correspondence between external clock pins and channels.

Table 11.31 Clock Input Pins in Phase Counting Mode

	External Clock Pins	
Channels	**A-Phase**	**B-Phase**
When channel 1 or 5 is set to phase counting mode	TCLKA	TCLKB
When channel 2 or 4 is set to phase counting mode	TCLKC	TCLKD

Example of Phase Counting Mode Setting Procedure: Figure 11.25 shows an example of the phase counting mode setting procedure.

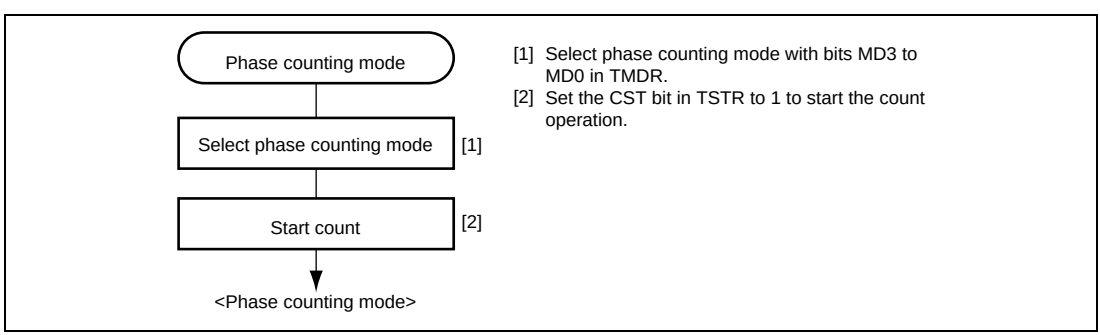


Figure 11.25 Example of Phase Counting Mode Setting Procedure

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 11.26 shows an example of phase counting mode 1 operation, and table 11.32 summarizes the TCNT up/down-count conditions.

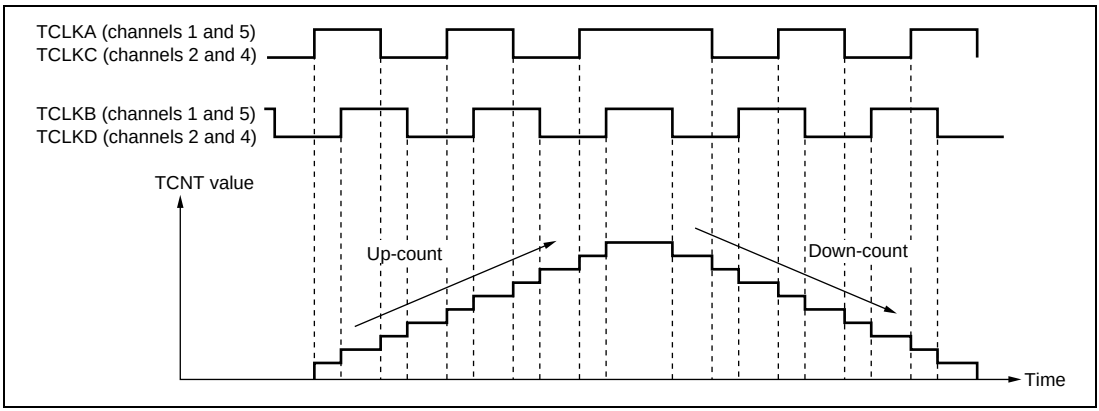


Figure 11.26 Example of Phase Counting Mode 1 Operation

Table 11.32 Up/Down-Count Conditions in Phase Counting Mode 1

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	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 11.27 shows an example of phase counting mode 2 operation, and table 11.33 summarizes the TCNT up/down-count conditions.

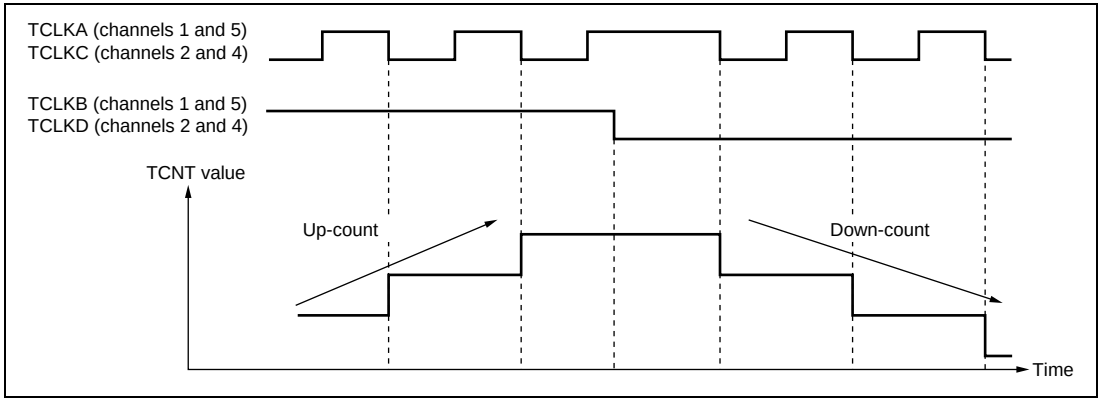


Figure 11.27 Example of Phase Counting Mode 2 Operation

Table 11.33 Up/Down-Count Conditions in Phase Counting Mode 2

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	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 11.28 shows an example of phase counting mode 3 operation, and table 11.34 summarizes the TCNT up/down-count conditions.

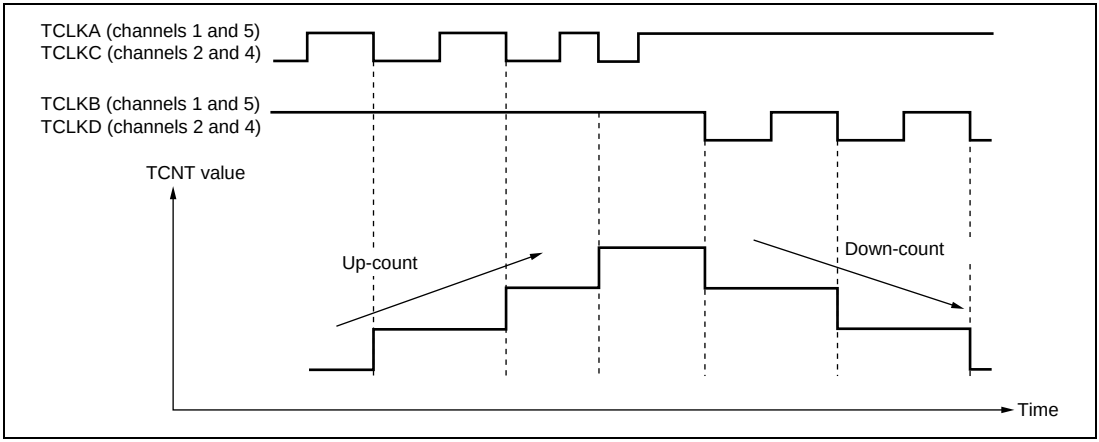


Figure 11.28 Example of Phase Counting Mode 3 Operation

Table 11.34 Up/Down-Count Conditions in Phase Counting Mode 3

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	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 11.29 shows an example of phase counting mode 4 operation, and table 11.35 summarizes the TCNT up/down-count conditions.

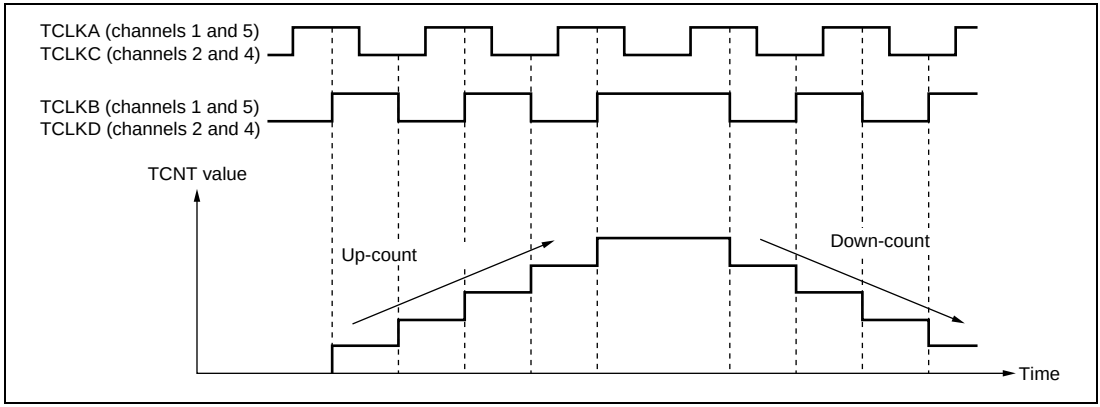


Figure 11.29 Example of Phase Counting Mode 4 Operation

Table 11.35 Up/Down-Count Conditions in Phase Counting Mode 4

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	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

Phase Counting Mode Application Example: Figure 11.30 shows an example in which phase counting mode is designated for channel 1, and channel 1 is coupled with channel 0 to input servo motor 2-phase encoder pulses in order to detect the position or speed.

Channel 1 is set to phase counting mode 1, and the encoder pulse A-phase and B-phase are input to TCLKA and TCLKB.

Channel 0 operates with TCNT counter clearing by TGRC_0 compare match; TGRA_0 and TGRC_0 are used for the compare match function, and are set with the speed control cycle and position control cycle. TGRB_0 is used for input capture, with TGRB_0 and TGRD_0 operating in buffer mode. The channel 1 counter input clock is designated as the TGRB_0 input capture source, and detection of the pulse width of 2-phase encoder 4-multiplication pulses is performed.

TGRA_1 and TGRB_1 for channel 1 are designated for input capture, channel 0 TGRA_0 and TGRC_0 compare matches are selected as the input capture source, and the up/down-counter values for the control cycles are stored.

This procedure enables accurate position/speed detection to be achieved.

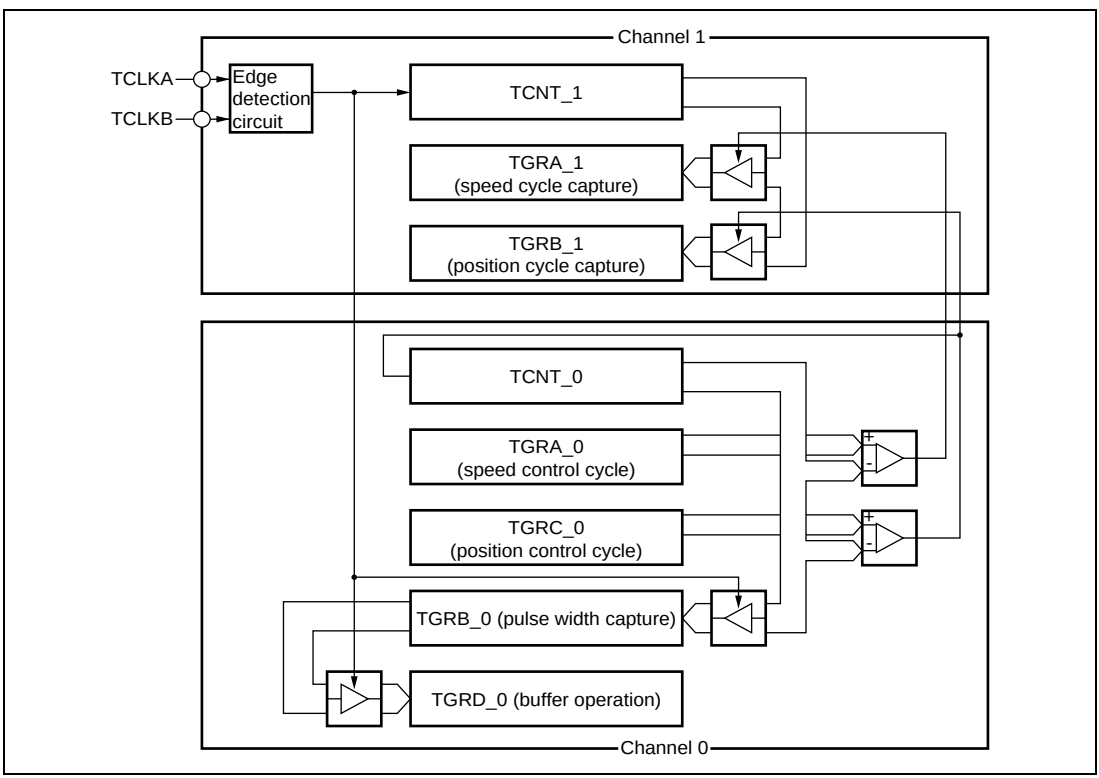


Figure 11.30 Phase Counting Mode Application Example

11.5 Interrupt Sources

There are three kinds of TPU interrupt source: TGR input capture/compare match, TCNT overflow, and TCNT underflow. Each interrupt source has its own status flag and enable/disable bit, allowing 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.

Relative channel priorities can be changed by the interrupt controller, but the priority order within a channel is fixed. For details, see section 5, Interrupt Controller.

Table 11.36 lists the TPU interrupt sources.

Table 11.36 TPU Interrupts

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	DMAC Activation*[1]
0	TGI0A	TGRA_0 input capture/compare match	TGFA_0	Possible	Possible
	TGI0B	TGRB_0 input capture/compare match	TGFB_0	Possible	Not possible
	TGI0C	TGRC_0 input capture/compare match	TGFC_0	Possible	Not possible
	TGI0D	TGRD_0 input capture/compare match	TGFD_0	Possible	Not possible
	TGI0V	TCNT_0 overflow	TCFV_0	Not possible	Not possible
1	TGI1A	TGRA_1 input capture/compare match	TGFA_1	Possible	Possible
	TGI1B	TGRB_1 input capture/compare match	TGFB_1	Possible	Not possible
	TCI1V	TCNT_1 overflow	TCFV_1	Not possible	Not possible
	TCI1U	TCNT_1 underflow	TCFU_1	Not possible	Not possible
2	TGI2A	TGRA_2 input capture/compare match	TGFA_2	Possible	Possible
	TGI2B	TGRB_2 input capture/compare match	TGFB_2	Possible	Not possible
	TCI2V	TCNT_2 overflow	TCFV_2	Not possible	Not possible
	TCI2U	TCNT_2 underflow	TCFU_2	Not possible	Not possible
3*[2]	TGI3A	TGRA_3 input capture/compare match	TGFA_3	Possible	Possible
	TGI3B	TGRB_3 input capture/compare match	TGFB_3	Possible	Not possible
	TGI3C	TGRC_3 input capture/compare match	TGFC_3	Possible	Not possible
	TGI3D	TGRD_3 input capture/compare match	TGFD_3	Possible	Not possible
	TCI3V	TCNT_3 overflow	TCFV_3	Not possible	Not possible
4*[2]	TGI4A	TGRA_4 input capture/compare match	TGFA_4	Possible	Possible
	TGI4B	TGRB_4 input capture/compare match	TGFB_4	Possible	Not possible
	TCI4V	TCNT_4 overflow	TCFV_4	Not possible	Not possible
	TCI4U	TCNT_4 underflow	TCFU_4	Not possible	Not possible
5*[2]	TGI5A	TGRA_5 input capture/compare match	TGFA_5	Possible	Possible
	TGI5B	TGRB_5 input capture/compare match	TGFB_5	Possible	Not possible
	TCI5V	TCNT_5 overflow	TCFV_5	Not possible	Not possible
	TCI5U	TCNT_5 underflow	TCFU_5	Not possible	Not possible

Notes: This table shows the initial state immediately after a reset. The relative channel priorities can be changed by the interrupt controller.

1. Supported only by the H8S/2239 Series.
2. Not available in the H8S/2227 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 TPU has 16 input capture/compare match interrupts, four each for channels 0 and 3, and two each for channels 1, 2, 4, and 5.

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 TPU has six overflow interrupts, one for each channel.

Underflow Interrupt: 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 four underflow interrupts, one each for channels 1, 2, 4, and 5.

11.6 DTC Activation

The DTC can be activated by the TGR input capture/compare match interrupt for a channel. For details, see section 9, Data Transfer Controller (DTC).

A total of 16 TPU input capture/compare match interrupts can be used as DTC activation sources, four each for channels 0 and 3, and two each for channels 1, 2, 4, and 5.

11.7 DMAC Activation (H8S/2239 Series Only)

The DMAC can be activated by the TGRA input capture/compare match interrupt for a channel. For details, see section 8, DMA Controller (DMAC).

In the TPU, a total of six TGRA input capture/compare match interrupts can be used as DMAC activation sources, one for each channel.

11.8 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 start 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 started.

In the TPU, a total of six TGRA input capture/compare match interrupts can be used as A/D converter conversion start sources, one for each channel.

11.9 Operation Timing

11.9.1 Input/Output Timing

TCNT Count Timing: Figure 11.31 shows TCNT count timing in internal clock operation, and figure 11.32 shows TCNT count timing in external clock operation.

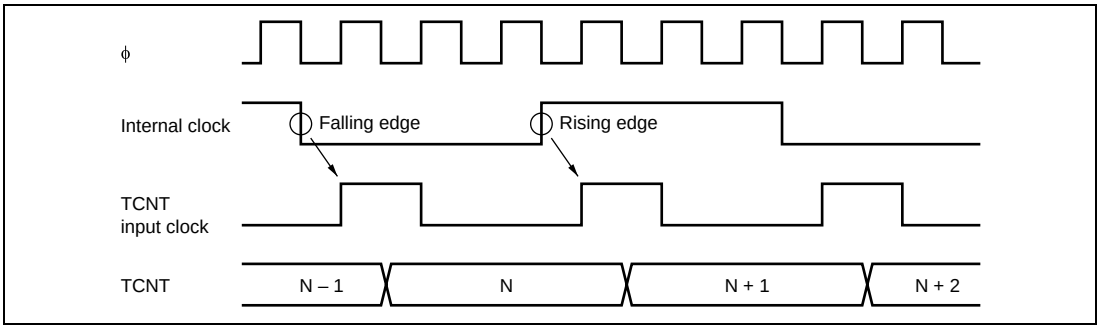


Figure 11.31 Count Timing in Internal Clock Operation

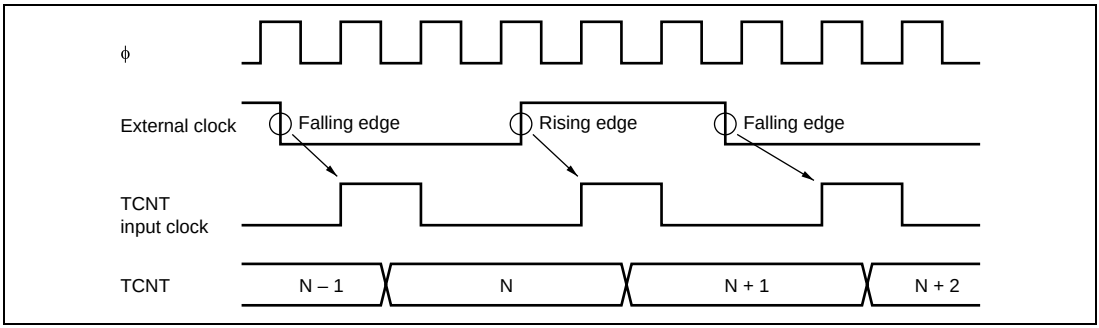


Figure 11.32 Count Timing in External Clock Operation

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 (TIOC pin) TCNT input clock is generated.

Figure 11.33 shows output compare output timing.

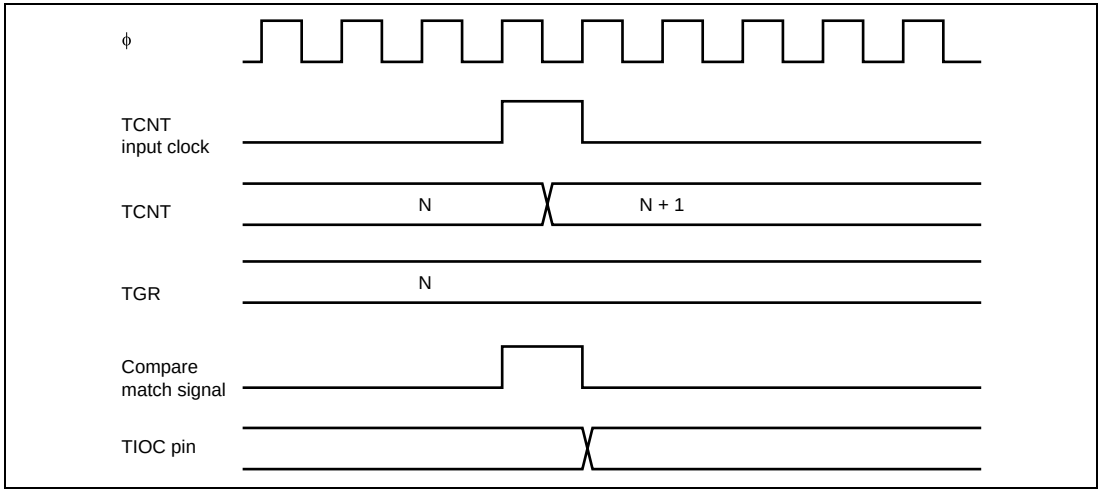


Figure 11.33 Output Compare Output Timing

Input Capture Signal Timing: Figure 11.34 shows input capture signal timing.

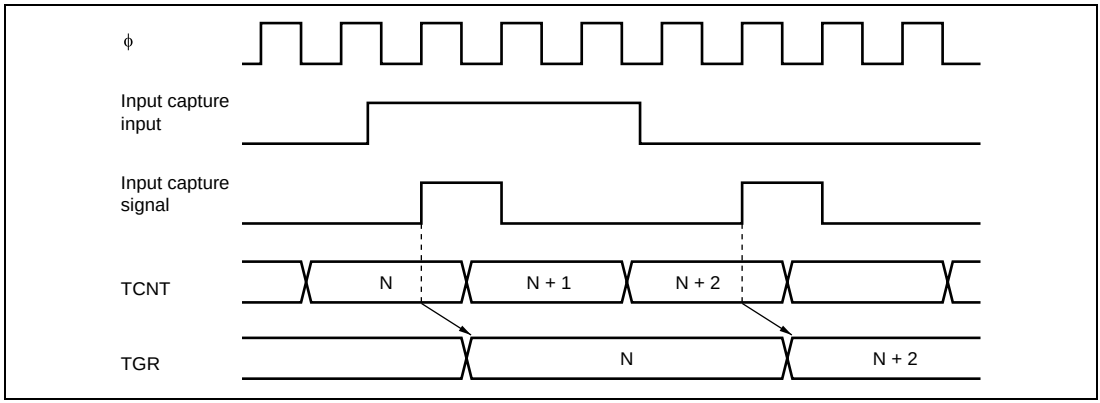


Figure 11.34 Input Capture Input Signal Timing

Timing for Counter Clearing by Compare Match/Input Capture: Figure 11.35 shows the timing when counter clearing by compare match occurrence is specified, and figure 11.36 shows the timing when counter clearing by input capture occurrence is specified.

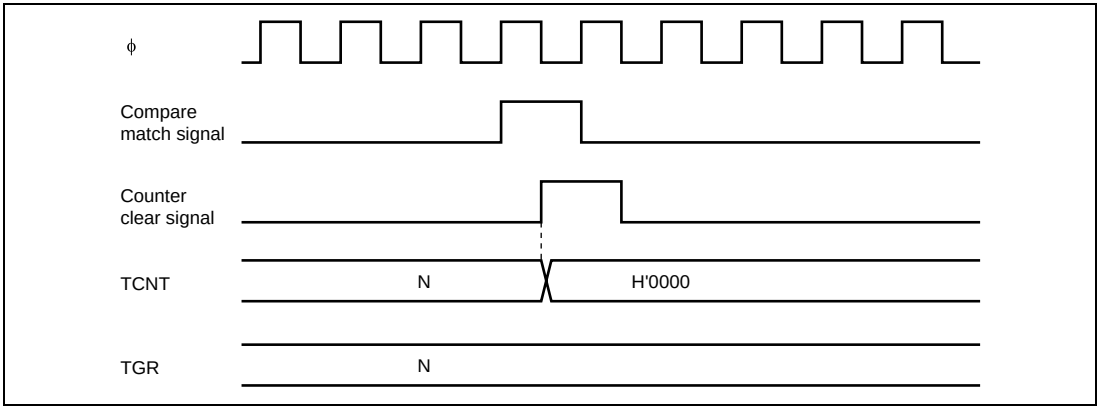


Figure 11.35 Counter Clear Timing (Compare Match)

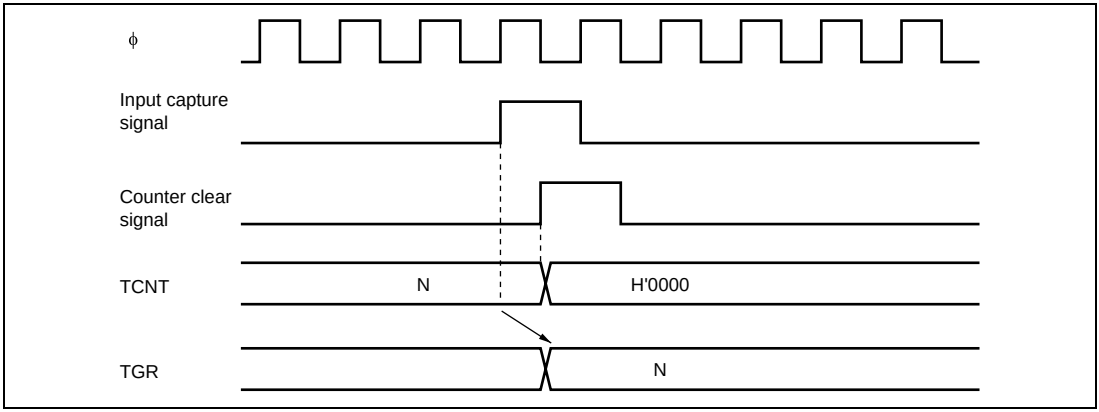


Figure 11.36 Counter Clear Timing (Input Capture)

Buffer Operation Timing: Figures 11.37 and 11.38 show the timings in buffer operation.

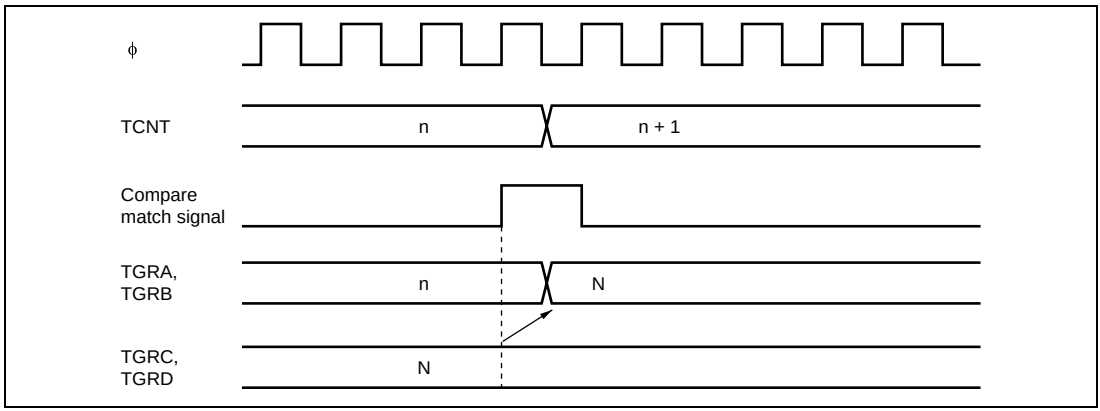


Figure 11.37 Buffer Operation Timing (Compare Match)

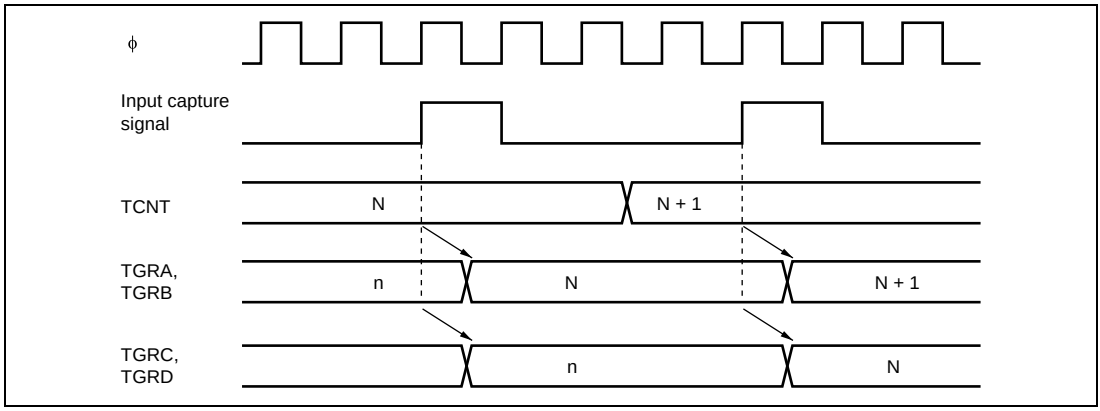


Figure 11.38 Buffer Operation Timing (Input Capture)

11.9.2 Interrupt Signal Timing

TGF Flag Setting Timing in Case of Compare Match: Figure 11.39 shows the timing for setting of the TGF flag in TSR by compare match occurrence, and the TGI interrupt request signal timing.

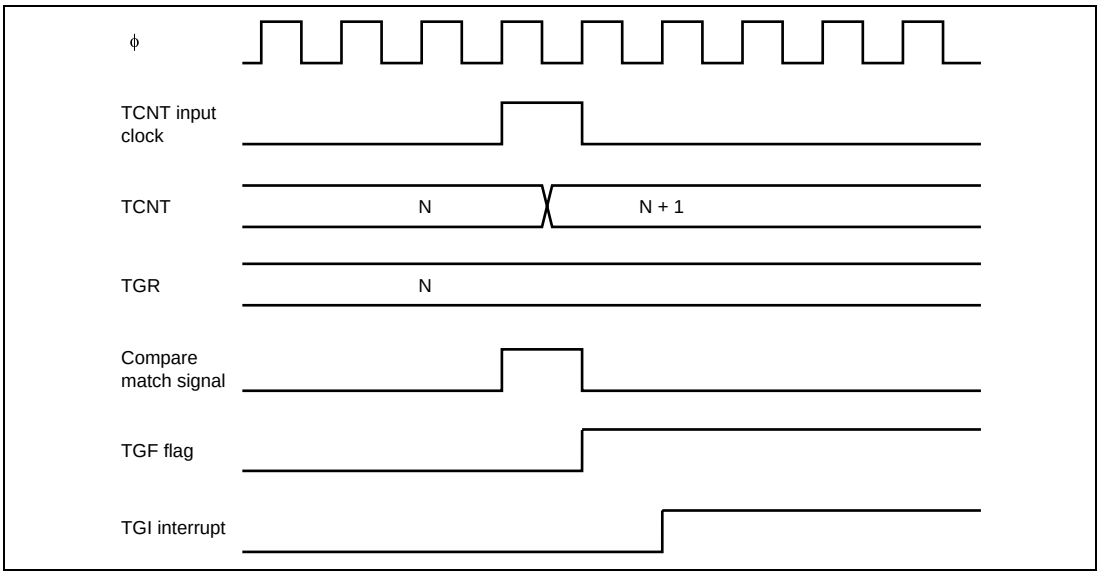


Figure 11.39 TGI Interrupt Timing (Compare Match)

TGF Flag Setting Timing in Case of Input Capture: Figure 11.40 shows the timing for setting of the TGF flag in TSR by input capture occurrence, and the TGI interrupt request signal timing.

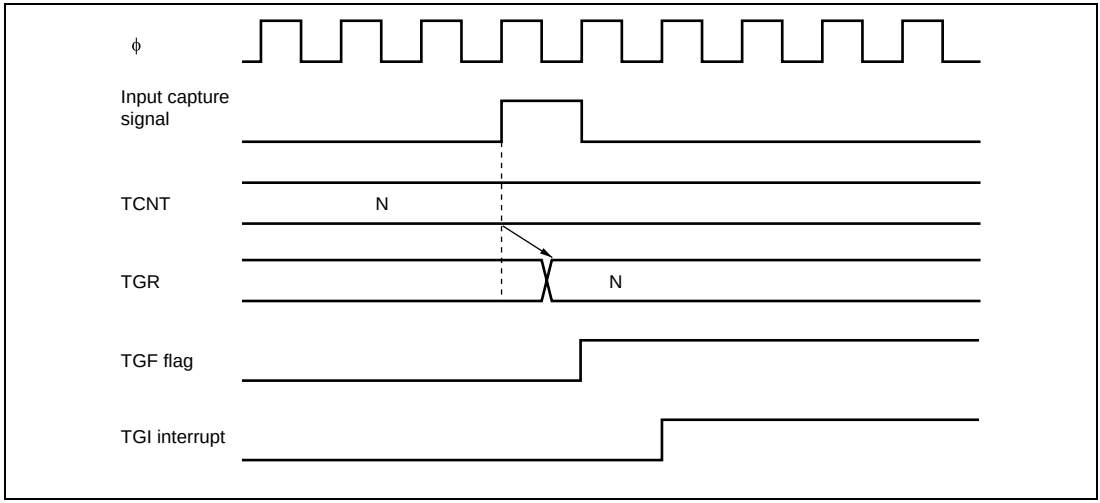


Figure 11.40 TGI Interrupt Timing (Input Capture)

TCFV Flag/TCFU Flag Setting Timing: Figure 11.41 shows the timing for setting of the TCFV flag in TSR by overflow occurrence, and the TCIV interrupt request signal timing.

Figure 11.42 shows the timing for setting of the TCFU flag in TSR by underflow occurrence, and the TCIU interrupt request signal timing.

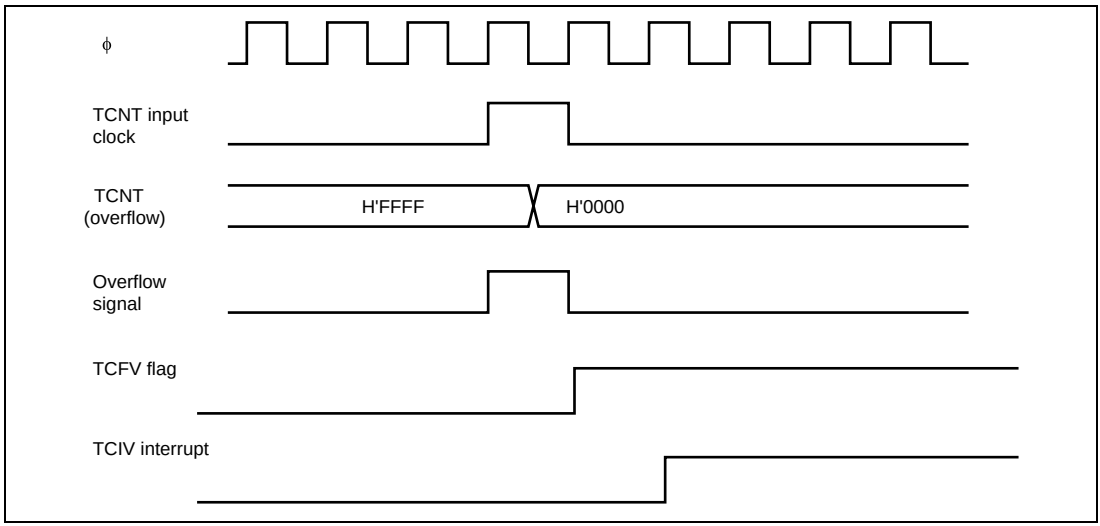


Figure 11.41 TCIV Interrupt Setting Timing

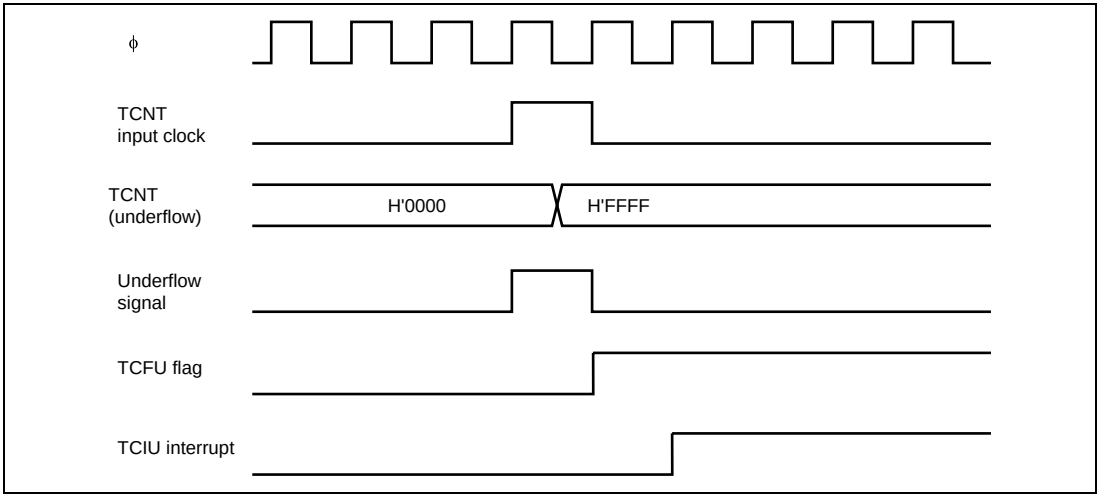


Figure 11.42 TCIU Interrupt Setting Timing

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 or DMAC* is activated, the flag is cleared automatically. Figure 11.43 shows the timing for status flag clearing by the CPU, and figure 11.44 shows the timing for status flag clearing by the DTC or DMAC*.

Note: * Supported only by the H8S/2239 Series.

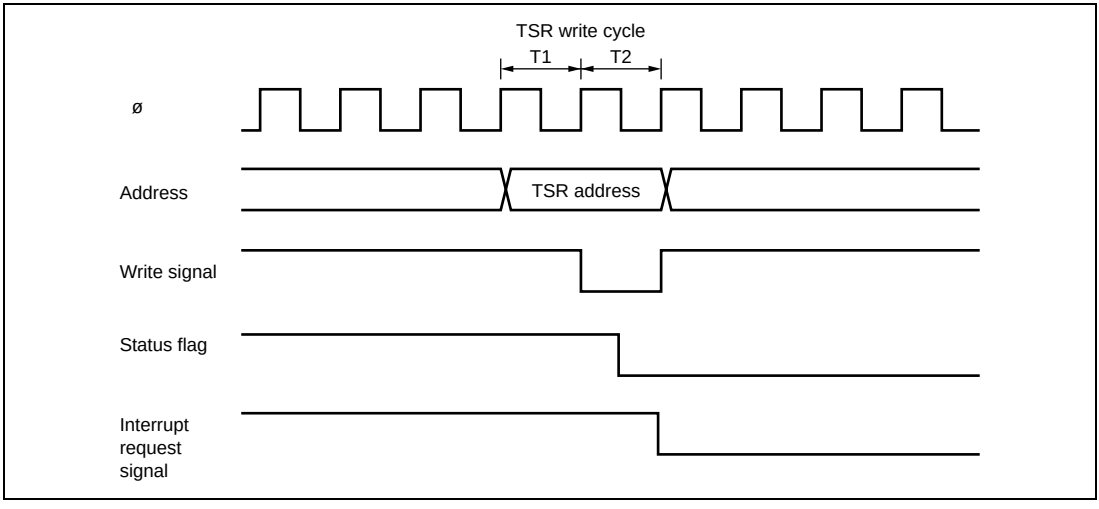


Figure 11.43 Timing for Status Flag Clearing by CPU

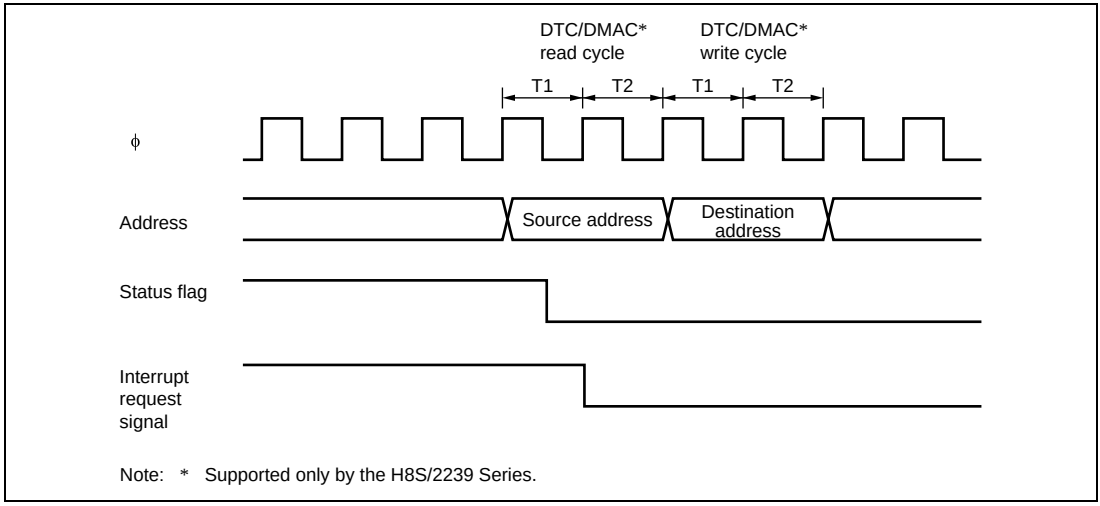


Figure 11.44 Timing for Status Flag Clearing by DTC/DMAC Activation

11.10 Usage Notes

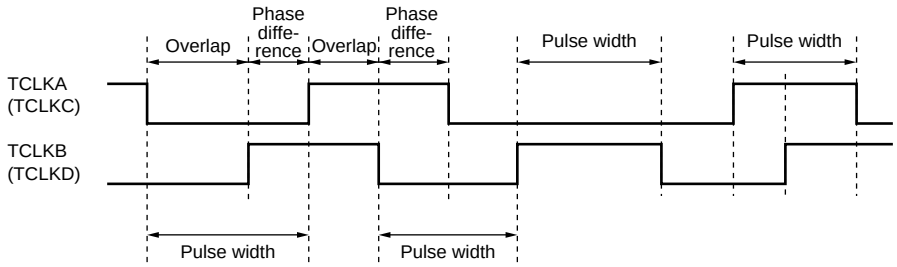
11.10.1 Module Stop Mode Setting

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 23, Power-Down Modes.

11.10.2 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 with a narrower pulse width.

In phase counting mode, the phase difference and overlap between the two input clocks must be at least 1.5 states, and the pulse width must be at least 2.5 states. Figure 11.45 shows the input clock conditions in phase counting mode.



Notes: Phase difference and overlap : 1.5 states or more
Pulse width : 2.5 states or more

Figure 11.45 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode

11.10.3 Caution on Cycle Setting

When counter clearing by 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

11.10.4 Contention between TCNT Write and Clear Operations

If the counter clearing signal is generated in the T2 state of a TCNT write cycle, TCNT clearing takes precedence and the TCNT write is not performed. Figure 11.46 shows the timing in this case.

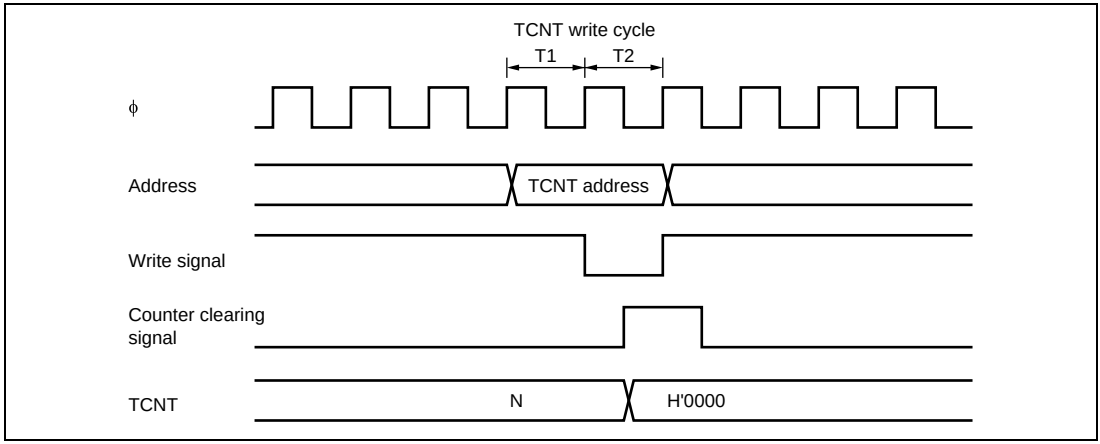


Figure 11.46 Contention between TCNT Write and Clear Operations

11.10.5 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 11.47 shows the timing in this case.

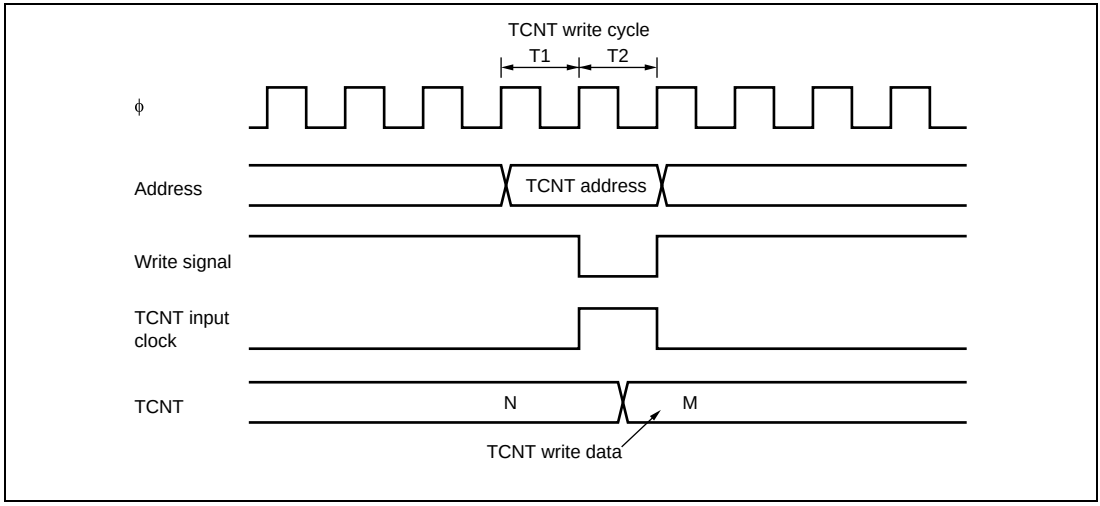


Figure 11.47 Contention between TCNT Write and Increment Operations

11.10.6 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 disabled. A compare match also does not occur when the same value as before is written.

Figure 11.48 shows the timing in this case.

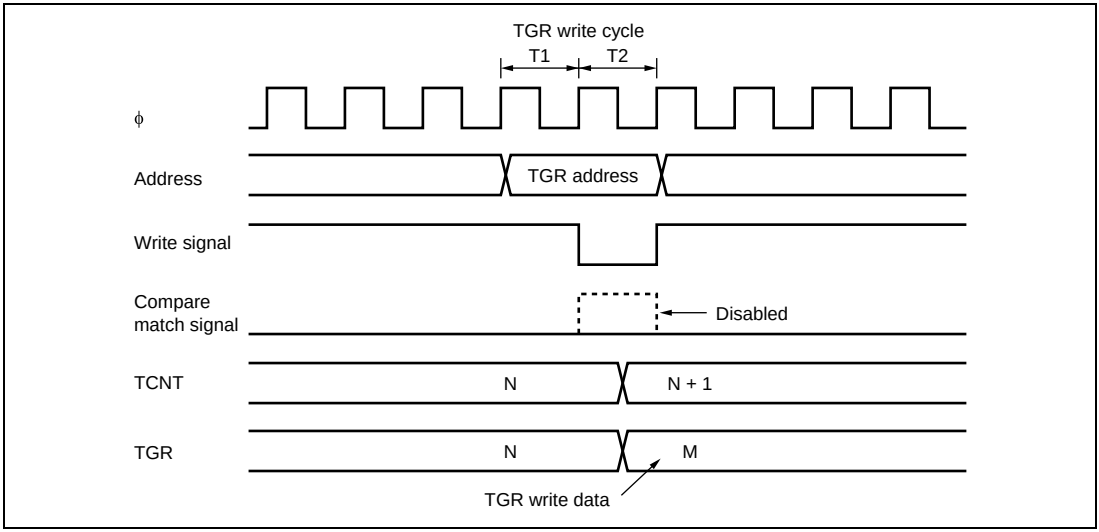


Figure 11.48 Contention between TGR Write and Compare Match

11.10.7 Contention between Buffer Register Write and Compare Match

If a compare match occurs in the T2 state of a TGR write cycle, the data transferred to TGR by the buffer operation will be the data prior to the write.

Figure 11.49 shows the timing in this case.

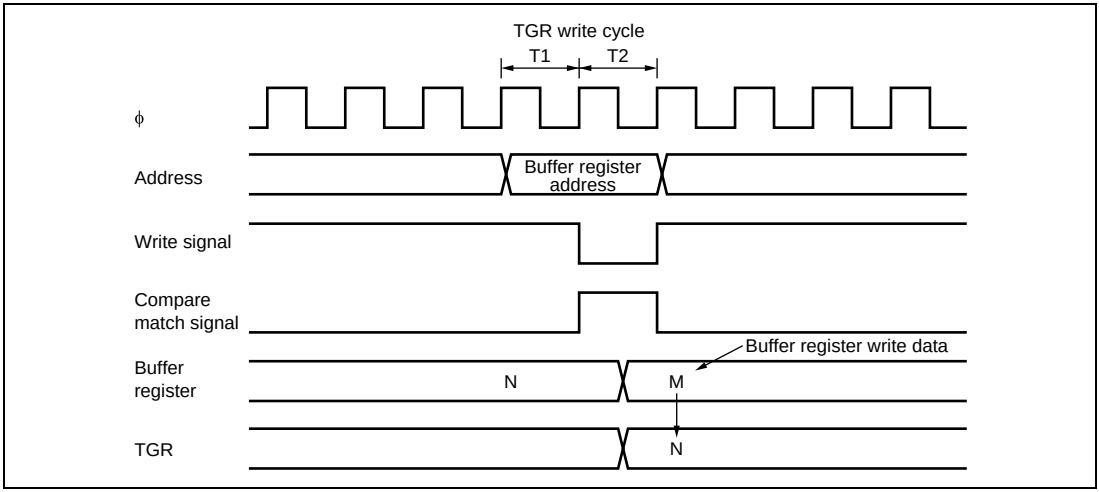


Figure 11.49 Contention between Buffer Register Write and Compare Match

11.10.8 Contention between TGR Read and Input Capture

If the input capture signal is generated in the T1 state of a TGR read cycle, the data that is read will be the data after input capture transfer.

Figure 11.50 shows the timing in this case.

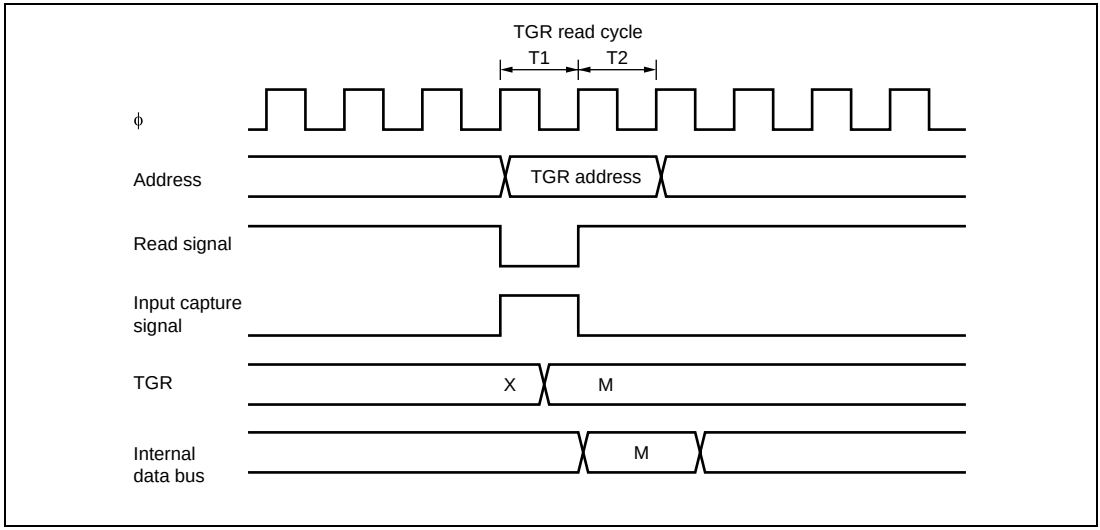


Figure 11.50 Contention between TGR Read and Input Capture

11.10.9 Contention between TGR Write and Input Capture

If the 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 11.51 shows the timing in this case.

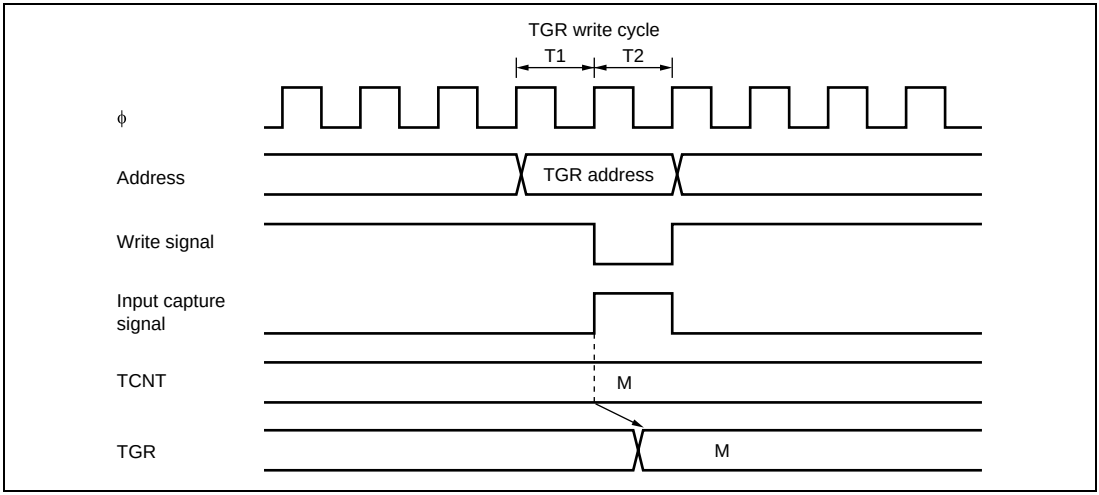


Figure 11.51 Contention between TGR Write and Input Capture

11.10.10 Contention between Buffer Register Write and Input Capture

If the 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 11.52 shows the timing in this case.

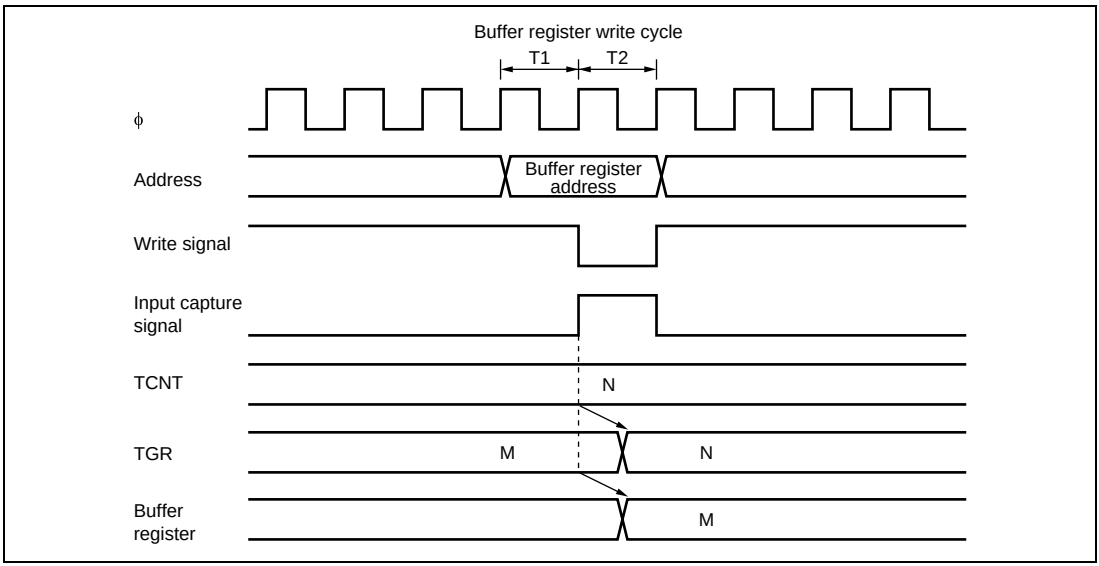


Figure 11.52 Contention between Buffer Register Write and Input Capture

11.10.11 Contention between Overflow/Underflow and Counter Clearing

If overflow/underflow and counter clearing occur simultaneously, the TCFV/TCFU flag in TSR is not set and TCNT clearing takes precedence.

Figure 11.53 shows the operation timing when a TGR compare match is specified as the clearing source, and H′FFFF is set in TGR.

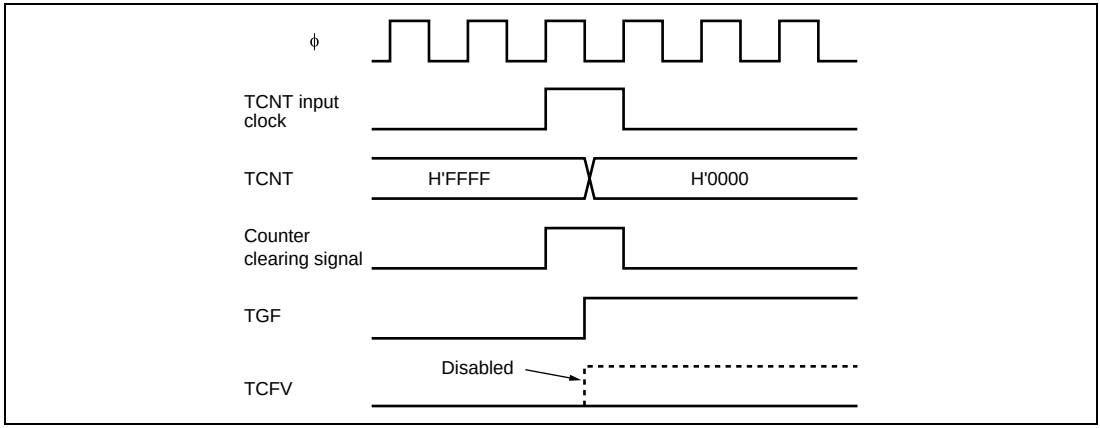


Figure 11.53 Contention between Overflow and Counter Clearing

11.10.12 Contention between TCNT Write and Overflow/Underflow

If there is an up-count or down-count in the T2 state of a TCNT write cycle, when overflow/underflow occurs, the TCNT write takes precedence and the TCFV/TCFU flag in TSR is not set.

Figure 11.54 shows the operation timing when there is contention between TCNT write and overflow.

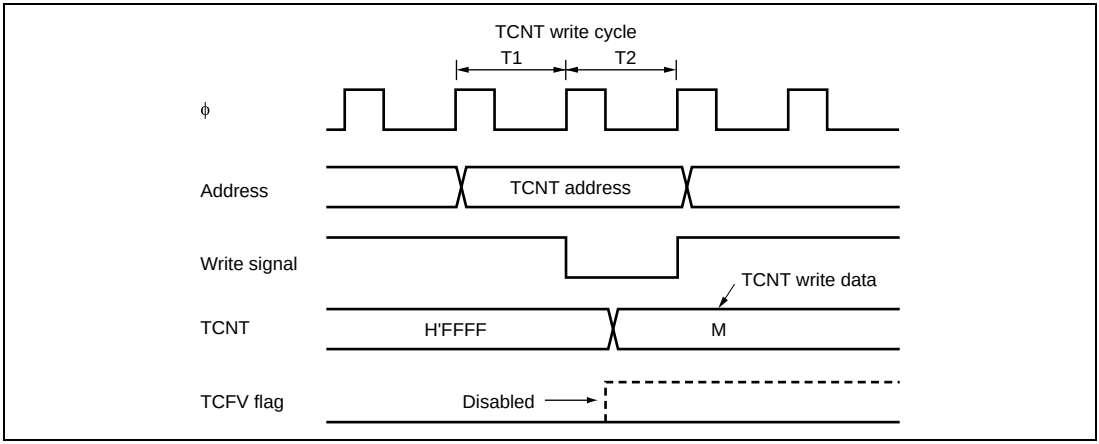


Figure 11.54 Contention between TCNT Write and Overflow

11.10.13 Multiplexing of I/O Pins

In this LSI, 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. When an external clock is input, compare match output should not be performed from a multiplexed pin.

11.10.14 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 DMAC or DTC activation source. Interrupts should therefore be disabled before entering module stop mode.

Section 12 8-Bit Timers

The H8S/2239 Series and H8S/2238R Series have 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.

The H8S/2237 Series and H8S/2227 Series have an on-chip 8-bit timer module with two channels (TMR_0 and TMR_1) operating on the basis of an 8-bit counter.

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.

12.1 Features

- Selection of clock sources
  Selected from three internal clocks (φ/8, φ/64, and φ/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
  TMR_0 and TMR_1 cascading
    The module can operate as a 16-bit timer using TMR_0 as the upper half and channel TMR_1 as the lower half (16-bit count mode).
    TMR_1 can be used to count TMR_0 compare-match occurrences (compare-match count mode).
  TMR_2 and TMR_3 cascading
    The module can operate as a 16-bit timer using TMR_2 as the upper half and channel TMR_3 as the lower half (16-bit count mode).
    TMR_3 can be used to count TMR_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.

Figure 12.1 shows a block diagram of the 8-bit timer module (TMR_0 and TMR_1).

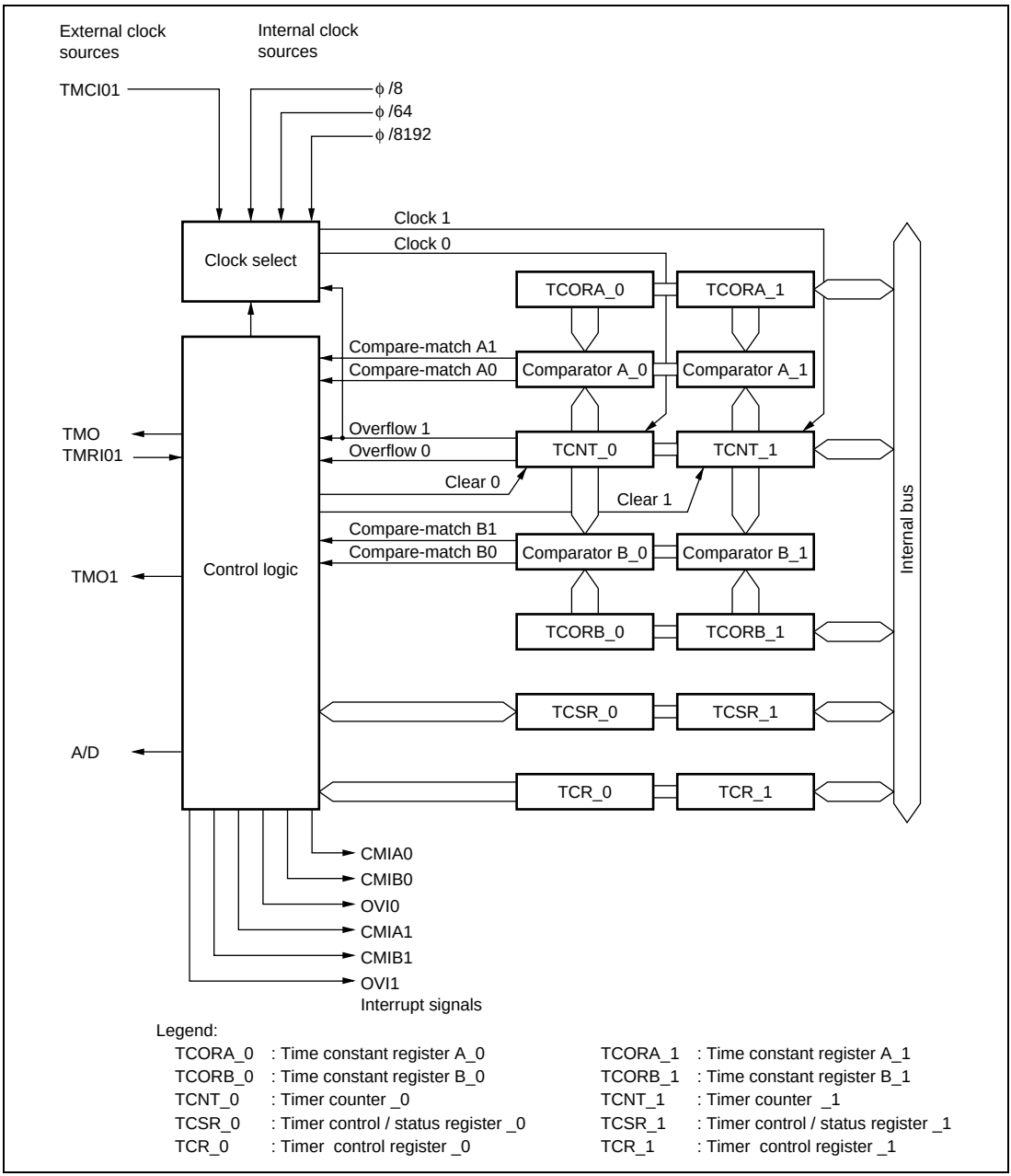


Figure 12.1 Block Diagram of 8-Bit Timer Module

12.2 Input/Output Pins

Table 12.1 summarizes the input and output pins of the 8-bit timer module.

Table 12.1 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	TMCI01	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	TMCI23*	Input	External clock input for the counter
	Timer reset input	TMRI23*	Input	External reset input for the counter

Note: * Supported by the H8S/2239 Series and H8S/2238R Series.

12.3 Register Descriptions

The 8-bit timer has the following registers. For details on the module stop register, refer to section 23.1.2, Module Stop Registers A to C (MSTPCRA to MSTPCRC).

- 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 by the H8S/2239 and H8S/2238R Series.

12.3.1 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. The initial value of TCNT is H′00.

12.3.2 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.

12.3.3 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.

12.3.4 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	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.
	CKS0	0	R/W	
				000: Clock input disabled
				001: φ /8 internal clock source, counted on the falling edge
				010: φ /64 internal clock source, counted on the falling edge
				011: φ /8192 internal clock source, counted on the falling edge
				100: For channel 0: Counted on TCNT1 overflow signal* For channel 1: Counted on TCNT0 overflow signal* For channel 2: Counted on TCNT3 overflow signal* For channel 3: Counted on TCNT2 overflow signal*
				101: External clock source, counted at rising edge
				110: External clock source, counted at falling edge
				111: External clock source, counted at both rising and falling edges

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 TCNT1 (TCNT3) compare-match signal, no incrementing clock will be generated. Do not use this setting.

12.3.5 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)*	Compare-Match Flag B [Setting condition] When TCNT = TCORB [Clearing condition] Read CMFB when CMFB = 1, then write 0 in CMFB. The DTC is activated by the CMIB interrupt and the DISEL bit = 0 in MRB of the DTC.
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When TCNT = TCORA [Clearing condition] Read CMFA when CMFA = 1, then write 0 in CMFA. The DTC is activated by the CMIA interrupt and DISEL bit = 0 in MRB of the DTC.
5	OVF	0	R/(W)*	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	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)

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

- TCSR_1 and TCSR_3

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W)*	Compare-Match Flag B [Setting condition] When TCNT = TCORB [Clearing condition] Read CMFB when CMFB = 1, then write 0 in CMFB The DTC is activated by the CMIB interrupt and the DISEL Bit = 0 in MRB of the DTC.
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When TCNT = TCORA [Clearing condition] Read CMFA when CMFA = 1, then write 0 in CMFA The DTC is activated by the CMIA interrupt and the DISEL Bit = 0 in MRB of the DTC.
5	OVF	0	R/(W)*	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 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)
2	OS2	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
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)

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

- TCSR_2

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W)*	Compare-Match Flag B [Setting condition] When TCNT = TCORB [Clearing condition] Read CMFB when CMFB = 1, then write 0 in CMFB The DTC is activated by the CMIB interrupt and the DISEL Bit = 0 in MRB of the DTC.
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When TCNT = TCORA [Clearing condition] Read CMFA when CMFA = 1, then write 0 in CMFA The DTC is activated by the CMIA interrupt and the DISEL Bit = 0 in MRB of the DTC.
5	OVF	0	R/(W)*	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

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 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)
2	OS2	0	R/W	
1	OS1	0	R/W	Output Select 1 and 0 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)
0	OS0	0	R/W	

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

12.4 Operation

12.4.1 Pulse Output

Figure 12.2 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 compare-match A and 0 by compare-match B.

By the above settings, waveforms with the cycle of TCORA and the pulse width of TCRB can be output without software intervention.

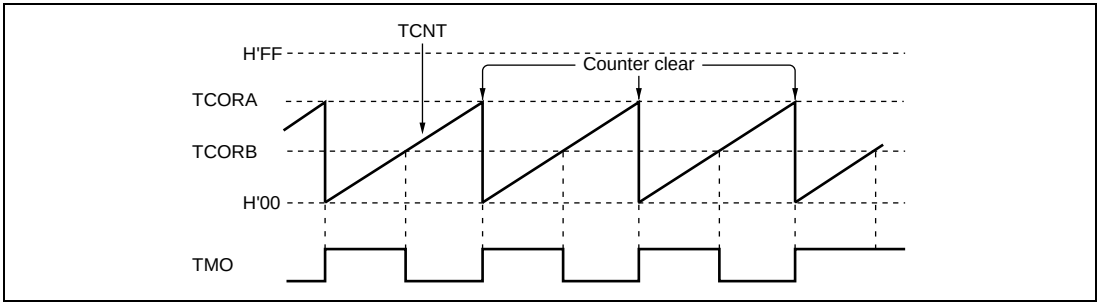


Figure 12.2 Example of Pulse Output

12.5 Operation Timing

12.5.1 TCNT Incrementation Timing

Figure 12.3 shows the TCNT count timing with internal clock source. Figure 12.4 shows the TCNT incrementation timing with external clock source. The pulse width of the external clock for incrementation at signal edge must be at least 1.5 system clock (ϕ) periods, 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.

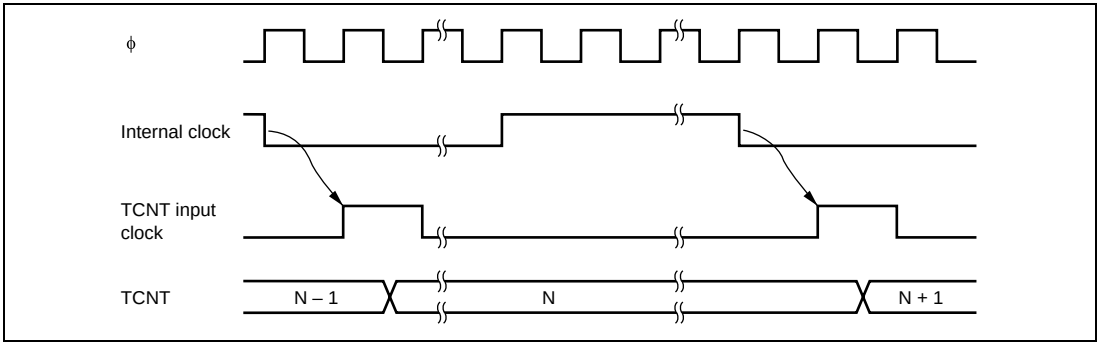


Figure 12.3 Count Timing for Internal Clock Input

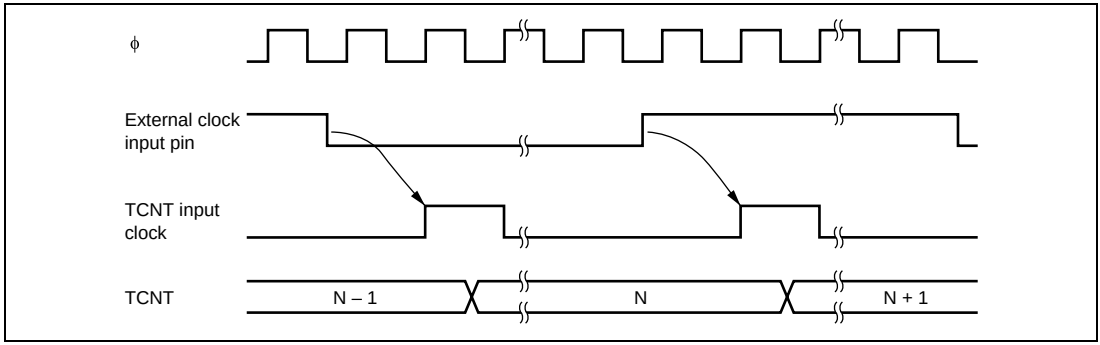


Figure 12.4 Count Timing for External Clock Input

12.5.2 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 12.5 shows the timing of CMF flag setting.

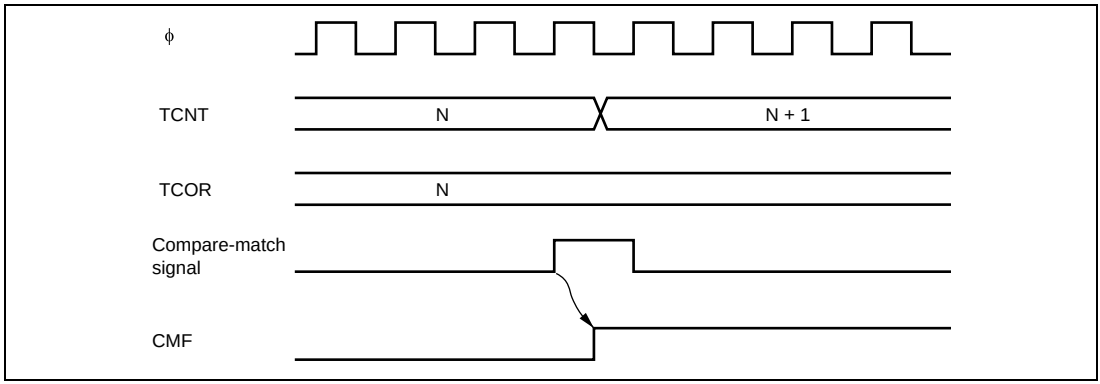


Figure 12.5 Timing of CMF Setting

12.5.3 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 12.6 shows the timing when the output is set to toggle at compare-match A.

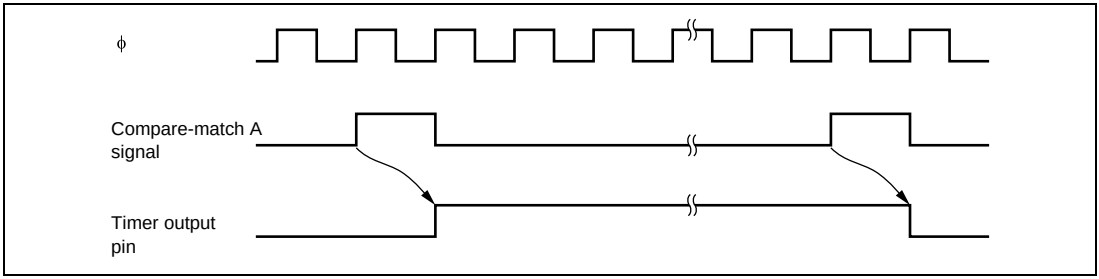


Figure 12.6 Timing of Timer Output

12.5.4 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 12.7 shows the timing of this operation.

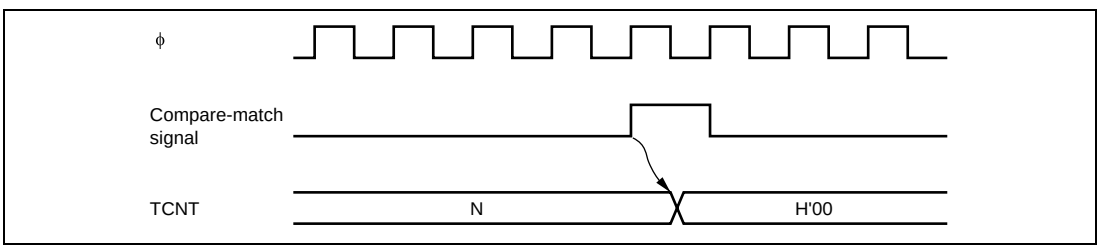


Figure 12.7 Timing of Compare-Match Clear

12.5.5 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 12.8 shows the timing of this operation.

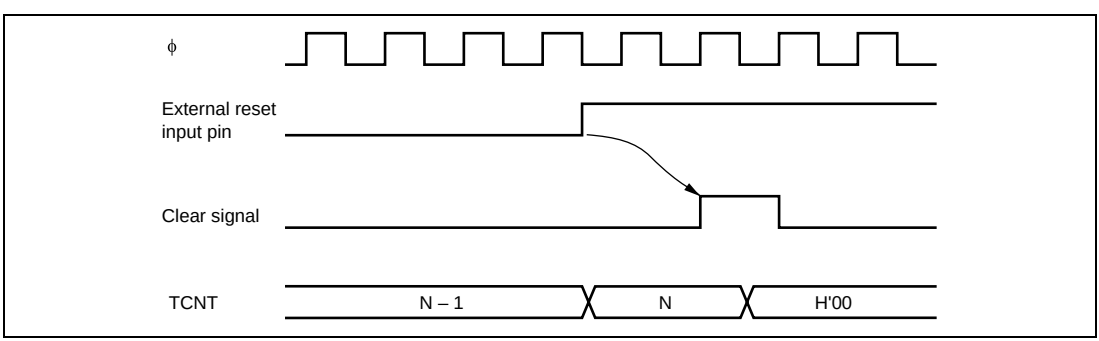


Figure 12.8 Timing of Clearing by External Reset Input

12.5.6 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 12.9 shows the timing of this operation.

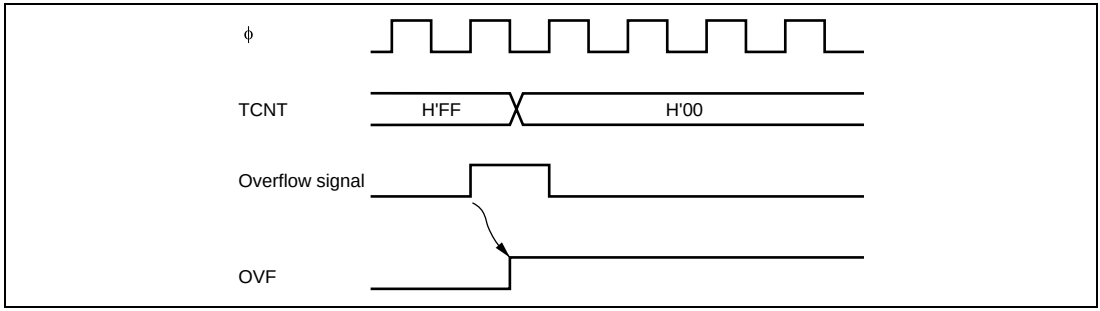


Figure 12.9 Timing of OVF Setting

12.6 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.

12.6.1 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.

12.6.2 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.

12.7 Interrupt Sources

12.7.1 Interrupt Sources and DTC Activation

The 8-bit timer can generate three types of interrupt: CMIA, CMIB, and OVI. Table 12.2 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. It is also possible to activate the DTC by means of CMIA and CMIB interrupts.

Table 12.2 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

12.7.2 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.

12.8 Usage Notes

12.8.1 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 12.10 shows this operation.

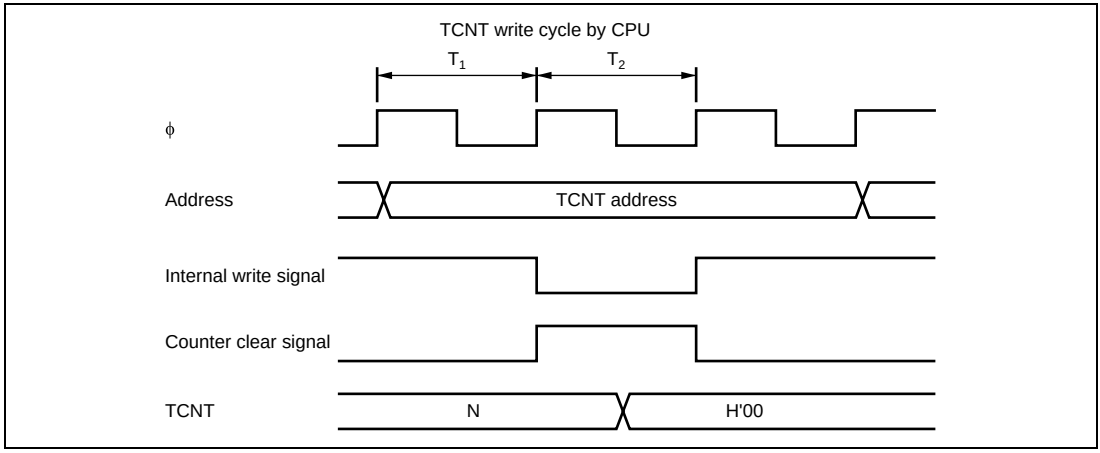


Figure 12.10 Contention between TCNT Write and Clear

12.8.2 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 12.11 shows this operation.

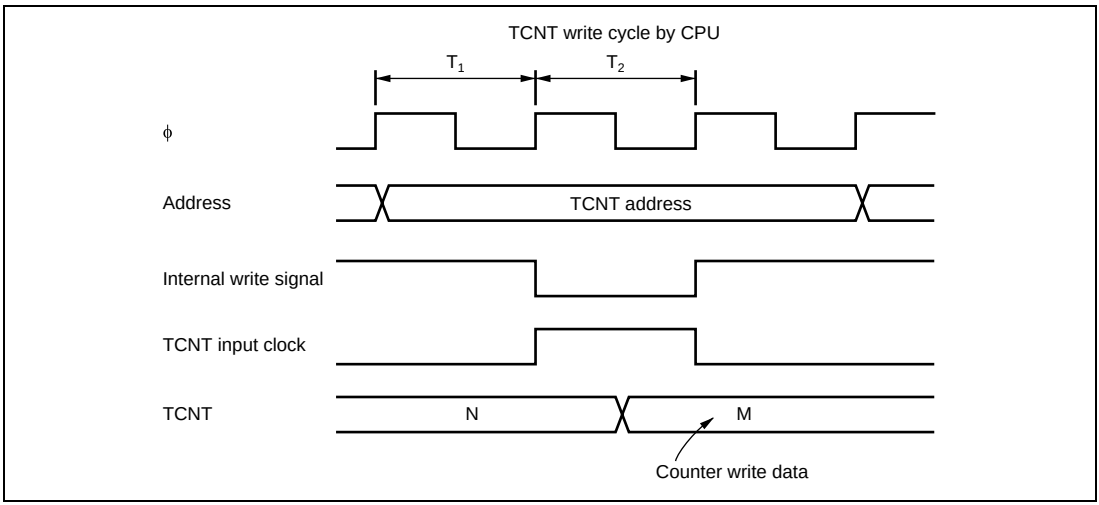


Figure 12.11 Contention between TCNT Write and Increment

12.8.3 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 12.12 shows this operation.

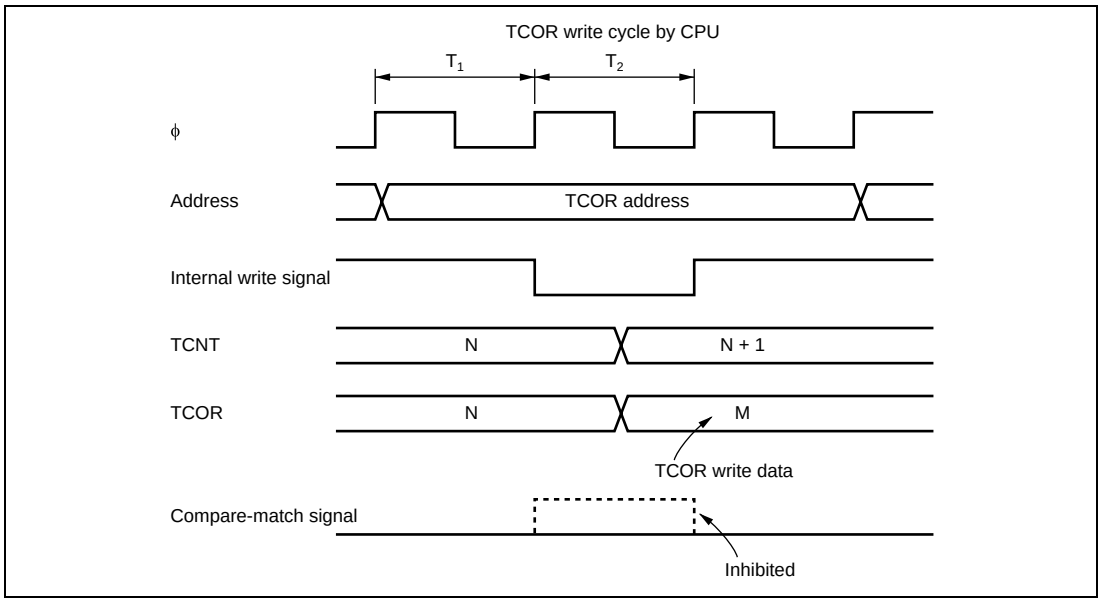


Figure 12.12 Contention between TCOR Write and Compare-Match

12.8.4 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 12.3.

Table 12.3 Timer Output Priorities

Output Setting	Priority
Toggle output	High
1 output	↑
0 output	↑
No change	Low

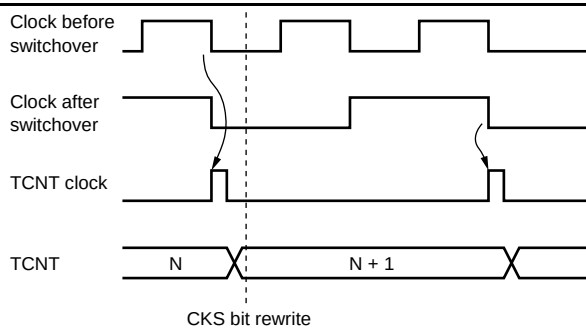
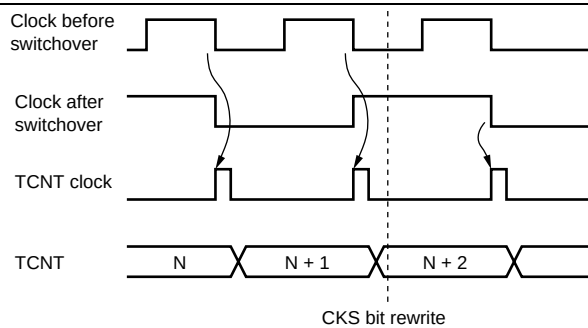
12.8.5 Switching of Internal Clocks and TCNT Operation

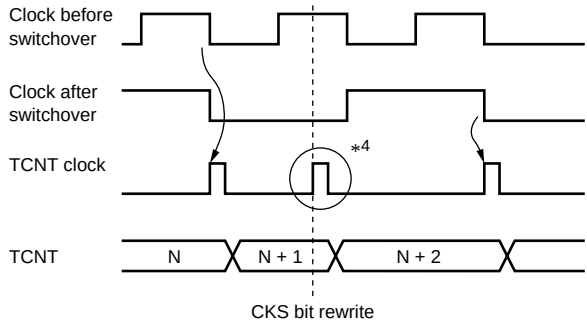
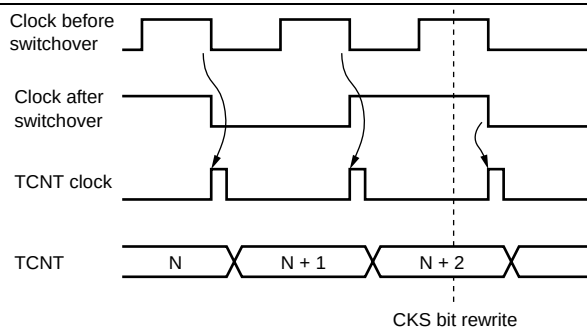
TCNT may increment erroneously when the internal clock is switched over. Table 12.4 shows the relationship between the timing at which the internal clock is switched (by writing to the CKS1 and CKS0 bits) and the TCNT operation

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 12.4, 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 12.4 Switching of Internal Clock and TCNT Operation

No.	Timing of Switchover by Means of CKS1 and CKS0 Bits	TCNT Clock Operation
1	Switching from low to low*[1]	
2	Switching from low to high*[2]	

No.	Timing of Switchover by Means of CKS1 and CKS0 Bits	TCNT Clock Operation
3	Switching from high to low*[3]	
4	Switching from high to high	

Notes: 1. Includes switching from low to stop, and from stop to low.
2. Includes switching from stop to high.
3. Includes switching from high to stop.
4. Generated on the assumption that the switchover is a falling edge; TCNT is incremented.

12.8.6 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.

12.8.7 Mode Setting of Cascaded Connection

When the 16-bit count mode and the compare-match count mode are set at the same time, input clocks for TCNT_0 and TCNT_1 (TCNT_2 and TCNT_3) are not generated and the timer stops incrementation. This setting is prohibited.

Section 13 Watchdog Timer (WDT)

The watchdog timer (WDT) is an 8-bit timer that can generate an internal reset signal for this LSI if a system crash prevents the CPU from writing to the timer counter, thus allowing it to overflow.

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 figure 13.1.

13.1 Features

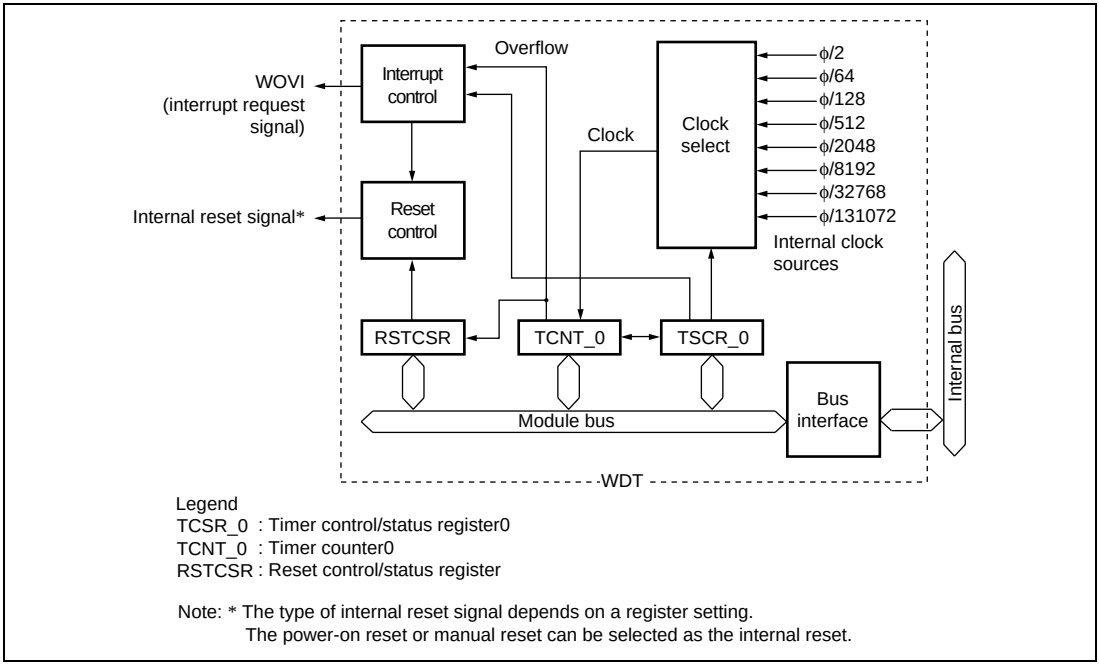
- Selectable from eight counter input clocks for WDT_0
  Selectable from 16 counter input clocks for WDT_1
- Switchable between watchdog timer mode and interval timer mode

In watchdog timer mode

- Choosable between power-on reset or manual reset as internal reset
- 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

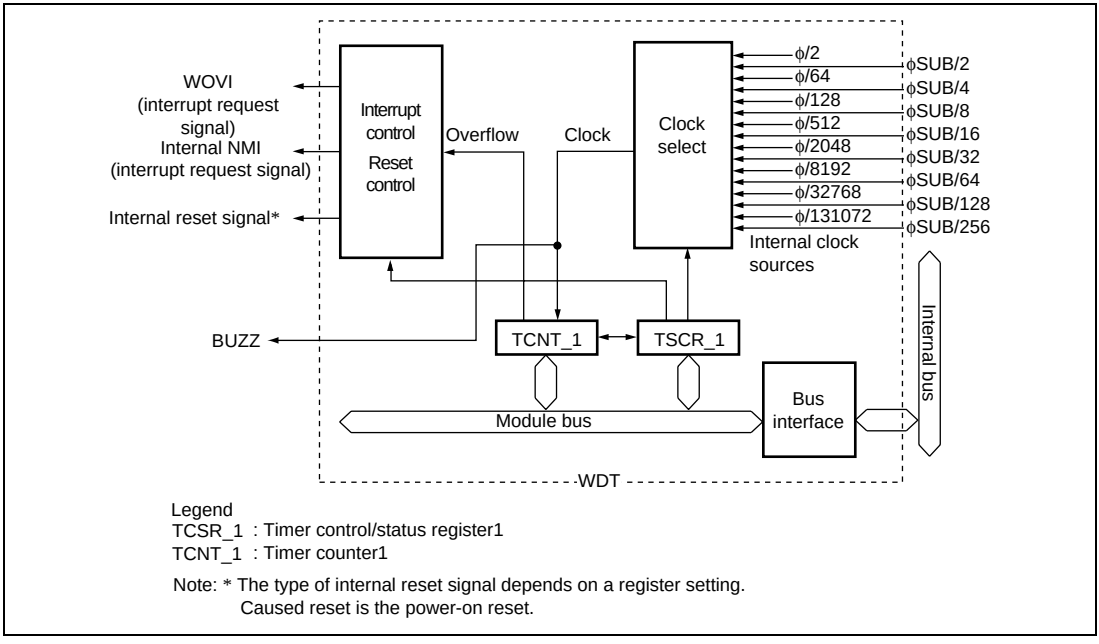
- If the counter overflows, the WDT generates an interval timer interrupt (WOVI).
- The selected clock can be output from the BUZZ output pin (WDT_1).



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.
The power-on reset or manual reset can be selected as the internal reset.

Figure 13.1 Block Diagram of WDT_0 (1)



Legend
TCSR_1 : Timer control/status register1
TCNT_1 : Timer counter1

Note: * The type of internal reset signal depends on a register setting.
Caused reset is the power-on reset.

Figure 13.1 Block Diagram of WDT_1 (2)

13.2 Input/Output Pins

Table 13.1 lists WDT pin

Name	Symbol	I/O	Function
Buzzer Output	BUZZ	Output	Output the clock selected by WDT_1.

13.3 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 13.6.1, Notes on Register Access. For detained description on the system control register, refer to section 7.3.6, Pin Function Control Register (PFCR).

- Timer counter (TCNT)
- Timer control/status register (TCSR)
- Reset control/status register (RSTCSR)

13.3.1 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.

13.3.2 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]	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
5	TME	0	R/W	Timer Enable When this bit is set to 1, TCNT starts counting. When this bit is cleared, TCNT stops counting and is initialized to H'00.
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	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 = 10 MHz is enclosed in parentheses.
0	CKS0	0	R/W	
				000: Clock ϕ/2 (frequency: 51.2 μs)
				001: Clock ϕ/64 (frequency: 1.6 ms)
				010: Clock ϕ/128 (frequency: 3.2 ms)
				011: Clock ϕ/512 (frequency: 13.2 ms)
				100: Clock ϕ/2048 (frequency: 52.4 ms)
				101: Clock ϕ/8192 (frequency: 209.8 ms)
				110: Clock ϕ/32768 (frequency: 838.8 ms)
				111: Clock ϕ/131072 (frequency: 3.36 s)

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	Timer Enable When this bit is set to 1, TCNT starts counting. When this bit is cleared, TCNT stops counting and is initialized to H'00.
4	PSS	0	R/W	Prescaler Select Selects the clock source input to TCNT of WDT_1 0: TCNT counts divided clock of ϕ-base prescaler (PSM). 1: TCNT counts divided clock of ϕ_{SUB}-base prescaler (PSS)
3	RST/NMI	0	R/W	Reset or NMI (REST//NMI) 0: An NMI interrupt is requested. 1: reset is requested.

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 = 10 MHz is enclosed in parentheses.
0	CKS0	0	R/W	
				When PSS = 0:
				000: Clock ϕ/2 (frequency: 51.2 μs)
				001: Clock ϕ/64 (frequency: 1.6 ms)
				010: Clock ϕ/128 (frequency: 3.2 ms)
				011: Clock ϕ/512 (frequency: 13.2 ms)
				100: Clock ϕ/2048 (frequency: 52.4 ms)
				101: Clock ϕ/8192 (frequency: 209.8 ms)
				110: Clock ϕ/32768 (frequency: 838.8 ms)
				111: Clock ϕ/131072 (frequency: 3.36 s)
				When PSS = 1:
				000: Clock ϕ_{SUB}/2 (frequency: 15.6 ms)
				001: Clock ϕ_{SUB}/4 (frequency: 31.3 ms)
				010: Clock ϕ_{SUB}/8 (frequency: 62.5 ms)
				011: Clock ϕ_{SUB}/16 (frequency: 125 ms)
				100: Clock ϕ_{SUB}/32 (frequency: 250 ms)
				101: Clock ϕ_{SUB}/64 (frequency: 500 ms)
				110: Clock ϕ_{SUB}/128 (frequency: 1 s)
				111: Clock ϕ_{SUB}/256 (frequency: 2 s)

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.

13.3.3 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 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)*	Watchdog Overflow Flag 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. [Setting condition] Set when TCNT overflows (changed from H'FF to H'00) in watchdog timer mode [Clearing condition] Cleared by reading RSTCSR when WOVF = 1, and then writing 0 to WOVF
6	RSTE	0	R/W	Reset Enable Specifies whether or not a reset signal is generated in the chip if TCNT overflows during watchdog timer operation. 0: Reset signal is not generated even if TCNT overflows (Though this LSI is not reset, TCNT and TCSR in WDT are reset) 1: Reset signal is generated if TCNT overflows
5	RSTS	0	R/W	Reset Select This bit selects the type of the internal reset that is generated by TCNT overflowing in watchdog timer mode. 0: Power-on reset 1: Manual reset
4 to 0	—	All 1	—	Reserved These bits are always read as 1 and cannot be modified.

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

13.4 Operation

13.4.1 Watchdog Timer Mode

To use the WDT as a watchdog timer, set the WT/IT bit in TCSR and the TME bit to 1.

Software must prevent TCNT overflows by rewriting the TCNT value (normally be 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 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 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 RES pin are both treated as having the same vector. If a WDT internal reset request and the RES pin reset occur at the same time, the 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.

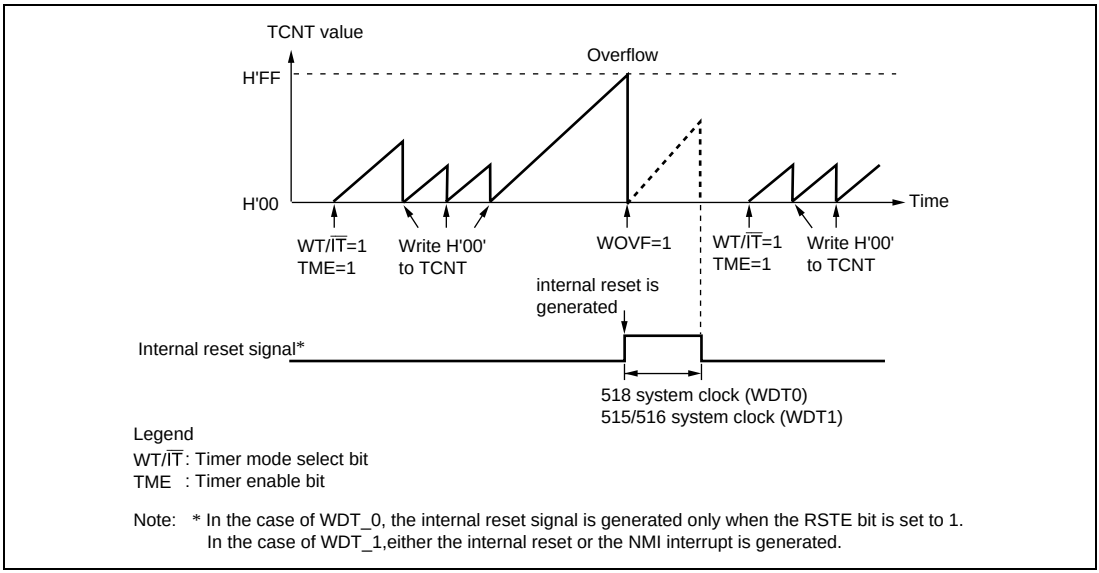


Figure 13.2 Watchdog Timer Mode Operation

13.4.2 Interval Timer Mode

To use the WDT as a watchdog timer, set the WT/IT and TME bits in TCSR to 1.

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.

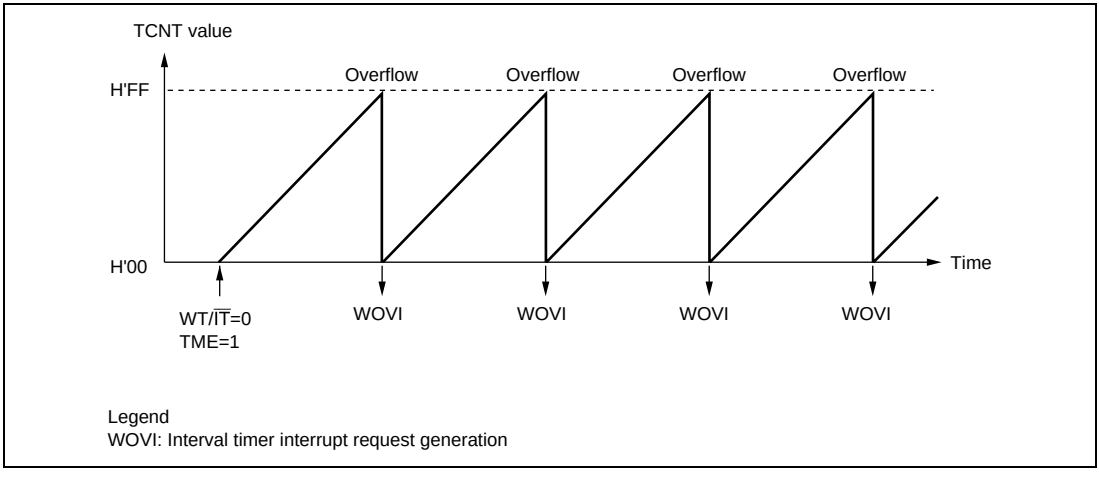


Figure 13.3 Interval Timer Mode Operation

13.4.3 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 13.4.

When NMI request is chosen in watchdog timer mode for WDT_1, TCNT overflow sets the OVF flog to 1. At the same time, NMI interrupt is requested.

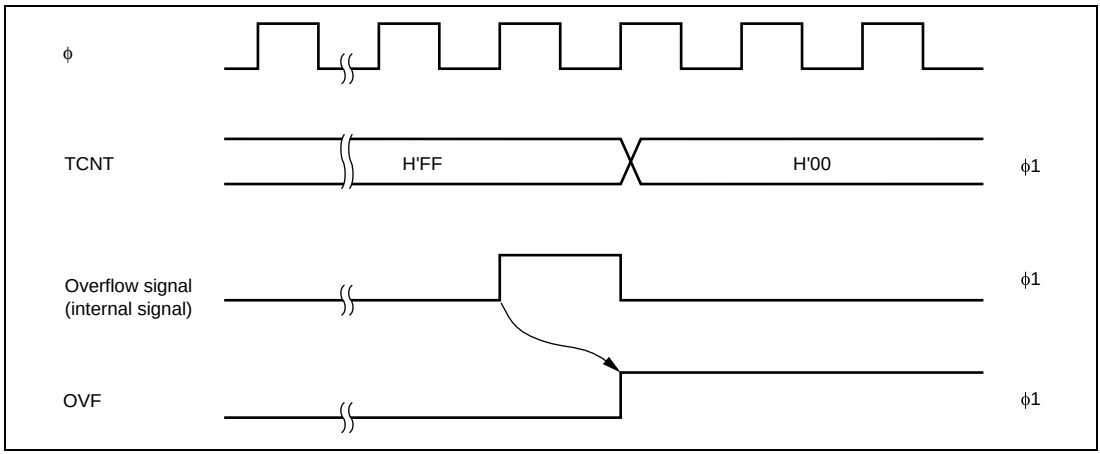


Figure 13.4 Timing of OVF Setting

13.4.4 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 13.5.

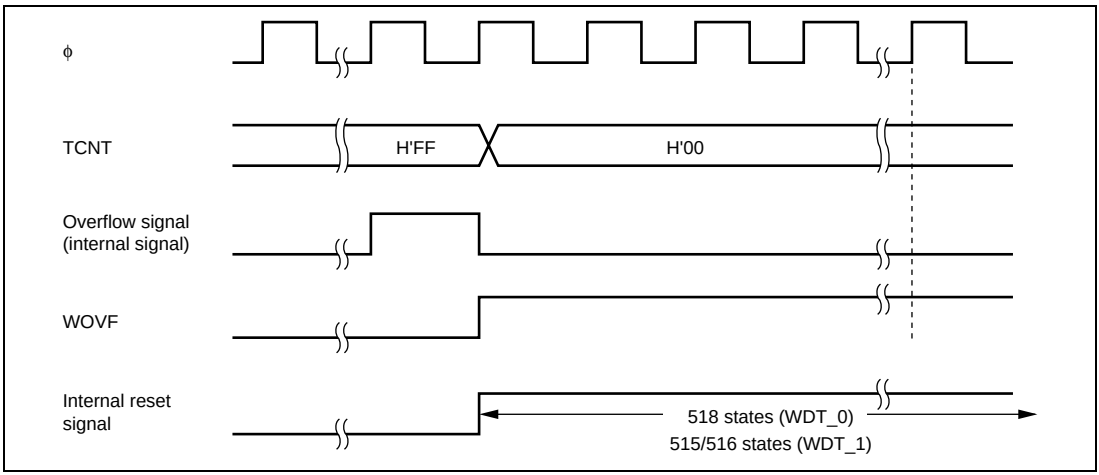


Figure 13.5 Timing of WOVF Setting

13.5 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 interrupt request has been chosen in the watchdog timer mode, an NMI interrupt request is generated when a TCNT overflow occurs.

Table 13.2 WDT Interrupt Source

Name	Interrupt Source	Interrupt Flag
WOVI	TCNT overflow (interval timer mode)	OVF
NMI	TCNT overflow (watchdog timer mode)	OVF

13.6 Usage Notes

13.6.1 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 13.6 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 WOVF bit differs from that of writing to the RSTE and RSTS bits. To write 0 to the WOVF bit, satisfy the condition shown in figure 13.6. If satisfied, the transfer instruction clears the WOVF bit to 0, but has no effect on the RSTE and RSTS bits. To write to the RSTE and RSTS bits, satisfy the condition shown in figure 13.6. If satisfied, the transfer instruction writes the values in bits 6 and 5 of the lower byte into the RSTE and RSTS bits, but has no effect on the WOVF bit.

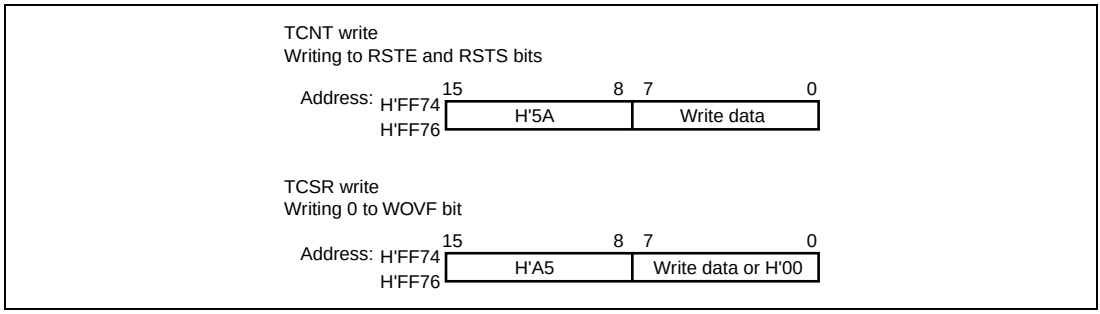


Figure 13.6 Writing to TCNT and TCSR (example for WDT_0)

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.

13.6.2 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 13.7 shows this operation.

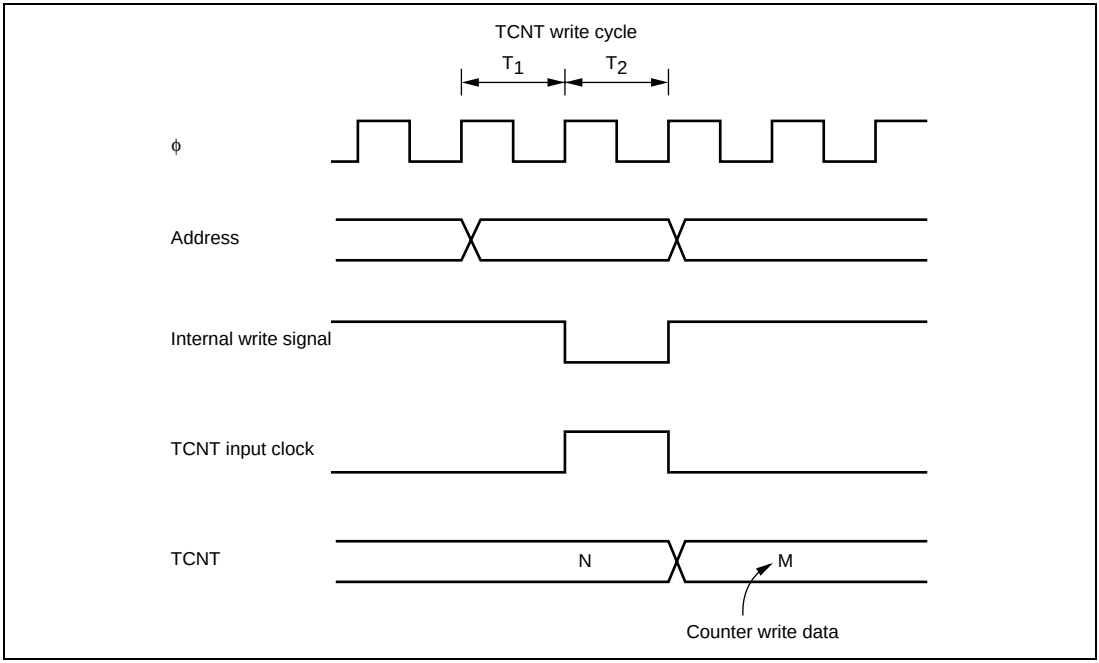


Figure 13.7 Contention between TCNT Write and Increment

13.6.3 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.

13.6.4 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.

13.6.5 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.

13.6.6 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 14 Serial Communication Interface (SCI)

This LSI has independent serial communication interfaces (SCIs). 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 extended function.

14.1 Features

- The number of on-chip channels

  H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series: Four channels (channels 0, 1, 2, and 3)

  H8S/2227 Series: Three channels (channels 0, 1, and 3)
- 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) or the direct memory access controller (DMAC) (H8S/2239 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 115.192 kbps can be selected at 16 MHz operation (H8S/2239 Series only).
- Transfer rate clock can be input from the TPU (SCI_0) (H8S/2239 Series only).
- Communications between multi-processors are possible.

Clocked Synchronous mode

- Data length: 8 bits
- Receive error detection: Overrun errors detected
- SCI selection (SCI_0) : When IRQ7 = 1, fixed input of TxD0 = Hiz and SCK0 = High can be selected. (H8S/2239 Series only)

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 14.1 shows a block diagram of the SCI (except SCI_0 of the H8S/2239 Series), and figure 14.2 shows that of the SCI_0 of the H8S/2239 Series.

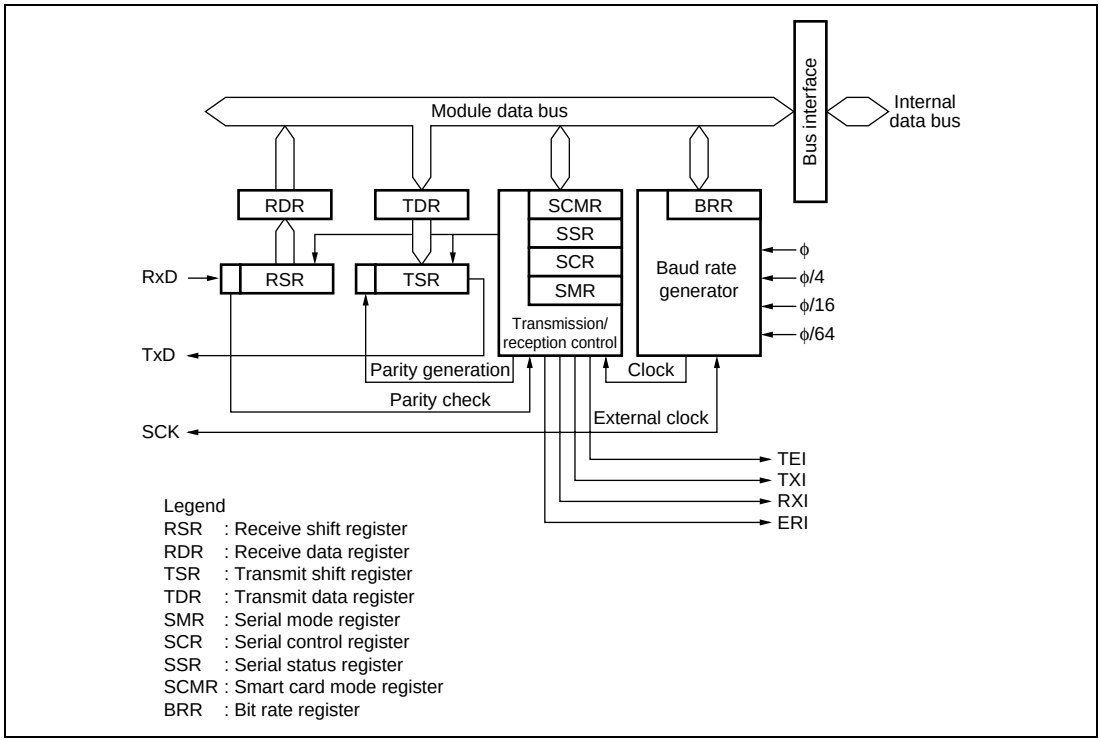
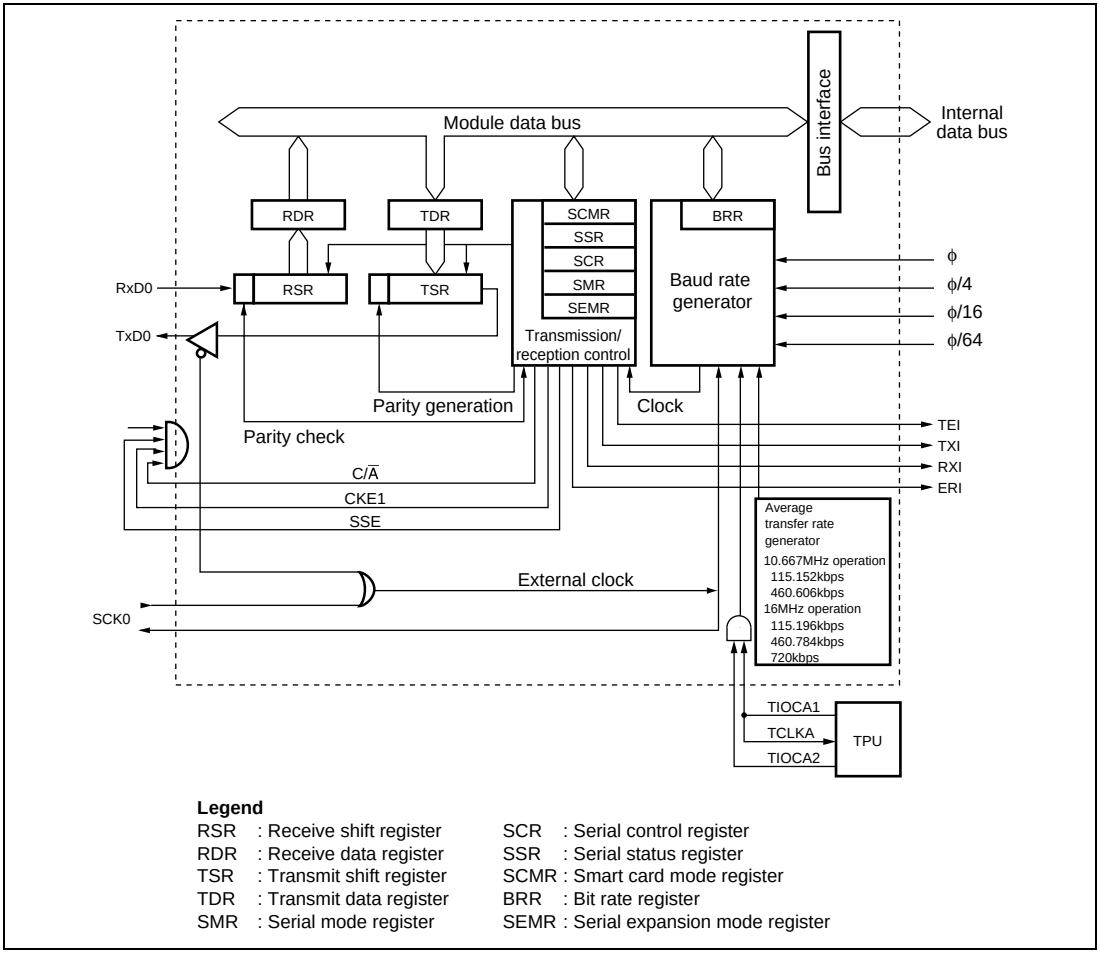


Figure 14.1 Block Diagram of SCI



Legend

RSR	: Receive shift register	SCR	: Serial control register
RDR	: Receive data register	SSR	: Serial status register
TSR	: Transmit shift register	SCMR	: Smart card mode register
TDR	: Transmit data register	BRR	: Bit rate register
SMR	: Serial mode register	SEMR	: Serial expansion mode register

Figure 14.2 Block Diagram of SCI_0 of H8S/2239 Series

14.2 Input/Output Pins

Table 14.1 shows the pin configuration for each SCI channel.

Table 14.1 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*[2]	SCK2	I/O	SCI2 clock input/output
	RxD2	Input	SCI2 receive data input
	TxD2	Output	SCI2 transmit data output
3	SCK3	I/O	SCI3 clock input/output
	RxD3	Input	SCI3 receive data input
	TxD3	Output	SCI3 transmit data output

Notes: 1. Pin names SCK, RxD, and TxD are used in the text for all channels, omitting the channel designation.

2. The channel is not provided for the H8S/2227 Series.

14.3 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)
- Serial expansion mode register (SEMR0)*

Note: * This register is in the channel 0 of the H8S/2239 Series only.

14.3.1 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.

14.3.2 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, subsleep mode or module stop mode.

14.3.3 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.

14.3.4 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.

14.3.5 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/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/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	Stop Bit Length (enabled only in asynchronous mode) Selects the stop bit length in transmission. 0: 1 stop bit 1: 2 stop bits 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.
2	MP	0	R/W	Multiprocessor Mode (enabled only in asynchronous mode) When this bit is set to 1, the multiprocessor communication function is enabled. The PE bit and O/E bit settings are invalid in multiprocessor mode. For details, see 14.5, Multiprocessor Communication Function.
1	CKS1	0	R/W	Clock Select 0 and 1
0	CKS0	0	R/W	These bits select the clock source for the baud rate generator. 00: ϕ clock (n = 0) 01: ϕ/4 clock (n = 1) 10: ϕ/16 clock (n = 2) 11: ϕ/64 clock (n = 3) For the relationship between the bit rate register setting and the baud rate, see section 14.3.9, Bit Rate Register (BRR). n is the decimal representation of the value of n in BRR (see section 14.3.9, Bit Rate Register (BRR)).

- Smart Card Interface Mode (When SMIF in SCMR is 1)

Bit	Bit Name	Initial Value	R/W	Description
7	GM	0	R/W	GSM Mode 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 14.7.8, Clock Output Control.
6	BLK	0	R/W	When this bit is set to 1, the SCI operates in block transfer mode. For details on block transfer mode, refer to section 14.7.3, Block Transfer Mode.
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 in transmission, and the parity bit is checked in reception. In Smart Card interface mode, this bit must be set to 1.
4	O/E	0	R/W	Parity Mode (enabled only when the PE bit is 1 in asynchronous mode) 0: Selects even parity. 1: Selects odd parity. For details on setting this bit in Smart Card interface mode, refer to section 14.7.2, Data Format (Except for Block Transfer Mode).
3	BCP1	0	R/W	Base Clock Pulse 0 and 1
2	BCP0	0	R/W	These bits specify the number of base clock periods in a 1-bit transfer interval on the Smart Card interface. 00: 32 clock (S = 32) 01: 64 clock (S = 64) 10: 372 clock (S = 372) 11: 256 clock (S = 256) For details, refer to section 14.7.4, Receive Data Sampling Timing and Reception Margin in Smart Card Interface Mode. S stands for the value of S in BRR (see section 14.3.9, Bit Rate Register (BRR)).

Bit	Bit Name	Initial Value	R/W	Description
1	CKS1	0	R/W	Clock Select 0 and 1
0	CKS0	0	R/W	These bits select the clock source for the baud rate generator. 00: ϕ clock (n = 0) 01: ϕ/4 clock (n = 1) 10: ϕ/16 clock (n = 2) 11: ϕ/64 clock (n = 3) For the relationship between the bit rate register setting and the baud rate, see section 14.3.9, Bit Rate Register (BRR). n is the decimal representation of the value of n in BRR (see section 14.3.9, Bit Rate Register (BRR)).

Note: etu (Elementary Time Unit): Abbreviation for the transfer period for one bit.

14.3.6 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 14.9, 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	Transmit Interrupt Enable When this bit is set to 1, the TXI interrupt request is enabled. 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.
6	RIE	0	R/W	Receive Interrupt Enable When this bit is set to 1, RXI and ERI interrupt requests are enabled. 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.

Bit	Bit Name	Initial Value	R/W	Description
5	TE	0	R/W	Transmit Enable When this bit s set to 1, transmission is enabled. In this state, serial transmission is started when transmit data is written to TDR and the TDRE flag in SSR is cleared to 0. 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.
4	RE	0	R/W	Receive Enable When this bit is set to 1, reception is enabled. 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. SMR setting must be performed to decide the reception format before setting the RE bit to 1. Clearing the RE bit to 0 does not affect the RDRF, FER, and ORER flags, which retain their states.
3	MPIE	0	R/W	Multiprocessor Interrupt Enable (enabled only when the MP bit in SMR is 1 in asynchronous mode) When this bit is set to 1, receive data in which the multiprocessor bit is 0 is skipped, and setting of the RDRF, FER, and 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 14.5, Multiprocessor Communication Function. 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. 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.

Bit	Bit Name	Initial Value	R/W	Description
2	TEIE	0	R/W	Transmit End Interrupt Enable This bit is set to 1, TEI interrupt request is enabled. TEI cancellation can be performed by reading 1 from the DRE flag in SSR, then clearing it to 0 and clearing the TEND flag to 0, or clearing the TEIE bit to 0.
1	CKE1	0	R/W	Clock Enable 0 and 1
0	CKE0	0	R/W	Selects the clock source and SCK pin function. Asynchronous mode 00: On-chip baud rate generator SCK pin functions as I/O port 01: On-chip baud rate generator Outputs a clock of the same frequency as the bit rate from the SCK pin. 1X: External clock Inputs a clock with a frequency 16 times the bit rate from the SCK pin. Clocked synchronous mode 0X: Internal clock (SCK pin functions as clock output) 1X: External clock (SCK pin functions as clock input)

Legend

X: Don't care

- Smart Card Interface Mode (When SMIF in SCMR is 1)

Bit	Bit Name	Initial Value	R/W	Description
7	TIE	0	R/W	Transmit Interrupt Enable When this bit is set to 1, TXI interrupt request is enabled. 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.
6	RIE	0	R/W	Receive Interrupt Enable When this bit is set to 1, RXI and ERI interrupt requests are enabled. 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.
5	TE	0	R/W	Transmit Enable When this bit s set to 1, transmission is enabled. In this state, serial transmission is started when transmit data is written to TDR and the TDRE flag in SSR is cleared to 0. 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.
4	RE	0	R/W	Receive Enable When this bit is set to 1, reception is enabled. 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. SMR setting must be performed to decide the reception format before setting the RE bit to 1. Clearing the RE bit to 0 does not affect the RDRF, FER, and ORER flags, which retain their states.

Bit	Bit Name	Initial Value	R/W	Description
3	MPIE	0	R/W	Multiprocessor Interrupt Enable (enabled only when the MP bit in SMR is 1 in asynchronous mode) Write 0 to this bit in Smart Card interface mode. 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. 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.
2	TEIE	0	R/W	Transmit End Interrupt Enable Write 0 to this bit in Smart Card interface mode. 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.
1	CKE1	0	R/W	Clock Enable 0 and 1
0	CKE0	0		Enables or disables clock output from the SCK pin. The clock output can be dynamically switched in GSM mode. For details, refer to section 14.7.8, Clock Output Control. When the GM bit in SMR is 0: 00: Output disabled (SCK pin can be used as an I/O port pin) 01: Clock output 1X: Reserved When the GM bit in SMR is 1: 00: Output fixed low 01: Clock output 10: Output fixed high 11: Clock output

Legend

X: Don't care

14.3.7 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)*[1]	Transmit Data Register Empty Displays whether TDR contains transmit data. [Setting conditions] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR [Clearing conditions] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC*[2] or the DTC is activated by a TXI interrupt request and writes data to TDR
6	RDRF	0	R/(W)*[1]	Receive Data Register Full Indicates that the received data is stored in RDR. [Setting condition] • When serial reception ends normally and receive data is transferred from RSR to RDR [Clearing conditions] • When 0 is written to RDRF after reading RDRF = 1 • When the DMAC*[2] or the DTC is activated by an RXI interrupt and transferred data from RDR The RDRF flag is not affected and retains their previous values when the RE bit in SCR is cleared to 0. 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.

Bit	Bit Name	Initial Value	R/W	Description
5	ORER	0	R/(W)*[1]	Overrun Error Indicates that an overrun error occurred during reception, causing abnormal termination. [Setting condition] • When the next serial reception is completed while RDRF = 1 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. [Clearing condition] • When 0 is written to ORER after reading ORER = 1 The ORER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.
4	FER	0	R/(W)*[1]	Framing Error Indicates that a framing error occurred during reception in asynchronous mode, causing abnormal termination. [Setting condition] • When the stop bit is 0 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. [Clearing condition] • When 0 is written to FER after reading FER = 1 In 2-stop-bit mode, only the first stop bit is checked. The FER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.

Bit	Bit Name	Initial Value	R/W	Description
3	PER	0	R/(W)*[1]	Parity Error Indicates that a parity error occurred during reception using parity addition in asynchronous mode, causing abnormal termination. [Setting condition.] • When a parity error is detected during reception 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. [Clearing condition] • When 0 is written to PER after reading PER = 1 The PER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.
2	TEND	1	R	Transmit End Indicates that transmission has been ended. [Setting conditions] • When the TE bit in SCR is 0 • When TDRE = 1 at transmission of the last bit of a 1-byte serial transmit character [Clearing conditions] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC*[2] or the DTC is activated by a TXI interrupt request and transfer transmission data to TDR
1	MPB	0	R	Multiprocessor Bit MPB stores the multiprocessor bit in the receive data. When the RE bit in SCR is cleared to 0 its previous state is retained.
0	MPBT	0	R/W	Multiprocessor Bit Transfer MPBT stores the multiprocessor bit to be added to the transmit data.

Notes: 1. Only a 0 can be written to this bit, to clear the flag.

2. Supported only by the H8S/2239 Series.

- Smart Card Interface Mode (When SMIF in SCMR is 1)

Bit	Bit Name	Initial Value	R/W	Description
7	TDRE	1	R/(W)*[1]	Transmit Data Register Empty Indicates whether TDR contains transmit data. [Setting conditions] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR [Clearing conditions] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC*[2] or the DTC is activated by a TXI interrupt request and writes data to TDR
6	RDRF	0	R/(W)*[1]	Receive Data Register Full Indicates that the received data is stored in RDR. [Setting condition] • When serial reception ends normally and receive data is transferred from RSR to RDR [Clearing conditions] • When 0 is written to RDRF after reading RDRF = 1 • When the DTC is activated by an RXI interrupt and transferred data from RDR The RDRF flag is not affected and retains their previous values when the RE bit in SCR is cleared to 0. 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.

Bit	Bit Name	Initial Value	R/W	Description
5	ORER	0	R/(W)*[1]	Overrun Error Indicates that an overrun error occurred during reception, causing abnormal termination. [Setting condition] • When the next serial reception is completed while RDRF = 1 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. [Clearing condition] • When 0 is written to ORER after reading ORER = 1 The ORER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.
4	ERS	0	R/(W)*[1]	Error Signal Status Indicates that the status of an error signal returned from the receiving end at reception [Setting condition] • When the low level of the error signal is sampled [Clearing conditions] • When 0 is written to ERS after reading ERS = 1 The ERS flag is not affected and retains its previous state when the TE bit in SCR is cleared to 0.

Bit	Bit Name	Initial Value	R/W	Description
3	PER	0	R/(W)*[1]	Parity Error Indicates that a parity error occurred during reception using parity addition in asynchronous mode, causing abnormal termination. [Setting condition] • When a parity error is detected during reception 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. [Clearing condition] • When 0 is written to PER after reading PER = 1 The PER flag is not affected and retains its previous state when the RE bit in SCR is cleared to 0.

Bit	Bit Name	Initial Value	R/W	Description
2	TEND	1	R	Transmit End 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. [Setting conditions] • When the TE bit in SCR is 0 and the ERS bit is also 0 • When the ESR bit is 0 and the TDRE bit is 1 after the specified interval following transmission of 1-byte data. The timing of bit setting differs according to the register setting as follows: When GM = 0 and BLK = 0, 2.5 etu after transmission starts When GM = 0 and BLK = 1, 1.0 etu after transmission starts When GM = 1 and BLK = 0, 1.5 etu after transmission starts When GM = 1 and BLK = 1, 1.0 etu after transmission starts [Clearing conditions] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC*[2] or the DTC is activated by a TXI interrupt and transfers transmission data to TDR
1	MPB	0	R	Multiprocessor Bit This bit is not used in Smart Card interface mode.
0	MPBT	0	R/W	Multiprocessor Bit Transfer Write 0 to this bit in Smart Card interface mode.

Notes: 1. Only 0 can be written to this bit, to clear the flag.
2. Supported only by the H8S/2239 Series.

14.3.8 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	—	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

14.3.9 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 14.2 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 14.2 The Relationships between The N Setting in BRR and Bit Rate B

Communication Mode	ABCS bit	Bit Rate	Error
Asynchronous Mode	0	$B = \frac{\phi \times 10^6}{64 \times 2^{2n-1} \times (N + 1)}$	$\text{Error (\%)} = \{ \frac{\phi \times 10^6}{B \times 64 \times 2^{2n-1} \times (N + 1)} - 1 \} \times 100$
	1	$B = \frac{\phi \times 10^6}{32 \times 2^{2n-1} \times (N + 1)}$	$\text{Error (\%)} = \{ \frac{\phi \times 10^6}{B \times 32 \times 2^{2n-1} \times (N + 1)} - 1 \} \times 100$
Clocked Synchronous Mode	—	$B = \frac{\phi \times 10^6}{8 \times 2^{2n-1} \times (N + 1)}$	—
Smart Card Interface Mode	—	$B = \frac{\phi \times 10^6}{S \times 2^{2n-1} \times (N + 1)}$	$\text{Error (\%)} = \{ \frac{\phi \times 10^6}{B \times S \times 2^{2n-1} \times (N + 1)} - 1 \} \times 100$

Notes: 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	
CKS1	CKS0	Source	n
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 14.3 shows sample N settings in BRR in normal asynchronous mode. Table 14.4 shows the maximum bit rate for each frequency in normal asynchronous mode. Table 14.6 shows sample N settings in BRR in clocked synchronous mode. Table 14.8 shows sample N settings in BRR in Smart Card interface mode. In Smart Card interface mode, S (the number of base clock periods in a 1-bit transfer interval) can be selected. For details, refer to section 14.7.4, Receive Data Sampling Timing and Reception Margin. Tables 14.5 and 14.7 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 14.4 and 14.5.

Table 14.3 BRR Settings for Various Bit Rates (Asynchronous Mode)

	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	0.03
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	—	—	—

	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	0.03	2	86	0.31	2	88	–0.25
150	1	191	0.00	1	207	0.16	1	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	0	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	—	—	—

	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*		
Bit Rate (bps)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	248	–0.17	3	64	0.70	3	70	0.03
150	2	181	0.16	2	191	0.00	2	207	0.16
300	2	90	0.16	2	95	0.00	2	103	0.16
600	1	181	0.16	1	191	0.00	1	207	0.16
1200	1	90	0.16	1	95	0.00	1	103	0.16
2400	0	181	0.16	0	191	0.00	0	207	0.16
4800	0	90	0.16	0	95	0.00	0	103	0.16
9600	0	45	–0.93	0	47	0.00	0	51	0.16
19200	0	22	–0.93	0	23	0.00	0	25	0.16
31250	0	13	0.00	0	14	–1.70	0	15	0.00
38400	—	—	—	0	11	0.00	0	12	0.16

Note: * Supported only by the H8S/2239 Series.

Table 14.4 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	7.3728	230.4	0	0
2.097152	65.536	0	0	8	250.0	0	0
2.4576	76.8	0	0	9.8304	307.2	0	0
3	93.75	0	0	10	312.5	0	0
3.6864	115.2	0	0	12	375.0	0	0
4	125.0	0	0	12.288	384.0	0	0
4.9152	153.6	0	0	14*	437.5	0	0
5	156.25	0	0	14.7456*	460.8	0	0
6	187.5	0	0	16*	500.0	0	0
6.144	192.0	0	0				

Note: * Supported only by the H8S/2239 Series.

Table 14.5 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			
6	1.5000	93.75			
6.144	1.5360	96.0			
7.3728	1.8432	115.2			
8	2.0000	125.0			

Note: * Supported only by the H8S/2239 Series.

Table 14.6 BRR Settings for Various Bit Rates (Clocked Synchronous Mode)

Bit Rate (bps)	Operating Frequency ϕ (MHz)									
	2		4		8		10		16	
	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
1 k	1	124	1	249	2	124	—	—	2	249
2.5 k	0	199	1	99	1	199	1	249	2	99
5 k	0	99	0	199	1	99	1	124	1	199
10 k	0	49	0	99	0	199	0	249	1	99
25 k	0	19	0	39	0	79	0	99	0	159
50 k	0	9	0	19	0	39	0	49	0	79
100 k	0	4	0	9	0	19	0	24	0	39
250 k	0	1	0	3	0	7	0	9	0	15
500 k	0	0*	0	1	0	3	0	4	0	7
1 M			0	0*	0	1			0	3
2.5 M							0	0*		
5 M										

Legend

Blank : Cannot be set.

— : Can be set, but there will be a degree of error.

* : Continuous transfer is not possible.

Note: * Supported only by the H8S/2239 Series.

Table 14.7 Maximum Bit Rate with External Clock Input (Clocked Synchronous Mode)

ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bps)
2	0.3333	0.333
4	0.6667	0.667
6	1.0000	1.000
8	1.3333	1.333
10	1.6667	1.667
12	2.0000	2.000
14*	2.3333	2.333
16*	2.6667	3.667

Note: * Supported only by the H8S/2239 Series.

Table 14.8 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	0.00	1	30	1	25

Bit Rate (bps)	Operating Frequency ϕ (MHz)					
	13.00		14.2848*		16.00*	
	N	Error (%)	N	Error (%)	N	Error (%)
6720	2	13.33	2	4.76	2	6.67
9600	1	8.99	1	0.00	1	12.01

Note: * Supported only by the H8S/2239 Series.

Table 14.9 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

Note: * Supported only by the H8S/2239 Series.

14.3.10 Serial Expansion Mode Register (SEMR_0)

SEMR_0 is an 8-bit register that expands SCI_0 functions; such as setting of the base clock, selecting of the clock source, and automatic setting of the transfer rate.

Note: Supported only by the H8S/2239 Series only.

Bit	Bit Name	Initial Value	R/W	Description
7	SSE	0	R/W	SCI_0 Select Enable This bit enables or disables the SCI_0 select function when an external clock is input in clocked synchronous mode. When 1 is set to the PG1/IRQ7 pin, while the SCI_0 select function is enabled, the TxD0 output becomes Hi-Z and the SCK0 input in this LSI is fixed high making the SCI_0 data transfer terminated. The SSE setting is valid when the external clock input is selected (CKE in SCR = 0) in clocked synchronous mode (C/A in SMR = 1). 0: SCI_0 select is disabled. 1: SCI_0 select is enabled. When then PG1/IRQ7 pin = 1, the TxD0 output becomes Hi-Z and the SCK0 clock input is fixed high.
6 to 4	—	Undefined	—	Reserved These bits are always read as 0, and cannot be modified.
3	ABCS	0	R/W	Asynchronous Base Clock Select Selects the 1-bit-interval base clock in asynchronous mode. The ABCS setting is valid in asynchronous mode (C/A in SMR = 0). 0: Operates on a base clock with a frequency of 16 times the transfer rate. 1: Operates on a base 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.
0	ACS0	0	R/W	The ACS0 to ACS0 settings are valid when the external clock input is selected (CKE in SCR = 0) in asynchronous mode (C/A in SMR = 0). 000: External clock input 001: Selects the average transfer rate 115.152 kbps only for ϕ = 10.667 MHz (operates on a base clock with a frequency of 16 times the transfer rate). 001: Selects the average transfer rate 460.606 kbps only for ϕ = 10.667 MHz (operates on a base clock with a frequency of 8 times the transfer rate). 011: Reserved 100: TPU clock input (logical AND of TIOCA1 and TIOCA2) 101: Selects the average transfer rate 115.196 kbps only for ϕ = 16 MHz (operates on a base clock with a frequency of 16 times the transfer rate). 110: Selects the average transfer rate 460.784 kbps only for ϕ = 16 MHz (operates on a base clock with a frequency of 16 times the transfer rate). 111: Selects the average transfer rate 720 kbps only for ϕ = 16 MHz (operates on a base clock with a frequency of 8 times the transfer rate).

Figures 14.3 and 14.4 show an example of the internal base clock when the average transfer rate is selected.

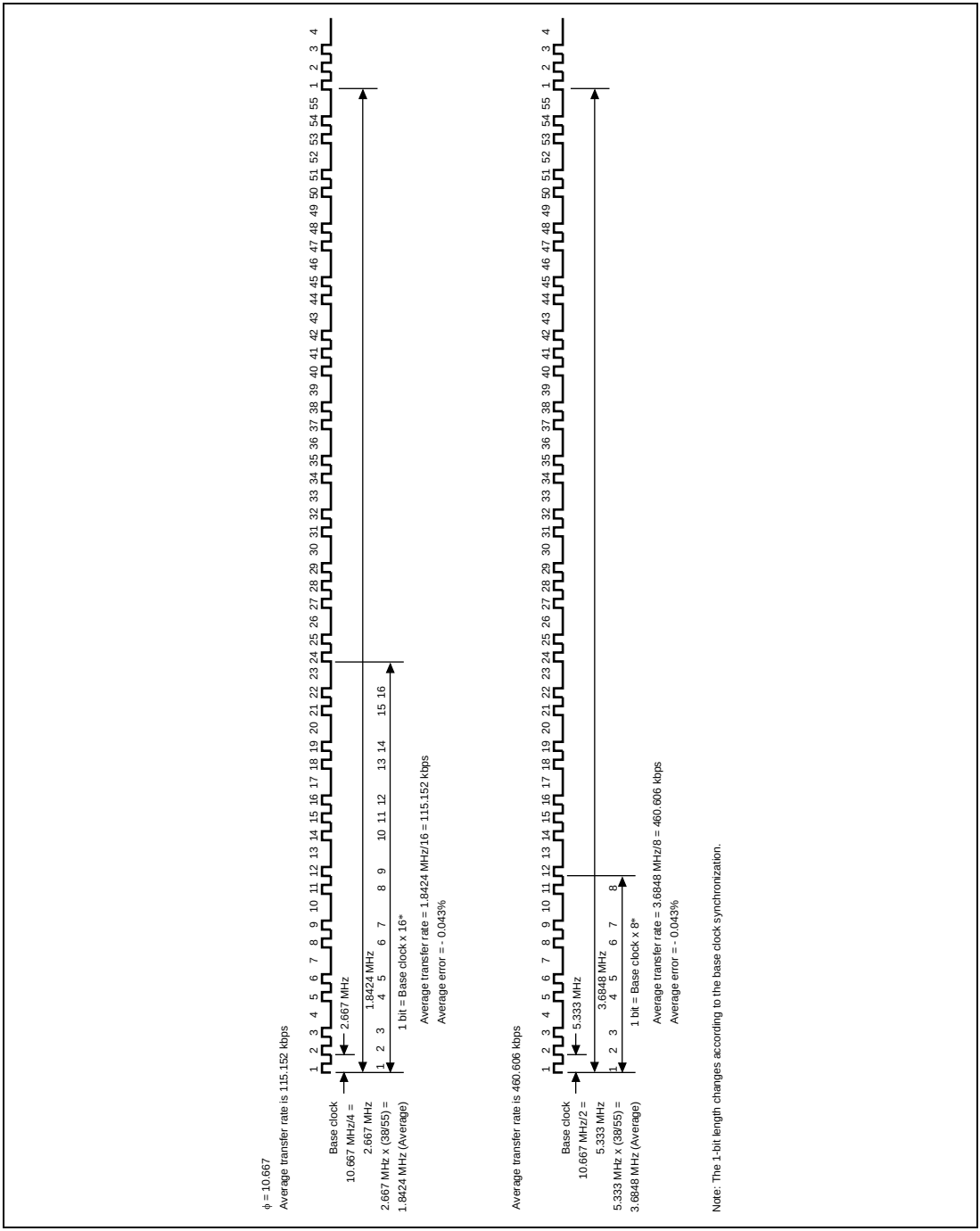


Figure 14.3 Example of the Internal Base Clock When the Average Transfer Rate is Selected (1)

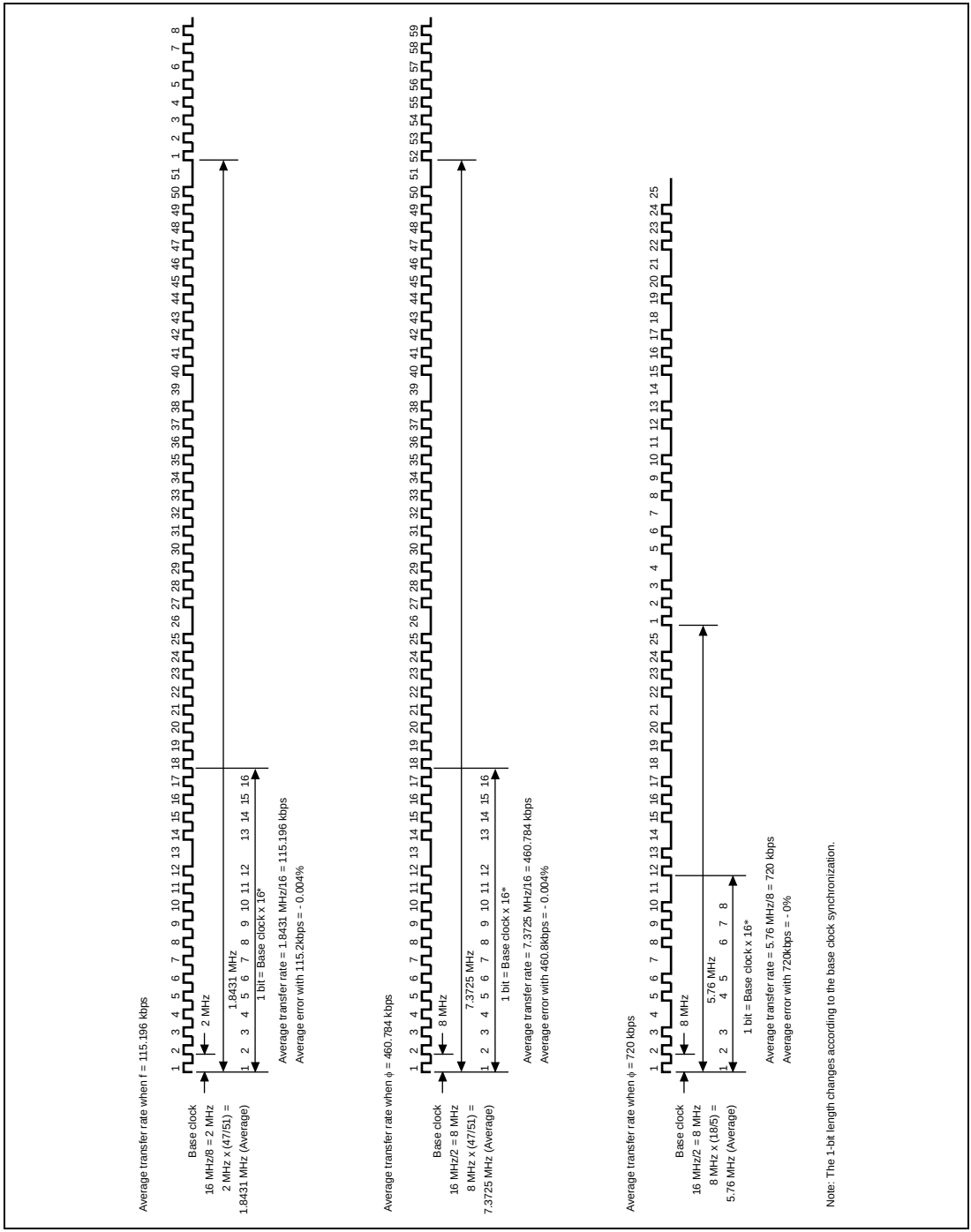


Figure 14.4 Example of the Internal Base Clock When the Average Transfer Rate is Selected (2)

14.4 Operation in Asynchronous Mode

Figure 14.5 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.

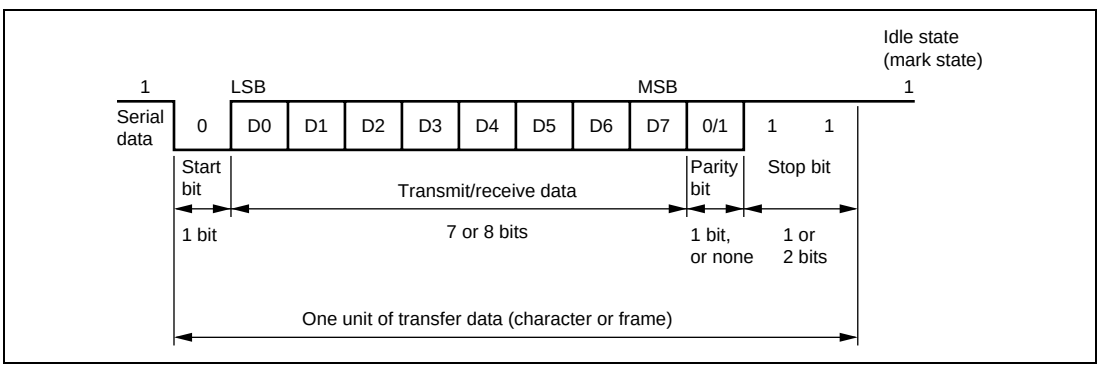


Figure 14.5 Data Format in Asynchronous Communication (Example with 8-Bit Data, Parity, Two Stop Bits)

14.4.1 Data Transfer Format

Table 14.10 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 14.5, Multiprocessor Communication Function.

Table 14.10 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

14.4.2 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI operates on a base clock with a frequency of 16 times the transfer rate. In reception, the SCI samples the falling edge of the start bit using the base clock, and performs internal synchronization. Receive data is latched internally at the rising edge of the 8th pulse of the base clock as shown in figure 14.6. Thus, the reception margin in asynchronous mode is given by formula (1) below.

$$M = \{ (0.5 - \frac{1}{2N}) - \frac{D - 0.5}{N} - (L - 0.5) F\} \times 100 \ [\%]$$

... 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.

$M = \{0.5 - 1/(2 \times 16)\} \times 100 \ [\%] = 46.875\%$

However, this is only the computed value, and a margin of 20% to 30% should be allowed for in system design.

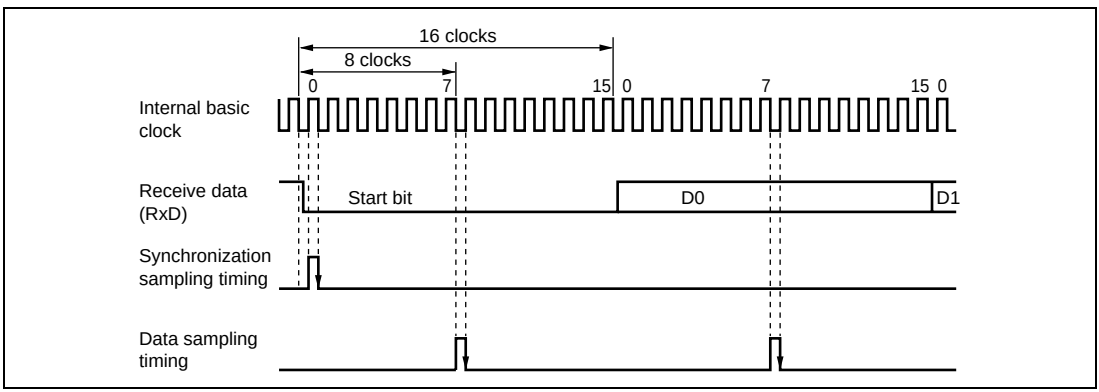


Figure 14.6 Receive Data Sampling Timing in Asynchronous Mode

14.4.3 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/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 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 14.7.

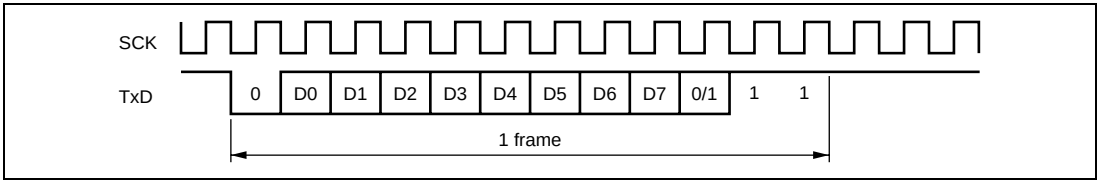


Figure 14.7 Relationship between Output Clock and Transfer Data Phase (Asynchronous Mode)

14.4.4 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 in figure 14.8. 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.

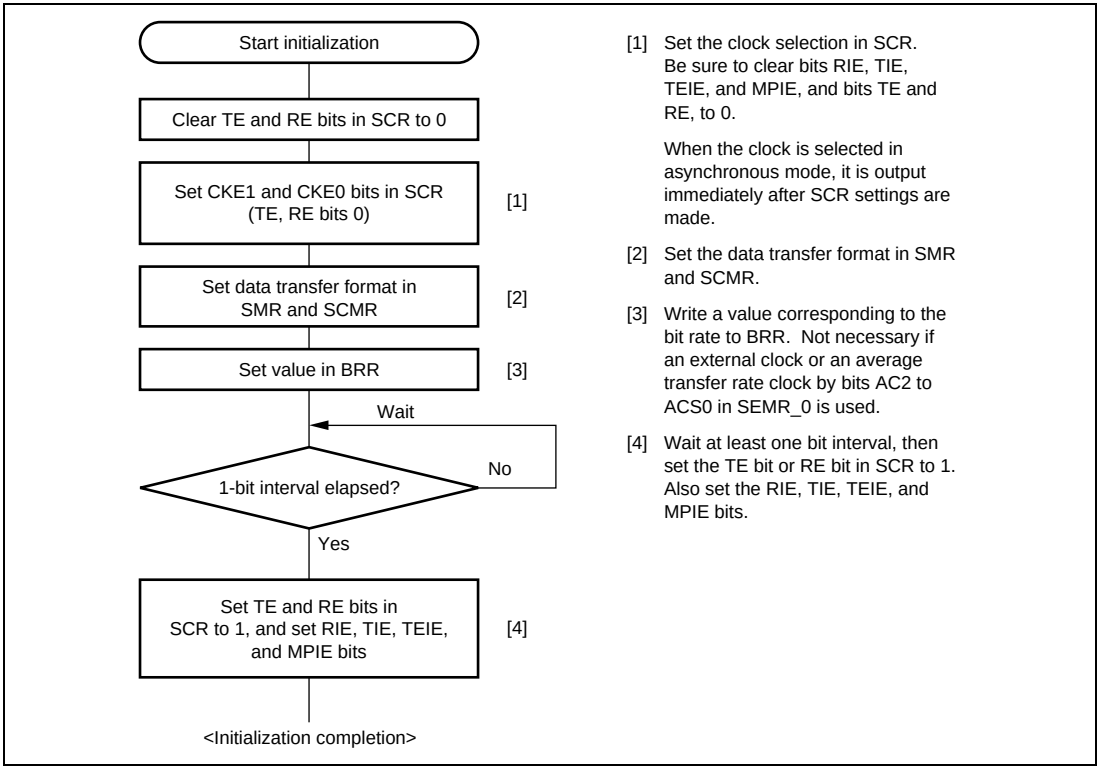


Figure 14.8 Sample SCI Initialization Flowchart

14.4.5 Serial Data Transmission (Asynchronous Mode)

Figure 14.9 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.

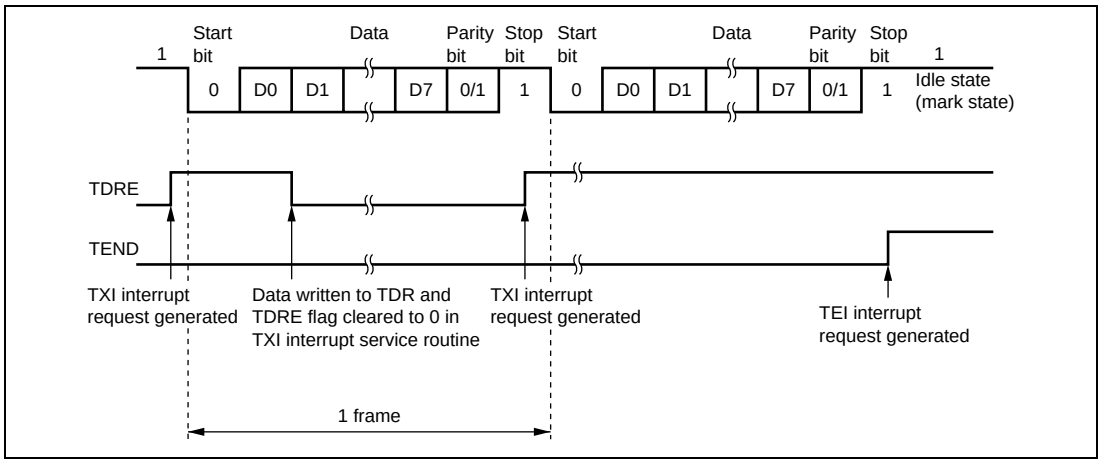
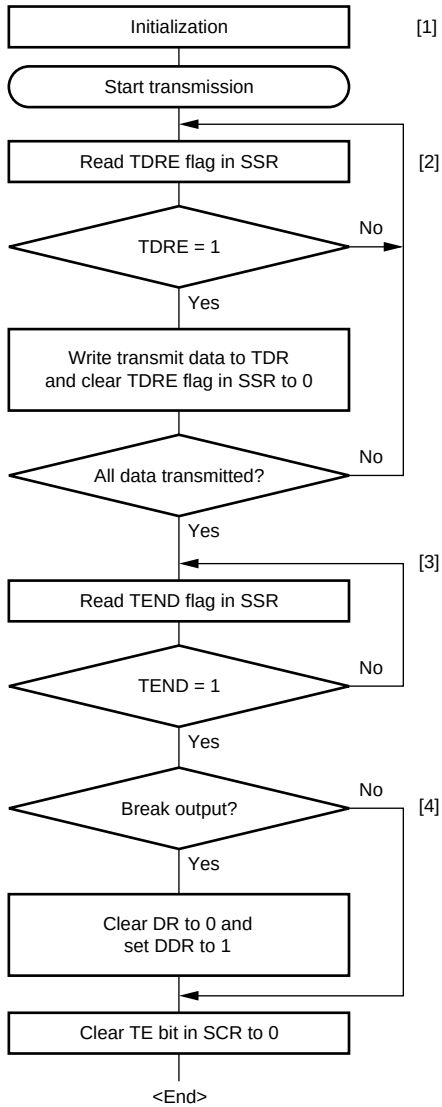


Figure 14.9 Example of Operation in Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)

Figure 14.10 shows a sample flowchart for data transmission.



[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 and clear the TDRE flag to 0.

[3] Serial transmission continuation procedure:
To continue serial transmission, 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 DMAC* or the DTC is activated by a transmit-data -empty interrupt (TXI) request, and data is written to TDR.

[4] Break output at the end of serial transmission:
To output a break in serial transmission, set DR for the port corresponding to the TxD pin to 0, clear DDR to 1, then clear the TE bit in SCR to 0.

Note: * Supprted only by the H8S/2239 Series.

Figure 14.10 Sample Serial Transmission Flowchart

14.4.6 Serial Data Reception (Asynchronous Mode)

Figure 14.11 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 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. 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.

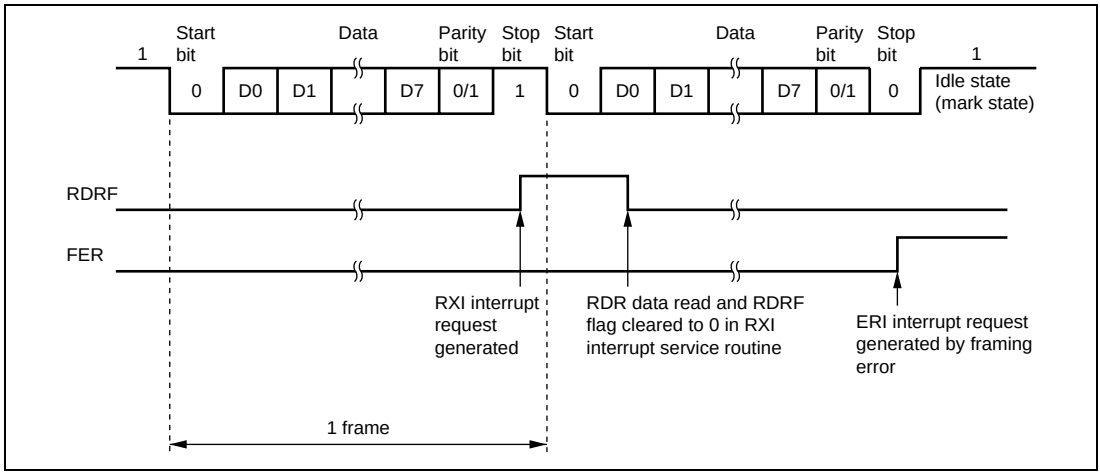


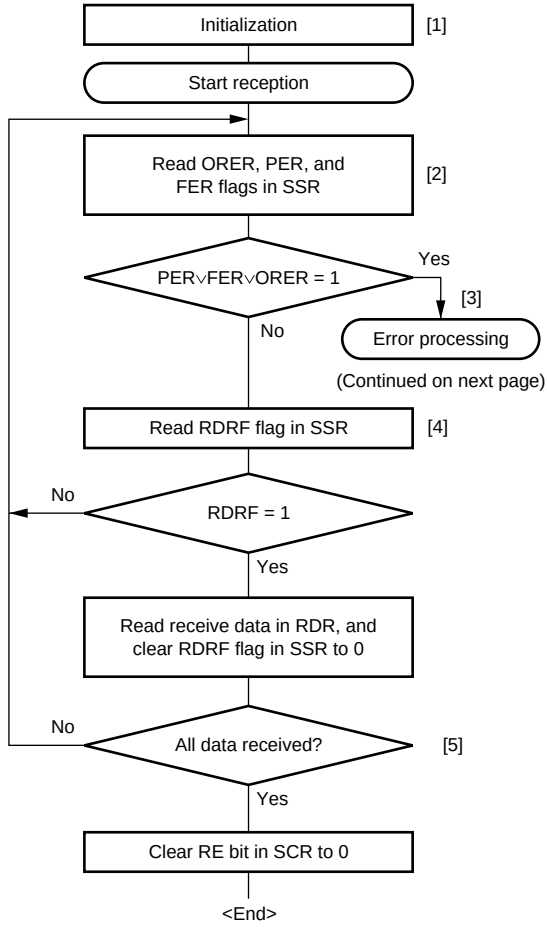
Figure 14.11 Example of SCI Operation in Reception (Example with 8-Bit Data, Parity, One Stop Bit)

Table 14.11 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 14.12 shows a sample flow chart for serial data reception.

Table 14.11 SSR Status Flags and Receive Data Handling

SSR Status Flag					
RDRF*	**ORER**	**FER**	**PER**	**Receive Data**	**Receive Error Type**
1	1	0	0	Lost	Overrun error
0	0	1	0	Transferred to RDR	Framing error
0	0	0	1	Transferred to RDR	Parity error
1	1	1	0	Lost	Overrun error + framing error
1	1	0	1	Lost	Overrun error + parity error
0	0	1	1	Transferred to RDR	Framing error + parity error
1	1	1	1	Lost	Overrun error + framing error + parity error

Note: * The RDRF flag retains the state it had before data reception.



[1] SCI initialization:
The RxD 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 RxD 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 the DMAC* or the DTC is activated by an RXI interrupt and the RDR value is read.

Note: * Supprted only by the H8S/2239 Series.

Figure 14.12 Sample Serial Reception Data Flowchart (1)

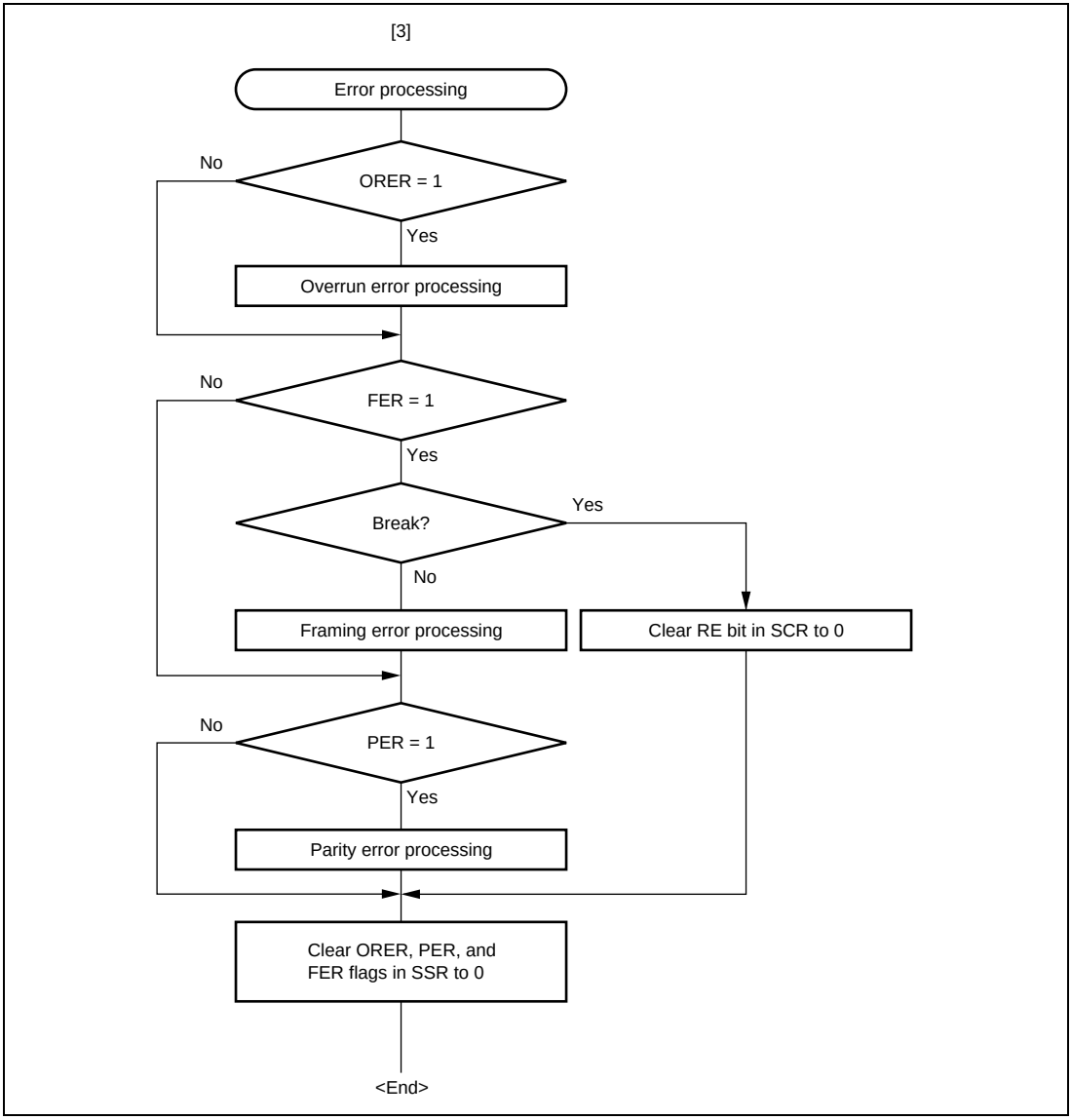


Figure 14.12 Sample Serial Reception Data Flowchart (2)

14.5 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 14.13 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.

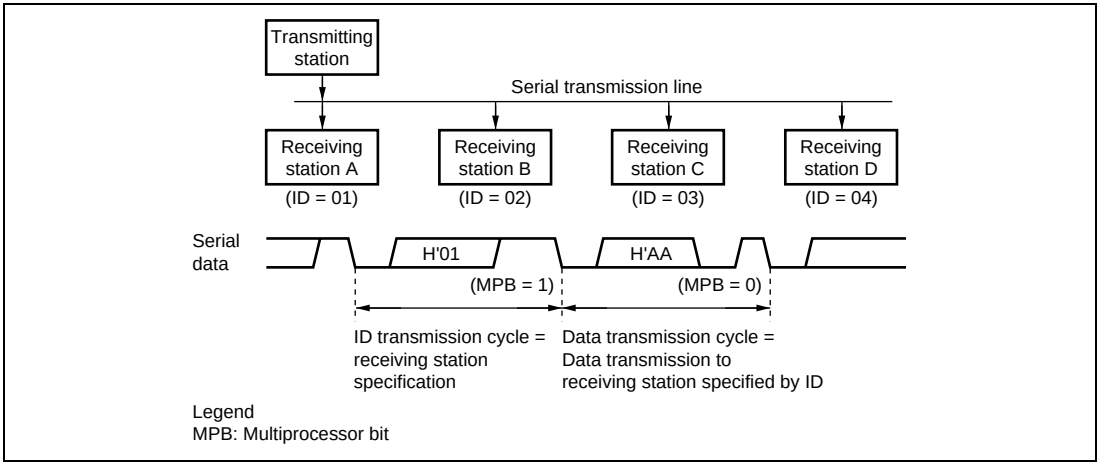
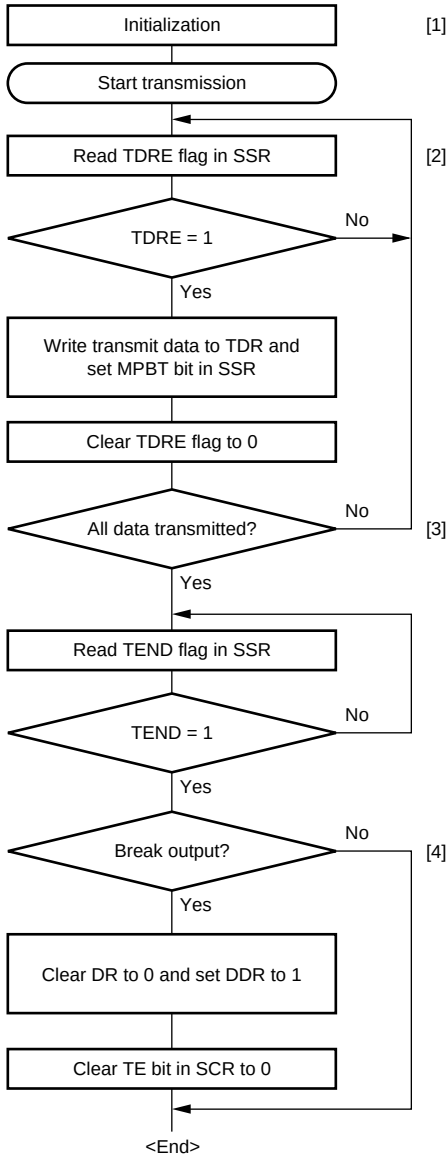


Figure 14.13 Example of Communication Using Multiprocessor Format (Transmission of Data H'AA to Receiving Station A)

14.5.1 Multiprocessor Serial Data Transmission

Figure 14.14 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 DMAC* or the DTC is activated by a transmit-data-empty interrupt (TXI) request, and data is written to TDR.

[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.

Note: * Supprted only by the H8S/2239 Series.

Figure 14.14 Sample Multiprocessor Serial Transmission Flowchart

14.5.2 Multiprocessor Serial Data Reception

Figure 14.16 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 14.15 shows an example of SCI operation for multiprocessor format reception.

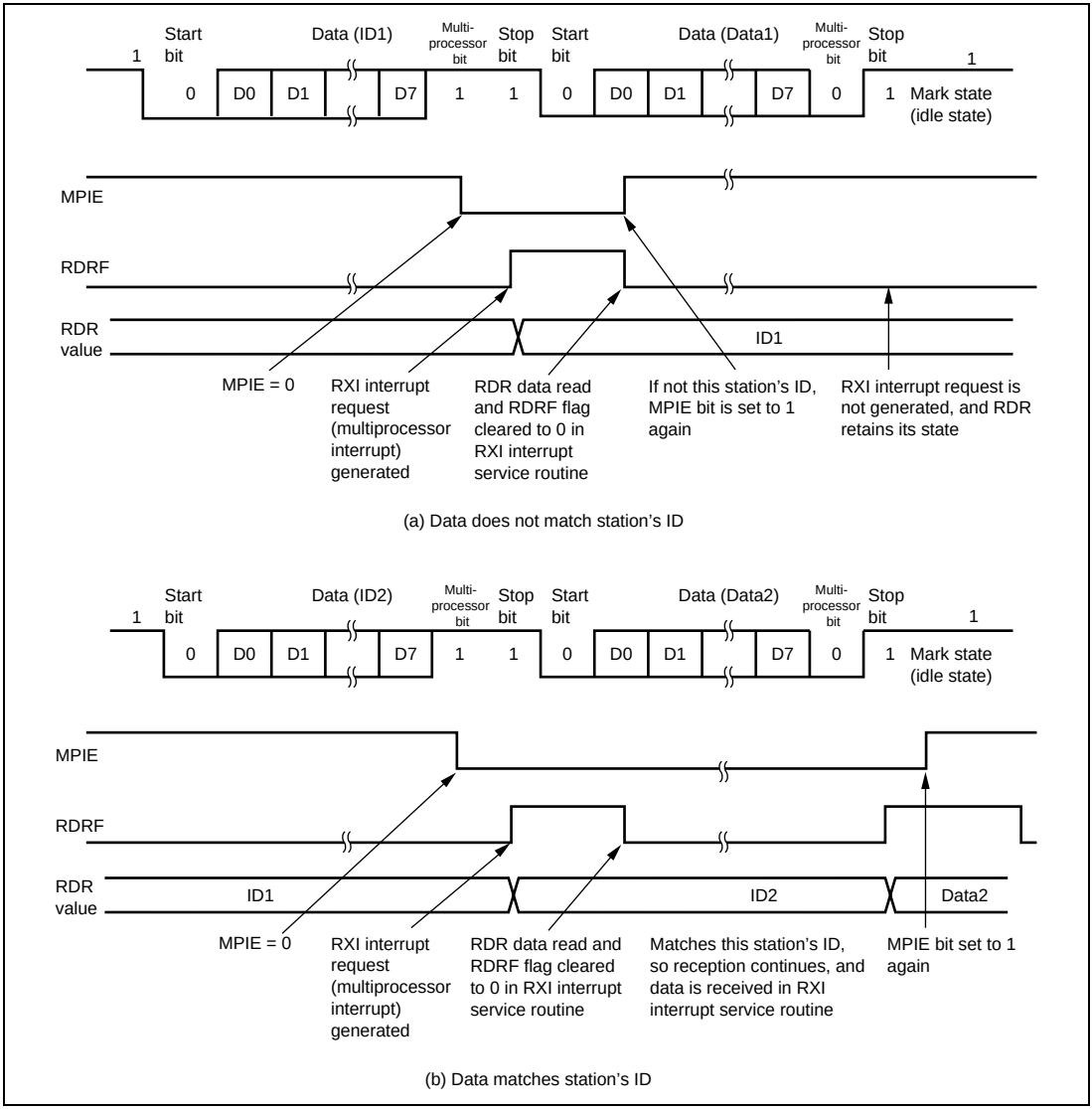
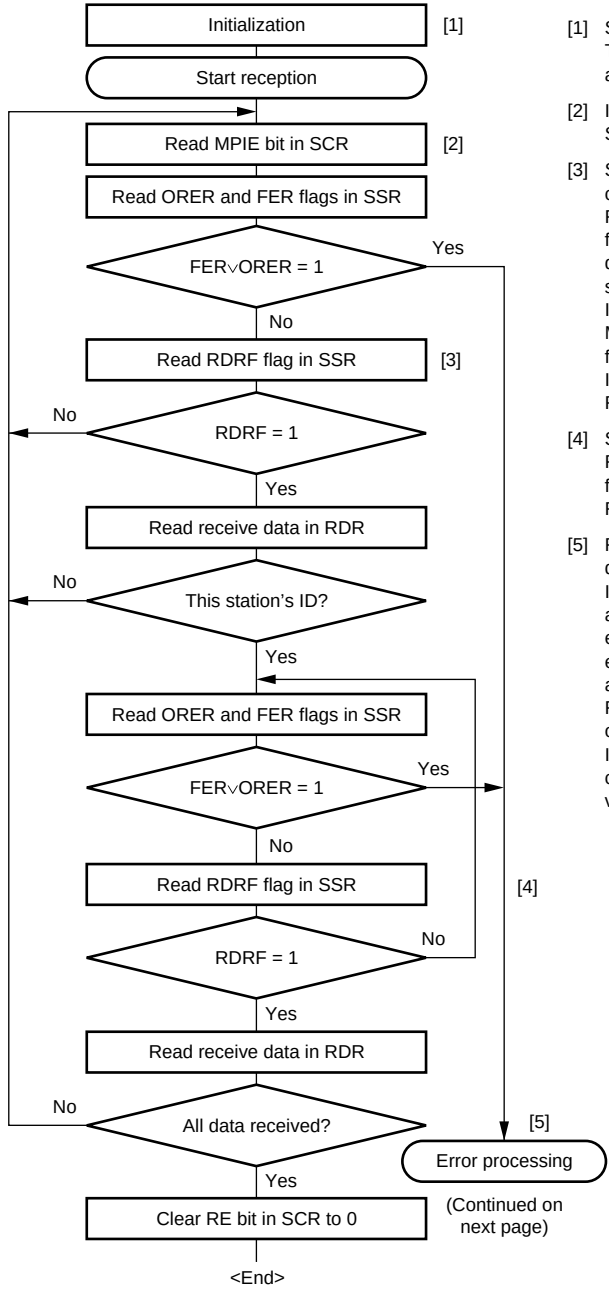


Figure 14.15 Example of SCI Operation in Reception (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)



[1] SCI initialization:
The RxD 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 RxD pin value.

Figure 14.16 Sample Multiprocessor Serial Reception Flowchart (1)

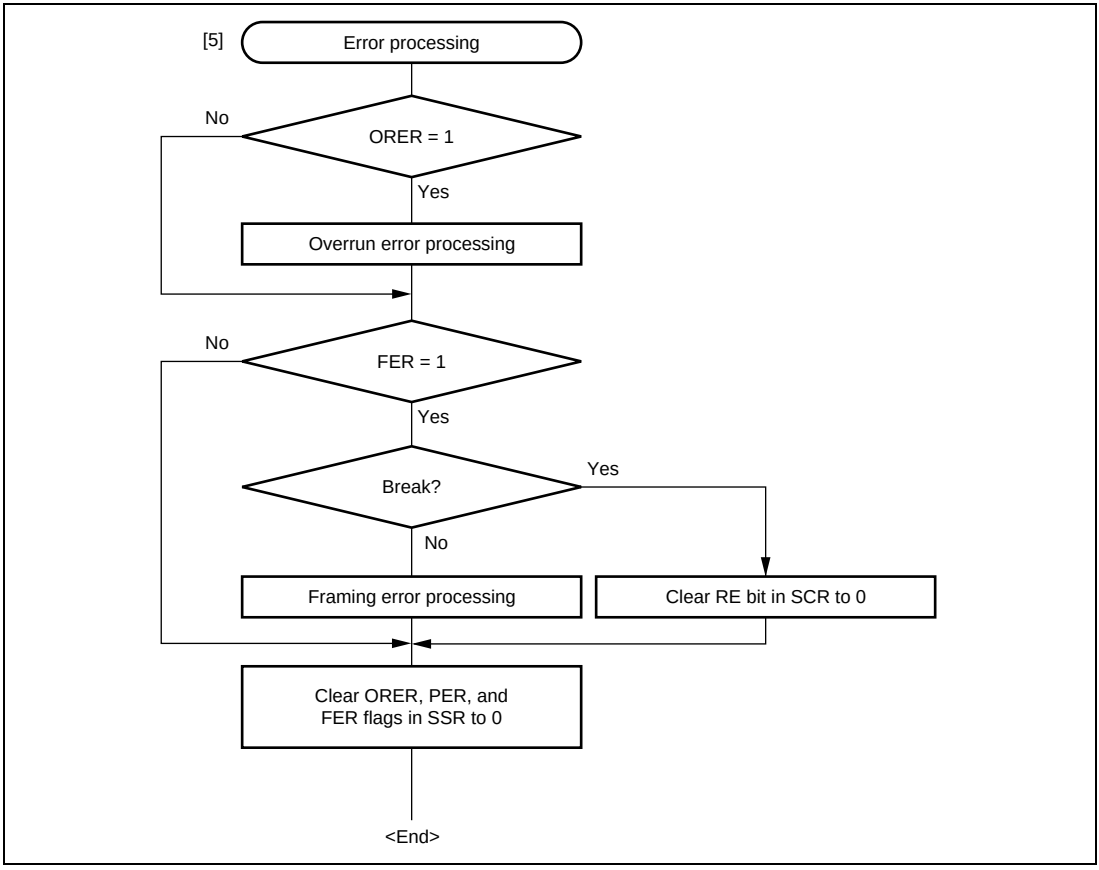


Figure 14.16 Sample Multiprocessor Serial Reception Flowchart (2)

14.6 Operation in Clocked Synchronous Mode

Figure 14.17 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.

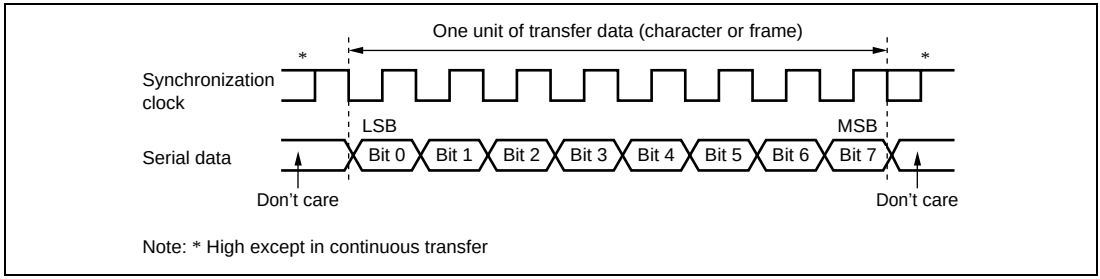


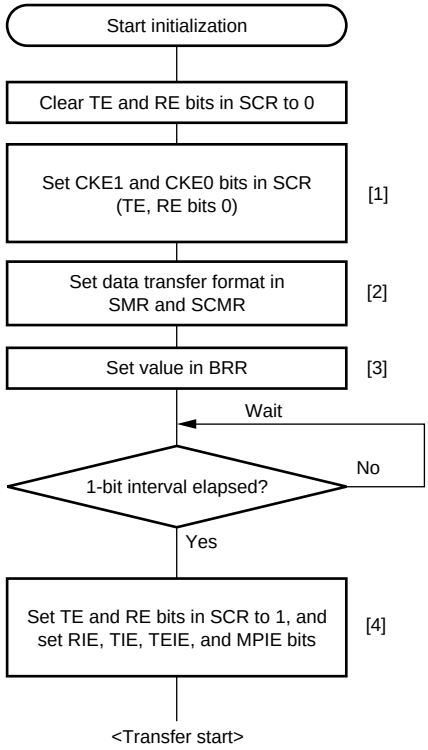
Figure 14.17 Data Format in Synchronous Communication (For LSB-First)

14.6.1 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.

14.6.2 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 14.18. 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 14.18 Sample SCI Initialization Flowchart

14.6.3 Serial Data Transmission (Clocked Synchronous Mode)

Figure 14.19 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 14.20 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.

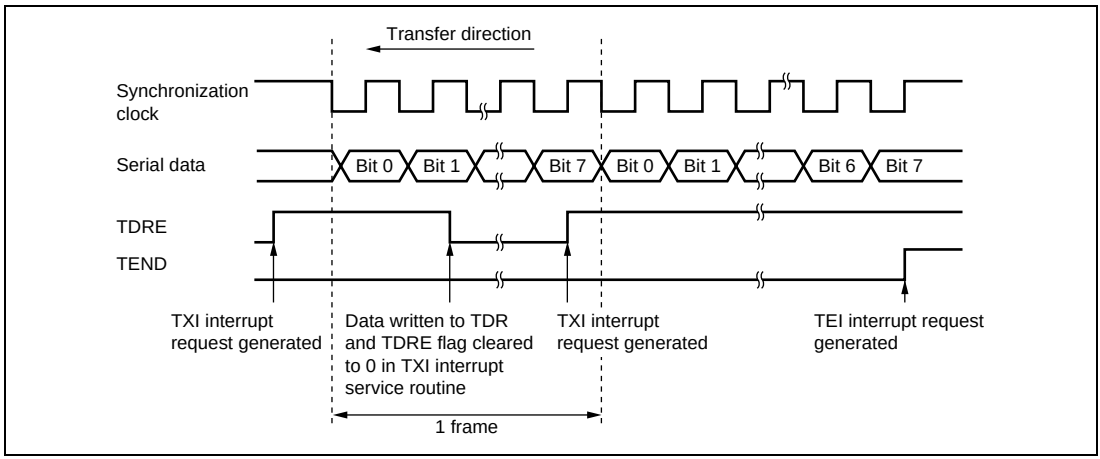
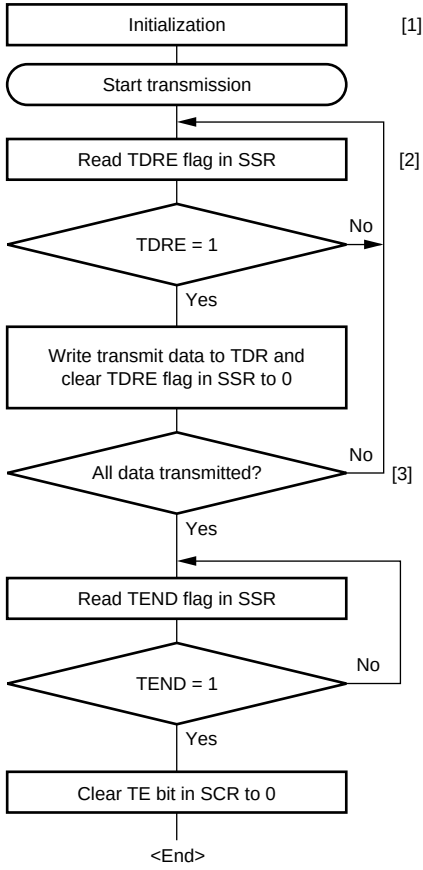


Figure 14.19 Sample SCI Transmission Operation in Clocked Synchronous Mode



[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 DMAC* or the DTC is activated by a transmit data empty interrupt (TXI) request and data is written to TDR.

Note: * Supprted only by the H8S/2239 Series.

Figure 14.20 Sample Serial Transmission Flowchart

14.6.4 Serial Data Reception (Clocked Synchronous Mode)

Figure 14.21 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.

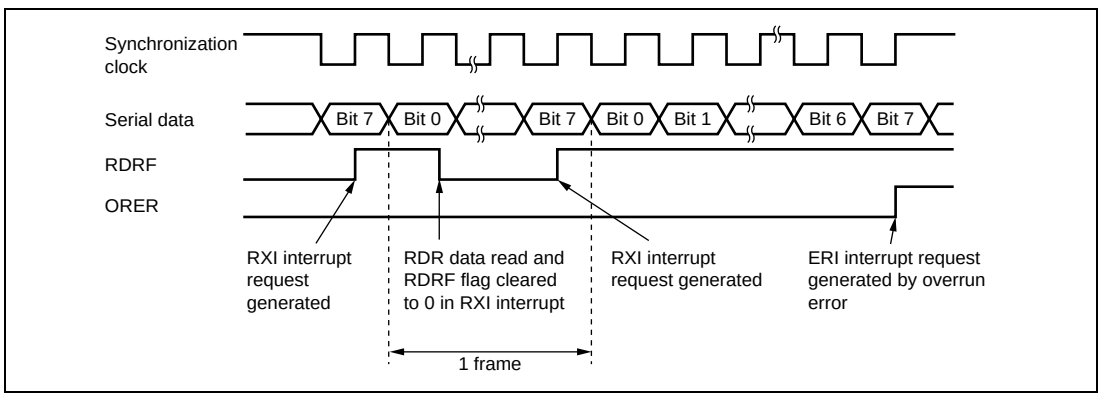
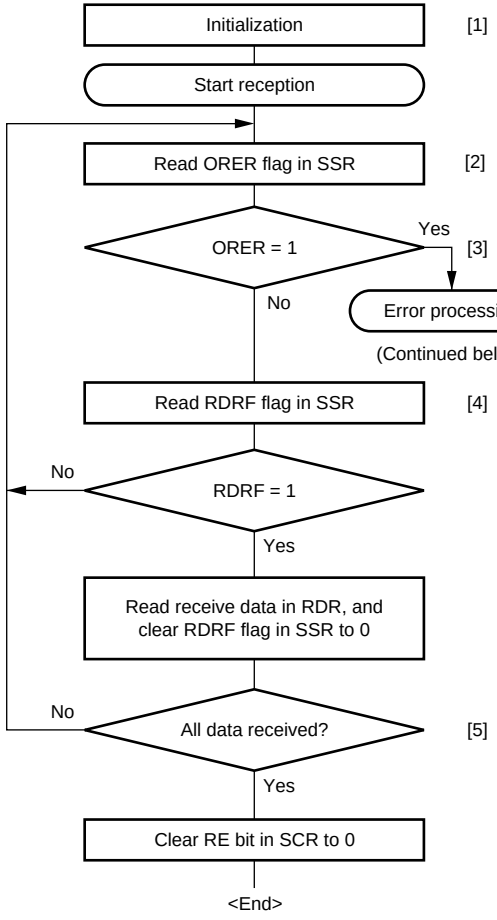
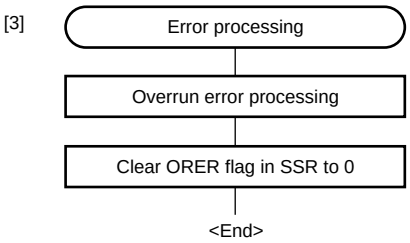


Figure 14.21 Example of SCI Operation in Reception

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 14.22 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.





[1] SCI initialization:
The RxD pin is automatically designated as the receive data input pin.

[2] [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. Transfer 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.

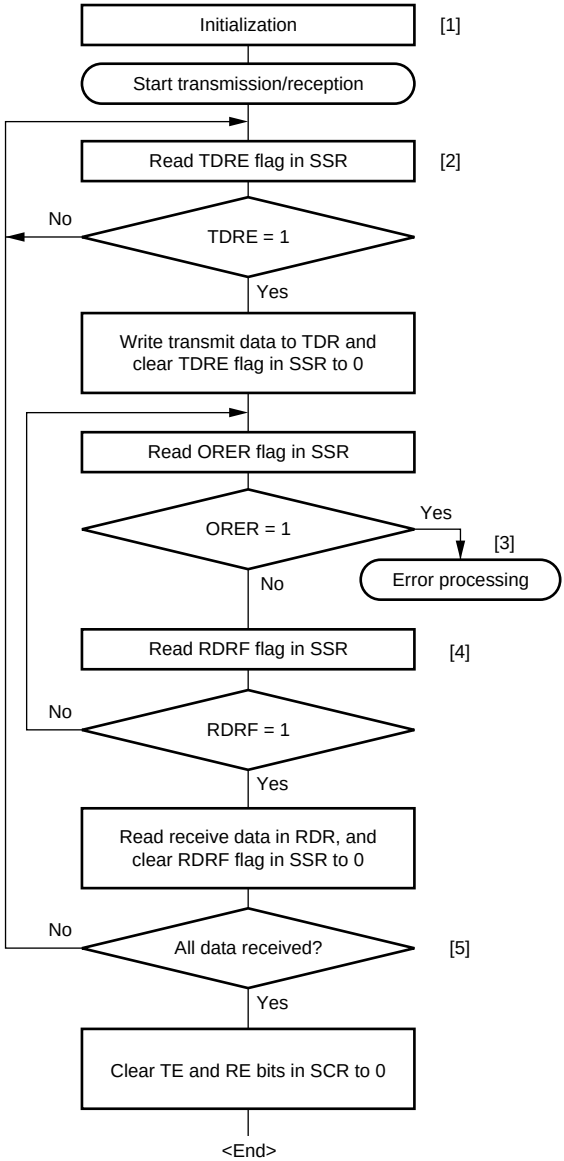
[5] Serial reception continuation procedure:
To continue serial reception, before the final bit of the current frame is received, reading the RDRF flag, reading RDR, and clearing the RDRF flag to 0 should be finished. The RDRF flag is cleared automatically when the DMAC* or the DTC is activated by a receive data full interrupt (RXI) request and the RDR value is read.

Note: * Supprted only by the H8S/2239 Series.

Figure 14.22 Sample Serial Reception Flowchart

14.6.5 Simultaneous Serial Data Transmission and Reception (Clocked Synchronous Mode)

Figure 14.23 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 bitof 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 DMAC* or the DTC is activated by a receive data full interrupt (RXI) request and the RDR value is read.

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.
* Supprted only by the H8S/2239

Figure 14.23 Sample Flowchart of Simultaneous Serial Transmit and Receive Operations

14.7 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.

14.7.1 Pin Connection Example

Figure 14.24 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 TxD pin and RxD 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.

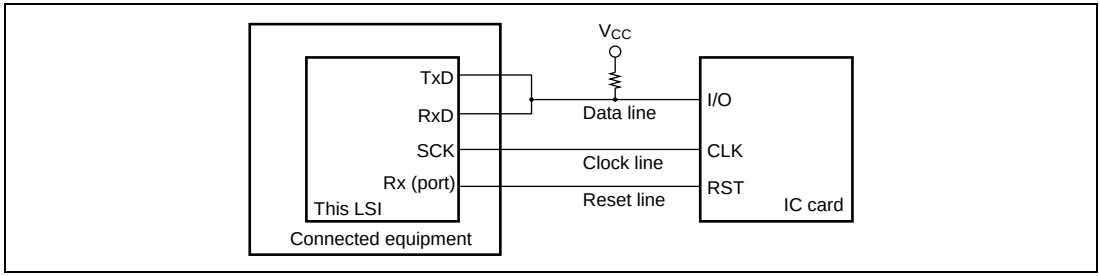


Figure 14.24 Schematic Diagram of Smart Card Interface Pin Connections

14.7.2 Data Format (Except for Block Transfer Mode)

Figure 14.25 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.

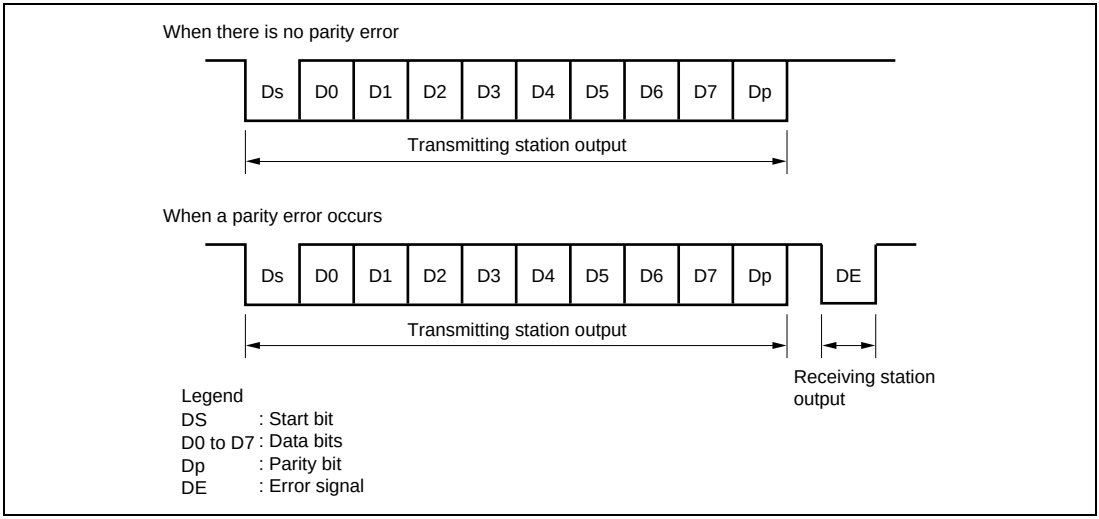


Figure 14.25 Normal Smart Card Interface Data Format

Data transfer with other types of IC cards (direct convention and inverse convention) are performed as described in the following.

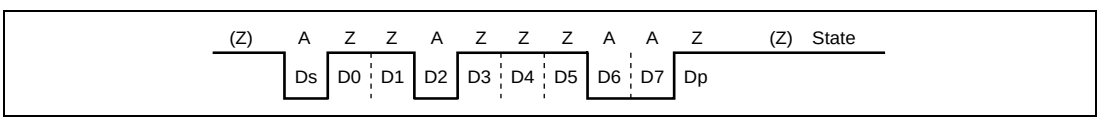


Figure 14.26 Direct Convention (SDIR = SINV = O/E = 0)

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 O/E bit in SMR to 0 to select even parity mode.

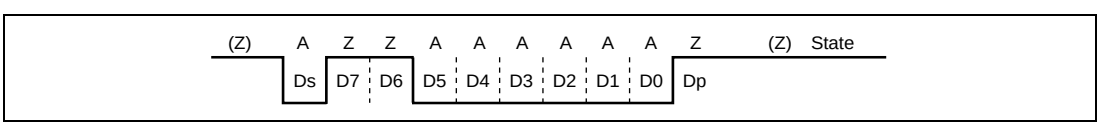


Figure 14.27 Inverse Convention (SDIR = SINV = O/E = 1)

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 O/E bit in SMR to 1 to invert the parity bit for both transmission and reception.

14.7.3 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.

14.7.4 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 base 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 base clock, and performs internal synchronization. As shown in figure 14.28, by sampling receive data at the rising-edge of the 16th, 32nd, 186th, or 128th pulse of the base 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.

$$M = (0.5 - 1/2 \times 372) \times 100\%$$
$$= 49.866\%$$

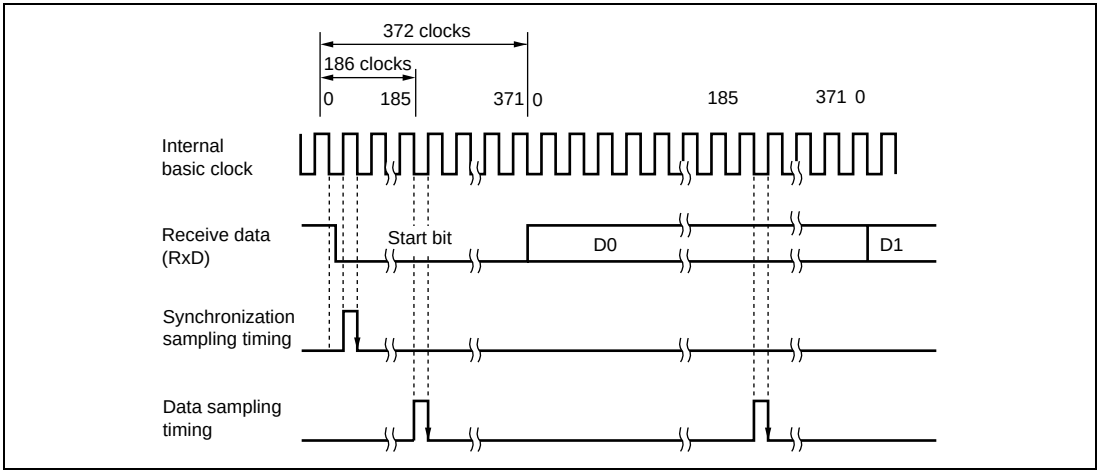


Figure 14.28 Receive Data Sampling Timing in Smart Card Mode (Using Clock of 372 Times the Transfer Rate)

14.7.5 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/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.

14.7.6 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 14.29 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 14.31 shows a flowchart for transmission. 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 9, Data Transfer Controller (DTC).

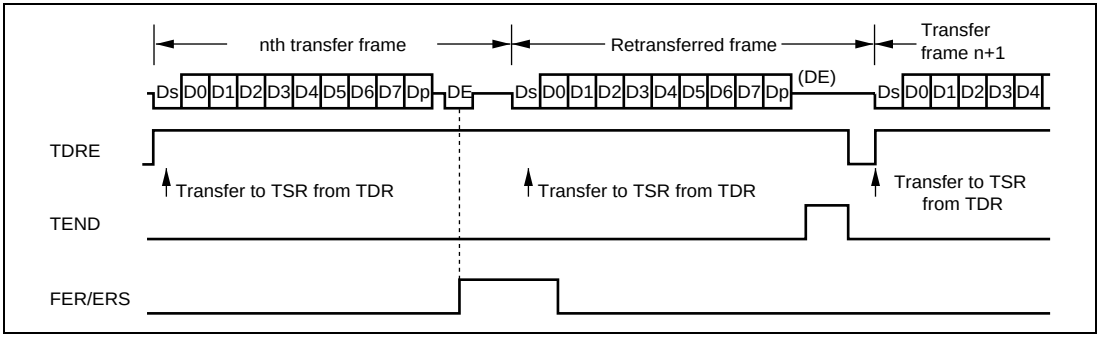


Figure 14.29 Retransfer Operation in SCI Transmit Mode

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 14.30.

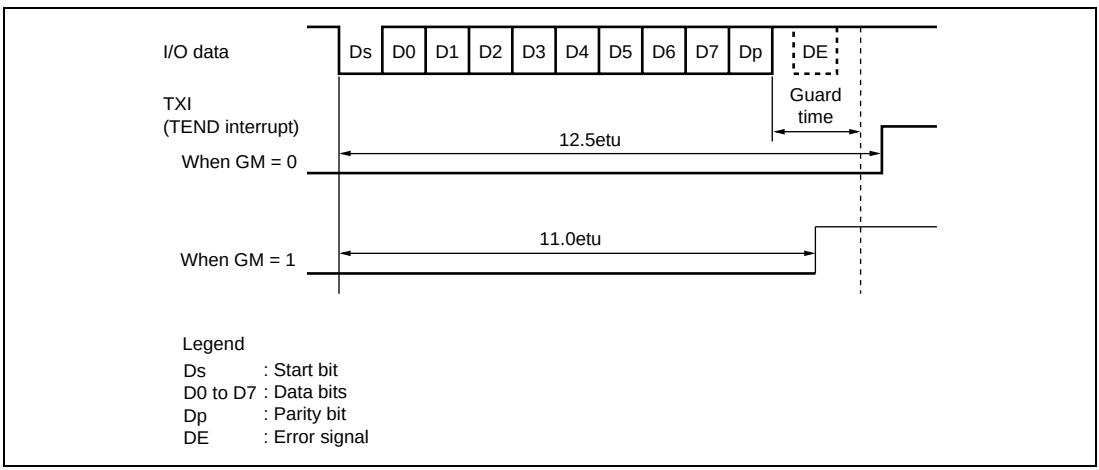


Figure 14.30 TEND Flag Generation Timing in Transmission Operation

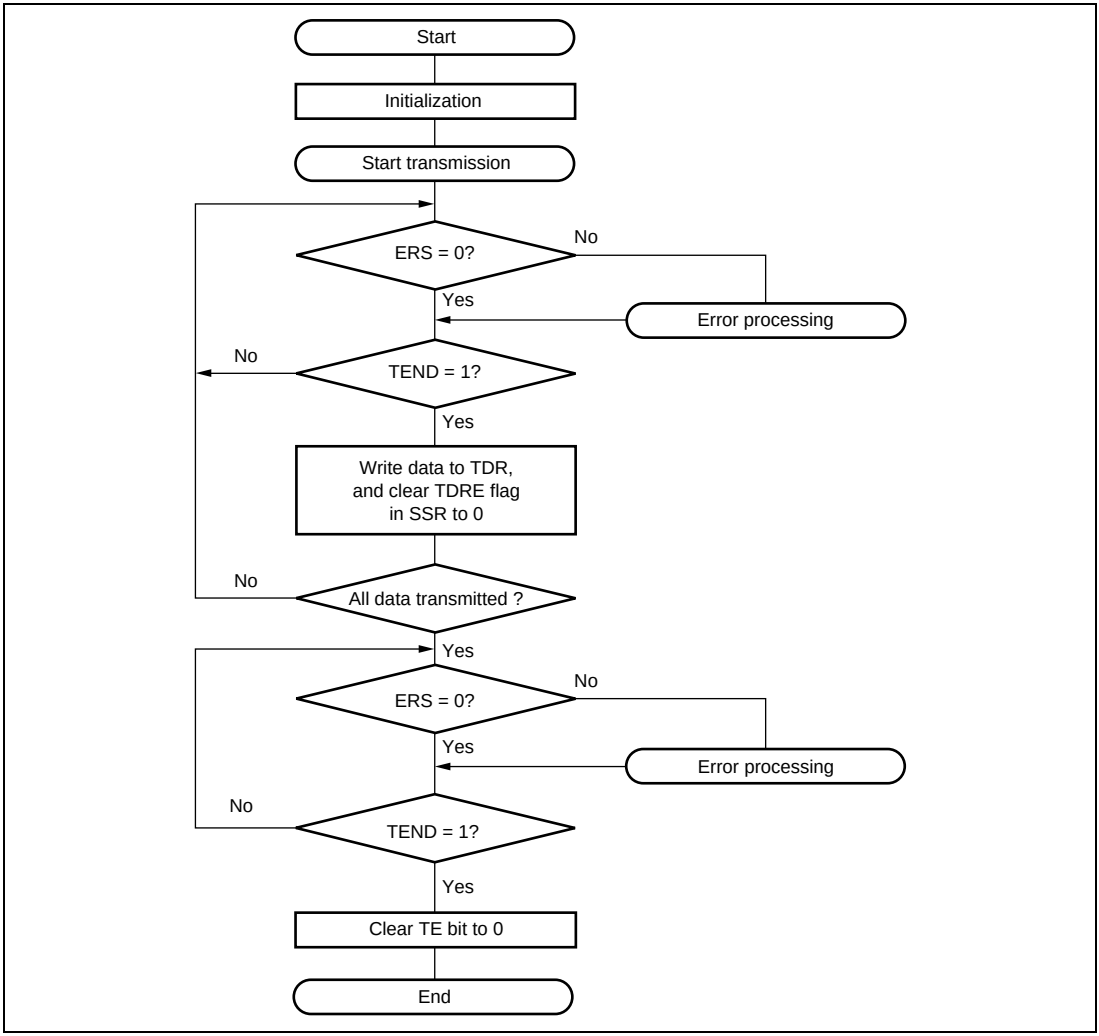


Figure 14.31 Example of Transmission Processing Flow

14.7.7 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 14.32 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 14.33 shows a flowchart for reception. 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 14.4, Operation in Asynchronous Mode.

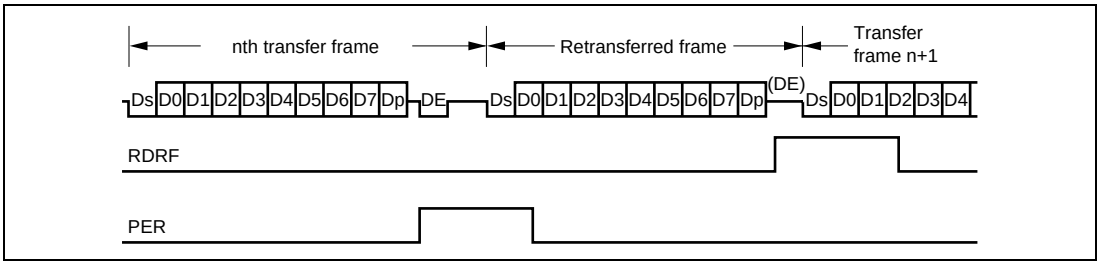


Figure 14.32 Retransfer Operation in SCI Receive Mode

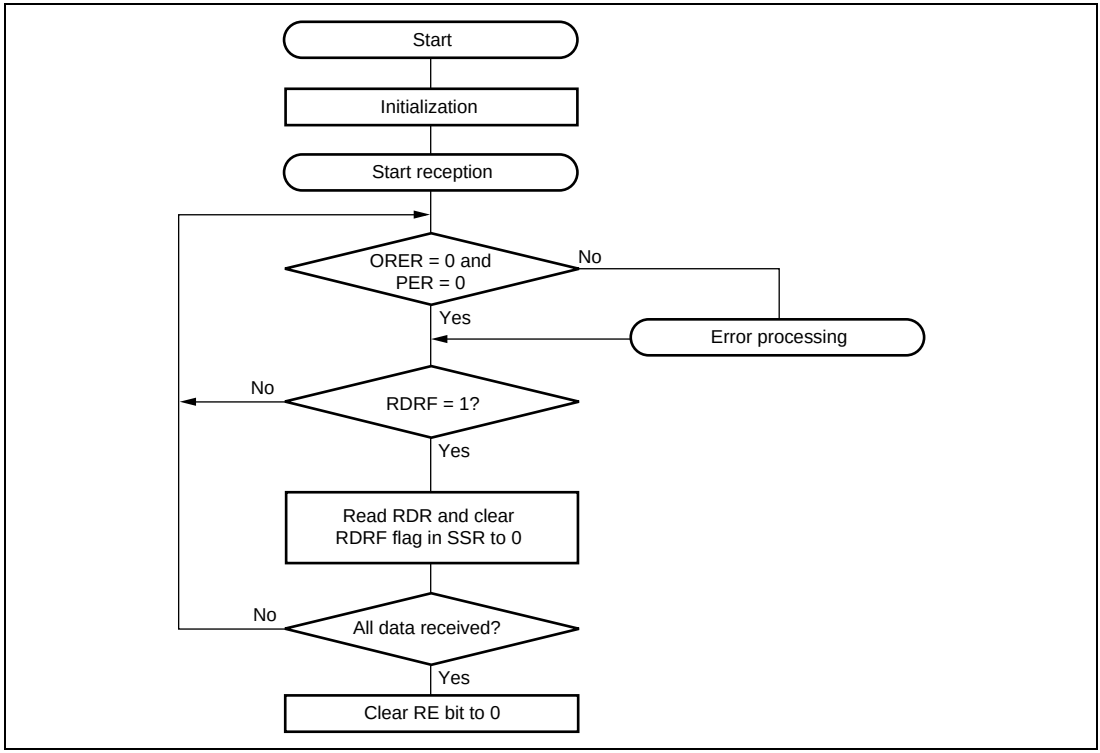


Figure 14.33 Example of Reception Processing Flow

14.7.8 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 14.34 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.

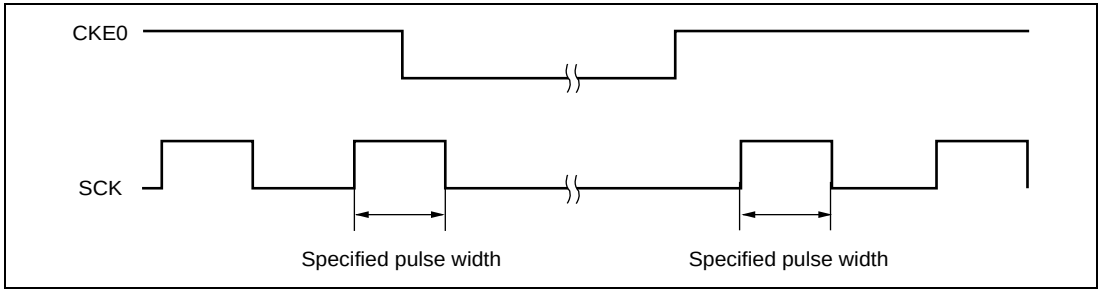


Figure 14.34 Timing for Fixing Clock Output Level

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.

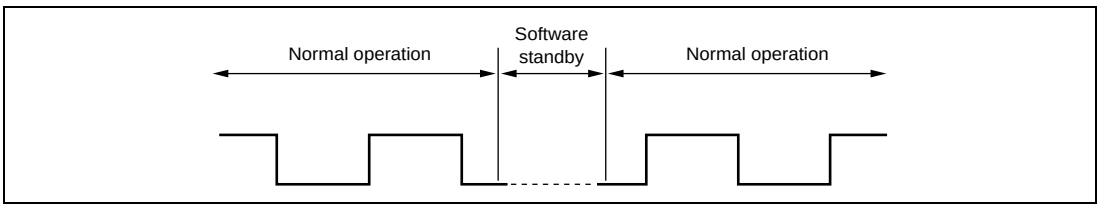


Figure 14.35 Clock Halt and Restart Procedure

14.8 SCI Select Function (H8S/2239 Series Only)

SCI_0 provides the SCI select function that enables one-to-one clocked synchronous communication between a master LSI and multiple slave LSIs (these LSIs). Figure 14.36 shows an example of communication using the SCI select function and figure 14.37 shows the summary of its operation.

The master LSI enables to communicate with the slave LSI_A by setting the SEL_A signal to low and the SEL_B signal to high. In this case, the TxD0_B pin of the slave LSI_B becomes Hi-Z and that fixes the on-chip SCK0_B signal high, causing the communication terminated. To communicate with the slave LSI_B, set the SEL_A signal to high and the SEL_B signal to low.*

The slave LSI detects its being selected by the low input interrupt of IRQ7 and handles data transferring smoothly.

Note:* Change the select signal of the master LSI (SEL_A or SEL_B) while the serial clock (M_SCK) is high after the last bit of the transmit data has been output. In addition, set only one select signal to low at a time.

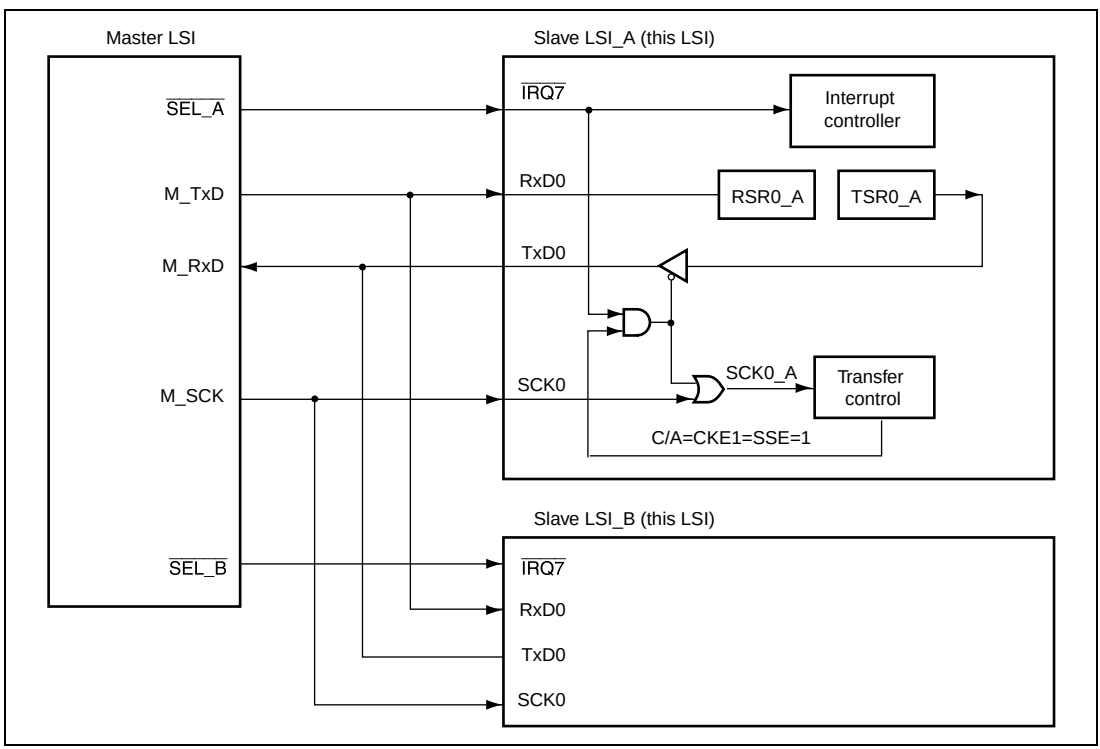


Figure 14.36 Example of Communication Using SCI Select Function

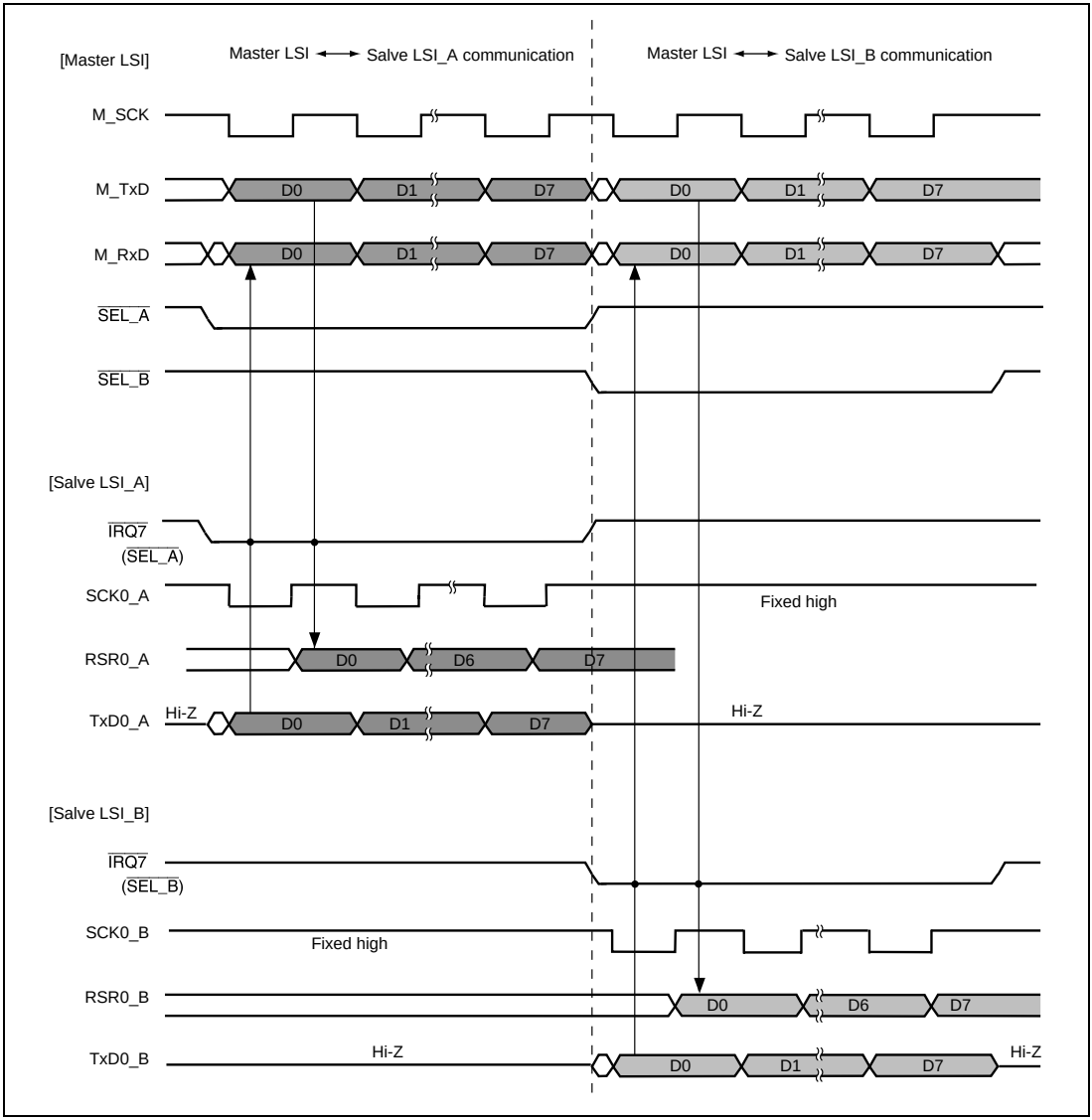


Figure 14.37 Summary of SCI Select Function Operation

14.9 Interrupt Sources

14.9.1 Interrupts in Normal Serial Communication Interface Mode

Table 14.12 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 DMAC* or the DTC.

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 DMAC* or the DTC to transfer data. The RDRF flag is cleared to 0 automatically when data is transferred by the DMAC* or the DTC.

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.

Note: * Supported only by the H8S/2239 Series.

Table 14.12 Interrupt Sources of Serial Communication Interface Mode

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	DMAC Activation*[2]	Priority*[1]
0	ERI0	Receive Error	ORER, FER, PER	Not possible	Not possible	High
	RXI0	Receive Data Full	RDRF	Possible	Possible	
	TXI0	Transmit Data Empty	TDRE	Possible	Possible	
	TEI0	Transmission End	TEND	Not possible	Not possible	
1	ERI1	Receive Error	ORER, FER, PER	Not possible	Not possible	
	RXI1	Receive Data Full	RDRF	Possible	Possible	
	TXI1	Transmit Data Empty	TDRE	Possible	Possible	
	TEI1	Transmission End	TEND	Not possible	Not possible	
2*[3]	ERI2	Receive Error	ORER, FER, PER	Not possible	Not possible	
	RXI2	Receive Data Full	RDRF	Possible	Not possible	
	TXI2	Transmit Data Empty	TDRE	Possible	Not possible	
	TEI2	Transmission End	TEND	Not possible	Not possible	
3	ERI3	Receive Error	ORER, FER, PER	Not possible	Not possible	
	RXI3	Receive Data Full	RDRF	Possible	Not possible	
	TXI3	Transmit Data Empty	TDRE	Possible	Not possible	
	TEI3	Transmission End	TEND	Not possible	Not possible	Low

Notes: 1. Indicates the initial state immediately after a reset. Priorities in channels can be changed by the interrupt controller.
2. Supported only by the H8S/2239 Series.
3. Not available in the H8S/2227 Series.

14.9.2 Interrupts in Smart Card Interface Mode

Table 14.13 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 section 14.9.1, Interrupts in Normal Serial Communication Interface Mode.

Table 14.13 Interrupt Sources in Smart Card Interface Mode

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	DMAC Activation*2	Priority*1
0	ERI0	Receive Error, detection	ORER, PER, ERS	Not possible	Not possible	High
	RXI0	Receive Data Full	RDRF	Possible	Possible	
	TXI0	Transmit Data Empty	TEND	Possible	Possible	
1	ERI1	Receive Error, detection	ORER, PER, ERS	Not possible	Not possible	
	RXI1	Receive Data Full	RDRF	Possible	Possible	
	TXI1	Transmit Data Empty	TEND	Possible	Possible	
2*3	ERI2	Receive Error, detection	ORER, PER, ERS	Not possible	Not possible	
	RXI2	Receive Data Full	RDRF	Possible	Not possible	
	TXI2	Transmit Data Empty	TEND	Possible	Not possible	
3	ERI3	Receive Error, detection	ORER, PER, ERS	Not possible	Not possible	
	RXI3	Receive Data Full	RDRF	Possible	Not possible	
	TXI3	Transmit Data Empty	TEND	Possible	Not possible	Low

Notes: 1. Indicates the initial state immediately after a reset. Priorities in channels can be changed by the interrupt controller.
2. Supported only by the H8S/2239 Series.
3. Not available in the H8S/2227 Series.

14.10 Usage Notes

14.10.1 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 23, Power-Down Modes.

14.10.2 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.

14.10.3 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.

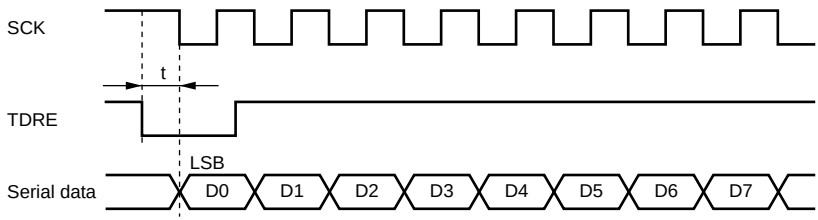
14.10.4 Receive Error Flags and Transmit Operations (Clocked Synchronous Mode Only)

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.

14.10.5 Restrictions on Use of DMAC or DTC

- 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 the TDR is updated by the DMAC* or the DTC. Misoperation may occur if the transmit clock is input within 4 ϕ clocks after TDR is updated (figure 14.38).
- When RDR is read by the DMAC* or the DTC, be sure to set the activation source to the relevant SCI reception data full interrupt (RXI).

Note: * Supported only by theH8S/2239 Series.



Note: When operating on an external clock, set t >4 clocks.

Figure 14.38 Example of Clocked Synchronous Transmission by DMAC or DTC

14.10.6 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 14.39 shows a sample flowchart for mode transition during transmission. Port pin states are shown in figures 14.40 and 14.41.

  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.

- 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 14.42 shows a sample flowchart for mode transition during reception.

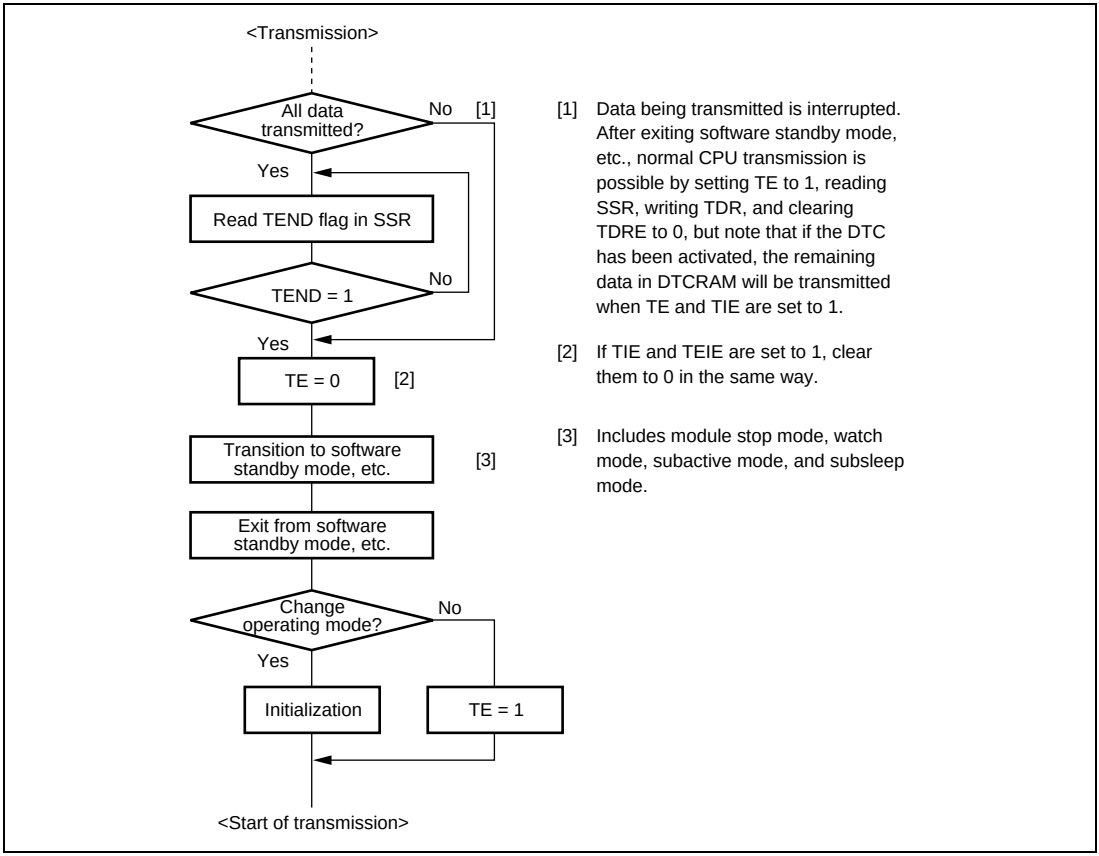


Figure 14.39 Sample Flowchart for Mode Transition during Transmission

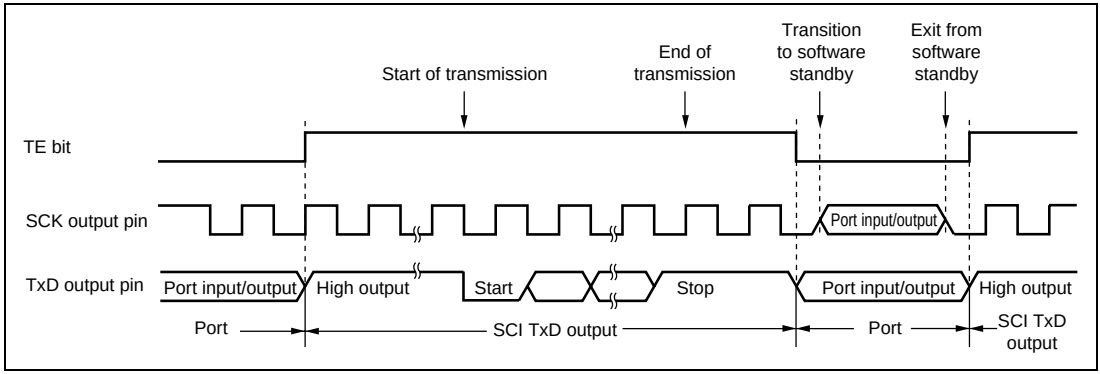


Figure 14.40 Asynchronous Transmission Using Internal Clock

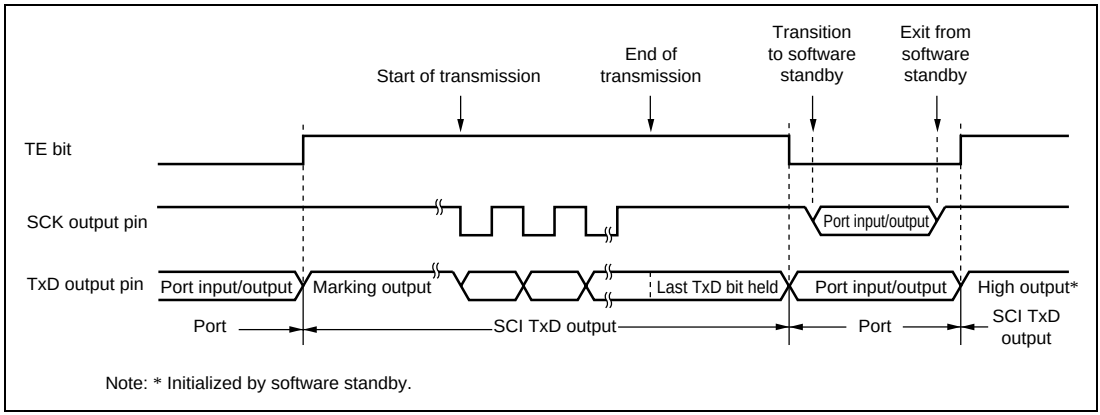


Figure 14.41 Synchronous Transmission Using Internal Clock

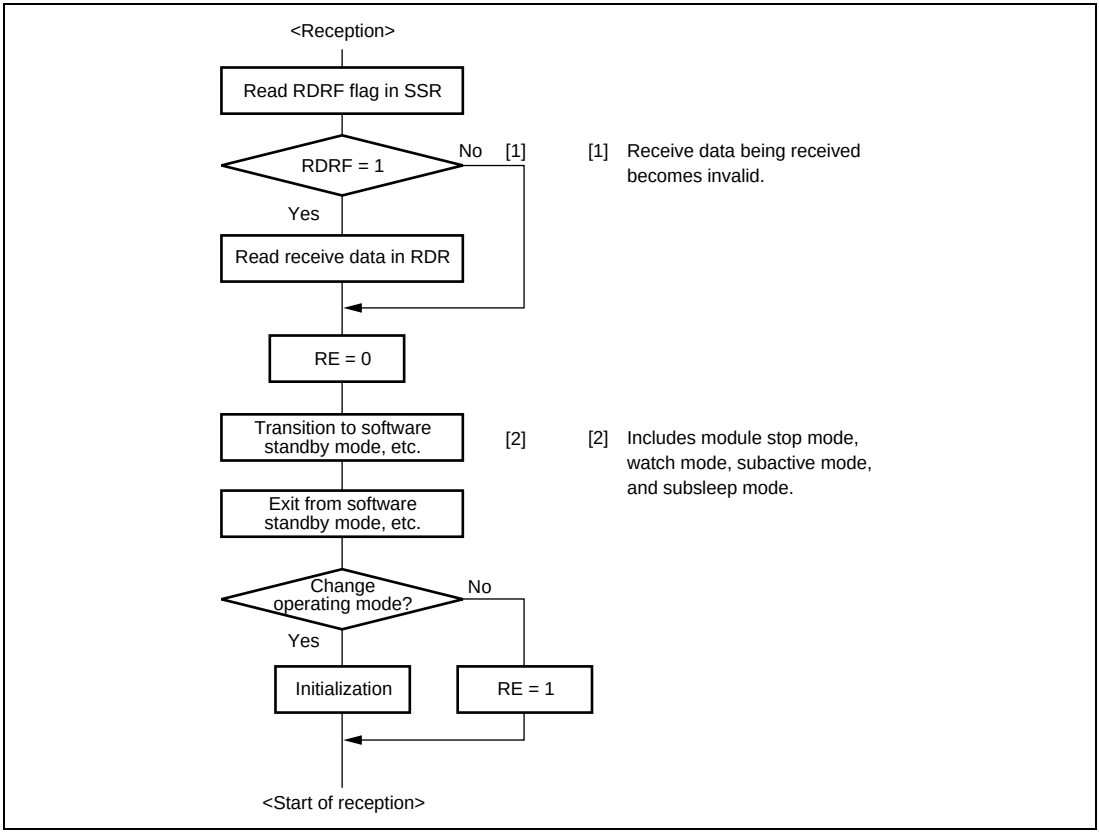


Figure 14.42 Sample Flowchart for Mode Transition during Reception

14.10.7 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 DDR = 1, DR = 1, C/A = 1, CKE1 = 0, CKE0 = 0, and TE = 1 (synchronous mode), low-level output occurs for one half-cycle.

1. End of serial data transmission
2. TE bit = 0
3. C/A bit = 0: Switchover to port output
4. Occurrence of low-level output

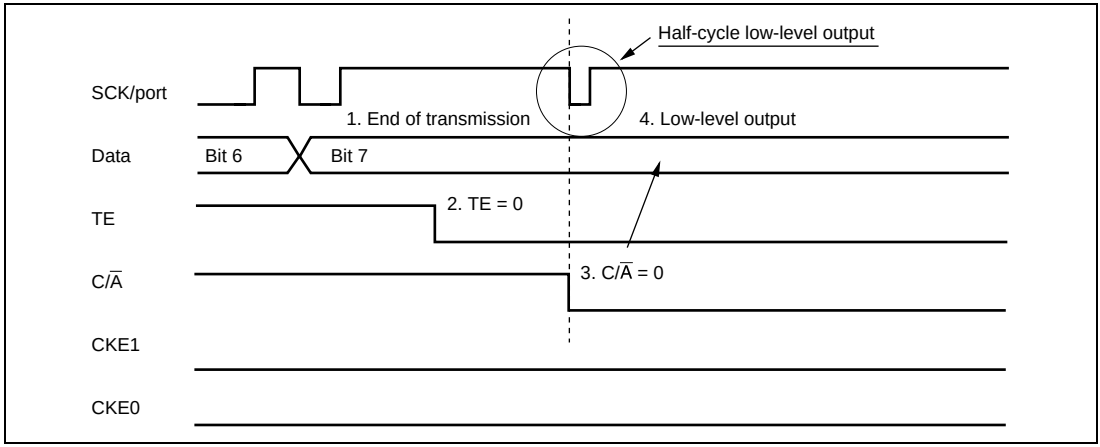


Figure 14.43 Operation when Switching from SCK Pin Function to Port Pin Function

- 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 DDR = 1, DR = 1, C/A = 1, CKE1 = 0, CKE0 = 0, and TE = 1, make the following settings in the order shown.

1. End of serial data transmission
2. TE bit = 0
3. CKE1 bit = 1
4. C/A bit = 0: Switchover to port output
5. CKE1 bit = 0

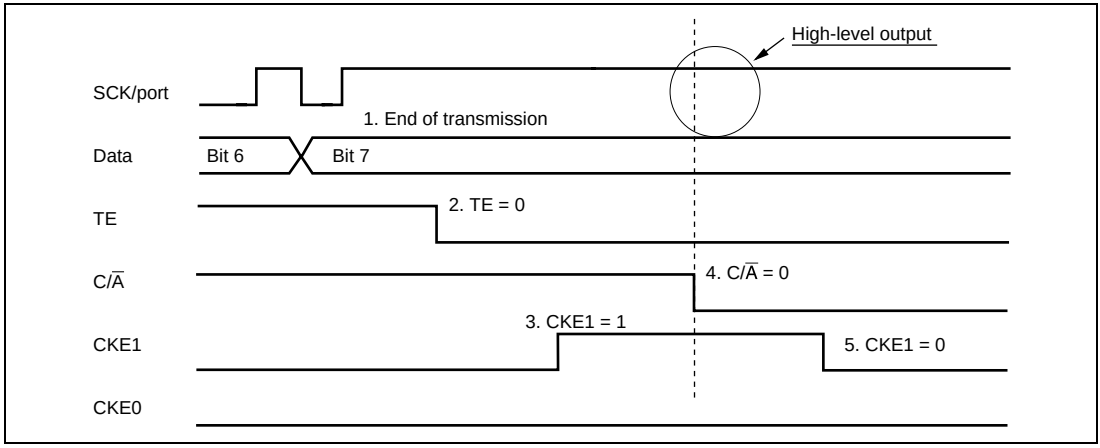


Figure 14.44 Operation when Switching from SCK Pin Function to Port Pin Function (Example of Preventing Low-Level Output)

14.10.8 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 24, List of Registers.

Section 15 I^2C Bus Interface (IIC) (Option)

An I^2C 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: HD6432239WTE
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/2239 Series and the H8S/2238R Series have an internal I^2C bus interface of two channels.

The I^2C bus interface conforms to and provides a subset of the Philips I^2C bus (inter-IC bus) interface functions. The register configuration that controls the I^2C bus differs partly from the Philips configuration, however.

The I^2C 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.

Note: An I^2C bus interface is not available in the H8S/2237 Series and H8S/2227 Series.

15.1 Features

- Selection of I^2C format or clocked synchronous serial format
  - — I^2C 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

I^2C 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.

Figure 15.1 shows a block diagram of the I^2C bus interface. Figure 15.2 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 (Vcc) voltage for this LSI. Set the upper limit of voltage applied to the power supply (Vcc) power supply range +0.3 V, i.e.3.9 V. Channel 1 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 (Vcc) of this LSI.

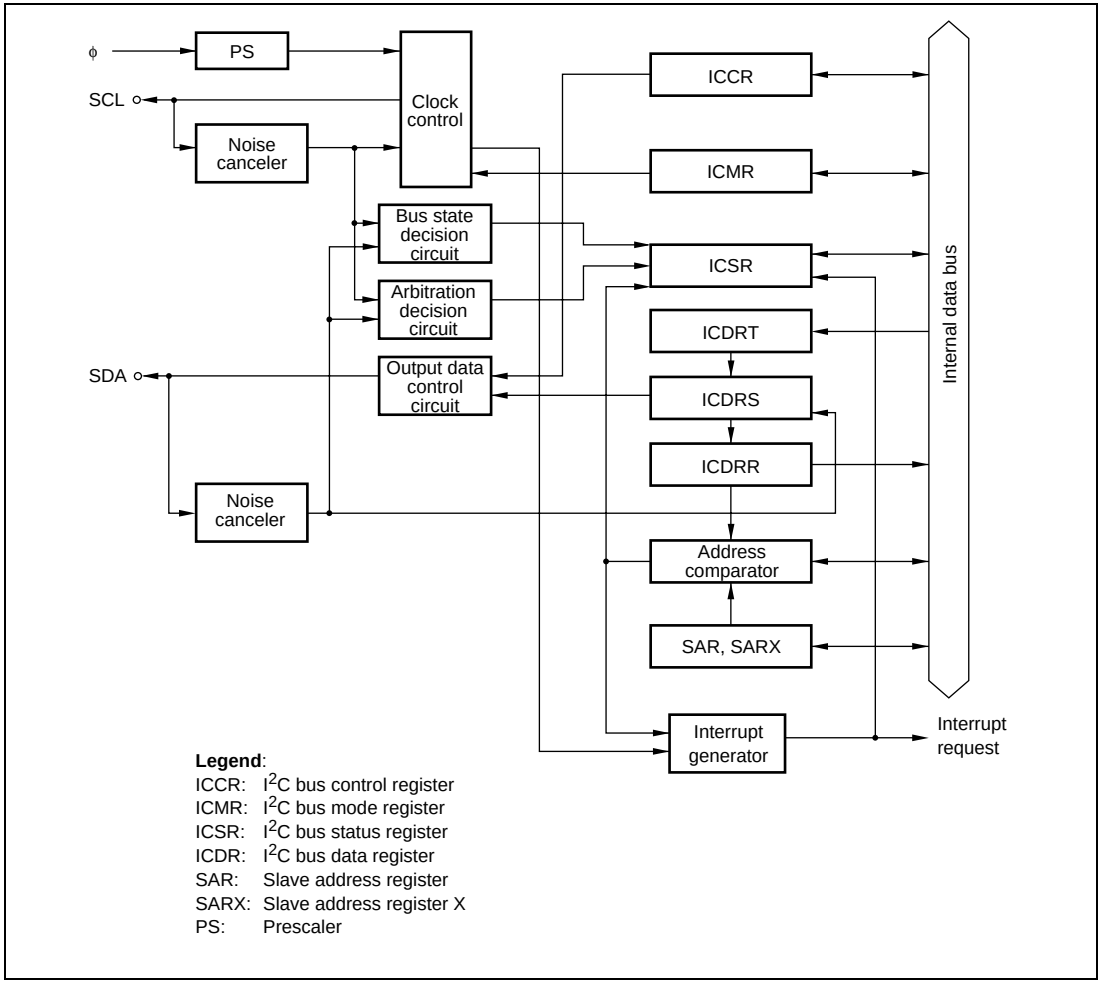


Figure 15.1 Block Diagram of I²C Bus Interface

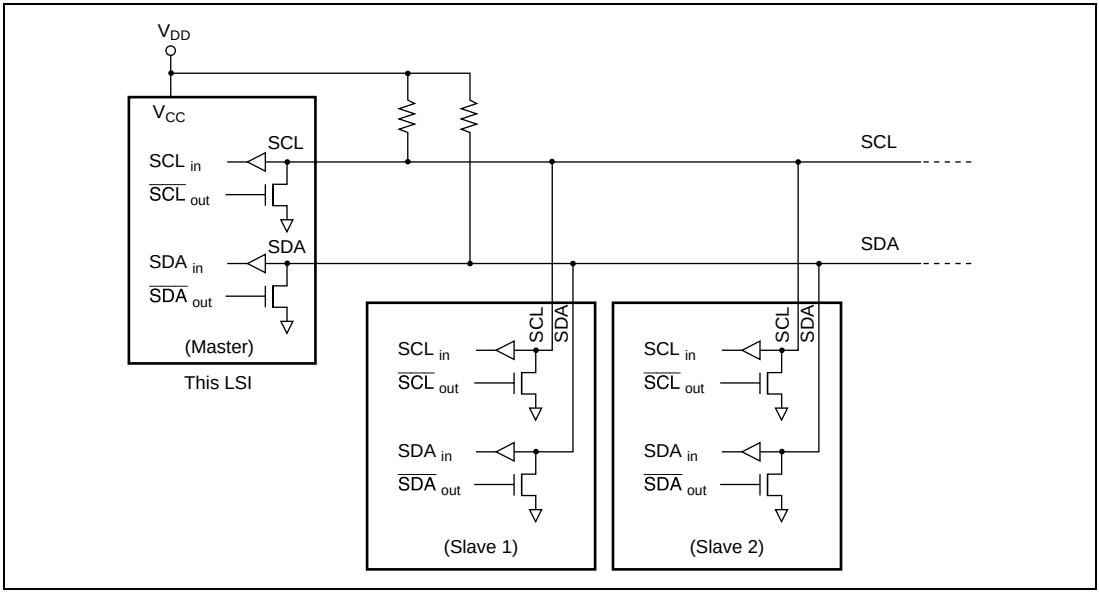


Figure 15.2 I²C Bus Interface Connections (Example: This LSI as Master)

15.2 Input/Output Pins

Table 15.1 shows the pin configuration for the I²C bus interface.

Table 15.1 Pin Configuration

Name	Abbreviation*	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	SCL1	I/O	IIC_1 serial clock input/output
Serial data	SDA1	I/O	IIC_1 serial data input/output

Note:* Pin names SCL and SDA are used in the text for all channels, omitting the channel designation.

15.3 Register Descriptions

The I^{2}C 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 23.1.2, Module Stop Control Registers A to C (MSTPCRA to MSTPCRC).

- I^{2}C bus data register (ICDR)
- Slave address register (SAR)
- Second slave address register (SARX)
- I^{2}C bus mode register (ICMR)
- I^{2}C bus control register (ICCR)
- I^{2}C bus status register (ICSR)
- DDC switch register (DDCSWR)
- Serial control register (SCRX)

15.3.1 I^{2}C 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 I^{2}C 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 I^{2}C 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] • 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 I^2C 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] • 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 I^2C bus format or serial format selected • When a stop condition is detected with the I^2C 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

15.3.2 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 15.2.

15.3.3 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 15.2.

Table 15.2 Transfer Format

SAR	SARX	
FS	**FSX**	**I²C Transfer Format**
0	0	SAR and SARX are used as the slave addresses with the I²C bus format.
0	1	Only SAR is used as the slave address with the I²C bus format.
1	0	Only SARX is used as the slave address with the I²C bus format.
1	1	Clock synchronous serial format (SAR and SARX are invalid)

15.3.4 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 I²C bus format is used.
6	WAIT	0	R/W	Wait Insertion Bit This bit is valid only in master mode with the I²C 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 15.3.

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^2C 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^2C Bus Format	Clocked Synchronous Mode
000: 9 bits	000: 8 bits
001: 2 bits	001: 1 bits
010: 3 bits	010: 2 bits
011: 4 bits	011: 3 bits
100: 5 bits	100: 4 bits
101: 6 bits	101: 5 bits
110: 7 bits	110: 6 bits
111: 8 bits	111: 7 bits

Table 15.3 I²C Transfer Rate

SCRX	ICMR							
Bit 5 or 6	Bit 5	Bit 4	Bit 3		Transfer Rate			
IICX	CKS2	CKS1	CKS0	Clock	φ = 5 MHz	φ = 8 MHz	φ = 16 MHz	φ = 16 MHz*[2]
0	0	0	0	φ/28	179 MHz	286 kHz	357 kHz	571 kHz*[1]
0	0	0	1	φ/40	125 kHz	200 kHz	250 kHz	400 kHz
0	0	1	0	φ/48	104 kHz	167 kHz	208 kHz	333 kHz
0	0	1	1	φ/64	78.1 kHz	125 kHz	156 kHz	250 kHz
0	1	0	0	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz
0	1	0	1	φ/100	50.0 kHz	80.0 kHz	100 kHz	160 kHz
0	1	1	0	φ/112	44.6 kHz	71.4 kHz	89.3 kHz	143 kHz
0	1	1	1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz
1	0	0	0	φ/56	89.3 kHz	143 kHz	179 kHz	286 kHz
1	0	0	1	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz
1	0	1	0	φ/96	52.1 kHz	83.3 kHz	104 kHz	167 kHz
1	0	1	1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz
1	1	0	0	φ/160	31.3 kHz	50.0 kHz	62.5 kHz	100 kHz
1	1	0	1	φ/200	25.0 kHz	40.0 kHz	50.0 kHz	80.0 kHz
1	1	1	0	φ/224	22.3 kHz	35.7 kHz	44.6 kHz	71.4 kHz
1	1	1	1	φ/256	19.5 kHz	31.3 kHz	39.1 kHz	62.5 kHz

Notes: 1. Out of the range of the I²C bus interface specification (normal mode: 100 kHz in max. and high-speed mode: 400 kHz in max)

2. Supported only by the H8S/2239 Series.

15.3.5 Serial Control RegisterX (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^2C 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 15.3. IICX1 controls IIC_1 and IICX0 controls IIC_0.
4	IICE	0	R/W	I^2C 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 19.5.7, Serial Control Register X (SCRX).
2 to 0	—	All 0	R/W	Reserved The initial value should not be changed.

15.3.6 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	I²C Bus Interface Enable 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. When this bit is cleared, the module is halted and separated from the SCL and SDA pins. SAR and SARX can be accessed.
6	IEIC	0	R/W	I²C Bus Interface Interrupt Enable When this bit is 1, interrupts are enabled by IRIC.
5	MST	0	R/W	Master/Slave Select
4	TRS	0		Transmit/Receive Select 00: Slave receive mode 01: Slave transmit mode 10: Master receive mode 11: Master transmit mode 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.

Bit	Bit Name	Initial Value	R/W	Description
3	ACKE	0	R/W	Acknowledge Bit Judgement Selection 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. 1: If the acknowledge bit is 1, continuous transfer is interrupted. In this LSI, 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. 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 continuos 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. 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.
2	BBSY	0	R/W	Bus Busy In slave mode, reading the BBSY flag enables to confirm whether the I^2C 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. 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 I^2C bus interface must be set in master transmit mode before the issue of a start condition.

Bit	Bit Name	Initial Value	R/W	Description
1	IRIC	0	R/W	I^2C Bus Interface Interrupt Request Flag Also see table 15.4. [Setting conditions] In I^2C bus format master mode • 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 to1) • When 1 is received as the acknowledge bit when the ACKE bit is 1(when the ACKB bit is set to 1) In I^2C bus format slave mode • 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) With clocked synchronous serial format • 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 When a condition occurs in which internal flag of TDRE and RDFR is set to 1 except for the above [Clearing condition] When 0 is written in IRIC after reading IRIC = 1 • When ICDR is read/written by DTC (When TDRE or RDRF flag is cleared to 0) (AS it might not be a condition to clear, for details, see description of DTC operation below)

Bit	Bit Name	Initial Value	R/W	Description
0	SCP	1	R/W	Start Condition/Stop Condition Prohibit bit The SCP bit controls the issue of start/stop conditions in master mode. To issue a start condition, write 1 in BBSY and 0 in SCP. A retransmit start condition is issued in the same way. To issue a stop condition, write 0 in BBSY and 0 in SCP. This bit is always read as 1. If 1 is written, the data is not stored.

When, with the I^2C 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. 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 I^2C 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, 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 15.4 shows the relationship between the flags and the transfer states.

Table 15.4 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 0	1/0 1	1 1	0 0	0 0	1 0	1 1	0 0	0 0	0 0	0 1	Slave mode transmit/receive end(after SARX match)
0	1/0	0	1/0	1/0	0	0	0	0	0	0/1	Stop condition detected

15.3.7 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 I²C bus format slave mode. [Setting condition] When a stop condition is detected during frame transfer. [Clearing condition] • 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 I²C bus format slave mode. [Setting condition] When a stop condition is detected during frame transfer. [Clearing condition] • 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)*	I^2C Bus Interface Continuous Transmission/Reception Interrupt Request Flag [Setting conditions] In I^2C bus interface slave mode • When the TDRE or RDRF flag is set to 1 when AASX = 1 In I^2C bus interface other modes • When the TDRE or RDRF flag is set to 1 [Clearing conditions] • When 0 is written in IRTR after reading IRTR = 1 • When the IRIC flag is cleared to 0
4	AASX	0	R/(W)*	Second Slave Address Recognition Flag [Setting condition] When the second slave address is detected in slave receive mode and FSX = 0 [Clearing conditions] • When 0 is written in AASX after reading AASX = 1 • When a start condition is detected • In master mode
3	AL	0	R/(W)*	Arbitration Lost Flag Indicates that bus arbitration was lost in master mode. [Setting condition] • 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. [Clearing conditions] • 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)*	Slave Address Recognition Flag [Setting condition] When the slave address or general call address is detected in slave receive mode and FS = 0. [Clearing conditions] • 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)*	General Call Address Recognition Flag This bit is valid in I^2C bus format slave receive mode. [Setting condition] When the general call address is detected in slave receive mode and FSX = 0 or FS = 0. [Clearing conditions] • 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)*	Acknowledge Bit Stores acknowledge bit. 0: At reception, outputs 0 in the acknowledge output timing. At transmission, indicates that acknowledge was sent (0) from the receive device. 1: At reception, outputs 1 in the acknowledge output timing. At transmission, indicates that acknowledge was not sent (1) from the receive device.

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

15.3.8 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)*	Reserved The write value should always be 0.
3	CLR3	1	W	I²C Bus Interface Clear 3 to 0: When bits CLR3 to CLR0 are set, a clear signal is generated for the I²C bus interface internal latch circuit, and the internal state is initialized. The write data for these bits is not retained. To perform I²C 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 internal latch cleared 0111: IIC_0, IIC_1 internal latch cleared 1XXX: Invalid setting
2	CLR2	1	W	
1	CLR1	1	W	
0	CLR0	1	W	

Legend

X: Don't care

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

15.4 Operation

The I²C bus interface has serial and I²C bus formats.

15.4.1 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 15.3. The serial format is a non-addressing format with no acknowledge bit. This is shown in figure 15.4. Figure 15.5 shows the I²C bus timing.

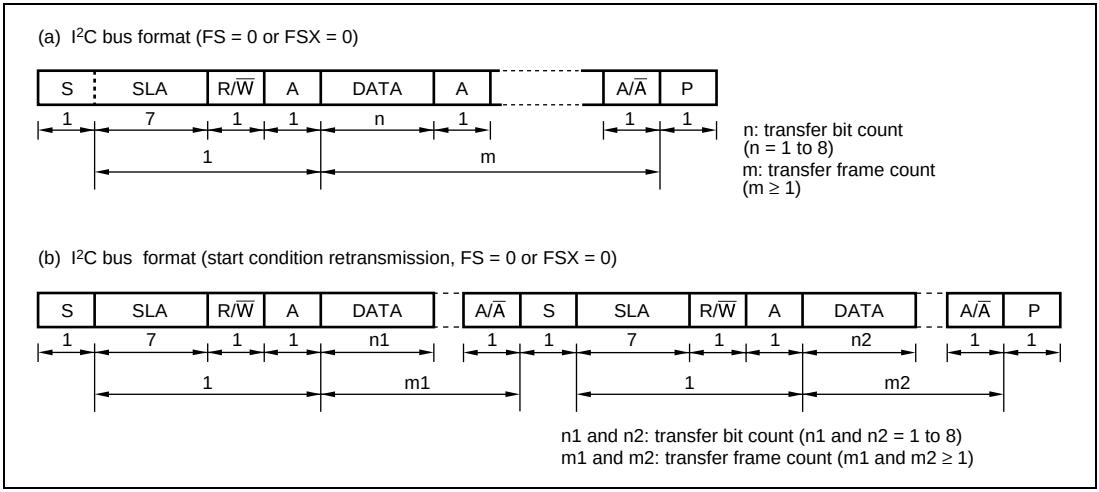


Figure 15.3 I²C Bus Data Formats (I²C Bus Formats)

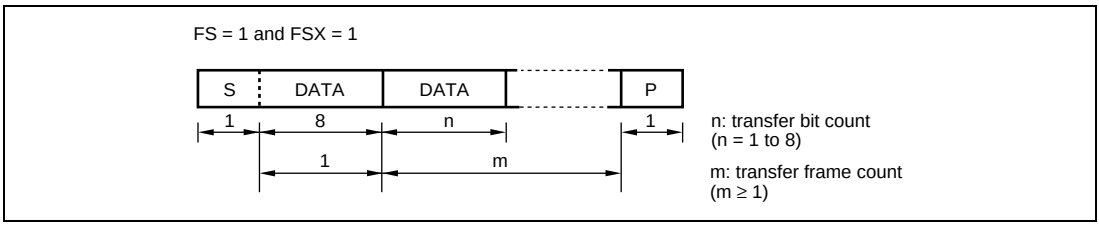


Figure 15.4 I²C Bus Data Format (Serial Format)

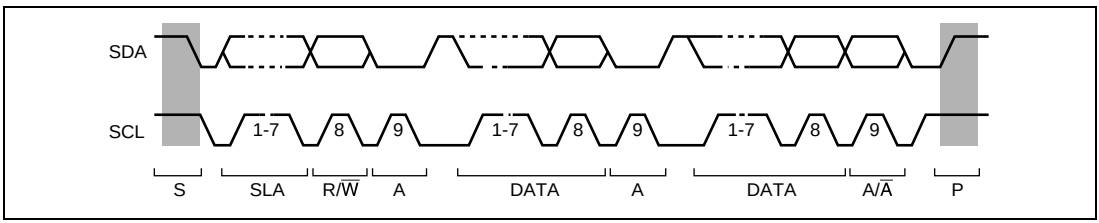


Figure 15.5 I²C Bus Timing

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

15.4.2 Master Transmit Operation

In I^2C 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/W) to ICDR. With the I^2C 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 15.6. 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.

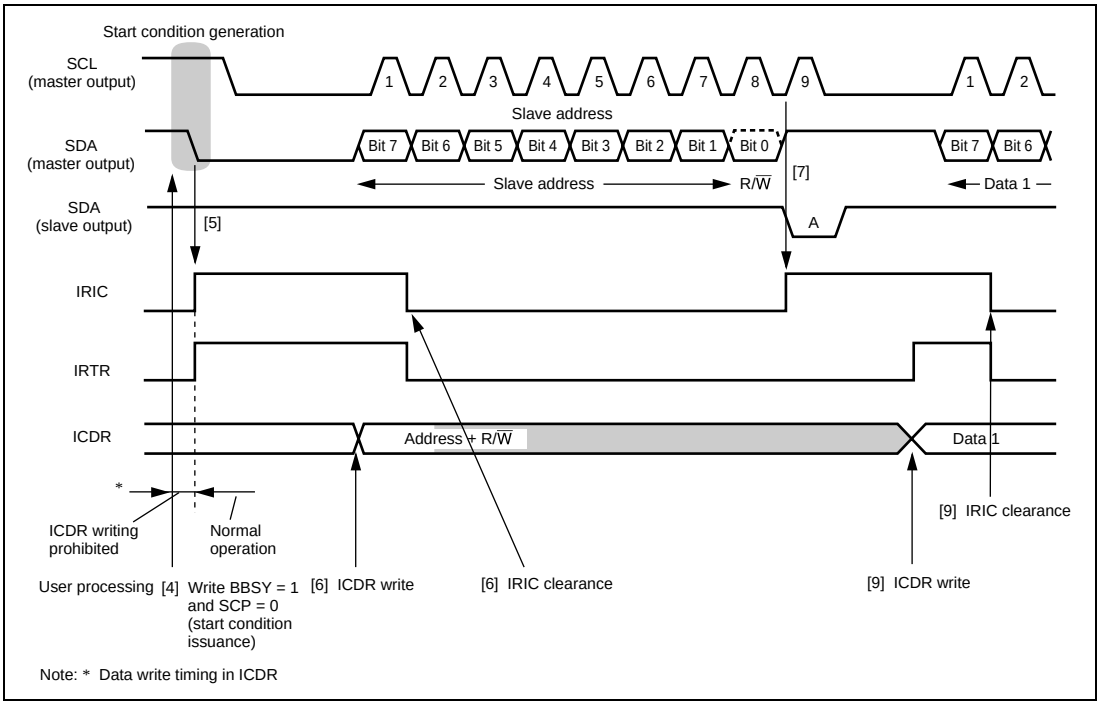


Figure 15.6 Master Transmit Mode Operation Timing Example (MLS = WAIT = 0)

15.4.3 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.
   Data can be received continuously by repeating step [5] to [9].
10. 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.
11. Clear IRIC flag to 0 to release from the Wait State.
12. When one frame of data has been received, the IRIC flag is set to 1 at the rise of the 9th receive clock pulse.
13. 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.
14. 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.

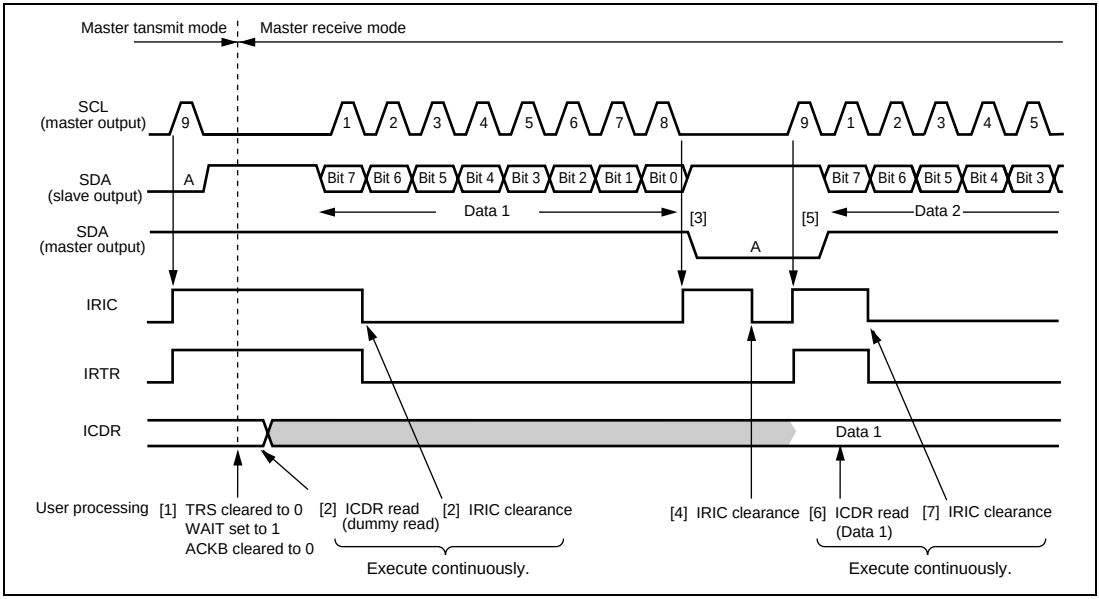


Figure 15.7 (1) Master Receive Mode Operation Timing Example (MLS = ACKB = 0, WAIT = 1)

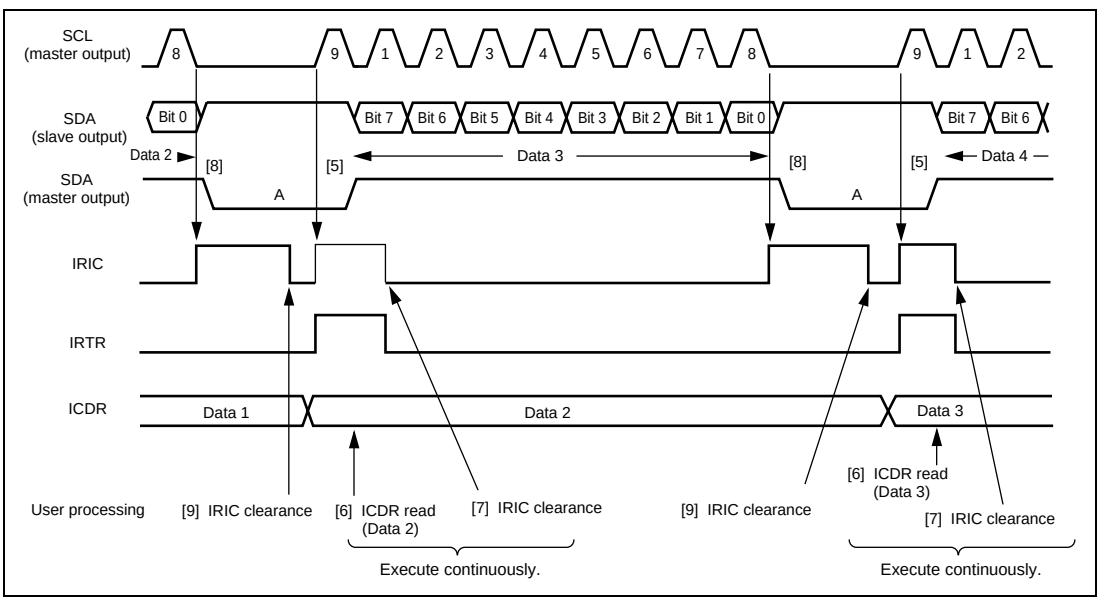


Figure 15.7 (2) Master Receive Mode Operation Timing Example (MLS = ACKB = 0, WAIT = 1)

15.4.4 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/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.

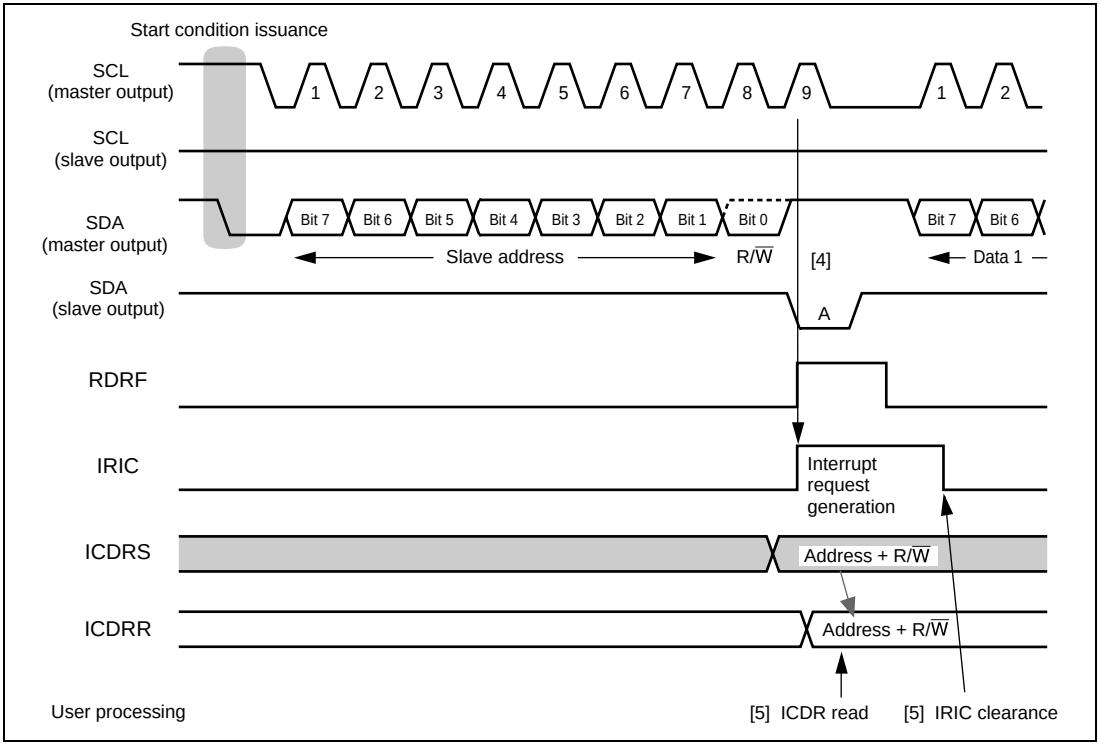


Figure 15.8 Example of Slave Receive Mode Operation Timing (1)
(MLS = ACKB = 0)

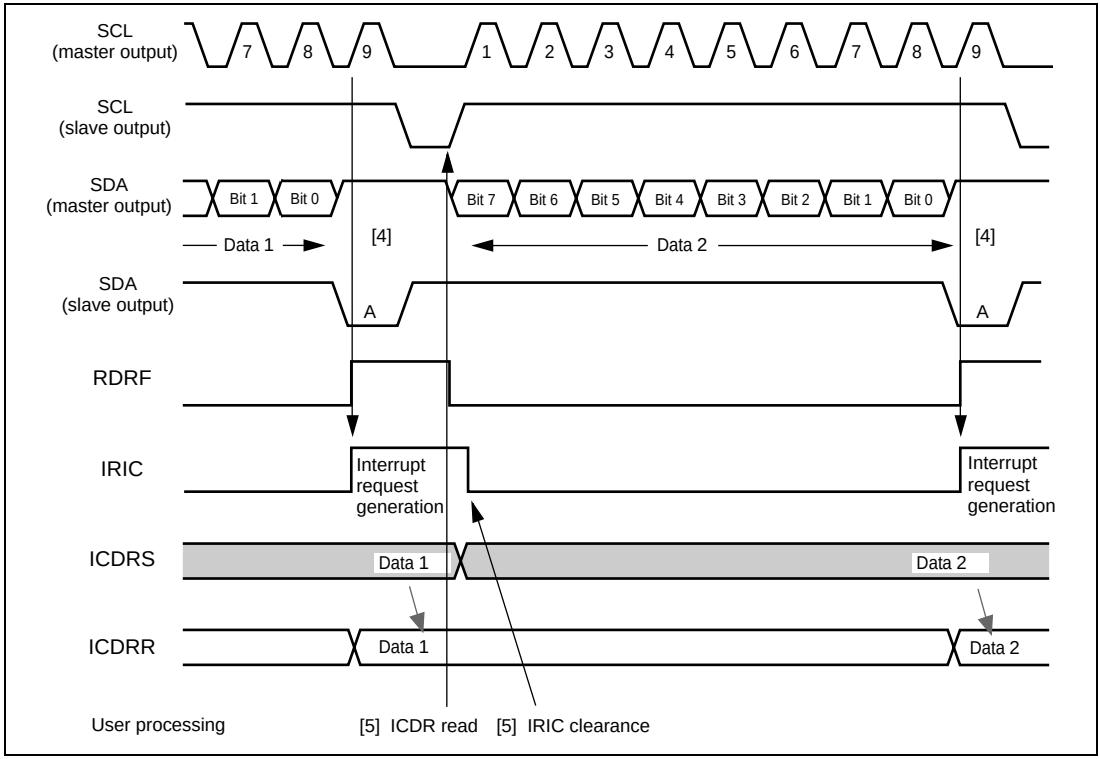


Figure 15.9 Example of Slave Receive Mode Operation Timing (2)
(MLS = ACKB = 0)

15.4.5 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/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 15.10.
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.

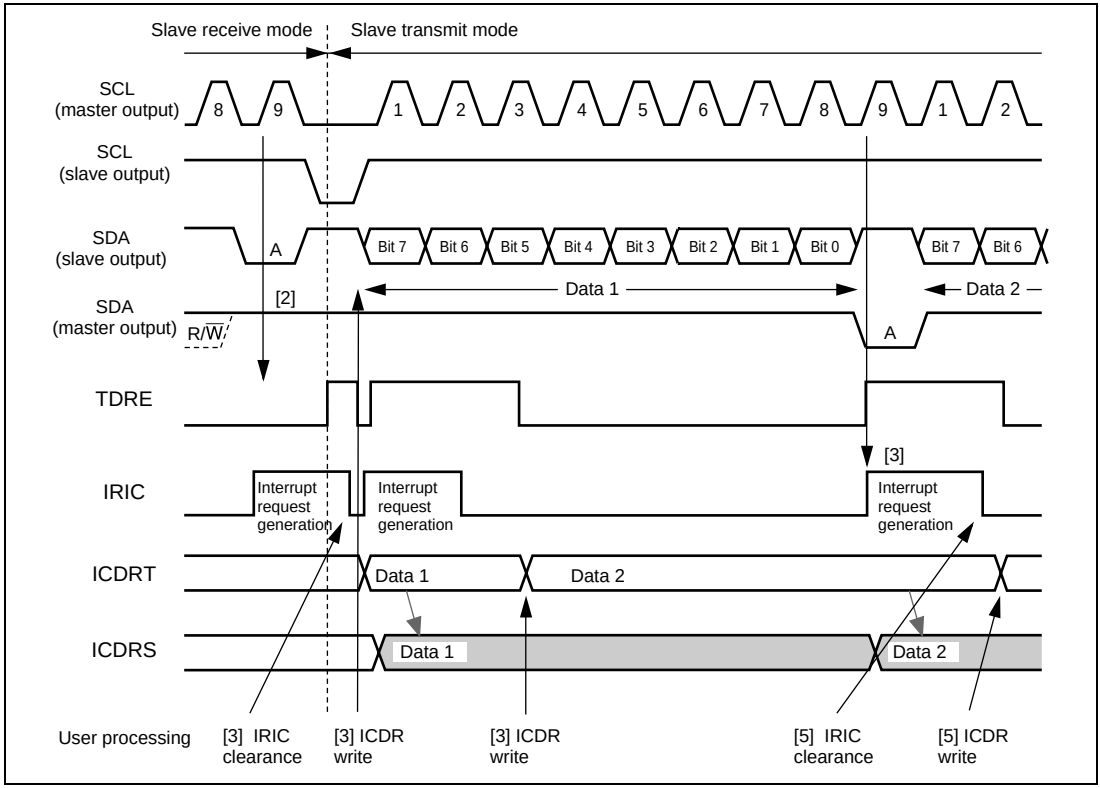


Figure 15.10 Example of Slave Transmit Mode Operation Timing (MLS = 0)

15.4.6 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 15.11 shows the IRIC set timing and SCL control.

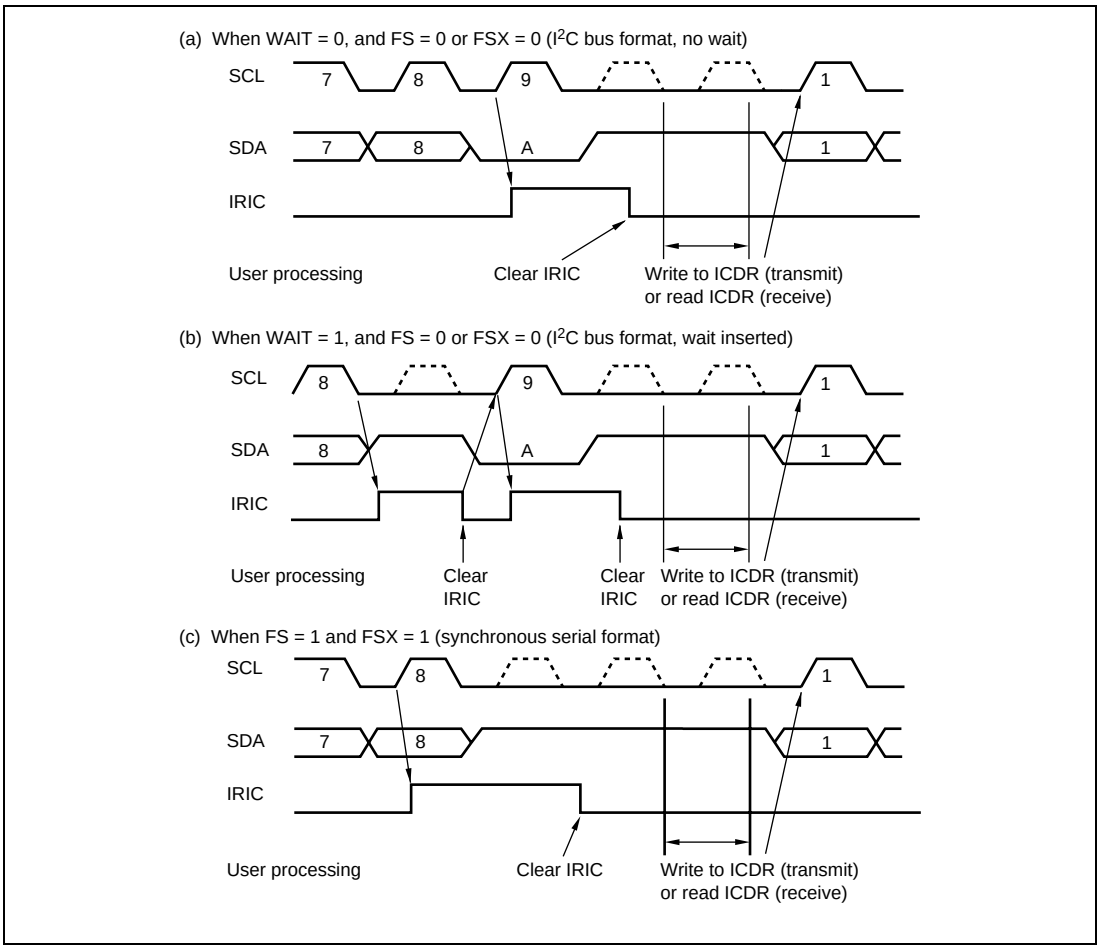


Figure 15.11 IRIC Setting Timing and SCL Control

15.4.7 Operation Using the DTC

The I^{2}C bus format provides for selection of the slave device and transfer direction by means of the slave address and the R/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 15.5 shows some example of processing using the DTC. These examples assume that the number of transfer data bytes is know in slave mode.

Table 15.5 Flags and Transfer States

Item	Master Transmit Mode	Master Receive Mode	Slave Transmit Mode	Slave Receive Mode
Slave address + R/W bit Transmission/ reception	Transmission by DTC (ICDR rite)	Transmission by DTC (ICDR rite)	Reception by CPU (ICDR read)	Reception by CPU (ICDR read)
Dummy data read	—	Processing by DTC (ICDR read)	—	—
Actual data transmission/reception	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 + R/W bits)	Reception: Actual data count	Transmission: Actual data count + 1 (+ 1 equivalent to dummy data (H′FF))	Reception: Actual data count

15.4.8 Noise Chancellor

The logic levels at the SCL and SDA pins are routed through noise chancellors before being latched internally. Figure 15.12 shows a block diagram of the noise cancelled circuit.

The noise chancellor 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.

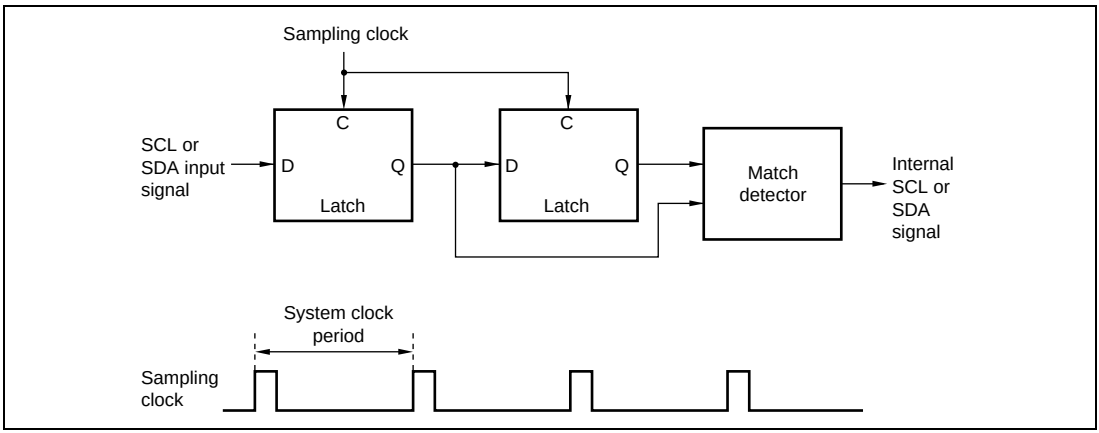


Figure 15.12 Block Diagram of Noise Chancellor

15.4.9 Sample Flowcharts

Figures 15.13 to 15.16 show sample flowcharts for using the I^2C bus interface in each mode.

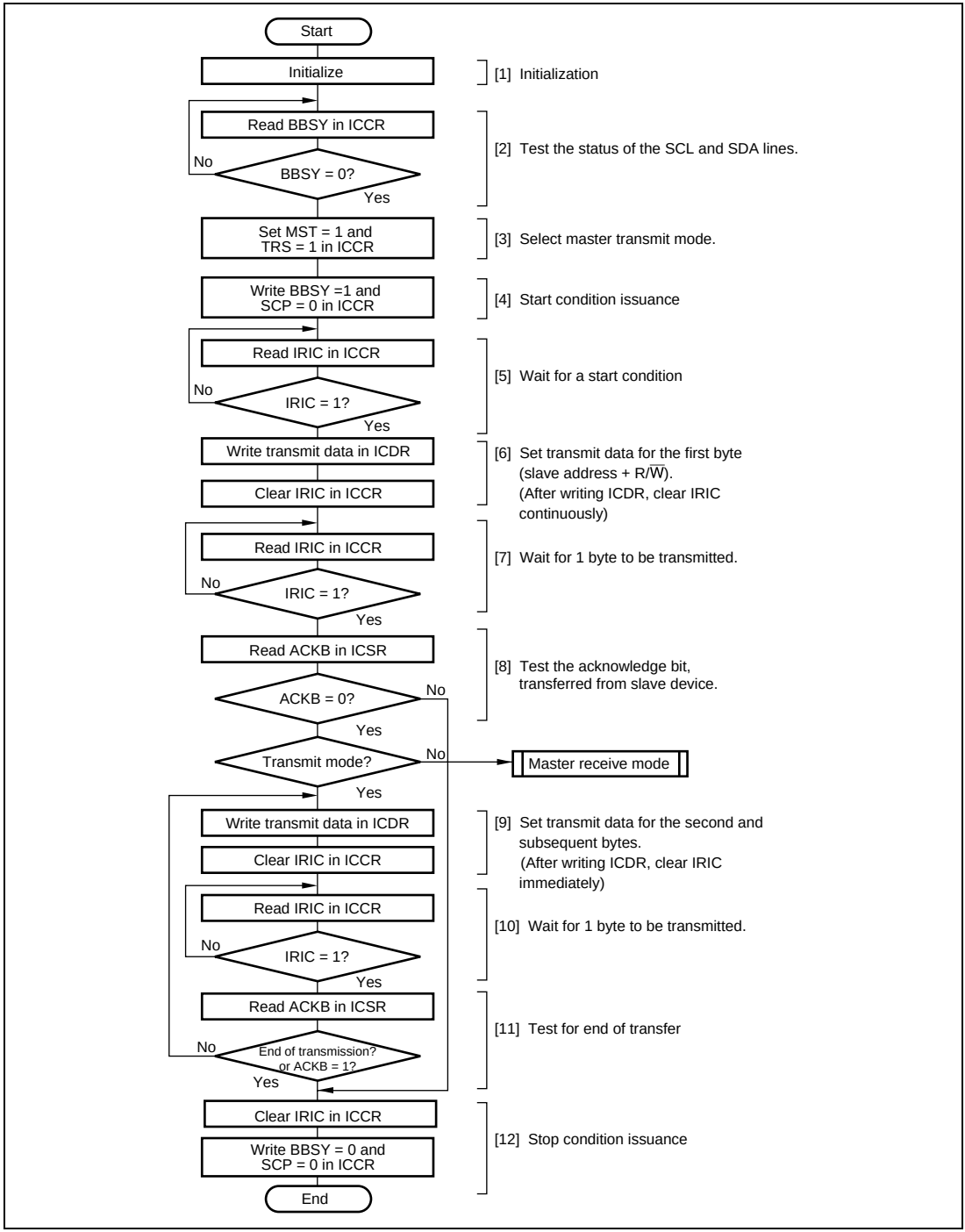


Figure 15.13 Sample Flowchart for Master Transmit Mode

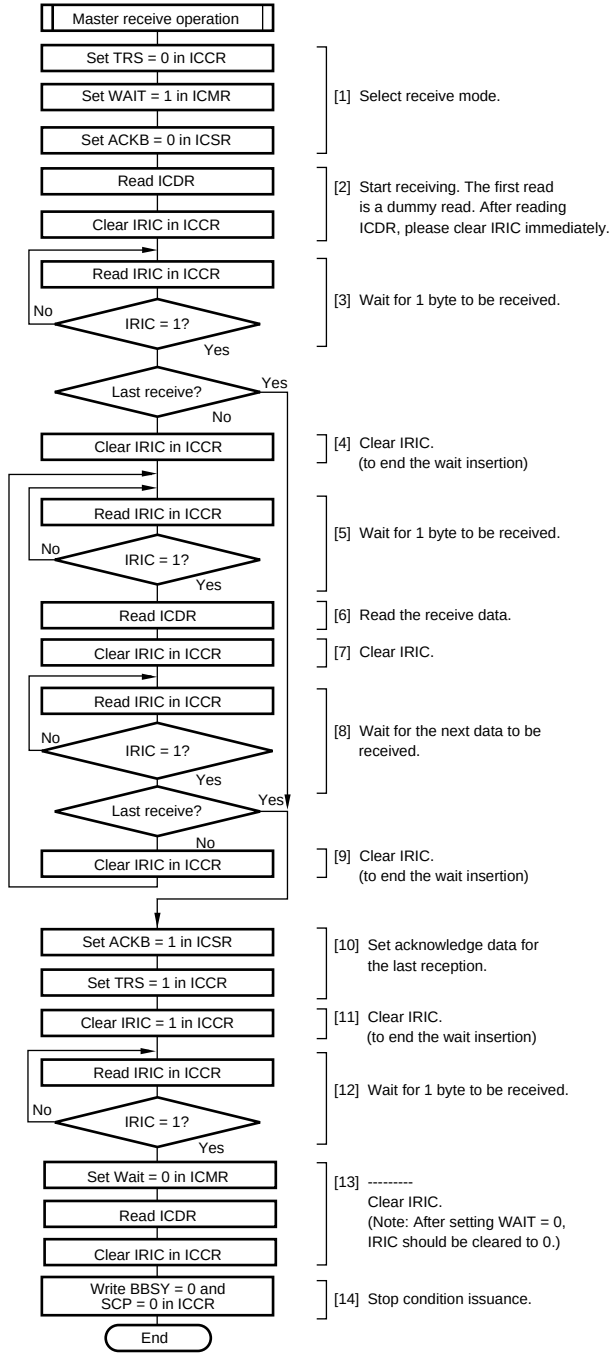


Figure 15.14 Sample Flowchart for Master Receive Mode

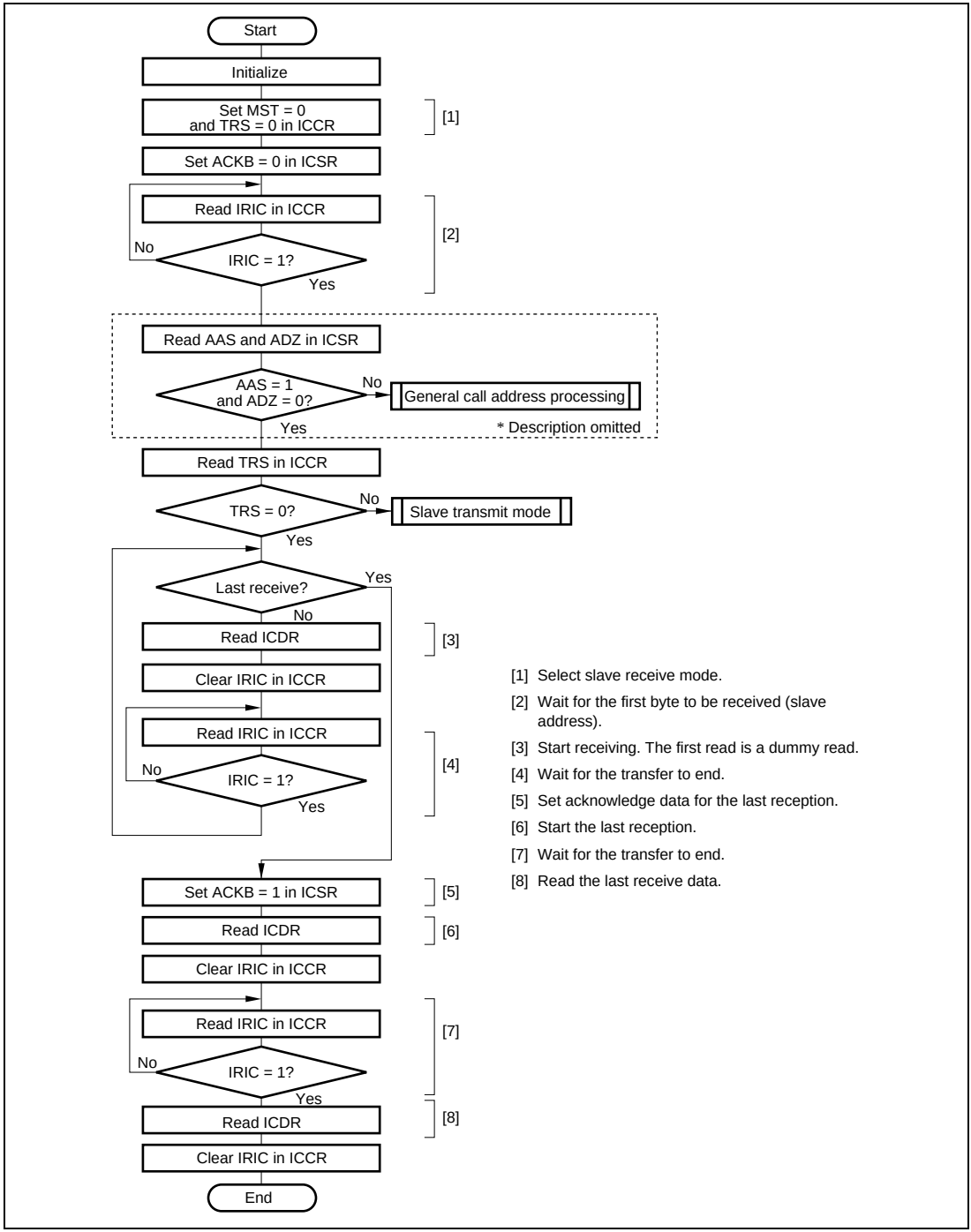


Figure 15.15 Sample Flowchart for Slave Receive Mode

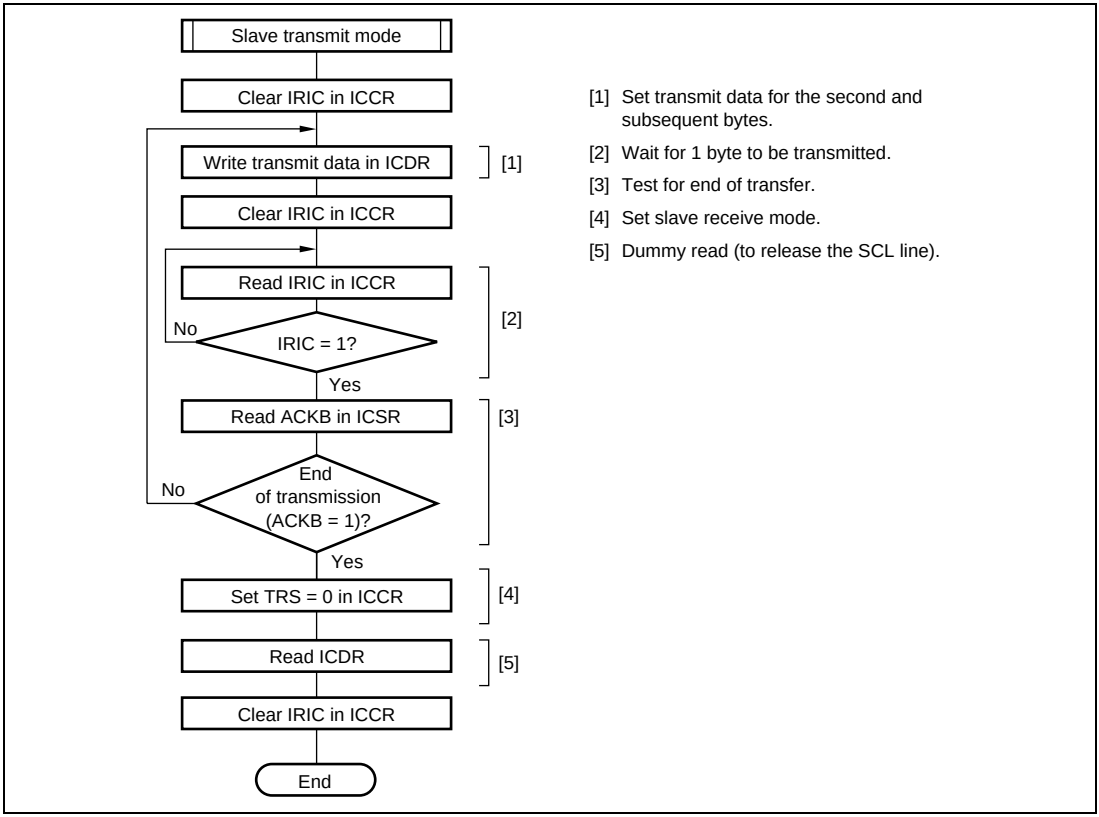


Figure 15.16 Sample Flowchart for Slave Transmit Mode

15.5 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 15.6 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 15.6 I^2C Bus Timing (SCL and SDA Output)

Item	Symbol	Output Timing	Unit	Notes
SCL output cycle time	t_{SCLO}	$28t_{cyc}$ to $256t_{cyc}$	ns	Figure 25.29
SCL output high pulse width	t_{SCLHO}	$0.5t_{SCLO}$	ns	
SCL output low pulse width	t_{SCLLO}	$0.5t_{SCLO}$	ns	
SDA output bus free time	t_{BUFO}	$0.5t_{SCLO} – 1t_{cyc}$	ns	
Start condition output hold time	t_{STAHO}	$0.5t_{SCLO} – 1t_{cyc}$	ns	
Retransmission start condition output setup time	t_{STASO}	$1t_{SCLO}$	ns	
Stop condition output setup time	t_{STOSO}	$0.5t_{SCLO} + 2t_{cyc}$	ns	
Data output setup time (master)	t_{SDASO}	$1t_{SCLLO} – 3t_{cyc}$	ns	
Data output setup time (slave)		$1t_{SCLL} – 3t_{cyc}$	ns	
Data output hold time	t_{SDAHO}	$3t_{cyc}$	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 25.10 (H8S/2239 Series) and table 25.22 (H8S/2238R Series) in section 25, Electrical Characteristics. Note that the I^2C bus interface AC timing specifications will not be met with a system clock frequency of less than 5 MHz.

5. The I^2C bus interface specification for the SCL rise time t_{sr} is under 1000 ns (300 ns for high-speed mode). In master mode, the I^2C 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 I^2C 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 15.7.

Table 15.7 Permissible SCL Rise Time (t_{sr}) Values

			Time Indication				
IICX	t_{cyc} Indication		I^2C Bus Specification (Max.)	φ = 5 MHz	φ = 8 MHz	φ = 10 MHz	φ = 16 MHz
0	$7.5t_{cyc}$	Normal mode	1000 ns	1000 ns	937 ns	750 ns	468 ns
		High-speed mode	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
		High-speed mode	300 ns	300 ns	300 ns	300 ns	300 ns

6. The I^2C bus interface specifications for the SCL and SDA rise and fall times are under 1000 ns and 300 ns. The I^2C bus interface SCL and SDA output timing is prescribed by t_{Scyc} and t_{cyc}, as shown in table 15.6. However, because of the rise and fall times, the I^2C bus interface specifications may not be satisfied at the maximum transfer rate. Table 15.8 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 I^2C bus interface specifications are met must be determined in accordance with the actual setting conditions.

   t_{BUFO} fails to meet the I^2C bus interface specifications at any frequency. The solution is either (a) to provide coding to secure the necessary interval (approximately 1 µs) 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 I^2C bus.

   t_{SCLLO} in high-speed mode and t_{STASO} in standard mode fail to satisfy the I^2C 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 I^2C bus.

Table 15.8 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.)	I²C Bus Specification (Min.)	φ = 5 MHz	φ = 8 MHz	φ = 10 MHz	φ = 16 MHz
t_{SCLHO}	$0.5t_{SCLO}$ $(-t_{Sr})$	Standard mode	–1000	4000	4000	4000	4000	4000
		High-speed mode	–300	600	950	950	950	950
t_{SCLLO}	$0.5t_{SCLO}$ $(-t_{Sf})$	Standard mode	–250	4700	4750	4750	4750	4750
		High-speed mode	–250	1300	1000*[1]	1000*[1]	1000*[1]	1000*[1]
t_{BUFO}	$0.5t_{SCLO}-1t_{cyc}$ $(-t_{Sr})$	Standard mode	–1000	4700	3800*[1]	3875*[1]	3900*[1]	3938*[1]
		High-speed mode	–300	1300	750*[1]	825*[1]	850*[1]	888*[1]
t_{STAHO}	$0.5t_{SCLO}-1t_{cyc}$ $(-t_{Sf})$	Standard mode	–250	4000	4550	4625	4650	4688
		High-speed mode	–250	600	800	875	900	938
t_{STASO}	$1t_{SCLO}$ $(-t_{Sr})$	Standard mode	–1000	4700	9000	9000	9000	9000
		High-speed mode	–300	600	2200	2200	2200	2200
t_{STOSO}	$0.5t_{SCLO}+2t_{cyc}$ $(-t_{Sr})$	Standard mode	–1000	4000	4400	4250	4200	412
		High-speed mode	–300	600	1350	1200	1150	1075
t_{SDASO} (master)	$1t_{SCLLO}$*[2] $-3t_{cyc}$ $(-t_{Sr})$	Standard mode	–1000	250	3100	3325	3400	3513
		High-speed mode	–300	100	400	625	700	813
t_{SDASO} (slave)	$1t_{SCLL}$*[2] $-3t_{cyc}$*[2] $(-t_{Sr})$	Standard mode	–1000	250	3100	3325	3400	3513
		High-speed mode	–300	100	400	625	700	813
t_{SDAHO}	$3t_{cyc}$	Standard mode	0	0	600	375	300	188
		High-speed mode	0	0	600	375	300	188

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 15.17 (after confirming that the BBSY bit has been cleared to 0 in the ICCR register).

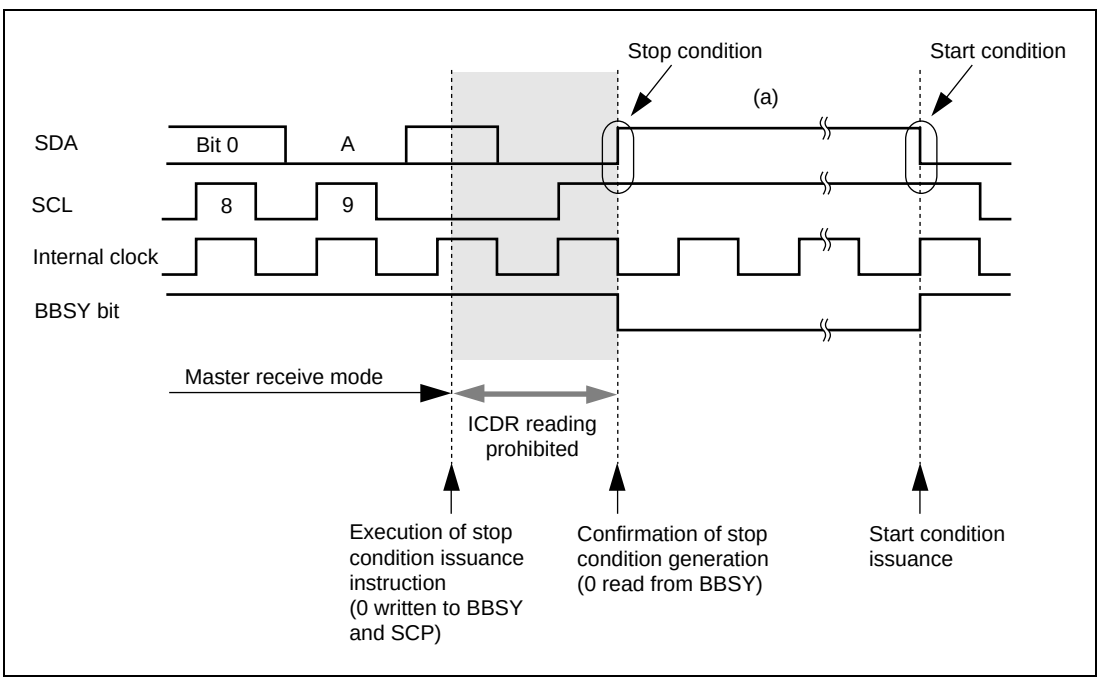


Figure 15.17 Points for Attention Concerning Reading of Master Receive Data

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 15.18 shows the timing of start condition issuance for retransmission, and the timing for subsequently writing data to ICDR, together with the corresponding flowchart.

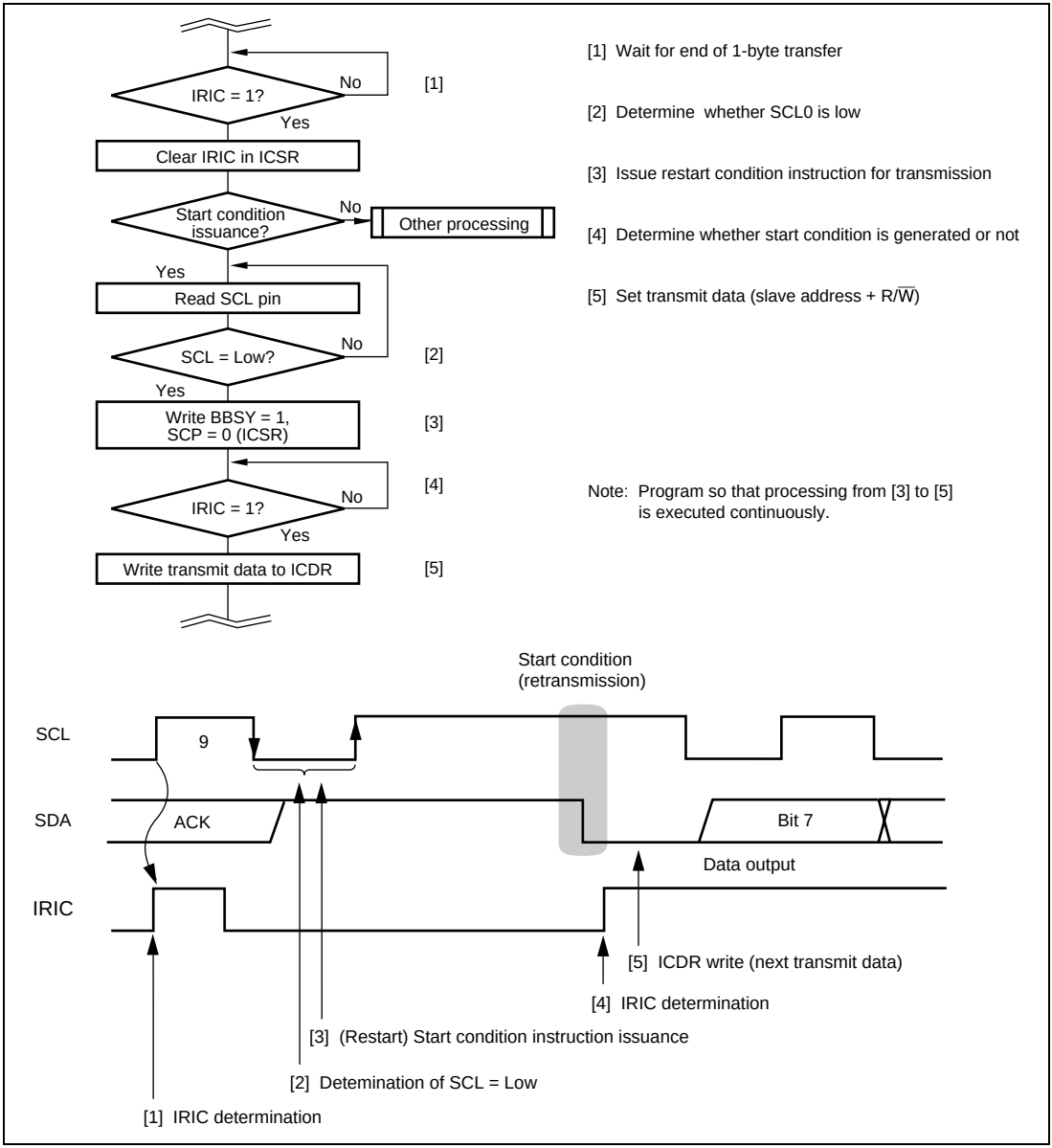


Figure 15.18 Flowchart and Timing of Start Condition Instruction Issuance for Retransmission

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.

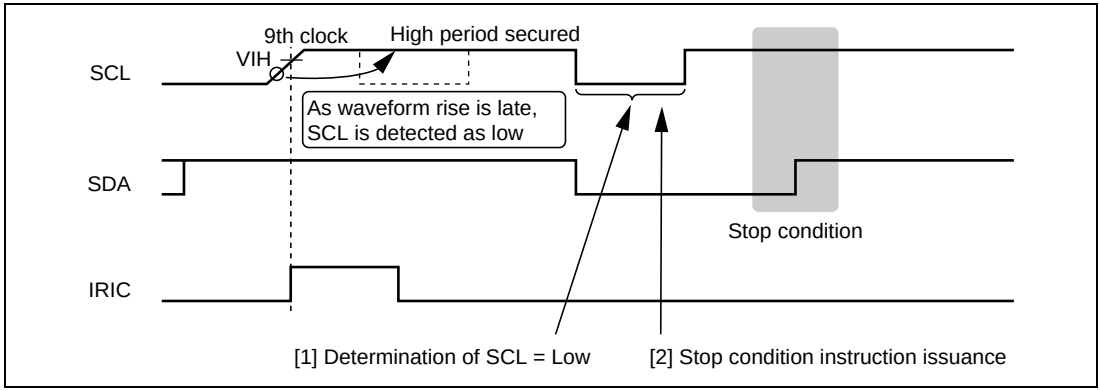


Figure 15.19 Timing of Stop Condition Issuance

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 DDCSWR register. For details see section 15.3.8 DDC Switch Register (DDCSWR).

- 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, DDCSWR, STCR)
  - — Internal latches used t retain register read information setting/clearing flags in the ICMR,.ICCR, ICSR, and DDCSWR 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.

12. Assignment and Selection of Register Addresses

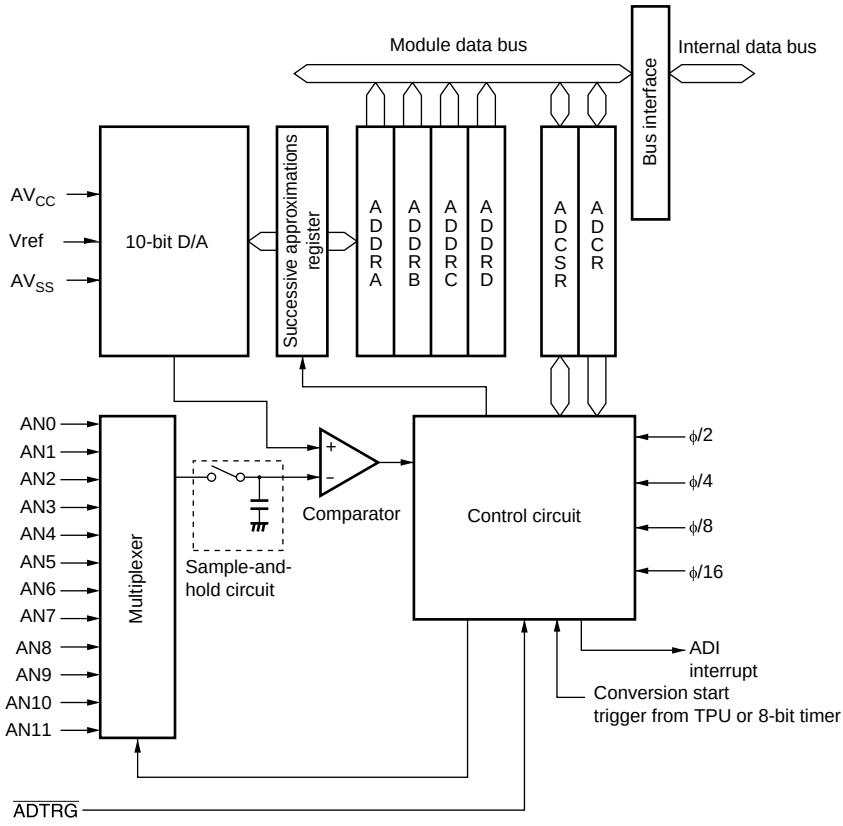
    Some I^2C bus interface registers are assigned to the same address as other registers. Register selection is performed by means of the IICE bit in the serial control register X (SCRX). For details on register addresses, see section 24, List of Registers.

Section 16 A/D Converter

This LSI includes a successive approximation type 10-bit A/D converter that allows up to eight analog input channels to be selected. A block diagram of the A/D converter is shown in figure 16.1.

16.1 Features

- 10-bit resolution
- Eight input channels
- Conversion time: 9.6 µs per channel (at 13 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 TNR) 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



Legend

ADCR : A/D control register
ADCSR : A/D control/status register
ADDRA : A/D data register A
ADDRB : A/D data register B
ADDRC : A/D data register C
ADDRD : A/D data register D

Figure 16.1 Block Diagram of A/D Converter

16.2 Input/Output Pins

Table 16.1 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 16.1 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	
A/D external trigger input pin	ADTRG	Input	External trigger input pin for starting A/D conversion

16.3 Register Descriptions

The A/D converter has the following registers. For details on the module stop control register, refer to section 23.1.2, Module Stop Control Registers A to C (MSTPCRA to MSTPCRC).

- 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)

16.3.1 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 16.2.

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 16.2 Analog Input Channels and Corresponding ADDR Registers

Analog Input Channel		A/D Data Register to Be Stored the Results of A/D Conversion
Group 0 (CH2 = 0)	Group 1 (CH2 = 1)	
AN0	AN4	ADDRA
AN1	AN5	ADDRB
AN2	AN6	ADDRC
AN3	AN7	ADDRD

16.3.2 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)*	A/D End Flag A status flag that indicates the end of A/D conversion. [Setting conditions] • When A/D conversion ends in single mode • When A/D conversion ends on all specified channels in scan mode [Clearing conditions] • When 0 is written after reading ADF = 1 • When the DTC is activated by an ADI interrupt and ADDR is read
6	ADIE	0	R/W	A/D Interrupt Enable A/D conversion end interrupt (ADI) request enabled when 1 is set
5	ADST	0	R/W	A/D Start Clearing this bit to 0 stops A/D conversion, and the A/D converter enters the wait state. 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, software standby mode, hardware standby mode, or module stop mode. The ADST bit can be set to 1 by software, a timer conversion start trigger, or the A/D external trigger input pin (ADTRG).

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	—	0	R/W	Reserved	
				This bit is always read as 0. The write value should always be 0.	
2	CH2	0	R/W	Channel Select 0 to 2	
1	CH1	0	R/W	Select analog input channels.	
0	CH0	0	R/W	When SCAN = 0	When SCAN = 1
				000: AN0	000: AN0
				001: AN1	001: AN0 and AN1
				010: AN2	010: AN0 to AN2
				011: AN3	011: AN0 to AN3
				100: AN4	100: AN4
				101: AN5	101: AN4 and AN5
				110: AN6	110: AN4 to AN6
				111: AN7	111: AN4 to AN7

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

16.3.3 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 25.11 (H8S/2239 Series), table 25.23 (H8S/2238R Series), or table 25.33 (H8S2237 Series) in section 25, 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.

16.4 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.

16.4.1 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.

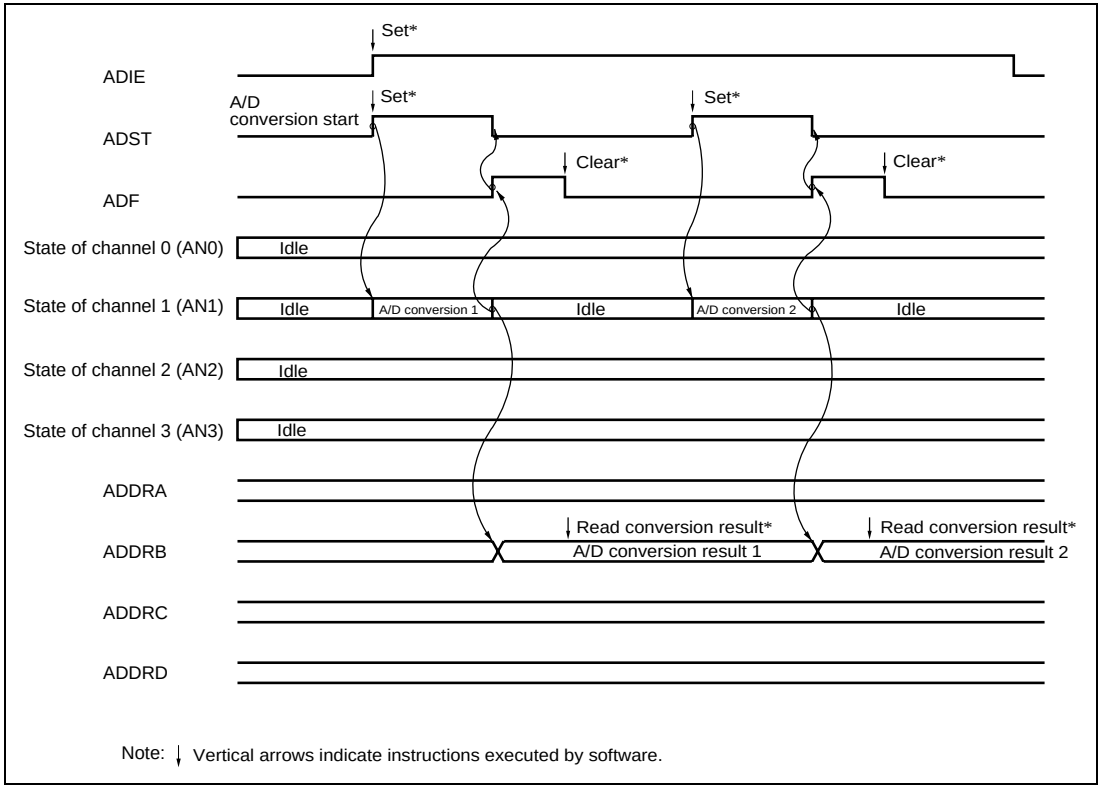


Figure 16.2 Example of A/D converter Operation (Single Mode, Channel 1 Selected)

16.4.2 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 CH2 = 0, AN4 when CH2 = 1).
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.

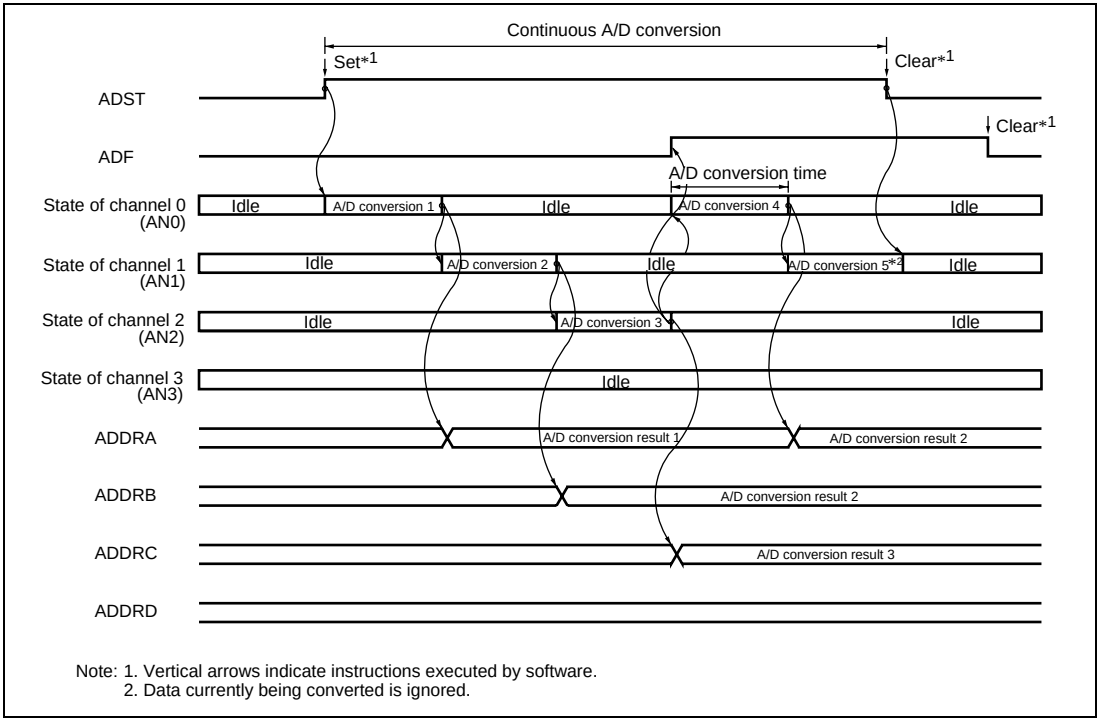


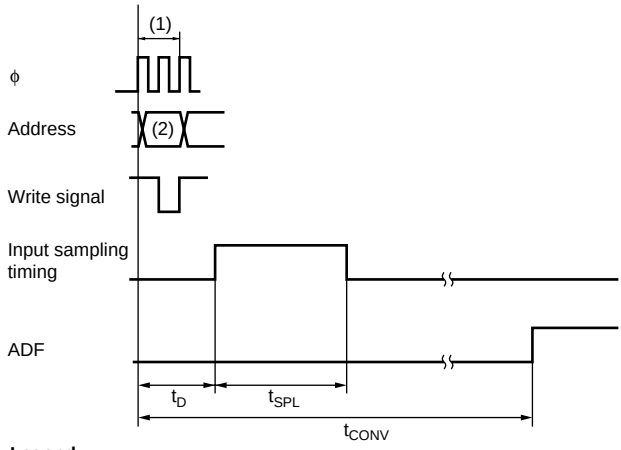
Figure 16.3 Example of A/D Converter Operation (Scan Mode, Channels AN0 to AN2 Selected)

16.4.3 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 16.4 shows the A/D conversion timing. Table 16.3 shows the A/D conversion time.

As indicated in figure 16.4, 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 16.3.

In scan mode, the values given in table 16.3 apply to the first conversion time. The values given in table 16.4 apply to the second and subsequent conversions.



Legend
(1) : ADCSR write cycle
(2) : ADCSR address
t_D : A/D conversion start delay
t_{SPL} : Input sampling time
t_{CONV} : A/D conversion time

Figure 16.4 A/D Conversion Timing

Table 16.3 A/D Conversion Time (Single Mode)

		CKS1 = 0						CKS1 = 1					
		CKS0 = 0			CKS0 = 1			CKS0 = 0			CKS0 = 1		
Item	**Symbol**	**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 16.4 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)

16.4.4 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 ADTRG pin. A falling edge at the 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 16.5 shows the timing.

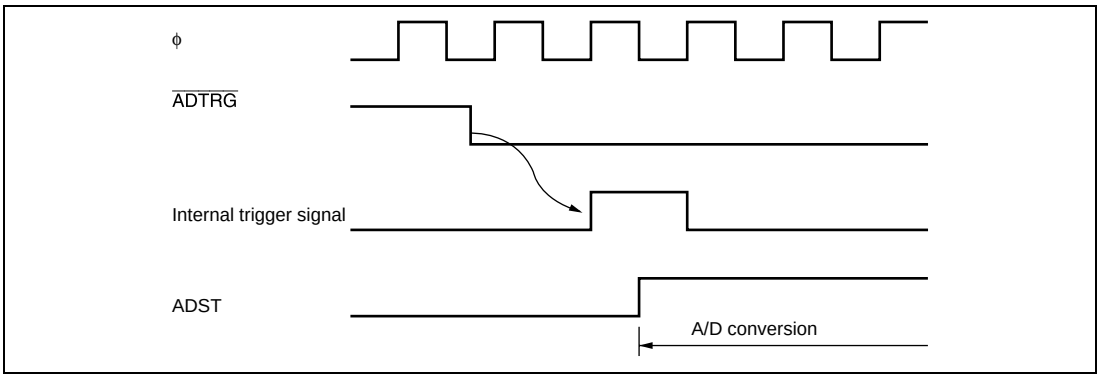


Figure 16.5 External Trigger Input Timing

16.5 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. The DMAC* and the DTC can be activated by an ADI interrupt. Having the converted data read by the DMAC* or the DTC in response to an ADI interrupt enables continuous conversion without imposing a load on software.

Note: * Supported only by the H8S/2239 Series.

Table 16.5 A/D Converter Interrupt Source

Name	Interrupt Source	Interrupt Source Flag	DTC Activation	DMAC* Activation
ADI	A/D conversion completed	ADF	Possible	Possible

Note: * Supported only by the H8S/2239 Series.

16.6 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 16.6).
- 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'0000000000 (H'000) to B'0000000001 (H'001) (see figure 16.7).
- 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'1111111110 (H'3FE) to B'1111111111 (H'3FF) (see figure 16.7).
- 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 16.7).

- Absolute accuracy

  The deviation between the digital value and the analog input value. Includes offset error, full-scale error, quantization error, and nonlinearity error.

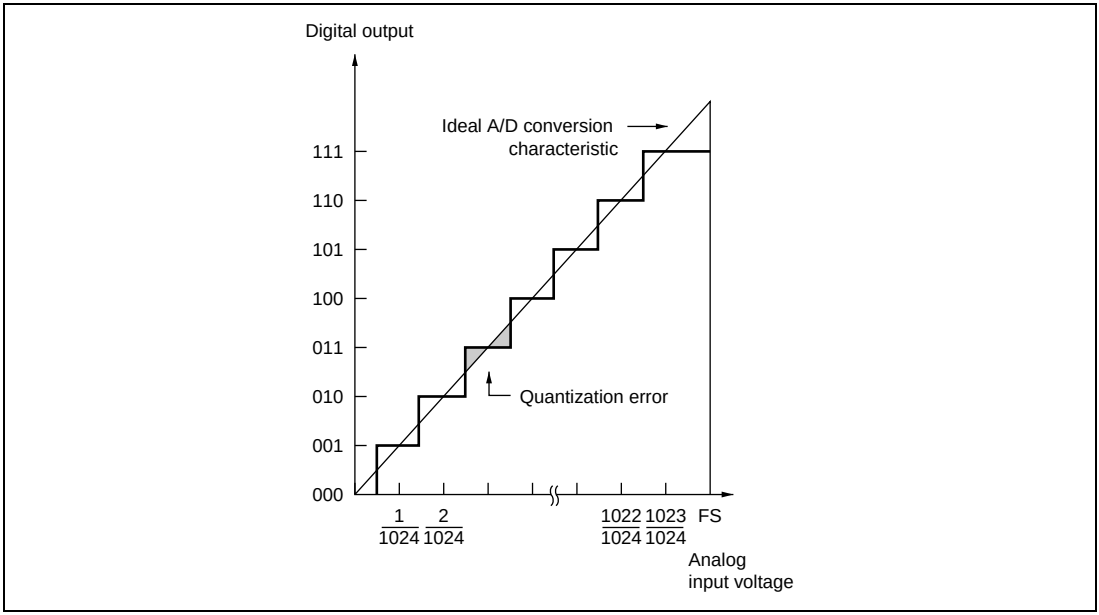


Figure 16.6 A/D Conversion Accuracy Definitions

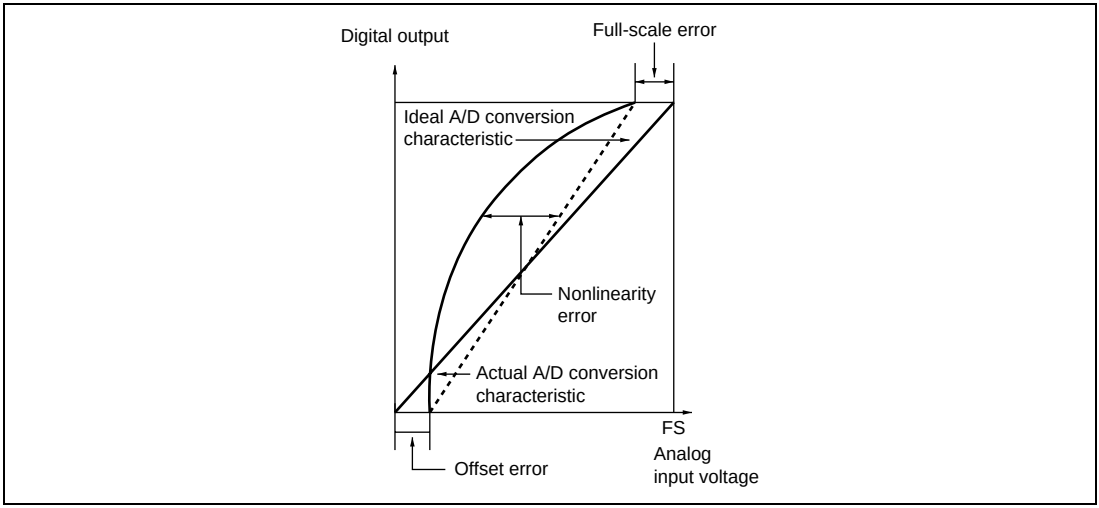


Figure 16.7 A/D Conversion Accuracy Definitions

16.7 Usage Notes

16.7.1 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 23, Power-Down Modes.

16.7.2 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 kΩ or less. This specification is provided to enable the A/D converter's sample-and-hold circuit input capacitance to be charged within the sampling time; if the sensor output impedance exceeds 5 kΩ, 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 kΩ, 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 mV/µs or greater) (see figure 16.8). When converting a high-speed analog signal, a low-impedance buffer should be inserted.

16.7.3 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).

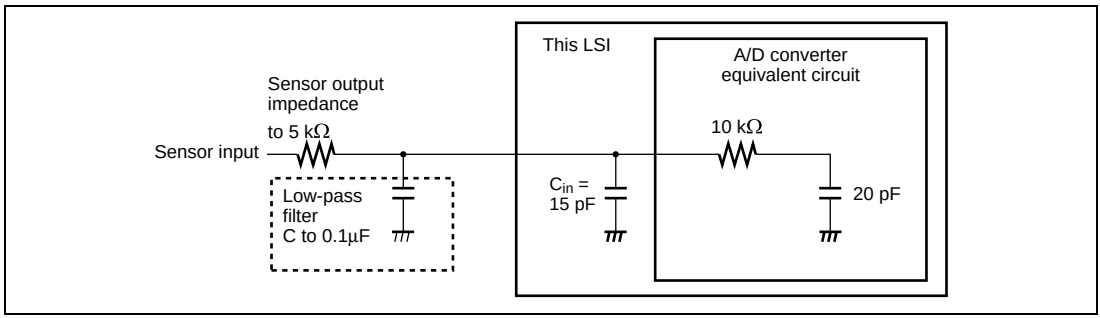


Figure 16.8 Example of Analog Input Circuit

16.7.4 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 AVss ≤ ANn ≤ AVcc.
- Relationship between AVcc, AVss and Vcc, Vss

  Set AVss = Vss as the relationship between AVcc, AVss and Vcc, Vss. If the A/D converter is not used, the AVcc and AVss pins must not be left open.
- Vref range

  The reference voltage input from the Vref pin should be set to AVcc or less.

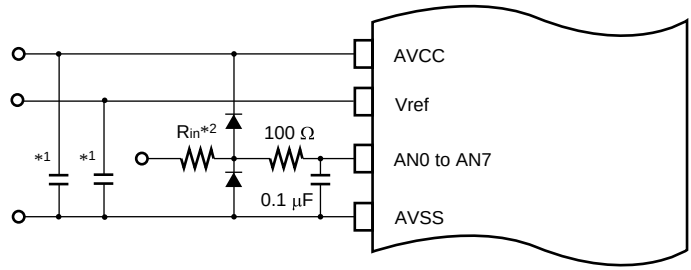
16.7.5 Notes on Board Design

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 AN7), and analog power supply (AVcc) by the analog ground (AVss). Also, the analog ground (AVss) should be connected at one point to a stable digital ground (Vss) on the board.

16.7.6 Notes on Noise Countermeasures

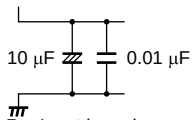
A protection circuit should be connected in order to prevent damage due to abnormal voltage, such as an excessive surge at the analog input pins (AN0 to AN7), between AVcc and AVss, as shown in figure 16.9. Also, the bypass capacitors connected to AVcc and the filter capacitor connected to AN0 to AN7 must be connected to AVss.

If a filter capacitor is connected, the input currents at the analog input pins (AN0 to AN7) 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.

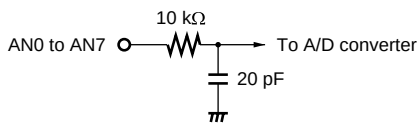


2. R_{in}: Input impedance

Figure 16.9 Example of Analog Input Protection Circuit

Table 16.6 Analog Pin Specifications

Item	Min	Max	Unit
Analog input capacitance	—	20	pF
Permissible signal source impedance	—	5	kΩ



Note: Values are reference values.

Figure 16.10 Analog Input Pin Equivalent Circuit

Section 17 D/A Converter

17.1 Features

- 8-bit resolution
- Two output channels
- Conversion time: 10 µs, 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

Note: The D/A converter is not included in the H8S/2227 Series.

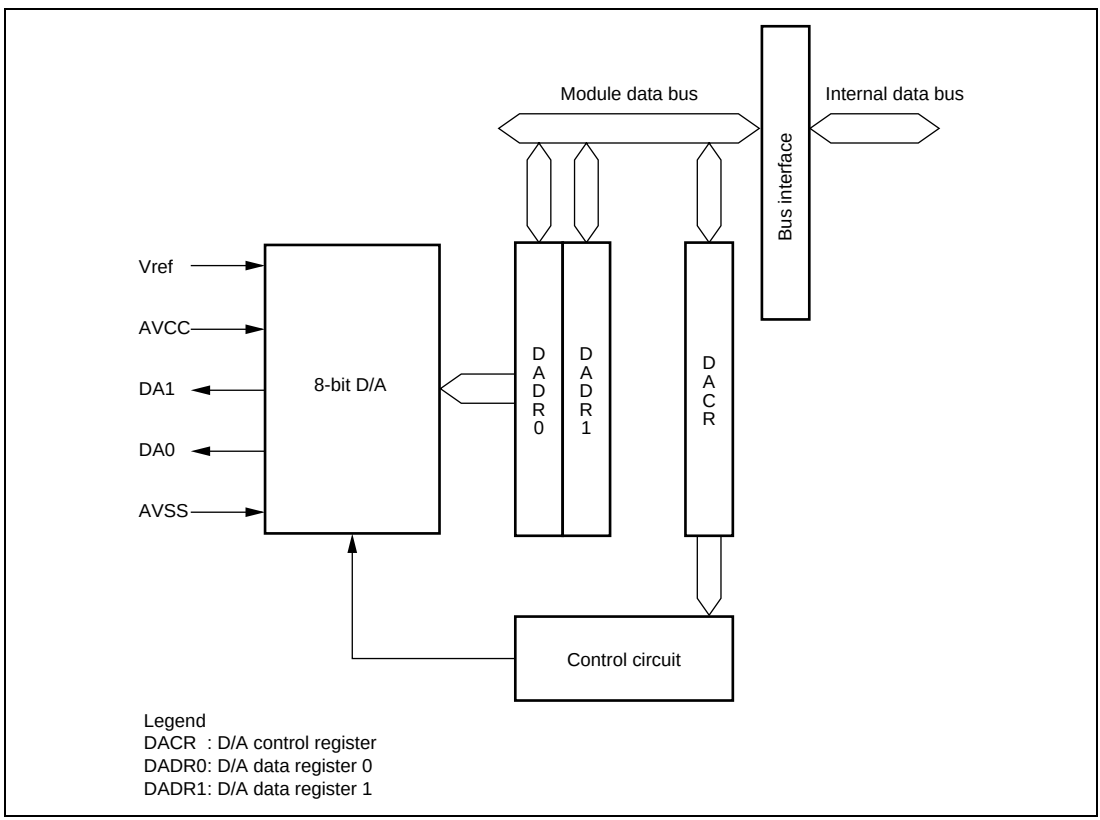


Figure 17.1 Block Diagram of D/A Converter

17.2 Input/Output Pins

Table 17.1 shows the pin configuration for the D/A converter.

Table 17.1 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

17.3 Register Description

The D/A converter has the following registers. For details on the module stop control register, refer to section 23.1.2, Module Stop Control Registers A to C (MSTPCRA to MSTPCRC).

- D/A data register 0 (DADR0)
- D/A data register 1 (DADR1)
- D/A control register (DACR)

17.3.1 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.

17.3.2 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 17.2, D/A Conversion Control.
4 to 0	—	All 1	—	Reserved These bits are always read as 1 and cannot be modified.

Table 17.2 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	

17.4 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 17.2.

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:

   (DADR contents)/256 x Vref
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.

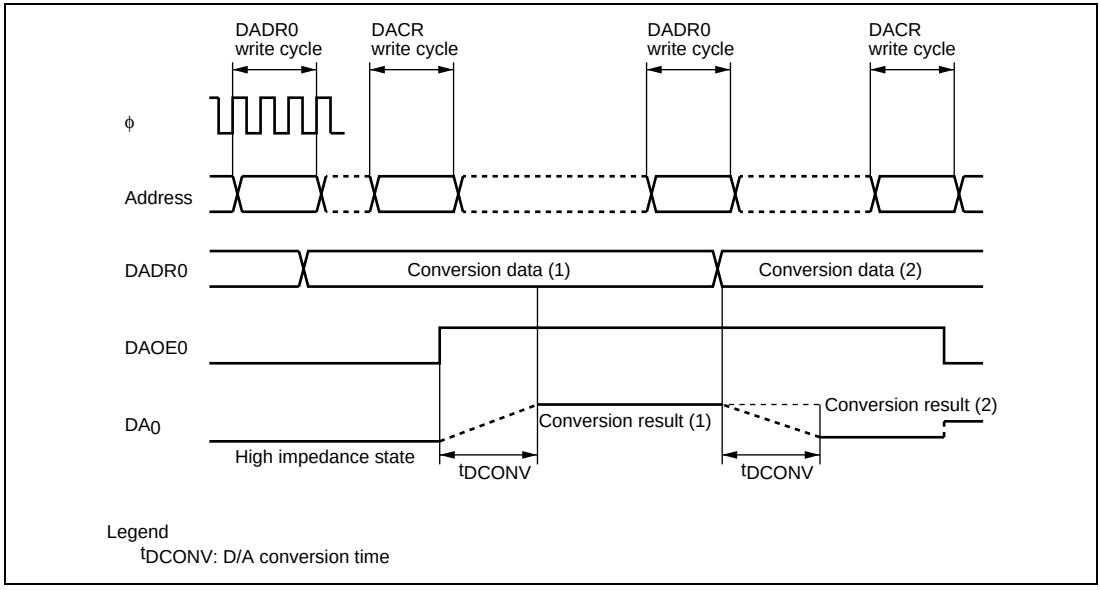


Figure 17.2 D/A Converter Operation Example

17.5 Usage notes

17.5.1 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.

17.5.2 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 23, Power-Down Modes.

Section 18 RAM

The H8S/2239 has 32 kbytes of on-chip high-speed static RAM. The H8S/2238R, H8S/2237, and H8S/2227 have 16 kbytes of on-chip high-speed static RAM. The H8S/2236 has 8 kbytes of on-chip high-speed static RAM. The H8S/2235, H8S/2233, H8S/2225, H8S/2224, and H8S/2223 have 4 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 19 ROM

The features of the flash memory are summarized below.

The block diagram of the flash memory is shown in figure 19.1.

19.1 Features

- Capacity

  H8S/2239: 384 kbytes

  H8S/2238R: 256kbytes

  H8S/2227: 128 kbytes
- 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/2239 is configured as follows: 64 kbytes × 5 blocks, 32 kbytes × 1 block, and 4 kbytes × 8 blocks. The flash memory of the H8S/2238R is configured as follows: 64 kbytes × 3 block, 32 kbytes × 1 block, and 4 kbytes × 8 blocks. The flash memory of the H8S/2227 is configured as follows: 32 kbytes × 2 blocks, 28 kbytes × 1 block, 16 kbytes × 8 block, 8 kbytes × 1 block, and 1 kbyte × 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.

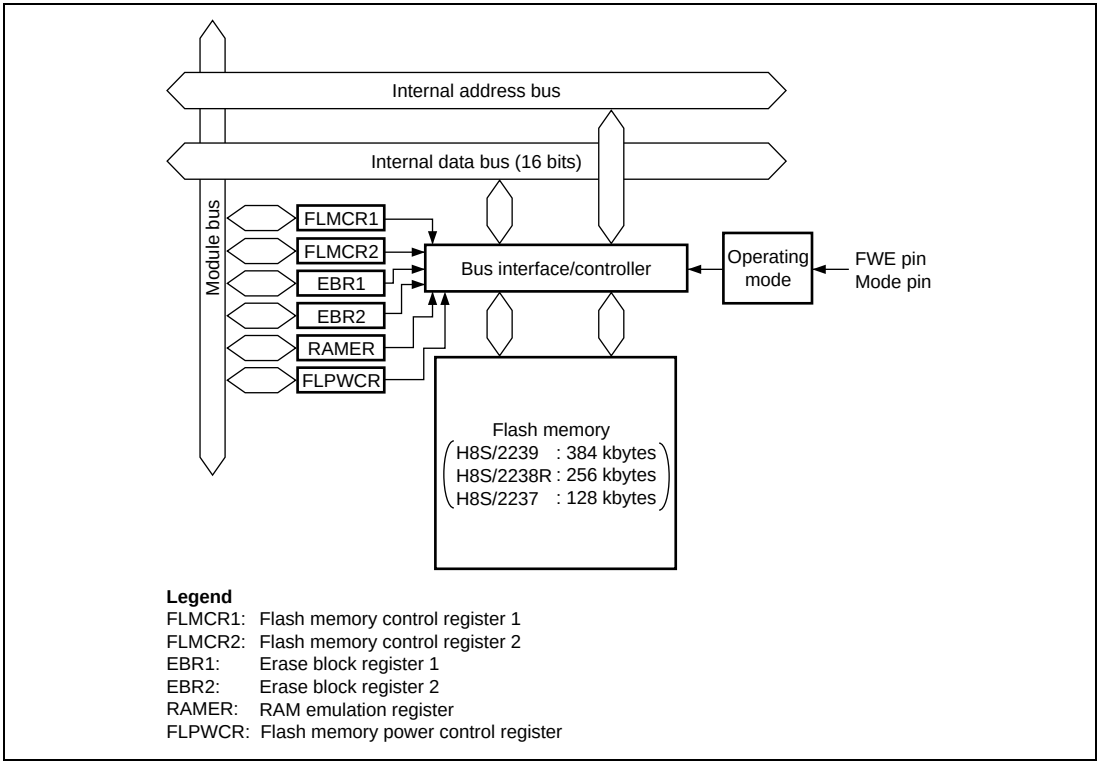


Figure 19.1 Block Diagram of Flash Memory

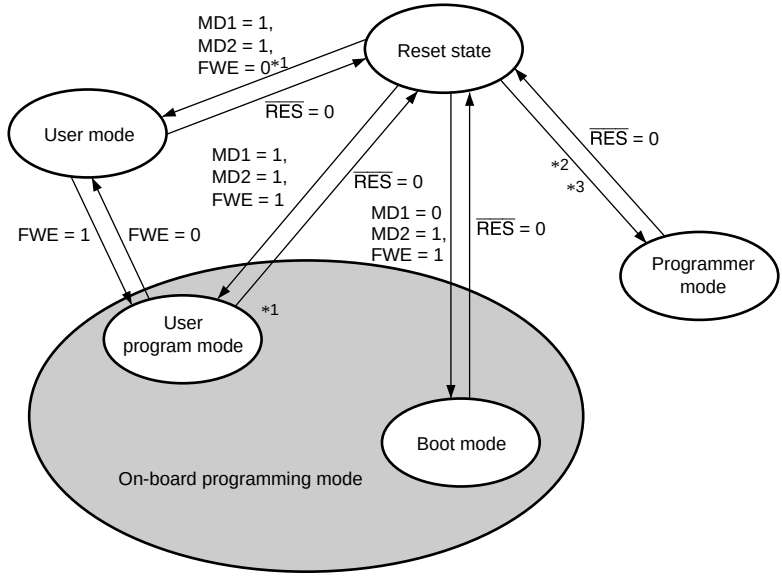
19.2 Mode Transitions

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 shown in figure 19.2. 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 19.1.

Figure 19.3 shows the operation flow for boot mode and figure 19.4 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. IN the H8S/2239 Series and H8S/2238R Series, MD0 = 0, MD1 = 0, MD2 = 0, P14 = 0, P16 = 0, PF0 = 1.
3. IN the H8S/2227 Series, MD0 = 0, MD1 = 0, MD2 = 0, P14 = 0, P16 = 0, PF0 = 1, PF3 = 1.

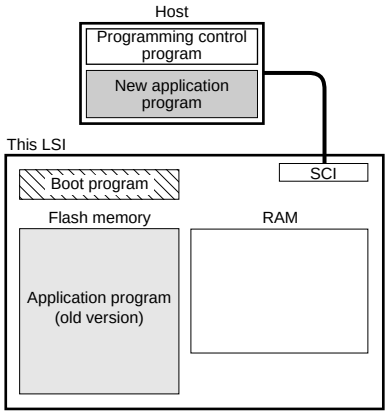
Figure 19.2 Flash Memory State Transitions

Table 19.1 Differences between Boot Mode and User Program Mode

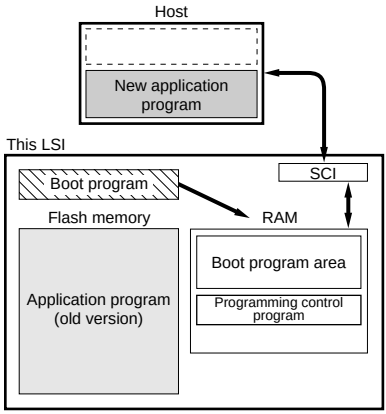
	Boot Mode	User Program Mode
Total erase	Yes	Yes
Block erase	No	Yes
Programming control program*	Program/program-verify	Program/program-verify/erase/ erase-verify/emulation

Note: * To be provided by the user, in accordance with the recommended algorithm.

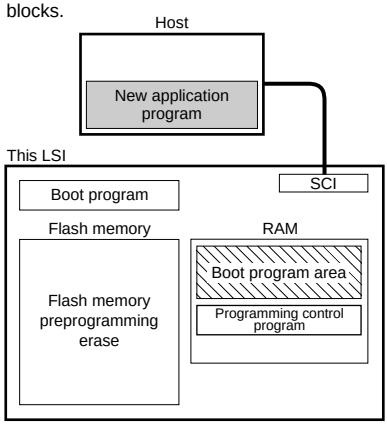
1. Initial state
   The old program version or data remains written in the flash memory. The user should prepare the programming control program and new application program beforehand in the host.



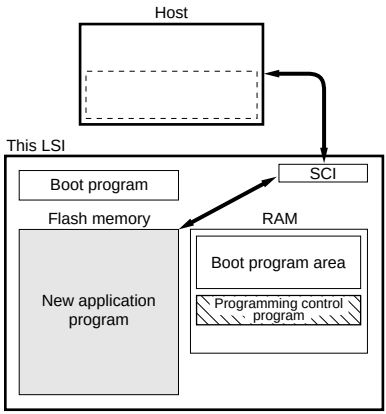
2. Programming control program transfer
   When boot mode is entered, the boot program in this LSI (originally incorporated in the chip) is started and the programming control program in the host is transferred to RAM via SCI communication. The boot program required for flash memory erasing is automatically 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.

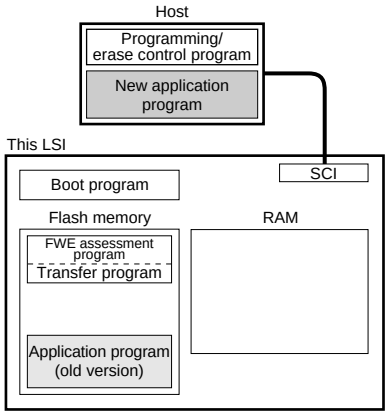


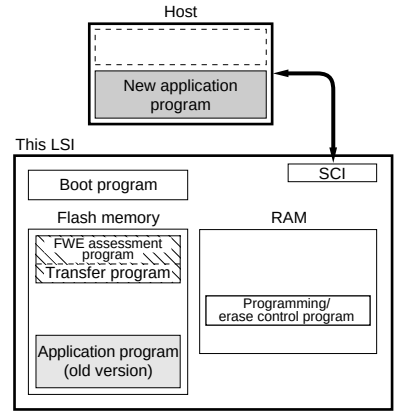
Program execution state

Figure 19.3 Boot Mode (Example)

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.

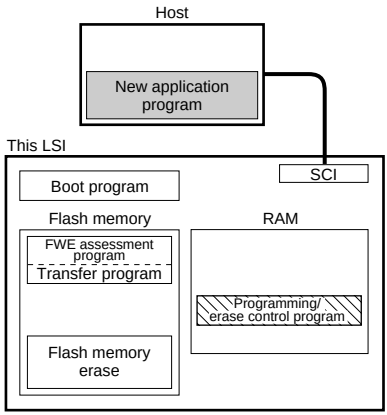
2. Programming/erase control program transfer
   When user program mode is entered, user software confirms this fact, executes transfer program in the flash memory, and transfers the programming/erase control program to RAM.





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.



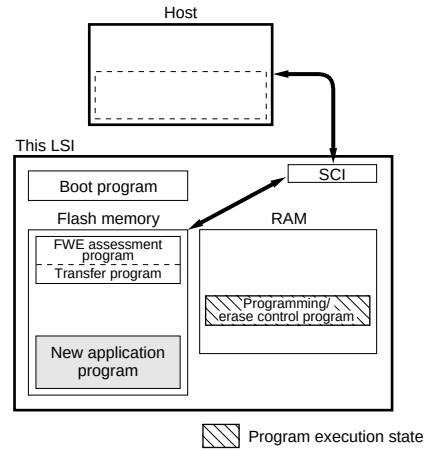


Figure 19.4 User Program Mode (Example)

19.3 Block Configuration

Figure 19.5 shows the block configuration of 384-kbyte flash memory. Figure 19.6 shows the block configuration of 256-kbyte flash memory. Figure 19.7 shows the block configuration of 128-kbyte flash memory. The thick lines indicate erasing units, the narrow lines indicate programming units, and the values are addresses. The 384-kbyte flash memory is divided into 4 kbytes (8 blocks), 32 kbytes (1 block), and 64 kbytes (5 blocks). The 256-kbyte flash memory is divided into 4 kbytes (8 blocks), 32 kbytes (1 block), and 64 kbytes (3 blocks). The 128-kbyte flash memory is divided into 1 kbyte (4 blocks), 16 kbytes (1 block), 28 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.

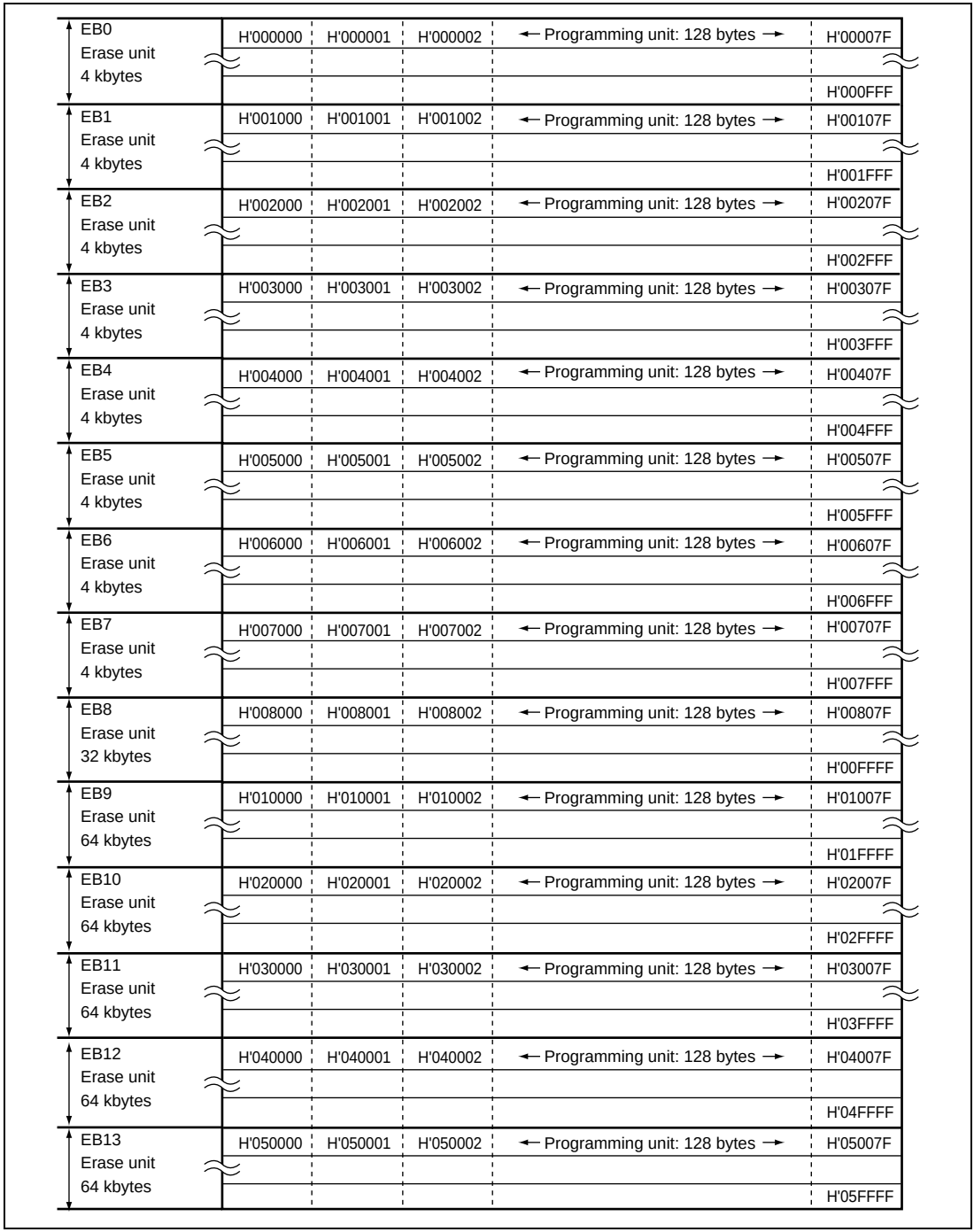


Figure 19.5 Block Configuration of 384-kbyte Flash Memory

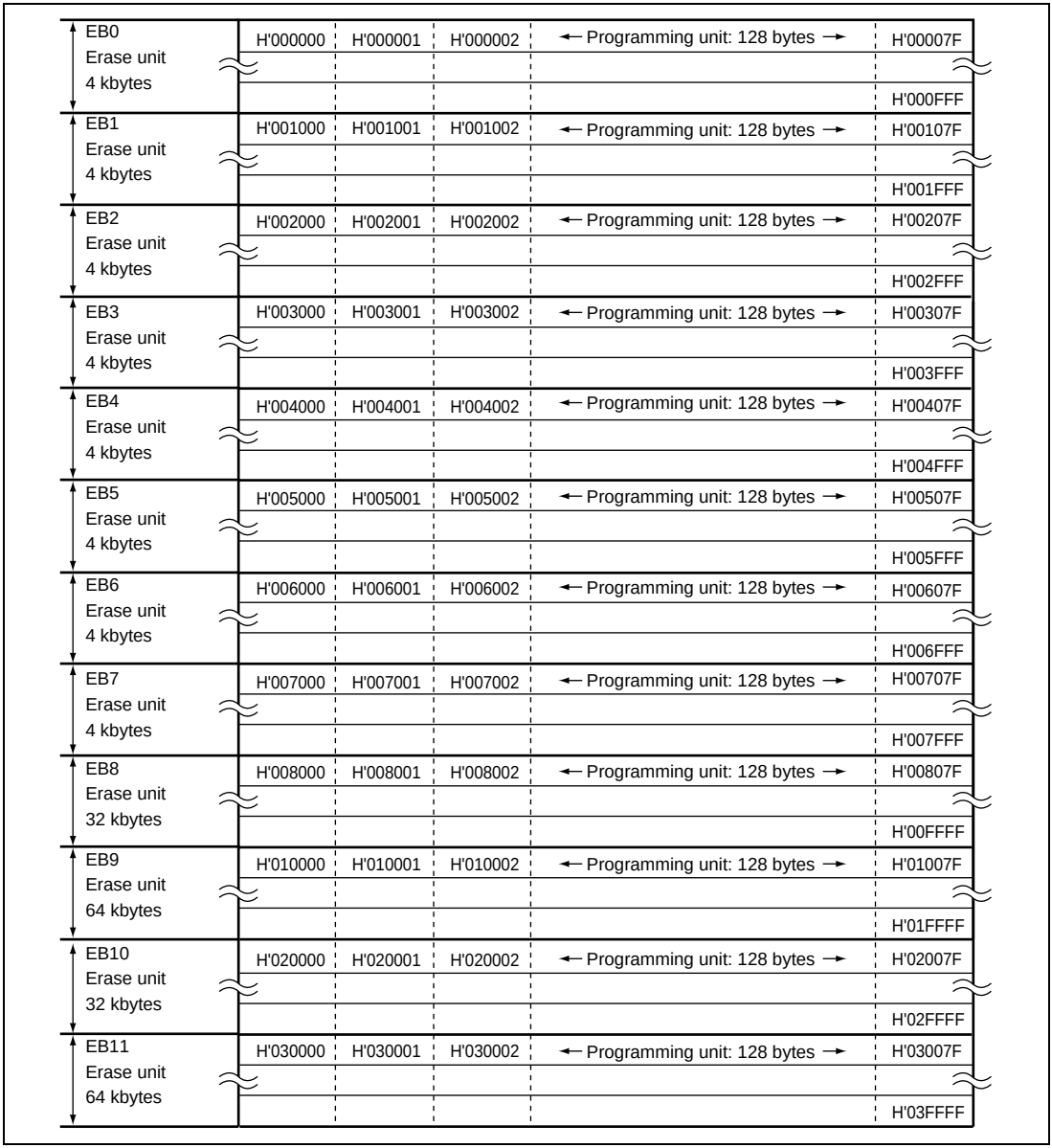


Figure 19.6 Block Configuration of 256-kbyte Flash Memory

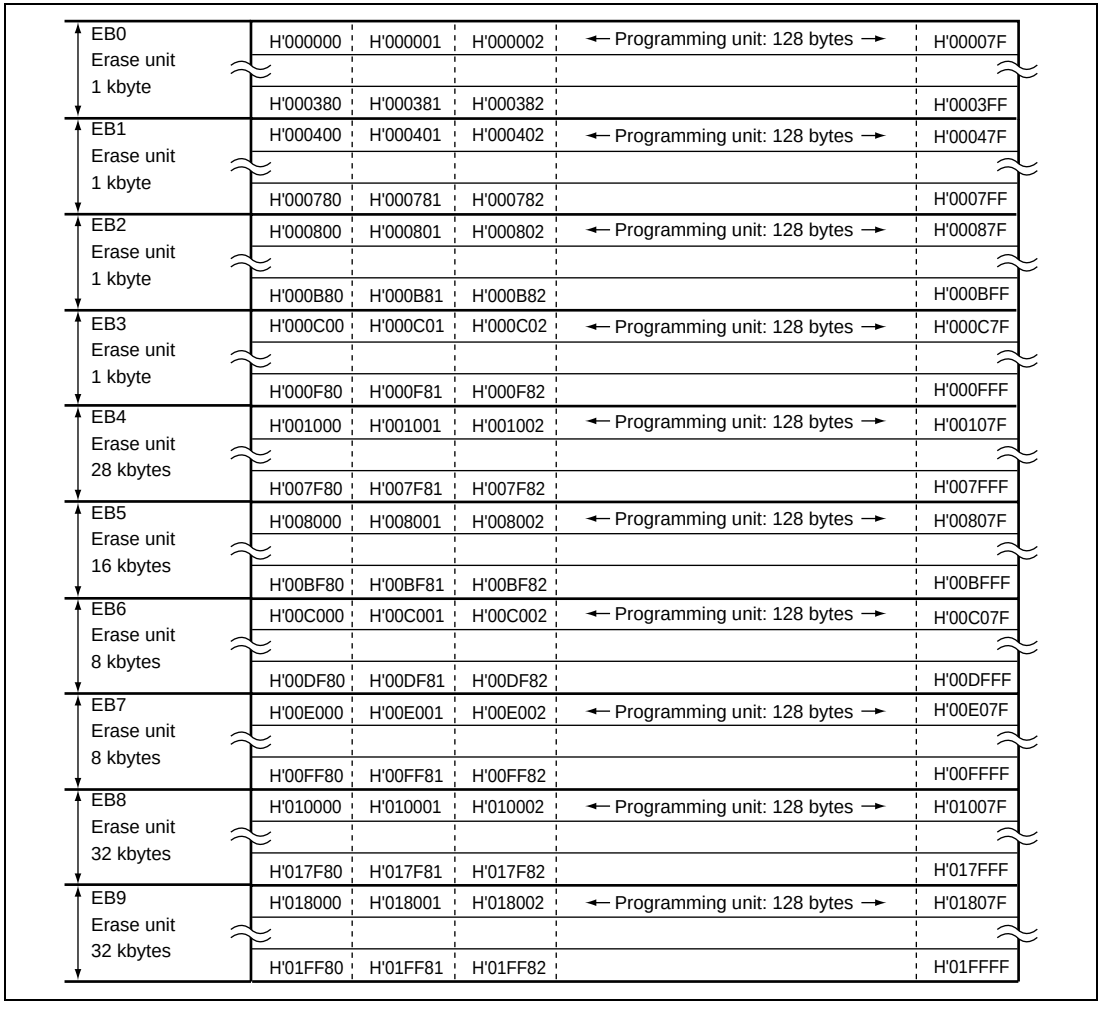


Figure 19.7 Block Configuration of 128-kbyte Flash Memory

19.4 Input/Output Pins

The flash memory is controlled by means of the pins shown in table 19.2.

Table 19.2 Pin Configuration

Pin Name	I/O	Function
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
MD0	Input	Sets this LSI's operating mode
PF0	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
TxD*	Output	Serial transmit data output
RxD*	Input	Serial receive data input

Note:* SCI_2 (TxD2, TxD2) is used for the H8S/2239 and H8S/2238R, and SCI_0 (TxD0, RxD0) for the H8S/2227.

19.5 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.

19.5.1 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 19.8, 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

19.5.2 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 19.9.3, Error Protection, for details.
6 to 0	—	All 0	R	Reserved These bits are always read as 0.

19.5.3 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.

- 384-kbyte or 256-kbyte Flash Memory

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.

- 128-kbyte Flash Memory

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.

19.5.4 Erase Block Register 2 (EBR2)

EBR2 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.

- 384-kbyte Flash Memory

Bit	Bit Name	Initial Value	R/W	Description
7	—	0	R/W	Reserved
6	—	0	R/W	These bits are always read as 0. The write value should always be 0.
5	EB13	0	R/W	When this bit is set to 1, 64 kbytes of EB13 (H'050000 to H'05FFFF) will be erased.
4	EB12	0	R/W	When this bit is 1, 64 kbytes of EB12 (H'040000 to H'04FFFF) will be erased.
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.

- 256-kbyte Flash Memory

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 0	R/(W)	Reserved Initial values should not be changed.
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.

- 128-kbyte Flash Memory

Bit	Bit Name	Initial Value	R/W	Description
7 to 2	—	All 0	R/W	Reserved Initial values should not be changed.
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.

19.5.5 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.

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	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 for the 384-kbyte or 256-kbyte flash memory, 1-kbyte erase block for the 128-kbyte flash memory.
0	RAM0	0	R/W	384-kbyte or 256-kbyte flash memory 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) 128-kbyte flash memory 000: H'000000 to H'0003FF (EB0) 001: H'000400 to H'0007FF (EB1) 010: H'000800 to H'000BFF (EB2) 011: H'000C00 to H'000FFF (EB3) 100: Setting prohibited 101: Setting prohibited 110: Setting prohibited 111: Setting prohibited

19.5.6 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.

19.5.7 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^2C Transfer Select 1, 0
5	IICX0	0	R/W	For details, see section 15.3.5, Serial Control Register X (SCRX).
4	IICE	0	R/W	I^2C Master Enable For details, see section 15.3.5, Serial Control Register X (SCRX).

Bit	Bit Name	Initial Value	R/W	Description
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'FFFFA8 to H'FFFFAC not selected for the flash memory control registers. 1: Area at H'FFFFA8 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.

19.6 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 19.3. For a diagram of the transitions to the various flash memory modes, see figure 19.2.

Table 19.3 Setting On-Board Programming Modes

FWE	MD2	MD1	MD0	Mode Setting	
1	0	1	0	Extended mode	Boot mode
1	0	1	1	Single-chip mode	
1	1	1	0	Extended mode	User program mode
1	1	1	1	Single-chip 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.

19.6.1 Boot Mode

Table 19.4 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 19.8, 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 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 bit rate to match that of the host. The reset should end with the RxD pin high. The RxD and TxD 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 19.5.
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. 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 (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 ns) at the reset release timing.

Table 19.4 Boot Mode Operation

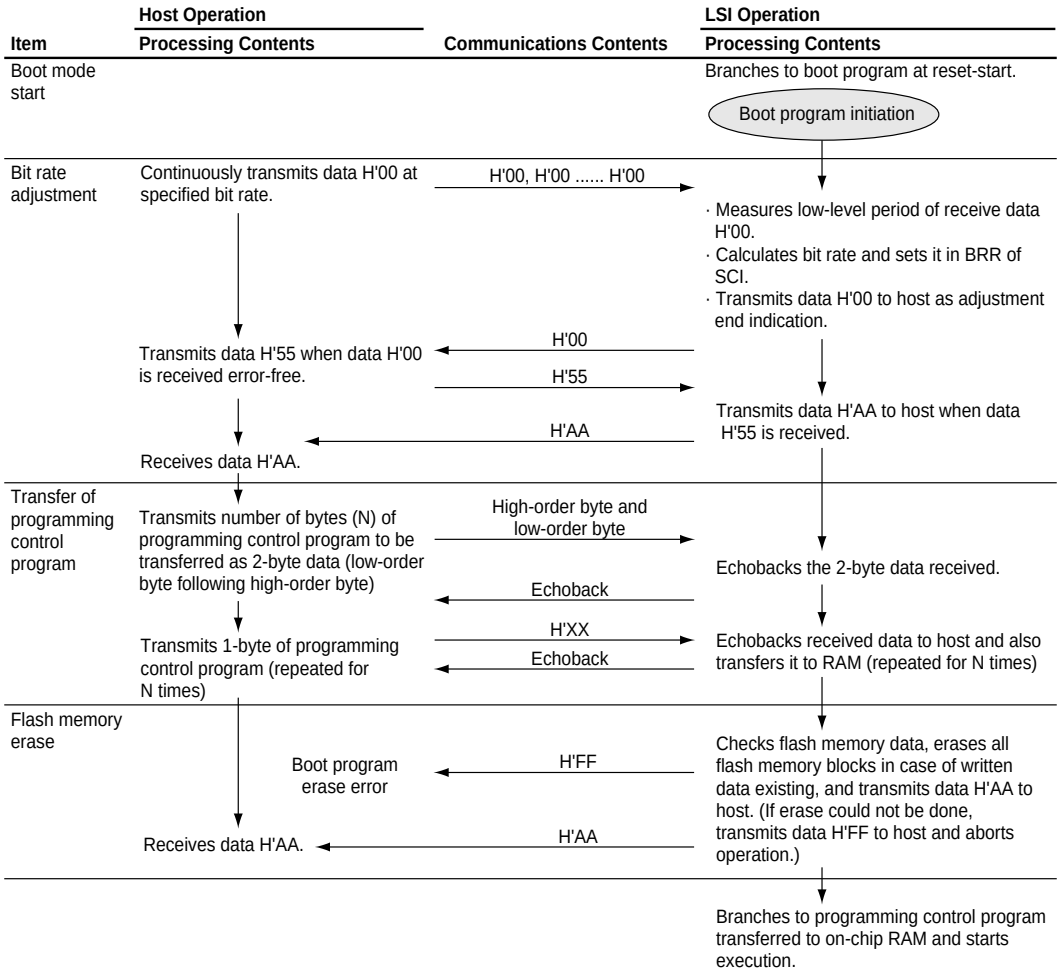


Table 19.5 System Clock Frequencies for which Automatic Adjustment of LSI Bit Rate is Possible

	System Clock Frequency Range of this LSI	
Host Bit Rate	**H8S/2227, H8S/2238R**	**H8S2239**
19,200 bps	8 to 13.5 MHz	8 to 16 MHz
9,600 bps	4 to 13.5 MHz	4 to 16 MHz
4,800 bps	2 to 13.5 MHz	2 to 16 MHz

19.6.2 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 19.8 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 19.8, Flash Memory Programming/Erasing.

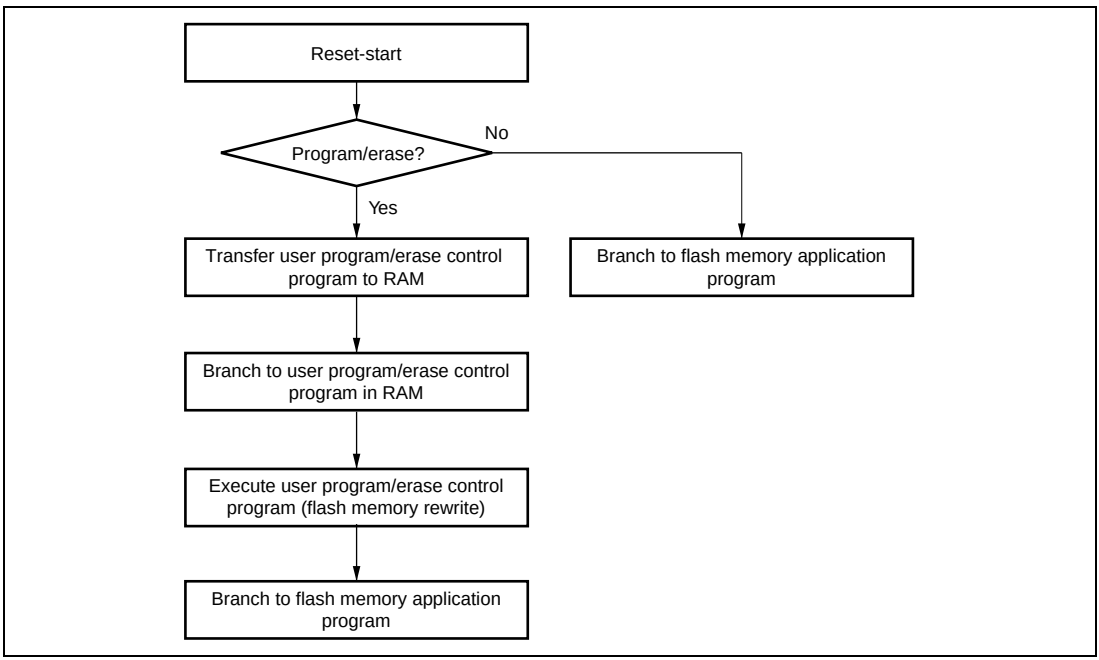


Figure 19.8 Programming/Erasing Flowchart Example in User Program Mode

19.7 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. Figure19.9 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.

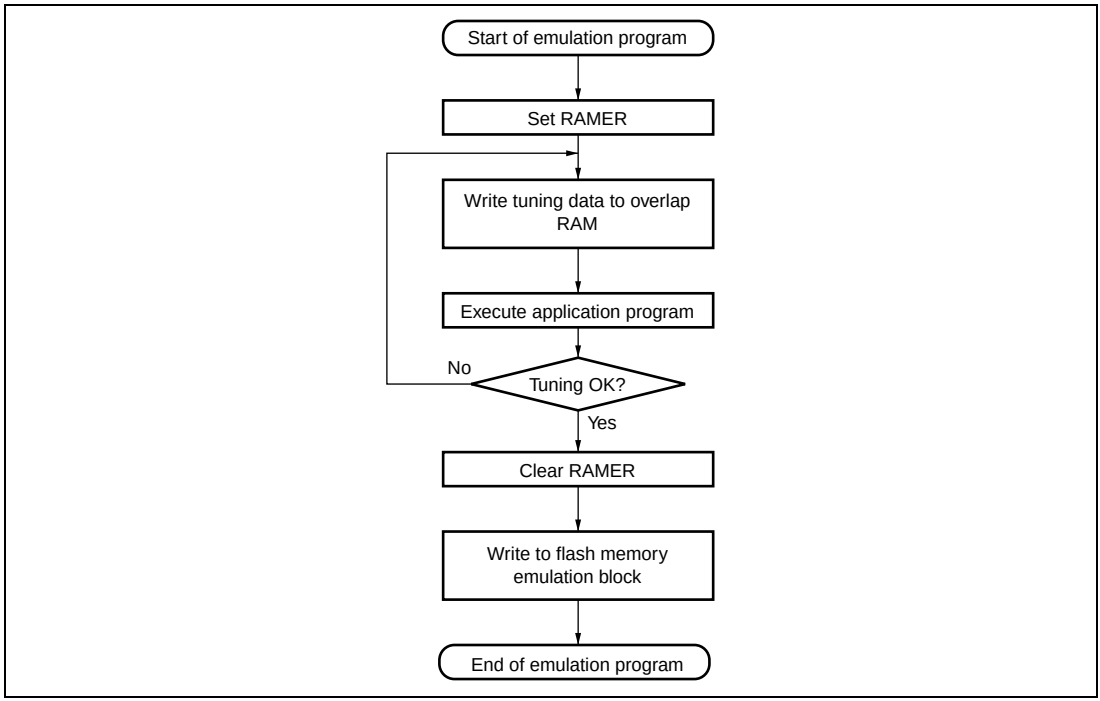


Figure 19.9 Flowchart for Flash Memory Emulation in RAM

An example in which flash memory block area EB0 is overlapped is shown in figure 19.10.

1. The RAM area to be overlapped is fixed at a 4-kbyte area in the range H'FFD000 to H'FFDFFF in the 384-kbyte or 256-kbyte flash memory . The RAM area to be overlapped is fixed at a 1-byte area in the range H'FFD000 to H'FFD3FF in the 128-kbyte flash memory.
2. The flash memory area to be overlapped is selected by RAMER from a 4-kbyte area of the EB0 to EB7 blocks.
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.

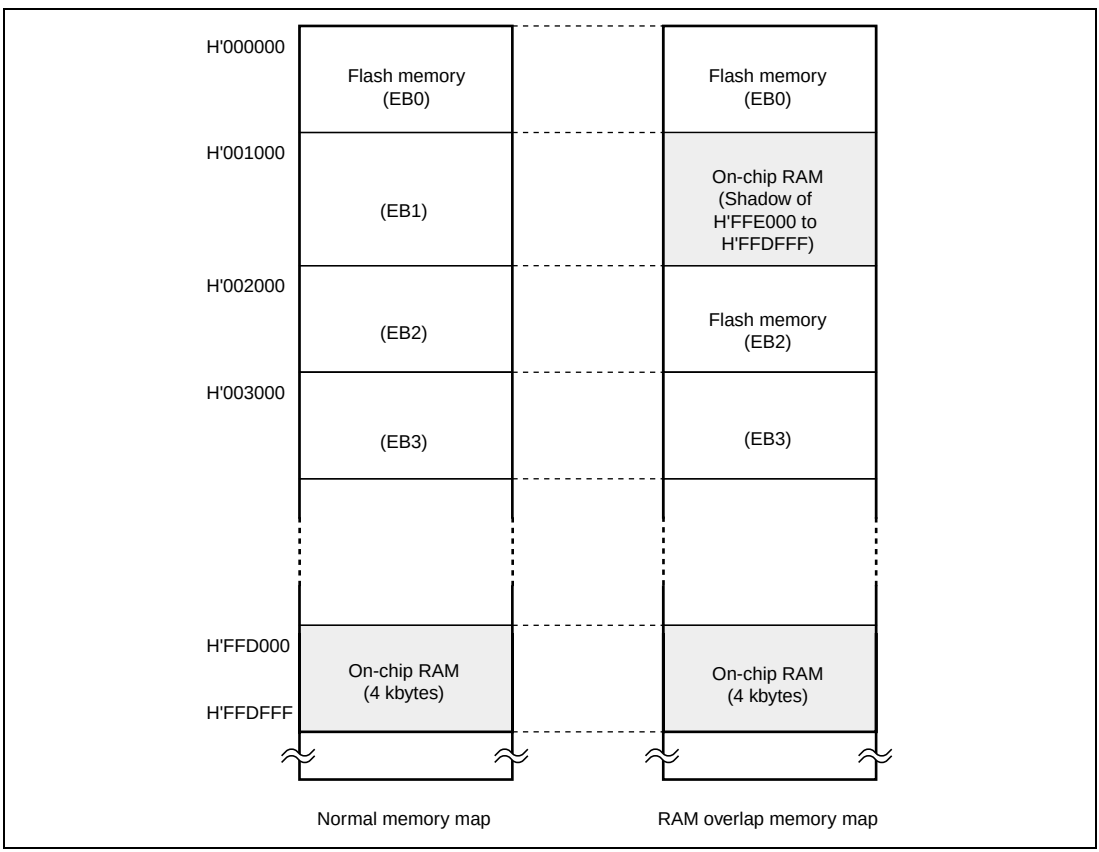


Figure 19.10 Example of RAM Overlap Operation

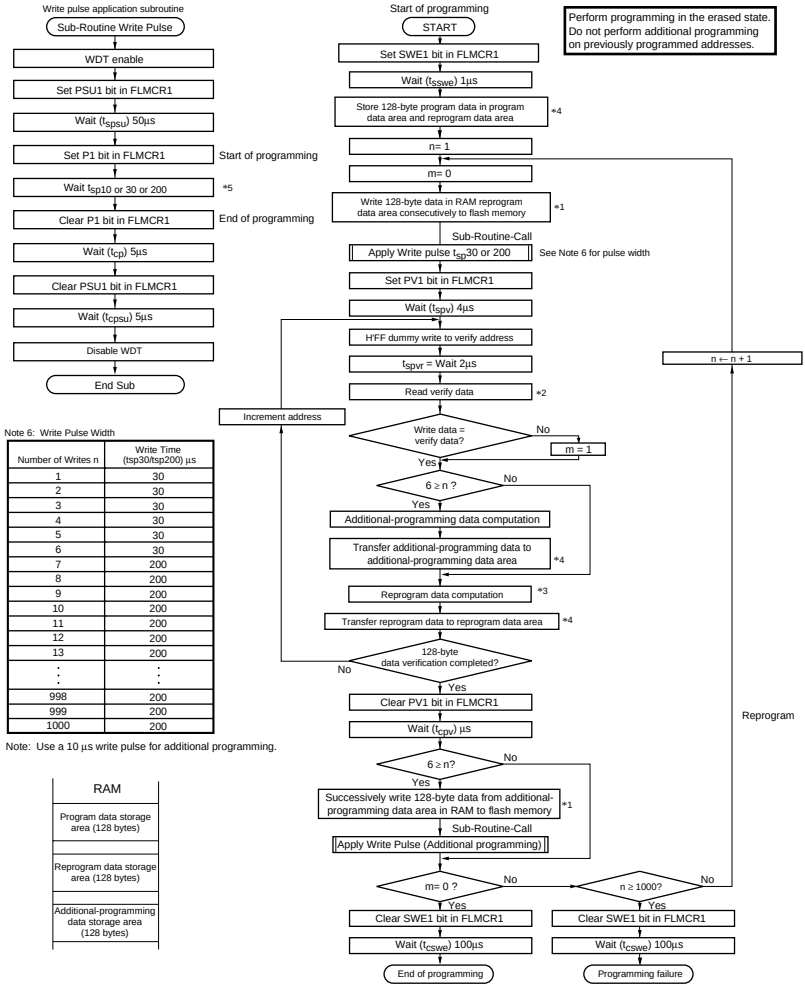
19.8 Flash Memory Programming/Erasing

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 19.8.1, Program/Program-Verify and section 19.8.2, Erase/Erase-Verify, respectively.

19.8.1 Program/Program-Verify

When writing data or programs to the flash memory, the program/program-verify flowchart shown in figure 19.11 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 19.11.
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 19.11 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 (tspsu + tsp200 + tcp + tcpsu) µs 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 longwords 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).



Note 6: Write Pulse Width

Number of Writes n	Write Time (tsp30/tsp200) µs
1	30
2	30
3	30
4	30
5	30
6	30
7	200
8	200
9	200
10	200
11	200
12	200
13	200
⋮	⋮
998	200
999	200
1000	200

Note: Use a 10 µs write pulse for additional programming.

Notes: 1. Data transfer is performed by byte transfer. The lower 8 bits of the first address written to must be H'00 or H'80.
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.
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

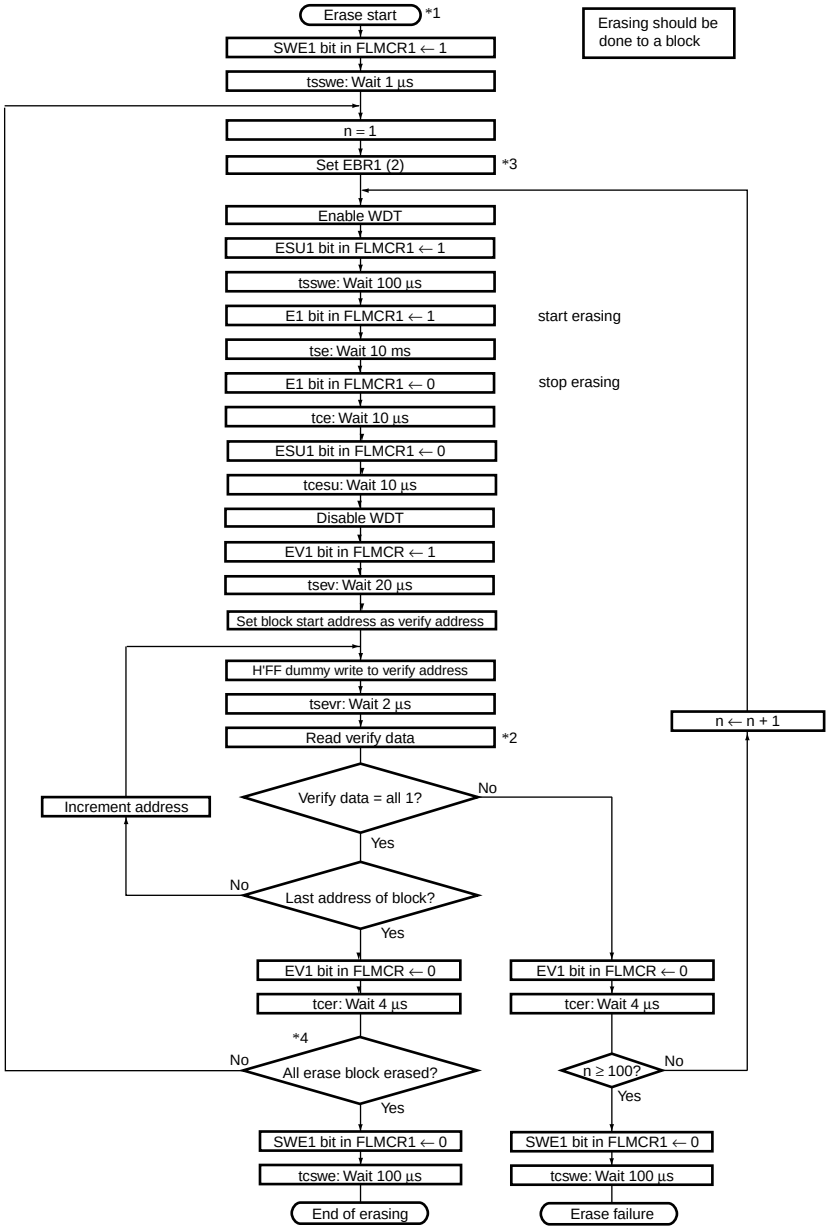
Reprogram Data (X')	Verify Data (V)	Additional-Programming Data (Y)	Comments
0	0	0	Additional programming to be executed
0	1	1	Additional programming not to be executed
1	0	1	Additional programming not to be executed
1	1	1	Additional programming not to be executed

Figure 19.11 Program/Program-Verify Flowchart

19.8.2 Erase/Erase-Verify

When erasing flash memory, the erase/erase-verify flowchart shown in figure 19.12 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 ($t_{sesu} + t_{se} + t_{ce} + t_{cesu}$) 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).



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 19.12 Erase/Erase-Verify Flowchart

19.9 Program/Erase Protection

There are three kinds of flash memory program/erase protection; hardware protection, software protection, and error protection.

19.9.1 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 RES pin, the reset state is not entered unless the RES pin is held low until oscillation stabilizes after powering on. In the case of a reset during operation, hold the RES pin low for the RES pulse width specified in the AC Characteristics section.

19.9.2 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.

19.9.3 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 releases the bus to the DMAC or DTC during programming/erasing

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.

19.10 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.

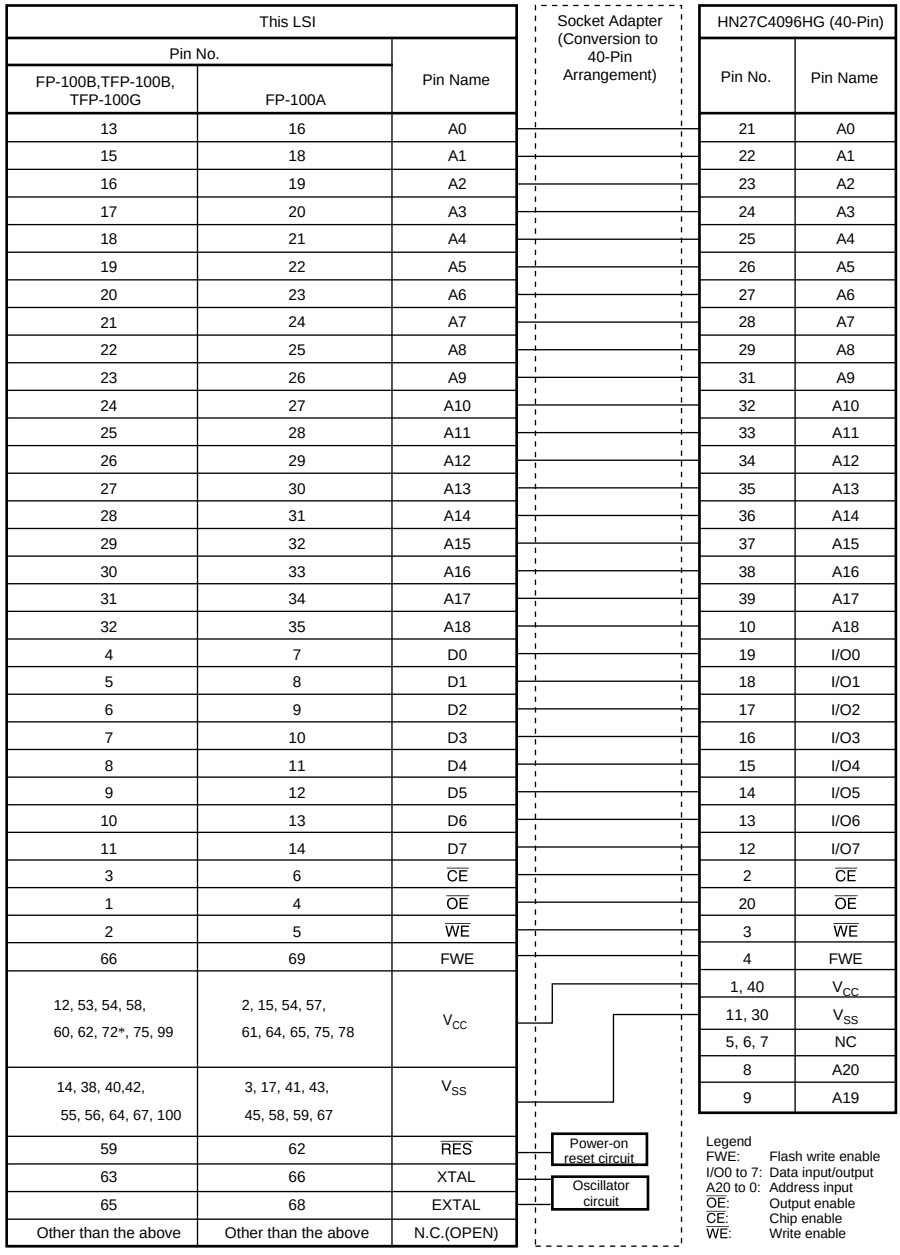
Notes: 1. Interrupt requests must be disabled inside and outside the CPU until the programming control program has completed programming.

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.

19.11 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 512-kbyte, 256-kbyte, or 128-kbyte flash memory on-chip microcomputer device type. It requires the 12-MHz input clock.

The socket adapter pin correspondence diagram is shown in figure 19.13.



This LSI			Socket Adapter (Conversion to 40-Pin Arrangement)	HN27C4096HG (40-Pin)	
Pin No.		Pin Name		Pin No.	Pin Name
FP-100B,TFP-100B, TFP-100G	FP-100A				
13	16	A0		21	A0
15	18	A1		22	A1
16	19	A2		23	A2
17	20	A3		24	A3
18	21	A4		25	A4
19	22	A5		26	A5
20	23	A6		27	A6
21	24	A7		28	A7
22	25	A8		29	A8
23	26	A9		31	A9
24	27	A10		32	A10
25	28	A11		33	A11
26	29	A12		34	A12
27	30	A13		35	A13
28	31	A14		36	A14
29	32	A15		37	A15
30	33	A16		38	A16
31	34	A17		39	A17
32	35	A18		10	A18
4	7	D0		19	I/O0
5	8	D1		18	I/O1
6	9	D2		17	I/O2
7	10	D3		16	I/O3
8	11	D4		15	I/O4
9	12	D5		14	I/O5
10	13	D6		13	I/O6
11	14	D7		12	I/O7
3	6	$\overline{CE}$		2	$\overline{CE}$
1	4	$\overline{OE}$		20	$\overline{OE}$
2	5	$\overline{WE}$		3	$\overline{WE}$
66	69	FWE		4	FWE
12, 53, 54, 58, 60, 62, 72*, 75, 99	2, 15, 54, 57, 61, 64, 65, 75, 78	V_{CC}		1, 40	V_{CC}
				11, 30	V_{SS}
				5, 6, 7	NC
				8	A20
14, 38, 40,42, 55, 56, 64, 67, 100	3, 17, 41, 43, 45, 58, 59, 67	V_{SS}		9	A19
59	62	$\overline{RES}$	Power-on reset circuit		
63	66	XTAL	Oscillator circuit		
65	68	EXTAL			
Other than the above	Other than the above	N.C.(OPEN)			

Note: * Supported only by H8S/2227 Series.

Figure 19.13 Socket Adapter Pin Correspondence Diagram

19.12 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 19.6 shows the correspondence between the operating modes of this LSI 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 µs, even when the external clock is being used.

Table 19.6 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
Subactive mode Subsleep mode	PDWND = 0: Power-down mode (read only) PDWND = 1: Normal operating mode (read only)

19.13 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 flash memory on-chip microcomputer device type (FZTAT512V3A, FZTAT256V3A, or FZTAT128V3A).

Do not select the HN27C4096 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 19.14 to 19.16): 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 19.14 to 19.16): 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 µs 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.

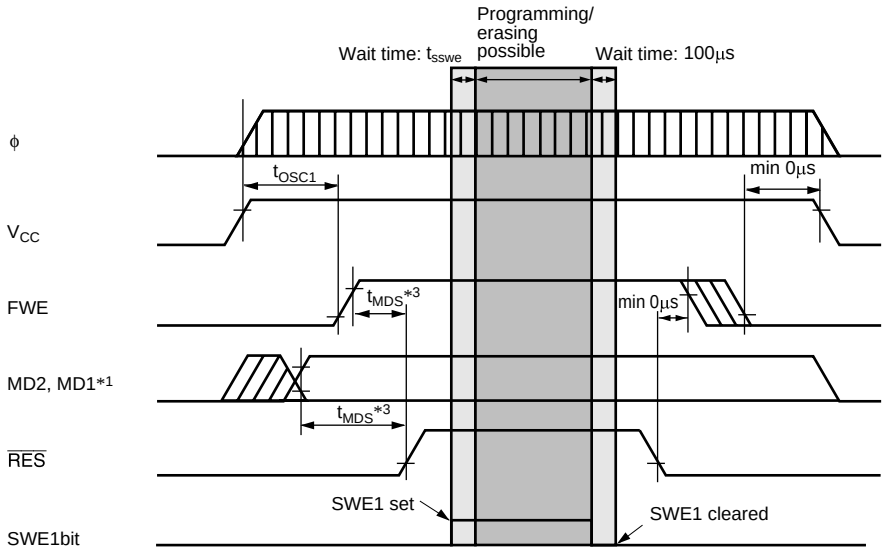
Do not perform additional programming. Erase the memory before reprogramming: In on-board programming, perform only one programming operation on a 128-byte programming unit block. In programmer mode, too, perform only one programming operation on a 128-byte programming unit block. Programming should 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 µs.

Apply the reset signal while SWE is low to reset the flash memory during its operation: The reset signal is applied at least 100 µs after the SWE bit has been cleared.

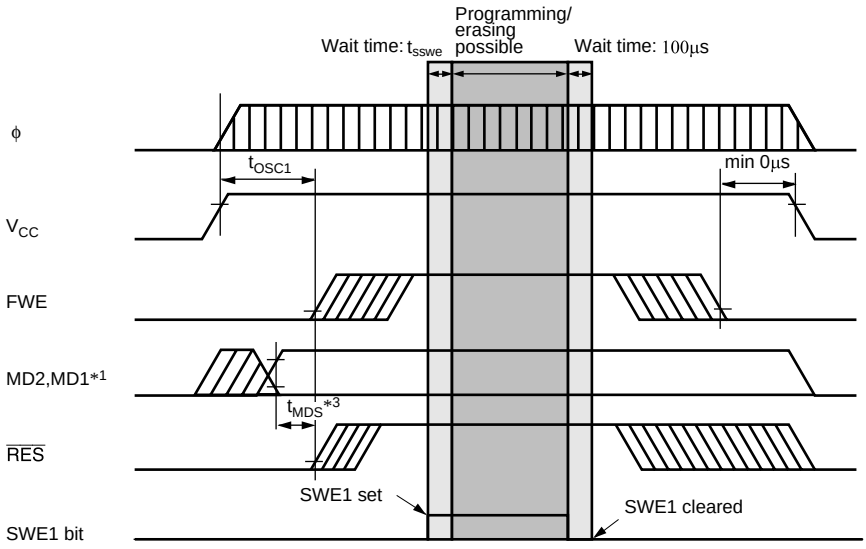


Period during which flash memory access is prohibited
(t_{sswe}: Wait time after setting SWE1 bit)*2

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 to MD0) must be fixed until power-off by pulling the pins up or down.
2 See sections 25.2.6, 25.3.6, and 25.4.6, Flash Memory Characteristics.
3 Mode programming setup time t_{MDS} (min) = 200ns.

Figure 19.14 Power-On/Off Timing (Boot Mode)

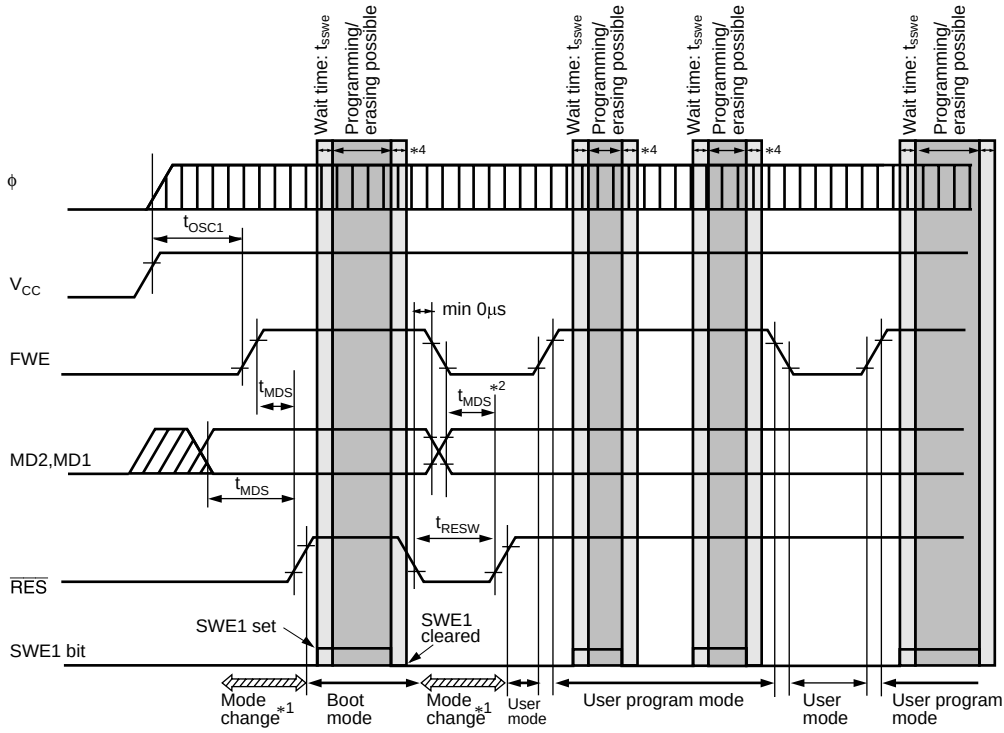


Period during which flash memory access is prohibited
(t_{sswe}: Wait time after setting SWE1 bit)*2

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 to MD0) must be fixed until power-off by pulling the pins up or down.
2 See sections 25.2.6, 25.3.6, and 25.4.6, Flash Memory Characteristics.
3 Mode programming setup time t_{MDS} (min) = 200ns.

Figure 19.15 Power-On/Off Timing (User Program Mode)



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 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
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 25.2.6, 26.3.6, and 25.4.6, Flash Memory Characteristics.
4 Wait time: 100µs.

Figure 19.16 Mode Transition Timing
(Example: Boot Mode → User Mode ↔ User Program Mode)

19.14 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 19.7 lists the registers that are present in the F-ZTAT version but not in the masked ROM version. If a register listed in table 19.7 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 19.7 have no effect.

Table 19.7 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 20 Masked ROM

This LSI incorporates a masked ROM which has the following features.

20.1 Features

- Size:

Product Class		ROM Size	ROM Address (Modes 6 and 7)
H8S/2239 Series	HD6432239	384 kbytes	H'000000 to H'05FFFF
H8S/2238R Series	HD6432238R	256 kbytes	H'000000 to H'03FFFF
	HD6432236R	128 kbytes	H'000000 to H'01FFFF
H8S/2237 Series	HD6432237	128 kbytes	H'000000 to H'01FFFF
	HD6432235	128 kbytes	H'000000 to H'01FFFF
	HD6432233	64 kbytes	H'000000 to H'00FFFF
H8S/2227 Series	HD6432227	128 kbytes	H'000000 to H'01FFFF
	HD6432225	128 kbytes	H'000000 to H'01FFFF
	HD6432224	96 kbytes	H'000000 to H'017FFF
	HD6432223	64 kbytes	H'000000 to H'00FFFF

- Connected to the bus master through 16-bit data bus, enabling one-state access to both byte data and word data.

Figure 20.1 shows a block diagram of the on-chip masked ROM.

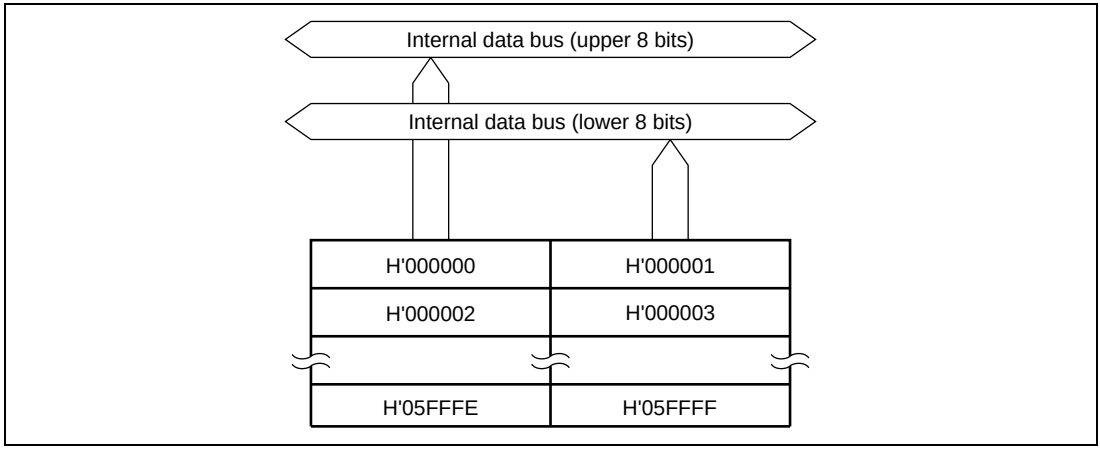


Figure 20.1 Block Diagram of On-Chip Masked ROM (384 kbytes)

Section 21 PROM

The PROM version can be set to PROM mode and programmed with a PROM programmer.

21.1 PROM Mode Setting

The PROM version (HD6472237) suspends its microcomputer functions when placed in PROM mode, enabling the on-chip PROM to be programmed. This programming can be done with a PROM programmer set up in the same way as for the HN27C101 (V_{PP} = 12.5 V) EPROM. Use of a socket adapter to convert from 100 pins to 32 pins enables programming with a commercial PROM programmer.

Caution is required when selecting the PROM programmer, as this LSI does not support page mode.

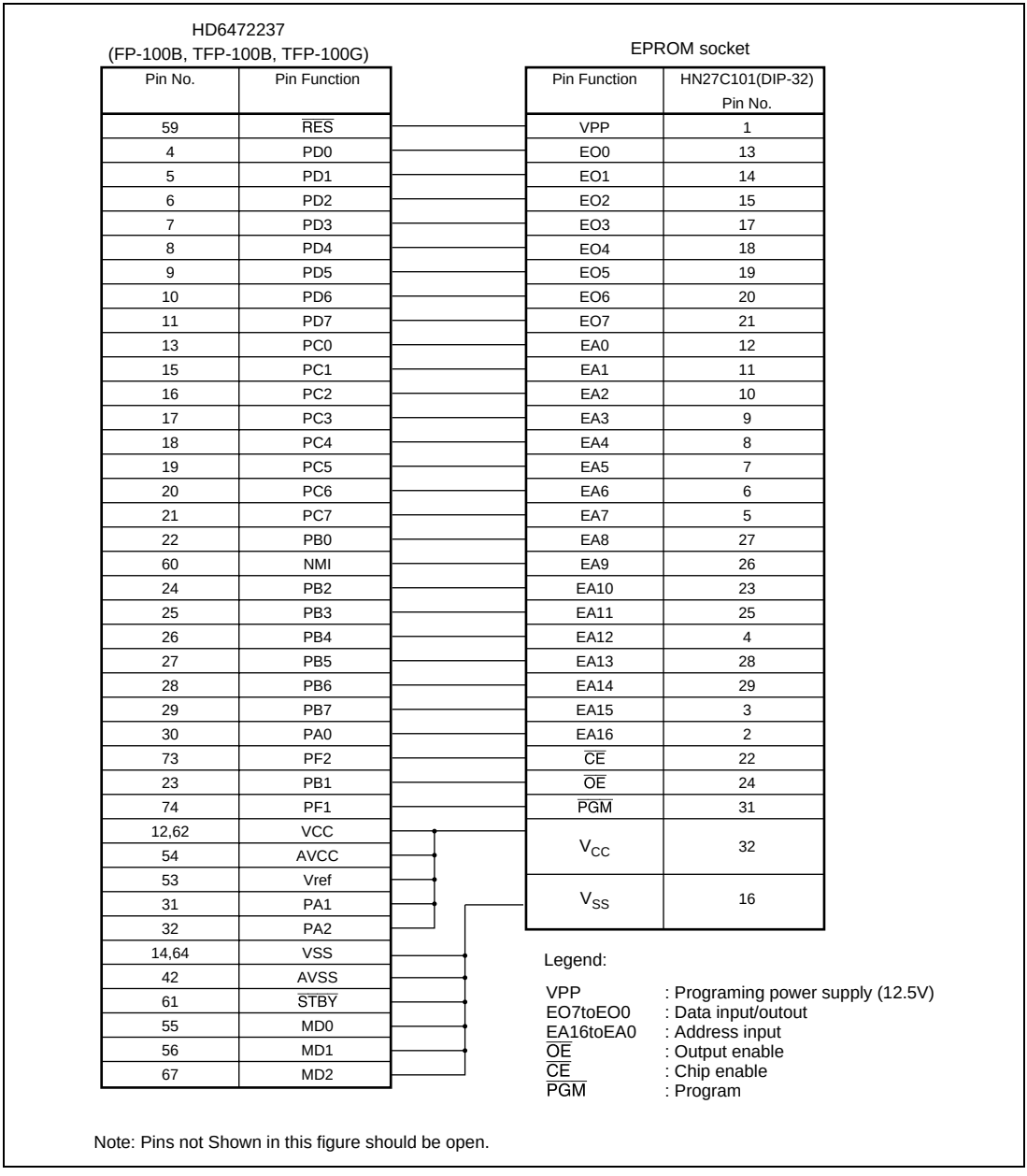
Table 21.1 shows how PROM mode is selected.

Table 21.1 Selecting PROM Mode

Pin Names	Setting
MD2, MD1, MD0	Low
STBY	
PA2, PA1	High

21.2 Socket Adapter and Memory Map

Programs can be written and verified by attaching a socket adapter to convert from 100 pins to 32 pins to the PROM programmer. Figure 21.1 shows the wiring of the socket adapter, and table 21.2 gives ordering information for the socket adapter. Figure 21.2 shows the memory map in PROM mode.



Note: Pins not Shown in this figure should be open.

Figure 21.1 HD6472237 Socket Adapter Pin Correspondence Diagram (FP-100B, TFP-100B, TFP-100G)

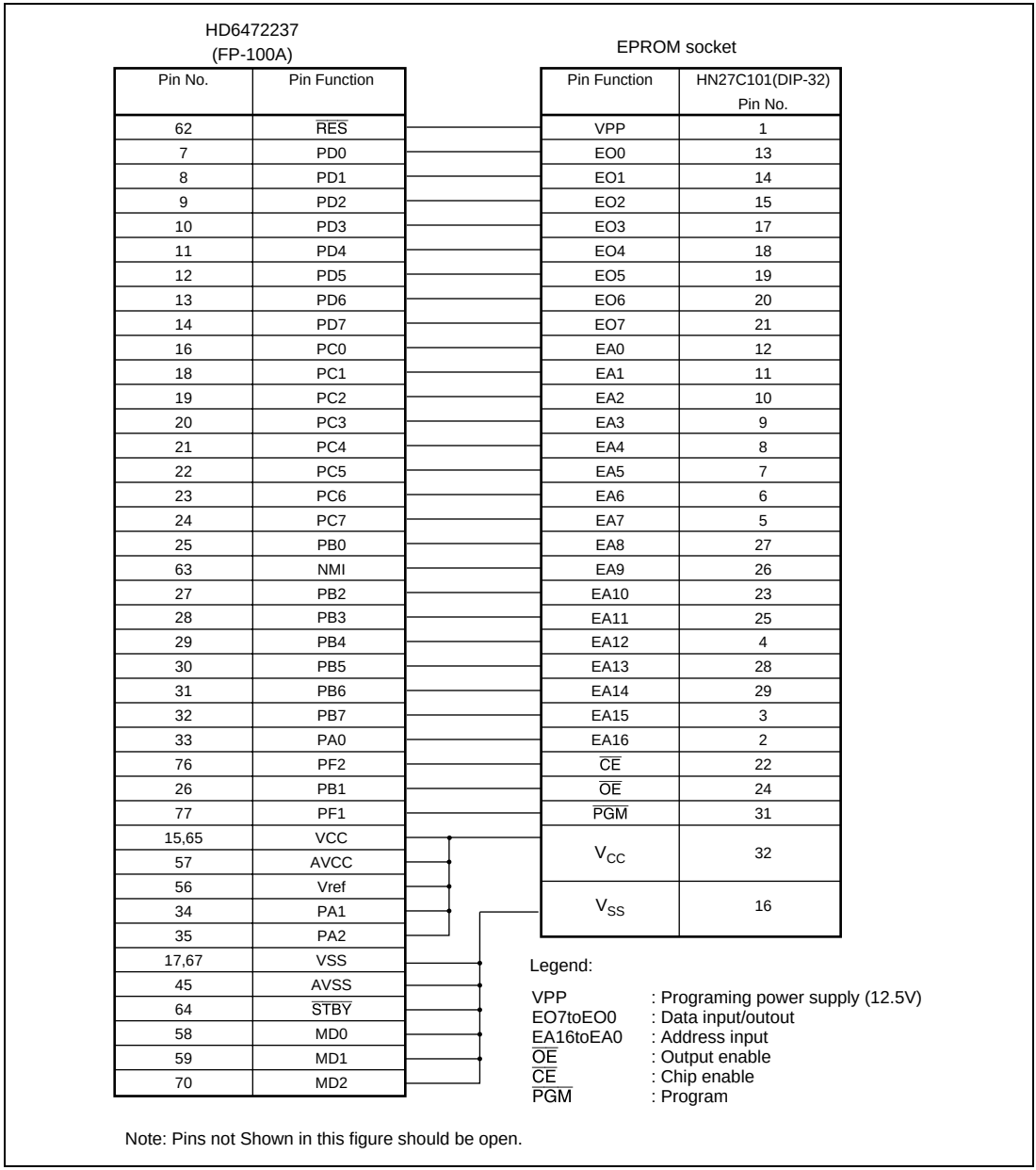


Figure 21.2 HD6472237 Socket Adapter Pin Correspondence Diagram (FP-100A)

Table 21.2 Socket Adapters

		Socket Adapter	
Product Name	**Package**	**Minato Electronics**	**Data IO Japan**
H8S/2237	100-pin TQFP (TFP-100B)	ME2237ESNS1H	H7223BT100D3201
	100-pin TQFP (TFP-100G)	ME2237ESMS1H	H7223GT100D3201
	100-pin QFP (FP-100A)	ME2237ESFS1H	H7223AQ100D3201
	100-pin QFP (FP-100B)	ME2237ESHS1H	H7223BQ100D3201

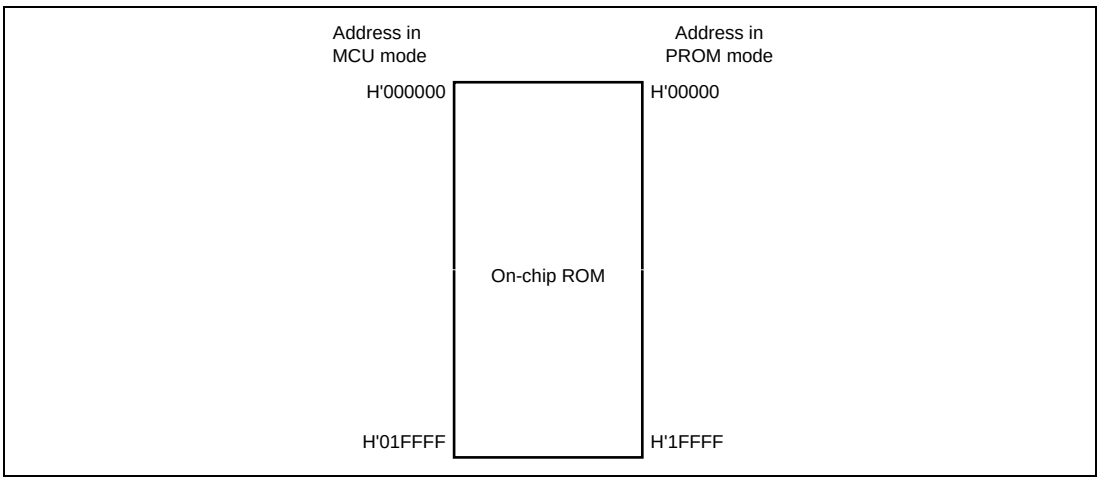


Figure 21.3 Memory Map in PROM Mode

21.3 Programming

Table 21.3 shows how to select the program, verify, and other modes in PROM mode.

Table 21.3 Mode Selection in PROM Mode

	Pins						
Mode	**CE**	**OE**	PGM	**VPP**	**VCC**	**EO7 to EO0**	**EA16 to EA0**
Program	L	H	L	V_{PP}	V_{CC}	Data input	Address input
Verify	L	L	H	V_{PP}	V_{CC}	Data output	Address input
Programming prohibited	L	L	L	V_{PP}	V_{CC}	High impedance	Address input
	L	H	H				
	H	L	L				
	H	H	H				

Legend

L : Low voltage level
H : High voltage level
V_{PP} : V_{PP} voltage level
V_{CC} : V_{CC} voltage level

Programming and verification should be carried out using the same specifications as for the standard HN27C101 EPROM.

However, do not set the PROM programmer to page mode does not support page programming. A PROM programmer that only supports page programming cannot be used. When choosing a PROM programmer, check that it supports high-speed programming in byte units. Always set addresses within the range H′00000 to H′1FFFF.

21.3.1 Programming and Verification

An efficient, high-speed programming procedure can be used to program and verify PROM data. This procedure writes data quickly without subjecting the chip to voltage stress or sacrificing data reliability. It leaves the data H′FF in unused addresses. Figure 21.4 shows the basic high-speed programming flowchart. Tables 21.4 and 21.5 list the electrical characteristics of the chip during programming. Figure 21.5 shows a timing chart.

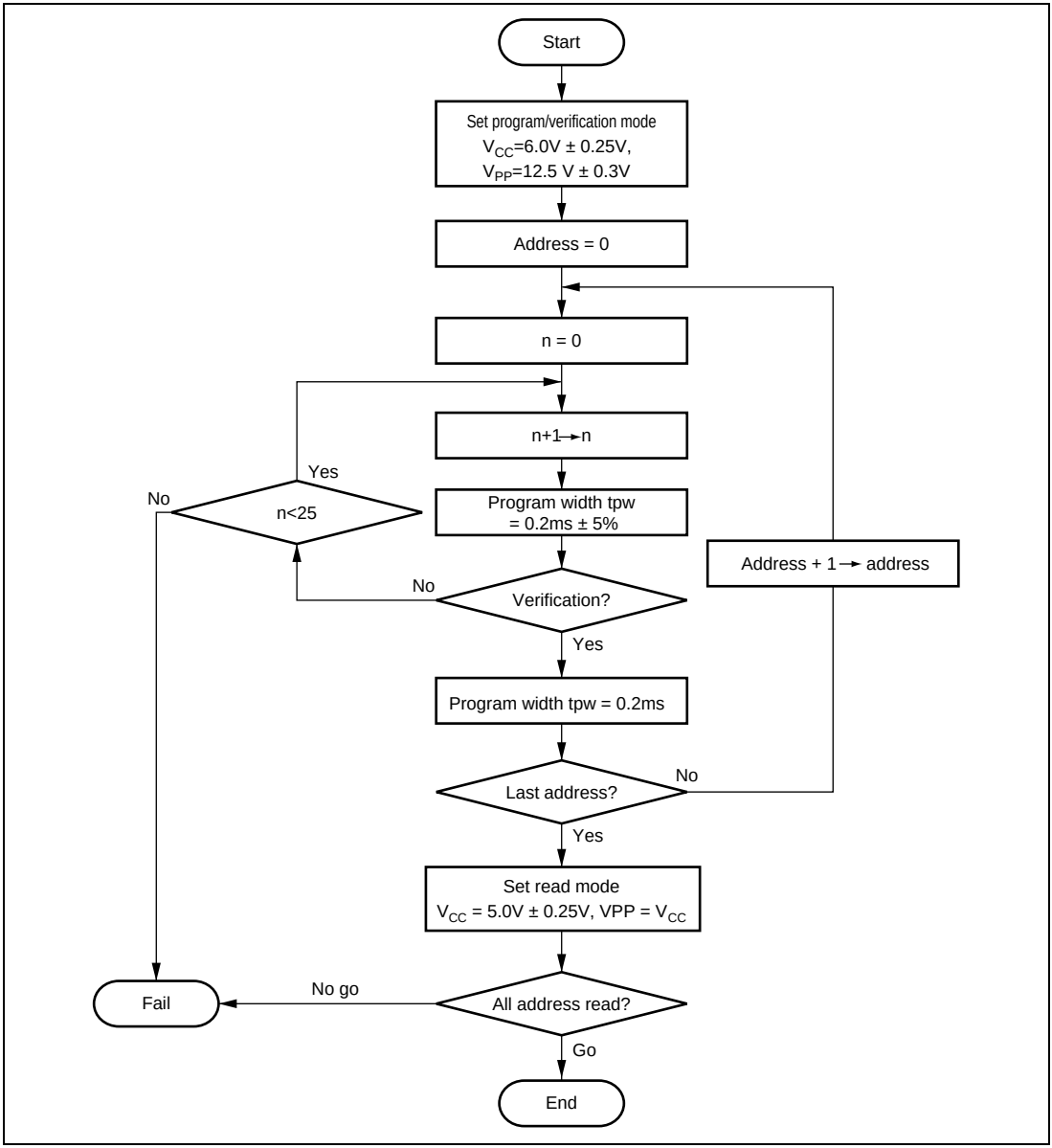


Figure 21.4 High-Speed Programming Flowchart

Table 21.4 DC Characteristics in PROM Mode

(Conditions: V_{CC} = 6.0 V ± 0.25 V, V_{PP} = 12.5 V ± 0.3 V, V_{SS} = 0 V, T_a = 25°C ± 5°C)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input high voltage	EO7 to EO0, EA16 to EA0, OE, CE, PGM	V_{IH}	2.4	—	V_{CC} + 0.3	V	
Input low voltage	EO7 to EO0, EA16 to EA0, OE, CE, PGM	V_{IL}	–0.3	—	0.8	V	
Output high voltage	EO7 to EO0	V_{OH}	2.4	—	—	V	I_{OH} = –200 µA
Output low voltage	EO7 to EO0	V_{OL}	—	—	0.45	V	I_{OL} = 1.6 mA
Input leakage current	EO7 to EO0, EA16 to EA0, OE, CE, PGM	$\lvert I_{LI} \rvert$	—	—	2	µA	V_{in} = 5.25 V/0.5 V
V_{CC} current		I_{CC}	—	—	40	mA	
V_{PP} current		I_{PP}	—	—	40	mA	

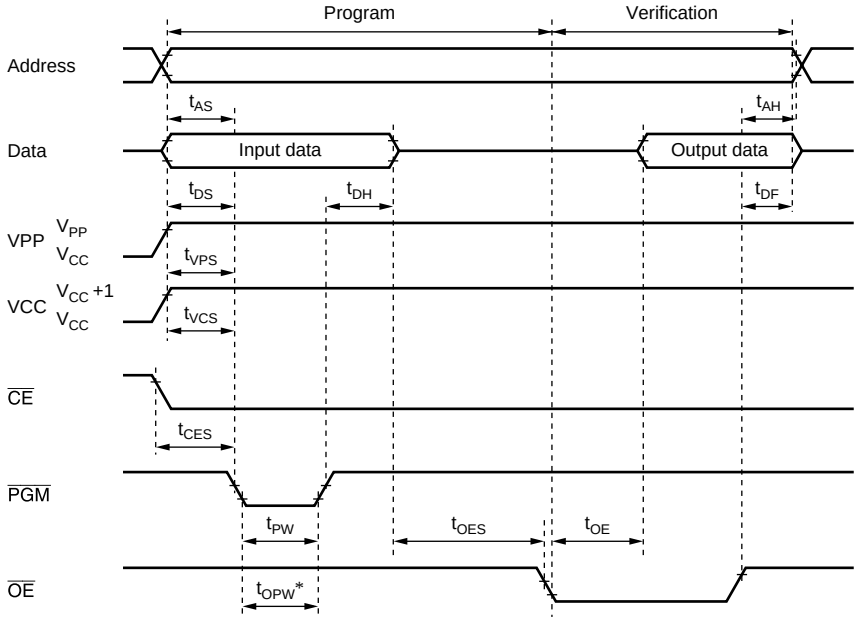
Table 21.5 AC Characteristics in PROM Mode

(Conditions: V_{CC} = 6.0 V ± 0.25 V, V_{PP} = 12.5 V ± 0.3 V, T_a = 25°C ± 5°C)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Address setup time	t_{AS}	2	—	—	µs	Figure 21.5*[1]
OE setup time	t_{OES}	2	—	—	µs	
Data setup time	t_{DS}	2	—	—	µs	
Address hold time	t_{AH}	0	—	—	µs	
Data hold time	t_{DH}	2	—	—	µs	
Data output disable time	t_{DF}*[2]	—	—	130	ns	
V_{PP} setup time	t_{VPS}	2	—	—	µs	
Programming pulse width	t_{PW}	0.19	0.20	0.21	ms	
PGM pulse width for overwrite programming	t_{OPW}*[3]	0.19	—	5.25	ms	
V_{CC} setup time	t_{VCS}	2	—	—	µs	
CE setup time	t_{CES}	2	—	—	µs	
Data output delay time	t_{OE}	0	—	150	ns	

Notes: 1. Input pulse level: 0.8 V to 2.2 V
Input rise time/fall time ≤ 20 ns
Timing reference levels: Input: 1.0 V, 2.0 V
Output: 0.8 V, 2.0 V

2. t_{DF} is defined to be when output has reached the open state, and the output level can no longer be referenced.
3. t_{OPW} is defined by the value shown in the flowchart.



Note: * tpow is defined by the value shown in the flowchart.

Figure 21.5 PROM Programming/Verification Timing

21.3.2 Programming Precautions

- Program using the specified voltages and timing.

  The programming voltage (V_{PP}) in PROM mode is 12.5 V.

  Applied voltages in excess of the specified values can permanently destroy the MCU. Be particularly careful about the PROM programmer's overshoot characteristics.
  If the PROM programmer is set to Hitachi HN27C101 specifications, V_{PP} will be 12.5 V.

- Before programming, check that the MCU is correctly mounted in the PROM programmer. Overcurrent damage to the MCU can result if the index marks on the PROM programmer, socket adapter, and MCU are not correctly aligned.

- Do not touch the socket adapter or MCU while programming. Touching either of these can cause contact faults and programming errors.

- The MCU cannot be programmed in page programming mode. Select the programming mode carefully.

- The size of the PROM is 128 kbytes. Always set addresses within the range H′00000 to H′1FFFF. During programming, write H′FF to unused addresses to avoid verification errors.

21.3.3 Reliability of Programmed Data

An effective way to assure the data retention characteristics of the programmed chips is to bake them at 150°C, then screen them for data errors. This procedure quickly eliminates chips with PROM memory cells prone to early failure.

Figure 21.6 shows the recommended screening procedure.

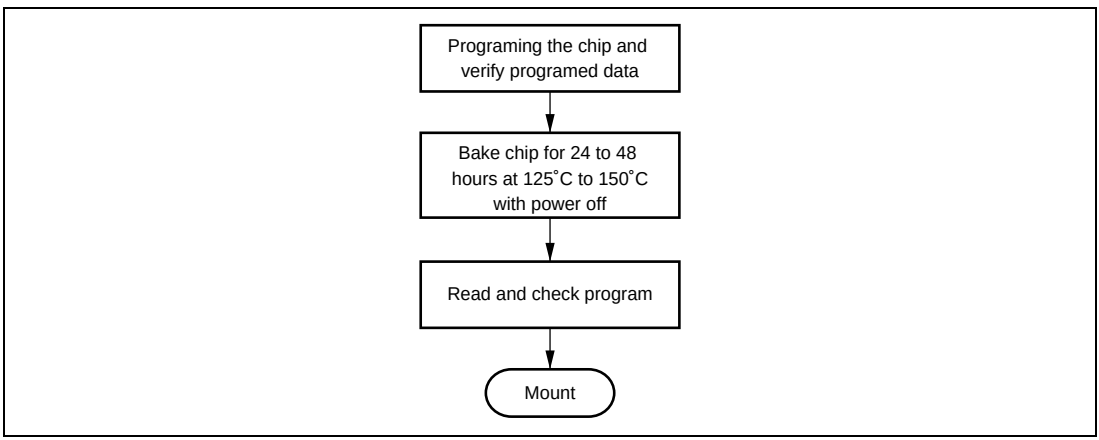


Figure 21.6 Recommended Screening Procedure

If a series of programming errors occurs while the same PROM programmer is being used, stop programming and check the PROM programmer and socket adapter for defects.

Please inform Hitachi of any abnormal conditions noted during or after programming or in screening of program data after high-temperature baking.

Section 22 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 is shown in figure 22.1.

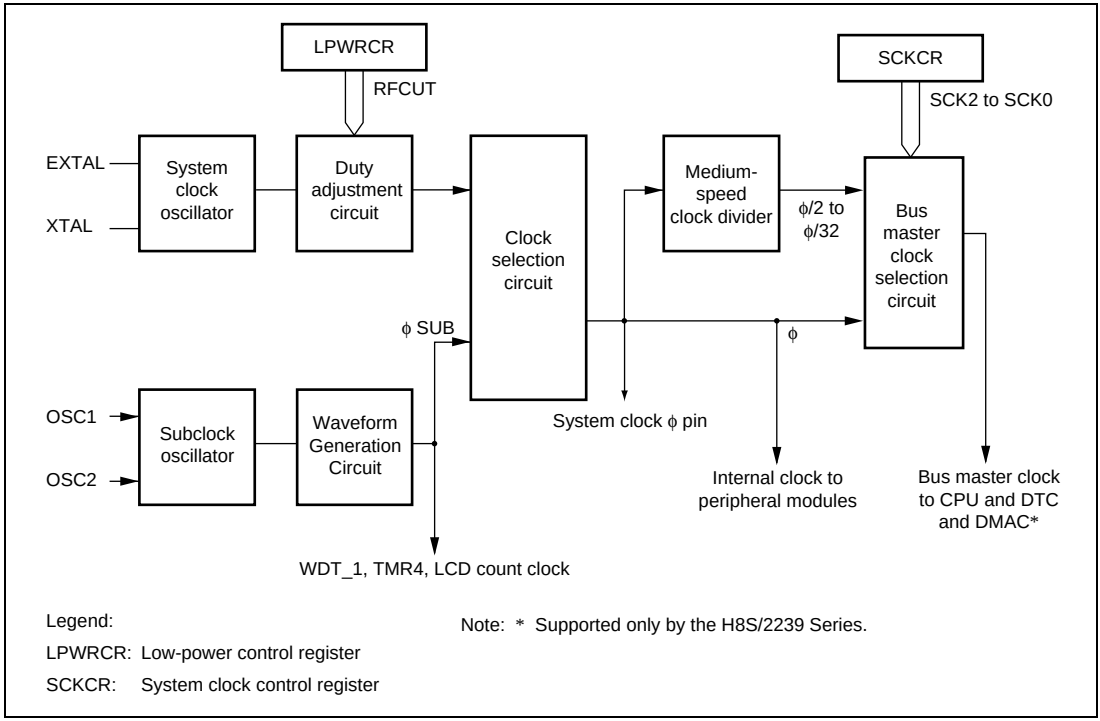


Figure 22.1 Block Diagram of Clock Pulse Generator

Frequency changes are performed by software by settings in the low-power control register (LPWRCR) and system clock control register (SCKCR).

22.1 Register Descriptions

The on-chip clock pulse generator has the following registers.

- System clock control register (SCKCR)
- Low-power control register (LPWRCR)

22.1.1 System Clock Control Register (SCKCR)

SCKCR performs medium-speed mode control.

Bit	Bit Name	Initial Value	R/W	Description
7	PSTOP	0	R/W	φ Clock Output Prohibited Controls φ output. • High-speed mode, medium-speed mode, subactive mode, sleep mode, and subsleep mode 0: φ output 1: Fixed to high • Software standby mode, watch mode, and direct transition 0: Fixed to high 1: Fixed to high • Hardware standby mode 0: High impedance 1: High impedance
6	—	0	R/W	Reserved This bit is readable/writable, but the write value should always be 0.
5	—	0	—	Reserved
4	—	0	—	These bits are always read as 0, and cannot be modified.
3	—	0	R/W	Reserved This bit is readable/writable, but the write value should always be 0.

Bit	Bit Name	Initial Value	R/W	Description
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 ϕ/2
				010: Medium-speed clock ϕ/4
				011: Medium-speed clock ϕ/8
				100: Medium-speed clock ϕ/16
				101: Medium-speed clock ϕ/32
				11X: Setting prohibited

Legend
X: Don't care

22.1.2 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	Direct Transition ON Flag 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. When the SLEEP instruction is executed in sub-active mode, operation shifts to sub-sleep mode or watch mode. 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. When the SLEEP instruction is executed in sub-active mode, operation shifts directly to high-speed mode, or shifts to sub-sleep mode.
6	LSON	0	R/W	Low Speed ON Fag 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*. When the SLEEP instruction is executed in sub-active mode, operation shifts to watch mode* or shifts directly to high-speed mode. Operation shifts to high-speed mode when watch mode is cancelled. 1: When the SLEEP instruction is executed in high-speed mode, operation shifts to watch mode or sub-active mode. When the SLEEP instruction is executed in sub-active mode, operation shifts to sub-sleep mode or watch mode. Operation shifts to sub-active mode when watch mode is cancelled.

Bit	Bit Name	Initial Value	R/W	Description
5	NESEL	0	R/W	Noise Elimination Sampling Frequency Select 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 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. 0: Sampling using 1/32 x ϕ 1: Sampling using 1/4 x ϕ
4	SUBSTP	0	R/W	Subclock Enable This bit enables/disables subclock generation. This bit should be set to 1 when subclock is not used. 0: Enables subclock generation. 1: Disables subclock generation.
3	RFCUT	0	R/W	Oscillation Circuit Feedback Resistance Control Bit 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. 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. 0: Built-in feedback resistance and duty adjustment circuit of the system clock generator used. 1: Built-in feedback resistance and duty adjustment circuit of the system clock generator not used.
2	—	0	R/W	Reserved This bit is readable/writable, but the write value should always be 0.

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

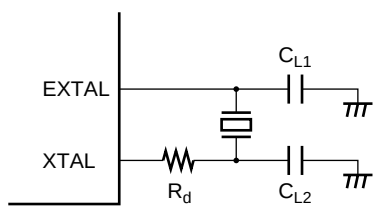
Note: When watch mode or subactive mode is entered, set high-speed mode.

22.2 System Clock Oscillator

System clock pulses can be supplied by connecting a crystal resonator, or by input of an external clock.

22.2.1 Connecting a Crystal Resonator

A crystal resonator can be connected as shown in the example in figure 22.2. Select the damping resistance R_d according to table 22.1. An AT-cut parallel-resonance crystal should be used.



$C_{L1} = C_{L2}$ = 10 to 22pF

Note: C_{L1} and C_{L2} are reference values including the floating capacitance of the board.

Figure 22.2 Connection of Crystal Resonator (Example)

Table 22.1 Damping Resistance Value

Frequency (MHz)	2	4	6	8	10	12	16
R_d (Ω)	1 k	500	300	200	100	0	0

Figure 22.3 shows the equivalent circuit of the crystal resonator. Use a crystal resonator that has the characteristics shown in table 22.2.

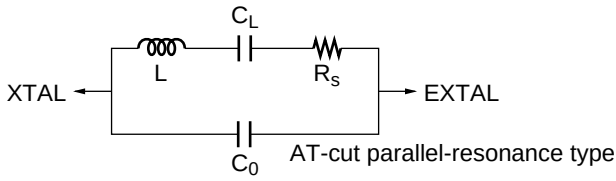


Figure 22.3 Crystal Resonator Equivalent Circuit

Table 22.2 Crystal Resonator Characteristics

Frequency (MHz)	2	4	6	8	10	12	16
R_S max (Ω)	500	120	100	80	60	60	50
C_0 max (pF)	7	7	7	7	7	7	7

22.2.2 External Clock Input

An external clock signal can be input as shown in the examples in figure 22.4. 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.

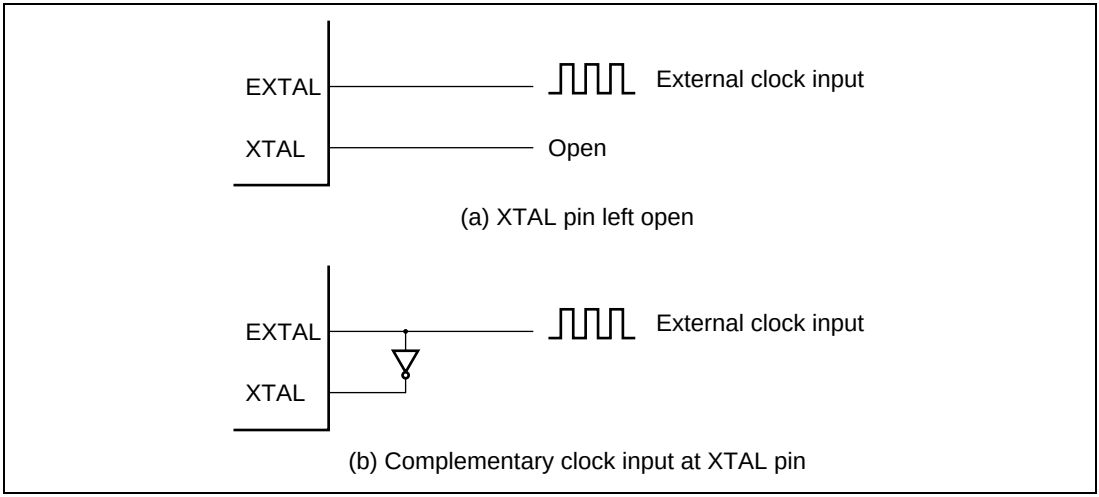


Figure 22.4 External Clock Input (Examples)

Table 22.3 shows the input conditions for the external clock. Table 22.4 shows the input conditions for the external clock when duty adjustment circuit is not used.

Table 22.3 External Clock Input Conditions (1)
(H8S/2238R Series, H8S/2237 Series, H8S/2227 Series)

		V_{cc}= 2.7 V to 5.0 V		V_{cc}= 2.2 V to 3.6 V				
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**	
External clock input low pulse width	t_{EXL}	30	—	65	—	ns	Figure 22.5	
External clock input high pulse width	t_{EXH}	30	—	65	—	ns		
External clock rise time	t_{EXr}	—	7	—	15	ns		
External clock fall time	t_{EXf}	—	7	—	15	ns		
Clock low pulse width	t_{CL}	0.4	0.6	0.35	0.65	t_{CYC}	$\phi \geq 5$ MHz	Figure
		80	—	70	—	ns	$\phi < 5$ MHz	25.5
Clock high pulse width	t_{CH}	0.4	0.6	0.35	0.65	t_{CYC}	$\phi \geq 5$ MHz	
		80	—	70	—	ns	$\phi < 5$ MHz	

Table 22.3 External Clock Input Conditions (2) (H8S/2239 Series)

		F-ZTAT and Masked ROM				
		V_{cc}= 2.7 V to 3.6 V				
Item	**Symbol**	**Min**	**Max**	**Unit**	**Test Conditions**	
External clock input low pulse width	t_{EXL}	25	—	ns	Figure 22.5	
External clock input high pulse width	t_{EXH}	25	—	ns		
External clock rise time	t_{EXr}	—	6.25	ns		
External clock fall time	t_{EXf}	—	6.25	ns		
Clock low pulse width	t_{CL}	0.4	0.6	t_{CYC}	$\phi \geq 5$ MHz	Figure
		80	—	ns	$\phi < 5$ MHz	25.5
Clock high pulse width	t_{CH}	0.4	0.6	t_{CYC}	$\phi \geq 5$ MHz	
		80	—	ns	$\phi < 5$ MHz	

Table 22.4 External Clock Input Conditions (Duty Adjustment Circuit Unused) (1) (H8S/2238R Series, H8S/2237 Series, H8S/2227 Series)

		V_{cc}= 2.7 V to 5.5 V		V_{cc}= 2.2 V to 3.6 V			
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**
External clock input low pulse width	t_{EXL}	37	—	80	—	ns	Figure 22.5
External clock input high pulse width	t_{EXH}	37	—	80	—	ns	
External clock rise time	t_{EXr}	—	7	—	15	ns	
External clock fall time	t_{EXf}	—	7	—	15	ns	

Note: When a duty adjustment circuit is not used, maximum operating frequency is lowered according to the input waveform.
(Example: When $t_{EXL} = t_{EXH}$ = 50 ns, $t_{EXr} = t_{EXf}$ = 10 ns, clock cycle time = 120 ns, and maximum operating frequency = 8.3 MHz)

Table 22.4 External Clock Input Conditions (Duty Adjustment Circuit Unused) (2) (H8S/2239 Series)

	F-ZTAT and Masked ROM			
	V_{cc}= 2.7 V to 3.6 V			
Item	**Symbol**	**Min**	**Max**	**Unit**	**Test Conditions**
External clock input low pulse width	t_{EXL}	31.25	—	ns	Figure 22.5
External clock input high pulse width	t_{EXH}	31.25	—	ns	
External clock rise time	t_{EXr}	—	6.25	ns	
External clock fall time	t_{EXf}	—	6.25	ns	

Note: When a duty adjustment circuit is not used, maximum operating frequency is lowered according to the input waveform.

(Example: When t_{EXL} = t_{EXH} = 50 ns, t_{EXr} = t_{EXf} = 10 ns, clock cycle time = 120 ns, and maximum operating frequency = 8.3 MHz)

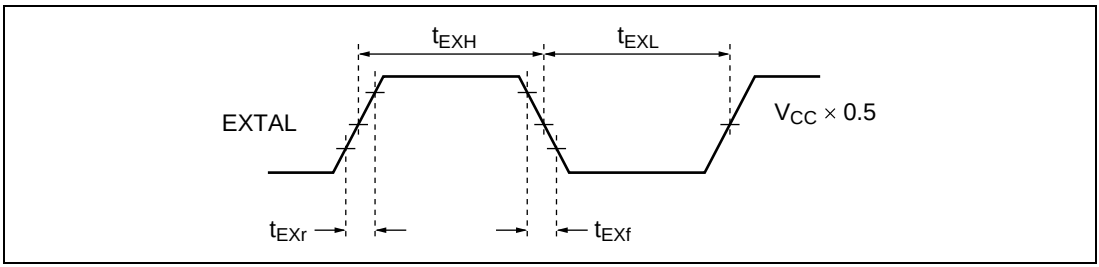


Figure 22.5 External Clock Input Timing

22.2.3 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 22.6. An example of external clock switching timing is shown in figure 22.7.

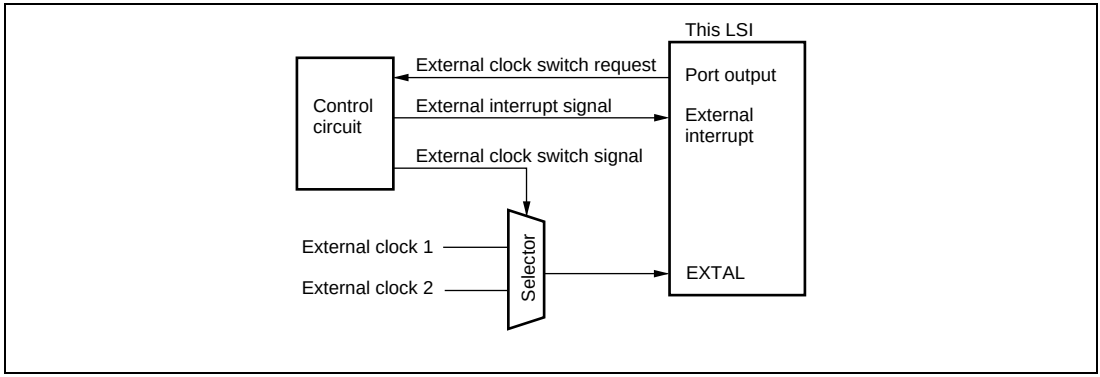


Figure 22.6 External Clock Switching Circuit (Example)

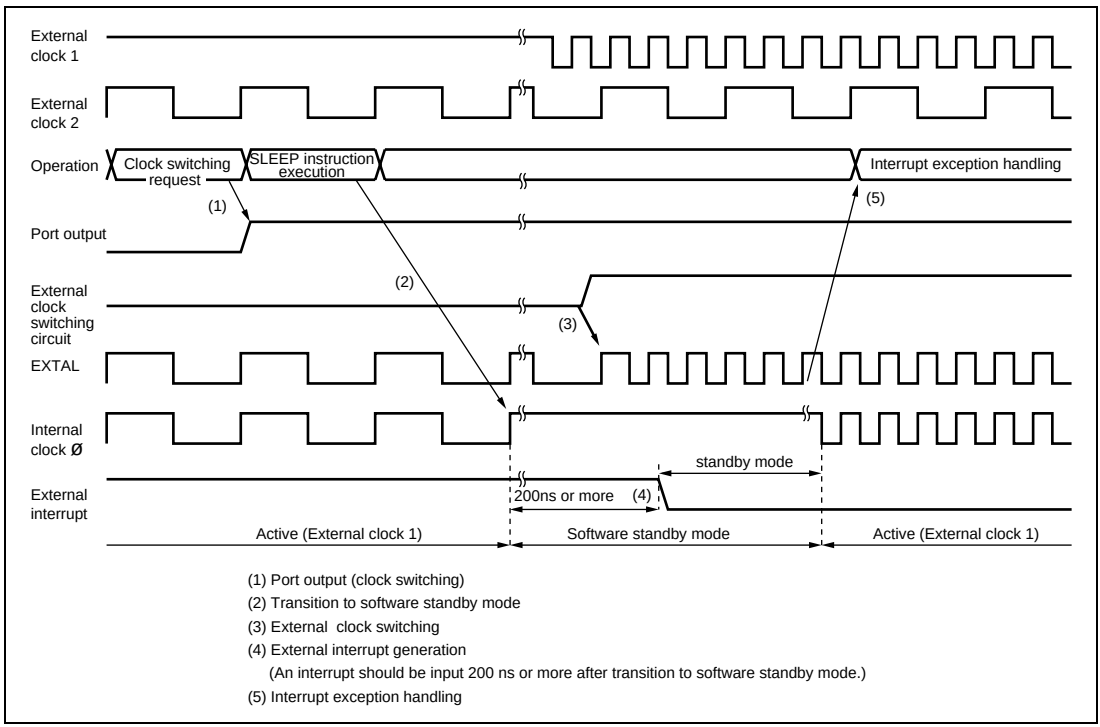


Figure 22.7 External Clock Switching Timing (Example)

22.3 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).

22.4 Medium-Speed Clock Divider

The medium-speed clock divider divides the system clock to generate ϕ/2, ϕ/4, ϕ/8, ϕ/16, and ϕ/32.

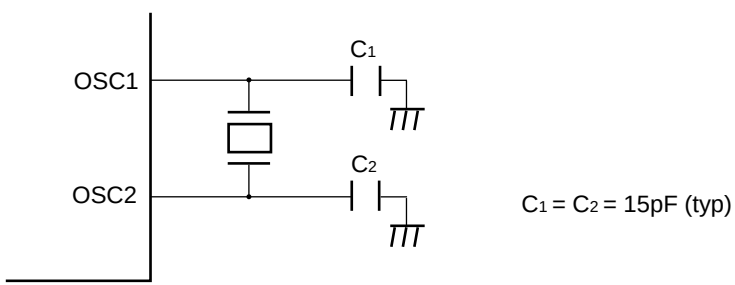
22.5 Bus Master Clock Selection Circuit

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 (ϕ/2, ϕ/4, ϕ/8, ϕ/16, ϕ/32).

22.6 Subclock Oscillator

22.6.1 Connecting 32.768kHz Crystal Resonator

To supply a clock to the subclock divider, connect a 32.768-kHz crystal resonator, as shown in figure 22.8. Figure 22.9 shows the equivalence circuit for a 32.768-kHz oscillator.



Note: CL1 and CL2 are reference values including the floating capacitance of the board.

Figure 22.8 Connection Example of 32.768-kHz Quartz Oscillator

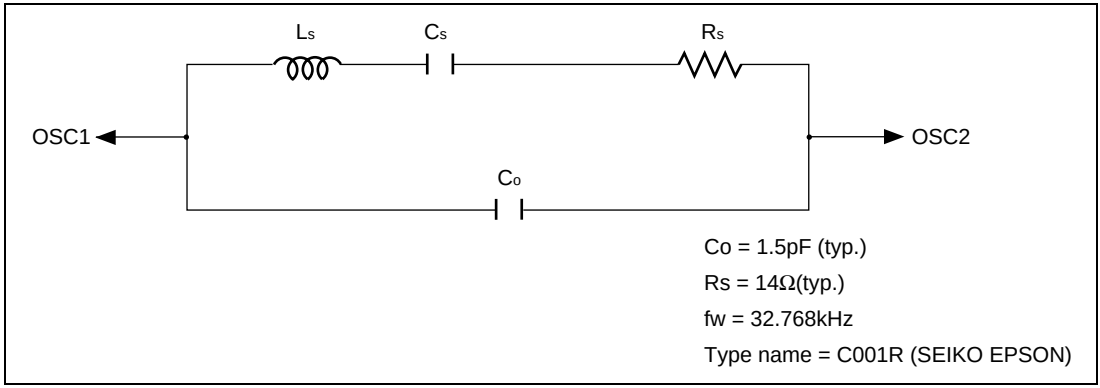


Figure 22.9 Equivalence Circuit for 32.768-kHz Oscillator

22.6.2 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 22.10. Set the SUBSTP bit of LPWRCR to 1.

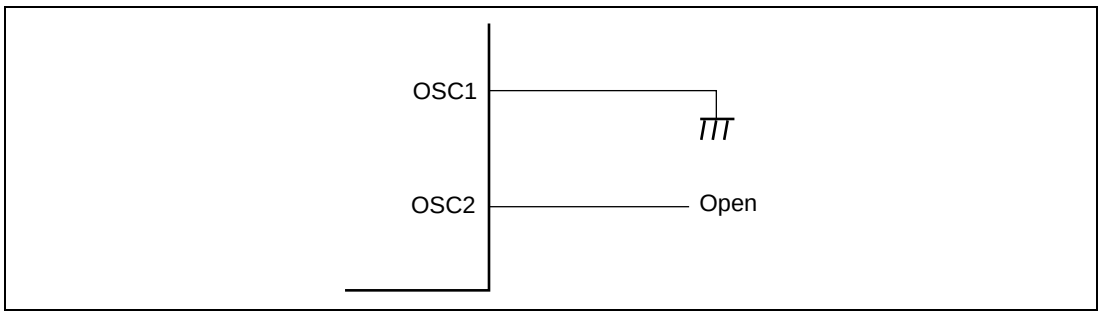


Figure 22.10 Pin Handling When Subclock Not Required

22.7 Subclock Waveform Generation Circuit

To eliminate noise from the subclock input to OSCI, the subclock is sampled using the dividing clock ϕ. The sampling frequency is set using the NESEL bit of LPWRCR. For details, see section 22.1.2, Low Power Control Register (LPWRCR).

No sampling is performed in sub-active mode, sub-sleep mode, or watch mode.

22.8 Usage Notes

22.8.1 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.

22.8.2 Note on Board Design

When designing the board, place the crystal resonator and its load capacitors as close as possible to the EXTAL, XTAL, OSC1, and OSC2 pins. Make wires as short as possible. Other signal lines should be routed away from the oscillator circuit, as shown in figure 22.11. This is to prevent induction from interfering with correct oscillation.

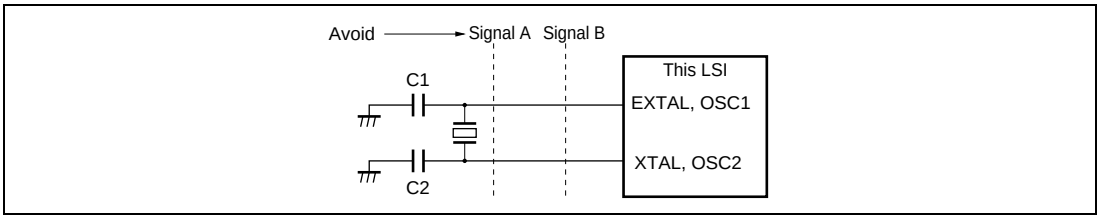


Figure 22.11 Note on Board Design of Oscillator Circuit

Section 23 Power-Down Modes

In addition to the normal program execution state, this LSI has 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.

This LSI 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 subsleep mode are CPU states, medium-speed mode is a CPU and bus master state, subactive 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 23.1 shows the internal state of the LSI in the respective modes. Table 23.2 shows the conditions for shifting between the low power dissipation modes.

Figure 23.1 is a mode transition diagram.

Table 23.1 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

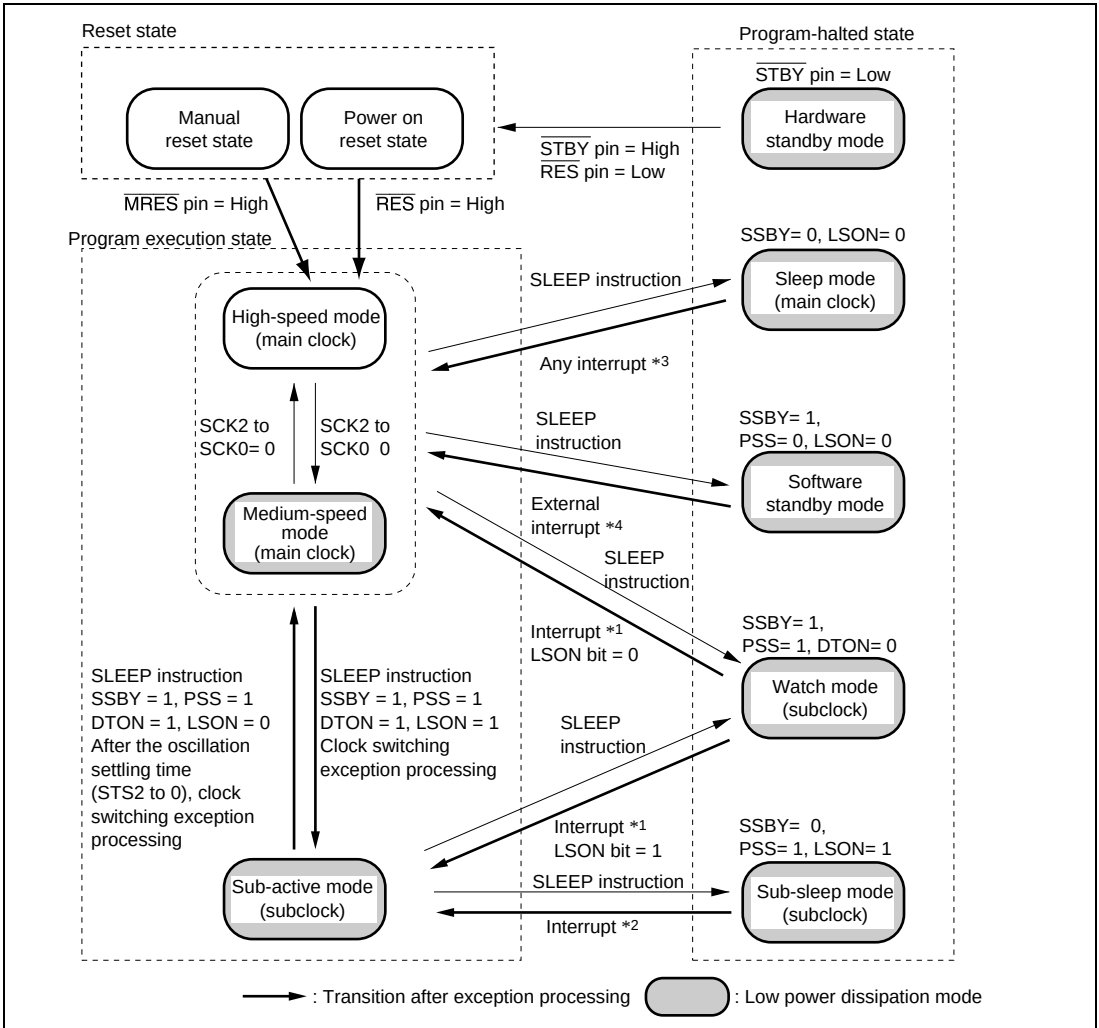
Function		High-Speed	Medium-Speed	Sleep	Module Stop	Watch	Sub active	Subsleep	Software Standby	Hardware Standby
CPU	Instructions	Functioning	Medium-speed operation	Halted	Functioning	Halted	Subclock operation	Halted	Halted	Halted
	Registers			Retained		Retained		Retained	Retained	Undefined
RAM		Functioning	Functioning	Functioning (DTC)	Functioning	Retained	Functioning	Retained	Retained	Retained
I/O		Functioning	Functioning	Functioning	Functioning	Retained	Functioning	Functioning	Retained	High impedance
External interrupts	NMI	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Halted
	IRQn									
Peripheral functions	PBC	Functioning	Medium-speed operation	Functioning	Functioning/halted (retained)	Halted (retained)	Subclock operation	Halted (retained)	Halted (retained)	Halted (reset)
	DTC	Functioning	Medium-speed operation	Functioning	Functioning/halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (reset)
	DMAC*[1]									
	WDT_1	Functioning	Functioning	Functioning	Functioning	Subclock operation	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	WDT_0	Functioning	Functioning	Functioning	Functioning	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	TMR	Functioning	Functioning	Functioning	Functioning/halted (retained)	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	TPU	Functioning	Functioning	Functioning	Functioning/halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (reset)
	SCI									
	I^2C*[2]									
	D/A									
	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. Supported only by the H8S/2239 Series.
2. Not available in the H8S/2237 Series and H8S/2227 Series.



Notes: 1. NMI, IRQ0 to IRQ7, and WDT interrupts.
2. NMI, IRQ0 to IRQ7, and WDT0, WDT1 and TMR0 to TMR3 interrupts.
3. All interrupts
4. NMI, IRQ0 to IRQ7

- 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. At any state except hardware standby mode and power-on reset state, a transition to the manual reset state occurs when the $\overline{\text{MRES}}$ pin 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 23.1 Mode Transition Diagram

Table 23.2 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	Subactive
	1	1	0	1	—	—
	1	1	1	1	Subactive	—
Subactive	0	0	X	X	—	—
	0	1	0	X	—	—
	0	1	1	X	Subsleep	Subactive
	1	0	X	X	—	—
	1	1	0	0	Watch	High-speed
	1	1	1	0	Watch	Subactive
	1	1	0	1	High-speed	—
	1	1	1	1	—	—

Legend:

X : Don't care

—: Do not set.

23.1 Register Description

The following registers relates to the power-down modes. For details on system clock control register (SCKCR), refer to section 22.1.1, System Clock Control Register (SCKCR). For details on low power control register (LPWRCR), refer to section 22.1.2, Low Power Control Register (LPWRCR). For details on timer control status register (TCSR), refer to section 12.3.5, 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)
- Low power control register (LPWRCR)
- System clock control register (SCKCR)
- Timer control status register (TCSR)

23.1.1 Standby Control Register (SBYCR)

SBYCR performs power-down mode control.

Bit	Bit Name	Initial Value	R/W	Description
7	SSBY	0	R/W	Software Standby Specifies transition destination when the SLEEP instruction is executed. 0: Shifts to sleep mode when the SLEEP instruction is executed in high-speed mode or medium-speed mode. Shifts to subsleep mode when the SLEEP instruction is executed in subactive mode. 1: Shifts to software standby mode, subactive 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 subactive mode. 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.

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 subactive mode.
4	STS0	0	R/W	With a crystal resonator (table 23.3), 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. 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: Reserved 111: Standby time = 16 states*
3	OPE	1	R/W	Output Port Enable Specifies whether the output of the address bus and bus control signals (CS0 to CS7, AS, RD, HWR, and LWR) should be retained or driven to the high impedance state, when shifting to software standby mode, watch mode, or direct transition. 0: High impedance 1: Output is retained.
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 F-ZTAT version. 8192 states or more should be set.

23.1.2 Module Stop Control Registers A to C (MSTPCRA to MSTPCRC)

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	0	R/W	DMA controller (DMAC)
6	MSTPA6	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	R/W	
2	MSTPA2*	1	R/W	
1	MSTPA1	1	R/W	A/D converter
0	MSTPA0	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	R/W	Serial communication interface 1 (SCI_2)
4	MSTPB4	1	R/W	I2C bus interface 0 (IIC_0) (optional)
3	MSTPB3	1	R/W	I2C bus interface 1 (IIC_1) (optional)
2	MSTPB2*	1	R/W	
1	MSTPB1*	1	R/W	
0	MSTPB0*	1	R/W	

- MSTPCRC

Bit	Bit Name	Initial Value	R/W	Target Module
7	MSTPC7	1	R/W	Serial communication interface 3 (SCI_3)
6	MSTPC6*	1	R/W	
5	MSTPC5	1	R/W	D/A converter
4	MSTPC4	1	R/W	PC break controller (PBC)
3	MSTPC3*	1	R/W	
2	MSTPC2*	1	R/W	
1	MSTPC1*	1	R/W	
0	MSTPC0*	1	R/W	

Note: * Bits MSTPA3, MSTPA2, MSTPB5, MSTPB2 to MSTPB0, MSTPC6, MSTPC3 to RMSTPC0 are readable/writable. The initial value of them is 1. The write value should always be 1.

23.2 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 (DMAC and 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, the LSON bit in LPWRCR = 0, and the PSS bit in TCSR (WDT_1) = 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 $\overline{\text{RES}}$ or $\overline{\text{MRES}}$ 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 23.2 shows the timing for transition to and clearance of medium-speed mode.

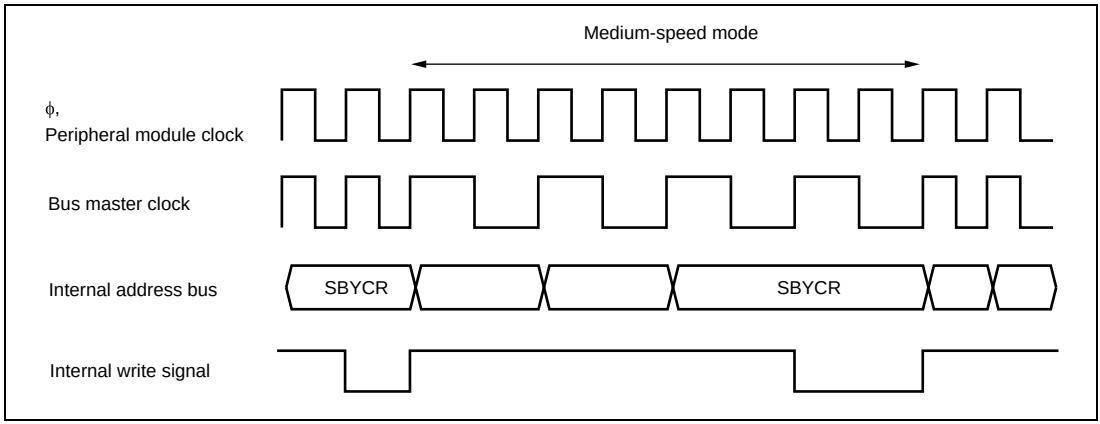


Figure 23.2 Medium-Speed Mode Transition and Clearance Timing

23.3 Sleep Mode

23.3.1 Sleep Mode

When the SLEEP instruction is executed while the SSBY bit in SBYCR = 0 and the LSON bit in LPWRCR = 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.

23.3.2 Exiting Sleep Mode

Sleep mode is exited by any interrupt, or signals at the RES pin, MRES pin, or STBY pin.

- 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 RES Pin or MRES Pin

  Setting the RES pin or MRES pin level low selects the reset state. After the stipulated reset input duration, driving the RES pin or MRES pin high starts the CPU performing reset exception processing.
- Exiting Sleep Mode by STBY Pin

  When the STBY pin level is driven low, a transition is made to hardware standby mode.

23.4 Software Standby Mode

23.4.1 Software Standby Mode

A transition is made to software standby mode when the SLEEP instruction is executed while the SSBY bit in SBYCR = 1 and the LSON bit in LPWRCR = 0, and the PSS bit in TCSR (WDT_1) = 0. In this mode, the CPU, on-chip peripheral modules, and system clock oscillator all stop. However, the contents of the CPU's internal registers, RAM data, and the states of on-chip peripheral modules other than SCI and 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.

23.4.2 Clearing Software Standby Mode

Software standby mode is cleared by an external interrupt (NMI pin, or pins IRQ0 to IRQ7), or by means of the MRES pin or STBY pin.

- Clearing with an Interrupt

  When an NMI, or IRQ0 to IRQ7 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 this LSI chip, software standby mode is cleared, and interrupt exception handling is started.

  When clearing software standby mode with an IRQ0 to IRQ7 interrupt, set the corresponding enable bit/pin function switching bit to 1 and ensure that no interrupt with a higher priority than interrupts IRQ0 to IRQ7 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 RES Pin or MRES Pin

  When the RES pin or MRES pin is driven low, clock oscillation is started. At the same time as clock oscillation starts, clocks are supplied to the entire this LSI chip. Note that the RES pin or MRES pin must be held low until clock oscillation settles. When the RES pin or MRES pin goes high, the CPU begins reset exception handling.
- Clearing with the STBY Pin

  When the STBY pin is driven low, a transition is made to hardware standby mode.

23.4.3 Oscillation Settling Time after Clearing Software Standby Mode

Bits STS2 to STS0 in SBYCR should be set as described below.

- Using a Crystal Oscillator

  Set bits STS2 to STS0 so that the standby time is at least 8 ms (the oscillation settling time). Table 23.3 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 F-ZTAT version. 8192 states or more should be set.

Table 23.3 Oscillation Settling Time Settings

STS2	STS1	STS0	Standby Time	16 MHz	13 MHz	10 MHz	8 MHz	6 MHz	4 MHz	2 MHz	Unit
0	0	0	8192 states	0.51	0.6	0.8	1.0	1.4	2.0	4.1	ms
		1	16384 states	1.0	1.3	1.6	2.0	2.7	4.1	8.2	
	1	0	32768 states	2.0	2.5	3.3	4.1	5.5	8.2	16.4	
		1	65536 states	4.1	5.0	6.6	8.2	10.9	16.4	32.8	
1	0	0	131072 states	8.2	10.1	13.1	16.4	21.8	32.8	65.5	
		1	262144 states	16.4	20.2	26.2	32.8	43.7	65.5	131.1	
	1	0	Reserved	—	—	—	—	—	—	—	—
		1	16 states	1.0	1.2	1.6	2.0	1.7	4.0	8.0	µs

: Recommended time setting

23.4.4 Software Standby Mode Application Example

Figure 23.3 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.

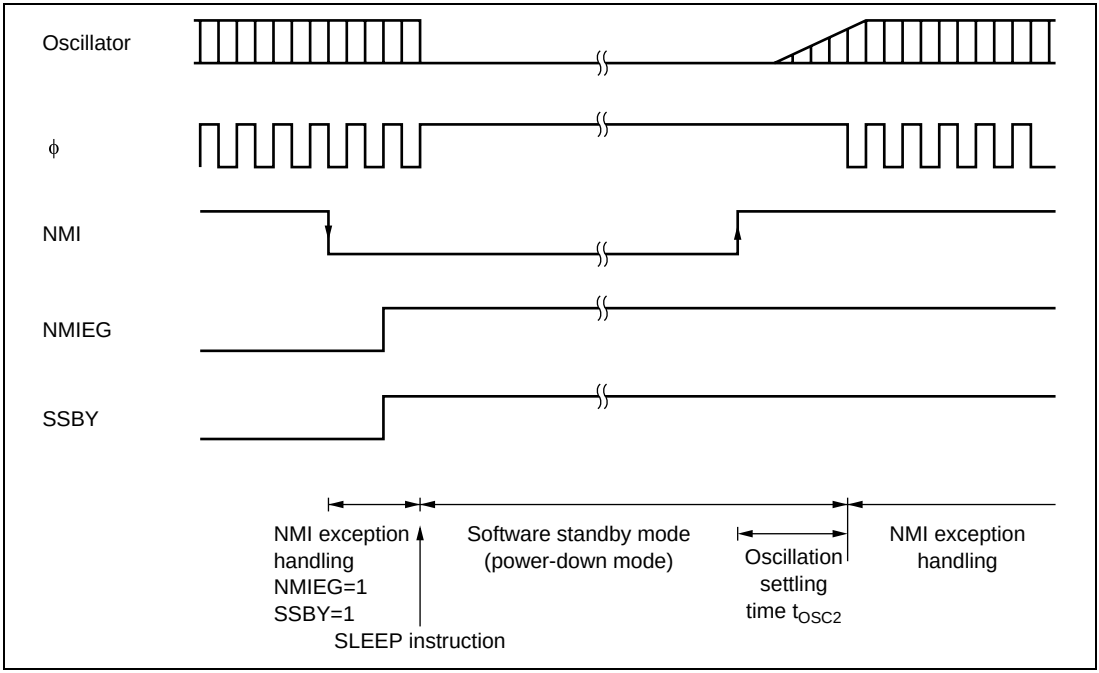


Figure 23.3 Software Standby Mode Application Example

23.5 Hardware Standby Mode

23.5.1 Hardware Standby Mode

When the 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 to MD0) while this LSI is in hardware standby mode.

23.5.2 Clearing Hardware Standby Mode

Hardware standby mode is cleared by means of the STBY pin and the RES pin. When the STBY pin is driven high while the RES pin is low, the reset state is set and clock oscillation is started. Ensure that the RES pin is held low until the clock oscillator settles (at least t_{osc1} ms—the oscillation settling time—when using a crystal oscillator). When the RES pin is subsequently driven high, a transition is made to the program execution state via the reset exception handling state.

23.5.3 Hardware Standby Mode Timing

Figure 23.4 shows an example of hardware standby mode timing.

When the STBY pin is driven low after the RES pin has been driven low, a transition is made to hardware standby mode. Hardware standby mode is cleared by driving the STBY pin high, waiting for the oscillation settling time, then changing the RES pin from low to high.

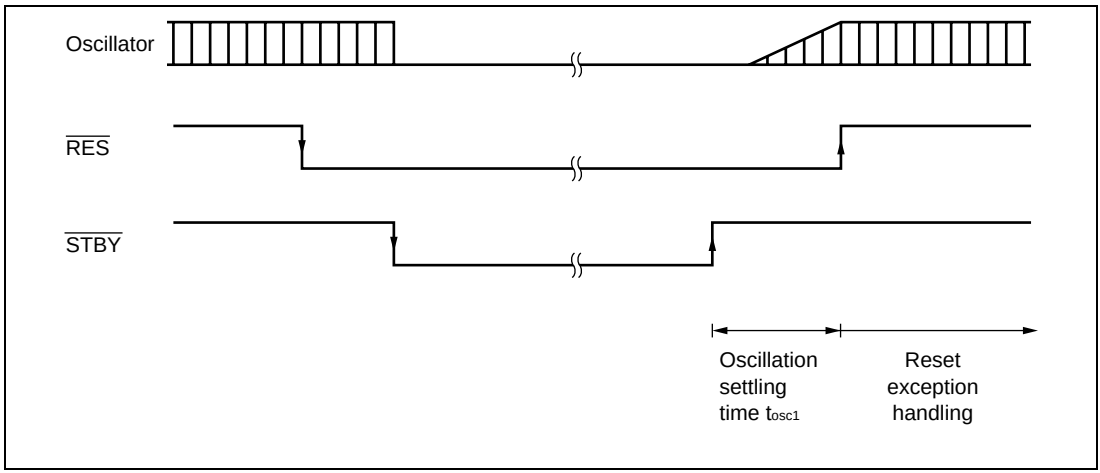


Figure 23.4 Hardware Standby Mode Timing

23.6 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 SCI and the A/D converter are retained.

After reset clearance, all modules other than DMAC and 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′FFFFFFFF), power consumption can further be reduced.

23.7 Watch Mode

23.7.1 Transition to Watch Mode

CPU operation makes a transition to watch mode when the SLEEP instruction is executed in high-speed mode or subactive mode with SSBY in SBYCR =1, DTON in LPWRCR = 0, and PSS in TCSR (WDT_1) = 1.

In watch mode, the CPU is stopped and peripheral modules other than WDT_1 and system clock oscillator 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 SCI and 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.

23.7.2 Exiting Watch Mode

Watch mode is exited by any interrupt (WOVI1 interrupt, NMI pin, or IRQ0 to IRQ7), or signals at the RES, MRES, or STBY pin.

- 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 subactive 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 IRQ0 to IRQ7 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 23.4.3, 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 RES Pin or MRES Pin

  For exiting watch mode by the RES or MRES pin, see section 23.4.2, Clearing Software Standby Mode.
- Exiting Watch Mode by STBY Pin

  When the STBY pin level is driven low, a transition is made to hardware standby mode.

23.8 Subsleep Mode

23.8.1 Transition to Subsleep Mode

When the SLEEP instruction is executed with the SSBY bit in SBYCR = 0, the LSON bit in LPWRCR = 1, and the PSS bit in TCSR (WDT_1) = 1 in subactive mode, CPU operation shifts to subsleep mode.

In subsleep mode, the CPU is stopped. Peripheral modules other than TMR_0 to TMR3, WDT_0, and WDT_1 and system clock oscillator 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 SCI and the A/D converter) and I/O ports are retained.

23.8.2 Exiting Subsleep Mode

Subsleep mode is exited by an interrupt (interrupts from internal peripheral modules, NMI pin, or IRQ0 to IRQ7), or signals at the RES or STBY pin.

- Exiting Subsleep Mode by Interrupts

  When an interrupt occurs, subsleep mode is exited and interrupt exception processing starts.

  In the case of IRQ0 to IRQ7 interrupts, subsleep 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 Subsleep Mode by RES Pin or MRES Pin

  For exiting subsleep mode by the RES or MRES pin, see section 23.4.2, Clearing Software Standby Mode.
- Exiting Subsleep Mode by STBY Pin

  When the STBY pin or MRES pin level is driven low, a transition is made to hardware standby mode.

23.9 Subactive Mode

23.9.1 Transition to Subactive Mode

When the SLEEP instruction is executed in high-speed mode with the SSBY bit in SBYCR = 1, the DTON bit in LPWRCR = 1, the LSON bit = 1, and the PSS bit in TCSR (WDT_1) = 1, CPU operation shifts to subactive mode. When an interrupt occurs in watch mode, and if the LSON bit of LPWRCR is 1, a transition is made to subactive mode. And if an interrupt occurs in subsleep mode, a transition is made to subactive mode.

In subactive 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 to TMR_3, WDT_0, and WDT_1, and system clock oscillator are also stopped.

When operating the CPU in subactive mode, the SCKCR SCK2 to SCK0 bits must be set to 0.

23.9.2 Exiting Subactive Mode

Subactive mode is exited by the SLEEP instruction or the RES, MRES or STBY pin.

- Exiting Subactive Mode by SLEEP Instruction

  When the SLEEP instruction is executed with the SSBY bit in SBYCR = 1, the DTON bit in LPWRCR = 0, and the PSS bit in TCSR (WDT_1) = 1, the CPU exits subactive mode and a transition is made to watch mode. When the SLEEP instruction is executed with the SSBY bit in SBYCR = 0, the LSON bit in LPWRCR = 1, and the PSS bit in TCSR (WDT_1) = 1, a transition is made to subsleep mode. Finally, when the SLEEP instruction is executed with the SSBY bit in SBYCR = 1, the DTON bit in LPWRCR = 1, the LSON bit = 0, and the PSS bit in TCSR (WDT_1) = 1, a direct transition is made to high-speed mode (SCK0 to SCK2 all 0).
- Exiting Subactive Mode by RES Pin or MRES Pin

  For exiting subactive mode by the RES or MRES pin, see section 23.4.2, Clearing Software Standby Mode.
- Exiting Subactive Mode by STBY Pin

  When the STBY pin level is driven low, a transition is made to hardware standby mode.

23.10 Direct Transitions

There are three modes, high-speed, medium-speed, and subactive, 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 subactive 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.

23.10.1 Direct Transitions from High-Speed Mode to Subactive Mode

Execute the SLEEP instruction in high-speed mode when the SSBY bit in SBYCR = 1, the LSON bit in LPWRCR = 1, and the DTON bit = 1, and the PSS bit in TSCR (WDT_1) = 1 to make a transition to subactive mode.

23.10.2 Direct Transitions from Subactive Mode to High-Speed Mode

Execute the SLEEP instruction in subactive mode when the SSBY bit in SBYCR = 1, the LSON bit in LPWRCR = 0, and the DTON bit = 1, and the PSS bit in TSCR (WDT_1) = 1 to make a direct transition to high-speed mode after the time set in STS2 to STS0 bits in SBYCR has elapsed.

23.11 φ Clock Output Enable

The PSTOP bit in SCKCR and the DDR of the corresponding port control the φ clock output. When the PSTOP bit is set to 1, φ clock stops at the end of the bus cycle and the φ clock output is fixed high. When the PSTOP bit is cleared to 0, the φ clock output is enabled. When the DDR of the corresponding port is cleared to 0, the φ clock output is disabled and it functions as an input port. Table 23.4 lists the φ pin states in respective process.

Table 23.4 φ Pin States in Respective Processes

DDR	0	1	
PSTOP	—	0	1
Hardware standby mode	High impedance	High impedance	High impedance
Software standby mode, watch mode, direct transition	High impedance	Fixed to high	Fixed high
Sleep mode, subsleep mode	High impedance	φ output	Fixed high
High-speed mode, medium-speed mode, subactive mode	High impedance	φ output	Fixed high

23.12 Usage Notes

23.12.1 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.

23.12.2 Current Dissipation during Oscillation Settling Wait Period

Current dissipation increases during the oscillation settling wait period.

23.12.3 DTC and DMAC Module Stop

Depending on the operating status of the DTC and DMAC*, the MSTPA6 bit and MSTPA7 bit may not be set to 1. Setting of the DTC and DMAC module stop mode should be carried out only when the respective module is not activated.

For details, refer to section 8, DMA Controller (DMAC) and section 9, Data Transfer Controller (DTC).

Note: The DMAC is supported only by the H8S/2239 Series.

23.12.4 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 DMAC* or DTC activation source. Interrupts should therefore be disabled before entering module stop mode.

- Subactive Mode/Watch Mode

  On-chip peripheral modules (DMAC*, 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 before executing the SLEEP instruction and entering subactive or watch mode.

Note: Supported only by the H8S/2239 Series.

23.12.5 Writing to MSTPCR

MSTPCR should only be written to by the CPU.

23.12.6 Entering Subactive/Watch mode and DMAC and DTC Module Stop

To enter subactive or watch mode, set DMAC* and DTC to module stop (write 1 to the MSTPA6 bit and MSTPA7 bit) and reading the MSTPA6 bit and MSTPA7 bit as 1 before transiting mode. After transiting from subactive mode to active mode, clear module stop.

When DMAC* or DTC activation factor occurs in subactive mode, DMAC* or DTC is activated when module stop is cleared after active mode is entered.

Note: * Supported only by the H8S/2239 Series.

Section 24 List of Registers

This section gives information on the on-chip I/O registers and is configured as described below.

1. Register Addresses (in address order)
- Descriptions by functional module, in ascending order of addresses
- Descriptions by functional module
- 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 (in address order).
- Reserved bits are indicated by — in the bit name.
- A blank in the bit name indicates that the corresponding whole register is allocated to the counter or data.

3. Register States in Each Operating Mode
- Register states are described in the same order as the Register Addresses (in address order).
- 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.

24.1 Register Addresses (in address order)

The data bus width indicates the number 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	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
DTC mode register A	MRA	8	H'EBC0 to	DTC	16/32*[2]	2
DTC mode register B	MRB	8	H'EFBF	DTC	16/32*[2]	2
DTC source address register	SAR	24		DTC	16/32*[2]	2
DTC destination address register	DAR	24		DTC	16/32*[2]	2
DTC transfer count register A	CRA	16		DTC	16/32*[2]	2
DTC transfer count register B	CRB	16		DTC	16/32*[2]	2
D/A data register_0	DADR_0	8	H'FDAC	D/A converter	8	2
D/A data register_1	DADR_1	8	H'FDAD	D/A converter	8	2

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
D/A control register	DACR	8	H'FDAE	D/A converter	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	TCR_2	8	H'FDC0	TMR_2	8	2
Timer control register_3	TCR_3	8	H'FDC1	TMR_3	8	2
Timer control/status register_2	TCSR_2	8	H'FDC2	TMR_2	8	2
Timer control/status register_3	TCSR_3	8	H'FDC3	TMR_3	8	2
Time constant register A_2	TCORA_2	8	H'FDC4	TMR_2	8/16	2
Time constant register A_3	TCORA_3	8	H'FDC5	TMR_3	8/16	2
Time constant register B_2	TCORB_2	8	H'FDC6	TMR_2	8/16	2
Time constant register B_3	TCORB_3	8	H'FDC7	TMR_3	8/16	2
Timer counter_2	TCNT_2	8	H'FDC8	TMR_2	8/16	2
Timer counter_3	TCNT_3	8	H'FDC9	TMR_3	8/16	2
Serial mode register_3	SMR_3	8	H'FDD0	SCI_3	8	2
Bit rate register_3	BRR_3	8	H'FDD1	SCI_3	8	2
Serial control register_3	SCR_3	8	H'FDD2	SCI_3	8	2
Transmit data register_3	TDR_3	8	H'FDD3	SCI_3	8	2
Serial status register_3	SSR_3	8	H'FDD4	SCI_3	8	2
Receive data register_3	RDR_3	8	H'FDD5	SCI_3	8	2
Smart card mode register_3	SCMR_3	8	H'FDD6	SCI_3	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
Pin function control register	PFCR	8	H'FDEB	BSC	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

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
Break address register A	BARA	32	H'FE00	PBC	8/16	2
Break address register B	BARB	32	H'FE04	PBC	8/16	2
Break control register A	BCRA	8	H'FE08	PBC	8/16	2
Break control register B	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 A	DTCERA	8	H'FE16	DTC	8	2
DTC enable register B	DTCERB	8	H'FE17	DTC	8	2
DTC enable register C	DTCERC	8	H'FE18	DTC	8	2
DTC enable register D	DTCERD	8	H'FE19	DTC	8	2
DTC enable register E	DTCERE	8	H'FE1A	DTC	8	2
DTC enable register F	DTCERF	8	H'FE1B	DTC	8	2
DTC enable register I	DTCERI	8	H'FE1E	DTC	8	2
DTC vector register	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
Port 7 data direction register	P7DDR	8	H'FE36	PORT	8	2
Port A data direction register	PADDR	8	H'FE39	PORT	8	2
Port B data direction register	PBDDR	8	H'FE3A	PORT	8	2
Port C data direction register	PCDDR	8	H'FE3B	PORT	8	2
Port D data direction register	PDDDR	8	H'FE3C	PORT	8	2
Port E data direction register	PEDDR	8	H'FE3D	PORT	8	2
Port F data direction register	PFDDR	8	H'FE3E	PORT	8	2
Port G data direction register	PGDDR	8	H'FE3F	PORT	8	2
Port A pull-up MOS control register	PAPCR	8	H'FE40	PORT	8	2
Port B pull-up MOS control register	PBPCR	8	H'FE41	PORT	8	2
Port C pull-up MOS control register	PCPCR	8	H'FE42	PORT	8	2

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
Port D pull-up MOS control register	PDPCR	8	H'FE43	PORT	8	2
Port E pull-up MOS control register	PEPCR	8	H'FE44	PORT	8	2
Port 3 open drain control register	P3ODR	8	H'FE46	PORT	8	2
Port A open drain control register	PAODR	8	H'FE47	PORT	8	2
Timer control register_3	TCR_3	8	H'FE80	TPU_3	8	2
Timer mode register_3	TMDR_3	8	H'FE81	TPU_3	8	2
Timer I/O control register H_3	TIORH_3	8	H'FE82	TPU_3	8	2
Timer I/O control register L_3	TIORL_3	8	H'FE83	TPU_3	8	2
Timer interrupt enable register_3	TIER_3	8	H'FE84	TPU_3	8	2
Timer status register_3	TSR_3	8	H'FE85	TPU_3	8	2
Timer counter_3	TCNT_3	16	H'FE86	TPU_3	16	2
Timer general register A_3	TGRA_3	16	H'FE88	TPU_3	16	2
Timer general register B_3	TGRB_3	16	H'FE8A	TPU_3	16	2
Timer general register C_3	TGRC_3	16	H'FE8C	TPU_3	16	2
Timer general register D_3	TGRD_3	16	H'FE8E	TPU_3	16	2
Timer control register_4	TCR_4	8	H'FE90	TPU_4	8	2
Timer mode register_4	TMDR_4	8	H'FE91	TPU_4	8	2
Timer I/O control register_4	TIOR_4	8	H'FE92	TPU_4	8	2
Timer interrupt enable register_4	TIER_4	8	H'FE94	TPU_4	8	2
Timer status register_4	TSR_4	8	H'FE95	TPU_4	8	2
Timer counter_4	TCNT_4	16	H'FE96	TPU_4	16	2
Timer general register A_4	TGRA_4	16	H'FE98	TPU_4	16	2
Timer general register B_4	TGRB_4	16	H'FE9A	TPU_4	16	2
Timer control register_5	TCR_5	8	H'FEA0	TPU_5	8	2
Timer mode register_5	TMDR_5	8	H'FEA1	TPU_5	8	2
Timer I/O control register_5	TIOR_5	8	H'FEA2	TPU_5	8	2
Timer interrupt enable register_5	TIER_5	8	H'FEA4	TPU_5	8	2
Timer status register_5	TSR_5	8	H'FEA5	TPU_5	8	2
Timer counter_5	TCNT_5	16	H'FEA6	TPU_5	16	2
Timer general register A_5	TGRA_5	16	H'FEA8	TPU_5	16	2
Timer general register B_5	TGRB_5	16	H'FEAA	TPU_5	16	2

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
Timer start register	TSTR	8	H'FEB0	TPU	8	2
Timer synchro register	TSYR	8	H'FEB1	TPU	8	2
Interrupt priority register A	IPRA	8	H'FEC0	INT	8	2
Interrupt priority register B	IPRB	8	H'FEC1	INT	8	2
Interrupt priority register C	IPRC	8	H'FEC2	INT	8	2
Interrupt priority register D	IPRD	8	H'FEC3	INT	8	2
Interrupt priority register E	IPRE	8	H'FEC4	INT	8	2
Interrupt priority register F	IPRF	8	H'FEC5	INT	8	2
Interrupt priority register G	IPRG	8	H'FEC6	INT	8	2
Interrupt priority register H	IPRH	8	H'FEC7	INT	8	2
Interrupt priority register I	IPRI	8	H'FEC8	INT	8	2
Interrupt priority register J	IPRJ	8	H'FEC9	INT	8	2
Interrupt priority register K	IPRK	8	H'FECA	INT	8	2
Interrupt priority register L	IPRL	8	H'FECB	INT	8	2
Interrupt priority register O	IPRO	8	H'FECE	INT	8	2
Bus width control register	ABWCR	8	H'FED0	BSC	8	2
Access state control register	ASTCR	8	H'FED1	BSC	8	2
Wait control register H	WCRH	8	H'FED2	BSC	8	2
Wait control register L	WCRL	8	H'FED3	BSC	8	2
Bus control register H	BCRH	8	H'FED4	BSC	8	2
Bus control register L	BCRL	8	H'FED5	BSC	8	2
RAM emulation register	RAMER	8	H'FEDB	FLASH	8	2
Memory address register_0AH	MAR_0AH	16	H'FEE0	DMAC	16	2
Memory address register_0AL	MAR_0AL	16	H'FEE2	DMAC	16	2
I/O address register_0A	IOAR_0A	16	H'FEE4	DMAC	16	2
Execute transfer count register_0A	ETCR_0A	16	H'FEE6	DMAC	16	2
Memory address register_0BH	MAR_0BH	16	H'FEE8	DMAC	16	2
Memory address register_0BL	MAR_0BL	16	H'FEEA	DMAC	16	2
I/O address eegister_0B	IOAR_0B	16	H'FEEC	DMAC	16	2
Execute transfer count register_0B	ETCR_0B	16	H'FEEE	DMAC	16	2
Memory address register_1AH	MAR_1AH	16	H'FEF0	DMAC	16	2
Memory address register_1AL	MAR_1AL	16	H'FEF2	DMAC	16	2

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
I/O address register_1A	IOAR_1A	16	H'FEF4	DMAC	16	2
Execute transfer count register_1A	ETCR_1A	16	H'FEF6	DMAC	16	2
Memory address register_1BH	MAR_1BH	16	H'FEF8	DMAC	16	2
Memory address register_1BL	MAR_1BL	16	H'FEFA	DMAC	16	2
I/O address register_1B	IOAR_1B	16	H'FEFC	DMAC	16	2
Execute transfer count register_1B	ETCR_1B	16	H'FEFE	DMAC	16	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 A data register	PADR	8	H'FF09	PORT	8	2
Port B data register	PBDR	8	H'FF0A	PORT	8	2
Port C data register	PCDR	8	H'FF0B	PORT	8	2
Port D data register	PDDR	8	H'FF0C	PORT	8	2
Port E data register	PEDR	8	H'FF0D	PORT	8	2
Port F data register	PFDR	8	H'FF0E	PORT	8	2
Port G data register	PGDR	8	H'FF0F	PORT	8	2
Timer control register_0	TCR_0	8	H'FF10	TPU_0	8	2
Timer mode register_0	TMDR_0	8	H'FF11	TPU_0	8	2
Timer I/O control register H_0	TIORH_0	8	H'FF12	TPU_0	8	2
Timer I/O control register L_0	TIORL_0	8	H'FF13	TPU_0	8	2
Timer interrupt enable register_0	TIER_0	8	H'FF14	TPU_0	8	2
Timer status register_0	TSR_0	8	H'FF15	TPU_0	8	2
Timer counter_0	TCNT_0	16	H'FF16	TPU_0	16	2
Timer general register A_0	TGRA_0	16	H'FF18	TPU_0	16	2
Timer general register B_0	TGRB_0	16	H'FF1A	TPU_0	16	2
Timer general register C_0	TGRC_0	16	H'FF1C	TPU_0	16	2
Timer general register D_0	TGRD_0	16	H'FF1E	TPU_0	16	2

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
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
DMA write enable register	DMAWER	8	H'FF60	DMAC	8	2
DMA terminal control register	DMATCR	8	H'FF61	DMAC	8	2
DMA control register_0A	DMACR_0A	8	H'FF62	DMAC	16	2
DMA control register_0B	DMACR_0B	8	H'FF63	DMAC	16	2
DMA control register_1A	DMACR_1A	8	H'FF64	DMAC	16	2
DMA control register_1B	DMACR_1B	8	H'FF65	DMAC	16	2
DMA band control register H	DMABCRH	8	H'FF66	DMAC	16	2
DMA band control register L	DMABCRL	8	H'FF67	DMAC	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

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
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	WDT_0	16	2
Timer counter_0	TCNT_0	8	H'FF74 (write)	WDT_0	16	2
Timer counter_0	TCNT_0	8	H'FF75 (read)	WDT_0	16	2
Reset control/status register	RSTCSR	8	H'FF76 (write)	WDT_0	16	2
Reset control/status register	RSTCSR	8	H'FF77 (read)	WDT_0	16	2
Serial mode register_0	SMR_0	8	H'FF78*[3]	SCI_0	8	2
I^2C 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^2C 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^2C bus data register_0	ICDR_0	8	H'FF7E*[3]	IIC_0	8	2
Second slave address register_0	SARX_0	8	H'FF7E*[3]	IIC_0	8	2
I^2C bus mode register_0	ICMR_0	8	H'FF7F	IIC_0	8	2
Slave address register_0	SAR_0	8	H'FF7F	IIC_0	8	2

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
Serial mode register_1	SMR_1	8	H'FF80*[3]	SCI_1	8	2
I^2C bus control register_1	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^2C bus status register_1	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^2C bus data register_1	ICDR_1	8	H'FF86*[3]	IIC_1	8	2
Second slave address register_1	SARX_1	8	H'FF86*[3]	IIC_1	8	2
I^2C bus mode register_1	ICMR_1	8	H'FF87	IIC_1	8	2
Slave address register_1	SAR_1	8	H'FF87	IIC_1	8	2
Serial mode register_2	SMR_2	8	H'FF88	SCI_2	8	2
Bit rate register_2	BRR_2	8	H'FF89	SCI_2	8	2
Serial control register_2	SCR_2	8	H'FF8A	SCI_2	8	2
Transmit data register_2	TDR_2	8	H'FF8B	SCI_2	8	2
Serial status register_2	SSR_2	8	H'FF8C	SCI_2	8	2
Receive data register_2	RDR_2	8	H'FF8D	SCI_2	8	2
Smart card mode register_2	SCMR_2	8	H'FF8E	SCI_2	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
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

Register Name	Abbreviation	Bit No.	Address*[1]	Module	Data Bus Width	Access State
Timer control/status register_1	TCSR_1	8	H'FFA2	WDT_1	16	2
Timer counter_1	TCNT_1	8	H'FFA2 (write)	WDT_1	16	2
Timer counter_1	TCNT_1	8	H'FFA3 (read)	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 A register	PORTA	8	H'FFB9	PORT	8	2
Port B register	PORTB	8	H'FFBA	PORT	8	2
Port C register	PORTC	8	H'FFBB	PORT	8	2
Port D register	PORTD	8	H'FFBC	PORT	8	2
Port E register	PORTE	8	H'FFBD	PORT	8	2
Port F register	PORTF	8	H'FFBE	PORT	8	2
Port G register	PORTG	8	H'FFBF	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 are allocated to the same address. Use the IICE bit of the serial control register X (SCRX) to select the register.

24.2 Register Bits

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

Each line covers eight bits, and 16-bit register is shown as 2 lines.

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
MRA	SM1	SM0	DM1	DM0	MD1	MD0	DTS	Sz	DTC
SAR	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	
	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
MRB	CHNE	DISEL	—	—	—	—	—	—	
DAR	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	
	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
CRA	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
CRB	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
DADR_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	D/A converter
DADR_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
DACR	DAOE1	DAOE0	DAE	—	—	—	—	—	
SCRX	—	IICX1	IICX0	IICE	FLSHE	—	—	—	IIC, FLASH
DDCSWR	—	—	—	—	CLR3	CLR2	CLR1	CLR0	IIC
TCR_2	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_2
TCR_3	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_3
TCSR_2	CMFB	CMFA	OVF	—	OS3	OS2	OS1	OS0	TMR_2
TCSR_3	CMFB	CMFA	OVF	—	OS3	OS2	OS1	OS0	TMR_3
TCORA_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_2
TCORA_3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_3
TCORB_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_2
TCORB_3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_3
TCNT_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_2
TCNT_3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_3

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
SMR_3*[1]	C/A	CHR	PE	O/E	STOP	MP	CKS1	CKS0	SCI_3
	(GM)	(BLK)	(PE)	(O/E)	(BCP1)	(BCP0)	(CKS1)	(CKS0)	
BRR_3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCR_3	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	
TDR_3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SSR_3*[1]	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT	
	(TDRE)	(RDRF)	(ORER)	(ERS)	(PER)	(TEND)	(MPB)	(MPBT)	
RDR_3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCMR_3	—	—	—	—	SDIR	SINV	—	SMIF	
SBYCR	SSBY	STS2	STS1	STS0	OPE	—	—	—	SYSTEM
SYSCR	—	—	INTM1	INTM0	NMIEG	MRESE	—	RAME	
SCKCR	PSTOP	—	—	—	—	SCK2	SCK1	SCK0	
MDCR	—	—	—	—	—	MDS2	MDS1	MDS0	
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	
PFCR	—	—	BUZZE	—	AE3	AE2	AE1	AE0	BSC
LPWRCR	DTON	LSON	NESEL	SUBSTP	RFCUT	—	STC1	STC0	SYSTEM
SEMR_0	SSE	—	—	—	ABCS	ACS2	ACS1	ACS0	SCI_0
BARA	—	—	—	—	—	—	—	—	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	—	—	—	—	—	—	—	—	
	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	CMFA	CDA	BAMRA2	BAMRA1	BAMRA0	CSELA1	CSELA0	BIEA	
BCRB	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	IRQ7SCB	IRQ7SCA	IRQ6SCB	IRQ6SCA	IRQ5SCB	IRQ5SCA	IRQ4SCB	IRQ4SCA	INT
ISCRL	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0SCA	
IER	IRQ7E	IRQ6E	IRQ5E	IRQ4E	IRQ3E	IRQ2E	IRQ1E	IRQ0E	
ISR	IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F	IRQ0F	
DTCERA	DTCEA7	DTCEA6	DTCEA5	DTCEA4	DTCEA3	DTCEA2	DTCEA1	DTCEA0	DTC
DTCERB	—	DTCEB6	DTCEB5	DTCEB4	DTCEB3	DTCEB2	DTCEB1	DTCEB0	
DTCERC	DTCEC7	DTCEC6	DTCEC5	DTCEC4	DTCEC3	DTCEC2	DTCEC1	DTCEC0	
DTCERD	—	—	DTCED5	DTCED4	DTCED3	DTCED2	DTCED1	DTCED0	
DTCERE	DTCEE7	DTCEE6	DTCEE5	DTCEE4	DTCEE3	DTCEE2	DTCEE1	DTCEE0	
DTCERF	DTCEF7	DTCEF6	DTCEF5	DTCEF4	DTCEF3	DTCEF2	DTCEF1	DTCEF0	
DTCERI	DTCEI7	DTCEI6	—	—	—	—	—	—	
DTVECR	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0	
P1DDR	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR	PORT
P3DDR	—	P36DDR	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR	P30DDR	
P7DDR	P77DDR	P76DDR	P75DDR	P74DDR	P73DDR	P72DDR	P71DDR	P70DDR	
PADDR	—	—	—	—	PA3DDR	PA2DDR	PA1DDR	PA0DDR	
PBDDR	PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR	PB0DDR	
PCDDR	PC7DDR	PC6DDR	PC5DDR	PC4DDR	PC3DDR	PC2DDR	PC1DDR	PC0DDR	
PDDDR	PD7DDR	PD6DDR	PD5DDR	PD4DDR	PD3DDR	PD2DDR	PD1DDR	PD0DDR	
PEDDR	PE7DDR	PE6DDR	PE5DDR	PE4DDR	PE3DDR	PE2DDR	PE1DDR	PE0DDR	
PFDDR	PF7DDR	PF6DDR	PF5DDR	PF4DDR	PF3DDR	PF2DDR	PF1DDR	PF0DDR	
PGDDR	—	—	—	PG4DDR	PG3DDR	PG2DDR	PG1DDR	PG0DDR	
PAPCR	—	—	—	—	PA3PCR	PA2PCR	PA1PCR	PA0PCR	
PBPCR	PB7PCR	PB6PCR	PB5PCR	PB4PCR	PB3PCR	PB2PCR	PB1PCR	PB0PCR	
PCPCR	PC7PCR	PC6PCR	PC5PCR	PC4PCR	PC3PCR	PC2PCR	PC1PCR	PC0PCR	
PDPCR	PD7PCR	PD6PCR	PD5PCR	PD4PCR	PD3PCR	PD2PCR	PD1PCR	PD0PCR	
PEPCR	PE7PCR	PE6PCR	PE5PCR	PE4PCR	PE3PCR	PE2PCR	PE1PCR	PE0PCR	
P3ODR	—	P36ODR	P35ODR	P34ODR	P33ODR	P32ODR	P31ODR	P30ODR	
PAODR	—	—	—	—	PA3ODR	PA2ODR	PA1ODR	PA0ODR	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCR_3	CCLR2	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_3
TMDR_3	—	—	BFB	BFA	MD3	MD2	MD1	MD0	
TIORH_3	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIORL_3	IOD3	IOD2	IOD1	IOD0	IOC3	IOC2	IOC1	IOC0	
TIER_3	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA	
TSR_3	—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA	
TCNT_3	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRA_3	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRB_3	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRC_3	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRD_3	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCR_4	—	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_4
TMDR_4	—	—	—	—	MD3	MD2	MD1	MD0	
TIOR_4	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIER_4	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA	
TSR_4	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA	
TCNT_4	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRA_4	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRB_4	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCR_5	—	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_5
TMDR_5	—	—	—	—	MD3	MD2	MD1	MD0	
TIOR_5	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIER_5	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA	
TSR_5	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA	
TCNT_5	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRA_5	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRB_5	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TSTR	—	—	CST5	CST4	CST3	CST2	CST1	CST0	TPU
TSYR	—	—	SYNC5	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0	
IPRA	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	INT
IPRB	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRC	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRD	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRE	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRF	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRG	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRH	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRI	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRJ	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRK	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRL	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
IPRO	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0	
ABWCR	ABW7	ABW6	ABW5	ABW4	ABW3	ABW2	ABW1	ABW0	BSC
ASTCR	AST7	AST6	AST5	AST4	AST3	AST2	AST1	AST0	
WCRH	W71	W70	W61	W60	W51	W50	W41	W40	
WCRL	W31	W30	W21	W20	W11	W10	W01	W00	
BCRH	ICIS1	ICIS0	BRSTRM	BRSTS1	BRSTS0	—	—	—	
BCRL	BRLE	—	—	—	—	—	—	WAITE	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
RAMER	—	—	—	—	RAMS	RAM2	RAM1	RAM0	FLASH
MAR_0A	—	—	—	—	—	—	—	—	DMAC
	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	
	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
IOAR_0A	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ETCR_0A	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
MAR_0B	—	—	—	—	—	—	—	—	
	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	
	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
IOAR_0B	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ETCR_0B	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
MAR_1A	—	—	—	—	—	—	—	—	
	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	
	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
IOAR_1A	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ETCR_1A	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
MAR_1B	—	—	—	—	—	—	—	—	
	Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	
	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
IOAR_1B	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ETCR_1B	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
P1DR	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR	PORT
P3DR	—	P36DR	P35DR	P34DR	P33DR	P32DR	P31DR	P30DR	
P7DR	P77DR	P76DR	P75DR	P74DR	P73DR	P72DR	P71DR	P70DR	
PADR	—	—	—	—	PA3DR	PA2DR	PA1DR	PA0DR	
PBDR	PB7DR	PB6DR	PB5DR	PB4DR	PB3DR	PB2DR	PB1DR	PB0DR	
PCDR	PC7DR	PC6DR	PC5DR	PC4DR	PC3DR	PC2DR	PC1DR	PC0DR	
PDDR	PD7DR	PD6DR	PD5DR	PD4DR	PD3DR	PD2DR	PD1DR	PD0DR	
PEDR	PE7DR	PE6DR	PE5DR	PE4DR	PE3DR	PE2DR	PE1DR	PE0DR	
PFDR	PF7DR	PF6DR	PF5DR	PF4DR	PF3DR	PF2DR	PF1DR	PF0DR	
PGDR	—	—	—	PG4DR	PG3DR	PG2DR	PG1DR	PG0DR	
TCR_0	CCLR2	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU_0
TMDR_0	—	—	BFB	BFA	MD3	MD2	MD1	MD0	
TIORH_0	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0	
TIORL_0	IOD3	IOD2	IOD1	IOD0	IOC3	IOC2	IOC1	IOC0	
TIER_0	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA	
TSR_0	—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA	
TCNT_0	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRA_0	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRB_0	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRC_0	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRD_0	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
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	TCIEV	—	—	TGIEB	TGIEA	
TSR_1	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA	
TCNT_1	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRA_1	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRB_1	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
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	TCIEV	—	—	TGIEB	TGIEA	
TSR_2	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA	
TCNT_2	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRA_2	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TGRB_2	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
DMAWER	—	—	—	—	WE1B	WE1A	WE0B	WE0A	DMAC
DMATCR	—	—	TEE1	TEE0	—	—	—	—	
DMACR_0A*[2]	DTSZ	DTID	RPE	DTDIR	DTF3	DTF2	DTF1	DTF0	
DMACR_0A*[3]	DTSZ	SAID	SAIDE	BLKDIR	BLKE	—	—	—	
DMACR_0B*[2]	DTSZ	DTID	RPE	DTDIR	DTF3	DTF2	DTF1	DTF0	
DMACR_0B*[3]	—	DAID	DAIDE	—	DTF3	DTF2	DTF1	DTF0	
DMACR_1A*[2]	DTSZ	DTID	RPE	DTDIR	DTF3	DTF2	DTF1	DTF0	
DMACR_1A*[3]	DTSZ	SAID	SAIDE	BLKDIR	BLKE	—	—	—	
DMACR_1B*[2]	DTSZ	DTID	RPE	DTDIR	DTF3	DTF2	DTF1	DTF0	
DMACR_1B*[3]	—	DAID	DAIDE	—	DTF3	DTF2	DTF1	DTF0	
DMABCRH*[2]	FAE1	FAE0	SAE1	SAE0	DTA1B	DTA1A	DTA0B	DTA0A	
DMABCRH*[3]	FAE1	FAE0	—	—	DTA1	—	DTA0	—	
DMABCRL*[2]	DTE1B	DTE1A	DTE0B	DTE0A	DTIE1B	DTIE1A	DTIE0B	DTIE0A	
DMABCRL*[3]	DTME1	DTE1	DTME0	DTE0	DTIE1B	DTIE1A	DTIE0B	DTIE0A	
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	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_0
TCORA_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_1
TCORB_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_0
TCORB_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_1
TCNT_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_0
TCNT_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_1
TCSR_0	OVF	WT/IT	TME	—	—	CKS2	CKS1	CKS0	WDT_0
TCNT_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
RSTCSR	WOVF	RSTE	RSTS	—	—	—	—	—	
SMR_0*[1]	C/A (GM)	CHR (BLK)	PE (PE)	O/E (O/E)	STOP (BCP1)	MP (BCP0)	CKS1 (CKS1)	CKS0 (CKS0)	SCI_0
ICCR_0	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP	IIC_0
BRR_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	SCI_0
ICSR_0	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	IIC_0

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
SCR_0	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	SCI_0
TDR_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SSR_0*[1]	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	MPB (MPB)	MPBT (MPBT)	
RDR_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCMR_0	—	—	—	—	SDIR	SINV	—	SMIF	
ICDR_0	ICDR7	ICDR6	ICDR5	ICDR4	ICDR3	ICDR2	ICDR1	ICDR0	IIC_0
SARX_0	SVAX6	SVAX5	SVAX4	SVAX3	SVAX2	SVAX1	SVAX0	FSX	
ICMR_0	MLS	WAIT	CKS2	CKS1	CKS0	BC2	BC1	BC0	
SAR_0	SVA6	SVA5	SVA4	SVA3	SVA2	SVA1	SVA0	FS	
SMR_1*[1]	C/A (GM)	CHR (BLK)	PE (PE)	O/E (O/E)	STOP (BCP1)	MP (BCP0)	CKS1 (CKS1)	CKS0 (CKS0)	SCI_1
ICCR_1	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP	IIC_1
BRR_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	SCI_1
ICSR_1	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	IIC_1
SCR_1	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	SCI_1
TDR_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SSR_1*[1]	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	MPB (MPB)	MPBT (MPBT)	
RDR_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCMR_1	—	—	—	—	SDIR	SINV	—	SMIF	
ICDR_1	ICDR7	ICDR6	ICDR5	ICDR4	ICDR3	ICDR2	ICDR1	ICDR0	IIC_1
SARX_1	SVAX6	SVAX5	SVAX4	SVAX3	SVAX2	SVAX1	SVAX0	FSX	
ICMR_1	MLS	WAIT	CKS2	CKS1	CKS0	BC2	BC1	BC0	
SAR_1	SVA6	SVA5	SVA4	SVA3	SVA2	SVA1	SVA0	FS	
SMR_2*[1]	C/A (GM)	CHR (BLK)	PE (PE)	O/E (O/E)	STOP (BCP1)	MP (BCP0)	CKS1 (CKS1)	CKS0 (CKS0)	SCI_2
BRR_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCR_2	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	
TDR_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SSR_2*[1]	TDRE (TDRE)	RDRF (RDRF)	ORER (ORER)	FER (ERS)	PER (PER)	TEND (TEND)	MPB (MPB)	MPBT (MPBT)	
RDR_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCMR_2	—	—	—	—	SDIR	SINV	—	SMIF	

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
ADDRAH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	A/D converter
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	—	CH2	CH1	CH0	
ADCR	TRGS1	TRGS0	—	—	CKS1	CKS0	—	—	
TCSR_1	OVF	WT/IT	TME	PSS	RST/NMI	CKS2	CKS1	CKS0	WDT_1
TCNT_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
FLMCR1	FWE	SWE1	ESU1	PSU1	EV1	PV1	E1	P1	FLASH
FLMCR2	FLER	—	—	—	—	—	—	—	
EBR1	EB7	EB6	EB5	EB4	EB3	EB2	EB1	EB0	
EBR2	—	—	EB13	EB12	EB11	EB10	EB9	EB8	
FLPWCR	PDWND	—	—	—	—	—	—	—	
PORT1	P17	P16	P15	P14	P13	P12	P11	P10	PORT
PORT3	—	P36	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	—	—	—	—	—	—	
PORTA	—	—	—	—	PA3	PA2	PA1	PA0	
PORTB	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0	
PORTC	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0	
PORTD	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0	
PORTE	PE7	PE6	PE5	PE4	PE3	PE2	PE1	PE0	
PORTF	PF7	PF6	PF5	PF4	PF3	PF2	PF1	PF0	
PORTG	—	—	—	PG4	PG3	PG2	PG1	PG0	

Notes: 1. Some bit names differ depending on whether used in normal mode and Smart Card interface mode.
The name in ( ) indicates the name in Smart Card interface mode.
2. Short address mode
3. Full address mode

24.3 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	Initialized	—	—	—	—	—	—	—	—	Initialized	DTC
SAR	Initialized	—	—	—	—	—	—	—	—	Initialized	
MRB	Initialized	—	—	—	—	—	—	—	—	Initialized	
DAR	Initialized	—	—	—	—	—	—	—	—	Initialized	
CRA	Initialized	—	—	—	—	—	—	—	—	Initialized	
CRB	Initialized	—	—	—	—	—	—	—	—	Initialized	
DADR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	D/A
DADR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
DACR	Initialized	—	—	—	—	—	—	—	—	Initialized	
SCRX	Initialized	—	—	—	—	—	—	—	—	Initialized	IIC
DDCSWR	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_2
TCR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_3
TCSR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_2
TCSR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_3
TCORA_2	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_2
TCORA_3	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_3
TCORB_2	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_2
TCORB_3	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_3
TCNT_2	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_2
TCNT_3	Initialized	—	—	—	—	—	—	—	—	Initialized	TMR_3
SMR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	SCI_3
BRR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
SCR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TDR_3	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SSR_3	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_3	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High -speed	Medium- speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
SBYCR	Initialized	—	—	—	—	—	—	—	—	Initialized	SYSTEM
SYSCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
SCKCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
MDCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
MSTPCRA	Initialized	—	—	—	—	—	—	—	—	Initialized	
MSTPCRB	Initialized	—	—	—	—	—	—	—	—	Initialized	
MSTPCRC	Initialized	—	—	—	—	—	—	—	—	Initialized	
PFCR	Initialized	—	—	—	—	—	—	—	—	Initialized	BSC
LPWRCR	Initialized	—	—	—	—	—	—	—	—	Initialized	SYSTEM
SEMR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	SCI_0
BARA	Initialized	—	—	—	—	—	—	—	—	Initialized	PBC
BARB	Initialized	—	—	—	—	—	—	—	—	Initialized	
BCRA	Initialized	—	—	—	—	—	—	—	—	Initialized	
BCRB	Initialized	—	—	—	—	—	—	—	—	Initialized	
ISCRH	Initialized	—	—	—	—	—	—	—	—	Initialized	INT
ISCRL	Initialized	—	—	—	—	—	—	—	—	Initialized	
IER	Initialized	—	—	—	—	—	—	—	—	Initialized	
ISR	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTCERA	Initialized	—	—	—	—	—	—	—	—	Initialized	DTC
DTCERB	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTCERC	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTCERD	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTCERE	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTCERF	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTCERI	Initialized	—	—	—	—	—	—	—	—	Initialized	
DTVECR	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High -speed	Medium- speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
P1DDR	Initialized	—	—	—	—	—	—	—	—	Initialized	PORT
P3DDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
P7DDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PADDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PBDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PCDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PDDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PEDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PFDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PGDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PAPCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PBPCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PCPCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PDPCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PEPCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
P3ODR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PAODR	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_3
TMDR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIORH_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIORL_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRC_3	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRD_3	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High -speed	Medium- speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
TCR_4	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_4
TMDR_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIOR_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_4	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCR_5	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_5
TMDR_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIOR_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_5	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSTR	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU
TSYR	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRA	Initialized	—	—	—	—	—	—	—	—	Initialized	INT
IPRB	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRC	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRD	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRE	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRF	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRG	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRH	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRI	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRJ	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRK	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRL	Initialized	—	—	—	—	—	—	—	—	Initialized	
IPRO	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High -speed	Medium- speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
ABWCR	Initialized	—	—	—	—	—	—	—	—	Initialized	BSC
ASTCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
WCRH	Initialized	—	—	—	—	—	—	—	—	Initialized	
WCRL	Initialized	—	—	—	—	—	—	—	—	Initialized	
BCRH	Initialized	—	—	—	—	—	—	—	—	Initialized	
BCRL	Initialized	—	—	—	—	—	—	—	—	Initialized	
RAMER	Initialized	—	—	—	—	—	—	—	—	Initialized	FLASH
MAR_0A	—	—	—	—	—	—	—	—	—	—	DMAC
IOAR_0A	—	—	—	—	—	—	—	—	—	—	
ETCR_0A	—	—	—	—	—	—	—	—	—	—	
MAR_0B	—	—	—	—	—	—	—	—	—	—	
IOAR_0B	—	—	—	—	—	—	—	—	—	—	
ETCR_0B	—	—	—	—	—	—	—	—	—	—	
MAR_1A	—	—	—	—	—	—	—	—	—	—	
IOAR_1A	—	—	—	—	—	—	—	—	—	—	
ETCR_1A	—	—	—	—	—	—	—	—	—	—	
MAR_1B	—	—	—	—	—	—	—	—	—	—	
IOAR_1B	—	—	—	—	—	—	—	—	—	—	
ETCR_1B	—	—	—	—	—	—	—	—	—	—	
P1DR	Initialized	—	—	—	—	—	—	—	—	Initialized	PORT
P3DR	Initialized	—	—	—	—	—	—	—	—	Initialized	
P7DR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PADR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PBDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PCDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PDDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PEDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PFDR	Initialized	—	—	—	—	—	—	—	—	Initialized	
PGDR	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High -speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
TCR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_0
TMDR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIORH_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIORL_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRC_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRD_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_1
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	
TCR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	TPU_2
TMDR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIOR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TIER_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TSR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TCNT_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRA_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TGRB_2	Initialized	—	—	—	—	—	—	—	—	Initialized	

Register Name	Reset	High -speed	Medium- speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
DMAWER	Initialized	—	—	—	—	—	—	—	—	Initialized	DMAC
DMATCR	Initialized	—	—	—	—	—	—	—	—	Initialized	
DMACR_0A	Initialized	—	—	—	—	—	—	—	—	Initialized	
DMACR_0B	Initialized	—	—	—	—	—	—	—	—	Initialized	
DMACR_1A	Initialized	—	—	—	—	—	—	—	—	Initialized	
DMACR_1B	Initialized	—	—	—	—	—	—	—	—	Initialized	
DMABCRH	Initialized	—	—	—	—	—	—	—	—	Initialized	
DMABCRL	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	SCI_0
SSR_0	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_0	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
ICDR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	IIC_0
SARX_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
ICMR_0	Initialized	—	—	—	—	—	—	—	—	Initialized	
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	Initialized	—	—	—	—	—	—	—	—	Initialized	IIC_1
BRR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	SCI_1
ICSR_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	Initialized	—	—	—	—	—	—	—	—	Initialized	IIC_1
SARX_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
ICMR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
SAR_1	Initialized	—	—	—	—	—	—	—	—	Initialized	
SMR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	SCI_2
BRR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
SCR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
TDR_2	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SSR_2	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_2	Initialized	—	—	—	Initialized	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_2	Initialized	—	—	—	—	—	—	—	—	Initialized	
ADDRAH	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	

Register Name	Reset	High -speed	Medium-speed	Sleep	Module Stop	Watch	Subactive	Subsleep	Software Standby	Hardware Standby	Module
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	
PORT7	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORT9	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTA	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTB	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTC	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTD	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTE	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTF	Initialized	—	—	—	—	—	—	—	—	Initialized	
PORTG	Initialized	—	—	—	—	—	—	—	—	Initialized	

Note: — is not initialized.

25.1 Power Supply Voltage and Operating Frequency Range

Figures 25.1, 25.2, and 25.3 show power supply voltage and operating frequency ranges (shaded areas) of the H8S/2239 Series, H8S/2238R Series, and H8S/2237 Series and H8S/2227 Series respectively.

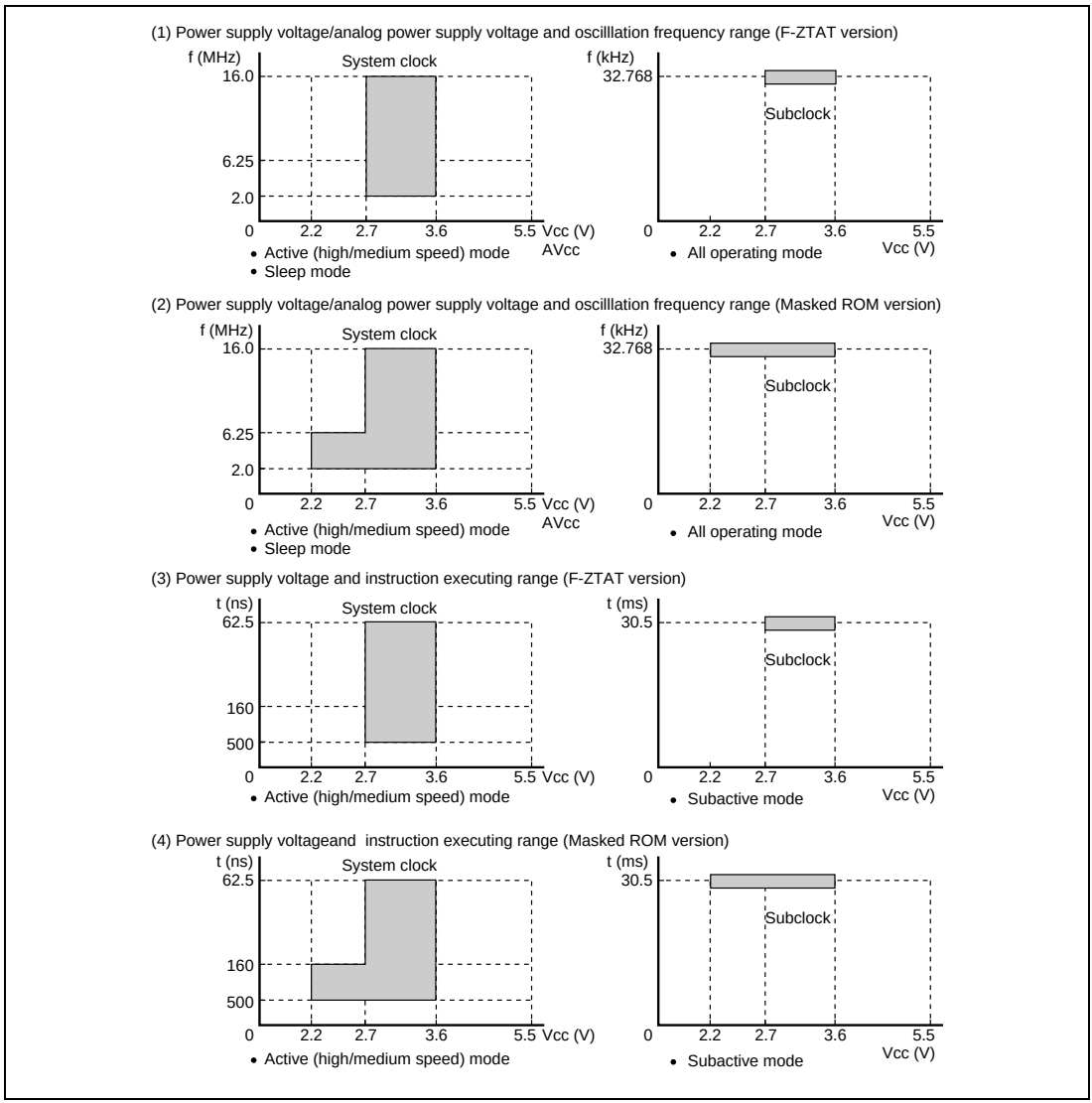
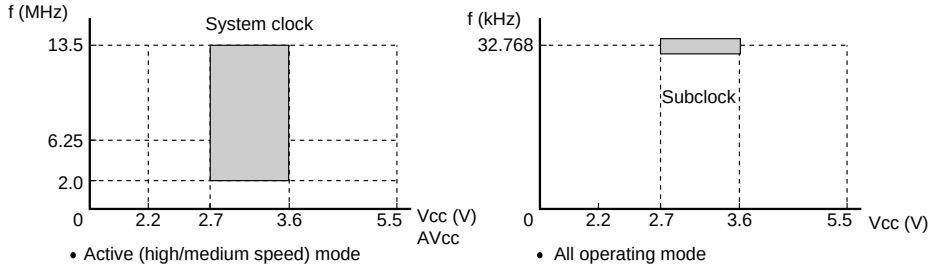


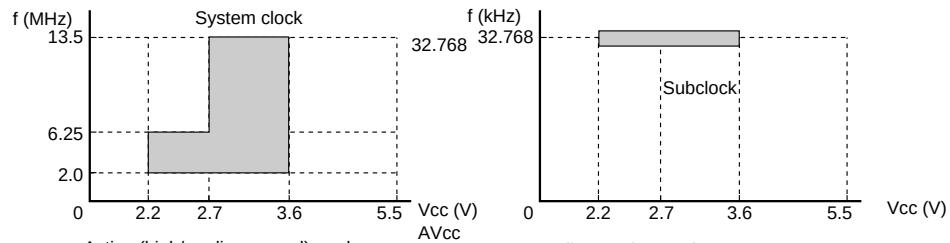
Figure 25.1 Power Supply Voltage and Operating Ranges (H8S/2239 Series)

(1) Power supply voltage/analog power supply voltage and oscilllation frequency range (F-ZTAT-version wide-range specifications)



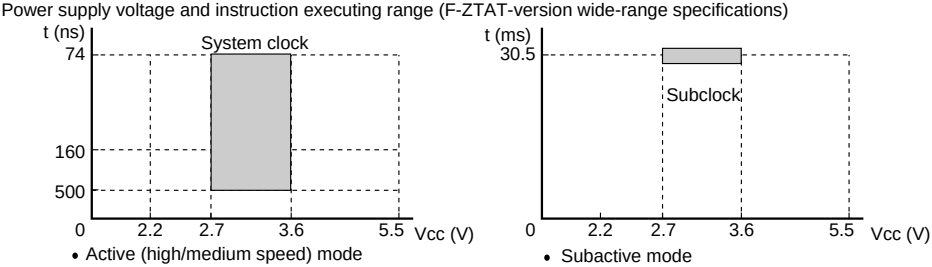
- Active (high/medium speed) mode
- Sleep mode
- All operating mode

(2) Power supply voltage/analog power supply voltage and oscilllation frequency range
(F-ZTAT-version regular specifications/Masked ROM version)



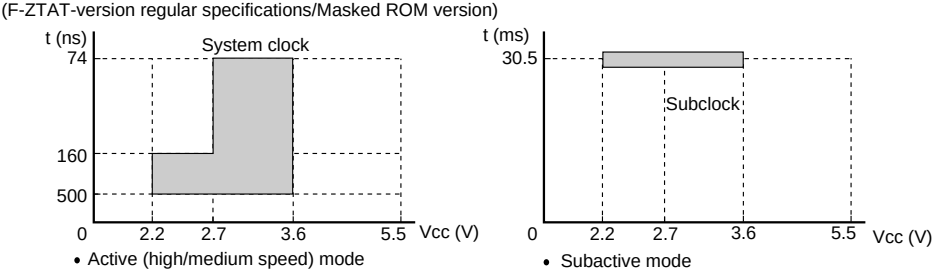
- Active (high/medium speed) mode
- Sleep mode
- All operating mode

(3) Power supply voltage and instruction executing range (F-ZTAT-version wide-range specifications)



- Active (high/medium speed) mode
- Subactive mode

(4) Power supply voltageand instruction executing range
(F-ZTAT-version regular specifications/Masked ROM version)



- Active (high/medium speed) mode
- Subactive mode

Figure 25.2 Power Supply Voltage and Operating Ranges (H8S/2238R Series)

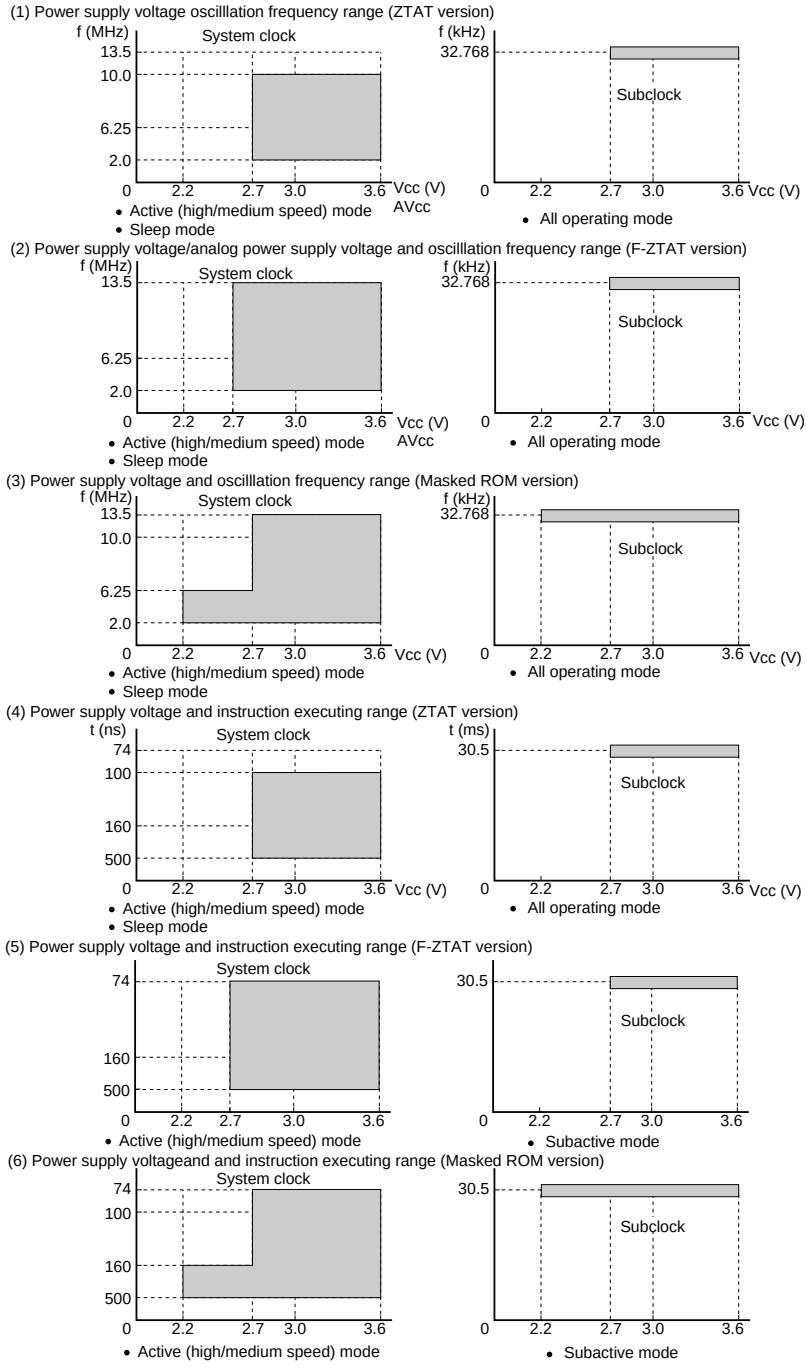


Figure 25.3 Power Supply Voltage and Operating Ranges (H8S/2237 Series and H8S/2227 Series)

25.2 Electrical Characteristics of H8S/2239 Series

25.2.1 Absolute Maximum Ratings

Table 25.1 lists the absolute maximum ratings.

Table 25.1 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	–0.3 to +4.3	V
	CV_{CC}	–0.3 to +4.3	V
Input voltage (except ports 4 and 9)	V_{in}	–0.3 to V_{CC} +0.3	V
Input voltage (ports 4 and 9)	V_{in}	–0.3 to AV_{CC} +0.3	V
Reference power supply voltage	V_{ref}	–0.3 to AV_{CC} +0.3	V
Analog power supply voltage	AV_{CC}	–0.3 to +4.3	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*	
Storage temperature	T_{stg}	–55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum rating are exceeded.

Note: The operating temperature ranges for flash memory programming/erasing are T_a = –20°C to +50°C (regular specifications).

25.2.2 DC Characteristics

Table 25.2 lists the DC characteristics. Table 25.3 lists the permissible output currents. Table 25.4 lists the bus driving characteristics.

Table 25.2 DC Characteristics (1)

Condition A (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications)*[1]

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	IRQ0 to IRQ7	VT^-	$V_{CC} \times 0.2$	—	—	V	
		VT^+	—	—	$V_{CC} \times 0.8$	V	
		$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	—	V	
Input high voltage	RES, STBY, NMI, FEW, MD2 to MD0	V_{IH}	$V_{CC} \times 0.9$	—	V_{CC} + 0.3	V	
	EXTAL, Ports 1, 3, 7, and A to G		$V_{CC} \times 0.8$	—	V_{CC} + 0.3	V	
	Ports 4 and 9		$V_{CC} \times 0.8$	—	AV_{CC} + 0.3	V	
Input low voltage	RES, STBY, FWE, MD2 to MD0	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, Ports 1, 3, 4, 7, 9, and A to G		–0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins*[4] except P34 and P35	V_{OH}	V_{CC} – 0.5	—	—	V	I_{OH} = –200 µA
			V_{CC} – 1.0	—	—	V	I_{OH} = –1 mA*[2]
	P34 and P35*[3]		V_{CC} – 2.0	—	—	V	I_{OH} = –100 µA (reference value)
Output low voltage	All output pins*[4]	V_{OL}	—	—	0.4	V	I_{OL} = 0.4 mA
			—	—	0.4	V	I_{OL} = 0.8 mA*[2]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input leakage current	RES	$\|I_{in}\|$	—	—	1.0	µA	V_{in} = 0.2 to V_{CC} – 0.2 V
	STBY, NMI, FWE, MD2 to MD0		—	—	1.0	µA	
	Ports 4, 9		—	—	1.0	µA	V_{in} = 0.2 to AV_{CC} – 0.2 V
Three states leakage current (off)	Ports 1, 3, 7, and A to G	$\|I_{TSI}\|$	—	—	1.0	µA	V_{in} = 0.2 to V_{CC} – 0.2 V
Input pull-up MOS current	Ports A to E	$-I_P$	10	—	300	µA	V_{in} = 0V

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AVSS pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. V_{CC} = 2.7 V to 3.6 V
3. P35/SCK1/SCL0 and P34/SDA0 function as NMOS push-pull output. To output the high voltage from SCL0 and SDA0 (ICE = 1), connect an external pull-up resistor. NMOS controls P35/SCK1 and P34 to output the high voltage. To output the high voltage from P35/SCK1 and P34, connect an external pull-up resistor.
4. In the case when ICE = 0. Low voltage output with bus driving function is specified in table 25.4, Bus Driving Characteristics.

Table 25.2 DC Characteristics (2)

Condition A (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	30	pF	V_{in} = 0 V
							f = 1 MHz
	NMI		—	—	30	pF	T_a = 25 °C
	P32 to P35		—	—	20	pF	
	All input pins other than above ones		—	—	15	pF	

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption*2	Normal operation	I_{CC}*4	—	25 V_{CC} = 3.0 V	42 V_{CC} = 3.6 V	mA	f = 16.0 MHz
	Sleep mode		—	17 V_{CC} = 3.0 V	32 V_{CC} = 3.6 V	mA	f = 16.0 MHz
	All modules stopped		—	15	—	mA	f = 16.0 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	13	—	mA	f = 16.0 MHz, V_{CC} = 3.0 V (reference value)
	Subactive mode		—	70	180	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Subsleep mode		—	50	130	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Watch mode		—	8	40	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Standby mode*3		—	1.0 V_{CC} = 3.0 V	10 V_{CC} = 3.6 V	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	50 V_{CC} = 3.6 V	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.5	1.5	mA	
	Idle		—	0.01	5.0	µA	

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{cc}, V_{ref}, and AV_{ss} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{cc}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.2 V and V_{IL} max = 0.2 V, with all output pins unloaded and the on-chip MOS pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.2$ 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:
   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)
   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.2 DC Characteristics (3)

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref}=2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	30	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25 °C
	NMI		—	—	30	pF	
	P32 to P35		—	—	20	pF	
	All input pins other than above ones		—	—	15	pF	

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption *2	Normal operation	I_{CC} *4	—	25 V_{CC} = 3.0 V	42 V_{CC} = 3.6 V	mA	f = 16.0 MHz
			—	10 V_{CC} = 3.0 V	18 V_{CC} = 3.6 V	mA	f = 6.25 MHz
	Sleep mode		—	17 V_{CC} = 3.0 V	32 V_{CC} = 3.6 V	mA	f = 16.0 MHz
			—	7.5 V_{CC} = 3.0 V	14 V_{CC} = 3.6 V	mA	f = 6.25 MHz
	All modules stopped		—	15	—	mA	f = 16.0 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	13	—	mA	f = 16.0 MHz, V_{CC} = 3.0 V (reference value)
	Subactive mode		—	45	180	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Subsleep mode		—	30	100	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Watch mode		—	8	40	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption *2	Standby mode*3		—	0.5 V_{CC} = 3.0 V	10 V_{CC} = 3.6 V	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	50 V_{CC} = 3.6 V	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.5	1.5	mA	
	Idle		—	0.01	5.0	µA	
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.2 V and V_{IL} max = 0.2 V, with all output pins unloaded and the on-chip MOS pull-up transistors 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:
   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)
   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.3 Permissible Output Currents

Condition A (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item			Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1 to SCL0, SDA1 to SDA0	V_{CC} = 2.7 V to 3.6 V	I_{OL}	—	—	10	mA
	Output pins other than above ones	V_{CC} = 2.2 V to 3.6 V	I_{OL}	—	—	0.5	
		V_{CC} = 2.7 V to 3.6 V		—	—	1.0	
Permissible output low current (total)	Total of all output pins	V_{CC} = 2.2 V to 3.6 V	$\sum I_{OL}$	—	—	30	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	60	
Permissible output high current (per pin)	All output pins	V_{CC} = 2.2 V to 3.6 V	$-I_{OH}$	—	—	0.5	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	1.0	
Permissible output high current (total)	Total of all output pins	V_{CC} = 2.2 V to 3.6 V	$\sum -I_{OH}$	—	—	15	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	30	

Note: * To protect chip reliability, do not exceed the output current values in table 25.3.

Table 25.4 Bus Driving Characteristics

Conditions: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)*,
Objective pins: SCL1 to 0 and SDA1 to 0

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	VT^-	$V_{CC} \times 0.3$	—	—	V	V_{CC} = 2.7 V to 3.6 V
	VT^+	—	—	$V_{CC} \times 0.7$	V	V_{CC} = 2.7 V to 3.6 V
	$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	—	V	V_{CC} = 2.7 V to 3.6 V
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	V_{CC} + 0.5	V	V_{CC} = 2.7 V to 3.6 V
Input low voltage	V_{IL}	–0.5	—	$V_{CC} \times 0.3$	V	V_{CC} = 2.7 V to 3.6 V
Output low voltage	V_{OL}	—	—	0.5	V	I_{OL} = 6 mA, V_{CC} = 3.0 V to 3.6 V
		—	—	0.4	V	I_{OL} = 3 mA
Input capacitance	C_{in}	—	—	20	pF	V_{iN} = 0 V f = 1 MHz T_a = 25 °C
Three states leakage current (off)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{iN} = 0.5 V to V_{CC} – 0.5 V
SCL, SDA output falling time	t_{of}	20 + 0.1Cb	—	250	ns	V_{CC} = 2.7 V to 3.6 V

Note: * If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

25.2.3 AC Characteristics

Figure 25.4 shows the test conditions for the AC characteristics.

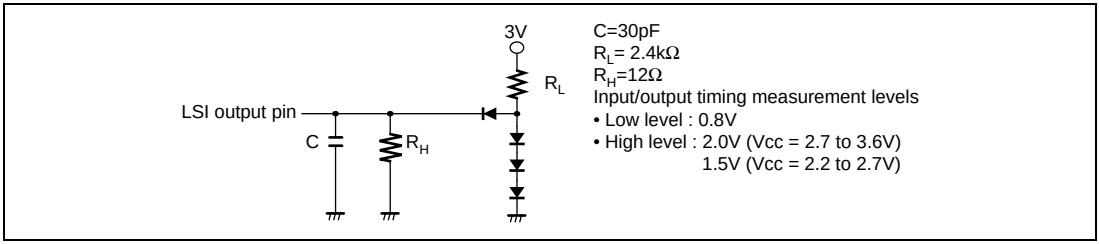


Figure 25.4 Output Load Circuit

(1) Clock Timing

Table 25.5 lists the clock timing.

Table 25.5 Clock Timing

Condition A (F-ZTAT version and masked ROM version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 32.768 kHz, 2 to 16.0 MHz, T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 32.768 kHz, 2 to 6.25 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

		Condition A			Condition B				
Item	**Symbol**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**	**Test Conditions**
Clock cycle time	t_{cyc}	62.5	—	500	160	—	500	ns	Figure 25.5
Clock high pulse width	t_{CH}	20	—	—	50	—	—	ns	
Clock low pulse width	t_{CL}	20	—	—	50	—	—	ns	
Clock rise time	t_{Cr}	—	—	10	—	—	25	ns	
Clock fall time	t_{Cf}	—	—	10	—	—	25	ns	
Oscillation stabilization time at reset (crystal)	t_{OSC1}	20	—	—	40	—	—	ms	Figure 25.6
Oscillation stabilization time in software standby (crystal)	t_{OSC2}	8	—	—	16	—	—	ms	Figure23.3
External clock output stabilization delay time	t_{DEXT}	500	—	—	1000	—	—	µs	Figure 25.6
Subclock oscillation stabilization time	t_{OSC3}	—	—	2	—	—	4	s	
Subclock oscillator frequency	f_{SUB}	—	32.768	—	—	32.768	—	kHz	
Subclock (ϕ_{SUB}) cycle time	t_{SUB}	—	30.5	—	—	30.5	—	µs	

(2) Control Signal Timing

Table 25.6 lists the control signal timing.

Table 25.6 Control Signal Timing

Condition A (F-ZTAT version and masked ROM version):

V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 32.768 kHz,
2 to 16.0 MHz, T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version):

V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B			
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**
RES setup time	t_{RESS}	250	—	350	—	ns	Figure 25.7
RES pulse width	t_{RESW}	20	—	20	—	t_{cyc}	
MRES setup time	t_{MRESS}	250	—	350	—	ns	
MRES pulse width	t_{MRESW}	20	—	20	—	t_{cyc}	
NMI setup time	t_{NMIS}	250	—	350	—	ns	Figure 25.8
NMI hold time	t_{NMIH}	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	300	—	ns	
IRQ setup time	t_{IRQS}	250	—	350	—	ns	
IRQ hold time	t_{IRQH}	10	—	10	—	ns	
IRQ pulse width (exiting software standby mode)	t_{IRQW}	200	—	300	—	ns	

(3) Bus Timing

Table 25.7 lists the bus timing.

Table 25.7 Bus Timing

Condition A (F-ZTAT version and masked ROM version):

V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 16.0 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B			Test
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Conditions**
Address delay time	t_{AD}	—	40	—	90	ns	Figures 25.9 to 25.13
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 42$	—	$0.5 \times t_{cyc} - 60$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 30$	—	ns	
CS delay time	t_{CSD}	—	40	—	90	ns	
AS delay time	t_{ASD}	—	40	—	90	ns	
RD delay time 1	t_{RSD1}	—	40	—	90	ns	
RD delay time 2	t_{RSD2}	—	40	—	90	ns	
Read data setup time	t_{RDS}	30	—	50	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	ns	
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 55$	—	$1.0 \times t_{cyc} - 90$	ns	
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 50$	—	$1.5 \times t_{cyc} - 90$	ns	
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 55$	—	$2.0 \times t_{cyc} - 90$	ns	
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 50$	—	$2.5 \times t_{cyc} - 90$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 55$	—	$3.0 \times t_{cyc} - 90$	ns	
WR delay time 1	t_{WRD1}	—	40	—	90	ns	
WR delay time 2	t_{WRD2}	—	40	—	90	ns	
WR pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 20$	—	$1.0 \times t_{cyc} - 60$	—	ns	
WR pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 20$	—	$1.5 \times t_{cyc} - 60$	—	ns	

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Unit	Test Conditions
Write data delay time	t_{WDD}	—	60	—	100	ns	
Write data setup time	t_{WDS}	$0.5 \times t_{cyc} - 57$	—	$0.5 \times t_{cyc} - 80$	—	ns	
Write data hold time	t_{WDH}	$0.5 \times t_{cyc} - 27$	—	$0.5 \times t_{cyc} - 60$	—	ns	
WAIT setup time	t_{WTS}	40	—	90	—	ns	Figure 25.11
WAIT hold time	t_{WTH}	10	—	10	—	ns	
BREQ setup time	t_{BRQS}	40	—	90	—	ns	Figure 25.14
BACK delay time	t_{BACD}	—	40	—	90	ns	
Bus-floating time	t_{BZD}	—	60	—	160	ns	

(4) DMAC Timing

Table 25.8 lists the DMAC timing.

Table 25.8 DMAC Timing

Condition A (F-ZTAT version and masked ROM version):

V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 16.0 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version):

V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Unit	Test Conditions
DREQ setup time	t_{DRQS}	40	—	60	—	ns	Figure 25.18
DREQ hold time	t_{DRQH}	10	—	20	—	ns	
TEND delay time	t_{TED}	—	30	—	50	ns	Figure 25.17
DACK delay time 1	t_{DACD1}	—	30	—	50	ns	Figure 25.15
DACK delay time 2	t_{DACD2}	—	30	—	50	ns	Figure 25.16

(5) Timing of On-Chip Peripheral Modules

Table 25.9 lists the timing of on-chip peripheral modules. Table 25.10 lists the I^2C bus timing.

Table 25.9 Timing of On-Chip Peripheral Modules

Condition A (F-ZTAT version and masked ROM version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 32.768 kHz, 2 to 16.0 MHz, T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 32.768 kHz, 2 to 6.25 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

				Condition A		Condition B			Test
Item			**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Conditions**
I/O port*	Output data delay time		t_{PWD}	—	70	—	150	ns	Figure 25.19
	Input data setup time		t_{PRS}	50	—	80	—		
	Input data hold time		t_{PRH}	50	—	80	—		
TPU	Timer output delay time		t_{TOCD}	—	70	—	150	ns	Figure 25.20
	Timer input setup time		t_{TICS}	40	—	60	—		
	Timer clock input setup time		t_{TCKS}	40	—	60	—	ns	Figure 25.21
	Timer clock pulse width	Single edge	t_{TCKWH}	1.5	—	1.5	—	t_{cyc}	
		Both edges	t_{TCKWL}	2.5	—	2.5	—		
TMR	Timer output delay time		t_{TMOD}	—	70	—	150	ns	Figure 25.22
	Timer reset input setup time		t_{TMRS}	50	—	80	—	ns	Figure 25.24
	Timer clock input setup time		t_{TMCS}	50	—	80	—	ns	Figure 25.23
	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	1.5	—	t_{cyc}	
		Both edges	t_{TMCWL}	2.5	—	2.5	—		
WDT_1	BUZZ output delay time		t_{BUZD}	—	70	—	150	ns	Figure 25.25

Item			Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Unit	Test Conditions
SCI*	Input clock cycle	Asynchronous	t_{Scyc}	4	—	4	—	t_{cyc}	Figure 25.26
		Synchronous		6	—	6	—		
	Input clock pulse width		t_{SCKW}	0.4	0.6	0.4	0.6	t_{Scyc}	
	Input clock rise time		t_{SCKr}	—	1.5	—	1.5	t_{cyc}	
	Input clock fall time		t_{SCKf}	—	1.5	—	1.5		
	Transmit data delay time		t_{TXD}	—	75	—	150	ns	Figure 25.27
	Receive data setup time (synchronous)		t_{RXS}	75	—	150	—	ns	
	Receive data hold time (synchronous)		t_{RXH}	75	—	150	—	ns	
A/D converter	Trigger input setup time		t_{TRGS}	40	—	60	—	ns	Figure 25.28

Note: * NMOS controls P35/SCK1 and P34 to output the high voltage. To output the high voltage from P35/SCK1 and P34, connect an external pull-up resistor.

Table 25.10 I^2C Bus Timing

Conditions V_{CC} = 2.7 V to 3.6 V, V_{SS} = 0 V, ϕ = 5 MHz to maximum operating frequency, T_a = –20°C to +75°C

Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Remarks
SCL input cycle time	t_{SCL}	12 t_{cyc}	—	—	ns		Figure 25.29
SCL input high pulse width	t_{SCLH}	3 t_{cyc}	—	—	ns		
SCL input low pulse width	t_{SCLL}	5 t_{cyc}	—	—	ns		
SCL, SDA input rise time	t_{Sr}	—	—	7.5 t_{cyc}*	ns		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse delete time	t_{SP}	—	—	1 t_{cyc}	ns		
SDA input bus free time	t_{BUF}	5 t_{cyc}	—	—	ns		
Operating condition input hold time	t_{STAH}	3 t_{cyc}	—	—	ns		
Retransmitting operating condition input setup time	t_{STAS}	3 t_{cyc}	—	—	ns		
Stop condition input setup time	t_{STOS}	3 t_{cyc}	—	—	ns		
Data input setup time	t_{SDAS}	0.5 t_{cyc}	—	—	ns		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA capacitor load	C_b	—	—	400	pF		

Note: * Maximum SCL and SDA input rise time 7.5 t_{cyc} or 17.5 t_{cyc} can be selected depending on the clock that is used in the I^2C module. For detail see section 15.5, Usage Note.

25.2.4 A/D Conversion Characteristics

Table 25.11 lists the A/D conversion characteristics.

Table 25.11 A/D Conversion Characteristics

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 16.0 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version):
V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item	Condition A			Condition B			Unit
	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	bits
Conversion time	8.1	—	—	20.9	—	—	µs
Analog input capacitance	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	5	kΩ
Nonlinearity error	—	—	±6.0	—	—	±6.0	LSB
Offset error	—	—	±4.0	—	—	±4.0	LSB
Full-scale error	—	—	±4.0	—	—	±4.0	LSB
Quantization error	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±8.0	LSB

25.2.5 D/A Conversion Characteristics

Table 25.12 lists the D/A conversion characteristics.

Table 25.12 D/A Conversion Characteristics

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 16.0 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition B (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item	Condition A			Condition B			Unit	Test Condition
	Min	Typ	Max	Min	Typ	Max		
Resolution	8	8	8	8	8	8	bits	
Conversion time	—	—	10	—	—	10	µs	Load capacitance = 20 pF
Absolute accuracy	—	±2.0	±3.0	—	±3.0	±4.0	LSB	Load resistance = 2 MΩ
	—	—	±2.0	—	—	±3.0	LSB	Load resistance = 4 M Ω

25.2.6 Flash Memory Characteristics

Table 25.13 lists the flash memory characteristics.

Table 25.13 Flash Memory Characteristics

Conditions: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
V_{CC} = 3.0 V to 3.6 V (Programming/erasing operating voltage range)
T_a = –20°C to +50°C (Programming/erasing operating temperature range; regular specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Programming time*1, *2, *4		t_P	—	10	200	ms/128 bytes	
Erase time*1, *3, *5		t_E	—	100	1200	ms/block	
Reprogramming count		N_{WEC}*6	100	10000*7	—	Times	
Data hold time		t_{DRP}	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	1 ≤ n ≤ 6
		t_{sp200}	198	200	202	µs	7 ≤ n ≤ 1000
	Wait time after P1 bit clear*1	t_{cp}	5	5	—	µs	
	Wait time after PSU1 bit clear*1	t_{cpsu}	5	5	—	µs	
	Wait time after PV1 bit setting*1	t_{spv}	4	4	—	µs	
	Wait time after H'FF dummy write*1	t_{spvr}	2	2	—	µs	
	Wait time after PV1 bit clear*1	t_{cpv}	2	2	—	µs	
	Wait time after SWE1 bit clear	t_{cswe}	100	100	—	µs	
	Maximum programming count*1, *4	N1	—	—	6*4	Times	
		N2	—	—	994*4		

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
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	
	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/program-verify flowchart or erase/erase-verify flowchart.
2. Programming time per 128 bytes (Shows the total period for which the P1 bit in the flash memory control register 1 (FLMCR1) is set. It does not include the program 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. Maximum programming time value
   t_p (max) = Wait time after P1 bit setting (t_{sp}) × maximum program count (N)
   ($t_{sp30} + t_{sp10}$) × 6 + (t_{sp200}) × 994
5. Relationship among the maximum erase time (t_E (max)), the wait time after E1 bit setting (t_{se}), and the maximum erase count (N) is shown below.
   t_E (max) = Wait time after E1 bit setting (t_{se}) × Maximum erase count (N)
6. Data can be reprogrammed less than minimum count.
7. Typical value at 25°C

25.3 Electrical Characteristics of H8S/2238R Series

25.3.1 Absolute Maximum Ratings

Table 25.14 lists the absolute maximum ratings.

Table 25.14 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	–0.3 to +4.3	V
	CV_{CC}	–0.3 to +4.3	V
Input voltage (except ports 4 and 9)	V_{in}	–0.3 to V_{CC} +0.3	V
Input voltage (ports 4 and 9)	V_{in}	–0.3 to AV_{CC} +0.3	V
Reference power supply voltage	V_{ref}	–0.3 to AV_{CC} +0.3	V
Analog power supply voltage	AV_{CC}	–0.3 to +4.3	V
Analog input voltage	V_{AN}	–0.3 to AV_{CC} +0.3	V
Operating temperature	T_{opr}	Regular specifications: –20 to +75*[1]	°C
		Wide-range specifications: –40 to +85*[2]	
Storage temperature	T_{stg}	–55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum rating are exceeded.

Notes: 1. When the operating voltage in read is V_{CC} = 2.7 V to 3.6 V, the operating temperature ranges for flash memory programming/erasing are T_a = –20°C to +75°C. When the operating voltage in read is V_{CC} = 2.2 V to 3.6 V, the operating temperature ranges for flash memory programming/erasing are T_a = –20°C to +50°C.

2. The operating temperature ranges for flash memory programming/erasing are T_a = –40°C to +80°C (regular specifications).

25.3.2 DC Characteristics

Table 25.15 lists the DC characteristics. Table 25.16 lists the permissible output currents. Table 25.17 lists the bus driving characteristics.

Table 25.15 DC Characteristics (1)

Condition A (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)*[1]

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	IRQ0 to IRQ7	VT^-	$V_{CC} \times 0.2$	—	—	V	
		VT^+	—	—	$V_{CC} \times 0.8$	V	
		$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	—	V	
Input high voltage	RES, STBY, NMI, FEW, MD2 to MD0	V_{IH}	$V_{CC} \times 0.9$	—	V_{CC} + 0.3	V	
	EXTAL, Ports 1, 3, 7, and A to G		$V_{CC} \times 0.8$	—	V_{CC} + 0.3	V	
	Ports 4 and 9		$V_{CC} \times 0.8$	—	AV_{CC} + 0.3	V	
Input low voltage	RES, STBY, FWE, MD2 to MD0	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, Ports 1, 3, 4, 7, 9, and A to G		–0.3	—	$V_{CC} \times 0.2$	V	

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Output high voltage	All output pins*[4] except P34 and P35	V_{OH}	V_{CC} – 0.5	—	—	V	I_{OH} = –200 µA
			V_{CC} – 1.0	—	—	V	I_{OH} = –1 mA*[2]
	P34 and P35*[3]		V_{CC} – 2.0	—	—	V	I_{OH} = –100 µA (reference value)
Output low voltage	All output pins*[4]	V_{OL}	—	—	0.4	V	I_{OL} = 0.4 mA
			—	—	0.4	V	I_{OL} = 0.8 mA*[2]
Input leakage current	RES	$\lvert I_{in} \rvert$	—	—	1.0	µA	V_{in} = 0.2 to V_{CC} – 0.2 V
	STBY, NMI, FWE, MD2 to MD0		—	—	1.0	µA	
	Ports 4, 9		—	—	1.0	µA	V_{in} = 0.2 to AV_{CC} – 0.2 V
Three states leakage current (off)	Ports 1, 3, 7, and A to G	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.2 to V_{CC} – 0.2 V
Input pull-up MOS current	Ports A to E	$-I_P$	10	—	300	µA	V_{in} = 0V

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. V_{CC} = 2.7 V to 3.6 V
3. P35/SCK1/SCL0 and P34/SDA0 function as NMOS push-pull output. To output the high voltage from SCL0 and SDA0 (ICE = 1), connect an external pull-up resistor. NMOS controls P35/SCK1 and P34 to output the high voltage. To output the high voltage from P35/SCK1 and P34, connect an external pull-up resistor.
4. In the case when ICE = 0. Low voltage output with bus driving function is specified in table 25.17, Bus Driving Characteristics.

Table 25.15 DC Characteristics (2)

Condition A (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)*[1]

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	30	pF	V_{in} = 0 V f = 1 MHz T_a = 25 °C
	NMI		—	—	30	pF	
	P32 to P35		—	—	20	pF	
	All input pins other than above ones		—	—	15	pF	
Current consumption*[2]	Normal operation	I_{CC}*[4]	—	20 V_{CC} = 3.0 V	37 V_{CC} = 3.6 V	mA	f = 13.5 MHz
	Sleep mode		—	15 V_{CC} = 3.0 V	29 V_{CC} = 3.6 V	mA	f = 13.5 MHz
	All modules stopped		—	15	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	13	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Subactive mode		—	70	180	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Subsleep mode		—	50	130	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption*[2]	Watch mode		—	8	40	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Standby mode*[3]		—	1.0 V_{CC} = 3.0 V	10 V_{CC} = 3.6 V	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	50 V_{CC} = 3.6 V	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.5	1.5	mA	
	Idle		—	0.01	5.0	µA	
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.2 V and V_{IL} max = 0.2 V, with all output pins unloaded and the on-chip MOS pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.2$ 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:

   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)

   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.15 DC Characteristics (3)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref}=2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	30	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25 °C
	NMI		—	—	30	pF	
	P32 to P35		—	—	20	pF	
	All input pins other than above ones		—	—	15	pF	
Current consumption*[2]	Normal operation	I_{CC}*[4]	—	20 V_{CC} = 3.0 V	37 V_{CC} = 3.6 V	mA	f = 13.5 MHz
			—	10 V_{CC} = 3.0 V	18 V_{CC} = 3.6 V	mA	f = 6.25 MHz
	Sleep mode		—	15 V_{CC} = 3.0 V	29 V_{CC} = 3.6 V	mA	f = 13.5 MHz
			—	7.5 V_{CC} = 3.0 V	14 V_{CC} = 3.6 V	mA	f = 6.25 MHz
	All modules stopped		—	15	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	13	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption*[2]	Subactive mode		—	45	180	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Subsleep mode		—	30	100	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Watch mode		—	8	40	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Standby mode*[3]		—	0.5 V_{CC} = 3.0 V	10 V_{CC} = 3.6 V	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	50 V_{CC} = 3.6 V	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.5	1.5	mA	
	Idle		—	0.01	5.0	µA	
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.2 V and V_{IL} max = 0.2 V, with all output pins unloaded and the on-chip MOS pull-up transistors in the off state.

3. The values are for $V_{RAM} \leq V_{CC} < 2.2$ 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:
   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)
   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.16 Permissible Output Currents

Condition A (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item			Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1 to SCL0, SDA1 to SDA0	V_{CC} = 2.7 V to 3.6 V	I_{OL}	—	—	10	mA
	Output pins other than above ones	V_{CC} = 2.2 V to 3.6 V	I_{OL}	—	—	0.5	
		V_{CC} = 2.7 V to 3.6 V		—	—	1.0	
Permissible output low current (total)	Total of all output pins	V_{CC} = 2.2 V to 3.6 V	$\sum I_{OL}$	—	—	30	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	60	
Permissible output high current (per pin)	All output pins	V_{CC} = 2.2 V to 3.6 V	$-I_{OH}$	—	—	0.5	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	1.0	
Permissible output high current (total)	Total of all output pins	V_{CC} = 2.2 V to 3.6 V	$\sum -I_{OH}$	—	—	15	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	30	

Note: * To protect chip reliability, do not exceed the output current values in table 25.16.

Table 25.17 Bus Driving Characteristics

Conditions V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)*,
Objective pins: SCL1 and 0 and SDA1 and 0

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	VT^-	$V_{CC} \times 0.3$	—	—	V	V_{CC} = 2.7 V to 3.6 V
	VT^+	—	—	$V_{CC} \times 0.7$	V	V_{CC} = 2.7 V to 3.6 V
	$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	—	V	V_{CC} = 2.7 V to 3.6 V
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	V_{CC} + 0.5	V	V_{CC} = 2.7 V to 3.6 V
Input low voltage	V_{IL}	–0.5	—	$V_{CC} \times 0.3$	V	V_{CC} = 2.7 V to 3.6 V
Output low voltage	V_{OL}	—	—	0.5	V	I_{OL} = 6 mA, V_{CC} = 3.0 V to 3.6 V
		—	—	0.4	V	I_{OL} = 3 mA
Input capacitance	C_{in}	—	—	20	pF	V_{in} = 0 V f = 1 MHz T_a = 25 °C
Three states leakage current (off)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 V to V_{CC} – 0.5 V
SCL, SDA output falling time	t_{of}	20 + 0.1Cb	—	250	ns	V_{CC} = 2.7 V to 3.6 V

Note: * If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

25.3.3 AC Characteristics

Figure 25.4 shows the test conditions for the AC characteristics.

(1) Clock Timing

Table 25.18 lists the clock timing.

Table 25.18 Clock Timing

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 13.5 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

		Condition A			Condition B and C				Test
Item	**Symbol**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
Clock cycle time	t_{cyc}	74	—	500	160	—	500	ns	Figure 25.5
Clock high pulse width	t_{CH}	25	—	—	50	—	—	ns	
Clock low pulse width	t_{CL}	25	—	—	50	—	—	ns	
Clock rise time	t_{Cr}	—	—	10	—	—	25	ns	
Clock fall time	t_{Cf}	—	—	10	—	—	25	ns	
Oscillation stabilization time at reset (crystal)	t_{OSC1}	20	—	—	40	—	—	ms	Figure 25.6
Oscillation stabilization time in software standby (crystal)	t_{OSC2}	8	—	—	16	—	—	ms	Figure23.3
External clock output stabilization delay time	t_{DEXT}	500	—	—	1000	—	—	µs	Figure 25.6
Subclock oscillation stabilization time	t_{OSC3}	—	—	2	—	—	4	s	
Subclock oscillator frequency	f_{SUB}	—	32.768	—	—	32.768	—	kHz	
Subclock (ϕ_{SUB}) cycle time	t_{SUB}	—	30.5	—	—	30.5	—	µs	

(2) Control Signal Timing

Table 25.19 lists the control signal timing.

Table 25.19 Control Signal Timing

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 13.5 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B and C			
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**
RES setup time	t_{RESS}	250	—	350	—	ns	Figure 25.7
RES pulse width	t_{RESW}	20	—	20	—	t_{cyc}	
MRES setup time	t_{MRESS}	250	—	350	—	ns	
MRES pulse width	t_{MRESW}	20	—	20	—	t_{cyc}	
NMI setup time	t_{NMIS}	250	—	350	—	ns	Figure 25.8
NMI hold time	t_{NMIH}	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	300	—	ns	
IRQ setup time	t_{IRQS}	250	—	350	—	ns	
IRQ hold time	t_{IRQH}	10	—	10	—	ns	
IRQ pulse width (exiting software standby mode)	t_{IRQW}	200	—	300	—	ns	

(3) Bus Timing

Table 25.20 lists the bus timing.

Table 25.20 Bus Timing

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 13.5 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B and C			Test
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Conditions**
Address delay time	t_{AD}	—	50	—	90	ns	Figures 25.9 to 25.13
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 30$	—	$0.5 \times t_{cyc} - 60$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 30$	—	ns	
CS delay time	t_{CSD}	—	50	—	90	ns	
AS delay time	t_{ASD}	—	50	—	90	ns	
RD delay time 1	t_{RSD1}	—	50	—	90	ns	
RD delay time 2	t_{RSD2}	—	50	—	90	ns	
Read data setup time	t_{RDS}	30	—	50	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	ns	
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 65$	—	$1.0 \times t_{cyc} - 90$	ns	
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 65$	—	$1.5 \times t_{cyc} - 90$	ns	
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 65$	—	$2.0 \times t_{cyc} - 90$	ns	
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 65$	—	$2.5 \times t_{cyc} - 90$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 65$	—	$3.0 \times t_{cyc} - 90$	ns	

Item	Symbol	Condition A Min	Condition A Max	Condition B and C Min	Condition B and C Max	Unit	Test Conditions
WR delay time 1	t_{WRD1}	—	50	—	90	ns	Figures
WR delay time 2	t_{WRD2}	—	50	—	90	ns	25.9 to
WR pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 60$	—	ns	25.13
WR pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 60$	—	ns	
Write data delay time	t_{WDD}	—	70	—	100	ns	
Write data setup time	t_{WDS}	$0.5 \times t_{cyc} - 37$	—	$0.5 \times t_{cyc} - 80$	—	ns	
Write data hold time	t_{WDH}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 60$	—	ns	
WAIT setup time	t_{WTS}	50	—	90	—	ns	Figure 25.11
WAIT hold time	t_{WTH}	10	—	10	—	ns	
BREQ setup time	t_{BRQS}	50	—	90	—	ns	Figure 25.14
BACK delay time	t_{BACD}	—	50	—	90	ns	
Bus-floating time	t_{BZD}	—	80	—	160	ns	

(4) Timing of On-Chip Peripheral Modules

Table 25.21 lists the timing of on-chip peripheral modules. Table 25.22 lists the I^2C bus timing.

Table 25.21 Timing of On-Chip Peripheral Modules

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 13.5 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version):
V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version):
V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item			Symbol	Condition A Min	Condition A Max	Condition B and C Min	Condition B and C Max	Unit	Test Conditions
I/O port*	Output data delay time		t_{PWD}	—	100	—	150	ns	Figure 25.19
	Input data setup time		t_{PRS}	50	—	80	—		
	Input data hold time		t_{PRH}	50	—	80	—		
TPU	Timer output delay time		t_{TOCD}	—	100	—	150	ns	Figure 25.20
	Timer input setup time		t_{TICS}	40	—	60	—		
	Timer clock input setup time		t_{TCKS}	40	—	60	—	ns	Figure 25.21
	Timer clock pulse width	Single edge	t_{TCKWH}	1.5	—	1.5	—	t_{cyc}	
		Both edges	t_{TCKWL}	2.5	—	2.5	—		
TMR	Timer output delay time		t_{TMOD}	—	100	—	150	ns	Figure 25.22
	Timer reset input setup time		t_{TMRS}	50	—	80	—	ns	Figure 25.24
	Timer clock input setup time		t_{TMCS}	50	—	80	—	ns	Figure 25.23
	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	1.5	—	t_{cyc}	
		Both edges	t_{TMCWL}	2.5	—	2.5	—		
WDT_1	BUZZ output delay time		t_{BUZD}	—	100	—	150	ns	Figure 25.25
SCI*	Input clock cycle	Asynchronous	t_{Scyc}	4	—	4	—	t_{cyc}	Figure 25.26
		Synchronous		6	—	6	—		
	Input clock pulse width		t_{SCKW}	0.4	0.6	0.4	0.6	t_{Scyc}	
	Input clock rise time		t_{SCKr}	—	1.5	—	1.5	t_{cyc}	
	Input clock fall time		t_{SCKf}	—	1.5	—	1.5		
	Transmit data delay time		t_{TXD}	—	100	—	150	ns	Figure 25.27
	Receive data setup time (synchronous)		t_{RXS}	75	—	150	—	ns	
	Receive data hold time (synchronous)		t_{RXH}	75	—	150	—	ns	
A/D converter	Trigger input setup time		t_{TRGS}	40	—	60	—	ns	Figure 25.28

Note: * NMOS controls P35/SCK1 and P34 to output the high voltage. To output the high voltage from P35/SCK1 and P34, connect an external pull-up resistor.

Table 25.22 I^2C Bus Timing

Conditions: V_{CC} = 2.7 V to 3.6 V, V_{SS} = 0 V, ϕ = 5 MHz to maximum operating frequency, T_a = –20°C to +75°C

Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Remarks
SCL input cycle time	t_{SCL}	12 t_{cyc}	—	—	ns		Figure 25.29
SCL input high pulse width	t_{SCLH}	3 t_{cyc}	—	—	ns		
SCL input low pulse width	t_{SCLL}	5 t_{cyc}	—	—	ns		
SCL, SDA input rise time	t_{Sr}	—	—	7.5 t_{cyc}*	ns		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse delete time	t_{SP}	—	—	1 t_{cyc}	ns		
SDA input bus free time	t_{BUF}	5 t_{cyc}	—	—	ns		
Operating condition input hold time	t_{STAH}	3 t_{cyc}	—	—	ns		
Retransmitting operating condition input setup time	t_{STAS}	3 t_{cyc}	—	—	ns		
Stop condition input setup time	t_{STOS}	3 t_{cyc}	—	—	ns		
Data input setup time	t_{SDAS}	0.5 t_{cyc}	—	—	ns		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA capacitor load	C_b	—	—	400	pF		

Note: * Maximum SCL and SDA input rise time 7.5 t_{cyc} or 17.5 t_{cyc} can be selected depending on the clock that is used in the I^2C module. For detail see section 15.5, Usage Note.

25.2.4 A/D Conversion Characteristics

Table 25.23 lists the A/D conversion characteristics.

Table 25.23 A/D Conversion Characteristics

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref}= 2.7 V to AV_{CC}, V_{SS} =AV_{SS} = 0 V,
ϕ = 2 to 13.5 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref}= 2.2 V to AV_{CC}, V_{SS} =AV_{SS} = 0 V, ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref}=2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

	Condition A			Condition B			
Item	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Resolution	10	10	10	10	10	10	bits
Conversion time	9.6	—	—	20.9	—	—	µs
Analog input capacitance	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	5	kΩ
Nonlinearity error	—	—	±6.0	—	—	±6.0	LSB
Offset error	—	—	±4.0	—	—	±4.0	LSB
Full-scale error	—	—	±4.0	—	—	±4.0	LSB
Quantization error	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±8.0	LSB

25.3.5 D/A Conversion Characteristics

Table 25.24 lists the D/A conversion characteristics.

Table 25.24 D/A Conversion Characteristics

Condition A (F-ZTAT version and masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 13.5 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 6.25 MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

	Condition A			Condition B				
Item	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**	**Test Condition**
Resolution	8	8	8	8	8	8	bits	
Conversion time	—	—	10	—	—	10	µs	Load capacitance = 20 pF
Absolute accuracy	—	±2.0	±3.0	—	±3.0	±4.0	LSB	Load resistance = 2 MΩ
	—	—	±2.0	—	—	±3.0	LSB	Load resistance = 4 M Ω

25.3.6 Flash Memory Characteristics

Table 25.25 lists the flash memory characteristics.

Table 25.25 Flash Memory Characteristics

Condition A: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC},
$V_{SS} = AV_{SS}$ = 0 V,
V_{CC} = 3.0 V to 3.6 V (Programming/erasing operating voltage range),
T_a = –20°C to +75°C (Programming/erasing operating temperature range; regular specifications),
T_a = –40°C to +85°C (Programming/erasing operating temperature range; wide-range specifications)

Condition B: V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref} = 2.2 V to AV_{CC},
$V_{SS} = AV_{SS}$ = 0 V,
V_{CC} = 3.0 V to 3.6 V (Programming/erasing operating voltage range),
T_a = –20°C to +50°C (Programming/erasing operating temperature range; regular specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Programming time*1, *2, *4		t_P	—	10	200	ms/128 bytes	
Erase time*1, *3, *5		t_E	—	100	1200	ms/block	
Reprogramming count		N_{WEC}*6	100	10000*7	—	Times	
Data holding time		t_{DRP}	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	1 ≤ n ≤ 6
		t_{sp200}	198	200	202	µs	7 ≤ n ≤ 1000
	Wait time after P1 bit clear*1	t_{cp}	5	5	—	µs	
	Wait time after PSU1 bit clear*1	t_{cpsu}	5	5	—	µs	
	Wait time after PV1 bit setting*1	t_{spv}	4	4	—	µs	
	Wait time after H'FF dummy write*1	t_{spvr}	2	2	—	µs	

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Programming	Wait time after PV1 bit clear*[1]	t_{cpv}	2	2	—	µs	
	Wait time after SWE1 bit clear	t_{cswe}	100	100	—	µs	
	Maximum programming count*[1, 4]	N1	—	—	6*[4]	Times	
		N2	—	—	994*[4]		
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	
	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/program-verify flowchart or erase/erase-verify flowchart.
2. Programming time per 128 bytes (Shows the total period for which the P1 bit in the flash memory control register 1 (FLMCR1) is set. It does not include the program 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. Maximum programming time value
   t_p(max) = Wait time after P1 bit setting (t_{sp}) × maximum program count (N)
   $(t_{sp30} + t_{sp10}) \times 6 + (t_{sp200}) \times 994$
5. Relationship among the maximum erase time (t_E (max)), the wait time after E1 bit setting (t_{se}), and the maximum erase count (N) is shown below.
   t_E (max) = Wait time after E1 bit setting (t_{se}) × Maximum erase count (N)
6. Data can be reprogrammed less than minimum count.
7. Typical value at 25°C

25.4 Electrical Characteristics of H8S/2237 Series and H8S/2227 Series

25.4.1 Absolute Maximum Ratings

Table 25.26 lists the absolute maximum ratings.

Table 25.26 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	–0.3 to +4.3	V
Program voltage	V_{PP}	–0.3 to +13.5	V
Input voltage (except ports4 and 9)	V_{in}	–0.3 to V_{CC} +0.3	V
Input voltage (ports 4 and 9)	V_{in}	–0.3 to AV_{CC} +0.3	V
Reference power supply voltage	V_{ref}	–0.3 to AV_{CC} +0.3	V
Analog power supply voltage	AV_{CC}	–0.3 to +4.6	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	
Storage temperature	T_{stg}	–55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum rating are exceeded.

Note: The operating temperature ranges for flash memory programming/erasing are T_a = –20°C to +75°C (regular specifications) and T_a = –40°C to +85°C (wide-range specifications).

25.4.2 DC Characteristics

Table 25.27 lists the DC characteristics. Table 25.28 lists the permissible output currents.

Table 25.27 DC Characteristics (1)

Conditions (ZTAT version and F-ZTAT version):	V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)*[1]
Conditions (Masked ROM version):	V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	IRQ0 to IRQ7	VT^-	$V_{CC} \times 0.2$	—	—	V	
		VT^+	—	—	$V_{CC} \times 0.8$	V	
		$VT^+ - VT^-$	$V_{CC} \times 0.07$	—	—	V	ZTAT version, masked ROM version
		$VT^+ - VT^-$	$V_{CC} \times 0.05$	—	—	V	F-ZTAT version
Input high voltage	RES, STBY, NMI, MD2 to MD0, FWE	V_{IH}	$V_{CC} \times 0.9$	—	V_{CC} + 0.3	V	
	EXTAL, Ports 1, 3, 7, and A to G		$V_{CC} \times 0.8$	—	V_{CC} + 0.3	V	
	Ports 4 and 9		$V_{CC} \times 0.8$	—	AV_{CC} + 0.3	V	
Input low voltage	RES, STBY, FWE, MD2 to MD0	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, Ports 1, 3, 4, 7, 9, and A to G		–0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins	V_{OH}	V_{CC} – 0.5	—	—	V	I_{OH} = –200 µA
			V_{CC} – 1.0	—	—	V	I_{OH} = –1 mA*[2]
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	I_{OL} = 0.4 mA
			—	—	0.4	V	I_{OL} = 0.8 mA*[2]
Input leakage current	RES	$\lvert I_{in} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V*[3] V_{in} = 0.2 to V_{CC} – 0.2 V*[4]
	STBY, NMI, FWE, MD2 to MD0		—	—	1.0	µA	
	Ports 4, 9		—	—	1.0	µA	V_{in} = 0.5 to AV_{CC} – 0.5 V*[3] V_{in} = 0.2 to AV_{CC} – 0.2 V*[4]
Three states leakage current (off)	Ports 1, 3, 7, and A to G	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V*[3] V_{in} = 0.2 to V_{CC} – 0.2 V*[4]
Input pull-up MOS current	Ports A to E	$-I_P$	10	—	300	µA	V_{in} = 0V

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. V_{CC} = 2.7 V to 3.6 V
3. For ZTAT version and masked ROM version
4. For F-ZTAT version

Table 25.27 DC Characteristics (2)

Conditions (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	30	pF	V_{in} = 0 V f = 1 MHz T_a = 25 °C
	NMI		—	—	30	pF	
	All input pins other than above ones		—	—	15	pF	
Current consumption*[2]	Normal operation	I_{CC}*[4]	—	20 V_{CC} = 3.0 V	37 V_{CC} = 3.6 V	mA	f = 13.5 MHz
	Sleep mode		—	15 V_{CC} = 3.0 V	29 V_{CC} = 3.6 V	mA	f = 13.5 MHz
	All modules stopped		—	15	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	11	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Subactive mode		—	60	160	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Subsleep mode		—	35	90	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Watch mode		—	8	40	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption*[2]	Standby mode*[3]		—	1.0 V_{CC} = 3.0 V	10 V_{CC} = 3.6 V	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	50 V_{CC} = 3.6 V	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.8	1.5	mA	AV_{CC} = 3.0 V
	Idle		—	0.01	5.0	µA	
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	V_{ref} = 3.0 V
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.2 V and V_{IL} max = 0.2 V, with all output pins unloaded and the on-chip MOS pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7$ V, V_{IH} min = $V_{CC} \times 0.9$, and V_{IL} max = 0.3 V.
4. I_{CC} depends on V_{CC} and f as follows:
   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)
   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.27 DC Characteristics (3)

Conditions (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	80	pF	V_{in} = 0 V f = 1 MHz T_a = 25 °C
	NMI		—	—	50	pF	
	All input pins other than above ones		—	—	15	pF	
Current consumption*[2]	Normal operation	I_{CC}*[4]	—	16 V_{CC} = 3.0 V	28 V_{CC} = 3.6 V	mA	f = 10 MHz
	Sleep mode		—	12 V_{CC} = 3.0 V	22 V_{CC} = 3.6 V	mA	f = 10 MHz
	All modules stopped		—	12	—	mA	f = 10 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	8.5	—	mA	f = 10 MHz, V_{CC} = 3.0 V (reference value)
	Subactive mode		—	80	120	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Subsleep mode		—	60	90	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Watch mode		—	8	12	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption*[2]	Standby mode*[3]		—	0.01	5.0	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	20.0	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.2	1.0	mA	AV_{CC} = 3.0 V
	Idle		—	0.01	5.0	µA	
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	V_{ref} = 3.0 V
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.5 V and V_{IL} max = 0.5 V, with all output pins unloaded and the on-chip MOS pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7$ V, V_{IH} min = $V_{CC} \times 0.9$, and V_{IL} max = 0.3 V.
4. I_{CC} depends on V_{CC} and f as follows:
   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)
   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.27 DC Characteristics (4)

Conditions (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V, V_{ref}=2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)*[1]

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	RES	C_{in}	—	—	80	pF	V_{in} = 0 V f = 1 MHz T_a = 25 °C
	NMI		—	—	50	pF	
	All input pins other than above ones		—	—	15	pF	
Current consumption*[2]	Normal operation	I_{CC}*[4]	—	20 V_{CC} = 3.0 V	37 V_{CC} = 3.6 V	mA	f = 13.5 MHz
			—	10 V_{CC} = 3.0 V	18 V_{CC} = 3.6 V	mA	f = 6.25 MHz
	Sleep mode		—	15 V_{CC} = 3.0 V	29 V_{CC} = 3.6 V	mA	f = 13.5 MHz
			—	7.5 V_{CC} = 3.0 V	14 V_{CC} = 3.6 V	mA	f = 6.25 MHz
	All modules stopped		—	15	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Medium-speed mode (ϕ/32)		—	11	—	mA	f = 13.5 MHz, V_{CC} = 3.0 V (reference value)
	Subactive mode		—	60	160	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current consumption*[2]	Subsleep mode		—	35	90	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Watch mode		—	8	40	µA	V_{CC} = 3.0 V When 32.768 kHz crystal resonator is used
	Standby mode*[3]		—	1.0 V_{CC} = 3.0 V	10 V_{CC} = 3.6 V	µA	$T_a \leq 50°C$ When 32.768 kHz crystal resonator is not used
			—	—	50 V_{CC} = 3.6 V	µA	$50°C < T_a$ When 32.768 kHz crystal resonator is not used
Analog power supply current	During A/D conversion	AI_{CC}	—	0.8	1.5	mA	AV_{CC} = 3.0 V
	Idle		—	0.01	5.0	µA	
Reference power supply current	During A/D conversion	AI_{CC}	—	1.3	2.5	mA	V_{ref} = 3.0 V
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D or D/A converter is not used, the AV_{CC}, V_{ref}, and AV_{SS} pins should not be open. Even if the A/D or D/A converter is not used, connect the AV_{CC} and V_{ref} pins to V_{CC} and supply 2.0 V to 3.6 V. In this case, $V_{ref} \leq AV_{CC}$.

2. Current consumption values are for V_{IH} min = V_{CC} – 0.5 V and V_{IL} max = 0.5 V, with all output pins unloaded and the on-chip MOS pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.2$ V, V_{IH} min = $V_{CC} \times 0.9$, and V_{IL} max = 0.3 V.
4. I_{CC} depends on V_{CC} and f as follows:
   I_{CC} max = 1.0 (mA) + 0.74 (mA/(MHz x V)) × V_{CC} × f (normal operation)
   I_{CC} max = 1.0 (mA) + 0.58 (mA/(MHz x V)) × V_{CC} × f (sleep mode)

Table 25.28 Permissible Output Currents

Conditions (F-ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Conditions (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item			Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	Output pins	V_{CC} = 2.2 V to 3.6 V	I_{OL}	—	—	0.5	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	1.0	
Permissible output low current (total)	Total of all output pins	V_{CC} = 2.2 V to 3.6 V	$\sum I_{OL}$	—	—	30	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	60	
Permissible output high current (per pin)	All output pins	V_{CC} = 2.2 V to 3.6 V	$-I_{OH}$	—	—	0.5	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	1.0	
Permissible output high current (total)	Total of all output pins	V_{CC} = 2.2 V to 3.6 V	$\sum -I_{OH}$	—	—	15	mA
		V_{CC} = 2.7 V to 3.6 V		—	—	30	

Note: To protect chip reliability, do not exceed the output current values in table 25.28.

25.4.3 AC Characteristics

Figure 25.4 shows the test conditions for the AC characteristics.

(1) Clock Timing

Table 25.29 lists the Clock timing

Condition A (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 10 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version, masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 13.5MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B		Condition C			
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**
Clock cycle time	t_{cyc}	100	500	74	500	160	500	ns	Figure 25.5
Clock high pulse width	t_{CH}	35	—	25	—	50	—	ns	
Clock low pulse width	t_{CL}	35	—	25	—	50	—	ns	
Clock rise time	t_{Cr}	—	15	—	10	—	25	ns	
Clock fall time	t_{Cf}	—	15	—	10	—	25	ns	
Oscillation stabilization time at reset (crystal)	t_{OSC1}	20	—	20	—	40	—	ms	Figure 25.6
Oscillation stabilization time in software standby (crystal)	t_{OSC2}	8	—	8	—	16	—	ms	Figure23.3

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Condition C Min	Condition C Max	Unit	Test Conditions
External clock output stabilization delay time	t_{DEXT}	500	—	500	—	1000	—	µs	Figure 25.6
Subclock oscillation stabilization time	t_{OSC3}	—	2	—	2	—	3	s	
Subclock oscillator frequency	f_{SUB}	32.768		32.768		32.768		kHz	
Subclock (ϕ_{SUB}) cycle time	t_{SUB}	30.5		30.5		30.5		µs	

(2) Control Signal Timing

Table 25.30 lists the control signal timing.

Table 25.30 Control Signal Timing

Condition A (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 10 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version, masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 13.5MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Condition C Min	Condition C Max	Unit	Test Conditions
RES setup time	t_{RESS}	250	—	250	—	350	—	ns	Figure 25.7
RES pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
MRES setup time	t_{MRESS}	250	—	250	—	350	—	ns	
MRES pulse width	t_{MRESW}	20	—	20	—	20	—	t_{cyc}	

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Condition C Min	Condition C Max	Unit	Test Conditions
NMI setup time	t_{NMIS}	250	—	250	—	350	—	ns	Figure 25.8
NMI hold time	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	300	—	ns	
IRQ setup time	t_{IRQS}	250	—	250	—	350	—	ns	
IRQ hold time	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (exiting software standby mode)	t_{IRQW}	200	—	200	—	300	—	ns	

(3) Bus Timing

Table 25.31 lists the bus timing.

Table 25.31 Bus Timing

Condition A (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 10 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version, masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 13.5MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Condition C Min	Condition C Max	Unit	Test Conditions
Address delay time	t_{AD}	—	60	—	50	—	90	ns	Figures 25.9 to 25.13
Address setup time	t_{AS}	$0.5 \times t_{cyc}$ – 40	—	$0.5 \times t_{cyc}$ – 30	—	$0.5 \times t_{cyc}$ – 60	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc}$ – 20	—	$0.5 \times t_{cyc}$ – 15	—	$0.5 \times t_{cyc}$ – 30	—	ns	

Item	Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Condition C Min	Condition C Max	Unit	Test Conditions
CS delay time	t_{CSD}	—	60	—	50	—	90	ns	Figures
AS delay time	t_{ASD}	—	60	—	50	—	90	ns	25.9 to
RD delay time 1	t_{RSD1}	—	60	—	50	—	90	ns	25.13
RD delay time 2	t_{RSD2}	—	60	—	50	—	90	ns	
Read data setup time	t_{RDS}	30	—	30	—	50	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns	
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 65$	—	$1.0 \times t_{cyc} - 65$	—	$1.0 \times t_{cyc} - 90$	ns	
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 65$	—	$1.5 \times t_{cyc} - 65$	—	$1.5 \times t_{cyc} - 90$	ns	
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 65$	—	$2.0 \times t_{cyc} - 65$	—	$2.0 \times t_{cyc} - 90$	ns	
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 65$	—	$2.5 \times t_{cyc} - 65$	—	$2.5 \times t_{cyc} - 90$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 65$	—	$3.0 \times t_{cyc} - 65$	—	$3.0 \times t_{cyc} - 90$	ns	
WR delay time 1	t_{WRD1}	—	60	—	50	—	90	ns	
WR delay time 2	t_{WRD2}	—	60	—	50	—	90	ns	
WR pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 60$	—	ns	
WR pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 40$	—	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 60$	—	ns	
Write data delay time	t_{WDD}	—	80	—	70	—	100	ns	
Write data setup time	t_{WDS}	$0.5 \times t_{cyc} - 50$	—	$0.5 \times t_{cyc} - 37$	—	$0.5 \times t_{cyc} - 80$	—	ns	
Write data hold time	t_{WDH}	$0.5 \times t_{cyc} - 30$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 60$	—	ns	
WAIT setup time	t_{WTS}	60	—	50	—	90	—	ns	Figure 25.11
WAIT hold time	t_{WTH}	10	—	10	—	10	—	ns	
BREQ setup time	t_{BRQS}	60	—	50	—	90	—	ns	Figure 25.14
BACK delay time	t_{BACD}	—	60	—	50	—	90	ns	
Bus-floating time	t_{BZD}	—	100	—	80	—	160	ns	

(4) Timing of On-Chip Peripheral Modules

Table 25.32 lists the timing of on-chip peripheral modules.

Table 25.32 Timing of On-Chip Peripheral Modules

Condition A (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 10 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version, masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 13.5MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 32.768 kHz, 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

			Condition A		Condition B		Condition C			
Item		**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**
I/O port	Output data delay time	t_{PWD}	—	100	—	100	—	150	ns	Figure 25.19
	Input data setup time	t_{PRS}	50	—	50	—	80	—		
	Input data hold time	t_{PRH}	50	—	50	—	50	—		
TPU	Timer output delay time	t_{TOCD}	—	100	—	100	—	150	ns	Figure 25.20
	Timer input setup time	t_{TICS}	50	—	40	—	60	—		
	Timer clock input setup time	t_{TCKS}	50	—	40	—	60	—	ns	Figure 25.21
	Timer clock pulse width — Single edge	t_{TCKWH}	1.5	—	1.5	—	1.5	—	t_{cyc}	
	Timer clock pulse width — Both edges	t_{TCKWL}	2.5	—	2.5	—	2.5	—		

Item			Symbol	Condition A Min	Condition A Max	Condition B Min	Condition B Max	Condition C Min	Condition C Max	Unit	Test Conditions
TMR	Timer output delay time		t_{TMOD}	—	100	—	100	—	150	ns	Figure 25.22
	Timer reset input setup time		t_{TMRS}	50	—	50	—	80	—	ns	Figure 25.24
	Timer clock input setup time		t_{TMCS}	50	—	50	—	80	—	ns	Figure 25.23
	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}	
		Both edges	t_{TMCWL}	2.5	—	2.5	—	2.5	—		
WDT_1	BUZZ output delay time		t_{BUZD}	—	100	—	100	—	150	ns	Figure 25.25
SCI*	Input clock cycle	Asynchronous	t_{Scyc}	4	—	4	—	4	—	t_{cyc}	Figure 25.26
		Synchronous		6	—	6	—	6	—		
	Input clock pulse width		t_{SCKW}	0.4	0.6	0.4	0.6	0.4	0.6	t_{Scyc}	
	Input clock rise time		t_{SCKr}	—	1.5	—	1.5	—	1.5	t_{cyc}	
	Input clock fall time		t_{SCKf}	—	1.5	—	1.5	—	1.5		
	Transmit data delay time		t_{TXD}	—	100	—	100	—	150	ns	Figure 25.27
	Receive data setup time (synchronous)		t_{RXS}	100	—	75	—	150	—	ns	
	Receive data hold time (synchronous)		t_{RXH}	100	—	75	—	150	—	ns	
A/D converter	Trigger input setup time		t_{TRGS}	50	—	40	—	60	—	ns	Figure 25.28

25.4.4 A/D Conversion Characteristics

Table 25.33 lists the A/D conversion characteristics.

Table 25.33 A/D Conversion Characteristics

Condition A (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 10 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (F-ZTAT version, Masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 13.5MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

	Condition A			Condition B			Condition C			
Item	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Resolution	10	10	10	10	10	10	10	10	10	bits
Conversion time	13.1	—	—	9.6	—	—	20.9	—	—	µs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	5	—	—	5	kΩ
Nonlinearity error	—	—	±6.0	—	—	±6.0	—	—	±6.0	LSB
Offset error	—	—	±4.0	—	—	±4.0	—	—	±4.0	LSB
Full-scale error	—	—	±4.0	—	—	±4.0	—	—	±4.0	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±8.0	—	—	±8.0	LSB

25.4.5 D/A Conversion Characteristics

Table 25.34 lists the D/A conversion characteristics.

Table 25.34 D/A Conversion Characteristics

Condition A (ZTAT version): V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 10 MHz,
T_a = –20°C to +75°C (regular specifications)
T_a = –40°C to +85°C (wide-range specifications)

Condition B (Masked ROM version):
V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V,
V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 13.5MHz,
T_a = –20°C to +75°C (regular specifications)

Condition C (Masked ROM version): V_{CC} = 2.2 V to 3.6 V, AV_{CC} = 2.2 V to 3.6 V,
V_{ref} = 2.2 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ϕ = 2 to 6.25 MHz
T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

	Condition A			Condition B			Condition C				
Item	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**	**Test Condition**
Resolution	8	8	8	8	8	8	8	8	8	bits	
Conversion time	—	—	10	—	—	10	—	—	10	µs	Load capacitance = 20 pF
Absolute accuracy	—	±2.0	±3.0	—	±2.0	±3.0	—	±3.0	±4.0	LSB	Load resistance = 2 MΩ
	—	—	±2.0	—	—	±2.0	—	—	±3.0	LSB	Load resistance = 4 M Ω

25.4.6 Flash Memory Characteristics

Table 25.35 lists the flash memory characteristics.

Table 25.35 Flash Memory Characteristics

Conditions: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, V_{ref} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V,
V_{CC} = 3.0 V to 3.6 V (Programming / erasing operating voltage range)
T_a = –20°C to +50°C (Programming / erasing operating temperature range; regular specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Programming time*1, *2, *4		t_P	—	10	200	ms/128 bytes	
Erase time*1, *3, *5		t_E	—	100	1200	ms/block	
Reprogramming count		N_{WEC}*6	100	10000*7	—	Times	
Data holding time		t_{DRP}	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	1 ≤ n ≤ 6
		t_{sp200}	198	200	202	µs	7 ≤ n ≤ 1000
	Wait time after P1 bit clear*1	t_{cp}	5	5	—	µs	
	Wait time after PSU1 bit clear*1	t_{cpsu}	5	5	—	µs	
	Wait time after PV1 bit setting*1	t_{spv}	4	4	—	µs	
	Wait time after H'FF dummy write*1	t_{spvr}	2	2	—	µs	
	Wait time after PV1 bit clear*1	t_{cpv}	2	2	—	µs	
	Wait time after SWE1 bit clear	t_{cswe}	100	100	—	µs	
	Maximum programming count*1, *4	N1	—	—	6*4	Times	
		N2	—	—	994*4		

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
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	
	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/program-verify flowchart or erase/erase-verify flowchart.
2. Programming time per 128 bytes (Shows the total period for which the P1 bit in the flash memory control register 1 (FLMCR1) is set. It does not include the program 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. Maximum programming time value
   t_p(max) = Wait time after P1 bit setting (t_{sp}) × maximum program count (N)
   (t_{sp30} + t_{sp10}) × 6 + (t_{sp200}) × 994
5. Relationship among the maximum erase time (t_E (max)), the wait time after E1 bit setting (t_{se}), and the maximum erase count (N) is shown below.
   t_E (max) = Wait time after E1 bit setting (t_{se}) × Maximum erase count (N)
6. Data can be reprogrammed less than minimum count.
7. Typical value at 25°C

25.5 Operating Timing

25.5.1 Clock Timing

The clock timing is shown below.

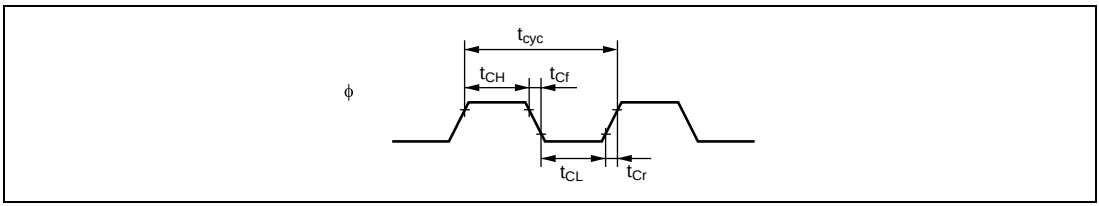


Figure 25.5 System Clock Timing

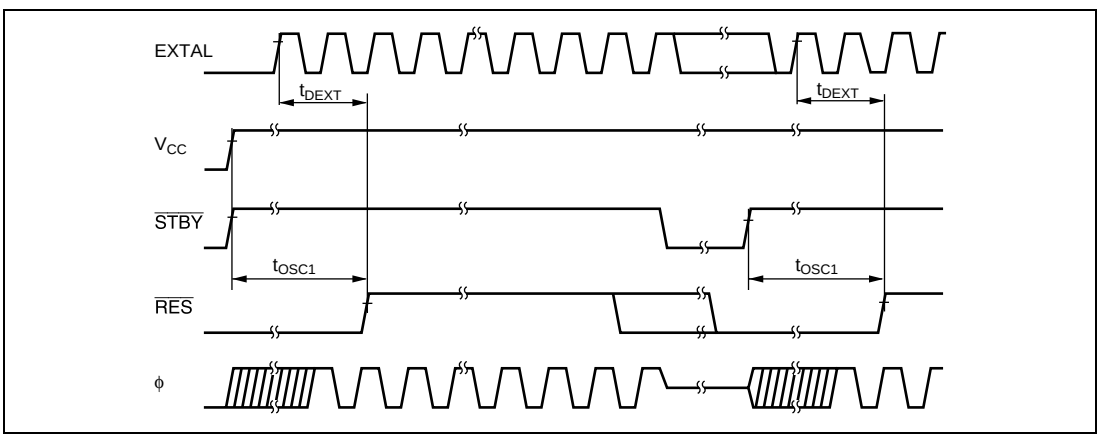


Figure 25.6 Oscillation Stabilization Timing

25.5.2 Control Signal Timing

The control signal timing is shown below.

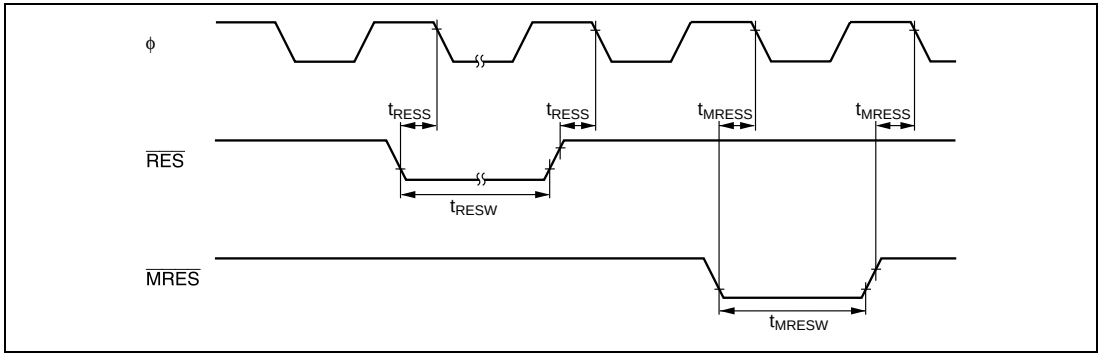


Figure 25.7 Reset Input Timing

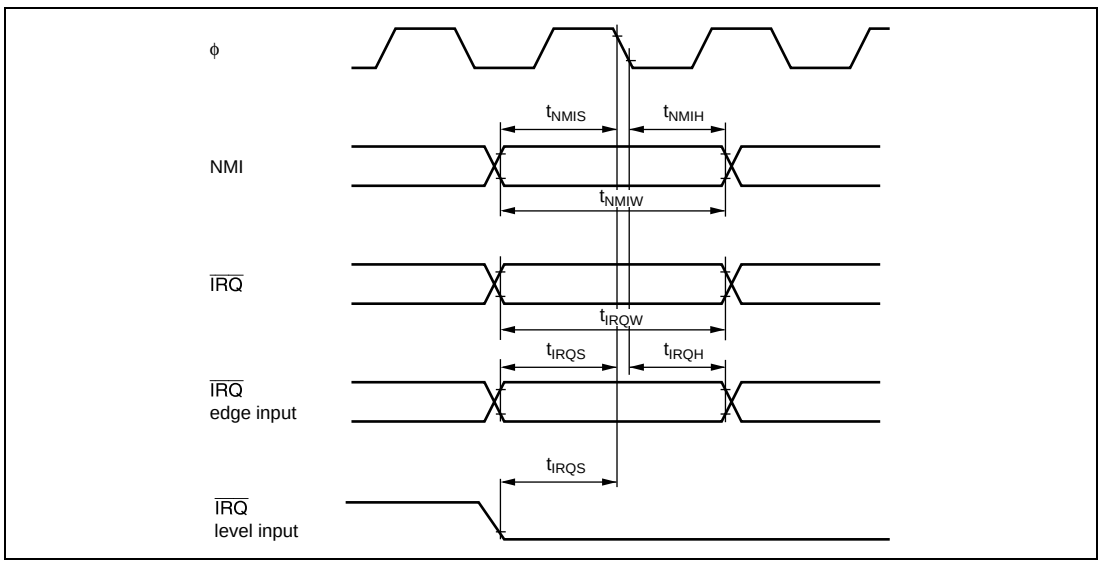


Figure 25.8 Interrupt Input Timing

25.5.3 Bus Timing

Figures 25.9 to 25.14 show the bus timing.

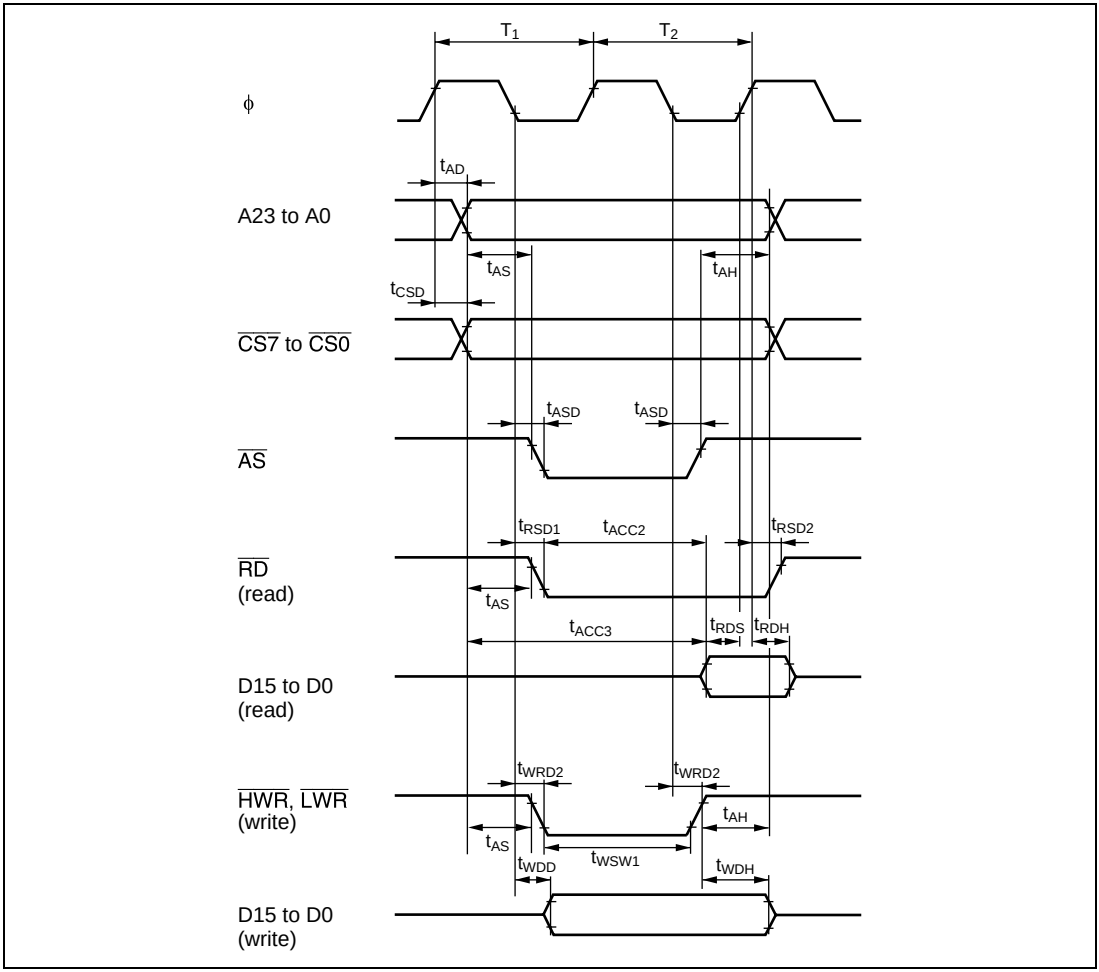


Figure 25.9 Basic Bus Timing (Two-State Access)

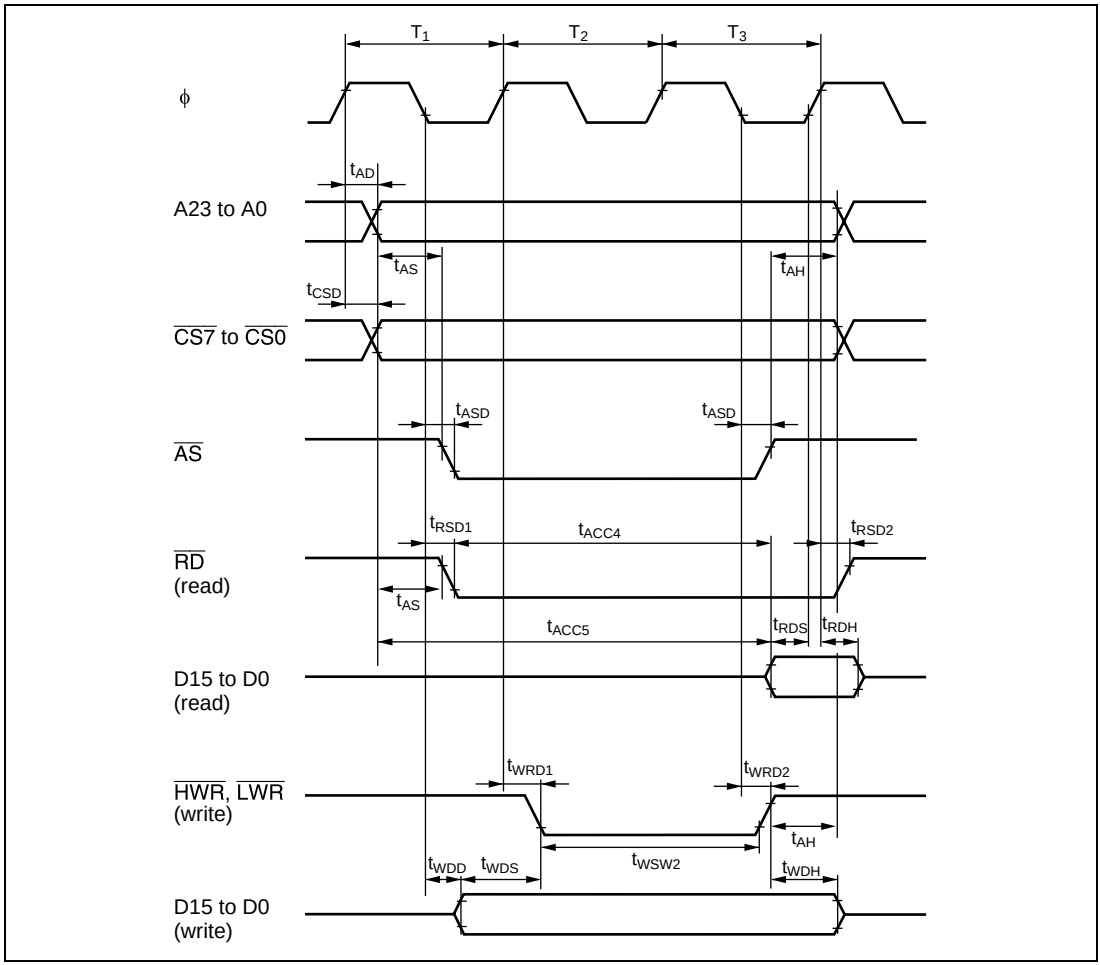


Figure 25.10 Basic Bus Timing (Three-State Access)

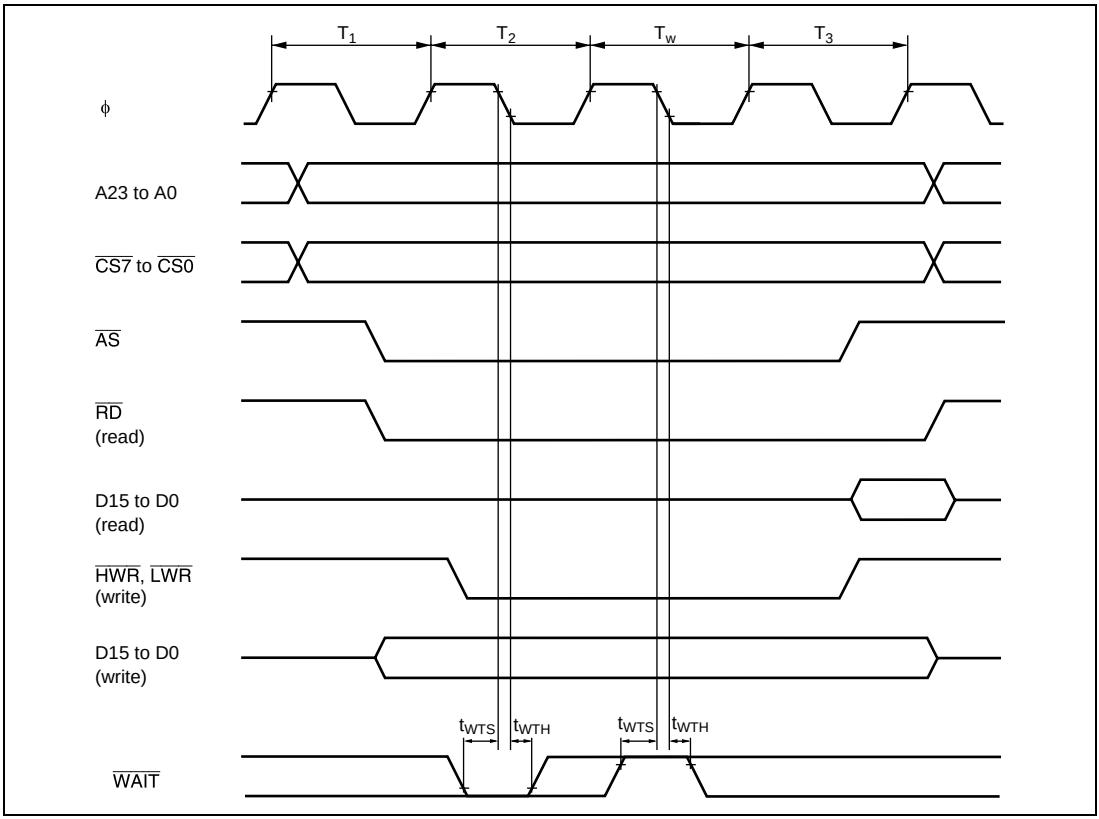


Figure 25.11 Basic Bus Timing (Three-State Access with One Wait State)

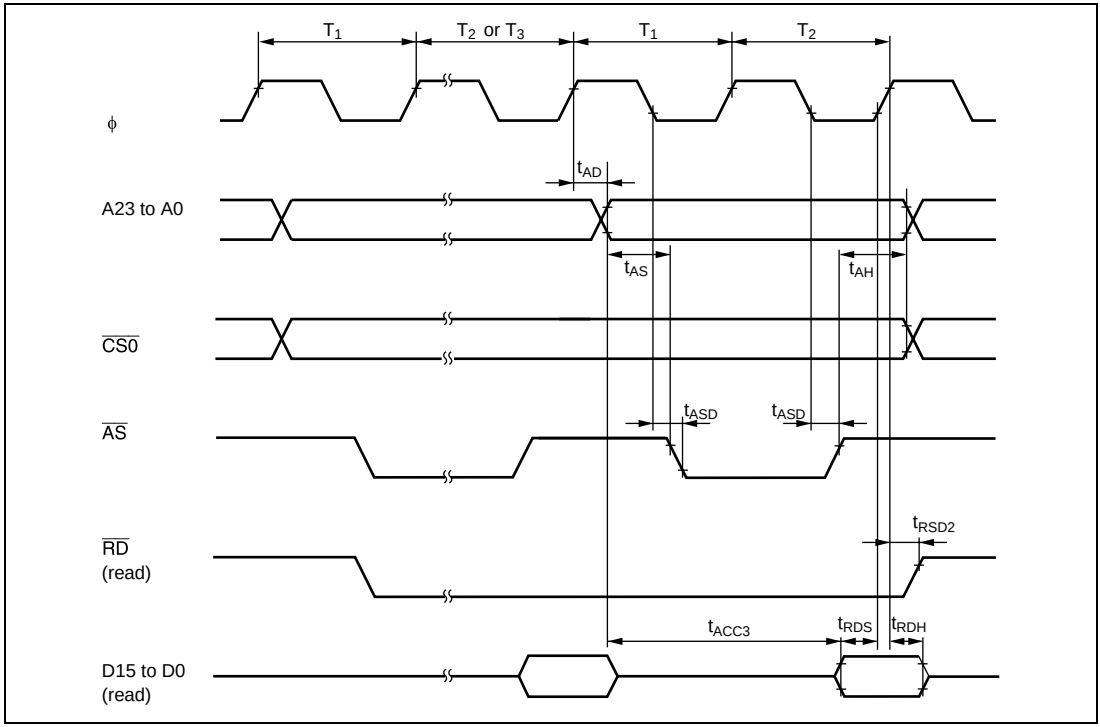


Figure 25.12 Burst ROM Access Timing (Two-State Access)

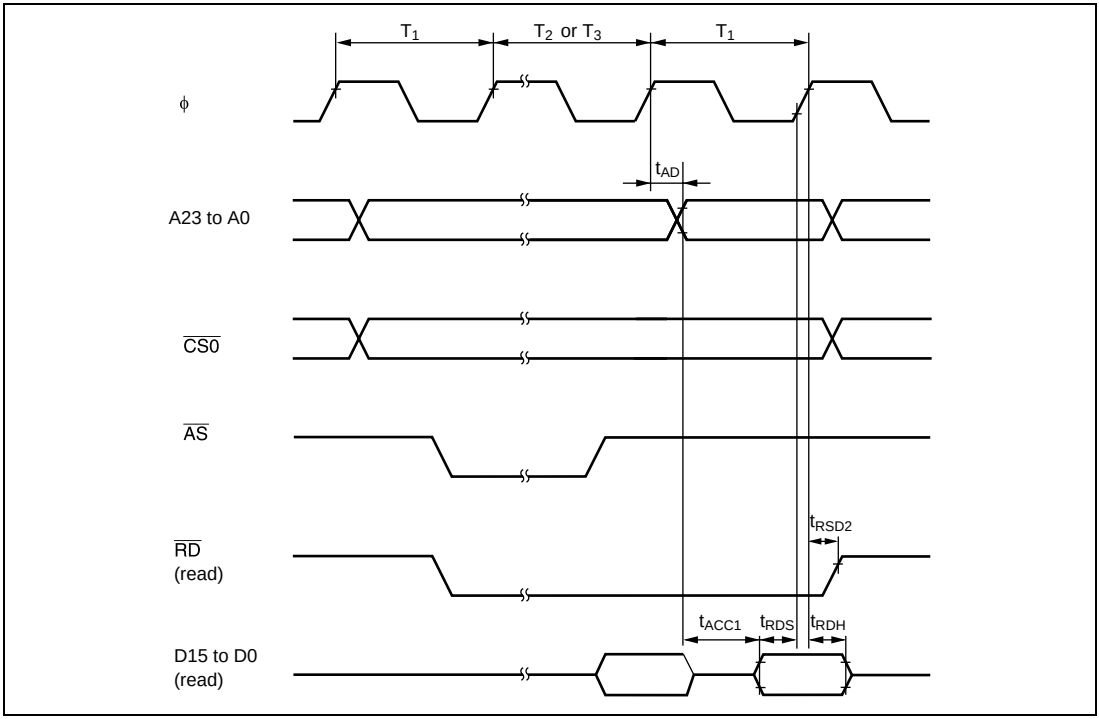


Figure 25.13 Burst ROM Access Timing (One-State Access)

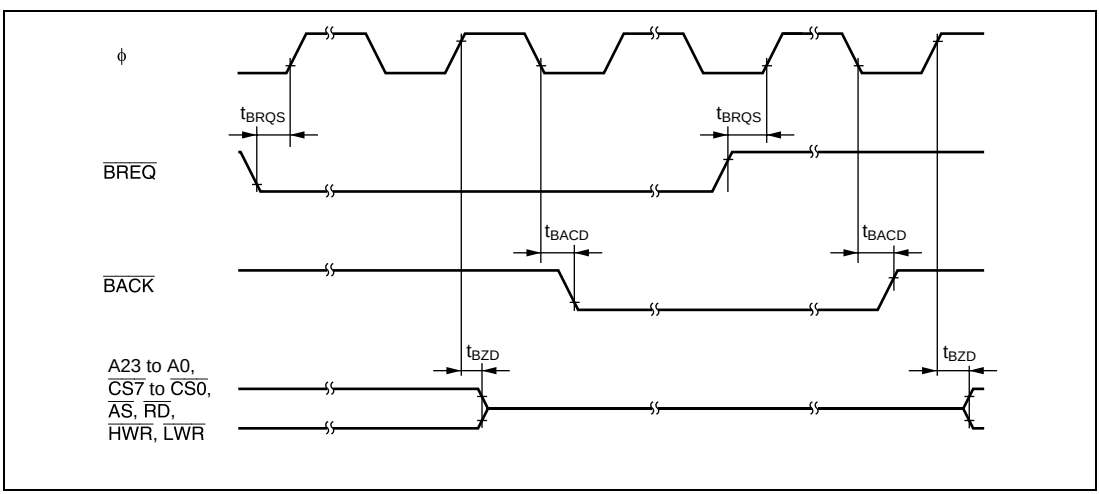


Figure 25.14 External Bus Release Timing

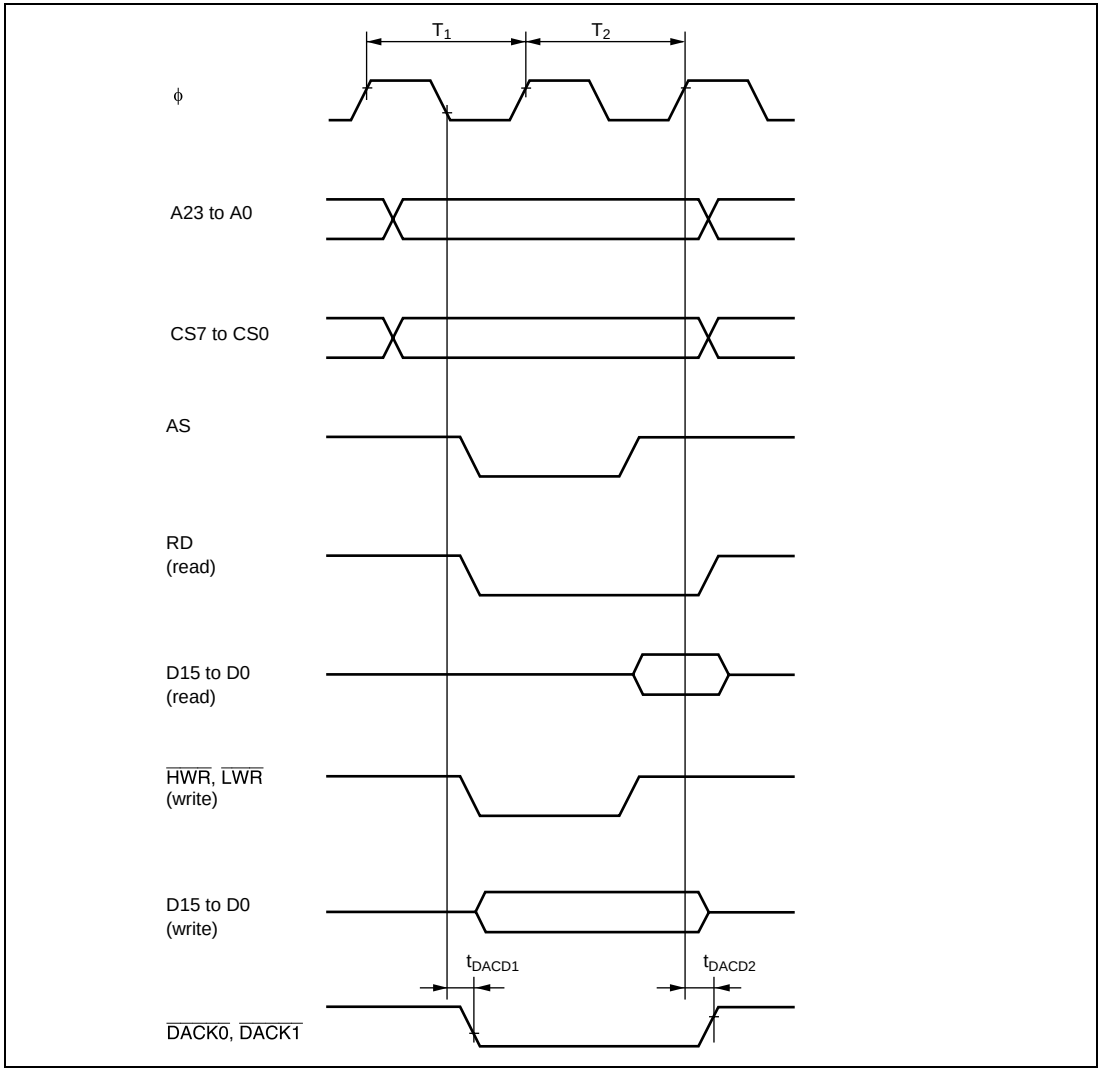


Figure 25.15 DMAC Single Address Transfer Timing (Two-State Access)

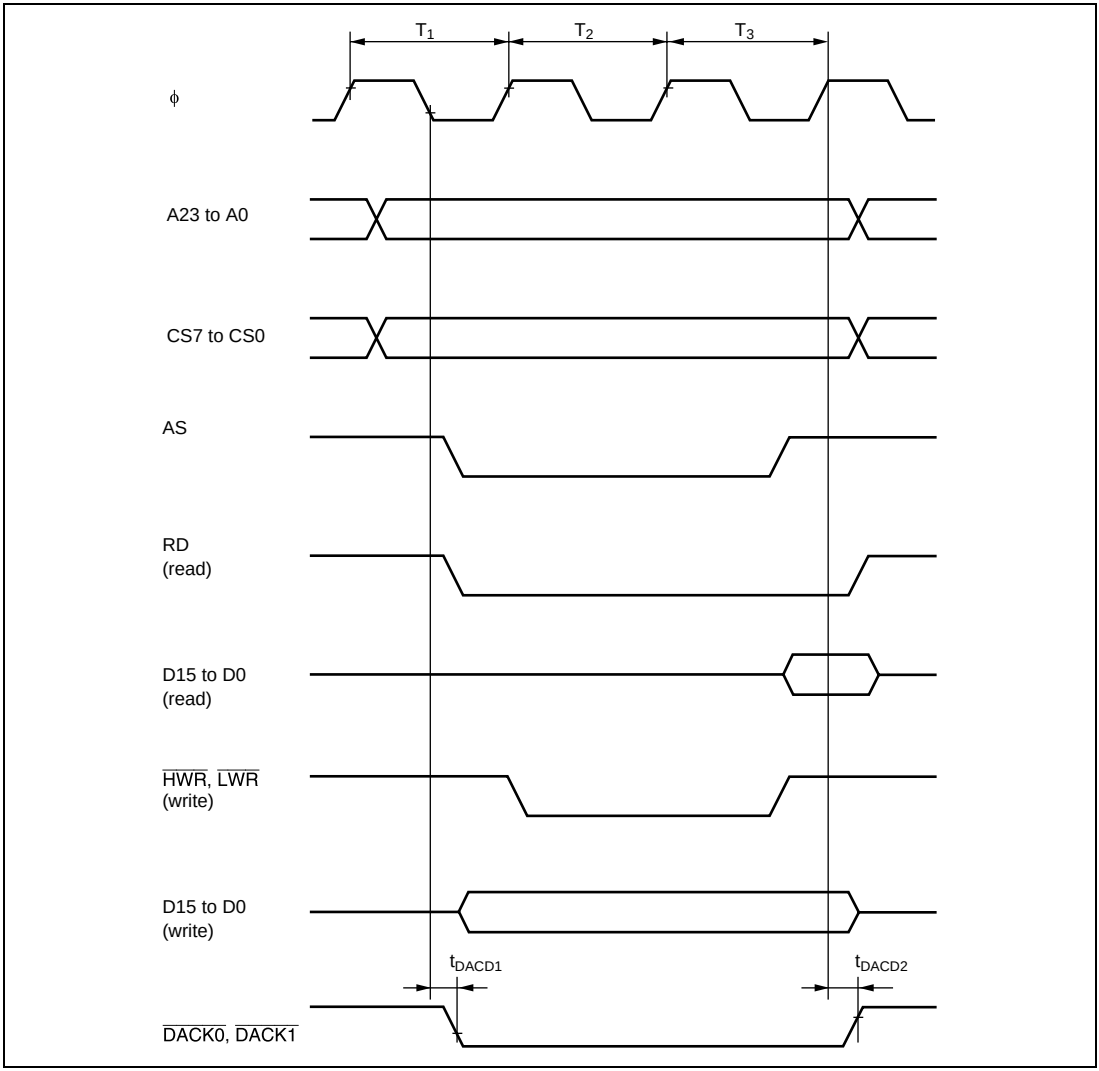


Figure 25.16 DMAC Single Address Transfer Timing (Three-State Access)

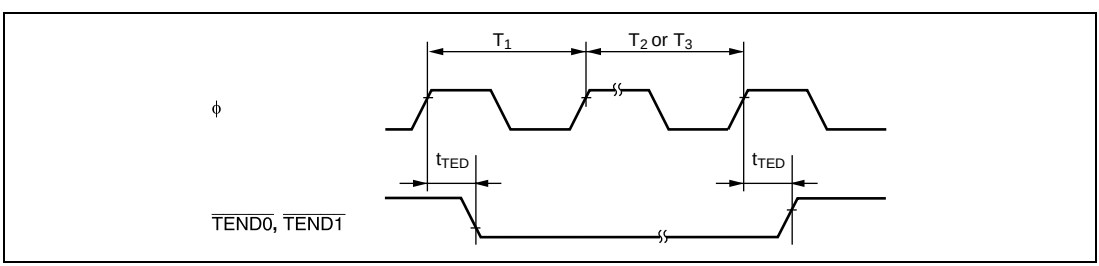


Figure 25.17 DMAC TEND Output Timing

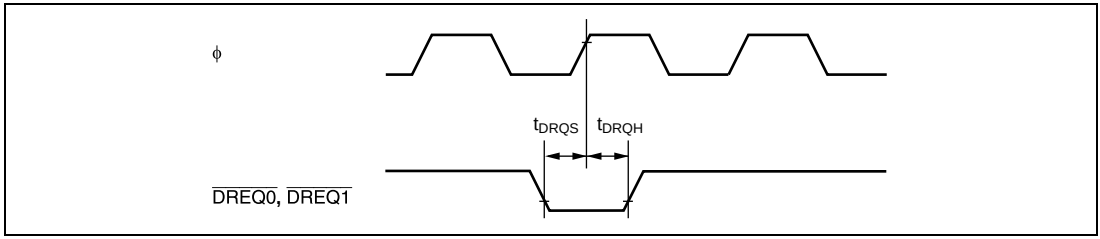


Figure 25.18 DMAC DREQ Input Timing

25.5.4 Timing of On-Chip Peripheral Modules

Figures 25.19 to 25.29 show the timing of on-chip peripheral modules.

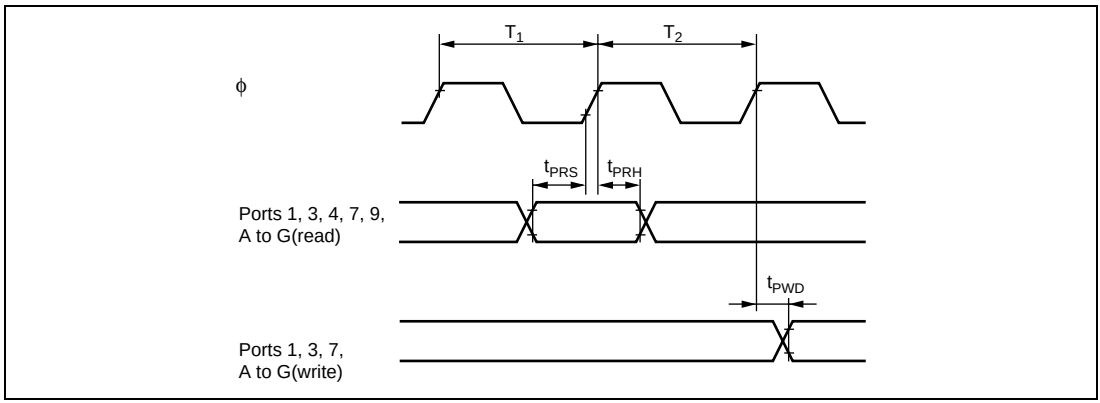
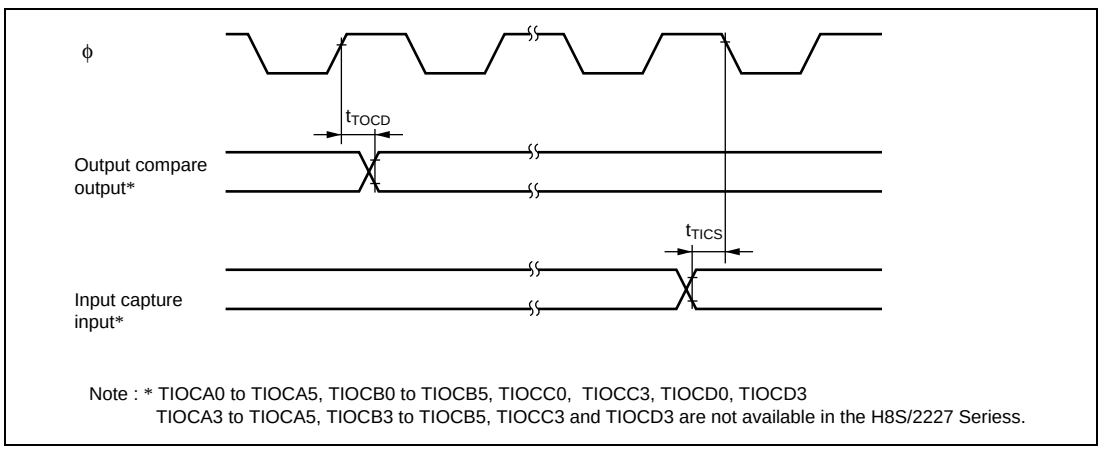


Figure 25.19 I/O Port Input/Output Timing



Note : * TIOCA0 to TIOCA5, TIOCB0 to TIOCB5, TIOCC0, TIOCC3, TIOCD0, TIOCD3
TIOCA3 to TIOCA5, TIOCB3 to TIOCB5, TIOCC3 and TIOCD3 are not available in the H8S/2227 Seriess.

Figure 25.20 TPU Input/Output Timing

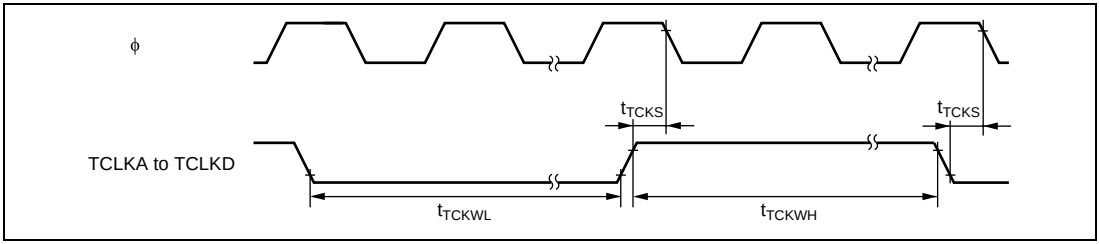
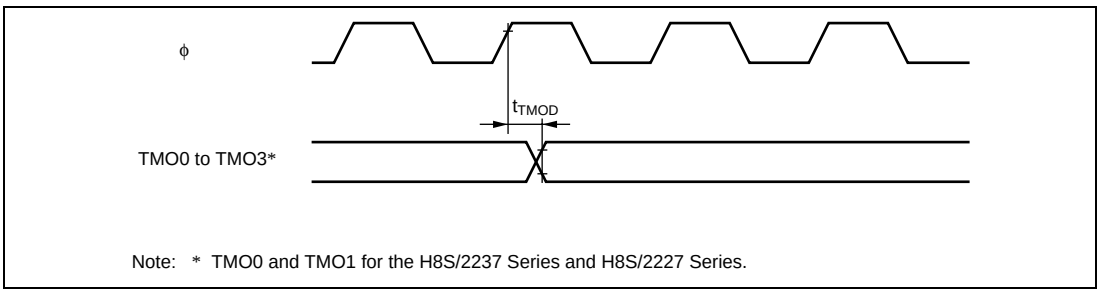
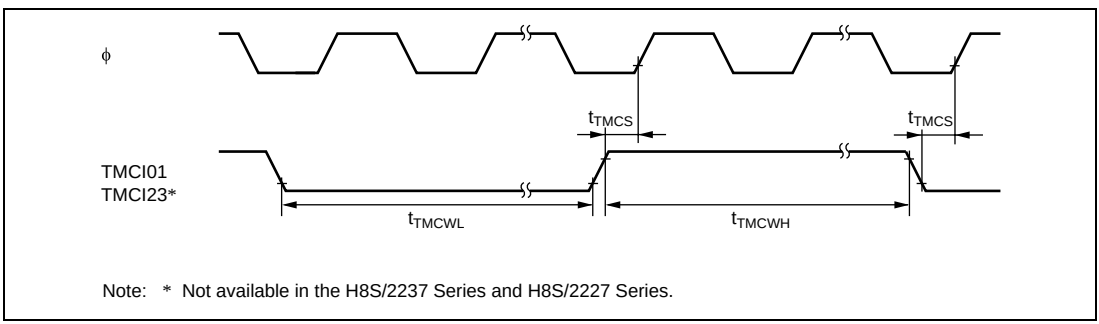


Figure 25.21 TPU Clock Input Timing



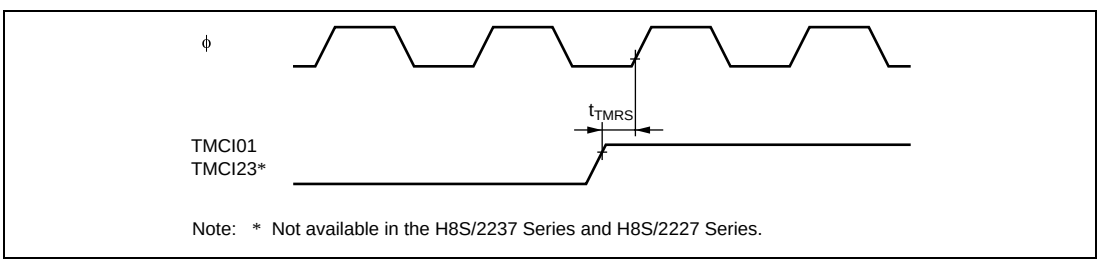
Note: * TMO0 and TMO1 for the H8S/2237 Series and H8S/2227 Series.

Figure 25.22 8-Bit Timer Output Timing



Note: * Not available in the H8S/2237 Series and H8S/2227 Series.

Figure 25.23 8-Bit Timer Clock Input Timing



Note: * Not available in the H8S/2237 Series and H8S/2227 Series.

A A **Figure 25.24 8-Bit Timer Reset Input Timing**

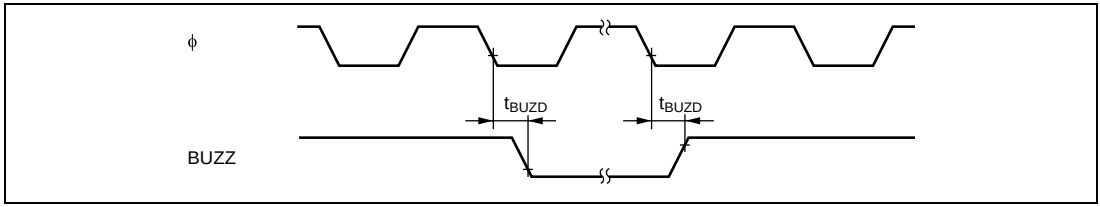


Figure 25.25 WDT_1 Output Timing

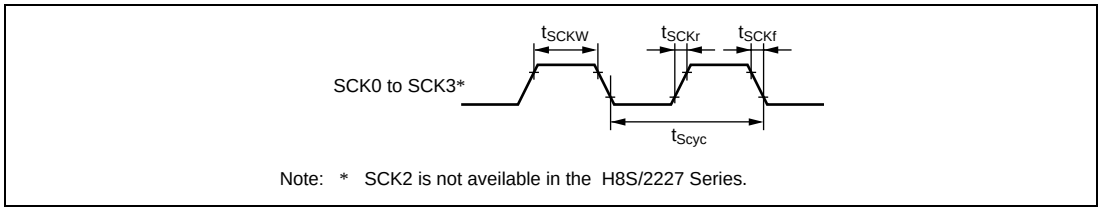


Figure 25.26 SCK Clock Input Timing

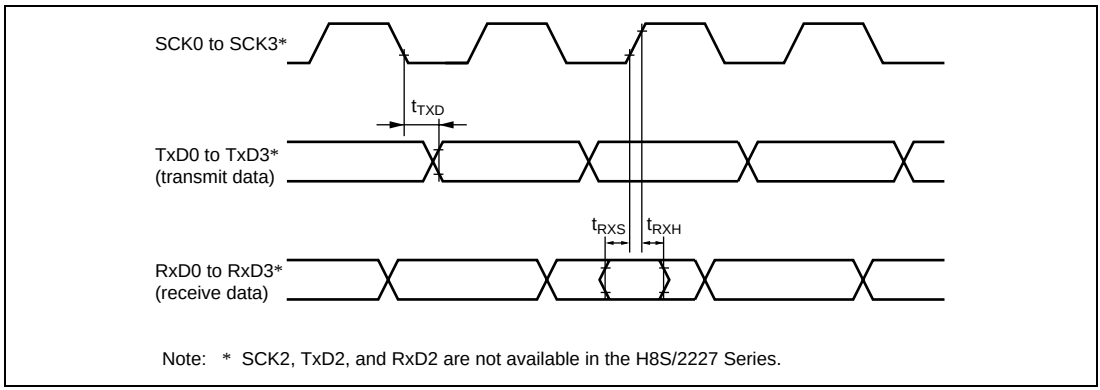


Figure 25.27 SCI Input/Output Timing (Clocked Synchronous Mode)

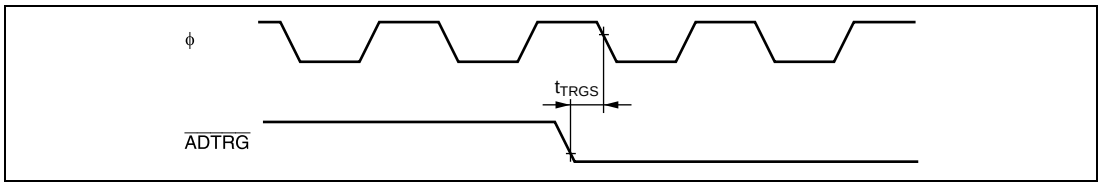


Figure 25.28 A/D Converter External Trigger Input Timing

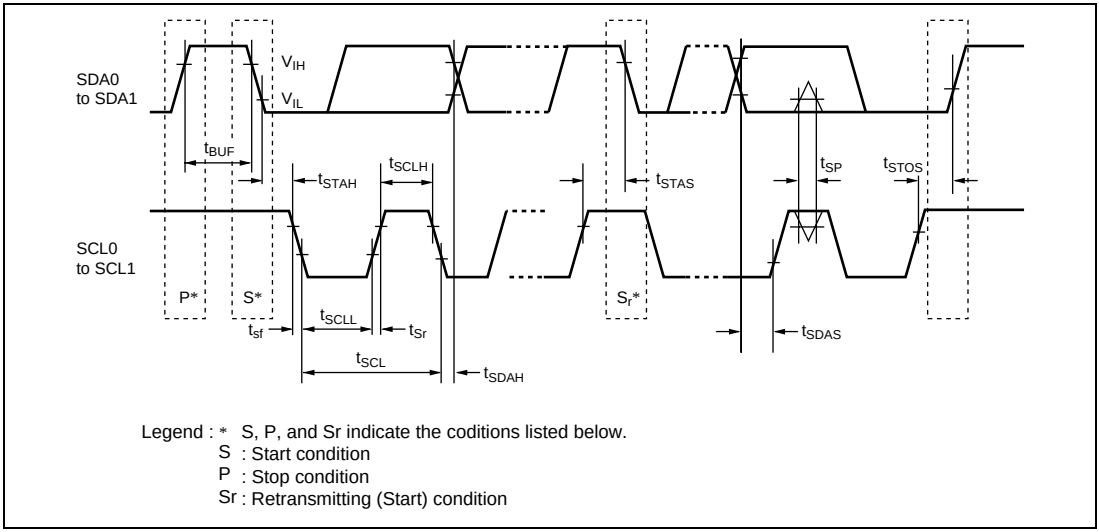


Figure 25.29 I^2C Bus Interface Input/Output Timing (Optional)

25.6 Usage Note

Though the F-ZTAT version and the masked ROM version satisfy electrical characteristics described in this manual, the actual value of electrical characteristics, operating margin, and noise margin may differ due to the differences of production process, on-chip ROM, and layout patterning.

When the system has been evaluated with the F-ZTAT version, the equivalent evaluation should be implemented to the masked ROM version when shifted to the masked ROM version.

Appendix A I/O Port States in Each Pin State

A.1 I/O Port State in Each Pin State

Port Name / Pin Name	MCU Operating Mode	Power-On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode, Watch Mode	Bus Mastership Release State	Program Execution State, Sleep Mode, Subsleep Mode
P17 to P14	4 to 7	T	keep	T	keep	keep	I/O port
P13/TIOCD0/TCLKB/A23 P12/TIOCC0/TCLKA/A22 P11/TIOCB0/A21	7	T	keep	T	keep	keep	I/O port
When the address output is selected by the AEn bit	4 to 6	T	keep	T	[OPE = 0] T [OPE = 1] keep	T	Address output
When a port is selected	4 to 6	T	keep	T	keep	keep	I/O port
P10/TIOCA0/DACK0*[3]/A20	7	T	keep	T	keep	keep	I/O port
When the address output is selected by the AEn bit	4, 5	L	keep	T	[OPE = 0] T [OPE = 1] keep	T	Address output
	6	T					
When a port is selected	4 to 6	T*[1]	keep	T	keep	keep	I/O port

Port Name / Pin Name	MCU Operating Mode	Power-On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode, Watch Mode	Bus Mastership Release State	Program Execution State, Sleep Mode, Subsleep Mode
Port 3	4 to 7	T	keep	T	keep	keep	I/O port
Port 4	4 to 7	T	T	T	T	T	Input port
P77 to P74	4 to 7	T	keep	T	keep	keep	I/O port
P73/TMO1/ TEND1*[3]/CS7	7	T	keep	T	keep	keep	I/O port
P72/TMO0/ TEND0*[3]/CS6 P71/TMRI23*[2]/ TMCI23*[2]/ DREQ1*[3]/CS5 P70/TMRI01/ TMCI01/ DREQ0*[3]/CS4	4 to 6	T	keep	T	[DDR · OPE = 0] T [DDR · OPE = 1] H	T	[DDR = 0] Input port [DDR = 1] CS7 to CS4
P97/DA1*[4] P96/DA0*[4]	4 to 7	T	T	T	[DAOEn = 1] keep [DAOEn = 0] T	keep	Input port
Port A	7	T	keep	T	keep	keep	I/O port
When the address output is selected by the AEn bit	4, 5	L	keep	T	[OPE = 0] T [OPE = 1] keep	T	Address output
	6	T					
When a port is selected	4 to 6	T*[1]	keep	T	keep	keep	I/O port

Port Name / Pin Name		MCU Operating Mode	Power-On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode, Watch Mode	Bus Mastership Release State	Program Execution State, Sleep Mode, Subsleep Mode
Port B		7	T	keep	T	keep	keep	I/O port
	When the address output is selected by the AEn bit	4, 5	L	keep	T	[OPE = 0] T [OPE = 1] keep	T	Address output
		6	T					
	When a port is selected	4 to 6	T*[1]	keep	T	keep	keep	I/O port
Port C		4, 5	L	keep	T	[OPE = 0] T [OPE = 1] keep	T	Address output
		6	T	keep	T	[DDR · OPE = 0] T [DDR · OPE = 1] keep	T	[DDR = 0] Input port [DDR = 1] Address output
		7	T	keep	T	keep	keep	I/O port
Port D		4 to 6	T	T	T	T	T	Data bus
		7	T	keep	T	keep	keep	I/O port
Port E	8-bit bus	4 to 6	T	keep	T	keep	keep	I/O port
	16-bit bus	4 to 6	T	T	T	T	T	Data bus
		7	T	keep	T	keep	keep	I/O port

Port Name Pin Name	MCU Operating Mode	Power-On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode, Watch Mode	Bus Mastership Release State	Program Execution State, Sleep Mode, Subsleep Mode
PF7/φ	4 to 6	Clock output	[DDR = 0] Input port [DDR = 1] Clock output	T	[DDR = 0] Input port [DDR = 1] H	[DDR = 0] Input port [DDR = 1] Clock output	[DDR = 0] Input port [DDR = 1] Clock output
	7	T	keep	T	[DDR = 0] Input port [DDR = 1] H	[DDR = 0] Input port [DDR = 1] Clock output	[DDR = 0] Input port [DDR = 1] Clock output
PF6/AS PF5/RD PF4/HWR	4 to 6	H	H	T	[OPE= 0] T [OPE= 1] H	T	AS, RD, HWR
	7	T	keep	T	keep	keep	I/O port
PF3/LWR/ ADTRG/IRQ3	7	T	keep	T	keep	keep	I/O port
8-bit bus	4 to 6	(Mode 4) H (Mode 5, 6) T	keep	T	keep	keep	I/O port
16-bit bus	4 to 6		H	T	[OPE = 0] T [OPE = 1] H	T	LWR
PF2/WAIT	4 to 6	T	keep	T	[WAITE = 0] keep [WAITE = 1] T	[WAITE= 0] keep [WAITE= 1] T	[WAITE= 0] I/O port [WAITE= 1] WAIT
	7	T	keep	T	keep	keep	I/O port
PF1/BACK/ BUZZ	4 to 6	T	keep	T	[BRLE = 0] keep [BRLE = 1] H	L	[BRLE = 0] I/O port [BRLE = 1] BACK
	7	T	keep	T	keep	keep	I/O port

Port Name Pin Name	MCU Operating Mode	Power-On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode, Watch Mode	Bus Mastership Release State	Program Execution State, Sleep Mode, Subsleep Mode
PF0/BREQ/ IRQ2	4 to 6	T	keep	T	[BRLE = 0] keep [BRLE = 1] T	T	[BRLE = 0] I/O port [BRLE = 1] BREQ
	7	T	keep	T	keep	keep	I/O port
PG4/CS0	4, 5	H	keep	T	[DDR · OPE = 0] T [DDR · OPE = 1] H	T	[DDR = 0] I/O port [DDR = 1] CS0 (H in sleep mode and subsleep mode.)
	6	T					
	7	T	keep	T	keep	keep	I/O port
PG3/CS1 PG2/CS2 PG1/CS3/ IRQ7	4 to 6	T	keep	T	[DDR · OPE = 0] T [DDR · OPE = 1] H	T	[DDR = 0] Input port [DDR = 1] CS1 to CS3
	7	T	keep	T	keep	keep	I/O port
PG0/IRQ6	4 to 7	T	keep	T	keep	keep	I/O port

Legend

H: High level

L: Low level

T: High-impedance

Keep: The input port becomes high-impedance, and the output port retains its state

DDR: Data direction register

OPE: Output port enable

WAITE: Wait input enable

BRLE: Bus release enable

Notes: 1. The port state is L (address input) in modes 4 and 5.

2. Supported only by the H8S/2239 Series and H8S/2238R Series.

3. Supported only by the H8S/2239 Series.

4. Not available in the H8S/2227 Series.

Appendix B Product Codes

Table B.1 Product Codes of H8S/2239 Series

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)
H8S/2239	Masked-ROM version	Standard product	HD6432239	HD6432239(***)TE	100-pin TQFP (TFP-100B)
				HD6432239(***)TF	100-pin TQFP (TFP-100G)
				HD6432239(***)FA	100-pin QFP (FP-100B)
		On-chip I^2C bus interface product	HD6432239W	HD6432239W(***)TE	100-pin TQFP (TFP-100B)
				HD6432239W(***)TF	100-pin TQFP (TFP-100G)
				HD6432239W(***)FA	100-pin QFP (FP-100B)
	F-ZTAT version	Standard product	HD64F2239	HD64F2239TE13	100-pin TQFP (TFP-100B)
				HD64F2239TF13	100-pin TQFP (TFP-100G)
				HD64F2239FA13	100-pin QFP (FP-100B)

Legend

(***): ROM code

Note: A standard product of F-ZTAT version includes an I^2C bus interface.

Some products above are in the developing or planning stage. Please contact Hitachi agency to confirm the current status of each product.

Table B.2 Product Codes of H8S/2238R Series

Product Type			Product Code	Mark Code	Package (Hitachi Package Code)
H8S/2238	Flash memory version	3V version	HD64F2238R	HD64F2238RTE13	100-pin TQFP (TFP-100B)
				HD64F2238RTF13	100-pin TQFP (TFP-100G)
				HD64F2238RFA13	100-pin QFP (FP-100B)
				HD64F2238RBR13	112-pin TFBGR (BP-112)
		2.2V version	HD64F2238R	HD64F2238RTE6	100-pin TQFP (TFP-100B)
				HD64F2238RTF6	100-pin TQFP (TFP-100G)
				HD64F2238RFA6	100-pin QFP (FP-100B)
				HD64F2238RBR6	112-pin TFBGA (BP-112)
	Masked ROM version	3V version	HD6432238R	HD6432238R(***)TE	100-pin TQFP (TFP-100B)
				HD6432238R(***)TF	100-pin TQFP (TFP-100G)
				HD6432238R(***)FA	100-pin QFP (FP-100B)
				HD6432238R(***)BR	112-pin TFBGA (BP-112)
		On-chip I^2C bus interface product (3V version)	HD6432238RW	HD6432238RW(***)TE	100-pin TQFP (TFP-100B)
				HD6432238RW(***)TF	100-pin TQFP (TFP-100G)
				HD6432238RW(***)FA	100-pin QFP (FP-100B)
				HD6432238RW(***)BR	112-pin TFBGA (BP-112)
H8S/2236	Masked ROM version	3V version	HD6432236R	HD6432236R(***)TE	100-pin TQFP (TFP-100B)
				HD6432236R(***)TF	100-pin TQFP (TFP-100G)
				HD6432236R(***)FA	100-pin QFP (FP-100B)
				HD6432236R(***)BR	112-pin TFBGA (BP-112)
		Version with on-chip I^2C bus interface (3V version)	HD6432236RW	HD6432236RW(***)TE	100-pin TQFP (TFP-100B)
				HD6432236RW(***)TF	100-pin TQFP (TFP-100G)
				HD6432236RW(***)FA	100-pin QFP (FP-100B)
				HD6432236RW(***)BR	112-pin TFBGA (BP-112)

Legend

(***): ROM code

Note: Some products above are in the developing or planning stage. Please contact Hitachi agency to confirm the current status of each product.

Table B.3 Product Codes of H8S/2237 Series and H8S/2227 Series

Product Type		Product Code	Mark Code	Package(Hitachi Package Code)
H8S/2237	Flash memory version	HD6472237	HD6472237TE10	100-pin TQFP (TFP-100B)
			HD6472237TF10	100-pin TQFP (TFP-100G)
			HD6472237F10	100-pin QFP (FP-100A)
			HD6472237FA10	100-pin QFP (FP-100B)
	Masked ROM version	HD6432237	HD6432237(***)TE	100-pin TQFP (TFP-100B)
			HD6432237(***)TF	100-pin TQFP (TFP-100G)
			HD6432237(***)F	100-pin QFP (FP-100A)
			HD6432237(***)FA	100-pin QFP (FP-100B)
H8S/2235	Masked ROM version	HD6432235	HD6432235(***)TE	100-pin TQFP (TFP-100B)
			HD6432235(***)TF	100-pin TQFP (TFP-100G)
			HD6432235(***)F	100-pin QFP (FP-100A)
			HD6432235(***)FA	100-pin QFP (FP-100B)
H8S/2233	Masked ROM version	HD6432233	HD6432233(***)TE	100-pin TQFP (TFP-100B)
			HD6432233(***)TF	100-pin TQFP (TFP-100G)
			HD6432233(***)F	100-pin QFP (FP-100A)
			HD6432233(***)FA	100-pin QFP (FP-100B)
H8S/2227	Flash memory version	HD6472227	HD64F2227TE13	100-pin TQFP (TFP-100B)
			HD64F2227TF13	100-pin TQFP (TFP-100G)
	Masked ROM version	HD6432227	HD6432227(***)TE	100-pin TQFP (TFP-100B)
			HD6432227(***)TF	100-pin TQFP (TFP-100G)
			HD6432227(***)F	100-pin QFP (FP-100A)
			HD6432227(***)FA	100-pin QFP (FP-100B)
H8S/2225*	Masked ROM version	HD6432225	HD6432225(***)TE	100-pin TQFP (TFP-100B)
			HD6432225(***)TF	100-pin TQFP (TFP-100G)
			HD6432225(***)FA	100-pin QFP (FP-100B)
H8S/2224*	Masked ROM version	HD6432224	HD6432224(***)TE	100-pin TQFP (TFP-100B)
			HD6432224(***)TF	100-pin TQFP (TFP-100G)
			HD6432224(***)FA	100-pin QFP (FP-100B)
H8S/2223*	Masked ROM version	HD6432223	HD6432223(***)TE	100-pin TQFP (TFP-100B)
			HD6432223(***)TF	100-pin TQFP (TFP-100G)
			HD6432223(***)FA	100-pin QFP (FP-100B)

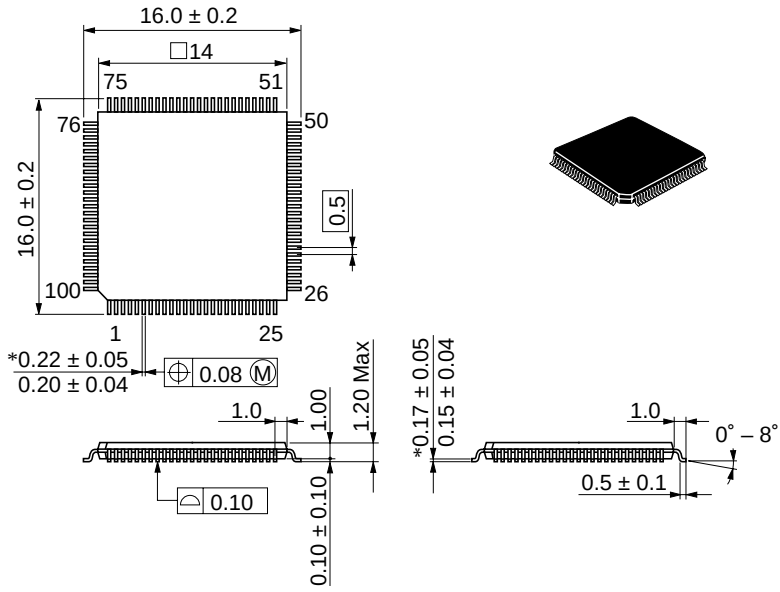
Legend

(***): ROM code

Note: * The 100-pin QFP (FP-100A) is not available for the HD6432225, HD6432224, and HD6432223. When the 100-pin QFP (FP-100A) is necessary, choose HD6432235(***)TF, HD6432233(***)F, or HD6432227(***)F.

Appendix C Package Dimensions

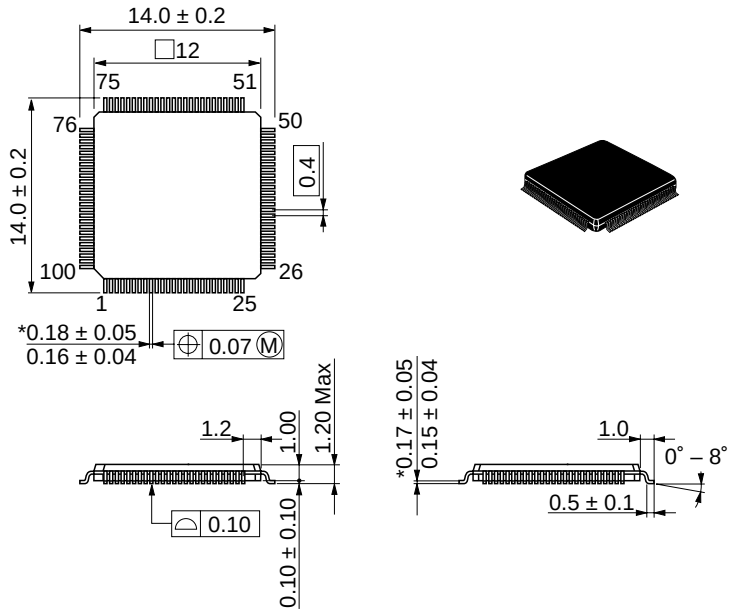
Unit: mm



Hitachi Code	TFP-100B
JEDEC	—
JEITA	Conforms
Mass (reference value)	0.5 g

*Dimension including the plating thickness
Base material dimension

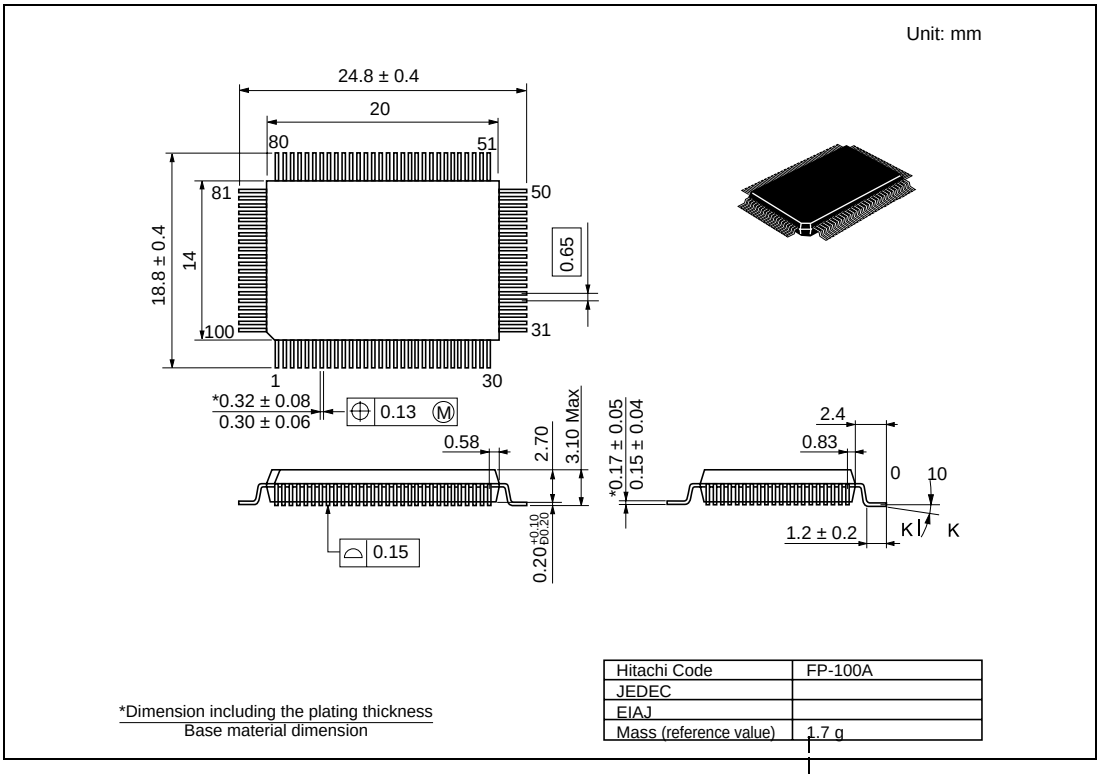
Figure C.1 TFP-100B Package Dimensions



Hitachi Code	TFP-100G
JEDEC	—
JEITA	Conforms
Mass (reference value)	0.4 g

*Dimension including the plating thickness
Base material dimension

Figure C.2 TFP-100G Package Dimensions

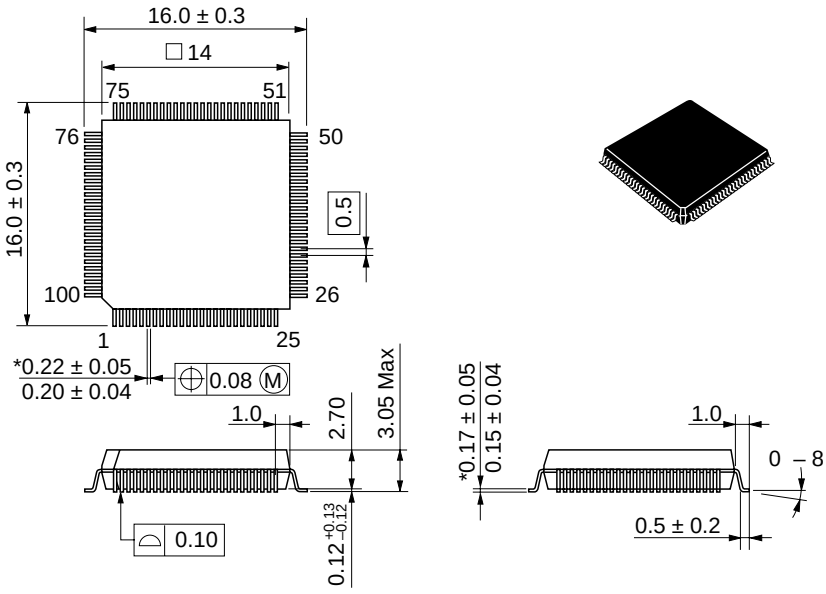


Hitachi Code	FP-100A
JEDEC	
EIAJ	
Mass (reference value)	1.7 g

*Dimension including the plating thickness
Base material dimension

Figure C.3 FP-100A Package Dimensions

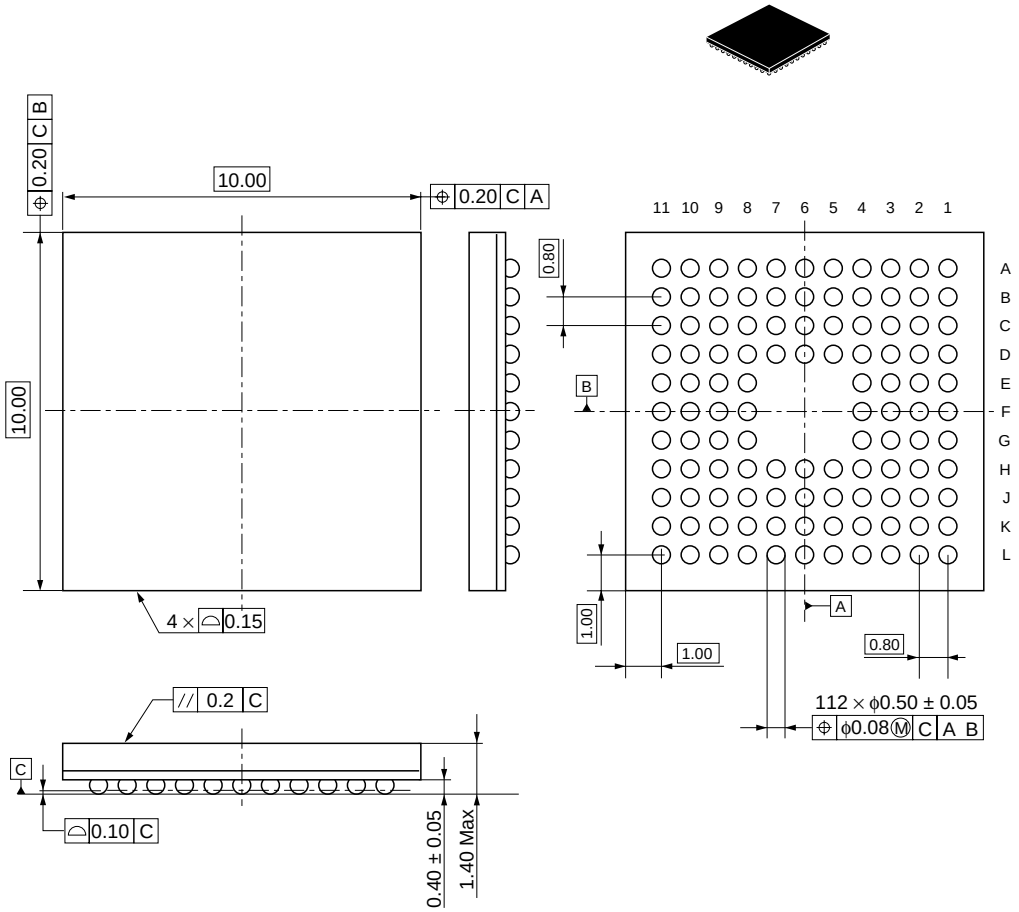
Unit: mm



Hitachi Code	FP-100B
JEDEC	—
EIAJ	Conforms
Weight (reference value)	1.2 g

*Dimension including the plating thickness
Base material dimension

Figure C.4 FP-100B Package Dimensions



Hitachi Code	BP-112
JEDEC	–
JEITA	–
Mass (reference value)	0.3 g

Figure C.5 BP-112 Package Dimensions

Index

16-Bit Access Space 156
16-Bit Count Mode 425
16-Bit Timer Pulse Unit 331
8-Bit Access Space 156
8-Bit Timers 411
A/D Conversion Time 582
A/D Converter 573
A/D Converter Activation 395
Absolute Address 74
ABWCR 142, 689, 699, 710
Activation by Auto-Request 208
Activation by External Request 208
Activation by Software 277
ADCR 579, 693, 705, 713
ADCSR 577, 693, 705, 713
ADDR 576, 693, 705, 713
Address Space 52
Addressing Modes 72
ADI 584
Advanced Mode 49
Analog Input Channel 576
Arithmetic Operations Instructions 64
ASTCR 142, 689, 699, 710
Asynchronous Mode 482
BARA 132, 687, 696, 707
BARB 133, 687, 696, 707
Basic Bus Interface 156
Bcc 69
BCRA 133, 687, 696, 707
BCRB 134, 687, 696, 707
BCRH 146, 689, 699, 710
BCRL 147, 689, 699, 710
Bit Manipulation Instructions 67
bit rate 471
Bit Rate 471
Block Data Transfer Instructions 71
block transfer mode 271
Block Transfer Mode 227
Boot Mode 617
Branch Instructions 69
Break 522
break address 131, 134
break conditions 134
BRR 471, 692, 703, 712
Buffer Operation 377
Burst Mode 235
Burst ROM Interface 168
Bus Arbitration 175
Bus Control 149
bus cycle 153
Cascaded Connection 425
Cascaded Operation 380
Chain Transfer 273
Clock Pulse Generator 651
CMIA 426
CMIB 426
Compare-Match Count Mode 426
Condition Field 71
Condition-Code Register 56
Controller 139
CPU 45
CRA 262, 685, 695, 706
CRB 262, 685, 695, 706
Cycle Steal Mode 234
D/A Converter 591
DACR 593, 686, 695, 706
DADR 592, 685, 695, 706
DAR 261, 685, 695, 706
data direction register 281
data register 281
Data Transfer Controller 257
Data Transfer Instructions 63
DDCSWR 547, 686, 695, 706
DEND0A 252
DEND0B 252
DEND1A 252
DEND1B 252
Direct Transitions 681

DMA Controller (DMAC) 179
DMABCR 193, 691, 703, 712
DMACR 185, 691, 703, 712
DMATCR 206, 691, 703, 712
DMAWER 204, 691, 703, 712
DTC Vector Table 265
DTCER 262, 687, 697, 707
DTVECR 263, 687, 697, 707
Dual Address Mode 233
EBR1 ..... 610, 694, 705, 714
EBR2 ..... 612, 694, 705, 714
Effective Address 76
Effective Address Extension 71
Emulation 621
Erase/Erase-Verify 625
erasing units 604
ERI 520
Error Protection 627
ETCR 184, 689, 700, 710
Exception Handling 95
Exception Handling Vector Table 96
Extended Control Register 55
External Trigger Input Timing 584
flash memory 599
FLMCR1 ..... 609, 694, 705, 714
FLMCR2 ..... 610, 694, 705, 714
FLPWCR 615, 694, 705, 714
framing error 489
Free-running count operation 371
General Registers 54
Hardware Protection 627
Hardware Standby Mode 676
I²C bus format 547
I²C Bus Interface 529
ICCR 540, 692, 703, 712
ICDR 533, 692, 704, 712
ICMR 536, 704, 712
ICMR/SAR 692
ICSR 544, 692, 703, 712
Idle Cycle 170
Idle Mode 214
IER 107, 687, 697, 707
Immediate 74
Input Capture Function 374
input pull-up MOS 281
Instruction Set 61
Internal Block Diagram 3
internal bus masters 139
Interrupt Control Modes 118
Interrupt Controller 103
Interrupt Exception Handling Sequence 124
Interrupt Exception Handling Vector Table 112
Interrupt Mask Bit 56
Interrupts 100
Interval Timer Mode 442
IOAR 183, 689, 700, 710
IPR 106, 689, 699, 709
ISCR 107, 687, 697, 707
ISR 110, 687, 697, 707
List of Registers 685
Logic Operations Instructions 66
LPWRCR 653, 686, 696, 707
MAR 183, 689, 700, 710
Mark State 522
Mask ROM 637
Master Receive Operation 550
Master Transmit Operation 549
MDCR 82, 686, 696, 707
Medium-Speed Mode 672
memory cycle 153
Memory Indirect 75
Memory Map 87
Module Stop Mode 677
MRA 260, 685, 695, 706
MRB 261, 685, 695, 706
MSTPCR 671, 686, 696, 707
Multi-Channel Operation 247
Multiprocessor Communication Function 493
NMI Interrupt 111
NMI interrupt request 444
Noise Chancellor 560
Normal Mode 48, 224, 269, 278
On-Board Programming 617
open-drain control register 281

Operating Mode Selection 81
Operation Field..... 71
overflow..... 442
overrun error 489
OVI 426
P1DDR 285, 687, 697, 708
P1DR..... 286, 690, 701, 710
P3DDR 291, 687, 697, 708
P3DR..... 292, 690, 701, 710
P3ODR..... 293, 688, 697, 708
P7DDR 297, 687, 697, 708
P7DR..... 297, 690, 701, 710
PADDR..... 302, 687, 697, 708
PADR 302, 690, 701, 710
PAODR 303, 688, 697, 708
PAPCR..... 303, 687, 697, 708
parity error..... 489
PBDDR..... 307, 687, 697, 708
PBDR 308, 690, 701, 710
PBPCR..... 309, 687, 697, 708
PC Break Controller..... 131
PCDDR 314, 687, 697, 708
PCDR 314, 690, 701, 710
PCPCR..... 315, 687, 697, 708
PDDDR 317, 687, 697, 708
PDDR 317, 690, 701, 710
PDPCR..... 318, 688, 697, 708
PEDDR..... 320, 687, 697, 708
PEDR 321, 690, 701, 710
PEPCR..... 322, 688, 697, 708
Periodic count operation 371
PFCR..... 148, 686, 696, 707
PFDDR..... 324, 687, 697, 708
PFDR..... 324, 690, 701, 710
PGDDR 328, 687, 697, 708
PGDR..... 328, 690, 701, 710
Phase Counting Mode 387
Pin Arrangements in Each Mode..... 14
Pin Functions 34
pointer (SP)..... 54
port register..... 281
PORT1 ..... 286, 694, 705, 714
PORT3..... 292, 694, 705, 714
PORT4..... 296, 694, 705, 714
PORT7..... 298, 694, 705, 714
PORT9..... 301, 694, 705, 714
PORTA 303, 694, 705, 714
PORTB 308, 694, 705, 714
PORTC 315, 694, 705, 714
PORTD 318, 694, 705, 714
PORTE 321, 694, 705, 714
PORTF..... 325, 694, 705, 714
PORTG..... 329, 694, 705, 714
Power-Down Modes 665
Program Counter 55
Program/Erase Protection 627
Program/Program-Verify 623
Program-Counter Relative..... 75
Programmer Mode..... 628
PROM..... 639
Pulse Output..... 421
PWM Modes..... 382
RAM..... 597
RAMER..... 613, 689, 700, 710
RDR..... 454, 692, 704, 712
Register Addresses (in address order) 685
Register Bits 695
Register Configuration..... 53
Register Direct..... 73
Register Field 71
Register Indirect 73
Register Indirect with Displacement..... 73
Register Indirect with Post-Increment 73
Register Indirect with Pre-Decrement 73
Register Information 265
Register States in Each Operating Mode..... 706
repeat mode..... 270
Repeat Mode 216
Reset 97
Reset Exception Handling 98
ROM 599
RSR 454
RSTCSR..... 440, 692, 703, 712
RXI..... 520

SAR.....261, 535, 685, 692, 695, 704, 706, 712
SARX.....535, 692, 704, 712
SBYCR.....669, 686, 696, 707
Scan Mode.....581
SCKCR.....652, 686, 696, 707
SCMR.....470, 692, 704, 712
SCR.....458, 692, 704, 712
SCRX.....539, 686, 695, 706
SEMR.....478, 686, 696, 707
Sequential Mode.....211
Serial Communication Interface.....449
serial format.....547
Shift Instructions.....66
Single Address Mode.....220, 241
Single Mode.....580
Slave Receive Operation.....553
Slave Transmit Operation.....555
Sleep Mode.....673
Smart Card.....449
Smart Card Interface.....507
SMR.....455, 692, 703, 712
software activation.....274, 278
Software Protection.....627
Software Standby Mode.....674
SSR.....463, 692, 704, 712
Stack Status.....101
Stack Structure.....48, 50
Sub-Active Mode.....680
Sub-Sleep Mode.....679
SWDTEND.....274
Synchronous Mode.....499
Synchronous Operation.....375
SYSCR.....83, 686, 696, 707
System Control Instructions.....70
TCI1U.....394
TCI1V.....394
TCI2U.....394
TCI2V.....394
TCI3V.....394
TCI4U.....394
TCI4V.....394
TCI5U.....394
TCI5V.....394
TCNT.....368, 414, 435, 690, 692, 701, 703, 711, 712
TCNT Incrementation Timing.....422
TCORA.....414, 692, 703, 712
TCORB.....414, 692, 703, 712
TCR.....339, 415, 690, 691, 701, 703, 711, 712
TCSR.....417, 435, 691, 692, 703, 712
TDR.....454, 692, 704, 712
TEI.....520
TGI0A.....394
TGI0B.....394
TGI0C.....394
TGI0D.....394
TGI0V.....394
TGI1A.....394
TGI1B.....394
TGI2A.....394
TGI2B.....394
TGI3A.....394
TGI3B.....394
TGI3C.....394
TGI3D.....394
TGI4A.....394
TGI4B.....394
TGI5A.....394
TGI5B.....394
TGR.....368, 690, 701, 711
TIER.....363, 690, 701, 711
TIOR.....345, 690, 701, 711
TMDR.....344, 690, 701, 711
Toggle output.....373, 429
Traces.....99
Transfer Mode.....209
Trap Instruction.....100
TSR.....365, 454, 690, 701, 711
TSTR.....368, 689, 699, 709
TSYR.....369, 689, 699, 709
TXI.....520
User Program Mode.....620
Valid Strobes.....157
vector number for the software activation interrupt.....263
Wait Control.....166, 170

Watch Mode 678
Watchdog Timer 433
Watchdog Timer Mode 441
Waveform Output by Compare Match 372
WCRH 143, 689, 699, 710
WCRL 143, 689, 699, 710
WOVI 444

H8S/2239 Series, H8S/2238R Series, H8S/2237 Series,

H8S/2227 Series, Hardware Manual

Publication Date: 1st.Edition, September 2002
Published by: Business Operation Division
Semiconductor & Integrated Circuits
Hitachi, Ltd.
Edited by: Technical Documentation Group
Hitachi Kodaira Semiconductor Co., Ltd.
Copyright © Hitachi, Ltd., 2002. All rights reserved. Printed in Japan.