REJ09B0300-0300

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The revision list summarizes the locations of revisions and additions. Details should always be checked by referring to the relevant text.

16

H8S/2140B Group Hardware Manual

Renesas 16-Bit Single-Chip Microcomputer H8S Family/H8S/2100 Series

H8S/2161B	HD64F2161BV
H8S/2160B	HD64F2160BV
H8S/2141B	HD64F2141BV
H8S/2140B	HD64F2140BV
H8S/2145B	HD64F2145BV
	HD64F2145B
H8S/2148B	HD64F2148BV
	HD64F2148B

Hardware Manual

Rev. 3.00
Revision Date: Mar 21, 2006

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General Precautions on Handling of Product

1. Treatment of NC Pins

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

2. Treatment of Unused Input Pins

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

3. Processing before Initialization

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

4. Prohibition of Access to Undefined or Reserved Addresses

Note: Access to undefined or reserved addresses is prohibited.
The undefined or reserved addresses may be used to expand functions, or test registers may have been 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. Main Revisions for This Edition

   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.
5. Contents
6. Overview
7. 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.

8. List of Registers
9. Electrical Characteristics
10. Appendix
11. Index

Preface

The H8S/2140B Group are microcomputers (MCUs) made up of the H8S/2000 CPU employing Renesas Technology original architecture as their cores, and the peripheral functions required to configure a system.

The H8S/2000 CPU has an internal 32-bit configuration, sixteen 16-bit general registers, and a simple and optimized instruction set for high-speed operation. The H8S/2000 CPU can handle a 16-Mbyte linear address space.

This LSI is equipped with a data transfer controller (DTC) as a bus master, ROM, RAM, an 8-bit PWM timer (PWM), a 14-bit PWM timer (PWMX), a 16-bit free-running timer (FRT), an 8-bit timer (TMR), timer connection, a watchdog timer (WDT), a serial communication interface (SCI), a keyboard buffer controller, a host interface X-bus interface (XBS), a host interface LPC interface (LPC), an 8-bit D/A converter, a 10-bit A/D converter, and I/O ports as on-chip peripheral modules required for system configuration. An I^2C bus interface (IIC) can also be included as an optional interface.

A high-functionality bus controller is also provided, enabling fast and easy connection of DRAM and other kinds of memory.

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

Note: * F-ZTAT is a trademark of Renesas Technology Corp.

Target Users: This manual was written for users who will be using the H8S/2140B Group in the design of application systems. Target users are expected to understand the fundamentals of electrical circuits, logical circuits, and microcomputers.

Objective: This manual was written to explain the hardware functions and electrical characteristics of the H8S/2140B Group to the target users.
Refer to the H8S/2600 Series, H8S/2000 Series Programming Manual for a detailed description of the instruction set.

Notes on reading this manual:

- In order to understand the overall functions of the chip
  Read the manual according to the contents. This manual can be roughly categorized into parts on the CPU, system control functions, peripheral functions and electrical characteristics.

- In order to understand the details of the CPU's functions
  Read the H8S/2600 Series, H8S/2000 Series Programming Manual.
- In order to understand the details of a register when its name is known

  Read the index that is the final part of the manual to find the page number of the entry on the register. The addresses, bits, and initial values of the registers are summarized in section 27, List of Registers.

Rules:	Register name:	The following notation is used for cases when the same or a similar function, e.g. serial communication interface, 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, 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 you require.
http://www.renesas.com/

H8S/2140B Group manuals:

Document Title	Document No.
H8S/2140B Group Hardware Manual	This manual
H8S/2600 Series, H8S/2000 Series Programming Manual	REJ09B0139

User's manuals for development tools:

Document Title	Document No.
H8S, H8/300 Series C/C++ Compiler, Assembler, Optimizing Linkage Editor User's Manual	REJ10B0058
H8S, H8/300 Series Simulator/Debugger User's Manual	ADE-702-282
H8S, H8/300 Series High-performance Embedded Workshop, High-performance Debugging Interface Tutorial	ADE-702-231
High-performance Embedded Workshop User's Manual	ADE-702-201

Main Revisions for This Edition

Item	Page	Revision (See Manual for Details)
All	—	• Notification of change in company name amended (Before) Hitachi, Ltd. → (After) Renesas Technology Corp. • Product naming convention amended (Before) H8S/2140B Series → (After) H8S/2140B Group
1.1 Features	1	• Various peripheral functions Note * added Host Interface LPC interface* Note: * The LPC function is not supported by H8S/2148B and H8S/2145B (5-V version).
	2	• On-chip memory Table amended

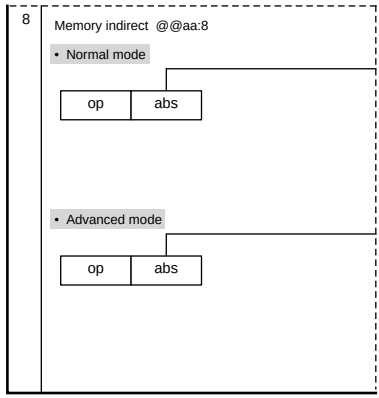
ROM	Model	ROM	RAM	Remarks
F-ZTAT Version	HD64F2161BV*	128 kbytes	4 kbytes	
	HD64F2160BV*	64 kbytes	4 kbytes	
	HD64F2141BV*	128 kbytes	4 kbytes	
	HD64F2140BV*	64 kbytes	4 kbytes	
	HD64F2145BV*	256 kbytes	8 kbytes	Under development
	HD64F2145B	256 kbytes	8 kbytes	
	HD64F2148BV*	128 kbytes	4 kbytes	
	HD64F2148B	128 kbytes	4 kbytes	

		• Compact package Table amended (Before) 18.0 × 18.0 mm → (After) 16.0 × 16.0 mm (Before) 16.0 × 16.0 mm → (After) 14.0 × 14.0 mm
1.2 Block Diagram Figure 1.1 Internal Block Diagram of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B	3	Note amended Note: * The LPC function and the $\overline{\text{WUE}}$ pin function are not supported by the H8S/2148B and H8S/2145B (5-V version).
Figure 1.2 Internal Block Diagram of H8S/2160B and H8S/2161B	4	Figure 1.2 amended (Before) ROM (Flash memory, Masked ROM) → (After) ROM (Flash memory)

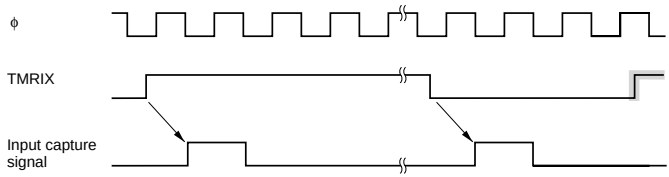
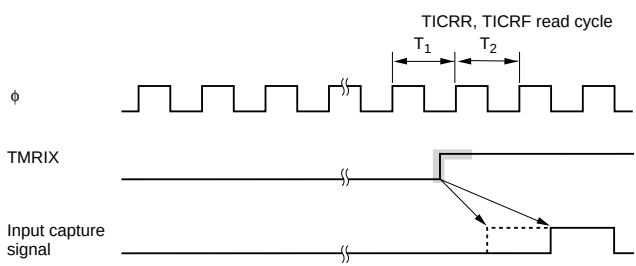
Item	Page	Revision (See Manual for Details)
1.3.1 Pin Arrangement Figure 1.3 Pin Arrangement of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B	5	Note amended Note: * The LPC function and the $\overline{\text{WUE}}$ pin function are not supported by the H8S/2148B and H8S/2145B (5-V version).
1.3.2 Pin Functions in Each Operating Mode Table 1.1 Pin Functions of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B in Each Operating Mode	11	Note * amended Note: * The LPC function and the $\overline{\text{WUE}}$ pin function are not supported by the H8S/2148B and H8S/2145B (5-V version).
2.4.4 Condition-Code Register (CCR)	36	Table amended Interrupt Mask Bit Masks interrupts when set to 1. NMI is accepted …
2.6.1 Table of Instructions Classified by Function Table 2.7 Bit Manipulation Instructions (1)	46	Table amended

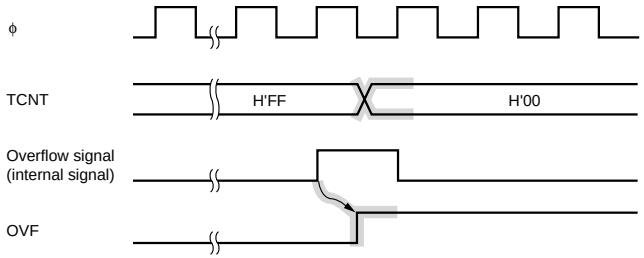
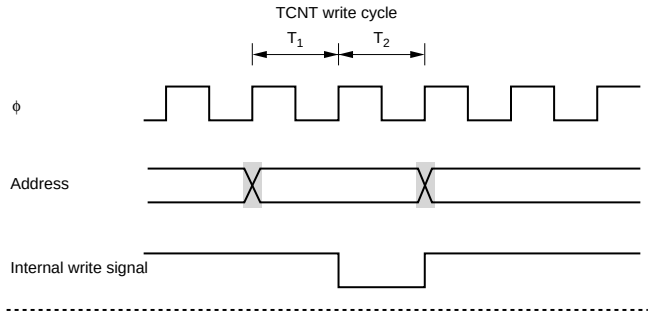
Instruction	Size*	Function
BIAND	B	C ∧ [~(<bit-No.> of <EAd>)] → C Logically ANDs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.
BIOR	B	C ∨ [~(<bit-No.> of <EAd>)] → C Logically ORs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.

2.7.5 Absolute Address—@aa:8, @aa:16, @aa:24, or @aa:32	53	Description amended … absolute address, the upper 24 bits are all assumed …

Item	Page	Revision (See Manual for Details)
2.7.9 Effective Address Calculation Table 2.13 Effective Address Calculation (2)	56	Table amended 
3.4 Address Map in Each Operating Mode Figure 3.7 Address Map for H8S/2145B (1) Figure 3.8 Address Map for H8S/2145B (2)	77, 78	Figure 3.7 and Figure 3.8 added
Figure 3.9 Address Map for H8S/2148B(1)	79	Figure 3.9 amended H'01FFFF H'020000 H'FFE080
4.7 Usage Note Figure 4.3 Operation when SP Value Is Old	87	Figure 4.3 amended H'FFEFFF
5.2 Input/Output Pins Table 5.1 Pin Configuration	91	Note * amended Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).
5.3.7 Keyboard Matrix Interrupt Mask Registers (KMIMRA, KMIMR) and Wake-Up Event Mask Register (WUEMRB)	98	• WUEMRB* Note * amended Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).

Item	Page	Revision (See Manual for Details)
5.6 Interrupt Control Modes and Interrupt Operation Table 5.4 Interrupt Control Modes	105	Table amended **Description** Interrupt mask control is performed by the I bit. Priority levels can be set with ICR. 3-level interrupt mask control is performed by the I and UI bits. Priority levels can be set with ICR.
5.6.5 DTC Activation by Interrupt	114	Description amended … the DTCE bit of DTC's DTCER, and the DISEL bit of …
7.2.8 DTC Vector Register (DTVECR)	151	Description amended … software activation interrupt. DTVECR is initialized to H'00 at a reset and in hardware standby mode.
7.4 Location of Register Information and DTC Vector Table Table 7.1 Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs	154	Note 2 amended Note: 2. Not supported by the H8S/2148B and H8S/2145B (5-V version).
8.1 Overview	167	Description amended … in addition to DDR, to control the on/off …
Table 8.1 Port Functions of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B	171	Note * amended Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).
8.4.4 Pin Functions	181	• P37/D15/HDB7/SERIRQ*, ... , P30/D8/HDB0/LAD0* Note amended Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).

Item	Page	Revision (See Manual for Details)
8.9.3 Pin Functions	197	• P83/$\overline{\text{LPCPD}}$*2 Note 2 amended Note: 2. Not supported by the H8S/2148B and H8S/2145B (5-V version).
	198	• P82/HIFSD/$\overline{\text{CLKRUN}}$*2 Note 2 amended Note: 2. Not supported by the H8S/2148B and H8S/2145B (5-V version).
	199	• P80/HA0/$\overline{\text{PME}}$*3 Note 3 amended Note: 3. Not supported by the H8S/2148B and H8S/2145B (5-V version).
8.12.4 Pin Functions	213 to 215	• PB7/D7/$\overline{\text{WUE7}}$*2, PB6/D6/$\overline{\text{WUE6}}$*2, PB5/D5/$\overline{\text{WUE5}}$*2, PB4/D4/$\overline{\text{WUE4}}$*2 to • PB0/D0/$\overline{\text{WUE0}}$/HIRQ3/LSMI*4 Notes amended Note: Not supported by the H8S/2148B and H8S/2145B (5-V version).
11.3.6 Timer Interrupt Enable Register (TIER)	265	Table amended Initial Value (Before) 0 → (After) 1
12.7 Input Capture Operation Figure 12.11 Timing of Input Capture Operation	307	Figure 12.11 amended 
Figure 12.12 Timing of Input Capture Signal (Input capture signal is input during TICRR and TICRF read)	307	Figure 12.12 amended 

Item	Page	Revision (See Manual for Details)
14.4.2 Interval Timer Mode Figure 14.4 OVF Flag Set Timing	354	Figure 14.4 amended 
14.6.2 Conflict between Timer Counter (TCNT) Write and Increment Figure 14.7 Conflict between TCNT Write and Increment	357	Figure 14.7 amended 
15.1 Features Figure 15.1 Block Diagram of SCI	360	Figure legend amended (Before) SCMR: Smart card mode register → (After) SCMR: Serial interface mode register
16.3.5 I²C Bus Control Register (ICCR)	424	Table amended

Bit	Bit Name	Initial Value	R/W	Description
5	MST	0	R/W	Master/Slave Select
4	TRS	0	R/W	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 with the I²C bus format. In slave receive mode with I²C bus format, the R/$\overline{W}$ bit in the first frame immediately after the start condition sets these bits in receive mode or transmit mode automatically by hardware. Modification of the TRS bit during transfer is deferred until transfer is completed, and the changeover is made after completion of the transfer.

Item	Page	Revision (See Manual for Details)
16.3.5 I²C Bus Register (ICCR)	427, 428	Table amended Bit 1 R/W of I²C Bus Interface Interrupt Request Flag (Before) R/W → (After) R/(W)*
Table 16.5 Flash and Transfer States (Slave Mode)	430	Table 16.5 amended

MST	TRS	BBSY	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	ICDRF	ICDRE	State
0	1	1	0	0	1↑/0*1	—	—	—	0	0	—	1↑	Transmission end with ICDRE = 0
0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICDR write with the above state
0	1	1	0	0	—	—	—	—	0	0	—	1	Transmission end with ICDRE = 1
0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICDR write with the above state
0	1	1	0	0	1↑/0*2	—	0	0	0	0	—	1↑	Automatic data transfer from ICDRT to ICDRS with the above state

16.4.4 Master Receive Operation Figure 16.12 Example of Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)	451	Figure 16.12 amended

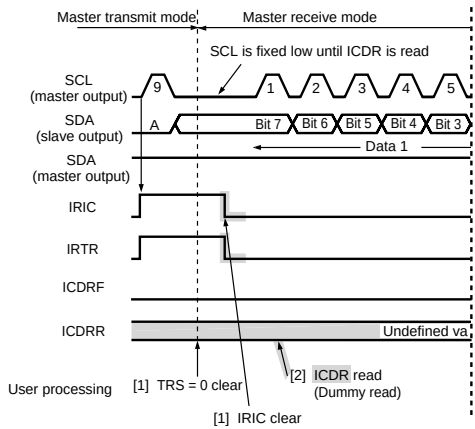
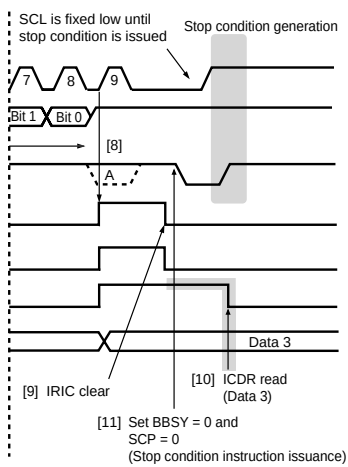
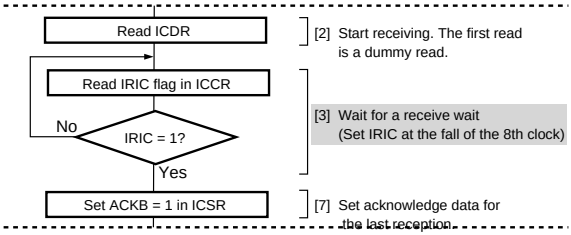
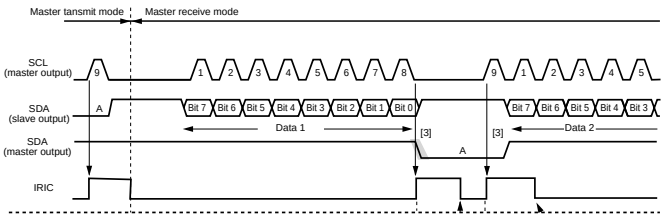


Figure 16.13 Example of Stop Condition Issuance Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)	451	Figure 16.13 amended



Item	Page	Revision (See Manual for Details)
16.4.4 Master Receive Operation Figure 16.15 Sample Flowchart for Operations in Master Receive (Receiving a Single Byte) (WAIT = 1)	453	Figure 16.15 amended 
Figure 16.16 Example of Master Receive Mode Operation Timing (MLS = ACKB = 0, WAIT = 1)	456	Figure 16.16 amended 
16.4.5 Slave Receive Operation Figure 16.22 Example of Slave Receive Mode Operation Timing (1) (MLS = ACKB = 0, HNDS = 0)	464	Figure title amended
Figure 16.23 Example of Slave Receive Mode Operation Timing (2) (MLS = ACKB = 0, HNDS = 0)	464	Figure title amended
16.6 Usage Notes	483	10. Notes on WAIT Function Description added
Figure 16.35 ICDR Read and ICCR Access Riming in Slave Transmit Mode	485	Figure 16.35 amended R/$\overline{W}$
	487, 488	14. Notes on Arbitration Lost in Master Mode Description added

Item	Page	Revision (See Manual for Details)
17.3.1 Keyboard Control Register H (KBCRH)	492	Table amended

Bit	Bit Name	Initial Value	R/W	Description
6	KCLKI	1	R	Keyboard Clock In Monitors the KCLK I/O pin. This bit cannot be modified. 0: KCLK I/O pin is low 1: KCLK I/O pin is high
5	KDI	1	R	Keyboard Data In Monitors the KDI I/O pin. This bit cannot be modified. 0: KD I/O pin is low 1: KD I/O pin is high

19.4.4 Host Interface Shutdown Function (LPCPD) — 569 — Table 19.5 amended

Table 19.5 Scope of Host Interface Pin Shutdown

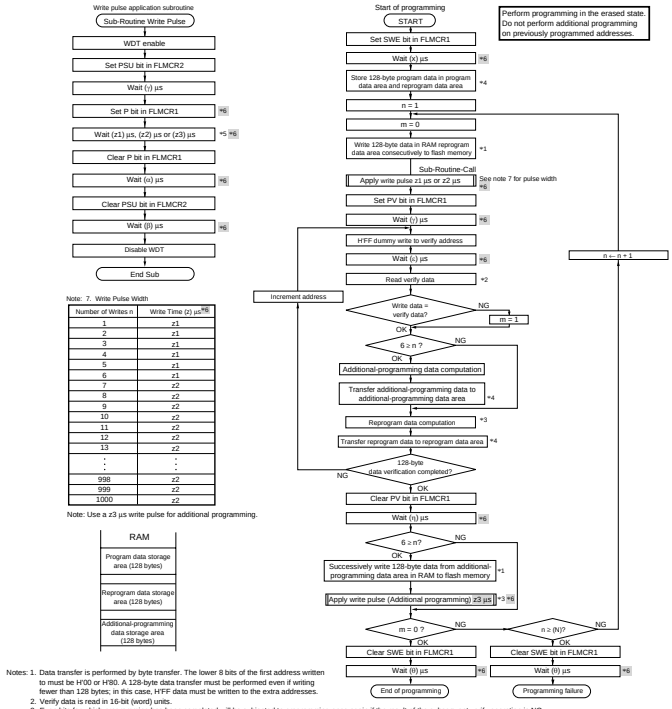
Abbreviation	Port	Scope of Shutdown	I/O	Notes
$\overline{\text{CLKRUN}}$	P82	O	Input	Hi-Z
$\overline{\text{LPCPD}}$	P83	×	Input	Needed to clear shutdown state

Section 22 RAM — 601 — Masked ROM version deleted

Product Classification		RAM Capacitance	RAM Address
Flash memory version	H8S/2161B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2160B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2141B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2140B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2145B	8 kbytes	H'D080–H'EFFF, H'FF00–H'FF7F
	H8S/2148B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F

Section 23 ROM — 603 — Description amended

(Before) This LSI has an on-chip ROM (flash memory or masked ROM). ··· → (After) This LSI has an on-chip flash memory. ···

Item	Page	Revision (See Manual for Details)
23.8.1 Program/ Program-Verify Figure 23.11 Program/Program-Verify Flowchart	625	Figure 23.11 amended  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, HFF data must be written to the extra addresses. 2. Verify data is read in 16-bit (word) units. 3. 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 z1 µs or z2 µs is applied according to the progress of the programming operation. See note 7 for details of the pulse widths. When writing of additional-programming data is executed, a z3 µs write pulse should be applied. Reprogram data when the write pulse is applied. 6. The values of x, y, z1, z2, z3, α, β, γ, ε, η, θ, and N are shown in sections 28.1.6 and 28.2.6, Flash Memory Characteristics. Reprogram Data Computation Table Additional-Programming Data Computation Table
		Section of “Masked ROM” deleted
Section 24 Clock Pulse Generator Figure 24.1 Block Diagram of Clock Pulse Generator	633	Figure 24.1 amended (Before) ϕ2 to f32 → (After) ϕ2 to ϕ32
24.5 Subclock Input Circuit	639	Description of “When Subclock Is Not Needed” and “Note on Subclock Usage” added
25.1.1 Standby Control Register (SBYCR)	643	Table amended … SCK2 to SCK0 must be cleared to B'000.

Item	Page	Revision (See Manual for Details)
25.1.1 Standby Control Register (SBYCR) Table 25.1 Operating Frequency and Wait Time	643	Table amended STS2 STS1 STS0 Wait Time 20 MHz 10 MHz 8 MHz 6 MHz 4 MHz 2 MHz Unit 0 0 0 8192 states 0.4 0.8 1.0 1.3 2.0 4.1 ms
26.1 Register Addresses (Address Order)	670	Note 2 amended Note: 2. Not supported by the H8S/2148B and H8S/2145B (5-V version).
26.2 Register Bits	679	Note 5 amended Note: 5. Not supported by the H8S/2148B and H8S/2145B (5-V version).
26.3 Register States in Each Operating Mode	688	Note 2 amended Note: 2. Not supported by the H8S/2148B and H8S/2145B (5-V version).
26.4 Register Select Conditions	690	Table amended H8S/2160B, H8S/2161B Register Select Condition (Before) — → (After) No condition
27.1.1 Absolute Maximum Ratings Table 27.1 Absolute Maximum Ratings	701	Table 27.1 amended item (Ports C to G are added in the H8S/2160B and H8S/2161B.) input voltage (P97, P86, P52, P42)
27.1.2 DC Characteristics Table 27.2 DC Characteristics (1)	703	Table 27.2 amended Item P97, P86, P52, P42 (Ports C to G are added in the H8S/2160B and H8S/2161B.)

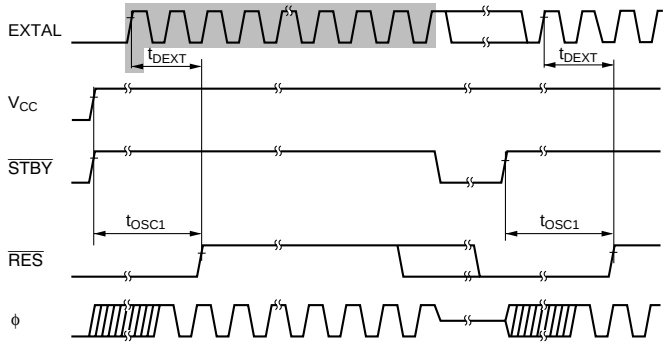
Item	Page	Revision (See Manual for Details)
27.1.6 Flash Memory Characteristics Table 27.15 Flash Memory Characteristics	722	Table 28.15 amended

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Programming time*1 *2 *4	t_P	—	10	200	ms/ 128 bytes	
Erase time*1 *3 *6	t_E	—	100	1200	ms/block	
Reprogramming count	N_{WEC}	100*8	10,000*9	—	times	
Data retention time*10	t_{DRP}	10	—	—	Years	

	723	Notes 8 to 10 added Notes: 8. Minimum number of times for which all characteristics are guaranteed after rewriting (Guarantee range is 1 to minimum value). 9. Reference value for 25°C (as a guideline, rewriting should normally function up to this value). 10. Data retention characteristic when rewriting is performed within the specification range, including the minimum value.
27.2.2 DC Characteristics Table 27.17 DC Characteristics (5)	736	Table 27.17 (5) amended

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 (KWUL = 00)*2 *6, $\overline{KIN15}$ to $\overline{KIN8}$*7 *8, $\overline{IRQ2}$ to $\overline{IRQ0}$*3, $\overline{IRQ5}$ to $\overline{IRQ3}$ (1)	V_T^-	$V_{CC} \times 0.2$ $V_{CC}B \times 0.2$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$ $V_{CC}B \times 0.7$		
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$ $V_{CC}B \times 0.05$	—	—		

27.2.3 AC Characteristics Table 27.23 Timing of On-Chip Peripheral Modules (1)	752	Table 27.23 (1) amended (Before) t_{cscyc} → (After) t_{Scyc}
27.2.7 Usage Notes Figure 27.5 Connection of VCL Capacitor	761	Figure 27.5 amended < Product with internal step-down function > HD64F2145B HD64F2148B

Item	Page	Revision (See Manual for Details)
27.3.1 Clock Timing Figure 27.7 Oscillation Settling Timing	762	Figure 27.7 amended 
Appendix B Product Codes	779	Table amended

Product Type		Product Code	Mark Code	Package (Package Code)
H8S/2145B	Flash memory version (3-V version)	HD64F2145BV	F2145BVFA10	100-pin QFP (FP-100B)
			F2145BVTE10	100-pin TQFP (TFP-100B)
	Flash memory version (5-V version)	HD64F2145B	F2145BFA20	100-pin QFP (FP-100B)
			F2145BTE20	100-pin TQFP (TFP-100B)

Appendix C Package Dimensions Figure C.1 Package Dimensions (FP-100B)	780	Figure replaced
Figure C.2 Package Dimensions (TFP-100B)	781	Figure replaced
Figure C.3 Package Dimensions (TFP-144)	782	Figure replaced

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Appendix A I/O Port States in Each Processing State

Table A.1 I/O Port States in Each Processing State 777

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
  Data transfer controller (DTC)
  8-bit PWM timer (PWM)
  14-bit PWM timer (PWMX)
  16-bit free-running timer (FRT)
  8-bit timer (TMR)
  Timer connection
  Watchdog timer (WDT)
  Asynchronous or clocked synchronous serial communication interface (SCI, IrDA)
  I^2C bus interface (IIC)
  Keyboard buffer controller
  Host interface X-BUS interface (XBS)
  Host interface LPC interface (LPC)*
  8-bit D/A converter
  10-bit A/D converter
  Clock pulse generator

Note: * The LPC function is not supported by H8S/2148B and H8S/2145B (5-V version).

- On-chip memory

ROM	Model	ROM	RAM	Remarks
F-ZTAT Version	HD64F2161BV*	128 kbytes	4 kbytes	
	HD64F2160BV*	64 kbytes	4 kbytes	
	HD64F2141BV*	128 kbytes	4 kbytes	
	HD64F2140BV*	64 kbytes	4 kbytes	
	HD64F2145BV*	256 kbytes	8 kbytes	Under development
	HD64F2145B	256 kbytes	8 kbytes	
	HD64F2148BV*	128 kbytes	4 kbytes	
	HD64F2148B	128 kbytes	4 kbytes	

Note: * 3-V version product

- General I/O ports

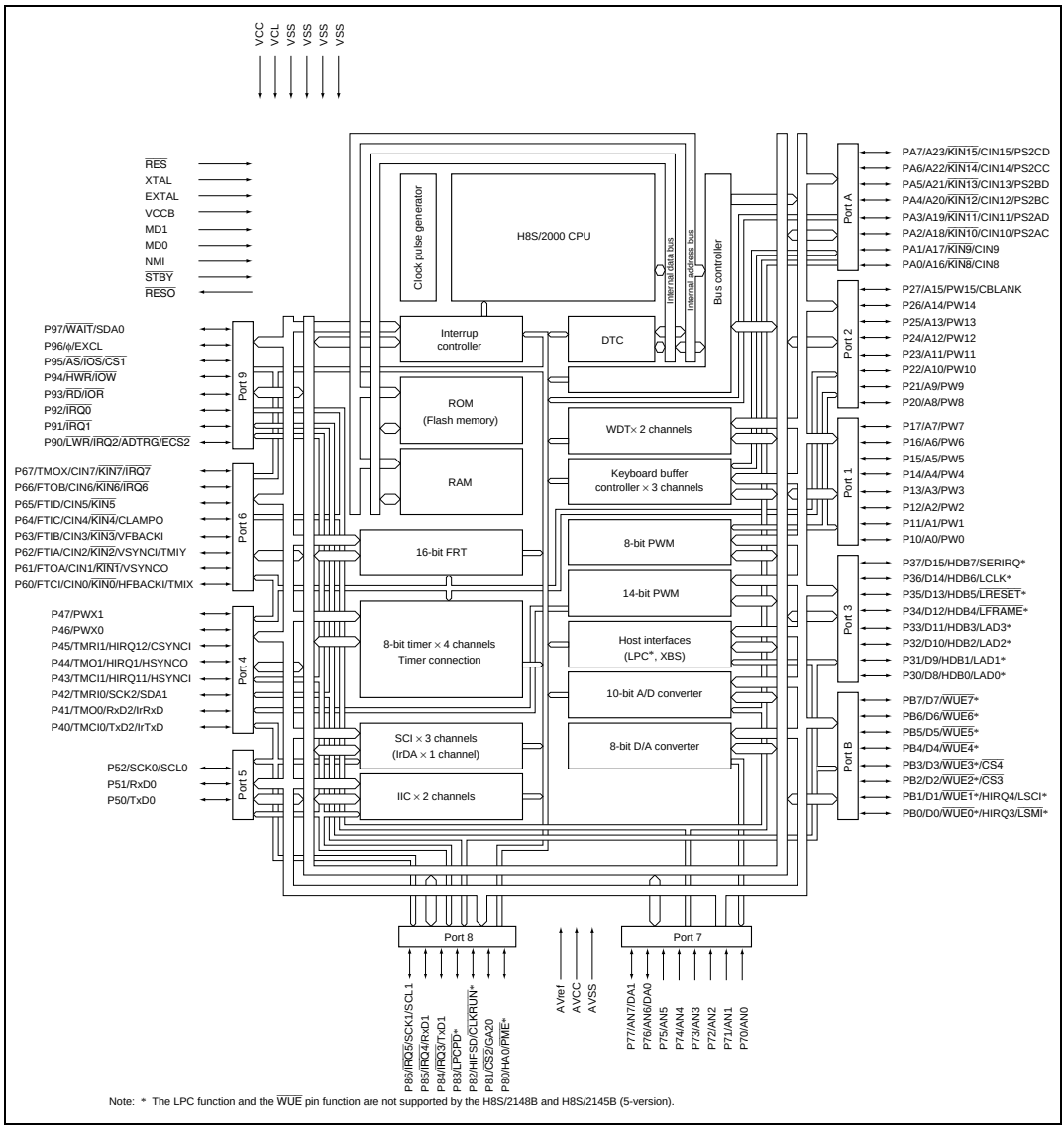
  I/O pins: 74 (H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B)

  I/O pins: 114 (H8S/2160B and H8S/2161B)

  Input-only pins: 8
- Supports various power-down states
- Compact package

Product	Package	Code	Body Size	Pin Pitch
H8S/2161B, H8S/2160B	TQFP-144	TFP-144	16.0 × 16.0 mm	0.4 mm
H8S/2141B, H8S/2140B	QFP-100B	FP-100B	14.0 × 14.0 mm	0.5 mm
H8S/2145B, H8S/2148B	TQFP-100B	TFP-100B		

1.2 Block Diagram



Note: * The LPC function and the WUE pin function are not supported by the H8S/2148B and H8S/2145B (5-version).

Figure 1.1 Internal Block Diagram of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B

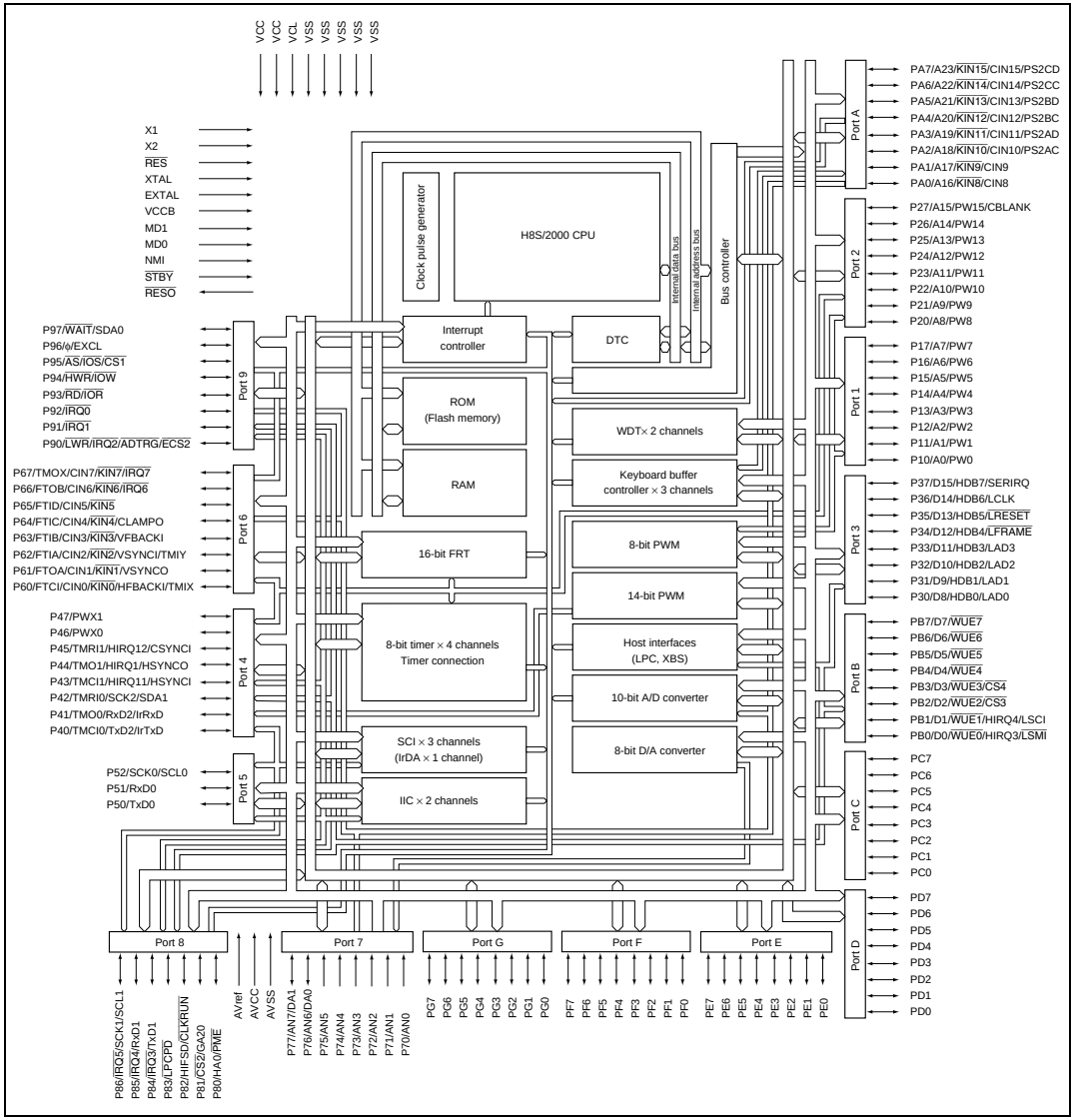
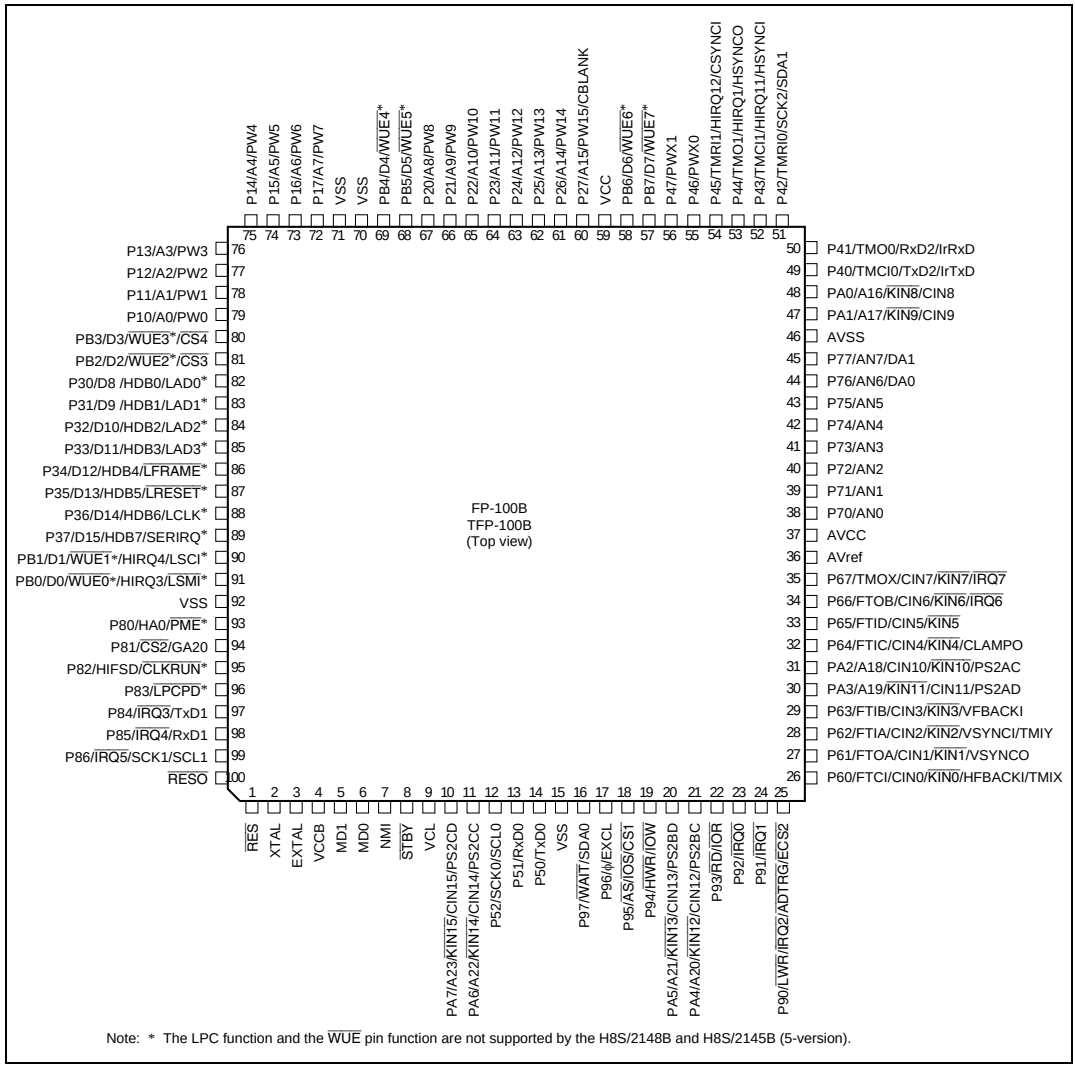


Figure 1.2 Internal Block Diagram of H8S/2160B and H8S/2161B

1.3 Pin Arrangement and Functions

1.3.1 Pin Arrangement



Note: * The LPC function and the WUE pin function are not supported by the H8S/2148B and H8S/2145B (5-version).

Figure 1.3 Pin Arrangement of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B

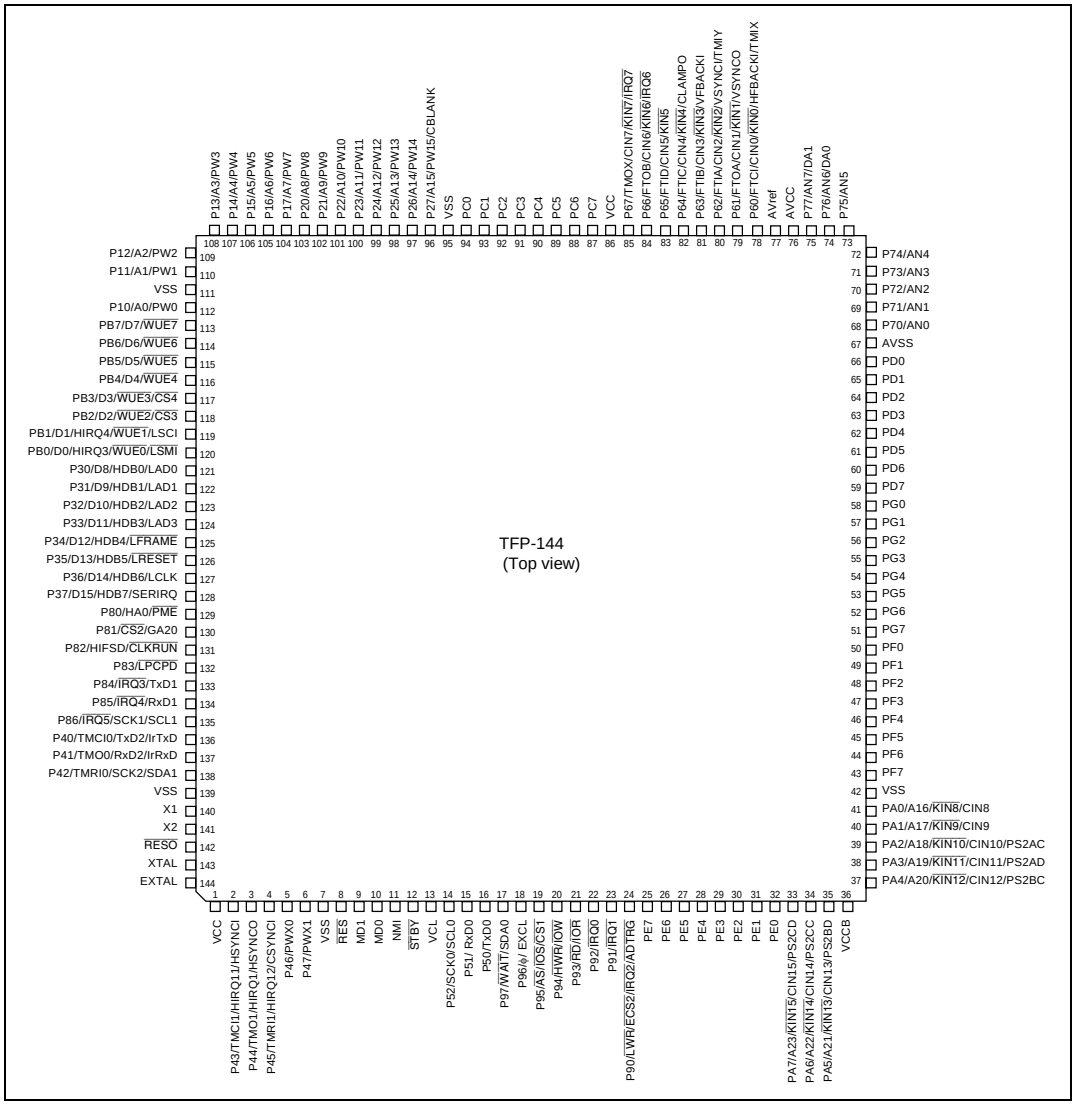


Figure 1.4 Pin Arrangement of H8S/2160B and H8S/2161B

1.3.2 Pin Functions in Each Operating Mode

Table 1.1 Pin Functions of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B in Each Operating Mode

Pin No.	Pin Name			
	Extended Modes		Single-Chip Modes	Flash Memory Programmer Mode
FP-100B TFP-100B	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
1	$\overline{RES}$	$\overline{RES}$	$\overline{RES}$	$\overline{RES}$
2	XTAL	XTAL	XTAL	XTAL
3	EXTAL	EXTAL	EXTAL	EXTAL
4	VCCB	VCCB	VCCB	VCC
5	MD1	MD1	MD1	VSS
6	MD0	MD0	MD0	VSS
7	NMI	NMI	NMI	FA9
8	$\overline{STBY}$	$\overline{STBY}$	$\overline{STBY}$	VCC
9	VCL	VCL	VCL	VCC
10 (B)	PA7/CIN15/$\overline{KIN15}$/ PS2CD	PA7/A23/CIN15/ $\overline{KIN15}$/PS2CD	PA7/CIN15/$\overline{KIN15}$/ PS2CD	NC
11 (B)	PA6/CIN14/$\overline{KIN14}$/ PS2CC	PA6/A22/CIN14/ $\overline{KIN14}$/PS2CC	PA6/CIN14/$\overline{KIN14}$/ PS2CC	NC
12 (N)	P52/SCK0/SCL0	P52/SCK0/SCL0	P52/SCK0/SCL0	NC
13	P51/RxD0	P51/RxD0	P51/RxD0	FA17
14	P50/TxD0	P50/TxD0	P50/TxD0	NC
15	VSS	VSS	VSS	VSS
16 (N)	P97/$\overline{WAIT}$/SDA0	P97/$\overline{WAIT}$/SDA0	P97/SDA0	VCC
17	P96/ϕ/EXCL	P96/ϕ/EXCL	P96/ϕ/EXCL	NC
18	$\overline{AS}$/$\overline{IOS}$	$\overline{AS}$/$\overline{IOS}$	P95/$\overline{CS1}$	FA16
19	$\overline{HWR}$	$\overline{HWR}$	P94/$\overline{IOW}$	FA15
20 (B)	PA5/CIN13/$\overline{KIN13}$/ PS2BD	PA5/A21/CIN13/ $\overline{KIN13}$/PS2BD	PA5/CIN13/$\overline{KIN13}$/ PS2BD	NC
21 (B)	PA4/CIN12/$\overline{KIN12}$/ PS2BC	PA4/A20/CIN12/ $\overline{KIN12}$/PS2BC	PA4/CIN12/$\overline{KIN12}$/ PS2BC	NC

Pin No.	Pin Name			
	Extended Modes		Single-Chip Modes	Flash Memory Programmer Mode
FP-100B TFP-100B	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
22	$\overline{RD}$	$\overline{RD}$	P93/$\overline{IOR}$	$\overline{WE}$
23	P92/$\overline{IRQ0}$	P92/$\overline{IRQ0}$	P92/$\overline{IRQ0}$	VSS
24	P91/$\overline{IRQ1}$	P91/$\overline{IRQ1}$	P91/$\overline{IRQ1}$	VCC
25	P90/$\overline{LWR}$/$\overline{IRQ2}$/ $\overline{ADTRG}$	P90/$\overline{LWR}$/$\overline{IRQ2}$/ $\overline{ADTRG}$	P90/$\overline{ECS2}$/$\overline{IRQ2}$/ $\overline{ADTRG}$	VCC
26	P60/FTCI/CIN0/ $\overline{KIN0}$/HFBACKI/ TMIX	P60/FTCI/CIN0/ $\overline{KIN0}$/HFBACKI/ TMIX	P60/FTCI/CIN0/ $\overline{KIN0}$/HFBACKI/ TMIX	NC
27	P61/FTOA/CIN1/ $\overline{KIN1}$/VSYNCO	P61/FTOA/CIN1/ $\overline{KIN1}$/VSYNCO	P61/FTOA/CIN1/ $\overline{KIN1}$/VSYNCO	NC
28	P62/FTIA/CIN2/ $\overline{KIN2}$/VSYNCI/TMIY	P62/FTIA/CIN2/ $\overline{KIN2}$/VSYNCI/TMIY	P62/FTIA/CIN2/ $\overline{KIN2}$/VSYNCI/TMIY	NC
29	P63/FTIB/CIN3/ $\overline{KIN3}$/VFBACKI	P63/FTIB/CIN3/ $\overline{KIN3}$/VFBACKI	P63/FTIB/CIN3/ $\overline{KIN3}$/VFBACKI	NC
30 (B)	PA3/CIN11/$\overline{KIN11}$/ PS2AD	PA3/A19/CIN11/ $\overline{KIN11}$/PS2AD	PA3/CIN11/$\overline{KIN11}$/ PS2AD	NC
31 (B)	PA2/CIN10/$\overline{KIN10}$/ PS2AC	PA2/A18/CIN10/ $\overline{KIN10}$/PS2AC	PA2/CIN10/$\overline{KIN10}$/ PS2AC	NC
32	P64/FTIC/CIN4/ $\overline{KIN4}$/CLAMPO	P64/FTIC/CIN4/ $\overline{KIN4}$/CLAMPO	P64/FTIC/CIN4/ $\overline{KIN4}$/CLAMPO	NC
33	P65/FTID/CIN5/ $\overline{KIN5}$	P65/FTID/CIN5/ $\overline{KIN5}$	P65/FTID/CIN5/ $\overline{KIN5}$	NC
34	P66/FTOB/CIN6/ $\overline{KIN6}$/$\overline{IRQ6}$	P66/FTOB/CIN6/ $\overline{KIN6}$/$\overline{IRQ6}$	P66/FTOB/CIN6/ $\overline{KIN6}$/$\overline{IRQ6}$	NC
35	P67/TMOX/CIN7/ $\overline{KIN7}$/$\overline{IRQ7}$	P67/TMOX/CIN7/ $\overline{KIN7}$/$\overline{IRQ7}$	P67/TMOX/CIN7/ $\overline{KIN7}$/$\overline{IRQ7}$	VSS
36	AVref	AVref	AVref	VCC
37	AVCC	AVCC	AVCC	VCC
38	P70/AN0	P70/AN0	P70/AN0	NC
39	P71/AN1	P71/AN1	P71/AN1	NC
40	P72/AN2	P72/AN2	P72/AN2	NC
41	P73/AN3	P73/AN3	P73/AN3	NC

Pin No.	Pin Name			
	Extended Modes		Single-Chip Modes	Flash Memory Programmer Mode
FP-100B TFP-100B	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
42	P74/AN4	P74/AN4	P74/AN4	NC
43	P75/AN5	P75/AN5	P75/AN5	NC
44	P76/AN6/DA0	P76/AN6/DA0	P76/AN6/DA0	NC
45	P77/AN7/DA1	P77/AN7/DA1	P77/AN7/DA1	NC
46	AVSS	AVSS	AVSS	VSS
47 (B)	PA1/CIN9/$\overline{\text{KIN9}}$	PA1/A17/CIN9/$\overline{\text{KIN9}}$	PA1/CIN9/$\overline{\text{KIN9}}$	NC
48 (B)	PA0/CIN8/$\overline{\text{KIN8}}$	PA0/A16/CIN8/$\overline{\text{KIN8}}$	PA0/CIN8/$\overline{\text{KIN8}}$	NC
49	P40/TMCI0/TxD2/ IrTxD	P40/TMCI0/TxD2/ IrTxD	P40/TMCI0/TxD2/ IrTxD	NC
50	P41/TMO0/RxD2/ IrRxD	P41/TMO0/RxD2/ IrRxD	P41/TMO0/RxD2/ IrRxD	NC
51 (N)	P42/TMRI0/SCK2/ SDA1	P42/TMRI0/SCK2/ SDA1	P42/TMRI0/SCK2/ SDA1	NC
52	P43/TMCI1/ HSYNCI	P43/TMCI1/ HSYNCI	P43/TMCI1/HIRQ11/ HSYNCI	NC
53	P44/TMO1/ HSYNCO	P44/TMO1/ HSYNCO	P44/TMO1/HIRQ1/ HSYNCO	NC
54	P45/TMRI1/ CSYNCI	P45/TMRI1/ CSYNCI	P45/TMRI1/HIRQ12/ CSYNCI	NC
55	P46/PWX0	P46/PWX0	P46/PWX0	NC
56	P47/PWX1	P47/PWX1	P47/PWX1	NC
57	PB7/D7/$\overline{\text{WUE7}}$*	PB7/D7/$\overline{\text{WUE7}}$*	PB7/$\overline{\text{WUE7}}$*	NC
58	PB6/D6/$\overline{\text{WUE6}}$*	PB6/D6/$\overline{\text{WUE6}}$*	PB6/$\overline{\text{WUE6}}$*	NC
59	VCC	VCC	VCC	VCC
60	A15	P27/A15/PW15/ CBLANK	P27/PW15/ CBLANK	$\overline{\text{CE}}$
61	A14	P26/A14/PW14	P26/PW14	FA14
62	A13	P25/A13/PW13	P25/PW13	FA13
63	A12	P24/A12/PW12	P24/PW12	FA12
64	A11	P23/A11/PW11	P23/PW11	FA11

Pin No.	Pin Name			
	Extended Modes		Single-Chip Modes	Flash Memory Programmer Mode
FP-100B TFP-100B	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
65	A10	P22/A10/PW10	P22/PW10	FA10
66	A9	P21/A9/PW9	P21/PW9	$\overline{OE}$
67	A8	P20/A8/PW8	P20/PW8	FA8
68	PB5/D5/$\overline{WUE5}$*	PB5/D5/$\overline{WUE5}$*	PB5/$\overline{WUE5}$*	NC
69	PB4/D4/$\overline{WUE4}$*	PB4/D4/$\overline{WUE4}$*	PB4/$\overline{WUE4}$*	NC
70	VSS	VSS	VSS	VSS
71	VSS	VSS	VSS	VSS
72	A7	P17/A7/PW7	P17/PW7	FA7
73	A6	P16/A6/PW6	P16/PW6	FA6
74	A5	P15/A5/PW5	P15/PW5	FA5
75	A4	P14/A4/PW4	P14/PW4	FA4
76	A3	P13/A3/PW3	P13/PW3	FA3
77	A2	P12/A2/PW2	P12/PW2	FA2
78	A1	P11/A1/PW1	P11/PW1	FA1
79	A0	P10/A0/PW0	P10/PW0	FA0
80	PB3/D3/$\overline{WUE3}$*	PB3/D3/$\overline{WUE3}$*	PB3/$\overline{WUE3}$*/$\overline{CS4}$	NC
81	PB2/D2/$\overline{WUE2}$*	PB2/D2/$\overline{WUE2}$*	PB2/$\overline{WUE2}$*/$\overline{CS3}$	NC
82	D8	D8	P30/HDB0/LAD0*	FO0
83	D9	D9	P31/HDB1/LAD1*	FO1
84	D10	D10	P32/HDB2/LAD2*	FO2
85	D11	D11	P33/HDB3/LAD3*	FO3
86	D12	D12	P34/HDB4/ $\overline{LFRAME}$*	FO4
87	D13	D13	P35/HDB5/ $\overline{LRESET}$*	FO5
88	D14	D14	P36/HDB6/LCLK*	FO6
89	D15	D15	P37/HDB7/SERIRQ*	FO7
90	PB1/D1/$\overline{WUE1}$*	PB1/D1/$\overline{WUE1}$*	PB1/HIRQ4/$\overline{WUE1}$*/ LSCI*	NC

Pin No.	Pin Name			
	Extended Modes		Single-Chip Modes	Flash Memory Programmer Mode
FP-100B TFP-100B	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
91	PB0/D0/$\overline{\text{WUE0}}$*	PB0/D0/$\overline{\text{WUE0}}$*	PB0/HIRQ3/$\overline{\text{WUE0}}$*/ $\overline{\text{LSMI}}$*	NC
92	VSS	VSS	VSS	VSS
93	P80	P80	P80/HA0/$\overline{\text{PME}}$*	NC
94	P81	P81	P81/$\overline{\text{CS2}}$/GA20	NC
95	P82	P82	P82/HIFSD/ $\overline{\text{CLKRUN}}$*	NC
96	P83	P83	P83/$\overline{\text{LPCPD}}$*	NC
97	P84/$\overline{\text{IRQ3}}$/TxD1	P84/$\overline{\text{IRQ3}}$/TxD1	P84/$\overline{\text{IRQ3}}$/TxD1	NC
98	P85/$\overline{\text{IRQ4}}$/RxD1	P85/$\overline{\text{IRQ4}}$/RxD1	P85/$\overline{\text{IRQ4}}$/RxD1	NC
99 (N)	P86/$\overline{\text{IRQ5}}$/SCK1/ SCL1	P86/$\overline{\text{IRQ5}}$/SCK1/ SCL1	P86/$\overline{\text{IRQ5}}$/SCK1/ SCL1	NC
100	$\overline{\text{RESO}}$	$\overline{\text{RESO}}$	$\overline{\text{RESO}}$	NC

Notes: The (B) in Pin No. means the VCCB drive and the (N) in Pin No. means the NMOS push-pull/open-drain drive.

* The LPC function and the $\overline{\text{WUE}}$ pin function are not supported by the H8S/2148B and H8S/2145B (5-version).

Table 1.2 Pin Functions of H8S/2160B and H8S/2161B in Each Operating Mode

Pin No.	Pin Name			
	Extended modes		Single-Chip Modes	Flash Memory Programmer Mode
TFP-144	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
1	VCC	VCC	VCC	VCC
2	P43/TMCI1/ HSYNCI	P43/TMCI1/ HSYNCI	P43/TMCI1/HIRQ11/ HSYNCI	NC
3	P44/TMO1/ HSYNCO	P44/TMO1/ HSYNCO	P44/TMO1/HIRQ1/ HSYNCO	NC
4	P45/TMRI1/ CSYNCI	P45/TMRI1/ CSYNCI	P45/TMRI1/HIRQ12/ CSYNCI	NC
5	P46/PWX0	P46/PWX0	P46/PWX0	NC
6	P47/PWX1	P47/PWX1	P47/PWX1	NC
7	VSS	VSS	VSS	VSS
8	$\overline{\text{RES}}$	$\overline{\text{RES}}$	$\overline{\text{RES}}$	$\overline{\text{RES}}$
9	MD1	MD1	MD1	VSS
10	MD0	MD0	MD0	VSS
11	NMI	NMI	NMI	FA9
12	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	VCC
13	VCL	VCL	VCL	VCC
14 (N)	P52/SCK0/SCL0	P52/SCK0/SCL0	P52/SCK0/SCL0	FA18
15	P51/RxD0	P51/RxD0	P51/RxD0	FA17
16	P50/TxD0	P50/TxD0	P50/TxD0	NC
17 (N)	P97/$\overline{\text{WAIT}}$/SDA0	P97/$\overline{\text{WAIT}}$/SDA0	P97/SDA0	VCC
18	P96/ϕ/EXCL	P96/ϕ/EXCL	P96/ϕ/EXCL	NC
19	$\overline{\text{AS}}$/$\overline{\text{IOS}}$	$\overline{\text{AS}}$/$\overline{\text{IOS}}$	P95/$\overline{\text{CS1}}$	FA16
20	$\overline{\text{HWR}}$	$\overline{\text{HWR}}$	P94/$\overline{\text{IOW}}$	FA15
21	$\overline{\text{RD}}$	$\overline{\text{RD}}$	P93/$\overline{\text{IOR}}$	$\overline{\text{WE}}$
22	P92/$\overline{\text{IRQ0}}$	P92/$\overline{\text{IRQ0}}$	P92/$\overline{\text{IRQ0}}$	VSS
23	P91/$\overline{\text{IRQ1}}$	P91/$\overline{\text{IRQ1}}$	P91/$\overline{\text{IRQ1}}$	VCC
24	P90/$\overline{\text{LWR}}$/$\overline{\text{IRQ2}}$/ $\overline{\text{ADTRG}}$	P90/$\overline{\text{LWR}}$/$\overline{\text{IRQ2}}$/ $\overline{\text{ADTRG}}$	P90/$\overline{\text{IRQ2}}$/$\overline{\text{ADTRG}}$/ $\overline{\text{ECS2}}$	VCC

Pin No.	Pin Name			
	Extended modes		Single-Chip Modes	Flash Memory Programmer Mode
TFP-144	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
25	PE7	PE7	PE7	NC
26	PE6	PE6	PE6	NC
27	PE5	PE5	PE5	NC
28	PE4	PE4	PE4	NC
29	PE3	PE3	PE3	NC
30	PE2	PE2	PE2	NC
31	PE1	PE1	PE1	NC
32	PE0	PE0	PE0	NC
33 (B)	PA7/CIN15/$\overline{\text{KIN15}}$/ PS2CD	PA7/A23/CIN15/ $\overline{\text{KIN15}}$/PS2CD	PA7/CIN15/$\overline{\text{KIN15}}$/ PS2CD	NC
34 (B)	PA6/CIN14/$\overline{\text{KIN14}}$/ PS2CC	PA6/A22/CIN14/ $\overline{\text{KIN14}}$/PS2CC	PA6/CIN14/$\overline{\text{KIN14}}$/ PS2CC	NC
35 (B)	PA5/CIN13/$\overline{\text{KIN13}}$/ PS2BD	PA5/A21/CIN13/ $\overline{\text{KIN13}}$/PS2BD	PA5/CIN13/$\overline{\text{KIN13}}$/ PS2BD	NC
36	VCCB	VCCB	VCCB	VCC
37 (B)	PA4/CIN12/$\overline{\text{KIN12}}$/ PS2BC	PA4/A20/CIN12/ $\overline{\text{KIN12}}$/PS2BC	PA4/CIN12/$\overline{\text{KIN12}}$/ PS2BC	NC
38 (B)	PA3/CIN11/$\overline{\text{KIN11}}$/ PS2AD	PA3/A19/CIN11/ $\overline{\text{KIN11}}$/PS2AD	PA3/CIN11/$\overline{\text{KIN11}}$/ PS2AD	NC
39 (B)	PA2/CIN10/$\overline{\text{KIN10}}$/ PS2AC	PA2/A18/CIN10/ $\overline{\text{KIN10}}$/PS2AC	PA2/CIN10/$\overline{\text{KIN10}}$/ PS2AC	NC
40 (B)	PA1/CIN9/$\overline{\text{KIN9}}$	PA1/A17/CIN9/$\overline{\text{KIN9}}$	PA1/CIN9/$\overline{\text{KIN9}}$	NC
41 (B)	PA0/CIN8/$\overline{\text{KIN8}}$	PA0/A16/CIN8/$\overline{\text{KIN8}}$	PA0/CIN8/$\overline{\text{KIN8}}$	NC
42	VSS	VSS	VSS	VSS
43	PF7	PF7	PF7	NC
44	PF6	PF6	PF6	NC
45	PF5	PF5	PF5	NC
46	PF4	PF4	PF4	NC
47	PF3	PF3	PF3	NC
48	PF2	PF2	PF2	NC

Pin No.	Pin Name			
	Extended modes		Single-Chip Modes	Flash Memory Programmer Mode
TFP-144	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
49	PF1	PF1	PF1	NC
50	PF0	PF0	PF0	NC
51 (N)	PG7	PG7	PG7	NC
52 (N)	PG6	PG6	PG6	NC
53 (N)	PG5	PG5	PG5	NC
54 (N)	PG4	PG4	PG4	NC
55 (N)	PG3	PG3	PG3	NC
56 (N)	PG2	PG2	PG2	NC
57 (N)	PG1	PG1	PG1	NC
58 (N)	PG0	PG0	PG0	NC
59	PD7	PD7	PD7	NC
60	PD6	PD6	PD6	NC
61	PD5	PD5	PD5	NC
62	PD4	PD4	PD4	NC
63	PD3	PD3	PD3	NC
64	PD2	PD2	PD2	NC
65	PD1	PD1	PD1	NC
66	PD0	PD0	PD0	NC
67	AVSS	AVSS	AVSS	VSS
68	P70/AN0	P70/AN0	P70/AN0	NC
69	P71/AN1	P71/AN1	P71/AN1	NC
70	P72/AN2	P72/AN2	P72/AN2	NC
71	P73/AN3	P73/AN3	P73/AN3	NC
72	P74/AN4	P74/AN4	P74/AN4	NC
73	P75/AN5	P75/AN5	P75/AN5	NC
74	P76/AN6/DA0	P76/AN6/DA0	P76/AN6/DA0	NC
75	P77/AN7/DA1	P77/AN7/DA1	P77/AN7/DA1	NC
76	AVCC	AVCC	AVCC	VCC

Pin No.	Pin Name			
	Extended modes		Single-Chip Modes	Flash Memory Programmer Mode
TFP-144	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
77	AVref	AVref	AVref	VCC
78	P60/FTCI/CIN0/ $\overline{\text{KIN0}}$/HFBACKI/ TMIX	P60/FTCI/CIN0/ $\overline{\text{KIN0}}$/HFBACKI/ TMIX	P60/FTCI/CIN0/ $\overline{\text{KIN0}}$/HFBACKI/ TMIX	NC
79	P61/FTOA/CIN1/ $\overline{\text{KIN1}}$/VSYNCO	P61/FTOA/CIN1/ $\overline{\text{KIN1}}$/VSYNCO	P61/FTOA/CIN1/ $\overline{\text{KIN1}}$/VSYNCO	NC
80	P62/FTIA/CIN2/ $\overline{\text{KIN2}}$/VSYNCI/TMIY	P62/FTIA/CIN2/ $\overline{\text{KIN2}}$/VSYNCI/TMIY	P62/FTIA/CIN2/ $\overline{\text{KIN2}}$/VSYNCI/TMIY	NC
81	P63/FTIB/CIN3/ $\overline{\text{KIN3}}$/VFBACKI	P63/FTIB/CIN3/ $\overline{\text{KIN3}}$/VFBACKI	P63/FTIB/CIN3/ $\overline{\text{KIN3}}$/VFBACKI	NC
82	P64/FTIC/CIN4/ $\overline{\text{KIN4}}$/CLAMPO	P64/FTIC/CIN4/ $\overline{\text{KIN4}}$/CLAMPO	P64/FTIC/CIN4/ $\overline{\text{KIN4}}$/CLAMPO	NC
83	P65/FTID/CIN5/ $\overline{\text{KIN5}}$	P65/FTID/CIN5/ $\overline{\text{KIN5}}$	P65/FTID/CIN5/ $\overline{\text{KIN5}}$	NC
84	P66/FTOB/CIN6/ $\overline{\text{KIN6}}$/$\overline{\text{IRQ6}}$	P66/FTOB/CIN6/ $\overline{\text{KIN6}}$/$\overline{\text{IRQ6}}$	P66/FTOB/CIN6/ $\overline{\text{KIN6}}$/$\overline{\text{IRQ6}}$	NC
85	P67/TMOX/CIN7/ $\overline{\text{KIN7}}$/$\overline{\text{IRQ7}}$	P67/TMOX/CIN7/ $\overline{\text{KIN7}}$/$\overline{\text{IRQ7}}$	P67/TMOX/CIN7/ $\overline{\text{KIN7}}$/$\overline{\text{IRQ7}}$	VSS
86	VCC	VCC	VCC	VCC
87	PC7	PC7	PC7	NC
88	PC6	PC6	PC6	NC
89	PC5	PC5	PC5	NC
90	PC4	PC4	PC4	NC
91	PC3	PC3	PC3	NC
92	PC2	PC2	PC2	NC
93	PC1	PC1	PC1	NC
94	PC0	PC0	PC0	NC
95	VSS	VSS	VSS	VSS
96	A15	P27/A15/PW15/ CBLANK	P27/PW15/ CBLANK	$\overline{\text{CE}}$
97	A14	P26/A14/PW14	P26/PW14	FA14

Pin No.	Pin Name			
	Extended modes		Single-Chip Modes	Flash Memory Programmer Mode
TFP-144	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
98	A13	P25/A13/PW13	P25/PW13	FA13
99	A12	P24/A12/PW12	P24/PW12	FA12
100	A11	P23/A11/PW11	P23/PW11	FA11
101	A10	P22/A10/PW10	P22/PW10	FA10
102	A9	P21/A9/PW9	P21/PW9	$\overline{OE}$
103	A8	P20/A8/PW8	P20/PW8	FA8
104	A7	P17/A7/PW7	P17/PW7	FA7
105	A6	P16/A6/PW6	P16/PW6	FA6
106	A5	P15/A5/PW5	P15/PW5	FA5
107	A4	P14/A4/PW4	P14/PW4	FA4
108	A3	P13/A3/PW3	P13/PW3	FA3
109	A2	P12/A2/PW2	P12/PW2	FA2
110	A1	P11/A1/PW1	P11/PW1	FA1
111	VSS	VSS	VSS	VSS
112	A0	P10/A0/PW0	P10/PW0	FA0
113	PB7/D7/$\overline{WUE7}$	PB7/D7/$\overline{WUE7}$	PB7/$\overline{WUE7}$	NC
114	PB6/D6/$\overline{WUE6}$	PB6/D6/$\overline{WUE6}$	PB6/$\overline{WUE6}$	NC
115	PB5/D5/$\overline{WUE5}$	PB5/D5/$\overline{WUE5}$	PB5/$\overline{WUE5}$	NC
116	PB4/D4/$\overline{WUE4}$	PB4/D4/$\overline{WUE4}$	PB4/$\overline{WUE4}$	NC
117	PB3/D3/$\overline{WUE3}$	PB3/D3/$\overline{WUE3}$	PB3/$\overline{WUE3}$/$\overline{CS4}$	NC
118	PB2/D2/$\overline{WUE2}$	PB2/D2/$\overline{WUE2}$	PB2/$\overline{WUE2}$/$\overline{CS3}$	NC
119	PB1/D1/$\overline{WUE1}$	PB1/D1/$\overline{WUE1}$	PB1/HIRQ4/$\overline{WUE1}$/ LSCI	NC
120	PB0/D0/$\overline{WUE0}$	PB0/D0/$\overline{WUE0}$	PB0/HIRQ3/$\overline{WUE0}$/ $\overline{LSMI}$	NC
121	D8	D8	P30/HDB0/LAD0	FO0
122	D9	D9	P31/HDB1/LAD1	FO1
123	D10	D10	P32/HDB2/LAD2	FO2
124	D11	D11	P33/HDB3/LAD3	FO3

Pin No.	Pin Name			
	Extended modes		Single-Chip Modes	Flash Memory Programmer Mode
TFP-144	Mode 1	Mode 2, Mode 3 (EXPE = 1)	Mode 2, Mode 3 (EXPE = 0)	
125	D12	D12	P34/HDB4/$\overline{\text{LFRAME}}$	FO4
126	D13	D13	P35/HDB5/$\overline{\text{LRESET}}$	FO5
127	D14	D14	P36/HDB6/LCLK	FO6
128	D15	D15	P37/HDB7/SERIRQ	FO7
129	P80	P80	P80/HA0/$\overline{\text{PME}}$	NC
130	P81	P81	P81/$\overline{\text{CS2}}$/GA20	NC
131	P82	P82	P82/HIFSD/ $\overline{\text{CLKRUN}}$	NC
132	P83	P83	P83/$\overline{\text{LPCPD}}$	NC
133	P84/$\overline{\text{IRQ3}}$/TxD1	P84/$\overline{\text{IRQ3}}$/TxD1	P84/$\overline{\text{IRQ3}}$/TxD1	NC
134	P85/$\overline{\text{IRQ4}}$/RxD1	P85/$\overline{\text{IRQ4}}$/RxD1	P85/$\overline{\text{IRQ4}}$/RxD1	NC
135 (N)	P86/$\overline{\text{IRQ5}}$/SCK1/ SCL1	P86/$\overline{\text{IRQ5}}$/SCK1/ SCL1	P86/$\overline{\text{IRQ5}}$/SCK1/ SCL1	NC
136	P40/TMCI0/TxD2/ IrTxD	P40/TMCI0/TxD2/ IrTxD	P40/TMCI0/TxD2/ IrTxD	NC
137	P41/TMO0/RxD2/ IrRxD	P41/TMO0/RxD2/ IrRxD	P41/TMO0/RxD2/ IrRxD	NC
138 (N)	P42/TMRI0/SCK2/ SDA1	P42/TMRI0/SCK2/ SDA1	P42/TMRI0/SCK2/ SDA1	NC
139	VSS	VSS	VSS	VSS
140	X1	X1	X1	NC
141	X2	X2	X2	NC
142	$\overline{\text{RESO}}$	$\overline{\text{RESO}}$	$\overline{\text{RESO}}$	NC
143	XTAL	XTAL	XTAL	XTAL
144	EXTAL	EXTAL	EXTAL	EXTAL

Note: The (B) in Pin No. means the VCCB drive and the (N) in Pin No. means the NMOS push-pull/open-drain drive.

1.3.3 Pin Functions

Table 1.3 Pin Functions

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
Power	VCC	59	1, 86	Input	Power supply pin. Connect the pin to the system power supply.
	VCL	9	13	Input	Power supply pin. Connect the pin to VCC.
	VCCB	4	36	Input	The power supply for the port A input/output buffer.
	VSS	15, 70, 71, 92	7, 42, 95, 111, 139	Input	Ground pin. Connect to the system power supply (0 V).
Clock	XTAL	2	143	Input	Pins for connection to crystal resonators. The EXTAL pin can also input an external clock. See section 25, Clock Pulse Generator, for typical connection diagrams.
	EXTAL	3	144	Input	
	ϕ	17	18	Output	Supplies the system clock to external devices.
	EXCL	17	18	Input	Input a 32.768 kHz external subclock.
	X1	—	140	Input	Leave open.
	X2	—	141	Input	Leave open.
Operating mode control	MD1 MD0	5 6	9 10	Input	These pins set the operating mode. These pins should not be changed while the MCU is operating.
System control	$\overline{\text{RES}}$	1	8	Input	Reset pin. When this pin becomes low, the chip is reset.
	$\overline{\text{RESO}}$	100	142	Output	Outputs reset signal to external device.
	$\overline{\text{STBY}}$	8	12	Input	When this pin is driven low, a transition is made to hardware standby mode.

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
Address bus	A23 to A16	10, 11, 20, 21, 30, 31, 47, 48	33, 34, 35, 37, 38, 39, 40, 41	Output	Address output pins when 16-Mbyte space is used.
	A15 to A0	60 to 67, 72 to 79	96 to 110, 112	Output	Address output pins
Data bus	D15 to D8	89 to 82	128 to 121	Input/ output	Bidirectional data bus for upper byte of 16-bit data.
	D7 to D0	57, 58, 68, 69, 80, 81, 90, 91	113 to 120	Input/ output	Bidirectional data bus for lower byte of 16-bit data.
Bus control	$\overline{\text{WAIT}}$	16	17	Input	Requests insertion of a wait state in the bus cycle when accessing external 3-state address space.
	$\overline{\text{RD}}$	22	21	Output	When this pin is low, it indicates that the external address space is being read.
	$\overline{\text{HWR}}$	19	20	Output	When this pin is low, it indicates that the external address space is being written to. The upper half of the data bus is valid.
	$\overline{\text{LWR}}$	25	24	Output	When this pin is low, it indicates that the external address space is being written to. The lower half of the data bus is valid.
	$\overline{\text{AS}}$/$\overline{\text{IOS}}$	18	19	Output	When this pin is low, it indicates that address output on the address bus is valid.
Interrupt signals	NMI	7	11	Input	Input pin for a nonmaskable interrupt request.
	$\overline{\text{IRQ0}}$ to $\overline{\text{IRQ7}}$	23 to 25, 97 to 99, 34, 35	22 to 24, 133 to 135, 84, 85	Input	These pins request a maskable interrupt.

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
16-bit free-running timer (FRT)	FTCI	26	78	Input	The counter clock input pin.
	FTOA	27	79	Output	The output compare A output pin.
	FTOB	34	84	Output	The output compare B output pin.
	FTIA	28	80	Input	The input capture A input pin.
	FTIB	29	81	Input	The input capture B input pin.
	FTIC	32	82	Input	The input capture C input pin.
	FTID	33	83	Input	The input capture D input pin.
8-bit timer (TMR_0, TMR_1, TMR_X)	TMO0 TMO1 TMOX	50 53 35	137 3 85	Output	The waveform output pins for the output compare function.
	TMCI0 TMCI1	49 52	136 2	Input	Input pins for the external clock input to counters.
	TMRI0 TMRI1	51 54	138 4	Input	The counter reset input pins.
8-bit timer (TMR_X, TMR_Y)	TMIX TMIY	26 28	78 80	Input	The counter event input and counter reset input pins.
8-bit PWM timer (PWM)	PW15 to PW0	60 to 67, 72 to 79	96 to 110, 112	Output	PWM timer pulse output pins.
14-bit PWM timer (PWMX)	PWX0 PWX1	55 56	5 6	Output	PWM D/A pulse output pins.
Serial communi-cation interface (SCI_0, SCI_1, SCI_2)	TxD0 TxD1 TxD2	14 97 49	16 133 136	Output	Transmit data output pins.
	RxD0 RxD1 RxD2	13 98 50	15 134 137	Input	Receive data input pins.
	SCK0 SCK1 SCK2	12 99 51	14 135 138	Input/ Output	Clock input/output pins. The output type is NMOS push-pull.
SCI with IrDA (SCI_2)	IrTxD	49	136	Output	Input and output pins for data encoded for IrDA use.
	IrRxD	50	137	Input	

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
Keyboard buffer controller	PS2AC PS2BC PS2CC	31 21 11	39 37 34	Input/ Output	Keyboard buffer controller synchronization clock input/output pins.
	PS2AD PS2BD PS2CD	30 20 10	38 35 33	Input/ Output	Keyboard buffer controller data input/output pins.
Host interface (XBS)	HDB7 to HDB0	89 to 82	128 to 121	Input/ Output	Bidirectional 8-bit bus for accessing XBS.
	$\overline{CS1}$, $\overline{CS2}$/ $\overline{ECS2}$, $\overline{CS3}$, $\overline{CS4}$	18, 94, 25, 81, 80	19, 130, 24, 118, 117	Input	Input pins for selecting XBS channels 1 to 4. The $\overline{CS2}$ or $\overline{ECS2}$ input pin is selected with the system control register.
	$\overline{IOR}$	22	21	Input	Input pin that enables reading from XBS.
	$\overline{IOW}$	19	20	Input	Input pin that enables writing to XBS.
	HA0	93	129	Input	Input pin that indicates whether an access is a data access or command access.
	GA20	94	130	Output	A20 gate control signal output pin.
	HIRQ11 HIRQ1 HIRQ12 HIRQ3 HIRQ4	52 53 54 91 90	2 3 4 120 119	Output	Output pins for interrupt requests to the host.
	HIFSD	95	131	Input	Control input pin used to place XBS input/output pins in the high-impedance/ cutoff state.
Host interface (LPC)	LAD3 to LAD0	85 to 82	124 to 121	Input/ Output	LPC command, address, and data input/output pins.
	$\overline{LFRAME}$	86	125	Input	Input pin that indicates the start of an LPC cycle or forced termination of an abnormal LPC cycle.
	$\overline{LRESET}$	87	126	Input	Input pin that indicates an LPC reset.
	LCLK	88	127	Input	The LPC clock input pin.

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
Host interface (LPC)	SERIRQ	89	128	Input/ Output	Input/output pin for LPC serialized host interrupts (HIRQ1, SMI, HIRQ6, HIRQ9 to HIRQ12).
	LSCI, $\overline{\text{LSMI}}$, $\overline{\text{PME}}$	90, 91, 93	119, 120, 129	Input/ Output	LPC auxiliary output pins. Functionally, they are general I/O ports.
	GA20	94	130	Input/ Output	A20 gate control signal output pin. Output state monitoring input is possible.
	$\overline{\text{CLKRUN}}$	95	131	Input/ Output	Input/output pin that requests the start of LCLK operation when LCLK is stopped.
	$\overline{\text{LPCPD}}$	96	132	Input	Input pin that controls LPC module shutdown.
Keyboard buffer controller	$\overline{\text{KIN0}}$ to $\overline{\text{KIN15}}$	26 to 29, 32 to 35, 48, 47, 31, 30, 21, 20, 11, 10	78 to 85, 41 to 37, 35 to 33	Input	Matrix keyboard input pins. $\overline{\text{KIN0}}$ to $\overline{\text{KIN15}}$ are used as key-scan inputs, and P10 to P17 and P20 to P27 are used as key-scan outputs. This allows a maximum 16-output $\times$ 16-input, 256-key matrix to be configured.
	$\overline{\text{WUE0}}$ to $\overline{\text{WUE7}}$	91, 90, 81, 80, 69, 68, 58, 57	120 to 113	Input	Wakeup event input pins. These pins allow the same kind of wakeup as key-wakeup from various sources.
A/D converter	AN7 to AN0	45 to 38	68 to 75	Input	Analog input pins.
	CIN0 to CIN15	26 to 29, 32 to 35, 48, 47, 31, 30, 21, 20, 11, 10	78 to 85, 41 to 37, 35 to 33	Input	A/D conversion input pins, but since they are also used as digital input/output pins, accuracy will fall.
	$\overline{\text{ADTRG}}$	25	24	Input	Pin for input of an external trigger to start A/D conversion.
D/A converter	DA0 DA1	44 45	74 75	Output	Analog output pins.

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
A/D converter D/A converter	AVCC	37	76	Input	The analog power supply pin for the A/D converter and D/A converter. When the A/D and D/A converters are not used, this pin should be connected to the system power supply (+3 V).
	AVref	36	77	Input	The reference power supply pin for the A/D converter and D/A converter. When the A/D and D/A converters are not used, this pin should be connected to the system power supply (+3 V).
	AVSS	46	67	Input	The ground pin for the A/D converter and D/A converter. This pin should be connected to the system power supply (0 V).
Timer connection	VSYNCI HSYNCI CSYNCI VFBACKI HFBACKI	28 52 54 29 26	80 2 4 81 78	Input	Timer connection synchronous signal input pins.
	VSYNCO HSYNCO CLAMPO CBLANK	27 53 32 60	79 3 82 96	Output	Timer connection synchronous signal output pins.
I^2C bus interface (IIC)	SCL0 SCL1	12 99	14 135	Input/ Output	I^2C clock I/O pins. The output type is NMOS open-drain output.
	SDA0 SDA1	16 51	17 138	Input/ Output	I^2C data I/O pins. The output type is NMOS open-drain output.
I/O ports	P17 to P10	72 to 79	104 to 110, 112	Input/ Output	Eight input/output pins.
	P27 to P20	60 to 67	96 to 103	Input/ Output	Eight input/output pins.
	P37 to P30	89 to 82	128 to 121	Input/ Output	Eight input/output pins.
	P47 to P40	56 to 49	6 to 2, 138 to 136	Input/ Output	Eight input/output pins. (The output type of P42 is NMOS push-pull.)

Type	Symbol	Pin No. FP-100B, TFP-100B	Pin No. TFP-144	I/O	Name and Function
I/O ports	P52 to P50	12 to 14	14 to 16	Input/ Output	Three input/output pins. (The output type of P52 is NMOS push-pull.)
	P67 to P60	35 to 32 29 to 26	85 to 78	Input/ Output	Eight input/output pins.
	P77 to P70	45 to 38	75 to 68	Input	Eight input pins.
	P86 to P80	99 to 93	135 to 129	Input/ Output	Seven input/output pins. (The output type of P86 is NMOS push-pull.)
	P97 to P90	16 to 19 22 to 25	17 to 24	Input/ Output	Eight input/output pins. (The output type of P97 is NMOS push-pull.)
	PA7 to PA0	10, 11, 20, 21, 30, 31, 47, 48	33 to 35, 37 to 41	Input/ Output	Eight input/output pins.
	PB7 to PB0	57, 58, 68, 69, 80, 81, 90, 91	113 to 120	Input/ Output	Eight input/output pins.
	PC7 to PC0	—	87 to 94	Input/ Output	Eight input/output pins.
	PD7 to PD0	—	59 to 66	Input/ Output	Eight input/output pins.
	PE7 to PE0	—	25 to 32	Input/ Output	Eight input/output pins.
	PF7 to PF0	—	43 to 50	Input/ Output	Eight input/output pins.
	PG7 to PG0	—	51 to 58	Input/ Output	Eight input/output pins. (The output type of PG7 to PG0 in the H8S/2160B and the H8S/2161B is NMOS push-pull.)

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-compatibility with H8/300 and H8/300H CPUs
  Can execute H8/300 CPU and H8/300H CPU object programs
- General-register architecture
  Sixteen 16-bit general registers also usable as sixteen 8-bit registers or eight 32-bit registers
- Sixty-five basic instructions
  8/16/32-bit arithmetic and logic instructions
  Multiply and divide instructions
  Powerful bit-manipulation instructions
- Eight addressing modes
  Register direct [Rn]
  Register indirect [@ERn]
  Register indirect with displacement [@(d:16,ERn) or @(d:32,ERn)]
  Register indirect with post-increment or pre-decrement [@ERn+ or @–ERn]
  Absolute address [@aa:8, @aa:16, @aa:24, or @aa:32]
  Immediate [#xx:8, #xx:16, or #xx:32]
  Program-counter relative [@(d:8,PC) or @(d:16,PC)]
  Memory indirect [@@aa:8]
- 16-Mbyte address space
  Program: 16 Mbytes
  Data: 16 Mbytes
- High-speed operation
  All frequently-used instructions are executed in one or two states
  8/16/32-bit register-register add/subtract: 1 state
  8 × 8-bit register-register multiply: 12 states (MULXU.B), 13 states (MULXS.B)
  16 ÷ 8-bit register-register divide: 12 states (DIVXU.B)

16 × 16-bit register-register multiply: 20 states (MULXU.W), 21 states (MULXS.W)

32 ÷ 16-bit register-register divide: 20 states (DIVXU.W)

- Two CPU operating modes

  Normal mode

  Advanced mode
- Power-down state

  Transition to power-down state by SLEEP instruction

  Selectable CPU clock speed

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

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

- Register configuration

  The MAC register is supported only by the H8S/2600 CPU.
- Basic instructions

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

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

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

2.1.2 Differences from H8/300 CPU

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

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

2.1.3 Differences from H8/300H CPU

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

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

2.2 CPU Operating Modes

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

2.2.1 Normal Mode

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

- Address space

  Linear access to a maximum address space of 64 kbytes is possible.
- 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 extended register 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 general register Rn is referenced in the register indirect addressing mode with pre-decrement (@–Rn) or post-increment (@Rn+) and a carry or borrow occurs, 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. The exception vector table in normal mode is shown in figure 2.1. For details on 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 in normal mode, and the PC and condition-code register (CCR) are pushed onto the stack in exception handling, they are stored as shown in figure 2.2. The extended control register (EXR) is not pushed onto the stack. For details, see section 4, Exception Handling.

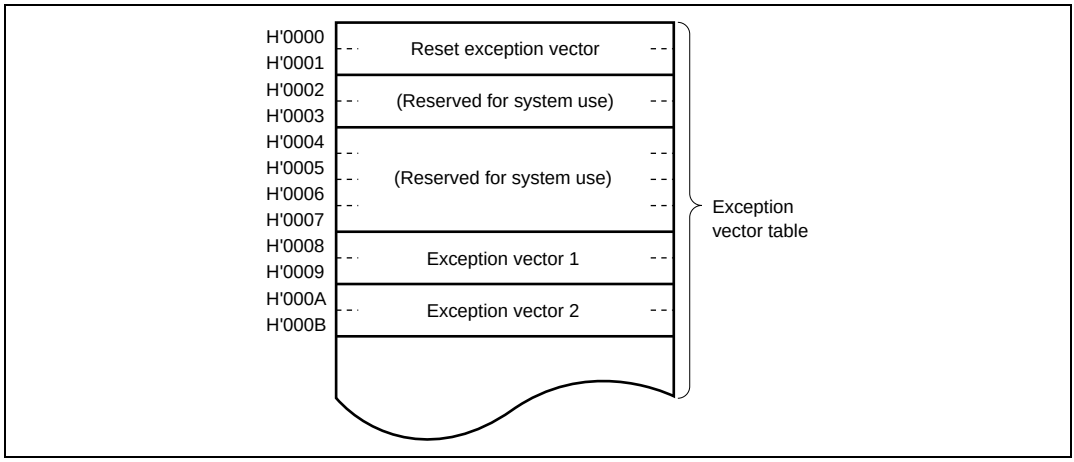


Figure 2.1 Exception Vector Table (Normal Mode)

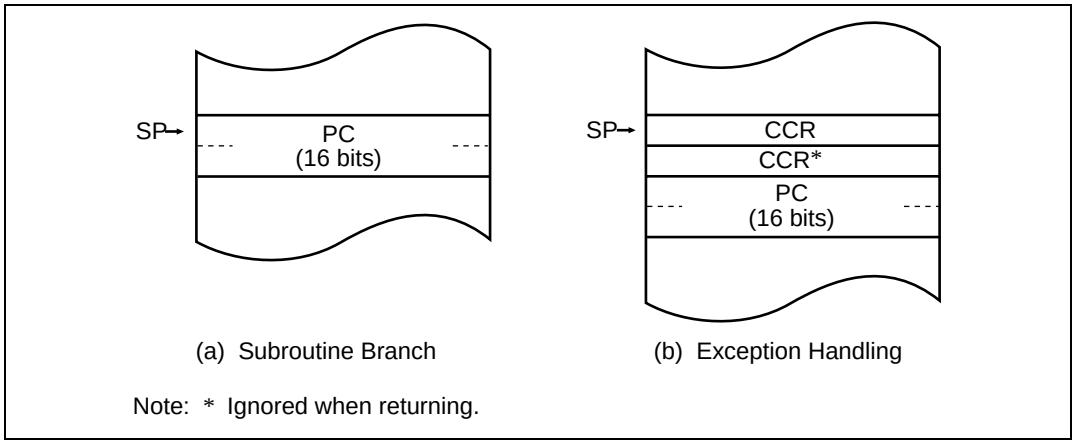


Figure 2.2 Stack Structure in Normal Mode

2.2.2 Advanced Mode

- Address space

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

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

- Instruction set

  All instructions and addressing modes can be used.

- Exception vector table and memory indirect branch addresses

  In advanced mode, the top area starting at H'00000000 is allocated to the exception vector table in 32-bit units. In each 32 bits, the upper 8 bits are ignored and a branch address is stored in the lower 24 bits (see figure 2.3). For details on the exception vector table, see section 4, Exception Handling.

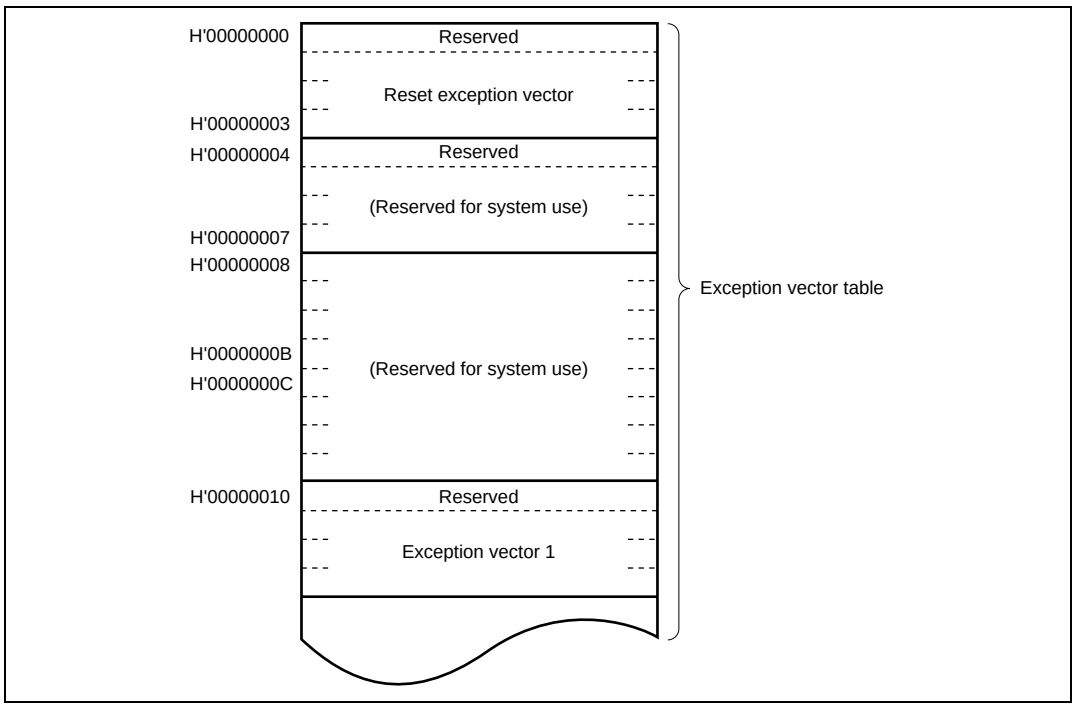


Figure 2.3 Exception Vector Table (Advanced Mode)

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 are a reserved area that is regarded as H'00. Branch addresses can be stored in the area from H'00000000 to H'000000FF. Note that the top area of this range is also used for the exception vector table.

- Stack structure

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

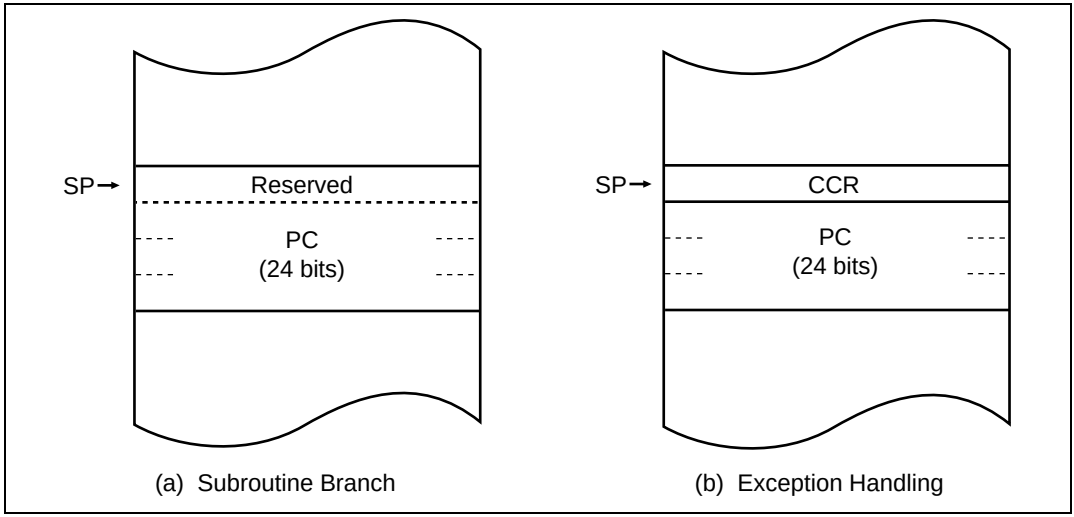


Figure 2.4 Stack Structure in Advanced Mode

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.

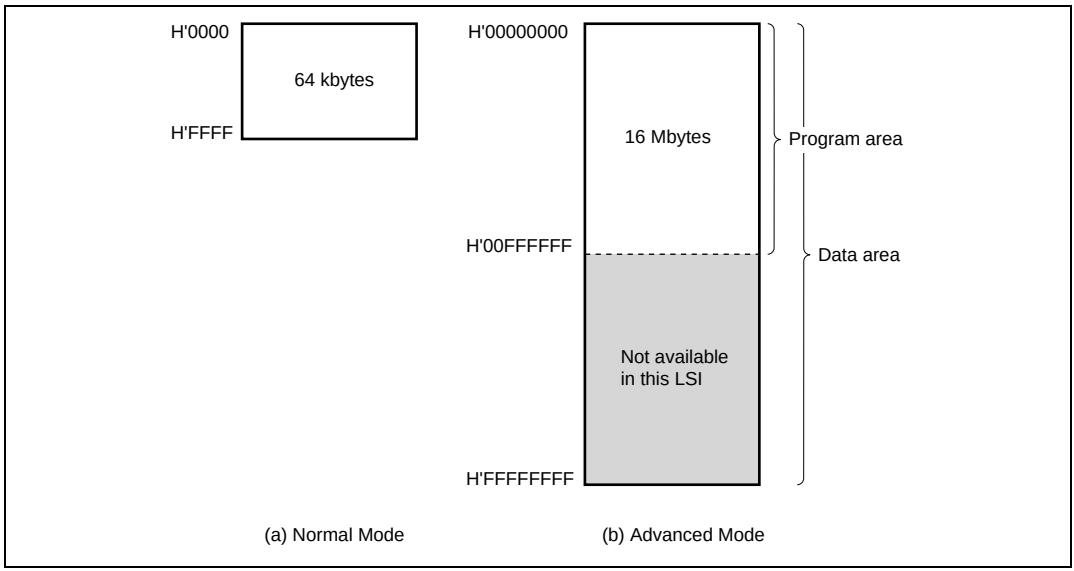


Figure 2.5 Memory Map

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).

General Registers (Rn) and Extended Registers (En)

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

Control Registers

	23 0
PC	PC

	7	6	5	4	3	2	1	0
EXR*	T	—	—	—	—	I2	I1	I0

	7	6	5	4	3	2	1	0
CCR	I	UI	H	U	N	Z	V	C

Legend:

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

Note: * Does not affect operation in this LSI.

Figure 2.6 CPU Internal Registers

2.4.1 General Registers

The H8S/2000 CPU has eight 32-bit general registers. These general registers are all functionally alike and can be used as both address registers and data registers. When a general register is used as a data register, it can be accessed as a 32-bit, 16-bit, or 8-bit register. Figure 2.7 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).

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

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

The usage of each register can be selected independently.

General register ER7 has the function of the stack pointer (SP) in addition to its general-register function, and is used implicitly in exception handling and subroutine calls. Figure 2.8 shows the stack.

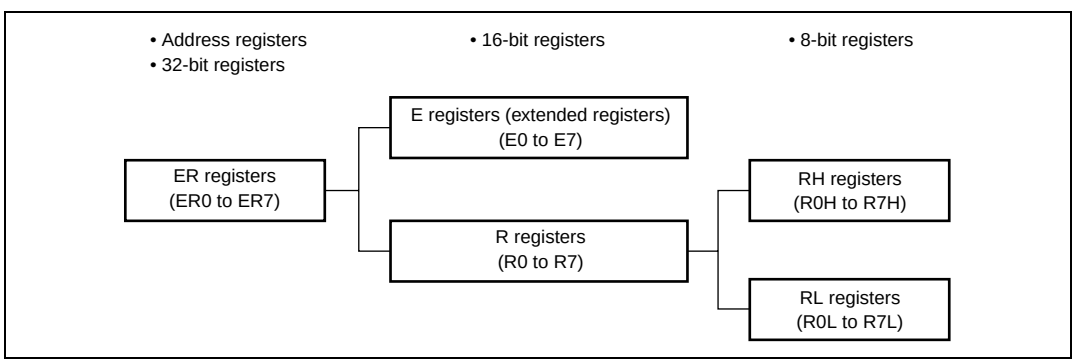


Figure 2.7 Usage of General Registers

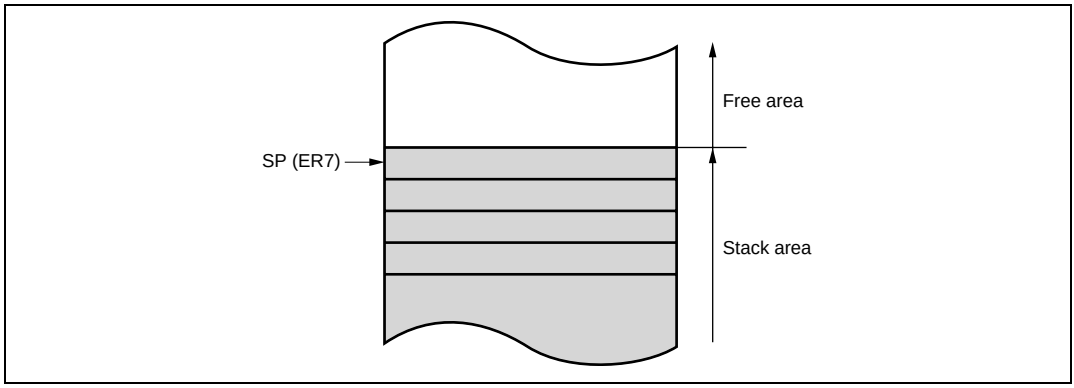


Figure 2.8 Stack

2.4.2 Program Counter (PC)

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

2.4.3 Extended Control Register (EXR)

EXR does not affect operation in this LSI.

Bit	Bit Name	Initial Value	R/W	Description
7	T	0	R/W	Trace Bit Does not affect operation in this LSI.
6 to 3	—	All 1	R	Reserved These bits are always read as 1.
2 to 0	I2 I1 I0	All 1	R/W	Interrupt Mask Bits 2 to 0 Do not affect operation in this LSI.

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 when set to 1. NMI is accepted regardless of the I bit setting. The I bit is set to 1 at the start of an exception-handling sequence. For details, refer to section 5, Interrupt Controller.
6	UI	Undefined	R/W	User Bit or Interrupt Mask Bit Can be written to and read from by software using the LDC, STC, ANDC, ORC, and XORC instructions.
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 to and read from 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.
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 otherwise.
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 Register Values

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

2.5 Data Formats

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

2.5.1 General Register Data Formats

Figure 2.9 shows the data formats of general registers.

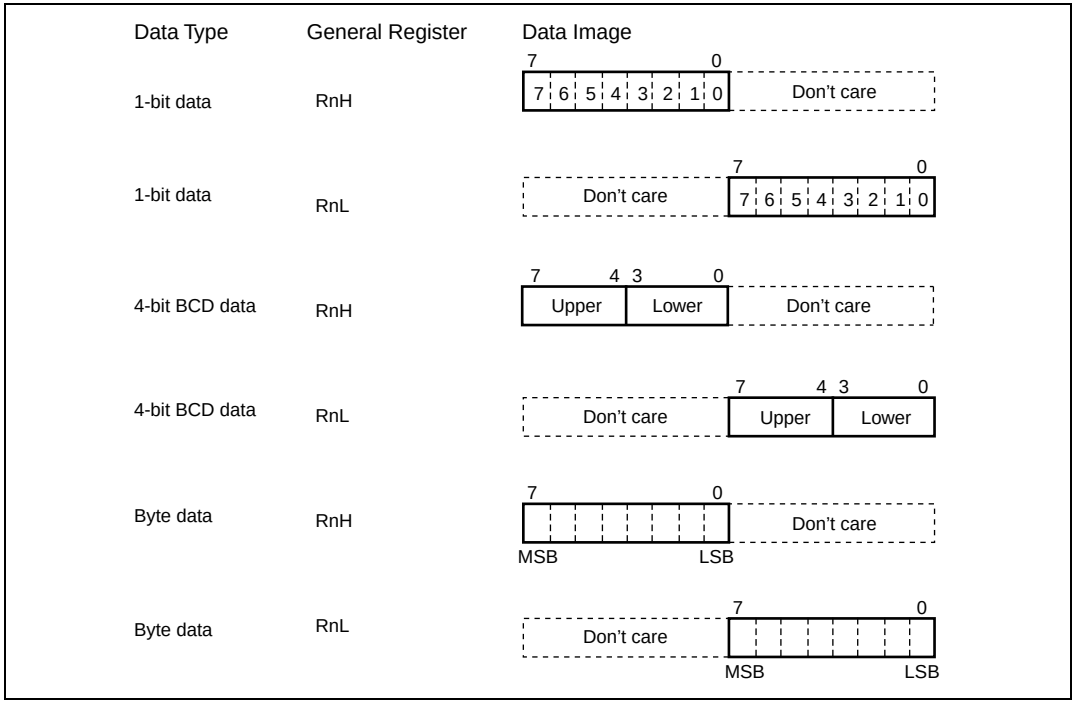


Figure 2.9 General Register Data Formats (1)

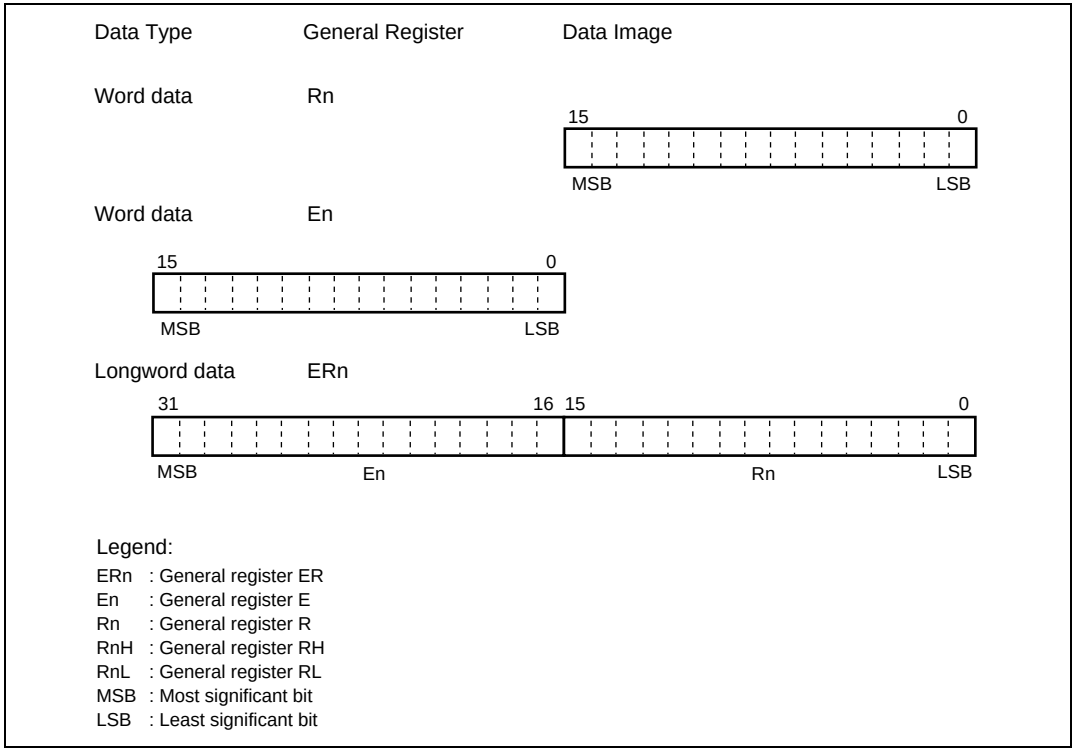


Figure 2.9 General Register Data Formats (2)

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

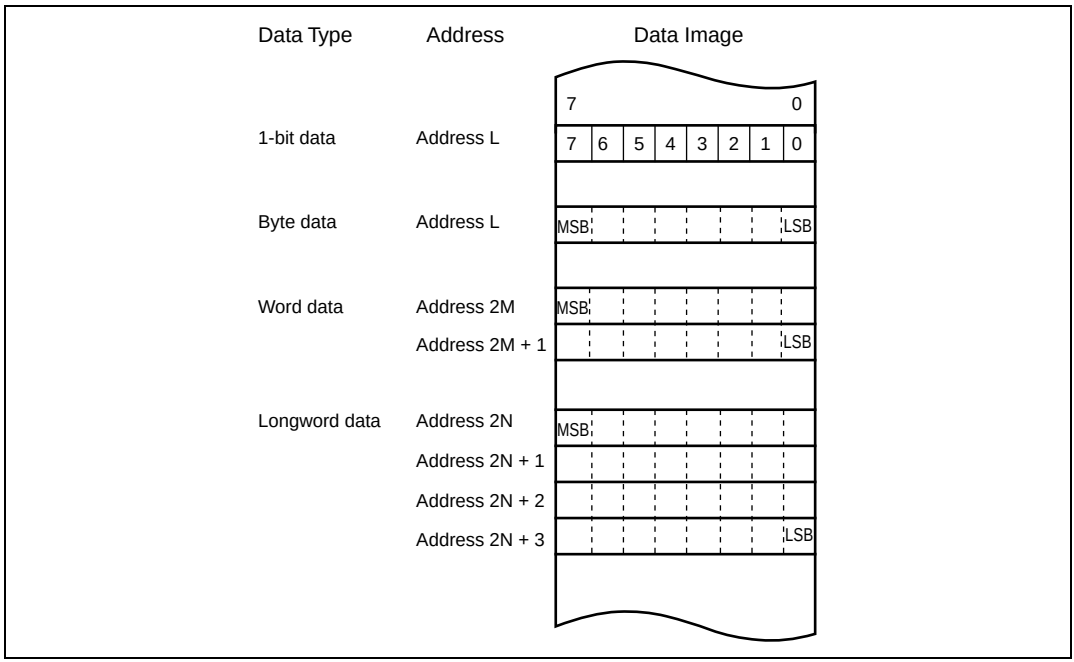


Figure 2.10 Memory Data Formats

2.6 Instruction Set

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

Table 2.1 Instruction Classification

Function	Instructions	Size	Types
Data transfer	MOV	B/W/L	5
	POP*1, PUSH*1	W/L	
	LDM*5, STM*5	L	
	MOVFPE*3, MOVTPE*3	B	
Arithmetic operations	ADD, SUB, CMP, NEG	B/W/L	19
	ADDX, SUBX, DAA, DAS	B	
	INC, DEC	B/W/L	
	ADDS, SUBS	L	
	MULXU, DIVXU, MULXS, DIVXS	B/W	
	EXTU, EXTS	W/L	
	TAS*4	B	
Logic operations	AND, OR, XOR, NOT	B/W/L	4
Shift	SHAL, SHAR, SHLL, SHLR, ROTL, ROTR, ROTXL, ROTXR	B/W/L	8
Bit manipulation	BSET, BCLR, BNOT, BTST, BLD, BILD, BST, BIST, BAND, BIAND, BOR, BIOR, BXOR, BIXOR	B	14
Branch	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

Legend: B: Byte size
W: Word size
L: Longword size.

Notes: 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. When using the TAS instruction, use registers ER0, ER1, ER4, and ER5.
5. ER7 is not used as the register that can be saved (STM)/restored (LDM) when using STM/LDM instruction, because ER7 is the stack pointer.

2.6.1 Table of Instructions Classified by Function

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

Table 2.2 Operation Notation

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

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

Table 2.3 Data Transfer Instructions

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

Notes: 1. Size refers to the operand size.
B: Byte
W: Word
L: Longword
2. ER7 is not used as the register that can be saved (STM)/restored (LDM) when using STM/LDM instruction, because ER7 is the stack pointer.

Table 2.4 Arithmetic Operations Instructions (1)

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

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

Table 2.4 Arithmetic Operations Instructions (2)

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

Notes: 1. Size refers to the operand size.
B: Byte
W: Word
L: Longword
2. When using the TAS instruction, use registers ER0, ER1, ER4 and ER5.

Table 2.5 Logic Operations Instructions

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

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

Table 2.6 Shift Instructions

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

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

Table 2.7 Bit Manipulation Instructions (1)

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

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

Table 2.7 Bit Manipulation Instructions (2)

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

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

Table 2.8 Branch Instructions

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

Mnemonic	Description	Condition
BRA (BT)	Always (true)	Always
BRN (BF)	Never (false)	Never
BHI	High	C ∨ Z = 0
BLS	Low or same	C ∨ 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 ⊕ V = 0
BLT	Less than	N ⊕ V = 1
BGT	Greater than	Z ∨ (N ⊕ V) = 0
BLE	Less or equal	Z ∨ (N ⊕ V) = 1

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

Table 2.9 System Control Instructions

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

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

Table 2.10 Block Data Transfer Instructions

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

2.6.2 Basic Instruction Formats

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

Figure 2.11 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, and some have no register field.
- Effective address extension

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

  Specifies the branching condition of Bcc instructions.

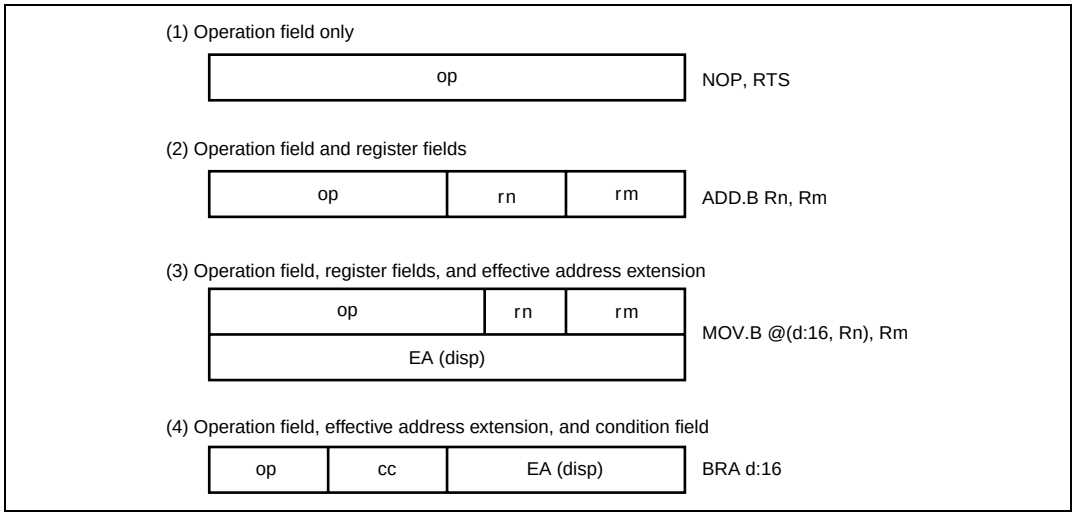


Figure 2.11 Instruction Formats (Examples)

2.7 Addressing Modes and Effective Address Calculation

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

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

Table 2.11 Addressing Modes

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

2.7.1 Register Direct—Rn

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

2.7.2 Register Indirect—@ERn

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

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

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

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

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

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

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

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

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

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

Table 2.12 Absolute Address Access Ranges

Absolute Address		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)		

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

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

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

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

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

2.7.8 Memory Indirect—@@aa:8

This mode can be used by the JMP and JSR instructions. The instruction code contains an 8-bit absolute address specifying a memory operand which contains a branch address. The upper bits of the 8-bit absolute address are all assumed to be 0, so the address range is 0 to 255 (H'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 top area of the address range in which the branch address is stored is also used for 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 the instruction code to be fetched at the address preceding the specified address. (For further information, see section 2.5.2, Memory Data Formats.)

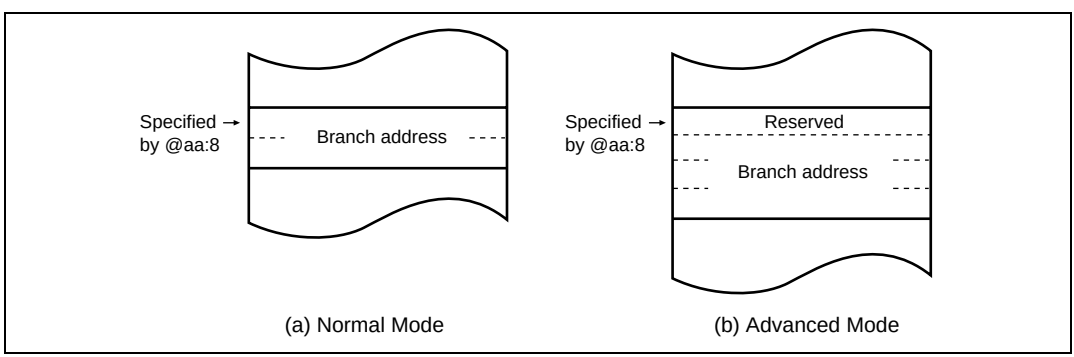
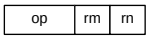
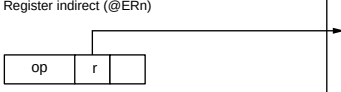
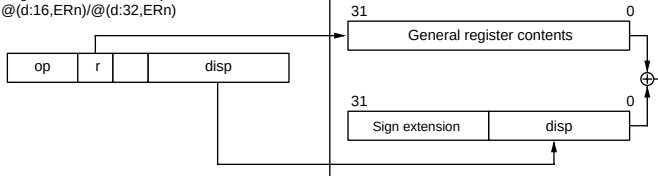
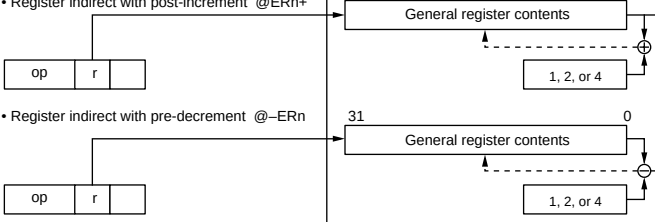


Figure 2.12 Branch Address Specification in Memory Indirect Addressing Mode

2.7.9 Effective Address Calculation

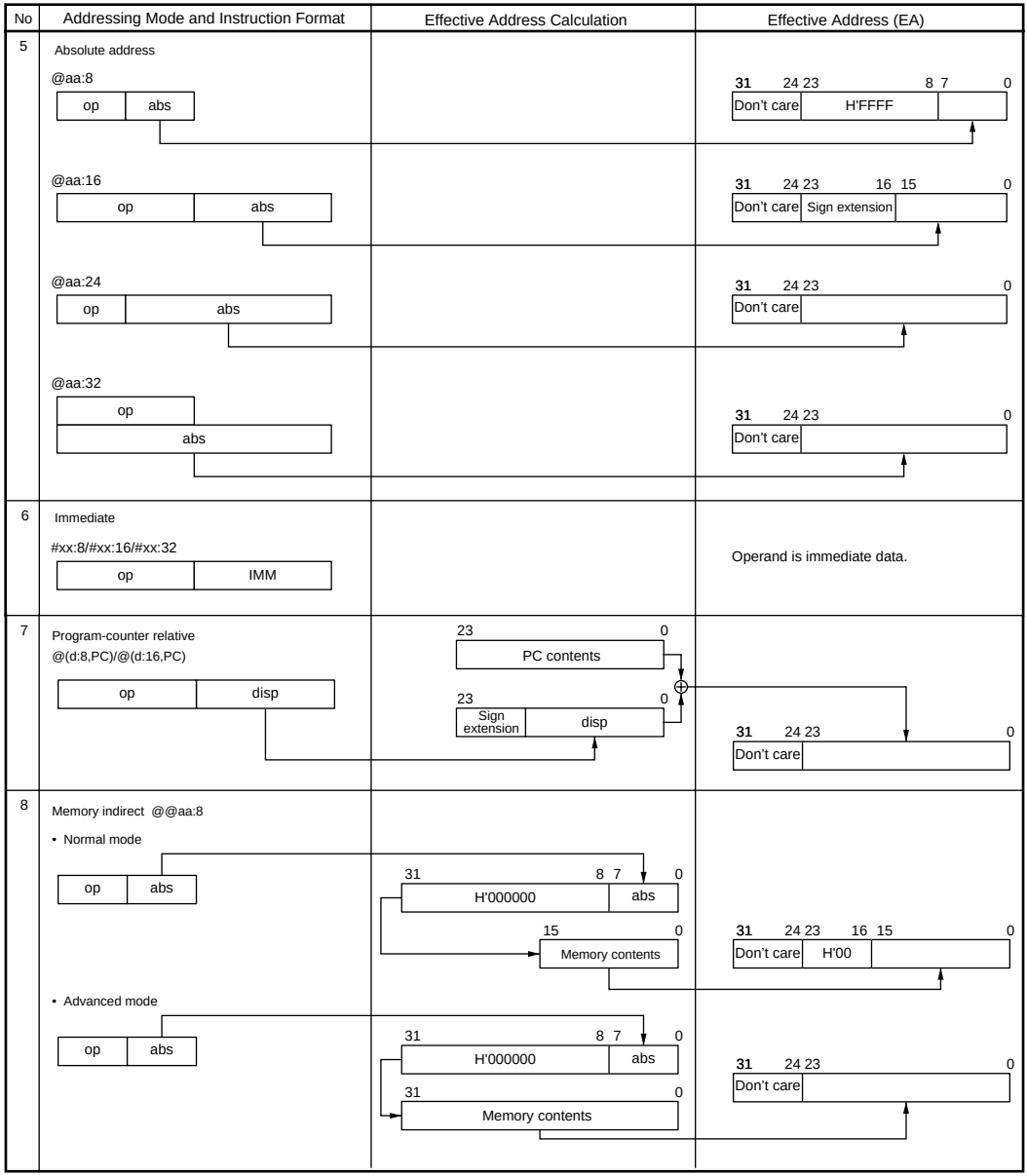
Table 2.13 indicates how effective addresses are calculated in each addressing mode. In normal mode, the upper 8 bits of the effective address are ignored in order to generate a 16-bit address.

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)/@(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)



2.8 Processing States

The H8S/2000 CPU has five main processing states: the reset state, exception handling state, program execution state, bus-released state, and program stop state. Figure 2.13 indicates the state transitions.

- Reset state

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

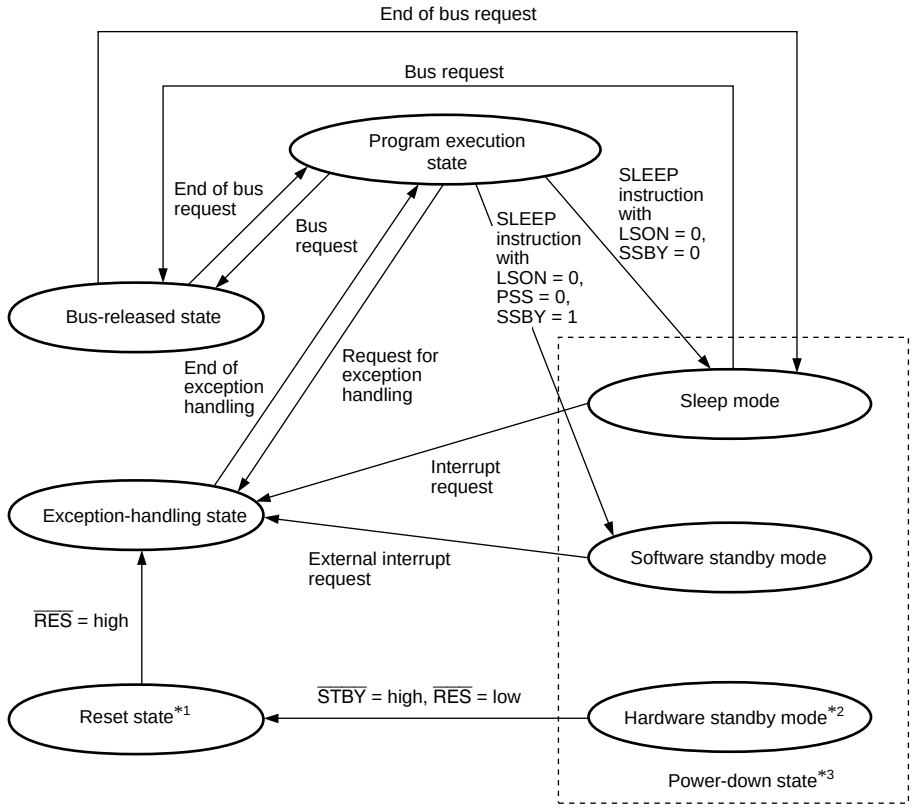
  In this state the CPU executes program instructions in sequence.

- Bus-released state

  In a product which has a bus master other than the CPU, such as a data transfer controller (DTC), the bus-released state occurs when the bus has been released in response to a bus request from a bus master other than the CPU. While the bus is released, the CPU halts operations. For details, see section 6, Bus Controller (BSC).

- Program stop state

  This is a power-down state in which the CPU stops operating. The program stop state occurs when a SLEEP instruction is executed or the CPU enters hardware standby mode. For details, refer to section 26, Power-Down Modes.



Notes: 1. From any state except hardware standby mode, a transition to the reset state occurs whenever $\overline{RES}$ goes low. A transition can also be made to the reset state when the watchdog timer overflows.
2. From any state, a transition to hardware standby mode occurs when $\overline{STBY}$ goes low.
3. The power-down state also includes watch mode, subactive mode, subsleep mode, etc. For details, refer to section 26, Power-Down Modes.

Figure 2.13 State Transitions

2.9 Usage Notes

2.9.1 Note on TAS Instruction Usage

When using the TAS instruction, use registers ER0, ER1, ER4 and ER5.

The TAS instruction is not generated by the Renesas Technology H8S and H8/300 series C/C++ compilers. When the TAS instruction is used as a user-defined intrinsic function, use registers ER0, ER1, ER4 and ER5.

2.9.2 Note on STM/LDM Instruction Usage

ER7 is not used as the register that can be saved (STM)/restored (LDM) when using STM/LDM instruction, because ER7 is the stack pointer. Two, three, or four registers can be saved/restored by one STM/LDM instruction. The following ranges can be specified in the register list.

Two registers: ER0–ER1, ER2–ER3, or ER4–ER5
Three registers: ER0–ER2 or ER4–ER6
Four registers: ER0–ER3

The STM/LDM instruction including ER7 is not generated by the Renesas Technology H8S and H8/300 series C/C++ compilers.

2.9.3 Note on Bit Manipulation Instructions

The BSET, BCLR, BNOT, BST, and BIST instructions read data from the specified address in byte units, manipulate the data of the target bit, and write data to the same address again in byte units. Special care is required when using these instructions in cases where a register containing a write-only bit is used or a bit is directly manipulated for a port, because this may rewrite data of a bit other than the bit to be manipulated.

Example: The BCLR instruction is executed for DDR in port 4.

P47 and P46 are input pins, with a low-level signal input at P47 and a high-level signal input at P46. P45 to P40 are output pins and output low-level signals. The following shows an example in which P40 is set to be an input pin with the BCLR instruction.

Prior to executing BCLR:

	P47	P46	P45	P44	P43	P42	P41	P40
Input/output	Input	Input	Output	Output	Output	Output	Output	Output
Pin state	Low level	High level	Low level	Low level	Low level	Low level	Low level	Low level
DDR	0	0	1	1	1	1	1	1
DR	1	0	0	0	0	0	0	0

BCLR instruction executed:

```
BCLR   #0,    @P4DDR
```

The BCLR instruction is executed for DDR in port 4.

After executing BCLR:

	P47	P46	P45	P44	P43	P42	P41	P40
Input/output	Output	Output	Output	Output	Output	Output	Output	Input
Pin state	Low level	High level	Low level	Low level	Low level	Low level	Low level	High level
DDR	1	1	1	1	1	1	1	0
DR	1	0	0	0	0	0	0	0

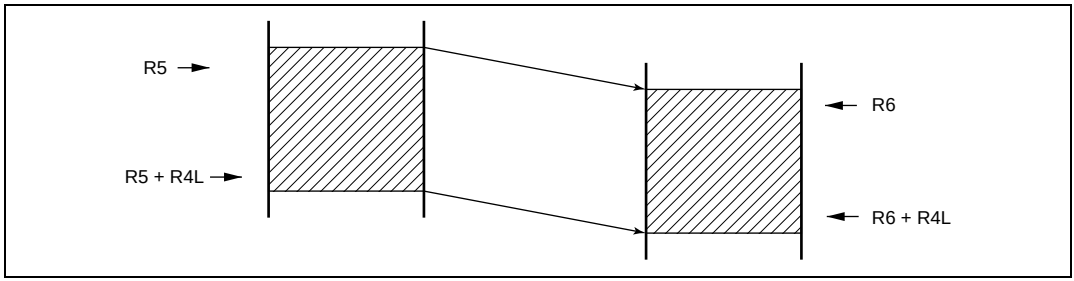
Operation:

1. When the BCLR instruction is executed, first the CPU reads P4DDR.
   Since P4DDR is a write-only register, so the CPU reads H'FF. In this example P4DDR has a value of H'3F, but the value read by the CPU is H'FF.
2. The CPU clears bit 0 of the read data to 0, changing data to H'FE.
3. The CPU writes H'FE to DDR, completing execution of BCLR.

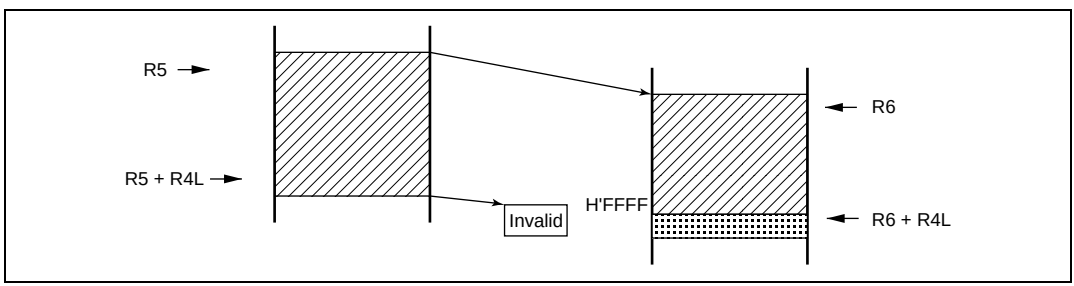
As a result of the BCLR instruction, bit 0 in DDR is set to 0, and P40 becomes an input pin. However, bits 7 and 6 of DDR are modified to 1, therefore P47 and P46 become output pins.

2.9.4 EEPMOV Instruction

1. EEPMOV is a block-transfer instruction and transfers the byte size of data indicated by R4L, which starts from the address indicated by R5, to the address indicated by R6.



2. Set R4L and R6 so that the end address of the destination address (value of R6 + R4L) does not exceed H'FFFF (the value of R6 must not change from H'FFFF to H'0000 during execution).



Section 3 MCU Operating Modes

3.1 MCU Operating Mode Selection

This LSI has three operating modes (modes 1 to 3). The operating mode is determined by the setting of the mode pins (MD1 and MD0). Table 3.1 shows the MCU operating mode selection.

Table 3.1 lists the MCU operating modes.

Table 3.1 MCU Operating Mode Selection

MCU Operating Mode	MD1	MD0	CPU Operating Mode	Description	On-Chip ROM
0	0	0	—	—	—
1		1	Normal	Expanded mode with on-chip ROM disabled	Disabled
2	1	0	Advanced	Expanded mode with on-chip ROM enabled	Enabled
				Single-chip mode	
3		1	Normal	Expanded mode with on-chip ROM enabled	
				Single-chip mode	

Mode 1 is an expanded mode that allows access to external memory and peripheral devices. With modes 2 and 3, operation begins in single-chip mode after reset release, but a transition can be made to external expansion mode by setting the EXPE bit in MDCR to 1.

Mode 0 cannot be used in this LSI. Thus, mode pins should be set to enable mode 1, 2 or 3 in normal program execution state. Mode pins should not be changed during operation.

3.2 Register Descriptions

The following registers are related to the operating mode. For details on the bus control register (BCR), refer to section 6.3.1, Bus Control Register (BCR).

- Mode control register (MDCR)
- System control register (SYSCR)
- Serial timer control register (STCR)

3.2.1 Mode Control Register (MDCR)

MDCR is used to set an operating mode and to monitor the current operating mode.

Bit	Bit Name	Initial Value	R/W	Description
7	EXPE	—*	R/W*	Extended Mode Enable Specifies extended mode. Fixed to 1 and cannot be modified in mode 1. Readable/writable and the initial value is 0 in mode 2 or 3. 0: Single-chip mode 1: Extended mode
6 to 2	—	All 0	R	Reserved These bits are always read as 0. These bits cannot be modified.
1	MDS1	—*	R	Mode Select 1 and 0
0	MDS0	—*	R	These bits indicate the input levels at mode pins (MD1 and MD0) (the current operating mode). Bits MDS1 and MDS0 correspond to MD1 and MD0, respectively. These bits are read-only bits and they cannot be written to. The mode pin (MD1 and MD0) input levels are latched into these bits when MDCR is read. These latches are canceled by a reset.

Note: * The initial values are determined by the settings of the MD1 and MD0 pins.

3.2.2 System Control Register (SYSCR)

SYSCR selects a system pin function, monitors a reset source, selects the interrupt control mode and the detection edge for NMI, pin location selection, enables or disables register access to the on-chip peripheral modules, and enables or disables on-chip RAM address space.

Bit	Bit Name	Initial Value	R/W	Description
7	CS2E	0	R/W	Chip Select 2 Enable Specifies the location of the control pin ($\overline{CS2}$) of the host interface together with the FGA20E bit in HICR. See section 18, Host Interface X-Bus Interface (XBS), for details.
6	IOSE	0	R/W	IOS Enable Enables or disables $\overline{AS}$/$\overline{IOS}$ pin function in extended mode. 0: $\overline{AS}$ pin Outputs low when an external area is accessed. 1: $\overline{IOS}$ pin Outputs low when a specified address of addresses H'(FF)F000 to H'(FF)F7FF is accessed.
5	INTM1	0	R	These bits select the control mode of the interrupt controller. For details on the interrupt control modes and interrupt control select modes 1 and 0, see section 5.6, Interrupt Control Modes and Interrupt Operation. 00: Interrupt control mode 0 01: Interrupt control mode 1 10: Setting prohibited 11: Setting prohibited
4	INTM0	0	R/W	
3	XRST	1	R	External Reset This bit indicates the reset source. A reset is caused by an external reset input, or when the watchdog timer overflows. 0: A reset is caused when the watchdog timer overflows. 1: A reset is caused by an external reset.

Bit	Bit Name	Initial Value	R/W	Description
2	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
1	HIE	0	R/W	Host Interface Enable Controls CPU access to the host interface registers (HICR, IDR1, ODR1, STR1, IDR2, ODR2, and STR2), the keyboard matrix interrupt and MOS input pull-up control registers (KMIMR, KMPCR, and KMIMRA), the 8-bit timer (TMR_X and TMR_Y) registers (TCR_X/TCR_Y, TCSR_X/TCSR_Y, TICRR/TCORA_Y, TICRF/TCORB_Y, TCNT_X/TCNT_Y, TCORC/TISR, TCORA_X, and TCORB_X), and the timer connection registers (TCONRI, TCONRO, TCONRS, and SEDGR). 0: In areas H'(FF)FFF0 to H'(FF)FFF7 and H'(FF)FFFC to H'(FF)FFFF, CPU access to 8-bit timer (TMR_X and TMR_Y) registers and timer connection registers is permitted 1: In areas H'(FF)FFF0 to H'(FF)FFF7 and H'(FF)FFFC to H'(FF)FFFF, CPU access to host interface registers and keyboard matrix interrupt and MOS input pull-up control registers is permitted
0	RAME	1	R/W	RAM Enable Enables or disables on-chip RAM. The RAME bit is initialized when the reset state is released. 0: On-chip RAM is disabled 1: On-chip RAM is enabled

3.2.3 Serial Timer Control Register (STCR)

STCR enables or disables register access, IIC operating mode, and on-chip flash memory, and selects the input clock of the timer counter.

Bit	Bit Name	Initial Value	R/W	Description
7	IICS	0	R/W	I^2C Extra Buffer Select Specifies bits 7 to 4 of port A as output buffers similar to SLC and SDA. These pins are used to implement an I^2C interface only by software. 0: PA7 to PA4 are normal input/output pins. 1: PA7 to PA4 are input/output pins enabling bus driving.
6	IICX1	0	R/W	I^2C Transfer Rate Select 1 and 0
5	IICX0	0	R/W	These bits control the IIC operation. These bits select a transfer rate in master mode together with bits CKS2 to CKS0 in the I^2C bus mode register (ICMR). For details on the transfer rate, refer to table 16.3.
4	IICE	0	R/W	I^2C Master Enable Enables or disables CPU access for IIC registers (ICCR, ICSR, ICDR/SARX, ICMR/SAR), PWMX registers (DADRAH/DACR, DADRAL, DADRBH/DACNTH, DADRBL/DACNTL), and SCI registers (SMR, BRR, SCMR). 0: SCI_1 registers are accessed in an area from H'(FF)FF88 to H'(FF)FF89 and from H'(FF)FF8E to H'(FF)FF8F. SCI_2 registers are accessed in an area from H'(FF)FFA0 to H'(FF)FFA1 and from H'(FF)FFA6 to H'(FF)FFA7. SCI_0 registers are accessed in an area from H'(FF)FFD8 to H'(FF)FFD9 and from H'(FF)FFDE to H'(FF)FFDF. 1: IIC_1 registers are accessed in an area from H'(FF)FF88 to H'(FF)FF89 and from H'(FF)FF8E to H'(FF)FF8F. PWMX registers are accessed in an area from H'(FF)FFA0 to H'(FF)FFA1 and from H'(FF)FFA6 to H'(FF)FFA7. IIC_0 registers are accessed in an area from H'(FF)FFD8 to H'(FF)FFD9 and from H'(FF)FFDE to H'(FF)FFDF.

Bit	Bit Name	Initial Value	R/W	Description
3	FLSHE	0	R/W	Flash Memory Control Register Enable Enables or disables CPU access for flash memory registers (FLMCR1, FLMCR2, EBR1, EBR2), control registers in power-down state (SBYCR, LPWRCR, MSTPCRH, MSTPCRL), and control registers of on-chip peripheral modules (PCSR, SYSCR2). 0: Registers in power-down state and control registers of on-chip peripheral modules are accessed in an area from H'(FF)FF80 to H'(FF)FF87. 1: Control registers of flash memory are accessed in an area from H'(FF)FF80 to H'(FF)FF87.
2	—	0	R/(W)	Reserved The initial value should not be changed.
1	ICKS1	0	R/W	Internal Clock Source Select 1, 0
0	ICKS0	0	R/W	These bits select a clock to be input to the timer counter (TCNT) and a count condition together with bits CKS2 to CKS0 in the timer control register (TCR). For details, refer to section 12.3.4, Timer Control Register (TCR).

3.3 Operating Mode Descriptions

3.3.1 Mode 1

The CPU can access a 64-kbyte address space in normal mode. The on-chip ROM is disabled.

Ports 1 and 2 function as an address bus, port 3 functions as a data bus, and part of port 9 carries bus control signals. Clearing the ABW bit to 0 in the WSCR register makes port B a data bus.

3.3.2 Mode 2

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

After a reset, the LSI is set to single-chip mode. To access an external address space, bit EXPE in MDCR should be set to 1.

When the EXPE bit in MDCR is set to 1, ports 1, 2 and A function as input ports after a reset. Ports 1, 2 and A output an address by setting 1 to the corresponding port data direction register (DDR). Port 3 functions as a data bus, and parts of port 9 carry bus control signals. Port B functions as a data bus when the ABW bit in WSCR is cleared to 0.

3.3.3 Mode 3

The CPU can access a 64-kbyte address space in normal mode. The on-chip ROM is enabled. The CPU can access a 56-kbyte address space in mode 3.

After a reset, the LSI is set to single-chip mode. To access an external address space, bit EXPE in MDCR should be set to 1.

When the EXPE bit in MDCR is set to 1, ports 1 and 2 function as input ports after a reset. Ports 1 and 2 function as an address bus by setting 1 to the corresponding port data direction register (DDR). Port 3 functions as a data bus, and parts of port 9 carry bus control signals. Port B functions as a data bus when the ABW bit in WSCR is cleared to 0.

3.3.4 Pin Functions in Each Operating Mode

Pin functions of ports 1 to 3, 9, A, and B depend on the operating mode. Table 3.2 shows pin functions in each operating mode.

Table 3.2 Pin Functions in Each Mode

Port		Mode 1	Mode 2	Mode 3
Port 1		A	P*/A	P*/A
Port 2		A	P*/A	P*/A
Port A		P	P*/A	P
Port 3		D	P*/D	P*/D
Port B		P*/D	P*/D	P*/D
Port 9	P97	P*/C	P*/C	P*/C
	P96	C*/P	P*/C	P*/C
	P95 to P93	C	P*/C	P*/C
	P92, P91	P	P	P
	P90	P*/C	P*/C	P*/C
Port C to Port G		P	P	P

Legend:

P: I/O port

A: Address bus output

D: Data bus I/O

C: Control signals, clock I/O

*: Immediately after reset

3.4 Address Map in Each Operating Mode

Figures 3.1 to 3.10 show the address map in each operating mode.

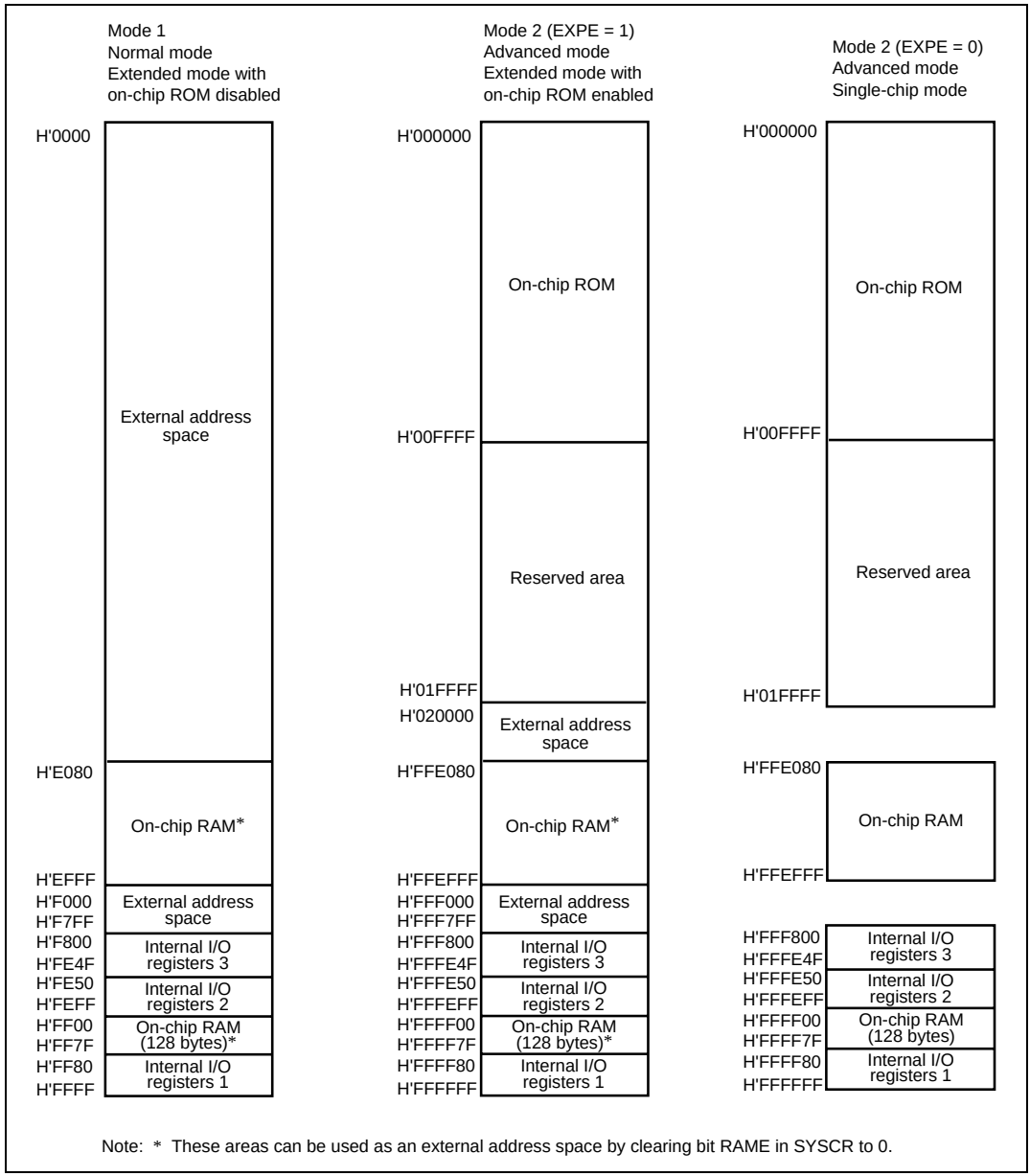
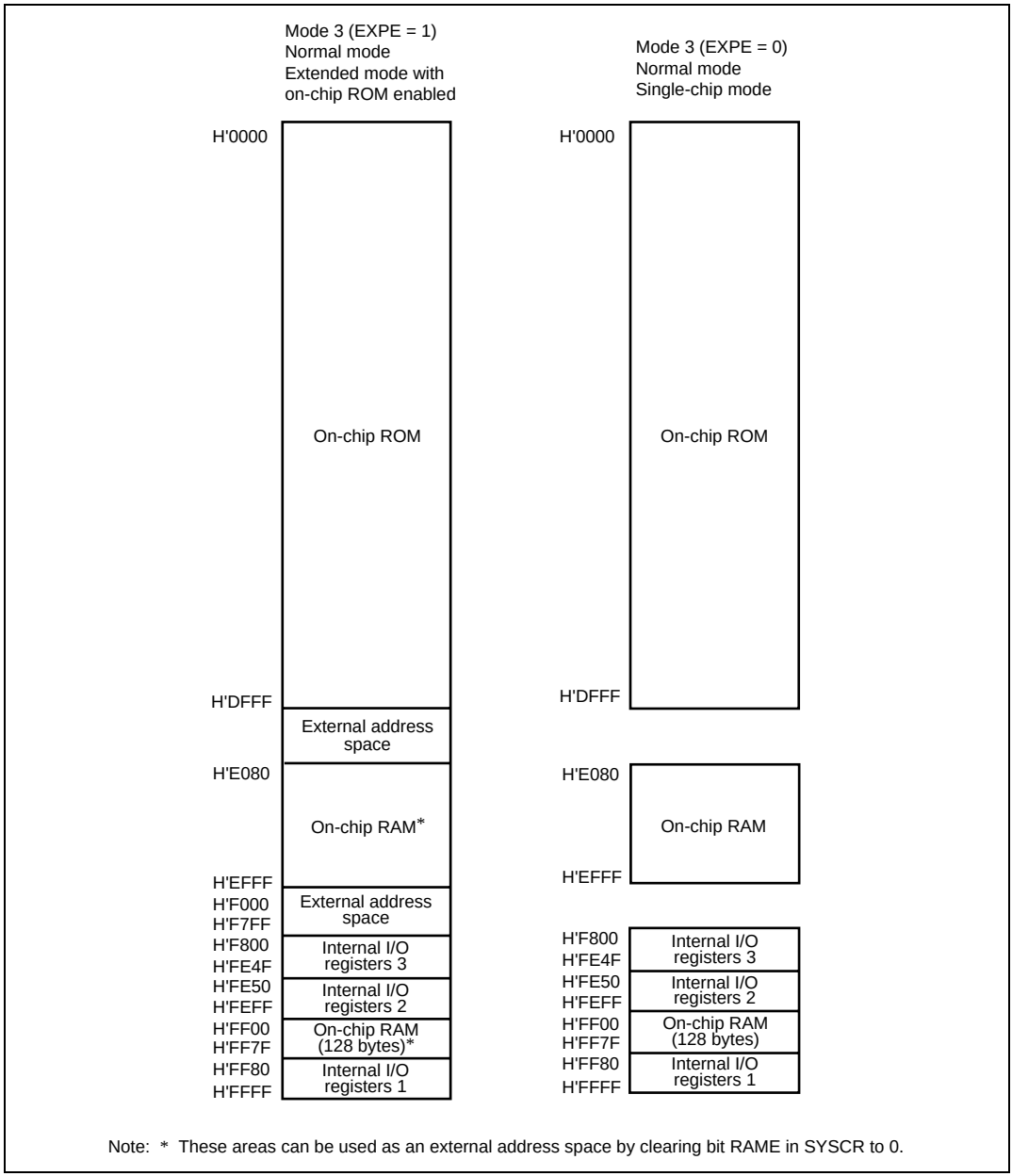
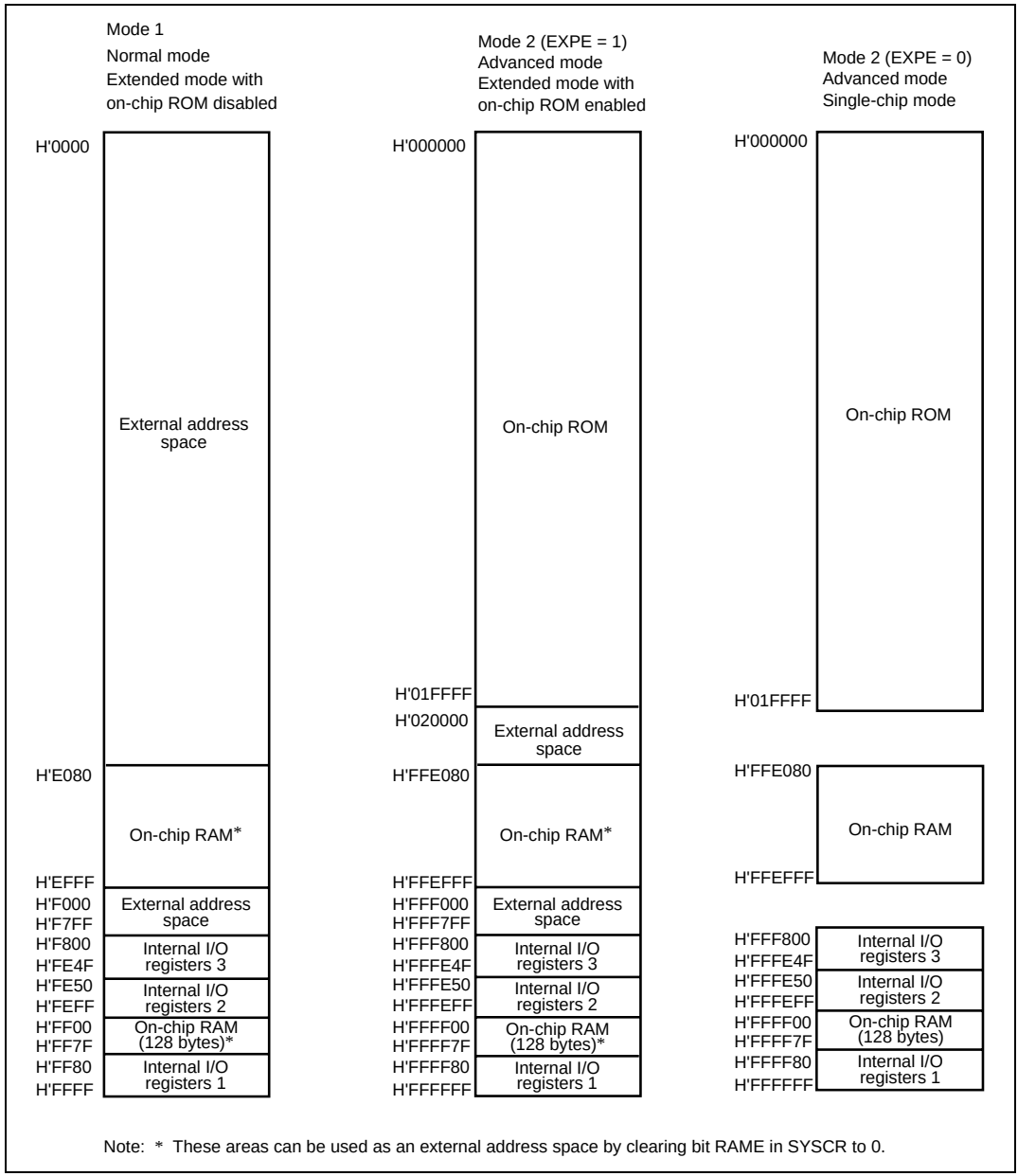


Figure 3.1 Address Map for H8S/2140B and H8S/2160B (1)



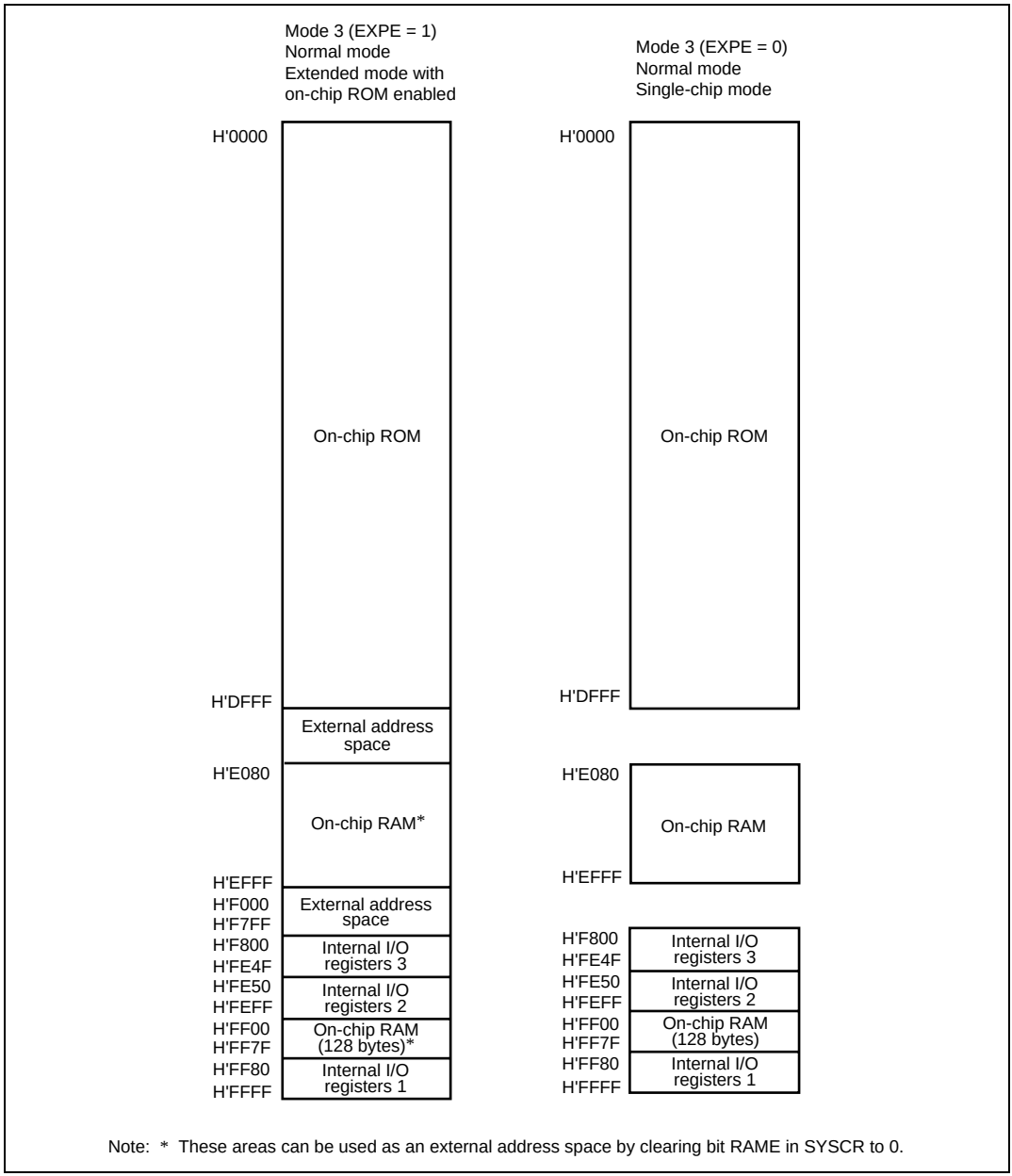
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.2 Address Map for H8S/2140B and H8S/2160B (2)



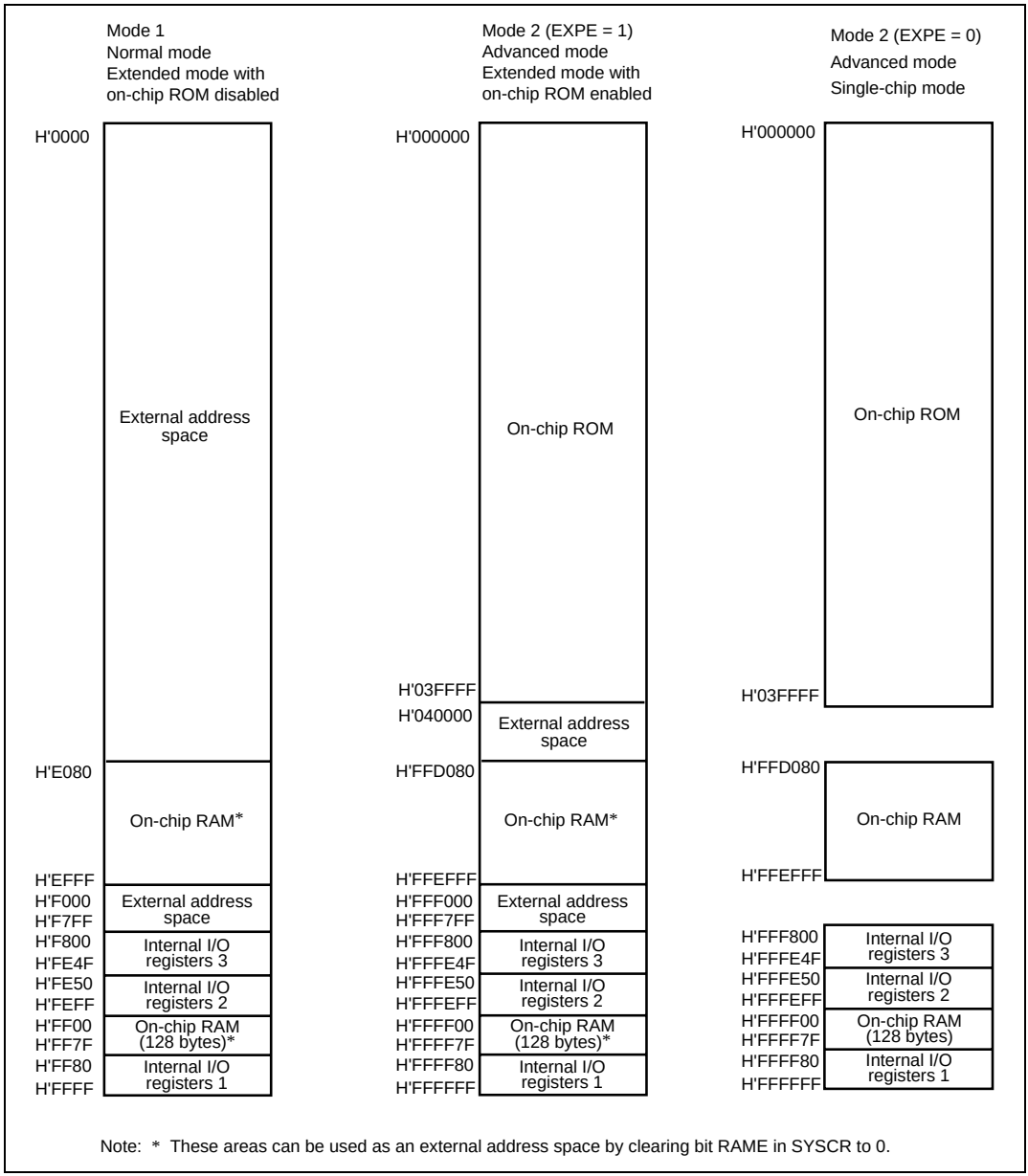
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.3 Address Map for H8S/2141B and H8S/2161B (1)



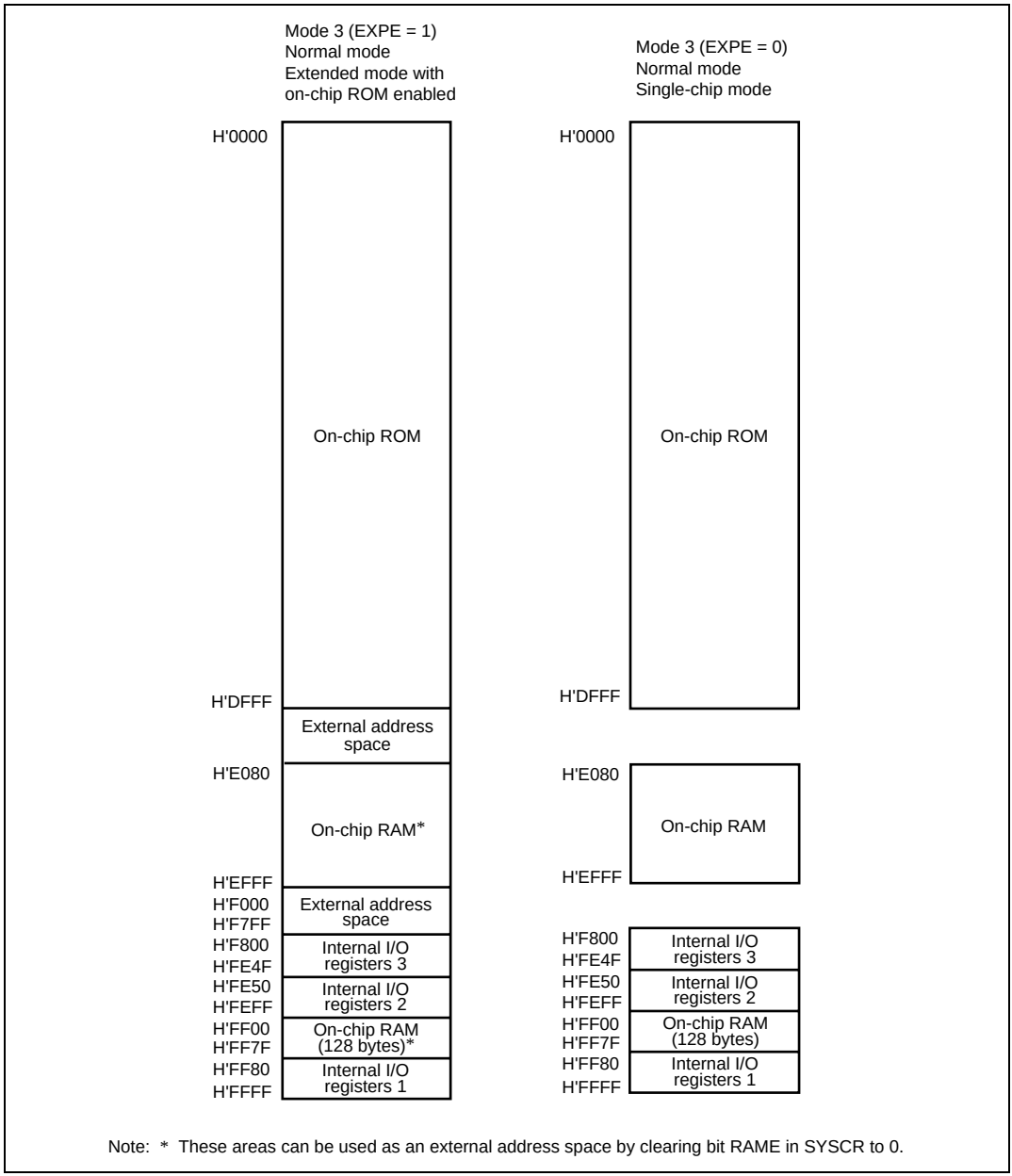
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.4 Address Map for H8S/2141B and H8S/2161B (2)



Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.5 Address Map for H8S/2145BV (1)



Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.6 Address Map for H8S/2145BV (2)

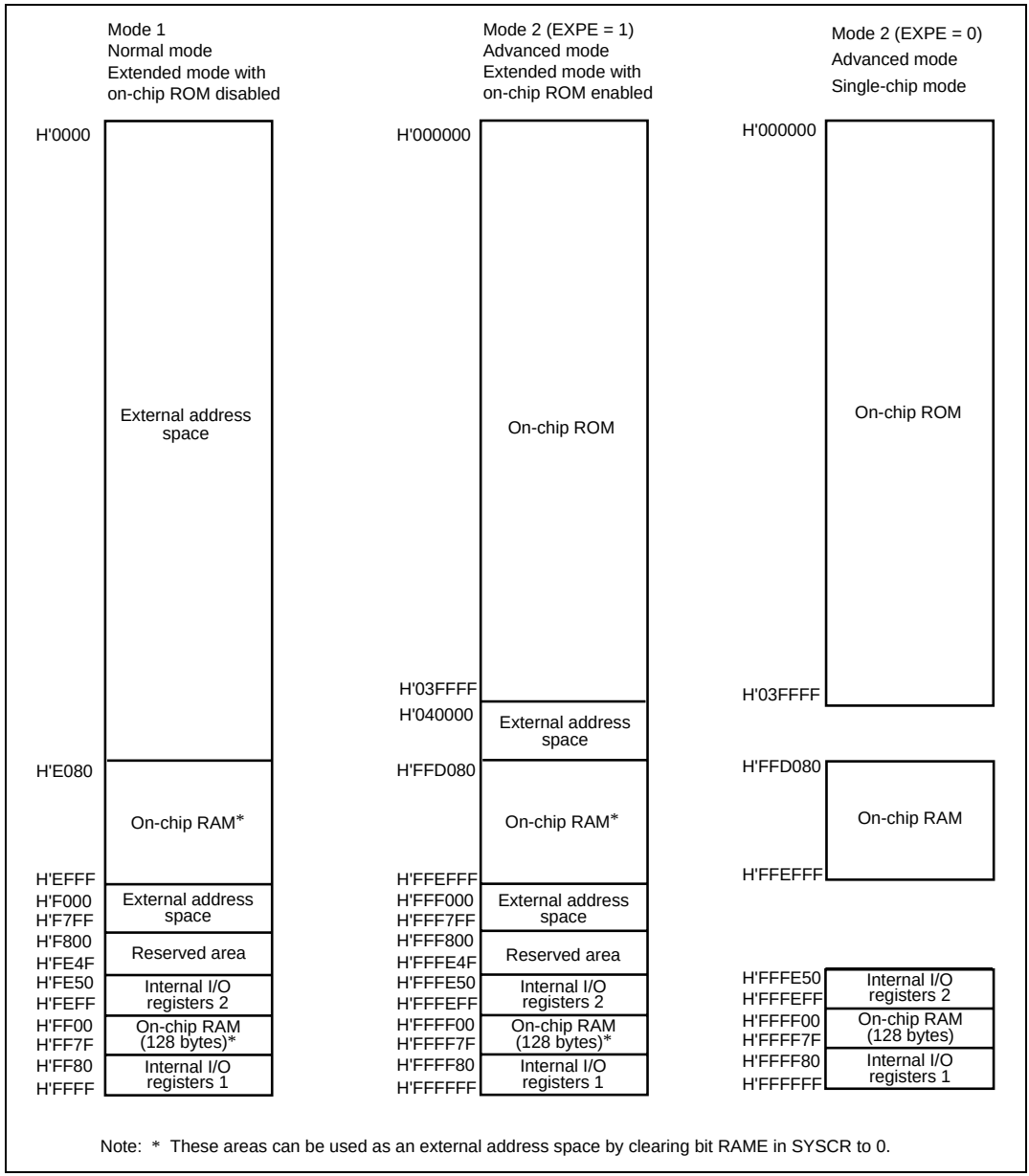
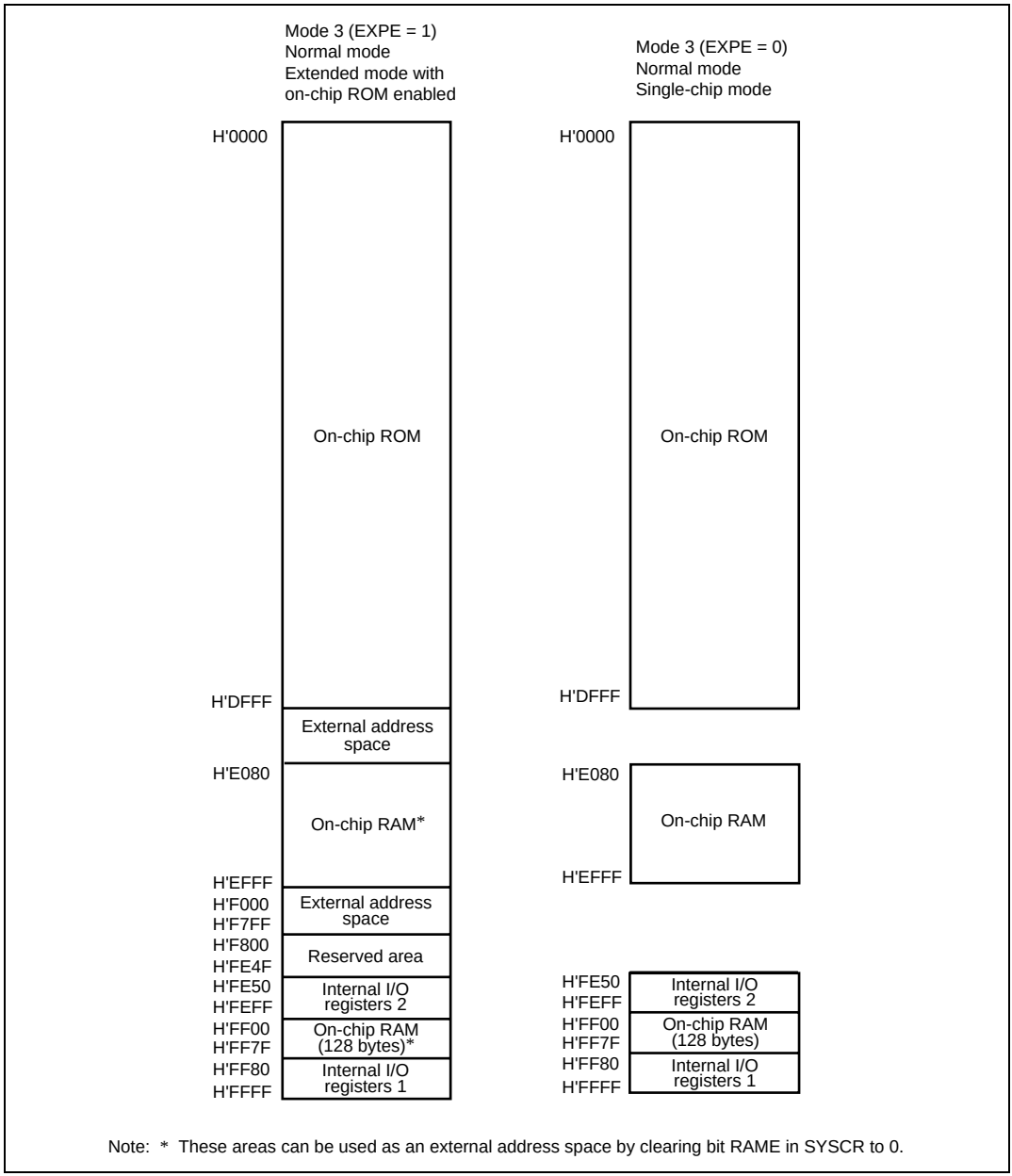
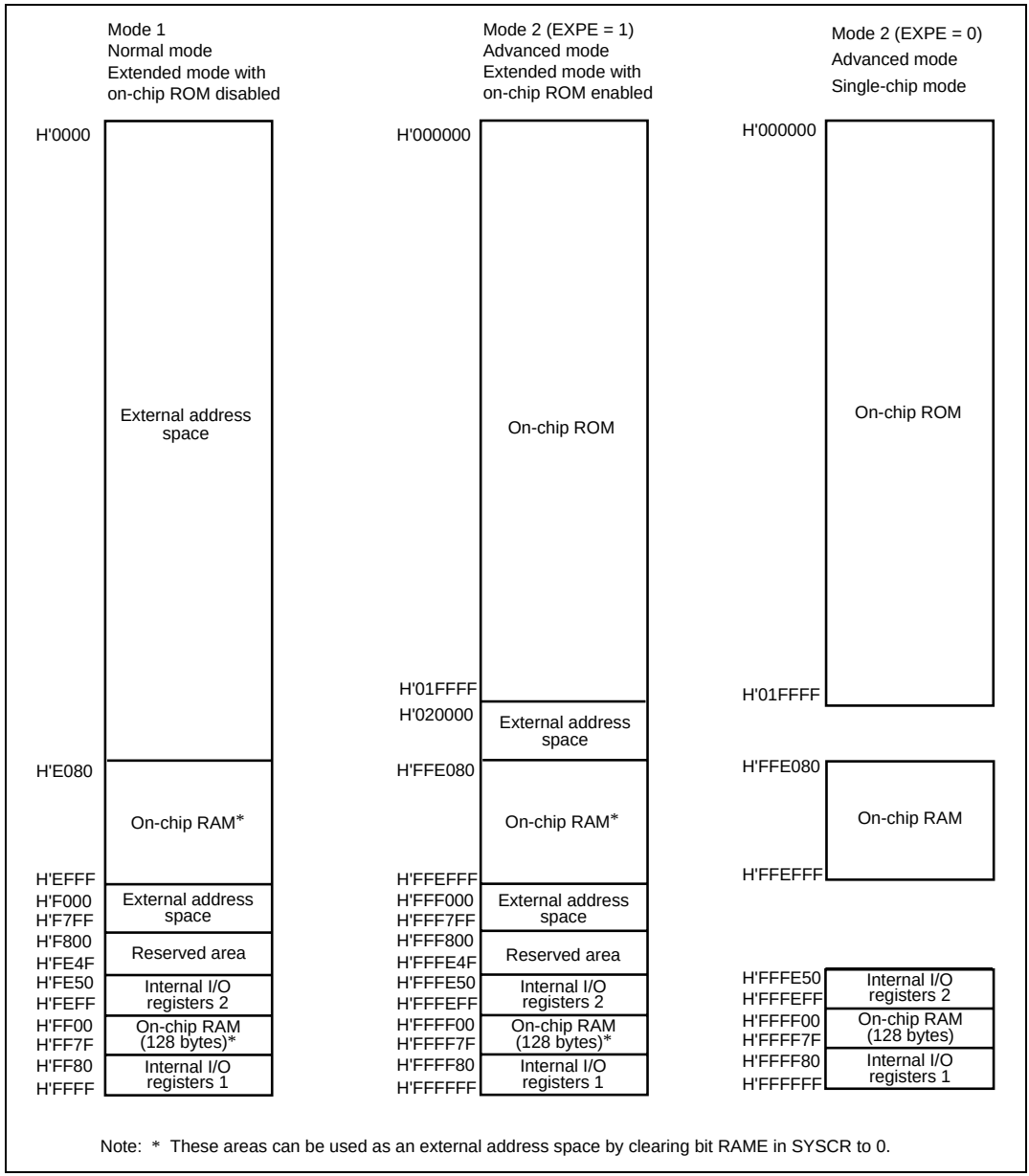


Figure 3.7 Address Map for H8S/2145B (1)



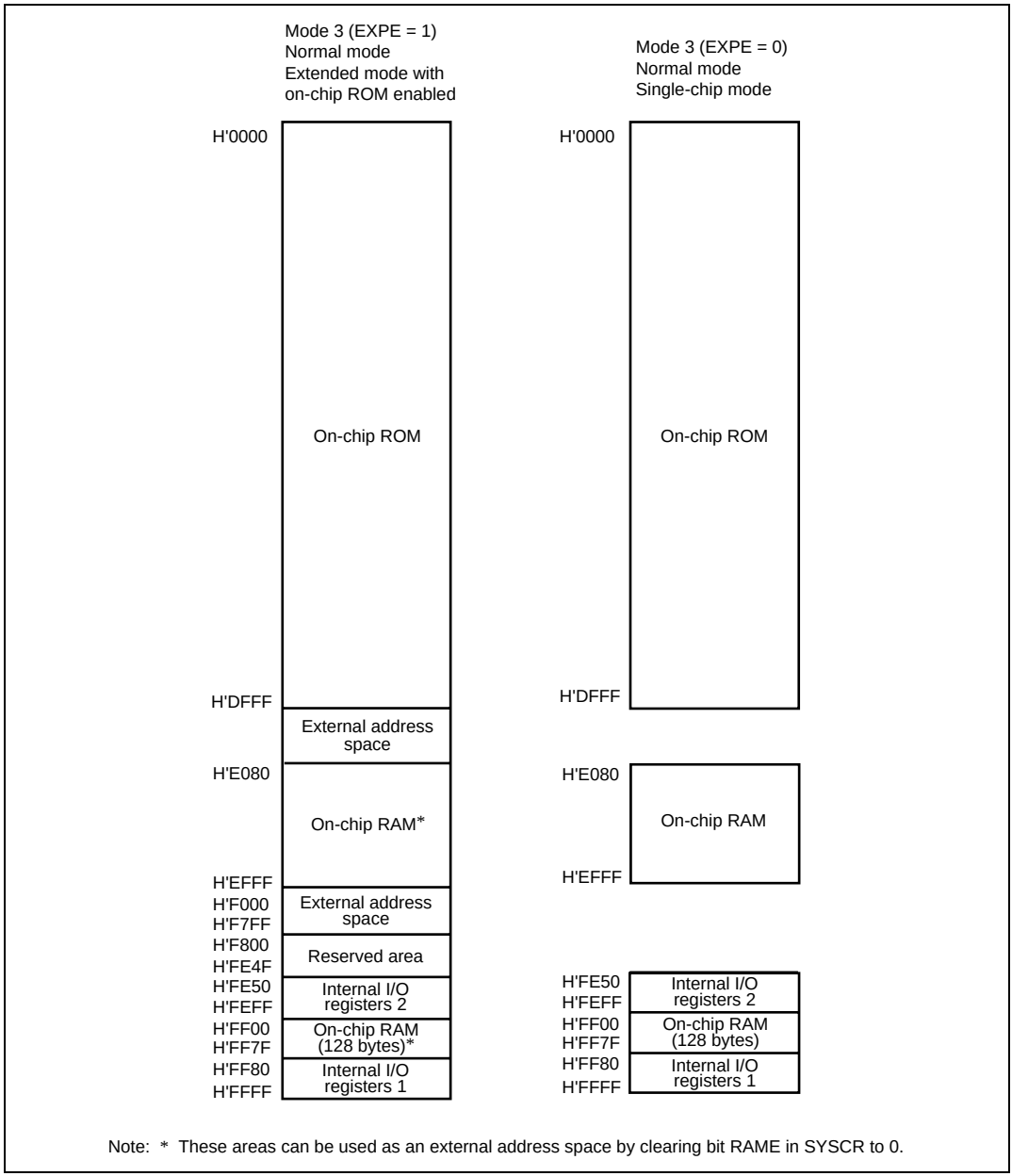
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.8 Address Map for H8S/2145B (2)



Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.9 Address Map for H8S/2148B (1)



Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

Figure 3.10 Address Map for H8S/2148B (2)

Section 4 Exception Handling

4.1 Exception Handling Types and Priority

As table 4.1 indicates, exception handling may be caused by a reset, interrupt, direct transition, or trap instruction. 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.

Table 4.1 Exception Types and Priority

Priority	Exception Type	Start of Exception Handling
High ▲	Reset	Starts immediately after a low-to-high transition of the $\overline{\text{RES}}$ pin, or when the watchdog timer overflows.
	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.
	Direct transition	Starts when a direction transition occurs as the result of SLEEP instruction execution.
	Trap instruction	Started by execution of a trap (TRAPA) instruction. 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

			Vector Address	
Exception Source		**Vector Number**	**Normal Mode**	**Advanced Mode**
Reset		0	H'0000 to H'0001	H'000000 to H'000003
Reserved for system use		1 ⋮ 5	H'0002 to H'0003 ⋮ H'000A to H'000B	H'000004 to H'000007 ⋮ H'000014 to H'000017
Direct transition		6	H'000C to H'000D	H'000018 to H'00001B
External interrupt (NMI)		7	H'000E to H'000F	H'00001C to H'00001F
Trap instruction (four sources)		8	H'0010 to H'0011	H'000020 to H'000023
		9	H'0012 to H'0013	H'000024 to H'000027
		10	H'0014 to H'0015	H'000028 to H'00002B
		11	H'0016 to H'0017	H'00002C to H'00002F
Reserved for system use		12 ⋮ 15	H'0018 to H'0019 ⋮ H'001E to H'001F	H'000030 to H'000033 ⋮ H'00003C to H'00003F
External interrupt	IRQ0	16	H'0020 to H'0021	H'000040 to H'000043
	IRQ1	17	H'0022 to H'0023	H'000044 to H'000047
	IRQ2	18	H'0024 to H'0025	H'000048 to H'00004B
	IRQ3	19	H'0026 to H'0027	H'00004C to H'00004F
	IRQ4	20	H'0028 to H'0029	H'000050 to H'000053
	IRQ5	21	H'002A to H'002B	H'000054 to H'000057
	IRQ6	22	H'002C to H'002D	H'000058 to H'00005B
	IRQ7	23	H'002E to H'002F	H'00005C to H'00005F
Internal interrupt*		24 ⋮ 107	H'0030 to H'0031 ⋮ H'00DE to H'00DF	H'000060 to H'000063 ⋮ H'0001BC to H'0001BF

Note: * For details on the internal interrupt vector table, see section 5.5, Interrupt Exception Handling Vector Table.

4.3 Reset

A reset has the highest exception priority. When the $\overline{\text{RES}}$ pin goes low, all processing halts and this LSI enters the reset. To ensure that this LSI is reset, hold the $\overline{\text{RES}}$ pin low for at least 20 ms at power-on. To reset the chip during operation, hold the $\overline{\text{RES}}$ pin low for at least 20 states. A reset initializes the internal state of the CPU and the registers of on-chip peripheral modules. The chip can also be reset by overflow of the watchdog timer. For details, see section 14, Watchdog Timer (WDT).

4.3.1 Reset Exception Handling

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

1. The internal state of the CPU and the registers of the on-chip peripheral modules are initialized and the I bit is set to 1 in CCR.
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.

Figure 4.1 shows an example of the reset sequence.

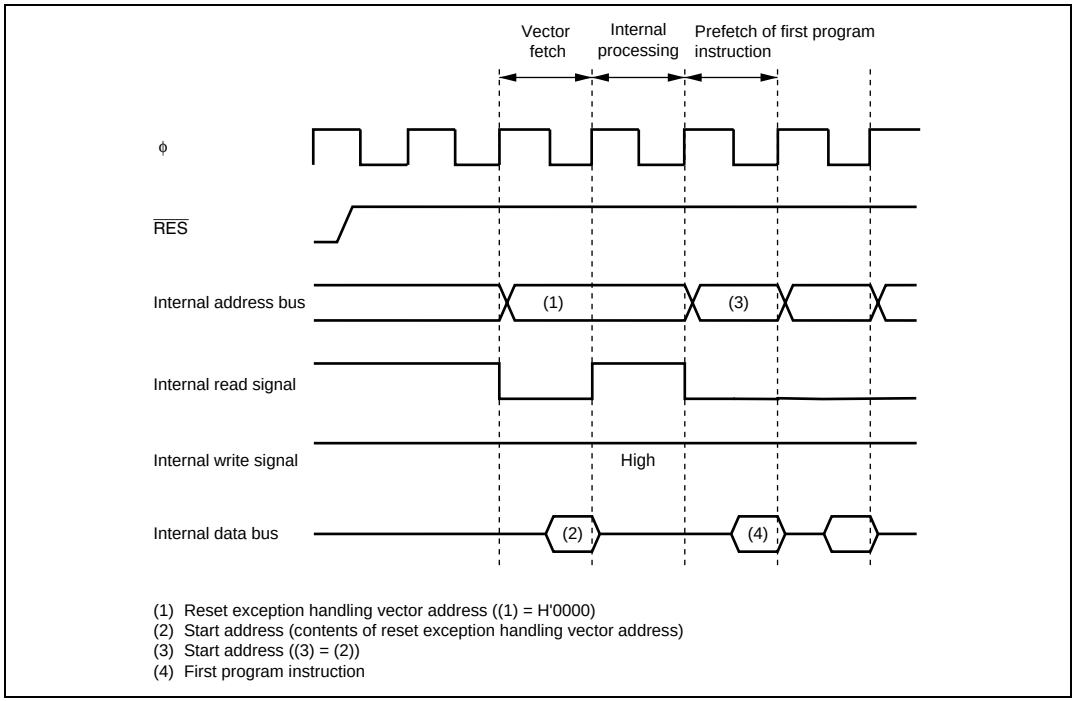


Figure 4.1 Reset Sequence (Mode 3)

4.3.2 Interrupts after Reset

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

4.3.3 On-Chip Peripheral Modules after Reset Is Cancelled

After a reset is cancelled, the module stop control registers (MSTPCR) are initialized, and all modules except the DTC operate in module stop mode. Therefore, the registers of on-chip peripheral modules cannot be read from or written to. To read from and write to these registers, clear module stop mode.

4.4 Interrupt Exception Handling

Interrupts are controlled by the interrupt controller. The sources to start interrupt exception handling are external interrupt sources (NMI, IRQ7 to IRQ0, KIN15 to KIN0, and WUE7 to WUE0) and internal interrupt sources from the on-chip peripheral modules. NMI is an interrupt with the highest priority. For details, refer to section 5, Interrupt Controller.

Interrupt exception handling is conducted as follows:

1. The values in the program counter (PC) and condition code register (CCR) are saved to the stack.
2. 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.

4.5 Trap Instruction Exception Handling

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

Trap instruction exception handling is conducted as follows:

1. The values in the program counter (PC) and condition code register (CCR) are saved to the stack.
2. 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 4.3 shows the status of CCR after execution of trap instruction exception handling.

Table 4.3 Status of CCR after Trap Instruction Exception Handling

	CCR	
Interrupt Control Mode	**I**	**UI**
0	1	—
1	1	1

Legend:
1: Set to 1
—: Retains value prior to execution

4.6 Stack Status after Exception Handling

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

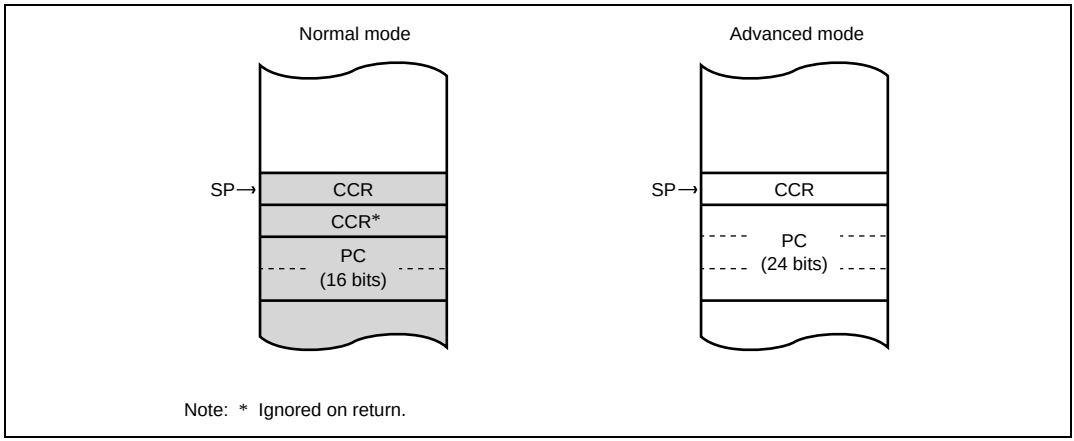


Figure 4.2 Stack Status after Exception Handling

4.7 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 in words or longwords, 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.

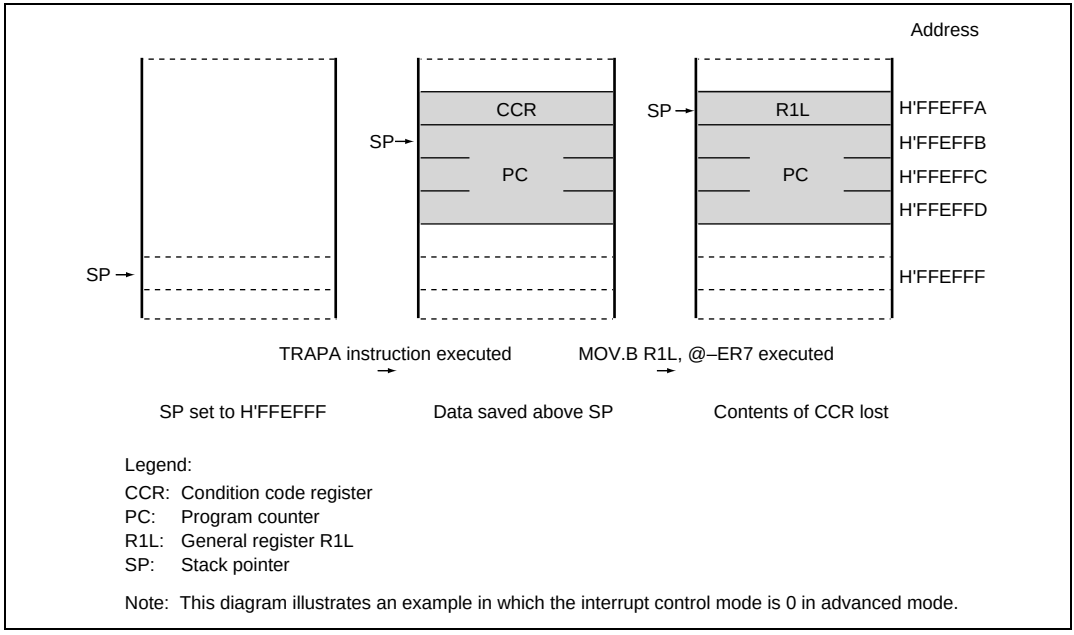


Figure 4.3 Operation when SP Value Is Odd

Section 5 Interrupt Controller

5.1 Features

- 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 ICR

  An interrupt control register (ICR) is provided for setting interrupt priorities. Three priority levels can be set for each module for all interrupts except NMI and address break.
- 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.
- Thirty-one external interrupts

  NMI is the highest-priority interrupt, and is accepted at all times. Rising edge or falling edge detection can be selected for NMI. Falling-edge, rising-edge, or both-edge detection, or level sensing, can be selected for $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$. The IRQ6 interrupt is shared by the interrupt from the $\overline{\text{IRQ6}}$ pin and eight external interrupt inputs ($\overline{\text{KIN7}}$ to $\overline{\text{KIN0}}$), and the IRQ7 interrupt is shared by the interrupt from the $\overline{\text{IRQ7}}$ pin and sixteen external interrupt inputs ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$ and $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$). $\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$ and $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$ can be masked individually by the user program.
- DTC control

  The DTC can be activated by an interrupt request.

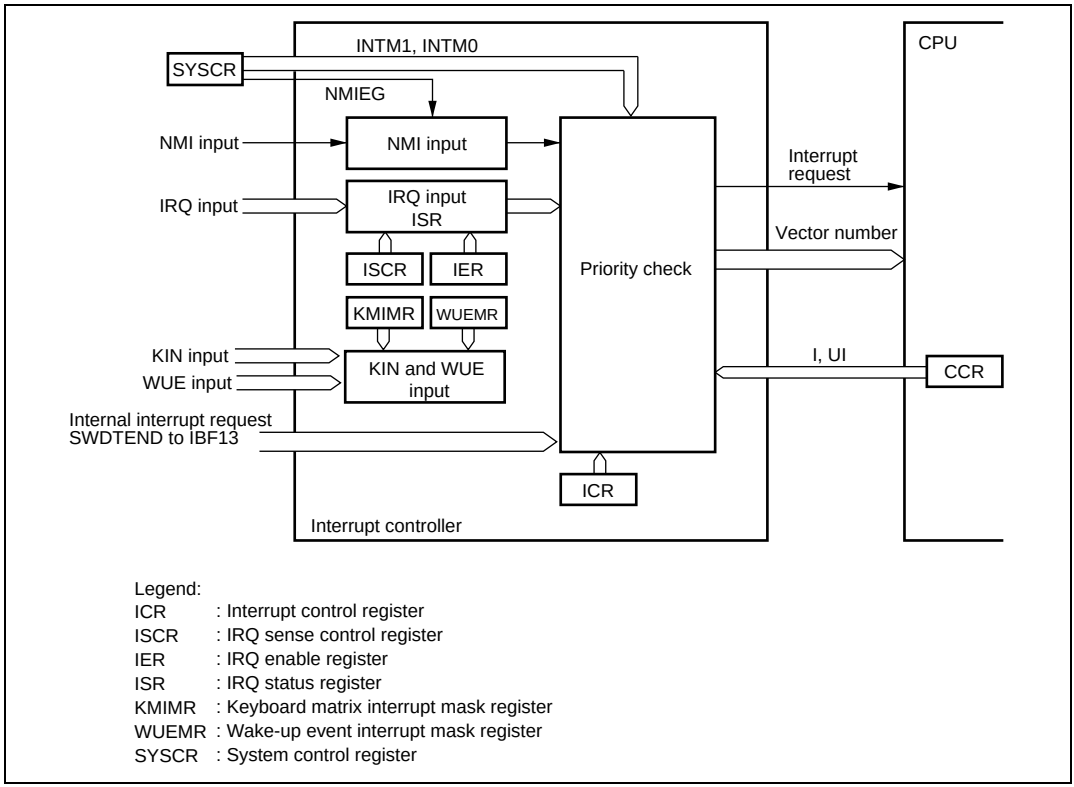


Figure 5.1 Block Diagram of Interrupt Controller

5.2 Input/Output Pins

Table 5.1 summarizes the pins of the interrupt controller.

Table 5.1 Pin Configuration

Symbol	I/O	Function
NMI	Input	Nonmaskable external interrupt Rising edge or falling edge can be selected
$\overline{IRQ7}$ to $\overline{IRQ0}$	Input	Maskable external interrupts Rising edge, falling edge, or both edges, or level sensing, can be selected individually for each pin.
$\overline{KIN15}$ to $\overline{KIN0}$	Input	Maskable external interrupts Falling edge or level sensing can be selected.
$\overline{WUE7}$ to $\overline{WUE0}$*	Input	Maskable external interrupts Falling edge or level sensing can be selected.

Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).

5.3 Register Descriptions

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

- Interrupt control registers A to C (ICRA to ICRC)
- Address break control register (ABRKCR)
- Break address registers A to C (BARA to BARC)
- IRQ sense control registers (ISCRH, ISCRL)
- IRQ enable register (IER)
- IRQ status register (ISR)
- Keyboard matrix interrupt mask registers (KMIMRA, KMIMR)
- Wake-up event interrupt mask register (WUEMRB)

5.3.1 Interrupt Control Registers A to C (ICRA to ICRC)

The ICR registers set interrupt control levels for interrupts other than NMI and address breaks.

The correspondence between interrupt sources and ICRA to ICRC settings is shown in table 5.2.

Bit	Bit Name	Initial Value	R/W	Description
7 to 0	ICRn7 to IRCn0	All 0	R/W	Interrupt Control Level 0: Corresponding interrupt source is interrupt control level 0 (no priority) 1: Corresponding interrupt source is interrupt control level 1 (priority)

n: A to C

Table 5.2 Correspondence between Interrupt Source and ICR

		Register		
Bit	**Bit Name**	**ICRA**	**ICRB**	**ICRC**
7	ICRn7	IRQ0	A/D converter	SCI_0
6	ICRn6	IRQ1	FRT	SCI_1
5	ICRn5	IRQ2, IRQ3	—	SCI_2
4	ICRn4	IRQ4, IRQ5	—	IIC_0
3	ICRn3	IRQ6, IRQ7	TMR_0	IIC_1
2	ICRn2	DTC	TMR_1	—
1	ICRn1	WDT_0	TMR_X, TMR_Y	LPC*
0	ICRn0	WDT_1	XBS, Keyboard buffer controller	—

Legend:

—: Reserved. The write value should always be 0.

Notes: n: A to C

* On products not including LPC, this bit is reserved. The write value should always be 0.

5.3.2 Address Break Control Register (ABRKCR)

ABRKCR controls the address breaks. When both the CMF flag and BIE flag are set to 1, an address break is requested.

Bit	Bit Name	Initial Value	R/W	Description
7	CMF	0	R	Condition Match Flag Address break source flag. Indicates that an address specified by BARA to BARC is prefetched. [Setting condition] When an address specified by BARA to BARC is prefetched while the BIE flag is set to 1. [Clearing condition] When an exception handling is executed for an address break interrupt.
6 to 1	—	All 0	R	Reserved These bits are always read as 0 and cannot be modified.
0	BIE	0	R/W	Break Interrupt Enable Enables or disables address break. 0: Disabled 1: Enabled

5.3.3 Break Address Registers A to C (BARA to BARC)

The BAR registers specify an address that is to be a break address. An address in which the first byte of an instruction exists should be set as a break address. In normal mode, addresses A23 to A16 are not compared.

- BARA

Bit	Bit Name	Initial Value	R/W	Description
7 to 0	A23 to A16	All 0	R/W	Addresses 23 to 16 The A23 to A16 bits are compared with A23 to A16 in the internal address bus.

- BARB

Bit	Bit Name	Initial Value	R/W	Description
7 to 0	A15 to A8	All 0	R/W	Addresses 15 to 8 The A15 to A8 bits are compared with A15 to A8 in the internal address bus.

- BARC

Bit	Bit Name	Initial Value	R/W	Description
7 to 1	A7 to A1	All 0	R/W	Addresses 7 to 1 The A7 to A1 bits are compared with A7 to A1 in the internal address bus.
0	—	0	R	Reserved This bit is always read as 0 and cannot be modified.

5.3.4 IRQ Sense Control Registers (ISCRH, ISCRL)

The ISCR registers select the source that generates an interrupt request at pins $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$.

- ISCRH

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ7SCB	0	R/W	IRQn Sense Control B
6	IRQ7SCA	0	R/W	IRQn Sense Control A
5	IRQ6SCB	0	R/W	00: Interrupt request generated at low level of $\overline{\text{IRQn}}$ input
4	IRQ6SCA	0	R/W	
3	IRQ5SCB	0	R/W	01: Interrupt request generated at falling edge of $\overline{\text{IRQn}}$ input
2	IRQ5SCA	0	R/W	
1	IRQ4SCB	0	R/W	10: Interrupt request generated at rising edge of $\overline{\text{IRQn}}$ input
0	IRQ4SCA	0	R/W	11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQn}}$ input
				(n = 7 to 4)

- ISCRL

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ3SCB	0	R/W	IRQn Sense Control B
6	IRQ3SCA	0	R/W	IRQn Sense Control A
5	IRQ2SCB	0	R/W	00: Interrupt request generated at low level of $\overline{\text{IRQn}}$ input
4	IRQ2SCA	0	R/W	
3	IRQ1SCB	0	R/W	01: Interrupt request generated at falling edge of $\overline{\text{IRQn}}$ input
2	IRQ1SCA	0	R/W	
1	IRQ0SCB	0	R/W	10: Interrupt request generated at rising edge of $\overline{\text{IRQn}}$ input
0	IRQ0SCA	0	R/W	11: Interrupt request generated at both falling and rising edges of $\overline{\text{IRQn}}$ input
				(n = 3 to 0)

5.3.5 IRQ Enable Register (IER)

IER controls the enabling and disabling of interrupt requests IRQ7 to IRQ0.

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ7E	0	R/W	IRQn Enable (n = 7 to 0)
6	IRQ6E	0	R/W	The IRQn interrupt request is enabled when this bit is 1.
5	IRQ5E	0	R/W	
4	IRQ4E	0	R/W	
3	IRQ3E	0	R/W	
2	IRQ2E	0	R/W	
1	IRQ1E	0	R/W	
0	IRQ0E	0	R/W	

5.3.6 IRQ Status Register (ISR)

The ISR register is a flag register that indicates the status of IRQ7 to IRQ0 interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	IRQ7F	0	R/(W)*2	[Setting condition]
6	IRQ6F	0	R/(W)*2	When the interrupt source selected by the ISCR registers occurs
5	IRQ5F	0	R/(W)*2	[Clearing conditions]
4	IRQ4F	0	R/(W)*2	• When reading IRQnF flag when IRQnF = 1, then writing 0 to IRQnF flag
3	IRQ3F	0	R/(W)*2	• When interrupt exception handling is executed when low-level detection is set and $\overline{\text{IRQn}}$ input is high (n = 7 to 0)*1
2	IRQ2F	0	R/(W)*2	• When IRQn interrupt exception handling is executed when falling-edge, rising-edge, or both-edge detection is set*1
1	IRQ1F	0	R/(W)*2	
0	IRQ0F	0	R/(W)*2	

Notes: 1. When a product, in which a DTC is incorporated, is used, the corresponding flag bit is not automatically cleared even when exception handing is executed. For details, refer to section 5.8.4, Setting on a Product Incorporating DTC.
2. Only 0 can be written, for flag clearing.

5.3.7 Keyboard Matrix Interrupt Mask Registers (KMIMRA, KMIMR) and Wake-Up Event Interrupt Mask Register (WUEMRB)

The KMIMRA, KMIMR, and WUEMRB registers enable or disable key-sensing interrupt inputs ($\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$), and wake-up event interrupt inputs ($\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$).

- KMIMRA

Bit	Bit Name	Initial Value	R/W	Description
7	KMIMR15	1	R/W	Keyboard Matrix Interrupt Mask 15 to 8
6	KMIMR14	1	R/W	These bits enable or disable a key-sensing input interrupt request (KIN15 to KIN8).
5	KMIMR13	1	R/W	0: Enables a key-sensing input interrupt request
4	KMIMR12	1	R/W	1: Disables a key-sensing input interrupt request
3	KMIMR11	1	R/W	
2	KMIMR10	1	R/W	
1	KMIMR9	1	R/W	
0	KMIMR8	1	R/W	

- KMIMR

Bit	Bit Name	Initial Value	R/W	Description
7	KMIMR7	1	R/W	Keyboard Matrix Interrupt Mask 7 to 0
6	KMIMR6	0	R/W	These bits enable or disable a key-sensing input interrupt request (KIN7 to KIN0).
5	KMIMR5	1	R/W	KMIMR6 also performs interrupt request mask control for pin $\overline{\text{IRQ6}}$.
4	KMIMR4	1	R/W	0: Enables a key-sensing input interrupt request
3	KMIMR3	1	R/W	1: Disables a key-sensing input interrupt request
2	KMIMR2	1	R/W	
1	KMIMR1	1	R/W	
0	KMIMR0	1	R/W	

- WUEMRB*

Bit	Bit Name	Initial Value	R/W	Description
7	WUEMR7	1	R/W	Wake-Up Event Interrupt Mask 7 to 0
6	WUEMR6	1	R/W	These bits enable or disable a wake-up event input interrupt request (WUE7 to WUE0). 0: Enables a wake-up event input interrupt request 1: Disables a wake-up event input interrupt request
5	WUEMR5	1	R/W	
4	WUEMR4	1	R/W	
3	WUEMR3	1	R/W	
2	WUEMR2	1	R/W	
1	WUEMR1	1	R/W	
0	WUEMR0	1	R/W	

Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).

Figure 5.2 shows the relationship between interrupts IRQ7 and IRQ6, interrupts KIN15 to KIN0, interrupts WUE7 to WUE0, and registers KMIMRA, KMIMR, and WUEMRB.

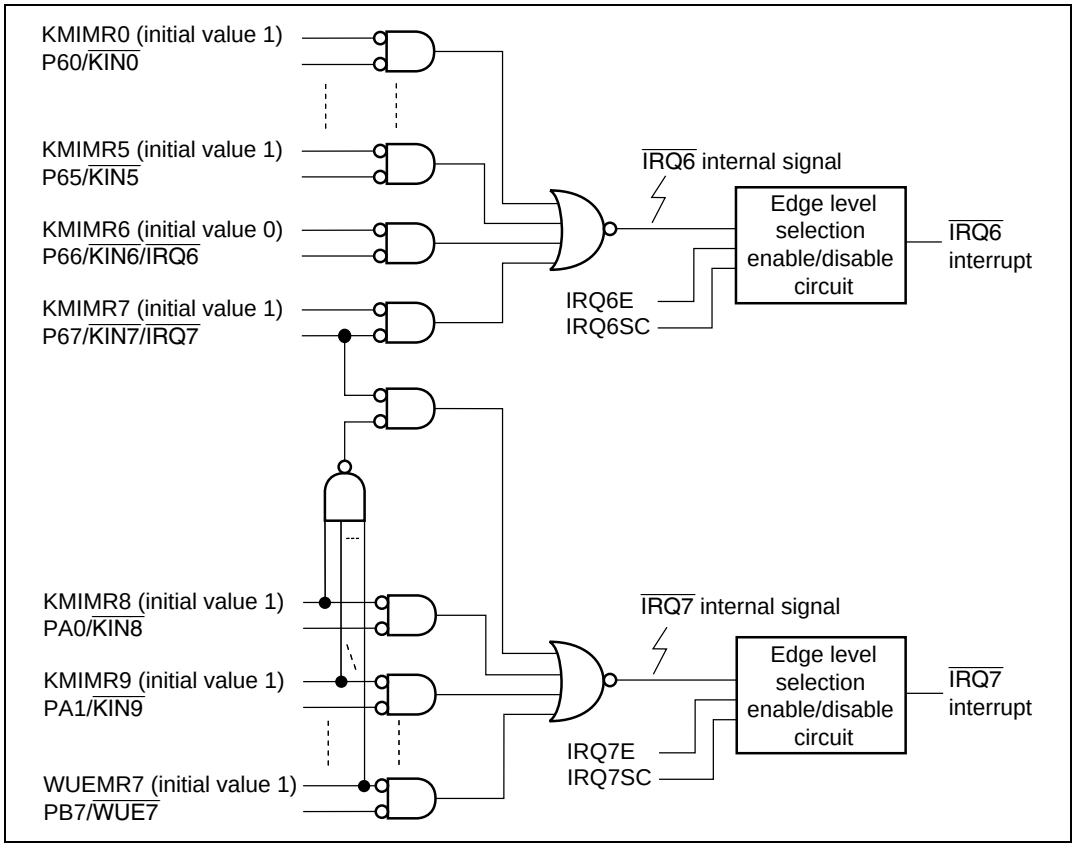


Figure 5.2 Relationship between Interrupts IRQ7 and IRQ6, Interrupts KIN15 to KIN0, Interrupts WUE7 to WUE0, and Registers KMIMR, KMIMRA, and WUEMRB

If any of bits KMIMR15 to KMIMR8 or WUEMRB7 to WUEMRB0 is cleared to 0, interrupt input from the $\overline{\text{IRQ7}}$ pin will be ignored. When pins $\overline{\text{KIN7}}$ to $\overline{\text{KIN0}}$, $\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$, or $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$ are used as key-sense interrupt input pins or wakeup event interrupt input pins, either low-level sensing or falling-edge sensing must be designated as the interrupt sense condition for the corresponding interrupt source (IRQ6 or IRQ7).

5.4 Interrupt Sources

5.4.1 External Interrupts

There are four types of external interrupts: NMI, IRQ7 to IRQ0, KIN15 to KIN0 and WUE7 to WUE0. WUE7 to WUE0 and KIN15 to KIN8 share the IRQ7 interrupt source, and KIN7 to KIN0 share the IRQ6 interrupt source. Of these, NMI, IRQ7, IRQ6, and IRQ2 to IRQ0 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.

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

- The interrupt exception handling for interrupt requests IRQ7 to IRQ0 can be started at an independent vector address.
- Using ISCR, it is possible to select whether an interrupt is generated by a low level, falling edge, rising edge, or both edges, at pins $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$.
- Enabling or disabling of interrupt requests IRQ7 to IRQ0 can be selected with IER.
- Interrupt control levels can be specified by the ICR settings.
- The status of interrupt requests IRQ7 to IRQ0 is indicated in ISR. ISR flags can be cleared to 0 by software.

The detection of IRQ7 to IRQ0 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 to use the pin as an I/O pin for another function.

A block diagram of interrupts IRQ7 to IRQ0 is shown in figure 5.3.

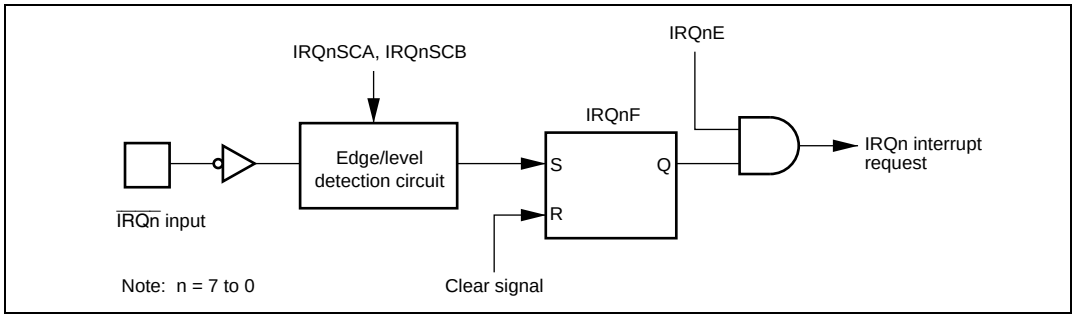


Figure 5.3 Block Diagram of Interrupts IRQ7 to IRQ0

When pin $\overline{\text{IRQ6}}$ is used as an IRQ6 interrupt input pin, clear the KMIMR6 bit to 0.

When pin $\overline{\text{IRQ7}}$ is used as an IRQ7 interrupt pin, set all of bits KMIMR15 to KMIMR8 and WUEMR7 to WUEMR0 to 1. If any of these bits is cleared to 0, IRQ7 interrupt input from the $\overline{\text{IRQ7}}$ pin will be ignored.

Since interrupt request flags IRQ7F to IRQ0F are set each time the setting condition is satisfied, regardless of the IER setting, refer to a needed flag only.

KIN15 to KIN0 Interrupts, WUE7 to WUE0 Interrupts: Interrupts KIN15 to KIN0 and WUE7 to WUE0 are requested by an input signal at pins $\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$ and $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$. When pins $\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$ and $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$ are used for key-sense input or wakeup event, clear the corresponding KMIMR and WUEMR bits to 0 in order to enable their key-sense input and wakeup event interrupts. Remaining unused KMIMR and WUEMR bits for key-sense input should be set to 1 in order to disable interrupts. Interrupts WUE7 to WUE0 and KIN15 to KIN8 generate IRQ7 interrupts, and interrupts KIN7 to KIN0 generate IRQ6 interrupts. The pin conditions for interrupt request generation, enable of interrupt requests, settings of interrupt control levels, and status display of interrupt requests depend on each setting and display of the IRQ7 or IRQ6 interrupt.

When pins $\overline{\text{KIN7}}$ to $\overline{\text{KIN0}}$, $\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$, or $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$ are used as key-sense interrupt input pins or wakeup event interrupt input pins, either low-level sensing or falling-edge sensing must be designated as the interrupt sense condition for the corresponding interrupt source (IRQ6 or IRQ7).

5.4.2 Internal Interrupts

Internal interrupts issued from the on-chip peripheral modules have the following features:

1. For each on-chip peripheral module there are flags that indicate the interrupt request status, and enable bits that individually select enabling or disabling of these interrupts. When the enable bit for a particular interrupt source is set to 1, an interrupt request is sent to the interrupt controller.
2. The control level for each interrupt can be set by ICR.
3. The DTC can be activated by an interrupt request from an on-chip peripheral module.
4. An interrupt request that activates the DTC is not affected by the interrupt control mode or the status of the CPU interrupt mask bits.

5.5 Interrupt Exception Handling Vector Table

Table 5.3 lists interrupt exception handling sources, vector addresses, and interrupt priorities. For default priorities, the lower the vector number, the higher the priority. Modules set at the same priority will conform to their default priorities. Priorities within a module are fixed.

An interrupt control level can be specified for a module to which an ICR bit is assigned. Interrupt requests from modules that are set to control level 1 (priority) by the ICR bit setting and the I and UI bits in CCR are given priority and processed before interrupt requests from modules that are set to control level 0 (no priority).

Table 5.3 Interrupt Sources, Vector Addresses, and Interrupt Priorities

Origin of Interrupt Source	Name	Vector Number	Vector Address: Normal Mode	Vector Address: Advanced Mode	ICR	Priority
External pin	NMI	7	H'000E	H'00001C	—	High
	IRQ0	16	H'0020	H'000040	ICRA7	
	IRQ1	17	H'0022	H'000044	ICRA6	
	IRQ2 IRQ3	18 19	H'0024 H'0026	H'000048 H'00004C	ICRA5	
	IRQ4 IRQ5	20 21	H'0028 H'002A	H'000050 H'000054	ICRA4	
	IRQ6, KIN7 to KIN0 IRQ7, KIN15 to KIN8, WUE7 to WUE0	22 23	H'002C H'002E	H'000058 H'00005C	ICRA3	
DTC	SWDTEND (Software activation data transfer end)	24	H'0030	H'000060	ICRA2	
WDT_0	WOVI0 (Interval timer)	25	H'0032	H'000064	ICRA1	
WDT_1	WOVI1 (Interval timer)	26	H'0034	H'000068	ICRA0	
—	Address break	27	H'0036	H'00006C	—	
A/D converter	ADI (A/D conversion end)	28	H'0038	H'000070	ICRB7	
—	Reserved for system use	29 to 47	H'003A to H'005E	H'000074 to H'0000BC	—	
FRT	ICIA (Input capture A) ICIB (Input capture B) ICIC (Input capture C) ICID (Input capture D) OCIA (Output compare A) OCIB (Output compare B) FOVI (Overflow) Reserved for system use	48 49 50 51 52 53 54 55	H'0060 H'0062 H'0064 H'0066 H'0068 H'006A H'006C H'006E	H'0000C0 H'0000C4 H'0000C8 H'0000CC H'0000D0 H'0000D4 H'0000D8 H'0000DC	ICRB6	
—	Reserved for system use	56 to 63	H'0070 to H'007E	H'0000E0 to H'0000FC	—	
TMR_0	CMIA0 (Compare match A) CMIB0 (Compare match A) OVI0 (Overflow) Reserved for system use	64 65 66 67	H'0080 H'0082 H'0084 H'0086	H'000100 H'000104 H'000108 H'00010C	ICRB3	Low

Origin of Interrupt Source	Name	Vector Number	Vector Address: Normal Mode	Vector Address: Advanced Mode	ICR	Priority
TMR_1	CMIA1 (Compare match A)	68	H'0088	H'000110	ICRB2	High
	CMIB1 (Compare match B)	69	H'008A	H'000114		
	OVI1 (Overflow)	70	H'008C	H'000118		
	Reserved for system use	71	H'008E	H'00011C		
TMR_X, TMR_Y	CMIAY (Compare match A)	72	H'0090	H'000120	ICRB1	
	CMIBY (Compare match B)	73	H'0092	H'000124		
	OVIY (Overflow)	74	H'0094	H'000128		
	ICIX (Input capture X)	75	H'0096	H'00012C		
XBS	IBF1 (IDR1 reception completion)	76	H'0098	H'000130	ICRB0	
	IBF2 (IDR2 reception completion)	77	H'009A	H'000134		
	IBF3 (IDR3 reception completion)	78	H'009C	H'000138		
	IBF4 (IDR4 reception completion)	79	H'009E	H'00013C		
SCI_0	ERI0 (Reception error 0)	80	H'00A0	H'000140	ICRC7	
	RXI0 (Reception completion 0)	81	H'00A2	H'000144		
	TXI0 (Transmission data empty 0)	82	H'00A4	H'000148		
	TEI0 (Transmission end 0)	83	H'00A6	H'00014C		
SCI_1	ERI1 (Reception error 1)	84	H'00A8	H'000150	ICRC6	
	RXI1 (Reception completion 1)	85	H'00AA	H'000154		
	TXI1 (Transmission data empty 1)	86	H'00AC	H'000158		
	TEI1 (Transmission end 1)	87	H'00AE	H'00015C		
SCI_2	ERI2 (Reception error 2)	88	H'00B0	H'000160	ICRC5	
	RXI2 (Reception completion 2)	89	H'00B2	H'000164		
	TXI2 (Transmission data empty 2)	90	H'00B4	H'000168		
	TEI2 (Transmission end 2)	91	H'00B6	H'00016C		
IIC_0	IICI0 (1-byte transmission/ reception completion)	92	H'00B8	H'000170	ICRC4	
	DDCSWI (Format switch)	93	H'00BA	H'000174		
IIC_1	IICI1 (1-byte transmission/ reception completion)	94	H'00BC	H'000178	ICRC3	
	Reserved for system use	95	H'00BE	H'00017C		
Keyboard buffer controller	KBIA (Reception completion A)	96	H'00C0	H'000180	ICRB0	
	KBIB (Reception completion B)	97	H'00C2	H'000184		
	KBIC (Reception completion C)	98	H'00C4	H'000188		
	Reserved for system use	99	H'00C6	H'00018C		
—	Reserved for system use	100 to 107	H'00C8 to H'00D6	H'000190 to H'0001AC	—	
LPC*	ERRI (Transfer error)	108	H'00D8	H'0001B0	ICRC1	
	IBF1 (IDR1 reception completion)	109	H'00DA	H'0001B4		
	IBF2 (IDR2 reception completion)	110	H'00DC	H'0001B8		
	IBF3 (IDR3 reception completion)	111	H'00DE	H'0001BC		Low

Note: * Reserved for system use on products not including LPC.

5.6 Interrupt Control Modes and Interrupt Operation

The interrupt controller has two modes: Interrupt control mode 0 and interrupt control mode 1. Interrupt operations differ depending on the interrupt control mode. NMI interrupts and address break interrupts are always accepted except for in reset state or in hardware standby mode. The interrupt control mode is selected by SYSCR. Table 5.4 shows the interrupt control modes.

Table 5.4 Interrupt Control Modes

Interrupt Control Mode	SYSCR		Priority Setting Registers	Interrupt Mask Bits	Description
	INTM1	INTM0			
0	0	0	ICR	I	Interrupt mask control is performed by the I bit. Priority levels can be set with ICR.
1		1	ICR	I, UI	3-level interrupt mask control is performed by the I and UI bits. Priority levels can be set with ICR.

5.6.1 Interrupt Control Mode 0

In interrupt control mode 0, interrupt requests other than NMI and address breaks are masked by ICR and the I bit of the CCR in the CPU. Figure 5.4 shows a flowchart of the interrupt acceptance operation.

1. If an interrupt source occurs when the corresponding interrupt enable bit is set to 1, an interrupt request is sent to the interrupt controller.
2. According to the interrupt control level specified in ICR, the interrupt controller only accepts an interrupt request with interrupt control level 1 (priority), and holds pending an interrupt request with interrupt control level 0 (no priority). If several interrupt requests are issued, an interrupt request with the highest priority is accepted according to the priority order, an interrupt handling is requested to the CPU, and other interrupt requests are held pending.
3. If the I bit in CCR is set to 1, only NMI and address break interrupts are accepted by the interrupt controller, and other interrupt requests are held pending. If the I bit is cleared to 0, any interrupt request 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 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 for NMI and address break interrupts.
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.

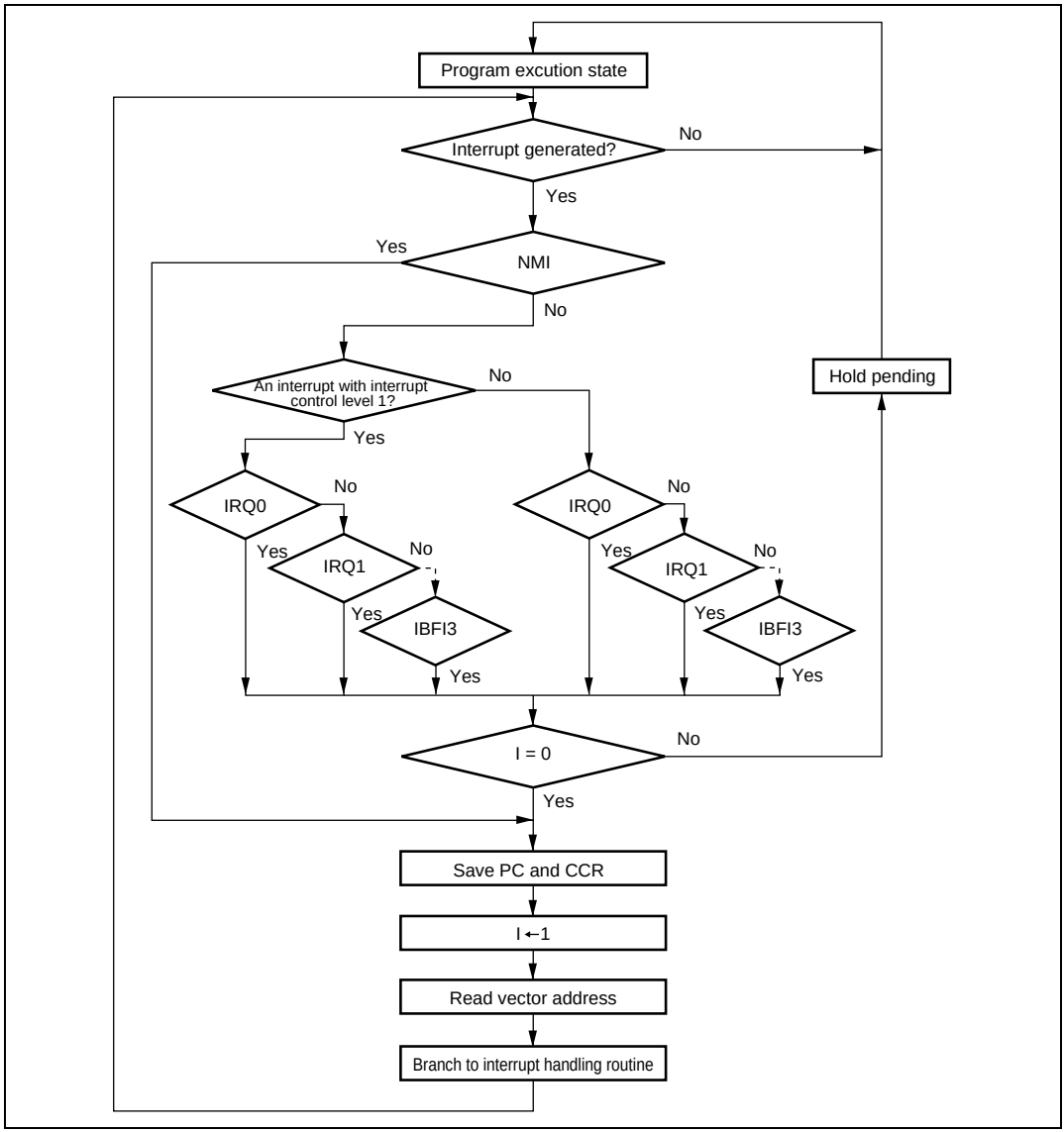


Figure 5.4 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 0

5.6.2 Interrupt Control Mode 1

In interrupt control mode 1, mask control is applied to three levels for IRQ and on-chip peripheral module interrupt requests by comparing the I and UI bits in CCR in the CPU, and the ICR setting.

- An interrupt request with interrupt control level 0 is accepted when the I bit in CCR is cleared to 0. When the I bit is set to 1, the interrupt request is held pending
- An interrupt request with interrupt control level 1 is accepted when the I bit or UI bit in CCR is cleared to 0. When both I and UI bits are set to 1, the interrupt request is held pending.

For instance, the state transition when the interrupt enable bit corresponding to each interrupt is set to 1, and ICRA to ICRC are set to H'20, H'00, and H'00, respectively (IRQ2 and IRQ3 interrupts are set to control level 1, and other interrupts are set to control level 0) is shown below. Figure 5.5 shows a state transition diagram.

- All interrupt requests are accepted when I = 0. (Priority order: NMI > IRQ2 > IRQ3 > address break > IRQ0 > IRQ1 …)
- Only NMI, IRQ2, IRQ3 and address break interrupt requests are accepted when I = 1 and UI = 0.
- Only an NMI and address break interrupt request is accepted when I = 1 and UI = 1.

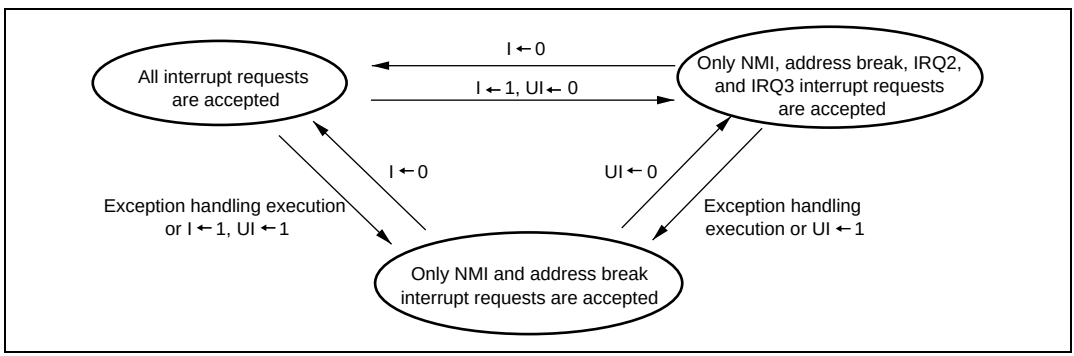


Figure 5.5 State Transition in Interrupt Control Mode 1

Figure 5.6 shows a flowchart of the interrupt acceptance operation.

1. If an interrupt source occurs when the corresponding interrupt enable bit is set to 1, an interrupt request is sent to the interrupt controller.
2. According to the interrupt control level specified in ICR, the interrupt controller only accepts an interrupt request with interrupt control level 1 (priority), and holds pending an interrupt request with interrupt control level 0 (no priority). If several interrupt requests are issued, an interrupt request with the highest priority is accepted according to the priority order, an interrupt handling is requested to the CPU, and other interrupt requests are held pending.
3. An interrupt request with interrupt control level 1 is accepted when the I bit is cleared to 0, or when the I bit is set to 1 while the UI bit is cleared to 0.

   An interrupt request with interrupt control level 0 is accepted when the I bit is cleared to 0. When the I bit is set to 1, only an NMI or address break interrupt request is accepted, and other interrupts are held pending.

   When both the I and UI bits are set to 1, only an NMI or address break interrupt request is accepted, and other interrupts are held pending.

   When the I bit is cleared to 0, the UI bit is not affected.
4. When the CPU accepts an interrupt request, it starts interrupt exception handling after execution of the current instruction has been completed.
5. The PC and CCR are saved to the stack area by interrupt exception handling. The PC saved on the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
6. The I and UI bits in CCR are set to 1. This masks all interrupts except for an NMI or address break interrupt.
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.

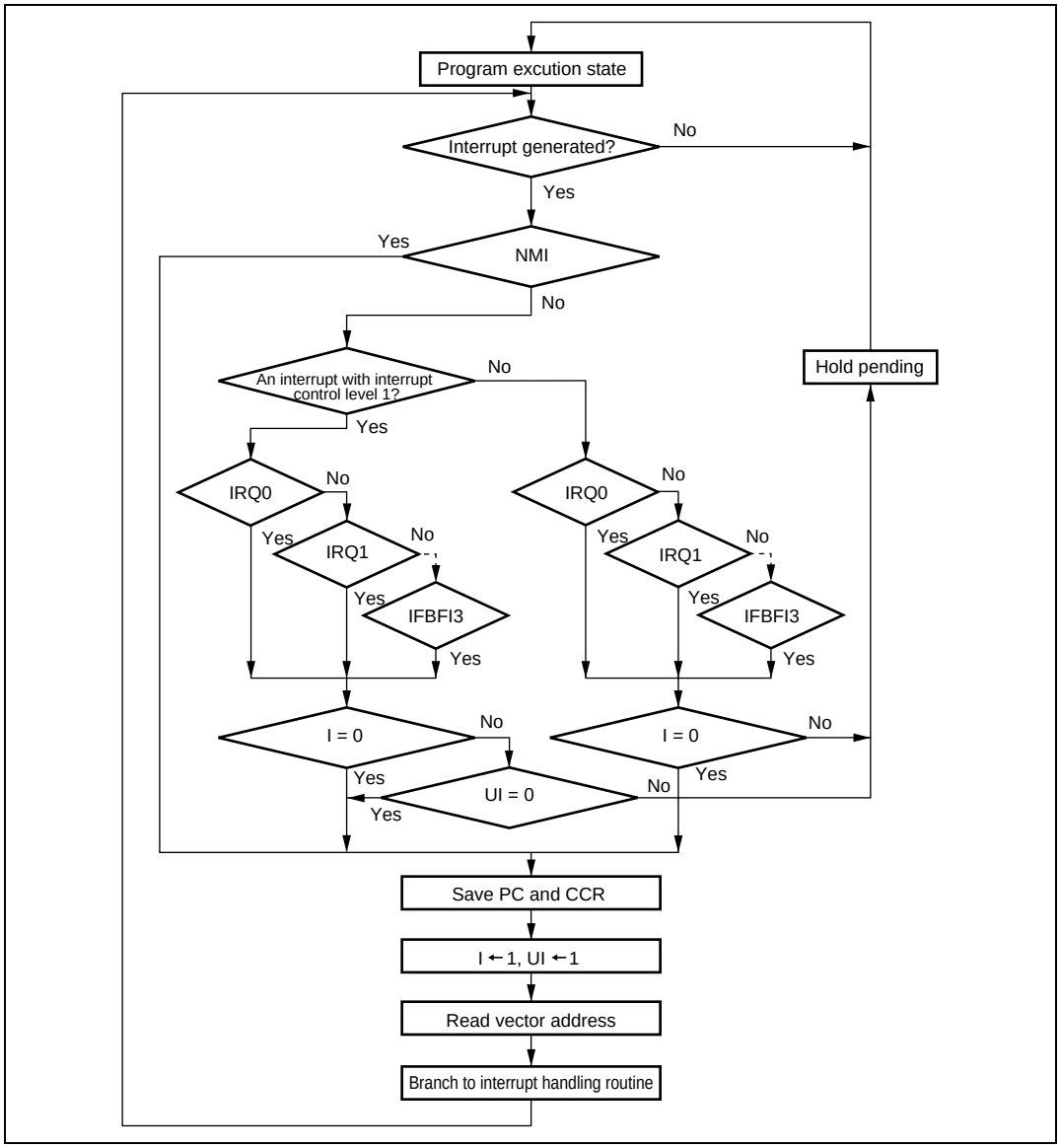


Figure 5.6 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 1

5.6.3 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.

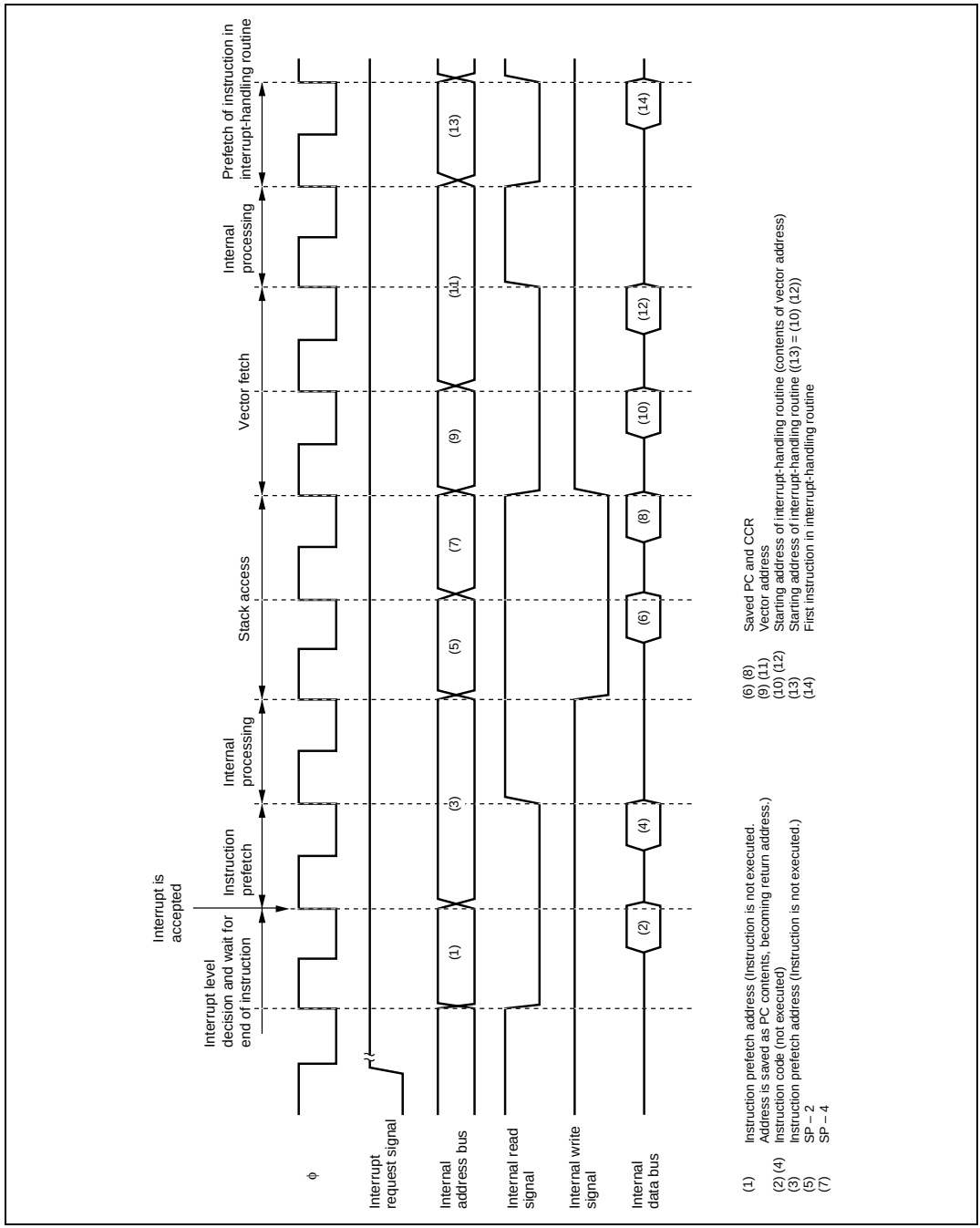


Figure 5.7 Interrupt Exception Handling

5.6.4 Interrupt Response Times

Table 5.5 shows interrupt response times – the intervals between generation of an interrupt request and execution of the first instruction in the interrupt handling routine. The execution status symbols used in table 5.5 are explained in table 5.6.

Table 5.5 Interrupt Response Times

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

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

Table 5.6 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 external device access

5.6.5 DTC Activation by Interrupt

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

- Interrupt request to CPU
- Activation request to DTC
- Selection of a number of the above

For details on interrupt requests that can be used to activate the DTC, see section 7, Data Transfer Controller (DTC).

Figure 5.8 shows a block diagram of the DTC and interrupt controller.

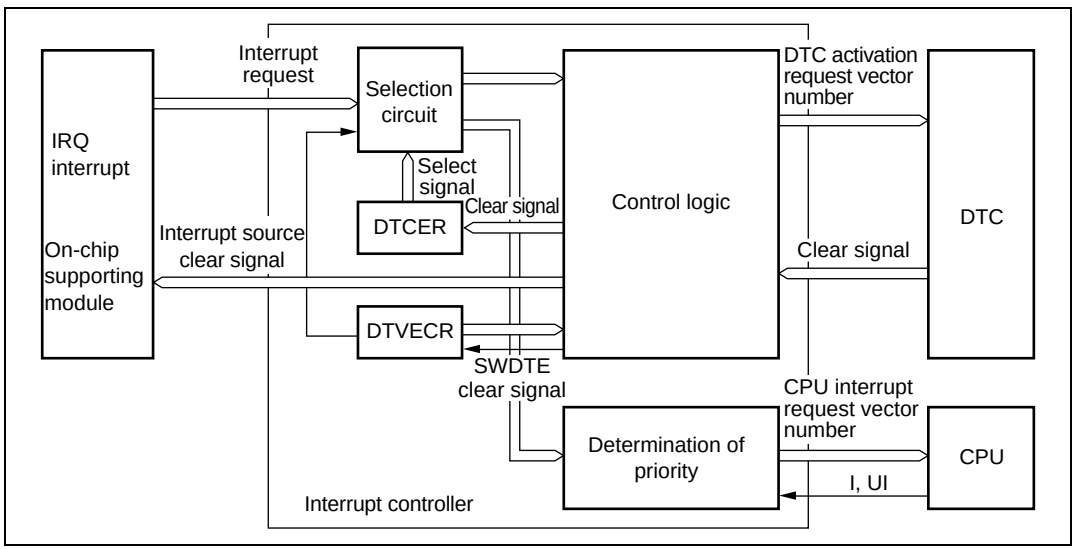


Figure 5.8 DTC and Interrupt Controller

Selection of Interrupt Source: Interrupt factors are selected as DTC activation source or CPU interrupt source by the DTCE bit of DTCERA to DTCERE of DTC.

By specifying the DISEL bit of the DTC's MRB, it is possible to clear the DTCE bit to 0 after DTC data transfer, and request a CPU interrupt.

If DTC carries out the designate number of data transfers and the transfer counter reads 0, after DTC data transfer, the DTCE bit is also cleared to 0, and an interrupt is requested to the CPU.

Determination of Priority: The DTC activation source is selected in accordance with the default priority order, and is not affected by mask or priority levels. See table 7.1 for the respective priority.

Operation Order: If the same interrupt is selected as a DTC activation source and a CPU interrupt source, the DTC data transfer is performed first, followed by CPU interrupt exception handling.

Table 5.7 shows the interrupt factor clear control and selection of interrupt factors by specification of the DTCE bit of DTC's DTCER, and the DISEL bit of DTC's MRB.

Table 5.7 Interrupt Source Selection and Clearing Control

Settings			
DTC		Interrupt Sources Selection/Clearing Control	
DTCE	DISEL	DTC	CPU
0	*	×	O
1	0	O	×
	1	o	O

Legend:

O: The relevant interrupt is used. Interrupt source clearing is performed.
(The CPU should clear the source flag in the interrupt handling routine.)

o: The relevant interrupt is used. The interrupt source is not cleared.

×: The relevant interrupt cannot be used.

*: Don't care

Note: The SCI, IIC, LPC, or A/D converter interrupt source is cleared when the DTC reads or writes to the prescribed register, and is not dependent upon the DISEL bit.

5.7 Address Break

5.7.1 Features

This LSI can determine the specific address prefetch by the CPU to generate an address break interrupt by setting ABRKCR and BAR. If an address break interrupt is generated, the address break interrupt exception handling is performed.

With this function, the execution start point of a program containing a bug is detected and execution is branched to the correcting program.

5.7.2 Block Diagram

Figure 5.9 shows a block diagram of the address break.

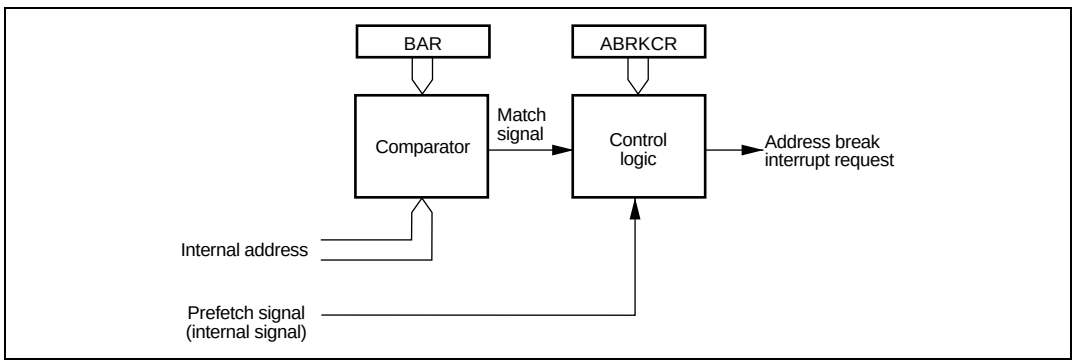


Figure 5.9 Address Break Block Diagram

5.7.3 Operation

If the CPU prefetches an address specified in BAR by setting ABRKCR and BAR, an address break interrupt can be generated. This address break function generates an interrupt request to the interrupt controller at prefetch, and determines the priority by the interrupt controller. When an interrupt is accepted, an interrupt exception handling is activated after the current instruction has been completed. Note that the interrupt mask control according to the I and UI bits in CCR of the CPU is invalid to an address break interrupt.

To use the address break function, set each register as follows:

1. Set a break address in the A23 to A1 bits in BAR.
2. Set the BIE bit in ABRKCR to 1 to enable the address break.
   When the BIE bit is cleared to 0, an address break is not requested.

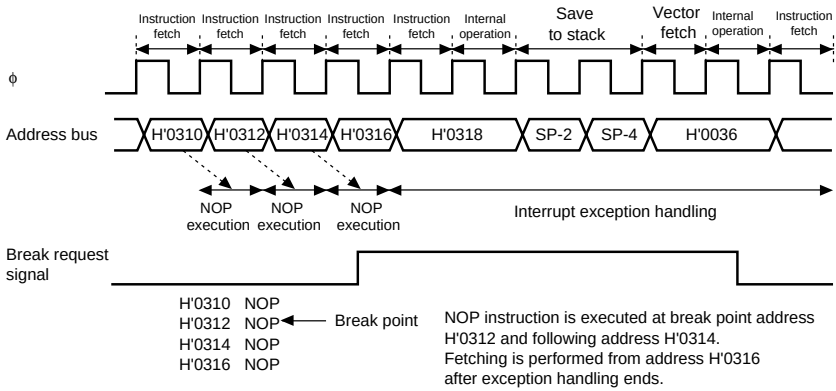
When the setting conditions are satisfied, the CMF flag in ABRKCR is set to 1 to request an interrupt. The interrupt source should be determined by the interrupt handling routine if necessary.

5.7.4 Usage Notes

1. In an address break, the break address should be an address where the first byte of the instruction exists. Otherwise, a break condition will not be satisfied.
2. In normal mode, addresses A23 to A16 are not compared.
3. When the branch instructions (Bcc, BSR), jump instructions (JMP, JSR), RST instruction, and RTE instruction are placed immediately prior to the address specified by BAR, a prefetch signal to the address may be output to request an address break by executing these instruction. It is necessary to take countermeasures: do not set a break address to an address immediately after these instructions, or determine whether interrupt handling is performed by satisfaction of a normal condition.
4. An address break interrupt is generated by combining the internal prefetch signal and an address. Therefore, the timing to enter the interrupt exception handling differs according to the instructions at the specified and at prior addresses and execution cycles.

Figure 5.10 shows an example of address timing.

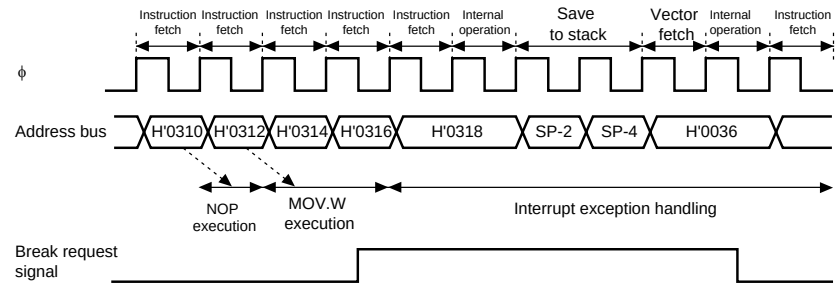
(1) When a break address specified instruction is executed for one state in the program area and on-chip memory



H'0310 NOP
H'0312 NOP ← Break point
H'0314 NOP
H'0316 NOP

NOP instruction is executed at break point address H'0312 and following address H'0314. Fetching is performed from address H'0316 after exception handling ends.

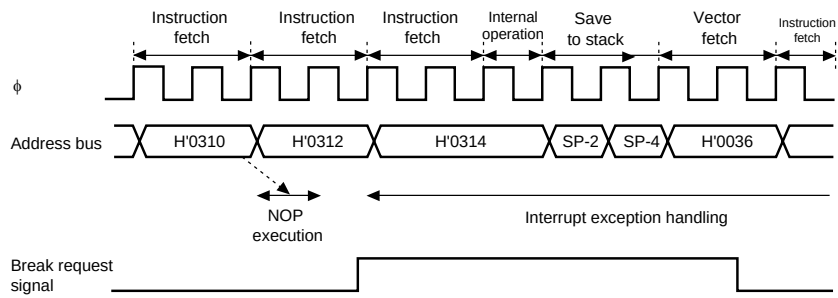
(2) When a break address specified instruction is executed for two states in the program area and on-chip memory



H'0310 NOP
H'0312 MOV.W #xx:16,Rd ← Break point
H'0316 NOP
H'0318 NOP

MOV instruction is executed at break point address H'0312, and NOP instruction is not executed at the following address H'0314. Fetching is performed from address H'0316 after exception handling ends.

(3) When a break address specified instruction is executed for one state in the program area and external memory (2-state access, 16-bit bus access)



H'0310 NOP
H'0312 NOP ← Break point
H'0314 NOP
H'0316 NOP

NOP instruction is not executed at break point address H'0312. Fetching is performed from address H'0312 after exception handling ends.

Figure 5.10 Address Break Timing Example

5.8 Usage Notes

5.8.1 Conflict between Interrupt Generation and Disabling

When an interrupt enable bit is cleared to 0 to disable interrupt requests, 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, 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 rule is also applied when an interrupt source flag is cleared to 0. Figure 5.11 shows an example in which the CMIEA bit in the TMR's TCR register is cleared to 0.

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

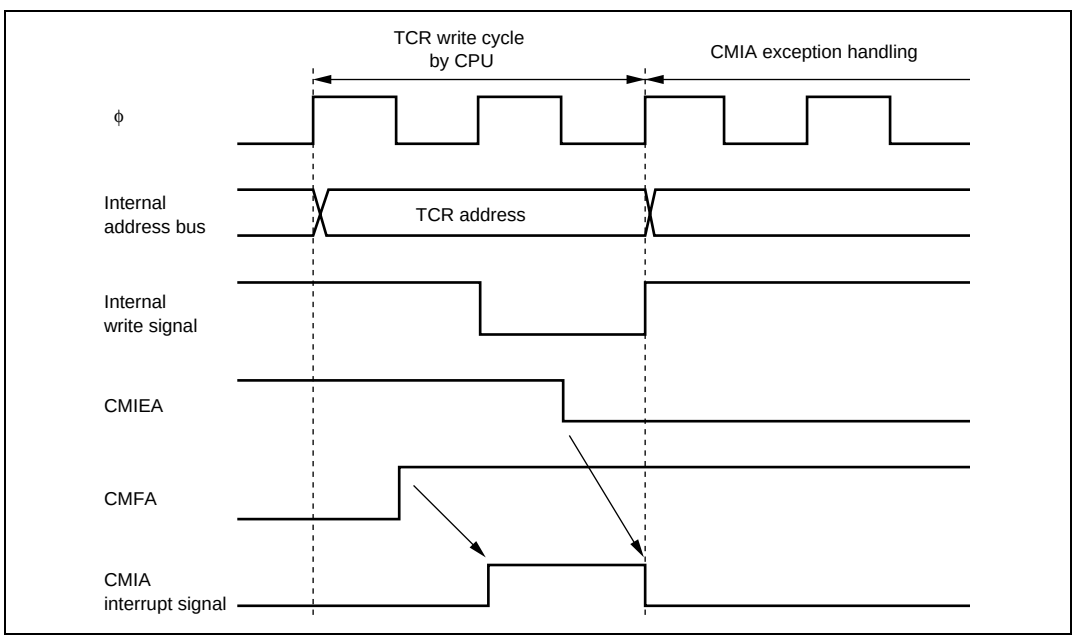


Figure 5.11 Conflict between Interrupt Generation and Disabling

5.8.2 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 or UI bit is set by one of these instructions, the new value becomes valid two states after execution of the instruction ends.

5.8.3 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
```

5.8.4 Setting on Product Incorporating DTC

When a product, in which a DTC is incorporated, is used in the following settings, the corresponding flag bit is not automatically cleared even when exception handing, which is a clear condition, is executed and the bit is held at 1.

1. When DTCEA3 is set to 1(ADI is set to an interrupt source), IRQ4F flag is not automatically cleared.
2. When DTCEA2 is set to 1(ICIA is set to an interrupt source), IRQ5F flag is not automatically cleared.
3. When DTCEA1 is set to 1(ICIB is set to an interrupt source), IRQ6F flag is not automatically cleared.
4. When DTCEA0 is set to 1(OCIA is set to an interrupt source), IRQ7F flag is not automatically cleared.

When activation interrupt sources of DTC and IRQ interrupts are used with the above combinations, clear the interrupt flag by software in the interrupt handling routine of the corresponding IRQ.

5.8.5 IRQ Status Register (ISR)

According to the pin status after a reset, IRQnF may be set to 1, so ISR should be read after a reset to write 0. (n = 7 to 0)

Section 6 Bus Controller (BSC)

This LSI has an on-chip bus controller (BSC) that manages the bus width and the number of access states of the external address space. The BSC also has a bus arbitration function, and controls the operation of the internal bus masters – CPU, and data transfer controller (DTC).

6.1 Features

- Basic bus interface
  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
  A burst ROM interface can be set for basic expansion areas
  1-state access or 2-state access can be selected for burst access
- Idle cycle insertion
  An idle cycle can be inserted for external write cycles immediately after external read cycles
- Bus arbitration function
  Includes a bus arbiter that arbitrates bus mastership between the CPU and DTC

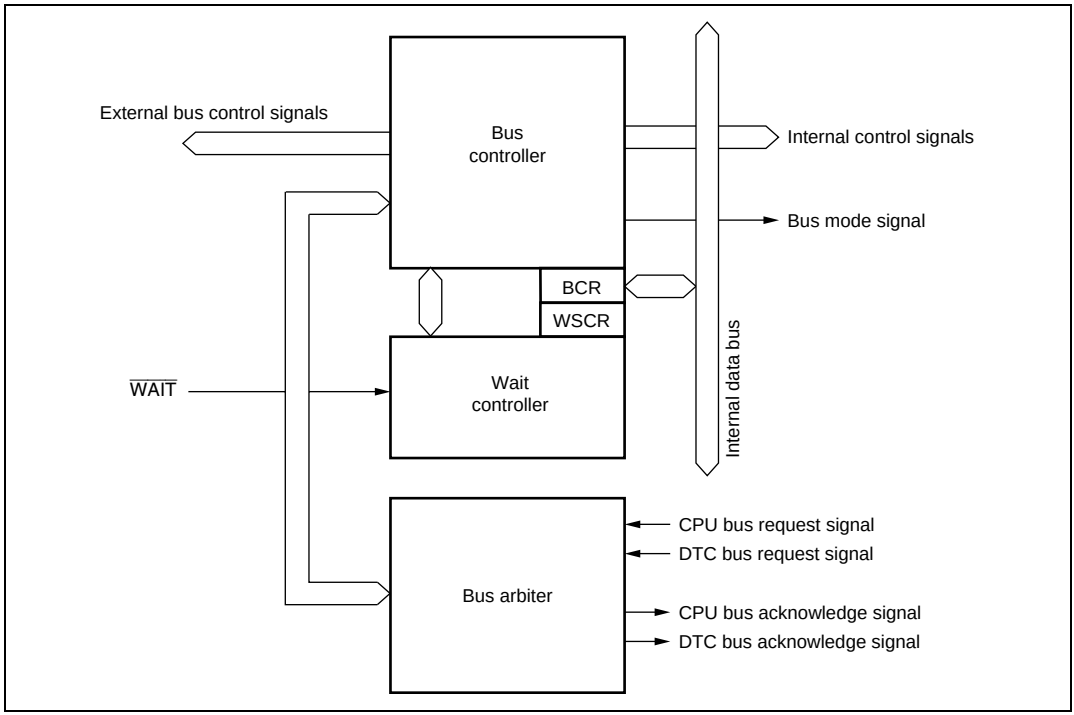


Figure 6.1 Block Diagram of Bus Controller

6.2 Input/Output Pins

Table 6.1 summarizes the pins of the bus controller.

Table 6.1 Pin Configuration

Symbol	I/O	Function
$\overline{AS}$	Output	Strobe signal indicating that address output on the address bus is enabled (when the IOSE bit in SYSCR is cleared to 0).
$\overline{IOS}$	Output	I/O select signal (when the IOSE bit in SYSCR is set to 1).
$\overline{RD}$	Output	Strobe signal indicating that the external address space is being read.
$\overline{HWR}$	Output	Strobe signal indicating that the external address space is being written to, and the upper half (D15 to D8) of the data bus is enabled.
$\overline{LWR}$	Output	Strobe signal indicating that the external address space is being written to, and the lower half (D7 to D0) of the data bus is enabled.
$\overline{WAIT}$	Input	Wait request signal when accessing the external 3-state access space.

6.3 Register Descriptions

The bus controller has the following registers. For details on the system control register, refer to section 3.2.2, System Control Register (SYSCR).

- Bus control register (BCR)
- Wait state control register (WSCR)

6.3.1 Bus Control Register (BCR)

BCR is used to specify the access mode for the external address space or the I/O area range when the $\overline{AS}$/$\overline{IOS}$ pin is specified as an I/O strobe pin.

Bit	Bit Name	Initial Value	R/W	Description
7	—	1	R/W	Reserved This bit should not be written by 0.
6	ICIS0	1	R/W	Idle Cycle Insertion Selects whether or not to insert 1-state of the idle cycle between bus cycles when the external write cycle follows the external read cycle. 0: Idle cycle not inserted when the external write cycle follows the external read cycle 1: 1-state idle cycle inserted when the external write cycle follows the external read cycle
5	BRSTRM	0	R/W	Burst ROM Enable Selects the bus interface for the external address space. 0: Basic bus interface 1: Burst ROM interface
4	BRSTS1	1	R/W	Burst Cycle Select 1 Selects the number of states in the burst cycle of the burst ROM interface. 0: 1 state 1: 2 states
3	BRSTS0	0	R/W	Burst Cycle Select 0 Selects the number of words that can be accessed by burst access via the burst ROM interface. 0: Max, 4 words 1: Max, 8 words
2	—	0	R/W	Reserved This bit should not be written by 0.
1	IOS1	1	R/W	IOS Select 1, 0
0	IOS0	1	R/W	Select the address range where the $\overline{IOS}$ signal is output. For details, refer to table 6.3.

6.3.2 Wait State Control Register (WSCR)

WSCR is used to specify the data bus width for external address space access, the number of access states, the wait mode, and the number of wait states for access to external address spaces. The bus width and the number of access states for internal memory and internal I/O registers are fixed regardless of the WSCR settings.

Bit	Bit Name	Initial Value	R/W	Description
7, 6	—	All 0	R/W	Reserved These bits should not be written by 1.
5	ABW	1	R/W	Bus Width Control Selects 8 or 16 bits for access to the external address space. 0: 16-bit access space 1: 8-bit access space
4	AST	1	R/W	Access State Control Selects 2 or 3 access states for access to the external address space. This bit also enables or disables wait-state insertion. 0: 2-state access space. Wait state insertion disabled in external address space access 1: 3-state access space. Wait state insertion enabled in external address space access
3	WMS1	0	R/W	Wait Mode Select 1, 0
2	WMS0	0	R/W	Select the wait mode for access to the external address space when the AST bit is set to 1. 00: Program wait mode 01: Wait disabled mode 10: Pin wait mode 11: Pin auto-wait mode

Bit	Bit Name	Initial Value	R/W	Description
1	WC1	1	R/W	Wait Count 1, 0
0	WC0	1	R/W	Select the number of program wait states to be inserted when the external address space is accessed while the AST bit is set to 1. 00: Program wait state is not inserted 01: 1 program wait state is inserted 10: 2 program wait states are inserted 11: 3 program wait states are inserted

6.4 Bus Control

6.4.1 Bus Specifications

The external address space bus specifications consist of three elements: Bus width, the number of access states, and the wait mode and the number of program wait states. The bus width and the number of access states for on-chip memory and internal I/O registers are fixed, and are not affected by the bus controller settings.

Bus Width: A bus width of 8 or 16 bits can be selected via the ABW bit in WSCR.

Number of Access States: Two or three access states can be selected via the AST bit in WSCR. When the 2-state access space is designated, wait-state insertion is disabled.

In the burst ROM interface, the number of access states is determined regardless of the AST bit setting.

Wait Mode and Number of Program Wait States: When a 3-state access space is designated by the AST bit in WSCR, the wait mode and the number of program wait states to be inserted automatically is selected by the WMS1, WMS0, WC1, and WC0 bits in WSCR. From 0 to 3 program wait states can be selected.

Table 6.2 shows the bus specifications for the basic bus interface of each area.

Table 6.2 Bus Specifications for Basic Bus Interface

						Bus Specifications		
ABW	AST	WMS1	WMS0	WC1	WC0	Bus Width	Number of Access States	Number of Program Wait States
0	0	—	—	—	—	16	2	0
	1	0	1	—	—	16	3	0
		—*	—*	0	0		3	0
					1			1
				1	0			2
					1			3
1	0	—	—	—	—	8	2	0
	1	0	1	—	—	8	3	0
		—*	—*	0	0		3	0
					1			1
				1	0			2
					1			3

Note: * Other than WMS1 = 0 and WMS0 = 1

6.4.2 Advanced Mode

The external address space is initialized as the basic bus interface and a 3-state access space. In on-chip ROM enable extended mode, the address space other than on-chip ROM, on-chip RAM, internal I/O registers, and their reserved areas is specified as the external address space. The on-chip RAM and its reserved area are enabled when the RAME bit in SYSCR is set to 1. The on-chip RAM and its reserved area are disabled and corresponding addresses are the external address space when the RAME bit is cleared to 0.

6.4.3 Normal Mode

The external address space is initialized as the basic bus interface and a 3-state access space. In on-chip ROM disable extended mode, the address space other than on-chip RAM and internal I/O registers is specified as the external address space. In on-chip ROM enable extended mode, the address space other than on-chip ROM, on-chip RAM, internal I/O registers, and their reserved areas is specified as the external address space. The on-chip RAM area is enabled when the

RAME bit in SYSCR is set to 1, and disabled and specified as the external address space when the RAME bit is cleared to 0.

6.4.4 I/O Select Signals

The LSI can output I/O select signals ($\overline{IOS}$); the signal is driven low when the corresponding external address space is accessed. Figure 6.2 shows an example of $\overline{IOS}$ signal output timing.

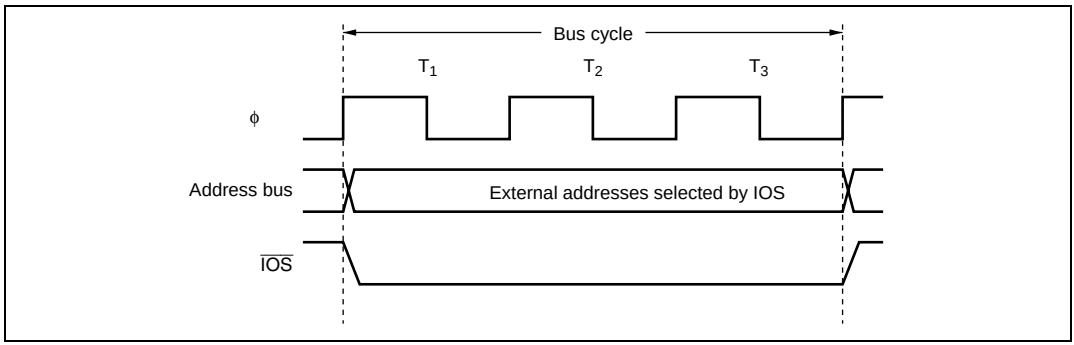


Figure 6.2 $\overline{IOS}$ Signal Output Timing

Enabling or disabling $\overline{IOS}$ signal output is performed by the IOSE bit in SYSCR. In extended mode, the $\overline{IOS}$ pin functions as an $\overline{AS}$ pin by a reset. To use this pin as an $\overline{IOS}$ pin, set the IOSE bit to 1. For details, refer to section 8, I/O Ports.

The address ranges of the $\overline{IOS}$ signal output can be specified by the IOS1 and IOS0 bits in BCR, as shown in table 6.3.

Table 6.3 Address Range for $\overline{IOS}$ Signal Output

IOS1	IOS0	$\overline{IOS}$ Signal Output Range	
0	0	H'(FF)F000 to H'(FF)F03F	
	1	H'(FF)F000 to H'(FF)F0FF	
1	0	H'(FF)F000 to H'(FF)F3FF	
	1	H'(FF)F000 to H'(FF)F7FF	(Initial value)

6.5 Basic Bus Interface

The basic bus interface enables direct connection to ROM and SRAM. For details on selection of the bus specifications when using the basic bus interface, see table 6.2

6.5.1 Data Size and Data Alignment

Data sizes for the CPU and other internal bus masters are byte, word, and longword. The BSC has a data alignment function, and controls whether the upper data bus (D15 to D8) or lower data bus (D7 to D0) is used when the external address space is accessed, 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 6.3 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 access is performed as two byte accesses, and a longword access, as four byte accesses.

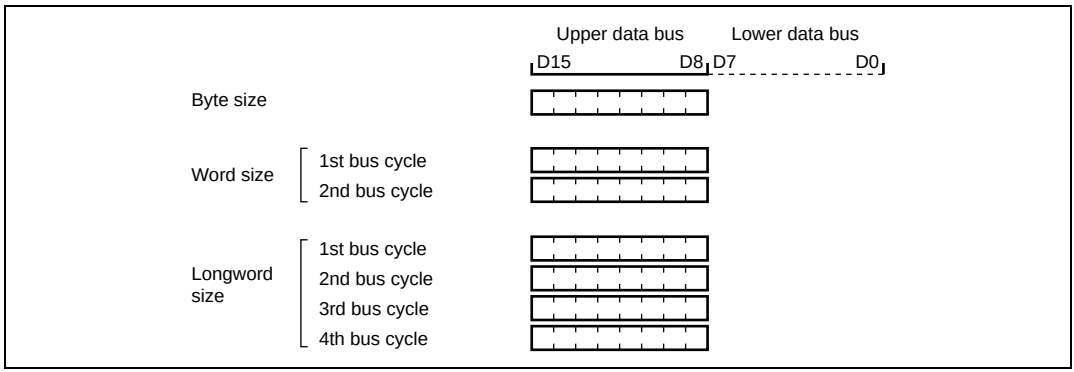


Figure 6.3 Access Sizes and Data Alignment Control (8-Bit Access Space)

16-Bit Access Space: Figure 6.4 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 access is executed as two word accesses.

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.

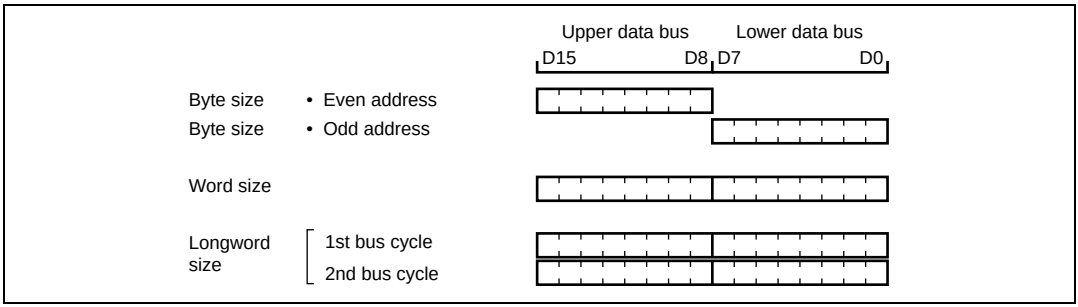


Figure 6.4 Access Sizes and Data Alignment Control (16-bit Access Space)

6.5.2 Valid Strobes

Table 6.4 shows the data buses used and valid strobes for each access space.

In a read, the $\overline{RD}$ signal is valid for both the upper and lower halves of the data bus. In a write, the $\overline{HWR}$ signal is valid for the upper half of the data bus, and the $\overline{LWR}$ signal for the lower half.

Table 6.4 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	—	$\overline{RD}$	Valid	Ports or others
		Write	—	$\overline{HWR}$		Ports or others
16-bit access space	Byte	Read	Even	$\overline{RD}$	Valid	Invalid
			Odd		Invalid	Valid
		Write	Even	$\overline{HWR}$	Valid	Undefined
			Odd	$\overline{LWR}$	Undefined	Valid
	Word	Read	—	$\overline{RD}$	Valid	Valid
		Write	—	$\overline{HWR}$, $\overline{LWR}$	Valid	Valid

Note: Undefined: Undefined data is output.
Invalid: Input state with the input value ignored.
Ports or others: Used as ports or I/O pins for on-chip peripheral modules, and are not used as the data bus.

6.5.3 Basic Operation Timing

8-Bit, 2-State Access Space: Figure 6.5 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.

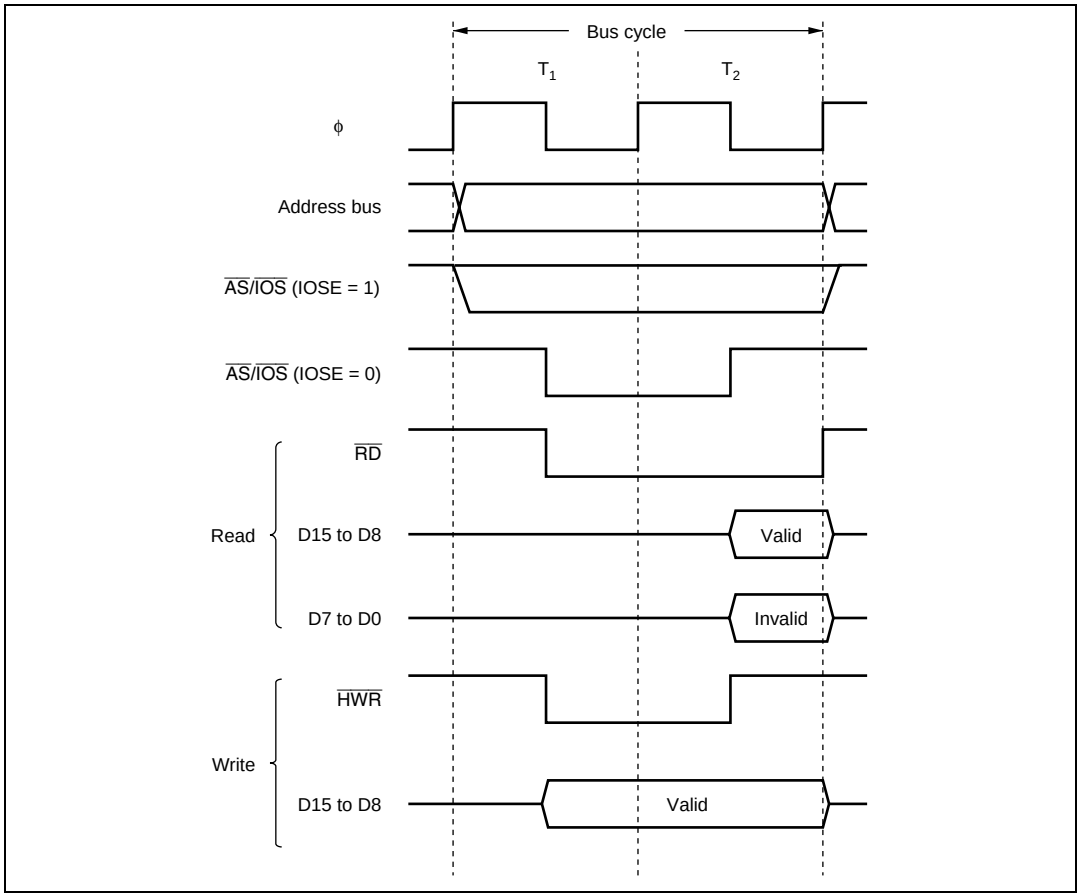


Figure 6.5 Bus Timing for 8-Bit, 2-State Access Space

8-Bit, 3-State Access Space: Figure 6.6 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.

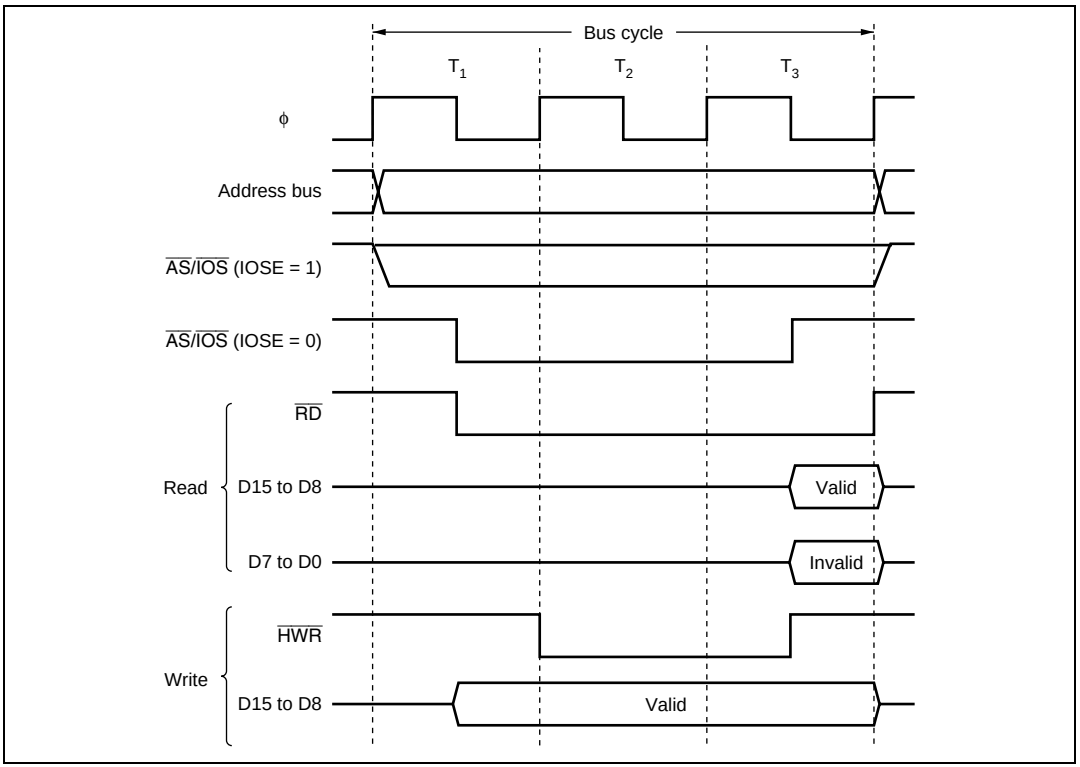


Figure 6.6 Bus Timing for 8-Bit, 3-State Access Space

16-Bit, 2-State Access Space: Figures 6.7 to 6.9 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 even addresses, and the lower half (D7 to D0) for odd addresses. Wait states cannot be inserted.

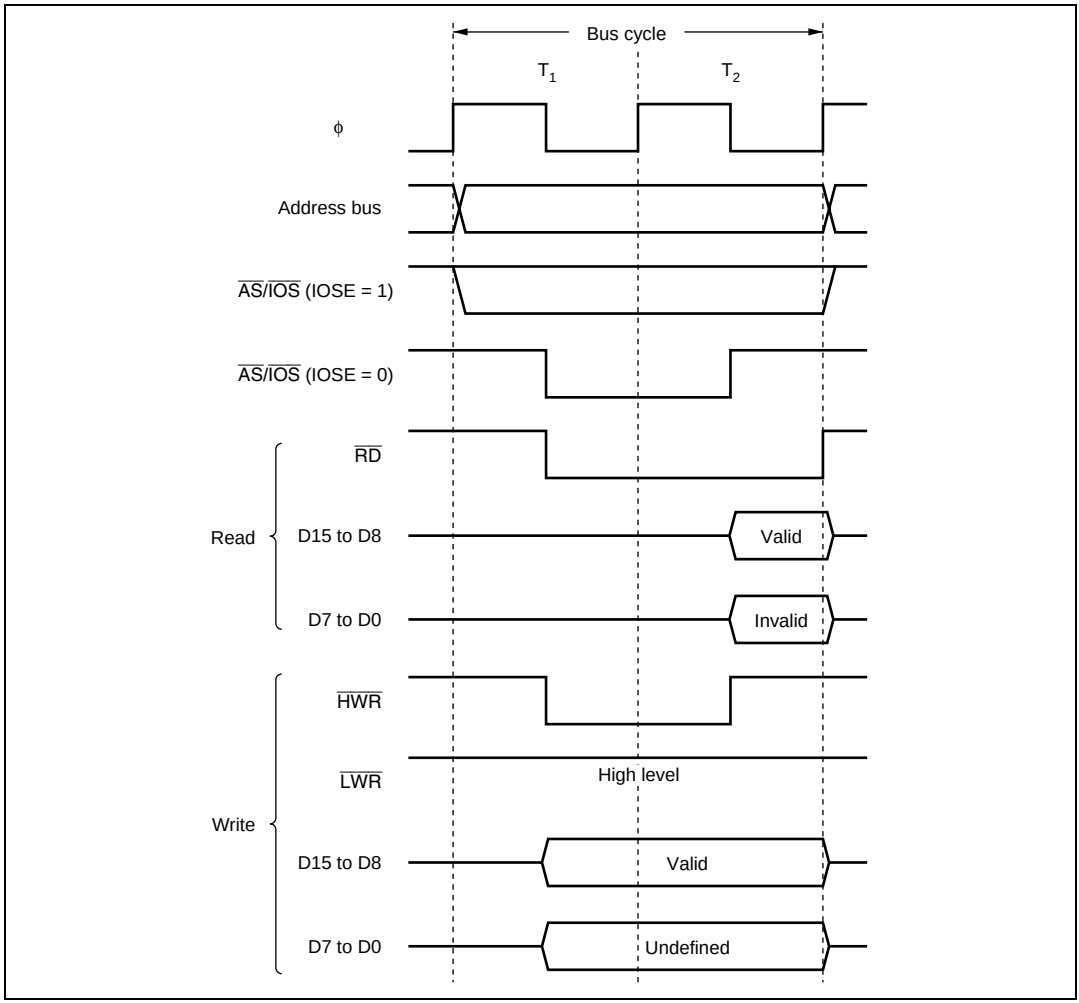


Figure 6.7 Bus Timing for 16-Bit, 2-State Access Space (Even Byte Access)

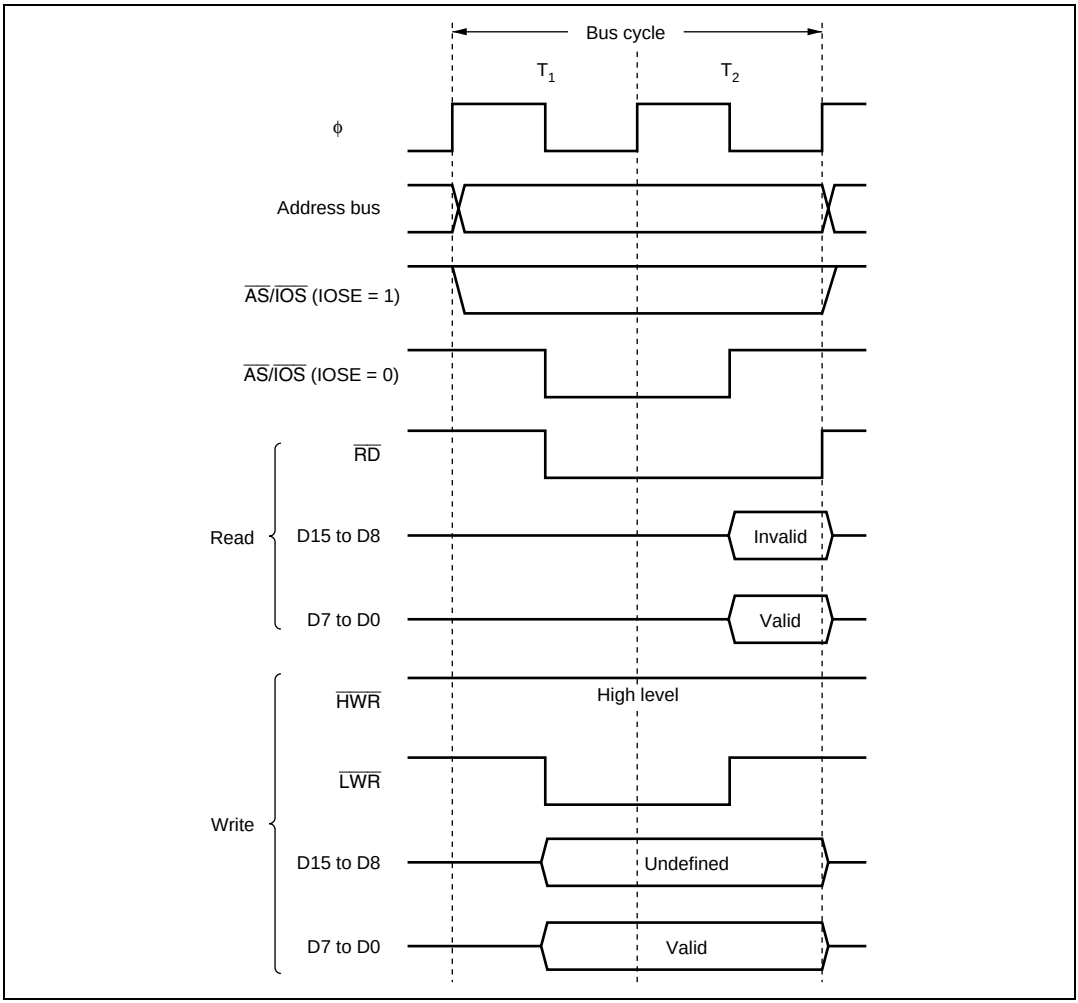


Figure 6.8 Bus Timing for 16-Bit, 2-State Access Space (Odd Byte Access)

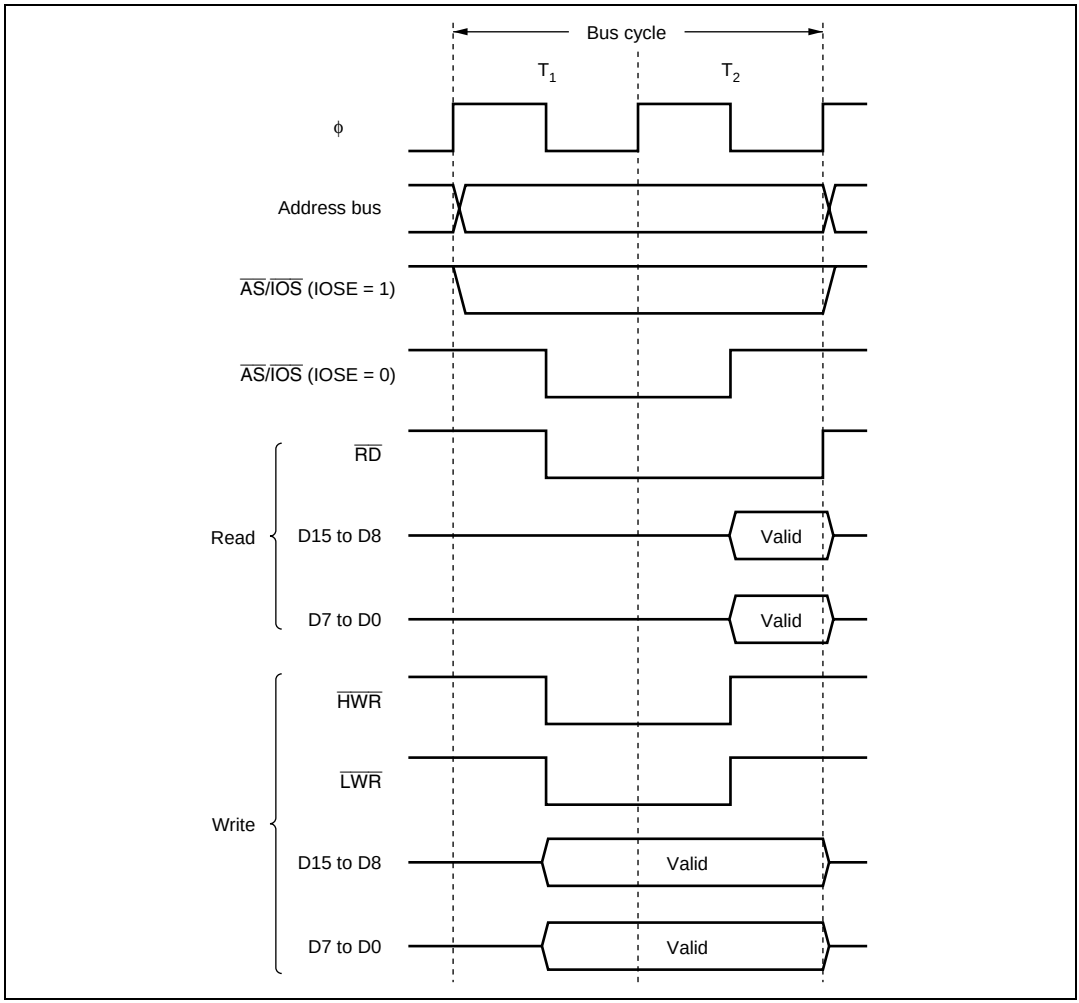


Figure 6.9 Bus Timing for 16-Bit, 2-State Access Space (Word Access)

16-Bit, 3-State Access Space: Figures 6.10 to 6.12 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 even addresses, and the lower half (D7 to D0) for odd addresses. Wait states can be inserted.

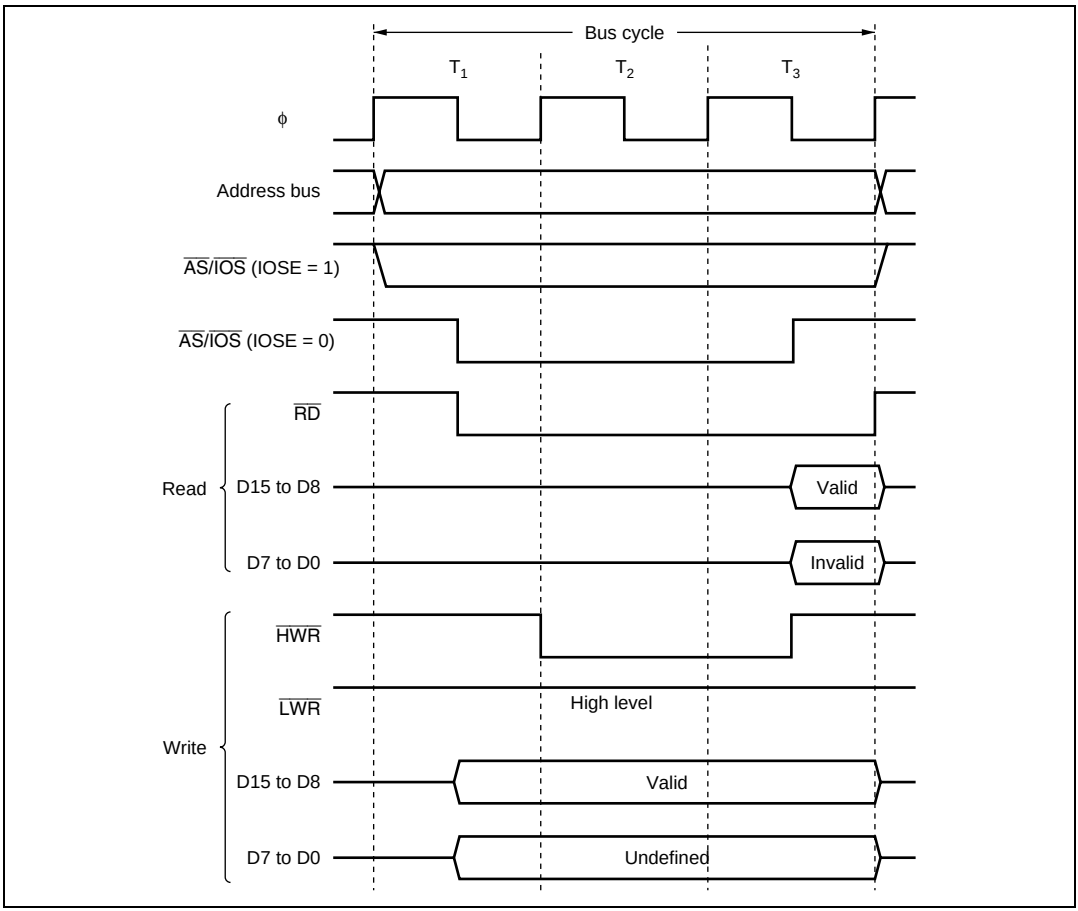


Figure 6.10 Bus Timing for 16-Bit, 3-State Access Space (Even Byte Access)

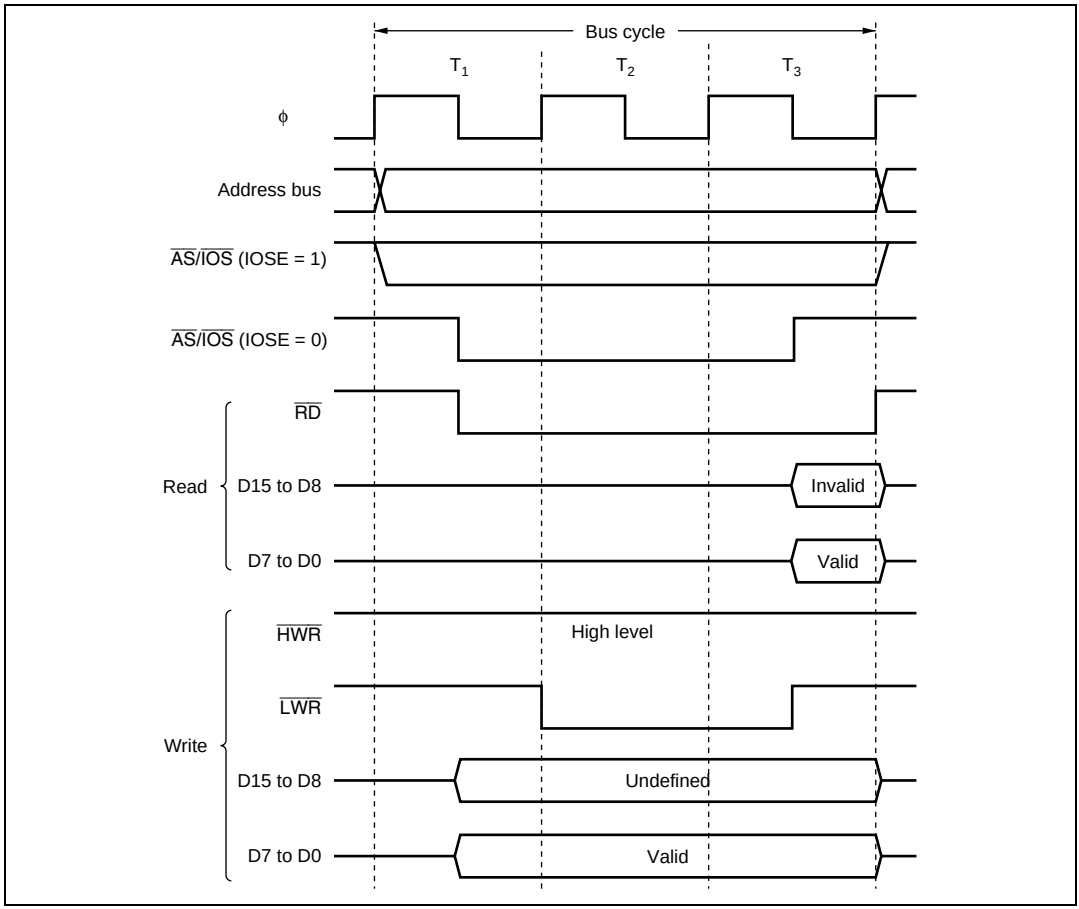


Figure 6.11 Bus Timing for 16-Bit, 3-State Access Space (Odd Byte Access)

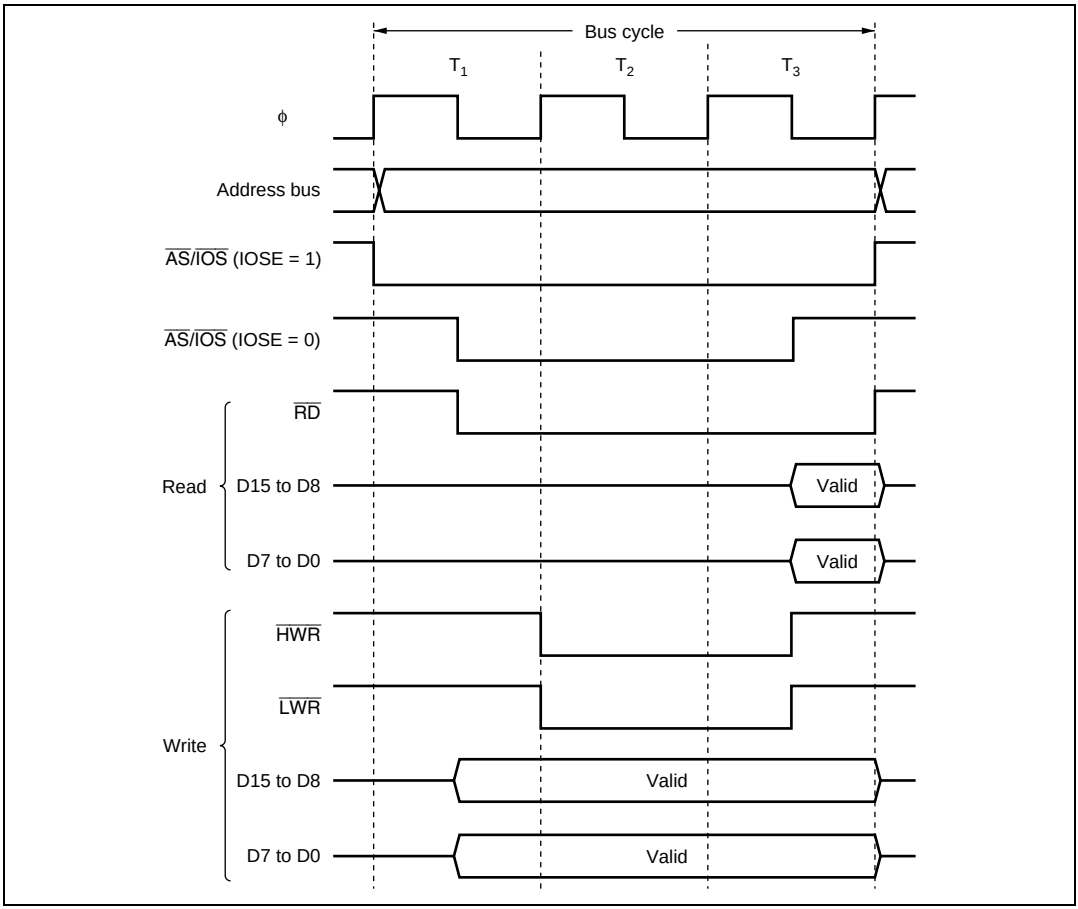


Figure 6.12 Bus Timing for 16-Bit, 3-State Access Space (Word Access)

6.5.4 Wait Control

When accessing the external address space, this LSI can extend the bus cycle by inserting one or more wait states (T_w). There are three ways of inserting wait states: Program wait insertion, pin wait insertion using the $\overline{\text{WAIT}}$ pin, and the combination of program wait and the $\overline{\text{WAIT}}$ pin.

Program Wait Mode: A specified number of wait states T_w can be inserted automatically between the T_2 state and T_3 state when accessing the external address space always according to the settings of the WC1 and WC0 bits in WSCR.

Pin Wait Mode: A specified number of wait states T_w can be inserted automatically between the T_2 state and T_3 state when accessing the external address space always according to the settings of the WC1 and WC0 bits. If the $\overline{\text{WAIT}}$ pin is low at the falling edge of ϕ in the last T_2 or T_w state, another T_w state is inserted. If the $\overline{\text{WAIT}}$ pin is held low, T_w states are inserted until it goes high.

This is useful when inserting four or more T_w states, or when changing the number of T_w states to be inserted for each external device.

Pin Auto-Wait Mode: A specified number of wait states T_w can be inserted automatically between the T_2 state and T_3 state when accessing the external address space according to the settings of the WC1 and WC0 bits if the $\overline{\text{WAIT}}$ pin is low at the falling edge of ϕ in the last T_2 state. Even if the $\overline{\text{WAIT}}$ pin is held low, T_w states can be inserted only up to the specified number of states.

This function enables the low-speed memory interface only by inputting the chip select signal to the $\overline{\text{WAIT}}$ pin.

Figure 6.13 shows an example of wait state insertion timing in pin wait mode.

The settings after a reset are: 3-state access, 3 program wait insertion, and $\overline{\text{WAIT}}$ pin input disabled.

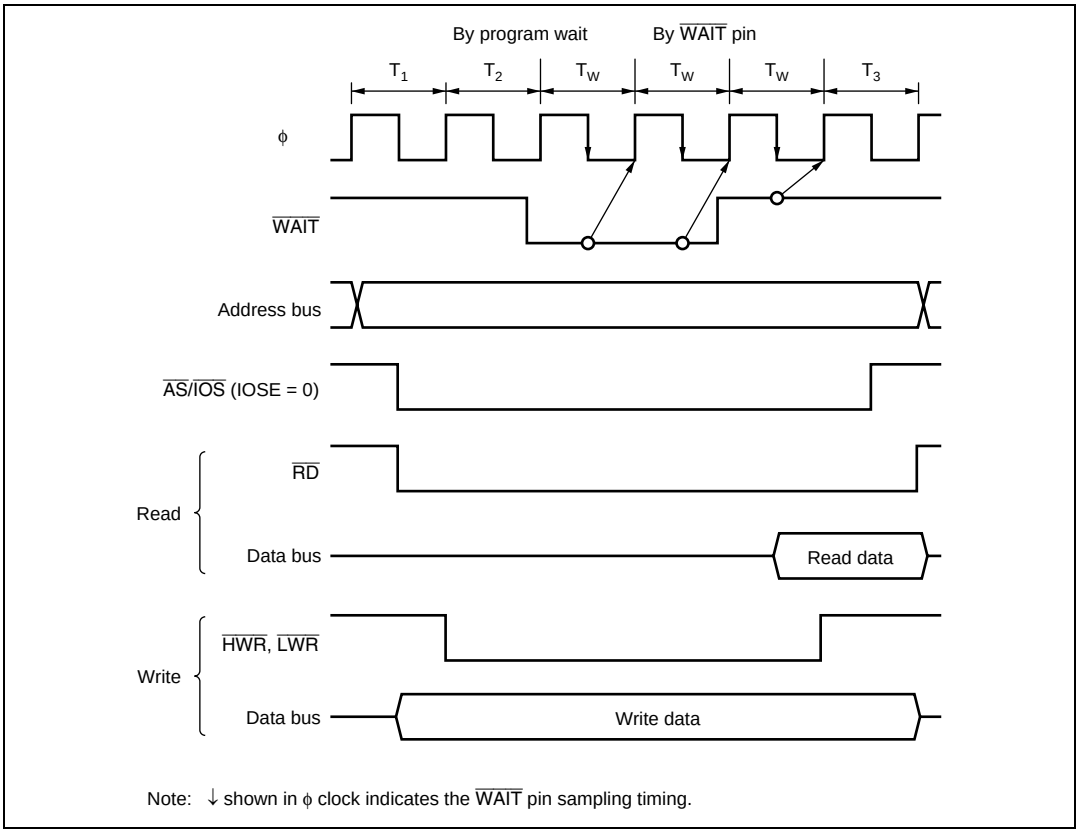


Figure 6.13 Example of Wait State Insertion Timing (Pin Wait Mode)

6.6 Burst ROM Interface

In this LSI, the external address space can be designated as the burst ROM space by setting the BRSTRM bit in BCR to 1, and the burst ROM interface enabled. Consecutive burst accesses of a maximum four or eight words can be performed only during CPU instruction fetch. 1 or 2 states can be selected for burst ROM access.

6.6.1 Basic Operation Timing

The number of access states in the initial cycle (full access) of the burst ROM interface is determined by the AST bit in WSCR. When the AST bit is set to 1, wait states can be inserted. 1 or 2 states can be selected for burst access according to the setting of the BRSTS1 bit in BCR. Wait states cannot be inserted in a burst cycle. Burst accesses of a maximum four words is performed when the BRSTS0 bit in BCR is cleared to 0, and burst accesses of a maximum eight words is performed when the BRSTS0 bit in BCR is set to 1.

The basic access timing for the burst ROM space is shown in figures 6.14 and 6.15.

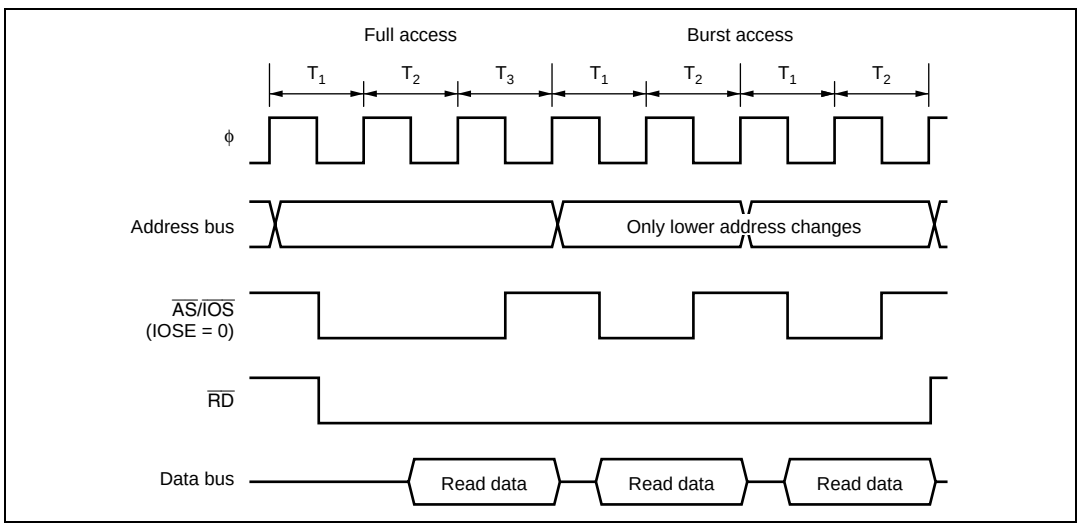


Figure 6.14 Access Timing Example in Burst ROM Space (AST = BRSTS1 = 1)

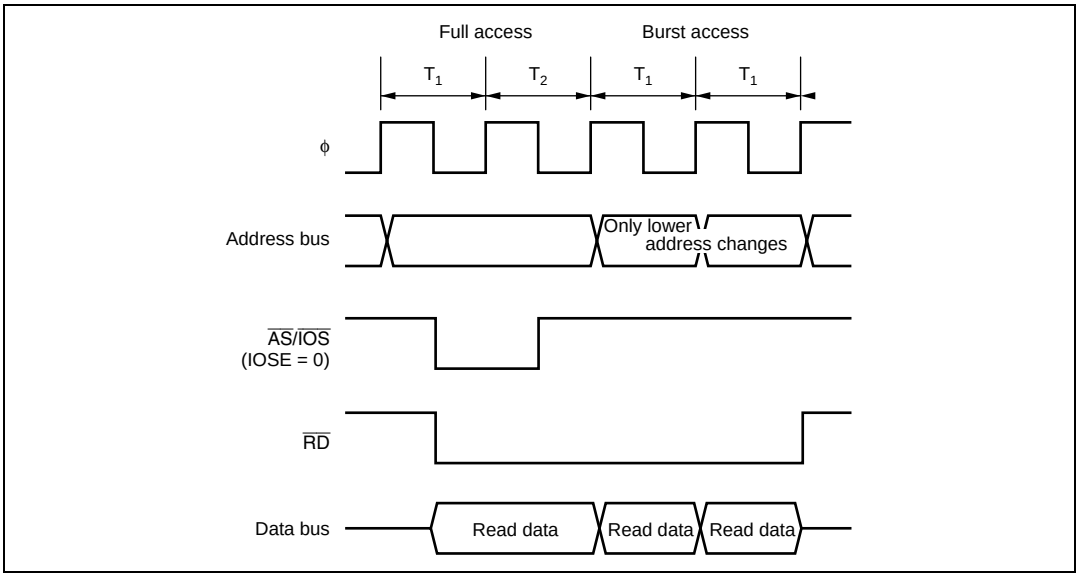


Figure 6.15 Access Timing Example in Burst ROM Space (AST = BRSTS1 = 0)

6.6.2 Wait Control

As with the basic bus interface, program wait insertion or pin wait insertion using the $\overline{\text{WAIT}}$ pin can be used in the initial cycle (full access) of the burst ROM interface. For details, see section 6.5.4, Wait Control. Wait states cannot be inserted in a burst cycle.

6.7 Idle Cycle

When this LSI accesses the external address space, it can insert a 1-state idle cycle (T_I) between bus cycles 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 and I/O interfaces.

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

Figure 6.16 shows examples of idle cycle operation. In these examples, bus cycle A is a read cycle for ROM with a long output floating time, and bus cycle B is a CPU write cycle. In figure 6.16 (a), with no idle cycle inserted, a collision occurs in bus cycle B between the read data from ROM and the CPU write data. In figure 6.16 (b), an idle cycle is inserted, thus preventing data collision.

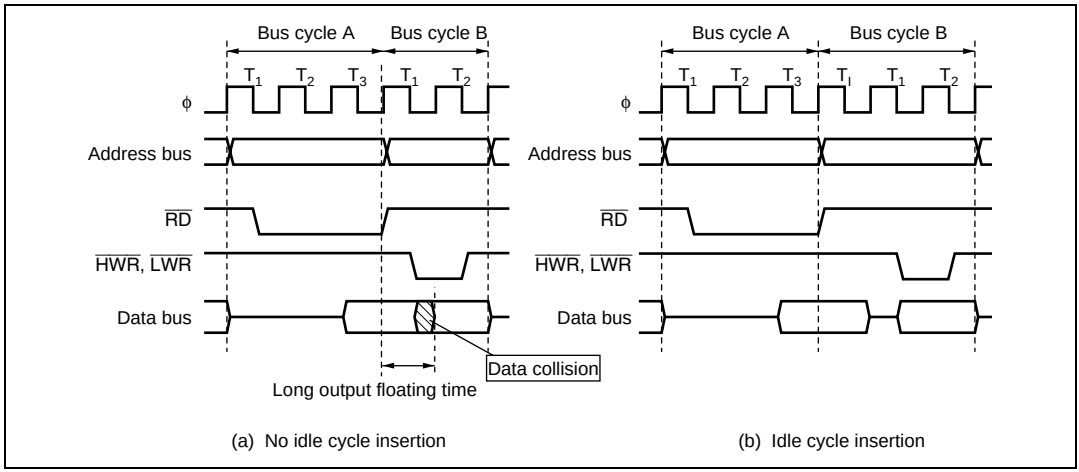


Figure 6.16 Examples of Idle Cycle Operation

Table 6.5 shows the pin states in an idle cycle.

Table 6.5 Pin States in Idle Cycle

Pins	Pin State
A23 to A0, $\overline{IOS}$	Contents of immediately following bus cycle
D15 to D0	High impedance
$\overline{AS}$	High
$\overline{RD}$	High
$\overline{HWR}$, $\overline{LWR}$	High

6.8 Bus Arbitration

The bus controller has a bus arbiter that arbitrates bus master operations. There are two bus masters – the CPU and DTC – that perform read/write operations when they have possession of the bus.

6.8.1 Priority of Bus Masters

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

(High) DTC > CPU (Low)

6.8.2 Bus Transfer Timing

When 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. Each bus master can relinquish the bus at the timings given below.

CPU: The CPU is the lowest-priority bus master, and if a bus request is received from the DTC, the bus arbiter transfers the bus to the DTC.

- DTC bus transfer timing
  - 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 component operations. For details, refer to the H8S/2600 Series, H8S/2000 Series Programming Manual.
  - If the CPU is in sleep mode, the bus is transferred immediately.

DTC: The DTC has the highest bus master priority. The DTC sends the bus arbiter a request for the bus when an activation request is generated. The DTC does not release the bus until it completes its operation.

Section 7 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 7.1 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 addresses H'(FF)EC00 to H'(FF)EFFF in on-chip RAM (1 kbyte), enabling 32-bit/1-state reading and writing of the DTC register information.

7.1 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)
- 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

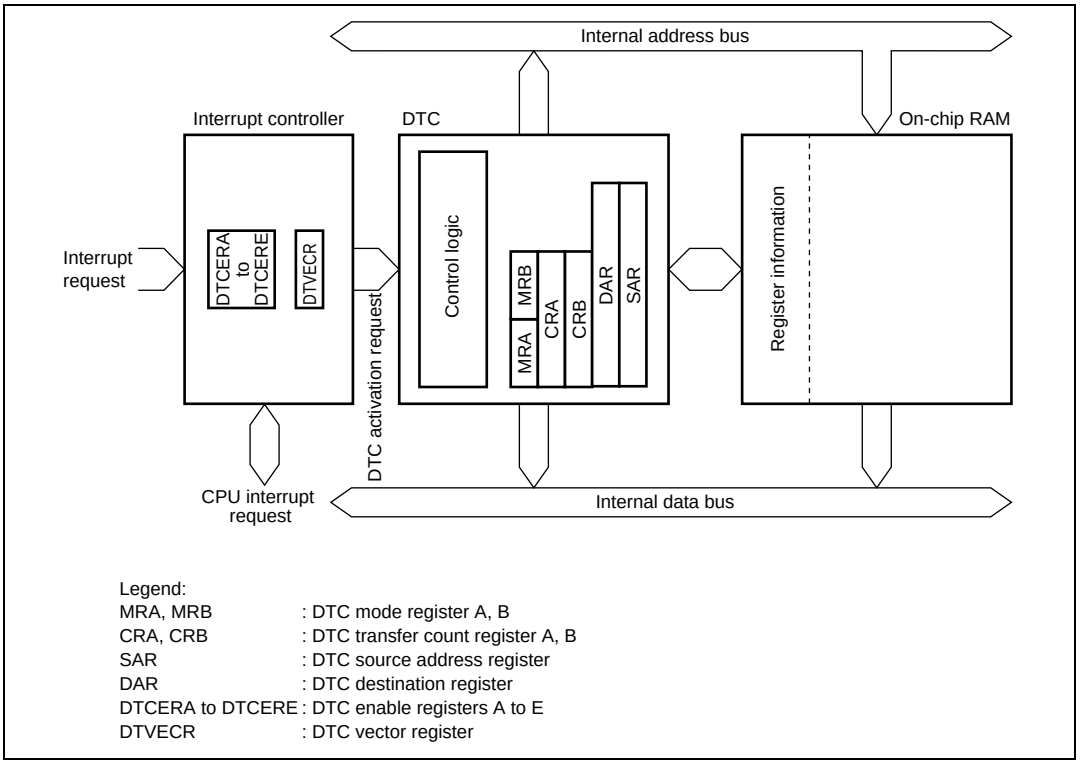


Figure 7.1 Block Diagram of DTC

7.2 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 a DTC activation interrupt source occurs, 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 on-chip RAM.

- DTC enable registers A to E (DTCERA to DTCERE)
- DTC vector register (DTVECR)

7.2.1 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, 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, 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
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

7.2.2 DTC Mode Register B (MRB)

MRB selects the DTC operating mode.

Bit	Bit Name	Initial Value	R/W	Description
7	CHNE	Undefined	—	DTC Chain Transfer Enable When this bit is set to 1, a chain transfer will be performed. For details, refer to section 7.5.4, Chain Transfer. In data transfer with CHNE set to 1, determination of the end of the specified number of data transfers, clearing of the interrupt source flag, and clearing of DTCER are not performed.
6	DISEL	Undefined	—	DTC Interrupt Select When this bit is set to 1, a CPU interrupt request is generated every time data transfer ends (the DTC clears the interrupt source flag for the activation source). When this bit is cleared to 0, a CPU interrupt request is generated only when the specified number of data transfer ends (the DTC does not clear the interrupt source flag for the activation source).
5 to 0	—	Undefined	—	Reserved These bits have no effect on DTC operation. Only 0 should be written to these bits.

7.2.3 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.

7.2.4 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.

7.2.5 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.

7.2.6 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.

7.2.7 DTC Enable Registers (DTCER)

DTCER specifies DTC activation interrupt sources. DTCER is comprised of five registers: DTCERA to DTCERE. The correspondence between interrupt sources and DTCE bits is shown in table 7.1. For DTCE bit setting, use bit manipulation instructions such as BSET and BCLR. Multiple DTC activation sources can be set at one time (only at the initial setting) by masking all interrupts and writing data after executing a dummy read on the relevant register.

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

7.2.8 DTC Vector Register (DTVECR)

DTVECR enables or disables DTC activation by software, and sets a vector number for the software activation interrupt.

DTVECR is initialized to H'00 at a reset and in hardware standby mode.

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 1 can always be written to this bit. 0 can be written to after reading 1 from this bit. [Clearing conditions] • When the DISEL bit is 0 and the specified number of transfers have not ended. • When 0 is written to the DISEL bit after a software-activated data transfer end interrupt (SWDTEND) request has been sent to the CPU. [Holding conditions] • When the DISEL bit is 1 and data transfer has ended • When the specified number of transfers have ended. • During data transfer activated by software
6	DTVEC6	0	R/W	DTC Software Activation Vectors 6 to 0 These bits specify a vector number for DTC software activation. The vector address is expressed as H'0400 + (vector number × 2). For example, when DTVEC6 to DTVEC0 = H'10, the vector address is H'0420. When the SWDTE bit is 0, these bits can be written to.
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	

7.3 Activation Sources

The DTC is activated by an interrupt request or by a write to DTVECR by software. The interrupt request source to activate the DTC is selected by DTCER. At the end of a data transfer (or the last consecutive transfer in the case of chain transfer), the interrupt flag that became the activation source or the corresponding DTCER bit is cleared. The activation source flag, in the case of RXI0, for example, is the RDRF flag in SCI_0.

When an interrupt has been designated as 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 7.2 shows a block diagram of DTC activation source control. For details on the interrupt controller, see section 5, Interrupt Controller.

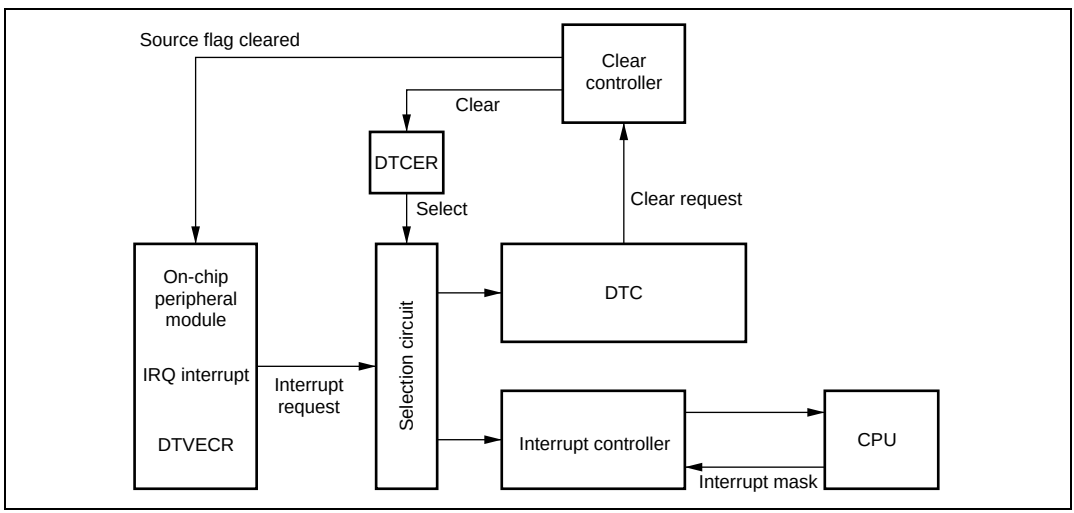


Figure 7.2 Block Diagram of DTC Activation Source Control

7.4 Location of Register Information and DTC Vector Table

Locate the register information in the on-chip RAM (addresses: H'(FF)EC00 to H'(FF)EFFF). Register information should be located at an address that is a multiple of four within the range. The method for locating the register information in address space is shown in figure 7.3. Locate MRA, SAR, MRB, DAR, CRA, and CRB, 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 7.3, and the register information start address should be located at the vector address corresponding to the interrupt source in the DTC vector table. The DTC reads the start address of the register information from the vector table 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 is used in both cases. Specify the lower two bits of the register information start address.

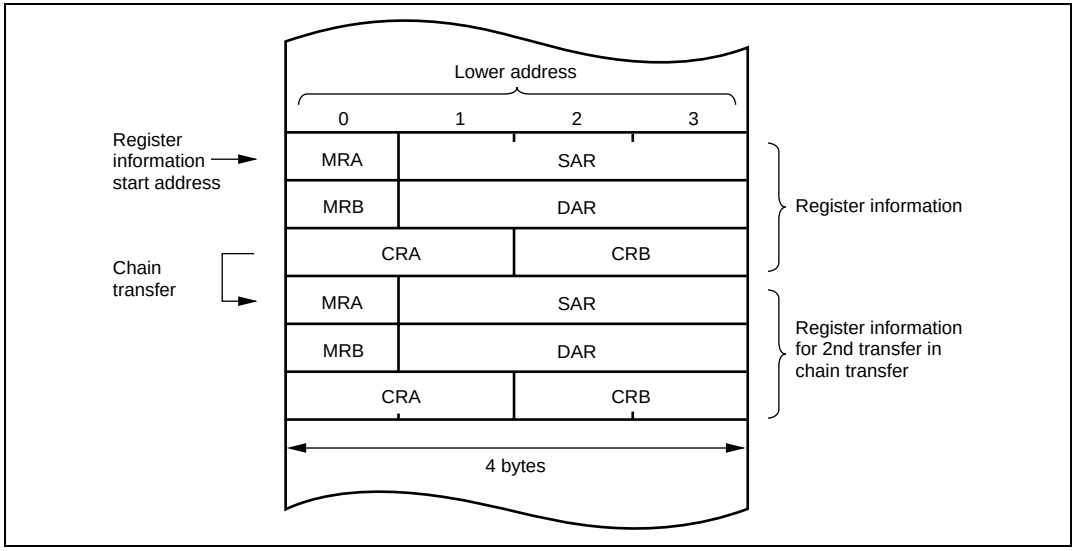


Figure 7.3 DTC Register Information Location in Address Space

Table 7.1 Interrupt Sources, DTC Vector Addresses, and Corresponding DTCEs

Activation Source Origin	Activation Source	Vector Number	DTC Vector Address	DTCE*1	Priority
Software	Write to DTVECR	DTVECR	H'0400 + (vector number × 2)	—	High
External pins	IRQ0	16	H'0420	DTCEA7	
	IRQ1	17	H'0422	DTCEA6	
	IRQ2	18	H'0424	DTCEA5	
	IRQ3	19	H'0426	DTCEA4	
A/D converter	ADI	28	H'0438	DTCEA3	
FRT	ICIA	48	H'0460	DTCEA2	
	ICIB	49	H'0462	DTCEA1	
	OCIA	52	H'0468	DTCEA0	
	OCIB	53	H'046A	DTCEB7	
TMR_0	CMIA0	64	H'0480	DTCEB2	
	CMIB0	65	H'0482	DTCEB1	
TMR_1	CMIA1	68	H'0488	DTCEB0	
	CMIB1	69	H'048A	DTCEC7	
TMR_Y	CMIAY	72	H'0490	DTCEC6	
	CMIBY	73	H'0492	DTCEC5	
XBS	IBF1	76	H'0498	DTCEC4	
	IBF2	77	H'049A	DTCEC3	
SCI_0	RXI0	81	H'04A2	DTCEC2	
	TXI0	82	H'04A4	DTCEC1	
SCI_1	RXI1	85	H'04AA	DTCEC0	
	TXI1	86	H'04AC	DTCED7	
SCI_2	RXI2	89	H'04B2	DTCED6	
	TXI2	90	H'04B4	DTCED5	
IIC_0	IICI0	92	H'04B8	DTCED4	
IIC_1	IICI1	94	H'04BC	DTCED3	
LPC*2	ERRI	108	H'04D8	DTCEE3	
	IBFI1	109	H'04DA	DTCEE2	
	IBFI2	110	H'04DC	DTCEE1	
	IBFI3	111	H'04DE	DTCEE0	Low

Notes: 1. DTCE bits with no corresponding interrupt are reserved, and only 0 should be written to this bit.

2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

7.5 Operation

The DTC stores register information 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 on-chip RAM. 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, or 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.

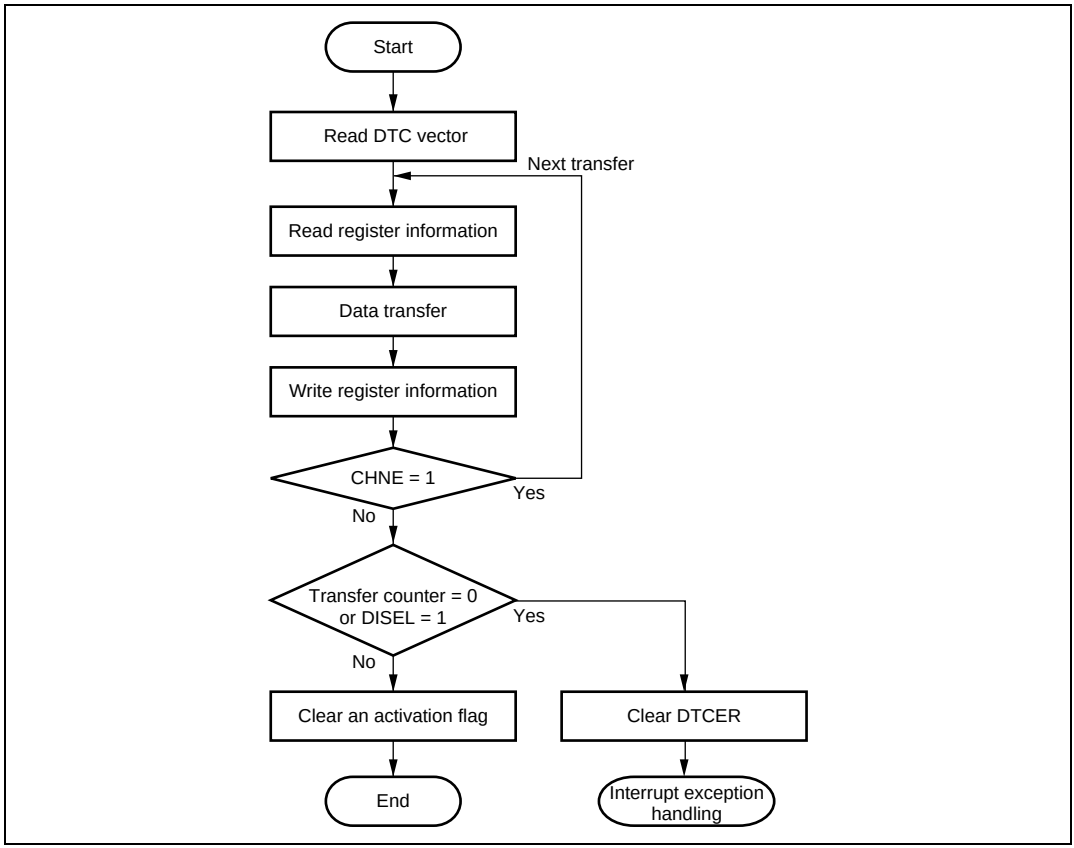


Figure 7.4 DTC Operation Flowchart

7.5.1 Normal Mode

In normal mode, one activation source transfers one byte or one word of data. Table 7.2 lists the register functions in normal mode. 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 7.2 Register Functions in Normal Mode

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

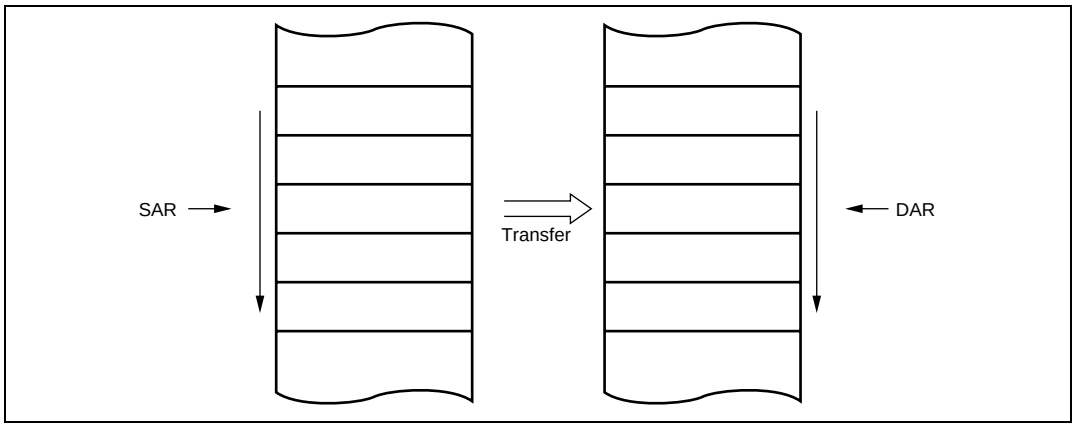


Figure 7.5 Memory Mapping in Normal Mode

7.5.2 Repeat Mode

In repeat mode, one activation source transfers one byte or one word of data. Table 7.3 lists the register functions in repeat mode. From 1 to 256 transfers can be specified. Once the specified number of transfers have completed, the initial states of the transfer counter and the address register that is 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 the DISEL bit in MRB is cleared to 0.

Table 7.3 Register Functions in Repeat Mode

Name	Abbreviation	Function
DTC source address register	SAR	Transfer source address
DTC destination address register	DAR	Transfer destination address
DTC transfer count register AH	CRAH	Holds number of transfers
DTC transfer count register AL	CRAL	Transfer Count
DTC transfer count register B	CRB	Not used

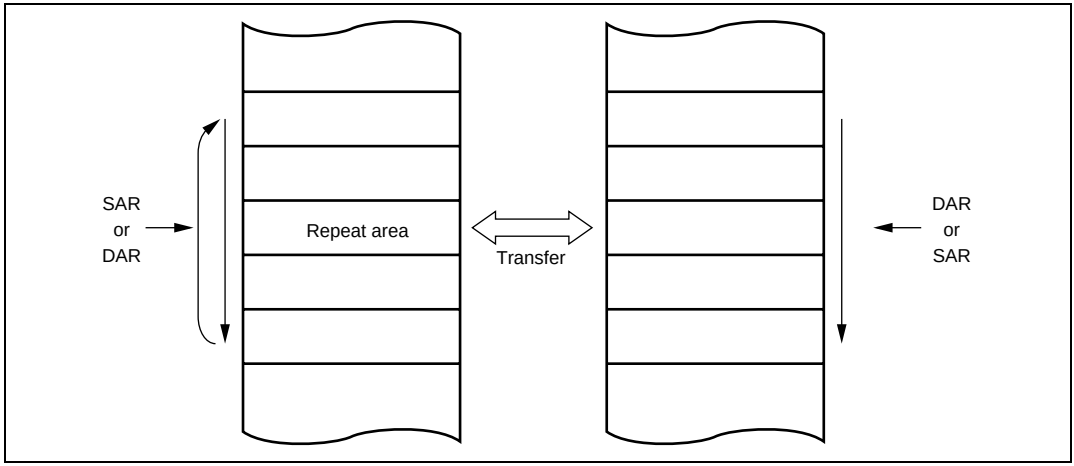


Figure 7.6 Memory Mapping in Repeat Mode

7.5.3 Block Transfer Mode

In block transfer mode, one activation source transfers one block of data. Either the transfer source or the transfer destination is designated as a block area. Table 7.4 lists the register functions in block transfer mode. The block size can be between 1 and 256. When the transfer of one block ends, the initial state of the block size counter and the address register that is specified as the block area is restored. The other address register is then incremented, decremented, or left fixed according to the register information. From 1 to 65,536 transfers can be specified. Once the specified number of transfers have been completed, a CPU interrupt is requested.

Table 7.4 Register Functions in Block Transfer Mode

Name	Abbreviation	Function
DTC source address register	SAR	Transfer source address
DTC destination address register	DAR	Transfer destination address
DTC transfer count register AH	CRAH	Holds block size
DTC transfer count register AL	CRAL	Block size counter
DTC transfer count register B	CRB	Transfer counter

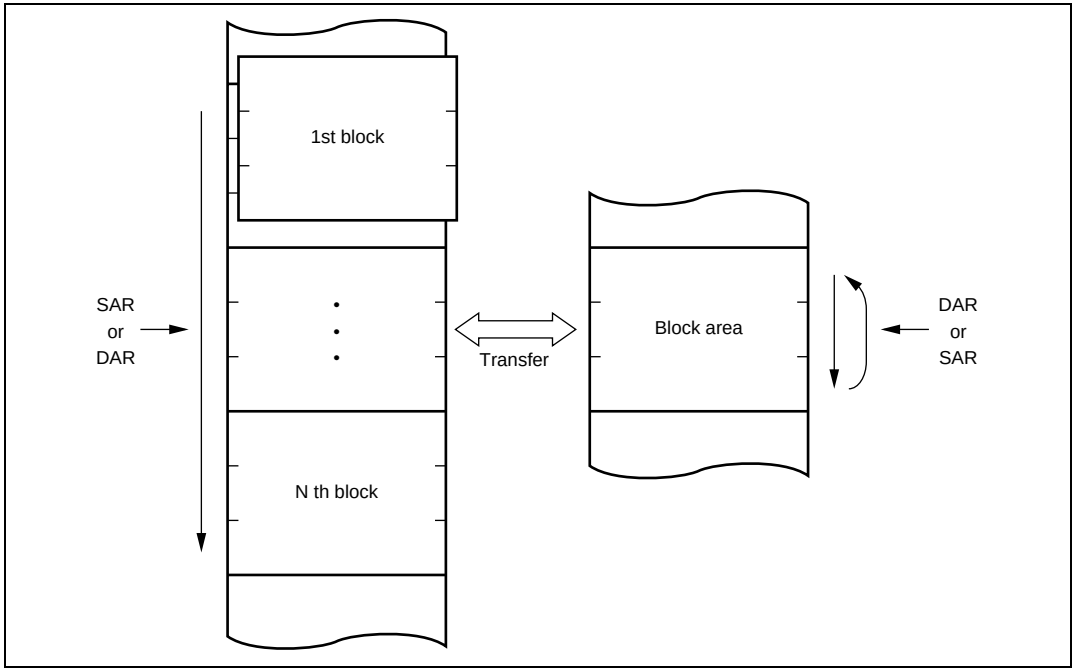


Figure 7.7 Memory Mapping in Block Transfer Mode

7.5.4 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 7.8 shows the overview of chain transfer operation. When activated, the DTC reads the register information start address stored at the DTC 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 the CHNE bit 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.

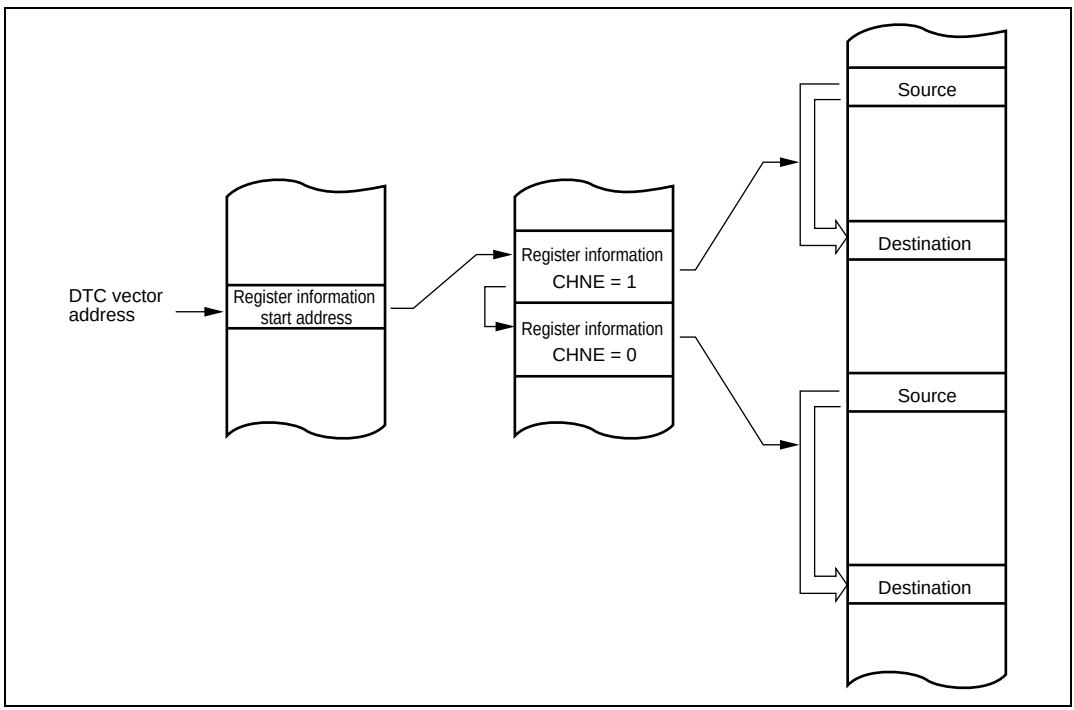


Figure 7.8 Chain Transfer Operation

7.5.5 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 priority level control by the interrupt controller.

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.

7.5.6 Operation Timing

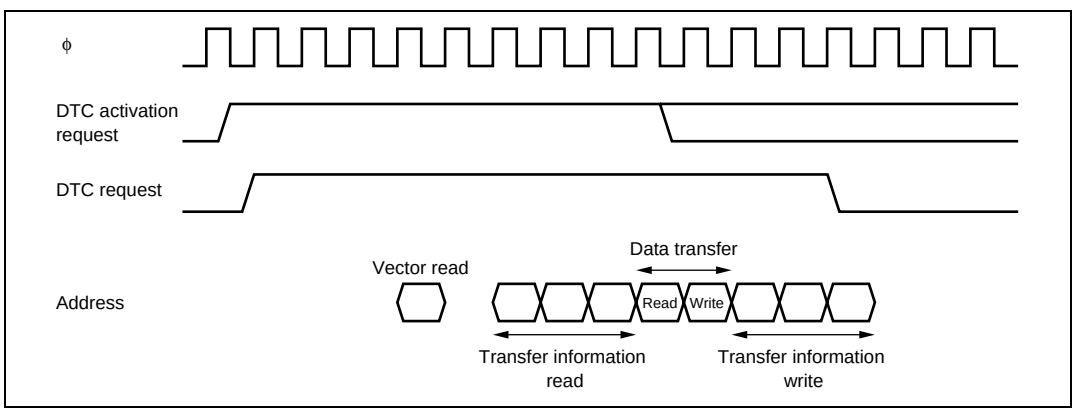


Figure 7.9 DTC Operation Timing (Example in Normal Mode or Repeat Mode)

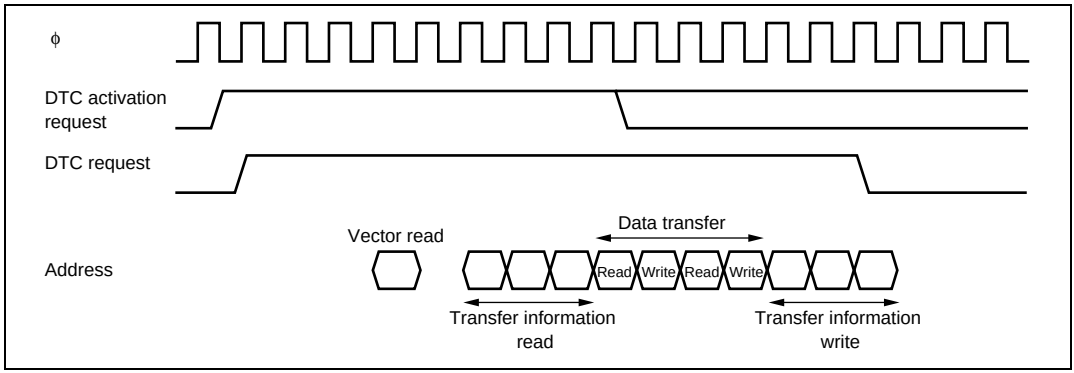


Figure 7.10 DTC Operation Timing (Example of Block Transfer Mode, with Block Size of 2)

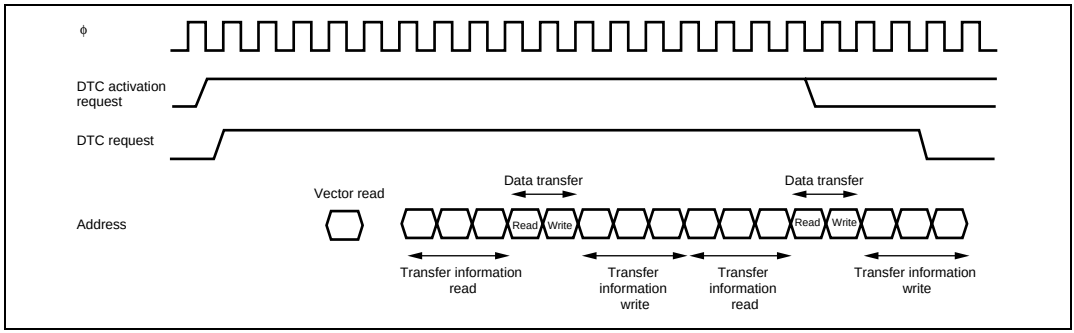


Figure 7.11 DTC Operation Timing (Example of Chain Transfer)

7.5.7 Number of DTC Execution States

Table 7.5 lists the execution status for a single DTC data transfer, and table 7.6 shows the number of states required for each execution status.

Table 7.5 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

N: Block size (initial setting of CRAH and CRAL)

Table 7.6 Number of States Required for Each Execution Status

Object to be Accessed			On-Chip RAM	On-Chip ROM	On-Chip 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							

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 source (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 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 data write is 10 states.

7.6 Procedures for Using DTC

7.6.1 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.

7.6.2 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 the 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.

7.7 Examples of Use of DTC

7.7.1 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 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.

7.7.2 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 transfer destination address is H'2000. The vector number is H'60, so the vector address is H'04C0.

1. Set MRA to incrementing source address (SM1 = 1, SM0 = 0), incrementing destination address (DM1 = 1, DM0 = 0), block transfer mode (MD1 = 1, MD0 = 0), and byte size (Sz = 0). The DTS bit can have any value. Set MRB for one block transfer by one interrupt (CHNE = 0). Set the transfer source address (H'1000) in SAR, the transfer destination address (H'2000) in DAR, and 128 (H'8080) in CRA. Set 1 (H'0001) in CRB.
2. Set the start address of the register information at the DTC vector address (H'04C0).
3. Check that the SWDTE bit in DTVECR is 0. Check that there is currently no transfer activated by software.
4. Write 1 to the SWDTE bit and the vector number (H'60) to DTVECR. The write data is H'E0.
5. Read DTVECR again and check that 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 wrap-up processing.

7.8 Usage Notes

7.8.1 Module Stop Mode Setting

DTC operation can be enabled or disabled by the module stop control register (MSTPCR). In the initial state, DTC operation is enabled. Access to DTC registers are disabled when module stop mode is set. Note that when the DTC is being activated, module stop mode cannot be specified. For details, refer to section 26, Power-Down Modes.

7.8.2 On-Chip RAM

MRA, MRB, SAR, DAR, CRA, and CRB are all located in on-chip RAM. When the DTC is used, the RAME bit in SYSCR should not be cleared to 0.

7.8.3 DTCE Bit Setting

For DTCE bit setting, use bit manipulation instructions such as BSET and BCLR, for reading and writing. Multiple DTC activation sources can be set at one time (only at the initial setting) by masking all interrupts and writing data after executing a dummy read on the relevant register.

7.8.4 Setting Required on Entering Subactive Mode or Watch Mode

Set the MSTP14 bit in MSTPCRH to 1 to make the DTC enter module stop mode, then confirm that is set to 1 before making a transition to subactive mode or watch mode.

7.8.5 DTC Activation by Interrupt Sources of SCI, IIC, LPC, or A/D Converter

Interrupt sources of the SCI, IIC, LPC, or A/D converter which activate the DTC are cleared when DTC reads from or writes to the respective registers, and they cannot be cleared by the DISEL bit in MRB.

Section 8 I/O Ports

8.1 Overview

This LSI has ten I/O ports (ports 1 to 6, 8, 9, A, and B), and one input-only port (port 7).

For additional ports C to G in H8S/2160B and H8S/2161B, see section 8.13 Additional Overview for H8S/2160B and H8S/2161B.

Table 8.1 is a summary of the port functions. The pins of each port also have other functions.

Each port includes a data direction register (DDR) that controls input/output (not provided for the input-only port) and data registers (DR, ODR) that store output data.

Ports 1 to 3, 6, A, and B have an on-chip input pull-up MOS function. For ports A and B, the on/off status of the input pull-up MOS is controlled by DDR and ODR. Ports 1 to 3 and 6 have an input pull-up MOS control register (PCR), in addition to DDR, to control the on/off status of the input pull-up MOS.

Ports 1 to 6, 8, 9, A, and B can drive a single TTL load and 30 pF capacitive load. All the I/O ports can drive a Darlington transistor when in output mode. Ports 1 to 3 can drive an LED (10 mA sink current).

Port A input and output use by the VccB power supply, which is independent of the V_{CC} power supply. When the VccB voltage is 5V, the pins on port A will be 5-V tolerant.

PA4 to PA7 of port A have bus-buffer drive capability.

P52 in port 5, P97 in port 9, P86 in port 8 and P42 in port 4 are NMOS push-pull outputs. P52, P97, P86 and P42 are thus 5-V tolerant, with DC characteristics that are dependent on the V_{CC} voltage.

For the P42/SCK2, P52/SCK0, P86/SCK1, and P97 outputs, connect pull-up resistors to pins to raise output-high-level voltage.

Table 8.1 Port Functions of H8S/2140B, H8S/2141B, H8S/2145B, and H8S/2148B

Port	Description	Mode 1	Modes 2 and 3		I/O Status
			(EXPE = 1)	(EXPE = 0)	
Port 1	General I/O port also functioning as address output and PWM output pins	A7 A6 A5 A4 A3 A2 A1 A0	A7/P17/PW7 A6/P16/PW6 A5/P15/PW5 A4/P14/PW4 A3/P13/PW3 A2/P12/PW2 A1/P11/PW1 A0/P10/PW0	P17/PW7 P16/PW6 P15/PW5 P14/PW4 P13/PW3 P12/PW2 P11/PW1 P10/PW0	On-chip input pull-up MOSs
Port 2	General I/O port also functioning as address output pin, PWM output pin, and timer connection output pin	A15 A14 A13 A12 A11 A10 A9 A8	A15/P27/PW15/CBLANK A14/P26/PW14 A13/P25/PW13 A12/P24/PW12 A11/P23/PW11 A10/P22/PW10 A9/P21/PW9 A8/P20/PW8	P27/PW15/CBLANK P26/PW14 P25/PW13 P24/PW12 P23/PW11 P22/PW10 P21/PW9 P20/PW8	On-chip input pull-up MOSs
Port 3	General I/O port also functioning as data bus input/output, XBS data bus input/output, and LPC input/output pins	D15 D14 D13 D12 D11 D10 D9 D8		P37/HDB7/SERIRQ* P36/HDB6/LCLK* P35/HDB5/$\overline{\text{LRESET}}$* P34/HDB4/$\overline{\text{LFRAME}}$* P33/HDB3/LAD3* P32/HDB2/LAD2* P31/HDB1/LAD1* P30/HDB0/LAD0*	On-chip input pull-up MOSs

Port	Description	Mode 1	Modes 2 and 3		I/O Status
			(EXPE = 1)	(EXPE = 0)	
Port 4	General I/O port also functioning as PWMX output, TMR_0 and TMR_1 input/output, timer connection input/output, XBS host interrupt request output, SCI_2 input/output, IrDA interface input/output, and IIC_1 input/output pins	P47/PWX1 P46/ PWX0 P45/TMRI1/CSYNCI P44/TMO1/HSYNCO P43/TMCI1/HSYNCI P42/TMRI0/SCK2/SDA1 P41/TMO0/RxD2/IrRxD P40/TMCI0/TxD2/IrTxD		P47/PWX1 P46/PWX0 P45/TMRI1/HIRQ12/ CSYNCI P44/TMO1/HIRQ1/ HSYNCO P43/TMCI1/HIRQ11/ HSYNCI P42/TMRI0/SCK2/SDA1 P41/TMO0/RxD2/IrRxD P40/TMCI0/TxD2/IrTxD	
Port 5	General I/O port also functioning as SCI_0 input/output and IIC_0 input/output pins	P52/SCK0/SCL0 P51/RxD0 P50/TxD0			
Port 6	General I/O port also functioning as interrupt input, FRT input/output, TMR_X and TMR_Y input/output, timer connection input/output, key-sense interrupt input, and expansion A/D input pins	P67/$\overline{\text{IRQ7}}$/TMOX/$\overline{\text{KIN7}}$/CIN7 P66/$\overline{\text{IRQ6}}$/FTOB/$\overline{\text{KIN6}}$/CIN6 P65/FTID/$\overline{\text{KIN5}}$/CIN5 P64/FTIC/$\overline{\text{KIN4}}$/CIN4/CLAMPO P63/FTIB/$\overline{\text{KIN3}}$/CIN3/VFBACKI P62/FTIA/TMIY/$\overline{\text{KIN2}}$/CIN2/VSYNCI P61/FTOA/$\overline{\text{KIN1}}$/CIN1/VSYNCO P60/FTCI/TMIX/$\overline{\text{KIN0}}$/CIN0/HFBACKI			On-chip input pull-up MOSs
Port 7	General input port also functioning as A/D converter analog input and D/A converter analog output pins	P77/AN7/DA1 P76/AN6/DA0 P75/AN5 P74/AN4 P73/AN3 P72/AN2 P71/AN1 P70/AN0			

Port	Description	Mode 1	Modes 2 and 3		I/O Status
			(EXPE = 1)	(EXPE = 0)	
Port 8	General I/O port also functioning as interrupt input, SCI_1 input/output, XBS control input/output, LPC input/output, and IIC_1 input/output pins	P86/$\overline{\text{IRQ5}}$/SCK1/SCL1 P85/$\overline{\text{IRQ4}}$/RxD1 P84/$\overline{\text{IRQ3}}$/TxD1 P83 P82 P81 P80		P86/$\overline{\text{IRQ5}}$/SCK1/SCL1 P85/$\overline{\text{IRQ4}}$/RxD1 P84/$\overline{\text{IRQ3}}$/TxD1 P83/$\overline{\text{LPCPD}}$* P82/HIFSD/$\overline{\text{CLKRUN}}$* P81/$\overline{\text{CS2}}$/GA20 P80/HA0/$\overline{\text{PME}}$*	
Port 9	General I/O port also functioning as extended data bus control input/output, IIC_0 input/output, subclock input, ϕ output, interrupt input, XBS control input, and A/D converter external trigger input pins	P97/$\overline{\text{WAIT}}$/SDA0 P96/ϕ/EXCL $\overline{\text{AS}}$/$\overline{\text{IOS}}$ $\overline{\text{HWR}}$ $\overline{\text{RD}}$ P92/$\overline{\text{IRQ0}}$ P91/$\overline{\text{IRQ1}}$ P90/$\overline{\text{LWR}}$/$\overline{\text{IRQ2}}$/$\overline{\text{ADTRG}}$		P97/SDA0 P96/ϕ/EXCL P95/$\overline{\text{CS1}}$ P94/$\overline{\text{IOW}}$ P93/$\overline{\text{IOR}}$ P92/$\overline{\text{IRQ0}}$ P91/$\overline{\text{IRQ1}}$ P90/$\overline{\text{IRQ2}}$/$\overline{\text{ADTRG}}$/ $\overline{\text{ECS2}}$	
Port A	General I/O port also functioning as address output, key-sense interrupt input, extended A/D input, and keyboard buffer controller input/output pins	PA7/$\overline{\text{KIN15}}$/CIN15/PS2CD PA6/$\overline{\text{KIN14}}$/CIN14/PS2CC PA5/$\overline{\text{KIN13}}$/CIN13/PS2BD PA4/$\overline{\text{KIN12}}$/CIN12/PS2BC PA3/$\overline{\text{KIN11}}$/CIN11/PS2AD PA2/$\overline{\text{KIN10}}$/CIN10/PS2AC PA1/$\overline{\text{KIN9}}$/CIN9 PA0/$\overline{\text{KIN8}}$/CIN8	PA7/A23/$\overline{\text{KIN15}}$/CIN15/PS2CD PA6/A22/$\overline{\text{KIN14}}$/CIN14/PS2CC PA5/A21/$\overline{\text{KIN13}}$/CIN13/PS2BD PA4/A20/$\overline{\text{KIN12}}$/CIN12/PS2BC PA3/A19/$\overline{\text{KIN11}}$/CIN11/PS2AD PA2/A18/$\overline{\text{KIN10}}$/CIN10/PS2AC PA1/A17/$\overline{\text{KIN9}}$/CIN9 PA0/A16/$\overline{\text{KIN8}}$/CIN8	PA7/$\overline{\text{KIN15}}$/CIN15/PS2CD PA6/$\overline{\text{KIN14}}$/CIN14/PS2CC PA5/$\overline{\text{KIN13}}$/CIN13/PS2BD PA4/$\overline{\text{KIN12}}$/CIN12/PS2BC PA3/$\overline{\text{KIN11}}$/CIN11/PS2AD PA2/$\overline{\text{KIN10}}$/CIN10/PS2AC PA1/$\overline{\text{KIN9}}$/CIN9 PA0/$\overline{\text{KIN8}}$/CIN8	On-chip input pull-up MOSs

Port	Description	Mode 1	Modes 2 and 3		I/O Status
			(EXPE = 1)	(EXPE = 0)	
Port B	General I/O port also functioning as wakeup event interrupt input, data bus input/output, XBS control input/output, and LPC input/output pins	PB7/D7/$\overline{\text{WUE7}}$* PB6/D6/$\overline{\text{WUE6}}$* PB5/D5/$\overline{\text{WUE5}}$* PB4/D4/$\overline{\text{WUE4}}$* PB3/D3/$\overline{\text{WUE3}}$* PB2/D2/$\overline{\text{WUE2}}$* PB1/D1/$\overline{\text{WUE1}}$* PB0/D0/$\overline{\text{WUE0}}$*		PB7/$\overline{\text{WUE7}}$* PB6/$\overline{\text{WUE6}}$* PB5/$\overline{\text{WUE5}}$* PB4/$\overline{\text{WUE4}}$* PB3/$\overline{\text{WUE3}}$*/$\overline{\text{CS4}}$ PB2/$\overline{\text{WUE2}}$*/$\overline{\text{CS3}}$ PB1/$\overline{\text{WUE1}}$*/HIRQ4/LSCI* PB0/$\overline{\text{WUE0}}$*/HIRQ3/$\overline{\text{LSMI}}$*	On-chip input pull-up MOSs

Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).

8.2 Port 1

Port 1 is an 8-bit I/O port. Port 1 pins also function as an address bus and PWM output pins. Port 1 functions change according to the operating mode. Port 1 has an on-chip input pull-up MOS function that can be controlled by software. Port 1 has the following registers.

- Port 1 data direction register (P1DDR)
- Port 1 data register (P1DR)
- Port 1 pull-up MOS control register (P1PCR)

8.2.1 Port 1 Data Direction Register (P1DDR)

P1DDR specifies input or output for the pins of port 1 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P17DDR	0	W	In mode 1: Each pin of port 1 is address output regardless of the set value of P1DDR. In modes 2 and 3 (EXPE=1): The corresponding port 1 pins are address output or PWM output ports when P1DDR bits are set to 1, and input ports when cleared to 0. In modes 2 and 3 (EXPE=0): The corresponding port 1 pins are output ports or PWM outputs when the P1DDR bits are set to 1, and input ports when cleared to 0.
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	

8.2.2 Port 1 Data Register (P1DR)

P1DR stores output data for the port 1 pins.

Bit	Bit Name	Initial Value	R/W	Description
7	P17DR	0	R/W	If a port 1 read is performed while the P1DDR bits are set to 1, the P1DR values are read. If a port 1 read is performed while the P1DDR bits are cleared to 0, the pin states are read.
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	

8.2.3 Port 1 Pull-Up MOS Control Register (P1PCR)

P1PCR controls the on/off status of the port 1 on-chip input pull-up MOSs.

Bit	Bit Name	Initial Value	R/W	Description
7	P17PCR	0	R/W	When the pins are in input state, the corresponding input pull-up MOS is turned on when a P1PCR bit is set to 1.
6	P16PCR	0	R/W	
5	P15PCR	0	R/W	
4	P14PCR	0	R/W	
3	P13PCR	0	R/W	
2	P12PCR	0	R/W	
1	P11PCR	0	R/W	
0	P10PCR	0	R/W	

8.2.4 Pin Functions

- P17/A7/PW7 to P10/A0/PW0

  The pin function is switched as shown below according to the combination of the OEn bit in PWOERA of PWM, the P1nDDR bit, and operating mode.

Operating Mode	Mode 1	Mode 2, 3 (EXPE = 1)			Mode 2, 3 (EXPE = 0)		
P1nDDR	—	0	1		0	1	
OEn	—	—	0	1	—	0	1
Pin Function	A7 to A0 output pins	P17 to P10 input pins	A7 to A0 output pins	PW7 to PW0 output pins	P17 to P10 input pins	P17 to P10 output pins	PW7 to PW0 output pins

Note: n = 7 to 0

8.2.5 Port 1 Input Pull-Up MOS

Port 1 has an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be specified as on or off on a bit-by-bit basis.

Table 8.2 summarizes the input pull-up MOS states.

Table 8.2 Input Pull-Up MOS States (Port 1)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
1	Off	Off	Off	Off
2, 3			On/Off	On/Off

Legend:

Off: Input pull-up MOS is always off.

On/Off: On when the pin is in the input state, P1DDR = 0, and P1PCR = 1; otherwise off.

8.3 Port 2

Port 2 is an 8-bit I/O port. Port 2 pins also function as address bus output function, 8-bit PWM output pins, and the timer connection output pin. Port 2 functions change according to the operating mode. Port 2 has an on-chip input pull-up MOS function that can be controlled by software. Port 2 has the following registers.

- Port 2 data direction register (P2DDR)
- Port 2 data register (P2DR)
- Port 2 pull-up MOS control register (P2PCR)

8.3.1 Port 2 Data Direction Register (P2DDR)

P2DDR specifies input or output for the pins of port 2 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P27DDR	0	W	In Mode 1: The corresponding port 2 pins are address outputs, regardless of the P2DDR setting. Modes 2 and 3 (EXPE = 1): The corresponding port 2 pins are address outputs or PWM outputs when P2DDR bits are set to 1, and input ports when cleared to 0. P27 to P24 are switched from address outputs to output ports by setting the IOSE bit to 1. P27 can be used as an on-chip peripheral module output pin regardless of the P27DDR setting, but to ensure normal access to external space, P27 should not be set as an on-chip peripheral module output pin when port 2 pins are used as address output pins. Modes 2 and 3 (EXPE = 0): The corresponding port 2 pins are output ports or PWM outputs when P2DDR bits are set to 1, and input ports when cleared to 0. P27 can be used as an on-chip peripheral module output pin regardless of the P27DDR setting.
6	P26DDR	0	W	
5	P25DDR	0	W	
4	P24DDR	0	W	
3	P23DDR	0	W	
2	P22DDR	0	W	
1	P21DDR	0	W	
0	P20DDR	0	W	

8.3.2 Port 2 Data Register (P2DR)

P2DR stores output data for port 2.

Bit	Bit Name	Initial Value	R/W	Description
7	P27DR	0	R/W	If a port 2 read is performed while P2DDR bits are set to 1, the P2DR values are read directly, regardless of the actual pin states. If a port 2 read is performed while P2DDR bits are cleared to 0, the pin states are read.
6	P26DR	0	R/W	
5	P25DR	0	R/W	
4	P24DR	0	R/W	
3	P23DR	0	R/W	
2	P22DR	0	R/W	
1	P21DR	0	R/W	
0	P20DR	0	R/W	

8.3.3 Port 2 Pull-Up MOS Control Register (P2PCR)

P2PCR controls the port 2 on-chip input pull-up MOSs.

Bit	Bit Name	Initial Value	R/W	Description
7	P27PCR	0	R/W	In modes 2 and 3, the input pull-up MOS is turned on when a P2PCR bit is set to 1 in the input port state.
6	P26PCR	0	R/W	
5	P25PCR	0	R/W	
4	P24PCR	0	R/W	
3	P23PCR	0	R/W	
2	P22PCR	0	R/W	
1	P21PCR	0	R/W	
0	P20PCR	0	R/W	

8.3.4 Pin Functions

To ensure normal access to external space, P27 should not be set as an on-chip peripheral module output pin when port 2 pins are used as address output pins.

- P27/A15/PW15/CBLANK

  The pin function is switched as shown below according to the combination of the IOSE bit in SYSCR, the CBOE bit in TCONRO of timer connection, the OE15 bit in PWOERB of PWM, the P27DDR bit, and operating mode.

Operating Mode	Mode 1	Mode 2, 3 (EXPE = 1)						Mode 2, 3 (EXPE = 0)			
CBOE	—	0					1	0			1
P27DDR	—	0	1				—	0	1		—
OE15	—	—	0		1		—	—	0	1	—
IOSE	—	—	0	1	—		—	—	—	—	—
Pin Function	A15 output pin	P27 input pin	A15 output pin	P27 output pin	PW15 output pin		CBLANK output pin	P27 input pin	P27 output pin	PW15 output pin	CBLANK output pin

- P26/A14/PW14, P25/A13/PW13, P24/A12/PW12

  The pin function is switched as shown below according to the combination of the IOSE bit in SYSCR, the OEm bit in PWOERB of PWM, the P2nDDR bit, and operating mode.

Operating Mode	Mode 1	Mode 2, 3 (EXPE = 1)				Mode 2, 3 (EXPE = 0)		
P2nDDR	—	0	1			0	1	
OEm	—	—	0		1	—	0	1
IOSE	—	—	0	1	—	—	1	—
Pin Function	A14 to A12 output pins	P26 to P24 input pins	A14 to A12 output pins	P26 to P24 output pins	PW14 to PW12 output pins	P26 to P24 input pins	P26 to P24 output pins	PW14 to PW12 output pins

Note: n = 6 to 4
m = 14 to 12

- P23/A11/PW11, P22/A10/PW10, P21/A9/PW9, P20/A8/PW8

  The pin function is switched as shown below according to the combination of the OEm bit in PWOERB of PWM, the P2nDDR bit, and operating mode.

Operating Mode	Mode 1	Mode 2, 3 (EXPE = 1)			Mode 2, 3 (EXPE = 0)		
P2nDDR	—	0	1		0	1	
OEm	—	—	0	1	—	0	1
Pin Function	A11 to A8 output pins	P23 to P20 input pins	A11 to A8 output pins	PW11 to PW8 output pins	P23 to P20 input pins	P23 to P20 output pins	PW11 to PW8 output pins

Note: n = 3 to 0
m = 11 to 8

8.3.5 Port 2 Input Pull-Up MOS

Port 2 has an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be specified as on or off on a bit-by-bit basis.

Table 8.3 summarizes the input pull-up MOS states.

Table 8.3 Input Pull-Up MOS States (Port 2)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
1	Off	Off	Off	Off
2, 3			On/Off	On/Off

Legend:
Off: Input pull-up MOS is always off.
On/Off: On when the pin is in the input state, P2DDR = 0, and P2PCR = 1; otherwise off.

8.4 Port 3

Port 3 is an 8-bit I/O port. Port 3 pins also function as a bidirectional data bus, XBS bidirectional data bus, and LPC input/output pins. Port 3 functions change according to the operating mode. Port 3 has the following registers.

- Port 3 data direction register (P3DDR)
- Port 3 data register (P3DR)
- Port 3 pull-up MOS control register (P3PCR)

8.4.1 Port 3 Data Direction Register (P3DDR)

P3DDR specifies input or output for the pins of port 3 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P37DDR	0	W	Modes 1, 2, and 3 (EXPE = 1) The input/output direction specified by P3DDR is ignored, and pins automatically function as data I/O pins. Modes 2 and 3 (EXPE = 0) The corresponding port 3 pins are output ports when P3DDR bits are set to 1, and input ports when cleared to 0.
6	P36DDR	0	W	
5	P35DDR	0	W	
4	P34DDR	0	W	
3	P33DDR	0	W	
2	P32DDR	0	W	
1	P31DDR	0	W	
0	P30DDR	0	W	

8.4.2 Port 3 Data Register (P3DR)

P3DR stores output data of port 3.

Bit	Bit Name	Initial Value	R/W	Description
7	P37DR	0	R/W	If a port 3 read is performed while P3DDR bits are set to 1, the P3DR values are read directly, regardless of the actual pin states. If a port 3 read is performed while P3DDR bits are cleared to 0, the pin states are read.
6	P36DR	0	R/W	
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	

8.4.3 Port 3 Pull-Up MOS Control Register (P3PCR)

P3PCR controls the port 3 on-chip input pull-up MOSs on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P37PCR	0	R/W	In modes 2 and 3 (when EXPE = 0), the input pull-up MOS is turned on when a P3PCR bit is set to 1 in the input port state. The input pull-up MOS function cannot be used when the host interface is enabled.
6	P36PCR	0	R/W	
5	P35PCR	0	R/W	
4	P34PCR	0	R/W	
3	P33PCR	0	R/W	
2	P32PCR	0	R/W	
1	P31PCR	0	R/W	
0	P30PCR	0	R/W	

8.4.4 Pin Functions

- P37/D15/HDB7/SERIRQ*, P36/D14/HDB6/LCLK*, P35/D13/HDB5/$\overline{\text{LRESET}}$*, P34/D12/HDB4/$\overline{\text{LFRAME}}$*, P33/D11/HDB3/LAD3*, P32/D10/HDB2/LAD2*, P31/D9/HDB1/LAD1*, P30/D8/HDB0/LAD0*

  The pin function is switched as shown below according to the combination of the HI12E bit in SYSCR2, the LPC3E to LPC1E bits in HICR0 of host interface (LPC), the P3nDDR bit, and operating mode.

Note: * Not supported by the H8S/2148B and H8S/2145B (5-V version).

Operating Mode	Mode 1, 2, 3 (EXPE = 1)	Mode 2, 3 (EXPE = 0)			
LPCmE	All 0	All 0			Not all 0
HI12E	0	0		1	0
P3nDDR	—	0	1	—	0
Pin Function	D15 to D8 input/output pins	P37 to P30 input pins	P37 to P30 output pins	HDB7 to HDB0 input/output pins	LPC input/output pins

Notes: The combination of bits not described in the above table must not be used.
m = 3 to 1: LPC input/output pins (SERIRQ, LCLK, $\overline{\text{LRESET}}$, $\overline{\text{LFRAME}}$, LAD3 to LAD0) when at least one of LPC3E to LPC1E is set to 1.
n = 7 to 0

8.4.5 Port 3 Input Pull-Up MOS

Port 3 has an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be specified as on or off on a bit-by-bit basis.

Table 8.4 summarizes the input pull-up MOS states.

Table 8.4 Input Pull-Up MOS States (Port 3)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
1, 2, 3 (EXPE = 1)	Off	Off	Off	Off
2, 3 (EXPE = 0)			On/Off	On/Off

Legend:
Off: Input pull-up MOS is always off.
On/Off: On when the pin is in the input state, P3DDR = 0, and P3PCR = 1; otherwise off.

8.5 Port 4

Port 4 is an 8-bit I/O port. Port 4 pins also function as PWMX output pins, TMR_0 and TMR_1 I/O pins, timer connection I/O pins, SCI_2 I/O pins, IrDA interface I/O pins, XBS output pins, and the IIC_1 I/O pin. The output type of P42 and SCK2 is NMOS push-pull output. The output type of SDA1 is NMOS open drain output. Port 4 pin functions are the same in all operating modes. Port 4 has the following registers.

- Port 4 data direction register (P4DDR)
- Port 4 data register (P4DR)

8.5.1 Port 4 Data Direction Register (P4DDR)

P4DDR specifies input or output for the pins of port 4 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P47DDR	0	W	When a bit in P4DDR is set to 1, the corresponding pin functions as an output port, and when cleared to 0, as an input port. As 14-bit PWM and SCI_2 are initialized in software standby mode, the pin states are determined by the TMR_0, TMR_1, XBS, IIC_1, P4DDR, and P4DR specifications.
6	P46DDR	0	W	
5	P45DDR	0	W	
4	P44DDR	0	W	
3	P43DDR	0	W	
2	P42DDR	0	W	
1	P41DDR	0	W	
0	P40DDR	0	W	

8.5.2 Port 4 Data Register (P4DR)

P4DR stores output data for port 4.

Bit	Bit Name	Initial Value	R/W	Description
7	P47DR	0	R/W	If a port 4 read is performed while P4DDR bits are set to 1, the P4DR values are read directly, regardless of the actual pin states. If a port 4 read is performed while P4DDR bits are cleared to 0, the pin states are read.
6	P46DR	0	R/W	
5	P45DR	0	R/W	
4	P44DR	0	R/W	
3	P43DR	0	R/W	
2	P42DR	0	R/W	
1	P41DR	0	R/W	
0	P40DR	0	R/W	

8.5.3 Pin Functions

- P47/PWX1

  The pin function is switched as shown below according to the combination of the OEB bit in DACR of the 14-bit PWM and the P47DDR bit.

OEB	0		1
P47DDR	0	1	—
Pin Function	P47 input pin	P47 output pin	PWX1 output pin

- P46/PWX0

  The pin function is switched as shown below according to the combination of the OEA bit in DACR of the 14-bit PWM and the P46DDR bit.

OEA	0		1
P46DDR	0	1	—
Pin Function	P46 input pin	P46 output pin	PWX0 output pin

- P45/TMRI1/HIRQ12/CSYNCI

  The pin function is switched as shown below according to the combination of the HI12E bit in SYSCR2 and the P45DDR bit.

P45DDR	0	1	
HI12E	0	0	1
Pin Function	P45 input pin	P45 output pin	HIRQ12 output pin
	TMRI1 input pin, CSYNCI input pin*		

Note: * When bits CCLR1 and CCLR0 in TCR1 of TMR_1 are set to 1, this pin is used as the TMRI1 input pin. It can also be used as the CSYNCI input pin.

- P44/TMO1/HIRQ1/HSYNCO

  The pin function is switched as shown below according to the combination of the HI12E bit in SYSCR2, the OS3 to OS0 bits in TCSR of TMR_1, the HOE bit in TCONRO of the timer connection function, and the P44DDR bit.

HOE	0				1
OS3 to OS0	All 0			Not all 0	—
P44DDR	0	1		—	—
HI12E	—	0	1	—	—
Pin Function	P44 input pin	P44 output pin	HIRQ1 output pin	TMO1 output pin	HSYNCO output pin

- P43/TMCI1/HIRQ11/HSYNCI

  The pin function is switched as shown below according to the combination of the HI12E bit in SYSCR2 and the P43DDR bit.

P43DDR	0	1	
HI12E	—	0	1
Pin Function	P43 input pin	P43 output pin	HIRQ11 output pin
	TMCI1 input pin, HSYNCI input pin*		

Note: * When the external clock is selected by bits CKS2 to CKS0 in TCR1 of TMR_1, this pin is used as the TMCI1 input pin. It can also be used as the HSYNCI input pin.

- P42/TMRI0/SCK2/SDA1

  The pin function is switched as shown below according to the combination of the ICE bit in ICCR of IIC1, the CKE1 and CKE0 bits in SCR of SCI_2, the C/$\overline{A}$ bit in SMR of SCI_2, and the P42DDR bit.

ICE	0					1
CKE1	0				1	0
C/$\overline{A}$	0			1	—	0
CKE0	0		1	—	—	0
P42DDR	0	1	—	—	—	—
Pin Function	P42 input pin	P42 output pin	SCK2 output pin	SCK2 output pin	SCK2 input pin	SDA1 I/O pin
	TMRI0 input pin*					

Note: * When this pin is used as the SDA1 I/O pin, bits CKE1 and CKE0 in SCR of SCI_2 and bit C/$\overline{A}$ in SMR of SCI_2 must all be cleared to 0. SDA1 is an NMOS-only output, and has direct bus drive capability.

When bits CCLR1 and CCLR0 in TCR0 of TMR_0 are set to 1, this pin is used as the TMRI0 input pin.

When the P42 output pin and SCK2 output pin are set, the output type is NMOS push-pull output.

- P41/TMO0/RxD2/IrRxD

  The pin function is switched as shown below according to the combination of the OS3 to OS0 bits in TCSR of TMR0, the RE bit in SCR of SCI_2 and the P41DDR bit.

OS3 to OS0	All 0			Not all 0
RE	0		1	0
P41DDR	0	1	—	—
Pin Function	P41 input pin	P41 output pin	RxD2/IrRxD input pin	TMO0 output pin

Note: When this pin is used as the TMO0 output pin, bit RE in SCR of SCI_2 must be cleared to 0.

- P40/TMCI0/TxD2/IrTxD

  The pin function is switched as shown below according to the combination of the TE bit in SCR of SCI_2 and the P40DDR bit.

TE	0		1
P40DDR	0	1	—
Pin Function	P40 input pin	P40 output pin	TxD2/IrTxD output pin
	TMCI0 input pin*		

Note: * When an external clock is selected with bits CKS2 to CKS0 in TCR0 of TMR_0, this pin is used as the TMCI0 input pin.

8.6 Port 5

Port 5 is a 3-bit I/O port. Port 5 pins also function as SCI_0 I/O pins, and the IIC_0 I/O pin. P52 and SCK0 are NMOS push-pull outputs, and SCL0 is an NMOS open-drain output. Port 5 has the following registers.

- Port 5 data direction register (P5DDR)
- Port 5 data register (P5DR)

8.6.1 Port 5 Data Direction Register (P5DDR)

P5DDR specifies input or output for the pins of port 5 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7 to 3	—	All 1	—	Reserved The initial value must not be changed.
2	P52DDR	0	W	The corresponding port 5 pins are output ports when P5DDR bits are set to 1, and input ports when cleared to 0. As SCI_0 is initialized in software standby mode, the pin states are determined by the IIC_0 ICCR, P5DDR, and P5DR specifications.
1	P51DDR	0	W	
0	P50DDR	0	W	

8.6.2 Port 5 Data Register (P5DR)

P5DR stores output data for port 5 pins.

Bit	Bit Name	Initial Value	R/W	Description
7 to 3	—	All 1	—	Reserved The initial value must not be changed.
2	P52DR	0	R/W	If a port 5 read is performed while P5DDR bits are set to 1, the P5DR values are read directly, regardless of the actual pin states. If a port 5 read is performed while P5DDR bits are cleared to 0, the pin states are read.
1	P51DR	0	R/W	
0	P50DR	0	R/W	

8.6.3 Pin Functions

- P52/SCK0/SCL0

  The pin function is switched as shown below according to the combination of the CKE1 and CKE0 bits in SCR of SCI_0, the C/$\overline{A}$ bit in SMR of SCI_0, the ICE bit in ICCR of IIC_0, and the P52DDR bit.

ICE	0					1
CKE1	0				1	0
C/$\overline{A}$	0			1	—	0
CKE0	0		1	—	—	0
P52DDR	0	1	—	—	—	—
Pin Function	P52 input pin	P52 output pin	SCK0 output pin	SCK0 output pin	SCK0 input pin	SCL0 I/O pin

Note: When this pin is used as the SCL0 I/O pin, bits CKE1 and CKE0 in SCR of SCI0 and bit C/$\overline{A}$ in SMR of SCI0 must all be cleared to 0.

SCL0 is an NMOS open-drain output, and has direct bus drive capability.

When set as the P52 output pin or SCK0 output pin, this pin is an NMOS push-pull output.

- P51/RxD0

  The pin function is switched as shown below according to the combination of the RE bit in SCR of SCI_0 and the P51DDR bit.

RE	0		1
P51DDR	0	1	—
Pin Function	P51 input pin	P51 output pin	RxD0 input pin

- P50/TxD0

  The pin function is switched as shown below according to the combination of the TE bit in SCR of SCI_0 and the P50DDR bit.

TE	0		1
P50DDR	0	1	—
Pin Function	P50 input pin	P50 output pin	TxD0 output pin

8.7 Port 6

Port 6 is an 8-bit I/O port. Port 6 pins also function as the FRT I/O pins, TMR_X I/O pins, the TMR_Y input pin, timer connection I/O pins, key-sense interrupt input pins, expansion A/D converter input pins, and external interrupt input pins. The port 6 input level can be switched in four stages. Port 6 pin functions are the same in all operating modes. For details on the system control register 2 (SYSCR2), refer to section 18, Host Interface X-Bus Interface (XBS). Port 6 has the following registers.

- Port 6 data direction register (P6DDR)
- Port 6 data register (P6DR)
- Port 6 pull-up MOS control register (KMPCR)
- System control register 2 (SYSCR2)

8.7.1 Port 6 Data Direction Register (P6DDR)

P6DDR specifies input or output for the pins of port 6 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P67DDR	0	W	The corresponding port 6 pins are output ports when P6DDR bits are set to 1, and input ports when cleared to 0.
6	P66DDR	0	W	
5	P65DDR	0	W	
4	P64DDR	0	W	
3	P63DDR	0	W	
2	P62DDR	0	W	
1	P61DDR	0	W	
0	P60DDR	0	W	

8.7.2 Port 6 Data Register (P6DR)

P6DR stores output data for port 6.

Bit	Bit Name	Initial Value	R/W	Description
7	P67DR	0	R/W	If a port 6 read is performed while P6DDR bits are set to 1, the P6DR values are read directly, regardless of the actual pin states. If a port 6 read is performed while P6DDR bits are cleared to 0, the pin states are read.
6	P66DR	0	R/W	
5	P65DR	0	R/W	
4	P64DR	0	R/W	
3	P63DR	0	R/W	
2	P62DR	0	R/W	
1	P61DR	0	R/W	
0	P60DR	0	R/W	

8.7.3 Port 6 Pull-Up MOS Control Register (KMPCR)

KMPCR controls the port 6 on-chip input pull-up MOSs on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	KM7PCR	0	R/W	The input pull-up MOS is turned on when a KMPCR bit is set to 1 while the corresponding P6DDR bit is cleared to 0 (input port setting).
6	KM6PCR	0	R/W	
5	KM5PCR	0	R/W	
4	KM4PCR	0	R/W	
3	KM3PCR	0	R/W	
2	KM2PCR	0	R/W	
1	KM1PCR	0	R/W	
0	KM0PCR	0	R/W	

8.7.4 Pin Functions

- P67/TMOX/CIN7/$\overline{\text{KIN7}}$/$\overline{\text{IRQ7}}$

  The pin function is switched as shown below according to the combination of the OS3 to OS0 bits in TCSR of TMR_X and the P67DDR bit.

OS3 to OS0	All 0		Not all 0
P67DDR	0	1	—
Pin Function	P67 input pin	P67 output pin	TMOX output pin
	$\overline{\text{IRQ7}}$ input pin, $\overline{\text{KIN7}}$ input pin, CIN7 input pin*		

Note: * This pin is used as the $\overline{\text{IRQ7}}$ input pin when bit IRQ7E is set to 1 in IER. It can always be used as the $\overline{\text{KIN7}}$ or CIN7 input pin.

- P66/FTOB/CIN6/$\overline{\text{KIN6}}$/$\overline{\text{IRQ6}}$

  The pin function is switched as shown below according to the combination of the OEB bit in TOCR of the FRT and the P66DDR bit.

OEB	0	1	
P66DDR	0	1	—
Pin Function	P66 input pin	P66 output pin	FTOB output pin
	$\overline{\text{IRQ6}}$ input pin, $\overline{\text{KIN6}}$ input pin, CIN6 input pin*		

Note: * This pin is used as the $\overline{\text{IRQ6}}$ input pin when bit IRQ6E is set to 1 in IER while the KMIMR6 bit in KMIMR is 0. It can always be used as the $\overline{\text{KIN6}}$ or CIN6 input pin.

- P65/FTID/CIN5/$\overline{\text{KIN5}}$

P65DDR	0	1
Pin Function	P65 input pin	P65 output pin
	FTID input pin, $\overline{\text{KIN5}}$ input pin, CIN5 input pin*	

Note: * This pin can always be used as the FTID, $\overline{\text{KIN5}}$, or CIN5 input pin.

- P64/FTIC/CIN4/$\overline{\text{KIN4}}$/CLAMPO

  The pin function is switched as shown below according to the combination of the CLOE bit in TCONRO of the timer connection function and the P64DDR bit.

CLOE	0		1
P64DDR	0	1	—
Pin Function	P64 input pin	P64 output pin	CLAMPO output pin
	FTIC input pin, $\overline{\text{KIN4}}$ input pin, CIN4 input pin*		

Note: * This pin can always be used as the FTIC, $\overline{\text{KIN4}}$, or CIN4 input pin.

- P63/FTIB/CIN3/$\overline{\text{KIN3}}$/VFBACKI

P63DDR	0	1
Pin Function	P63 input pin	P63 output pin
	FTIB input pin, VFBACKI input pin, $\overline{\text{KIN3}}$ input pin, CIN3 input pin*	

Note: * This pin can always be used as the FTIB, $\overline{\text{KIN3}}$, CIN3, or VFBACKI input pin.

- P62/FTIA/CIN2/$\overline{\text{KIN2}}$/VSYNCI/TMIY

P62DDR	0	1
Pin Function	P62 input pin	P62 output pin
	FTIA input pin, VSYNCI input pin, TMIY input pin, $\overline{\text{KIN2}}$ input pin, CIN2 input pin*	

Note: * This pin can always be used as the FTIA, TMIY, $\overline{\text{KIN2}}$, CIN2, or VSYNCI input pin.

- P61/FTOA/CIN1/$\overline{\text{KIN1}}$/VSYNCO

  The pin function is switched as shown below according to the combination of the OEA bit in TOCR of the FRT, the VOE bit in TCONRO of the timer connection function, and the P61DDR bit.

VOE	0			1
OEA	0		1	—
P61DDR	0	1	—	—
Pin Function	P61 input pin	P61 output pin	FTOA output pin	VSYNCO output pin
	$\overline{\text{KIN1}}$ input pin, CIN1 input pin*			

Note: * When this pin is used as the VSYNCO pin, bit OEA in TOCR of the FRT must be cleared to 0. This pin can always be used as the $\overline{\text{KIN1}}$ or CIN1 input pin.

- P60/FTCI/CIN0/$\overline{\text{KIN0}}$/HFBACKI/TMIX

P60DDR	0	1
Pin Function	P60 input pin	P60 output pin
	FTCI input pin, HFBACKI input pin, TMIX input pin, $\overline{\text{KIN0}}$ input pin, CIN0 input pin*	

Note: * This pin is used as the FTCI input pin when an external clock is selected with bits CKS1 and CKS0 in TCR of the FRT. It can always be used as the TMIX, $\overline{\text{KIN0}}$, CIN0, or HFBACKI input pin.

8.7.5 Port 6 Input Pull-Up MOS

Port 6 has an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be specified as on or off on a bit-by-bit basis.

The input pull-up MOS current specification can be changed by means of the P6PUE bit. When a pin is designated as an on-chip peripheral module output pin, the input pull-up MOS is always off.

Table 8.5 summarizes the input pull-up MOS states.

Table 8.5 Input Pull-Up MOS States (Port 6)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
1 to 3	Off	Off	On/Off	On/Off

Legend:
Off: Input pull-up MOS is always off.
On/Off: On when the pin is in the input state, P6DDR = 0, and KMPCR = 1; otherwise off.

8.8 Port 7

Port 7 is an 8-bit input only port. Port 7 pins also function as the A/D converter analog input pins and D/A converter analog output pins. Port 7 functions are the same in all operating modes. Port 7 has the following register.

- Port 7 input data register (P7PIN)

8.8.1 Port 7 Input Data Register (P7PIN)

P7PIN reflects the pin states of port 7.

Bit	Bit Name	Initial Value	R/W	Description
7	P77PIN	Undefined*	R	When a P7PIN read is performed, the pin states are always read. P7PIN has the same address as PBDDR; if a write is performed, data will be written into PBDDR and the port B setting will be changed.
6	P76PIN	Undefined*	R	
5	P75PIN	Undefined*	R	
4	P74PIN	Undefined*	R	
3	P73PIN	Undefined*	R	
2	P72PIN	Undefined*	R	
1	P71PIN	Undefined*	R	
0	P70PIN	Undefined*	R	

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

8.8.2 Pin Functions

- P77/AN7/DA1

  The pin function is switched as shown below according to the combination of the DAE bit in DACR of the D/A converter and the DAOE1 bit.

DAOE1	0		1
DAE	0	1	—
Pin Function	P77 input pin	DA1 input pin	DA1 output pin
	AN7 input pin*		

Note: * This pin can always be used as the AN7 input pin.

- P76/AN6/DA0

  The pin function is switched as shown below according to the combination of the DAE bit in DACR of the D/A converter and the DAOE0 bit.

DAOE0	0		1
DAE	0	1	—
Pin Function	P76 input pin	DA0 output pin	DA0 output pin
	AN6 input pin*		

Note: * This pin can always be used as the AN6 input pin.

- P75/AN5, P74/AN4, P73/AN3, P72/AN2, P71/AN1, P70/AN0

Pin Function	P75 to P70 input pins
	AN5 to AN0 input pin*

Note: * This pin can always be used as the AN5 to AN0 input pins.

8.9 Port 8

Port 8 is an 8-bit I/O port. Port 8 pins also function as SCI_1 I/O pins, the IIC_1 I/O pin, XBS I/O pins, LPC I/O pins, and interrupt input pins. The output type of P86 and SCK1 is NMOS push-pull output. The output type of SCL1 is NMOS open drain output and direct bus driving is enabled. Port 8 pin functions are the same in all operating modes except host interface function. Port 8 has the following registers.

- Port 8 data direction register (P8DDR)
- Port 8 data register (P8DR)

8.9.1 Port 8 Data Direction Register (P8DDR)

P8DDR specifies input or output for the pins of port 8 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	—	1	—	Reserved The initial value must not be changed.
6	P86DDR	0	W	P8DDR has the same address as PBPIN, and if read, the port B state will be returned. The corresponding port 8 pins are output ports when P8DDR bits are set to 1, and input ports when cleared to 0.
5	P85DDR	0	W	
4	P84DDR	0	W	
3	P83DDR	0	W	
2	P82DDR	0	W	
1	P81DDR	0	W	
0	P80DDR	0	W	

8.9.2 Port 8 Data Register (P8DR)

P8DR stores output data for the port 8 pins (P86 to P80).

Bit	Bit Name	Initial Value	R/W	Description
7	—	1	—	Reserved The initial value must not be changed.
6	P86DR	0	R/W	If a port 8 read is performed while P8DDR bits are set to 1, the P8DR values are read directly, regardless of the actual pin states. If a port 8 read is performed while P8DDR bits are cleared to 0, the pin states are read.
5	P85DR	0	R/W	
4	P84DR	0	R/W	
3	P83DR	0	R/W	
2	P82DR	0	R/W	
1	P81DR	0	R/W	
0	P80DR	0	R/W	

8.9.3 Pin Functions

- P86/$\overline{\text{IRQ5}}$/ SCK1/SCL1

  The pin function is switched as shown below according to the combination of the CKE1 and CKE0 bits in SCR of SCI_1, the C/$\overline{\text{A}}$ bit in SMR of SCI_1, the ICE bit in ICCR of IIC_1, and the P86DDR bit.

ICE	0					1
CKE1	0				1	0
C/$\overline{\text{A}}$	0			1	—	0
CKE0	0		1	—	—	0
P86DDR	0	1	—	—	—	—
Pin Function	P86 input pin	P86 output pin	SCK1 output pin	SCK1 output pin	SCK1 input pin	SCL1 I/O pin
	$\overline{\text{IRQ5}}$ input pin*					

Note: * When the IRQ5E bit in IER is set to 1, this pin is used as the $\overline{\text{IRQ5}}$ input pin. When this pin is used as the SCL1 I/O pin, bits CKE1 and CKE0 in SCR of SCI_1 and bit C/$\overline{\text{A}}$ in SMR of SCI_1 must all be cleared to 0. When the P86 output pin and SCK1 output pin are set, the output type is NMOS push-pull output. SCL1 is an NMOS-only output, and has direct bus drive capability.

- P85/$\overline{\text{IRQ4}}$/RxD1

  The pin function is switched as shown below according to the combination of the RE bit in SCR of SCI_1 and the P85DDR bit.

RE	0		1
P85DDR	0	1	—
Pin Function	P85 input pin	P85 output pin	RxD1 input pin
	$\overline{\text{IRQ4}}$ input pin*		

Note: * When the IRQ4E bit in IER is set to 1, this pin is used as the $\overline{\text{IRQ4}}$ input pin.

- P84/$\overline{\text{IRQ3}}$/TxD1

  The pin function is switched as shown below according to the combination of the TE bit in SCR of SCI_1 and the P84DDR bit.

TE	0		1
P84DDR	0	1	—
Pin Function	P84 input pin	P84 output pin	TxD1 output pin
	$\overline{\text{IRQ3}}$ input pin*		

Note: * When the IRQ3E bit in IER is set to 1, this pin is used as the $\overline{\text{IRQ3}}$ input pin.

- P83/$\overline{\text{LPCPD}}$*2

  The pin function is switched as shown below according to the P83DDR bit.

P83DDR	0	1
Pin Function	P83 input pin	P83 output pin
	$\overline{\text{LPCPD}}$ input pin*1*2	

Notes: 1. When at least one of bits LPC3E to LPC1E is set to 1 in HICR0, this pin is used as the $\overline{\text{LPCPD}}$ input pin. The $\overline{\text{LPCPD}}$ input pin can only be used in mode 2 or 3 (EXPE = 0).
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

- P82/HIFSD/$\overline{\text{CLKRUN}}$*2

  The pin function is switched as shown below according to the combination of the HI12E and SDE bits in SYSCR2, the LPC3E to LPC1E bits in HICR0, and the P82DDR bit.

LPC3E to LPC1E	All 0					Not all 0
HI12E	0		1			0*1
SDE	—		0		1	—
P82DDR	0	1	0	1	—	0*1
Pin Function	P82 input pin	P82 output pin	P82 input pin	P82 output pin	HIFSD input pin	$\overline{\text{CLKRUN}}$ I/O pin*2

Notes: The HIFSD input pin and $\overline{\text{CLKRUN}}$ I/O pin can only be used in mode 2 or 3 (EXPE = 0).

1. When at least one of bits LPC3E to LPC1E is set to 1, bits HI12E and P82DDR should be cleared to 0.
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

- P81/$\overline{\text{CS2}}$/GA20

  The pin function is switched as shown below according to the combination of the HI12E bit in SYSCR2, the CS2E bit in SYSCR, the FGA20E bit in HICR, the FGA20E bit in HICR0, and the P81DDR bit.

FGA20E (LPC)	0							1
HI12E	0		1					0*1
FGA20E (XBS)	—		0			1		—
CS2E	—		0		1	—		—
P81DDR	0	1	0	1	—	0	1	0*1
Pin Function	P81 input pin	P81 output pin	P81 input pin	P81 output pin	$\overline{\text{CS2}}$ input pin*2	P81 input pin	GA20 output pin	GA20 output pin
	GA20 input pin*2							

Notes: 1. When bit FGA20E is set to 1 in HICR0, bits HI12E and P81DDR should be cleared to 0.
2. The GA20 output pin and $\overline{\text{CS2}}$ input pin can only be used in mode 2 or 3 (EXPE = 0).

- P80/HA0/$\overline{\text{PME}}$*3

  The pin function is switched as shown below according to the combination of the HI12E bit in SYSCR2, the PMEE bit in HICR0, and the P80DDR bit.

PMEE	0			1
HI12E	0		1	0*1
P80DDR	0	1	—	0*1
Pin Function	P80 input pin	P80 output pin	HA0 input pin*2	$\overline{\text{PME}}$ output pin
	$\overline{\text{PME}}$ input pin*2*3			

Notes: 1. When bit PMEE is set to 1 in HICR0, bits HI12E and P80DDR should be cleared to 0.
2. The HA0 input pin can only be used in mode 2 or 3 (EXPE = 0).
3. Not supported by the H8S/2148B and H8S/2145B (5-V version).

8.10 Port 9

Port 9 is an 8-bit I/O port. Port 9 pins also function as external interrupt input pins, the A/D converter input pin, host interface (XBS) input pins, the IIC_0 I/O pin, the subclock input pin, bus control signal I/O pins, and the system clock (ϕ) output pin. P97 is an NMOS push-pull output. SDA0 is an NMOS open-drain output, and has direct bus drive capability. Port 9 has the following registers.

- Port 9 data direction register (P9DDR)
- Port 9 data register (P9DR)

8.10.1 Port 9 Data Direction Register (P9DDR)

P9DDR specifies input or output for the pins of port 9 on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	P97DDR	0	W	P9DDR is initialized to H'40 (mode 1) or H'00 (modes 2 and 3). Modes 1, 2, and 3 (EXPE = 1): Pin P97 functions as a bus control input ($\overline{\text{WAIT}}$), the IIC_0 I/O pin (SDA0), or an I/O port, according to the wait mode setting. When P97 functions as an I/O port, it becomes an output port when P97DDR is set to 1, and an input port when P97DDR is cleared to 0. Pin P96 functions as the ϕ output pin when P96DDR is set to 1, and as the subclock input (EXCL) or an input port when P96DDR is cleared to 0. Pins P95 to P93 automatically become bus control outputs ($\overline{\text{AS}}$/$\overline{\text{IOS}}$, $\overline{\text{HWR}}$, $\overline{\text{RD}}$), regardless of the input/output direction indicated by P95DDR to P93DDR. Pins P92 and P91 become output ports when P92DDR and P91DDR are set to 1, and input ports when P92DDR and P91DDR are cleared to 0. When the ABW bit in WSCR is cleared to 0, pin P90 becomes a bus control output ($\overline{\text{LWR}}$), regardless of the input/output direction indicated by P90DDR. When the ABW bit is 1, pin P90 becomes an output port if P90DDR is set to 1, and an input port if P90DDR is cleared to 0. Modes 2 and 3 (EXPE = 0): When the corresponding P9DDR bits are set to 1, pin P96 functions as the ϕ output pin and pins P97 and P95 to P90 become output ports. When P9DDR bits are cleared to 0, the corresponding pins become input ports.
6	P96DDR	1/0*	W	
5	P95DDR	0	W	
4	P94DDR	0	W	
3	P93DDR	0	W	
2	P92DDR	0	W	
1	P91DDR	0	W	
0	P90DDR	0	W	

Note: * The initial value of P96DDR is 1 (mode 1) or 0 (modes 2 and 3).

8.10.2 Port 9 Data Register (P9DR)

P9DR stores output data for the port 9 pins.

Bit	Bit Name	Initial Value	R/W	Description
7	P97DR	0	R/W	With the exception of P96, if a port 9 read is performed while P9DDR bits are set to 1, the P9DR values are read directly, regardless of the actual pin states. If a port 9 read is performed while P9DDR bits are cleared to 0, the pin states are read. For P96, the pin state is always read.
6	P96DR	Undefined*	R	
5	P95DR	0	R/W	
4	P94DR	0	R/W	
3	P93DR	0	R/W	
2	P92DR	0	R/W	
1	P91DR	0	R/W	
0	P90DR	0	R/W	

Note: * The initial value of bit 6 is determined according to the P96 pin state.

8.10.3 Pin Functions

- P97/$\overline{\text{WAIT}}$/SDA0

  The pin function is switched as shown below according to the combination of operating mode, the WMS1 bit in WSCR, the ICE bit in ICCR of IIC_0, and the P97DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)				Modes 2, 3 (EXPE = 0)		
WMS1	0			1	—		
ICE	0		1	—	0		1
P97DDR	0	1	—	—	0	1	—
Pin Function	P97 input pin	P97 output pin	SDA0 I/O pin	$\overline{\text{WAIT}}$ input pin	P97 input pin	P97 output pin	SDA0 I/O pin

Note: When this pin is set as the P97 output pin, it is an NMOS push-pull output. SDA0 is an NMOS open-drain output, and has direct bus drive capability.

- P96/φ/EXCL

  The pin function is switched as shown below according to the combination of the EXCLE bit in LPWRCR and the P96DDR bit.

P96DDR	0		1
EXCLE	0	1	0
Pin Function	P96 input pin	EXCL input pin	φ output pin

Note: When this pin is used as the EXCL input pin, P96DDR should be cleared to 0.

- P95/$\overline{\text{AS}}$/$\overline{\text{IOS}}$/$\overline{\text{CS1}}$

  The pin function is switched as shown below according to the combination of operating mode, the IOSE bit in SYSCR, the HI12E bit in SYSCR2, and the P95DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)		Modes 2, 3 (EXPE = 0)		
HI12E	—		0		1
P95DDR	—		0	1	—
IOSE	0	1	—	—	—
Pin Function	$\overline{\text{AS}}$ output pin	$\overline{\text{IOS}}$ output pin	P95 input pin	P95 output pin	$\overline{\text{CS1}}$ input pin

- P94/$\overline{\text{HWR}}$/$\overline{\text{IOW}}$

  The pin function is switched as shown below according to the combination of operating mode, the HI12E bit in SYSCR2, and the P94DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)	Modes 2, 3 (EXPE = 0)		
HI12E	—	0		1
P94DDR	—	0	1	—
Pin Function	$\overline{\text{HWR}}$ output pin	P94 input pin	P94 output pin	$\overline{\text{IOW}}$ input pin

- P93/$\overline{\text{RD}}$/$\overline{\text{IOR}}$

  The pin function is switched as shown below according to the combination of operating mode, the HI12E bit in SYSCR2, and the P93DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)	Modes 2, 3 (EXPE = 0)		
HI12E	—	0		1
P93DDR	—	0	1	—
Pin Function	$\overline{\text{RD}}$ output pin	P93 input pin	P93 output pin	$\overline{\text{IOR}}$ input pin

- P92/$\overline{\text{IRQ0}}$

P92DDR	0	1
Pin Function	P92 input pin	P92 output pin
	$\overline{\text{IRQ0}}$ input pin*	

Note: * When bit IRQ0E in IER is set to 1, this pin is used as the $\overline{\text{IRQ0}}$ input pin.

- P91/$\overline{\text{IRQ1}}$

P91DDR	0	1
Pin Function	P91 input pin	P91 output pin
	$\overline{\text{IRQ1}}$ input pin*	

Note: * When bit IRQ1E in IER is set to 1, this pin is used as the $\overline{\text{IRQ1}}$ input pin.

- P90/$\overline{\text{LWR}}$/$\overline{\text{IRQ2}}$/$\overline{\text{ADTRG}}$/$\overline{\text{ECS2}}$

  The pin function is switched as shown below according to the combination of operating mode, the ABW bit in WSCR, the HI12E and CS2E bits in SYSCR2, the FGA20E bit in HICR, and the P90DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)		
ABW	0	1		—		
HI12E	—			Any one 0		1
FGA20E	—					1
CS2E	—					1
P90DDR	—	0	1	0	1	—
Pin Function	$\overline{\text{LWR}}$ output pin	P90 input pin	P90 output pin	P90 input pin	P90 output pin	$\overline{\text{ECS2}}$ input pin
		$\overline{\text{IRQ2}}$ input pin, $\overline{\text{ADTRG}}$ input pin*				

Note: * When the IRQ2E bit in IER is set to 1 in mode 1, 2, or 3 (EXPE = 1) with the ABW bit in WSCR set to 1, or in mode 2 and 3 (EXPE = 0), this pin is used as the $\overline{\text{IRQ2}}$ input pin. When TRGS1 and TRGS0 in ADCR of the A/D converter are both set to 1, this pin is used as the $\overline{\text{ADTRG}}$ input pin.

8.11 Port A

Port A is an 8-bit I/O port. Port A pins also function as keyboard buffer controller I/O pins, key-sense interrupt input pins, expansion A/D converter input pins, and address output pins. Port A pin functions change according to the operating mode. Port A input/output operates by VccB power independent from the Vcc power. Up to 5 V can be applied to port A pins if VccB power is 5 V. Port A has the following registers. PADDR and PAPIN have the same address.

- Port A data direction register (PADDR)
- Port A output data register (PAODR)
- Port A input data register (PAPIN)

8.11.1 Port A Data Direction Register (PADDR)

PADDR specifies input or output for the pins of port A on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PA7DDR	0	W	In mode 1, 2 (EXPE = 0), or 3: The corresponding port A pins are output ports when PADDR bits are set to 1, and input ports when cleared to 0. In mode 2 (EXPE = 1): The corresponding port A pins are address output when PADDR bits are set to 1, and input ports when cleared to 0. The port A pins changes from the address I/O ports to output ports by setting the IOSE bit to 1. PA7 to PA2 pins are used as the keyboard buffer controller I/O pins by setting the KBIOE bit to 1 regardless of the operating mode, while the I/O direction according to PA7DDR to PA2DDR is ignored. PADDR has the same address as PAPIN, if read, port A status is returned.
6	PA6DDR	0	W	
5	PA5DDR	0	W	
4	PA4DDR	0	W	
3	PA3DDR	0	W	
2	PA2DDR	0	W	
1	PA1DDR	0	W	
0	PA0DDR	0	W	

8.11.2 Port A Output Data Register (PAODR)

PAODR stores output data for port A.

Bit	Bit Name	Initial Value	R/W	Description
7	PA7ODR	0	R/W	PAODR can always be read or written to, regardless of the contents of PADDR.
6	PA6ODR	0	R/W	
5	PA5ODR	0	R/W	
4	PA4ODR	0	R/W	
3	PA3ODR	0	R/W	
2	PA2ODR	0	R/W	
1	PA1ODR	0	R/W	
0	PA0ODR	0	R/W	

8.11.3 Port A Input Data Register (PAPIN)

PAPIN indicates the port A state.

Bit	Bit Name	Initial Value	R/W	Description
7	PA7PIN	Undefined*	R	Reading PAPIN always returns the pin states. PAPIN has the same address as PADDR. If a write is performed, the port A settings will change.
6	PA6PIN	Undefined*	R	
5	PA5PIN	Undefined*	R	
4	PA4PIN	Undefined*	R	
3	PA3PIN	Undefined*	R	
2	PA2PIN	Undefined*	R	
1	PA1PIN	Undefined*	R	
0	PA0PIN	Undefined*	R	

Note: * The initial value is determined according to the PA7 to PA0 pin states.

8.11.4 Pin Functions

- PA7/A23/$\overline{\text{KIN15}}$/CIN15/PS2CD

  The pin function is switched as shown below according to the combination of operating mode, the KBIOE bit in KBCRH_2 of the keyboard buffer controller, the IOSE bit in SYSCR, and the PA7DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)			
KBIOE	0		1	0			1
PA7DDR	0	1	—	0	1		—
IOSE	—	—	—	—	0	1	—
Pin Function	PA7 input pin	PA7 output pin	PS2CD output pin	PA7 input pin	A23 output pin	PA7 output pin	PS2CD output pin
	$\overline{\text{KIN15}}$ input pin, CIN15 input pin, PS2CD input pin*						

Note: * When the KBIOE bit is set to 1 or the IICS bit in STCR is set to 1, this pin is an NMOS open-drain output, and has direct bus drive capability. This pin can always be used as the PS2CD, $\overline{\text{KIN15}}$, or CIN15 input pin.

- PA6/A22/$\overline{\text{KIN14}}$/CIN14/PS2CC

  The pin function is switched as shown below according to the combination of operating mode, the KBIOE bit in KBCRH_2 of the keyboard buffer controller, the IOSE bit in SYSCR, and the PA6DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)			
KBIOE	0		1	0			1
PA6DDR	0	1	—	0	1		—
IOSE	—	—	—	—	0	1	—
Pin Function	PA6 input pin	PA6 output pin	PS2CC output pin	PA6 input pin	A22 output pin	PA6 output pin	PS2CC output pin
	$\overline{\text{KIN14}}$ input pin, CIN14 input pin, PS2CC input pin*						

Note: * When the KBIOE bit is set to 1 or the IICS bit in STCR is set to 1, this pin is an NMOS open-drain output, and has direct bus drive capability. This pin can always be used as the PS2CC, $\overline{\text{KIN14}}$, or CIN14 input pin.

- PA5/A21/$\overline{\text{KIN13}}$/CIN13/PS2BD

  The pin function is switched as shown below according to the combination of operating mode, the KBIOE bit in KBCRH_1 of the keyboard buffer controller, the IOSE bit in SYSCR, and the PA5DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)			
KBIOE	0		1	0			1
PA5DDR	0	1	—	0	1		—
IOSE	—	—	—	—	0	1	—
Pin Function	PA5 input pin	PA5 output pin	PS2BD output pin	PA5 input pin	A21 output pin	PA5 output pin	PS2BD output pin
	$\overline{\text{KIN13}}$ input pin, CIN13 input pin, PS2BD input pin*						

Note: * When the KBIOE bit is set to 1 or the IICS bit in STCR is set to 1, this pin is an NMOS open-drain output, and has direct bus drive capability. This pin can always be used as the PS2BD, $\overline{\text{KIN13}}$, or CIN13 input pin.

- PA4/A20/$\overline{\text{KIN12}}$/CIN12/PS2BC

  The pin function is switched as shown below according to the combination of operating mode, the KBIOE bit in KBCRH_1 of the keyboard buffer controller, the IOSE bit in SYSCR, and the PA4DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)			
KBIOE	0		1	0			1
PA4DDR	0	1	—	0	1		—
IOSE	—	—	—	—	0	1	—
Pin Function	PA4 input pin	PA4 output pin	PS2BC output pin	PA4 input pin	A20 output pin	PA4 output pin	PS2BC output pin
	$\overline{\text{KIN12}}$ input pin, CIN12 input pin, PS2BC input pin*						

Note: * When the KBIOE bit is set to 1 or the IICS bit in STCR is set to 1, this pin is an NMOS open-drain output, and has direct bus drive capability. This pin can always be used as the PS2BC, $\overline{\text{KIN12}}$, or CIN12 input pin.

- PA3/A19/$\overline{\text{KIN11}}$/CIN11/PS2AD

  The pin function is switched as shown below according to the combination of operating mode, the KBIOE bit in KBCRH_0 of the keyboard buffer controller, the IOSE bit in SYSCR, and the PA3DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)			
KBIOE	0		1	0			1
PA3DDR	0	1	—	0	1		—
IOSE	—	—	—	—	0	1	—
Pin Function	PA3 input pin	PA3 output pin	PS2AD output pin	PA3 input pin	A19 output pin	PA3 output pin	PS2AD output pin
	$\overline{\text{KIN11}}$ input pin, CIN11 input pin, PS2AD input pin*						

Note: * When the KBIOE bit is set to 1, this pin is an NMOS open-drain output, and has direct bus drive capability. This pin can always be used as the PS2AD, $\overline{\text{KIN11}}$, or CIN11 input pin.

- PA2/A18/$\overline{\text{KIN10}}$/CIN10/PS2AC

  The pin function is switched as shown below according to the combination of operating mode, the KBIOE bit in KBCRH_0 of the keyboard buffer controller, the IOSE bit in SYSCR, and the PA2DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)			
KBIOE	0		1	0			1
PA2DDR	0	1	—	0	1		—
IOSE	—	—	—	—	0	1	—
Pin Function	PA2 input pin	PA2 output pin	PS2AC output pin	PA2 input pin	A18 output pin	PA2 output pin	PS2AC output pin
	$\overline{\text{KIN10}}$ input pin, CIN10 input pin, PS2AC input pin*						

Note: * When the KBIOE bit is set to 1, this pin is an NMOS open-drain output, and has direct bus drive capability. This pin can always be used as the PS2AC, $\overline{\text{KIN10}}$, or CIN10 input pin.

- PA1/A17/$\overline{\text{KIN9}}$/CIN9

  The pin function is switched as shown below according to the combination of operating mode, the IOSE bit in SYSCR and the PA1DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3		Mode 2 (EXPE = 1)		
PA1DDR	0	1	0	1	
IOSE	—	—	—	0	1
Pin Function	PA1 input pin	PA1 output pin	PA1 input pin	A17 output pin	PA1 output pin
	$\overline{\text{KIN9}}$ input pin, CIN9 input pin*				

Note: * This pin can always be used as the $\overline{\text{KIN9}}$ or CIN9 input pin.

- PA0/A16/ $\overline{\text{KIN8}}$/CIN8

  The pin function is switched as shown below according to the combination of operating mode, the IOSE bit in SYSCR and the PA0DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3		Mode 2 (EXPE = 1)		
PA0DDR	0	1	0	1	
IOSE	—	—	—	0	1
Pin Function	PA0 input pin	PA0 output pin	PA0 input pin	A16 output pin	PA0 output pin
	$\overline{\text{KIN8}}$ input pin, CIN8 input pin*				

Note: * This pin can always be used as the $\overline{\text{KIN8}}$ or CIN8 input pin.

8.11.5 Port A Input Pull-Up MOS

Port A has an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be specified as on or off on a bit-by-bit basis.

The input pull-up MOS for pins PA7 to PA4 is always off when IICS is set to 1. When the keyboard buffer control pin function is selected for pins PA7 to PA2, the input pull-up MOS is always off.

Table 8.6 summarizes the input pull-up MOS states.

Table 8.6 Input Pull-Up MOS States (Port A)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
1 to 3	Off	Off	On/Off	On/Off

Legend:

Off: Input pull-up MOS is always off.

On/Off: On when the pin is in the input state, PADDR = 0, and PAODR = 1; otherwise off.

8.12 Port B

Port B is an 8-bit I/O port. Port B pins also have XBS input/output pins, LPC input/output pins, wakeup event interrupt input pins, and a data bus input/output function. The pin functions depend on the operating mode. Port B has the following registers.

- Port B data direction register (PBDDR)
- Port B output data register (PBODR)
- Port B input data register (PBPIN)

8.12.1 Port B Data Direction Register (PBDDR)

PBDDR specifies input or output for the pins of port B on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PB7DDR	0	W	PBDDR has the same address as P7PIN, and if read, the port 7 pin states will be returned. • Modes 1, 2, and 3 (EXPE = 1) When the ABW bit in WSCR is cleared to 0, port B pins automatically become data I/O pins (D7 to D0), regardless of the input/output direction indicated by PBDDR. When the ABW bit is 1, a port B pin becomes an output port if the corresponding PBDDR bit is set to 1, and an input port if the bit is cleared to 0. • Modes 2 and 3 (EXPE = 0) A port B pin becomes an output port if the corresponding PBDDR bit is set to 1, and an input port if the bit is cleared to 0.
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	

8.12.2 Port B Output Data Register (PBODR)

PBODR stores output data for port B.

Bit	Bit Name	Initial Value	R/W	Description
7	PB7ODR	0	R/W	PBODR can always be read or written to, regardless of the contents of PBDDR.
6	PB6ODR	0	R/W	
5	PB5ODR	0	R/W	
4	PB4ODR	0	R/W	
3	PB3ODR	0	R/W	
2	PB2ODR	0	R/W	
1	PB1ODR	0	R/W	
0	PB0ODR	0	R/W	

8.12.3 Port B Input Data Register (PBPIN)

PBPIN indicates the port B state.

Bit	Bit Name	Initial Value	R/W	Description
7	PB7PIN	Undefined*	R	Reading PBPIN always returns the pin states. PBPIN has the same address as P8DDR. If a write is performed, data will be written to P8DDR and the port 8 settings will change.
6	PB6PIN	Undefined*	R	
5	PB5PIN	Undefined*	R	
4	PB4PIN	Undefined*	R	
3	PB3PIN	Undefined*	R	
2	PB2PIN	Undefined*	R	
1	PB1PIN	Undefined*	R	
0	PB0PIN	Undefined*	R	

Note: * The initial value is determined according to the PB7 to PB0 pin states.

8.12.4 Pin Functions

- PB7/D7/$\overline{\text{WUE7}}$[*2], PB6/D6/$\overline{\text{WUE6}}$[*2], PB5/D5/$\overline{\text{WUE5}}$[*2], PB4/D4/$\overline{\text{WUE4}}$[*2]

  The pin function is switched as shown below according to the combination of the operating mode, the PBnDDR bit, and the ABW bit in WSCR.

Operating Mode	Mode 1 and Modes 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)	
ABW	0	1		—	
PBnDDR	—	0	1	0	1
Pin Function	Dn I/O pin	PBn input pin	PBn output pin	PBn input pin	PBn output pin
		$\overline{\text{WUEn}}$ input pin[*1]			

Notes: 1. Except when used as a data bus pin, this pin can always be used as the $\overline{\text{WUEn}}$ input pin. (n = 7 to 4)
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

- PB3/D3/$\overline{\text{WUE3}}$[*2]/$\overline{\text{CS4}}$

  The pin function is switched as shown below according to the combination of the operating mode, the HI12E and CS4E bits in SYSCR2, the ABW bit in WSCR, and the PB3DDR bit.

Operating Mode	Mode 1 and Modes 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)		
HI12E	—			Either cleared to 0		1
CS4E	—					1
ABW	0	1		—		—
PB3DDR	—	0	1	0	1	—
Pin Function	D3 I/O pin	PB3 input pin	PB3 output pin	PB3 input pin	PB3 output pin	$\overline{\text{CS4}}$ input pin
		$\overline{\text{WUE3}}$ input pin[*1]				

Notes: 1. Except when used as a data bus pin, this pin can always be used as the $\overline{\text{WUE3}}$ input pin. The $\overline{\text{CS4}}$ input pin can only be used in mode 2 or 3 (EXPE = 0).
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

- PB2/D2/$\overline{\text{WUE2}}$[*2]/$\overline{\text{CS3}}$

  The pin function is switched as shown below according to the combination of the operating mode, the HI12E and CS3E bits in SYSCR2, the ABW bit in WSCR, and the PB2DDR bit.

Operating Mode	Mode 1 and Modes 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)		
HI12E	—			Either cleared to 0		1
CS3E	—					1
ABW	0	1		—		—
PB2DDR	—	0	1	0	1	—
Pin Function	D2 I/O pin	PB2 input pin	PB2 output pin	PB2 input pin	PB2 output pin	$\overline{CS3}$ input pin
		$\overline{WUE2}$ input pin*1				

Notes: 1. Except when used as a data bus pin, this pin can always be used as the $\overline{WUE2}$ input pin. The $\overline{CS3}$ input pin can only be used in mode 2 or 3 (EXPE = 0).
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

- PB1/D1/$\overline{WUE1}$/HIRQ4/LSCI*4

  The pin function is switched as shown below according to the combination of the operating mode, the HI12E and CS4E bits in SYSCR2, the LSCIE bits in HICR0 of host interface (LPC), the ABW bit in WSCR, and the PB1DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)			Mode 2, 3 (EXPE = 0)			
LSCIE	0*3			0			1
HI12E	—			Either cleared to 0		1	0*1
CS4E	—					1	—
ABW	0	1		—		—	—
PB1DDR	—	0	1	0	1	—	0*1
Pin Function	D1 I/O pin	PB1 input pin	PB1 output pin	PB1 input pin	PB1 output pin	HIRQ4 output pin	LSCI*4 output pin
				LSCI input pin*2			
		$\overline{WUE1}$ input pin*2*4					

Notes: 1. When bit LSCIE is set to 1 in HICR0, bits HI12E and PB1DDR should be cleared to 0.
2. Except when used as a data bus pin, this pin can always be used as the $\overline{WUE1}$ input pin. The HIRQ4 output pin and LSCI I/O pin can only be used in mode 2 or 3 (EXPE = 0).
3. In mode 1, 2, 3 (EXPE = 1), clear the LSCIE bit to 0.
4. Not supported by the H8S/2148B and H8S/2145B (5-V version).

- PB0/D0/$\overline{\text{WUE0}}$/HIRQ3/$\overline{\text{LSMI}}$*4

  The pin function is switched as shown below according to the combination of the operating mode, the HI12E and CS3E bits in SYSCR2, the LSMIE bits in HICR0 of host interface (LPC), the ABW bit in WSCR, and the PB0DDR bit.

Operating Mode	Modes 1, 2, 3 (EXPE = 1)			Mode 2, 3 (EXPE = 0)			
LSMIE	0*3			0			1
HI12E	—			Either cleared to 0		1	0*1
CS3E	—					1	—
ABW	0	1		—		—	—
PB0DDR	—	0	1	0	1	—	0*1
Pin Function	D0 I/O pin	PB0 input pin	PB0 output pin	PB0 input pin	PB0 output pin	HIRQ3 output pin	$\overline{\text{LSMI}}$*4 output pin
				$\overline{\text{LSMI}}$ input pin*2			
		$\overline{\text{WUE0}}$ input pin*2					

Notes: 1. When bit LSMIE is set to 1 in HICR0, bits HI12E and PB0DDR should be cleared to 0.

2. Except when used as a data bus pin, this pin can always be used as the $\overline{\text{WUE0}}$ input pin. The HIRQ3 output pin and $\overline{\text{LSMI}}$ I/O pin can only be used in mode 2 or 3 (EXPE = 0).
3. In mode 1, 2, 3 (EXPE = 1), clear the LSMIE bit to 0.
4. Not supported by the H8S/2148B and H8S/2145B (5-V version).

8.12.5 Port B Input Pull-Up MOS

Port B has an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be specified as on or off on a bit-by-bit basis.

When a pin is designated as an on-chip peripheral module output pin, the input pull-up MOS is always off.

Table 8.7 summarizes the input pull-up MOS states.

Table 8.7 Input Pull-Up MOS States (Port B)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operations
1, 2, 3 (EXPE = 1) with ABW in WSCR = 0	Off	Off	Off	Off
1, 2, 3 (EXPE = 1) with ABW in WSCR = 1, or 2, 3 (EXPE = 0)			On/Off	On/Off

Legend:
Off: Input pull-up MOS is always off.
On/Off: On when the pin is in the input state, PBDDR = 0, and PBODR = 1; otherwise off.

8.13 Additional Overview for H8S/2160B and H8S/2161B

The H8S/2160B and H8S/2161B has fifteen I/O ports (ports 1 to 6, 8, 9, A to G), and one input-only port (port 7).

Table 8.8 is a summary of the additional port functions. As the functions of ports 1 to 9, A, and B are the same on the H8S/2140B, H8S/2141B, H8S/2148B, and H8S/2145B, table 8.1 provides a summary.

Each extra port includes a data direction register (DDR) that controls input/output, and data registers (ODR) for storing output data.

Ports C to E, and F have an on-chip input pull-up MOS function. On ports C to F, whether the input pull-up MOS is on or off is controlled by the corresponding DDR and ODR.

Ports C to F, and G can drive a single-TTL load and 30-pF-capacitive load. All I/O port pins are capable of driving a Darlington transistor when they are in output.

The output type on port G is NMOS push-pull output. Port G can be 5-V tolerant.

When port G is used as an output pin, connect a pull-up resistor to the pin for raise an output high-level voltage.

Table 8.8 H8S/2160B, H8S/2161B Additional Port Functions

Port	Description	Mode 1	Mode 2, 3		I/O Status
			(EXPE = 1)	(EXPE = 0)	
Port C	8-bit I/O port	PC7 to PC0			On-chip input pull-up MOSs
Port D	8-bit I/O port	PD7 to PD0			On-chip input pull-up MOSs
Port E	8-bit I/O port	PE7 to PE0			On-chip input pull-up MOSs
Port F	8-bit I/O port	PF7 to PF0			On-chip input pull-up MOSs
Port G	8-bit I/O port	PG7 to PG0			

8.14 Ports C, D

Port C and port D are two sets of 8-bit I/O ports. The pin functions are the same in all operating modes.

- Port C data direction register (PCDDR)
- Port C output data register (PCODR)
- Port C input data register (PCPIN)
- Port C Nch-OD control register (PCNOCR)
- Port D data direction register (PDDDR)
- Port D output data register (PDODR)
- Port D input data register (PDPIN)
- Port D Nch-OD control register (PDNOCR)

8.14.1 Port C and Port D Data Direction Registers (PCDDR, PDDDR)

PCDDR and PDDDR select input or output for the pins of port C and port D on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7DDR	0	W	0: Port C pin is an input pin
6	PC6DDR	0	W	1: Port C pin is an output pin
5	PC5DDR	0	W	PCDDR has the same address as PCPIN, and if read, the port C pin states will be returned.
4	PC4DDR	0	W	
3	PC3DDR	0	W	
2	PC2DDR	0	W	
1	PC1DDR	0	W	
0	PC0DDR	0	W	

Bit	Bit Name	Initial Value	R/W	Description
7	PD7DDR	0	W	0: Port D pin is an input pin
6	PD6DDR	0	W	1: Port D pin is an output pin
5	PD5DDR	0	W	PDDDR has the same address as PDPIN, and if read, the port D pin states will be returned.
4	PD4DDR	0	W	
3	PD3DDR	0	W	
2	PD2DDR	0	W	
1	PD1DDR	0	W	
0	PD0DDR	0	W	

8.14.2 Port C and Port D Output Data Registers (PCODR, PDODR)

PCODR and PDODR store output data for the pins on ports C and D.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7ODR	0	R/W	PCODR can always be read or written to, regardless of the contents of PCDDR.
6	PC6ODR	0	R/W	
5	PC5ODR	0	R/W	
4	PC4ODR	0	R/W	
3	PC3ODR	0	R/W	
2	PC2ODR	0	R/W	
1	PC1ODR	0	R/W	
0	PC0ODR	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
7	PD7ODR	0	R/W	PDODR can always be read or written to, regardless of the contents of PDDDR.
6	PD6ODR	0	R/W	
5	PD5ODR	0	R/W	
4	PD4ODR	0	R/W	
3	PD3ODR	0	R/W	
2	PD2ODR	0	R/W	
1	PD1ODR	0	R/W	
0	PD0ODR	0	R/W	

8.14.3 Port C and Port D Input Data Registers (PCPIN, PDPIN)

Reading PCPIN and PDPIN always returns the pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7PIN	Undefined*	R	PCPIN indicates the port C state. PCPIN has the same address as PCDDR. If a write is performed, the port C settings will change.
6	PC6PIN	Undefined*	R	
5	PC5PIN	Undefined*	R	
4	PC4PIN	Undefined*	R	
3	PC3PIN	Undefined*	R	
2	PC2PIN	Undefined*	R	
1	PC1PIN	Undefined*	R	
0	PC0PIN	Undefined*	R	

Note: * The initial value is determined according to the PC7 to PC0 pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PD7PIN	Undefined*	R	PDPIN indicates the port D state. PDPIN has the same address as PDDDR. If a write is performed, the port D settings will change.
6	PD6PIN	Undefined*	R	
5	PD5PIN	Undefined*	R	
4	PD4PIN	Undefined*	R	
3	PD3PIN	Undefined*	R	
2	PD2PIN	Undefined*	R	
1	PD1PIN	Undefined*	R	
0	PD0PIN	Undefined*	R	

Note: * The initial value is determined according to the PD7 to PD0 pin states.

8.14.4 Port C and Port D Nch-OD Control Register (PCNOCR, PDNOCR)

PCNOCR and PDNOCR specify the output driver type for pins on ports C and D which are configured as outputs on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PC7NOCR	0	R/W	0: CMOS (p-channel driver enabled)
6	PC6NOCR	0	R/W	1: N-channel open drain (p-channel driver disabled)
5	PC5NOCR	0	R/W	
4	PC4NOCR	0	R/W	
3	PC3NOCR	0	R/W	
2	PC2NOCR	0	R/W	
1	PC1NOCR	0	R/W	
0	PC0NOCR	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
7	PD7NOCR	0	R/W	0: CMOS (p-channel driver enabled)
6	PD6NOCR	0	R/W	1: N-channel open drain (p-channel driver disabled)
5	PD5NOCR	0	R/W	
4	PD4NOCR	0	R/W	
3	PD3NOCR	0	R/W	
2	PD2NOCR	0	R/W	
1	PD1NOCR	0	R/W	
0	PD0NOCR	0	R/W	

8.14.5 Pin Functions

DDR	0		1			
NOCR	—		0		1	
ODR	0	1	0	1	0	1
N-ch. driver	OFF		ON	OFF	ON	OFF
P-ch. driver	OFF		OFF	ON	OFF	
Input pull-up MOS	OFF	ON	OFF			
Pin function	Input pin		Output pin			

8.14.6 Input Pull-Up MOS in Ports C and D

Port C and port D have an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be switched on or off on a bit-by-bit basis.

Table 8.9 is a summary of the input pull-up MOS states.

Table 8.9 Input Pull-Up MOS States (Port C and port D)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	Other Operations
1 to 3	Off	Off	On/Off	On/Off

Legend:
Off: Input pull-up MOS is always off.
On/Off: On when PCDDR = 0 and PCODR = 1 (PDDDR = 0 and PDODR = 1); otherwise off.

8.15 Ports E, F

Port E and port F are two sets of 8-bit I/O ports. The pins of ports E and F have the same functions in all operating modes.

- Port E data direction register (PEDDR)
- Port E output data register (PEODR)
- Port E input data register (PEPIN)
- Port E Nch-OD control register (PENOCR)
- Port F data direction register (PFDDR)
- Port F output data register (PFODR)
- Port F input data register (PFPIN)
- Port F Nch-OD control register (PFNOCR)

8.15.1 Port E and Port F Data Direction Registers (PEDDR, PFDDR)

PEDDR and PFDDR select input or output for the pins of port E and port F on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7DDR	0	W	0: Port E pin is an input pin
6	PE6DDR	0	W	1: Port E pin is an output pin
5	PE5DDR	0	W	PEDDR has the same address as PEPIN, and if read, the port E pin states will be returned.
4	PE4DDR	0	W	
3	PE3DDR	0	W	
2	PE2DDR	0	W	
1	PE1DDR	0	W	
0	PE0DDR	0	W	

Bit	Bit Name	Initial Value	R/W	Description
7	PF7DDR	0	W	0: Port F pin is an input pin
6	PF6DDR	0	W	1: Port F pin is an output pin
5	PF5DDR	0	W	PFDDR has the same address as PFPIN, and if read, the port F pin states will be returned.
4	PF4DDR	0	W	
3	PF3DDR	0	W	
2	PF2DDR	0	W	
1	PF1DDR	0	W	
0	PF0DDR	0	W	

8.15.2 Port E and Port F Output Data Registers (PEODR, PFODR)

PEODR and PFODR store output data for the pins on ports E and F.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7ODR	0	R/W	PEODR can always be read or written to, regardless of the contents of PEDDR.
6	PE6ODR	0	R/W	
5	PE5ODR	0	R/W	
4	PE4ODR	0	R/W	
3	PE3ODR	0	R/W	
2	PE2ODR	0	R/W	
1	PE1ODR	0	R/W	
0	PE0ODR	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
7	PF7ODR	0	R/W	PFODR can always be read or written to, regardless of the contents of PFDDR.
6	PF6ODR	0	R/W	
5	PF5ODR	0	R/W	
4	PF4ODR	0	R/W	
3	PF3ODR	0	R/W	
2	PF2ODR	0	R/W	
1	PF1ODR	0	R/W	
0	PF0ODR	0	R/W	

8.15.3 Port E and Port F Input Data Registers (PEPIN, PFPIN)

Reading PEPIN and PFPIN always returns the pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7PIN	Undefined*	R	PEPIN indicates the port E state. PEPIN has the same address as PEDDR. If a write is performed, the port E settings will change.
6	PE6PIN	Undefined*	R	
5	PE5PIN	Undefined*	R	
4	PE4PIN	Undefined*	R	
3	PE3PIN	Undefined*	R	
2	PE2PIN	Undefined*	R	
1	PE1PIN	Undefined*	R	
0	PE0PIN	Undefined*	R	

Note: * The initial value is determined according to the PE7 to PE0 pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PF7PIN	Undefined*	R	PFPIN indicates the port F state. PFPIN has the same address as PFDDR. If a write is performed, the port F settings will change.
6	PF6PIN	Undefined*	R	
5	PF5PIN	Undefined*	R	
4	PF4PIN	Undefined*	R	
3	PF3PIN	Undefined*	R	
2	PF2PIN	Undefined*	R	
1	PF1PIN	Undefined*	R	
0	PF0PIN	Undefined*	R	

Note: * The initial value is determined according to the PF7 to PF0 pin states.

8.15.4 Port E and Port F Nch-OD Control Register (PENOCR, PFNOCR)

PENOCR and PFNOCR specify the output driver type for pins on ports E and F which are configured as outputs on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PE7NOCR	0	R/W	0: CMOS (p-channel driver enabled)
6	PE6NOCR	0	R/W	1: N-channel open drain (p-channel driver disabled)
5	PE5NOCR	0	R/W	
4	PE4NOCR	0	R/W	
3	PE3NOCR	0	R/W	
2	PE2NOCR	0	R/W	
1	PE1NOCR	0	R/W	
0	PE0NOCR	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
7	PF7NOCR	0	R/W	0: CMOS (p-channel driver enabled)
6	PF6NOCR	0	R/W	1: N-channel open drain (p-channel driver disabled)
5	PF5NOCR	0	R/W	
4	PF4NOCR	0	R/W	
3	PF3NOCR	0	R/W	
2	PF2NOCR	0	R/W	
1	PF1NOCR	0	R/W	
0	PF0NOCR	0	R/W	

8.15.5 Pin Functions

DDR	0		1			
NOCR	—		0		1	
ODR	0	1	0	1	0	1
N-ch. driver	OFF		ON	OFF	ON	OFF
P-ch. driver	OFF		OFF	ON	OFF	
Input pull-up MOS	OFF	ON	OFF			
Pin function	Input pin		Output pin			

8.15.6 Input Pull-Up MOS in Ports E and F

Port E and port F have an on-chip input pull-up MOS function that can be controlled by software. This input pull-up MOS function can be switched on or off on a bit-by-bit basis.

Table 8.10 is a summary of the input pull-up MOS states.

Table 8.10 Input Pull-Up MOS States (Port E and port F)

Mode	Reset	Hardware Standby Mode	Software Standby Mode	Other Operations
1 to 3	Off	Off	On/Off	On/Off

Legend:
Off: Input pull-up MOS is always off.
On/Off: On when PEDDR = 0 and PEODR = 1 (PFDDR = 0 and PFODR = 1); otherwise off.

8.16 Port G

Port G is an 8-bit I/O port. Port G pin functions are the same in all operating modes. The output type of port G is NMOS open-drain.

- Port G data direction register (PGDDR)
- Port G output data register (PGODR)
- Port G input data register (PGPIN)
- Port G Nch-OD control register (PGNOCR)

8.16.1 Port G Data Direction Register (PGDDR)

PGDDR selects input or output for the pins of port G on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PG7DDR	0	W	0: Port G pin is an input pin
6	PG6DDR	0	W	1: Port G pin is an output pin
5	PG5DDR	0	W	PGDDR has the same address as PGPIN, and if read, the port G pin states will be returned.
4	PG4DDR	0	W	
3	PG3DDR	0	W	
2	PG2DDR	0	W	
1	PG1DDR	0	W	
0	PG0DDR	0	W	

8.16.2 Port G Output Data Register (PGODR)

PGODR stores output data for the pins on port G.

Bit	Bit Name	Initial Value	R/W	Description
7	PG7ODR	0	R/W	PGODR can always be read or written to, regardless of the contents of PGDDR.
6	PG6ODR	0	R/W	
5	PG5ODR	0	R/W	
4	PG4ODR	0	R/W	
3	PG3ODR	0	R/W	
2	PG2ODR	0	R/W	
1	PG1ODR	0	R/W	
0	PG0ODR	0	R/W	

8.16.3 Port G Input Data Register (PGPIN)

Reading PGPIN always returns the pin states.

Bit	Bit Name	Initial Value	R/W	Description
7	PG7PIN	Undefined*	R	PGPIN indicates the port G state. PGPIN has the same address as PGDDR. If a write is performed, the port G settings will change.
6	PG6PIN	Undefined*	R	
5	PG5PIN	Undefined*	R	
4	PG4PIN	Undefined*	R	
3	PG3PIN	Undefined*	R	
2	PG2PIN	Undefined*	R	
1	PG1PIN	Undefined*	R	
0	PG0PIN	Undefined*	R	

Note: * The initial value is determined according to the PG7 to PG0 pin states.

8.16.4 Port G Nch-OD Control Register (PGNOCR)

PGNOCR specifies the output driver type for pins on port G which are configured as outputs on a bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PG7NOCR	0	R/W	0: NMOS push-pull (Vcc-side n-channel driver enabled) 1: Vss-side N-channel open drain (Vcc-side N-channel driver disabled)
6	PG6NOCR	0	R/W	
5	PG5NOCR	0	R/W	
4	PG4NOCR	0	R/W	
3	PG3NOCR	0	R/W	
2	PG2NOCR	0	R/W	
1	PG1NOCR	0	R/W	
0	PG0NOCR	0	R/W	

8.16.5 Pin Functions

DDR	0		1			
NOCR	—		0		1	
ODR	0	1	0	1	0	1
V_{ss}-side N-ch. driver	OFF		ON	OFF	ON	OFF
V_{cc}-side N-ch. driver	OFF		OFF	ON	OFF	
Pin function	Input pin		Output pin			

Section 9 8-Bit PWM Timer (PWM)

This LSI has an on-chip pulse width modulation (PWM) timer with sixteen outputs. Sixteen output waveforms are generated from a common time base, enabling PWM output with a high carrier frequency to be produced using pulse division.

9.1 Features

- Operable at a maximum carrier frequency of 625 kHz using pulse division (at 10 MHz operation)
- Duty cycles from 0 to 100% with 1/256 resolution (100% duty realized by port output)
- Direct or inverted PWM output, and PWM output enable/disable control

Figure 9.1 shows a block diagram of the PWM timer.

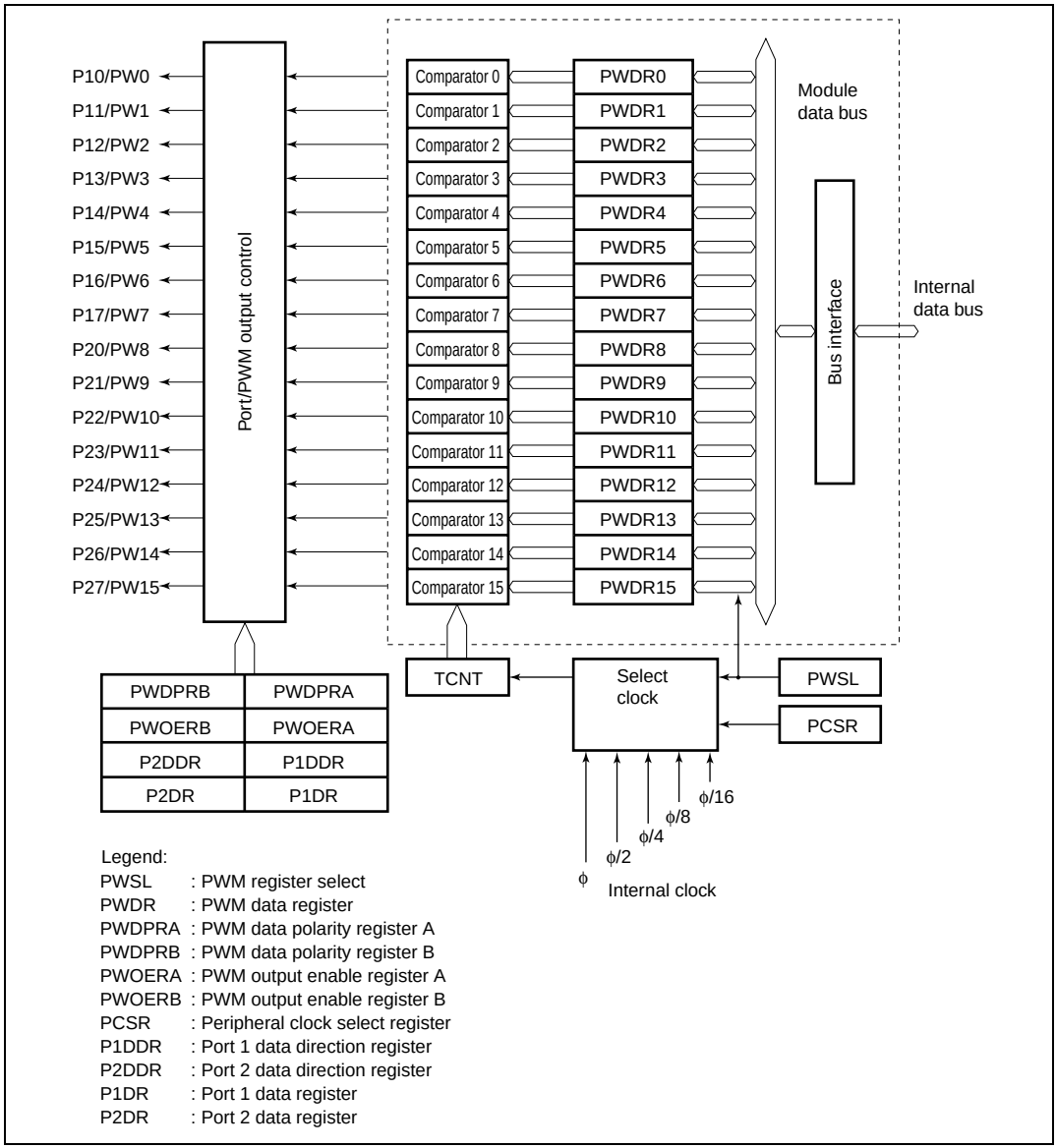


Figure 9.1 Block Diagram of PWM Timer

9.2 Input/Output Pin

Table 9.1 shows the PWM output pins.

Table 9.1 Pin Configuration

Name	Abbreviation	I/O	Function
PWM output 15 to 0	PW15 to PW0	Output	PWM timer pulse output 15 to 0

9.3 Register Descriptions

The PWM has the following registers. To access PCSR, the FLSHE bit in the serial timer control register (STCR) must be cleared to 0. For details on the serial timer control register (STCR), see section 3.2.3, Serial Timer Control Register (STCR).

- PWM register select (PWSL)
- PWM data registers 0 to 15 (PWDR0 to PWDR15)
- PWM data polarity register A (PWDPRA)
- PWM data polarity register B (PWDPRB)
- PWM output enable register A (PWOERA)
- PWM output enable register B (PWOERB)
- Peripheral clock select register (PCSR)

9.3.1 PWM Register Select (PWSL)

PWSL is used to select the input clock and the PWM data register.

Bit	Bit Name	Initial Value	R/W	Description
7	PWCKE	0	R/W	PWM Clock Enable
6	PWCKS	0	R/W	PWM Clock Select These bits, together with bits PWCKB and PWCKA in PCSR, select the internal clock input to TCNT in the PWM. For details, see table 9.2. The resolution, PWM conversion period, and carrier frequency depend on the selected internal clock, and can be obtained from the following equations. Resolution (minimum pulse width) = 1/internal clock frequency PWM conversion period = resolution × 256 Carrier frequency = 16/PWM conversion period With a 10 MHz system clock (ϕ), the resolution, PWM conversion period, and carrier frequency are as shown in table 9.3.
5	—	1	R	Reserved This bit is always read as 1 and cannot be modified.
4	—	0	R	Reserved This bit is always read as 0 and cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
3	RS3	0	R/W	Register Select
2	RS2	0	R/W	These bits select the PWM data register.
1	RS1	0	R/W	0000: PWDR0 selected
0	RS0	0	R/W	0001: PWDR1 selected
				0010: PWDR2 selected
				0011: PWDR3 selected
				0100: PWDR4 selected
				0101: PWDR5 selected
				0110: PWDR6 selected
				0111: PWDR7 selected
				1000: PWDR8 selected
				1001: PWDR9 selected
				1010: PWDR10 selected
				1011: PWDR11 selected
				1100: PWDR12 selected
				1101: PWDR13 selected
				1110: PWDR14 selected
				1111: PWDR15 selected

Table 9.2 Internal Clock Selection

PWSL		PCSR			
PWCKE	**PWCKS**	**PWCKB**	**PWCKA**	**Description**	
0	—	—	—	Clock input is disabled	(Initial value)
1	0	—	—	ϕ (system clock) is selected	
	1	0	0	ϕ/2 is selected	
			1	ϕ/4 is selected	
		1	0	ϕ/8 is selected	
			1	ϕ/16 is selected	

Table 9.3 Resolution, PWM Conversion Period and Carrier Frequency when ϕ = 10 MHz

Internal Clock Frequency	Resolution	PWM Conversion Period	Carrier Frequency
ϕ	100 ns	25.6 µs	625 kHz
ϕ/2	200 ns	51.2 µs	312.5 kHz
ϕ/4	400 ns	102.4 µs	156.3 kHz
ϕ/8	800 ns	204.8 µs	78.1 kHz
ϕ/16	1600 ns	409.6 µs	39.1 kHz

9.3.2 PWM Data Registers (PWDR0 to PWDR15)

PWDR are 8-bit readable/writable registers. The PWM has sixteen PWM data registers. Each PWDR specifies the duty cycle of the basic pulse to be output, and the number of additional pulses. The value set in PWDR corresponds to a 0 or 1 ratio in the conversion period. The upper four bits specify the duty cycle of the basic pulse as 0/16 to 15/16 with a resolution of 1/16. The lower four bits specify how many extra pulses are to be added within the conversion period comprising 16 basic pulses. Thus, a specification of 0/256 to 255/256 is possible for 0/1 ratios within the conversion period. For 256/256 (100%) output, port output should be used. PWDR0 to PWDR15 are initialized to H'00.

9.3.3 PWM Data Polarity Registers A and B (PWDPRA, PWDPRB)

Each PWDPR selects the PWM output phase.

- PWDPRA

Bit	Bit Name	Initial Value	R/W	Description
7	OS7	0	R/W	Output Select 7 to 0
6	OS6	0	R/W	These bits select the PWM output phase. Bits OS7 to OS0 correspond to outputs PW7 to PW0.
5	OS5	0	R/W	
4	OS4	0	R/W	0: PWM direct output (PWDR value corresponds to high width of output)
3	OS3	0	R/W	
2	OS2	0	R/W	1: PWM inverted output (PWDR value corresponds to low width of output)
1	OS1	0	R/W	
0	OS0	0	R/W	

- PWDPRB

Bit	Bit Name	Initial Value	R/W	Description
7	OS15	0	R/W	Output Select 15 to 8
6	OS14	0	R/W	These bits select the PWM output phase. Bits OS15 to OS8 correspond to outputs PW15 to PW8.
5	OS13	0	R/W	
4	OS12	0	R/W	0: PWM direct output (PWDR value corresponds to high width of output)
3	OS11	0	R/W	1: PWM inverted output (PWDR value corresponds to low width of output)
2	OS10	0	R/W	
1	OS9	0	R/W	
0	OS8	0	R/W	

9.3.4 PWM Output Enable Registers A and B (PWOERA, PWOERB)

Each PWOER switches between PWM output and port output.

- PWOERA

Bit	Bit Name	Initial Value	R/W	Description
7	OE7	0	R/W	Output Enable 7 to 0
6	OE6	0	R/W	These bits, together with P1DDR, specify the P1n/PWn pin state. Bits OE7 to OE0 correspond to outputs PW7 to PW0.
5	OE5	0	R/W	
4	OE4	0	R/W	P1nDDR OEn: Pin state
3	OE3	0	R/W	0X: Port input
2	OE2	0	R/W	10: Port output or PWM 256/256 output
1	OE1	0	R/W	11: PWM output (0 to 255/256 output)
0	OE0	0	R/W	

Legend:
X: Don't care

- PWOERB

Bit	Bit Name	Initial Value	R/W	Description
7	OE15	0	R/W	Output Enable 15 to 8
6	OE14	0	R/W	These bits, together with P2DDR, specify the P2n/PWn pin state. Bits OE15 to OE8 correspond to outputs PW15 to PW8.
5	OE13	0	R/W	
4	OE12	0	R/W	P2nDDR OEn: Pin state
3	OE11	0	R/W	0X: Port input
2	OE10	0	R/W	10: Port output or PWM 256/256 output
1	OE9	0	R/W	11: PWM output (0 to 255/256 output)
0	OE8	0	R/W	

Legend:
X: Don't care

To perform PWM 256/256 output when DDR = 1 and OE = 0, the corresponding pin should be set to port output. The corresponding pin can be set as port output in single-chip mode or when IOSE = 1 and CS256E = 0 in SYSCR in extended mode with on-chip ROM. Otherwise, it should be noted that an address bus is output to the corresponding pin.

DR data is output when the corresponding pin is used as port output. A value corresponding to PWM 256/256 output is determined by the OS bit, so the value should have been set to DR beforehand.

9.3.5 Peripheral Clock Select Register (PCSR)

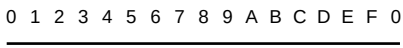
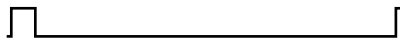
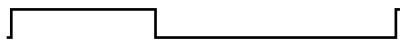
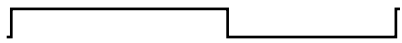
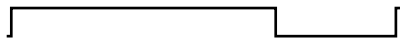
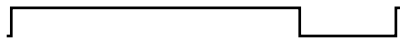
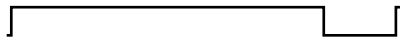
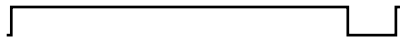
PCSR selects the PWM input clock.

Bit	Bit Name	Initial Value	R/W	Description
3	—	0	R	Reserved This bit is always read as 0. The initial value should not be changed.
2	PWCKB	0	R/W	PWM Clock Select B, A
1	PWCKA	0	R/W	Together with bits PWCKE and PWCKS in PWSL, these bits select the internal clock input to TCNT in the PWM. For details, see table 9.2.
0	—	0	R	Reserved This bit is always read as 0. The initial value should not be changed.

9.4 Operation

The upper four bits of PWDR specify the duty cycle of the basic pulse as 0/16 to 15/16 with a resolution of 1/16. Table 9.4 shows the duty cycles of the basic pulse.

Table 9.4 Duty Cycle of Basic Pulse

Upper 4 Bits	Basic Pulse Waveform (Internal)
0000	
0001	
0010	
0011	
0100	
0101	
0110	
0111	
1000	
1001	
1010	
1011	
1100	
1101	
1110	
1111	

The lower four bits of PWDR specify the position of pulses added to the 16 basic pulses. An additional pulse adds a high period (when OS = 0) with a width equal to the resolution before the rising edge of a basic pulse. When the upper four bits of PWDR are 0000, there is no rising edge of the basic pulse, but the timing for adding pulses is the same. Table 9.5 shows the positions of

the additional pulses added to the basic pulses, and figure 9.2 shows an example of additional pulse timing.

Table 9.5 Position of Pulses Added to Basic Pulses

Lower 4 Bits	Basic Pulse No.															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0000																
0001																Yes
0010								Yes								Yes
0011								Yes				Yes				Yes
0100				Yes				Yes				Yes				Yes
0101				Yes				Yes				Yes		Yes		Yes
0110				Yes		Yes		Yes				Yes		Yes		Yes
0111				Yes		Yes		Yes		Yes		Yes		Yes		Yes
1000		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes
1001		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes
1010		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes
1011		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes
1100		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes
1101		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes
1110		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes
1111		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

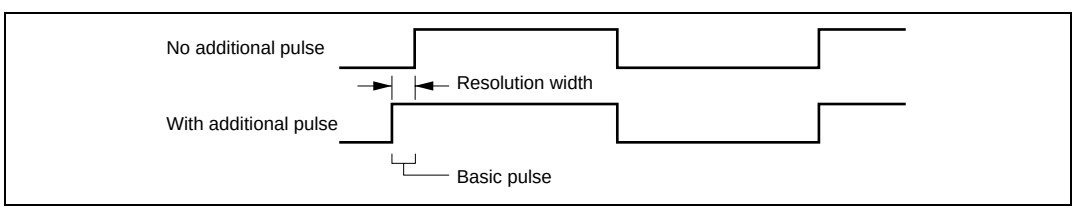


Figure 9.2 Example of Additional Pulse Timing (when Upper 4 Bits of PWDR = 1000)

9.5 Usage Note

9.5.1 Module Stop Mode Setting

PWM operation can be enabled or disabled using the module stop control register. The initial setting is for PWM operation to be halted. Register access is enabled by canceling the module stop mode. For details, refer to section 26, Power-Down Modes.

Section 10 14-Bit PWM Timer (PWMX)

This LSI has an on-chip 14-bit pulse-width modulator (PWM) timer with two output channels. It can be connected to an external low-pass filter to operate as a 14-bit D/A converter.

10.1 Features

- Division of pulse into multiple base cycles to reduce ripple
- Two resolution settings
  The resolution can be set equal to one or two system clock cycles.
- Two base cycle settings
  The base cycle can be set equal to T × 64 or T × 256, where T is the resolution.
- Four operating speeds
- Four operation clocks (by combination of two resolution settings and two base cycle settings)

Figure 10.1 shows a block diagram of the PWM (D/A) module.

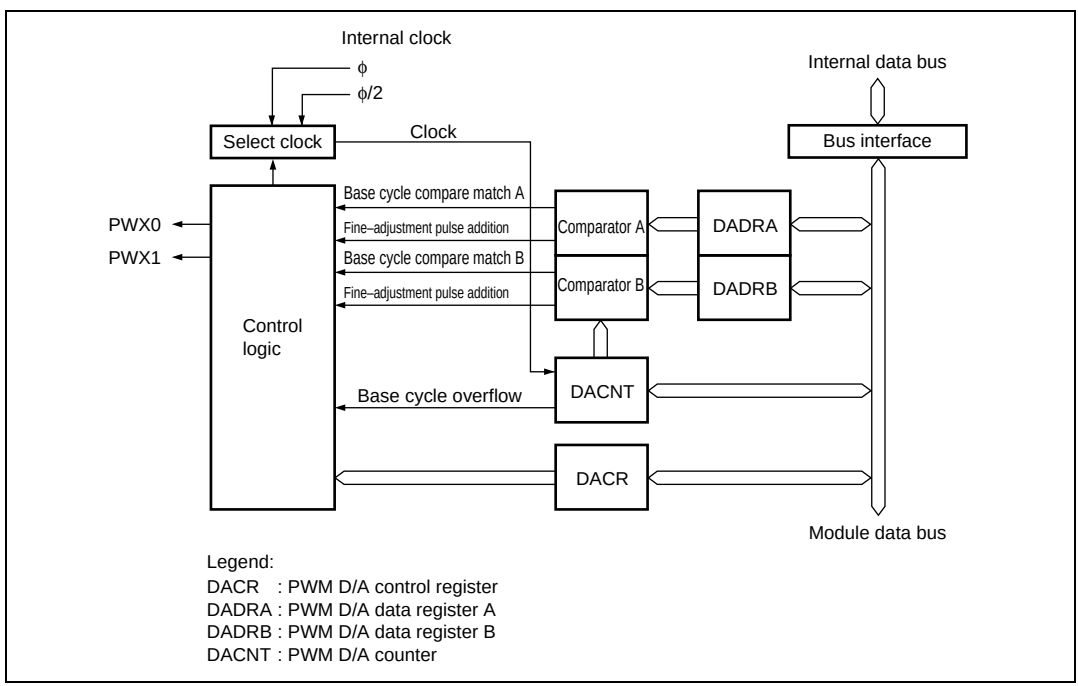


Figure 10.1 PWM (D/A) Block Diagram

10.2 Input/Output Pins

Table 10.1 lists the PWM (D/A) module input and output pins.

Table 10.1 Pin Configuration

Name	Abbreviation	I/O	Function
PWM output pin X0	PWX0	Output	PWM output of PWMX channel A
PWM output pin X1	PWX1	Output	PWM output of PWMX channel B

10.3 Register Descriptions

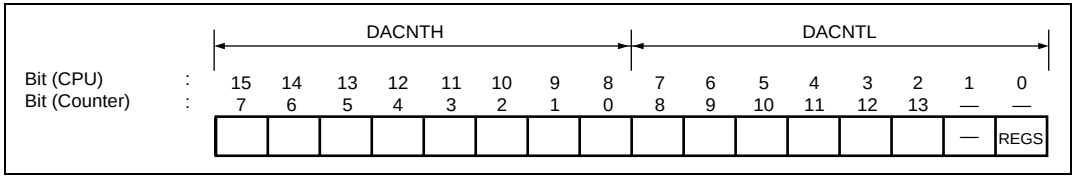
The PWM (D/A) module has the following registers. The PWM (D/A) registers are assigned to the same addresses with other registers. The registers are selected by the IICE bit in the serial timer control register (STCR). For details on STCR, see section 3.2.3, Serial Timer Control Register (STCR).

- PWM (D/A) counter H (DACNTH)
- PWM (D/A) counter L (DACNTL)
- PWM (D/A) data register AH (DADRAH)
- PWM (D/A) data register AL (DADRAL)
- PWM (D/A) data register BH (DADRBH)
- PWM (D/A) data register BL (DADRBL)
- PWM (D/A) control register (DACR)

Note: The same addresses are shared by DADRA and DACR, and by DADRB and DACNT. Switching is performed by the REGS bit in DACNT or DADRB.

10.3.1 PWM (D/A) Counters H and L (DACNTH, DACNTL)

DACNT is a 14-bit readable/writable up-counter. The input clock is selected by the clock select bit (CKS) in DACR. DACNT functions as the time base for both PWM (D/A) channels. When a channel operates with 14-bit precision, it uses all DACNT bits. When a channel operates with 12-bit precision, it uses the lower 12 bits and ignores the upper two bits. Since DACNT consists of 16-bit data, DACNT transfers data to the CPU via the temporary register (TEMP). For details, refer to section 10.4, Bus Master Interface.



- DACNTH

Bit	Bit Name	Initial Value	R/W	Description
7 to 0	UC7 to UC0	All 0	R/W	Upper Up-Counter

- DACNTL

Bit	Bit Name	Initial Value	R/W	Description
7 to 2	UC8 to UC13	All 0	R/W	Lower Up-Counter
1	—	1	R	Reserved This bit is always read as 1 and cannot be modified.
0	REGS	1	R/W	Register Select DADRA and DACR, and DADRB and DACNT, are located at the same addresses. The REGS bit specifies which registers can be accessed. 0: DADRA and DADRB can be accessed 1: DACR and DACNT can be accessed

10.3.2 PWM (D/A) Data Registers A and B (DADRA, DADRB)

DADRA corresponds to PWM (D/A) channel A, and DADRB to PWM (D/A) channel B. Since DADR consists of 16-bit data, DADR transfers data to the CPU via the temporary register (TEMP). For details, refer to section 10.4, Bus Master Interface.

- DADRA

Bit	Bit Name	Initial Value	R/W	Description
15	DA13	1	R/W	D/A Data 13 to 0 These bits set a digital value to be converted to an analog value. In each base cycle, the DACNT value is continually compared with the DADR value to determine the duty cycle of the output waveform, and to decide whether to output a fine-adjustment pulse equal in width to the resolution. To enable this operation, this register must be set within a range that depends on the CFS bit. If the DADR value is outside this range, the PWM output is held constant. A channel can be operated with 12-bit precision by keeping the two lowest data bits (DA1 and DA0) cleared to 0. The two lowest data bits correspond to the two highest bits in DACNT.
14	DA12	1	R/W	
13	DA11	1	R/W	
12	DA10	1	R/W	
11	DA9	1	R/W	
10	DA8	1	R/W	
9	DA7	1	R/W	
8	DA6	1	R/W	
7	DA5	1	R/W	
6	DA4	1	R/W	
5	DA3	1	R/W	
4	DA2	1	R/W	
3	DA1	1	R/W	
2	DA0	1	R/W	
1	CFS	1	R/W	Carrier Frequency Select 0: Base cycle = resolution (T) × 64 DADR range = H'0401 to H'FFFD 1: Base cycle = resolution (T) × 256 DADR range = H'0103 to H'FFFF
0	—	1	R	Reserved This bit is always read as 1 and cannot be modified.

- DADRB

Bit	Bit Name	Initial Value	R/W	Description
15	DA13	1	R/W	D/A Data 13 to 0 These bits set a digital value to be converted to an analog value. In each base cycle, the DACNT value is continually compared with the DADR value to determine the duty cycle of the output waveform, and to decide whether to output a fine-adjustment pulse equal in width to the resolution. To enable this operation, this register must be set within a range that depends on the CFS bit. If the DADR value is outside this range, the PWM output is held constant. A channel can be operated with 12-bit precision by keeping the two lowest data bits (DA1 and DA0) cleared to 0. The two lowest data bits correspond to the two highest bits in DACNT.
14	DA12	1	R/W	
13	DA11	1	R/W	
12	DA10	1	R/W	
11	DA9	1	R/W	
10	DA8	1	R/W	
9	DA7	1	R/W	
8	DA6	1	R/W	
7	DA5	1	R/W	
6	DA4	1	R/W	
5	DA3	1	R/W	
4	DA2	1	R/W	
3	DA1	1	R/W	
2	DA0	1	R/W	
1	CFS	1	R/W	Carrier Frequency Select 0: Base cycle = resolution (T) × 64 DADR range = H'0401 to H'FFFD 1: Base cycle = resolution (T) × 256 DADR range = H'0103 to H'FFFF
0	REGS	1	R/W	Register Select DADRA and DACR, and DADRB and DACNT, are located at the same addresses. The REGS bit specifies which registers can be accessed. 0: DADRA and DADRB can be accessed 1: DACR and DACNT can be accessed

10.3.3 PWM (D/A) Control Register (DACR)

DACR selects test mode, enables the PWM outputs, and selects the output phase and operating speed.

Bit	Bit Name	Initial Value	R/W	Description
7	TEST	0	R/W	Test Mode Selects test mode, which is used in testing this LSI. Normally this bit should be cleared to 0. 0: PWM (D/A) in user state: Normal operation 1: PWM (D/A) in test state: Correct conversion results unobtainable
6	PWME	0	R/W	PWM Enable Starts or stops the PWM D/A counter (DACNT). 0: DACNT operates as a 14-bit up-counter 1: DACNT halts at H'0003
5, 4	—	All 1	R	Reserved These bits are always read as 1 and cannot be modified.
3	OEB	0	R/W	Output Enable B Enables or disables output on PWM (D/A) channel B. 0: PWM (D/A) channel B output (at the PWX1 pin) is disabled 1: PWM (D/A) channel B output (at the PWX1 pin) is enabled

Bit	Bit Name	Initial Value	R/W	Description
2	OEA	0	R/W	Output Enable A Enables or disables output on PWM (D/A) channel A. 0: PWM (D/A) channel A output (at the PWX0 pin) is disabled 1: PWM (D/A) channel A output (at the PWX0 pin) is enabled
1	OS	0	R/W	Output Select Selects the phase of the PWM (D/A) output. 0: Direct PWM (D/A) output 1: Inverted PWM (D/A) output
0	CKS	0	R/W	Clock Select Selects the PWM (D/A) resolution. If the system clock (ϕ) frequency is 10 MHz, resolutions of 100 ns and 200 ns, can be selected. 0: Operates at resolution (T) = system clock cycle time (t_{cyc}) 1: Operates at resolution (T) = system clock cycle time (t_{cyc}) $\times$ 2

10.4 Bus Master Interface

DACNT, DADRA, and DADRB are 16-bit registers. The data bus linking the bus master and the on-chip peripheral modules, however, is only 8 bits wide. When the bus master accesses these registers, it therefore uses an 8-bit temporary register (TEMP).

These registers are written to and read from as follows.

Write: When the upper byte is written to, the upper-byte write data is stored in TEMP. Next, when the lower byte is written to, the lower-byte write data and TEMP value are combined, and the combined 16-bit value is written in the register.

Read: When the upper byte is read from, the upper-byte value is transferred to the CPU and the lower-byte value is transferred to TEMP. Next, when the lower byte is read from, the lower-byte value in TEMP is transferred to the CPU.

These registers should always be accessed 16 bits at a time with a MOV instruction, and the upper byte should always be accessed before the lower byte. Correct data will not be transferred if only the upper byte or only the lower byte is accessed. Also note that a bit manipulation instruction cannot be used to access these registers.

Example 1: Write to DACNT

```
MOV.W R0, @DACNT      ; Write R0 contents to DACNT
```

Example 2: Read DADRA

```
MOV.W @DADRA, R0      ; Copy contents of DADRA to R0
```

Table 10.2 Read and Write Access Methods for 16-Bit Registers

	Read		Write	
Register Name	**Word**	**Byte**	**Word**	**Byte**
DADRA and DADRB	Yes	Yes	Yes	×
DACNT	Yes	×	Yes	×

Legend:

Yes: Permitted type of access. Word access includes successive byte accesses to the upper byte (first) and lower byte (second).

×: This type of access may give incorrect results.

10.5 Operation

A PWM waveform like the one shown in figure 10.2 is output from the PWMX pin. The value in DADR corresponds to the total width (T_L) of the low (0) pulses output in one conversion cycle (256 pulses when CFS = 0, 64 pulses when CFS = 1). When OS = 0, this waveform is directly output. When OS = 1, the output waveform is inverted, and the DADR value corresponds to the total width (T_H) of the high (1) output pulses. Figures 10.3 and 10.4 show the types of waveform output available.

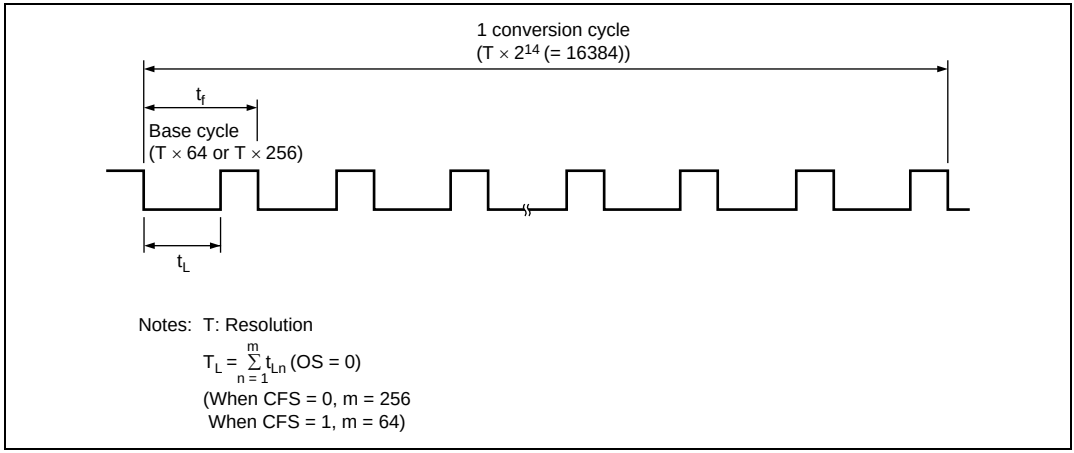


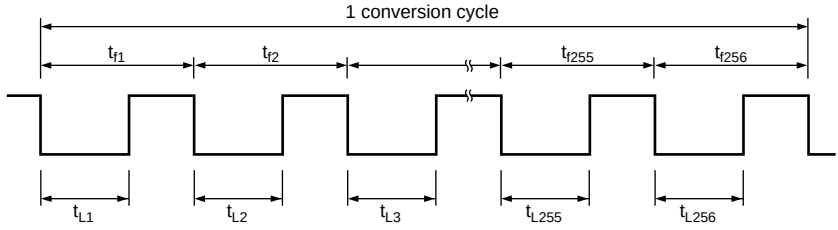
Figure 10.2 PWM D/A Operation

Table 10.3 summarizes the relationships between the CKS, CFS, and OS bit settings and the resolution, base cycle, and conversion cycle. The PWM output remains fixed unless DADR contains at least a certain minimum value.

Table 10.3 Settings and Operation (Examples when ϕ = 10 MHz)

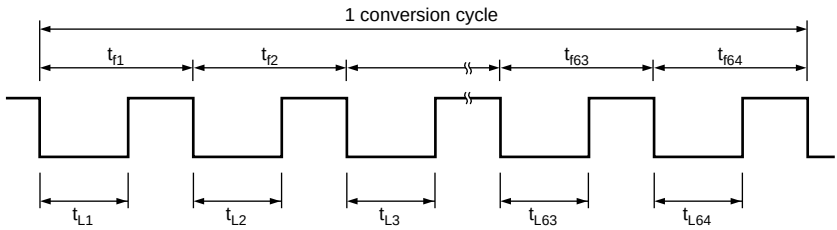
CKS	Resolution T (µs)	CFS	Base Cycle (µs)	Conversion Cycle (µs)	T_L (if OS = 0) T_H (if OS = 1)	Fixed DADR Bits					Conversion Cycle* (µs)
						Precision (Bits)	Bit Data				
							3	2	1	0	
0	0.1	0	6.4	1638.4	1. Always low (or high) (DADR = H'0001 to H'03FD)	14					1638.4
					2. (Data value) × T (DADR = H'0401 to H'FFFD)	12			0	0	409.6
						10	0	0	0	0	102.4
		1	25.6		1. Always low (or high) (DADR = H'0003 to H'00FF)	14					1638.4
					2. (Data value) × T (DADR = H'0103 to H'FFFF)	12			0	0	409.6
						10	0	0	0	0	102.4
1	0.2	0	12.8	3276.8	1. Always low (or high) (DADR = H'0001 to H'03FD)	14					3276.8
					2. (Data value) × T (DADR = H'0401 to H'FFFD)	12			0	0	819.2
						10	0	0	0	0	204.8
		1	51.2		1. Always low (or high) (DADR = H'0003 to H'00FF)	14					3276.8
					2. (Data value) × T (DADR = H'0103 to H'FFFF)	12			0	0	819.2
						10	0	0	0	0	204.8

Note: * This column indicates the conversion cycle when specific DADR bits are fixed.



$t_{f1} = t_{f2} = t_{f3} = \cdots = t_{f255} = t_{f256} = T \times 64$
$t_{L1} + t_{L2} + t_{L3} + \cdots + t_{L255} + t_{L256} = T_L$

a. CFS = 0 [base cycle = resolution (T) × 64]



$t_{f1} = t_{f2} = t_{f3} = \cdots = t_{f63} = t_{f64} = T \times 256$
$t_{L1} + t_{L2} + t_{L3} + \cdots + t_{L63} + t_{L64} = T_L$

b. CFS = 1 [base cycle = resolution (T) × 256]

Figure 10.3 Output Waveform (OS = 0, DADR Corresponds to T_L)

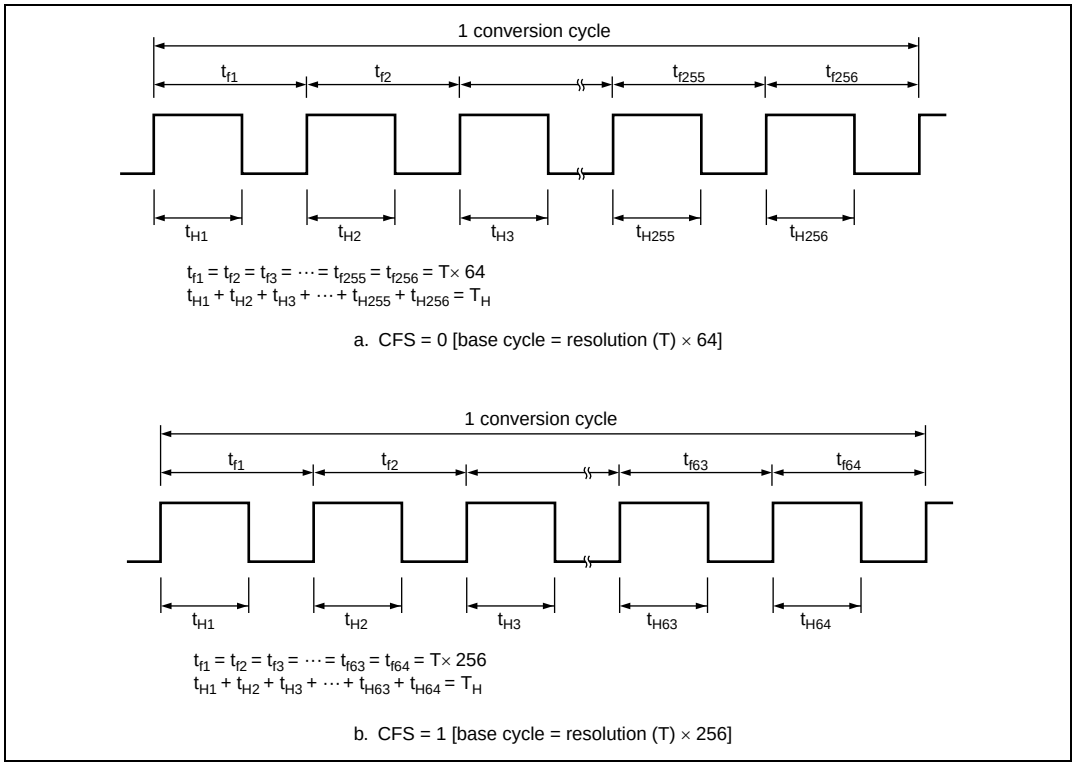


Figure 10.4 Output Waveform (OS = 1, DADR Corresponds to T_H)

An example of setting CFS to 1 (basic cycle = resolution (T) × 256) and OS to 1 (PWMX inverted output) is shown as an additional pulse. When CFS is set to 1, the duty ratio of the basic pulse is determined by the upper eight bits (DA13 to DA6) in DADR, and the position of the additional pulse is determined by the following six bits (DA5 to DA0) as shown in figure 10.5.

Table 10.4 shows the position of the additional pulse.

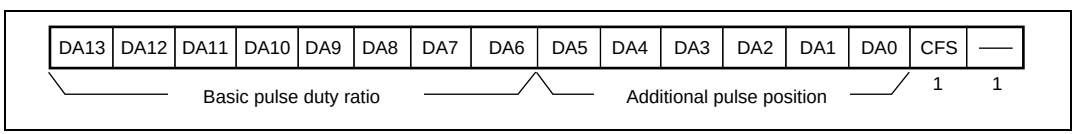


Figure 10.5 D/A Data Register Configuration when CFS = 1

Here, the case of DADR = H'0207 (B'0000 0010 0000 0111) is considered. Figure 10.6 shows an output waveform. Because CFS = 1 and the value of upper eight bits is B'0000 0010, the duty ratio of the basic pulse is 2/256 × (T) of high width.

Since the value of the following six bits is B'0000 01, the additional pulse is output at the position of basic pulse No. 63 as shown in table 10.4. Only 1/256 × (T) of the additional pulse is added to the basic pulse.

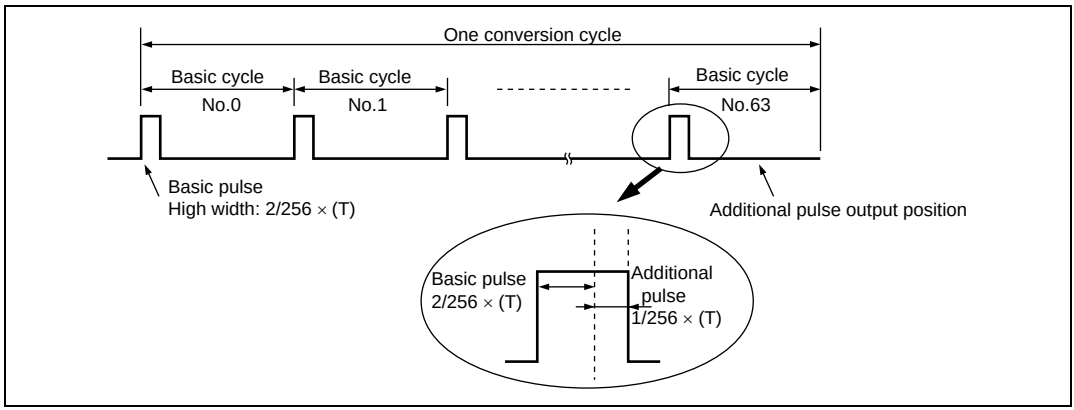


Figure 10.6 Output Waveform when DADR = H'0207 (OS = 1)

Note that the case of CFS = 0 (basic cycle = resolution (T) × 64) is similar other than the duty ratio of the basic pulse is determined by the upper six bits, and the position of the additional pulse is determined by the following eight bits.

Table 10.4 Position of Pulse to Be Added to Basic Pulse (CFS = 1)

| Lower 6 bits | Basic Pulse No. | | |

10.6 Usage Note

10.6.1 Module Stop Mode Setting

PWMX operation can be enabled or disabled using the module stop control register. The initial setting is for PWMX operation to be halted. Register access is enabled by canceling the module stop mode. For details, refer to section 26, Power-Down Modes.

Section 11 16-Bit Free-Running Timer (FRT)

This LSI has an on-chip 16-bit free-running timer (FRT). The FRT operates on the basis of the 16-bit free-running counter (FRC), and outputs two independent waveforms, and measures the input pulse width and external clock periods.

11.1 Features

- Selection of four clock sources

  One of the three internal clocks (ϕ/2, ϕ/8, or ϕ/32), or an external clock input can be selected (enabling use as an external event counter).
- Two independent comparators

  Two independent waveforms can be output.
- Four independent input capture channels

  The rising or falling edge can be selected.

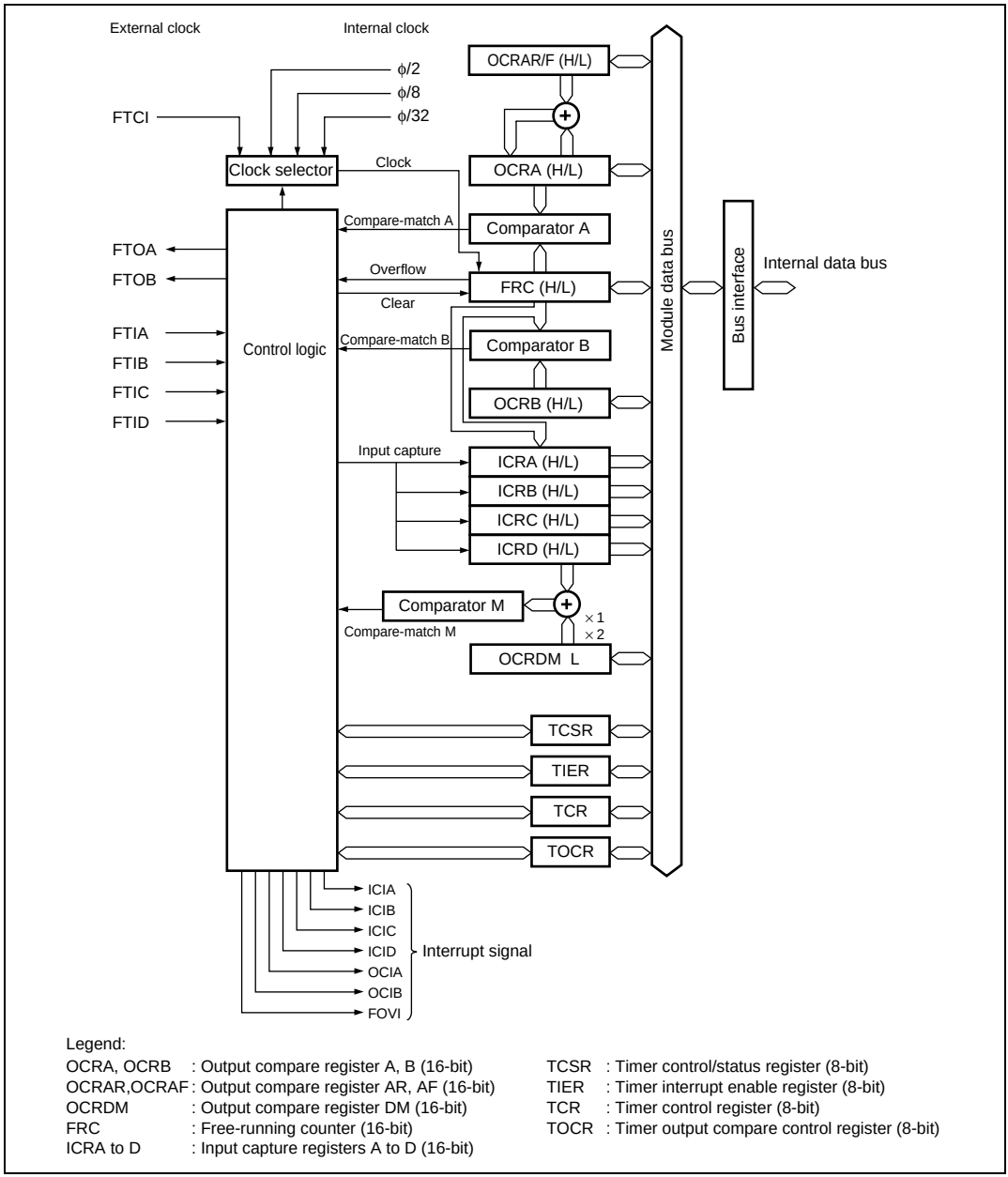
  Buffer modes can be specified.
- Counter clearing

  The free-running counters can be cleared on compare-match A.
- Seven independent interrupts

  Two compare-match interrupts, four input capture interrupts, and one overflow interrupt can be requested independently.
- Special functions provided by automatic addition function

  The contents of OCRAR and OCRAF can be added to the contents of OCRA automatically, enabling a periodic waveform to be generated without software intervention. The contents of ICRD can be added automatically to the contents of OCRDM × 2, enabling input capture operations in this interval to be restricted.

Figure 11.1 shows a block diagram of the FRT.



Legend:

OCRA, OCRB	: Output compare register A, B (16-bit)	TCSR	: Timer control/status register (8-bit)
OCRAR,OCRAF	: Output compare register AR, AF (16-bit)	TIER	: Timer interrupt enable register (8-bit)
OCRDM	: Output compare register DM (16-bit)	TCR	: Timer control register (8-bit)
FRC	: Free-running counter (16-bit)	TOCR	: Timer output compare control register (8-bit)
ICRA to D	: Input capture registers A to D (16-bit)		

Figure 11.1 Block Diagram of 16-Bit Free-Running Timer

11.2 Input/Output Pins

Table 11.1 lists the FRT input and output pins.

Table 11.1 Pin Configuration

Name	Abbreviation	I/O	Function
Counter clock input pin	FTCI	Input	FRC counter clock input
Output compare A output pin	FTOA	Output	Output compare A output
Output compare B output pin	FTOB	Output	Output compare B output
Input capture A input pin	FTIA	Input	Input capture A input
Input capture B input pin	FTIB	Input	Input capture B input
Input capture C input pin	FTIC	Input	Input capture C input
Input capture D input pin	FTID	Input	Input capture D input

11.3 Register Descriptions

The FRT has the following registers.

- Free-running counter (FRC)
- Output compare register A (OCRA)
- Output compare register B (OCRB)
- Input capture register A (ICRA)
- Input capture register B (ICRB)
- Input capture register C (ICRC)
- Input capture register D (ICRD)
- Output compare register AR (OCRAR)
- Output compare register AF (OCRAF)
- Output compare register DM (OCRDM)
- Timer interrupt enable register (TIER)
- Timer control/status register (TCSR)
- Timer control register (TCR)
- Timer output compare control register (TOCR)

Note: OCRA and OCRB share the same address. Register selection is controlled by the OCRS bit in TOCR. ICRA, ICRB, and ICRC share the same addresses with OCRAR, OCRAF, and OCRDM. Register selection is controlled by the ICRS bit in TOCR.

11.3.1 Free-Running Counter (FRC)

FRC is a 16-bit readable/writable up-counter. The clock source is selected by bits CKS1 and CKS0 in TCR. FRC can be cleared by compare-match A. When FRC overflows from H'FFFF to H'0000, the overflow flag bit (OVF) in TCSR is set to 1. FRC should always be accessed in 16-bit units; cannot be accessed in 8-bit units. FRC is initialized to H'0000.

11.3.2 Output Compare Registers A and B (OCRA, OCRB)

The FRT has two output compare registers, OCRA and OCRB, each of which is a 16-bit readable/writable register whose contents are continually compared with the value in FRC. When a match is detected (compare-match), the corresponding output compare flag (OCFA or OCFB) is set to 1 in TCSR. If the OEA or OEB bit in TOCR is set to 1, when the OCR and FRC values match, the output level selected by the OLVLA or OLVLB bit in TOCR is output at the output compare output pin (FTOA or FTOB). Following a reset, the FTOA and FTOB output levels are 0 until the first compare-match. OCR should always be accessed in 16-bit units; cannot be accessed in 8-bit units. OCR is initialized to H'FFFF.

11.3.3 Input Capture Registers A to D (ICRA to ICRD)

The FRT has four input capture registers, ICRA to ICRD, each of which is a 16-bit read-only register. When the rising or falling edge of the signal at an input capture input pin (FTIA to FTID) is detected, the current FRC value is transferred to the corresponding input capture register (ICRA to ICRD). At the same time, the corresponding input capture flag (ICFA to ICFD) in TCSR is set to 1. The FRC contents are transferred to ICR regardless of the value of ICF. The input capture edge is selected by the input edge select bits (IEDGA to IEDGD) in TCR.

ICRC and ICRD can be used as ICRA and ICRB buffer registers, respectively, by means of buffer enable bits A and B (BUFEA and BUFEB) in TCR. For example, if an input capture occurs when ICRC is specified as the ICRA buffer register, the FRC contents are transferred to ICRA, and then transferred to the buffer register ICRC.

To ensure input capture, the input capture pulse width should be at least 1.5 system clocks (ϕ) for a single edge. When triggering is enabled on both edges, the input capture pulse width should be at least 2.5 system clocks (ϕ).

ICRA to ICRD should always be accessed in 16-bit units; cannot be accessed in 8-bit units. ICR is initialized to H'0000.

11.3.4 Output Compare Registers AR and AF (OCRAR, OCRAF)

OCRAR and OCRAF are 16-bit readable/writable registers. When the OCRAMS bit in TOCR is set to 1, the operation of OCRA is changed to include the use of OCRAR and OCRAF. The contents of OCRAR and OCRAF are automatically added alternately to OCRA, and the result is written to OCRA. The write operation is performed on the occurrence of compare-match A. In the 1st compare-match A after setting the OCRAMS bit to 1, OCRAF is added. The operation due to compare-match A varies according to whether the compare-match follows addition of OCRAR or OCRAF. The value of the OLVLA bit in TOCR is ignored, and 1 is output on a compare-match A following addition of OCRAF, while 0 is output on a compare-match A following addition of OCRAR.

When using the OCRA automatic addition function, do not select internal clock $\phi/2$ as the FRC input clock together with a set value of H'0001 or less for OCRAR (or OCRAF).

OCRAR and OCRAF should always be accessed in 16-bit units; cannot be accessed in 8-bit units. OCRAR and OCRAF are initialized to H'FFFF.

11.3.5 Output Compare Register DM (OCRDM)

OCRDM is a 16-bit readable/writable register in which the upper 8 bits are fixed at H'00. When the ICRDMS bit in TOCR is set to 1 and the contents of OCRDM are other than H'0000, the operation of ICRD is changed to include the use of OCRDM. The point at which input capture D occurs is taken as the start of a mask interval. Next, twice the contents of OCRDM is added to the contents of ICRD, and the result is compared with the FRC value. The point at which the values match is taken as the end of the mask interval. New input capture D events are disabled during the mask interval. A mask interval is not generated when the contents of OCRDM are H'0000 while the ICRDMS bit is set to 1.

OCRDM should always be accessed in 16-bit units; cannot be accessed in 8-bit units. OCRDM is initialized to H'0000.

11.3.6 Timer Interrupt Enable Register (TIER)

TIER enables and disables interrupt requests.

Bit	Bit Name	Initial Value	R/W	Description
7	ICIAE	0	R/W	Input Capture Interrupt A Enable Selects whether to enable input capture interrupt A request (ICIA) when input capture flag A (ICFA) in TCSR is set to 1. 0: ICIA requested by ICFA is disabled 1: ICIA requested by ICFA is enabled
6	ICIBE	0	R/W	Input Capture Interrupt B Enable Selects whether to enable input capture interrupt B request (ICIB) when input capture flag B (ICFB) in TCSR is set to 1. 0: ICIB requested by ICFB is disabled 1: ICIB requested by ICFB is enabled
5	ICICE	0	R/W	Input Capture Interrupt C Enable Selects whether to enable input capture interrupt C request (ICIC) when input capture flag C (ICFC) in TCSR is set to 1. 0: ICIC requested by ICFC is disabled 1: ICIC requested by ICFC is enabled
4	ICIDE	0	R/W	Input Capture Interrupt D Enable Selects whether to enable input capture interrupt D request (ICID) when input capture flag D (ICFD) in TCSR is set to 1. 0: ICID requested by ICFD is disabled 1: ICID requested by ICFD is enabled
3	OCIAE	0	R/W	Output Compare Interrupt A Enable Selects whether to enable output compare interrupt A request (OCIA) when output compare flag A (OCFA) in TCSR is set to 1. 0: OCIA requested by OCFA is disabled 1: OCIA requested by OCFA is enabled

Bit	Bit Name	Initial Value	R/W	Description
2	OCIBE	0	R/W	Output Compare Interrupt B Enable Selects whether to enable output compare interrupt B request (OCIB) when output compare flag B (OCFB) in TCSR is set to 1. 0: OCIB requested by OCFB is disabled 1: OCIB requested by OCFB is enabled
1	OVIE	0	R/W	Timer Overflow Interrupt Enable Selects whether to enable a free-running timer overflow request interrupt (FOVI) when the timer overflow flag (OVF) in TCSR is set to 1. 0: FOVI requested by OVF is disabled 1: FOVI requested by OVF is enabled
0	—	1	R	Reserved This bit is always read as 1 and cannot be modified.

11.3.7 Timer Control/Status Register (TCSR)

TCSR is used for counter clear selection and control of interrupt request signals.

Bit	Bit Name	Initial Value	R/W	Description
7	ICFA	0	R/(W)*	Input Capture Flag A This status flag indicates that the FRC value has been transferred to ICRA by means of an input capture signal. When BUFEA = 1, ICFA indicates that the old ICRA value has been moved into ICRC and the new FRC value has been transferred to ICRA. Only 0 can be written to this bit to clear the flag. [Setting condition] When an input capture signal causes the FRC value to be transferred to ICRA [Clearing condition] Read ICFA when ICFA = 1, then write 0 to ICFA

Bit	Bit Name	Initial Value	R/W	Description
6	ICFB	0	R/(W)*	Input Capture Flag B This status flag indicates that the FRC value has been transferred to ICRB by means of an input capture signal. When BUFEB = 1, ICFB indicates that the old ICRB value has been moved into ICRD and the new FRC value has been transferred to ICRB. Only 0 can be written to this bit to clear the flag. [Setting condition] When an input capture signal causes the FRC value to be transferred to ICRB [Clearing condition] Read ICFB when ICFB = 1, then write 0 to ICFB
5	ICFC	0	R/(W)*	Input Capture Flag C This status flag indicates that the FRC value has been transferred to ICRC by means of an input capture signal. When BUFEA = 1, on occurrence of an input capture signal specified by the IEDGC bit at the FTIC input pin, ICFC is set but data is not transferred to ICRC. In buffer operation, ICFC can be used as an external interrupt signal by setting the ICICE bit to 1. Only 0 can be written to this bit to clear the flag. [Setting condition] When an input capture signal is received [Clearing condition] Read ICFC when ICFC = 1, then write 0 to ICFC
4	ICFD	0	R/(W)*	Input Capture Flag D This status flag indicates that the FRC value has been transferred to ICRD by means of an input capture signal. When BUFEB = 1, on occurrence of an input capture signal specified by the IEDGD bit at the FTID input pin, ICFD is set but data is not transferred to ICRD. In buffer operation, ICFD can be used as an external interrupt signal by setting the ICIDE bit to 1. Only 0 can be written to this bit to clear the flag. [Setting condition] When an input capture signal is received [Clearing condition] Read ICFD when ICFD = 1, then write 0 to ICFD

Bit	Bit Name	Initial Value	R/W	Description
3	OCFA	0	R/(W)*	Output Compare Flag A This status flag indicates that the FRC value matches the OCRA value. Only 0 can be written to this bit to clear the flag. [Setting condition] When FRC = OCRA [Clearing condition] Read OCFA when OCFA = 1, then write 0 to OCFA
2	OCFB	0	R/(W)*	Output Compare Flag B This status flag indicates that the FRC value matches the OCRB value. Only 0 can be written to this bit to clear the flag. [Setting condition] When FRC = OCRB [Clearing condition] Read OCFB when OCFB = 1, then write 0 to OCFB
1	OVF	0	R/(W)*	Timer Overflow This status flag indicates that the FRC has overflowed. Only 0 can be written to this bit to clear the flag. [Setting condition] When FRC overflows (changes from H'FFFF to H'0000) [Clearing condition] Read OVF when OVF = 1, then write 0 to OVF
0	CCLRA	0	R/W	Counter Clear A This bit selects whether the FRC is to be cleared at compare-match A (when the FRC and OCRA values match). 0: FRC clearing is disabled 1: FRC is cleared at compare-match A

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

11.3.8 Timer Control Register (TCR)

TCR selects the rising or falling edge of the input capture signals, enables the input capture buffer mode, and selects the FRC clock source.

Bit	Bit Name	Initial Value	R/W	Description
7	IEDGA	0	R/W	Input Edge Select A Selects the rising or falling edge of the input capture A signal (FTIA). 0: Capture on the falling edge of FTIA 1: Capture on the rising edge of FTIA
6	IEDGB	0	R/W	Input Edge Select B Selects the rising or falling edge of the input capture B signal (FTIB). 0: Capture on the falling edge of FTIB 1: Capture on the rising edge of FTIB
5	IEDGC	0	R/W	Input Edge Select C Selects the rising or falling edge of the input capture C signal (FTIC). 0: Capture on the falling edge of FTIC 1: Capture on the rising edge of FTIC
4	IEDGD	0	R/W	Input Edge Select D Selects the rising or falling edge of the input capture D signal (FTID). 0: Capture on the falling edge of FTID 1: Capture on the rising edge of FTID
3	BUFEA	0	R/W	Buffer Enable A Selects whether ICRC is to be used as a buffer register for ICRA. 0: ICRC is not used as a buffer register for ICRA 1: ICRC is used as a buffer register for ICRA
2	BUFEB	0	R/W	Buffer Enable B Selects whether ICRD is to be used as a buffer register for ICRB. 0: ICRD is not used as a buffer register for ICRB 1: ICRD is used as a buffer register for ICRB

Bit	Bit Name	Initial Value	R/W	Description
1	CKS1	0	R/W	Clock Select 1, 0
0	CKS0	0		Select clock source for FRC.
				00: ϕ/2 internal clock source
				01: ϕ/8 internal clock source
				10: ϕ/32 internal clock source
				11: External clock source (counting at FTCI rising edge)

11.3.9 Timer Output Compare Control Register (TOCR)

TOCR enables output from the output compare pins, selects the output levels, switches access between output compare registers A and B, controls the ICRD and OCRA operating modes, and switches access to input capture registers A, B, and C.

Bit	Bit Name	Initial Value	R/W	Description
7	ICRDMS	0	R/W	Input Capture D Mode Select
				Specifies whether ICRD is used in the normal operating mode or in the operating mode using OCRDM.
				0: The normal operating mode is specified for ICRD
				1: The operating mode using OCRDM is specified for ICRD
6	OCRAMS	0	R/W	Output Compare A Mode Select
				Specifies whether OCRA is used in the normal operating mode or in the operating mode using OCRAR and OCRAF.
				0: The normal operating mode is specified for OCRA
				1: The operating mode using OCRAR and OCRAF is specified for OCRA
5	ICRS	0	R/W	Input Capture Register Select
				The same addresses are shared by ICRA and OCRAR, by ICRB and OCRAF, and by ICRC and OCRDM. The ICRS bit determines which registers are selected when the shared addresses are read from or written to. The operation of ICRA, ICRB, and ICRC is not affected.
				0: ICRA, ICRB, and ICRC are selected
				1: OCRAR, OCRAF, and OCRDM are selected

Bit	Bit Name	Initial Value	R/W	Description
4	OCRS	0	R/W	Output Compare Register Select OCRA and OCRB share the same address. When this address is accessed, the OCRS bit selects which register is accessed. The operation of OCRA or OCRB is not affected. 0: OCRA is selected 1: OCRB is selected
3	OEA	0	R/W	Output Enable A Enables or disables output of the output compare A output pin (FTOA). 0: Output compare A output is disabled 1: Output compare A output is enabled
2	OEB	0	R/W	Output Enable B Enables or disables output of the output compare B output pin (FTOB). 0: Output compare B output is disabled 1: Output compare B output is enabled
1	OLVLA	0	R/W	Output Level A Selects the level to be output at the output compare A output pin (FTOA) in response to compare-match A (signal indicating a match between the FRC and OCRA values). When the OCRAMS bit is 1, this bit is ignored. 0: 0 is output at compare-match A 1: 1 is output at compare-match A
0	OLVLB	0	R/W	Output Level B Selects the level to be output at the output compare B output pin (FTOB) in response to compare-match B (signal indicating a match between the FRC and OCRB values). 0: 0 is output at compare-match B 1: 1 is output at compare-match B

11.4 Operation

11.4.1 Pulse Output

Figure 11.2 shows an example of 50%-duty pulses output with an arbitrary phase difference. When a compare match occurs while the CCLRA bit in TCSR is set to 1, the OLVLA and OLVLB bits are inverted by software.

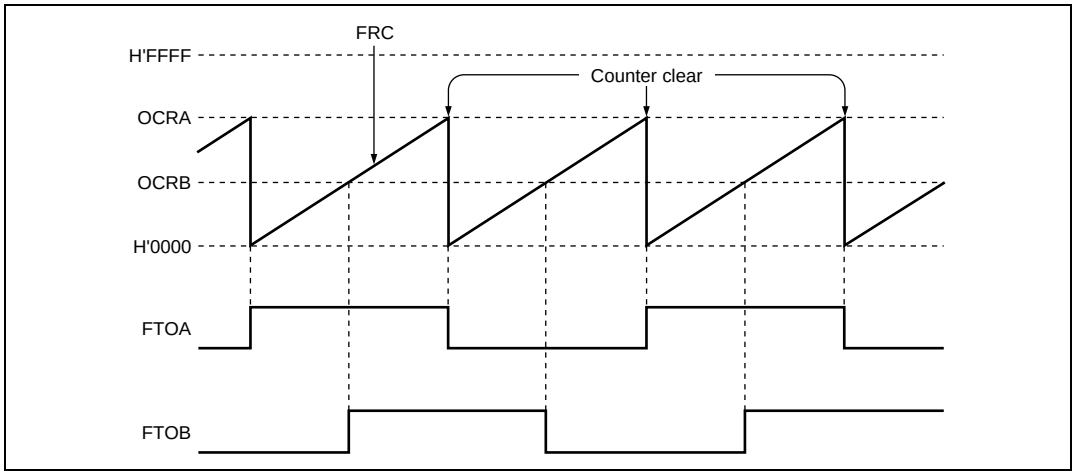


Figure 11.2 Example of Pulse Output

11.5 Operation Timing

11.5.1 FRC Increment Timing

Figure 11.3 shows the FRC increment timing with an internal clock source. Figure 11.4 shows the increment timing with an external clock source. The pulse width of the external clock signal must be at least 1.5 system clocks (ϕ). The counter will not increment correctly if the pulse width is shorter than 1.5 system clocks (ϕ).

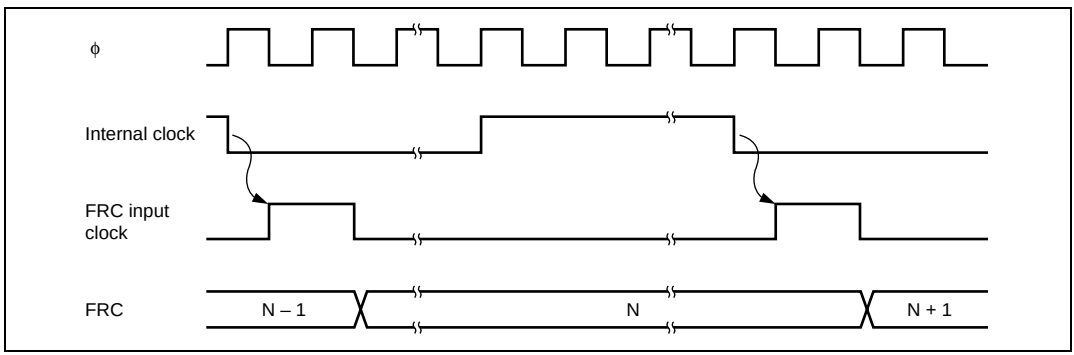


Figure 11.3 Increment Timing with Internal Clock Source

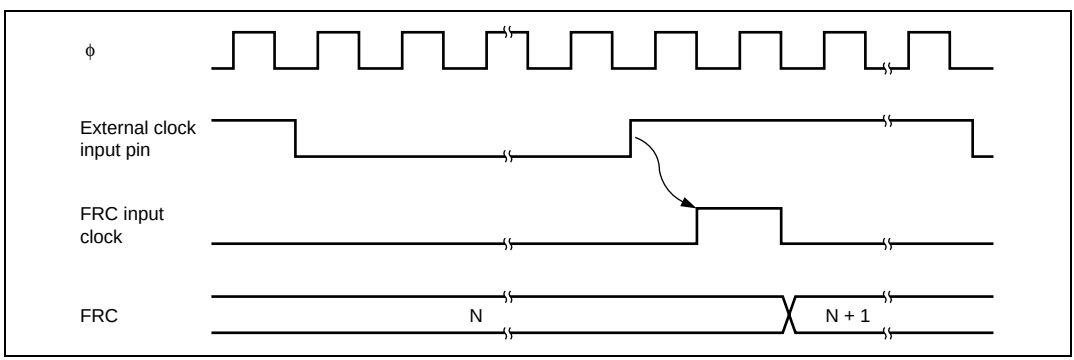


Figure 11.4 Increment Timing with External Clock Source

11.5.2 Output Compare Output Timing

A compare-match signal occurs at the last state when the FRC and OCR values match (at the timing when the FRC updates the counter value). When a compare-match signal occurs, the level selected by the OLVL bit in TOCR is output at the output compare pin (FTOA or FTOB). Figure 11.5 shows the timing of this operation for compare-match A.

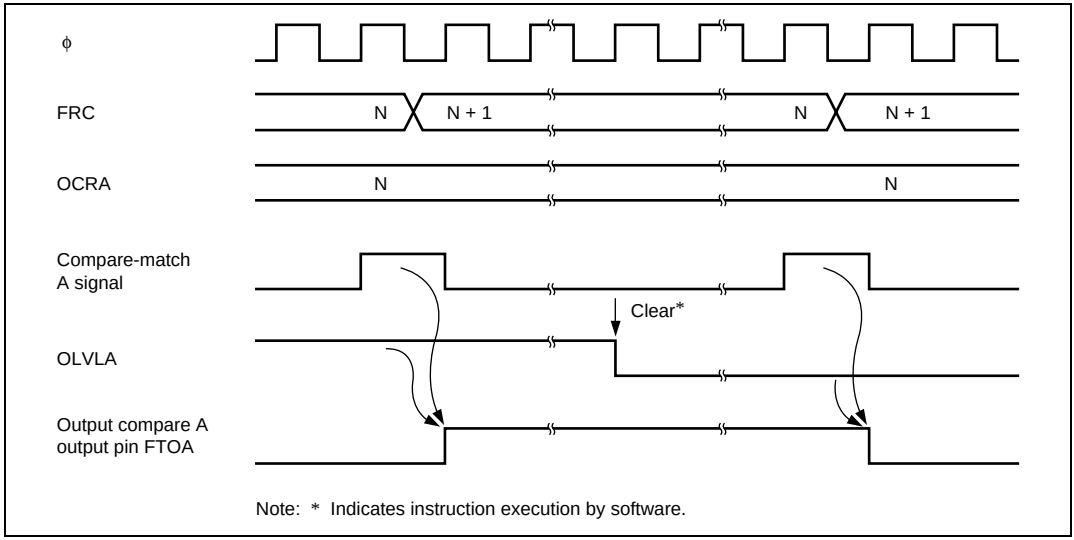


Figure 11.5 Timing of Output Compare A Output

11.5.3 FRC Clear Timing

FRC can be cleared when compare-match A occurs. Figure 11.6 shows the timing of this operation.

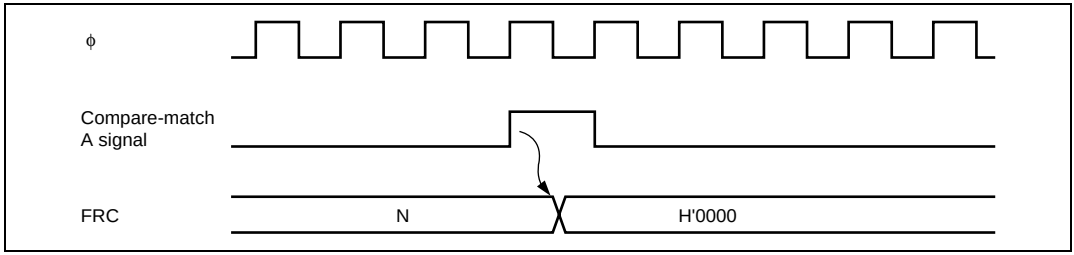


Figure 11.6 Clearing of FRC by Compare-Match A Signal

11.5.4 Input Capture Input Timing

The rising or falling edge can be selected for the input capture input timing by the IEDGA to IEDGD bits in TCR. Figure 11.7 shows the usual input capture timing when the rising edge is selected.

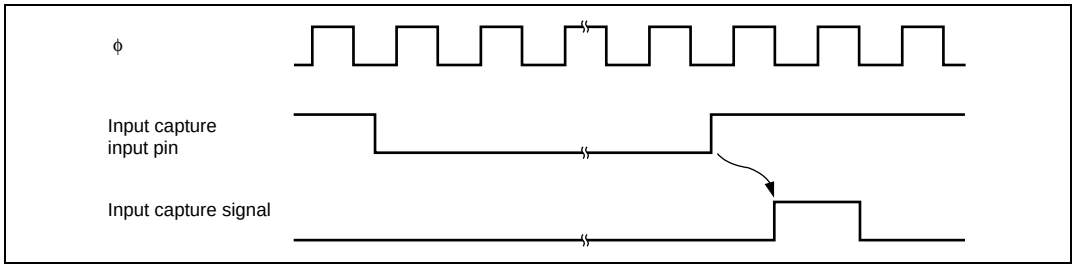


Figure 11.7 Input Capture Input Signal Timing (Usual Case)

If ICRA to ICRAD are read when the corresponding input capture signal arrives, the internal input capture signal is delayed by one system clock (ϕ). Figure 11.8 shows the timing for this case.

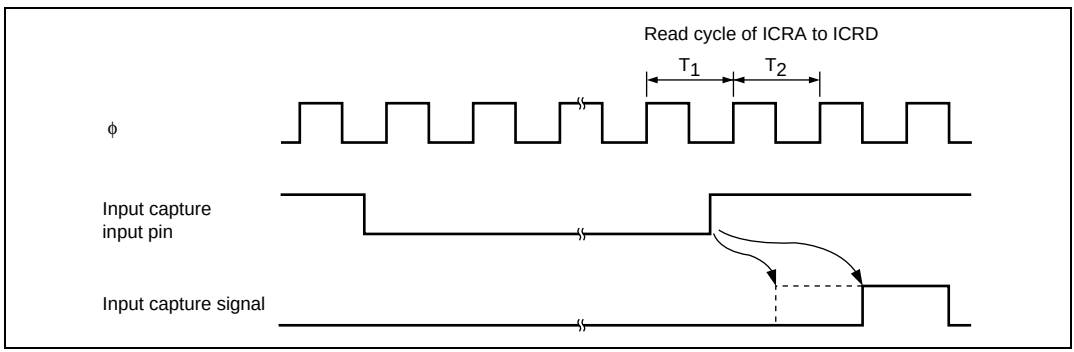


Figure 11.8 Input Capture Input Signal Timing (When ICRA to ICRD are Read)

11.5.5 Buffered Input Capture Input Timing

ICRC and ICRD can operate as buffers for ICRA and ICRB, respectively. Figure 11.9 shows how input capture operates when ICRC is used as ICRA's buffer register (BUFEA = 1) and IEDGA and IEDGC are set to different values (IEDGA = 0 and IEDGC = 1, or IEDGA = 1 and IEDGC = 0), so that input capture is performed on both the rising and falling edges of FTIA.

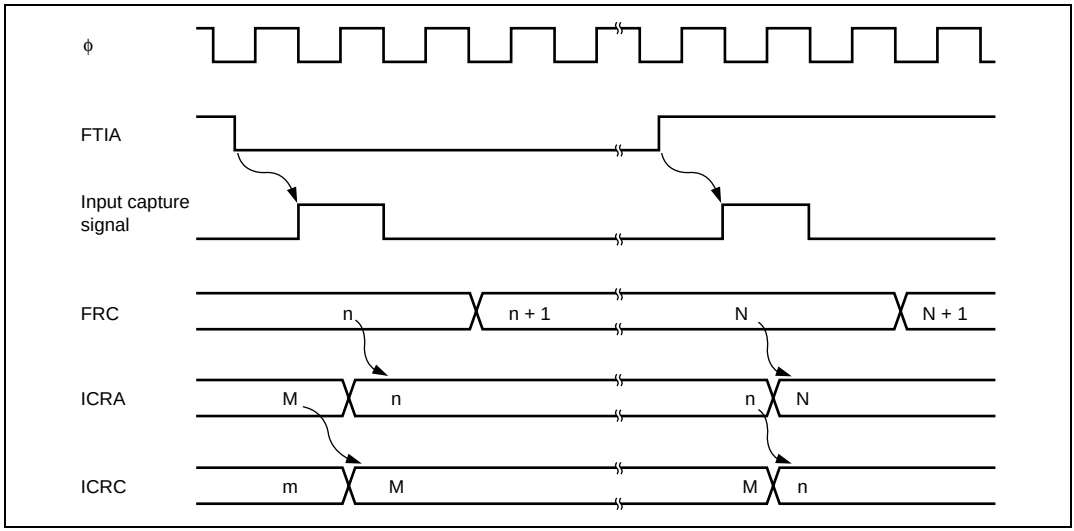


Figure 11.9 Buffered Input Capture Timing

Even when ICRC or ICRD is used as a buffer register, its input capture flag is set by the selected transition of its input capture signal. For example, if ICRC is used to buffer ICRA, when the edge transition selected by the IEDGC bit occurs on the FTIC input capture line, ICFC will be set, and if the ICICE bit is set at this time, an interrupt will be requested. The FRC value will not be transferred to ICRC, however. In buffered input capture, if either set of two registers to which data will be transferred (ICRA and ICRC, or ICRB and ICRD) is being read when the input capture input signal arrives, input capture is delayed by one system clock (ϕ). Figure 11.10 shows the timing when BUFEA = 1.

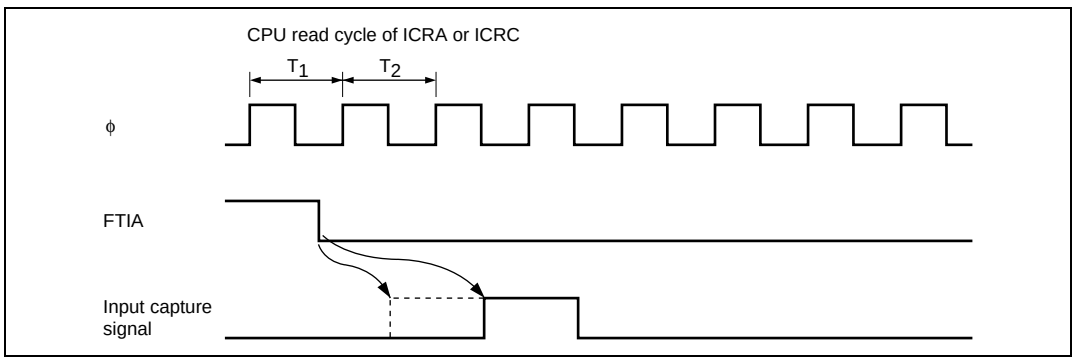


Figure 11.10 Buffered Input Capture Timing (BUFEA = 1)

11.5.6 Timing of Input Capture Flag (ICF) Setting

The input capture flag, ICFA, ICFB, ICFC, or ICFD, is set to 1 by the input capture signal. The FRC value is simultaneously transferred to the corresponding input capture register (ICRA, ICRB, ICRC, or ICRD). Figure 11.11 shows the timing of setting the ICFA to ICFD flag.

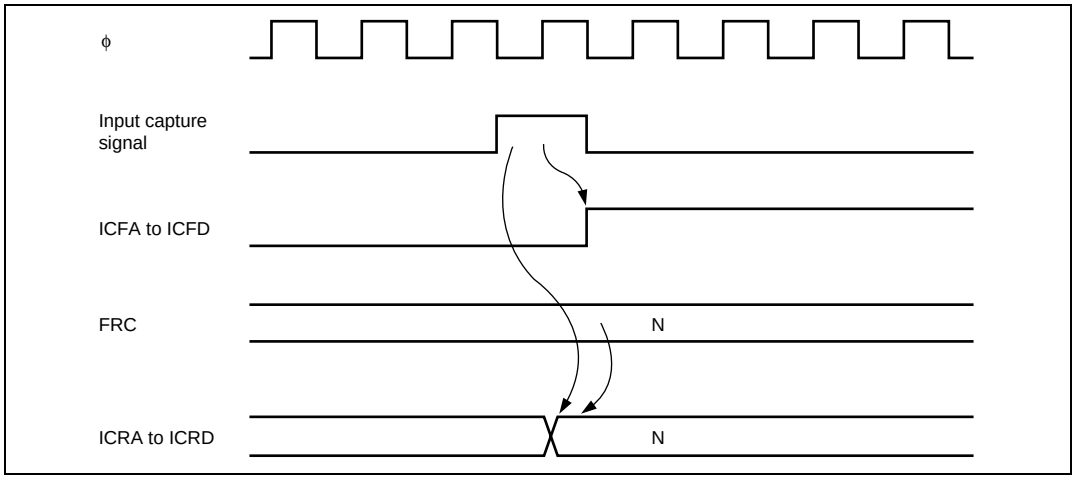


Figure 11.11 Timing of Input Capture Flag (ICFA, ICFB, ICFC, or ICFD) Setting

11.5.7 Timing of Output Compare Flag (OCF) setting

The output compare flag, OCFA or OCFB, is set to 1 by a compare-match signal generated when the FRC value matches the OCRA or OCRB value. This compare-match signal is generated at the last state in which the two values match, just before FRC increments to a new value. When the FRC and OCRA or OCRB value match, the compare-match signal is not generated until the next cycle of the clock source. Figure 11.12 shows the timing of setting the OCFA or OCFB flag.

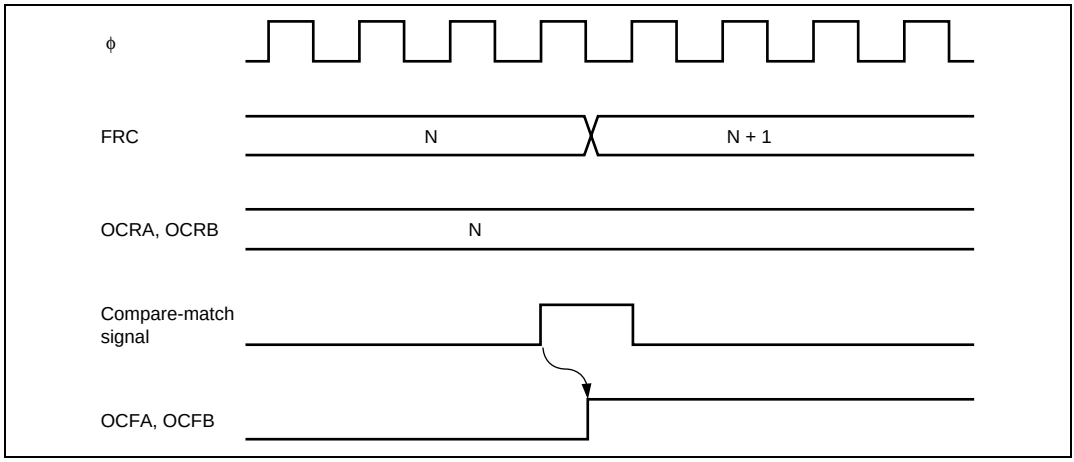


Figure 11.12 Timing of Output Compare Flag (OCFA or OCFB) Setting

11.5.8 Timing of FRC Overflow Flag Setting

The FRC overflow flag (OVF) is set to 1 when FRC overflows (changes from H'FFFF to H'0000). Figure 11.13 shows the timing of setting the OVF flag.

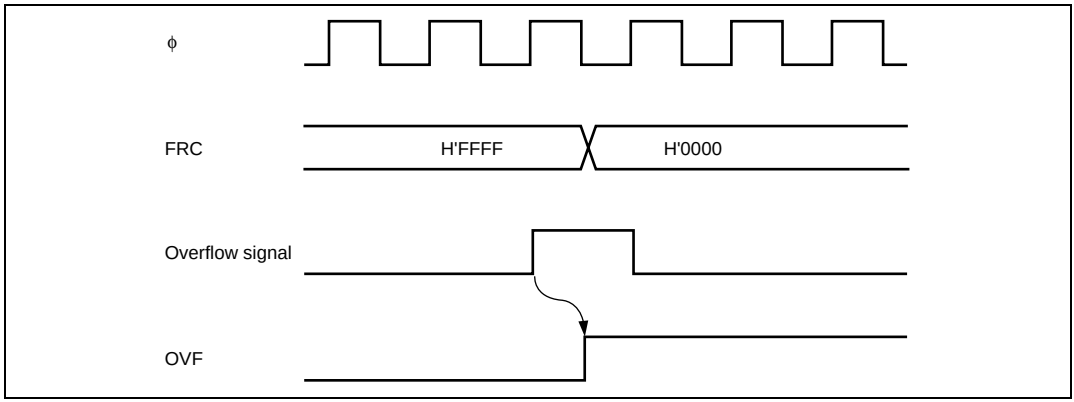


Figure 11.13 Timing of Overflow Flag (OVF) Setting

11.5.9 Automatic Addition Timing

When the OCRAMS bit in TOCR is set to 1, the contents of OCRAR and OCRAF are automatically added to OCRA alternately, and when an OCRA compare-match occurs a write to OCRA is performed. Figure 11.14 shows the OCRA write timing.

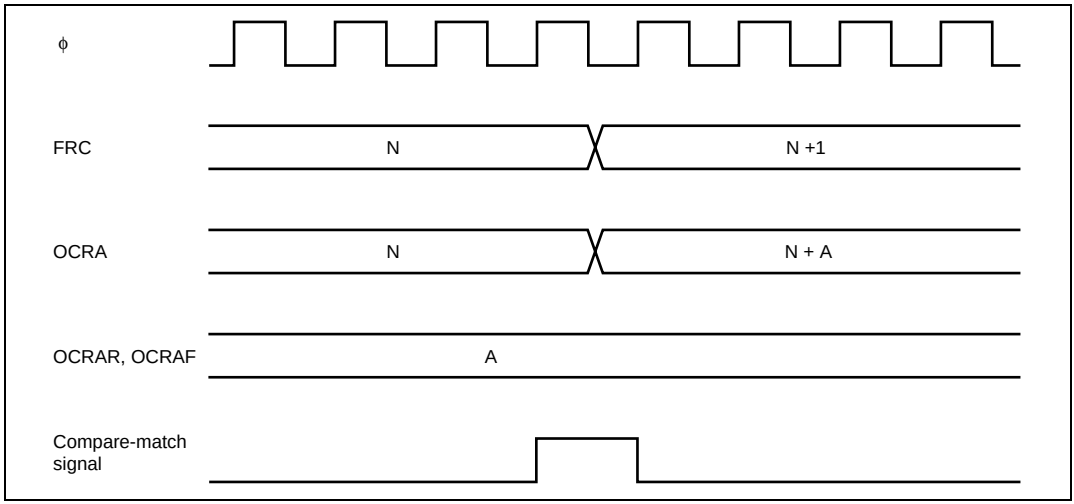


Figure 11.14 OCRA Automatic Addition Timing

11.5.10 Mask Signal Generation Timing

When the ICRDMS bit in TOCR is set to 1 and the contents of OCRDM are other than H'0000, a signal that masks the ICRD input capture signal is generated. The mask signal is set by the input capture signal. The mask signal is cleared by the sum of the ICRD contents and twice the OCRDM contents, and an FRC compare-match. Figure 11.15 shows the timing of setting the mask signal. Figure 11.16 shows the timing of clearing the mask signal.

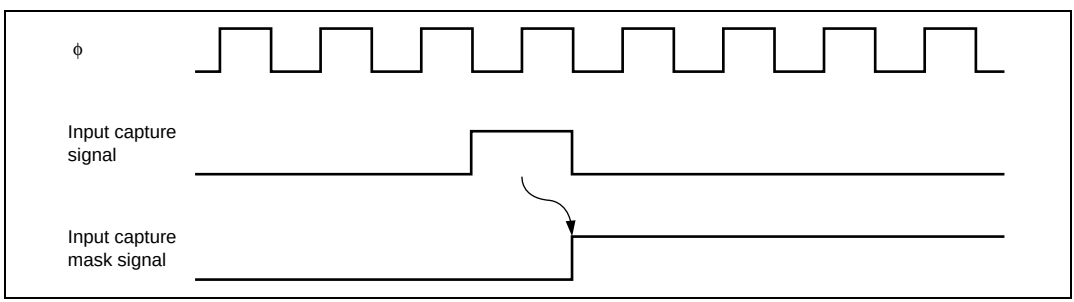


Figure 11.15 Timing of Input Capture Mask Signal Setting

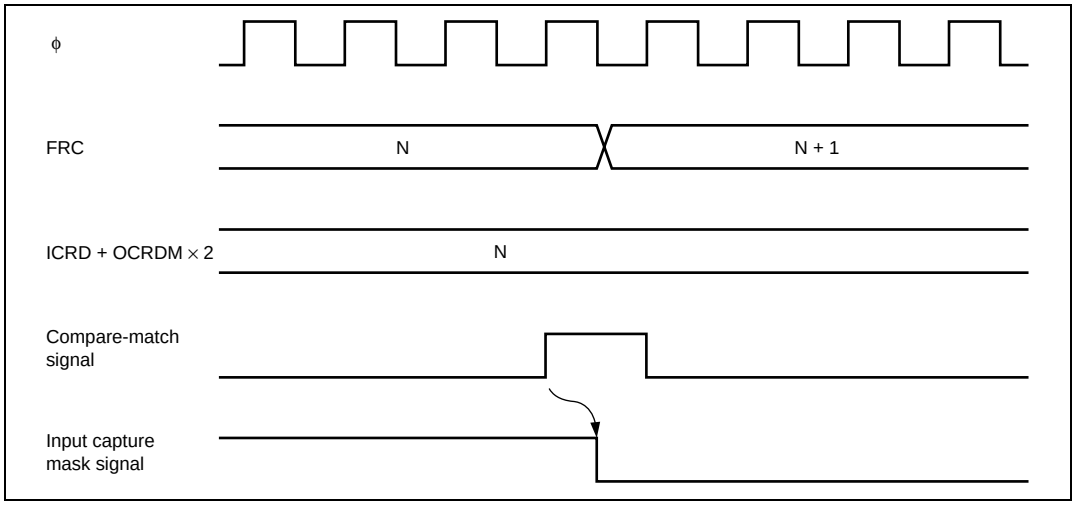


Figure 11.16 Timing of Input Capture Mask Signal Clearing

11.6 Interrupt Sources

The free-running timer can request seven interrupts: ICIA to ICID, OCIA, OCIB, and FOVI. Each interrupt can be enabled or disabled by an enable bit in TIER. Independent signals are sent to the interrupt controller for each interrupt. Table 11.2 lists the sources and priorities of these interrupts.

The ICIA, ICIB, OCIA, and OCIB interrupts can be used as the on-chip DTC activation sources.

Table 11.2 FRT Interrupt Sources

Interrupt	Interrupt Source	Interrupt Flag	DTC Activation	Priority
ICIA	Input capture of ICRA	ICFA	Enabled	High
ICIB	Input capture of ICRB	ICFB	Enabled	
ICIC	Input capture of ICRC	ICFC	Disabled	
ICID	Input capture of ICRD	ICFD	Disabled	
OCIA	Compare match of OCRA	OCFA	Enabled	
OCIB	Compare match of OCRB	OCFB	Enabled	
FOVI	Overflow of FRC	OVF	Disabled	Low

11.7 Usage Notes

11.7.1 Conflict between FRC Write and Clear

If an internal counter clear signal is generated during the state after an FRC write cycle, the clear signal takes priority and the write is not performed. Figure 11.17 shows the timing for this type of conflict.

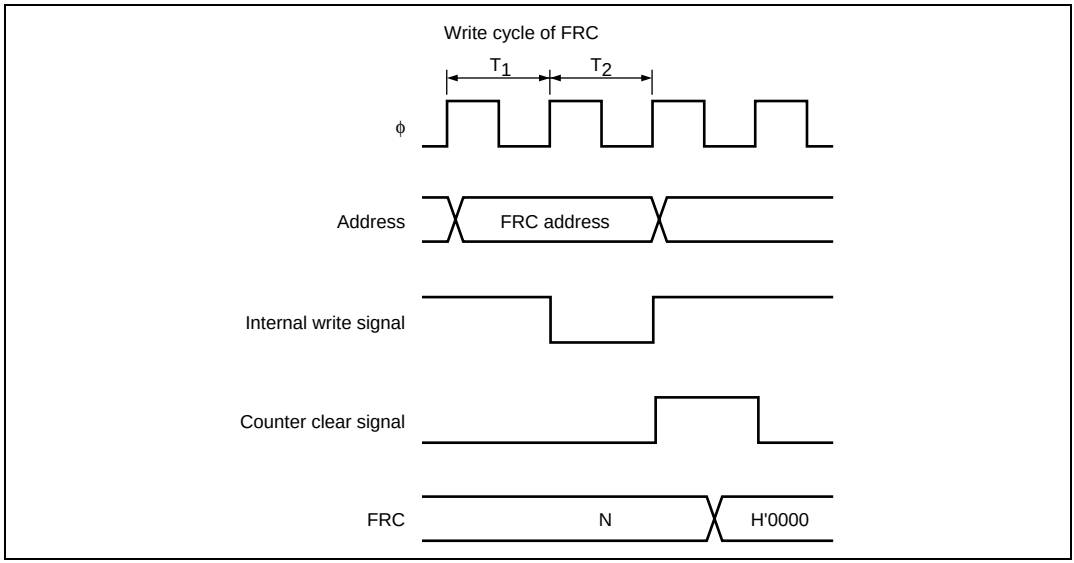


Figure 11.17 FRC Write-Clear Conflict

11.7.2 Conflict between FRC Write and Increment

If an FRC increment pulse is generated during the state after an FRC write cycle, the write takes priority and FRC is not incremented. Figure 11.18 shows the timing for this type of conflict.

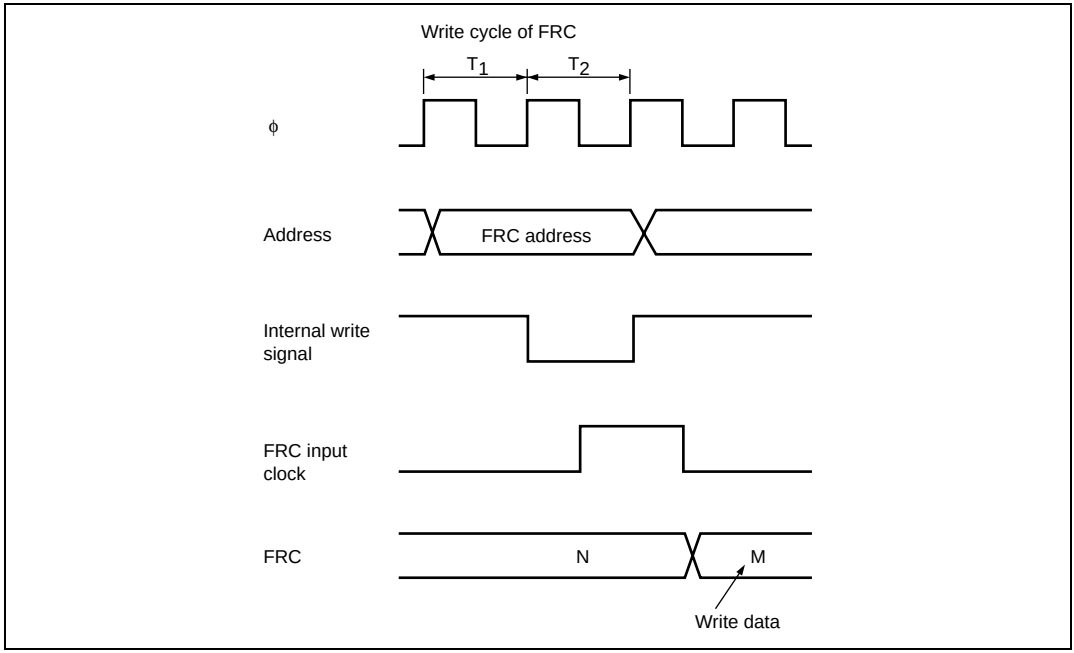


Figure 11.18 FRC Write-Increment Conflict

11.7.3 Conflict between OCR Write and Compare-Match

If a compare-match occurs during the state after an OCRA or OCRB write cycle, the write takes priority and the compare-match signal is disabled. Figure 11.19 shows the timing for this type of conflict.

If automatic addition of OCRAR and OCRAF to OCRA is selected, and a compare-match occurs in the cycle following the OCRA, OCRAR, and OCRAF write cycle, the OCRA, OCRAR and OCRAF write takes priority and the compare-match signal is disabled. Consequently, the result of the automatic addition is not written to OCRA. Figure 11.20 shows the timing for this type of conflict.

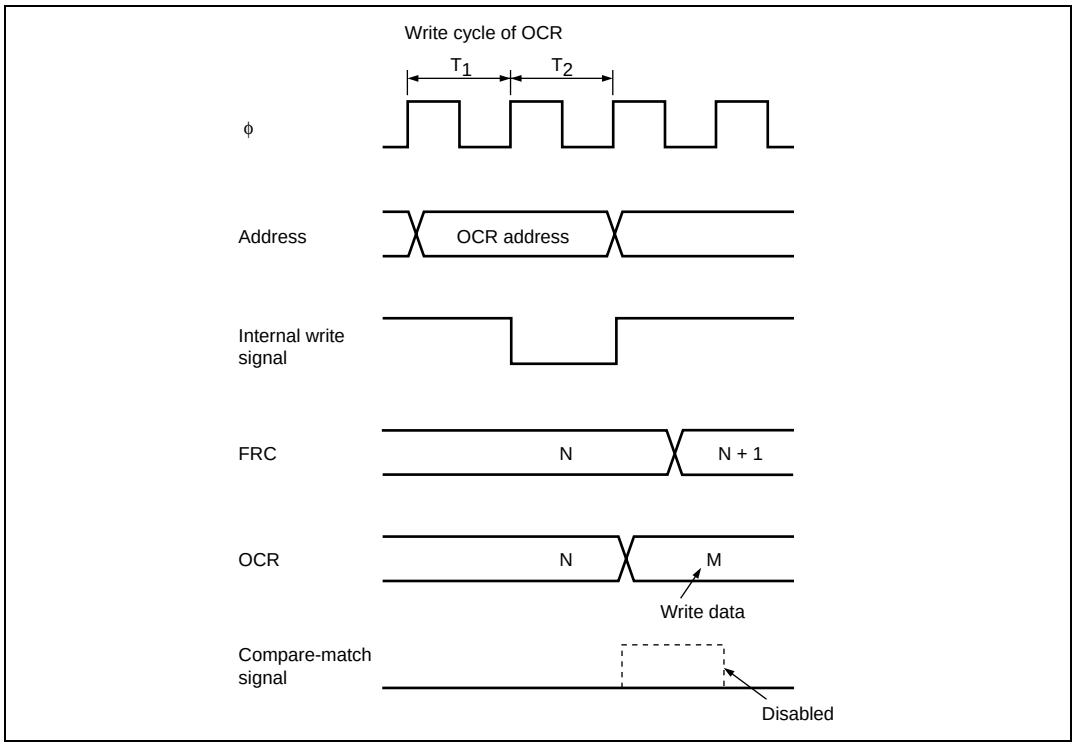


Figure 11.19 Conflict between OCR Write and Compare-Match (When Automatic Addition Function Is Not Used)

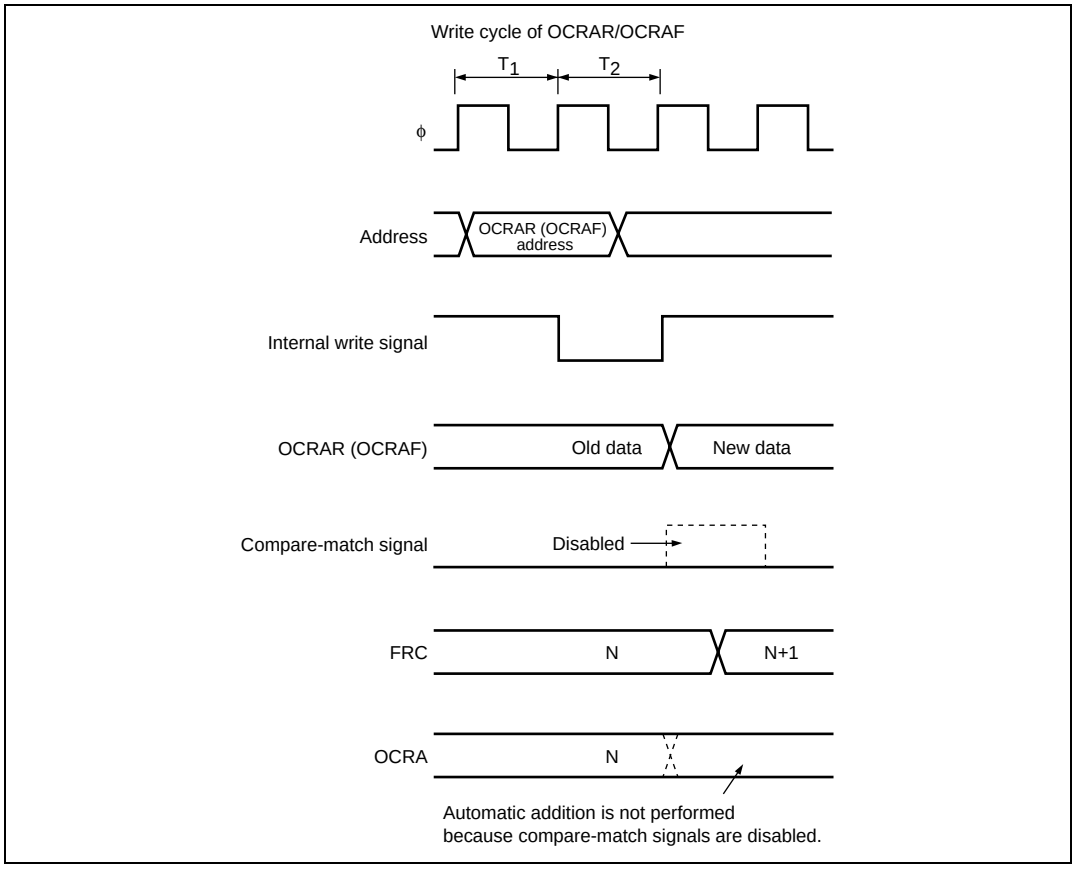


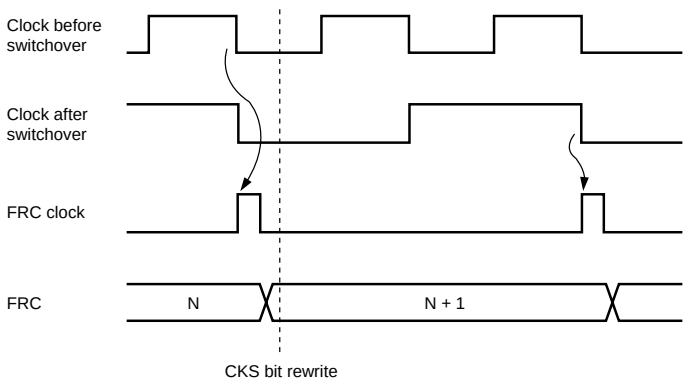
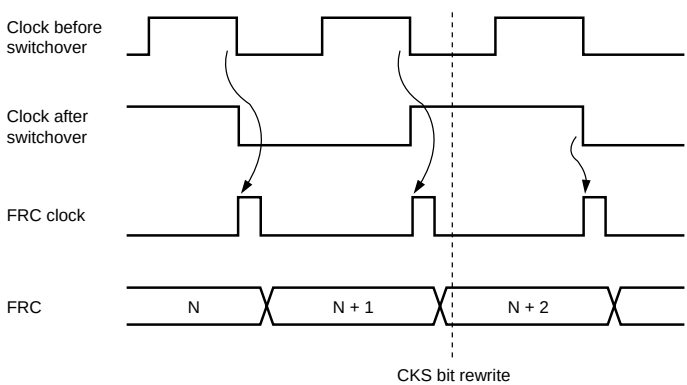
Figure 11.20 Conflict between OCRAR/OCRAF Write and Compare-Match (When Automatic Addition Function Is Used)

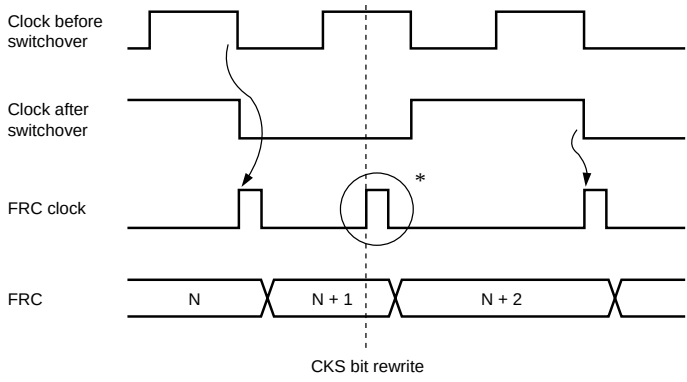
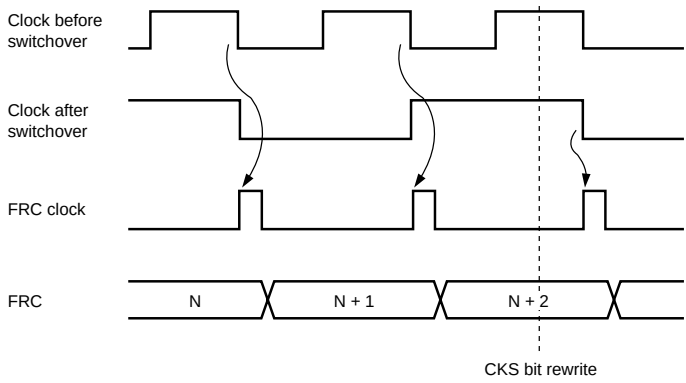
11.7.4 Switching of Internal Clock and FRC Operation

When the internal clock is changed, the changeover may cause FRC to increment. This depends on the time at which the clock is switched (bits CKS1 and CKS0 are rewritten), as shown in table 11.3.

When an internal clock is used, the FRC clock is generated on detection of the falling edge of the internal clock scaled from the system clock (ϕ). If the clock is changed when the old source is high and the new source is low, as in case no. 3 in table 11.3, the changeover is regarded as a falling edge that triggers the FRC clock, and FRC is incremented. Switching between an internal clock and external clock can also cause FRC to increment.

Table 11.3 Switching of Internal Clock and FRC Operation

No.	Timing of Switchover by Means of CKS1 and CKS0 Bits	FRC Operation
1	Switching from low to low	
2	Switching from low to high	

No.	Timing of Switchover by Means of CKS1 and CKS0 Bits	FRC Operation
3	Switching from high to low	
4	Switching from high to high	

Note: * Generated on the assumption that the switchover is a falling edge; FRC is incremented.

11.7.5 Module Stop Mode Setting

FRT operation can be enabled or disabled using the module stop control register. The initial setting is for FRT operation to be halted. Register access is enabled by canceling the module stop mode. For details, refer to section 26, Power-Down Modes.

Section 12 8-Bit Timer (TMR)

This LSI has an on-chip 8-bit timer module (TMR_0 and TMR_1) with two channels operating on the basis of an 8-bit counter. The 8-bit timer module can count external events, and can also 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.

This LSI also has a similar on-chip 8-bit timer module (TMR_Y and TMR_X) with two channels, which can be used through connection to the timer connection.

12.1 Features

- Selection of clock sources
  - TMR_0, TMR_1: The counter input clock can be selected from six internal clocks and an external clock
  - TMR_Y, TMR_X: The counter input clock can be selected from three internal clocks and an external clock
- Selection of three ways to clear the counters
  - The counters can be cleared on compare-match A or compare-match 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. (The TMR_Y does not have a timer output pin.)
- Cascading of TMR_0 and TMR_1
  - (TMR_Y and TMR_X cannot be cascaded.)

    Operation as a 16-bit timer can be performed using TMR_0 as the upper half and 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).
- Multiple interrupt sources for each channel
  - TMR_0, TMR_1, and TMR_Y: Three types of interrupts: Compare-match A, compare-match B, and overflow
  - TMR_X: Input capture

Figures 12.1 and 12.2 show block diagrams of the 8-bit timer module.

TMR_X and TMR_Y have a similar configuration, but cannot be cascaded. TMR_X also has an input capture function. For details, see section 13, Timer Connection.

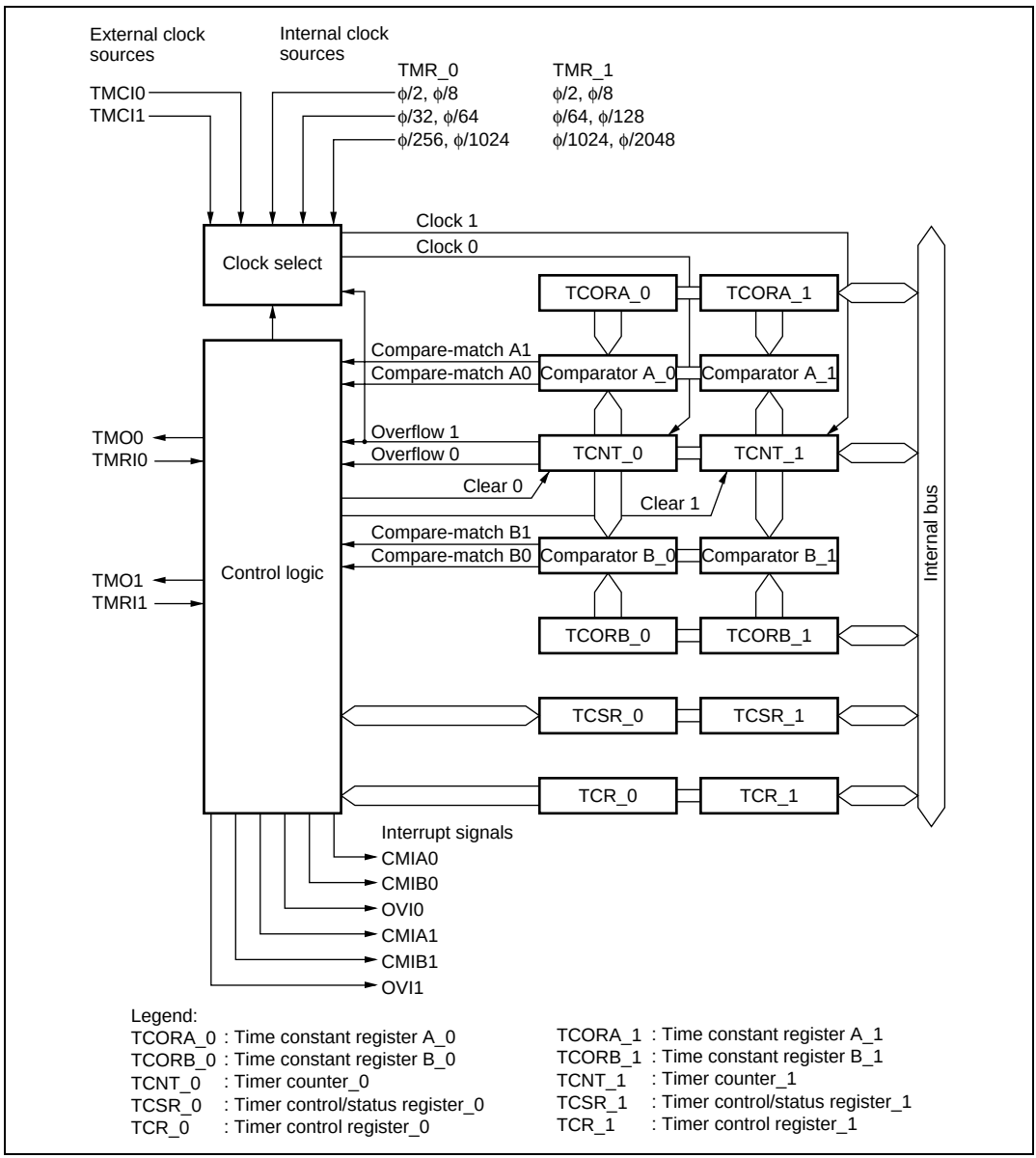
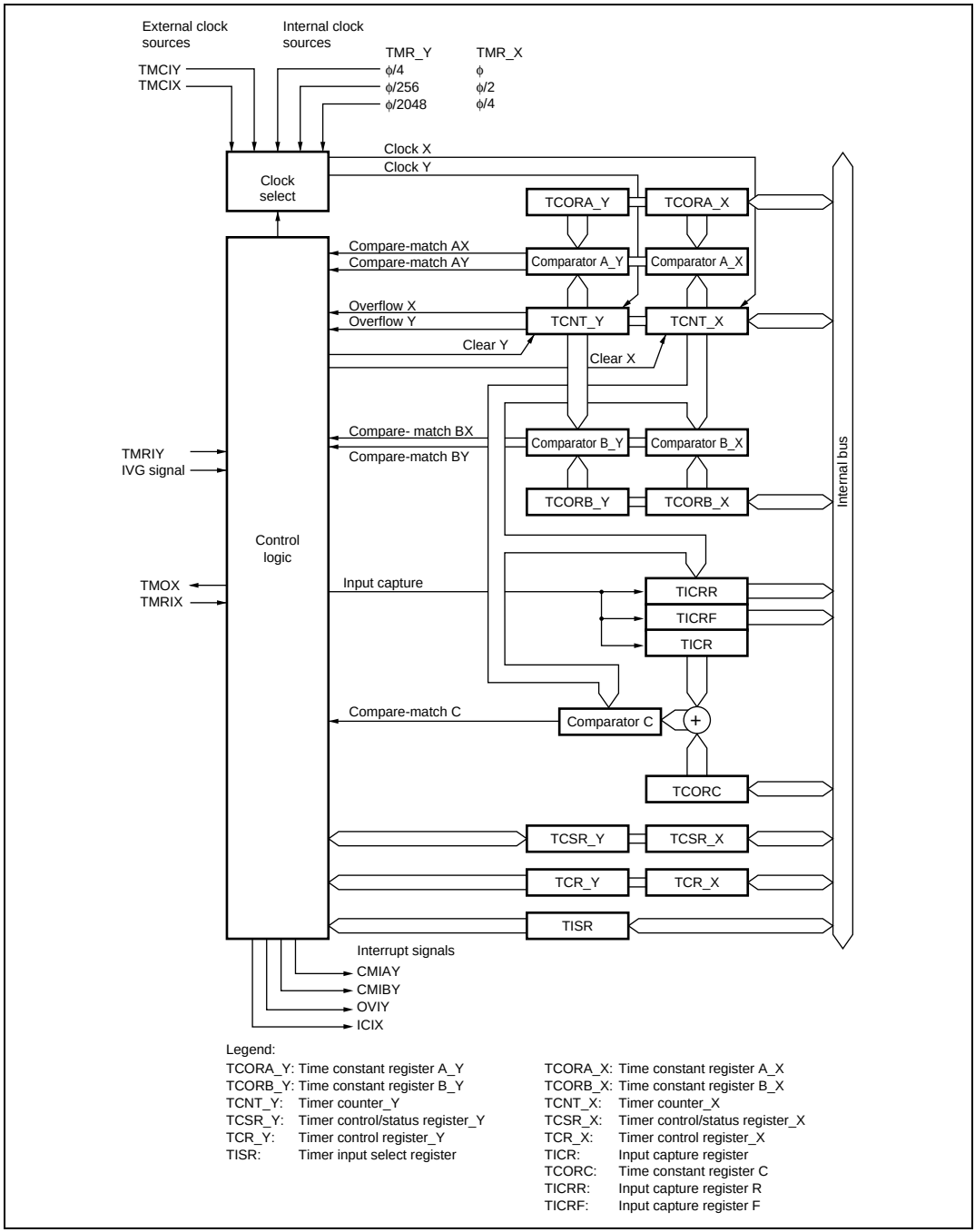


Figure 12.1 Block Diagram of 8-Bit Timers (TMR_0 and TMR_1)



Legend:

TCORA_Y:	Time constant register A_Y	TCORA_X:	Time constant register A_X
TCORB_Y:	Time constant register B_Y	TCORB_X:	Time constant register B_X
TCNT_Y:	Timer counter_Y	TCNT_X:	Timer counter_X
TCSR_Y:	Timer control/status register_Y	TCSR_X:	Timer control/status register_X
TCR_Y:	Timer control register_Y	TCR_X:	Timer control register_X
TISR:	Timer input select register	TICR:	Input capture register
		TCORC:	Time constant register C
		TICRR:	Input capture register R
		TICRF:	Input capture register F

Figure 12.2 Block Diagram of 8-Bit Timers (TMR_Y and TMR_X)

12.2 Input/Output Pins

Table 12.1 summarizes the input and output pins of the TMR.

Table 12.1 Pin Configuration

Channel	Name	Symbol	I/O	Function
TMR_0	Timer output	TMO0	Output	Output controlled by compare-match
	Timer clock input	TMCI0	Input	External clock input for the counter
	Timer reset input	TMRI0	Input	External reset input for the counter
TMR_1	Timer output	TMO1	Output	Output controlled by compare-match
	Timer clock input	TMCI1	Input	External clock input for the counter
	Timer reset input	TMRI1	Input	External reset input for the counter
TMR_Y	Timer clock/reset input	VSYNCI/TMIY (TMCIY/TMRIY)	Input	External clock input/external reset input for the counter
TMR_X	Timer output	TMOX	Output	Output controlled by compare-match
	Timer clock/reset input	HFBACKI/TMIX (TMCIX/TMRIX)	Input	External clock input/external reset input for the counter

12.3 Register Descriptions

The TMR has the following registers. For details on the serial timer control register, refer to section 3.2.3, Serial Timer Control Register (STCR). For details on timer connection register S, refer to section 13.3.3, Timer Connection Register S (TCONRS).

- Timer counter (TCNT)
- Time constant register A (TCORA)
- Time constant register B (TCORB)
- Timer control register (TCR)
- Timer control/status register (TCSR)
- Timer input select register (TISR)*1
- Time constant register C (TCORC)*2
- Input capture register R (TICRR)*2
- Input capture register F (TICRF)*2

Notes: 1. TISR is only for the TMR_Y.
2. TCORC, TICRR, and TICRF are only for the TMR_X.

12.3.1 Timer Counter (TCNT)

Each TCNT is an 8-bit readable/writable up-counter. TCNT_0 and TCNT_1 comprise a single 16-bit register, so they can be accessed together by word access. The clock source is selected by the CKS2 to CKS0 bits in TCR. TCNT can be cleared by an external reset input signal, compare-match A signal or compare-match B signal. The method of clearing can be selected by the CCLR1 and CCLR0 bits in TCR. When TCNT overflows (changes from H'FF to H'00), the OVF bit in TCSR is set to 1. TCNT is initialized to H'00.

12.3.2 Time Constant Register A (TCORA)

TCORA is an 8-bit readable/writable register. TCORA_0 and TCORA_1 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 to 1. 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 these compare-match A signals and the settings of output select bits OS1 and OS0 in TCSR. TCORA is initialized to H'FF.

12.3.3 Time Constant Register B (TCORB)

TCORB is an 8-bit readable/writable register. TCORB_0 and TCORB_1 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 to 1. 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 these compare-match B signals and the settings of output select bits OS3 and OS2 in TCSR. TCORB is initialized to H'FF.

12.3.4 Timer Control Register (TCR)

TCR selects the TCNT clock source and the condition by which TCNT is cleared, and enables/disables 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. Note that a CMIB interrupt is not generated by TMR_X, regardless of the CMIEB value. 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. Note that a CMIA interrupt is not generated by TMR_X, regardless of the CMIEA value. 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. Note that an OVI interrupt is not generated by TMR_X, regardless of the OVIE value. 0: OVF interrupt request (OVI) is disabled 1: OVF interrupt request (OVI) is enabled
4	CCLR1	0	R/W	Counter Clear 1, 0
3	CCLR0	0	R/W	These bits select the method by which the timer counter 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
2	CKS2	0	R/W	Clock Select 2 to 0
1	CKS1	0	R/W	These bits select the clock input to TCNT and count condition, together with the ICKS1 and ICKS0 bits in STCR. For details, see table 12.2.
0	CKS0	0	R/W	

Table 12.2 Clock Input to TCNT and Count Condition

	TCR			STCR		
Channel	**CKS2**	**CKS1**	**CKS0**	**ICKS1**	**ICKS0**	**Description**
TMR_0	0	0	0	—	—	Disables clock input
	0	0	1	—	0	Increments at falling edge of internal clock φ/8
	0	0	1	—	1	Increments at falling edge of internal clock φ/2
	0	1	0	—	0	Increments at falling edge of internal clock φ/64
	0	1	0	—	1	Increments at falling edge of internal clock φ/32
	0	1	1	—	0	Increments at falling edge of internal clock φ/1024
	0	1	1	—	1	Increments at falling edge of internal clock φ/256
	1	0	0	—	—	Increments at overflow signal from TCNT_1*
TMR_1	0	0	0	—	—	Disables clock input
	0	0	1	0	—	Increments at falling edge of internal clock φ/8
	0	0	1	1	—	Increments at falling edge of internal clock φ/2
	0	1	0	0	—	Increments at falling edge of internal clock φ/64
	0	1	0	1	—	Increments at falling edge of internal clock φ/128
	0	1	1	0	—	Increments at falling edge of internal clock φ/1024
	0	1	1	1	—	Increments at falling edge of internal clock φ/2048
	1	0	0	—	—	Increments at compare-match A from TCNT_0*
TMR_Y	0	0	0	—	—	Disables clock input
	0	0	1	—	—	Increments at falling edge of internal clock φ/4
	0	1	0	—	—	Increments at falling edge of internal clock φ/256
	0	1	1	—	—	Increments at falling edge of internal clock φ/2048
	1	0	0	—	—	Disables clock input
TMR_X	0	0	0	—	—	Disables clock input
	0	0	1	—	—	Increments at falling edge of internal clock φ
	0	1	0	—	—	Increments at falling edge of internal clock φ/2
	0	1	1	—	—	Increments at falling edge of internal clock φ/4
	1	0	0	—	—	Disables clock input
Common	1	0	1	—	—	Increments at rising edge of external clock
	1	1	0	—	—	Increments at falling edge of external clock
	1	1	1	—	—	Increments at both rising and falling edges of external clock.

Note: * If the TMR_0 clock input is set as the TCNT_1 overflow signal and the TMR_1 clock input is set as the TCNT_0 compare-match signal simultaneously, a count-up clock cannot be generated.

12.3.5 Timer Control/Status Register (TCSR)

TCSR indicates the 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 the values of TCNT_0 and TCORB_0 match [Clearing conditions] • Read CMFB when CMFB = 1, then write 0 in CMFB • When the DTC is activated by a CMIB interrupt
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When the values of TCNT_0 and TCORA_0 match [Clearing conditions] • Read CMFA when CMFA = 1, then write 0 in CMFA • When the DTC is activated by a CMIA interrupt
5	OVF	0	R/(W)*	Timer Overflow Flag [Setting condition] When TCNT_0 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, 2 These bits specify how the TMO0 pin output level is to be changed by compare-match B of TCORB_0 and TCNT_0. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)
2	OS2	0	R/W	
1	OS1	0	R/W	Output Select 1, 0 These bits specify how the TMO0 pin output level is to be changed by compare-match A of TCORA_0 and TCNT_0. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)
0	OS0	0	R/W	

Note: * Only 0 can be written, for flag clearing.

- TCSR_1

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W)*	Compare-Match Flag B [Setting condition] When the values of TCNT_1 and TCORB_1 match [Clearing conditions] • Read CMFB when CMFB = 1, then write 0 in CMFB • When the DTC is activated by a CMIB interrupt
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When the values of TCNT_1 and TCORA_1 match [Clearing conditions • Read CMFA when CMFA = 1, then write 0 in CMFA • When the DTC is activated by a CMIA interrupt

Bit	Bit Name	Initial Value	R/W	Description
5	OVF	0	R/(W)*	Timer Overflow Flag [Setting condition] When TCNT_1 overflows from H'FF to H'00 [Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
4	—	1	R	Reserved This bit is always read as 1 and cannot be modified.
3	OS3	0	R/W	Output Select 3, 2
2	OS2	0	R/W	These bits specify how the TMO1 pin output level is to be changed by compare-match B of TCORB_1 and TCNT_1. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)
1	OS1	0	R/W	Output Select 1, 0
0	OS0	0	R/W	These bits specify how the TMO1 pin output level is to be changed by compare-match A of TCORA_1 and TCNT_1. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)

Note: * Only 0 can be written, for flag clearing.

- TCSR_Y

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W)*1	Compare-Match Flag B [Setting condition] When the values of TCNT_Y and TCORB_Y match [Clearing conditions] • Read CMFB when CMFB = 1, then write 0 in CMFB • When the DTC is activated by a CMIB interrupt
6	CMFA	0	R/(W)*1	Compare-Match Flag A [Setting condition] When the values of TCNT_Y and TCORA_Y match [Clearing conditions] • Read CMFA when CMFA = 1, then write 0 in CMFA • When the DTC is activated by a CMIA interrupt
5	OVF	0	R/(W)*1	Timer Overflow Flag [Setting condition] When TCNT_Y overflows from H'FF to H'00 [Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
4	ICIE	0	R/W	Input Capture Interrupt Enable Enables or disables the ICF interrupt request (ICIX) when the ICF bit in TCSR_X is set to 1. 0: ICF interrupt request (ICIX) is disabled 1: ICF interrupt request (ICIX) is enabled

Bit	Bit Name	Initial Value	R/W	Description
3	OS3	0	R/W	Output Select 3, 2
2	OS2	0	R/W	These bits specify how the TMOY pin*2 output level is to be changed by compare-match B of TCORB_Y and TCNT_Y. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)
1	OS1	0	R/W	Output Select 1, 0
0	OS0	0	R/W	These bits specify how the TMOY pin*2 output level is to be changed by compare-match A of TCORA_Y and TCNT_Y. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)

Notes: 1. Only 0 can be written, for flag clearing.
2. This product does not have a TMOY external output pin.

- TCSR_X

Bit	Bit Name	Initial Value	R/W	Description
7	CMFB	0	R/(W)*	Compare-Match Flag B [Setting condition] When the values of TCNT_X and TCORB_X match [Clearing conditions] • Read CMFB when CMFB = 1, then write 0 in CMFB • When the DTC is activated by a CMIB interrupt
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When the values of TCNT_X and TCORA_X match [Clearing conditions] • Read CMFA when CMFA = 1, then write 0 in CMFA • When the DTC is activated by a CMIA interrupt

Bit	Bit Name	Initial Value	R/W	Description
5	OVF	0	R/(W)*	Timer Overflow Flag [Setting condition] When TCNT_X overflows from H'FF to H'00 [Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
4	ICF	0	R/(W)*	Input Capture Flag [Setting condition] When a rising edge and falling edge is detected in the external reset signal in that order, after the ICST bit in TCONRI of the timer connection is set to 1 [Clearing condition] Read ICF when ICF = 1, then write 0 in ICF
3	OS3	0	R/W	Output Select 3, 2 These bits specify how the TMOX pin output level is to be changed by compare-match B of TCORB_X and TCNT_X. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)
2	OS2	0	R/W	
1	OS1	0	R/W	Output Select 1, 0 These bits specify how the TMOX pin output level is to be changed by compare-match A of TCORA_X and TCNT_X. 00: No change 01: 0 is output 10: 1 is output 11: Output is inverted (toggle output)
0	OS0	0	R/W	

Note: * Only 0 can be written, for flag clearing.

12.3.6 Input Capture Register (TICR)

TICR is an 8-bit register. The contents of TCNT are transferred to TICR at the rising edge of the external reset input. TICR cannot be directly accessed by the CPU. The TICR function is used for the timer connection. For details, refer to section 13, Timer Connection.

12.3.7 Time Constant Register (TCORC)

TCORC is an 8-bit readable/writable register. The sum of contents of TCORC and TICR is always compared with TCNT. When a match is detected, a compare-match C signal is generated. However, comparison at the T2 state in the write cycle to TCORC and at the input capture cycle of TICR is disabled. TCORC is initialized to H'FF. The TCORC function is used for the timer connection. For details, refer to section 13, Timer Connection.

12.3.8 Input Capture Registers R and F (TICRR, TICRF)

TICRR and TICRF are 8-bit read-only registers. The contents of TCNT are transferred at the rising edge and falling edge of the external reset input in that order, when the ICST bit in TCONRI of the timer connection is set to 1. The ICST bit is cleared to 0 when one capture operation ends. TICRR and TICRF are initialized to H'00. The TICRR and TICRF functions are used for timer connection. For details, refer to section 13, Timer Connection.

12.3.9 Timer Input Select Register (TISR)

TISR selects a signal source of external clock/reset input for the counter.

Bit	Bit Name	Initial Value	R/W	Description
7 to 1	—	All 1	R/(W)	Reserved The initial values should not be modified.
0	IS	0	R/W	Input Select Selects an internal synchronization signal (IVG signal) or timer clock/reset input pin VSYNCI/TMIY (TMCIY/TMRIY) as the signal source of external clock/reset input for the TMR_Y counter. 0: IVG signal is selected 1: VSYNCI/TMIY (TMCIY/TMRIY) is selected

12.4 Operation

12.4.1 Pulse Output

Figure 12.3 shows an example for outputting an arbitrary duty pulse.

1. Clear the CCLR1 bit in TCR to 0 so that TCNT is cleared according to the compare match of TCORA, and then set the CCLR0 bit to 1.
2. Set the OS3 to OS0 bits in TCSR to B'0110 so that 1 is output according to the compare match of TCORA and 0 is output according to the compare match of TCORB.

According to the above settings, the waveforms with the TCORA cycle and TCORB pulse width can be output without the intervention of software.

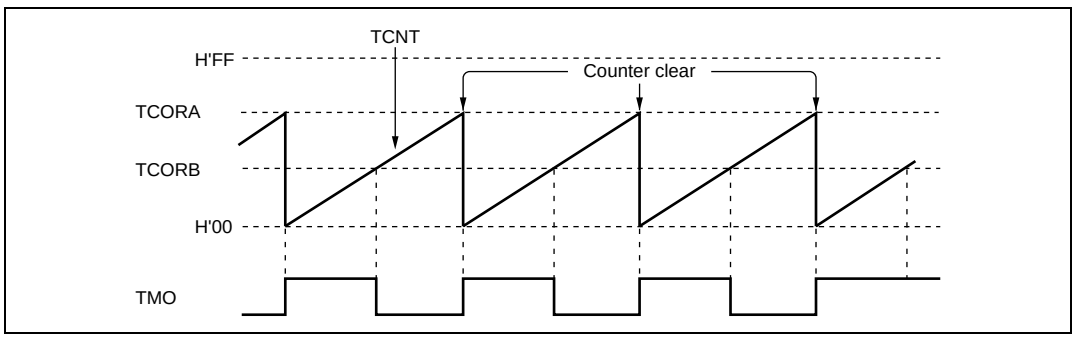


Figure 12.3 Pulse Output Example

12.5 Operation Timing

12.5.1 TCNT Count Timing

Figure 12.4 shows the TCNT count timing with an internal clock source. Figure 12.5 shows the TCNT count timing with an external clock source. The pulse width of the external clock signal must be at least 1.5 system clocks (ϕ) for a single edge and at least 2.5 system clocks (ϕ) for both edges. The counter will not increment correctly if the pulse width is less than these values.

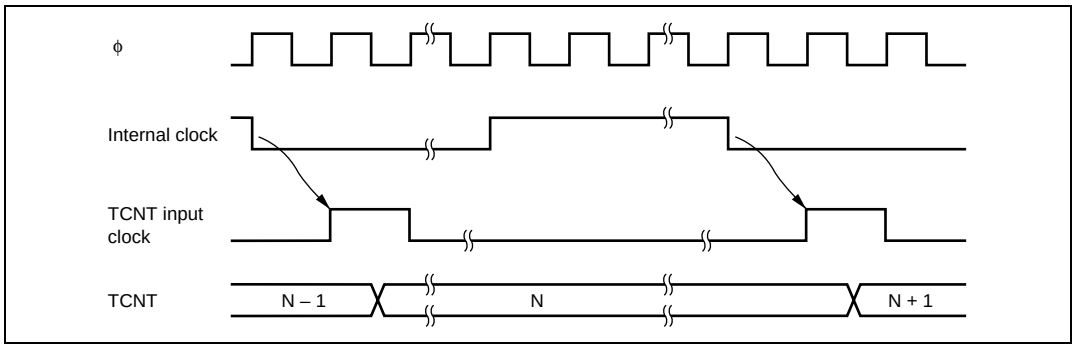


Figure 12.4 Count Timing for Internal Clock Input

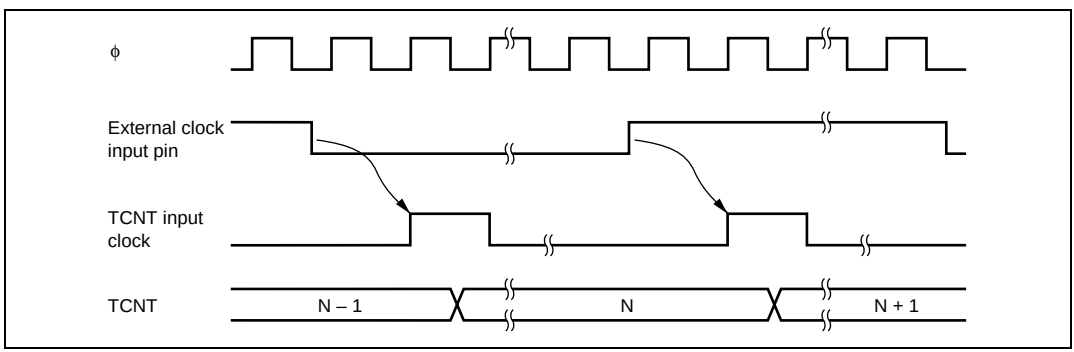


Figure 12.5 Count Timing for External Clock Input (Both Edges)

12.5.2 Timing of CMFA and CMFB Setting at Compare-Match

The CMFA and CMFB flags in TCSR are set to 1 by a compare-match signal generated when the TCNT and TCOR values match. The compare-match signal is generated at the last state in which the match is true, just when the timer counter is updated. Therefore, when TCNT and TCOR match, the compare-match signal is not generated until the next TCNT input clock. Figure 12.6 shows the timing of CMF flag setting.

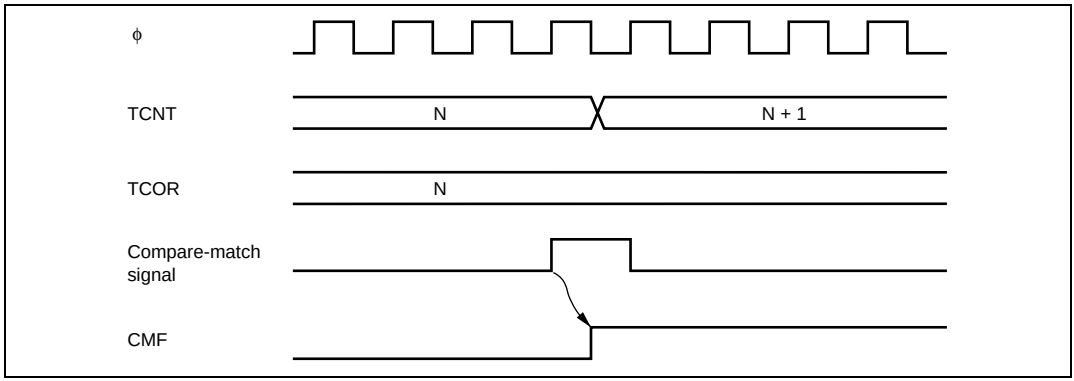


Figure 12.6 Timing of CMF Setting at Compare-Match

12.5.3 Timing of Timer Output at Compare-Match

When a compare-match signal occurs, the timer output changes as specified by the OS3 to OS0 bits in TCSR. Figure 12.7 shows the timing of timer output when the output is set to toggle by a compare-match A signal.

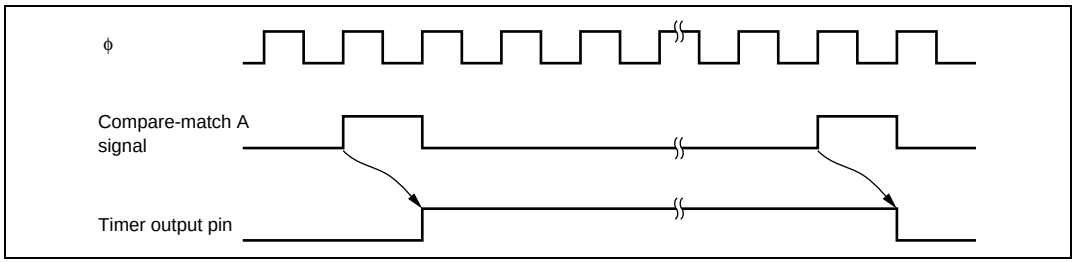


Figure 12.7 Timing of Toggled Timer Output by Compare-Match A Signal

12.5.4 Timing of Counter Clear at Compare-Match

TCNT is cleared when compare-match A or compare-match B occurs, depending on the setting of the CCLR1 and CCLR0 bits in TCR. Figure 12.8 shows the timing of clearing the counter by a compare-match.

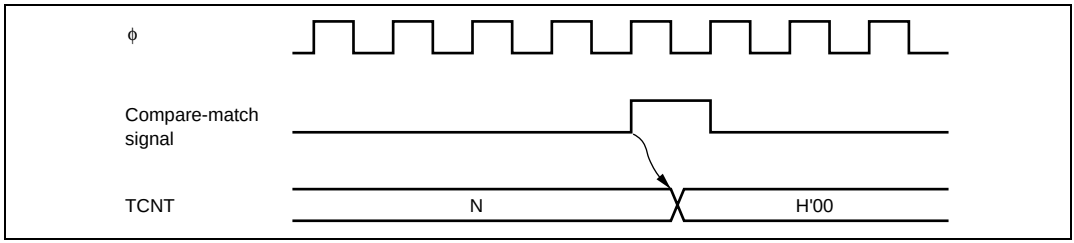


Figure 12.8 Timing of Counter Clear by Compare-Match

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 12.9 shows the timing of clearing the counter by an external reset input.

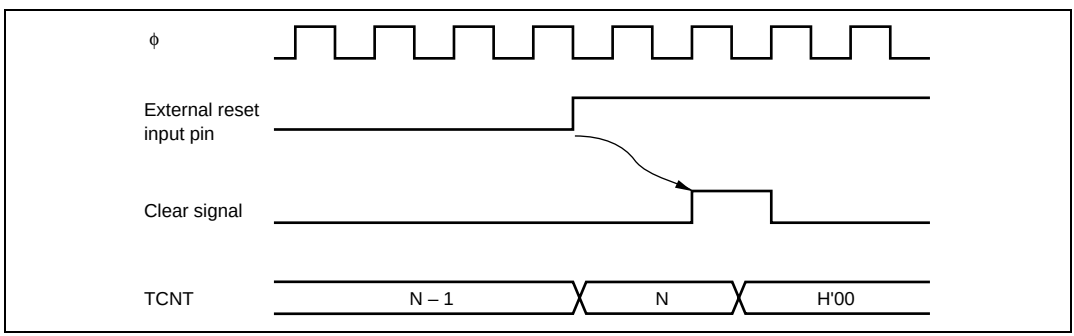


Figure 12.9 Timing of Counter Clear by External Reset Input

12.5.6 Timing of Overflow Flag (OVF) Setting

The OVF bit in TCSR is set to 1 when the TCNT overflows (changes from H'FF to H'00). Figure 12.10 shows the timing of OVF flag setting.

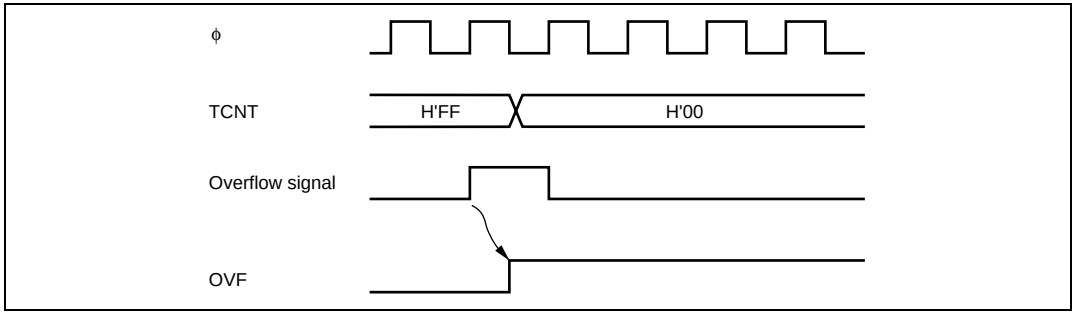


Figure 12.10 Timing of OVF Flag Setting

12.6 Operation with Cascaded Connection

If bits CKS2 to CKS0 in either TCR_0 or TCR_1 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 count mode) or the compare-matches of the 8-bit timer of channel 0 can be counted by the 8-bit timer of channel 1 (compare-match count mode).

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 also cleared when counter clear by the TMI0 pin has 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 the occurrence of 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 Input Capture Operation

TMR_X has input capture registers (TICR, TICRR and TICRF). A narrow pulse width can be measured with TICRR and TICRF, using a single capture operation controlled by the ICST bit in TCONRI of the timer connection. If the falling edge of TMRIX is detected after its rising edge has been detected while the ICST bit is set to 1, the value of TCNT at that time is transferred to both TICRR and TICRF, and the ICST bit is cleared to 0.

The input signal to TMRIX can be switched by the setting of the other bits in TCONRI.

Input Capture Signal Input Timing: Figure 12.11 shows the timing of the input capture operation.

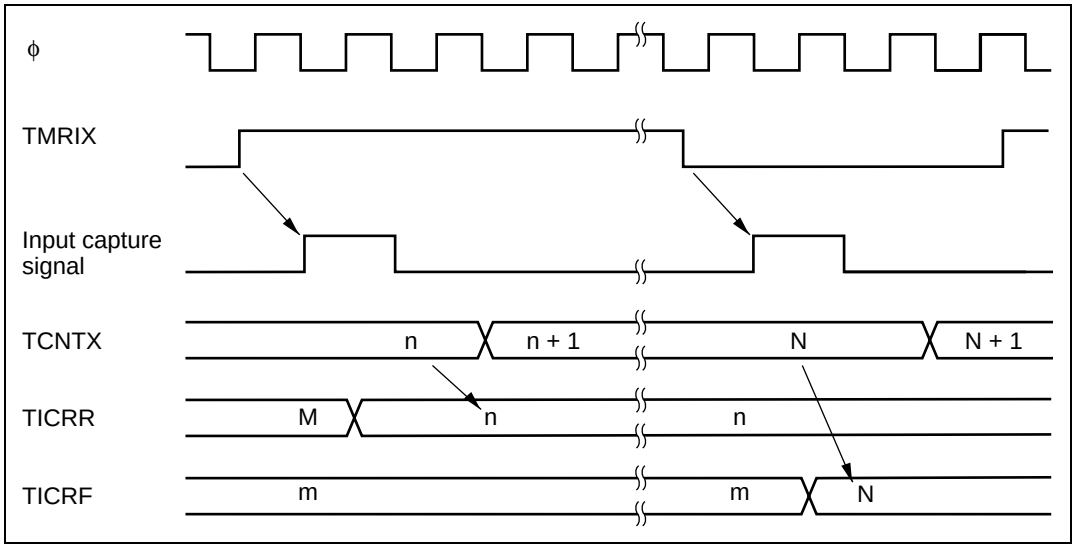


Figure 12.11 Timing of Input Capture Operation

If the input capture signal is input while TICRR and TICRF are being read, the input capture signal is delayed by one system clock (ϕ) cycle. Figure 12.12 shows the timing of this operation.

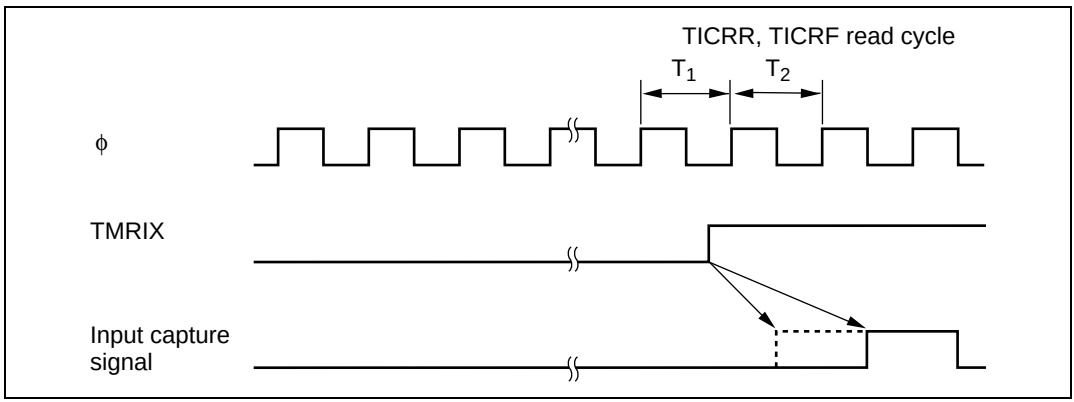


Figure 12.12 Timing of Input Capture Signal (Input Capture Signal Is Input during TICRR and TICRF Read)

Selection of Input Capture Signal Input: Input capture input signal of TMR_X (TMRIX) is switched according to the setting of the bits in TCONRI of the timer connection. Input capture signal selections are shown in figure 12.13 and table 12.3. For details, see section 13.3.1, Timer Connection Register I (TCONRI).

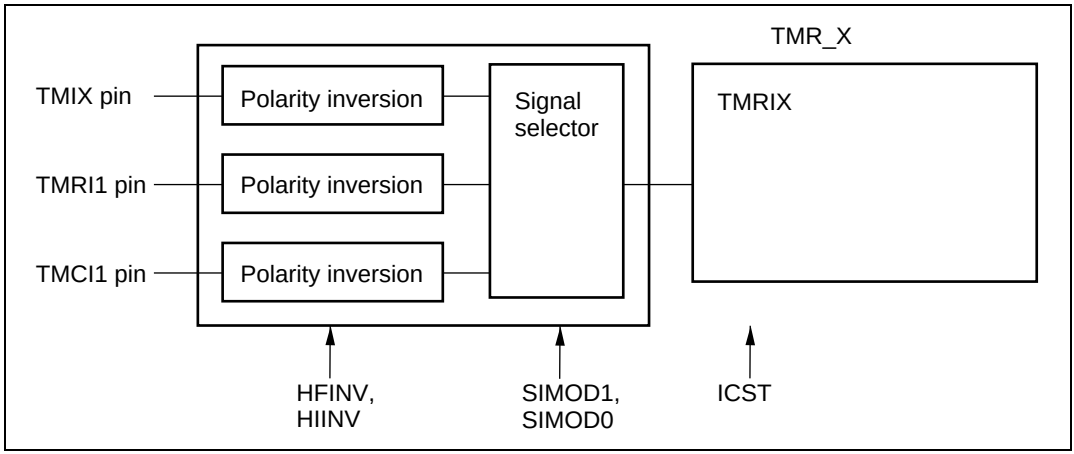


Figure 12.13 Input Capture Signal Selection

Table 12.3 Input Capture Signal Selection

		TCONRI			
Bit 4	**Bit 7**	**Bit 6**	**Bit 3**	**Bit 1**	
ICST	**SIMOD1**	**SIMOD0**	**HFINV**	**HIINV**	**Description**
0	—	—	—	—	Input capture function not used
1	0	0	0	—	TMIX pin input selection
			1	—	Inverted TMIX pin input selection
		1	—	0	TMRI1 pin input selection
			—	1	Inverted TMRI1 pin input selection
	1	1	—	0	TMCI1 pin input selection
			—	1	Inverted TMCI1 pin input selection

12.8 Interrupt Sources

TMR_0, TMR_1, and TMR_Y can generate three types of interrupts: CMIA, CMIB, and OVI. TMR_X can generate an ICIX interrupt. Table 12.4 shows the interrupt sources and priorities. Each interrupt source can be enabled or disabled independently by interrupt enable bits in TCR or TCSR. Independent signals are sent to the interrupt controller for each interrupt.

The CMIA and CMIB interrupts can be used as DTC activation interrupt sources.

Table 12.4 Interrupt Sources of 8-Bit Timers TMR_0, TMR_1, TMR_Y, and TMR_X

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	Interrupt Priority
TMR_0	CMIA0	TCORA_0 compare-match	CMFA	Enabled	High
	CMIB0	TCORB_0 compare-match	CMFB	Enabled	
	OVI0	TCNT_0 overflow	OVF	Disabled	
TMR_1	CMIA1	TCORA_1 compare-match	CMFA	Enabled	
	CMIB1	TCORB_1 compare-match	CMFB	Enabled	
	OVI1	TCNT_1 overflow	OVF	Disabled	
TMR_Y	CMIAY	TCORA_Y compare-match	CMFA	Enabled	
	CMIBY	TCORB_Y compare-match	CMFB	Enabled	
	OVIY	TCNT_Y overflow	OVF	Disabled	
TMR_X	ICIX	Input capture	ICF	Disabled	Low

12.9 Usage Notes

12.9.1 Conflict between TCNT Write and Clear

If a counter clear signal is generated during the T2 state of a TCNT write cycle as shown in figure 12.14, clearing takes priority, so that the counter is cleared and the write is not performed.

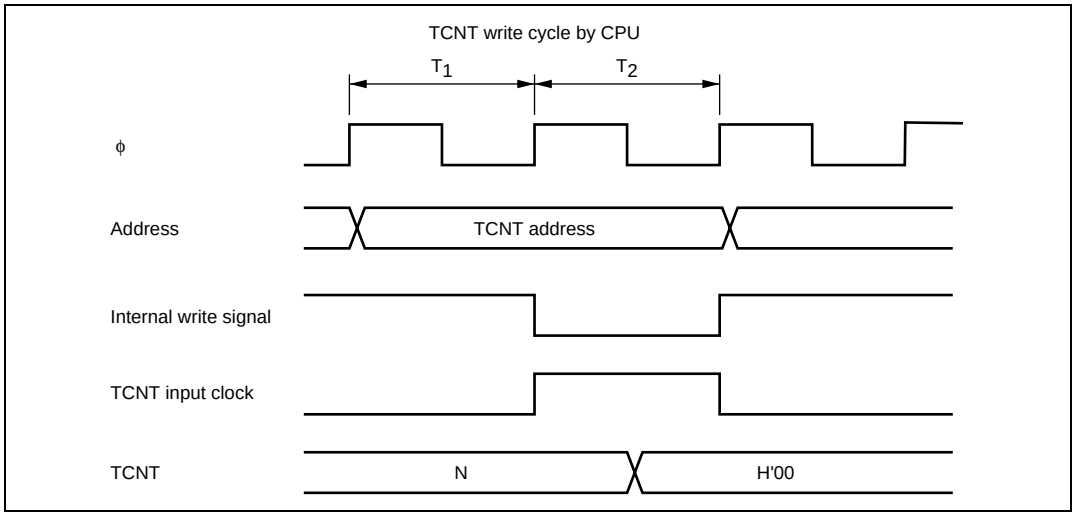


Figure 12.14 Conflict between TCNT Write and Clear

12.9.2 Conflict between TCNT Write and Increment

If a TCNT input clock is generated during the T2 state of a TCNT write cycle as shown in figure 12.15, the write takes priority and the counter is not incremented.

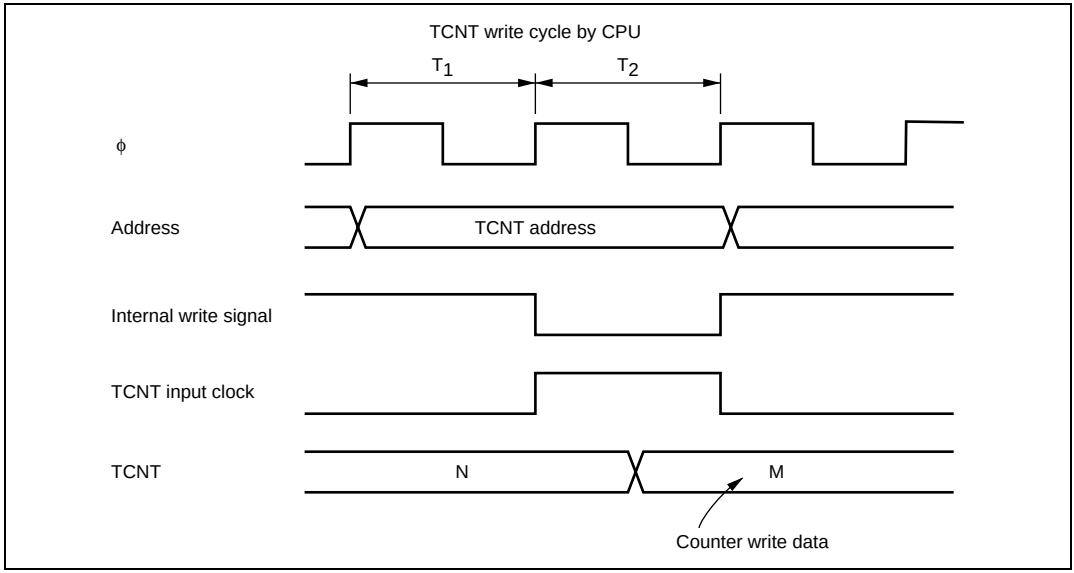


Figure 12.15 Conflict between TCNT Write and Increment

12.9.3 Conflict between TCOR Write and Compare-Match

If a compare-match occurs during the T2 state of a TCOR write cycle as shown in figure 12.16, the TCOR write takes priority and the compare-match signal is disabled. With TMR_X, a TICR input capture conflicts with a compare-match in the same way as with a write to TCORC. In this case also, the input capture takes priority and the compare-match signal is disabled.

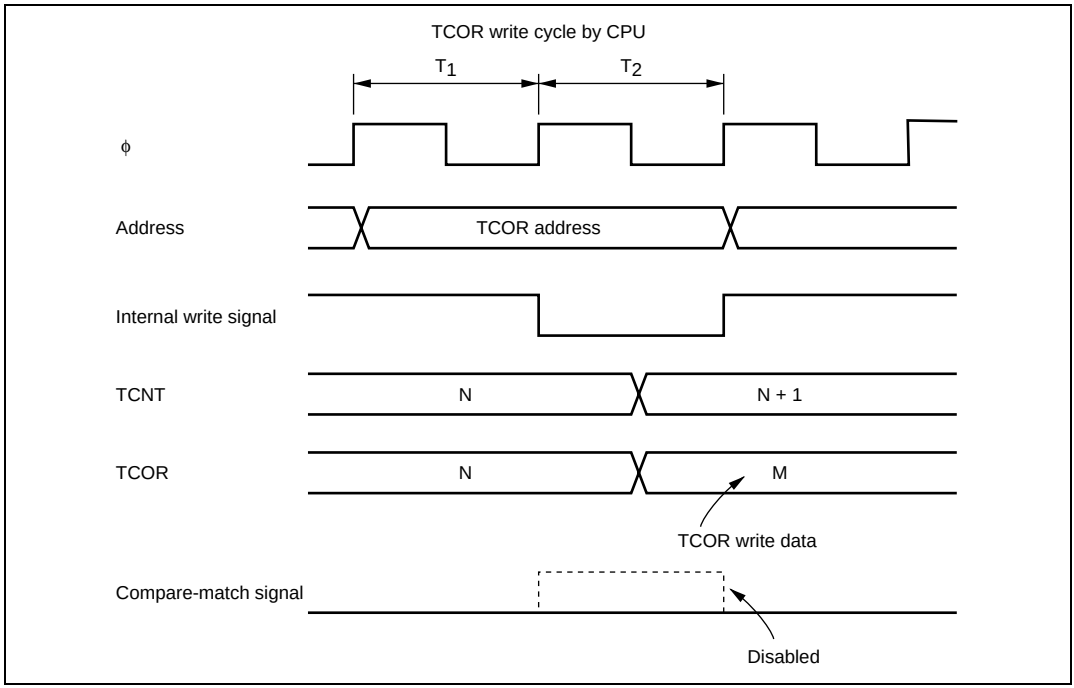


Figure 12.16 Conflict between TCOR Write and Compare-Match

12.9.4 Conflict 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 12.5.

Table 12.5 Timer Output Priorities

Output Setting	Priority
Toggle output	High
1 output	↑
0 output	
No change	Low

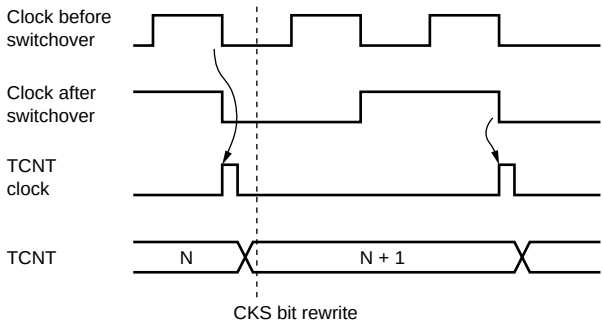
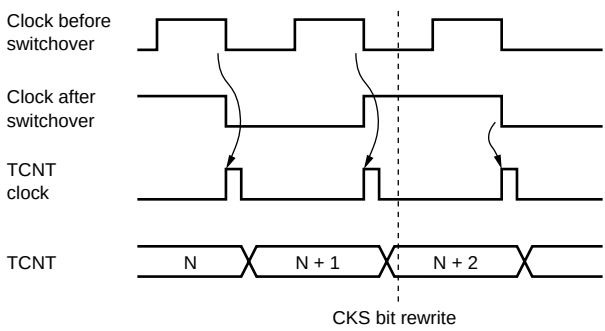
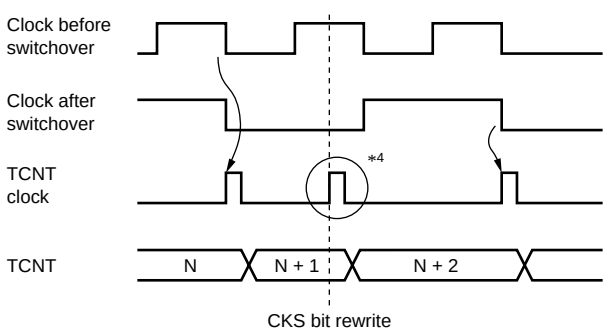
12.9.5 Switching of Internal Clocks and TCNT Operation

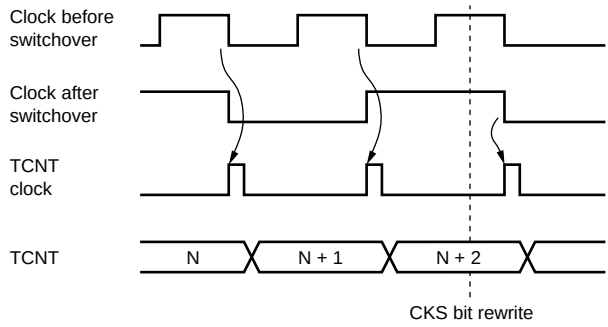
TCNT may increment erroneously when the internal clock is switched over. Table 12.6 shows the relationship between the timing at which the internal clock is switched (by writing to the CKS1 and CKS0 bits) and the TCNT operation.

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 12.6, a TCNT clock pulse is generated on the assumption that the switchover is a falling edge, and TCNT is incremented.

Erroneous incrementation can also happen when switching between internal and external clocks.

Table 12.6 Switching of Internal Clocks and TCNT Operation

No.	Timing of Switchover by Means of CKS1 and CKS0 Bits	TCNT Clock Operation
1	Clock switching from low to low level*1	
2	Clock switching from low to high level*2	
3	Clock switching from high to low level*3	

No.	Timing of Switchover by Means of CKS1 and CKS0 Bits	TCNT Clock Operation
4	Clock switching from high to high level	

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.

12.9.6 Mode Setting with Cascaded Connection

If the 16-bit count mode and compare-match count mode are set simultaneously, the input clock pulses for TCNT_0 and TCNT_1 are not generated, and thus the counters will stop operating. Simultaneous setting of these two modes should therefore be avoided.

12.9.7 Module Stop Mode Setting

TMR operation can be enabled or disabled using the module stop control register. The initial setting is for TMR operation to be halted. Register access is enabled by canceling the module stop mode. For details, refer to section 26, Power-Down Modes.

Section 13 Timer Connection

This LSI allows interconnection between a 16-bit free-running timer (FRT) and three 8-bit timer channels (TMR_1, TMR_X, and TMR_Y). This capability can be used to implement complex functions such as PWM decoding and clamp waveform output.

13.1 Features

- Five input pins and four output pins, all of which can be designated for phase inversion. Positive logic is assumed for all signals used within the timer connection facility.
- An edge-detection circuit is connected to the input pins, simplifying signal input detection.
- TMR_X can be used for PWM input signal decoding.
- TMR_X can be used for clamp waveform generation.
- An external clock signal divided by TMR_1 can be used as the FRT capture input signal.
- An internal synchronization signal can be generated using the FRT and TMR_Y.
- A signal generated/modified using an input signal and timer connection can be selected and output.

Figure 13.1 shows a block diagram of the timer connection facility.

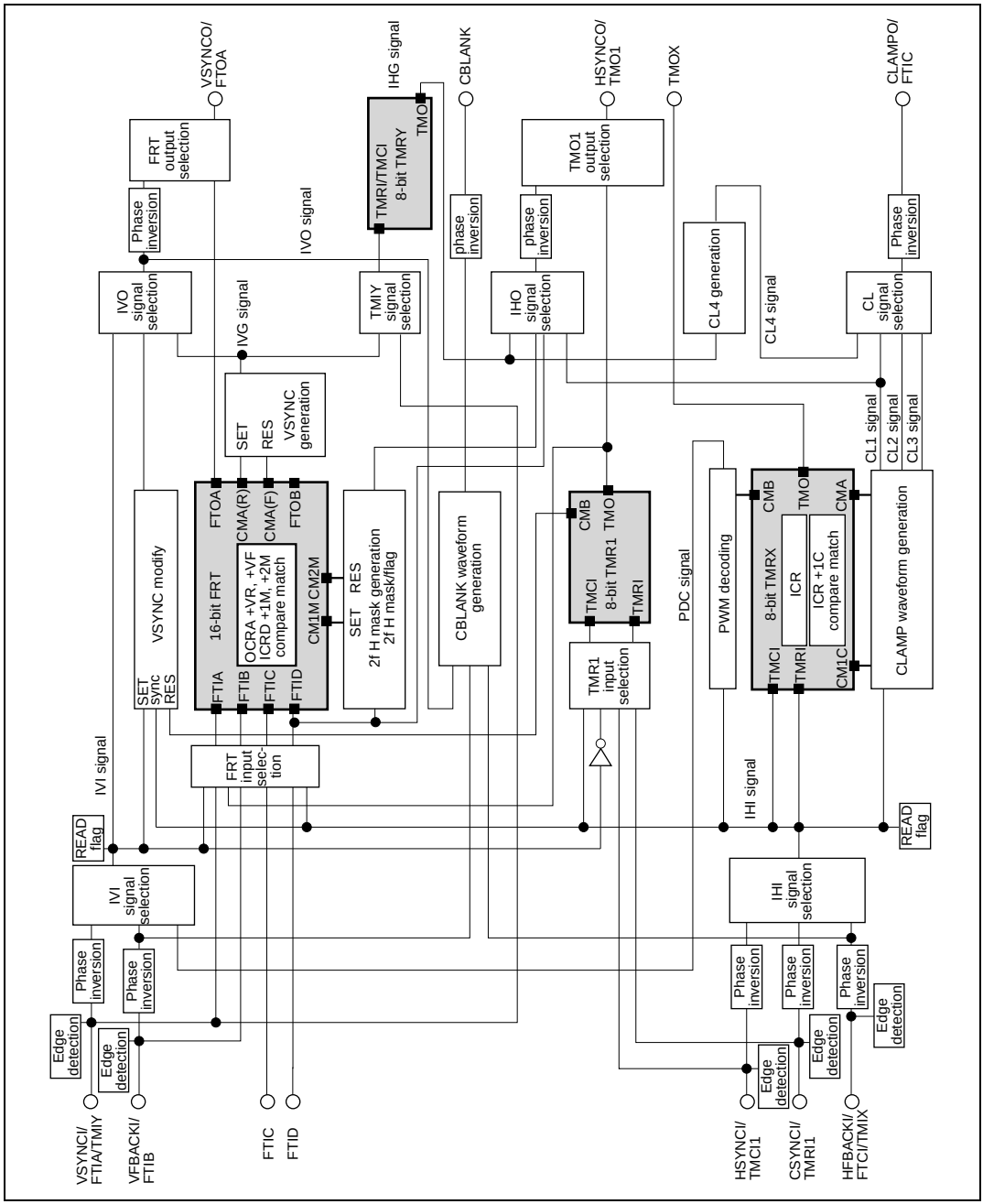


Figure 13.1 Block Diagram of Timer Connection

13.2 Input/Output Pins

Table 13.1 lists the timer connection input and output pins.

Table 13.1 Pin Configuration

Name	Abbreviation	Input/ Output	Function
Vertical synchronization signal input pin	VSYNCI	Input	Vertical synchronization signal input pin or FTIA input pin/TMIY input pin
Horizontal synchronization signal input pin	HSYNCI	Input	Horizontal synchronization signal input pin or TMCI1 input pin
Composite synchronization signal input pin	CSYNCI	Input	Composite synchronization signal input pin or TMRI1 input pin
Spare vertical synchronization signal input pin	VFBACKI	Input	Spare vertical synchronization signal input pin or FTIB input pin
Spare horizontal synchronization signal input pin	HFBACKI	Input	Spare horizontal synchronization signal input pin or FTCI input pin/TMIX input pin
Vertical synchronization signal output pin	VSYNCO	Output	Vertical synchronization signal output pin or FTOA output pin
Horizontal synchronization signal output pin	HSYNCO	Output	Horizontal synchronization signal output pin or TMO1 output pin
Clamp waveform output pin	CLAMPO	Output	Clamp waveform output pin or FTIC input pin
Blanking waveform output pin	CBLANK	Output	Blanking waveform output pin

13.3 Register Descriptions

The timer connection has the following registers.

- Timer connection register I (TCONRI)
- Timer connection register O (TCONRO)
- Timer connection register S (TCONRS)
- Edge sense register (SEDGR)

13.3.1 Timer Connection Register I (TCONRI)

TCONRI controls connection between timers, the signal source for synchronization signal input, phase inversion, etc.

Bit	Bit Name	Initial Value	R/W	Description
7	SIMOD1	0	R/W	Input Synchronization Mode Select 1, 0 These bits select the signal source of the IHI and IVI signals. • Mode 00: No signal 01: S-on-G mode 10: Composite mode 11: Separate mode • IHI Signal 00: HFBACKI input 01: CSYNCI input 1X: HSYNCI input • IVI Signal 00: VFBACKI input 01: PDC input 10: PDC input 11: VSYNCI input
6	SIMOD0	0	R/W	
5	SCONE	0	R/W	Synchronization Signal Connection Enable Selects the signal source of the FRT FTI input and the TMR_1 TMI1 input and TMCI1/TMRI1 input. For details, see table 13.2.

Bit	Bit Name	Initial Value	R/W	Description
4	ICST	0	R/W	Input Capture Start Bit The TMR_X external reset input (TMRIX) is connected to the IHI signal. TMR_X has input capture registers (TICR, TICRR, and TICRF). TICRR and TICRF can measure the width of a pulse by means of a single capture operation under the control of the ICST bit. When a rising edge followed by a falling edge is detected on TMRIX after the ICST bit is set to 1, the contents of TCNT at those points are captured into TICRR and TICRF, respectively, and the ICST bit is cleared to 0. [Clearing condition] When a rising edge followed by a falling edge is detected on TMRIX [Setting condition] When 1 is written in ICST after reading ICST = 0

Bit	Bit Name	Initial Value	R/W	Description
3	HFINV	0	R/W	Input Synchronization Signal Inversion
2	VFINV	0	R/W	These bits select inversion of the input phase of the spare horizontal synchronization signal (HFBACKI), the spare vertical synchronization signal (VFBACKI), the horizontal synchronization signal (HSYNCI), composite synchronization signal (CSYNCI), and the vertical synchronization signal (VSYNCI). • HFINV 0: The HFBACKI pin state is used directly as the HFBACKI input 1: The HFBACKI pin state is inverted before use as the HFBACKI input • VFINV 0: The VFBACKI pin state is used directly as the VFBACKI input 1: The VFBACKI pin state is inverted before use as the VFBACKI input • HIINV 0: The HSYNCI and CSYNCI pin states are used directly as the HSYNCI and CSYNCI inputs 1: The HSYNCI and CSYNCI pin states are inverted before use as the HSYNCI and CSYNCI inputs • VIINV 0: The VSYNCI pin state is used directly as the VSYNCI input 1: The VSYNCI pin state is inverted before use as the VSYNCI input
1	HIINV	0	R/W	
0	VIINV	0	R/W	

Legend:

X: Don't care

Table 13.2 Synchronization Signal Connection Enable

Bit 5		Description					
SCONE	**Mode**	**FTIA**	**FTIB**	**FTIC**	**FTID**	**TMCI1**	**TMRI1**
0	Normal connection (Initial value)	FTIA input	FTIB input	FTIC input	FTID input	TMCI1 input	TMRI1 input
1	Synchronization signal connection mode	IVI signal	TMO1 signal	VFBACKI input	IHI signal	IHI signal	IVI inverse signal

13.3.2 Timer Connection Register O (TCONRO)

TCONRO controls output signal output, phase inversion, etc.

Bit	Bit Name	Initial Value	R/W	Description
7	HOE	0	R/W	Output Enable
6	VOE	0	R/W	These bits control enabling/disabling of output of horizontal synchronization signal (HSYNCO), vertical synchronization signal (VSYNCO), clamp waveform (CLAMPO), and blanking waveform (CBLANK). When output is disabled, the state of the relevant pin is determined by port DR and DDR, FRT, TMR, and PWM settings. Output enabling/disabling control does not affect the port, FRT, or TMR input functions, but some FRT and TMR input signal sources are determined by the SCONE bit in TCONRI. HOE: 0: The P44/TMO1/HIRQ1/HSYNCO pin functions as the P44/TMO1/HIRQ1 pin 1: The P44/TMO1/HIRQ1/HSYNCO pin functions as the HSYNCO pin VOE: 0: The P61/FTOA/CIN1/$\overline{\text{KIN1}}$/VSYNCO pin functions as the P61/FTOA/CIN1/$\overline{\text{KIN1}}$ pin 1: The P61/FTOA/CIN1/$\overline{\text{KIN1}}$/VSYNCO pin functions as the VSYNCO pin CLOE: 0: The P64/FTIC/CIN4/$\overline{\text{KIN4}}$/CLAMPO pin functions as the P64/FTIC/CIN4/$\overline{\text{KIN4}}$ pin 1: The P64/FTIC/CIN4/$\overline{\text{KIN4}}$/CLAMPO pin functions as the CLAMPO pin CBOE: 0: The P27/A15/PW15/CBLANK pin functions as the P27/A15/PW15 pin In mode 1: 1: The P27/A15/PW15/CBLANK pin functions as the A15 pin In modes 2 and 3: 1: The P27/A15/PW15/CBLANK pin functions as the CBLANK pin
5	CLOE	0	R/W	
4	CBOE	0	R/W	

Bit	Bit Name	Initial Value	R/W	Description
3	HOINV	0	R/W	Output Synchronization Signal Inversion
2	VOINV	0	R/W	These bits select inversion of the output phase of the horizontal synchronization signal (HSYNCO), the vertical synchronization signal (VSYNCO), the clamp waveform (CLAMPO), and the blanking waveform (CBLANK). • HOINV: 0: The IHO signal is used directly as the HSYNCO output 1: The IHO signal is inverted before use as the HSYNCO output • VOINV: 0: The IVO signal is used directly as the VSYNCO output 1: The IVO signal is inverted before use as the VSYNCO output • CLOINV: 0: The CLO signal (CL1, CL2, CL3, or CL4 signal) is used directly as the CLAMPO output 1: The CLO signal (CL1, CL2, CL3, or CL4 signal) is inverted before use as the CLAMPO output • CBOINV: 0: The CBLANK signal is used directly as the CBLANK output 1: The CBLANK signal is inverted before use as the CBLANK output
1	CLOINV	0	R/W	
0	CBOINV	0	R/W	

13.3.3 Timer Connection Register S (TCONRS)

TCONRS selects whether to access TMR_X or TMR_Y registers, and the synchronization signal output signal source and generation method.

Bit	Bit Name	Initial Value	R/W	Description
7	TMRX/Y	0	R/W	TMR_X/TMR_Y Access Select For details, see table 13.3. 0: The TMR_X registers are accessed at addresses H'(FF)FFF0 to H'(FF)FFF5 1: The TMR_Y registers are accessed at addresses H'(FF)FFF0 to H'(FF)FFF5
6	ISGENE	0	R/W	Internal Synchronization Signal Selects internal synchronization signals (IHG, IVG, and CL4 signals) as the signal sources for the IHO, IVO, and CLO signals together with the HOMOD1, HOMOD0, VOMOD1, VOMOD0, CLMOD1, and CLMOD0 bits.
5	HOMOD1	0	R/W	Horizontal Synchronization Output Mode Select 1, 0
4	HOMOD0	0	R/W	These bits select the signal source and generation method for the IHO signal. • ISGENE = 0 00: The IHI signal (without 2fH modification) is selected 01: The IHI signal (with 2fH modification) is selected 1X: The CL1 signal is selected • ISGENE = 1 XX: The IHG signal is selected

Bit	Bit Name	Initial Value	R/W	Description
3	VOMOD1	0	R/W	Vertical Synchronization Output Mode Select 1, 0
2	VOMOD0	0	R/W	These bits select the signal source and generation method for the IVO signal. • ISGENE = 0 00: The IVI signal (without fall modification or IHI synchronization) is selected 01: The IVI signal (without fall modification, with IHI synchronization) is selected 10: The IVI signal (with fall modification, without IHI synchronization) is selected 11: The IVI signal (with fall modification and IHI synchronization) is selected • ISGENE = 1 XX: The IVG signal is selected
1	CLMOD1	0	R/W	Clamp Waveform Mode Select 1, 0
0	CLMOD0	0	R/W	These bits select the signal source for the CLO signal (clamp waveform). • ISGENE = 0 00: The CL1 signal is selected 01: The CL2 signal is selected 1X: The CL3 signal is selected • ISGENE = 1 XX: The CL4 signal is selected

Legend:

X: Don't care

Table 13.3 Registers Accessible by TMR_X/TMR_Y

TMRX/Y	H'FFF0	H'FFF1	H'FFF2	H'FFF3	H'FFF4	H'FFF5	H'FFF6	H'FFF7
0	TMR_X	TMR_X	TMR_X	TMR_X	TMR_X	TMR_X	TMR_X	TMR_X
	TCR_X	TCSR_X	TICRR	TICRF	TCNT_X	TCORC	TCORA_X	TCORB_X
1	TMR_Y	TMR_Y	TMR_Y	TMR_Y	TMR_Y	TMR_Y		
	TCR_Y	TCSR_Y	TCORA_Y	TCORB_Y	TCNT_Y	TISR		

13.3.4 Edge Sense Register (SEDGR)

SEDGR detects a rising edge on the timer connection input pins and the occurrence of 2fH modification, and determines the phase of the IVI and IHI signals.

Bit	Bit Name	Initial Value	R/W	Description
7	VEDG	0	R/(W)*1	VSYNCI Edge Detects a rising edge on the VSYNCI pin. [Clearing condition] When 0 is written in VEDG after reading VEDG = 1 [Setting condition] When a rising edge is detected on the VSYNCI pin
6	HEDG	0	R/(W)*1	HSYNCI Edge Detects a rising edge on the HSYNCI pin. [Clearing condition] When 0 is written in HEDG after reading HEDG = 1 [Setting condition] When a rising edge is detected on the HSYNCI pin
5	CEDG	0	R/(W)*1	CSYNCI Edge Detects a rising edge on the CSYNCI pin. [Clearing condition] When 0 is written in CEDG after reading CEDG = 1 [Setting condition] When a rising edge is detected on the CSYNCI pin
4	HFEDG	0	R/(W)*1	HFBACKI Edge Detects a rising edge on the HFBACKI pin. [Clearing condition] When 0 is written in HFEDG after reading HFEDG = 1 [Setting condition] When a rising edge is detected on the HFBACKI pin

Bit	Bit Name	Initial Value	R/W	Description
3	VFEDG	0	R/(W)*1	VFBACKI Edge Detects a rising edge on the VFBACKI pin. [Clearing condition] When 0 is written in VFEDG after reading VFEDG = 1 [Setting condition] When a rising edge is detected on the VFBACKI pin
2	PREQF	0	R/(W)*1	Pre-Equalization Flag Detects the occurrence of an IHI signal 2fH modification condition. The generation of a falling/rising edge in the IHI signal during a mask interval is expressed as the occurrence of a 2fH modification condition. For details, see section 13.4.4, 2fH Modification of IHI Signal. [Clearing condition] When 0 is written in PREQF after reading PREQF = 1 [Setting condition] When an IHI signal 2fH modification condition is detected
1	IHI	Undefined*2	R	IHI Signal Level Indicates the current level of the IHI signal. Signal source and phase inversion selection for the IHI signal depends on the contents of TCONRI. Read this bit to determine whether the input signal is positive or negative, then maintain the IHI signal at positive phase by modifying TCONRI. 0: The IHI signal is low 1: The IHI signal is high
0	IVI	Undefined*2	R	IVI Signal Level Indicates the current level of the IVI signal. Signal source and phase inversion selection for the IVI signal depends on the contents of TCONRI. Read this bit to determine whether the input signal is positive or negative, then maintain the IVI signal at positive phase by modifying TCONRI. 0: The IVI signal is low 1: The IVI signal is high

Notes: 1. Only 0 can be written, to clear the flag.
2. The initial value is undefined since it depends on the pin state.

13.4 Operation

13.4.1 PWM Decoding (PDC Signal Generation)

The timer connection facility and TMR_X can be used to decode a PWM signal in which 0 and 1 are represented by the pulse width. To do this, a signal in which a rising edge is generated at regular intervals must be selected as the IHI signal.

The timer counter (TCNT) in TMR_X is set to count the internal clock pulses and to be cleared on the rising edge of the external reset signal (IHI signal). The value to be used as the threshold for deciding the pulse width is written in TCORB. The PWM decoder contains a delay latch which uses the IHI signal as data and compare-match signal B (CMB) as a clock, and the state of the IHI signal (the result of the pulse width decision) at the first compare-match signal B timing after TCNT is reset by the rise of the IHI signal is output as the PDC signal.

The pulse width setting using TICRR and TICRF of TMR_X can be used to determine the pulse width decision threshold. Examples of TCR and TCORB settings of TMR_X are shown in tables 13.4 and 13.5, and the PWM decoding timing chart is shown in figure 13.2.

Table 13.4 Examples of TCR Settings

Bit	Abbreviation	Contents	Description
7	CMIEB	0	Interrupts due to compare-match and overflow are disabled
6	CMIEA	0	
5	OVIE	0	
4 and 3	CCLR1 and CCLR0	11	TCNT is cleared by the rising edge of the external reset signal (IHI signal)
2 to 0	CKS2 to CKS0	001	Incremented on internal clock (φ)

Table 13.5 Examples of TCORB (Pulse Width Threshold) Settings

	φ: 10 MHz	φ: 12 MHz	φ: 16 MHz	φ: 20 MHz
H'07	0.8 µs	0.67 µs	0.5 µs	0.4 µs
H'0F	1.6 µs	1.33 µs	1 µs	0.8 µs
H'1F	3.2 µs	2.67 µs	2 µs	1.6 µs
H'3F	6.4 µs	5.33 µs	4 µs	3.2 µs
H'7F	12.8 µs	10.67 µs	8 µs	6.4 µs

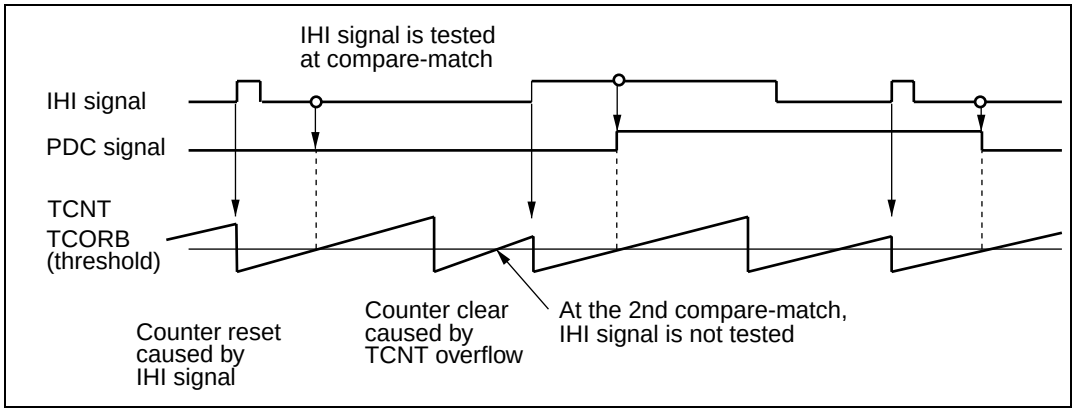


Figure 13.2 Timing Chart for PWM Decoding

13.4.2 Clamp Waveform Generation (CL1/CL2/CL3 Signal Generation)

The timer connection facility and TMR_X can be used to generate signals with different duty cycles and rising/falling edges (clamp waveforms) in synchronization with the input signal (IHI signal). Three clamp waveforms can be generated: the CL1 to CL3 signals. In addition, the CL4 signal can be generated using TMR_Y.

The CL1 signal rises simultaneously with the rise of the IHI signal, and when the CL1 signal is high, the CL2 signal rises simultaneously with the fall of the IHI signal. The fall of both the CL1 and CL2 signals can be specified by TCORA. The rise of the CL3 signal can be specified as simultaneous with the sampling of the fall of the IHI signal using the system clock, and the fall of the CL3 signal can be specified by TCORC. The CL3 signal can also fall when the IHI signal rises.

TCNT in TMR_X is set to count internal clock pulses and to be cleared on the rising edge of the external reset signal (IHI signal).

The value to be used as the CL1 signal pulse width is written in TCORA. Write a value of H'02 or more in TCORA when internal clock ϕ is selected as the TMR_X counter clock, and a value or H'01 or more when $\phi/2$ is selected. When internal clock ϕ is selected, the CL1 signal pulse width is (TCORA set value + 3 ± 0.5). When the CL2 signal is used, the setting must be made so that this pulse width is greater than the IHI signal pulse width.

The value to be used as the CL3 signal pulse width is written in TCORC. TICR in TMR_X captures the value of TCNT at the inverse of the external reset signal edge (in this case, the falling edge of the IHI signal). The timing of the fall of the CL3 signal is determined by the sum of the

contents of TICR and TCORC. Caution is required if the rising edge of the IHI signal precedes the fall timing set by the contents of TCORC, since the IHI signal will cause the CL3 signal to fall.

Examples of TCR settings of TMR_X are the same as those in table 13.4. The clamp waveform timing charts are shown in figures 13.3 and 13.4.

Since the rise of the CL1 and CL2 signals is synchronized with the edge of the IHI signal, and their fall is synchronized with the system clock, the pulse width variation is equivalent to the resolution of the system clock.

Both the rise and the fall of the CL3 signal are synchronized with the system clock and the pulse width is fixed, but there is a variation in the phase relationship with the IHI signal equivalent to the resolution of the system clock.

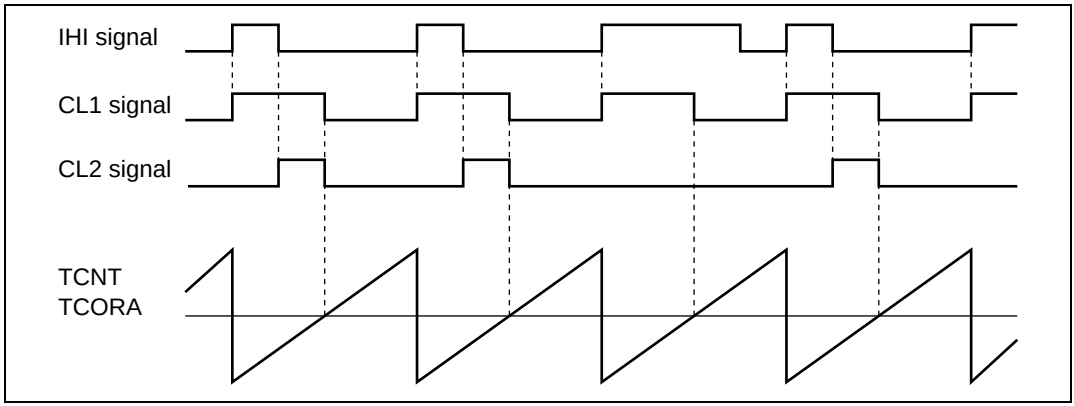


Figure 13.3 Timing Chart for Clamp Waveform Generation (CL1 and CL2 Signals)

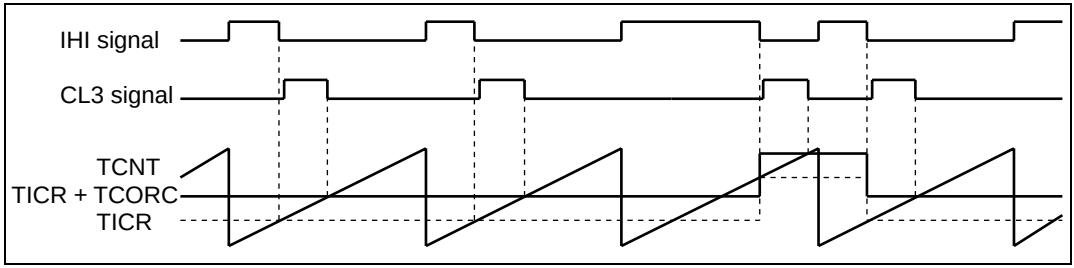


Figure 13.4 Timing Chart for Clamp Waveform Generation (CL3 Signal)

13.4.3 Measurement of 8-Bit Timer Divided Waveform Period

The timer connection facility, TMR_1, and the free-running timer (FRT) can be used to measure the period of an IHI signal divided waveform. Since TMR_1 can be cleared by a rising edge of the inverted IVI signal, the rise and fall of the IHI signal divided waveform can be synchronized with the IVI signal. This enables period measurement to be carried out efficiently.

To measure the period of an IHI signal divided waveform, TCNT in TMR_1 is set to count the external clock (IHI signal) pulses and to be cleared on the rising edge of the external reset signal (inverse of the IVI signal). The value to be used as the division factor is written in TCORA, and the TMO output method is specified by the OS bits in TCSR.

Examples of TCR and TCSR settings in TMR_1, and TCR and TCSR settings in the FRT are shown in table 13.6, and the timing chart for measurement of the IVI signal and IHI signal divided waveform periods is shown in figure 13.5. The period of the IHI signal divided waveform is given by (ICRD(3) – ICRD(2)) × resolution.

Table 13.6 Examples of TCR and TCSR Settings

Register	Bit	Abbreviation	Contents	Description
TCR in TMR_1	7	CMIEB	0	Interrupts due to compare-match and overflow are disabled
	6	CMIEA	0	
	5	OVIE	0	
	4 and 3	CCLR1 and CCLR0	11	TCNT is cleared by the rising edge of the external reset signal (inverse of the IVI signal)
	2 to 0	CKS2 to CKS0	101	TCNT is incremented on the rising edge of the external clock (IHI signal)
TCSR in TMR_1	3 to 0	OS3 to OS0	0011	Not changed by compare-match B; output inverted by compare-match A (toggle output): Division by 512
			1001	When TCORB < TCORA, 1 output on compare-match B, and 0 output on compare-match A: Division by 256
TCR in FRT	6	IEDGB	0/1	0: FRC value is transferred to ICRB on falling edge of input capture input B (IHI divided signal waveform) 1: FRC value is transferred to ICRB on rising edge of input capture input B (IHI divided signal waveform)
	1 and 0	CKS1 and CKS0	01	FRC is incremented on internal clock: $\phi/8$
TCSR in FRT	0	CCLRA	0	FRC clearing is disabled

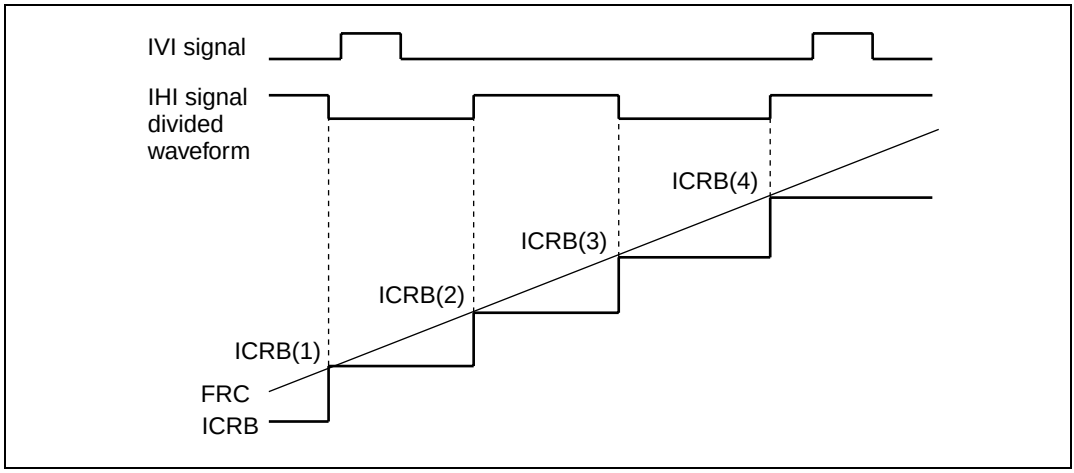


Figure 13.5 Timing Chart for Measurement of IVI Signal and IHI Signal Divided Waveform Periods

13.4.4 2fH Modification of IHI Signal

By using the timer connection facility and FRT, even if there is a part of the IHI signal with twice the frequency, this can be eliminated. In order for this function to operate properly, the duty cycle of the IHI signal must be approximately 30% or less, or approximately 70% or above.

The 8-bit OCRDM contents or twice the OCRDM contents can be added automatically to the data captured in ICRD in the FRT, and compare-matches generated at these points. The interval between the two compare-matches is called a mask interval. A value equivalent to approximately 1/3 the IHI signal period is written in OCRDM. ICRD is set so that capture is performed on the rise of the IHI signal.

Since the IHI signal supplied to the IHO signal selection circuit is normally set on the rise of the IHI signal and reset on the fall, its waveform is the same as that of the original IHI signal. When 2fH modification is selected, IHI signal edge detection is disabled during mask intervals. Capture is also disabled during these intervals.

Examples of TCR, TCSR, TOCR, and OCRDM settings in the FRT are shown in table 13.7, and the 2fH modification timing chart is shown in figure 13.6.

Table 13.7 Examples of TCR, TCSR, TOCR, and OCRDM Settings

Register	Bit	Abbreviation	Contents	Description
TCR in FRT	4	IEDGD	1	FRC value is transferred to ICRD on the rising edge of input capture input D (IHI signal)
	1 and 0	CKS1 and CKS0	01	FRC is incremented on internal clock: $\phi/8$
TCSR in FRT	0	CCLRA	0	FRC clearing is disabled
TOCR in FRT	7	ICRDMS	1	ICRD is set to the operating mode in which OCRDM is used
OCRDM in FRT	7 to 0	OCRDM7 to OCRDM0	H'01 to H'FF	Specifies the period during which ICRD operation is masked

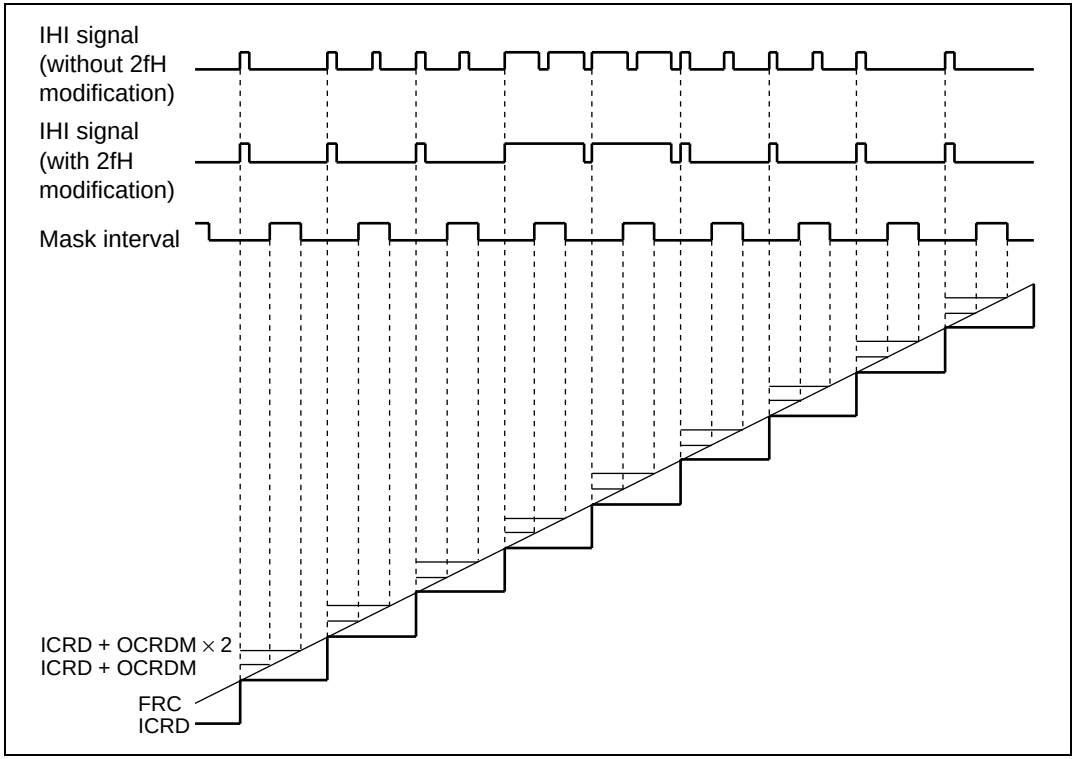


Figure 13.6 2fH Modification Timing Chart

13.4.5 IVI Signal Fall Modification and IHI Synchronization

By using the timer connection facility and TMR_1, the fall of the IVI signal can be shifted backward by the specified number of IHI signal waveforms. Also, the fall of the IVI signal can be synchronized with the rise of the IHI signal.

To perform 8-bit timer divided waveform period measurement, TCNT in TMR_1 is set to count external clock (IHI signal) pulses, and to be cleared on the rising edge of the external reset signal (inverse of the IVI signal). The number of IHI signal pulses until the fall of the IVI signal is written in TCORB.

Since the IVI signal supplied to the IVO signal selection circuit is normally set on the rise of the IVI signal and reset on the fall, its waveform is the same as that of the original IVI signal. When fall modification is selected, a reset is performed on a TMR_1 TCORB compare-match in TMR_1.

The fall of the waveform generated in this way can be synchronized with the rise of the IHI signal, regardless of whether or not fall modification is selected.

Examples of TCR, TCSR, and TCORB settings in TMR_1 are shown in table 13.8, and the fall modification/IHI synchronization timing chart is shown in figure 13.7.

Table 13.8 Examples of TCR, TCSR, and TCORB Settings

Register	Bit	Abbreviation	Contents	Description
TCR in TMR_1	7	CMIEB	0	Interrupts due to compare-match and overflow are disabled
	6	CMIEA	0	
	5	OVIE	0	
	4 and 3	CCLR1 and CCLR0	11	TCNT is cleared by the rising edge of the external reset signal (inverse of the IVI signal)
	2 to 0	CKS2 to CKS0	101	TCNT is incremented on the rising edge of the external clock (IHI signal)
TCSR in TMR_1	3 to 0	OS3 to OS0	0011	Not changed by compare-match B; output inverted by compare-match A (toggle output)
			1001	When TCORB < TCORA, 1 output on compare-match B, 0 output on compare-match A
TCORB in TMR_1			H'03 (example)	Compare-match on the 4th (example) rise of the IHI signal after the rise of the inverse of the IVI signal

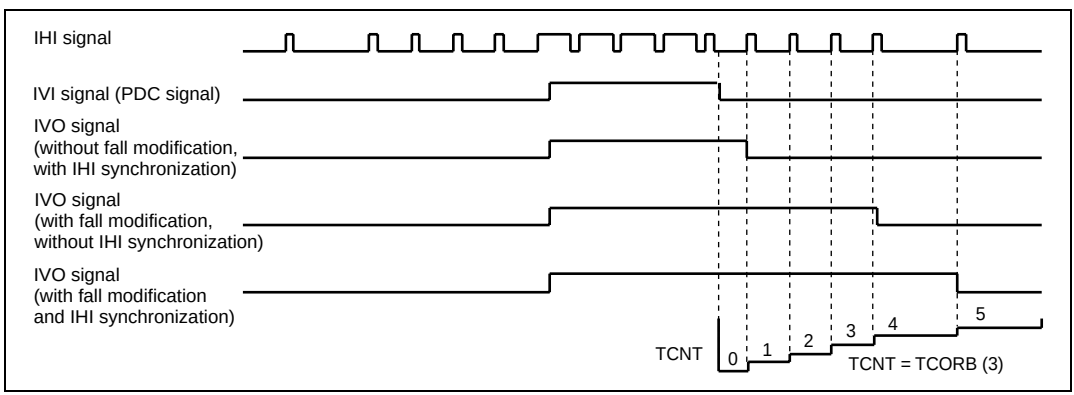


Figure 13.7 Fall Modification and IHI Synchronization Timing Chart

13.4.6 Internal Synchronization Signal Generation (IHG/IVG/CL4 Signal Generation)

By using the timer connection facility, FRT, and TMR_Y, it is possible to automatically generate internal signals (IHG and IVG signals) corresponding to the IHI and IVI signals. As the IHG signal is synchronized with the rise of the IVG signal, the IHG signal period must be made a divisor of the IVG signal period in order to keep it constant. In addition, the CL4 signal can be generated in synchronization with the IHG signal.

The contents of OCRA in the FRT are updated by the automatic addition of the contents of OCRAR or OCRAF, alternately, each time a compare-match occurs. A value corresponding to the 0 interval of the IVG signal is written in OCRAR, and a value corresponding to the 1 interval of the IVG signal is written in OCRAF. The IVG signal is set by a compare-match after an OCRAR addition, and reset by a compare-match after an OCRAF addition.

The IHG signal is the TMR_Y timer output. TMR_Y is set to count internal clock pulses, and to be cleared on a TCORA compare-match, to fix the period and set the timer output. TCORB is set so as to reset the timer output. The IVG signal is connected as the TMR_Y reset input (TMRI), and the rise of the IVG signal can be treated in the same way as a TCORA compare-match.

The CL4 signal is a waveform that rises within one system clock period after the fall of the IHG signal, and has an interval of 1 for 6 system clock periods.

Examples of TCR, TCSR, TCORA, and TCORB settings in TMR_Y, and TCR, OCRAR, OCRAF, and TOCR settings in the FRT are shown in table 13.9, and the IHG signal/IVG signal timing chart is shown in figure 13.8.

Table 13.9 Examples of OCRAR, OCRAF, TCORA, TCORB, TCR, and TCSR Settings

Register	Bit	Abbreviation	Contents	Description	
TCR in TMR_Y	7	CMIEB	0	Interrupts due to compare-match and overflow are disabled	
	6	CMIEA	0		
	5	OVIE	0		
	4 and 3	CCLR1 and CCLR0	01	TCNT is cleared by compare-match A	
	2 to 0	CKS2 to CKS0	001	TCNT is incremented on internal clock: $\phi/4$	
TCSR in TMR_Y	3 to 0	OS3 to OS0	0110	0 output on compare-match B 1 output on compare-match A	
TCORA in TMR_Y			H'3F (example)	IHG signal period = $\phi \times 256$	
TCORB in TMR_Y			H'03 (example)	IHG signal 1 interval = $\phi \times 16$	
TCR in FRT	1 and 0	CKS1 and CKS0	01	FRC is incremented on internal clock: $\phi/8$	
OCRAR in FRT			H'7FEF (example)	IVG signal 0 interval = $\phi \times 262016$	IVG signal period = $\phi \times 262144$ (1024 times IHG signal)
OCRAF in FRT			H'000F (example)	IVG signal 1 interval = $\phi \times 128$	
TOCR in FRT	6	OCRAMS	1	OCRA is set to the operating mode in which OCRAR and OCRAF are used	

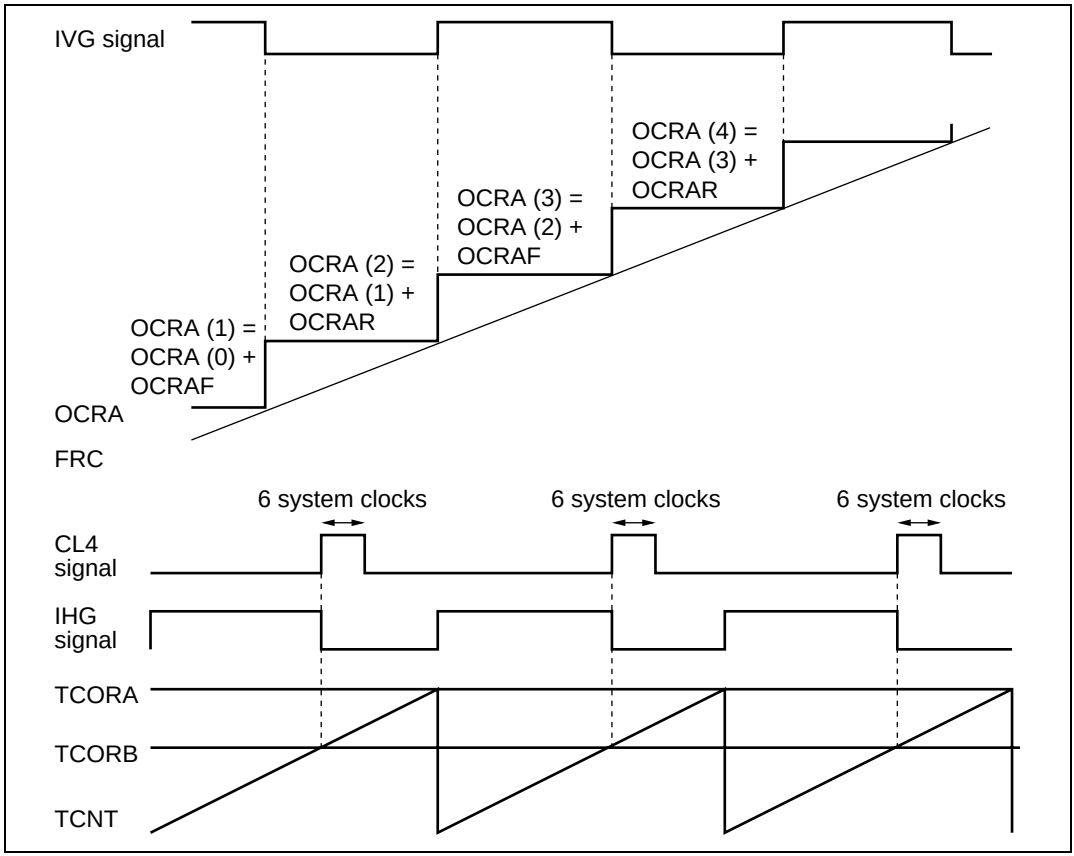


Figure 13.8 IVG Signal/IHG Signal/CL4 Signal Timing Chart

13.4.7 HSYNCO Output

With the HSYNCO output, the meaning of the signal source to be selected and use or non-use of modification varies according to the IHI signal source and the waveform required by external circuitry. The HSYNCO output modes are shown in table 13.10.

Table 13.10 HSYNCO Output Modes

Mode	IHI Signal	IHO Signal	Meaning of IHO Signal
No signal	HFBACKI input	IHI signal (without 2fH modification)	HFBACKI input is output directly
		IHI signal (with 2fH modification)	Meaningless unless there is a double-frequency part in the HFBACKI input
		CL1 signal	HFBACKI input 1 interval is changed before output
		IHG signal	Internal synchronization signal is output
S-on-G mode	CSYNCI input	IHI signal (without 2fH modification)	CSYNCI input (composite synchronization signal) is output directly
		IHI signal (with 2fH modification)	Double-frequency part of CSYNCI input (composite synchronization signal) is eliminated before output
		CL1 signal	CSYNCI input (composite synchronization signal) horizontal synchronization signal part is separated before output
		IHG signal	Internal synchronization signal is output
Composite mode	HSYNCI input	IHI signal (without 2fH modification)	HSYNCI input (composite synchronization signal) is output directly
		IHI signal (with 2fH modification)	Double-frequency part of HSYNCI input (composite synchronization signal) is eliminated before output
		CL1 signal	HSYNCI input (composite synchronization signal) horizontal synchronization signal part is separated before output
		IHG signal	Internal synchronization signal is output
Separate mode	HSYNCI input	IHI signal (without 2fH modification)	HSYNCI input (horizontal synchronization signal) is output directly
		IHI signal (with 2fH modification)	Meaningless unless there is a double-frequency part in the HSYNCI input (horizontal synchronization signal)
		CL1 signal	HSYNCI input (horizontal synchronization signal) 1 interval is changed before output
		IHG signal	Internal synchronization signal is output

13.4.8 VSYNCO Output

With the VSYNCO output, the meaning of the signal source to be selected and use or non-use of modification varies according to the IVI signal source and the waveform required by external circuitry. The VSYNCO output modes are shown in table 13.11.

Table 13.11 VSYNCO Output Modes

Mode	IVI Signal	IVO Signal	Meaning of IVO Signal
No signal	VFBACKI input	IVI signal (without fall modification or IHI synchronization)	VFBACKI input is output directly
		IVI signal (without fall modification, with IHI synchronization)	Meaningless unless VFBACKI input is synchronized with HFBACKI input
		IVI signal (with fall modification, without IHI synchronization)	VFBACKI input fall is modified before output
		IVI signal (with fall modification and IHI synchronization)	VFBACKI input fall is modified and signal is synchronized with HFBACKI input before output
		IVG signal	Internal synchronization signal is output
S-on-G mode or composite mode	PDC signal	IVI signal (without fall modification or IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is separated before output
		IVI signal (without fall modification, with IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is separated, and signal is synchronized with CSYNCI/HSYNCI input before output
		IVI signal (with fall modification, without IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is separated, and fall is modified before output
		IVI signal (with fall modification and IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is separated, fall is modified, and signal is synchronized with CSYNCI/HSYNCI input before output
		IVG signal	Internal synchronization signal is output

Mode	IVI Signal	IVO Signal	Meaning of IVO Signal
Separate mode	VSYNCI input	IVI signal (without fall modification or IHI synchronization)	VSYNCI input (vertical synchronization signal) is output directly
		IVI signal (without fall modification, with IHI synchronization)	Meaningless unless VSYNCI input (vertical synchronization signal) is synchronized with HSYNCI input (horizontal synchronization signal)
		IVI signal (with fall modification, without IHI synchronization)	VSYNCI input (vertical synchronization signal) fall is modified before output
		IVI signal (with fall modification and IHI synchronization)	VSYNCI input (vertical synchronization signal) fall is modified and signal is synchronized with HSYNCI input (horizontal synchronization signal) before output
		IVG signal	Internal synchronization signal is output

13.4.9 CBLANK Output

Using the signals generated/selected with timer connection, it is possible to generate a waveform based on the composite synchronization signal (blanking waveform).

One kind of blanking waveform is generated by combining HFBACKI and VFBACKI inputs, with the phase polarity made positive by means of bits HFINV and VFINV in TCONRI, with the IVO signal.

The logic of CBLANK output waveform generation is shown in figure 13.9.

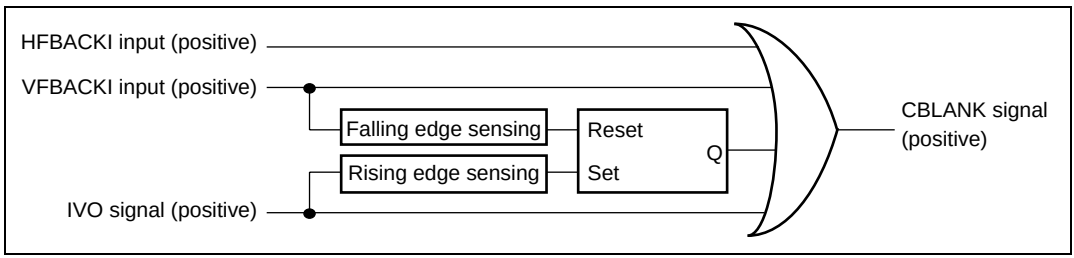


Figure 13.9 CBLANK Output Waveform Generation

13.5 Usage Note

13.5.1 Module Stop Mode Setting

Timer connection operation can be enabled or disabled using the module stop control register. The initial setting is for timer connection operation to be halted. Register access is enabled by canceling the module stop mode. For details, refer to section 26, Power-Down Modes.

Section 14 Watchdog Timer (WDT)

This LSI incorporates two watchdog timer channels (WDT_0 and WDT_1). The watchdog timer can generate an internal reset signal or an internal NMI interrupt signal if a system crash prevents the CPU from writing to the timer counter, thus allowing it to overflow. Simultaneously, it can output an overflow signal ($\overline{\text{RESO}}$) externally.

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. A block diagram of the WDT_0 and WDT_1 is shown in figure 14.1.

14.1 Features

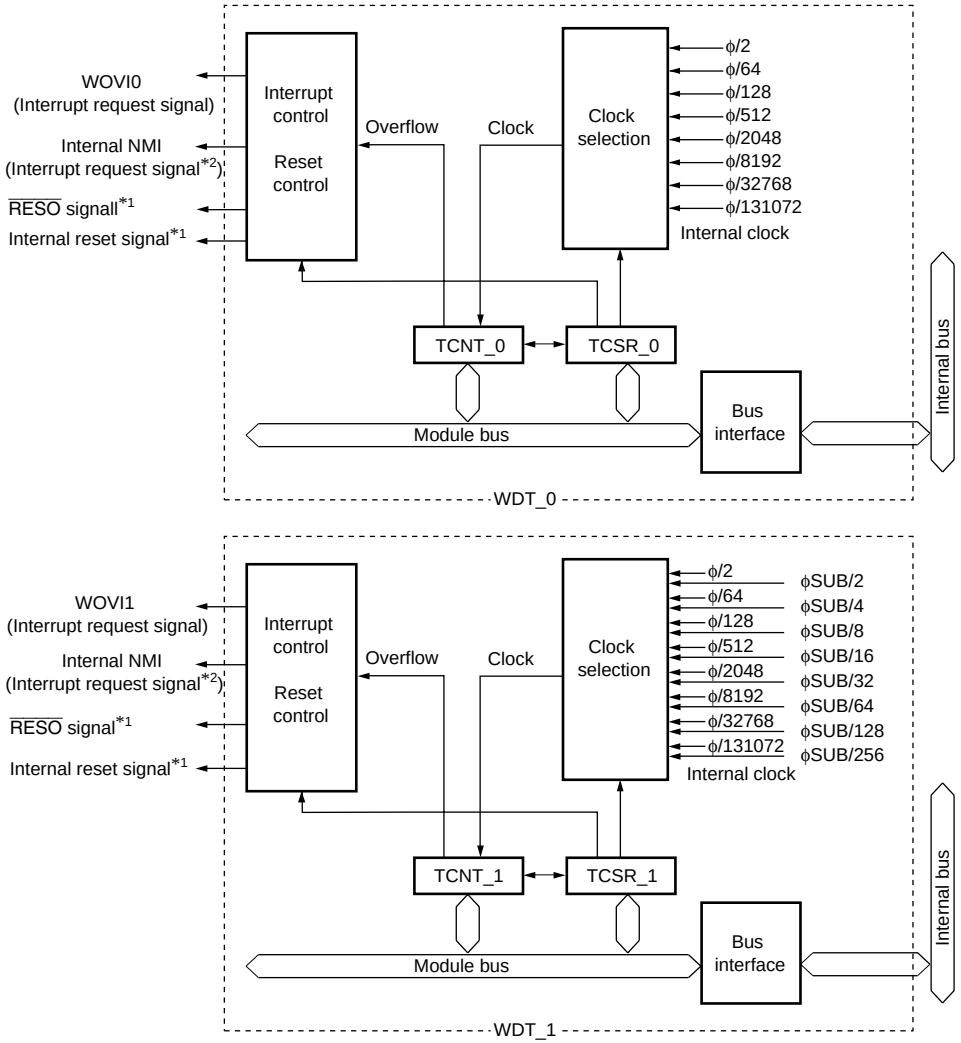
- Selectable from eight (WDT_0) or 16 (WDT_1) counter input clocks.
- Switchable between watchdog timer mode and interval timer mode

Watchdog Timer Mode:

- If the counter overflows, an internal reset or an internal NMI interrupt is generated.
- When the LSI is selected to be internally reset at counter overflow, a low level signal is output from the $\overline{\text{RESO}}$ pin if the counter overflows.

Internal Timer Mode:

- If the counter overflows, an internal timer interrupt (WOVI) is generated.



Legend:
TCSR_0 : Timer control/status register_0
TCNT_0 : Timer counter_0
TCSR_1 : Timer control/status register_1
TCNT_1 : Timer counter_1

Notes: 1. The RESO signal outputs the low level signal when the internal reset signal is generated due to a TCNT overflow of either WDT_0 or WDT_1. The internal reset signal first resets the WDT in which the overflow has occurred first.
2. The internal NMI interrupt signal can be independently output from either WDT_0 or WDT_1. The interrupt controller does not distinguish the NMI interrupt request from WDT_0 from that from WDT_1.

Figure 14.1 Block Diagram of WDT

14.2 Input/Output Pins

The WDT has the pins listed in table 14.1.

Table 14.1 Pin Configuration

Name	Symbol	I/O	Function
Reset output pin	$\overline{\text{RESO}}$	Output	Outputs the counter overflow signal in watchdog timer mode
External sub-clock input pin	EXCL	Input	Inputs the clock pulses to the WDT_1 prescaler counter

14.3 Register Descriptions

The WDT has the following registers. To prevent accidental overwriting, TCSR and TCNT have to be written to in a method different from normal registers. For details, refer to section 14.6.1, Notes on Register Access. For details on the system control register, refer to section 3.2.2, System Control Register (SYSCR).

- Timer counter (TCNT)
- Timer control/status register (TCSR)

14.3.1 Timer Counter (TCNT)

TCNT is an 8-bit readable/writable up-counter.

TCNT is initialized to H'00 when the TME bit in the timer control/status register (TCSR) is cleared to 0.

14.3.2 Timer Control/Status Register (TCSR)

TCSR selects 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 (changes from H'FF to H'00). [Setting condition] When TCNT overflows (changes from H'FF to H'00) However, when internal reset request generation is selected in watchdog timer mode, OVF is cleared automatically by the internal reset. [Clearing conditions] • When TCSR is read when OVF = 1*2, then 0 is written to OVF • When 0 is written to TME
6	WT/$\overline{IT}$	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	—	0	R/(W)	Reserved The initial value should not be modified.
3	RST/$\overline{NMI}$	0	R/W	Reset or NMI Selects to request an internal reset or an NMI interrupt when TCNT has overflowed. 0: An NMI interrupt is requested 1: An internal reset is requested

Bit	Bit Name	Initial Value	R/W	Description
2	CKS2	0	R/W	Clock Select 2 to 0
1	CKS1	0	R/W	Selects the clock source to be input to. The overflow frequency for ϕ = 10 MHz is enclosed in parentheses.
0	CKS0	0	R/W	000: ϕ/2 (frequency: 51.2 µs)
				001: ϕ/64 (frequency: 1.64 ms)
				010: ϕ/128 (frequency: 3.28 ms)
				011: ϕ/512 (frequency: 13.1 ms)
				100: ϕ/2048 (frequency: 52.4 ms)
				101: ϕ/8192 (frequency: 209.7 ms)
				110: ϕ/32768 (frequency: 0.84 s)
				111: ϕ/131072 (frequency: 3.36 s)

Notes: 1. Only 0 can be written, to clear the flag.
2. When OVF is polled with the interval timer interrupt disabled, OVF = 1 must be read at least twice.

- TCSR_1

Bit	Bit Name	Initial Value	R/W	Description
7	OVF	0	R/(W)*1	Overflow Flag Indicates that TCNT has overflowed (changes from H'FF to H'00). [Setting condition] When TCNT overflows (changes from H'FF to H'00) However, when internal reset request generation is selected in watchdog timer mode, OVF is cleared automatically by the internal reset. [Clearing conditions] • When TCSR is read when OVF = 1*2, then 0 is written to OVF • When 0 is written to TME
6	WT/$\overline{IT}$	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	PSS	0	R/W	Prescaler Select Selects the clock source to be input to TCNT. 0: Counts the divided cycle of φ–based prescaler (PSM) 1: Counts the divided cycle of φSUB–based prescaler (PSS)
3	RST/$\overline{NMI}$	0	R/W	Reset or NMI Selects to request an internal reset or an NMI interrupt when TCNT has overflowed. 0: An NMI interrupt is requested 1: An internal reset is requested

Bit	Bit Name	Initial Value	R/W	Description
2	CKS2	0	R/W	Clock Select 2 to 0
1	CKS1	0	R/W	Selects the clock source to be input to TCNT. The overflow cycle for ϕ = 10 MHz and ϕSUB = 32.768 kHz is enclosed in parentheses.
0	CKS0	0	R/W	
				When PSS = 0:
				000: ϕ/2 (frequency: 51.2 µs)
				001: ϕ/64 (frequency: 1.64 ms)
				010: ϕ/128 (frequency: 3.28 ms)
				011: ϕ/512 (frequency: 13.1 ms)
				100: ϕ/2048 (frequency: 52.4 ms)
				101: ϕ/8192 (frequency: 209.7 ms)
				110: ϕ/32768 (frequency: 0.84 s)
				111: ϕ/131072 (frequency: 3.36 s)
				When PSS = 1:
				000: ϕSUB/2 (cycle: 15.6 ms)
				001: ϕSUB/4 (cycle: 31.3 ms)
				010: ϕSUB/8 (cycle: 62.5 ms)
				011: ϕSUB/16 (cycle: 125 ms)
				100: ϕSUB/32 (cycle: 250 ms)
				101: ϕSUB/64 (cycle: 500 ms)
				110: ϕSUB/128 (cycle: 1 s)
				111: ϕSUB/256 (cycle: 2 s)

Notes: 1. Only 0 can be written, to clear the flag.
2. When OVF is polled with the interval timer interrupt disabled, OVF = 1 must be read at least twice.

14.4 Operation

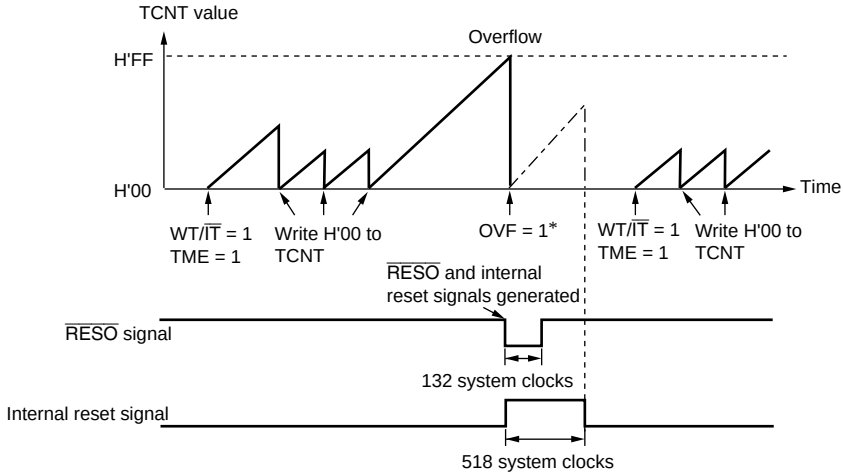
14.4.1 Watchdog Timer Mode

To use the WDT as a watchdog timer, set the WT/$\overline{IT}$ bit and the TME bit in TCSR to 1. While the WDT is used as a watchdog timer, if TCNT overflows without being rewritten because of a system malfunction or another error, an internal reset or NMI interrupt request is generated. TCNT does not overflow while the system is operating normally. Software must prevent TCNT overflows by rewriting the TCNT value (normally be writing H'00) before overflows occurs.

If the RST/$\overline{NMI}$ bit of TCSR is set to 1, when the TCNT overflows, an internal reset signal for this LSI is issued for 518 system clocks, and the low level signal is simultaneously output from the $\overline{RESO}$ pin for 132 states, as shown in figure 14.2. If the RST/$\overline{NMI}$ bit is cleared to 0, when the TCNT overflows, an NMI interrupt request is generated. Here, the output from the $\overline{RESO}$ pin remains high.

An internal reset request from the watchdog timer and a reset input from the $\overline{RES}$ pin are processed in the same vector. Reset source can be identified by the XRST bit status in SYSCR. If a reset caused by a signal input to the $\overline{RES}$ pin occurs at the same time as a reset caused by a WDT overflow, the $\overline{RES}$ pin reset has priority and the XRST bit in SYSCR is set to 1.

An NMI interrupt request from the watchdog timer and an interrupt request from the NMI pin are processed in the same vector. Do not handle an NMI interrupt request from the watchdog timer and an interrupt request from the NMI pin at the same time.



Legend:
WT/$\overline{IT}$: Timer mode select bit
TME : Timer enable bit
OVF : Overflow flag

Note: * After the OVF bit becomes 1, it is cleared to 0 by an internal reset.
The XRST bit is also cleared to 0.

Figure 14.2 Watchdog Timer Mode (RST/$\overline{NMI}$ = 1) Operation

14.4.2 Interval Timer Mode

When the WDT is used as an interval timer, an interval timer interrupt (WOVI) is generated each time the TCNT overflows, as shown in figure 14.3. Therefore, an interrupt can be generated at intervals.

When the TCNT overflows in interval timer mode, an interval timer interrupt (WOVI) is requested at the same time the OVF bit of TCSR is set to 1. The timing is shown figure 14.4.

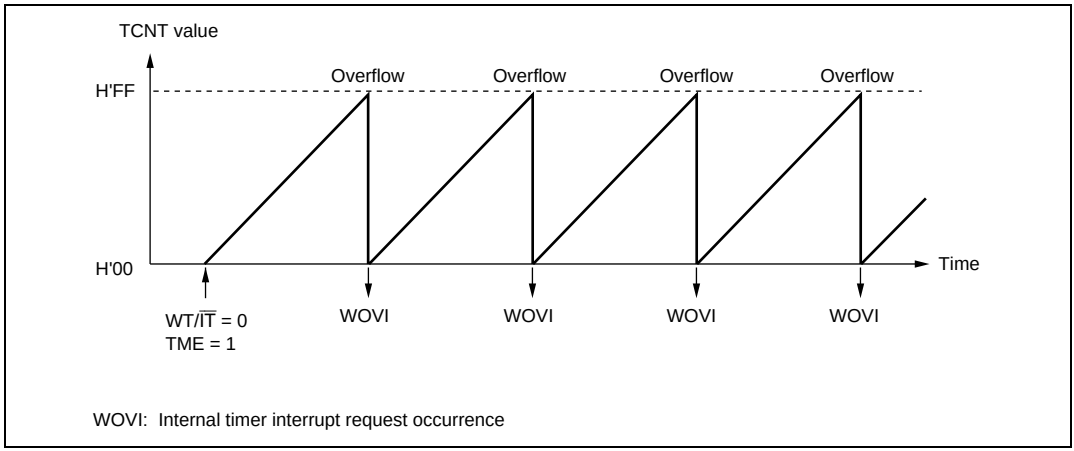


Figure 14.3 Interval Timer Mode Operation

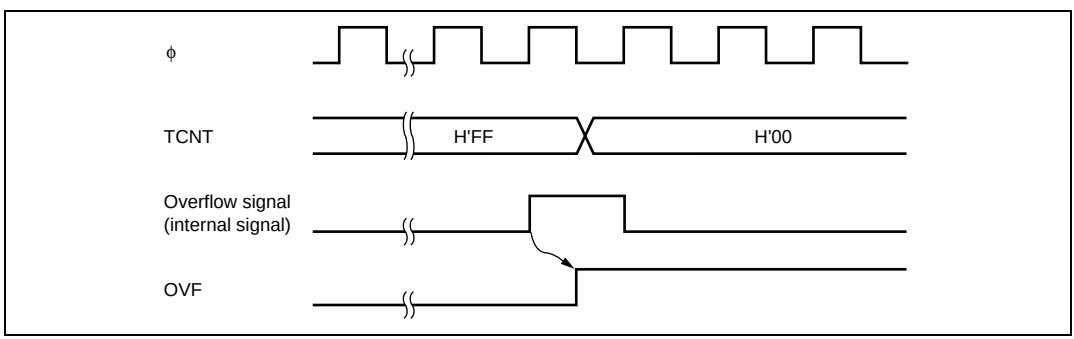


Figure 14.4 OVF Flag Set Timing

14.4.3 $\overline{\text{RESO}}$ Signal Output Timing

When TCNT overflows in watchdog timer mode, the OVF bit in TCSR is set to 1. When the RST/$\overline{\text{NMI}}$ bit is 1 here, the internal reset signal is generated for the entire LSI. At the same time, the low level signal is output from the $\overline{\text{RESO}}$ pin. The timing is shown in figure 14.5.

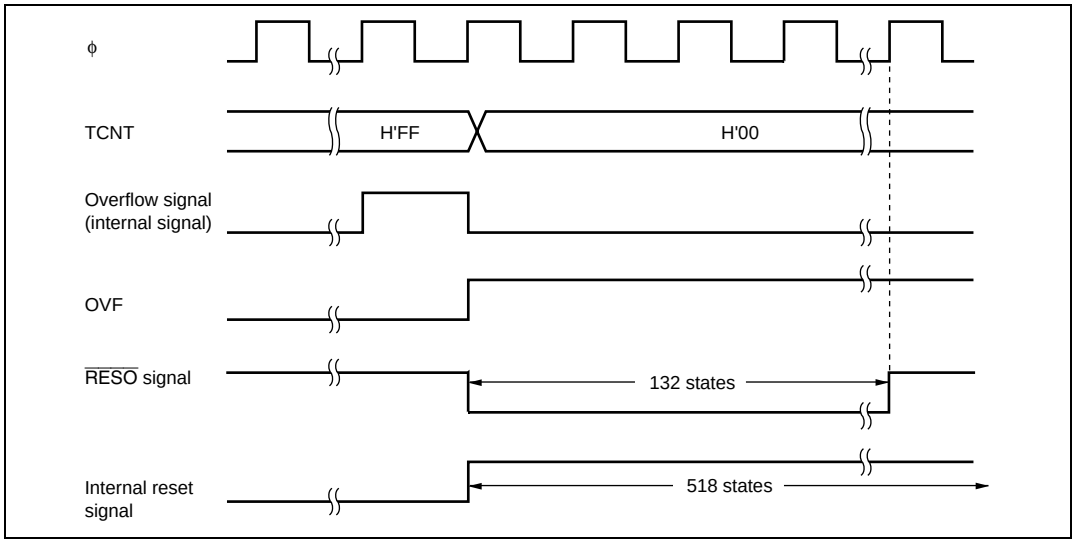


Figure 14.5 Output Timing of $\overline{\text{RESO}}$ signal

14.5 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.

When the NMI interrupt request is selected in watchdog timer mode, an NMI interrupt request is generated by an overflow.

Table 14.2 WDT Interrupt Source

Name	Interrupt Source	Interrupt Flag	DTC Activation
WOVI	TCNT overflow	OVF	Not possible

14.6 Usage Notes

14.6.1 Notes on Register Access

The watchdog timer's registers, TCNT and TCSR differ from other registers in being more difficult to write to. The procedures for writing to and reading from these registers are given below.

Writing to TCNT and TCSR (Example of WDT_0): 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, satisfy the relative condition shown in figure 14.6 to write to TCNT or TCSR. To write to TCNT, the upper bytes must contain the value H'5A and the lower bytes must contain the write data before the transfer instruction execution. To write to TCSR, the upper bytes must contain the value H'A5 and the lower bytes must contain the write data.

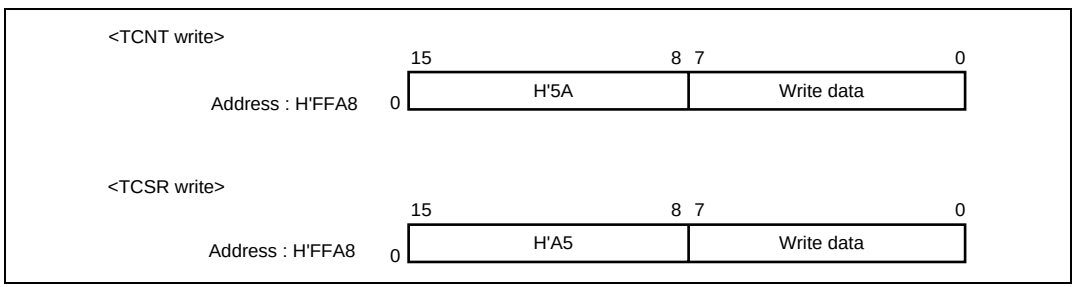


Figure 14.6 Writing to TCNT and TCSR (WDT_0)

Reading from TCNT and TCSR (Example of WDT_0): These registers are read in the same way as other registers. The read address is H'FFA8 for TCSR and H'FFA9 for TCNT.

14.6.2 Conflict 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 14.7 shows this operation.

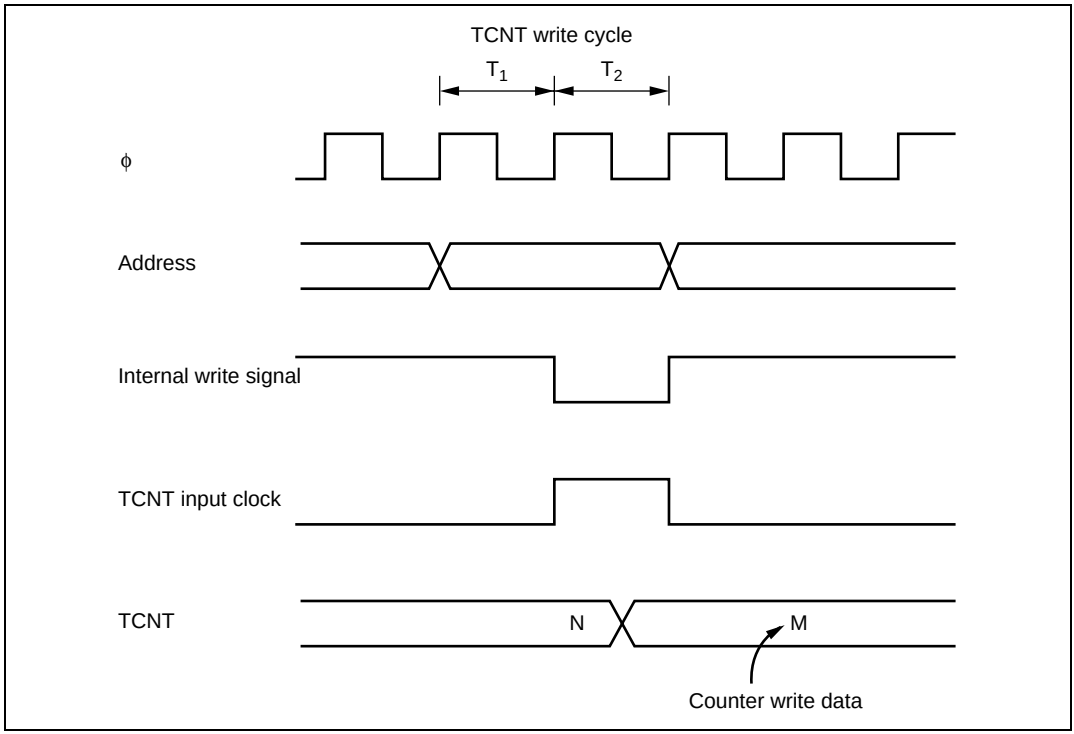


Figure 14.7 Conflict between TCNT Write and Increment

14.6.3 Changing Values of CKS2 to CKS0 Bits

If bits CKS2 to CKS0 in TCSR are written to while the WDT is operating, errors could occur in the incrementation. Software must stop the watchdog timer (by clearing the TME bit to 0) before changing the values of bits CKS2 to CKS0.

14.6.4 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 stop the watchdog timer (by clearing the TME bit to 0) before switching the mode.

14.6.5 System Reset by $\overline{\text{RESO}}$ Signal

Inputting the $\overline{\text{RESO}}$ output signal to the $\overline{\text{RESO}}$ pin of this LSI prevents the LSI from being initialized correctly; the $\overline{\text{RESO}}$ signal must not be logically connected to the $\overline{\text{RES}}$ pin of the LSI. To reset the entire system by the $\overline{\text{RESO}}$ signal, use the circuit as shown in figure 14.8.

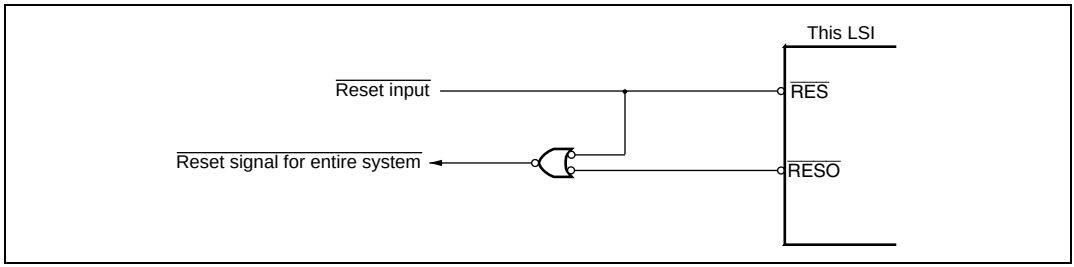


Figure 14.8 Sample Circuit for Resetting System by $\overline{\text{RESO}}$ Signal

14.6.6 Counter Values during Transitions between High-Speed, Sub-Active, and Watch Modes

When WDT_1 is used as a clock counter and is allowed to transit between high-speed mode and sub-active or watch mode, the counter does not display the correct value due to internal clock switching.

Specifically, when transiting from high-speed mode to sub-active or watch mode, that is, when the control clock for WDT_1 switches from the main clock to the sub-clock, the counter incrementing timing is delayed for approximately two to three clock cycles.

Similarly, when transiting from sub-active or watch mode to high-speed mode, the clock is not supplied until stabilized internal oscillation is available because the main clock oscillator is halted in sub-clock mode. The counter is therefore prevented from incrementing for the time specified by the STS2 to STS0 bits in SBYCR after internal oscillation starts, thus producing counter value differences for this time.

Special care must be taken when using WDT_1 as a clock counter. Note that no counter value difference is produced while operated in the same mode.

Section 15 Serial Communication Interface (SCI and IrDA)

This LSI has three independent serial communication interface (SCI) channels. The SCI can handle both asynchronous and clocked synchronous serial communication. Asynchronous serial data communication can be carried out with standard asynchronous communication chips such as a Universal Asynchronous Receiver/Transmitter (UART) or Asynchronous Communication Interface Adapter (ACIA). A function is also provided for serial communication between processors (multiprocessor communication function) in asynchronous mode.

SCI_2 can handle communication using the waveform based on the Infrared Data Association (IrDA) standard version 1.0.

15.1 Features

- Choice of asynchronous or clocked synchronous serial communication mode
- Full-duplex communication capability

  The transmitter and receiver are mutually independent, enabling transmission and reception to be executed simultaneously. Double-buffering is used in both the transmitter and the receiver, enabling continuous transmission and continuous reception of serial data.
- The on-chip baud rate generator allows any bit rate to be selected

  An external clock can be selected as a transfer clock source.
- Choice of LSB-first or MSB-first transfer (except in the case of asynchronous mode 7-bit data)
- Four interrupt sources

  Four interrupt sources — transmit-end, transmit-data-empty, receive-data-full, and receive error — that can issue requests.

  The transmit-data-empty and receive-data-full interrupt sources can activate the DTC.

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 case of a framing error

Clocked Synchronous Mode:

- Data length: 8 bits
- Receive error detection: Overrun errors
- Serial data communication with other LSIs that have the clock synchronized communication function

A block diagram of the SCI is shown in figure 15.1.

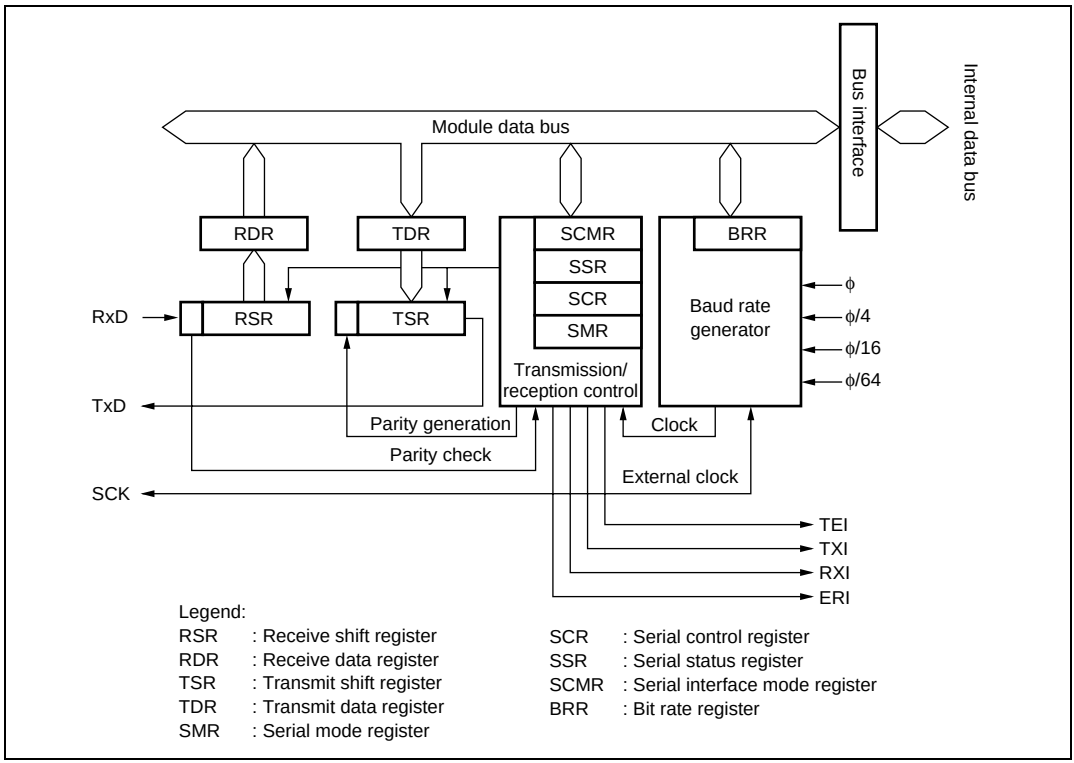


Figure 15.1 Block Diagram of SCI

15.2 Input/Output Pins

Table 15.1 shows the input/output pins for each SCI channel.

Table 15.1 Pin Configuration

Channel	Symbol*	Input/Output	Function
0	SCK0	Input/Output	Channel 0 clock input/output
	RxD0	Input	Channel 0 receive data input
	TxD0	Output	Channel 0 transmit data output
1	SCK1	Input/Output	Channel 1 clock input/output
	RxD1	Input	Channel 1 receive data input
	TxD1	Output	Channel 1 transmit data output
2	SCK2	Input/Output	Channel 2 clock input/output
	RxD2/IrRxD	Input	Channel 2 receive data input (normal/IrDA)
	TxD2/IrTxD	Output	Channel 2 transmit data output (normal/IrDA)

Note: * Pin names SCK, RxD, and TxD are used in the text for all channels, omitting the channel designation.

15.3 Register Descriptions

The SCI has the following registers for each channel.

- 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)
- Serial interface mode register (SCMR)
- Bit rate register (BRR)
- Keyboard comparator control register (KBCOMP)

15.3.1 Receive Shift Register (RSR)

RSR is a shift register used to receive serial data that converts it into parallel data. When one frame of data has been received, it is transferred to RDR automatically. RSR cannot be directly accessed by the CPU.

15.3.2 Receive Data Register (RDR)

RDR is an 8-bit register that stores receive data. When the SCI has received one frame of serial data, it transfers the received serial data from RSR to RDR where it is stored. After this, RSR can receive the next data. Since RSR and RDR function as a double buffer in this way, continuous receive operations can be performed. After confirming that the RDRF bit in SSR is set to 1, read RDR for only once. RDR cannot be written to by the CPU. RDR is initialized to H'00.

15.3.3 Transmit Data Register (TDR)

TDR is an 8-bit register that stores transmit data. When the SCI detects that TSR is empty, it transfers the transmit data written in TDR to TSR and starts transmission. The double-buffered structures of TDR and TSR enables continuous serial transmission. If the next transmit data has already been written to TDR when one frame of data is transmitted, the SCI transfers the written data to TSR to continue transmission. Although TDR can be read from or written to by the CPU at all times, to achieve reliable serial transmission, write transmit data to TDR for only once after confirming that the TDRE bit in SSR is set to 1. TDR is initialized to H'FF.

15.3.4 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.

15.3.5 Serial Mode Register (SMR)

SMR is used to set the SCI's serial transfer format and select the on-chip baud rate generator clock source.

Bit	Bit Name	Initial Value	R/W	Description
7	C/$\overline{A}$	0	R/W	Communication Mode 0: Asynchronous mode 1: Clocked synchronous mode
6	CHR	0	R/W	Character Length (enabled only in asynchronous mode) 0: Selects 8 bits as the data length. 1: Selects 7 bits as the data length. LSB-first is fixed and the MSB of TDR is not transmitted in transmission. In clocked synchronous mode, a fixed data length of 8 bits is used.
5	PE	0	R/W	Parity Enable (enabled only in asynchronous mode) When this bit is set to 1, the parity bit is added to transmit data before transmission, and the parity bit is checked in reception. For a multiprocessor format, parity bit addition and checking are not performed regardless of the PE bit setting.
4	O/$\overline{E}$	0	R/W	Parity Mode (enabled only when the PE bit is 1 in asynchronous mode) 0: Selects even parity. 1: Selects odd parity.
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 frame.

Bit	Bit Name	Initial Value	R/W	Description
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/$\overline{E}$ bit settings are invalid in multiprocessor mode.
1	CKS1	0	R/W	Clock Select 1,0
0	CKS0	0	R/W	These bits select the clock source for the on-chip 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 relation between the bit rate register setting and the baud rate, see section 15.3.9, Bit Rate Register (BRR). n is the decimal display of the value of n in BRR.

15.3.6 Serial Control Register (SCR)

SCR is a register that performs enabling or disabling of SCI transfer operations and interrupt requests, and selection of the transfer clock source. For details on interrupt requests, refer to section 15.8, Interrupt Sources.

Bit	Bit Name	Initial Value	R/W	Description
7	TIE	0	R/W	Transmit Interrupt Enable When this bit is set to 1, a TXI interrupt request is enabled.
6	RIE	0	R/W	Receive Interrupt Enable When this bit is set to 1, RXI and ERI interrupt requests are enabled.
5	TE	0	R/W	Transmit Enable When this bit is set to 1, transmission is enabled.
4	RE	0	R/W	Receive Enable When this bit is set to 1, reception is enabled.

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) 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 disabled. 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 15.5, Multiprocessor Communication Function.
2	TEIE	0	R/W	Transmit End Interrupt Enable When this bit is set to 1, a TEI interrupt request is enabled.
1	CKE1	0	R/W	Clock Enable 1, 0
0	CKE0	0	R/W	These bits select the clock source and SCK pin function. Asynchronous mode 00: Internal clock (SCK pin functions as I/O port.) 01: Internal clock (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

15.3.7 Serial Status Register (SSR)

SSR is a register containing status flags of the SCI and multiprocessor bits for transfer. TDRE, RDRF, ORER, PER, and FER can only be cleared.

Bit	Bit Name	Initial Value	R/W	Description
7	TDRE	1	R/(W)*	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 TDR is ready for data write [Clearing conditions] • When 0 is written to TDRE after reading TDRE = 1 • When a TXI interrupt request is issued allowing the DTC to write data to TDR
6	RDRF	0	R/(W)*	Receive Data Register Full Indicates that receive 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 an RXI interrupt request is issued allowing the DTC to read data from RDR The RDRF flag is not affected and retains its previous value when the RE bit in SCR is cleared to 0.
5	ORER	0	R/(W)*	Overrun Error [Setting condition] When the next data is received while RDRF = 1 [Clearing condition] When 0 is written to ORER after reading ORER = 1

Bit	Bit Name	Initial Value	R/W	Description
4	FER	0	R/(W)*	Framing Error [Setting condition] When the stop bit is 0 [Clearing condition] When 0 is written to FER after reading FER = 1 In 2-stop-bit mode, only the first stop bit is checked.
3	PER	0	R/(W)*	Parity Error [Setting condition] When a parity error is detected during reception [Clearing condition] When 0 is written to PER after reading PER = 1
2	TEND	1	R	Transmit End [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 a TXI interrupt request is issued allowing the DTC to write data to TDR
1	MPB	0	R	Multiprocessor Bit MPB stores the multiprocessor bit in the receive frame. 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 frame.

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

15.3.8 Serial Interface Mode Register (SCMR)

SCMR selects SCI functions and its format.

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 1	R	Reserved These bits are always read as 1 and cannot be modified.
3	SDIR	0	R/W	Data Transfer Direction Selects the serial/parallel conversion format. 0: TDR contents are transmitted with LSB-first. Receive data is stored as LSB first in RDR. 1: TDR contents are transmitted with MSB-first. Receive data is stored as MSB first in RDR. The SDIR bit is valid only when the 8-bit data format is used for transmission/reception; when the 7-bit data format is used, data is always transmitted/received with LSB-first.
2	SINV	0	R/W	Data Invert Specifies inversion of the data logic level. The SINV bit does not affect the logic level of the parity bit. When the parity bit is inverted, invert the O/$\overline{E}$ 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	R	Reserved This bit is always read as 1 and cannot be modified.
0	SMIF	0	R/W	Serial Communication Interface Mode Select: 0: Normal asynchronous or clocked synchronous mode 1: Reserved mode

15.3.9 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 15.2 shows the relationships between the N setting in BRR and bit rate B for normal asynchronous mode and clocked synchronous mode. The initial value of BRR is H'FF, and it can be read from or written to by the CPU at all times.

Table 15.2 Relationships between N Setting in BRR and Bit Rate B

Mode	Bit Rate	Error
Asynchronous mode	$B = \frac{\phi \times 10^6}{64 \times 2^{2n-1} \times (N+1)}$	$\text{Error (\%)} = \{ \frac{\phi \times 10^6}{B \times 64 \times 2^{2n-1} \times (N+1)} - 1 \} \times 100$
Clocked synchronous mode	$B = \frac{\phi \times 10^6}{64 \times 2^{2n-1} \times (N+1)}$	—

Legend:

B: Bit rate (bit/s)

N: BRR setting for baud rate generator ($0 \leq N \leq 255$)

ϕ: Operating frequency (MHz)

n: Determined by the SMR settings shown in the following table.

SMR Setting

CKS1	CKS0	n
0	0	0
0	1	1
1	0	2
1	1	3

Table 15.3 shows sample N settings in BRR in normal asynchronous mode. Table 15.4 shows the maximum bit rate settable for each frequency. Table 15.6 shows sample N settings in BRR in clocked synchronous mode. Tables 15.5 and 15.7 show the maximum bit rates with external clock input.

Table 15.3 BRR Settings for Various Bit Rates (Asynchronous Mode)

	Operating Frequency ϕ (MHz)											
	2			2.097152			2.4576			3		
Bit Rate (bit/s)	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 (bit/s)	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

Legend:

—: Can be set, but there will be a degree of error.

Note: Make the settings so that the error does not exceed 1%.

	Operating Frequency φ (MHz)											
	6			6.144			7.3728			8		
Bit Rate (bit/s)	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 (bit/s)	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

Legend:

—: Can be set, but there will be a degree of error.

Note: Make the settings so that the error does not exceed 1%.

	Operating Frequency ϕ (MHz)											
	14			14.7456			16			17.2032		
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	248	–0.17	3	64	0.70	3	70	0.03	3	75	0.48
150	2	181	0.16	2	191	0.00	2	207	0.16	2	223	0.00
300	2	90	0.16	2	95	0.00	2	103	0.16	2	111	0.00
600	1	181	0.16	1	191	0.00	1	207	0.16	1	223	0.00
1200	1	90	0.16	1	95	0.00	1	103	0.16	1	111	0.00
2400	0	181	0.16	0	191	0.00	0	207	0.16	0	223	0.00
4800	0	90	0.16	0	95	0.00	0	103	0.16	0	111	0.00
9600	0	45	–0.93	0	47	0.00	0	51	0.16	0	55	0.00
19200	0	22	–0.93	0	23	0.00	0	25	0.16	0	27	0.00
31250	0	13	0.00	0	14	–1.70	0	15	0.00	0	16	1.20
38400	—	—	—	0	11	0.00	0	12	0.16	0	16	0.00

	Operating Frequency ϕ (MHz)								
	18			19.6608			20		
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	3	79	–0.12	3	86	0.31	3	88	–0.25
150	2	233	0.16	2	255	0.00	3	64	0.16
300	2	116	0.16	2	127	0.00	2	129	0.16
600	1	233	0.16	1	255	0.00	2	64	0.16
1200	1	166	0.16	1	127	0.00	1	129	0.16
2400	0	233	0.16	0	255	0.00	1	64	0.16
4800	0	166	0.16	0	127	0.00	0	129	0.16
9600	0	58	–0.69	0	63	0.00	0	64	0.16
19200	0	28	1.02	0	31	0.00	0	32	–1.36
31250	0	17	0.00	0	19	–1.70	0	19	0.00
38400	0	14	–2.34	0	15	0.00	0	15	1.73

Legend:

—: Can be set, but there will be a degree of error.

Note: Make the settings so that the error does not exceed 1%.

Table 15.4 Maximum Bit Rate for Each Frequency (Asynchronous Mode)

φ (MHz)	Maximum Bit Rate (bit/s)	n	N	φ (MHz)	Maximum Bit Rate (bit/s)	n	N
2	62500	0	0	9.8304	307200	0	0
2.097152	65536	0	0	10	312500	0	0
2.4576	76800	0	0	12	375000	0	0
3	93750	0	0	12.288	384000	0	0
3.6864	115200	0	0	14	437500	0	0
4	125000	0	0	14.7456	460800	0	0
4.9152	153600	0	0	16	500000	0	0
5	156250	0	0	17.2032	537600	0	0
6	187500	0	0	18	562500	0	0
6.144	192000	0	0	19.6608	614400	0	0
7.3728	230400	0	0	20	625000	0	0
8	250000	0	0				

Table 15.5 Maximum Bit Rate with External Clock Input (Asynchronous Mode)

φ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bit/s)	φ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bit/s)
2	0.5000	31250	9.8304	2.4576	153600
2.097152	0.5243	32768	10	2.5000	156250
2.4576	0.6144	38400	12	3.0000	187500
3	0.7500	46875	12.288	3.0720	192000
3.6864	0.9216	57600	14	3.5000	218750
4	1.0000	62500	14.7456	3.6864	230400
4.9152	1.2288	76800	16	4.0000	250000
5	1.2500	78125	17.2032	4.3008	268800
6	15.000	93750	18	4.5000	281250
6.144	1.5360	96000	19.6608	4.9152	307200
7.3728	1.8432	115200	20	5.0000	312500
8	2.0000	125000			

Table 15.6 BRR Settings for Various Bit Rates (Clocked Synchronous Mode)

Bit Rate (bit/s)	Operating Frequency ϕ (MHz)											
	2		4		8		10		16		20	
	n	N	n	N	n	N	n	N	n	N	n	N
110	3	70	—	—								
250	2	124	2	249	3	124	—	—	3	249		
500	1	249	2	124	2	249	—	—	3	124	—	—
1k	1	124	1	249	2	124	—	—	2	249	—	—
2.5k	0	199	1	99	1	199	1	249	2	99	2	124
5k	0	99	0	199	1	99	1	124	1	199	1	249
10k	0	49	0	99	0	199	0	249	1	99	1	124
25k	0	19	0	39	0	79	0	99	0	159	0	199
50k	0	9	0	19	0	39	0	49	0	79	0	99
100k	0	4	0	9	0	19	0	24	0	39	0	49
250k	0	1	0	3	0	7	0	9	0	15	0	19
500k	0	0*	0	1*	0	3	0	4	0	7	0	9
1M			0	0	0	1			0	3	0	4
2.5M							0	0*			0	1
5M											0	0*

Legend:

Blank: Cannot be set.

—: Can be set, but there will be a degree of error.

*: Continuous transfer or reception is not possible.

Table 15.7 Maximum Bit Rate with External Clock Input (Clocked Synchronous Mode)

ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bit/s)	ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bit/s)
2	0.3333	333333.3	12	2.0000	2000000.0
4	0.6667	666666.7	14	2.3333	2333333.3
6	1.0000	1000000.0	16	2.6667	2666666.7
8	1.3333	1333333.3	18	3.0000	3000000.0
10	1.6667	1666666.7	20	3.3333	3333333.3

15.3.10 Keyboard Comparator Control Register (KBCOMP)

KBCOMP selects the functions of the SCI and A/D converter.

Bit	Bit Name	Initial Value	R/W	Description
7	IrE	0	R/W	IrDA Enable Specifies SCI_2 I/O pins for either normal SCI or IrDA. 0: TxD2/IrTxD and RxD2/IrRxD pins function as TxD2 and RxD2 pins, respectively 1: TxD2/IrTxD and RxD2/IrRxD pins function as IrTxD and IrRxD pins, respectively
6 5 4	IrCKS2 IrCKS1 IrCKS0	0 0 0	R/W R/W R/W	IrDA Clock Select 2 to 0 These bits specify the high-level width of the clock pulse during IrTxD output pulse encoding when the IrDA function is enabled. 000: B × 3/16 (B: Bit rate) 001: ϕ/2 010: ϕ/4 011: ϕ/8 100: ϕ/16 101: ϕ/32 110: ϕ/64 111: ϕ/128
3 2 1 0	KBADE KBCH2 KBCH1 KBCH0	0 0 0 0	R/W R/W R/W R/W	Bits related to the A/D converter For details, refer to section 21.3.4, Keyboard Comparator Control Register (KBCOMP).

15.4 Operation in Asynchronous Mode

Figure 15.2 shows the general format for asynchronous serial communication. One frame consists of a start bit (low level), followed by transmit/receive 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 and reception.

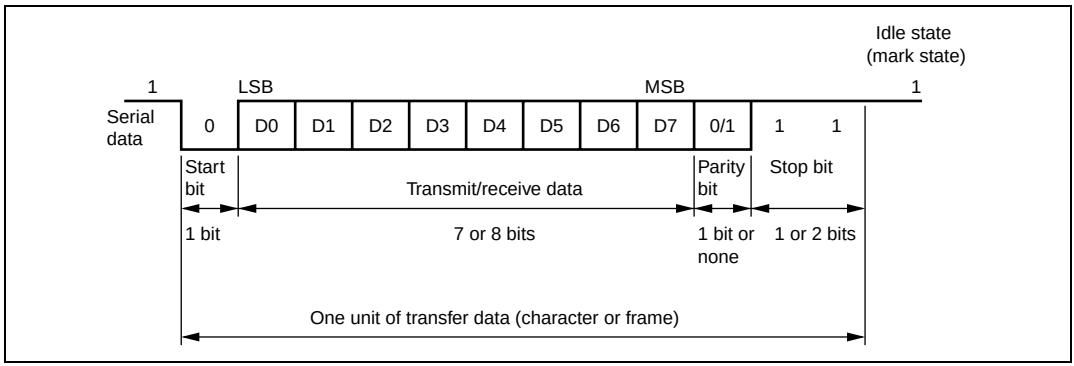


Figure 15.2 Data Format in Asynchronous Communication (Example with 8-Bit Data, Parity, Two Stop Bits)

15.4.1 Data Transfer Format

Table 15.8 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 15.5, Multiprocessor Communication Function.

Table 15.8 Serial Transfer Formats (Asynchronous Mode)

SMR Settings				Serial Transmit/Receive 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

15.4.2 Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI operates on a basic clock with a frequency of 16 times the bit rate. In reception, the SCI samples the falling edge of the start bit using the basic clock, and performs internal synchronization. Since receive data is latched internally at the rising edge of the 8th pulse of the basic clock, data is latched at the middle of each bit, as shown in figure 15.3. Thus the reception margin in asynchronous mode is determined by formula (1) below.

$$M = \{ (0.5 - \frac{1}{2N}) - \frac{D - 0.5}{N} (1 + F) - (L - 0.5) F \} \times 100 \quad [\%] \quad \cdots \quad \text{Formula (1)}$$

M: Reception margin (%)
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 = 0 and D = 0.5 in formula (1), the reception margin is determined by the formula below.

$$M = \{0.5 - 1/(2 \times 16)\} \times 100 \quad [\%] = 46.875\ \%$$

However, this is only the computed value, and a margin of 20% to 30% should be allowed in system design.

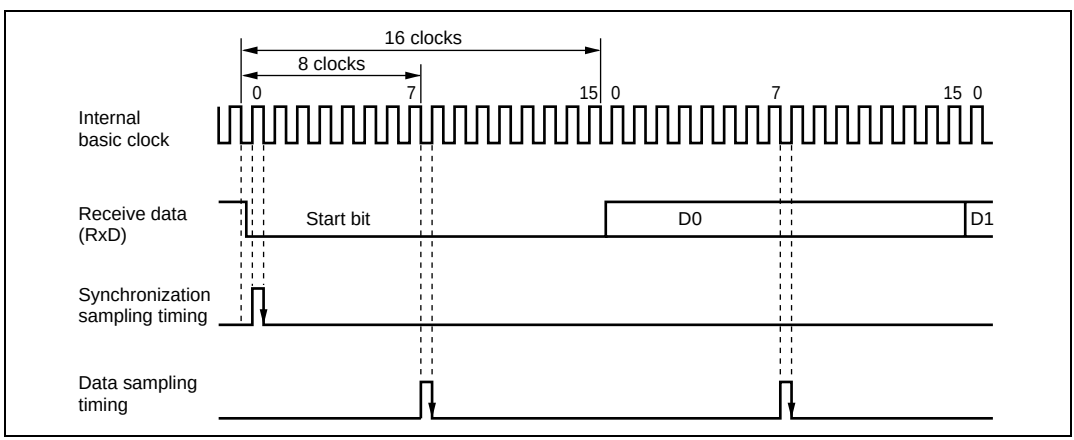


Figure 15.3 Receive Data Sampling Timing in Asynchronous Mode

15.4.3 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 transfer clock, according to the setting of the C/$\overline{A}$ bit in SMR and the CKE1 and CKE0 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. 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 15.4.

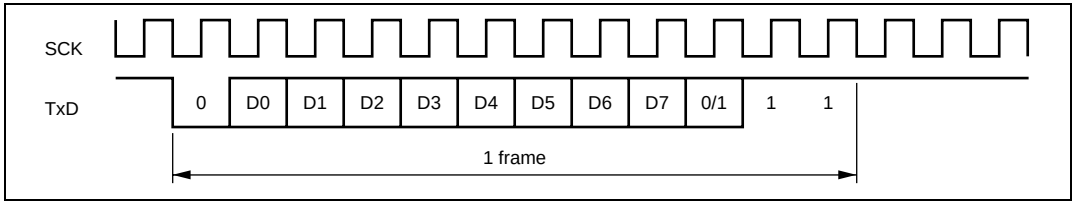


Figure 15.4 Relation between Output Clock and Transmit Data Phase (Asynchronous Mode)

15.4.4 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 shown in figure 15.5. When the operating mode, transfer format, etc., is changed, 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 in SSR 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 in SSR, or the contents of RDR. When an external clock is used in asynchronous mode, the clock must be supplied even during initialization.

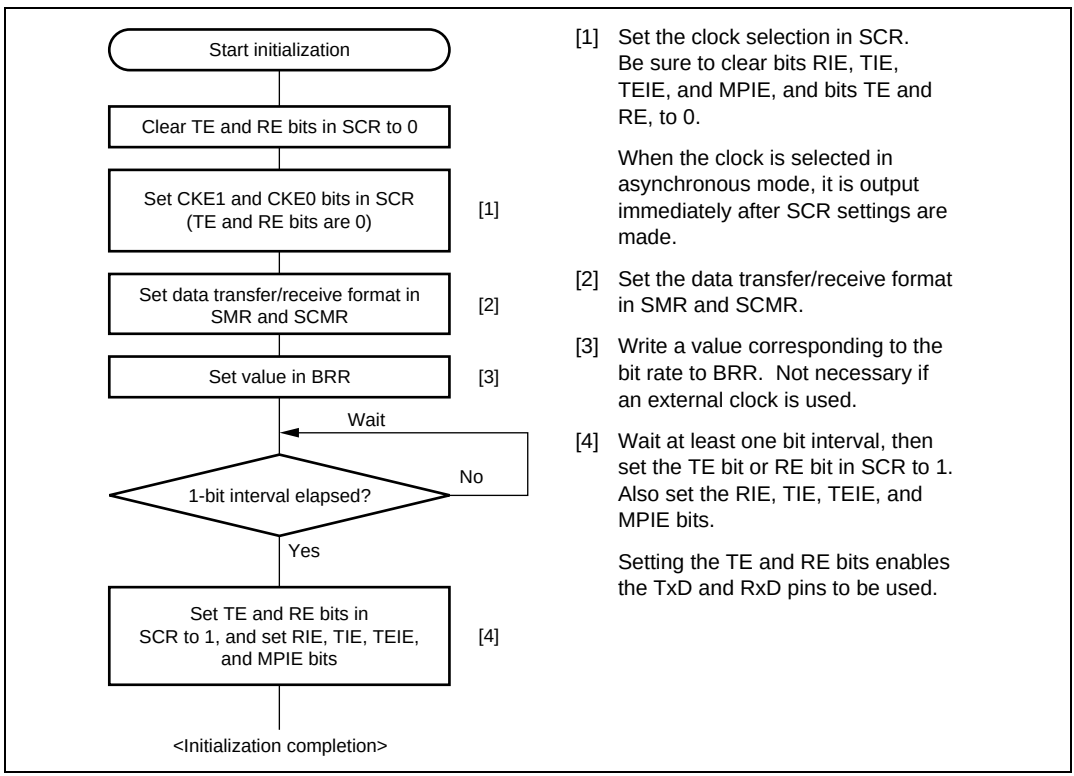


Figure 15.5 Sample SCI Initialization Flowchart

15.4.5 Data Transmission (Asynchronous Mode)

Figure 15.6 shows an example of the operation for transmission in asynchronous mode. In transmission, the SCI operates as described below.

1. The SCI monitors the TDRE flag in SSR, and if it is cleared to 0, 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 request (TXI) is generated. Because the TXI interrupt routine writes the next transmit data to TDR before transmission of the current transmit data has finished, continuous transmission can be enabled.
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 15.7 shows a sample flowchart for transmission in asynchronous mode.

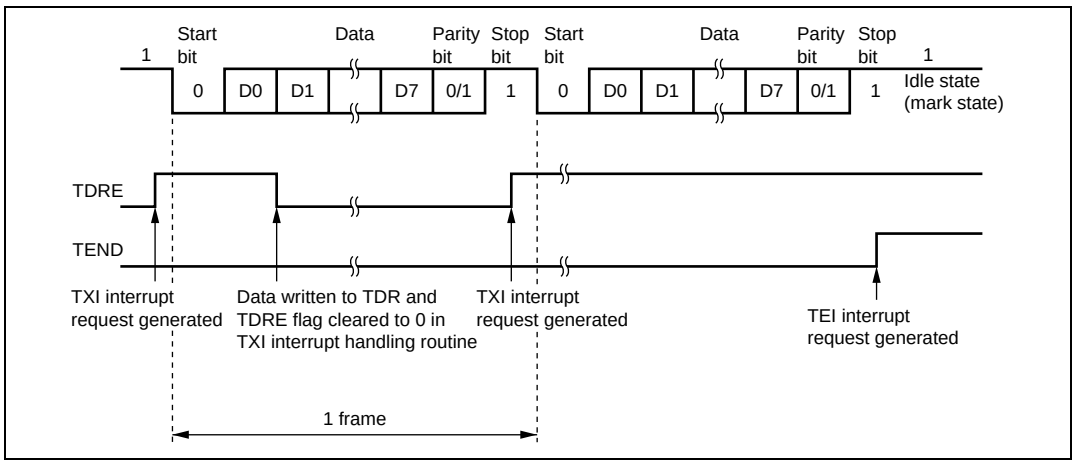
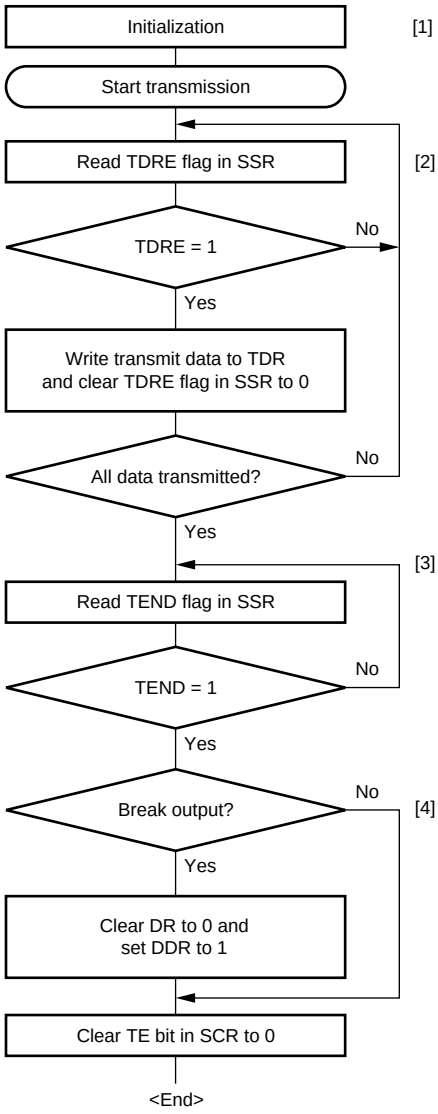


Figure 15.6 Example of SCI Transmit Operation in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)



[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 clear the TDRE flag to 0. However, the TDRE flag is checked and cleared automatically when the DTC is initiated by a transmit data empty interrupt (TXI) request and writes data to TDR.

[4] Break output at the end of serial transmission:
To output a break in serial transmission, set DDR for the port corresponding to the TxD pin to 1, clear DR to 0, then clear the TE bit in SCR to 0.

Figure 15.7 Sample Serial Transmission Flowchart

15.4.6 Serial Data Reception (Asynchronous Mode)

Figure 15.8 shows an example of the operation for reception in asynchronous mode. In serial reception, the SCI operates as described below.

1. The SCI monitors the communication line, and if a start bit is detected, performs internal synchronization, receives receive data in RSR, and checks the parity bit and stop bit.
2. If an overrun error (when reception of the next data is completed while the RDRF flag in SSR is still set to 1) occurs, the ORER bit in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR. 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 (when the stop bit is 0) is detected, the FER bit in SSR is set to 1 and receive data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated.
5. If reception finishes 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. Because the RXI interrupt routine reads the receive data transferred to RDR before reception of the next receive data has finished, continuous reception can be enabled.

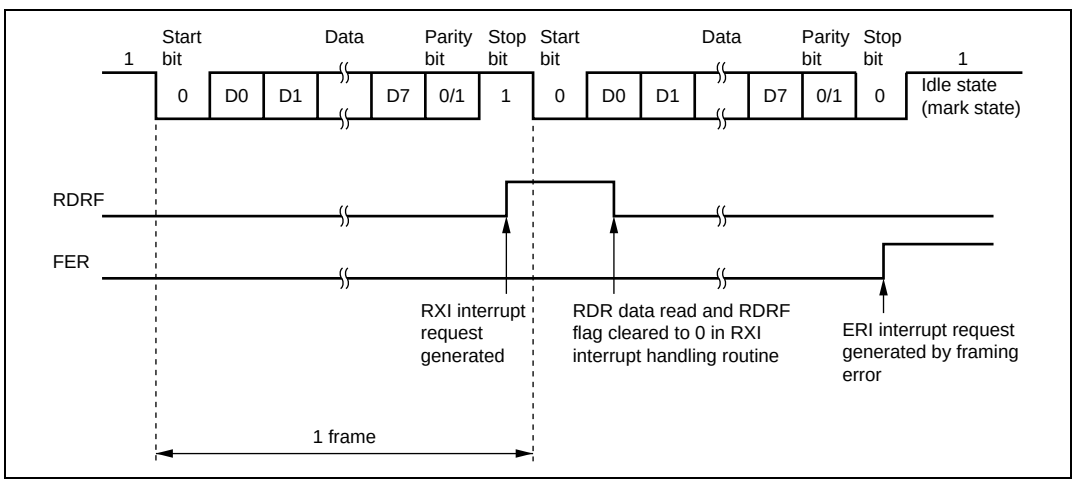


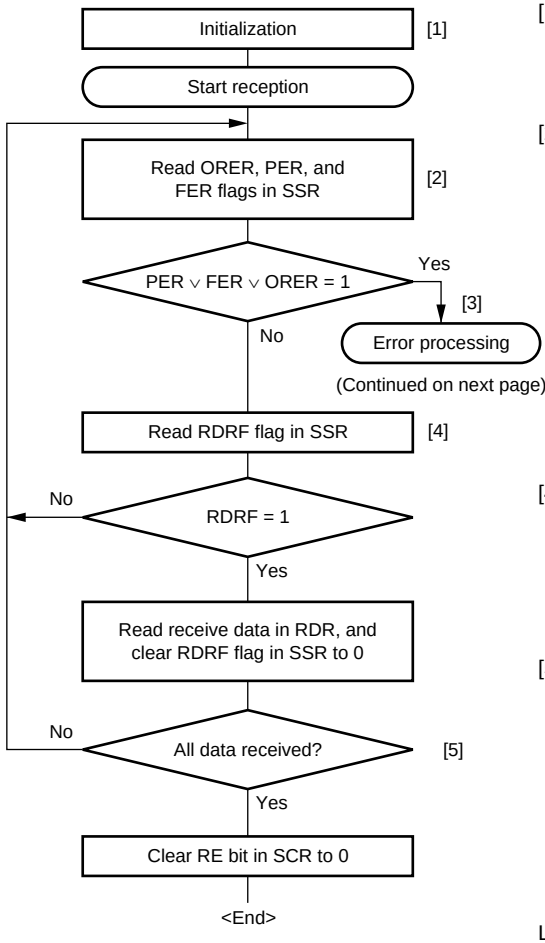
Figure 15.8 Example of SCI Receive Operation in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)

Table 15.9 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 15.9 shows a sample flow chart for serial data reception.

Table 15.9 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. However, the RDRF flag is cleared automatically when the DTC is initiated by an RXI interrupt and reads data from RDR.

Legend:
∨ : Logical OR

Figure 15.9 Sample Serial Reception Flowchart (1)

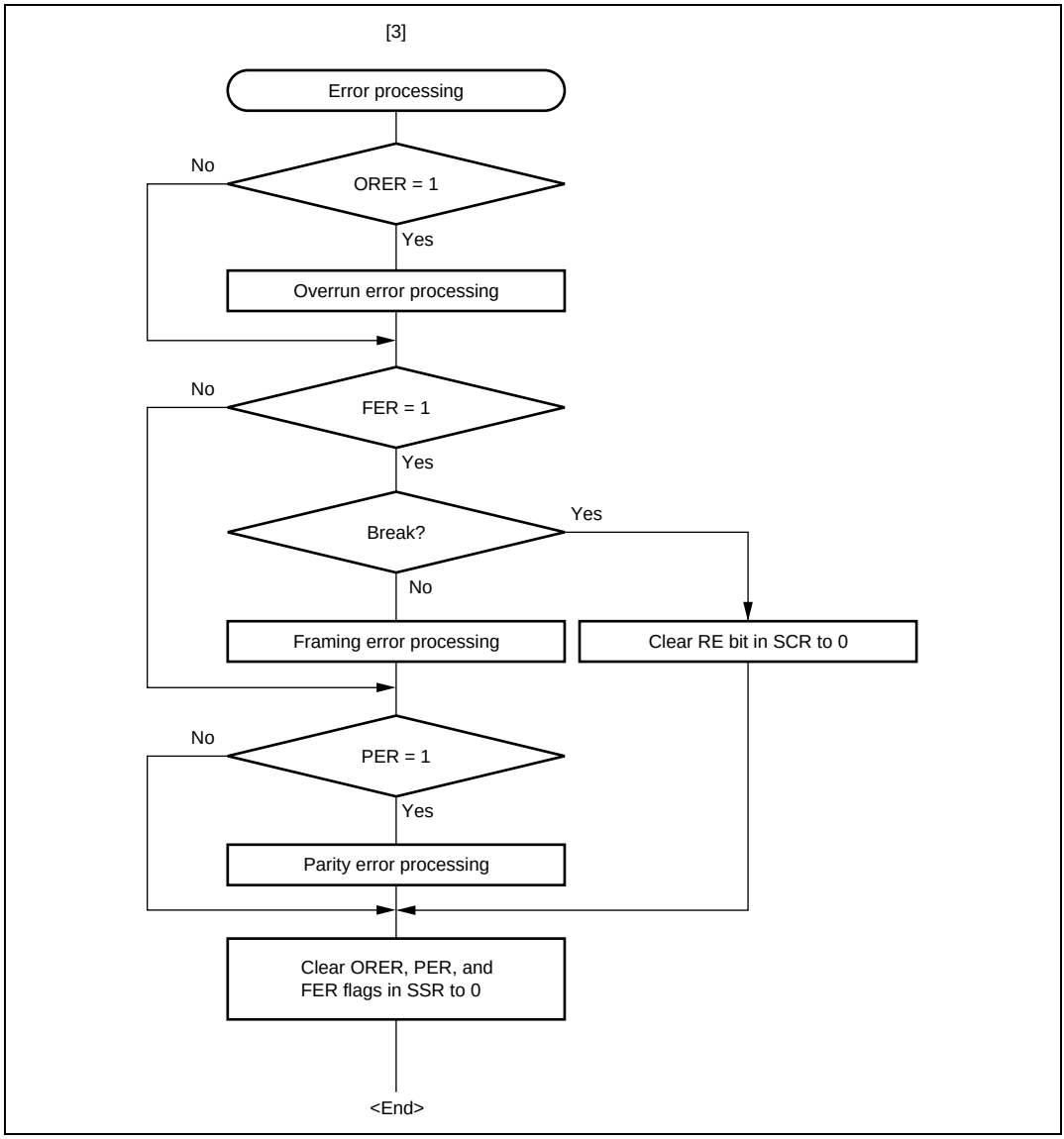


Figure 15.9 Sample Serial Reception Flowchart (2)

15.5 Multiprocessor Communication Function

Use of the multiprocessor communication function enables data transfer to be performed among a number of processors sharing communication lines by means of asynchronous serial communication using the multiprocessor format, in which a multiprocessor bit is added to the transfer data. When multiprocessor communication is carried out, each receiving station is addressed by a unique ID code. The serial communication cycle consists of two component cycles: an ID transmission cycle which specifies the receiving station, and a data transmission cycle for the specified receiving station. 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, and if the multiprocessor bit is 0, the cycle is a data transmission cycle. Figure 15.10 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. The receiving station skips data until data with a 1 multiprocessor bit is sent. 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 ID does 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 in SSR to 1 are prohibited 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 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.

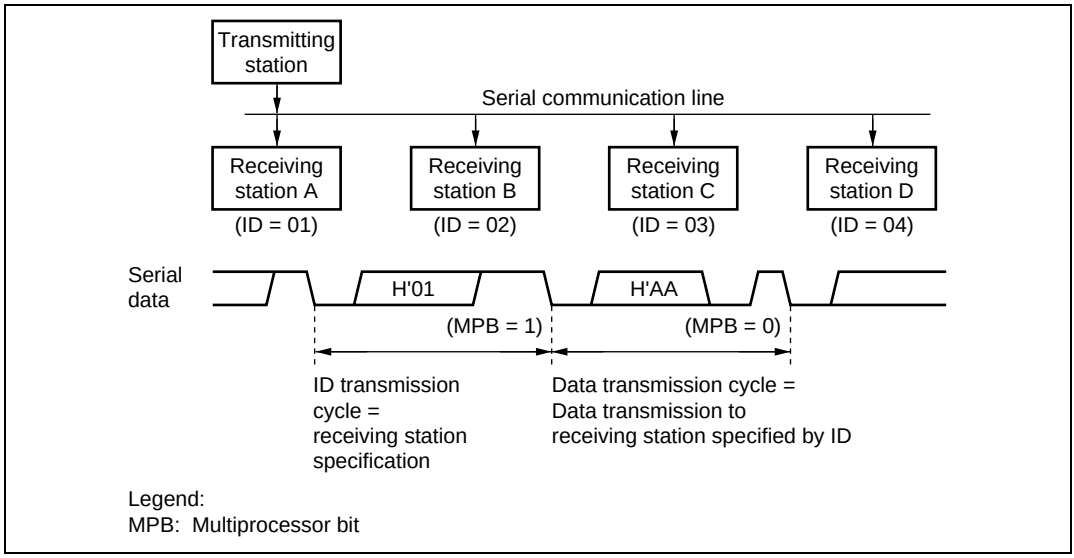
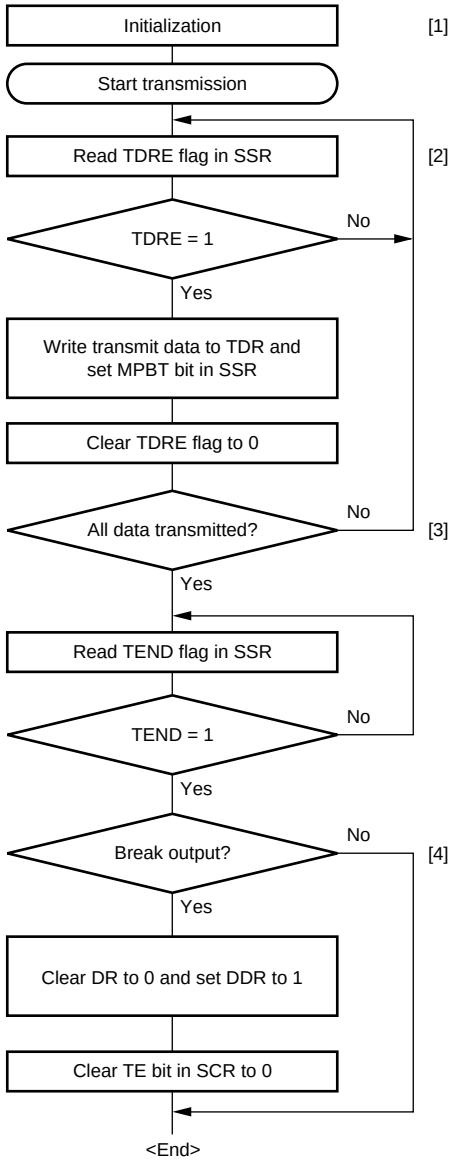


Figure 15.10 Example of Communication Using Multiprocessor Format (Transmission of Data H'AA to Receiving Station A)

15.5.1 Multiprocessor Serial Data Transmission

Figure 15.11 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. However, the TDRE flag is checked and cleared automatically when the DTC is initiated by a transmit data empty interrupt (TXI) request and writes data to TDR.

[4] Break output at the end of serial transmission:
To output a break in serial transmission, set port DDR to 1, clear DR to 0, and then clear the TE bit in SCR to 0.

Figure 15.11 Sample Multiprocessor Serial Transmission Flowchart

15.5.2 Multiprocessor Serial Data Reception

Figure 15.13 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 15.12 shows an example of SCI operation for multiprocessor format reception.

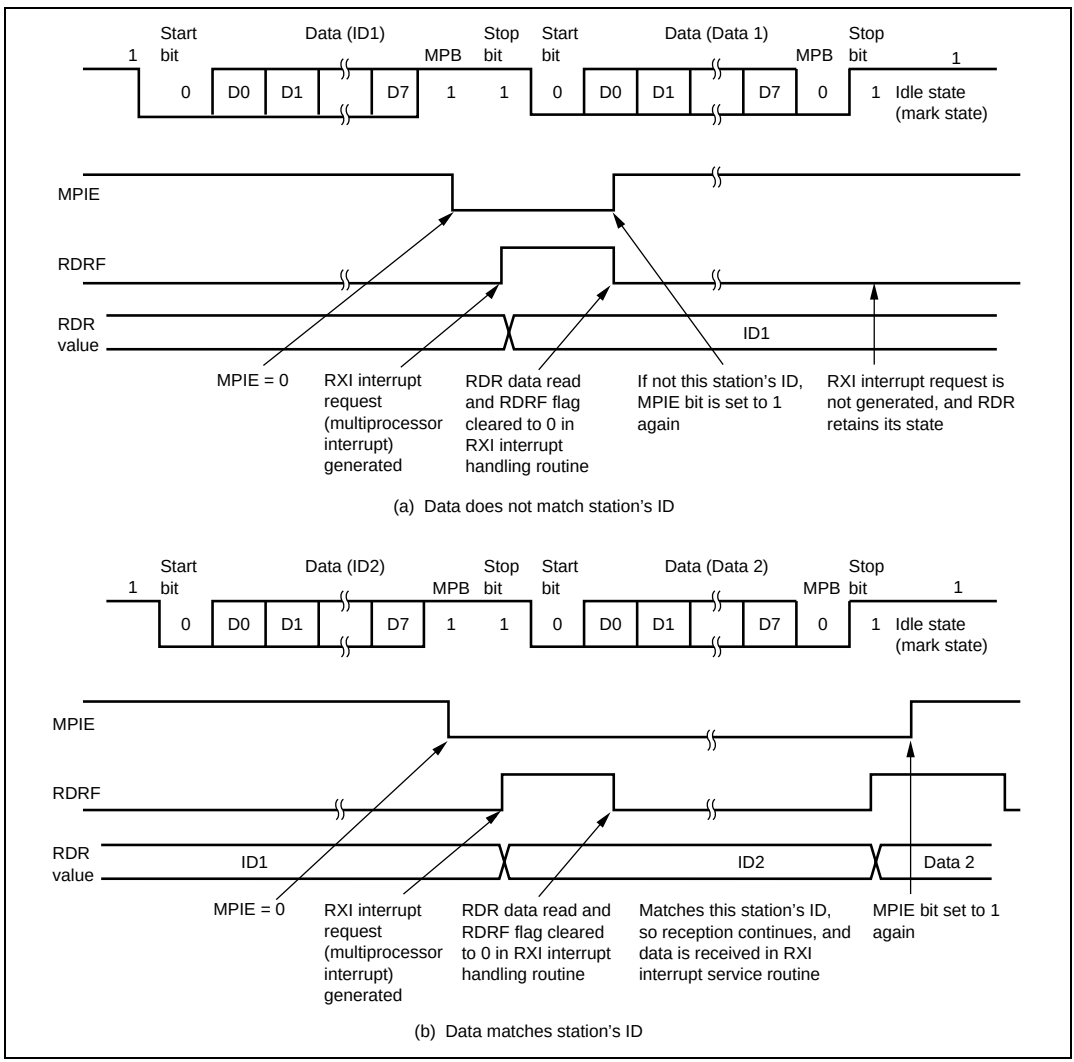
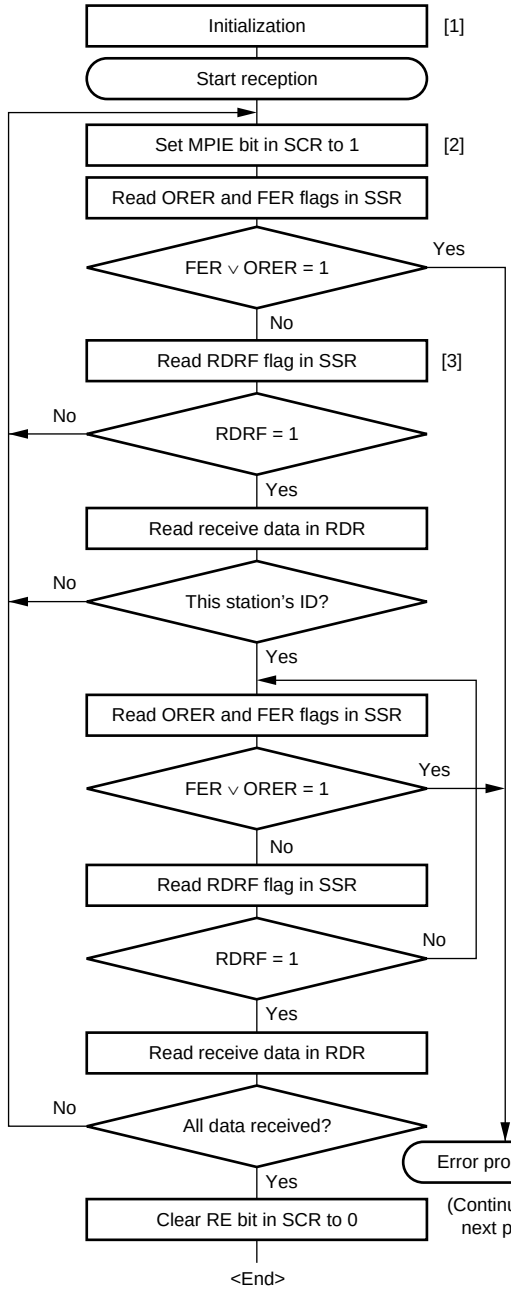


Figure 15.12 Example of SCI Receive Operation
(Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)



[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.

Legend:
∨ : Logical OR

Figure 15.13 Sample Multiprocessor Serial Reception Flowchart (1)

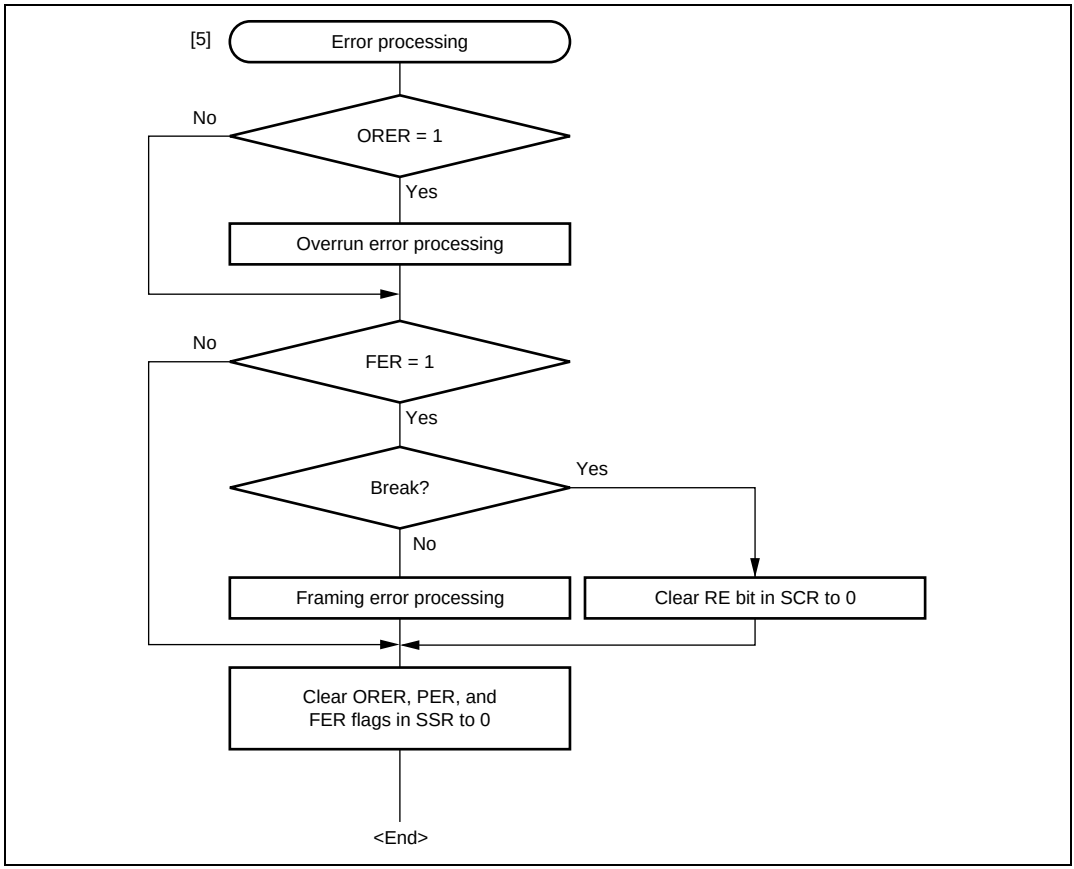


Figure 15.13 Sample Multiprocessor Serial Reception Flowchart (2)

15.6 Operation in Clocked Synchronous Mode

Figure 15.14 shows the general format for clocked synchronous communication. In clocked synchronous mode, data is transmitted or received in synchronization with clock pulses. One character in transfer data consists of 8-bit data. In data transmission, the SCI outputs data from one falling edge of the synchronization clock to the next. In data reception, the SCI receives data in synchronization with the rising edge of the synchronization clock. After 8-bit data is output, the transmission line holds the MSB 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 by use of a common clock. Both the transmitter and the receiver also have a double-buffered structure, so that the next transmit data can be written during transmission or the previous receive data can be read during reception, enabling continuous data transfer.

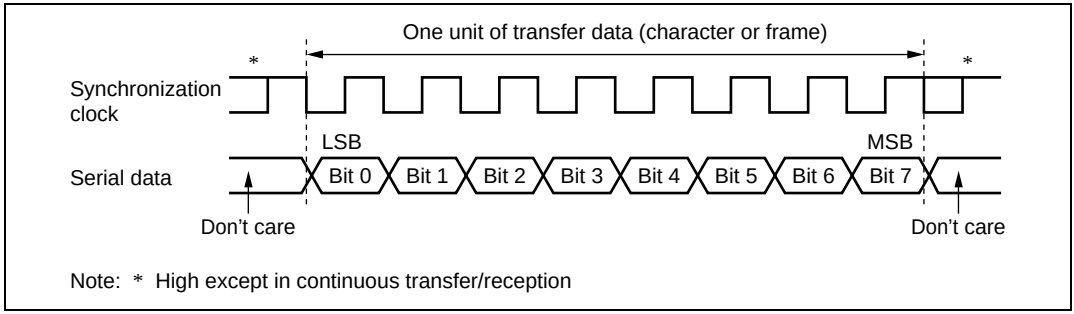


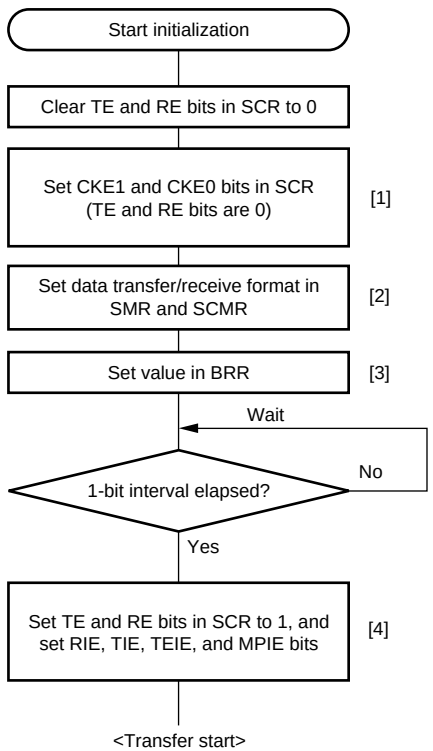
Figure 15.14 Data Format in Clocked Synchronous Communication (LSB-First)

15.6.1 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 the CKE1 and CKE0 bits in SCR. When the SCI is operated on an internal clock, the synchronization clock is output from the SCK pin. Eight synchronization clock pulses are output in the transfer of one character, and when no transfer is performed the clock is fixed high.

15.6.2 SCI Initialization (Clocked Synchronous 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 a sample flowchart in figure 15.15. When the operating mode, transfer format, etc., is changed, 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 in SSR is set to 1. However, clearing the RE bit to 0 does not initialize the RDRF, PER, FER, and ORER flags in SSR, or 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/receive format in SMR and SCMR.

[3] Write a value corresponding to the bit rate to BRR. This step is 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 15.15 Sample SCI Initialization Flowchart

15.6.3 Serial Data Transmission (Clocked Synchronous Mode)

Figure 15.16 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 it is 0, 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 TXI interrupt request is generated. Because the TXI interrupt routine writes the next transmit data to TDR before transmission of the current transmit data has finished, continuous transmission can be enabled.
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 last bit.
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 TxD pin 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 15.17 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 to clear the receive error flags to 0 before starting transmission. Note that clearing the RE bit to 0 does not clear the receive error flags.

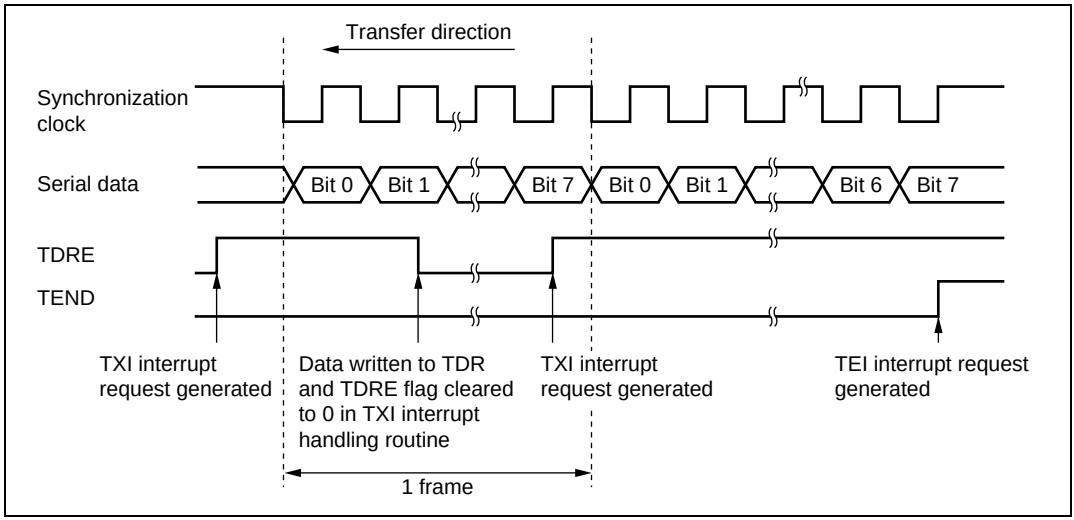
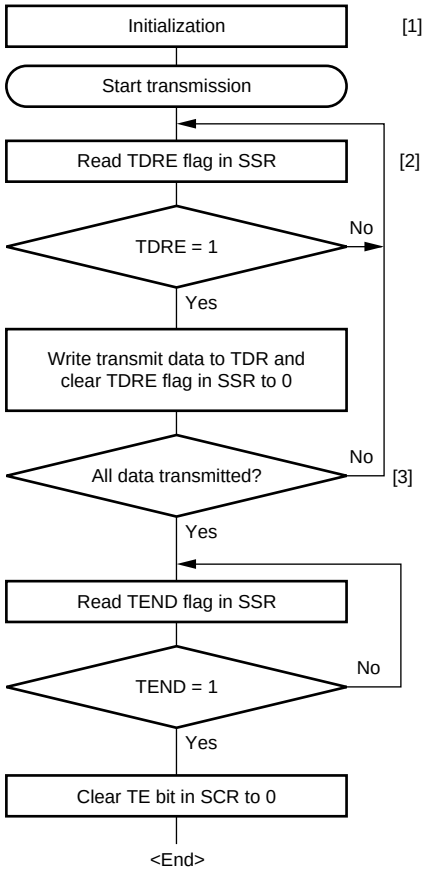


Figure 15.16 Example of SCI Transmit Operation in Clocked Synchronous Mode



[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.
However, the TDRE flag is checked and cleared automatically when the DTC is initiated by a transmit data empty interrupt (TXI) request and writes data to TDR.

Figure 15.17 Sample Serial Transmission Flowchart

15.6.4 Serial Data Reception (Clocked Synchronous Mode)

Figure 15.18 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 in synchronization with a synchronization clock input or output, starts receiving data, and stores the receive data in RSR.
2. If an overrun error (when reception of the next data is completed while the RDRF flag is still set to 1) occurs, the ORER bit in SSR is set to 1. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is generated. Receive data is not transferred to RDR. The RDRF flag remains to be set to 1.
3. If reception finishes 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. Because the RXI interrupt routine reads the receive data transferred to RDR before reception of the next receive data has finished, continuous reception can be enabled.

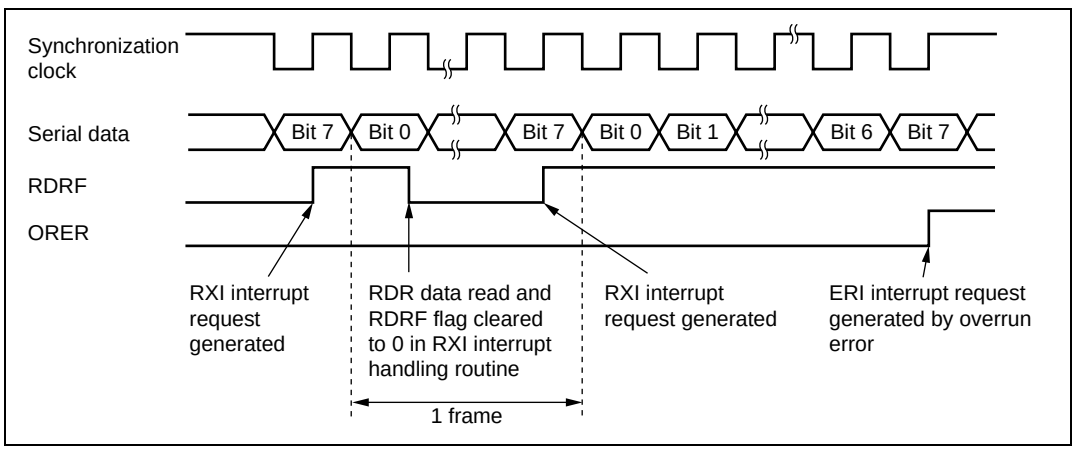
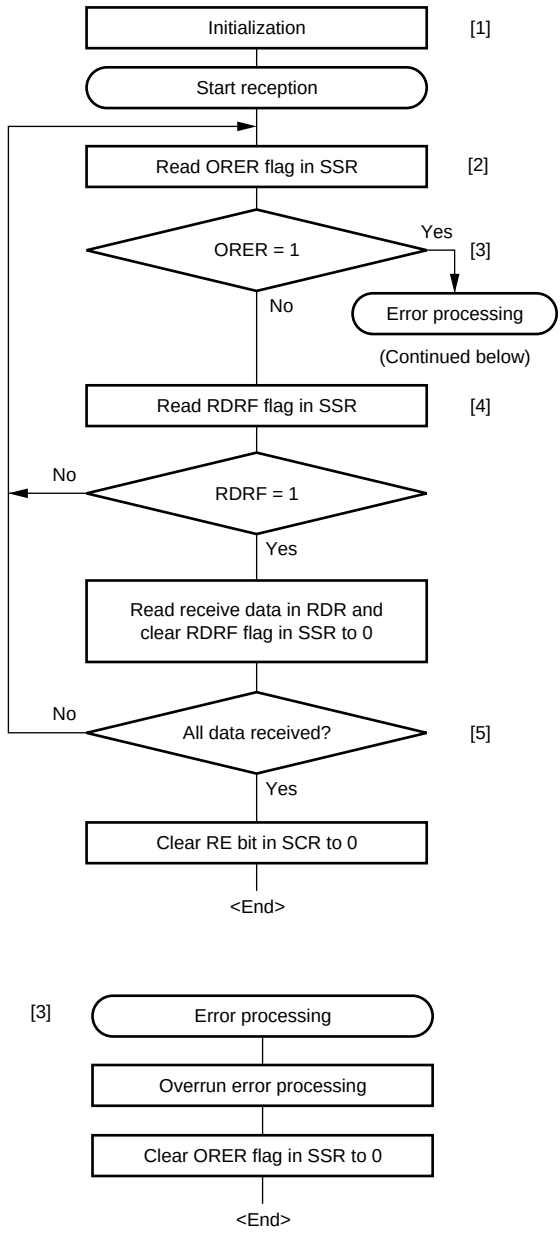


Figure 15.18 Example of SCI Receive Operation in Clocked Synchronous Mode

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 15.19 shows a sample flowchart for serial data reception.



[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.

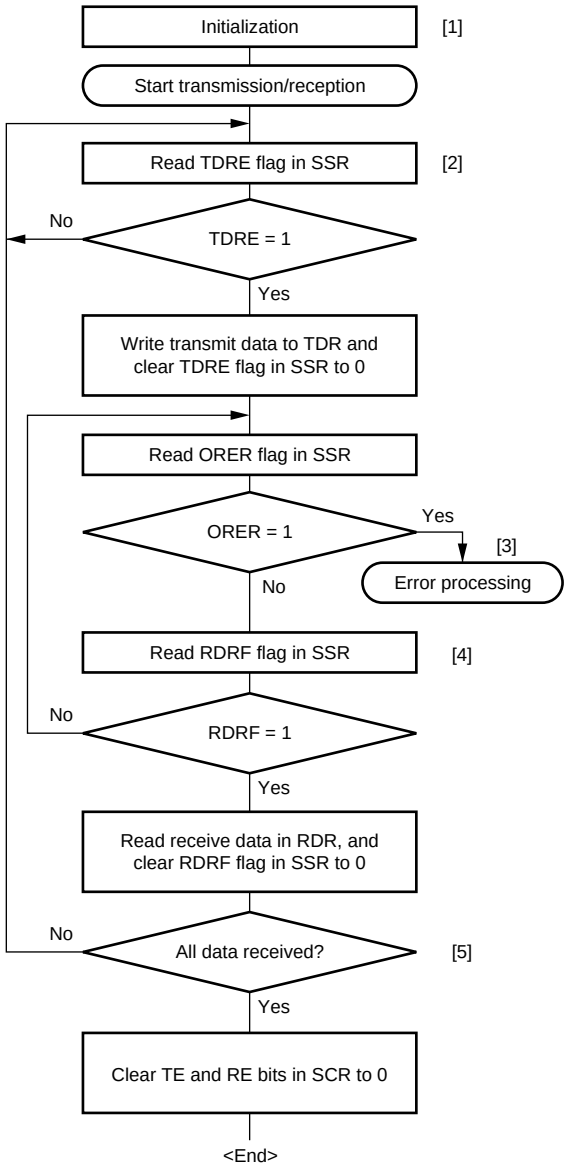
[4] SCI status check and receive data read:
Read SSR and check that the RDRF flag is set to 1, then read the receive data in RDR and clear the RDRF flag to 0.
Transition of the RDRF flag from 0 to 1 can also be identified by an RXI interrupt.

[5] Serial reception continuation procedure:
To continue serial reception, before the MSB (bit 7) of the current frame is received, reading the RDRF flag, reading RDR, and clearing the RDRF flag to 0 should be finished.
However, the RDRF flag is cleared automatically when the DTC is initiated by a receive data full interrupt (RXI) and reads data from RDR.

Figure 15.19 Sample Serial Reception Flowchart

15.6.5 Simultaneous Serial Data Transmission and Reception (Clocked Synchronous Mode)

Figure 15.20 shows a sample flowchart for simultaneous serial transmit and receive operations. After initializing the SCI, the following procedure should be used for simultaneous serial data transmit and receive operations. To switch from transmit mode to simultaneous transmit and receive mode, check that the SCI has finished transmission and the TDRE and TEND flags in SSR are set to 1, clear the TE bit in SCR to 0, and then set the TE and RE bits to 1 simultaneously with a single instruction. To switch from receive mode to simultaneous transmit and receive mode, check that the SCI has finished reception, and clear the RE bit to 0. Then after checking that the RDRF bit in SSR and receive error flags (ORER, FER, and PER) are cleared to 0, set the TE and RE bits to 1 simultaneously with a single instruction.



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 simultaneously.

[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 MSB (bit 7) of the current frame is received, finish reading the RDRF flag, reading RDR, and clearing the RDRF flag to 0. Also, before the MSB (bit 7) of the current frame is transmitted, read 1 from the TDRE flag to confirm that writing is possible. Then write data to TDR and clear the TDRE flag to 0.
However, the TDRE flag is checked and cleared automatically when the DTC is initiated by a transmit data empty interrupt (TXI) request and writes data to TDR. Similarly, the RDRF flag is cleared automatically when the DTC is initiated by a receive data full interrupt (RXI) and reads data from RDR.

Figure 15.20 Sample Flowchart of Simultaneous Serial Transmission and Reception

15.7 IrDA Operation

IrDA operation can be used with SCI_2. Figure 15.21 shows an IrDA block diagram.

If the IrDA function is enabled using the IrE bit in KBCOMP, the TxD2 and RxD2 pins in SCI_2 are allowed to encode and decode the waveform based on the IrDA standard version 1.0 (function as the IrTxD and IrRxD pins). Connecting these pins to the infrared data transceiver achieves infrared data communication based on the system defined by the IrDA standard version 1.0.

In the system defined by the IrDA standard version 1.0, communication is started at a transfer rate of 9600 bps, which can be modified as required. The IrDA interface provided by this LSI does not incorporate the capability of automatic modification of the transfer rate; the transfer rate must be modified through programming.

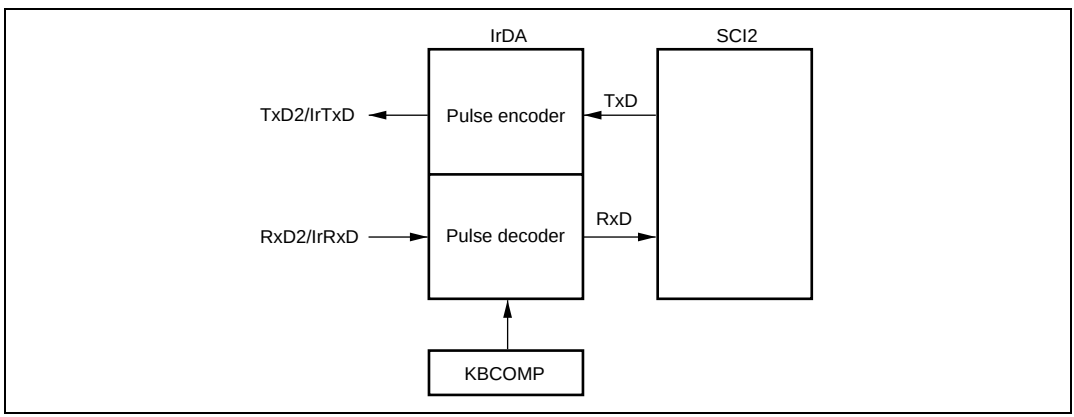


Figure 15.21 IrDA Block Diagram

Transmission: During transmission, the output signals from the SCI (UART frames) are converted to IR frames using the IrDA interface (see figure 15.22).

For serial data of level 0, a high-level pulse having a width of 3/16 of the bit rate (1-bit interval) is output (initial setting). The high-level pulse can be selected using the IrCKS2 to IrCKS0 bits in KBCOMP.

The high-level pulse width is defined to be 1.41 µs at minimum and (3/16 + 2.5%) × bit rate or (3/16 × bit rate) + 1.08 µs at maximum. For example, when the frequency of system clock ϕ is 20 MHz, a high-level pulse width of at least 1.4 µs to 1.6 µs can be specified.

For serial data of level 1, no pulses are output.

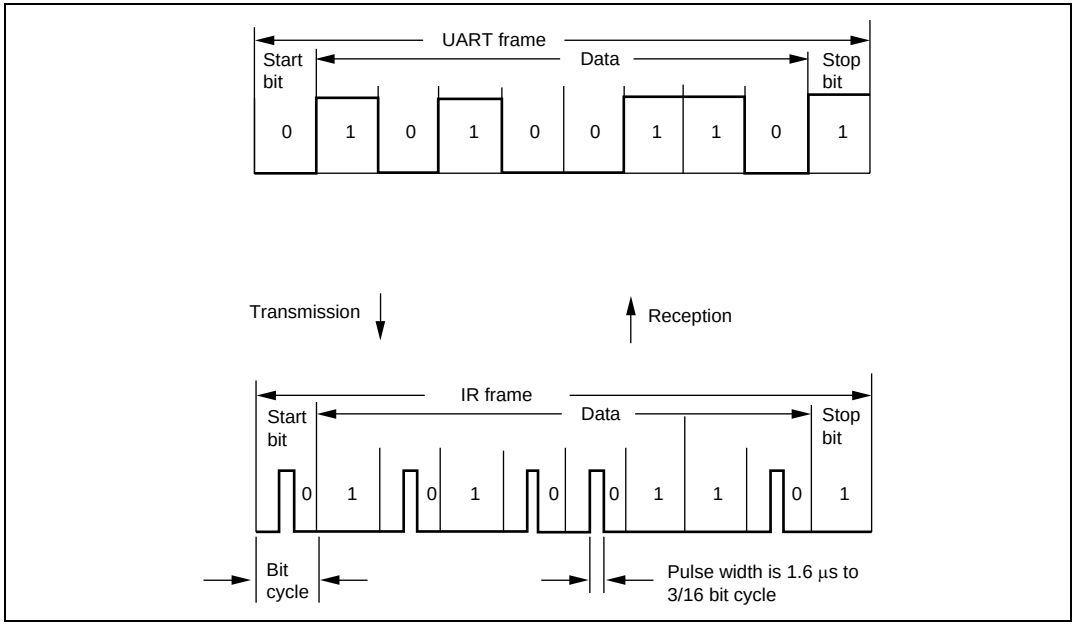


Figure 15.22 IrDA Transmission and Reception

Reception: During reception, IR frames are converted to UART frames using the IrDA interface before inputting to SCI_2.

Data of level 0 is output each time a high-level pulse is detected and data of level 1 is output when no pulse is detected in a bit cycle. If a pulse has a high-level width of less than 1.41 µs, the minimum width allowed, the pulse is recognized as level 0.

High-Level Pulse Width Selection: Table 15.10 shows possible settings for bits IrCKS2 to IrCKS0 (minimum pulse width), and this LSI's operating frequencies and bit rates, for making the pulse width shorter than 3/16 times the bit rate in transmission.

Table 15.10 IrCKS2 to IrCKS0 Bit Settings

Operating Frequency ϕ (MHz)	Bit Rate (bps) (Upper Row) / Bit Interval × 3/16 (µs) (Lower Row)					
	2400	9600	19200	38400	57600	115200
	78.13	19.53	9.77	4.88	3.26	1.63
2	010	010	010	010	010	—
2.097152	010	010	010	010	010	—
2.4576	010	010	010	010	010	—
3	011	011	011	011	011	—
3.6864	011	011	011	011	011	011
4.9152	011	011	011	011	011	011
5	011	011	011	011	011	011
6	100	100	100	100	100	100
6.144	100	100	100	100	100	100
7.3728	100	100	100	100	100	100
8	100	100	100	100	100	100
9.8304	100	100	100	100	100	100
10	100	100	100	100	100	100
12	101	101	101	101	101	101
12.288	101	101	101	101	101	101
14	101	101	101	101	101	101
14.7456	101	101	101	101	101	101
16	101	101	101	101	101	101
16.9344	101	101	101	101	101	101
17.2032	101	101	101	101	101	101
18	101	101	101	101	101	101
19.6608	101	101	101	101	101	101
20	101	101	101	101	101	101

Legend:

—: An SCI bit rate setting cannot be made.

15.8 Interrupt Sources

Table 15.11 shows the interrupt sources in serial communication interface. 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 allow data transfer. The TDRE flag is automatically cleared to 0 at data transfer by 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 can activate the DTC to allow data transfer. The RDRF flag is automatically cleared to 0 at data transfer by the DTC.

A TEI interrupt is requested when the TEND flag is set to 1 while 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, note that if the TDRE and TEND flags are cleared simultaneously by the TXI interrupt routine, the SCI cannot branch to the TEI interrupt routine later.

Table 15.11 SCI Interrupt Sources

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	Priority
0	ERI0	Receive error	ORER, FER, PER	Not possible	High
	RXI0	Receive data full	RDRF	Possible	
	TXI0	Transmit data empty	TDRE	Possible	
	TEI0	Transmit end	TEND	Not possible	
1	ERI1	Receive error	ORER, FER, PER	Not possible	
	RXI1	Receive data full	RDRF	Possible	
	TXI1	Transmit data empty	TDRE	Possible	
	TEI1	Transmit end	TEND	Not possible	
2	ERI2	Receive error	ORER, FER, PER	Not possible	
	RXI2	Receive data full	RDRF	Possible	
	TXI2	Transmit data empty	TDRE	Possible	
	TEI2	Transmit end	TEND	Not possible	Low

15.9 Usage Notes

15.9.1 Module Stop Mode Setting

SCI operation can be disabled or enabled using the module stop control register. The initial setting is for SCI operation to be halted. Register access is enabled by clearing module stop mode. For details, refer to section 26, Power-Down Modes.

15.9.2 Break Detection and Processing

When framing error detection is performed, a break can be detected by reading the RxD pin value directly. In a break, the input from the RxD pin becomes all 0s, and so the FER flag in SSR is set, and the PER flag may also be set. Note that, since the SCI continues the receive operation even after receiving a break, even if the FER flag is cleared to 0, it will be set to 1 again.

15.9.3 Mark State and Break Detection

When the TE bit in SCR is 0, the TxD pin is used as an I/O port whose direction (input or output) and level are determined by DR and DDR of the port. This can be used to set the TxD pin to the 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. Since the TE bit is cleared to 0 at this point, the TxD pin becomes an I/O port, and 1 is output from the TxD pin. To send a break during serial transmission, first set DDR to 1 and DR to 0, and then clear the TE bit to 0. When the TE bit is cleared to 0, the transmitter is initialized regardless of the current transmission state, the TxD pin becomes an I/O port, and 0 is output from the TxD pin.

15.9.4 Receive Error Flags and Transmit Operations (Clocked Synchronous Mode Only)

Transmission cannot be started when a receive error flag (ORER, FER, or RER) is SSR is set to 1, even if the TDRE flag in SSR is cleared to 0. Be sure to clear the receive error flags to 0 before starting transmission. Note also that the receive error flags cannot be cleared to 0 even if the RE bit in SCR is cleared to 0.

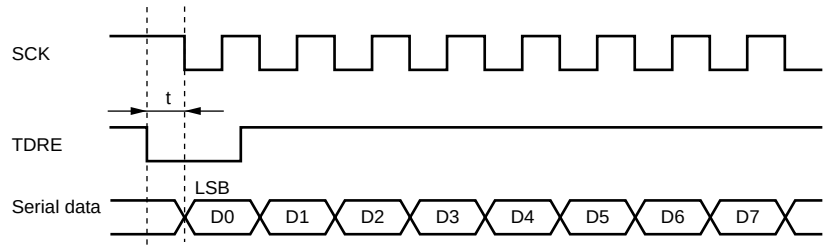
15.9.5 Relation between Writing to TDR and TDRE Flag

Data can be written to TDR irrespective of the TDRE flag status in SSR. However, if the new data is written to TDR when the TDRE flag is 0, that is, when the previous data has not been transferred to TSR yet, the previous data in TDR is lost. Be sure to write transmit data to TDR after verifying that the TDRE flag is set to 1.

15.9.6 Restrictions on Using DTC

When an external clock source is used as a synchronization clock, update TDR by the DTC or RFU and wait for at least five ϕ clock cycles before allowing the transmit clock to be input. If the transmit clock is input within four clock cycles after TDR modification, the SCI may malfunction (figure 15.23).

When using the DTC to read RDR, be sure to set the receive end interrupt source (RXI) as a DTC activation source.



Note: * When external clock is supplied, t must be more than four clock cycles.

Figure 15.23 Example of Transmission Using DTC in Clocked Synchronous Mode

15.9.7 SCI Operations during Mode Transitions

Transmission: Before making a transition to module stop, software standby, or sub-sleep mode, stop all transmit operations (TE = TIE = TEIE = 0). TSR, TDR, and SSR are reset. The states of the output pins during each mode depend on the port settings, and the pins output a high-level signal after mode cancellation. If a transition is made during data transmission, the data being transmitted will be undefined.

To transmit data in the same transmission mode after mode cancellation, set TE to 1, read SSR, write to TDR, clear TDRE in this order, and then start transmission. To transmit data in a different transmission mode, initialize the SCI first.

Figure 15.24 shows a sample flowchart for mode transition during transmission. Figures 15.25 and 15.26 show the pin states during transmission.

Before making a transition from the transmission mode using DTC transfer to module stop, software standby, or sub-sleep mode, stop all transmit operations (TE = TIE = TEIE = 0). Setting TE and TIE to 1 after mode cancellation generates a TXI interrupt request to start transmission using the DTC.

Reception: Before making a transition to module stop, software standby, watch, sub-active, or sub-sleep mode, stop reception (RE = 0). RSR, RDR, and SSR are reset. If a transition is made during data reception, the data being received will be invalid.

To receive data in the same reception mode after mode cancellation, set RE to 1, and then start reception. To receive data in a different reception mode, initialize the SCI first.

Figure 15.27 shows a sample flowchart for mode transition during reception.

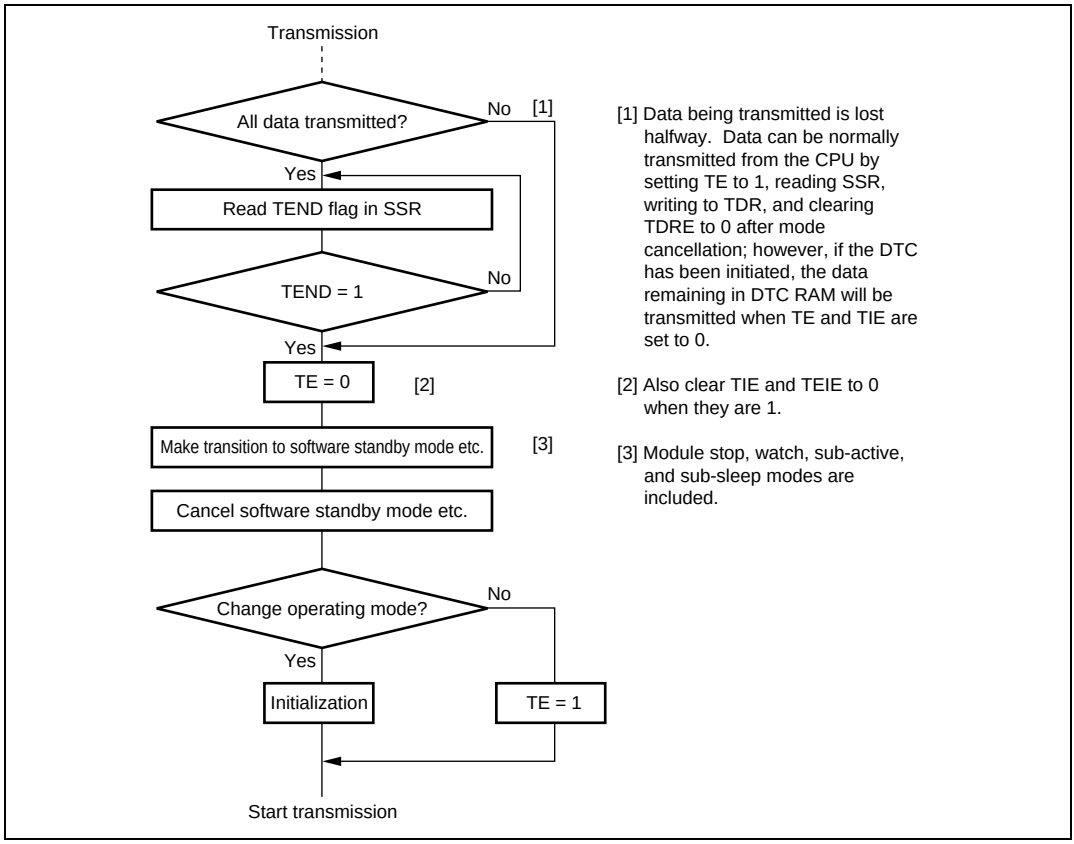


Figure 15.24 Sample Flowchart for Mode Transition during Transmission

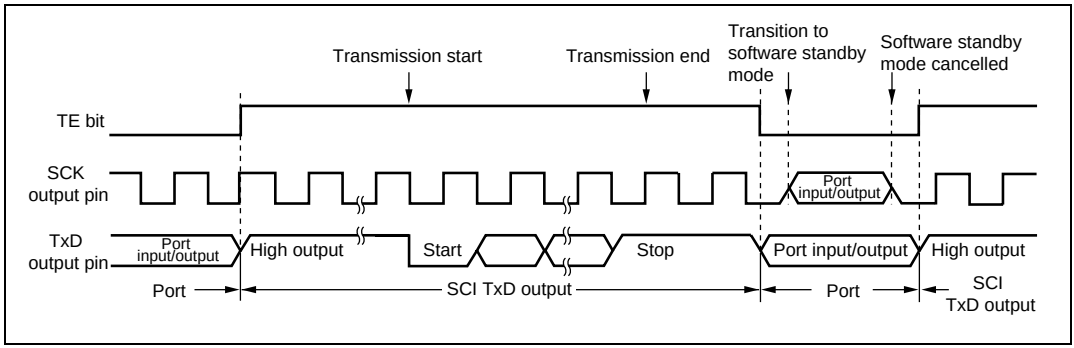


Figure 15.25 Pin States during Transmission in Asynchronous Mode (Internal Clock)

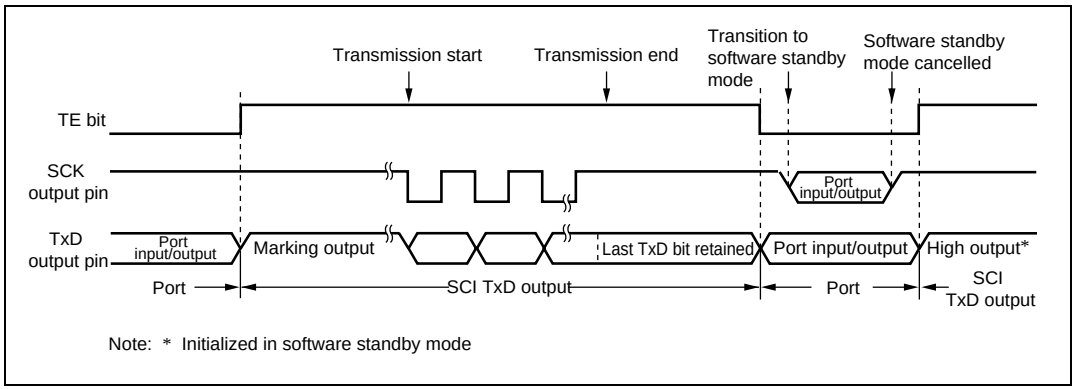


Figure 15.26 Pin States during Transmission in Clocked Synchronous Mode (Internal Clock)

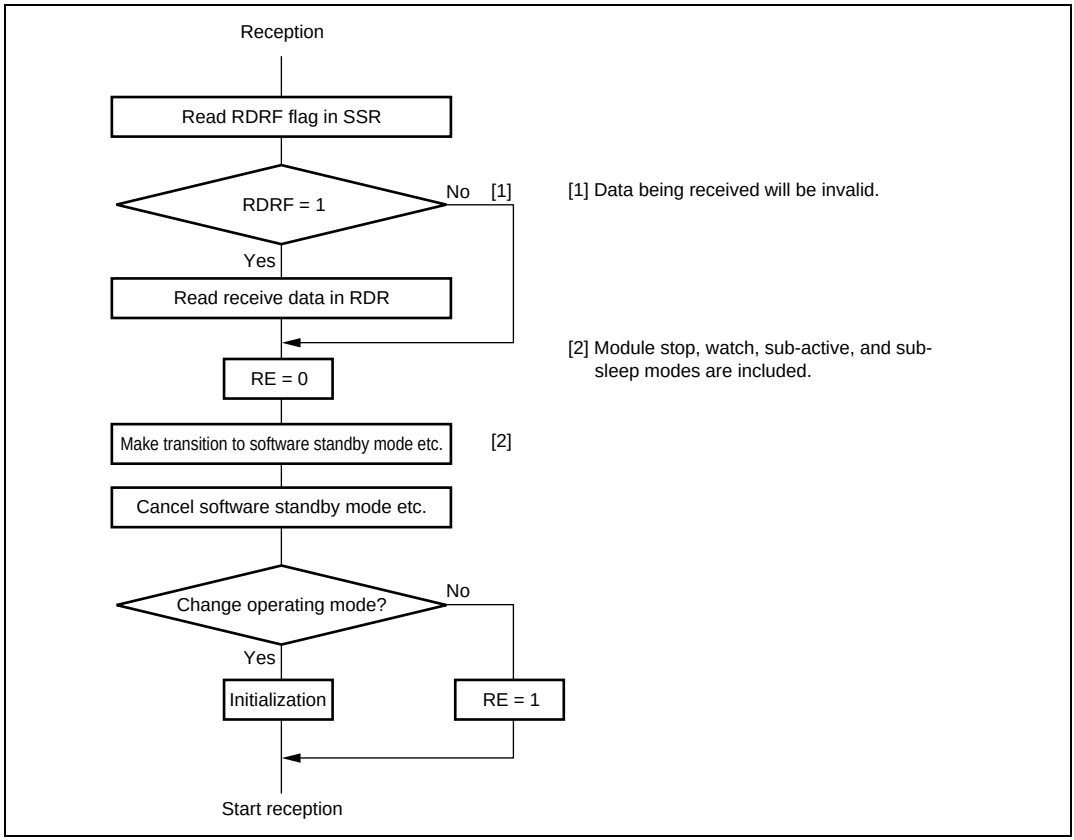


Figure 15.27 Sample Flowchart for Mode Transition during Reception

15.9.8 Notes on Switching from SCK Pins to Port Pins

When SCK pins are switched to port pins after transmission has completed, pins are enabled for port output after outputting a low pulse of half a cycle as shown in figure 15.28.

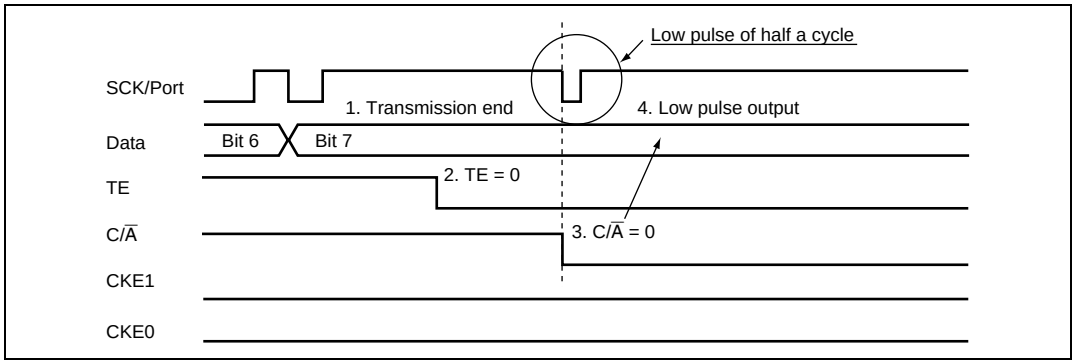


Figure 15.28 Switching from SCK Pins to Port Pins

To prevent the low pulse output that is generated when switching the SCK pins to the port pins, specify the SCK pins for input (pull up the SCK/port pins externally), and follow the procedure below with DDR = 1, DR = 1, C/$\overline{A}$ = 1, CKE1 = 0, CKE1 = 0, and TE = 1.

1. End serial data transmission
2. TE bit = 0
3. CKE1 bit = 1
4. C/$\overline{A}$ bit = 0 (switch to port output)
5. CKE1 bit = 0

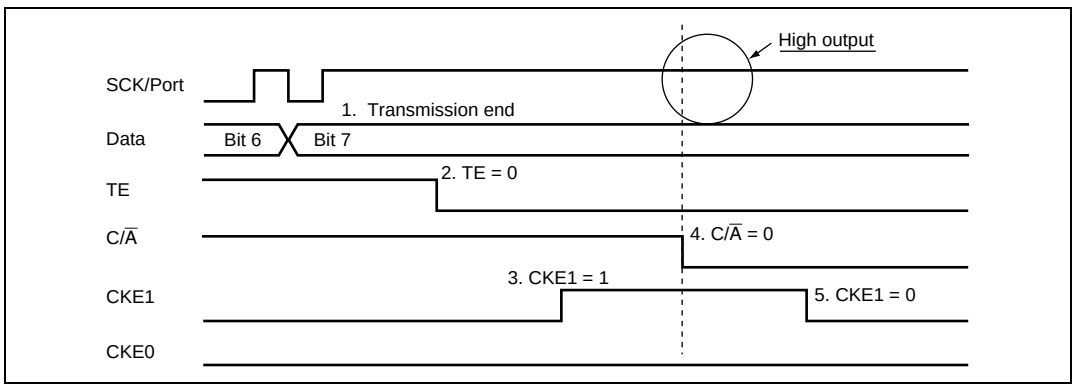


Figure 15.29 Prevention of Low Pulse Output at Switching from SCK Pins to Port Pins

Section 16 I²C Bus Interface (IIC) (Optional)

The I²C bus interface is provided as an optional function. Note the following point when using this optional function.

- Although the product type name is identical, please contact Renesas before using this optional function on an F-ZTAT version product.

This LSI has a two-channel I²C bus interface. The I²C bus interface conforms to and provides a subset of the Philips I²C bus (inter-IC bus) interface functions. The register configuration that controls the I²C bus differs partly from the Philips configuration, however.

16.1 Features

- Selection of addressing format or non-addressing format
  - I²C bus format: addressing format with an acknowledge bit, for master/slave operation
  - Clocked synchronous serial format: non-addressing format without an acknowledge bit, for master operation only
  - Formatless (for IIC_0 only): non-addressing format with a clock pin dedicated for formatless; for slave operation only
- Conforms to Philips I²C bus interface (I²C bus format)
- Two ways of setting slave address (I²C bus format)
- Start and stop conditions generated automatically in master mode (I²C bus format)
- Selection of the acknowledge output level in reception (I²C bus format)
- Automatic loading of an acknowledge bit in transmission (I²C bus format)
- Wait function in master mode (I²C bus format)
  - 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 (I²C bus format)
  - A wait request can be generated by driving the SCL pin low after data transfer.
  - The wait request is cleared when the next transfer becomes possible.
- Interrupt sources
  - Data transfer end (including when a transition to transmit mode with I²C bus format occurs, when ICDR data is transferred, or during a wait state)

  - Address match: When any slave address matches or the general call address is received in slave receive mode with I²C bus format (including address reception after loss of master arbitration)
  - Start condition detection (in master mode)
  - Stop condition detection (in slave mode)
- Selection of 16 internal clocks (in master mode)
- Direct bus drive (SCL/SDA pin)
  - Four pins—P52/SCL0, P97/SDA0, P86/SCL1, and P42/SDA1 —(normally NMOS push-pull outputs) function as NMOS open-drain outputs when the bus drive function is selected.
- Automatic switching from formatless mode to I²C bus format (IIC_0 only)
  - Formatless operation (no start/stop conditions, non-addressing mode) in slave mode
  - Operation using a common data pin (SDA) and independent clock pins (VSYNCI, SCL)
  - Automatic switching from formatless mode to I²C bus format on the fall of the SCL pin

Figure 16.1 shows a block diagram of the I²C bus interface. Figure 16.2 shows an example of I/O pin connections to external circuits. Since I²C bus interface I/O pins are different in structure from normal port pins, they have different specifications for permissible applied voltages. For details, see section 28, Electrical Characteristics.

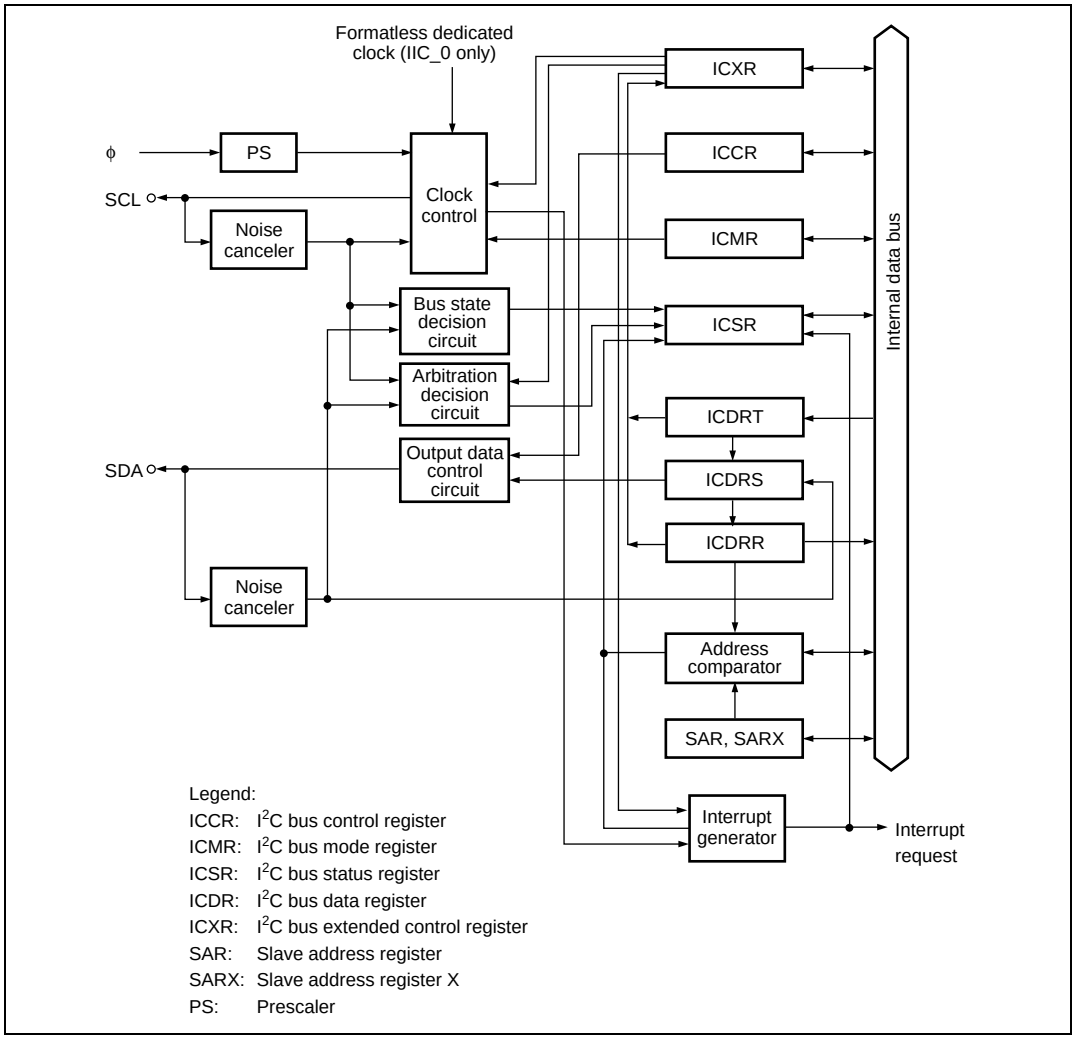


Figure 16.1 Block Diagram of I²C Bus Interface

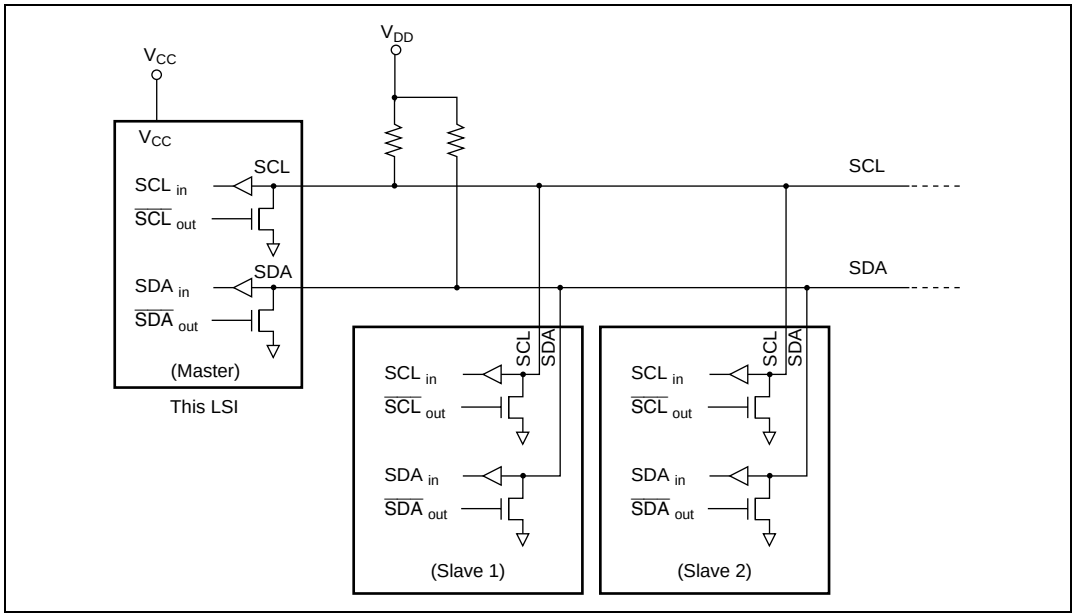


Figure 16.2 I²C Bus Interface Connections (Example: This LSI as Master)

16.2 Input/Output Pins

Table 16.1 summarizes the input/output pins used by the I²C bus interface.

Table 16.1 Pin Configuration

Channel	Symbol*	Input/Output	Function
0	SCL0	Input/Output	Serial clock input/output pin of IIC_0
	SDA0	Input/Output	Serial data input/output pin of IIC_0
	VSYNCI	Input	Formatless serial clock input pin of IIC_0
1	SCL1	Input/Output	Serial clock input/output pin of IIC_1
	SDA1	Input/Output	Serial data input/output pin of IIC_1

Note: * In the text, the channel subscript is omitted, and only SCL and SDA are used.

16.3 Register Descriptions

The I²C bus interface has the following registers. Registers ICDR and SARX and registers ICMR and SAR are allocated to the same addresses. Accessible registers differ depending on the ICE bit in ICCR. When the ICE bit is cleared to 0, SAR and SARX can be accessed, and when the ICE bit is set to 1, ICMR and ICDR can be accessed. For details on the serial timer control register, refer to section 3.2.3, Serial Timer Control Register (STCR).

- I²C bus control register (ICCR)
- I²C bus status register (ICSR)
- I²C bus data register (ICDR)
- I²C bus mode register (ICMR)
- Slave address register (SAR)
- Second slave address register (SARX)
- I²C bus extended control register (ICXR)
- DDC switch register (DDCSWR) (for IIC_0 only)

16.3.1 I²C Bus Data Register (ICDR)

ICDR is an 8-bit readable/writable register that is used as a transmit data register when transmitting and a receive data register when receiving. ICDR is internally divided into a shift register (ICDRS), receive buffer (ICDRR), and transmit buffer (ICDRT). Data transfers among these three registers are performed automatically in accordance with changes in the bus state, and they affect the status of internal flags such as ICDRE and ICDRF.

In master transmit mode with the I²C bus format, writing transmit data to ICDR should be performed after start condition detection. When the start condition is detected, previous write data is ignored. In slave transmit mode, writing should be performed after the slave addresses match and the TRS bit is automatically changed to 1.

If the IIC is in transmit mode (TRS = 1) and ICDRT has the next transmit data (the ICDRE flag is 0) after successful transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRT to ICDRS.

If the IIC is in transmit mode (TRS = 1) and ICDRT has the next data (the ICDRE flag is 0), data is transferred automatically from ICDRT to ICDRS, following transmission of one frame of data using ICDRS. When the ICDRE flag is 1 and the next transmit data writing is waited, data is transferred automatically from ICDRT to ICDRS by writing to ICDR. If I²C is in receive mode (TRS = 0), no data is transferred from ICDRT to ICDRS. Note that data should not be written to ICDR in receive mode.

Reading receive data from ICDR is performed after data is transferred from ICDRS to ICDRR.

If I²C is in receive mode and no previous data remains in ICDRR (the ICDRF flag is 0), data is transferred automatically from ICDRS to ICDRR, following reception of one frame of data using ICDRS. If additional data is received while the ICDRF flag is 1, data is transferred automatically from ICDRS to ICDRR by reading from ICDR. In transmit mode, no data is transferred from ICDRS to ICDRR. Always set I²C to receive mode before reading from ICDR.

If the number of bits in a frame, excluding the acknowledge bit, is less than eight, transmit data and receive data are stored differently. Transmit data should be written justified toward the MSB side when MLS = 0 in ICMR, and toward the LSB side when MLS = 1. Receive data bits should be read from the LSB side when MLS = 0, and from the MSB side when MLS = 1.

ICDR can be written to and read from only when the ICE bit is set to 1 in ICCR. The initial value of ICDR is undefined.

16.3.2 Slave Address Register (SAR)

SAR sets the slave address and selects the communication format. If the LSI is in slave mode with the I²C bus format selected, when the FS bit is set to 0 and the upper 7 bits of SAR match the upper 7 bits of the first frame received after a start condition, the LSI operates as the slave device specified by the master device. SAR can be accessed only when the ICE bit in ICCR is cleared to 0.

Bit	Bit Name	Initial Value	R/W	Description
7	SVA6	0	R/W	Slave Address 6 to 0 Set a slave address.
6	SVA5	0	R/W	
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	Format Select Selects the communication format together with the FSX bit in SARX and the SW bit in DDCSWR. Refer to table 16.2. This bit should be set to 0 when general call address recognition is performed.

16.3.3 Second Slave Address Register (SARX)

SARX sets the second slave address and selects the communication format. In slave mode, transmit/receive operations by the DTC are possible when the received address matches the second slave address. If the LSI is in slave mode with the I²C bus format selected, when the FSX bit is set to 0 and the upper 7 bits of SARX match the upper 7 bits of the first frame received after a start condition, the LSI operates as the slave device specified by the master device. SARX can be accessed only when the ICE bit in ICCR is cleared to 0.

Bit	Bit Name	Initial Value	R/W	Description
7	SVAX6	0	R/W	Second Slave Address 6 to 0
6	SVAX5	0	R/W	Set 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	Format Select X Selects the communication format together with the FS bit in SAR and the SW bit in DDCSWR. Refer to table 16.2.

Table 16.2 Communication Format

DDCSWR	SAR	SARX	
SW	**FS**	**FSX**	**Operating Mode**
0	0	0	I²C bus format • SAR and SARX slave addresses recognized • General call address recognized
		1	I²C bus format • SAR slave address recognized • SARX slave address ignored • General call address recognized
	1	0	I²C bus format • SAR slave address ignored • SARX slave address recognized • General call address ignored
		1	Clocked synchronous serial format • SAR and SARX slave addresses ignored • General call address ignored
1	0	0	Formatless mode (start/stop conditions not detected)
		1	• Acknowledge bit used
	1	0	
		1	Formatless mode (start/stop conditions not detected) • No acknowledge bit Do not set this mode when automatic switching to the I²C bus format is performed by means of the DDCSWR setting.

- I²C bus format: addressing format with an acknowledge bit
- Clocked synchronous serial format: non-addressing format without an acknowledge bit, for master mode only
- Formatless mode (for IIC_0 only): non-addressing format with or without an acknowledge bit, slave mode only, start/stop conditions not detected

16.3.4 I²C Bus Mode Register (ICMR)

ICMR sets the communication format and transfer rate. It can only be accessed when the ICE bit in ICCR is set to 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. 0: Data and the acknowledge bit are transferred consecutively with no wait inserted. 1: After the fall of the clock for the final data bit (8th clock), 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. For details, refer to section 16.4.7, IRIC Setting Timing and SCL Control.
5	CKS2	0	R/W	Transfer Clock Select 2 to 0 These bits are used only in master mode. These bits select the required transfer rate, together with the IICX1 (IIC_1) and IICX0 (IIC_0) bits in STCR. Refer to table 16.3.
4	CKS1	0	R/W	
3	CKS0	0	R/W	

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. 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.
0	BC0	0	R/W	The bit counter is initialized to 000 when a start condition is detected. The value returns to 000 at the end of a data transfer.

I²C Bus Format	Clocked Synchronous Serial 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 16.3 I²C Transfer Rate

STCR	ICMR								
Bits 5 and 6	Bit 5	Bit 4	Bit 3		Transfer Rate				
IICX	CKS2	CKS1	CKS0	Clock	φ = 5 MHz	φ = 8 MHz	φ = 10 MHz	φ = 16 MHz	φ = 20 MHz
0	0	0	0	φ/28	179 kHz	286 kHz	357 kHz	517 kHz*	714 kHz*
0	0	0	1	φ/40	125 kHz	200 kHz	250 kHz	400 kHz	500 kHz*
0	0	1	0	φ/48	104 kHz	167 kHz	208 kHz	333 kHz	417 kHz*
0	0	1	1	φ/64	78.1 kHz	125 kHz	156 kHz	250 kHz	313 kHz
0	1	0	0	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz	250 kHz
0	1	0	1	φ/100	50.0 kHz	80.0 kHz	100 kHz	160 kHz	200 kHz
0	1	1	0	φ/112	44.6 kHz	71.4 kHz	89.3 kHz	143 kHz	179 kHz
0	1	1	1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz	156 kHz
1	0	0	0	φ/56	89.3 kHz	143 kHz	179 kHz	286 kHz	357 kHz
1	0	0	1	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz	250 kHz
1	0	1	0	φ/96	52.1 kHz	83.3 kHz	104 kHz	167 kHz	208 kHz
1	0	1	1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz	156 kHz
1	1	0	0	φ/160	31.3 kHz	50.0 kHz	62.5 kHz	100 kHz	125 kHz
1	1	0	1	φ/200	25.0 kHz	40.0 kHz	50.0 kHz	80.0 kHz	100 kHz
1	1	1	0	φ/224	22.3 kHz	35.7 kHz	44.6 kHz	71.4 kHz	89.3 kHz
1	1	1	1	φ/256	19.5 kHz	31.3 kHz	39.1 kHz	62.5 kHz	78.1 kHz

Note: * Outside the I²C bus interface specifications (standard mode: max. 100 kHz; high-speed mode: max. 400 kHz)

16.3.5 I²C Bus Control Register (ICCR)

ICCR controls the I²C bus interface and performs interrupt flag confirmation.

Bit	Bit Name	Initial Value	R/W	Description
7	ICE	0	R/W	I²C Bus Interface Enable 0: I²C bus interface modules are stopped and I²C bus interface module internal state is initialized. SAR and SARX can be accessed. 1: I²C bus interface modules can perform transfer operation, and the ports function as the SCL and SDA input/output pins. ICMR and ICDR can be accessed.
6	IEIC	0	R/W	I²C Bus Interface Interrupt Enable 0: Disables interrupts from the I²C bus interface to the CPU 1: Enables interrupts from the I²C bus interface to the CPU.
5	MST	0	R/W	Master/Slave Select
4	TRS	0	R/W	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 with the I²C bus format. In slave receive mode with I²C bus format, the R/$\overline{W}$ bit in the first frame immediately after the start condition sets these bits in receive mode or transmit mode automatically by hardware. Modification of the TRS bit during transfer is deferred until transfer is completed, and the changeover is made after completion of the transfer.

Bit	Bit Name	Initial Value	R/W	Description
5	MST	0	R/W	[MST clearing conditions]
4	TRS	0		1. When 0 is written by software 2. When lost in bus contention in I²C bus format master mode [MST setting conditions] 1. When 1 is written by software (for MST clearing condition 1) 2. When 1 is written in MST after reading MST = 0 (for MST clearing condition 2) [TRS clearing conditions] 1. When 0 is written by software (except for TRS setting condition 3) 2. When 0 is written in TRS after reading TRS = 1 (for TRS setting condition 3) 3 When lost in bus contention in I²C bus format master mode 4. When the SW bit in DDCSWR is changed from 1 to 0 [TRS setting conditions] 1. When 1 is written by software (except for TRS clearing conditions 3 and 4) 2. When 1 is written in TRS after reading TRS = 0 (for TRS clearing conditions 3 and 4) 3. When 1 is received as the R/$\overline{W}$ bit after the first frame address matching in I²C bus format slave mode
3	ACKE	0	R/W	Acknowledge Bit Decision and 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 in ICSR, which is always 0. 1: If the received acknowledge bit is 1, continuous transfer is halted. 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.

Bit	Bit Name	Initial Value	R/W	Description
2	BBSY	0	R/W	Bus Busy
0	SCP	1	W	Start Condition/Stop Condition Prohibit In master mode: • Writing 0 in BBSY and 0 in SCP: A stop condition is issued • Writing 1 in BBSY and 0 in SCP: A start condition and a restart condition are issued In slave mode: • Writing to the BBSY flag is disabled. [BBSY setting condition] When the SDA level changes from high to low under the condition of SCL = high, assuming that the start condition has been issued. [BBSY clearing condition] When the SDA level changes from low to high under the condition of SCL = high, assuming that the stop condition has been issued. To issue a start/stop condition, use the MOV instruction. The I²C bus interface must be set in master transmit mode before the issue of a start condition. Set MST to 1 and TRS to 1 before writing 1 in BBSY and 0 in SCP. The BBSY flag can be read to check whether the I²C bus (SCL, SDA) is busy or free. The SCP bit is always read as 1. If 0 is written, the data is not stored.

Bit	Bit Name	Initial Value	R/W	Description
1	IRIC	0	R/(W)*	I²C Bus Interface Interrupt Request Flag Indicates that the I²C bus interface has issued an interrupt request to the CPU. IRIC is set at different times depending on the FS bit in SAR, the FSX bit in SARX, and the WAIT bit in ICMR. See section 16.4.7, IRIC Setting Timing and SCL Control. The conditions under which IRIC is set also differ depending on the setting of the ACKE bit in ICCR. [Setting conditions] I²C bus format master mode: • When a start condition is detected in the bus line state after a start condition is issued (when the ICDRE flag is set to 1 because of first frame transmission) • When a wait is inserted between the data and acknowledge bit when the WAIT bit is 1 (fall of the 8th transmit/receive clock) • At the end of data transfer (rise of the 9th transmit/receive clock while no wait is inserted) • When a slave address is received after bus arbitration is lost (the first frame after the start condition) • If 1 is received as the acknowledge bit (when the ACKB bit in ICSR is set to 1) when the ACKE bit is 1 • When the AL flag is set to 1 after bus arbitration is lost while the ALIE bit is 1 I²C bus format slave mode: • When the slave address (SVA or SVAX) matches (when the AAS or AASX flag in ICSR is set to 1) and at the end of data transfer up to the subsequent retransmission start condition or stop condition detection (rise of the 9th transmit/receive clock) • When the general call address is detected (when 0 is received as the R/$\overline{W}$ bit and the ADZ flag in ICSR is set to 1) and at the end of data reception up to the subsequent retransmission start condition or stop condition detection (rise of the 9th receive clock) • If 1 is received as the acknowledge bit (when the ACKB bit in ICSR is set to 1) while the ACKE bit is 1 • When a stop condition is detected (when the STOP or ESTP flag in ICSR is set to 1) while the STOPIM bit is 0

Bit	Bit Name	Initial Value	R/W	Description
1	IRIC	0	R/(W)*	Clocked synchronous serial format and formatless modes: • At the end of data transfer (rise of the 8th transmit/receive clock with serial format selected and rise of the 9th transmit/receive clock with formatless selected) • When a start condition is detected with serial format selected • When the SW bit in DDCSWR is set to 1 When the ICDRE or ICDRF flag is set to 1 in any operating mode: • When a start condition is detected in transmit mode (when a start condition is detected in transmit mode and the ICDRE flag is set to 1) • When data is transferred among the ICDR register and buffer (when data is transferred from ICDRT to ICDRS in transmit mode and the ICDRE flag is set to 1, or when data is transferred from ICDRS to ICDRR in receive mode and the ICDRF flag is set to 1) [Clearing conditions] • When 0 is written in IRIC after reading IRIC = 1 • When ICDR is read from or written to by the DTC (This may not function as a clearing condition depending on the situation. For details, see the description of the DTC operation given below.)

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

When the DTC is used, IRIC is cleared automatically and transfer can be performed continuously without CPU intervention.

When, with the I²C bus format selected, IRIC is set to 1 and an interrupt is generated, other flags must be checked in order to identify the source that set IRIC to 1. Although each source has a corresponding flag, caution is needed at the end of a transfer.

When the ICDRE or ICDRF flag is set, the IRTR flag may or may not be set. The IRTR flag (the DTC start request flag) is not set at the end of a data transfer up to detection of a retransmission start condition or stop condition after a slave address (SVA) or general call address match in I²C bus format slave mode.

Even when the IRIC flag and IRTR flag are set, the ICDRE or ICDRF flag may not be set. The IRIC and IRTR flags are not cleared at the end of the specified number of transfers in continuous

transfer using the DTC. The ICDRE or ICDRF flag is cleared, however, since the specified number of ICDR reads or writes have been completed.

Tables 16.4 and 16.5 show the relationship between the flags and the transfer states.

Table 16.4 Flags and Transfer States (Master Mode)

MST	TRS	BBSY	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	ICDRF	ICDRE	State
1	1	0	0	0	0	0↓	0	0↓	0↓	0	—	0	Idle state (flag clearing required)
1	1	1↑	0	0	1↑	0	0	0	0	0	—	1↑	Start condition detected
1	—	1	0	0	—	0	0	0	0	—	—	—	Wait state
1	1	1	0	0	—	0	0	0	0	1↑	—	—	Transmission end (ACKE=1 and ACKB=1)
1	1	1	0	0	1↑	0	0	0	0	0	—	1↑	Transmission end with ICDRE=0
1	1	1	0	0	—	0	0	0	0	0	—	0↓	ICDR write with the above state
1	1	1	0	0	—	0	0	0	0	0	—	1	Transmission end with ICDRE=1
1	1	1	0	0	—	0	0	0	0	0	—	0↓	ICDR write with the above state or after start condition detected
1	1	1	0	0	1↑	0	0	0	0	0	—	1↑	Automatic data transfer from ICDRT to ICDRS with the above state
1	0	1	0	0	1↑	0	0	0	0	—	1↑	—	Reception end with ICDRF=0
1	0	1	0	0	—	0	0	0	0	—	0↓	—	ICDR read with the above state
1	0	1	0	0	—	0	0	0	0	—	1	—	Reception end with ICDRF=1
1	0	1	0	0	—	0	0	0	0	—	0↓	—	ICDR read with the above state
1	0	1	0	0	1↑	0	0	0	0	—	1↑	—	Automatic data transfer from ICDRS to ICDRR with the above state
0↓	0↓	1	0	0	—	0	1↑	0	0	—	—	—	Arbitration lost
1	—	0↓	0	0	—	0	0	0	0	—	—	0↓	Stop condition detected

Legend:

0: 0-state retained

1: 1-state retained

—: Previous state retained

0↓: Cleared to 0

1↑: Set to 1

Table 16.5 Flags and Transfer States (Slave Mode)

MST	TRS	BBSY	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	ICDRF	ICDRE	State
0	0	0	0	0	0	0	0	0	0	0	—	0	Idle state (flag clearing required)
0	0	1↑	0	0	0	0↓	0	0	0	0	—	1↑	Start condition detected
0	1↑/0*1	1	0	0	0	0	—	1↑	0	0	1↑	1	SAR match in first frame (SARX ≠ SAR)
0	0	1	0	0	0	0	—	1↑	1↑	0	1↑	1	General call address match in first frame (SARX ≠ H'00)
0	1↑/0*1	1	0	0	1↑	1↑	—	0	0	0	1↑	1	SARS match in first frame (SAR ≠ SARX)
0	1	1	0	0	—	—	—	—	0	1↑	—	—	Transmission end (ACKE = 1 and ACKB =1)
0	1	1	0	0	1↑/0*2	—	—	—	0	0	—	1↑	Transmission end with ICDRE = 0
0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICDR write with the above state
0	1	1	0	0	—	—	—	—	0	0	—	1	Transmission end with ICDRE = 1
0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICDR write with the above state
0	1	1	0	0	1↑/0*2	—	0	0	0	0	—	1↑	Automatic data transfer from ICDRT to ICDRS with the above state
0	0	1	0	0	1↑/0*2	—	—	—	—	—	1↑	—	Reception end with ICDRF=0
0	0	1	0	0	—	—	0↓	0↓	0↓	—	0↓	—	ICDR read with the above state
0	0	1	0	0	—	—	—	—	—	—	1	—	Reception end with ICDRF = 1
0	0	1	0	0	—	—	0↓	0↓	0↓	—	0↓	—	ICDR read with the above state
0	0	1	0	0	1↑/0*2	—	0	0	0	—	1↑	—	Automatic data transfer from ICDRS to ICDRR with the above state
0	—	0↓	1↑/0*3	0/1↑*3	—	—	—	—	—	—	—	0↓	Stop condition detected

Legend:
0: 0-state retained
1: 1-state retained
—: Previous state retained
0↓: Cleared to 0
1↑: Set to 1

Notes: 1. Set to 1 when 1 is received as a R/$\overline{W}$ bit following an address.
2. Set to 1 when the AASX bit is set to 1.
3. When ESTP=1, STOP is 0, or when STOP=1, ESTP is 0.

16.3.6 I²C Bus Status Register (ICSR)

ICSR consists of status flags. Also see tables 16.4 and 16.5.

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 conditions] • When 0 is written in ESTP after reading ESTP = 1 • When the IRIC flag in ICCR 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 after frame transfer completion. [Clearing conditions] • 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)*	I²C Bus Interface Continuous Transfer Interrupt Request Flag Indicates that the I²C bus interface has issued an interrupt request to the CPU, and the source is completion of reception/transmission of one frame in continuous transmission/reception for which DTC activation is possible. When the IRTR flag is set to 1, the IRIC flag is also set to 1 at the same time. [Setting conditions] I²C bus format slave mode: • When the ICDRE or ICDRF flag in ICDR is set to 1 when AASX = 1 Master mode or clocked synchronous serial format mode with I²C bus format, or formatless mode: • When the ICDRE or ICDRF flag is set to 1 [Clearing conditions] • When 0 is written after reading IRTR = 1 • When the IRIC flag is cleared to 0 while ICE is 1
4	AASX	0	R/(W)*	Second Slave Address Recognition Flag In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition matches bits SVAX6 to SVAX0 in SARX. [Setting condition] When the second slave address is detected in slave receive mode and FSX = 0 in SARX [Clearing conditions] • When 0 is written in AASX after reading AASX = 1 • When a start condition is detected • In master mode

Bit	Bit Name	Initial Value	R/W	Description
3	AL	0	R/(W)*	Arbitration Lost Flag Indicates that arbitration was lost in master mode. [Setting conditions] When ALSL = 0 • If the internal SDA and SDA pin disagree at the rise of SCL in master transmit mode • If the internal SCL line is high at the fall of SCL in master transmit mode When ALSL = 1 • If the internal SDA and SDA pin disagree at the rise of SCL in master transmit mode • If the SDA pin is driven low by another device before the I²C bus interface drives the SDA pin low, after the start condition instruction was executed in master transmit mode [Clearing conditions] • When ICDR is written to (transmit mode) or read from (receive mode) • When 0 is written in AL after reading AL = 1
2	AAS	0	R/(W)*	Slave Address Recognition Flag In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition matches bits SVA6 to SVA0 in SAR, or if the general call address (H'00) is detected. [Setting condition] When the slave address or general call address (one frame including a R/$\overline{W}$ bit is H'00) is detected in slave receive mode and FS = 0 in SAR [Clearing conditions] • When ICDR is written to (transmit mode) or read from (receive mode) • When 0 is written in AAS after reading AAS = 1 • In master mode

Bit	Bit Name	Initial Value	R/W	Description
1	ADZ	0	R/(W)*	General Call Address Recognition Flag In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition is the general call address (H'00). [Setting condition] When the general call address (one frame including a R/$\overline{W}$ bit is H'00) is detected in slave receive mode and FS = 0 or FSX = 0 [Clearing conditions] • When ICDR is written to (transmit mode) or read from (receive mode) • When 0 is written in ADZ after reading ADZ = 1 • In master mode If a general call address is detected while FS=1 and FSX=0, the ADZ flag is set to 1; however, the general call address is not recognized (AAS flag is not set to 1).

Bit	Bit Name	Initial Value	R/W	Description
0	ACKB	0	R/W	Acknowledge Bit Stores acknowledge data. Transmit mode: [Setting condition] When 1 is received as the acknowledge bit when ACKE=1 in transmit mode [Clearing conditions] • When 0 is received as the acknowledge bit when ACKE=1 in transmit mode • When 0 is written to the ACKE bit Receive mode: 0: Returns 0 as acknowledge data after data reception 1: Returns 1 as acknowledge data after data reception When this bit is read, the value loaded from the bus line (returned by the receiving device) is read in transmission (when TRS = 1). In reception (when TRS = 0), the value set by internal software is read. When this bit is written, acknowledge data that is returned after receiving is rewritten regardless of the TRS value. If the ICSR register bit is written using bit-manipulation instructions, the acknowledge data should be re-set since the acknowledge data setting is rewritten by the ACKB bit reading value. Write the ACKE bit to 0 to clear the ACKB flag to 0, before transmission is ended and a stop condition is issued in master mode, or before transmission is ended and SDA is released to issue a stop condition by a master device.

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

16.3.7 DDC Switch Register (DDCSWR)

DDCSWR controls the IIC_0 automatic format switching function and IIC internal latch clearance.

Bit	Bit Name	Initial Value	R/W	Description
7	SWE	0	R/W	DDC Mode Switch Enable 0: Disables automatic switching of IIC channel 0 from formatless mode to I²C bus format 1: Enables automatic switching of IIC channel 0 from formatless mode to I²C bus format
6	SW	0	R/W	DDC Mode Switch 0: Uses IIC channel 0 with the I²C bus format 1: Uses IIC channel 0 in formatless mode [Setting condition] When 1 is written in SW after reading SW = 0 [Clearing conditions] • When 0 is written by software • When a falling edge is detected on the SCL pin when SWE = 1
5	IE	0	R/W	DDC Mode Switch Interrupt Enable Bit 0: Disables interrupts when automatic format switching is executed 1: Enables interrupts when automatic format switching is executed
4	IF	0	R/(W)*1	DDC Mode Switch Interrupt Flag Indicates an interrupt request to the CPU is generated when automatic format switching is executed for IIC_0. [Setting condition] When a falling edge is detected on the SCL pin when SWE = 1 [Clearing condition] When 0 is written in IF after reading IF = 1

Bit	Bit Name	Initial Value	R/W	Description
3	CLR3	1	W*2	IIC Clear 3 to 0
2	CLR2	1	W*2	Controls initialization of the internal state of IIC_0 and IIC_1.
1	CLR1	1	W*2	00--: Setting prohibited
0	CLR0	1	W*2	0100: Setting prohibited
				0101: IIC_0 internal latch cleared
				0110: IIC_1 internal latch cleared
				0111: IIC_0 and IIC_1 internal latches cleared
				1---: Invalid setting
				When a write operation is performed on these bits, a clear signal is generated for the internal latch circuit of the corresponding module, and the internal state of the IIC module is initialized.
				These bits can only be written to; they are always read as 1. Write data to this bit 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.
				When clearing is required again, all the bits must be written to in accordance with the setting.
				If the function of these bits is not used, set all of the CLR3 to CLR0 bits to 1 when writing to DDCSWR.

Notes: 1. Only 0 can be written, to clear the flag.
2. This bit is always read as 1.

16.3.8 I²C Bus Extended Control Register (ICXR)

ICXR enables or disables the I²C bus interface interrupt generation and continuous receive operation, and indicates the status of receive/transmit operations.

Bit	Bit Name	Initial Value	R/W	Description
7	STOPIM	0	R/W	Stop Condition Interrupt Source Mask Enables or disables the interrupt generation when the stop condition is detected in slave mode. 0: Enables IRIC flag setting and interrupt generation when the stop condition is detected (STOP = 1 or ESTP = 1) in slave mode. 1: Disables IRIC flag setting and interrupt generation when the stop condition is detected.
6	HNDS	0	R/W	Handshake Receive Operation Select Enables or disables continuous receive operation in receive mode. 0: Enables continuous receive operation 1: Disables continuous receive operation When the HNDS bit is cleared to 0, receive operation is performed continuously after data has been received successfully while ICDRF flag is 0. When the HNDS bit is set to 1, SCL is fixed to the low level and the next data transfer is disabled after data has been received successfully while the ICDRF flag is 0. The bus line is released and next receive operation is enabled by reading the receive data in ICDR.

Bit	Bit Name	Initial Value	R/W	Description
5	ICDRF	0	R	Receive Data Read Request Flag Indicates the ICDR (ICDRR) status in receive mode. 0: Indicates that the data has been already read from ICDR (ICDRR) or ICDR is initialized. 1: Indicates that data has been received successfully and transferred from ICDRS to ICDRR, and the data is ready to be read out. [Setting conditions] • When data is received successfully and transferred from ICDRS to ICDRR. (1) When data is received successfully while ICDRF = 0 (at the rise of the 9th clock pulse). (2) When ICDR is read successfully in receive mode after data was received while ICDRF = 1. [Clearing conditions] • When ICDR (ICDRR) is read. • When 0 is written to the ICE bit. • When the IIC is internally initialized using the CLR3 to CLR0 bits in DDCSWR. When ICDRF is set due to the condition (2) above, ICDRF is temporarily cleared to 0 when ICDR (ICDRR) is read; however, since data is transferred from ICDRS to ICDRR immediately, ICDRF is set to 1 again. Note that ICDR cannot be read successfully in transmit mode (TRS = 1) because data is not transferred from ICDRS to ICDRR. Be sure to read data from ICDR in receive mode (TRS = 0).

Bit	Bit Name	Initial Value	R/W	Description
4	ICDRE	0	R	Transmit Data Write Request Flag Indicates the ICDR (ICDRT) status in transmit mode. 0: Indicates that the data has been already written to ICDR (ICDRT) or ICDR is initialized. 1: Indicates that data has been transferred from ICDRT to ICDRS and is being transmitted, or the start condition has been detected or transmission has been complete, thus allowing the next data to be written to. [Setting conditions] • When the start condition is detected from the bus line state with I²C bus format or serial format. • When I²C bus mode is switched to formatless (when the SW bit in DDCSWR is set to 1). • When data is transferred from ICDRT to ICDRS. 1. When data transmission completed while ICDRE = 0 (at the rise of the 9th clock pulse). 2. When data is written to ICDR in transmit mode after data transmission was completed while ICDRE = 1. [Clearing conditions] • When data is written to ICDR (ICDRT). • When the stop condition is detected with I²C bus format or serial format. • When 0 is written to the ICE bit. • When the IIC is internally initialized using the CLR3 to CLR0 bits in DDCSWR. Note that if the ACKE bit is set to 1 with I²C bus format thus enabling acknowledge bit decision, ICDRE is not set when data transmission is completed while the acknowledge bit is 1. When ICDRE is set due to the condition (2) above, ICDRE is temporarily cleared to 0 when data is written to ICDR (ICDRT); however, since data is transferred from ICDRT to ICDRS immediately, ICDRE is set to 1 again. Do not write data to ICDR when TRS = 0 because the ICDRE flag value is invalid during the time.

Bit	Bit Name	Initial Value	R/W	Description
3	ALIE	0	R/W	Arbitration Lost Interrupt Enable Enables or disables IRIC flag setting and interrupt generation when arbitration is lost. 0: Disables interrupt request when arbitration is lost. 1: Enables interrupt request when arbitration is lost.
2	ALSL	0	R/W	Arbitration Lost Condition Select Selects the condition under which arbitration is lost. 0: When the SDA pin state disagrees with the data that IIC bus interface outputs at the rise of SCL, or when the SCL pin is driven low by another device. 1: When the SDA pin state disagrees with the data that IIC bus interface outputs at the rise of SCL, or when the SDA line is driven low by another device in idle state or after the start condition instruction was executed.
1	FNC1	0	R/W	Function Bit
0	FNC0	0	R/W	Cancels some restrictions on usage. For details, refer to section 16.6, Usage Notes. 00: Restrictions on operation remaining in effect 01: Setting prohibited 10: Setting prohibited 11: Restrictions on operation canceled

16.4 Operation

The I²C bus interface has an I²C bus format and a serial format.

16.4.1 I²C Bus Data Format

The I²C bus format is an addressing format with an acknowledge bit. This is shown in figure 16.3. The first frame following a start condition always consists of 9 bits.

IIC_0 only is capable of formatless operation, as shown in figure 16.4.

The serial format is a non-addressing format with no acknowledge bit. This is shown in figure 16.5.

Figure 16.6 shows the I²C bus timing.

The symbols used in figures 16.3 to 16.6 are explained in table 16.6.

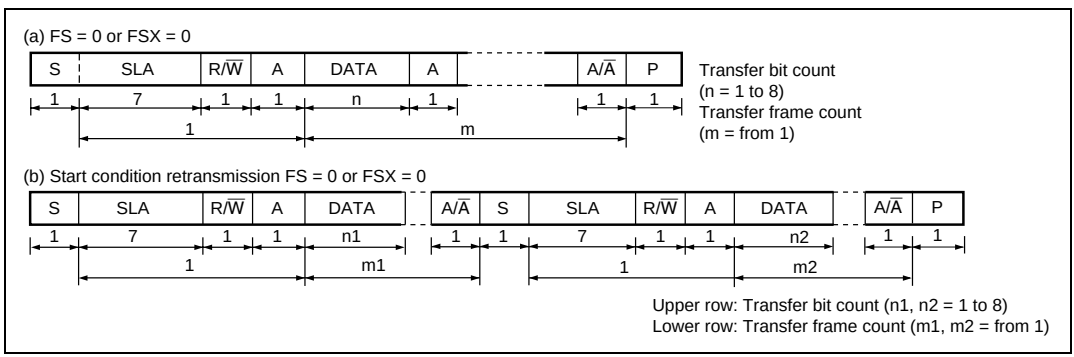


Figure 16.3 I²C Bus Data Format (I²C Bus Format)

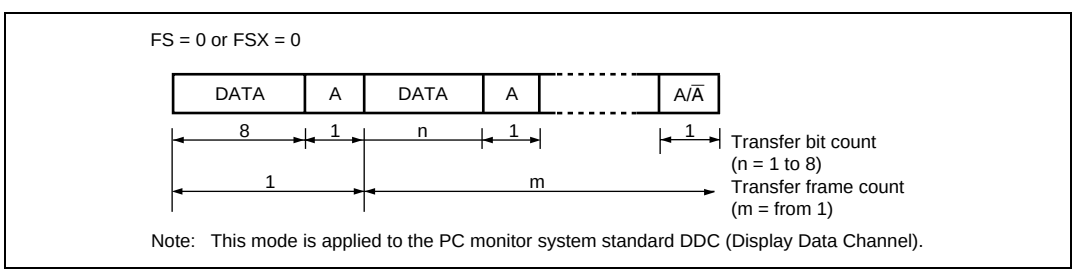


Figure 16.4 I²C Bus Data Format (Formatless) (IIC_0 Only)

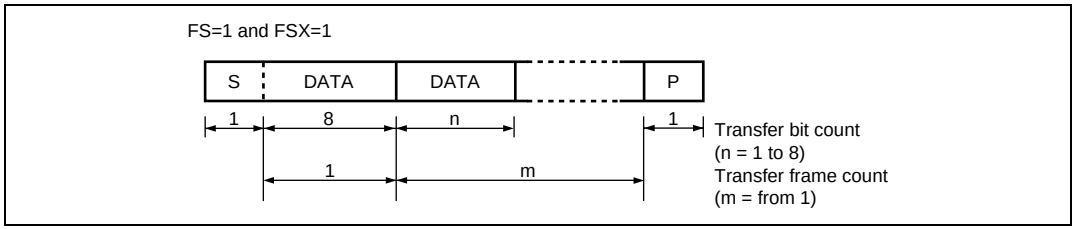


Figure 16.5 I²C Bus Data Format (Serial Format)

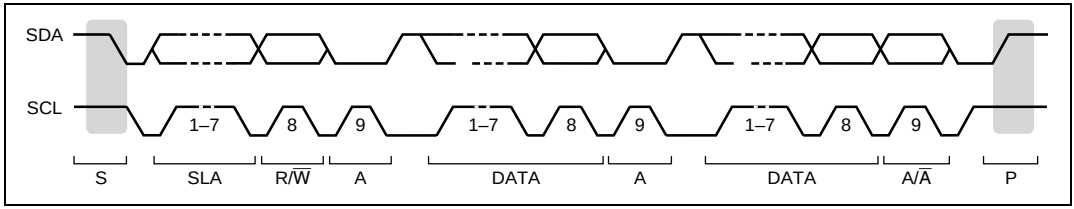


Figure 16.6 I²C Bus Timing

Table 16.6 I²C Bus Data Format Symbols

Legend	
S	Start condition. The master device drives SDA from high to low while SCL is high
SLA	Slave address. The master device selects the slave device.
R/$\overline{W}$	Indicates the direction of data transfer: from the slave device to the master device when R/$\overline{W}$ is 1, or from the master device to the slave device when R/$\overline{W}$ is 0
A	Acknowledge. The receiving device drives SDA low to acknowledge a transfer. (The slave device returns acknowledge in master transmit mode, and the master device returns acknowledge in master receive mode.)
DATA	Transferred data. The bit length of transferred data is set with the BC2 to BC0 bits in ICMR. The MSB first or LSB first is switched with the MLS bit in ICMR.
P	Stop condition. The master device drives SDA from low to high while SCL is high

16.4.2 Initialization

Initialize the IIC by the procedure shown in figure 16.7 before starting transmission/reception of data.

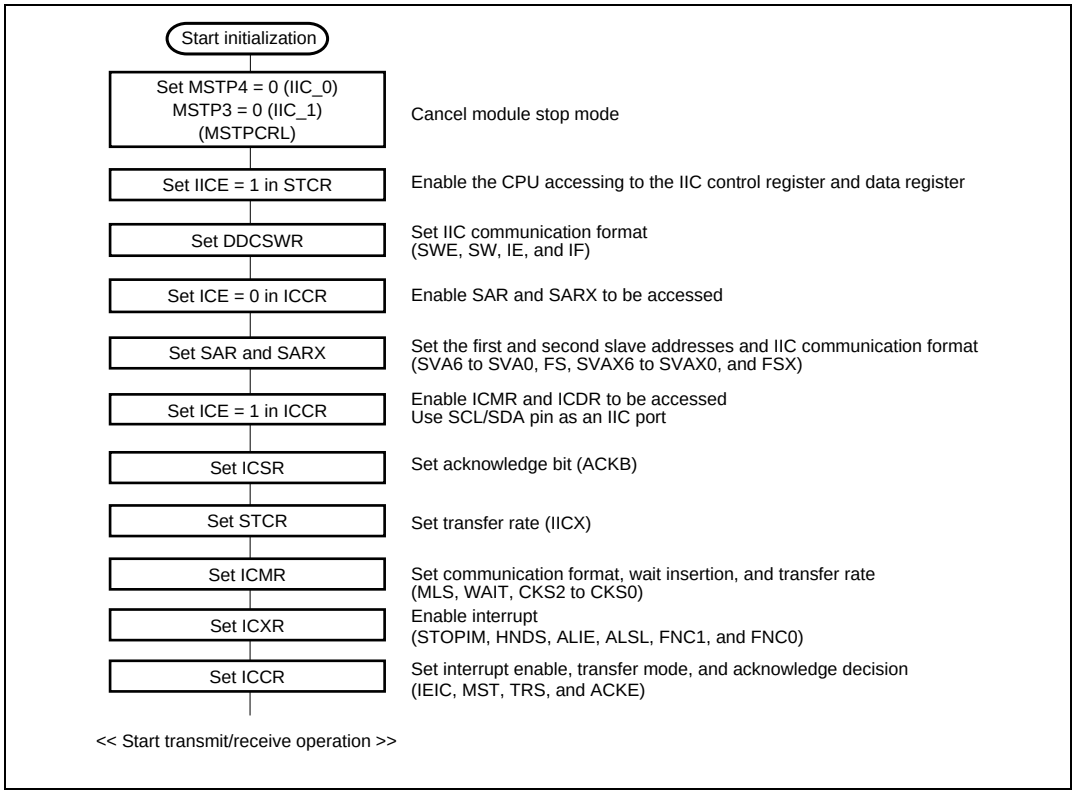


Figure 16.7 Sample Flowchart for IIC Initialization

Note: Be sure to modify the ICMR register after transmit/receive operation has been completed. If the ICMR register is modified during transmit/receive operation, bit counter BC2 to BC0 will be modified erroneously, thus causing incorrect operation.

16.4.3 Master Transmit Operation

In I²C bus format master transmit mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal.

Figure 16.8 shows the sample flowchart for the operations in master transmit mode.

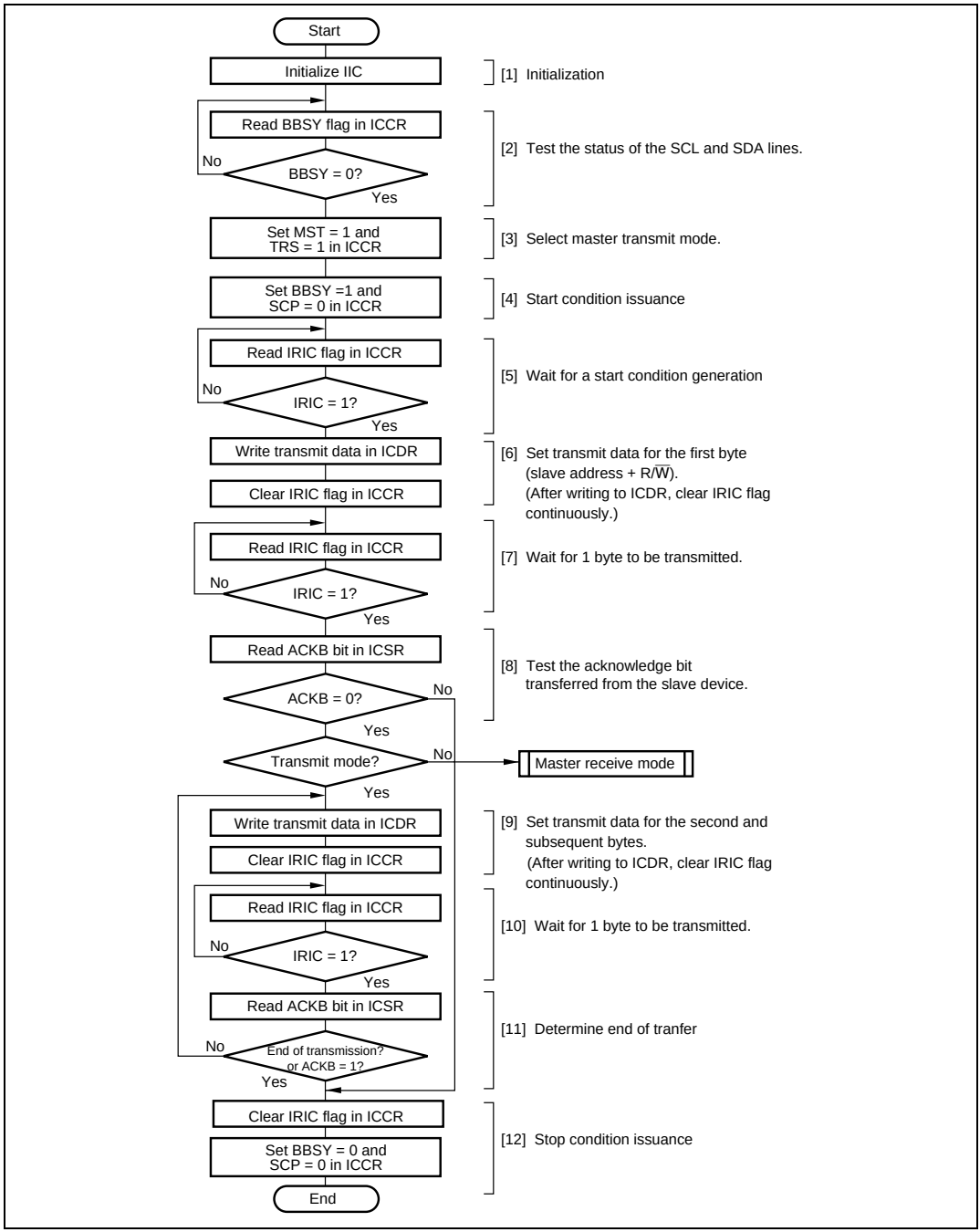


Figure 16.8 Sample Flowchart for Operations in Master Transmit Mode

The transmission procedure and operations by which data is sequentially transmitted in synchronization with ICDR (ICDRT) write operations, are described below.

1. Initialize the IIC as described in section 16.4.2, Initialization.
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 in ICCR. This changes SDA from high to low when SCL is high, and generates the start condition.
5. Then the IRIC and IRTR flags are set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU.
6. Write the data (slave address + R/$\overline{W}$) to ICDR.

   With the I²C bus format (when the FS bit in SAR or the FSX bit in SARX is 0), the first frame data following the start condition indicates the 7-bit slave address and transmit/receive direction (R/$\overline{W}$).

   To determine the end of the transfer, the IRIC flag is cleared to 0. After writing to ICDR, clear IRIC continuously so no other interrupt handling routine is executed. If the time for transmission of one frame of data has passed before the IRIC clearing, the end of transmission cannot be determined. The master device sequentially sends the transmission clock and the data written to ICDR. 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 step [12] to end transmission, and retry the transmit operation.
9. Write the transmit data to ICDR.

   As indicating the end of the transfer, the IRIC flag is cleared to 0. Perform the ICDR write and the IRIC flag clearing sequentially, just as in step [6]. 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 still data to be transmitted, go to step [9] to continue the next transmission operation. When the slave device has not acknowledged (ACKB bit is set to 1), operate step [12] to end transmission.

12. Clear the IRIC flag to 0.

    Write 0 to ACKE in ICCR, to clear received ACKB contents to 0.

    Write 0 to BBSY and SCP in ICCR. This changes SDA from low to high when SCL is high, and generates the stop condition.

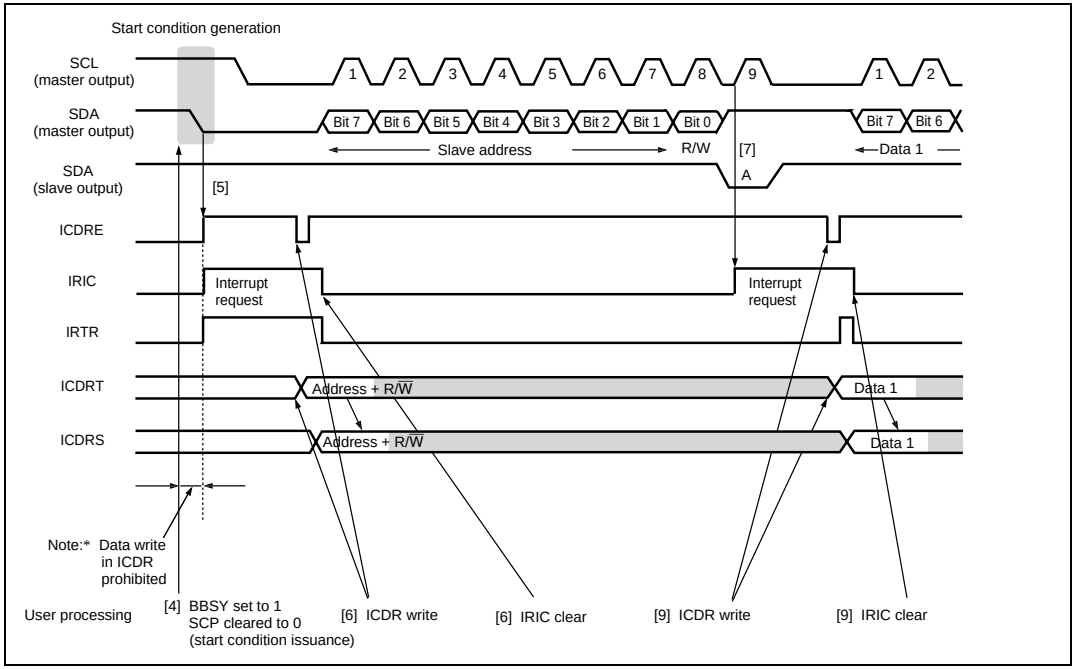


Figure 16.9 Example of Operation Timing in Master Transmit Mode (MLS = WAIT = 0)

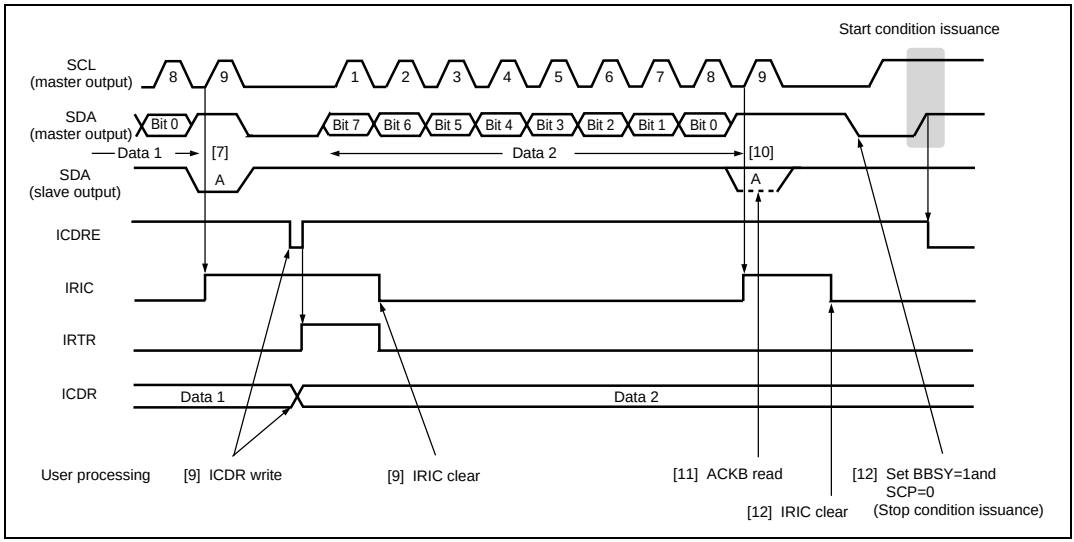


Figure 16.10 Example of Stop Condition Issuance Operation Timing in Master Transmit Mode (MLS = WAIT = 0)

16.4.4 Master Receive Operation

In I²C bus format master receive mode, the master device outputs the receive clock, receives data, and returns an acknowledge signal. The slave device transmits data.

The master device transmits data containing the slave address and R/$\overline{W}$ (1: read) in the first frame following the start condition issuance in master transmit mode, selects the slave device, and then switches the mode for receive operation.

Receive Operation Using the HNDS Function (HNDS = 1):

Figure 16.11 shows the sample flowchart for the operations in master receive mode (HNDS = 1).

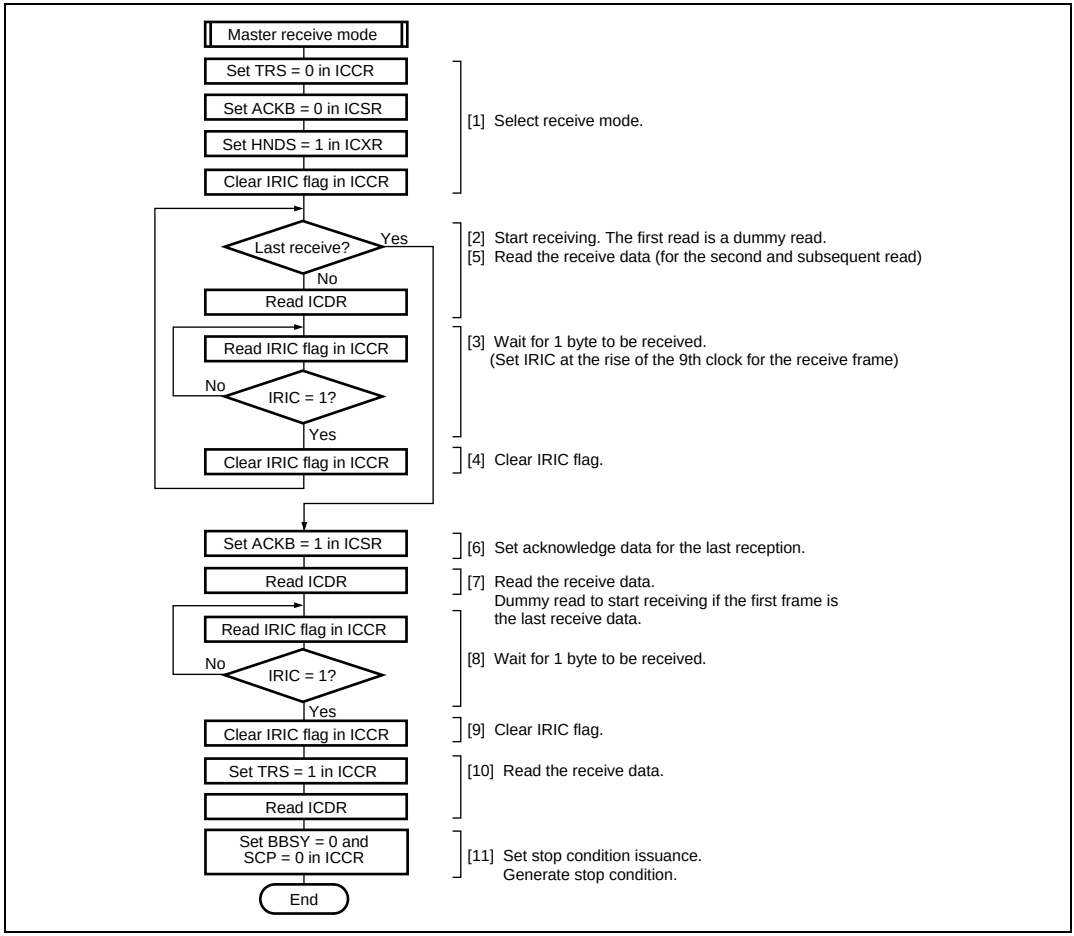


Figure 16.11 Sample Flowchart for Operations in Master Receive Mode (HNDS = 1)

The reception procedure and operations using the HNDS function, by which the data reception process is provided in 1-byte units with SCL fixed low at each data reception, are described below.

1. Clear the TRS bit in ICCR to 0 to switch from transmit mode to receive mode.
   Clear the ACKB bit in ICSR to 0 (acknowledge data setting).
   Set the HNDS bit in ICXR to 1.
   Clear the IRIC flag to 0 to determine the end of reception.
   Go to step [6] to halt reception operation if the first frame is the last receive data.
2. When ICDR is read (dummy data read), reception is started, the receive clock is output in synchronization with the internal clock, and data is received. (Data from the SDA pin is sequentially transferred to ICDRS in synchronization with the rise of the receive clock pulses.)
3. The master device drives SDA low to return the acknowledge data at the 9th receive clock pulse. The receive data is transferred from ICDRS to ICDRR at the rise of the 9th clock pulse, setting the ICDRF, IRIC, and IRTR flags to 1. If the IEIC bit has been set to 1, an interrupt request is sent to the CPU.
   The master device drives SCL low from the fall of the 9th receive clock pulse to the ICDR data reading.
4. Clear the IRIC flag to clear the wait state.
   Go to step [6] to halt reception operation if the next frame is the last receive data.
5. Read ICDR receive data. This clears the ICDRF flag to 0. The master device outputs the receive clock continuously to receive the next data.

Data can be received continuously by repeating steps [3] to [5].

6. Set the ACKB bit to 1 so as to return the acknowledge data for the last reception.
7. Read ICDR receive data. This clears the ICDRF flag to 0. The master device outputs the receive clock to receive data.
8. When one frame of data has been received, the ICDRF, IRIC, and IRTR flags are set to 1 at the rise of the 9th receive clock pulse.
9. Clear the IRIC flag to 0.
10. Read ICDR receive data after setting the TRS bit. This clears the ICDRF flag to 0.
11. Clear the BBSY bit and SCP bit to 0 in ICCR. This changes SDA from low to high when SCL is high, and generates the stop condition.

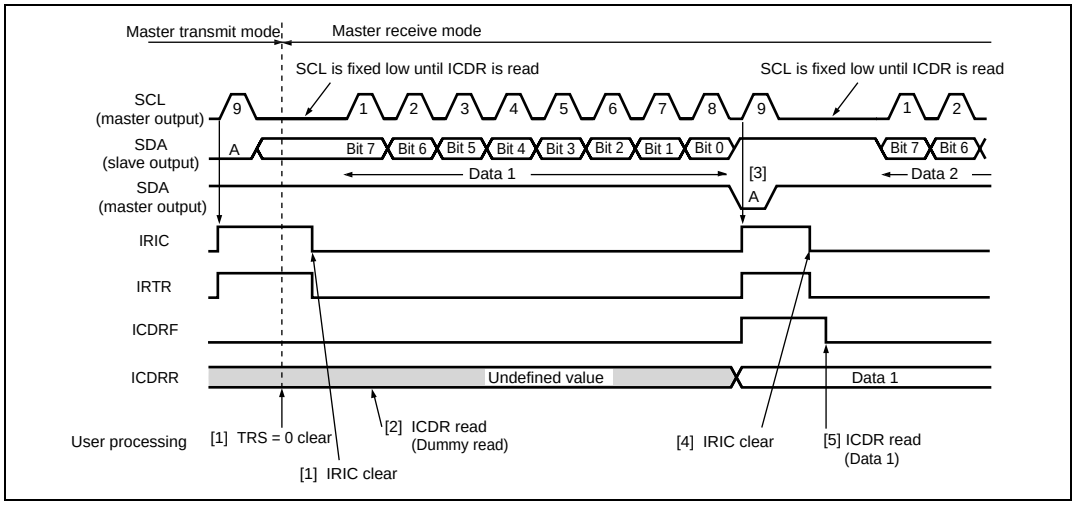


Figure 16.12 Example of Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)

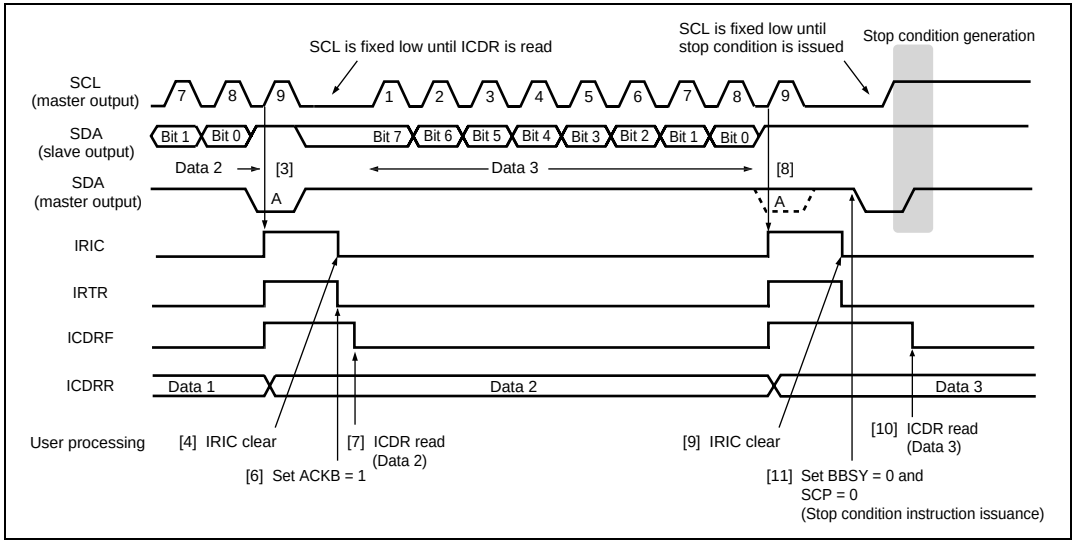


Figure 16.13 Example of Stop Condition Issuance Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)

Receive Operation Using the Wait Function:

Figures 16.14 and 16.15 show the sample flowcharts for the operations in master receive mode (WAIT = 1).

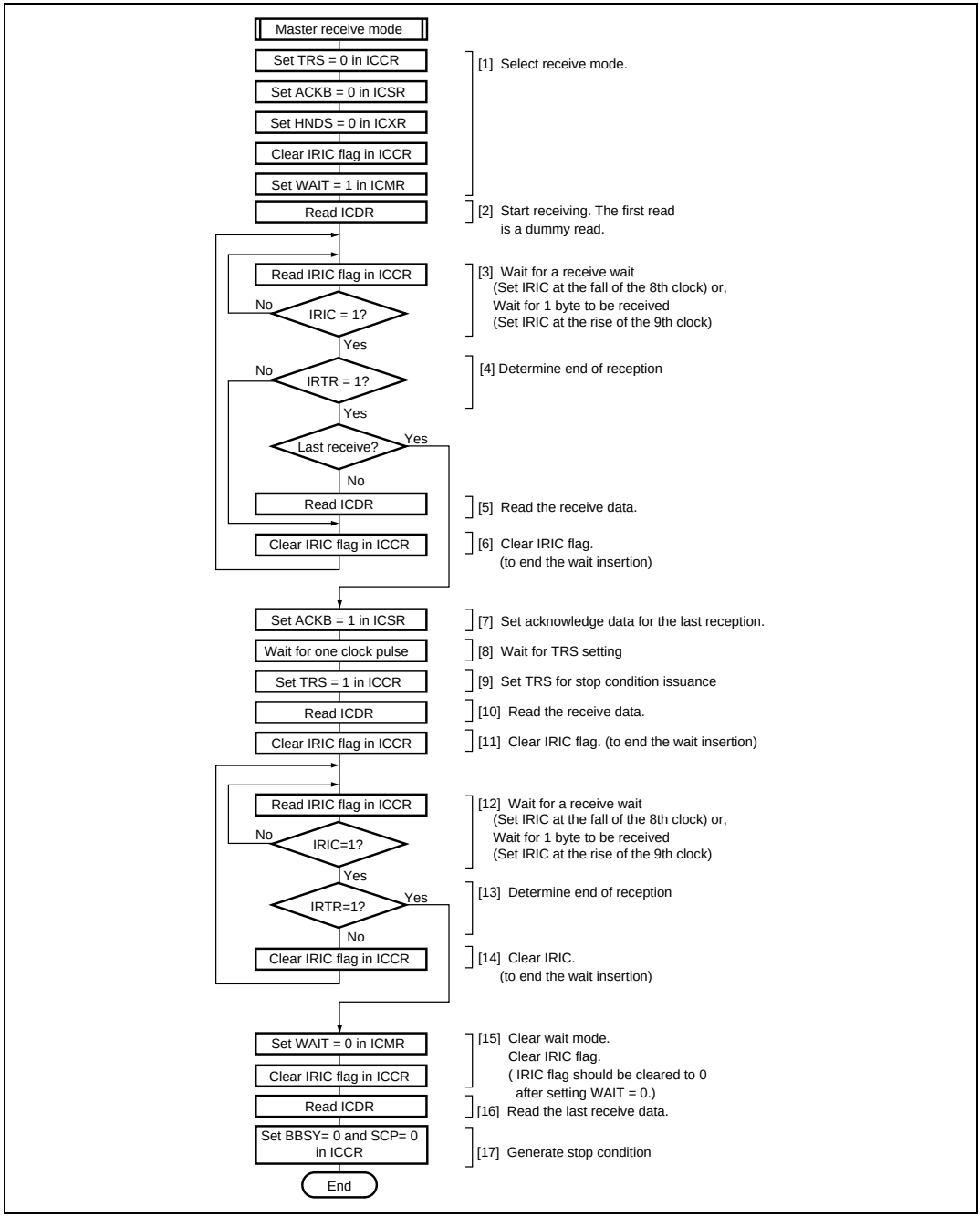


Figure 16.14 Sample Flowchart for Operations in Master Receive Mode (Receiving Multiple Bytes) (WAIT = 1)

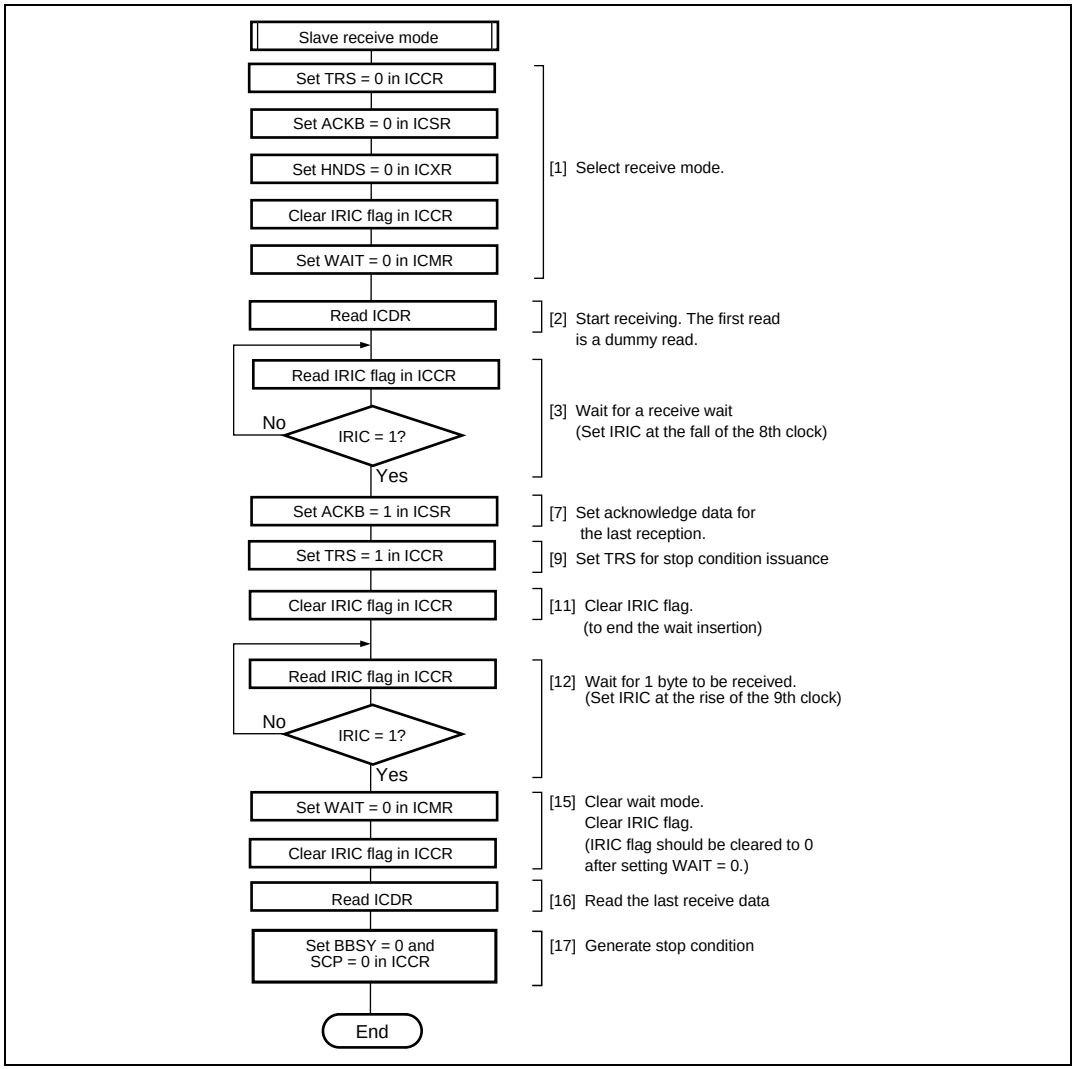


Figure 16.15 Sample Flowchart for Operations in Master Receive Mode (Receiving a Single Byte) (WAIT = 1)

The reception procedure and operations using the wait function (WAIT bit), by which data is sequentially received in synchronization with ICDR (ICDRR) read operations, are described below.

The following describes the multiple-byte reception procedure. In single-byte reception, some steps of the following procedure are omitted. At this time, follow the procedure shown in figure 16.15.

1. Clear the TRS bit in ICCR to 0 to switch from transmit mode to receive mode.
   Clear the ACKB bit in ICSR to 0 to set the acknowledge data.
   Clear the HNDS bit in ICXR to 0 to cancel the handshake function.
   Clear the IRIC flag to 0, and then set the WAIT bit in ICMR to 1.
2. When ICDR is read (dummy data is read), reception is started, the receive clock is output in synchronization with the internal clock, and data is received.
3. The IRIC flag is set to 1 in either of the following cases. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU.
   — At the fall of the 8th receive clock pulse for one frame
     SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag clearing.
   — At the rise of the 9th receive clock pulse for one frame
     The IRTR and ICDRF flags are set to 1, indicating that one frame of data has been received. The master device outputs the receive clock continuously to receive the next data.
4. Read the IRTR flag in ICSR.
   If the IRTR flag is 0, execute step [6] to clear the IRIC flag to 0 to release the wait state.
   If the IRTR flag is 1 and the next data is the last receive data, execute step [7] to halt reception.
5. If IRTR flag is 1, read ICDR receive data.
6. Clear the IRIC flag. When the flag is set as the first case in step [3], the master device outputs the 9th clock and drives SDA low at the 9th receive clock pulse to return an acknowledge signal.

Data can be received continuously by repeating steps [3] to [6].

7. Set the ACKB bit in ICSR to 1 so as to return the acknowledge data for the last reception.
8. After the IRIC flag is set to 1, wait for at least one clock pulse until the rise of the first clock pulse for the next receive data.
9. Set the TRS bit in ICCR to 1 to switch from receive mode to transmit mode. The TRS bit value becomes valid when the rising edge of the next 9th clock pulse is input.
10. Read the ICDR receive data.

11. Clear the IRIC flag to 0.
12. The IRIC flag is set to 1 in either of the following cases.
    - At the fall of the 8th receive clock pulse for one frame

      SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag is cleared.
    - At the rise of the 9th receive clock pulse for one frame

      The IRTR and ICDRF flags are set to 1, indicating that one frame of data has been received. The master device outputs the receive clock continuously to receive the next data.
13. Read the IRTR flag in ICSR.

    If the IRTR flag is 0, execute step [14] to clear the IRIC flag to 0 to release the wait state.

    If the IRTR flag is 1 and data reception is complete, execute step [15] to issue the stop condition.
14. If IRTR flag is 0, clear the IRIC flag to 0 to release the wait state.

    Execute step [12] to read the IRIC flag to detect the end of reception.
15. Clear the WAIT bit in CMR to cancel the wait mode.

    Then, clear the IRIC flag. Clearing of the IRIC flag should be done while 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 may not be issued correctly.)
16. Read the last ICDR receive data.
17. Clear the BBSY bit and SCP bit to 0 in ICCR. This changes SDA from low to high when SCL is high, and generates the stop condition.

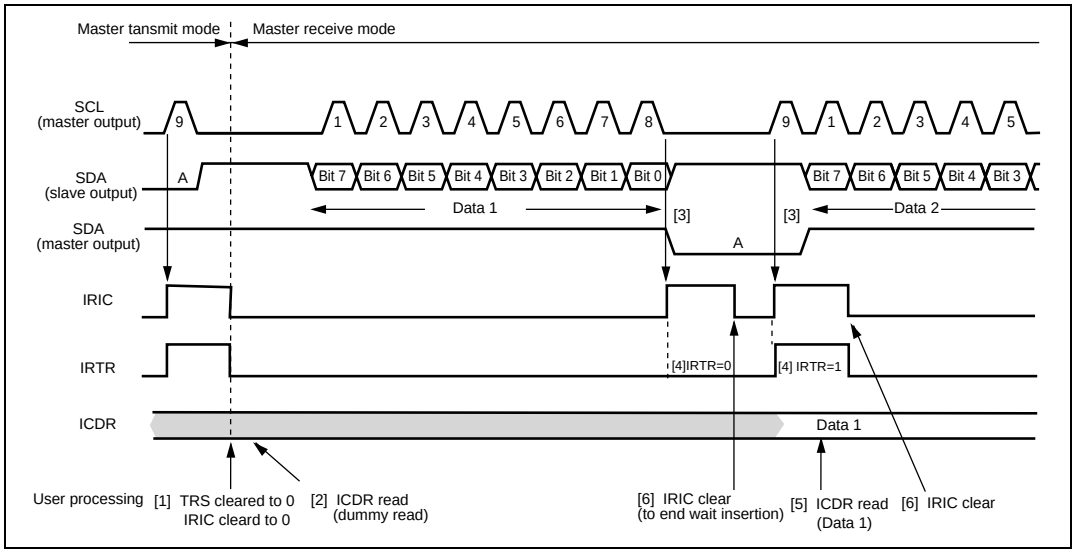


Figure 16.16 Example of Master Receive Mode Operation Timing (MLS = ACKB = 0, WAIT = 1)

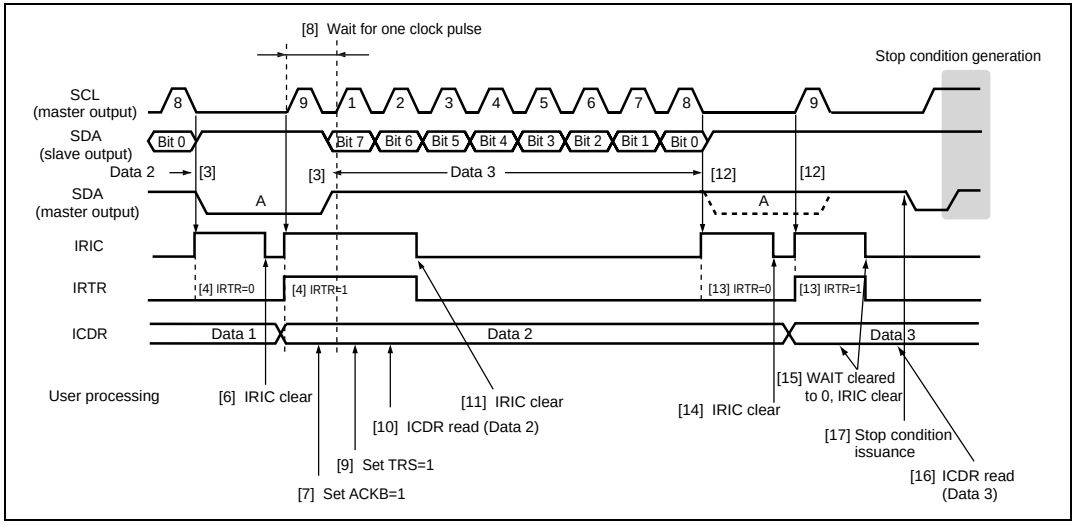


Figure 16.17 Example of Stop Condition Issuance Timing in Master Receive Mode (MLS = ACKB = 0, WAIT = 1)

16.4.5 Slave Receive Operation

In I²C bus format slave receive mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal.

The slave device operates as the device specified by the master device when the slave address in the first frame following the start condition that is issued by the master device matches its own address.

Receive Operation Using the HNDS Function (HNDS = 1):

Figure 16.18 shows the sample flowchart for the operations in slave receive mode (HNDS = 1).

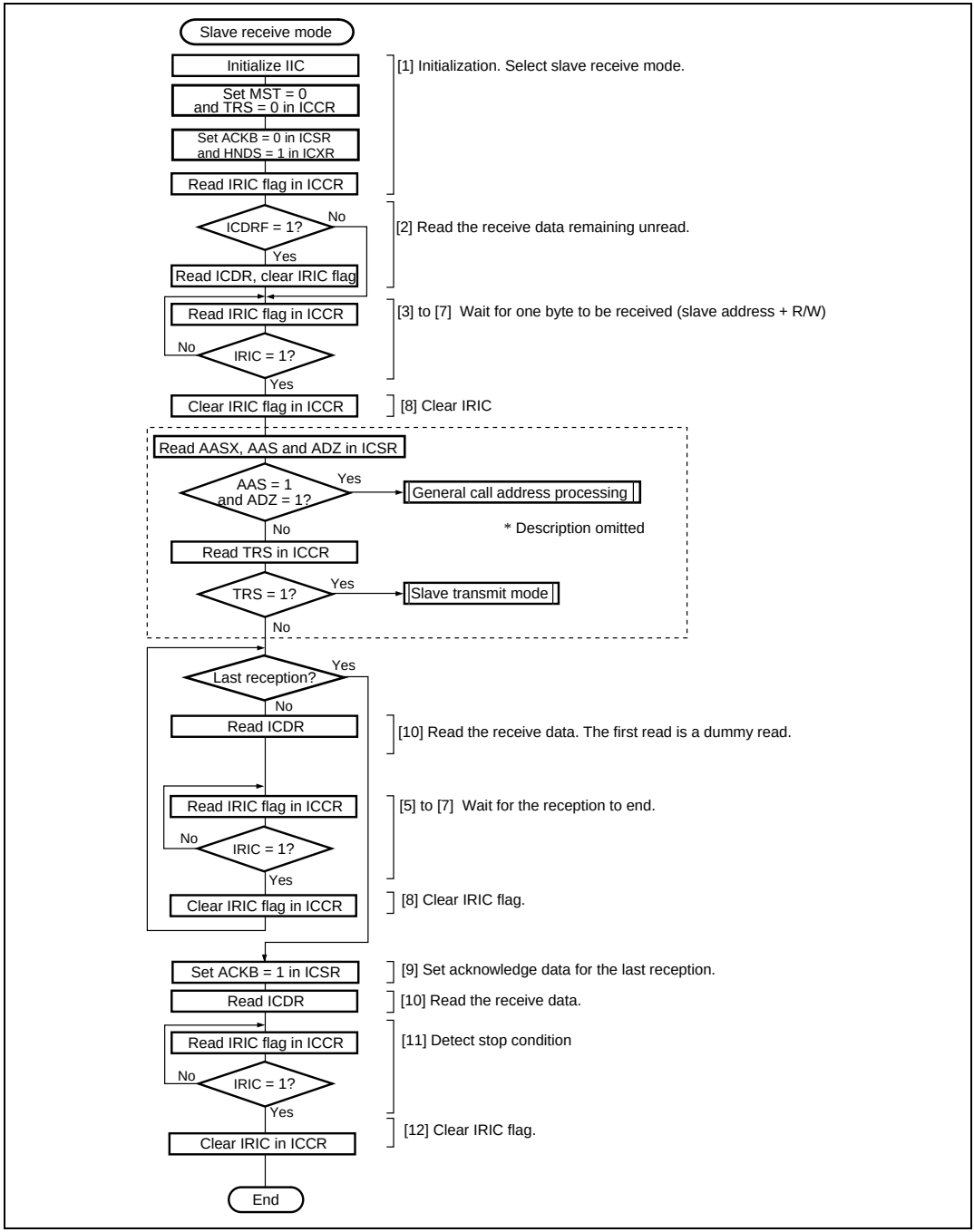


Figure 16.18 Sample Flowchart for Operations in Slave Receive Mode (HNDS = 1)

The reception procedure and operations using the HNDS bit function, by which data reception process is provided in 1-byte unit with SCL being fixed low at every data reception, are described below.

1. Initialize the IIC as described in section 16.4.2, Initialization.

   Clear the MST and TRS bits to 0 to set slave receive mode, and set the HNDS bit to 1 and the ACKB bit to 0. Clear the IRIC flag in ICCR to 0 to see the end of reception.
2. Confirm that the ICDRF flag is 0. If the ICDRF flag is set to 1, read the ICDR and then clear the IRIC flag to 0.
3. When the start condition output by the master device is detected, the BBSY flag in ICCR is set to 1. The master device then outputs the 7-bit slave address and transmit/receive direction (R/W), in synchronization with the transmit clock pulses.
4. When the slave address matches in the first frame following the start condition, the device operates as the slave device specified by the master device. If the 8th data bit (R/$\overline{W}$) is 0, the TRS bit remains cleared to 0, and slave receive operation is performed. If the 8th data bit (R/$\overline{W}$) is 1, the TRS bit is set to 1, and slave transmit operation is performed. When the slave address does not match, receive operation is halted until the next start condition is detected.
5. At the 9th clock pulse of the receive frame, the slave device returns the data in the ACKB bit as an acknowledge signal.
6. At the rise of the 9th clock pulse, the IRIC flag is set to 1. If the IEIC bit has been set to 1, an interrupt request is sent to the CPU.

   If the AASX bit has been set to 1, IRTR flag is also set to 1.
7. At the rise of the 9th clock pulse, the receive data is transferred from ICDRS to ICDRR, setting the ICDRF flag to 1. The slave device drives SCL low from the fall of the 9th receive clock pulse until data is read from ICDR.
8. Confirm that the STOP bit is cleared to 0, and clear the IRIC flag to 0.
9. If the next frame is the last receive frame, set the ACKB bit to 1.
10. If ICDR is read, the ICDRF flag is cleared to 0, releasing the SCL bus line. This enables the master device to transfer the next data.

Receive operations can be performed continuously by repeating steps [5] to [10].

11. When the stop condition is detected (SDA is changed from low to high when SCL is high), the BBSY flag is cleared to 0 and the STOP bit is set to 1. If the STOPIM bit has been cleared to 0, the IRIC flag is set to 1.
12. Confirm that the STOP bit is set to 1, and clear the IRIC flag to 0.

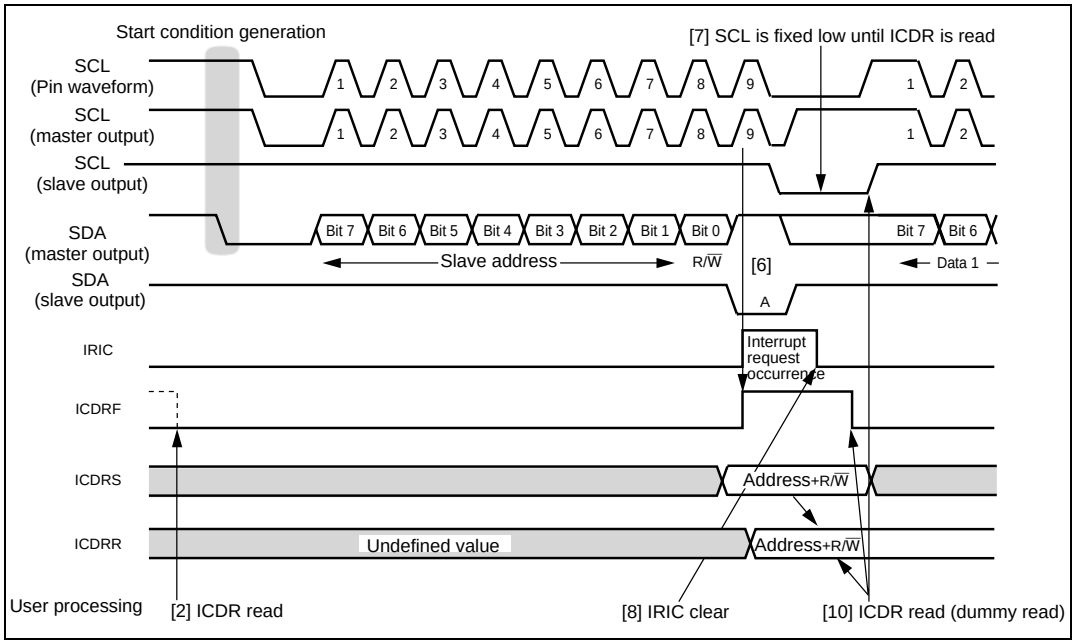


Figure 16.19 Example of Slave Receive Mode Operation Timing (1)
(MLS = 0, HNDS= 1)

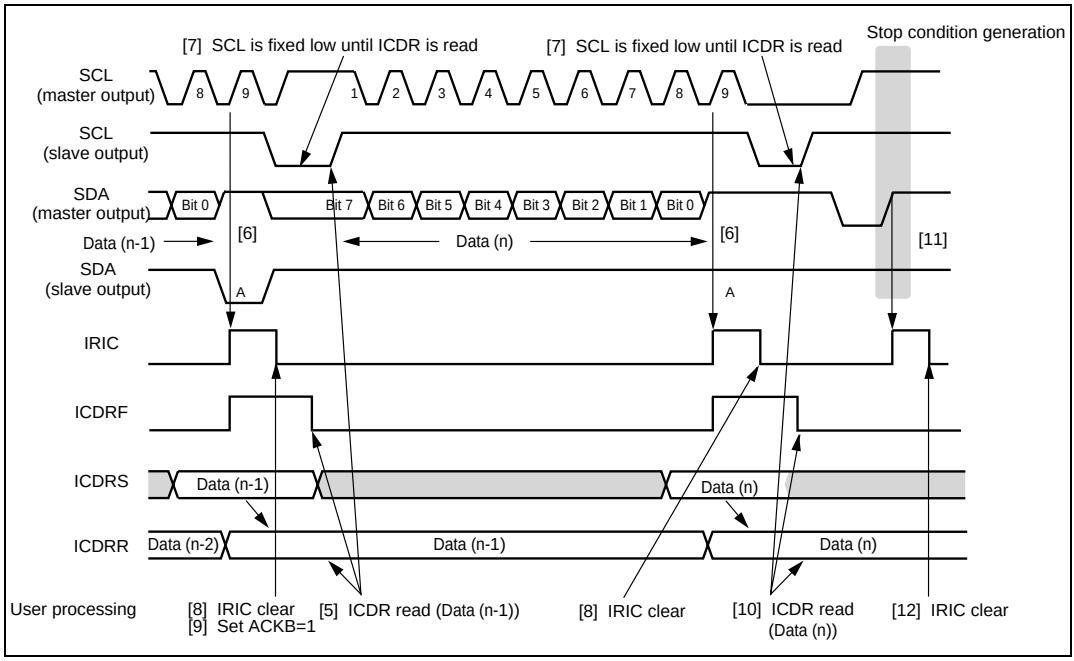


Figure 16.20 Example of Slave Receive Mode Operation Timing (2) (MLS = 0, HNDS= 1)

Continuous Receive Operation:

Figure 16.21 shows the sample flowchart for the operations in slave receive mode (HNDS = 0).

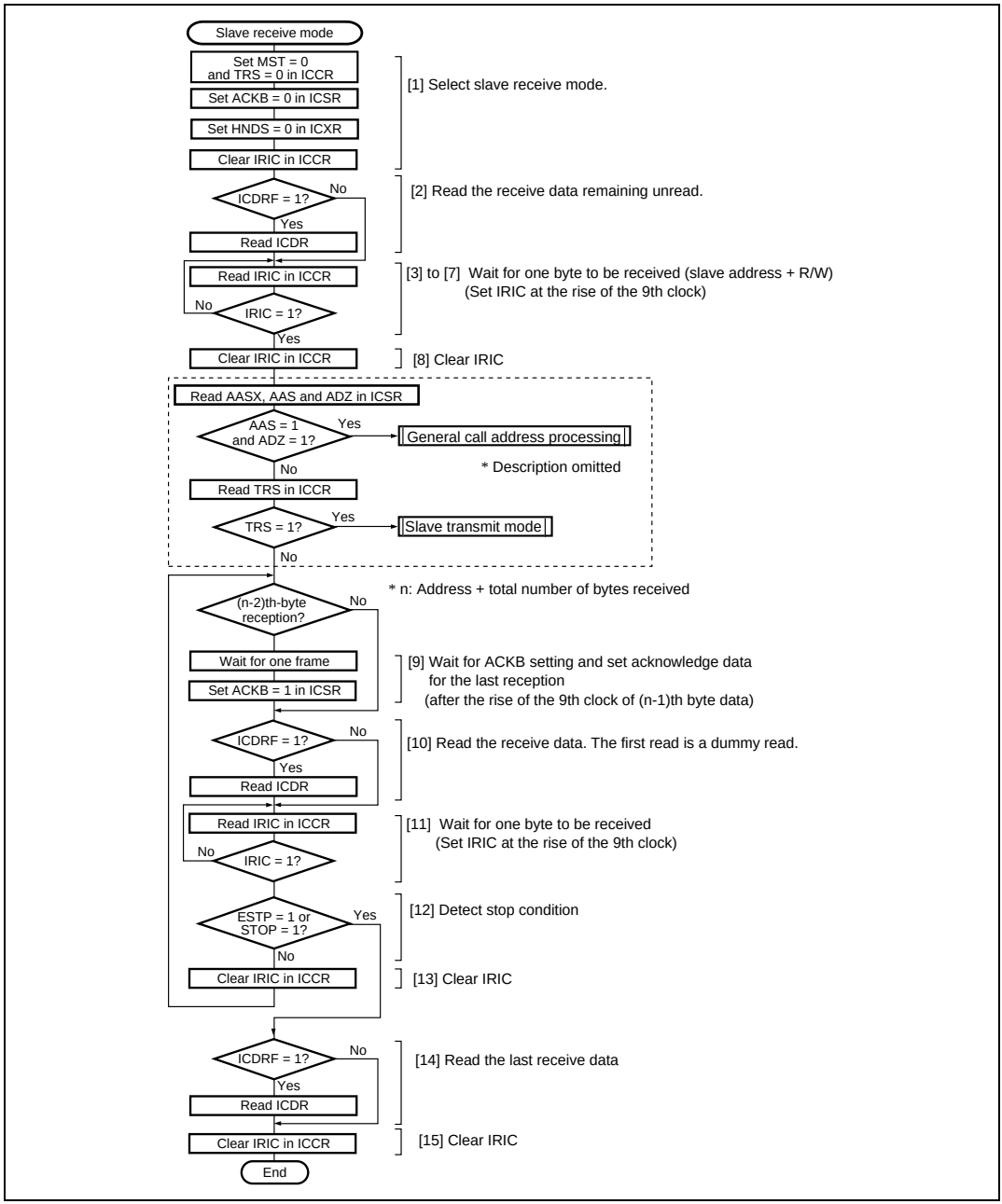


Figure 16.21 Sample Flowchart for Operations in Slave Receive Mode (HNDS = 0)

The reception procedure and operations in slave receive are described below.

1. Initialize the IIC as described in section 16.4.2, Initialization.

   Clear the MST and TRS bits to 0 to set slave receive mode, and set the HNDS and ACKB bits to 0. Clear the IRIC flag in ICCR to 0 to see the end of reception.
2. Confirm that the ICDRF flag is 0. If the ICDRF flag is set to 1, read the ICDR and then clear the IRIC flag to 0.
3. When the start condition output by the master device is detected, the BBSY flag in ICCR is set to 1. The master device then outputs the 7-bit slave address and transmit/receive direction (R/W) in synchronization with the transmit clock pulses.
4. When the slave address matches in the first frame following the start condition, the device operates as the slave device specified by the master device. If the 8th data bit (R/$\overline{W}$) is 0, the TRS bit remains cleared to 0, and slave transmit operation is performed. When the slave address does not match, receive operation is halted until the next start condition is detected.
5. At the 9th clock pulse of the receive frame, the slave device returns the data in the ACKB bit as an acknowledge signal.
6. At the rise of the 9th clock pulse, the IRIC flag is set to 1. If the IEIC bit has been set to 1, an interrupt request is sent to the CPU.

   If the AASX bit has been set to 1, the IRTR flag is also set to 1.
7. At the rise of the 9th clock pulse, the receive data is transferred from ICDRS to ICDRR, setting the ICDRF flag to 1.
8. Confirm that the STOP bit is cleared to 0 and clear the ICIC flag to 0.
9. If the next read data is the third last receive frame, wait for at least one frame time to set the ACKB bit. Set the ACKB bit after the rise of the 9th clock pulse of the second last receive frame.
10. Confirm that the ICDRF flag is set to 1 and read ICDR. This clears the ICDRF flag to 0.
11. At the rise of the 9th clock pulse or when the receive data is transferred from IRDRS to ICDRR due to ICDR read operation, the IRIC and ICDRF flags are set to 1.
12. When the stop condition is detected (SDA is changed from low to high when SCL is high), the BBSY flag is cleared to 0 and the STOP or ESTP flag is set to 1. If the STOPIM bit has been cleared to 0, the IRIC flag is set to 1. In this case, execute step [14] to read the last receive data.
13. Clear the IRIC flag to 0.

Receive operations can be performed continuously by repeating steps [9] to [13].

14. Confirm that the ICDRF flag is set to 1, and read ICDR.
15. Clear the IRIC flag.

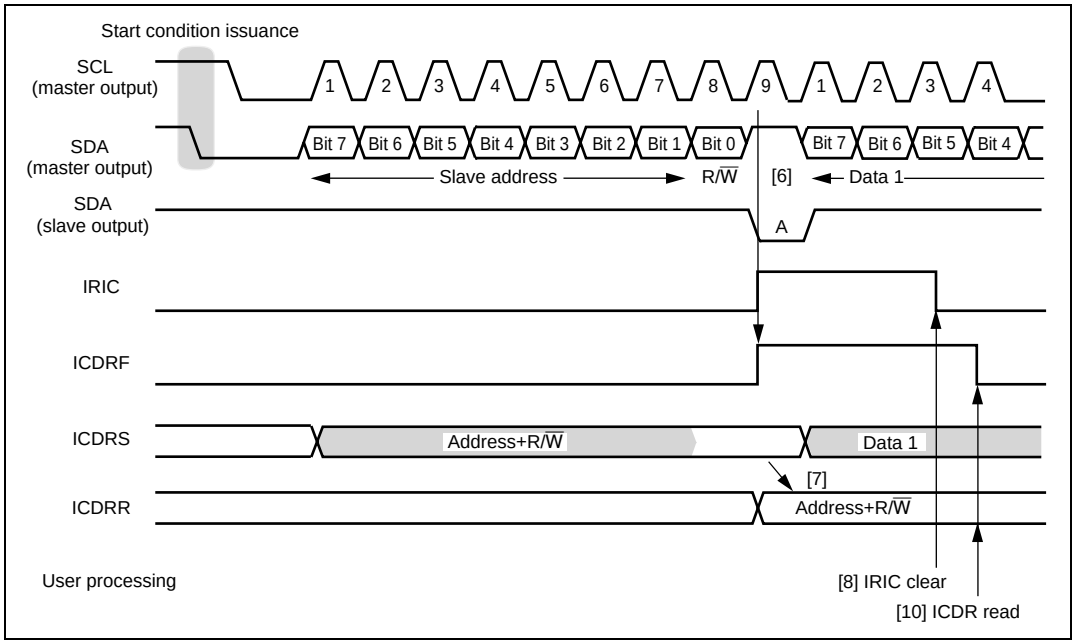


Figure 16.22 Example of Slave Receive Mode Operation Timing (1)
(MLS = ACKB = 0, HNDS = 0)

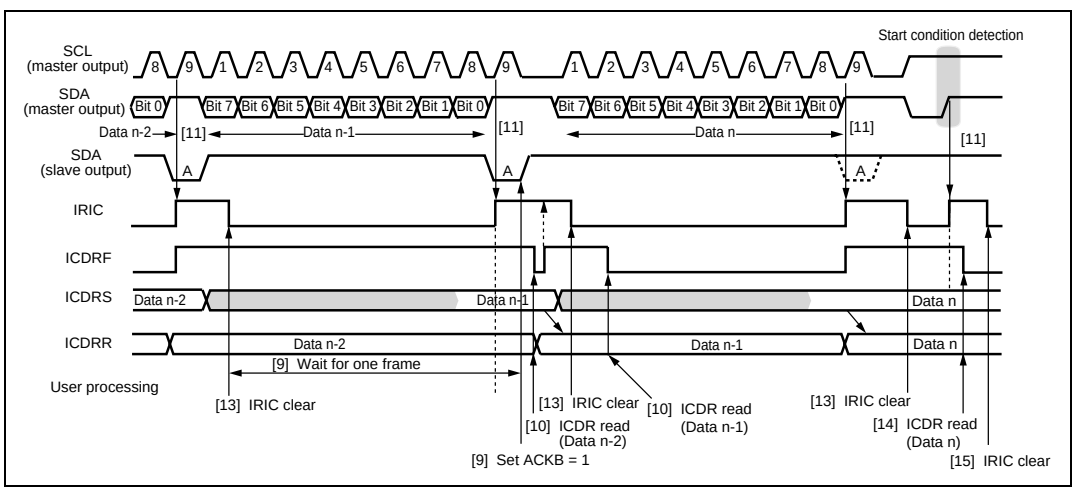


Figure 16.23 Example of Slave Receive Mode Operation Timing (2)
(MLS = ACKB = 0, HNDS = 0)

16.4.6 Slave Transmit Operation

If the slave address matches to the address in the first frame (address reception frame) following the start condition detection when the 8th bit data (R/$\overline{W}$) is 1 (read), the TRS bit in ICCR is automatically set to 1 and the mode changes to slave transmit mode.

Figure 16.24 shows the sample flowchart for the operations in slave transmit mode.

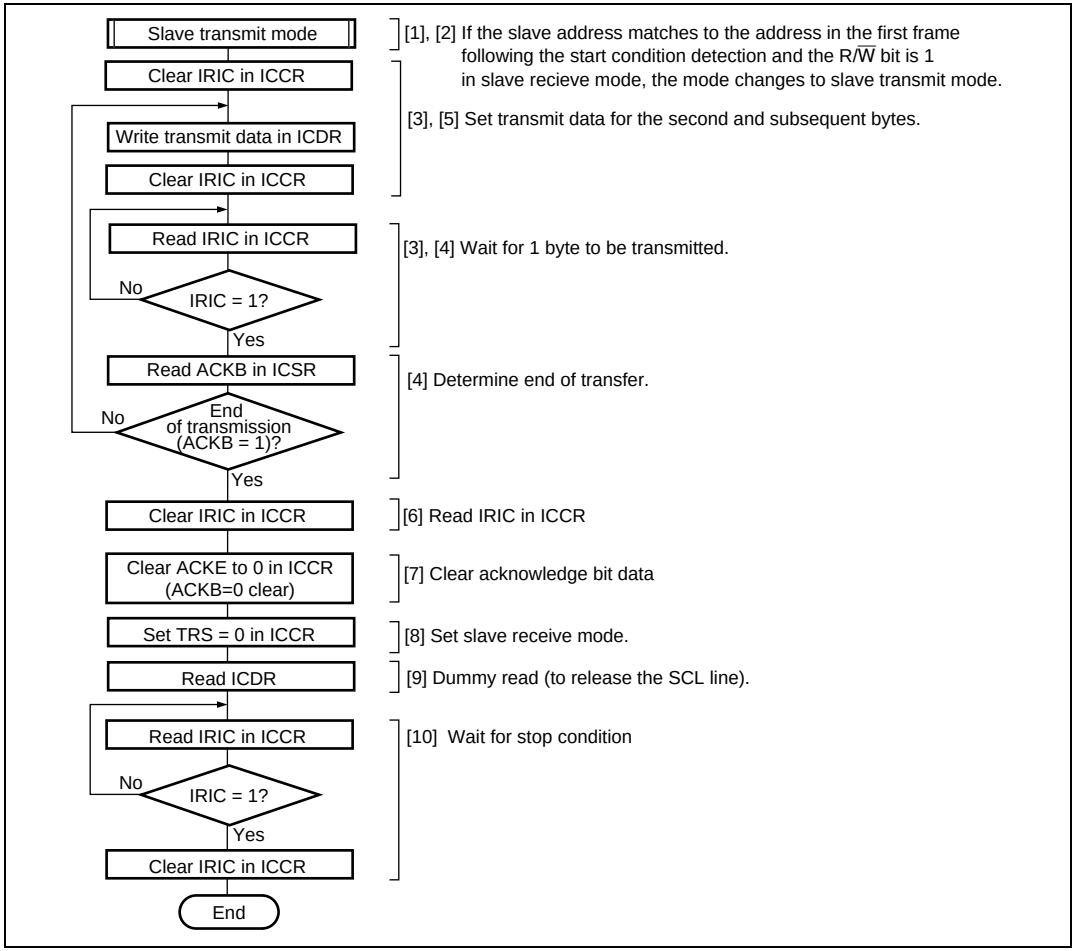


Figure 16.24 Sample Flowchart for Slave Transmit Mode

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. Initialize slave receive mode and wait for slave address reception.
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. If the 8th data bit (R/$\overline{W}$) is 1, the TRS bit in ICCR is set to 1, and the mode changes to slave transmit mode automatically. The IRIC flag is set to 1 at the rise of the 9th clock. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. At the same time, the ICDRE flag is set to 1. The slave device drives SCL low from the fall of the transmit clock until ICDR data is written, to disable the master device to output the next transfer clock.
3. After clearing the IRIC flag to 0, write data to ICDR. At this time, the ICDRE flag is cleared to 0. The written data is transferred to ICDRS, and the ICDRE and IRIC flags are set to 1 again. The slave device sequentially sends the data written into ICDRS in accordance with the clock output by the master device.

   The IRIC flag is cleared to 0 to detect the end of transmission. Processing from the ICDR register writing to the IRIC flag clearing should be performed continuously. Prevent any other interrupt processing from being inserted.
4. 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 successfully. 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. When the ICDRE flag is 0, the data written into ICDR is transferred to ICDRS, transmission starts, and the ICDRE and IRIC flags are set to 1 again. If the ICDRE 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.
5. To continue transmission, write the next data to be transmitted into ICDR. The ICDRE flag is cleared to 0. The IRIC flag is cleared to 0 to detect the end of transmission. Processing from the ICDR register writing to the IRIC flag clearing should be performed continuously. Prevent any other interrupt processing from being inserted.

Transmit operations can be performed continuously by repeating steps [4] and [5].

6. Clear the IRIC flag to 0.
7. To end transmission, clear the ACKE bit in ICCR to 0, to clear the acknowledge bit stored in the ACKB bit to 0.
8. Clear the TRS bit to 0 for the next address reception, to set slave receive mode.
9. Dummy-read ICDR to release SDA on the slave side.

10. When the stop condition is detected, that is, when SDA is changed from low to high when SCL is high, the BBSY flag in ICCR is cleared to 0 and the STOP flag in ICSR is set to 1. When the STOPIM bit in ICXR is 0, the IRIC flag is set to 1. If the IRIC flag has been set, it is cleared to 0.

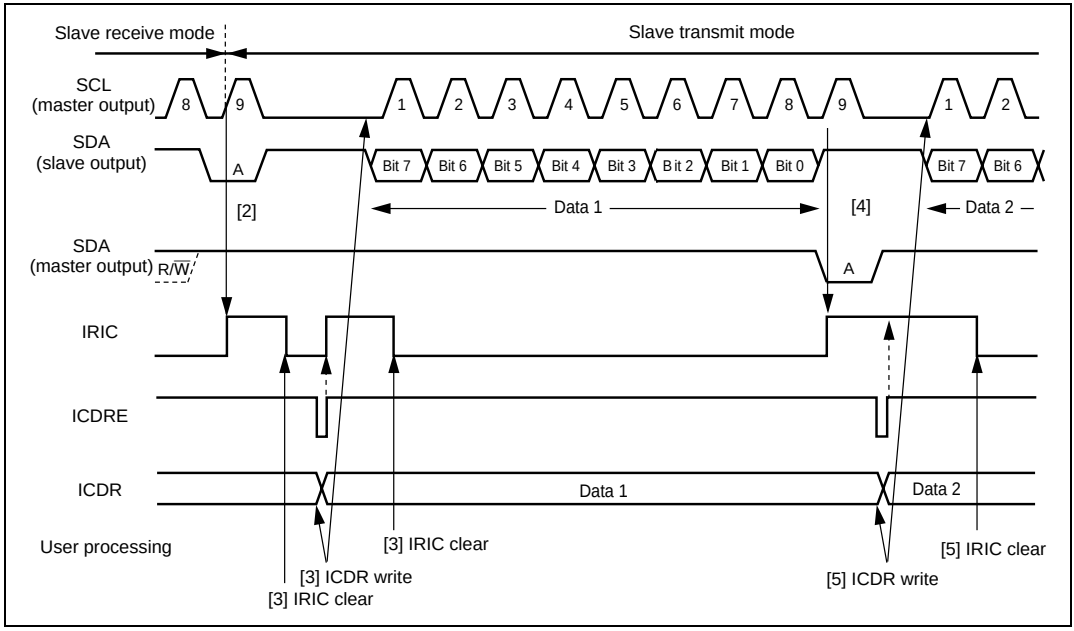


Figure 16.25 Example of Slave Transmit Mode Operation Timing (MLS = 0)

16.4.7 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 ICDRE or ICDRF flag is set to 1, SCL is automatically held low after one frame has been transferred in synchronization with the internal clock. Figures 16.26 to 16.28 show the IRIC set timing and SCL control.

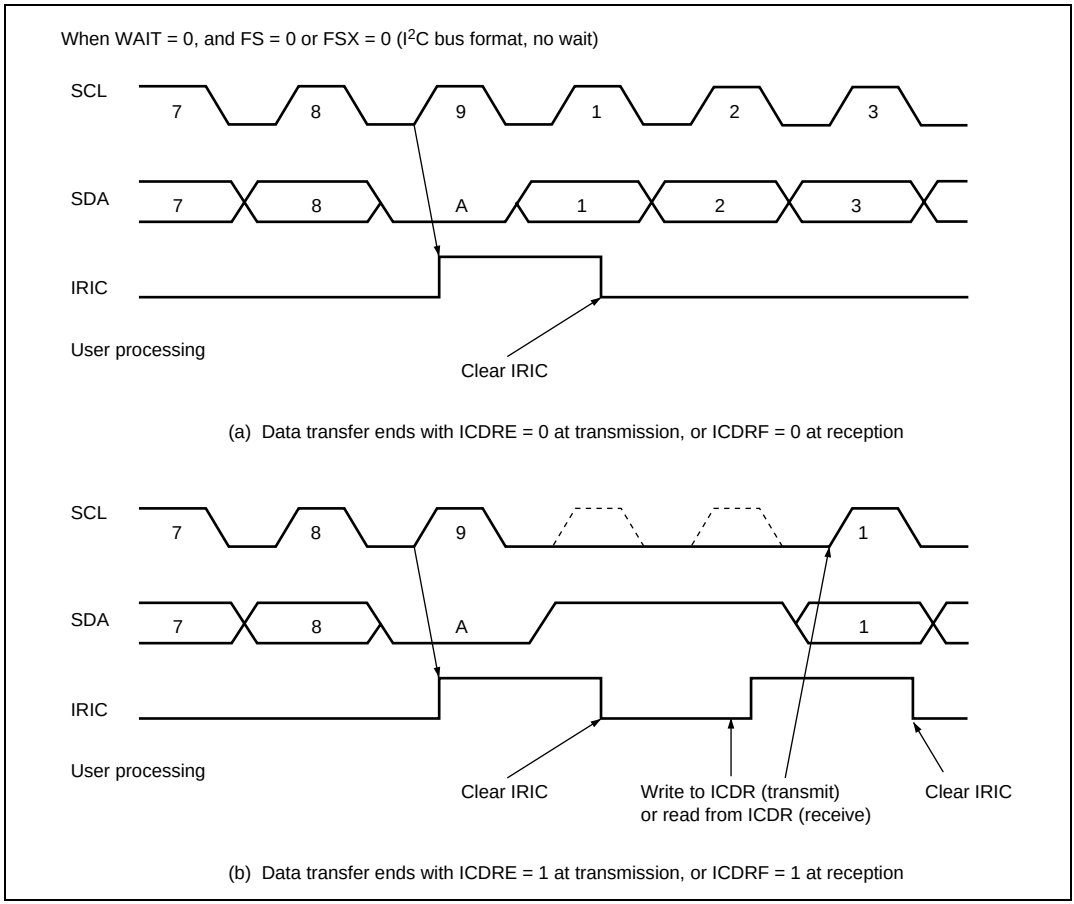
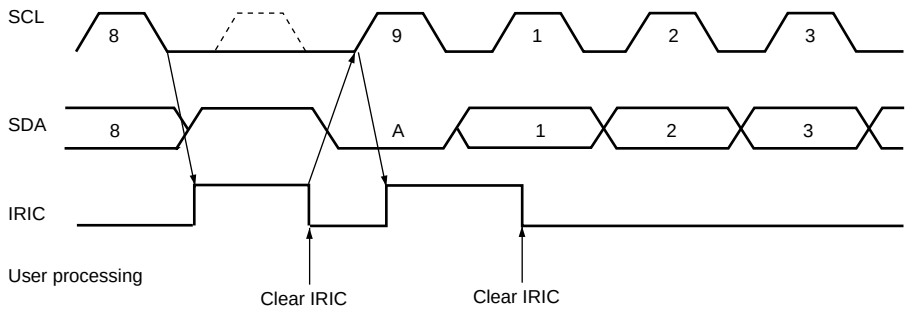
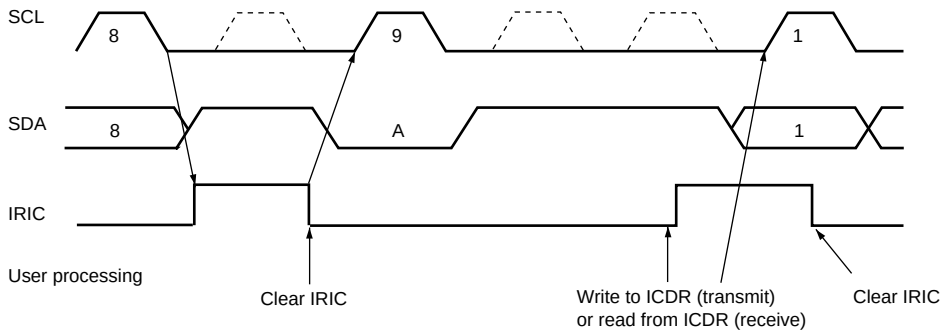


Figure 16.26 IRIC Setting Timing and SCL Control (1)

When WAIT = 1, and FS = 0 or FSX = 0 (I²C bus format, wait inserted)



(a) Data transfer ends with ICDRE = 0 at transmission, or ICDRF = 0 at reception



(b) Data transfer ends with ICDRE = 1 at transmission, or ICDRF = 1 at reception

Figure 16.27 IRIC Setting Timing and SCL Control (2)

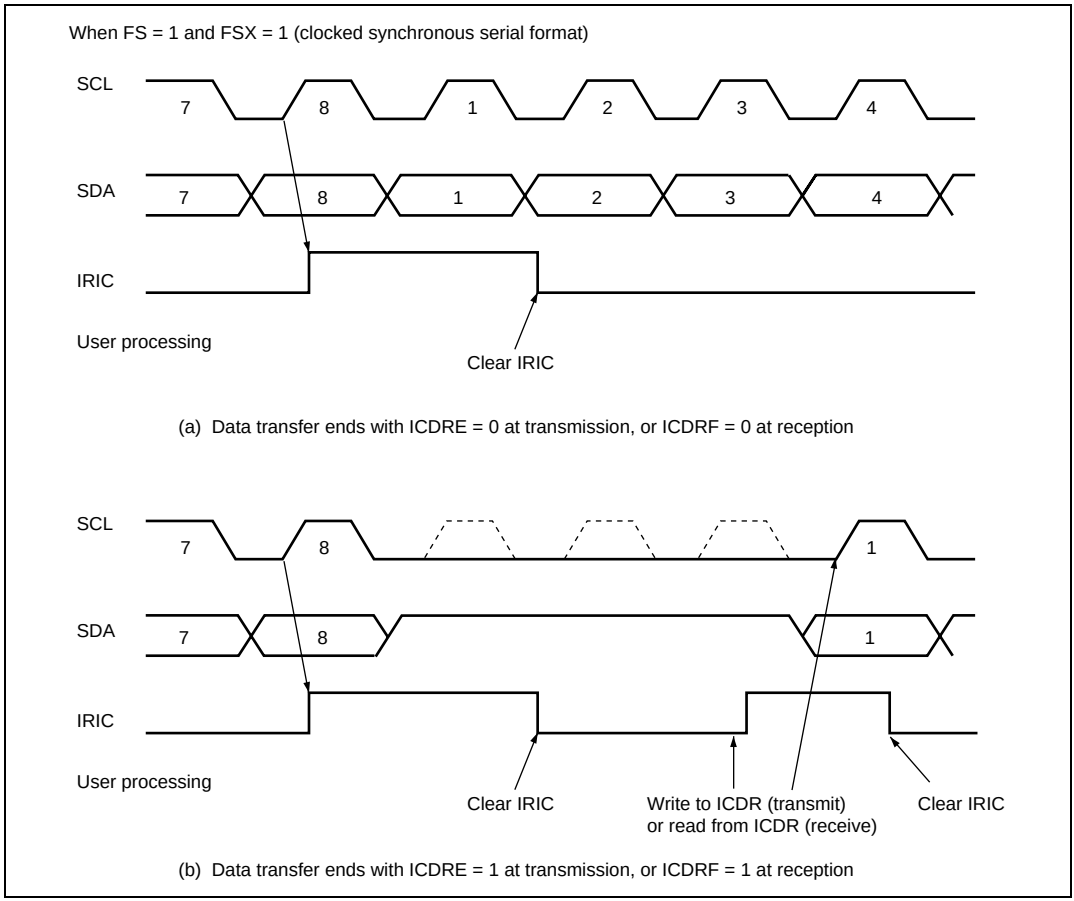


Figure 16.28 IRIC Setting Timing and SCL Control (3)

16.4.8 Automatic Switching from Formatless Mode to I²C Bus Format

Setting the SW bit to 1 in DDCSWR enables formatless mode to be selected as the IIC_0 operating mode. Switching from formatless mode to the I²C bus format (slave mode) is performed automatically when a falling edge is detected on the SCL pin.

The following four preconditions are necessary for this operation:

- A common data pin (SDA) for formatless and I²C bus format operation
- Separate clock pins for formatless operation (VSYNCI) and I²C bus format operation (SCL)
- A fixed 1 level for the SCL pin during formatless operation (the SCL pin does not output a low level)

- Settings of bits other than TRS in ICCR that allow I²C bus format operation

Automatic switching is performed from formatless mode to the I²C bus format when the SW bit in DDCSWR is automatically cleared to 0 on detection of a falling edge on the SCL pin. Switching from the I²C bus format to formatless mode is achieved by setting the SW bit in DDCSWR to 1 by software.

In formatless mode, bits (such as MSL and TRS) that control the I²C bus interface operating mode must not be modified. When switching from the I²C bus format to formatless mode, set the TRS bit to 1 or clear it to 0 according to the transfer direction (transmission or reception) in formatless mode, then set the SW bit to 1. After automatic switching from formatless mode to the I²C bus format (slave mode), the TRS bit is automatically cleared to 0 in order to wait for slave address reception.

If a falling edge is detected on the SCL pin during formatless operation, the mode of the I²C bus interface is immediately switched to I²C bus format before a stop condition is detected.

16.4.9 Operation Using DTC

This LSI provides the DTC to allow continuous data transfer. The DTC is initiated when the IRTR flag is set to 1, which is one of the two interrupt flags (IRTR and IRIC). When the ACKE bit is 0, the ICDRE, IRIC, and IRTR flags are set at the end of data transmission regardless of the acknowledge bit value. If the ACKE bit is 1, the ICDRE, IRIC, and IRTR flags are set when data transmission is completed with the acknowledge bit value of 0, and if the ACKE bit is 1, only the IRIC flag is set when data transmission is completed with the acknowledge bit value of 1.

When initiated, the DTC transfers specified number of bytes, clears the ICDRE, IRIC, and IRTR flags to 0. Therefore, no interrupt is generated during continuous data transfer; however, if data transmission is completed with the acknowledge bit value of 1 when the ACKE bit is 1, the DTC is not initiated, thus allowing an interrupt to be generated if enabled.

The acknowledge bit may indicate specific events such as completion of receive data processing for some receiving devices, and for other receiving devices, the acknowledge bit may be fixed at 1, indicating no specific events.

The I²C bus format provides for selection of the slave device and transfer direction by means of the slave address and the R/$\overline{W}$ bit, confirmation of reception with the acknowledge bit, indication of the last frame, and so on. Therefore, continuous data transfer using the DTC must be carried out in conjunction with CPU processing by means of interrupts.

Table 16.7 shows some examples of processing using the DTC. These examples assume that the number of transfer data bytes is known in slave mode.

Table 16.7 Examples of Operation Using DTC

Item	Master Transmit Mode	Master Receive Mode	Slave Transmit Mode	Slave Receive Mode
Slave address + R/$\overline{W}$ bit transmission/ reception	Transmission by DTC (ICDR write)	Transmission by CPU (ICDR write)	Reception by CPU (ICDR read)	Reception by CPU (ICDR read)
Dummy data read	—	Processing by CPU (ICDR read)	—	—
Actual data transmission/ reception	Transmission by DTC (ICDR write)	Reception by DTC (ICDR read)	Transmission by DTC (ICDR write)	Reception by DTC (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: Stop condition issuance by CPU	Not necessary	Automatic clearing on detection of stop 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/$\overline{W}$ bits)	Reception: Actual data count	Transmission: Actual data count + 1 (+1 equivalent to dummy data (H'FF))	Reception: Actual data count

16.4.10 Noise Canceler

The logic levels at the SCL and SDA pins are routed through noise cancelers before being latched internally. Figure 16.29 shows a block diagram of the noise canceler.

The noise canceler consists of two cascaded latches and a match detector. The SCL (or SDA) pin 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.

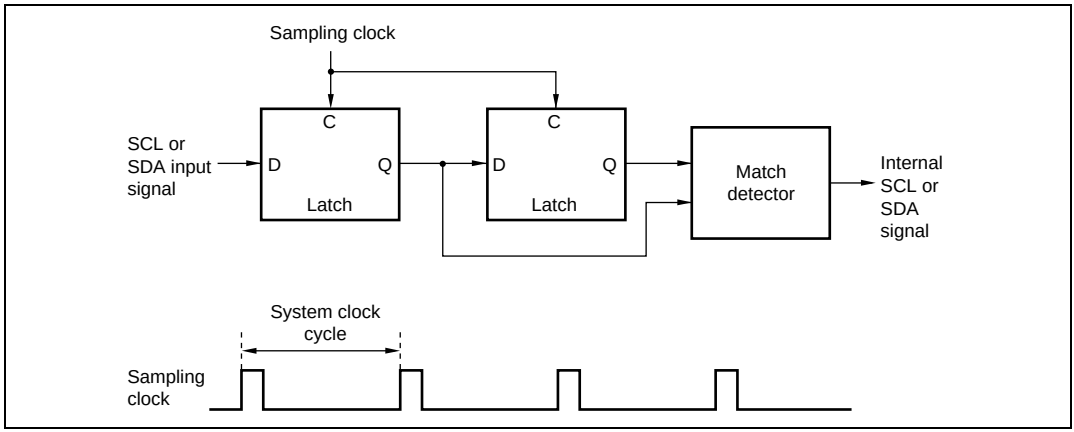


Figure 16.29 Block Diagram of Noise Canceler

16.4.11 Initialization of Internal State

The IIC has a function for forcible initialization of its internal state if a deadlock occurs during communication.

Initialization is executed in accordance with the setting of bits CLR3 to CLR0 in DDCSWR or clearing ICE bit. For details on the setting of bits CLR3 to CLR0, see section 16.3.7, DDC Switch Register (DDCSWR).

Scope of Initialization: The initialization executed by this function covers the following items:

- ICDRE and ICDRF 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, ICXR (except for the ICDRE and ICDRF flags), DDCSWR)
- Internal latches used to retain register read information for setting/clearing flags in ICMR, ICCR, ICSR, and DDCSWR
- The value of the ICMR 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 DDCSWR, 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.

1. Execute initialization of the internal state according to the setting of bits CLR3 to CLR0 or ICE bit clearing.
2. 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.
3. Re-execute initialization of the internal state according to the setting of bits CLR3 to CLR0 or ICE bit clearing.
4. Initialize (re-set) the IIC registers.

16.5 Interrupt Sources

The IIC has interrupt sources IICI and DDCSWI. Table 16.8 shows the interrupt sources and priority. Individual interrupt sources can be enabled or disabled using the enable bits in ICCR and DDCSWR, and are sent to the interrupt controller independently.

An IICI interrupt can activate the DTC to allow data transfer.

Table 16.8 IIC Interrupt Sources

Channel	Name	Enable Bit	Interrupt Source	Interrupt Flag	DTC Activation	Priority
0	IICI0	IEIC	I²C bus interface interrupt request	IRIC	Possible	High
	DDCSWI	IE	Format automatic switch interrupt	IF	Not possible	
1	IICI1	IEIC	I²C bus interface interrupt request	IRIC	Possible	Low

16.6 Usage Notes

1. In master mode, if an instruction to generate a start condition is issued and then an instruction to generate a stop condition is issued before the start condition is output to the I²C bus, neither condition will be output correctly. To output the start condition followed by the stop condition, after issuing the instruction that generates the start condition, read DR in each I²C bus output pin, and check that SCL and SDA are both low. The pin states can be monitored by reading DR even if the ICE bit is set to 1. 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 accessing to ICDR.
   - Write to ICDR when ICE = 1 and TRS = 1 (including automatic transfer from ICDRT to ICDRS)
   - Read from ICDR when ICE = 1 and TRS = 0 (including automatic transfer from ICDRS to ICDRR)
3. Table 16.9 shows the timing of SCL and SDA outputs 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 16.9 I²C Bus Timing (SCL and SDA Outputs)

Item	Symbol	Output Timing	Unit	Notes
SCL output cycle time	t_{SCLO}	$28t_{cyc}$ to $256t_{cyc}$	ns	See figure 28.29.
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)		$1t_{SCLL} – (6t_{cyc}$ or $12t_{cyc}$ *)		
Data output hold time	t_{SDAHO}	$3t_{cyc}$	ns	

Note: * $6t_{cyc}$ when IICX is 0, $12t_{cyc}$ when 1.

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 section 28, Electrical Characteristics. Note that the I²C bus interface AC timing specifications will not be met with a system clock frequency of less than 5 MHz.
5. The I²C bus interface specification for the SCL rise time t_{sr} is 1000 ns or less (300 ns for high-speed mode). In master mode, the I²C bus interface monitors the SCL line and synchronizes one bit at a time during communication. If t_{sr} (the time for SCL to go from low to V_{IH}) exceeds the time determined by the input clock of the I²C bus interface, the high period of SCL is extended. The SCL rise time is determined by the pull-up resistance and load capacitance of the SCL line. To insure proper operation at the set transfer rate, adjust the pull-up resistance and load capacitance so that the SCL rise time does not exceed the values given in table 16.10.

Table 16.10 Permissible SCL Rise Time (t_{sr}) Values

IICX	t_{cyc} Indication		Time Indication [ns]: I²C Bus Specification (Max.)	φ = 5 MHz	φ = 8 MHz	φ = 10 MHz	φ = 16 MHz	φ = 20 MHz
0	7.5 t_{cyc}	Standard mode	1000	1000	937	750	468	375
		High-speed mode	300	300	300	300	300	300
1	17.5 t_{cyc}	Standard mode	1000	100	1000	1000	1000	875
		High-speed mode	300	300	300	300	300	300

6. The I²C bus interface specifications for the SCL and SDA rise and fall times are under 1000 ns and 300 ns. The I²C bus interface SCL and SDA output timing is prescribed by t_{cyc}, as shown in table 16.9. However, because of the rise and fall times, the I²C bus interface specifications may not be satisfied at the maximum transfer rate. Table 16.11 shows output timing calculations for different operating frequencies, including the worst-case influence of rise and fall times.

   t_{BUFO} fails to meet the I²C bus interface specifications at any frequency. The solution is either (a) to provide coding to secure the necessary interval (approximately 1 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 I²C bus.

   t_{SCLLO} in high-speed mode and t_{STASO} in standard mode fail to satisfy the I²C bus interface specifications for worst-case calculations of t_{Sr}/t_{Sf}. Possible solutions that should be investigated include (a) adjusting the rise and fall times by means of a pull-up resistor and capacitive load, (b) reducing the transfer rate to meet the specifications, or (c) selecting devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

Table 16.11 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	ϕ = 20 MHz
t_{SCLHO}	0.5 t_{SCLO} ($-t_{Sr}$)	Standard mode	–1000	4000	4000	4000	4000	4000	4000
		High-speed mode	–300	600	950	950	950	950	950
t_{SCLLO}	0.5 t_{SCLO} ($-t_{Sf}$)	Standard mode	–250	4700	4750	4750	4750	4750	4750
		High-speed mode	–250	1300	1000*1	1000*1	1000*1	1000*1	1000*1
t_{BUFO}	0.5 t_{SCLO} –1 t_{cyc} ($-t_{Sr}$)	Standard mode	–1000	4700	3800*1	3875*1	3900*1	3938*1	3950*1
		High-speed mode	–300	1300	750*1	825*1	850*1	888*1	900*1
t_{STAHO}	0.5 t_{SCLO} –1 t_{cyc} ($-t_{Sf}$)	Standard mode	–250	4000	4550	4625	4650	4688	4700
		High-speed mode	–250	600	800	875	900	938	950
t_{STASO}	1 t_{SCLO} ($-t_{Sr}$)	Standard mode	–1000	4700	9000	9000	9000	9000	9000
		High-speed mode	–300	600	2200	2200	2200	2200	2200
t_{STOSO}	0.5 t_{SCLO} + 2 t_{cyc} ($-t_{Sr}$)	Standard mode	–1000	4000	4400	4250	4200	4125	4100
		High-speed mode	–300	600	1350	1200	1150	1075	1050
t_{SDASO} (master)	1 t_{SCLLO}*3 –3 t_{cyc} ($-t_{Sr}$)	Standard mode	–1000	250	3100	3325	3400	3513	3550
		High-speed mode	–300	100	400	625	700	813	850
t_{SDASO} (slave)	1 t_{SCLL}*3 –12 t_{cyc}*2 ($-t_{Sr}$)	Standard mode	–1000	250	1300	2200	2500	2950	3100
		High-speed mode	–300	100	–1400*1	–500*1	–200*1	250	400
t_{SDAHO}	3 t_{cyc}	Standard mode	0	0	600	375	300	188	150
		High-speed mode	0	0	600	375	300	188	150

Notes: 1. Does not meet the I²C bus interface specification. Remedial action such as the following is necessary: (a) secure a start/stop condition issuance interval; (b) adjust the rise and fall times by means of a pull-up resistor and capacitive load; (c) reduce the transfer rate; (d) select slave devices whose input timing permits this output timing.

The values in the above table will vary depending on the settings of the IICX bit and bits CKS0 to CKS2. Depending on the frequency it may not be possible to achieve the maximum transfer rate; therefore, whether or not the I²C bus interface specifications are met must be determined in accordance with the actual setting conditions.

2. Value when the IICX bit is set to 1. When the IICX bit is cleared to 0, the value is ($t_{SCLL} - 6t_{cyc}$).
3. Calculated using the I²C bus specification values (standard mode: 4700 ns min.; high-speed mode: 1300 ns min.).

7. Notes on ICDR read at end of master reception

   To halt reception at the end 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 SDA from low to high when SCL 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 (ICDRR), 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 16.30 (after confirming that the BBSY bit in ICCR has been cleared to 0).

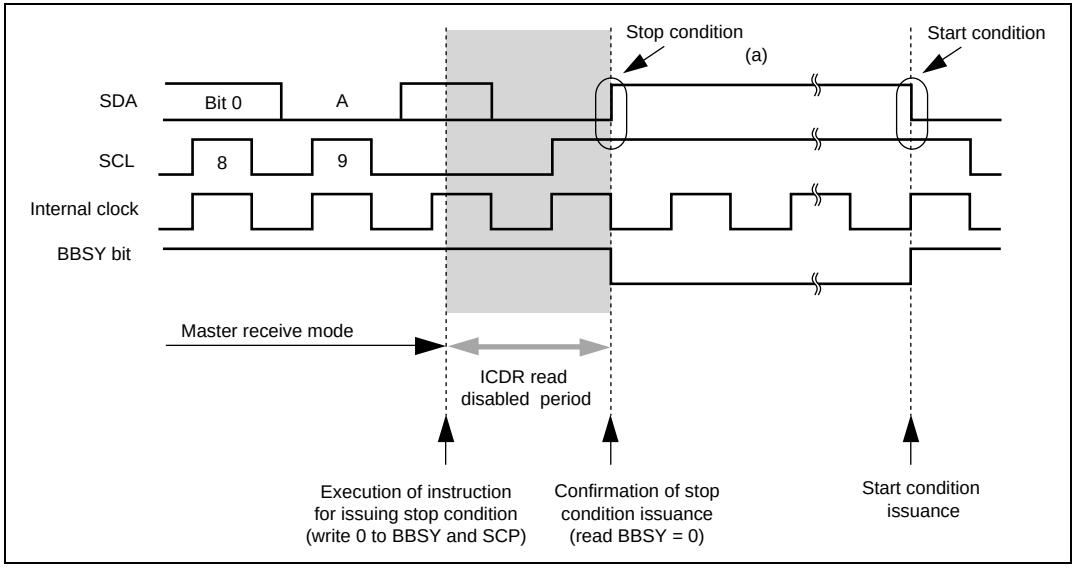


Figure 16.30 Notes on Reading Master Receive Data

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to 1 in ICXR.

8. Notes on start condition issuance for retransmission

   Figure 16.31 shows the timing of start condition issuance for retransmission, and the timing for subsequently writing data to ICDR, together with the corresponding flowchart. Write the transmit data to ICDR after the start condition for retransmission is issued and then the start condition is actually generated.

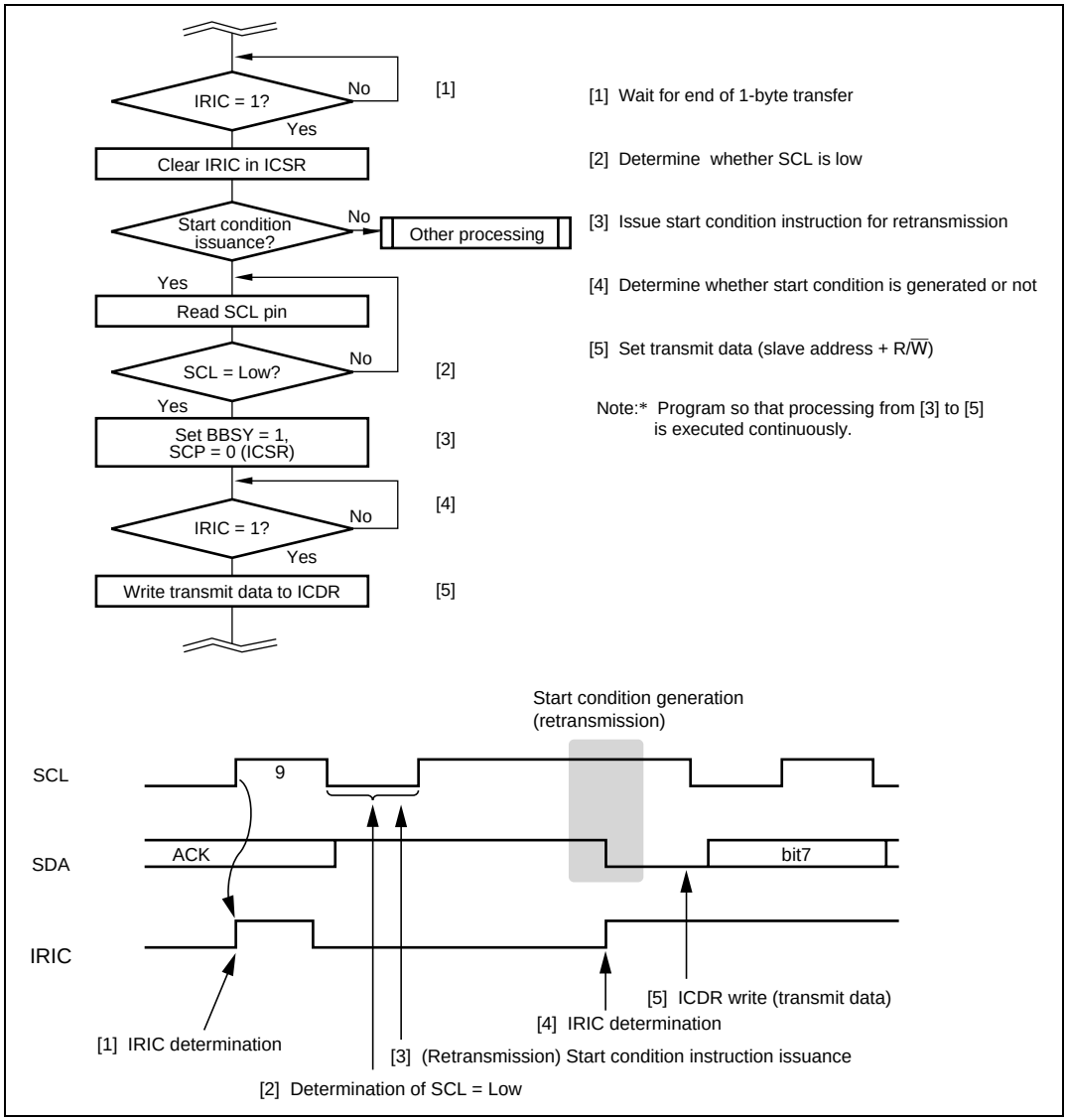


Figure 16.31 Flowchart for Start Condition Issuance Instruction for Retransmission and Timing

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to 1 in ICXR.

9. Note on when I²C bus interface stop condition instruction is issued

   In cases where the rise time of the 9th clock of SCL exceeds the stipulated value because of a large bus load capacity or where a slave device in which a wait can be inserted by driving the SCL pin low is used, the stop condition instruction should be issued after reading SCL after the rise of the 9th clock pulse and determining that it is low.

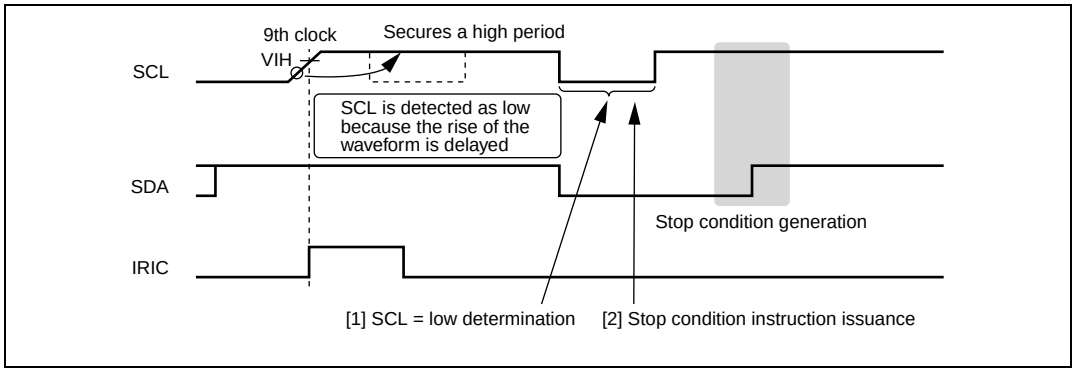


Figure 16.32 Stop Condition Issuance Timing

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to 1 in ICXR.

10. Notes on WAIT Function

— Conditions to cause this phenomenon

When both of the following conditions are satisfied, the clock pulse of the 9th clock could be outputted continuously in master mode using the WAIT function due to the failure of the WAIT insertion after the 8th clock fall.

(1) Setting the WAIT bit of the ICMR register to 1 and operating WAIT, in master mode

(2) If the IRIC bit of interrupt flag is cleared from 1 to 0 between the fall of the 7th clock and the fall of the 8th clock.

— Error phenomenon

Normally, WAIT State will be cancelled by clearing the IRIC flag bit from 1 to 0 after the fall of the 8th clock in WAIT State. In this case, if the IRIC flag bit is cleared between the 7th clock fall and the 8th clock fall, the IRIC flag clear- data will be retained internally. Therefore, the WAIT State will be cancelled right after WAIT insertion on 8th clock fall.

— Restrictions

Please clear the IRIC flag before the rise of the 7th clock (the counter value of BC2 through BC0 should be 2 or greater), after the IRIC flag is set to 1 on the rise of the 9th clock.

If the IRIC flag-clear is delayed due to the interrupt or other processes and the value of BC counter is turned to 1 or 0, please confirm the SCL pins are in L' state after the counter value of BC2 through BC0 is turned to 0, and clear the IRIC flag. (See figure 16.33.)

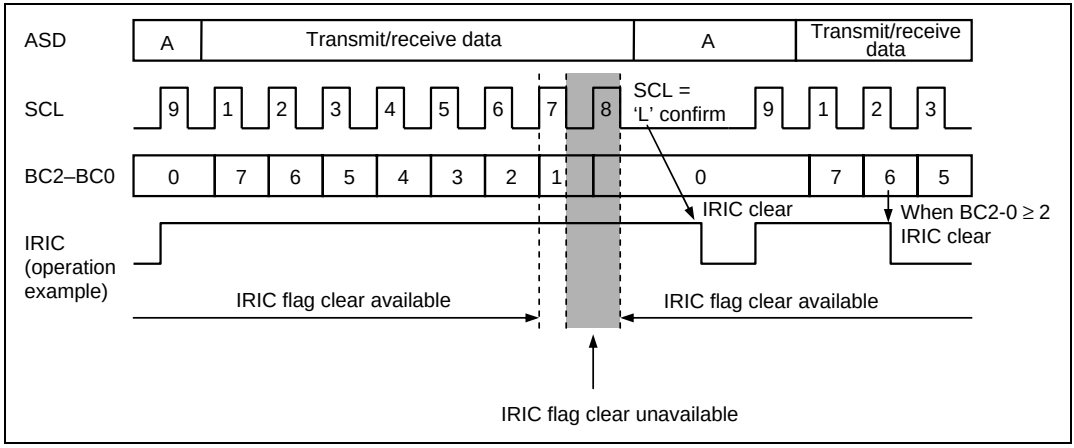


Figure 16.33 IRIC Flag Clear Timing on WAIT Operation

11. Note on IRIC flag clear when the wait function is used

    If the rise time of SCL exceeds the stipulated value or a slave device in which a wait can be inserted by driving the SCL pin low is used when the wait function is used in I²C bust interface master mode, the IRIC flag should be cleared after determining that the SCL is low, as described below.

    If the IRIC flag is cleared to 0 when WAIT = 1 while the SCL is extending the high level time, the SDA level may change before the SCL goes low, which may generate a start or stop condition erroneously.

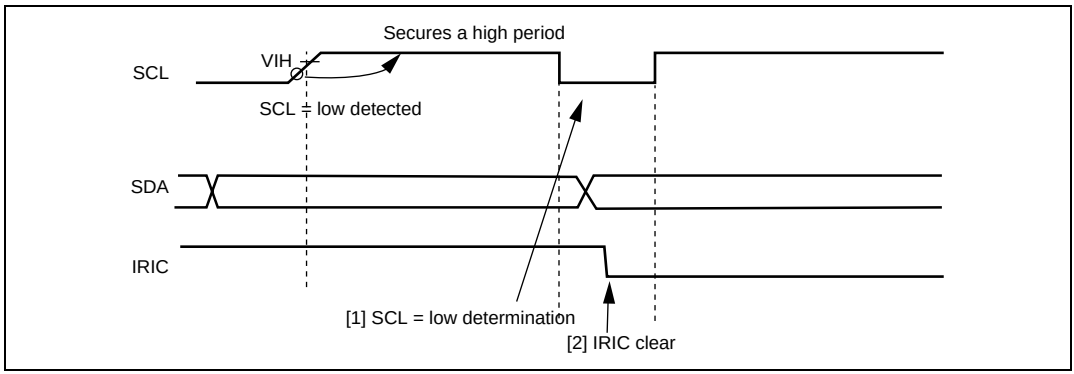


Figure 16.34 IRIC Flag Clearing Timing When WAIT = 1

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to 1 in ICXR.

12. Note on ICDR read and ICCR access in slave transmit mode

In I²C bus interface slave transmit mode, do not read ICDR or do not read/write from/to ICCR during the time shaded in figure 16.35. However, such read and write operations cause no problem in interrupt handling processing that is generated in synchronization with the rising edge of the 9th clock pulse because the shaded time has passed before making the transition to interrupt handling.

To handle interrupts securely, be sure to keep either of the following conditions.

— Read ICDR data that has been received so far or read/write from/to ICCR before starting the receive operation of the next slave address.

— Monitor the BC2 to BC0 bit counter in ICMR; when the count is 000 (8th or 9th clock pulse), wait for at least two transfer clock times in order to read ICDR or read/write from/to ICCR during the time other than the shaded time.

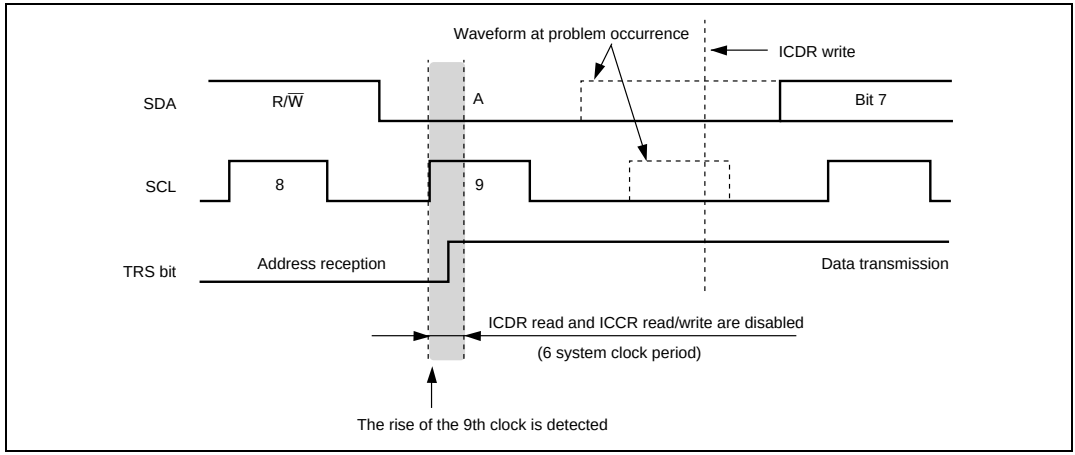


Figure 16.35 ICDR Read and ICCR Access Timing in Slave Transmit Mode

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to 1 in ICXR.

13. Note on TRS bit setting in slave mode

In I²C bus interface slave mode, if the TRS bit value in ICCR is set after detecting the rising edge of the 9th clock pulse or the stop condition before detecting the next rising edge on the SCL pin (the time indicated as (a) in figure 16.36), the bit value becomes valid immediately when it is set. However, if the TRS bit is set during the other time (the time indicated as (b) in figure 16.36), the bit value is suspended and remains invalid until the rising edge of the 9th clock pulse or the stop condition is detected. Therefore, when the address is received after the restart condition is input without the stop condition, the effective TRS bit value remains 1 (transmit mode) internally and thus the acknowledge bit is not transmitted after the address has been received at the 9th clock pulse.

To receive the address in slave mode, clear the TRS bit to 0 during the time indicated as (a) in figure 16.36. To release the SCL low level that is held by means of the wait function in slave mode, clear the TRS bit to and then dummy-read ICDR.

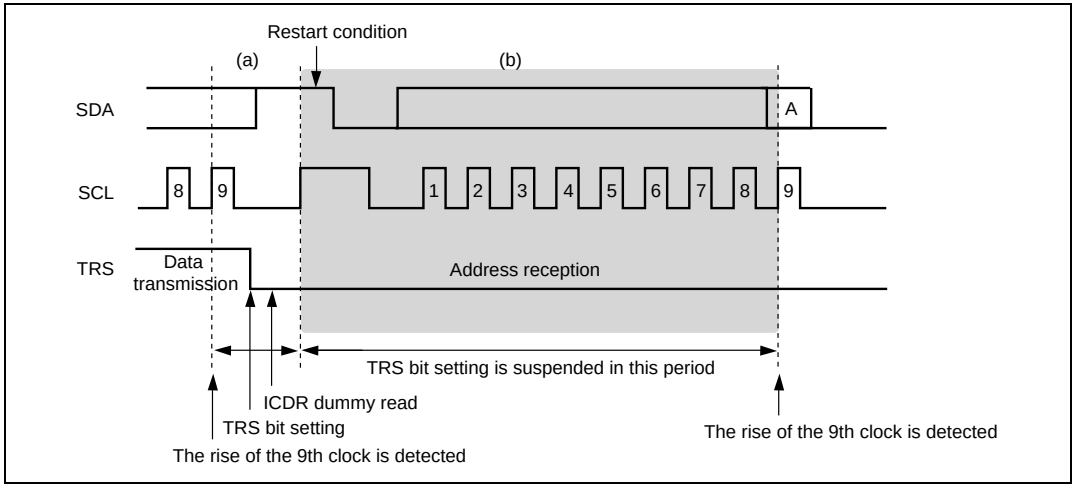


Figure 16.36 TRS Bit Set Timing in Slave Mode

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to 1 in ICXR.

14. Notes on Arbitration Lost in Master Mode

The I²C bus interface recognizes the data in transmit/receive frame as an address when arbitration is lost in master mode and a transition to slave receive mode is automatically carried out.

When arbitration is lost not in the first frame but in the second frame or subsequent frame, transmit/receive data that is not an address is compared with the value set in the SAR or SARX register as an address. If the receive data matches with the address in the SAR or SARX register, the I²C bus interface erroneously recognizes that the address call has occurred. (See figure 16.37.)

In multi-master mode, a bus conflict could happen. When The I²C bus interface is operated in master mode, check the state of the AL bit in the ICSR register every time after one frame of data has been transmitted or received.

When arbitration is lost during transmitting the second frame or subsequent frame, take avoidance measures.

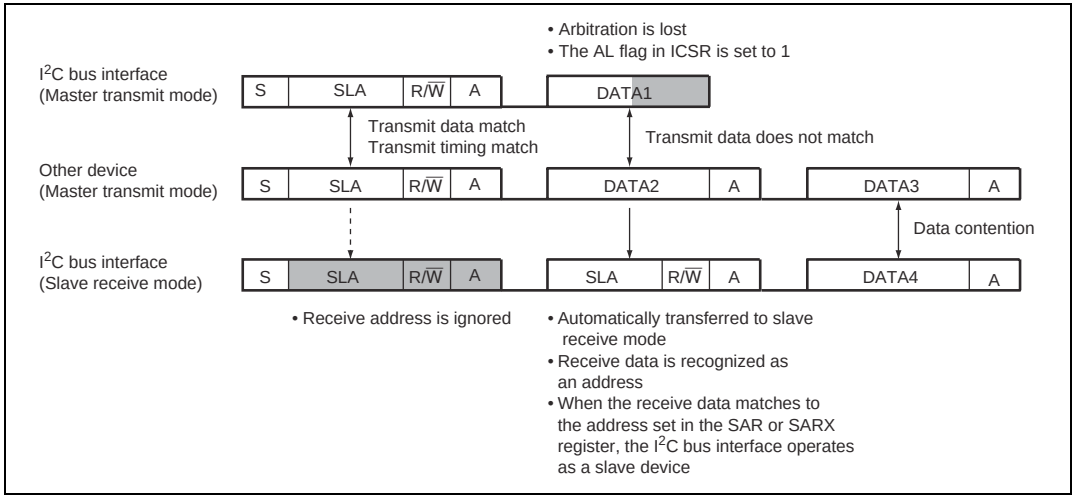


Figure 16.37 Diagram of Erroneous Operation when Arbitration is Lost

Though it is prohibited in the normal I²C protocol, the same problem may occur when the MST bit is erroneously set to 1 and a transition to master mode is occurred during data transmission or reception in slave mode. In multi-master mode, pay attention to the setting of the MST bit when a bus conflict may occur. In this case, the MST bit in the ICCR register should be set to 1 according to the order below.

(a) Make sure that the BBSY flag in the ICCR register is 0 and the bus is free before setting the MST bit.

(b) Set the MST bit to 1.

(c) To confirm that the bus was not entered to the busy state while the MST bit is being set, check that the BBSY flag in the ICCR register is 0 immediately after the MST bit has been set.

15. Note on ICDR read in transmit mode and ICDR write in receive mode

If ICDR is read in transmit mode (TRS = 1) or ICDR is written to in receive mode (TRS = 0), the SCL pin may not be held low in some cases after transmit/receive operation has been completed, thus inconveniently allowing clock pulses to be output on the SCL bus line before ICDR is accessed correctly. To access ICDR correctly, read ICDR after setting receive mode or write to ICDR after setting transmit mode.

16. Note on ACKE and TRS bits in slave mode

In the I²C bus interface, if 1 is received as the acknowledge bit value (ACKB = 1) in transmit mode (TRS = 1) and then the address is received in slave mode without performing appropriate processing, interrupt handling may start at the rising edge of the 9th clock pulse even when the address does not match. Similarly, if the start condition or address is transmitted from the master device in slave transmit mode (TRS = 1), the IRIC flag may be set after the ICDRE flag is set and 1 received as the acknowledge bit value (ACKB = 1), thus causing an interrupt source even when the address does not match.

To use the I²C bus interface module in slave mode, be sure to follow the procedures below.

A. When having received 1 as the acknowledge bit value for the last transmit data at the end of a series of transmit operation, clear the ACKE bit in ICCR once to initialize the ACKB bit to 0.

B. Set receive mode (TRS = 0) before the next start condition is input in slave mode. Complete transmit operation by the procedure shown in figure 16.24, in order to switch from slave transmit mode to slave receive mode.

16.6.1 Module Stop Mode Setting

The IIC operation can be enabled or disabled using the module stop control register. The initial setting is for the IIC operation to be halted. Register access is enabled by canceling module stop mode. For details, refer to section 26, Power-Down Modes.

Section 17 Keyboard Buffer Controller

This LSI has three on-chip keyboard buffer controller channels. The keyboard buffer controller is provided with functions conforming to the PS/2 interface specifications.

Data transfer using the keyboard buffer controller employs a data line (KD) and a clock line (KCLK), providing economical use of connectors, board surface area, etc. Figure 17.1 shows a block diagram of the keyboard buffer controller.

17.1 Features

- Conforms to PS/2 interface specifications
- Direct bus drive (via the KCLK and KD pins)
- Interrupt sources: on completion of data reception and on detection of clock edge
- Error detection: parity error and stop bit monitoring

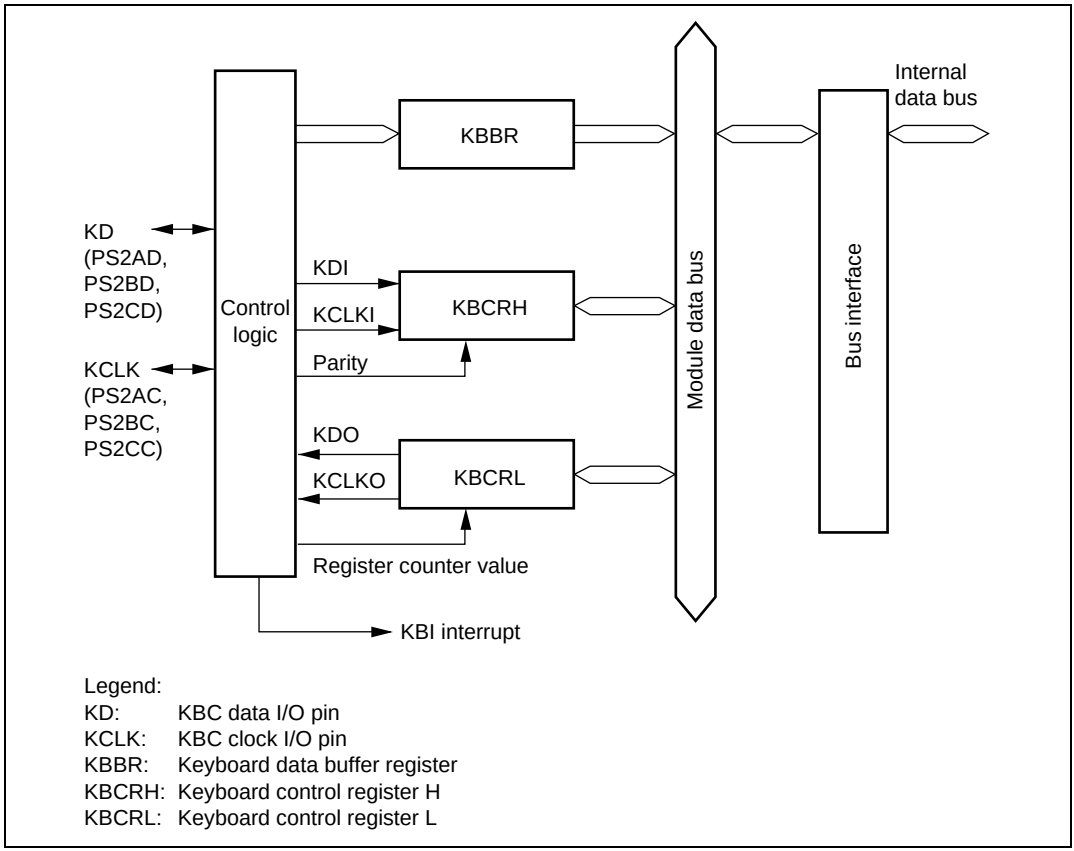


Figure 17.1 Block Diagram of Keyboard Buffer Controller

Figure 17.2 shows how the keyboard buffer controller is connected.

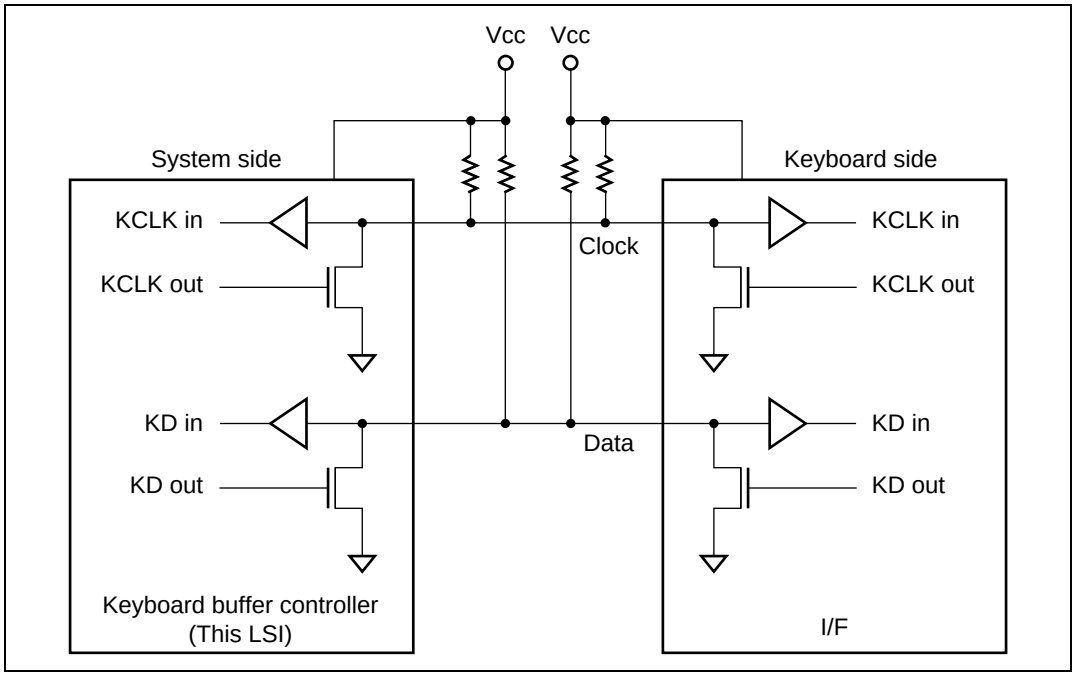


Figure 17.2 Keyboard Buffer Controller Connection

17.2 Input/Output Pins

Table 17.1 lists the input/output pins used by the keyboard buffer controller.

Table 17.1 Pin Configuration

Channel	Name	Abbreviation*	I/O	Function
0	KBC clock I/O pin (KCLK0)	PS2AC	I/O	KBC clock input/output
	KBC data I/O pin (KD0)	PS2AD	I/O	KBC data input/output
1	KBC clock I/O pin (KCLK1)	PS2BC	I/O	KBC clock input/output
	KBC data I/O pin (KD1)	PS2BD	I/O	KBC data input/output
2	KBC clock I/O pin (KCLK2)	PS2CC	I/O	KBC clock input/output
	KBC data I/O pin (KD2)	PS2CD	I/O	KBC data input/output

Note: * These are the external I/O pin names. In the text, clock I/O pins are referred to as KCLK and data I/O pins as KD, omitting the channel designations.

17.3 Register Descriptions

The keyboard buffer controller has the following registers for each channel.

- Keyboard control register H (KBCRH)
- Keyboard control register L (KBCRL)
- Keyboard data buffer register (KBBR)

17.3.1 Keyboard Control Register H (KBCRH)

KBCRH indicates the operating status of the keyboard buffer controller.

Bit	Bit Name	Initial Value	R/W	Description
7	KBIOE	0	R/W	Keyboard In/Out Enable Selects whether or not the keyboard buffer controller is used. 0: The keyboard buffer controller is non-operational (KCLK and KD signal pins have port functions) 1: The keyboard buffer controller is enabled for transmission and reception (KCLK and KD signal pins are in the bus drive state)
6	KCLKI	1	R	Keyboard Clock In Monitors the KCLK I/O pin. This bit cannot be modified. 0: KCLK I/O pin is low 1: KCLK I/O pin is high
5	KDI	1	R	Keyboard Data In Monitors the KDI I/O pin. This bit cannot be modified. 0: KD I/O pin is low 1: KD I/O pin is high
4	KBFSEL	1	R/W	Keyboard Buffer Register Full Select Selects whether the KBF bit is used as the keyboard buffer register full flag or as the KCLK fall interrupt flag. When KBFSEL is cleared to 0, the KBE bit in KBCRL should be cleared to 0 to disable reception. 0: KBF bit is used as KCLK fall interrupt flag 1: KBF bit is used as keyboard buffer register full flag

Bit	Bit Name	Initial Value	R/W	Description
3	KBIE	0	R/W	Keyboard Interrupt Enable Enables or disables interrupts from the keyboard buffer controller to the CPU. 0: Interrupt requests are disabled 1: Interrupt requests are enabled
2	KBF	0	R/(W)*	Keyboard Buffer Register Full Indicates that data reception has been completed and the received data is in KBBR. 0: [Clearing condition] Read KBF when KBF =1, then write 0 in KBF 1: [Setting conditions] • When data has been received normally and has been transferred to KBBR while KBFSEL = 1 (keyboard buffer register full flag) • When a KCLK falling edge is detected while KBFSEL = 0 (KCLK interrupt flag)
1	PER	0	R/(W)*	Parity Error Indicates that an odd parity error has occurred. 0: [Clearing condition] Read PER when PER =1, then write 0 in PER 1: [Setting condition] When an odd parity error occurs
0	KBS	0	R	Keyboard Stop Indicates the receive data stop bit. Valid only when KBF = 1. 0: 0 stop bit received 1: 1 stop bit received

Note: * Only 0 can be written for clearing the flag.

17.3.2 Keyboard Control Register L (KBCRL)

KBCRL enables the receive counter count and controls the keyboard buffer controller pin output.

Bit	Bit Name	Initial Value	R/W	Description
7	KBE	0	R/W	Keyboard Enable Enables or disables loading of receive data into KBBR. 0: Loading of receive data into KBBR is disabled 1: Loading of receive data into KBBR is enabled
6	KCLKO	1	R/W	Keyboard Clock Out Controls KBC clock I/O pin output. 0: KBC clock I/O pin is low 1: KBC clock I/O pin is high
5	KDO	1	R/W	Keyboard Data Out Controls KBC data I/O pin output. 0: KBC data I/O pin is low 1: KBC data I/O pin is high
4	—	1	—	Reserved This bit is always read as 1 and cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
3	RXCR3	0	R	Receive Counter
2	RXCR2	0	R	These bits indicate the received data bit. Their value is incremented on the fall of KCLK. These bits cannot be modified.
1	RXCR1	0	R	
0	RXCR0	0	R	The receive counter is initialized to 0000 by a reset and when 0 is written in KBE. Its value returns to 0000 after a stop bit is received.
				0000: —
				0001: Start bit
				0010: KB0
				0011: KB1
				0100: KB2
				0101: KB3
				0110: KB4
				0111: KB5
				1000: KB6
				1001: KB7
				1010: Parity bit
				1011: —
				11- - : —

17.3.3 Keyboard Data Buffer Register (KBBR)

KBBR stores receive data. Its value is valid only when KBF = 1.

Bit	Bit Name	Initial Value	R/W	Description
7	KB7	0	R	Keyboard Data 7 to 0
6	KB6	0	R	8-bit read only data.
5	KB5	0	R	Initialized to H'00 by a reset, in standby mode, watch mode, subactive mode, subsleep mode, and module stop mode, and when KBIOE is cleared to 0.
4	KB4	0	R	
3	KB3	0	R	
2	KB2	0	R	
1	KB1	0	R	
0	KB0	0	R	

17.4 Operation

17.4.1 Receive Operation

In a receive operation, both KCLK (clock) and KD (data) are outputs on the keyboard side and inputs on this LSI chip (system) side. KD receives a start bit, 8 data bits (LSB-first), an odd parity bit, and a stop bit, in that order. The KD value is valid when KCLK is low. A sample receive processing flowchart is shown in figure 17.3, and the receive timing in figure 17.4.

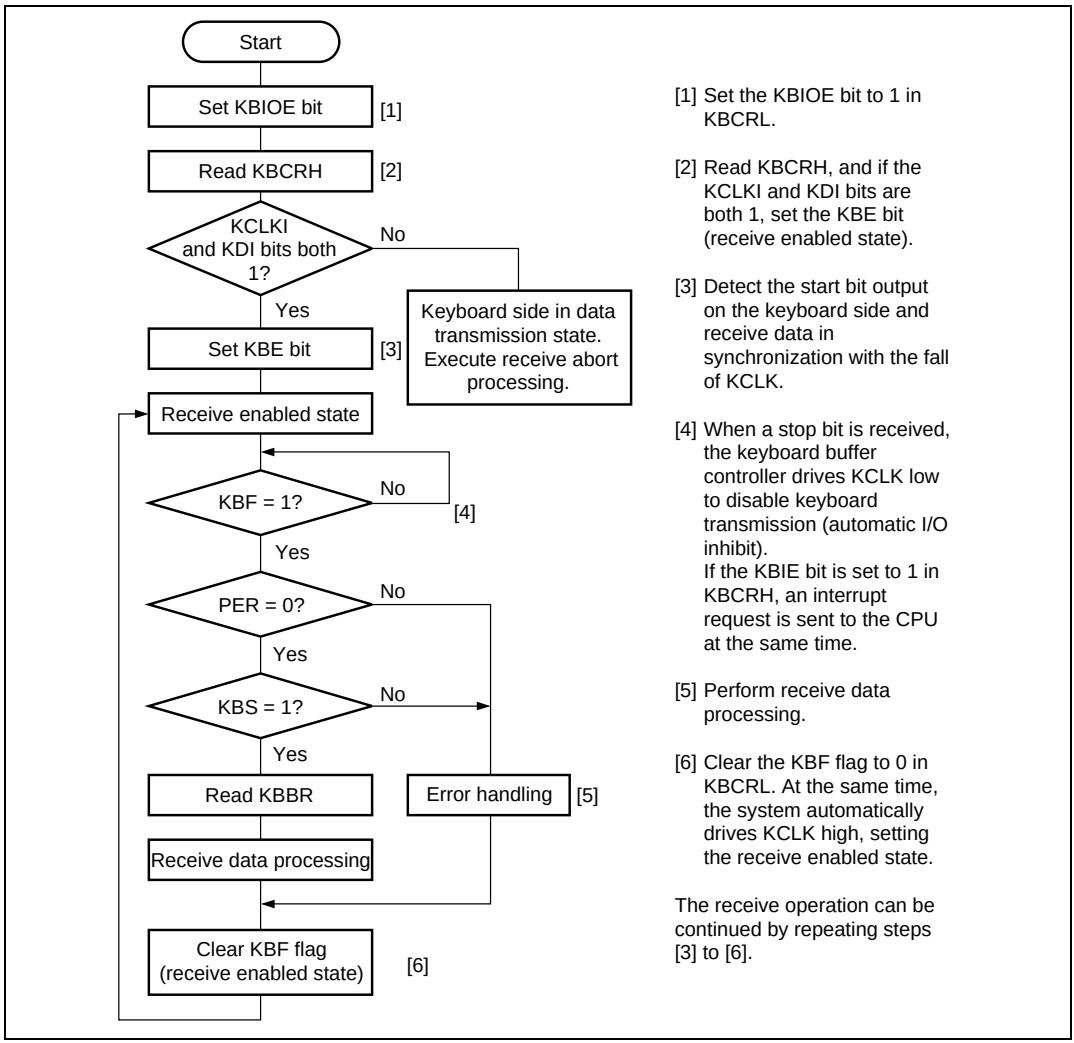


Figure 17.3 Sample Receive Processing Flowchart

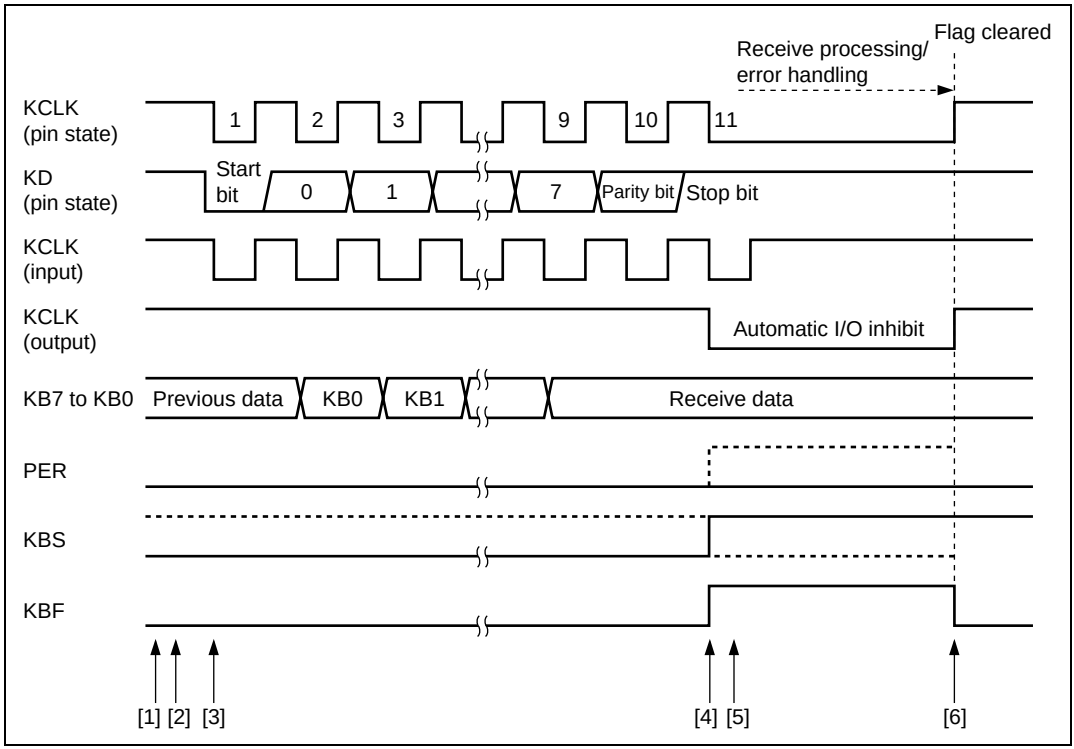
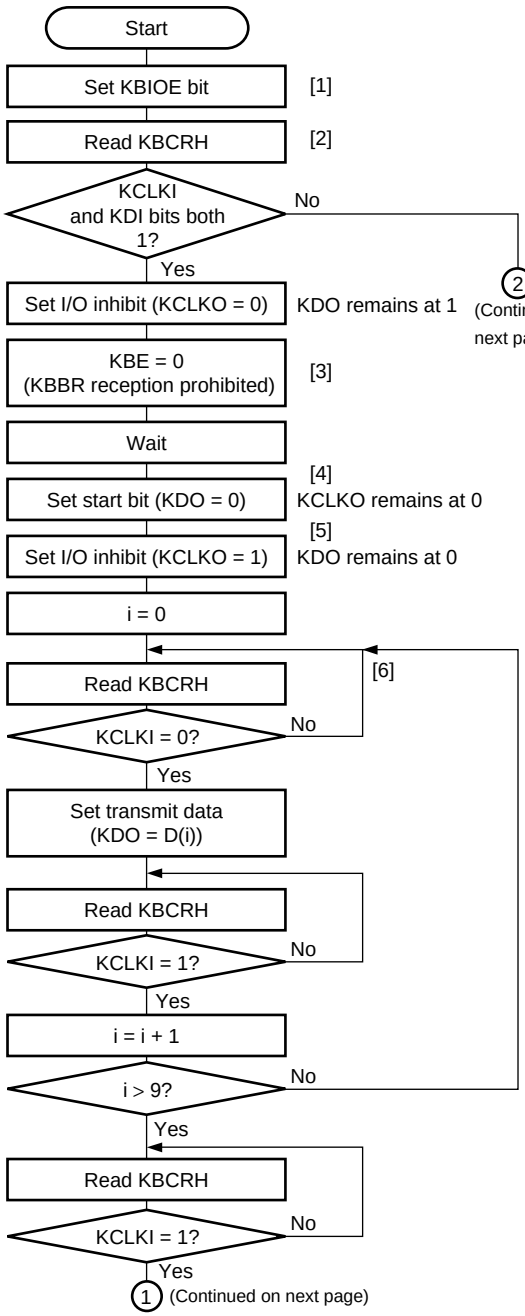


Figure 17.4 Receive Timing

17.4.2 Transmit Operation

In a transmit operation, KCLK (clock) is an output on the keyboard side, and KD (data) is an output on the chip (system) side. KD outputs a start bit, 8 data bits (LSB-first), an odd parity bit, and a stop bit, in that order. The KD value is valid when KCLK is high. A sample transmit processing flowchart is shown in figure 17.5, and the transmit timing in figure 17.6.



[1] Set the KBE bit to 1 in KBCRH.

[2] Read KBCRH, and if the KCLKI and KDI bits are both 1, write 0 in the KCLKO bit (set I/O inhibit).

[3] Write 0 in the KBE bit (prohibit KBBR receive operation).

[4] Write 0 in the KDO bit (set start bit).

[5] Write 1 in the KCLKO bit (clear I/O inhibit).

[6] Read KBCRH, and when KCLKI = 0, set the transmit data in the KDO bit (LSB-first). Next, set the parity bit and stop bit in the KDO bit.

[7] After transmitting the stop bit, read KBCRL and confirm that KDI = 0 (receive completed notification from the keyboard).

[8] Read KBCRH. Confirm that the KCLKI and KDI bits are both 1.

The transmit operation can be continued by repeating steps [2] to [8].

i = 0 to 7: Transmit data
i = 8: Parity bit
i = 9: Stop bit

Figure 17.5 (1) Sample Transmit Processing Flowchart

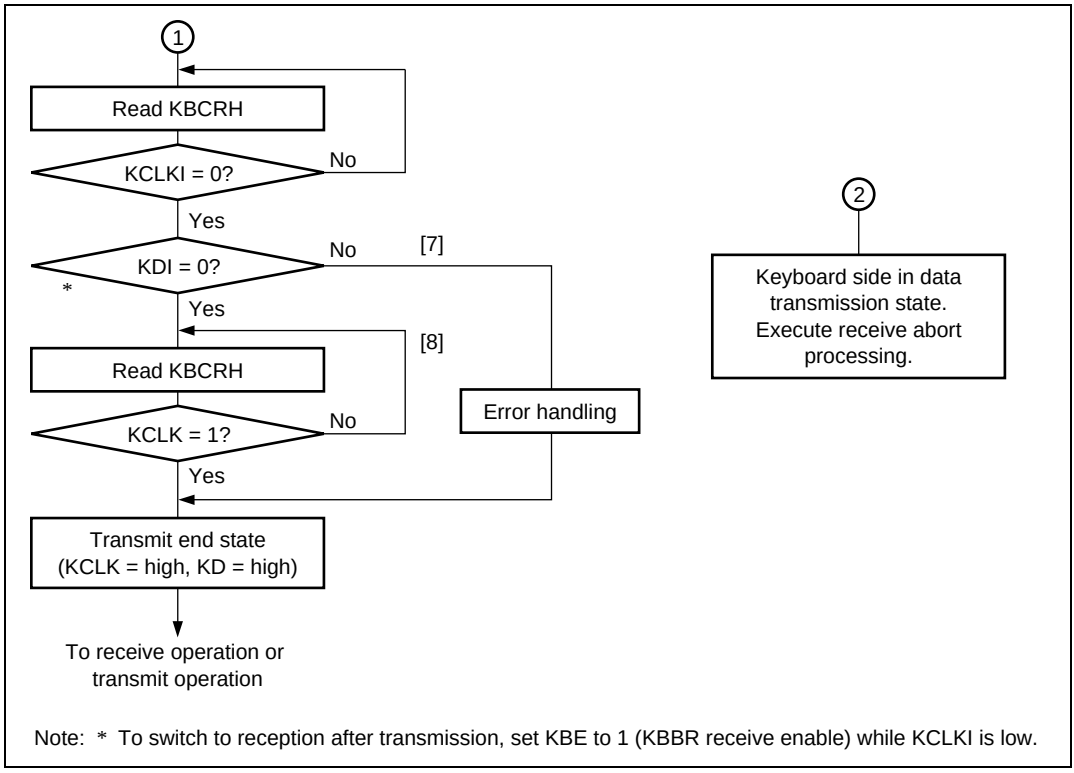


Figure 17.5 (2) Sample Transmit Processing Flowchart

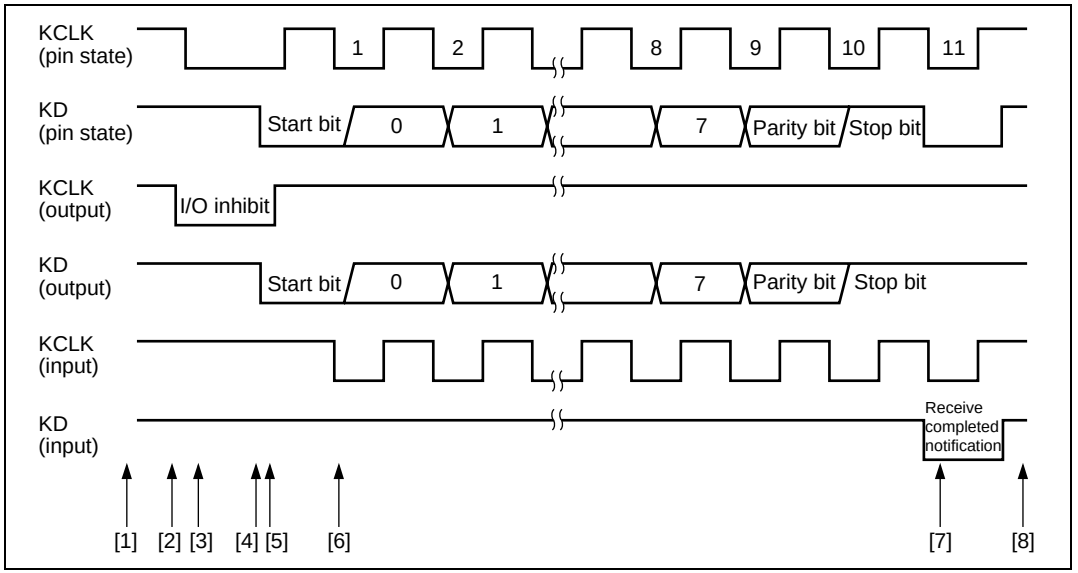


Figure 17.6 Transmit Timing

17.4.3 Receive Abort

This LSI (system side) can forcibly abort transmission from the device connected to it (keyboard side) in the event of a protocol error, etc. In this case, the system holds the clock low. During reception, the keyboard also outputs a clock for synchronization, and the clock is monitored when the keyboard output clock is high. If the clock is low at this time, the keyboard judges that there is an abort request from the system, and data transmission from the keyboard is aborted. Thus the system can abort reception by holding the clock low for a certain period. A sample receive abort processing flowchart is shown in figure 17.7, and the receive abort timing in figure 17.8.

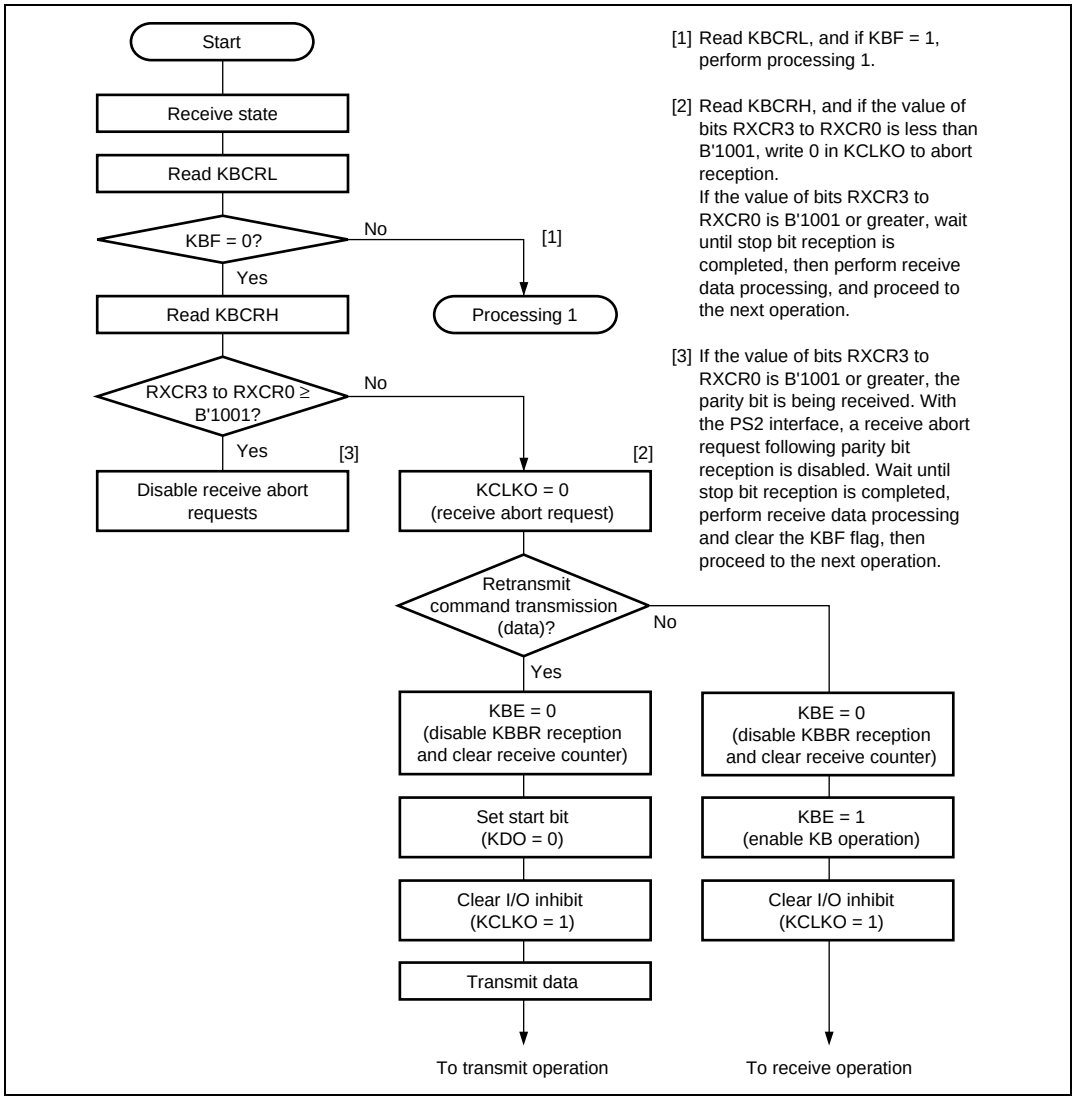


Figure 17.7 (1) Sample Receive Abort Processing Flowchart

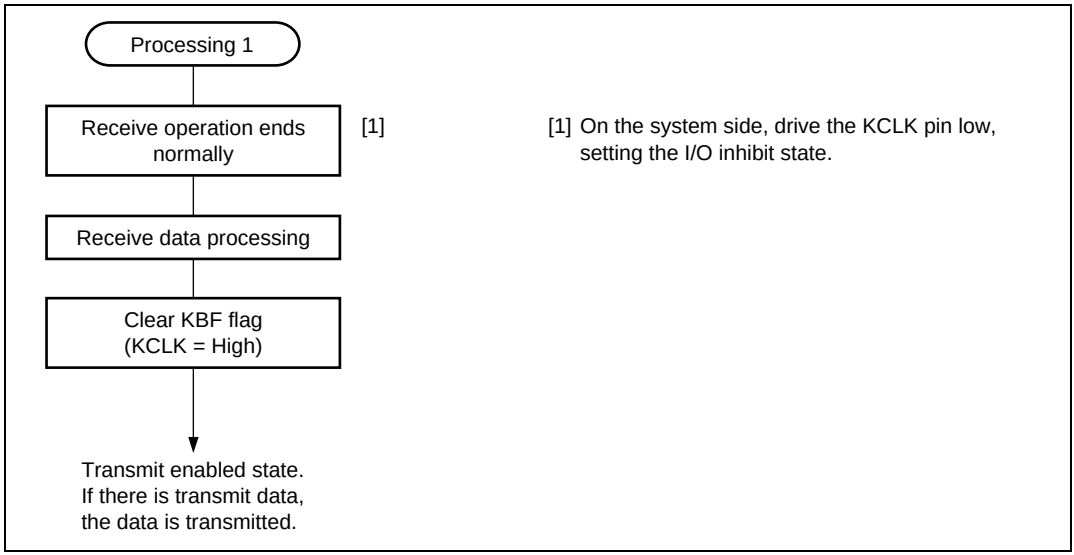


Figure 17.7 (2) Sample Receive Abort Processing Flowchart

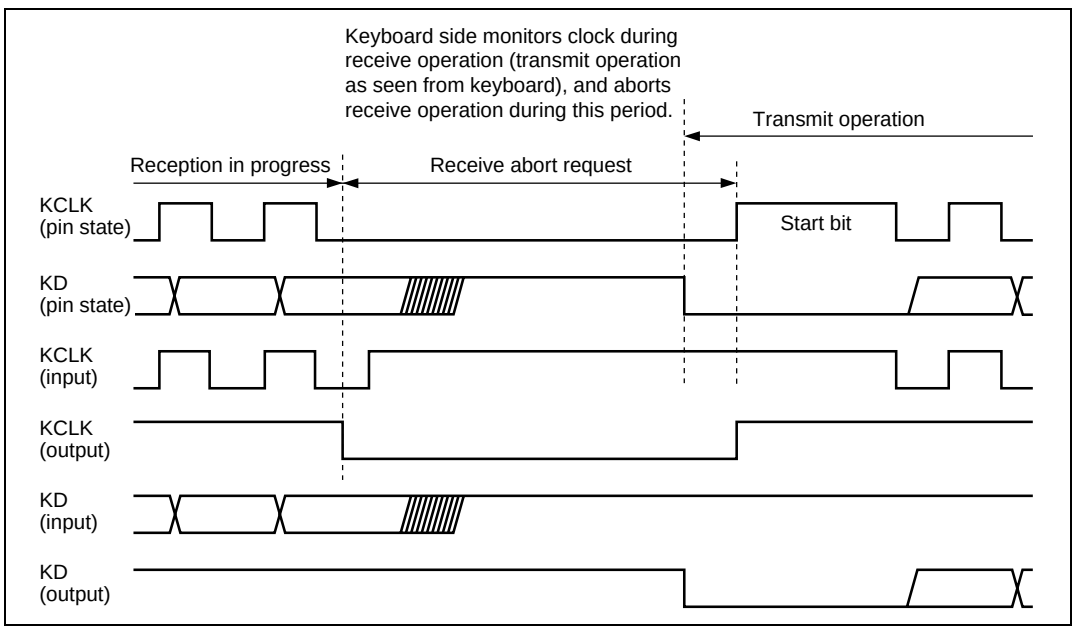
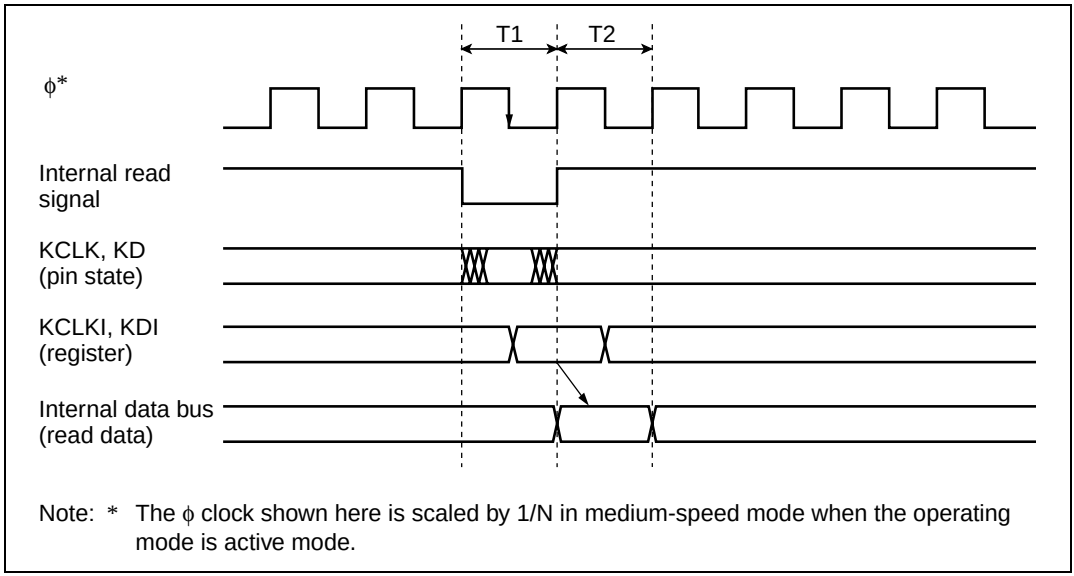


Figure 17.8 Receive Abort and Transmit Start (Transmission/Reception Switchover) Timing

17.4.4 KCLKI and KDI Read Timing

Figure 17.9 shows the KCLKI and KDI read timing.

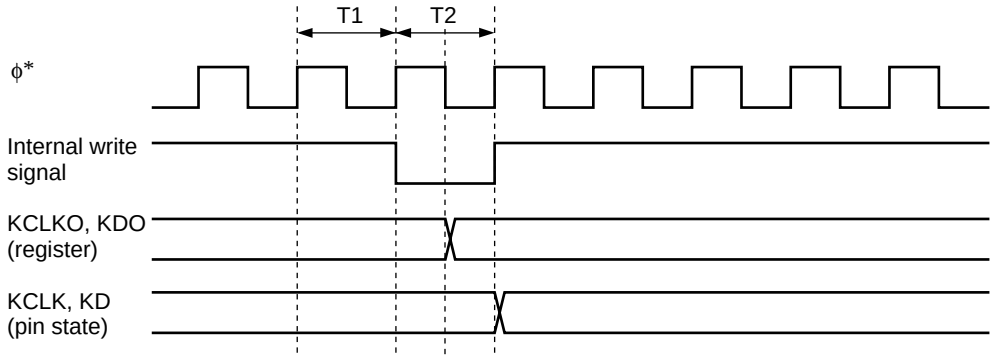


Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the operating mode is active mode.

Figure 17.9 KCLKI and KDI Read Timing

17.4.5 KCLKO and KDO Write Timing

Figure 17.10 shows the KLCKO and KDO write timing and the KCLK and KD pin states.

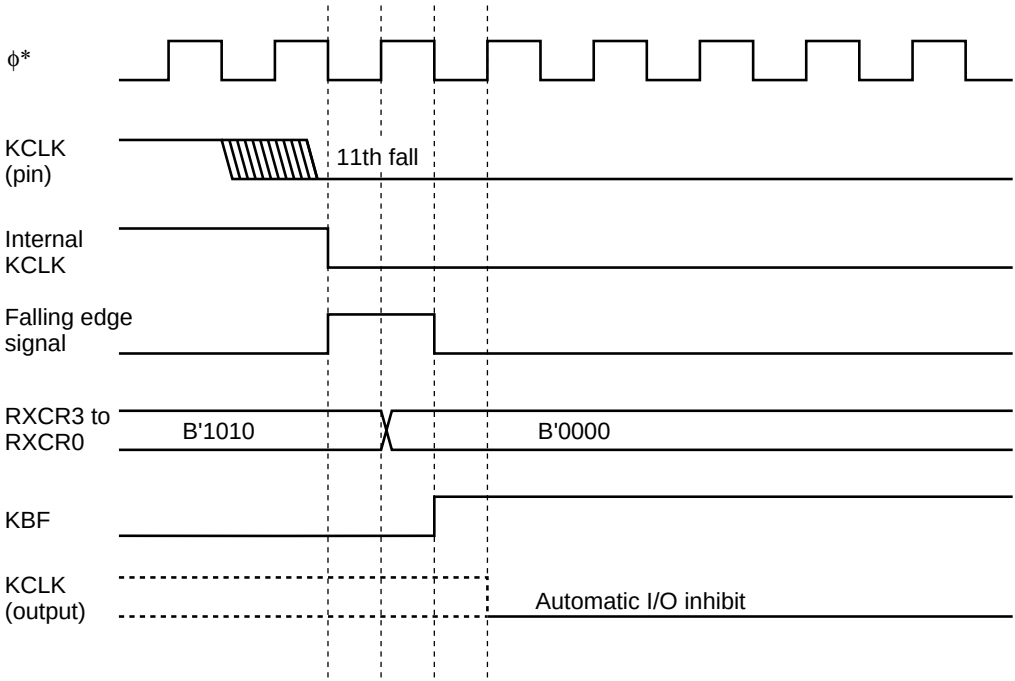


Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the operating mode is active mode.

Figure 17.10 KCLKO and KDO Write Timing

17.4.6 KBF Setting Timing and KCLK Control

Figure 17.11 shows the KBF setting timing and the KCLK pin states.

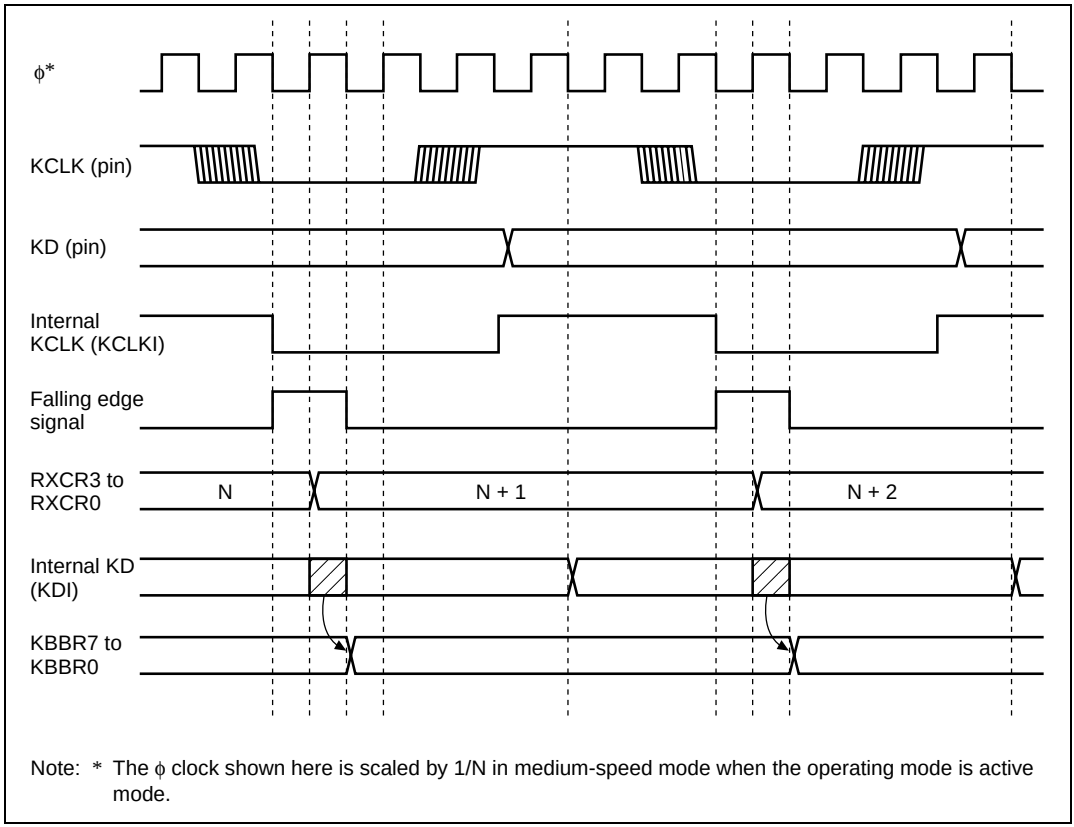


Note: * The φ clock shown here is scaled by 1/N in medium-speed mode when the operating mode is active mode.

Figure 17.11 KBF Setting and KCLK Automatic I/O Inhibit Generation Timing

17.4.7 Receive Timing

Figure 17.12 shows the receive timing.



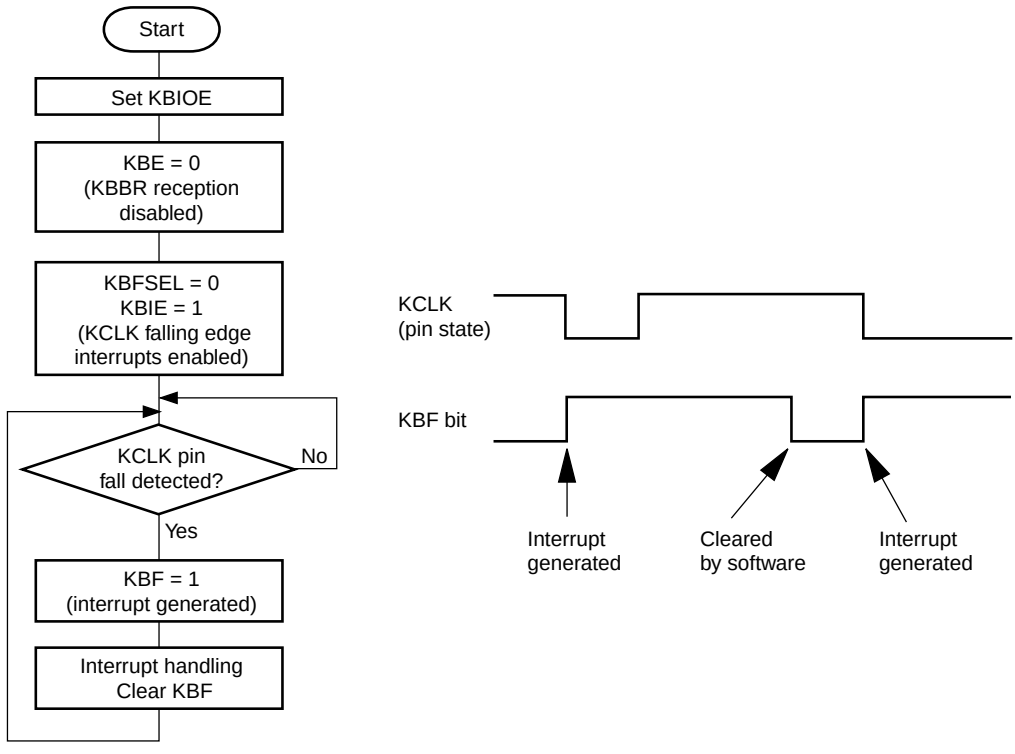
Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the operating mode is active mode.

Figure 17.12 Receive Counter and KBBR Data Load Timing

17.4.8 KCLK Fall Interrupt Operation

In this device, clearing the KBFSEL bit to 0 in KBCRH enables the KBF bit in KBCRL to be used as a flag for the interrupt generated by the fall of KCLK input.

Figure 17.13 shows the setting method and an example of operation.



Note: * The KBF setting timing is the same as the timing of KBF setting and KCLK automatic I/O inhibit bit generation in figure 17.11. When the KBF bit is used as the KCLK input fall interrupt flag, the automatic I/O inhibit function does not operate.

Figure 17.13 Example of KCLK Input Fall Interrupt Operation

17.5 Usage Notes

17.5.1 KBIOE Setting and KCLK Falling Edge Detection

When KBIOE is 0, the internal KCLK and internal KD settings are fixed at 1. Therefore, if the KCLK pin is low when the KBIOE bit is set to 1, the edge detection circuit operates and the KCLK falling edge is detected.

If the KBFSEL bit and KBE bit are both 0 at this time, the KBF bit is set. Figure 17.14 shows the timing of KBIOE setting and KCLK falling edge detection.

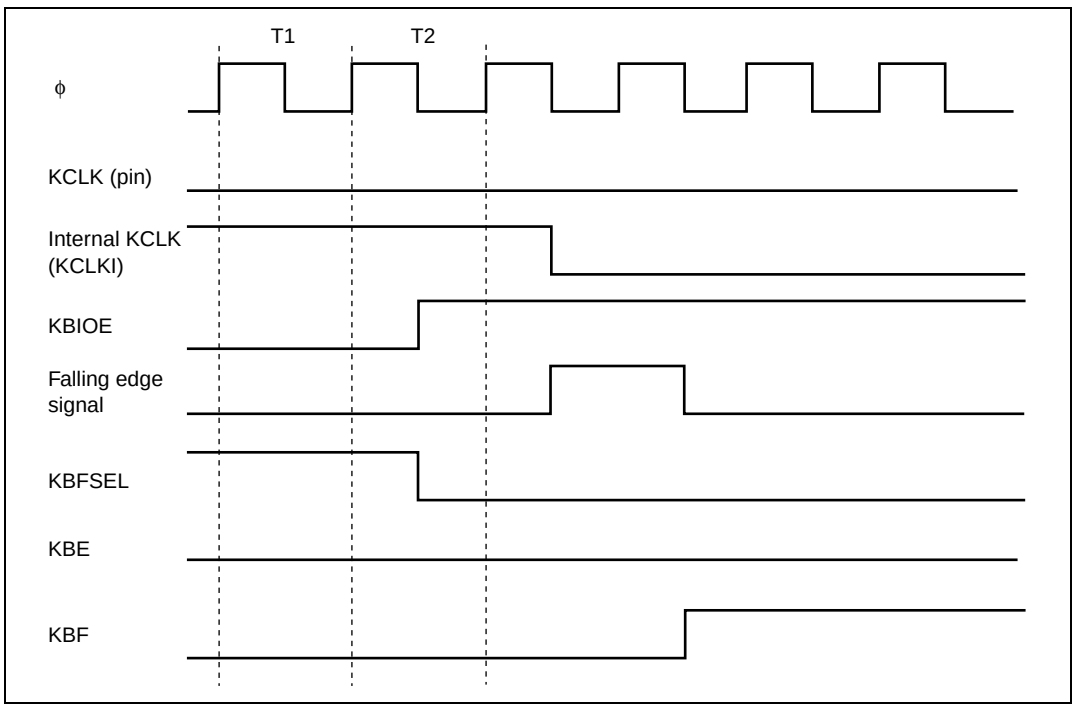


Figure 17.14 KBIOE Setting and KCLK Falling Edge Detection Timing

17.5.2 Module Stop Mode Setting

Keyboard buffer controller operation can be enabled or disabled using the module stop control register. The initial setting is for keyboard buffer controller operation to be halted. Register access is enabled by canceling module stop mode. For details, refer to section 26, Power-Down Modes.

Section 18 Host Interface X-Bus Interface (XBS)

This LSI has an on-chip host interface (HIF) that enables connection to the ISA bus (X-BUS) and has an on-chip LPC interface. In the following text, these two host interfaces (HIFs) are referred to as XBS and LPC, respectively.

The XBS provides a four-channel parallel interface between the chip's internal CPU and a host processor.

Communication is carried out via seven control signals from the host processor ($\overline{CS1}$, $\overline{CS2}$ or $\overline{ECS2}$, $\overline{CS3}$, $\overline{CS4}$, HA0, $\overline{IOR}$, and $\overline{IOW}$), six output signals to the host processor (GA20, HIRQ1, HIRQ11, HIRQ12, HIRQ3, and HIRQ4), and an 8-bit bidirectional command/data bus (HDB7 to HDB0). The $\overline{CS1}$, $\overline{CS2}$ (or $\overline{ECS2}$), $\overline{CS3}$ and $\overline{CS4}$ signals select one of the four interface channels.

18.1 Features

- Control of the fast GATE A20 function
- Shutdown of the XBS module by the HIFSD pin
- Five host interrupt requests

Figure 18.1 shows a block diagram of the XBS.

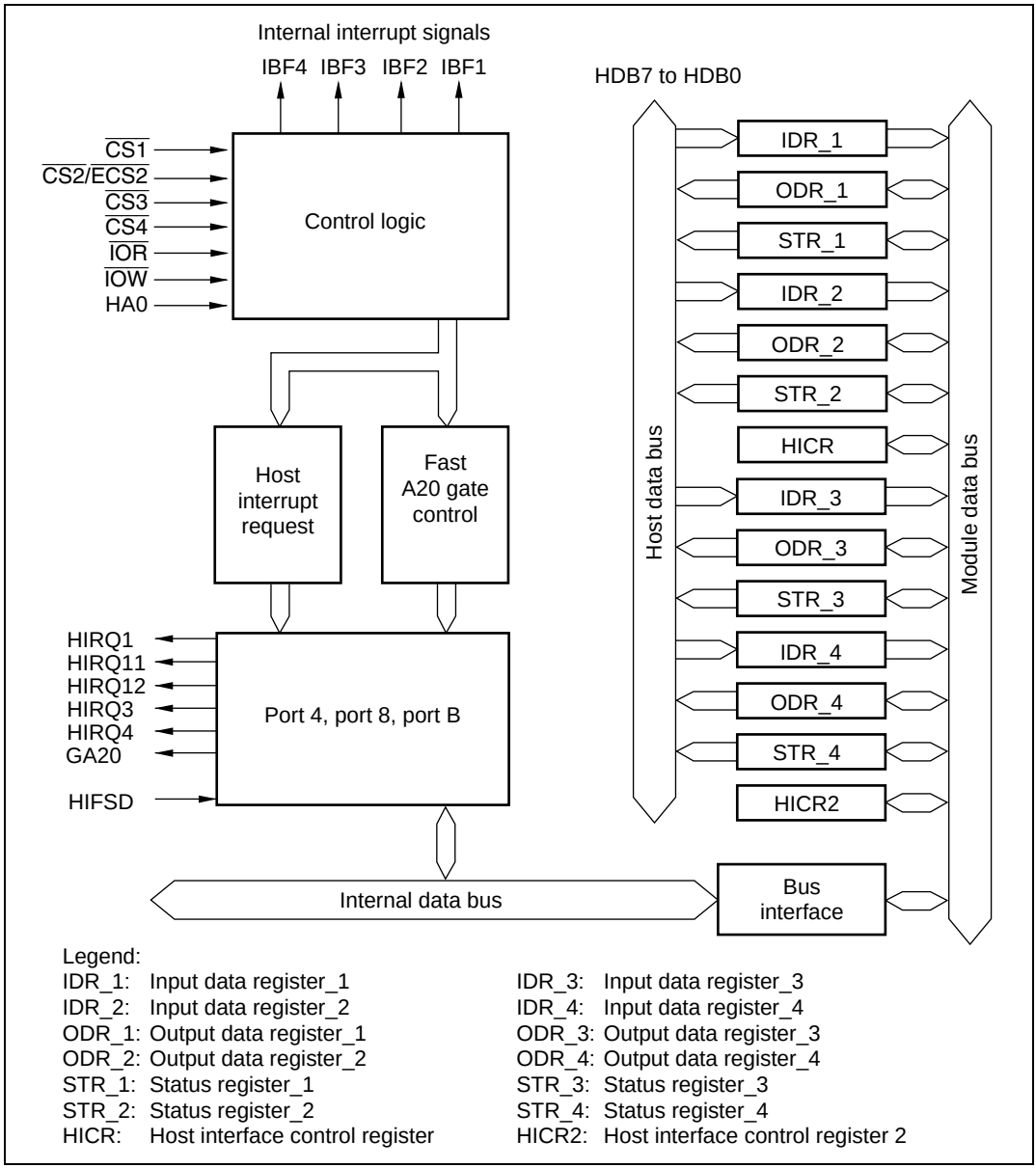


Figure 18.1 Block Diagram of XBS

18.2 Input/Output Pins

Table 18.1 lists the input and output pins of the XBS module.

Table 18.1 Pin Configuration

Name	Abbreviation	Port	I/O	Function
I/O read	$\overline{\text{IOR}}$	P93	Input	Host interface read signal
I/O write	$\overline{\text{IOW}}$	P94	Input	Host interface write signal
Chip select 1	$\overline{\text{CS1}}$	P95	Input	Host interface chip select signal for IDR_1, ODR_1, STR_1
Chip select 2*	$\overline{\text{CS2}}$	P81	Input	Host interface chip select signal for IDR_2, ODR_2, STR_2
	$\overline{\text{ECS2}}$	P90		
Chip select 3	$\overline{\text{CS3}}$	PB2	Input	Host interface chip select signal for IDR_3, ODR_3, STR_3
Chip select 4	$\overline{\text{CS4}}$	PB3	Input	Host interface chip select signal for IDR_4, ODR_4, STR_4
Command/data	HA0	P80	Input	Host interface address select signal In host read access, this signal selects the status registers (STR_1 to STR_4) or data registers (ODR_1 to ODR_4). In host write access to the data registers (IDR_1 to IDR_4), this signal indicates whether the host is writing a command or data.
Data bus	HDB7 to HDB0	P37 to P30	I/O	Host interface data bus
Host interrupt 11	HIRQ11	P43	Output	Interrupt output 11 to host
Host interrupt 1	HIRQ1	P44	Output	Interrupt output 1 to host
Host interrupt 12	HIRQ12	P45	Output	Interrupt output 12 to host
Host interrupt 3	HIRQ3	PB0	Output	Interrupt output 3 to host
Host interrupt 4	HIRQ4	PB1	Output	Interrupt output 4 to host
Gate A20	GA20	P81	Output	A20 gate control signal output
HIF shutdown	HIFSD	P82	Input	Host interface shutdown control signal

Note: * Selection of $\overline{\text{CS2}}$ or $\overline{\text{ECS2}}$ is by means of the CS2E bit in STCR and the FGA20E bit in HICR. XBS channel 2 and the $\overline{\text{CS2}}$ pin can be used when CS2E = 1. When CS2E = 1, $\overline{\text{CS2}}$ is used when FGA20E =0, and $\overline{\text{ECS2}}$ is used when FGA20E = 1. In this manual, both are referred to as $\overline{\text{CS2}}$.

18.3 Register Descriptions

XBS has the following registers. XBS registers HICR, IDR_1, IDR_2, ODR_1, ODR_2, STR_1, and STR_2 can only be accessed when the HIE bit is set to 1 in SYSCR. For details on SYSCR, refer to section 3.2.2, System Control Register (SYSCR).

- System control register 2 (SYSCR2)
- Host interface control register (HICR)
- Host interface control register 2 (HICR2)
- Input data register (IDR)
- Output data register (ODR)
- Status register (STR)

18.3.1 System Control Register 2 (SYSCR2)

SYSCR2 controls the operations of port 6 and host interface.

Bit	Bit Name	Initial Value	R/W	Description
7	KWUL1	0	R/W	Key Wakeup Level 1 and 0
6	KWUL0	0	R/W	Sets the port 6 input level. The input level of port-6 multiplexing pins is also changed by these settings. 00: Port 6 is in the standard input level 01: Port 6 is in input level 1 10: Port 6 is in input level 2 11: Port 6 is in input level 3
5	P6PUE	0	R/W	Port 6 Input Pull-Up MOS Extra (P6PUE) Controls and selects the current specification for the port 6 input pull-up MOS. 0: Standard current specification 1: Current limited specification
4	—	0	—	Reserved Only 0 should be written to this bit.

Bit	Bit Name	Initial Value	R/W	Description
3	SDE	0	R/W	Shutdown Enable 0: Host interface pin shutdown function disabled 1: Host interface pin shutdown function enabled When the shutdown function is enabled, host interface pin functions can be halted, and the pins placed in the high-impedance state, according to the state of the HIFSD pin.
2	CS4E	0	R/W	CS4 Enable 0: Channel 4 functions disabled 1: Channel 4 functions enabled (channel 4 pin is enabled) Enabling setting is valid when the HI12E bit is 1.
1	CS3E	0	R/W	CS3 Enable 0: Channel 3 functions disabled 1: Channel 3 functions enabled (channel 3 pin is enabled) Enabling setting is valid when the HI12E bit is 1.
0	HI12E	0	R/W	Host Interface Enable Bit 0: Host interface functions are disabled 1: Host interface functions are enabled (settings of bits CS2E to CS4E, FGA20E, and SDE are enabled) Enabling setting is valid in single-chip mode.

18.3.2 Host Interface Control Register (HICR)
Host Interface Control Register 2 (HICR2)

HICR controls host interface channel 1 and 2 interrupts and the fast A20 gate function. HICR2 controls host interface channel 3 and 4 interrupts.

- HICR

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
7 to 3	—	All 1	—	—	Reserved These bits are always read as 1 and cannot be modified.
2	IBFIE2	0	R/W	—	Input Data Register Full Interrupt Enable 2 Enables or disables the IBF2 interrupt to the internal CPU. 0: Input data register (IDR_2) reception completed interrupt request disabled 1: Input data register (IDR_2) reception completed interrupt request enabled
1	IBFIE1	0	R/W	—	Input Data Register Full Interrupt Enable 1 Enables or disables the IBF1 interrupt to the internal CPU. 0: Input data register (IDR_1) reception completed interrupt request disabled 1: Input data register (IDR_1) reception completed interrupt request enabled

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
0	FGA20E	0	R/W	—	Fast A20 Gate Function Enable When P81DDR=0: 0: XBS fast A20 gate function disabled 1: Setting prohibited When P81DDR=1: 0: XBS fast A20 gate function disabled 1: XBS fast A20 gate function enabled When the fast A20 gate is disabled, the normal A20 gate can be implemented by the firmware operation of the P81 output. When the host interface (XBS) fast A20 gate function is enabled, the DDR bit for P81 must be set to 1. Therefore, the state of the P81/GA20 pin cannot be monitored by reading the DR bit for P81. A fast A20 gate function is also provided in the LPC. The state of the P81/GA20 pin can be monitored by reading the LPC's GA20 bit.

- HICR2

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7 to 3	—	All 1	—	—	Reserved These bits are always read as 1, and cannot be modified.
2	IBFIE4	0	R/W	—	Input Data Register Full Interrupt Enable 4 Enables or disables the IBF4 interrupt to the internal CPU. 0: Input data register (IDR_4) reception completed interrupt request disabled 1: Input data register (IDR_4) reception completed interrupt request enabled
1	IBFIE3	0	R/W	—	Input Data Register Full Interrupt Enable 3 Enables or disables the IBF3 interrupt to the internal CPU. 0: Input data register (IDR_3) reception completed interrupt request disabled 1: Input data register (IDR_3) reception completed interrupt request enabled
0	—	0	—	—	Reserved The initial value should not be changed.

18.3.3 Input Data Register (IDR)

IDR is a register in which data to be input from the host processor to the slave processor (this LSI) is stored.

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
7	IDR7	—	R	W	When $\overline{CSn}$ (n = 1 to 4) is low, information on the host data bus is written into IDR_n at the rising edge of $\overline{IOW}$. The HA0 state is also latched into the C/$\overline{D}$ bit in STR_n to indicate whether the written information is a command or data.
6	IDR6	—	R	W	
5	IDR5	—	R	W	
4	IDR4	—	R	W	
3	IDR3	—	R	W	
2	IDR2	—	R	W	
1	IDR1	—	R	W	
0	IDR0	—	R	W	

18.3.4 Output Data Register 1 (ODR)

ODR is a register in which data to be output from the slave processor (this LSI) to the host processor is stored.

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
7	ODR7	—	R/W	R	The ODR_n contents are output on the host data bus when HA0 is low, $\overline{CSn}$ (n = 1 to 4) is low, and $\overline{IOR}$ is low.
6	ODR6	—	R/W	R	
5	ODR5	—	R/W	R	
4	ODR4	—	R/W	R	
3	ODR3	—	R/W	R	
2	ODR2	—	R/W	R	
1	ODR1	—	R/W	R	
0	ODR0	—	R/W	R	

18.3.5 Status Register (STR)

STR indicates status information during host interface processing.

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
7 to 4	DBU	All 0	R/W	R	Defined by User The user can use these bits as necessary.
3	C/$\overline{D}$	0	R	R	Command/Data Receives the HA0 input when the host processor writes to IDR, and indicates whether IDR contains data or a command. 0: Contents of input data register (IDR) are data 1: Contents of input data register (IDR) are a command
2	DBU	0	R/W	R	Defined by User The user can use these bits as necessary.
1	IBF	0	R	R	Input Buffer Full This bit is an internal interrupt source to the slave processor (this LSI). The IBF flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 18.5. [Clearing Condition] 0: When the slave processor reads IDR [Setting Condition] 1: When the host processor writes to IDR
0	OBF	0	R/(W)*	R	Output Buffer Full [Clearing Condition] 0: When the host processor reads ODR or the slave writes 0 in the OBF bit [Setting Condition] 1: When the slave processor writes to ODR

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

Table 18.2 shows the conditions for setting and clearing the STR flags.

Table 18.2 Set/Clear Timing for STR Flags

Flag	Setting Condition	Clearing Condition
C/$\overline{D}$	Rising edge of host's write signal ($\overline{IOW}$) when HA0 is high	Rising edge of host's write signal ($\overline{IOW}$) when HA0 is low
IBF*	Rising edge of host's write signal ($\overline{IOW}$) when writing to IDR1	Falling edge of slave's internal read signal when reading IDR1
OBF	Falling edge of slave's internal write signal when writing to ODR1	Rising edge of host's read signal ($\overline{IOR}$) when reading ODR1

Note: * The IBF flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 18.5.

18.4 Operation

18.4.1 Host Interface Activation

The host interface is activated by setting the HI12E bit in SYSCR2 to 1 in single-chip mode. When the host interface is activated, all related I/O ports (data port 3, control ports 8 and 9, and host interrupt request port 4) become dedicated host interface ports. Setting the CS3E bit and CS4E bit to 1 enables the number of host interface channels to be extended to four, and makes the channel 3 and 4 related I/O port (part of port B for control and host interrupt requests) a dedicated host interface port.

Table 18.3 shows HIF host interface channel selection and pin operation.

Table 18.3 Host Interface Channel Selection and Pin Operation

HI12E	CS2E	CS3E	CS4E	Operation
0	—	—	—	Host interface functions halted
1	0	0	0	Host interface channel 1 only operating Operation of channels 2 to 4 halted Pins P43, P81, P90, and PB0 to PB3 operate as I/O ports. $\overline{CS2}$ or $\overline{ECS2}$, $\overline{CS3}$, and $\overline{CS4}$ inputs do not operate.
			1	Host interface channel 1 and 4 functions operating Operation of channels 2 and 3 halted Pins P43, P81, P90, PB0, and PB2 operate as I/O ports. $\overline{CS2}$ or $\overline{ECS2}$ and $\overline{CS3}$ inputs do not operate.
		1	0	Host interface channel 1 and 3 functions operating Operation of channels 2 and 4 halted Pins P43, P81, P90, PB1, and PB3 operate as I/O ports. $\overline{CS2}$ or $\overline{ECS2}$ and $\overline{CS4}$ inputs do not operate.
			1	Host interface channel 1, 3, and 4 functions operating Operation of channel 2 halted Pins P43, P81, and P90 operate as I/O ports. $\overline{CS2}$ or $\overline{ECS2}$ input does not operate.
	1	0	0	Host interface channel 1 and 2 functions operating Operation of channels 3 and 4 halted Pins PB0 to PB3 operate as I/O ports. $\overline{CS3}$ and $\overline{CS4}$ inputs do not operate.
			1	Host interface channel 1, 2, and 4 functions operating Operation of channel 3 halted Pins PB0 and PB2 operate as I/O ports. $\overline{CS3}$ input does not operate.
		1	0	Host interface channel 1 to 3 functions operating Operation of channel 4 halted Pins PB1 and PB3 operate as I/O ports. $\overline{CS4}$ input does not operate.
			1	Host interface channel 1 to 4 functions operating

18.4.2 Control States

Table 18.4 shows host interface operations from the HIF host, and slave (this LSI) operation.

Table 18.4 Host Interface Operations from HIF Host, and Slave Operation

Other than $\overline{CSn}$	$\overline{CSn}$	$\overline{IOR}$	$\overline{IOW}$	HA0	Operation
1	0	0	0	0	Setting prohibited
				1	Setting prohibited
			1	0	Data read from output data register n (ODR_n)
				1	Status read from status register n (STR_n)
		1	0	0	Data written to input data register n (IDR_n)
				1	Command written to input data register n (IDR_n)
			1	0	Idle state
				1	Idle state

Note: n = 1 to 4

18.4.3 A20 Gate

The A20 gate signal can mask address A20 to emulate an addressing mode used by personal computers with an 8086*-family CPU. A regular-speed A20 gate signal can be output under firmware control. Fast A20 gate output is enabled by setting the FGA20E bit (bit 0) to 1 in HICR (H'FFF0).

Note: * Intel microprocessor.

Regular A20 Gate Operation: Output of the A20 gate signal can be controlled by an H'D1 command followed by data. When the slave processor (this LSI) receives data, it normally uses an interrupt routine activated by the IBF1 interrupt to read IDR1. If the data follows an H'D1 command, software copies bit 1 of the data and outputs it at the gate A20 pin.

Fast A20 Gate Operation: When the FGA20E bit is set to 1, P81/GA20 is used for output of a fast A20 gate signal. Bit P81DDR must be set to 1 to assign this pin for output. When the DDR bit for P81 is set to 1, the state of the P81/GA20 pin cannot be monitored by reading the DR bit for P81. The state of the P81/GA20 pin can be monitored by reading the GA20 bit in the LPC's HICR2 register. The initial output from this pin will be a logic 1, which is the initial value. Afterward, the host processor can manipulate the output from this pin by sending commands and data. This function is available only when register IDR1 is accessed using $\overline{CS1}$. The slave processor (this LSI) decodes the commands input from the host processor. When an H'D1 host

command is detected, bit 1 of the data following the host command is output from the GA20 output pin. This operation does not depend on firmware or interrupts, and is faster than the regular processing using interrupts. Table 18.5 lists the conditions that set and clear GA20 (P81). Figure 18.2 shows the GA20 output in flowchart form. Table 18.6 indicates the GA20 output signal values.

Table 18.5 GA20 (P81) Set/Clear Timing

Pin Name	Setting Condition	Clearing Condition
GA20 (P81)	Rising edge of the host's write signal ($\overline{IOW}$) when bit 1 of the written data is 1 and the data follows an H'D1 host command	Rising edge of the host's write signal ($\overline{IOW}$) when bit 1 of the written data is 0 and the data follows an H'D1 host command Also, when bit FGA20E in HICR is cleared to 0

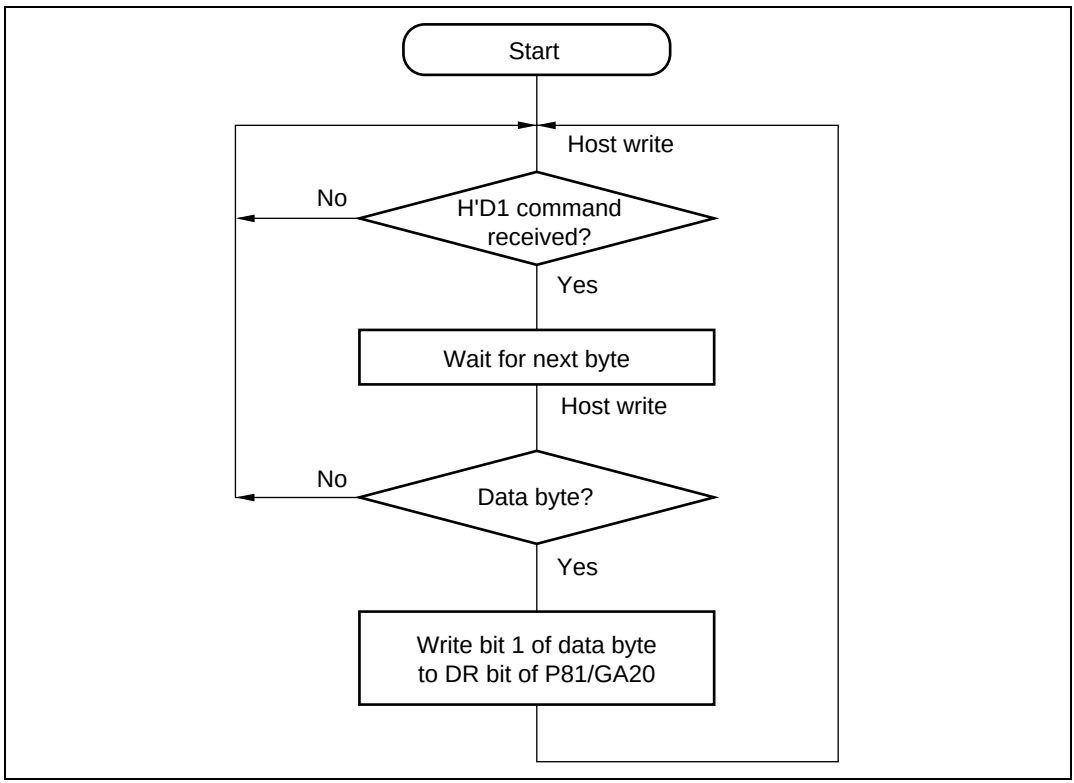


Figure 18.2 GA20 Output

Table 18.6 Fast A20 Gate Output Signal

HA0	Data/Command	Internal CPU Interrupt Flag (IBF)	GA20 (P81)	Remarks
1	H'D1 command	0	Q	Turn-on sequence
0	1 data*1	0	1	
1	H'FF command	0	Q (1)	
1	H'D1 command	0	Q	Turn-off sequence
0	0 data*2	0	0	
1	H'FF command	0	Q (0)	
1	H'D1 command	0	Q	Turn-on sequence
0	1 data*1	0	1	(abbreviated form)
1/0	Command other than H'FF and H'D1	1	Q (1)	
1	H'D1 command	0	Q	Turn-off sequence
0	0 data*2	0	0	(abbreviated form)
1/0	Command other than H'FF and H'D1	1	Q (0)	
1	H'D1 command	0	Q	Cancelled sequence
1	Command other than H'D1	1	Q	
1	H'D1 command	0	Q	Retriggered sequence
1	H'D1 command	0	Q	
1	H'D1 command	0	Q	Consecutively executed
0	Any data	0	1/0	sequences
1	H'D1 command	0	Q (1/0)	

Notes: 1. Arbitrary data with bit 1 set to 1.
2. Arbitrary data with bit 1 cleared to 0.

18.4.4 Host Interface Pin Shutdown Function

Host interface output can be placed in the high-impedance state according to the state of the HIFSD pin. Setting the SDE bit to 1 in the SYSCR2 register when the HI12E bit is set to 1 enables the HIFSD pin. The HIF constantly monitors the HIFSD pin, and when this pin goes low, places the host interface output pins (HIRQ1, HIRQ11, HIRQ12, HIRQ3, HIRQ4, and GA20) in the high-impedance state. At the same time, the host interface input pins ($\overline{CS1}$, $\overline{CS2}$ or $\overline{ECS2}$, $\overline{CS3}$, $\overline{CS4}$, $\overline{IOW}$, $\overline{IOR}$, and HA0) are disabled (fixed at the high input state internally) regardless of the pin states, and the signals of the multiplexed functions of these pins (input block) are similarly fixed internally. As a result, the host interface I/O pins (HDB7 to HDB0) also go to the high-impedance state.

This state is maintained while the HIFSD pin is low, and when the HIFSD pin returns to the high-level state, the pins are restored to their normal operation as host interface pins.

Table 18.7 shows the scope of HIF pin shutdown.

Table 18.7 Scope of HIF Pin Shutdown

Abbreviation	Port	Scope of Shutdown in Slave Mode	I/O	Selection Conditions
$\overline{\text{IOR}}$	P93	O	Input	HI12E = 1
$\overline{\text{IOW}}$	P94	O	Input	HI12E = 1
$\overline{\text{CS1}}$	P95	O	Input	HI12E = 1
$\overline{\text{CS2}}$	P81	Δ	Input	HI12E = 1 and CS2E = 1 and FGA20E = 0
$\overline{\text{ECS2}}$	P90	Δ	Input	HI12E = 1 and CS2E = 1 and FGA20E = 1
$\overline{\text{CS3}}$	PB2	Δ	Input	HI12E = 1 and CS3E = 1
$\overline{\text{CS4}}$	PB3	Δ	Input	HI12E = 1 and CS4E = 1
HA0	P80	O	Input	HI12E = 1
HDB7 to HDB0	P37 to P30	O	I/O	HI12E = 1
HIRQ11	P43	Δ	Output	HI12E = 1 and CS2E = 1 and P43DDR = 1
HIRQ1	P44	Δ	Output	HI12E = 1 and P44DDR = 1
HIRQ12	P45	Δ	Output	HI12E = 1 and P45DDR = 1
HIRQ3	PB0	Δ	Output	HI12E = 1 and CS3E = 1 and PB0DDR = 1
HIRQ4	PB1	Δ	Output	HI12E = 1 and CS4E = 1 and PB1DDR = 1
GA20	P81	Δ	Output	HI12E = 1 and FGA20E = 1
HIFSD	P82	—	Input	HI12E = 1 and SDE = 1

Legend:

O: Pins shut down by shutdown function
The $\overline{\text{IRQ2}}$/$\overline{\text{ADTRG}}$ input signal is also fixed in the case of P90 shutdown, the TMCI1/HSYNCI signal in the case of P43 shutdown, and the TMRI/CSYNCI in the case of P45 shutdown.

Δ: Pins shut down only when the XBS function is selected by means of a register setting

—: Pin not shut down

18.5 Interrupt Sources

18.5.1 IBF1, IBF2, IBF3, and IBF4

The host interface can issue four interrupt requests to the slave processor: IBF1 to IBF4. They are input buffer full interrupts for input data registers IDR_1 to IDR_4 respectively. Each interrupt is enabled when the corresponding enable bit is set.

Table 18.8 Input Buffer Full Interrupts

Interrupt	Description
IBF1	Requested when IBFIE1 is set to 1 and IDR_1 is full
IBF2	Requested when IBFIE2 is set to 1 and IDR_2 is full
IBF3	Requested when IBFIE3 is set to 1 and IDR_3 is full
IBF4	Requested when IBFIE4 is set to 1 and IDR_4 is full

18.5.2 HIRQ11, HIRQ1, HIRQ12, HIRQ3, and HIRQ4

Bits P45DR to P43DR in the port 4 data register (P4DR) and bits PB1ODR and PB0ODR in the port B data register (PBODR) can be used as host interrupt request latches. When they are used as host interrupt request output, set each bit in the data direction register (DDR) of the pin to 1.

The corresponding bits in P4DR are cleared to 0 by the host processor's read signal ($\overline{IOR}$). If $\overline{CS1}$ and HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_1, HIRQ1 and HIRQ12 are cleared to 0. If $\overline{CS2}$ and HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_2, HIRQ11 is cleared to 0. The corresponding bit in PBODR is cleared to 0 by the host's read signal ($\overline{IOR}$). If $\overline{CS3}$ and HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_3, HIRQ3 is cleared to 0. If $\overline{CS4}$ and HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_4, HIRQ4 is cleared to 0. To generate a host interrupt request, normally on-chip firmware writes 1 in the corresponding bit. In processing the interrupt, the host's interrupt handling routine reads the output data register (ODR_1, ODR_2, ODR_3, or ODR_4) and this clears the host interrupt latch to 0.

Table 18.9 indicates how these bits are set and cleared. Figure 18.3 shows the processing in flowchart form.

Table 18.9 HIRQ Setting/Clearing Conditions

Host Interrupt Signal	Setting Condition	Clearing Condition
HIRQ11 (P43)	Internal CPU reads 0 from bit P43DR, then writes 1	Internal CPU writes 0 in bit P43DR, or host reads output data register_2 (ODR_2)
HIRQ1 (P44)	Internal CPU reads 0 from bit P44DR, then writes 1	Internal CPU writes 0 in bit P44DR, or host reads output data register_1 (ODR_1)
HIRQ12 (P45)	Internal CPU reads 0 from bit P45DR, then writes 1	Internal CPU writes 0 in bit P45DR, or host reads output data register_1 (ODR_1)
HIRQ3 (PB0)	Internal CPU reads 0 from bit PB0ODR, then writes 1	Internal CPU writes 0 in bit PB0ODR, or host reads output data register_3 (ODR_3)
HIRQ4 (PB1)	Internal CPU reads 0 from bit PB1ODR, then writes 1	Internal CPU writes 0 in bit PB1ODR, or host reads output data register_4 (ODR_4)

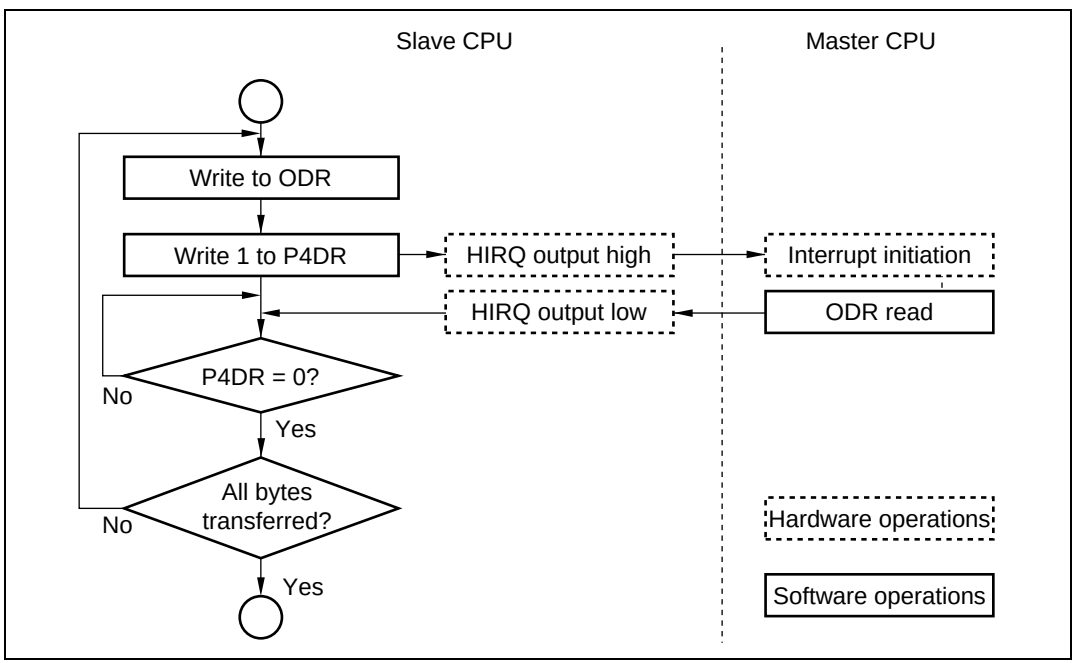


Figure 18.3 HIRQ Output Flowchart (Example of Channels 1 and 2)

HIRQ Setting/Clearing Conflict: If there is conflict between a P4DR or PBODR read/write by the CPU and P4DR (HIRQ11, HIRQ1, HIRQ12) or PBODR (HIRQ3, HIRQ4) clearing by the host, clearing by the host is held pending during the P4DR or PBODR read/write by the CPU. P4DR or PBODR clearing is executed after completion of the read/write.

18.6 Usage Notes

18.6.1 Note on Host Interface

The host interface provides buffering of asynchronous data from the host processor and slave processor (this LSI), but an interface protocol must be followed to implement necessary functions and avoid data contention. For example, if the host and slave processors try to access the same input or output data register simultaneously, the data will be corrupted. Interrupts can be used to design a simple and effective protocol.

Also, if two or more of pins $\overline{CS1}$ to $\overline{CS4}$ are driven low simultaneously in attempting IDR or ODR access, signal contention will occur within the chip, and a through-current may result. This usage must therefore be avoided.

18.6.2 Module Stop Mode Setting

XBS operation can be enabled or disabled using the module stop control register. The initial setting is for XBS operation to be halted. Register access is enabled by canceling module stop mode. For details, refer to section 26, Power-Down Modes.

Section 19 Host Interface LPC Interface (LPC)

This LSI has an on-chip LPC interface.

The LPC performs serial transfer of cycle type, address, and data, synchronized with the 33 MHz PCI clock. It uses four signal lines for address/data, and one for host interrupt requests. This LPC module supports only I/O read cycle and I/O write cycle transfers.

It is also provided with power-down functions that can control the PCI clock and shut down the host interface.

19.1 Features

- Supports LPC interface I/O read cycles and I/O write cycles
  - Uses four signal lines (LAD3 to LAD0) to transfer the cycle type, address, and data.
  - Uses three control signals: clock (LCLK), reset ($\overline{\text{LRESET}}$), and frame ($\overline{\text{LFRAME}}$).
- Has three register sets comprising data and status registers
  - The basic register set comprises three bytes: an input register (IDR), output register (ODR), and status register (STR).
  - Channels 1 and 2 have fixed I/O addresses of H'60/H'64 and H'62/H'66, respectively. A fast A20 gate function is also provided.
  - The I/O address can be set for channel 3. Sixteen bidirectional data register bytes can be manipulated in addition to the basic register set.
- Supports SERIRQ
  - Host interrupt requests are transferred serially on a single signal line (SERIRQ).
  - On channel 1, HIRQ1 and HIRQ12 can be generated.
  - On channels 2 and 3, SMI, HIRQ6, and HIRQ9 to HIRQ11 can be generated.
  - Operation can be switched between quiet mode and continuous mode.
  - The $\overline{\text{CLKRUN}}$ signal can be manipulated to restart the PCI clock (LCLK).
- Eleven interrupt sources
  - The LPC module can be shut down by inputting the $\overline{\text{LPCPD}}$ signal.
  - Three pins, $\overline{\text{PME}}$, $\overline{\text{LSMI}}$, and LSCI, are provided for general input/output.

Figure 19.1 shows a block diagram of the LPC.

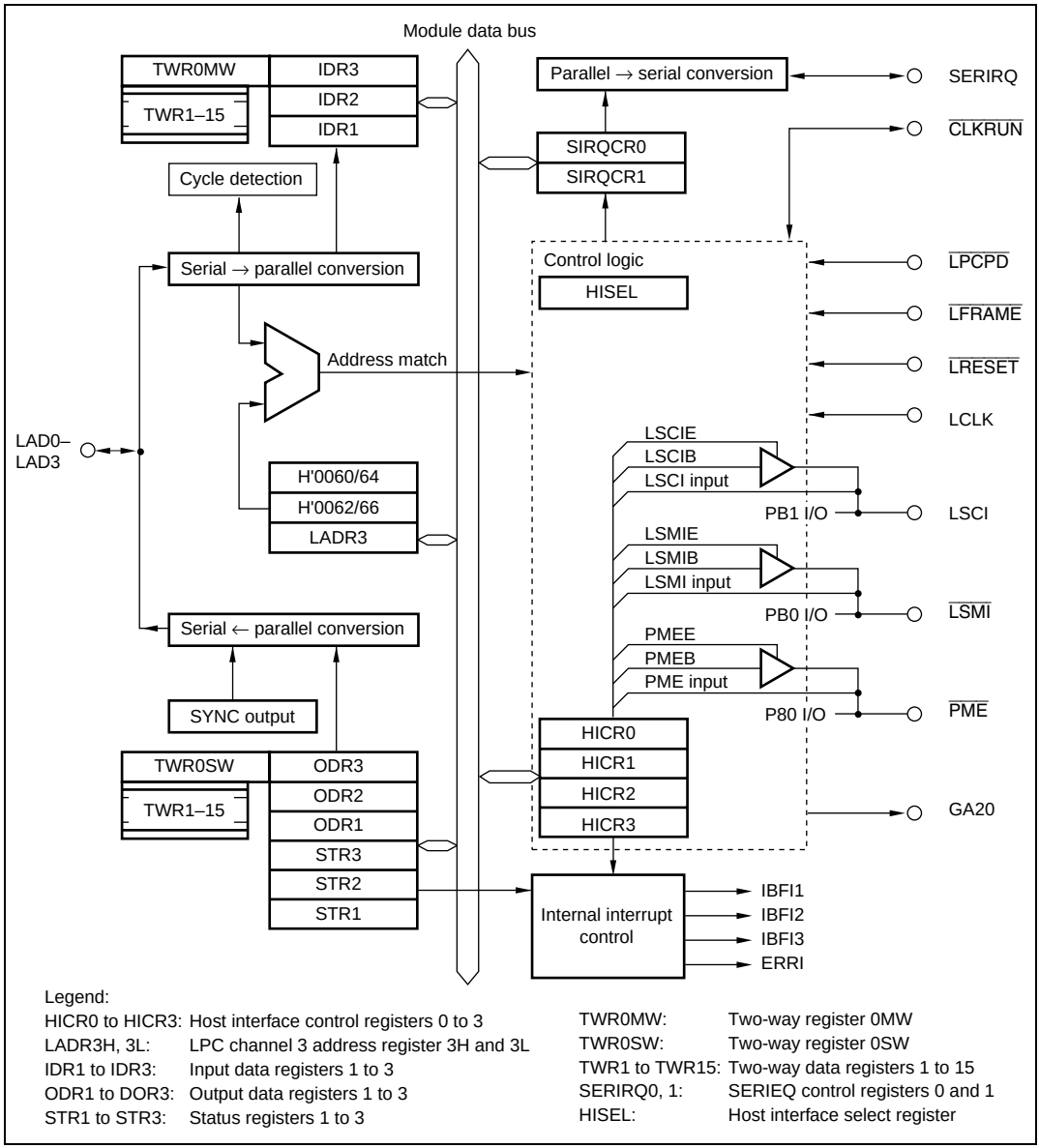


Figure 19.1 Block Diagram of LPC

19.2 Input/Output Pins

Table 19.1 lists the input and output pins of the LPC module.

Table 19.1 Pin Configuration

Name	Abbreviation	Port	I/O	Function
LPC address/ data 3 to 0	LAD3 to LAD0	P33 to P30	Input/ output	Serial (4-signal-line) transfer cycle type/address/data signals, synchronized with LCLK
LPC frame	$\overline{\text{LFRAME}}$	P34	Input*1	Transfer cycle start and forced termination signal
LPC reset	$\overline{\text{LRESET}}$	P35	Input*1	LPC interface reset signal
LPC clock	LCLK	P36	Input	33 MHz PCI clock signal
Serialized interrupt request	SERIRQ	P37	Input/ output*1	Serialized host interrupt request signal, synchronized with LCLK (SMI, IRQ1, IRQ6, IRQ9 to IRQ12)
LSCI general output	LSCI	PB1	Output*1*2	General output
LSMI general output	$\overline{\text{LSMI}}$	PB0	Output*1*2	General output
PME general output	$\overline{\text{PME}}$	P80	Output*1*2	General output
GATE A20	GA20	P81	Output*1*2	A20 gate control signal output
LPC clock run	$\overline{\text{CLKRUN}}$	P82	Input/ output*1*2	LCLK restart request signal in case of serial host interrupt request
LPC power-down	$\overline{\text{LPCPD}}$	P83	Input*1	LPC module shutdown signal

Notes: 1. Pin state monitoring input is possible in addition to the LPC interface control input/output function.

2. Only 0 can be output. If 1 is output, the pin goes to the high-impedance state, so an external resistor is necessary to pull the signal up to V_{CC}.

19.3 Register Descriptions

The LPC has the following registers. The settings of XBS related bits do not affect the operation of this LSI's LPC. However, for reasons relating to the configuration of the program development tool (emulator), when the LPC is used, bit HI12E in SYSCR2 should not be set to 1. For details, see section 3.2.2, System Control Register (SYSCR), and section 18.3.1, System Control Register 2 (SYSCR2).

- Host interface control register 0 (HICR0)
- Host interface control register 1 (HICR1)
- Host interface control register 2 (HICR2)
- Host interface control register 3 (HICR3)
- LPC channel 3 address registers (LADR3H, LADR3L)
- Input data register 1 (IDR1)
- Output data register 1 (ODR1)
- Status register 1 (STR1)
- Input data register 2 (IDR2)
- Output data register 2 (ODR2)
- Status register 2 (STR2)
- Input data register 3 (IDR3)
- Output data register 3 (ODR3)
- Status register 3 (STR3)
- Bidirectional data registers 0 to 15 (TWR0 to TWR15)
- SERIRQ control register 0 (SIRQCR0)
- SERIRQ control register 1 (SIRQCR1)
- Host interface select register (HISEL)

19.3.1 Host Interface Control Registers 0 and 1 (HICR0, HICR1)

HICR0 and HICR1 contain control bits that enable or disable host interface functions, control bits that determine pin output and the internal state of the host interface, and status flags that monitor the internal state of the host interface.

- HICR0

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
7	LPC3E	0	R/W	—	LPC Enable 3 to 1
6	LPC2E	0	R/W	—	Enable or disable the host interface function in single-chip mode. When the host interface is enabled (one of the three bits is set to 1), processing for data transfer between the slave processor (this LSI) and the host processor is performed using pins LAD3 to LAD0, $\overline{\text{LFRAME}}$, $\overline{\text{LRESET}}$, LCLK, SERIRQ, $\overline{\text{CLKRUN}}$, and $\overline{\text{LPCPD}}$. • LPC3E 0: LPC channel 3 operation is disabled No address (LADR3) matches for IDR3, ODR3, STR3, or TWR0 to TWR15 1: LPC channel 3 operation is enabled • LPC2E 0: LPC channel 2 operation is disabled No address (H'0062, 66) matches for IDR2, ODR2, or STR2 1: LPC channel 2 operation is enabled • LPC1E 0: LPC channel 1 operation is disabled No address (H'0060, 64) matches for IDR1, ODR1, or STR1 1: LPC channel 1 operation is enabled
5	LPC1E	0	R/W	—	

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
4	FGA20E	0	R/W	—	Fast A20 Gate Function Enable Enables or disables the fast A20 gate function. When the fast A20 gate is disabled, the normal A20 gate can be implemented by firmware operation of the P81 output. When the fast A20 gate function is enabled, the DDR bit for P81 must not be set to 1. 0: Fast A20 gate function disabled • Other function of pin P81 is enabled • GA20 output internal state is initialized to 1 1: Fast A20 gate function enabled • GA20 pin output is open-drain (external VCC pull-up resistor required)
3	SDWNE	0	R/W	—	LPC Software Shutdown Enable Controls host interface shutdown. For details of the LPC shutdown function, and the scope of initialization by an LPC reset and an LPC shutdown, see section 19.4.4, Host Interface Shutdown Function (LPCPD). 0: Normal state, LPC software shutdown setting enabled [Clearing conditions] • Writing 0 • LPC hardware reset or LPC software reset • LPC hardware shutdown release (rising edge of $\overline{\text{LPCPD}}$ signal) 1: LPC hardware shutdown state setting enabled • Hardware shutdown state when $\overline{\text{LPCPD}}$ signal is low [Setting condition] • Writing 1 after reading SDWNE = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
2	PMEE	0	R/W	—	PME output Enable Controls PME output in combination with the PMEB bit in HICR1. $\overline{\text{PME}}$ pin output is open-drain, and an external pull-up resistor is needed to pull the output up to V_{cc} When the PME output function is used, the DDR bit for P80 must not be set to 1. PMEE PMEB 0 x: PME output disabled, other function of pin is enabled 1 0: PME output enabled, $\overline{\text{PME}}$ pin output goes to 0 level 1 1: PME output enabled, $\overline{\text{PME}}$ pin output is high-impedance
1	LSMIE	0	R/W	—	LSMI output Enable Controls LSMI output in combination with the LSMIB bit in HICR1. $\overline{\text{LSMI}}$ pin output is open-drain, and an external pull-up resistor is needed to pull the output up to V_{cc} When the LSMI output function is used, the DDR bit for PB0 must not be set to 1. LSMIE LSMIB 0 x: LSMI output disabled, other function of pin is enabled 1 0: LSMI output enabled, $\overline{\text{LSMI}}$ pin output goes to 0 level 1 1: LSMI output enabled, $\overline{\text{LSMI}}$ pin output is high-impedance

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
0	LSCIE	0	R/W	—	LSCI output Enable Controls LSCI output in combination with the LSCIB bit in HICR1. LSCI pin output is open-drain, and an external pull-up resistor is needed to pull the output up to V_{CC} When the LSCI output function is used, the DDR bit for PB1 must not be set to 1. LSCIE LSCIB 0 x: LSCI output disabled, other function of pin is enabled 1 0: LSCI output enabled, LSCI pin output goes to 0 level 1 1: LSCI output enabled, LSCI pin output is high-impedance

Legend:

X: Don't care

- HICR1

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	LPCBSY	0	R/W	—	LPC Busy Indicates that the host interface is processing a transfer cycle. 0: Host interface is in transfer cycle wait state • Bus idle, or transfer cycle not subject to processing is in progress • Cycle type or address indeterminate during transfer cycle [Clearing conditions] • LPC hardware reset or LPC software reset • LPC hardware shutdown or LPC software shutdown • Forced termination (abort) of transfer cycle subject to processing • Normal termination of transfer cycle subject to processing 1: Host interface is performing transfer cycle processing [Setting condition] Match of cycle type and address

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
6	CLKREQ	0	R	—	LCLK Request Indicates that the host interface's SERIRQ output is requesting a restart of LCLK. 0: No LCLK restart request [Clearing conditions] • LPC hardware reset or LPC software reset • LPC hardware shutdown or LPC software shutdown • SERIRQ is set to continuous mode • There are no further interrupts for transfer to the host in quiet mode 1: LCLK restart request issued [Setting condition] In quiet mode, SERIRQ interrupt output becomes necessary while LCLK is stopped
5	IRQBSY	0	R	—	SERIRQ Busy Indicates that the host interface's SERIRQ signal is engaged in transfer processing. 0: SERIRQ transfer frame wait state [Clearing conditions] • LPC hardware reset or LPC software reset • LPC hardware shutdown or LPC software shutdown • End of SERIRQ transfer frame 1: SERIRQ transfer processing in progress [Setting condition] Start of SERIRQ transfer frame

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
4	LRSTB	0	—	—	LPC Software Reset Bit Resets the host interface. For the scope of initialization by an LPC reset, see section 19.4.4, Host Interface Shutdown Function (LPCPD). 0: Normal state [Clearing conditions] • Writing 0 • LPC hardware reset 1: LPC software reset state [Setting condition] Writing 1 after reading LRSTB = 0
3	SDWNB	0	R/W	—	LPC Software Shutdown Bit Controls host interface shutdown. For details of the LPC shutdown function, and the scope of initialization by an LPC reset and an LPC shutdown, see section 19.4.4, Host Interface Shutdown Function (LPCPD). 0: Normal state [Clearing conditions] • Writing 0 • LPC hardware reset or LPC software reset • LPC hardware shutdown • LPC hardware shutdown release (rising edge of $\overline{\text{LPCPD}}$ signal when SDWNE = 0) 1: LPC software shutdown state [Setting condition] Writing 1 after reading SDWNB = 0
2	PMEB	0	R/W	—	PME Output Bit Controls PME output in combination with the PMEE bit. For details, refer to description on the PMEE bit in HICR0.

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
1	LSMIB	0	R/W	—	LSMI Output Bit Controls LSMI output in combination with the LSMIE bit. For details, refer to description on the LSMIE bit in HICR0.
0	LSCIB	0	R/W	—	LSCI output Bit Controls LSCI output in combination with the LSCIE bit. For details, refer to description on the LSCIE bit in HICR0.

19.3.2 Host Interface Control Registers 2 and 3 (HICR2, HICR3)

Bits 6 to 0 in HICR2 control interrupts from the host interface (LPC) module to the slave processor (this LSI). Bit 7 in HICR2 and HICR3 monitor host interface pin states.

The pin states can be monitored regardless of the host interface operating state or the operating state of the functions that use pin multiplexing.

- HICR2

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	GA20	Undefined	R	—	GA20 Pin Monitor
6	LRST	0	R/(W)*	—	LPC Reset Interrupt Flag This bit is a flag that generates an ERRI interrupt when an LPC hardware reset occurs. 0: [Clearing condition] Writing 0 after reading LRST = 1 1: [Setting condition] LRESET pin falling edge detection

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
5	SDWN	0	R/(W)*	—	LPC Shutdown Interrupt Flag This bit is a flag that generates an ERRI interrupt when an LPC hardware shutdown request is generated. 0: [Clearing conditions] • Writing 0 after reading SDWN = 1 • LPC hardware reset and LPC software reset 1: [Setting condition] LPCPD pin falling edge detection
4	ABRT	0	R/(W)*	—	LPC Abort Interrupt Flag This bit is a flag that generates an ERRI interrupt when a forced termination (abort) of an LPC transfer cycle occurs. 0: [Clearing conditions] • Writing 0 after reading ABRT = 1 • LPC hardware reset and LPC software reset • LPC hardware shutdown and LPC software shutdown 1: [Setting condition] $\overline{\text{LFRAME}}$ pin falling edge detection during LPC transfer cycle
3	IBFIE3	0	R/W	—	IDR3 and TWR Receive Completion Interrupt Enable Enables or disables IBFI3 interrupt to the slave processor (this LSI). 0: Input data register IDR3 and TWR receive completed interrupt requests disabled 1: [When TWRIE = 0 in LADR3] Input data register (IDR3) receive completed interrupt requests enabled [When TWRIE = 1 in LADR3] Input data register (IDR3) and TWR receive completed interrupt requests enabled

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
2	IBFIE2	0	R/W	—	IDR2 Receive Completion Interrupt Enable Enables or disables IBFI2 interrupt to the slave processor (this LSI). 0: Input data register (IDR2) receive completed interrupt requests disabled 1: Input data register (IDR2) receive completed interrupt requests enabled
1	IBFIE1	0	R/W	—	IDR1 Receive Completion Interrupt Enable Enables or disables IBFI1 interrupt to the slave processor (this LSI). 0: Input data register (IDR1) receive completed interrupt requests disabled 1: Input data register (IDR1) receive completed interrupt requests enabled
0	ERRIE	0	R/W	—	Error Interrupt Enable Enables or disables ERRI interrupt to the slave processor (this LSI). 0: Error interrupt requests disabled 1: Error interrupt requests enabled

Note: * Only 0 can be written to bits 6 to 4, to clear the flag.

- HICR3

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	LFRAME	Undefined	R	—	$\overline{\text{LFRAME}}$ Pin Monitor
6	CLKRUN	Undefined	R	—	$\overline{\text{CLKRUN}}$ Pin Monitor
5	SERIRQ	Undefined	R	—	SERIRQ Pin Monitor
4	LRESET	Undefined	R	—	$\overline{\text{LRESET}}$ Pin Monitor
3	LPCPD	Undefined	R	—	$\overline{\text{LPCPD}}$ Pin Monitor
2	PME	Undefined	R	—	$\overline{\text{PME}}$ Pin Monitor
1	LSMI	Undefined	R	—	$\overline{\text{LSMI}}$ Pin Monitor
0	LSCI	Undefined	R	—	LSCI Pin Monitor

19.3.3 LPC Channel 3 Address Register (LADR3)

LADR3 comprises two 8-bit readable/writable registers that perform LPC channel-3 host address setting and control the operation of the bidirectional data registers. The contents of the address field in LADR3 must not be changed while channel 3 is operating (while LPC3E is set to 1).

- LADR3H

Bit	Bit Name	Initial Value	R/W	Description
7	Bit 15	0	R/W	Channel 3 Address Bits 15 to 8: When LPC3E = 1, an I/O address received in an LPC I/O cycle is compared with the contents of LADR3. When determining an IDR3, ODR3, or STR3 address match, bit 0 of LADR3 is regarded as 0, and the value of bit 2 is ignored. When determining a TWR0 to TWR15 address match, bit 4 of LADR3 is inverted, and the values of bits 3 to 0 are ignored. Register selection according to the bits ignored in address match determination is as shown in table 19.2.
6	Bit 14	0	R/W	
5	Bit 13	0	R/W	
4	Bit 12	0	R/W	
3	Bit 11	0	R/W	
2	Bit 10	0	R/W	
1	Bit 9	0	R/W	
0	Bit 8	0	R/W	

- LADR3L

Bit	Bit Name	Initial Value	R/W	Description
7	Bit 7	0	R/W	Channel 3 Address Bits 7 to 3
6	Bit 6	0	R/W	
5	Bit 5	0	R/W	
4	Bit 4	0	R/W	
3	Bit 3	0	R/W	
2	—	0	R/W	Reserved This bit is readable/writable, however, only 0 should be written to this bit.
1	Bit 1	0	R/W	Channel 3 Address Bit 1
0	TWRE	0	R/W	Bidirectional Data Register Enable Enables or disables bidirectional data register operation. 0: TWR operation is disabled TWR-related I/O address match determination is halted 1: TWR operation is enabled

Table 19.2 Register Selection

I/O Address					Transfer	
Bit 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**Cycle**	**Host Register Selection**
Bit 4	Bit 3	0	Bit 1	0	I/O write	IDR3 write, C/$\overline{D}$3 ← 0
Bit 4	Bit 3	1	Bit 1	0	I/O write	IDR3 write, C/$\overline{D}$3 ← 1
Bit 4	Bit 3	0	Bit 1	0	I/O read	ODR3 read
Bit 4	Bit 3	1	Bit 1	0	I/O read	STR3 read
$\overline{\text{Bit 4}}$	0	0	0	0	I/O write	TWR0MW write
$\overline{\text{Bit 4}}$	0	0	0	1	I/O write	TWR1 to TWR15 write
	1	1	1	1		
$\overline{\text{Bit 4}}$	0	0	0	0	I/O read	TWR0SW read
$\overline{\text{Bit 4}}$	0	0	0	1	I/O read	TWR1 to TWR15 read
	1	1	1	1		

19.3.4 Input Data Registers 1 to 3 (IDR1 to IDR3)

The IDR registers are 8-bit read-only registers for the slave processor (this LSI), and 8-bit write-only registers for the host processor. The registers selected from the host according to the I/O address are shown in the following table. For information on IDR3 selection, see section 19.3.3, LPC Channel 3 Address Register (LADR3). Data transferred in an LPC I/O write cycle is written to the selected register. The state of bit 2 of the I/O address is latched into the C/$\overline{D}$ bit in STR, to indicate whether the written information is a command or data. The initial values of IDR1 to IDR3 are undefined.

I/O Address					Transfer	
Bits 15 to 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**Cycle**	**Host Register Selection**
0000 0000 0110	0	0	0	0	I/O write	IDR1 write, C/$\overline{D}$1 ← 0
0000 0000 0110	0	1	0	0	I/O write	IDR1 write, C/$\overline{D}$1 ← 1
0000 0000 0110	0	0	1	0	I/O write	IDR2 write, C/$\overline{D}$2 ← 0
0000 0000 0110	0	1	1	0	I/O write	IDR2 write, C/$\overline{D}$2 ← 1

19.3.5 Output Data Registers 1 to 3 (ODR1 to ODR3)

The ODR registers are 8-bit readable/writable registers for the slave processor (this LSI), and 8-bit read-only registers for the host processor. The registers selected from the host according to the I/O address are shown in the following table. For information on ODR3 selection, see section 19.3.3, LPC Channel 3 Address Register (LADR3). In an LPC I/O read cycle, the data in the selected register is transferred to the host. The initial values of ODR1 to ODR3 are undefined.

	I/O Address				Transfer	
Bits 15 to 4	Bit 3	Bit 2	Bit 1	Bit 0	Cycle	Host Register Selection
0000 0000 0110	0	0	0	0	I/O read	ODR1 read
0000 0000 0110	0	0	1	0	I/O read	ODR2 read

19.3.6 Bidirectional Data Registers 0 to 15 (TWR0 to TWR15)

The TWR registers are sixteen 8-bit readable/writable registers to both the slave processor (this LSI) and the host processor. In TWR0, however, two registers (TWR0MW and TWR0SW) are allocated to the same address for both the host address and the slave address. TWR0MW is a write-only register for the host processor, and a read-only register for the slave processor, while TWR0SW is a write-only register for the slave processor and a read-only register for the host processor. When the host and slave processors begin a write, after the respective TWR0 registers have been written to, access right arbitration for simultaneous access is performed by checking the status flags to see if those writes were valid. For the registers selected from the host according to the I/O address, see section 19.3.3, LPC Channel 3 Address Register (LADR3).

Data transferred in an LPC I/O write cycle is written to the selected register; in an LPC I/O read cycle, the data in the selected register is transferred to the host. The initial values of TWR0 to TWR15 are undefined.

19.3.7 Status Registers 1 to 3 (STR1 to STR3)

The STR registers are 8-bit registers that indicate status information during host interface processing. Bits 3, 1, and 0 of STR1 to STR3, and bits 7 to 4 of STR3, are read-only bits for both the host processor and the slave processor (this LSI). However, only 0 can be written to bit 0 of STR1 to STR3 and bits 6 and 4 of STR3, from the slave processor (this LSI), in order to clear the flags to 0. The registers selected from the host processor according to the I/O address are shown in the following table. For information on STR3 selection, see section 19.3.3, LPC Channel 3 Address Register (LADR3). In an LPC I/O read cycle, the data in the selected register is transferred to the host processor. The initial values of STR1 to STR3 are H'00.

I/O Address					Transfer	
Bits 15 to 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**Cycle**	**Host Register Selection**
0000 0000 0110	0	1	0	0	I/O read	STR1 read
0000 0000 0110	0	1	1	0	I/O read	STR2 read

- STR1

			R/W		
Bit	**Bit Name**	**Initial Value**	**Slave**	**Host**	**Description**
7	DBU17	0	R/W	R	Defined by User
6	DBU16	0	R/W	R	The user can use these bits as necessary.
5	DBU15	0	R/W	R	
4	DBU14	0	R/W	R	
3	C/$\overline{D}$1	0	R	R	Command/Data When the host processor writes to an IDR register, bit 2 of the I/O address is written into this bit to indicate whether IDR contains data or a command. 0: Contents of data register (IDR) are data 1: Contents of data register (IDR) are a command
2	DBU12	0	R/W	R	Defined by User The user can use this bit as necessary.
1	IBF1	0	R	R	Input Buffer Full Set to 1 when the host processor writes to IDR. This bit is an internal interrupt source to the slave processor (this LSI). IBF is cleared to 0 when the slave processor reads IDR. The IBF1 flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR using I/O write cycle

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
0	OBF1	0	R/(W)*	R	Output Buffer Full Set to 1 when the slave processor (this LSI) writes to ODR. Cleared to 0 when the host processor reads ODR. 0: [Clearing condition] When the host processor reads ODR using I/O read cycle, or the slave processor writes 0 to the OBF bit 1: [Setting condition] When the slave processor writes to ODR

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

- STR2

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	DBU27	0	R/W	R	Defined by User
6	DBU26	0	R/W	R	The user can use these bits as necessary.
5	DBU25	0	R/W	R	
4	DBU24	0	R/W	R	
3	C/$\overline{D}$2	0	R	R	Command/Data When the host processor writes to an IDR register, bit 2 of the I/O address is written into this bit to indicate whether IDR contains data or a command. 0: Contents of data register (IDR) are data 1: Contents of data register (IDR) are a command
2	DBU22	0	R/W	R	Defined by User The user can use this bit as necessary.

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
1	IBF2	0	R	R	Input Buffer Full Set to 1 when the host processor writes to IDR. This bit is an internal interrupt source to the slave processor (this LSI). IBF is cleared to 0 when the slave processor reads IDR. The IBF1 flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR using I/O write cycle
0	OBF2	0	R/(W)*	R	Output Buffer Full Set to 1 when the slave processor (this LSI) writes to ODR. Cleared to 0 when the host processor reads ODR. 0: [Clearing condition] When the host processor reads ODR using I/O read cycle, or the slave processor writes 0 to the OBF bit 1: [Setting condition] When the slave processor writes to ODR

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

- STR3 (TWRE = 1 or SELSTR3 = 0)

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	IBF3B	0	R	R	Bidirectional Data Register Input Buffer Full Set to 1 when the host processor writes to TWR15. This is an internal interrupt source to the slave processor (this LSI). IBF3B is cleared to 0 when the slave processor reads TWR15. 0: [Clearing condition] When the slave processor reads TWR15 1: [Setting condition] When the host processor writes to TWR15 using I/O write cycle
6	OBF3B	0	R/(W)*	R	Bidirectional Data Register Output Buffer Full Set to 1 when the slave processor (this LSI) writes to TWR15. OBF3B is cleared to 0 when the host processor reads TWR15. 0: [Clearing condition] When the host processor reads TWR15 using I/O read cycle, or the slave processor writes 0 to the OBF3B bit 1: [Setting condition] When the slave processor writes to TWR15
5	MWMF	0	R	R	Master Write Mode Flag Set to 1 when the host processor writes to TWR0. MWMF is cleared to 0 when the slave processor (this LSI) reads TWR15. 0: [Clearing condition] When the slave processor reads TWR15 1: [Setting condition] When the host processor writes to TWR0 using I/O write cycle while SWMF = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
4	SWMF	0	R/(W)*	R	Slave Write Mode Flag Set to 1 when the slave processor (this LSI) writes to TWR0. In the event of simultaneous writes by the master and the slave, the master write has priority. SWMF is cleared to 0 when the host reads TWR15 0: [Clearing condition] When the host processor reads TWR15 using I/O read cycle, or the slave processor writes 0 to the SWMF bit 1: [Setting condition] When the slave processor writes to TWR0 while MWMF = 0
3	C/D3	0	R	R	Command/Data When the host processor writes to an IDR register, bit 2 of the I/O address is written into this bit to indicate whether IDR contains data or a command. 0: Contents of data register (IDR) are data 1: Contents of data register (IDR) are a command
2	DBU32	0	R/W	R	Defined by User The user can use this bit as necessary.
1	IBF3A	0	R	R	Input Buffer Full Set to 1 when the host processor writes to IDR. This bit is an internal interrupt source to the slave processor (this LSI). IBF is cleared to 0 when the slave processor reads IDR. The IBF1 flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR using I/O write cycle

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
0	OBF3A	0	R/(W)*	R	Output Buffer Full Set to 1 when the slave processor (this LSI) writes to ODR. OBF3A is cleared to 0 when the host processor reads ODR. 0: [Clearing condition] When the host processor reads ODR using I/O read cycle, or the slave processor writes 0 to the OBF bit 1: [Setting condition] When the slave processor writes to ODR

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

- STR3 (TWRE = 0 and SELSTR3 = 1)

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	DBU37	0	R/W	R	Defined by User
6	DBU36	0	R/W	R	The user can use these bits as necessary.
5	DBU35	0	R/W	R	
4	DBU34	0	R/W	R	
3	C/$\overline{D}$3	0	R	R	Command/Data When the host processor writes to an IDR register, bit 2 of the I/O address is written into this bit to indicate whether IDR contains data or a command. 0: Contents of data register (IDR) are data 1: Contents of data register (IDR) are a command
2	DBU32	0	R/W	R	Defined by User The user can use this bit as necessary.

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
1	IBF3A	0	R	R	Input Buffer Full Set to 1 when the host processor writes to IDR. This bit is an internal interrupt source to the slave processor (this LSI). IBF is cleared to 0 when the slave processor reads IDR. The IBF1 flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR using I/O write cycle
0	OBF3A	0	R/(W)*	R	Output Buffer Full Set to 1 when the slave processor (this LSI) writes to ODR. OBF3A is cleared to 0 when the host processor reads ODR. 0: [Clearing condition] When the host processor reads ODR using I/O read cycle, or the slave processor writes 0 to the OBF bit 1: [Setting condition] When the slave processor writes to ODR

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

19.3.8 SERIRQ Control Registers 0 and 1 (SIRQCR0, SIRQCR1)

The SIRQCR registers contain status bits that indicate the SERIRQ operating mode and bits that specify SERIRQ interrupt sources.

- SIRQCR0

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
7	Q/$\overline{C}$	0	R	—	Quiet/Continuous Mode Flag Indicates the mode specified by the host at the end of an SERIRQ transfer cycle (stop frame). 0: Continuous mode [Clearing conditions] • LPC hardware reset, LPC software reset • Specification by SERIRQ transfer cycle stop frame 1: Quiet mode [Setting condition] Specification by SERIRQ transfer cycle stop frame.
6	SELREQ	0	R/W	—	Start Frame Initiation Request Select Selects whether start frame initiation is requested when one or more interrupt requests are cleared, or when all interrupt requests are cleared, in quiet mode. 0: Start frame initiation is requested when all interrupt requests are cleared in quiet mode. 1: Start frame initiation is requested when one or more interrupt requests are cleared in quiet mode.
5	IEDIR	0	R/W	—	Interrupt Enable Direct Mode Specifies whether LPC channel 2 and channel 3 SERIRQ interrupt source (SMI, IRQ6, IRQ9 to IRQ11) generation is conditional upon OBF, or is controlled only by the host interrupt enable bit. 0: Host interrupt is requested when host interrupt enable bit and corresponding OBF are both set to 1 1: Host interrupt is requested when host interrupt enable bit is set to 1

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
4	SMIE3B	0	R/W	—	Host SMI Interrupt Enable 3B Enables or disables a host SMI interrupt request when OBF3B is set by a TWR15 write. 0: Host SMI interrupt request by OBF3B and SMIE3B is disabled [Clearing conditions] • Writing 0 to SMIE3B • LPC hardware reset, LPC software reset • Clearing OBF3B to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host SMI interrupt request by setting OBF3B to 1 is enabled [When IEDIR = 1] Host SMI interrupt is requested [Setting condition] Writing 1 after reading SMIE3B = 0
3	SMIE3A	0	R/W	—	Host SMI Interrupt Enable 3A Enables or disables a host SMI interrupt request when OBF3A is set by an ODR3 write. 0: Host SMI interrupt request by OBF3A and SMIE3A is disabled [Clearing conditions] • Writing 0 to SMIE3A • LPC hardware reset, LPC software reset • Clearing OBF3A to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host SMI interrupt request by setting OBF3A to 1 is enabled [When IEDIR = 1] Host SMI interrupt is requested [Setting condition] Writing 1 after reading SMIE3A = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
2	SMIE2	0	R/W	—	Host SMI Interrupt Enable 2 Enables or disables a host SMI interrupt request when OBF2 is set by an ODR2 write. 0: Host SMI interrupt request by OBF2 and SMIE2 is disabled [Clearing conditions] • Writing 0 to SMIE2 • LPC hardware reset, LPC software reset • Clearing OBF2 to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host SMI interrupt request by setting OBF2 to 1 is enabled [When IEDIR = 1] Host SMI interrupt is requested [Setting condition] Writing 1 after reading SMIE2 = 0
1	IRQ12E1	0	R/W	—	Host IRQ12 Interrupt Enable 1 Enables or disables a host IRQ12 interrupt request when OBF1 is set by an ODR1 write. 0: Host IRQ12 interrupt request by OBF1 and IRQ12E1 is disabled [Clearing conditions] • Writing 0 to IRQ12E1 • LPC hardware reset, LPC software reset • Clearing OBF1 to 0 1: Host IRQ12 interrupt request by setting OBF1 to 1 is enabled [Setting condition] Writing 1 after reading IRQ12E1 = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
0	IRQ1E1	0	R/W	—	Host IRQ1 Interrupt Enable 1 Enables or disables a host IRQ1 interrupt request when OBF1 is set by an ODR1 write. 0: Host IRQ1 interrupt request by OBF1 and IRQ1E1 is disabled [Clearing conditions] • Writing 0 to IRQ1E1 • LPC hardware reset, LPC software reset • Clearing OBF1 to 0 1: Host IRQ1 interrupt request by setting OBF1 to 1 is enabled [Setting condition] Writing 1 after reading IRQ1E1 = 0

- SIRQCR1

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
7	IRQ11E3	0	R/W	—	Host IRQ11 Interrupt Enable 3 Enables or disables a host IRQ11 interrupt request when OBF3A is set by an ODR3 write. 0: Host IRQ11 interrupt request by OBF3A and IRQ11E3 is disabled [Clearing conditions] • Writing 0 to IRQ11E3 • LPC hardware reset, LPC software reset • Clearing OBF3A to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ11 interrupt request by setting OBF3A to 1 is enabled [When IEDIR = 1] Host IRQ11 interrupt is requested. [Setting condition] Writing 1 after reading IRQ11E3 = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
6	IRQ10E3	0	R/W	—	Host IRQ10 Interrupt Enable 3 Enables or disables a host IRQ10 interrupt request when OBF3A is set by an ODR3 write. 0: Host IRQ10 interrupt request by OBF3A and IRQ10E3 is disabled [Clearing conditions] • Writing 0 to IRQ10E3 • LPC hardware reset, LPC software reset • Clearing OB3FA to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ10 interrupt request by setting OBF3A to 1 is enabled [When IEDIR = 1] Host IRQ10 interrupt is requested. [Setting condition] Writing 1 after reading IRQ10E3 = 0
5	IRQ9E3	0	R/W	—	Host IRQ9 Interrupt Enable 3 Enables or disables a host IRQ9 interrupt request when OBF3A is set by an ODR3 write. 0: Host IRQ9 interrupt request by OBF3A and IRQ9E3 is disabled [Clearing conditions] • Writing 0 to IRQ9E3 • LPC hardware reset, LPC software reset • Clearing OBF3A to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ9 interrupt request by setting OBF3A to 1 is enabled [When IEDIR = 1] Host IRQ9 interrupt is requested. [Setting condition] Writing 1 after reading IRQ9E3 = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
4	IRQ6E3	0	R/W	—	Host IRQ6 Interrupt Enable 3 Enables or disables a host IRQ6 interrupt request when OBF3A is set by an ODR3 write. 0: Host IRQ6 interrupt request by OBF3A and IRQ6E3 is disabled [Clearing conditions] • Writing 0 to IRQ6E3 • LPC hardware reset, LPC software reset • Clearing OBF3A to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ6 interrupt request by setting OBF3A to 1 is enabled [When IEDIR = 1] Host IRQ6 interrupt is requested. [Setting condition] Writing 1 after reading IRQ6E3 = 0
3	IRQ11E2	0	R/W	—	Host IRQ11 Interrupt Enable 2 Enables or disables a host IRQ11 interrupt request when OBF2 is set by an ODR2 write. 0: Host IRQ11 interrupt request by OBF2 and IRQ11E2 is disabled [Clearing conditions] • Writing 0 to IRQ11E2 • LPC hardware reset, LPC software reset • Clearing OBF2 to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ11 interrupt request by setting OBF2 to 1 is enabled [When IEDIR = 1] Host IRQ11 interrupt is requested. [Setting condition] Writing 1 after reading IRQ11E2 = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
2	IRQ10E2	0	R/W	—	Host IRQ10 Interrupt Enable 2 Enables or disables a host IRQ10 interrupt request when OBF2 is set by an ODR2 write. 0: Host IRQ10 interrupt request by OBF2 and IRQ10E2 is disabled [Clearing conditions] • Writing 0 to IRQ10E2 • LPC hardware reset, LPC software reset • Clearing OBF2 to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ10 interrupt request by setting OBF2 to 1 is enabled [When IEDIR = 1] Host IRQ10 interrupt is requested. [Setting condition] Writing 1 after reading IRQ10E2 = 0
1	IRQ9E2	0	R/W	—	Host IRQ9 Interrupt Enable 2 Enables or disables a host IRQ9 interrupt request when OBF2 is set by an ODR2 write. 0: Host IRQ9 interrupt request by OBF2 and IRQ9E2 is disabled [Clearing conditions] • Writing 0 to IRQ9E2 • LPC hardware reset, LPC software reset • Clearing OBF2 to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ9 interrupt request by setting OBF2 to 1 is enabled [When IEDIR = 1] Host IRQ9 interrupt is requested. [Setting condition] Writing 1 after reading IRQ9E2 = 0

Bit	Bit Name	Initial Value	R/W Slave	R/W Host	Description
0	IRQ6E2	0	R/W	—	Host IRQ6 Interrupt Enable 2 Enables or disables a host IRQ6 interrupt request when OBF2 is set by an ODR2 write. 0: Host IRQ6 interrupt request by OBF2 and IRQ6E2 is disabled [Clearing conditions] • Writing 0 to IRQ6E2 • LPC hardware reset, LPC software reset • Clearing OBF2 to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ6 interrupt request by setting OBF2 to 1 is enabled [When IEDIR = 1] Host IRQ6 interrupt is requested. [Setting condition] Writing 1 after reading IRQ6E2 = 0

19.3.9 Host Interface Select Register (HISEL)

HISEL selects the function of bits 7 to 4 in STR3 and specifies the output of the host interrupt request signal of each frame.

			R/W		
Bit	**Bit Name**	**Initial Value**	**Slave**	**Host**	**Description**
7	SELSTR3	0	W		STR3 Register Function Select 3 Selects the function of bits 7 to 4 in STR3 in combination with the TWRE bit in LADR3L. See description on STR3 in section 19.3.7, Status Registers 1 to 3 (STR1 to STR3), for details. 0: Bits 7 to 4 in STR3 are status bits of the host interface. 1: [When TWRE = 1] Bits 7 to 4 in STR3 are status bits of the host interface. [When TWRE = 0] Bits 7 to 4 in STR3 are user bits.
6	SELIRQ11	0	W	—	SERIRQ Output Select Selects the pin output status of host interrupt requests (HIRQ11, HIRQ10, HIRQ9, HIRQ6, SMI, HIRQ12, and HIRQ1) of the LPC. 0: [When host interrupt request is cleared] SERIRQ pin output is in the high-impedance state. [When host interrupt request is set] SERIRQ pin output is 0. 1: [When host interrupt request is cleared] SERIRQ pin output is 0. [When host interrupt request is set] SERIRQ pin output is in the high-impedance state.
5	SELIRQ10	0	W	—	
4	SELIRQ9	0	W	—	
3	SELIRQ6	0	W	—	
2	SELSMI	0	W	—	
1	SELIRQ12	1	W	—	
0	SELIRQ1	1	W	—	

19.4 Operation

19.4.1 Host Interface Activation

The host interface is activated by setting one of bits LPC3E to LPC1E in HICR0 to 1 in single-chip mode. When the host interface is activated, the related I/O ports (ports 37 to 30, ports 83 and 82) function as dedicated host interface input/output pins. In addition, setting the FGA20E, PMEE, LSMIE, and LSCIE bits to 1 adds the related I/O ports (ports 81 and 80, ports B0 and B1) to the host interface's input/output pins.

Use the following procedure to activate the host interface after a reset release.

1. Read the signal line status and confirm that the LPC module can be connected. Also check that the LPC module is initialized internally.
2. When using channel 3, set LADR3 to determine the channel 3 I/O address and whether bidirectional data registers are to be used.
3. Set the enable bit (LPC3E to LPC1E) for the channel to be used.
4. Set the enable bits (GA20E, PMEE, LSMIE, and LSCIE) for the additional functions to be used.
5. Set the selection bits for other functions (SDWNE, IEDIR).
6. As a precaution, clear the interrupt flags (LRST, SDWN, ABRT, OBF). Read IDR or TWR15 to clear IBF.
7. Set interrupt enable bits (IBFIE3 to IBFIE1, ERRIE) as necessary.

19.4.2 LPC I/O Cycles

There are ten kinds of LPC transfer cycle: memory read, memory write, I/O read, I/O write, DMA read, DMA write, bus master memory read, bus master memory write, bus master I/O read, and bus master I/O write. Of these, the chip's LPC supports only I/O read and I/O write cycles.

An LPC transfer cycle is started when the $\overline{\text{LFRAME}}$ signal goes low in the bus idle state. If the $\overline{\text{LFRAME}}$ signal goes low when the bus is not idle, this means that a forced termination (abort) of the LPC transfer cycle has been requested.

In an I/O read cycle or I/O write cycle, transfer is carried out using LAD3 to LAD0 in the following order, in synchronization with LCLK. The host can be made to wait by sending back a value other than B′0000 in the slave's synchronization return cycle, but with the chip's LPC a value of B′0000 is always returned.

If the received address matches the host address in an LPC register (IDR, ODR, STR, TWR), the host interface enters the busy state; it returns to the idle state by output of a state count 12 turnaround. Register and flag changes are made at this timing, so in the event of a transfer cycle forced termination (abort) before state #12, registers and flags are not changed.

	I/O Read Cycle			I/O Write Cycle		
State Count	**Contents**	**Drive Source**	**Value (3 to 0)**	**Contents**	**Drive Source**	**Value (3 to 0)**
1	Start	Host	0000	Start	Host	0000
2	Cycle type/direction	Host	0000	Cycle type/direction	Host	0010
3	Address 1	Host	Bits 15 to 12	Address 1	Host	Bits 15 to 12
4	Address 2	Host	Bits 11 to 8	Address 2	Host	Bits 11 to 8
5	Address 3	Host	Bits 7 to 4	Address 3	Host	Bits 7 to 4
6	Address 4	Host	Bits 3 to 0	Address 4	Host	Bits 3 to 0
7	Turnaround (recovery)	Host	1111	Data 1	Host	Bits 3 to 0
8	Turnaround	None	ZZZZ	Data 2	Host	Bits 7 to 4
9	Synchronization	Slave	0000	Turnaround (recovery)	Host	1111
10	Data 1	Slave	Bits 3 to 0	Turnaround	None	ZZZZ
11	Data 2	Slave	Bits 7 to 4	Synchronization	Slave	0000
12	Turnaround (recovery)	Slave	1111	Turnaround (recovery)	Slave	1111
13	Turnaround	None	ZZZZ	Turnaround	None	ZZZZ

The timing of the $\overline{\text{LFRAME}}$, LCLK, and LAD signals is shown in figures 19.2 and 19.3.

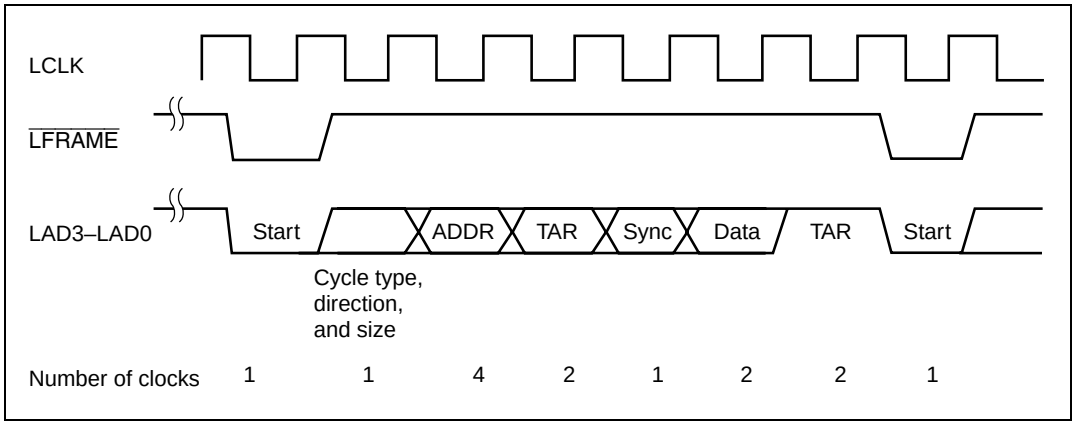


Figure 19.2 Typical LFRAME Timing

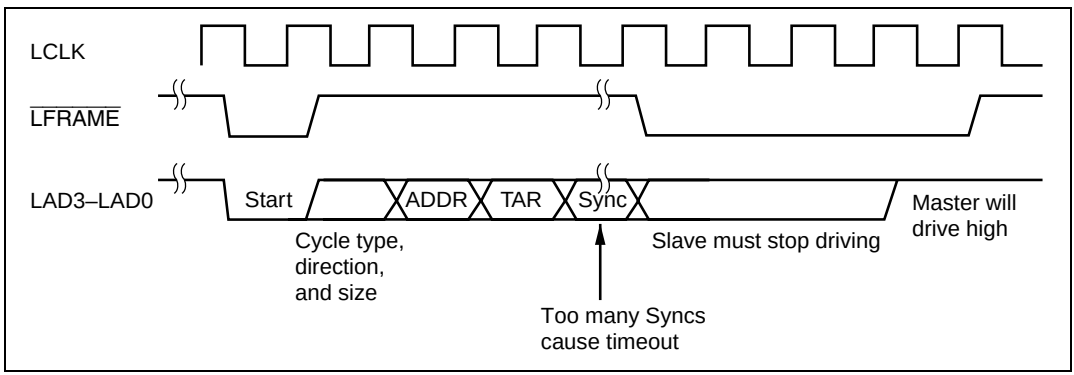


Figure 19.3 Abort Mechanism

19.4.3 A20 Gate

The A20 gate signal can mask address A20 to emulate an addressing mode used by personal computers with an 8086*-family CPU. A regular-speed A20 gate signal can be output under firmware control. The fast A20 gate function that is speeded up by hardware is enabled by setting the FGA20E bit to 1 in HICR0.

Note: An Intel microprocessor

Regular A20 Gate Operation: Output of the A20 gate signal can be controlled by an H'D1 command followed by data. When the slave processor (this LSI) receives data, it normally uses an interrupt routine activated by the IBF1 interrupt to read IDR1. At this time, firmware copies bit 1 of data following an H'D1 command and outputs it at the gate A20 pin.

Fast A20 Gate Operation: The internal state of GA20 output is initialized to 1 when FGA20E = 0. When the FGA20E bit is set to 1, P81/GA20 is used for output of a fast A20 gate signal. The state of the P81/GA20 pin can be monitored by reading the GA20 bit in HICR2.

The initial output from this pin will be a logic 1, which is the initial value. Afterward, the host processor can manipulate the output from this pin by sending commands and data. This function is only available via the IDR1 register. The host interface decodes commands input from the host. When an H'D1 host command is detected, bit 1 of the data following the host command is output from the GA20 output pin. This operation does not depend on firmware or interrupts, and is faster than the regular processing using interrupts. Table 19.3 shows the conditions that set and clear GA20 (P81). Figure 19.4 shows the GA20 output in flowchart form. Table 19.4 indicates the GA20 output signal values.

Table 19.3 GA20 (P81) Set/Clear Timing

Pin Name	Setting Condition	Clearing Condition
GA20 (P81)	When bit 1 of the data that follows an H'D1 host command is 1	When bit 1 of the data that follows an H'D1 host command is 0

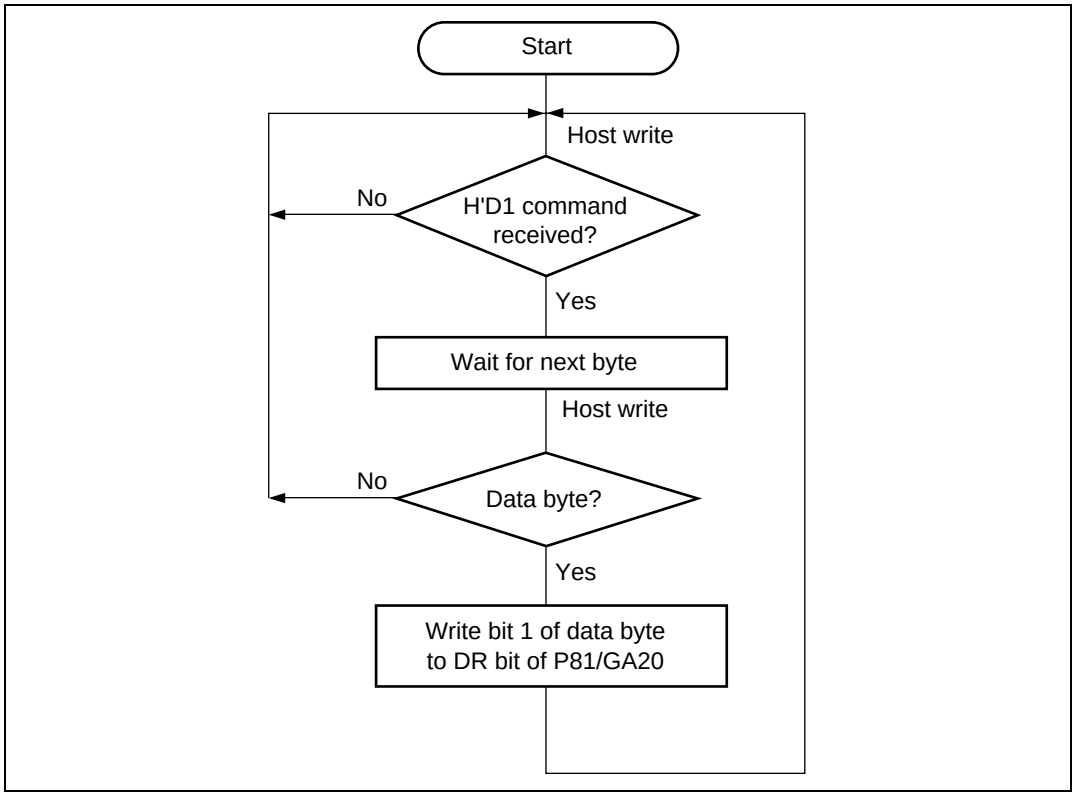


Figure 19.4 GA20 Output

Table 19.4 Fast A20 Gate Output Signals

HA0	Data/Command	Internal CPU Interrupt Flag (IBF)	GA20 (P81)	Remarks
1	H'D1 command	0	Q	Turn-on sequence
0	1 data*1	0	1	
1	H'FF command	0	Q (1)	
1	H'D1 command	0	Q	Turn-off sequence
0	0 data*2	0	0	
1	H'FF command	0	Q (0)	
1	H'D1 command	0	Q	Turn-on sequence (abbreviated form)
0	1 data*1	0	1	
1/0	Command other than H'FF and H'D1	1	Q (1)	
1	H'D1 command	0	Q	Turn-off sequence (abbreviated form)
0	0 data*2	0	0	
1/0	Command other than H'FF and H'D1	1	Q (0)	
1	H'D1 command	0	Q	Cancelled sequence
1	Command other than H'D1	1	Q	
1	H'D1 command	0	Q	Retriggered sequence
1	H'D1 command	0	Q	
1	H'D1 command	0	Q	Consecutively executed sequences
0	Any data	0	1/0	
1	H'D1 command	0	Q (1/0)	

Notes: 1. Arbitrary data with bit 1 set to 1.
2. Arbitrary data with bit 1 cleared to 0.

19.4.4 Host Interface Shutdown Function (LPCPD)

The host interface can be placed in the shutdown state according to the state of the $\overline{\text{LPCPD}}$ pin. There are two kinds of host interface shutdown state: LPC hardware shutdown and LPC software shutdown. The LPC hardware shutdown state is controlled by the $\overline{\text{LPCPD}}$ pin, while the software shutdown state is controlled by the SDWNB bit. In both states, the host interface enters the reset state by itself, and is no longer affected by external signals other than the $\overline{\text{LRESET}}$ and $\overline{\text{LPCPD}}$ signals.

Placing the slave processor in sleep mode or software standby mode is effective in reducing current dissipation in the shutdown state. If software standby mode is set, some means must be provided for exiting software standby mode before clearing the shutdown state with the $\overline{\text{LPCPD}}$ signal.

If the SDWNE bit has been set to 1 beforehand, the LPC hardware shutdown state is entered at the same time as the $\overline{\text{LPCPD}}$ signal falls, and prior preparation is not possible. If the LPC software shutdown state is set by means of the SDWNB bit, on the other hand, the LPC software shutdown state cannot be cleared at the same time as the rise of the $\overline{\text{LPCPD}}$ signal. Taking these points into consideration, the following operating procedure uses a combination of LPC software shutdown and LPC hardware shutdown.

1. Clear the SDWNE bit to 0.
2. Set the ERRIE bit to 1 and wait for an interrupt by the SDWN flag.
3. When an ERRI interrupt is generated by the SDWN flag, check the host interface internal status flags and perform any necessary processing.
4. Set the SDWNB bit to 1 to set LPC software standby mode.
5. Set the SDWNE bit to 1 and make a transition to LPC hardware standby mode. The SDWNB bit is cleared automatically.
6. Check the state of the $\overline{\text{LPCPD}}$ signal to make sure that the $\overline{\text{LPCPD}}$ signal has not risen during steps 3 to 5. If the signal has risen, clear SDWNE to 0 to return to the state in step 1.
7. Place the slave processor in sleep mode or software standby mode as necessary.
8. If software standby mode has been set, exit software standby mode by some means independent of the LPC.
9. When a rising edge is detected in the $\overline{\text{LPCPD}}$ signal, the SDWNE bit is automatically cleared to 0. If the slave processor has been placed in sleep mode, the mode is exited by means of $\overline{\text{LRESET}}$ signal input, on completion of the LPC transfer cycle, or by some other means.

Table 19.5 shows the scope of the host interface pin shutdown.

Table 19.5 Scope of Host Interface Pin Shutdown

Abbreviation	Port	Scope of Shutdown	I/O	Notes
LAD3 to LAD0	P33–P30	O	I/O	Hi-Z
$\overline{\text{LFRAME}}$	P34	O	Input	Hi-Z
$\overline{\text{LRESET}}$	P35	×	Input	LPC hardware reset function is active
LCLK	P36	O	Input	Hi-Z
SERIRQ	P37	O	I/O	Hi-Z
LSCI	PB1	Δ	I/O	Hi-Z, only when LSCIE = 1
$\overline{\text{LSMI}}$	PB0	Δ	I/O	Hi-Z, only when LSMIE = 1
$\overline{\text{PME}}$	P80	Δ	I/O	Hi-Z, only when PMEE = 1
GA20	P81	Δ	I/O	Hi-Z, only when FGA20E = 1
$\overline{\text{CLKRUN}}$	P82	O	Input	Hi-Z
$\overline{\text{LPCPD}}$	P83	×	Input	Needed to clear shutdown state

Legend:

O: Pin that is shutdown by the shutdown function

Δ: Pin that is shutdown only when the LPC function is selected by register setting

×: Pin that is not shutdown

In the LPC shutdown state, the LPC's internal state and some register bits are initialized. The order of priority of LPC shutdown and reset states is as follows.

1. System reset (reset by $\overline{\text{STBY}}$ or $\overline{\text{RES}}$ pin input, or WDT0 overflow)
   — All register bits, including bits LPC3E to LPC1E, are initialized.
2. LPC hardware reset (reset by $\overline{\text{LRESET}}$ pin input)
   — LRSTB, SDWNE, and SDWNB bits are cleared to 0.
3. LPC software reset (reset by LRSTB)
   — SDWNE and SDWNB bits are cleared to 0.
4. LPC hardware shutdown
   — SDWNB bit is cleared to 0.
5. LPC software shutdown

The scope of the initialization in each mode is shown in table 19.6.

Table 19.6 Scope of Initialization in Each Host Interface Mode

Items Initialized	System Reset	LPC Reset	LPC Shutdown
LPC transfer cycle sequencer (internal state), LPCBSY and ABRT flags	Initialized	Initialized	Initialized
SERIRQ transfer cycle sequencer (internal state), CLKREQ and IRQBSY flags	Initialized	Initialized	Initialized
Host interface flags (IBF1, IBF2, IBF3A, IBF3B, MWMF, C/$\overline{D}$1 to C/$\overline{D}$3, OBF1, OBF2, OBF3A, OBF3B, SWMF, DBU), GA20 (internal state)	Initialized	Initialized	Retained
Host interrupt enable bits (IRQ1E1, IRQ12E1, SMIE2, IRQ6E2, IRQ9E2 to IRQ11E2, SMIE3B, SMIE3A, IRQ6E3, IRQ9E3 to IRQ11E3), Q/$\overline{C}$ flag, SELREQ bit	Initialized	Initialized	Retained
LRST flag	Initialized (0)	Can be set/cleared	Can be set/cleared
SDWN flag	Initialized (0)	Initialized (0)	Can be set/cleared
LRSTB bit	Initialized (0)	HR: 0 SR: 1	0 (can be set)
SDWNB bit	Initialized (0)	Initialized (0)	HS: 0 SS: 1
SDWNE bit	Initialized (0)	Initialized (0)	HS: 1 SS: 0 or 1
Host interface operation control bits (LPC3E to LPC1E, FGA20E, LADR3, IBFIE1 to IBFIE3, PMEE, PMEB, LSMIE, LSMIB, LSCIE, LSCIB, TWRE, SELSTR3, SELIRQ1, SELSMI, SELIRQ6, SELIRQ9 to SELIRQ12)	Initialized	Retained	Retained
$\overline{\text{LRESET}}$ signal	Input (port function	Input	Input
$\overline{\text{LPCPD}}$ signal		Input	Input
LAD3 to LAD0, $\overline{\text{LFRAME}}$, LCLK, SERIRQ, $\overline{\text{CLKRUN}}$ signals		Input	Hi-Z
$\overline{\text{PME}}$, $\overline{\text{LSMI}}$, LSCI, GA20 signals (when function is selected)		Output	Hi-Z
$\overline{\text{PME}}$, $\overline{\text{LSMI}}$, LSCI, GA20 signals (when function is not selected)		Port function	Port function

Note: System reset: Reset by STBY input, RES input, or WDT overflow
LPC reset: Reset by LPC hardware reset (HR) or LPC software reset (SR)
LPC shutdown: Reset by LPC hardware shutdown (HS) or LPC software shutdown (SS)

Figure 19.5 shows the timing of the $\overline{\text{LPCPD}}$ and $\overline{\text{LRESET}}$ signals.

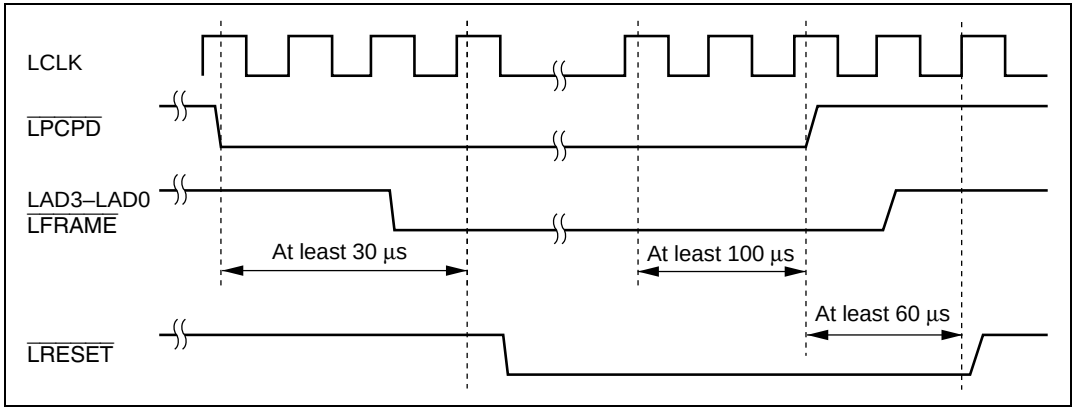


Figure 19.5 Power-Down State Termination Timing

19.4.5 Host Interface Serialized Interrupt Operation (SERIRQ)

A host interrupt request can be issued from the host interface by means of the SERIRQ pin. In a host interrupt request via the SERIRQ pin, LCLK cycles are counted from the start frame of the serialized interrupt transfer cycle generated by the host or a peripheral function, and a request signal is generated by the frame corresponding to that interrupt. The timing is shown in figure 19.6.

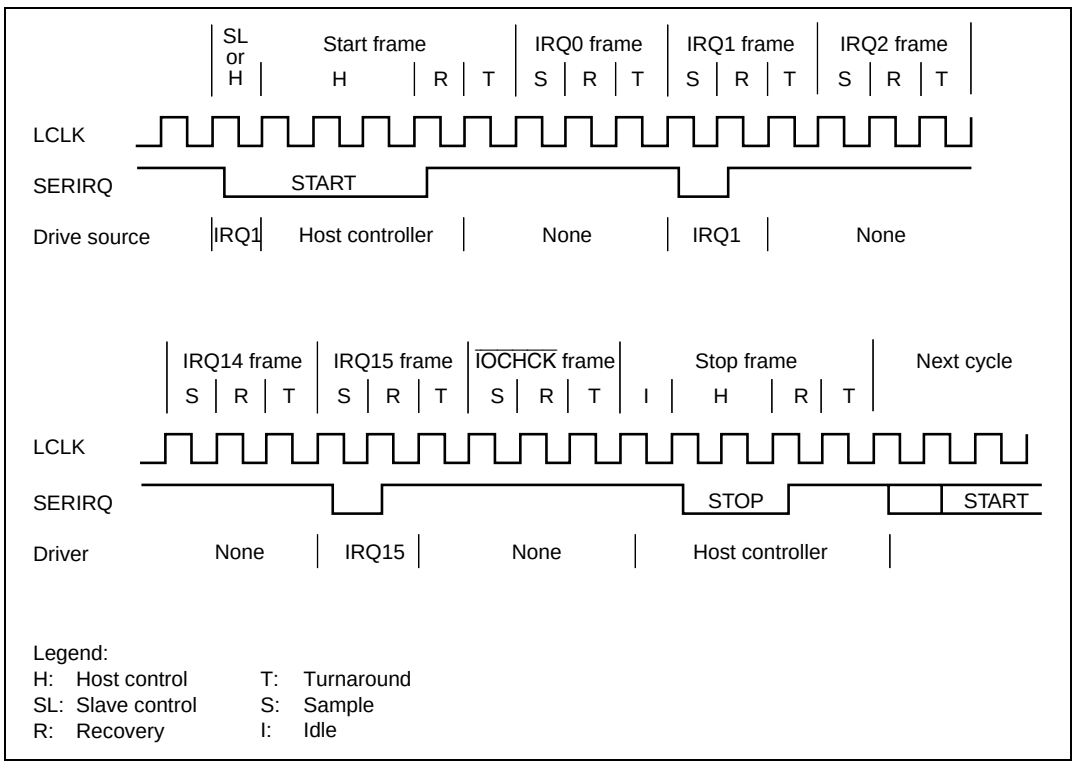


Figure 19.6 SERIRQ Timing

The serialized interrupt transfer cycle frame configuration is as follows. Two of the states comprising each frame are the recover state in which the SERIRQ signal is returned to the 1-level at the end of the frame, and the turnaround state in which the SERIRQ signal is not driven. The recover state must be driven by the host or slave processor that was driving the preceding state.

Serial Interrupt Transfer Cycle				
Frame Count	**Contents**	**Drive Source**	**Number of States**	**Notes**
0	Start	Slave Host	6	In quiet mode only, slave drive possible in first state, then next 3 states 0-driven by host
1	IRQ0	Slave	3	
2	IRQ1	Slave	3	Drive possible in LPC channel 1
3	SMI	Slave	3	Drive possible in LPC channels 2 and 3
4	IRQ3	Slave	3	
5	IRQ4	Slave	3	
6	IRQ5	Slave	3	
7	IRQ6	Slave	3	Drive possible in LPC channels 2 and 3
8	IRQ7	Slave	3	
9	IRQ8	Slave	3	
10	IRQ9	Slave	3	Drive possible in LPC channels 2 and 3
11	IRQ10	Slave	3	Drive possible in LPC channels 2 and 3
12	IRQ11	Slave	3	Drive possible in LPC channels 2 and 3
13	IRQ12	Slave	3	Drive possible in LPC channel 1
14	IRQ13	Slave	3	
15	IRQ14	Slave	3	
16	IRQ15	Slave	3	
17	IOCHCK	Slave	3	
18	Stop	Host	Undefined	First, 1 or more idle states, then 2 or 3 states 0-driven by host 2 states: Quiet mode next 3 states: Continuous mode next

There are two modes—continuous mode and quiet mode—for serialized interrupts. The mode initiated in the next transfer cycle is selected by the stop frame of the serialized interrupt transfer cycle that ended before that cycle.

In continuous mode, the host initiates host interrupt transfer cycles at regular intervals. In quiet mode, the slave processor with interrupt sources requiring a request can also initiate an interrupt transfer cycle, in addition to the host. In quiet mode, since the host does not necessarily initiate interrupt transfer cycles, it is possible to suspend the clock (LCLK) supply and enter the power-down state. In order for a slave to transfer an interrupt request in this case, a request to restart the

clock must first be issued to the host. For details see section 19.4.6, Host Interface Clock Start Request (CLKRUN).

19.4.6 Host Interface Clock Start Request (CLKRUN)

A request to restart the clock (LCLK) can be sent to the host processor by means of the $\overline{\text{CLKRUN}}$ pin. With LPC data transfer and SERIRQ in continuous mode, a clock restart is never requested since the transfer cycles are initiated by the host. With SERIRQ in quiet mode, when a host interrupt request is generated the $\overline{\text{CLKRUN}}$ signal is driven and a clock (LCLK) restart request is sent to the host. The timing for this operation is shown in figure 19.7.

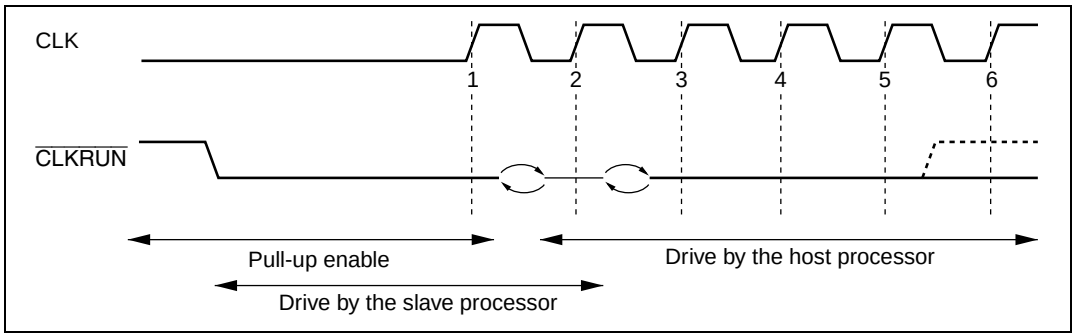


Figure 19.7 Clock Start Request Timing

Cases other than SERIRQ in quiet mode when clock restart is required must be handled with a different protocol, using the $\overline{\text{PME}}$ signal, etc.

19.5 Interrupt Sources

19.5.1 IBFI1 to IBFI3, and ERRI

The host interface has four interrupt requests for the slave processor (this LSI): IBF1 to IBF3, and ERRI. IBFI1 to IBFI3 are IDR receive complete interrupts for IDR1 to IDR3 and TWR, respectively. The ERRI interrupt indicates the occurrence of a special state such as an LPC reset, LPC shutdown, or transfer cycle abort. An interrupt request is enabled by setting the corresponding enable bit.

Table 19.7 Receive Complete Interrupts and Error Interrupt

Interrupt	Description
IBFI1	When IBFIE1 is set to 1 and IDR1 reception is completed
IBFI2	When IBFIE2 is set to 1 and IDR2 reception is completed
IBFI3	When IBFIE3 is set to 1 and IDR3 reception is completed, or when TWRE and IBFIE3 are set to 1 and reception is completed up to TWR15
ERRI	When ERRIE is set to 1 and one of LRST, SDWN and ABRT is set to 1

19.5.2 SMI, HIRQ1, HIRQ6, HIRQ9 to HIRQ12

The host interface can request seven kinds of host interrupt by means of SERIRQ. HIRQ1 and HIRQ12 are used on LPC channel 1 only, while SMI, HIRQ6, HIRQ9 to HIRQ11 can be requested from LPC channel 2 or 3.

There are two ways of clearing a host interrupt request.

When the IEDIR bit is cleared to 0 in SIRQCR0, host interrupt sources and LPC channels are all linked to the host interrupt request enable bits. When the OBF flag is cleared to 0 by a read of ODR or TWR15 by the host in the corresponding LPC channel, the corresponding host interrupt enable bit is automatically cleared to 0, and the host interrupt request is cleared.

When the IEDIR bit is set to 1 in SIRQCR0, LPC channel 2 and 3 interrupt requests are dependent only upon the host interrupt enable bits. The host interrupt enable bit is not cleared when OBF for channel 2 or 3 is cleared. Therefore, SMIE2, SMIE3A and SMIE3B, IRQ6E2 and IRQ6E3, IRQ9E2 and IRQ9E3, IRQ10E2 and IRQ10E3, and IRQ11E2 and IRQ11E3 lose their respective functional differences. In order to clear a host interrupt request, it is necessary to clear the host interrupt enable bit.

Table 19.8 summarizes the methods of setting and clearing these bits, and figure 19.8 shows the processing flowchart.

Table 19.8 HIRQ Setting and Clearing Conditions

Host Interrupt	Setting Condition	Clearing Condition
HIRQ1 (independent from IEDIR)	Internal CPU writes to ODR1, then reads 0 from bit IRQ1E1 and writes 1	Internal CPU writes 0 to bit IRQ1E1, or host reads ODR1
HIRQ12 (independent from IEDIR)	Internal CPU writes to ODR1, then reads 0 from bit IRQ12E1 and writes 1	Internal CPU writes 0 to bit IRQ12E1, or host reads ODR1
SMI (IEDIR = 0)	Internal CPU • writes to ODR2, then reads 0 from bit SMIE2 and writes 1 • writes to ODR3, then reads 0 from bit SMIE3A and writes 1 • writes to TWR15, then reads 0 from bit SMIE3B and writes 1	Internal CPU • writes 0 to bit SMIE2, or host reads ODR2 • writes 0 to bit SMIE3A, or host reads ODR3 • writes 0 to bit SMIE3B, or host reads TWR15
SMI (IEDIR = 1)	Internal CPU • reads 0 from bit SMIE2, then writes 1 • reads 0 from bit SMIE3A, then writes 1 • reads 0 from bit SMIE3B, then writes 1	Internal CPU • writes 0 to bit SMIE2 • writes 0 to bit SMIE3A • writes 0 to bit SMIE3B
HIRQi (i = 6, 9 to 11) (IEDIR = 0)	Internal CPU • writes to ODR2, then reads 0 from bit IRQiE2 and writes 1 • writes to ODR3, then reads 0 from bit IRQiE3 and writes 1	Internal CPU • writes 0 to bit IRQiE2, or host reads ODR2 • CPU writes 0 to bit IRQiE3, or host reads ODR3
HIRQi (i = 6, 9 to 11) (IEDIR = 1)	Internal CPU • reads 0 from bit IRQiE2, then writes 1 • reads 0 from bit IRQiE3, then writes 1	Internal CPU • writes 0 to bit IRQiE2 • writes 0 to bit IRQiE3

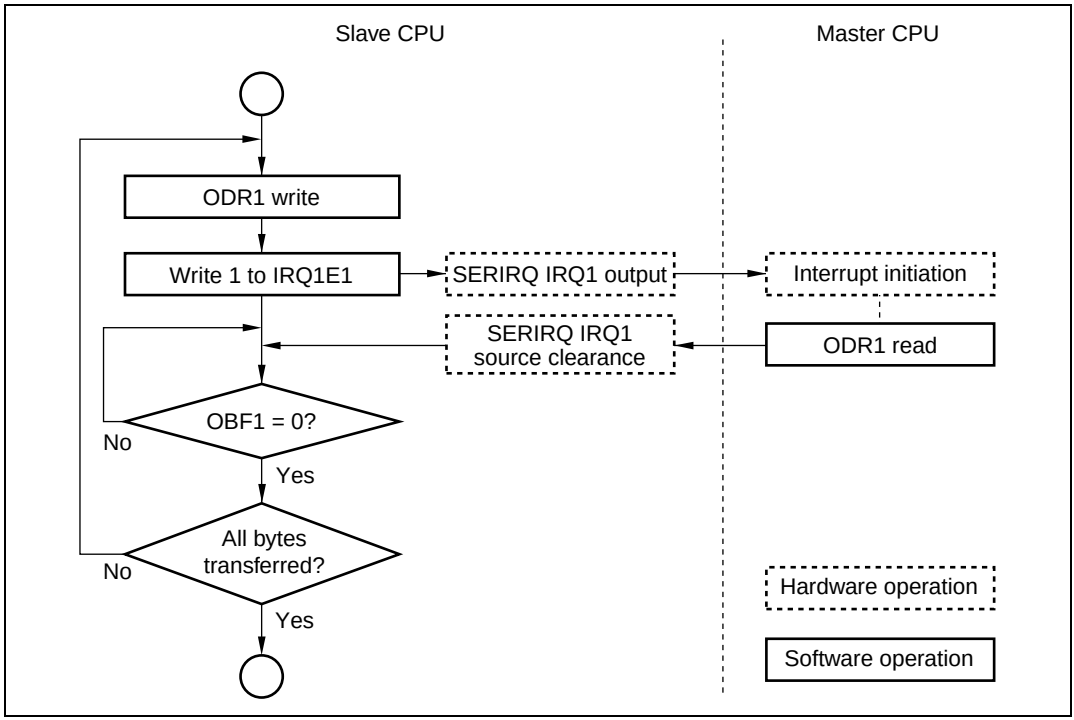


Figure 19.8 HIRQ Flowchart (Example of Channel 1)

19.6 Usage Notes

19.6.1 Module Stop Mode Setting

LPC operation can be enabled or disabled using the module stop control register. The initial setting is for LPC operation to be halted. Register access is enabled by canceling module stop mode. For details, refer to section 26, Power-Down Modes.

19.6.2 Notes on Using Host Interface

The host interface provides buffering of asynchronous data from the host processor and slave processor (this LSI), but an interface protocol that uses the flags in STR must be followed to avoid data contention. For example, if the host and slave processor both try to access IDR or ODR at the same time, the data will be corrupted. To prevent simultaneous accesses, IBF and OBF must be used to allow access only to data for which writing has finished.

Unlike the IDR and ODR registers, the transfer direction is not fixed for the bidirectional data registers (TWR). MWMF and SWMF are provided in STR to handle this situation. After writing to TWR0, MWMF and SWMF must be used to confirm that the write authority for TWR1 to TWR15 has been obtained.

Table 19.9 shows host address examples for LADR3 and registers, IDR3, ODR3, STR3, TWR0MW, TWR0SW, and TWR1 to TWR15 when LADR3 = H'A24F and LADR3 = H'3FD0.

Table 19.9 Host Address Example

Register	Host Address when LADR3 = H'A24F	Host Address when LADR3 = H'3FD0
IDR3	H'A24A and H'A24E	H'3FD0 and H'3FD4
ODR3	H'A24A	H'3FD0
STR3	H'A24E	H'3FD4
TWR0MW	H'A250	H'3FC0
TWR0SW	H'A250	H'3FC0
TWR1	H'A251	H'3FC1
TWR2	H'A252	H'3FC2
TWR3	H'A253	H'3FC3
TWR4	H'A254	H'3FC4
TWR5	H'A255	H'3FC5
TWR6	H'A256	H'3FC6
TWR7	H'A257	H'3FC7
TWR8	H'A258	H'3FC8
TWR9	H'A259	H'3FC9
TWR10	H'A25A	H'3FCA
TWR11	H'A25B	H'3FCB
TWR12	H'A25C	H'3FCC
TWR13	H'A25D	H'3FCD
TWR14	H'A25E	H'3FCE
TWR15	H'A25F	H'3FCF

Section 20 D/A Converter

20.1 Features

- 8-bit resolution
- Two output channels
- Conversion time: Max. 10 µs (when load capacitance is 20 pF)
- Output voltage: 0 V to AVref
- D/A output retaining function in software standby mode

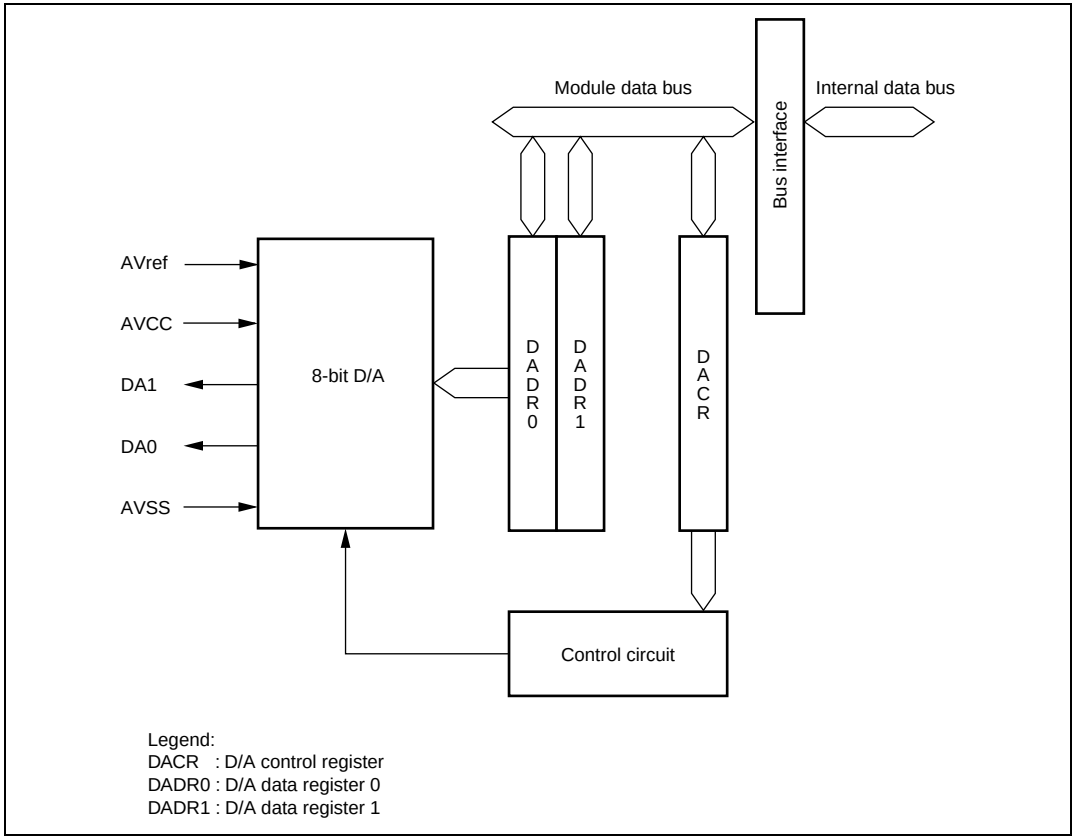


Figure 20.1 Block Diagram of D/A Converter

20.2 Input/Output Pins

Table 20.1 summarizes the input/output pins used by the D/A converter.

Table 20.1 Pin Configuration

Pin Name	Symbol	I/O	Function
Analog power supply pin	AVCC	Input	Analog block power supply
Analog ground pin	AVSS	Input	Analog block ground and reference voltage
Analog output pin 0	DA0	Output	Channel 0 analog output
Analog output pin 1	DA1	Output	Channel 1 analog output
Reference power supply pin	AVref	Input	Analog block reference voltage

20.3 Register Descriptions

The D/A converter has the following registers.

- D/A data register 0 (DADR0)
- D/A data register 1 (DADR1)
- D/A control register (DACR)

20.3.1 D/A Data Registers 0 and 1 (DADR0, 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. DADR0 and DADR1 are initialized to H'00.

20.3.2 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 is controlled individually. When the DAE bit 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 20.2 below.
4 to 0	—	All 1	R	Reserved These bits are always read as 1 and cannot be modified.

Table 20.2 D/A Channel Enable

Bit 7	Bit 6	Bit 5	
DAOE1	**DAOE0**	**DAE**	**Description**
0	0	—	Disables D/A conversion
	1	0	Enables D/A conversion for channel 0
			Disables D/A conversion for channel 1
		1	Enables D/A conversion for channels 0 and 1
1	0	0	Disables D/A conversion for channel 0
			Enables D/A conversion for channel 1
		1	Enables D/A conversion for channels 0 and 1
	1	—	Enables D/A conversion for channels 0 and 1

20.4 Operation

The D/A converter incorporates two channels of the D/A circuits and can be converted individually.

When the DAOE bit in DACR is set to 1, D/A conversion is enabled and conversion results are output.

An example of D/A conversion of channel 0 is shown below. The operation timing is shown in figure 20.2.

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}, conversion results are output from the analog output pin DA0. The conversion results are output continuously until DADR0 is modified or the DAOE0 bit is cleared to 0. The output value is calculated by the following formula:

   DADR contents/256 × AVref

3. Conversion starts immediately after DADR0 is modified. After the interval of t_{DCONV}, conversion results are output.
4. When the DAOE0 bit is cleared to 0, analog output is disabled.

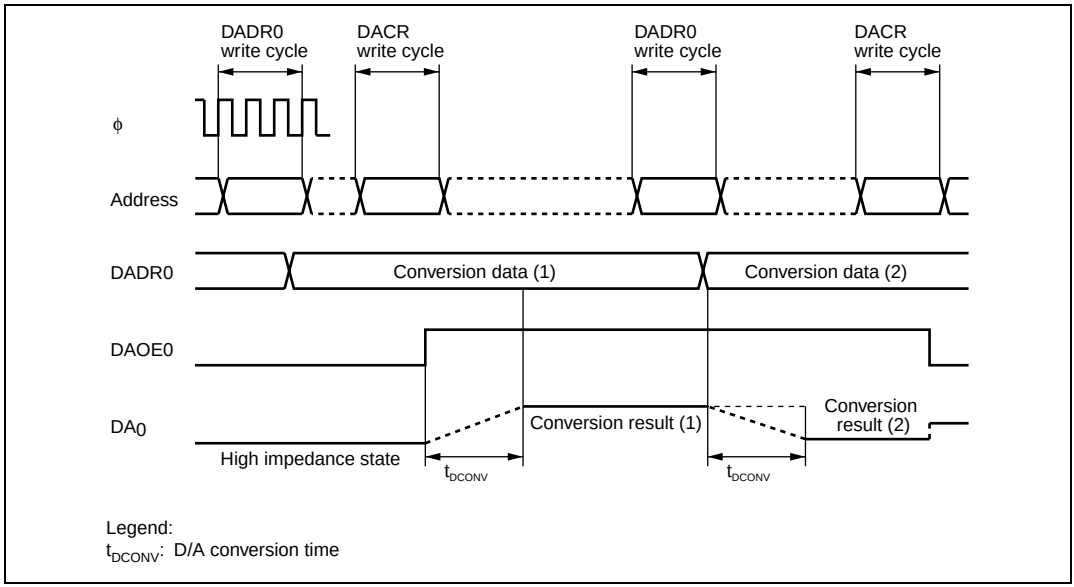


Figure 20.2 D/A Converter Operation Example

20.5 Usage Note

When this LSI enters software standby mode with D/A conversion enabled, the D/A output is retained, and the analog power supply current is equal to as during D/A conversion. If the analog power supply current needs to be reduced in software standby mode, clear the DAOE1, DAOE0, and DAE bits all to 0 to disable D/A output.

20.5.1 Module Stop Mode Setting

D/A converter operation can be enabled or disabled using the module stop control register. The initial setting is for D/A converter operation to be halted. Register access is enabled by canceling module stop mode. For details, refer to section 26, Power-Down Modes.

Section 21 A/D Converter

This LSI includes a successive-approximation-type 10-bit A/D converter that allows up to eight analog input channels and up to 16 digital input to be selected. A/D conversion for digital input is effective as a comparator in multiple input testing.

21.1 Features

- 10-bit resolution
- Input channels: eight analog input channels and 16 digital input channels
- Analog conversion voltage range can be specified using the reference power supply voltage pin (AVref) as an analog reference voltage.
- Conversion time: 13.4 µs per channel (at 10-MHz operation)
- Two kinds of 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 kinds of conversion start
  - Software, 8-bit timer (TMR) conversion start trigger, or external trigger signal.
- Interrupt request
  - A/D conversion end interrupt (ADI) request can be generated

A block diagram of the A/D converter is shown in figure 21.1.

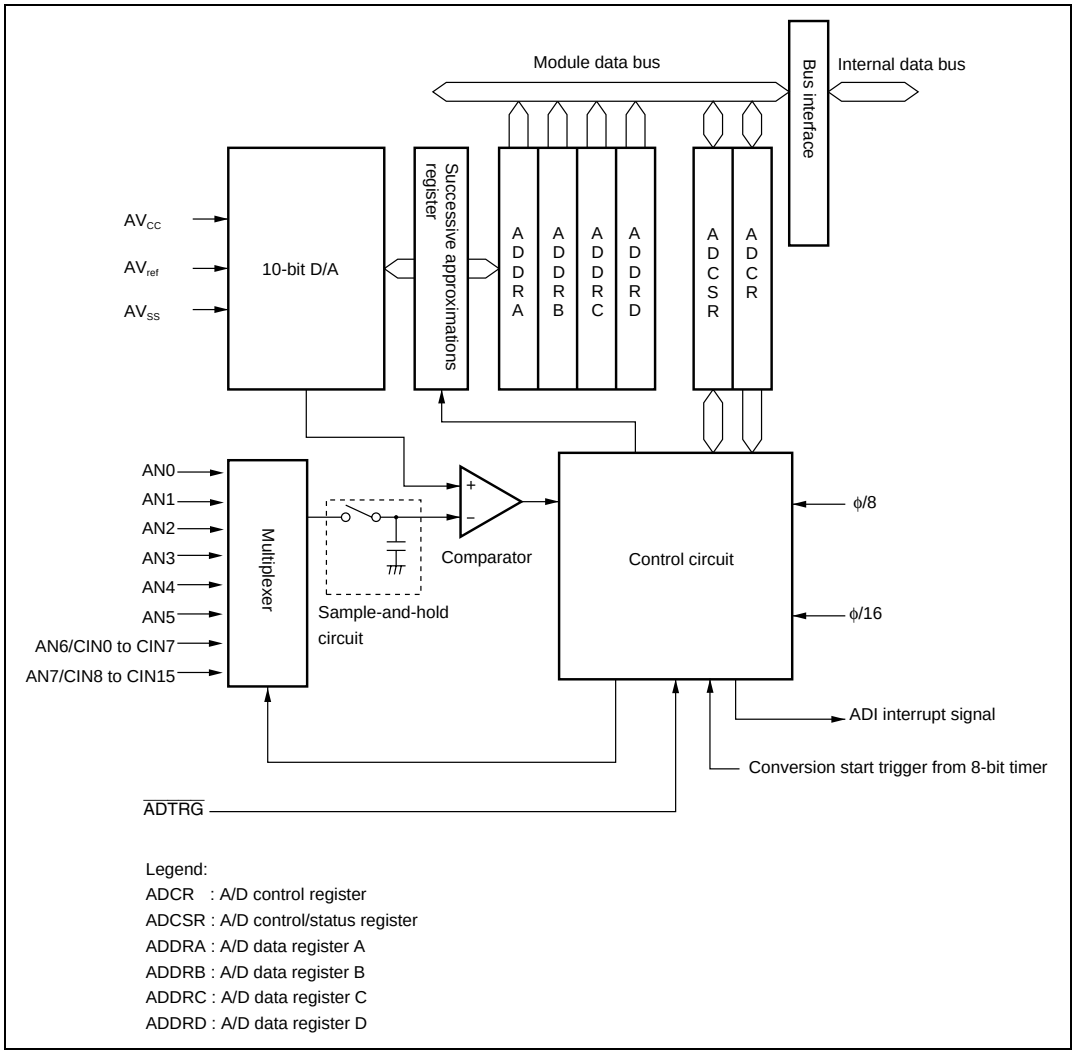


Figure 21.1 Block Diagram of A/D Converter

21.2 Input/Output Pins

Table 21.1 summarizes the pins used by the A/D converter. The 8 analog input pins are divided into two groups consisting 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. Expanded A/D conversion input pins (CIN0 to CIN15) can be selected with the AN6 and AN7 pins. The AVcc and AVss pins are the power supply pins for the analog block in the A/D converter.

Table 21.1 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 power supply pin	AVref	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	$\overline{\text{ADTRG}}$	Input	External trigger input pin for starting A/D conversion
Expanded A/D conversion input pins 0 to 15	CIN0 to CIN15	Input	Expanded A/D conversion input (digital input) channels 0 to 15 Can be used as digital input pins

21.3 Register Descriptions

The A/D converter has the following registers.

- 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)
- Keyboard comparator control register (KBCOMP)

21.3.1 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 21.2.

The converted 10-bit data is stored to bits 15 to 6. The lower 6-bit data is always read as 0.

The data bus between the CPU and the A/D converter is 8-bit width. The upper byte can be read directly from the CPU, but the lower byte should be read via a temporary register. The temporary register contents are transferred from the ADDR when the upper byte data is read. When reading the ADDR, read the upper byte before lower byte or in word units.

Table 21.2 Analog Input Channels and Corresponding ADDR Registers

Analog Input Channel		A/D Data Register to Store A/D Conversion Results
Group 0	**Group 1**	
AN0	AN4	ADDRA
An1	AN5	ADDRB
AN2	AN6, or CIN0 to CIN7	ADDRC
AN3	AN7, or CIN8 to CIN15	ADDRD

21.3.2 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 channels specified in scan mode [Clearing conditions] • When 0 is written after reading ADF = 1 • When DTC starts by an ADI interrupt and ADDR is read
6	ADIE	0	R/W	A/D Interrupt Enable Enables ADI interrupt by ADF when this bit is set to 1
5	ADST	0	R/W	A/D Start Setting this bit to 1 starts A/D conversion. Clearing this bit to 0 stops A/D conversion. In single mode, this bit is cleared to 0 automatically when conversion on the specified channel ends. In scan mode, conversion continues sequentially on the specified channels until this bit is cleared to 0 by software, a reset, or a transition to standby mode or module stop mode.
4	SCAN	0	R/W	Scan Mode Selects the A/D conversion operating mode. The setting of this bit must be made when conversion is halted (ADST = 0). 0: Single mode 1: Scan mode
3	CKS	0	R/W	Clock Select Sets A/D conversion time. The input channel setting must be made when conversion is halted (ADST = 0). 0: Conversion time is 266 states (max) 1: Conversion time is 134 states (max) Switch conversion time while ADST is 0.

Bit	Bit Name	Initial Value	R/W	Description	
2	CH2	0	R/W	Channel Select 2 to 0	
1	CH1	0	R/W	Select analog input channels. The input channel setting must be made when conversion is halted (ADST = 0).	
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, or CIN0 to CIN7	110: AN4 to AN6 or CIN0 to CIN7
				111: AN7, or CIN8 to CIN15	111: AN4 to AN6 or CIN0 to CIN7, or AN7 or CIN8 to CIN15

Note: * Only 0 can be written for clearing the flag.

21.3.3 A/D Control Register (ADCR)

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 1 and 0
6	TRGS0	0	R/W	Enable the start of A/D conversion by a trigger signal. Only set bits TRGS1 and TRGS0 when conversion is halted (ADST = 0).
				00: A/D conversion start by external trigger is disabled
				01: A/D conversion start by external trigger is disabled
				10: A/D conversion start by conversion trigger from TMR is enabled
				11: A/D conversion start by $\overline{\text{ADTRG}}$ pin is enabled
5 to 0	—	All 1	R	Reserved
				These bits are always read as 1 and cannot be modified.

21.3.4 Keyboard Comparator Control Register (KBCOMP)

KBCOMP selects the CIN input channel for which A/D conversion is performed and enables or disables the comparator scan function of CIN7 to CIN0.

Bit	Bit Name	Initial Value	R/W	Description
7	IrE	0	R/W	These bits are related to the SCI. For details, refer to section 15.3.10, Keyboard Comparator Control Register (KBCOMP).
6	IrCKS2	0	R/W	
5	IrCKS1	0	R/W	
4	IrCKS0	0	R/W	
3	KBADE	0	R/W	Keyboard A/D Enable (AN6, AN7) Selects whether channels 6 and 7 of the A/D converter are used as analog pins or digital pins, in combination with the KBCH2 to KBCH0 bits. For details, refer to description for bits 2 to 0. Analog pins of the A/D converter are set to digital pins (CIN0 to CIN7 and CIN8 to CIN15).
2	KBCH2	0	R/W	Keyboard A/D Channel Select 2 to 0
1	KBCH1	0	R/W	These bits select a channel of digital input pins for A/D conversion, in combination with the KBADE bit. The input channel setting must be made while conversion is halted.
0	KBCH0	0	R/W	Channel 6 — Channel 7 0xxx: Selects AN6 — AN7 1000: Selects CIN0 — CIN8 1001: Selects CIN1 — CIN9 1010: Selects CIN2 — CIN10 1011: Selects CIN3 — CIN11 1100: Selects CIN4 — CIN12 1101: Selects CIN5 — CIN13 1110: Selects CIN6 — CIN14 1111: Selects CIN7 — CIN15

Legend:

x: Don’t care

21.4 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, to prevent incorrect operation, first clear the ADST bit to 0 in ADCSR to halt A/D conversion. The ADST bit can be set at the same time as the operating mode or analog input channel is changed.

21.4.1 Single Mode

In single mode, A/D conversion is to be performed only once on the specified single channel. Operations are as follows.

1. A/D conversion on the specified channel is started when the ADST bit in ADCSR is set to 1, by software or an external trigger input.
2. When A/D conversion is completed, the result is transferred to the A/D data register corresponding to the channel.
3. On completion of A/D 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 conversion ends, the ADST bit is automatically cleared to 0, and the A/D converter enters wait state.

21.4.2 Scan Mode

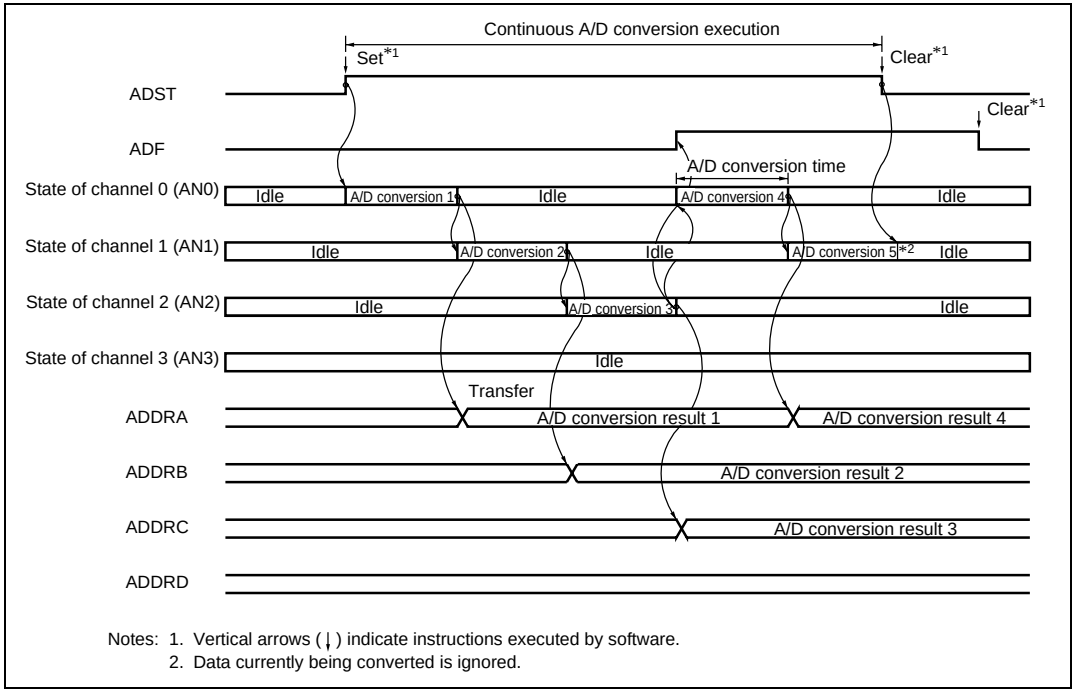
Scan mode is useful for monitoring analog inputs in a group of one or more channels. When the ADST bit is set to 1 by software, or by timer or external trigger input, A/D conversion starts on the first channel in the group (AN0 when CH2 = 0; AN4 when CH2 = 1).

When two or more channels are selected, after conversion of the first channel ends, conversion of the second channel (AN1 or AN5) starts immediately. A/D conversion continues cyclically on the selected channels until the ADST bit is cleared to 0. The conversion results are transferred for storage into the ADDR registers corresponding to the channels.

Typical operations when three channels (AN0 to AN2) are selected in scan mode are described below.

Figure 21.2 shows the operation timing.

1. Scan mode is selected (SCAN = 1), scan group 0 is selected (CH2 = 0), analog input channels AN0 to AN2 are selected (CH1 = 1, CH0 = 0), and A/D conversion is started (ADST = 1).
2. When A/D conversion of the first channel (AN0) is completed, the result is transferred to ADDRA. Next, conversion of the second channel (AN1) starts automatically.
3. Conversion proceeds in the same way through the third channel (AN2).
4. When conversion of all the selected channels (AN0 to AN2) is completed, the ADF flag is set to 1 and conversion of the first channel (AN0) starts again. If the ADIE bit is set to 1 at this time, an ADI interrupt is requested after A/D conversion ends.
5. Steps 2 to 4 are repeated as long as the ADST bit remains set to 1. When the ADST bit is cleared to 0, A/D conversion stops. After that, if the ADST bit is set to 1, A/D conversion starts again from the first channel (AN0).



Notes: 1. Vertical arrows (↓) indicate instructions executed by software.
2. Data currently being converted is ignored.

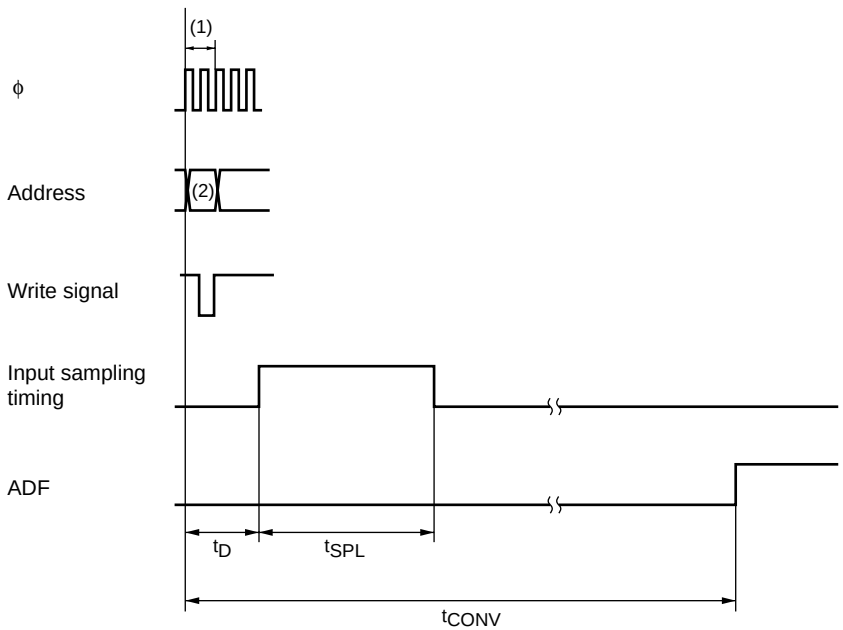
Figure 21.2 Example of A/D Converter Operation (Scan Mode, Channels AN0 to AN2 Selected)

21.4.3 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) passes after the ADST bit in ADCSR is set to 1, then starts A/D conversion. Figure 21.3 shows the A/D conversion timing. Table 21.3 indicates the A/D conversion time.

As indicated in figure 21.3, 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 21.3.

In scan mode, the values given in table 21.3 apply to the first conversion time. In the second and subsequent conversions, the conversion time is 256 state (fixed) when CKS = 0 and 128 states (fixed) when CKS = 1.



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 21.3 A/D Conversion Timing

Table 21.3 A/D Conversion Time (Single Mode)

		CKS = 0			CKS = 1		
Item	**Symbol**	**min**	**typ**	**max**	**min**	**typ**	**max**
A/D conversion start delay time	t_D	10	—	17	6	—	9
Input sampling time	t_{SPL}	—	63	—	—	31	—
A/D conversion time	t_{CONV}	259	—	266	131	—	134

Note: * Values in the table indicate the number of states.

21.4.4 External Trigger Input Timing

A/D conversion can be externally triggered. When the TRGS1 and TRGS0 bits are set to B'11 in ADCR, external trigger input is enabled at the $\overline{\text{ADTRG}}$ pin. A falling edge at the $\overline{\text{ADTRG}}$ pin sets the ADST bit to 1 in ADCSR, starting A/D conversion. Other operations, in both single and scan modes, are the same as when the ADST bit has been set to 1 by software. Figure 21.4 shows the timing.

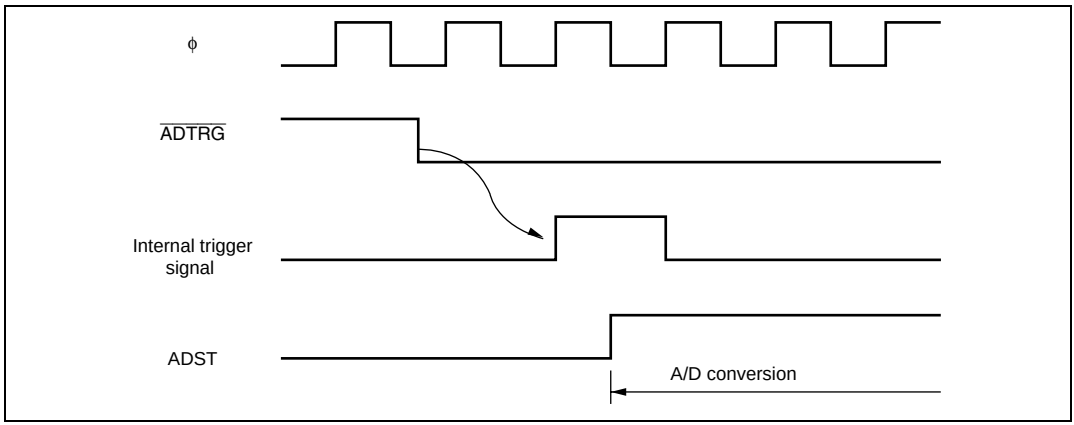


Figure 21.4 External Trigger Input Timing

21.5 Interrupt Sources

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 ADF bit in ADCSR is set to 1 after A/D conversion is completed.

21.6 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 21.5).
- 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 21.6).
- 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 21.6).
- Nonlinearity error

  The error with respect to the ideal A/D conversion characteristics between the zero voltage and the full-scale voltage. Does not include the offset error, full-scale error, or quantization error (see figure 21.6).
- Absolute accuracy

  The deviation between the digital value and the analog input value. Includes the offset error, full-scale error, quantization error, and nonlinearity error.

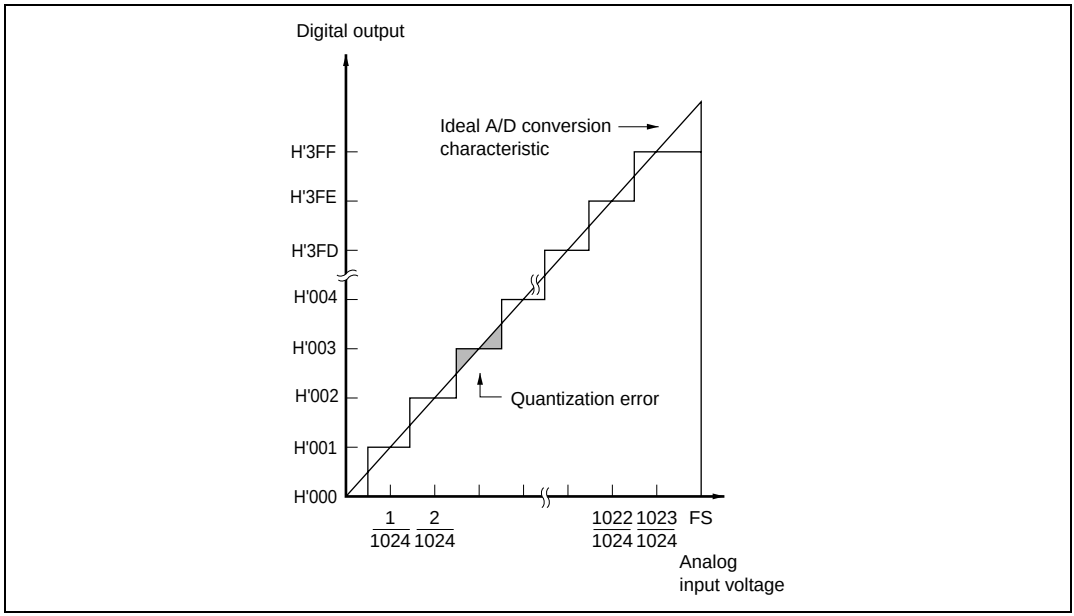


Figure 21.5 A/D Conversion Accuracy Definitions

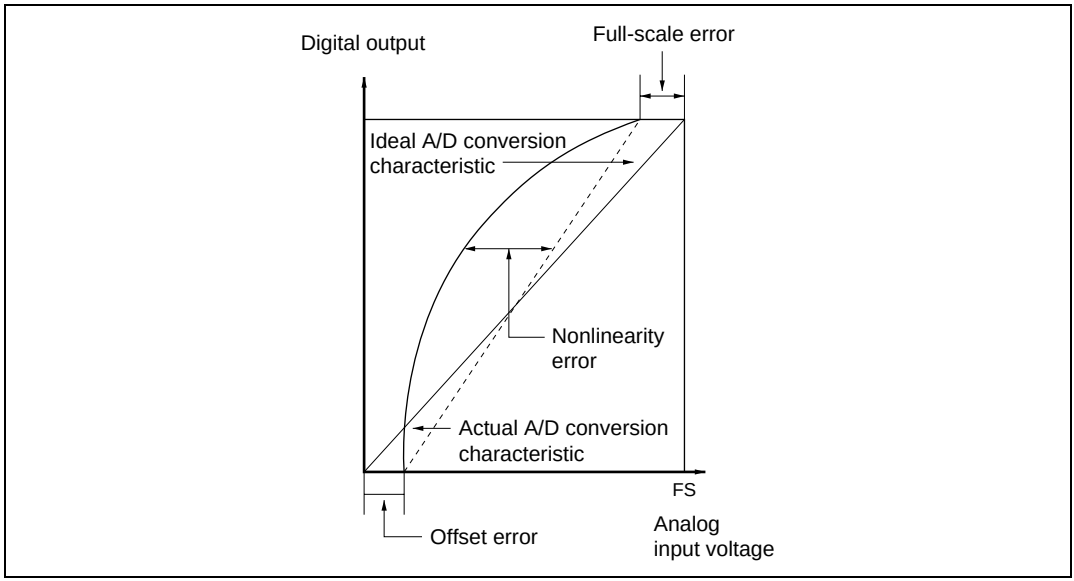


Figure 21.6 A/D Conversion Accuracy Definitions

21.7 Usage Notes

21.7.1 Permissible Signal Source Impedance

This LSI's analog input (3-V version) is designed so that the 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 the A/D conversion accuracy. However, if a large capacitance is provided externally in single mode, the input load will essentially comprise only the internal input resistance of 10 kΩ, and the signal source impedance is ignored. However, since a low-pass filter effect is obtained in this case, it may not be possible to follow an analog signal with a large differential coefficient (e.g., voltage fluctuation ratio of 5 mV/µs or greater) (see figure 21.7). When converting a high-speed analog signal or converting in scan mode, a low-impedance buffer should be inserted. For details on the 5-V version, refer to section 28, Electrical Characteristics.

21.7.2 Influences on Absolute Accuracy

Adding capacitance results in coupling with ground, and therefore noise in ground may adversely affect the absolute accuracy. Be sure to make the connection to an electrically stable ground such as AVss.

Care is also required to insure that filter circuits do not communicate with digital signals on the mounting board, so acting as antennas.

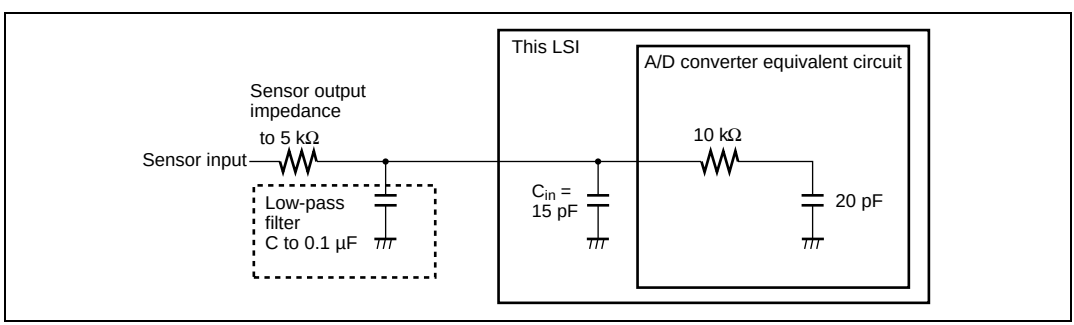


Figure 21.7 Example of Analog Input Circuit

21.7.3 Setting Range of Analog Power Supply and Other Pins

If conditions shown below are not met, the reliability of this LSI 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 ≤ AVref (n = 0 to 7).
- Digital input voltage range
  The voltage applied to digital input pin CINn should be in the range AVss ≤ CINn ≤ AVref and Vss ≤ CINn ≤ Vcc (n = 0 to 15).
- Relation between AVcc, AVss and Vcc, Vss
  For the relationship between AVcc, AVss and Vcc, Vss, set AVss = Vss. If the A/D converter is not used, the AVcc and AVss pins must on no account be left open.
- AVref pin reference voltage specification range
  The reference voltage of the AVref pin should be in the range AVref ≤ AVcc.

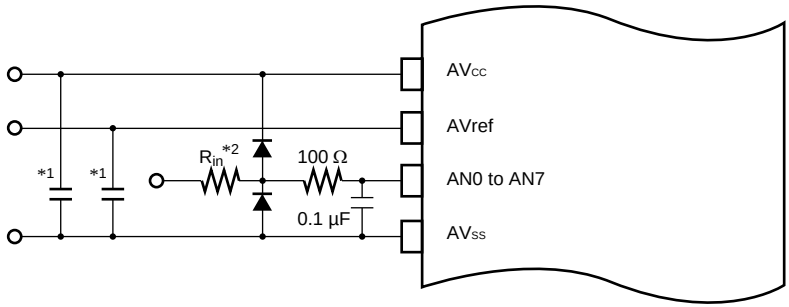
21.7.4 Notes on Board Design

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), analog reference voltage (AV_{ref}), and analog power supply (AV_{CC}) by the analog ground (AV_{SS}). Also, the analog ground (AV_{SS}) should be connected at one point to a stable digital ground (V_{SS}) on the board.

21.7.5 Notes on Noise Countermeasures

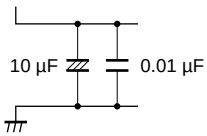
A protection circuit connected to prevent damage due to an abnormal voltage such as an excessive surge at the analog input pins (AN0 to AN7) and analog reference voltage (AV_{ref}) should be connected between AVcc and AVss as shown in figure 21.8. Also, the bypass capacitors connected to AVcc and AV_{ref}, and the filter capacitor connected to AN2 to AN7, must be connected to AV_{SS}.

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 the circuit constants.



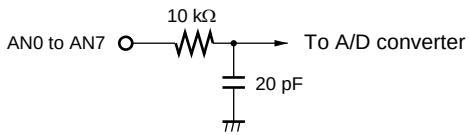
Notes: Values are reference values.

1.



2. R_{in}: Input impedance

Figure 21.8 Example of Analog Input Protection Circuit



Note: Values are reference values.

Figure 21.9 Equivalent Circuit of Analog Input Pin

21.7.6 Module Stop Mode Setting

A/D converter operation can be enabled or disabled using the module stop control register. The initial setting is for A/D converter operation to be halted. Register access is enabled by canceling module stop mode. For details, refer to section 26, Power-Down Modes.

Section 22 RAM

This LSI has an 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.

The on-chip RAM can be enabled or disabled by means of the RAME bit in the system control register (SYSCR). For details on SYSCR, refer to section 3.2.2, System Control Register (SYSCR).

Product Classification		RAM Capacitance	RAM Address
Flash memory version	H8S/2161B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2160B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2141B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2140B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F
	H8S/2145B	8 kbytes	H'D080–H'EFFF, H'FF00–H'FF7F
	H8S/2148B	4 kbytes	H'E080–H'EFFF, H'FF00–H'FF7F

Section 23 ROM

This LSI has an on-chip flash memory. The features of the flash memory are summarized below.

A block diagram of the flash memory is shown in figure 23.1.

23.1 Features

- Size

Product Classification	RAM Capacitance	RAM Address
H8S/2161B	128 kbytes	H'000000–H'01FFFF (mode 2) H'0000–H'DFFF (mode 3)
H8S/2160B	64 kbytes	H'000000–H'00FFFF (mode 2) H'0000–H'DFFF (mode 3)
H8S/2141B	128 kbytes	H'000000–H'01FFFF (mode 2) H'0000–H'DFFF (mode 3)
H8S/2140B	64 kbytes	H'000000–H'00FFFF (mode 2) H'0000–H'DFFF (mode 3)
H8S/2145B	256 kbytes	H'000000–H'03FFFF (mode 2) H'0000–H'DFFF (mode 3)
H8S/2148B	128 kbytes	H'000000–H'01FFFF (mode 2) H'0000–H'DFFF (mode 3)

- Programming/erase methods

  The flash memory is programmed 128 bytes at a time. Erase is performed in single-block units. The flash memory is configured as follows:

  — 64-kbyte version: 8 kbytes × 2 blocks, 16 kbytes × 1 block, 28 kbytes × 1 block, and 1 kbyte × 4 blocks

  — 128-kbyte version: 32 kbytes × 2 blocks, 8 kbytes × 2 blocks, 16 kbytes × 1 block, 28 kbytes × 1 block, and 1 kbyte × 4 blocks

  — 256-kbyte version: 64 kbytes × 3 blocks, 32 kbytes × 1 block, and 4 kbytes × 8 blocks.

  To erase the entire flash memory, each block must be erased in turn.

- Programming/erase time

  It takes 10 ms (typ.) to program the flash memory 128 bytes at a time; 80 µs (typ.) per 1 byte. Erasing one block takes 100 ms (typ.).

- Reprogramming capability

  The flash memory can be reprogrammed up to 100 times.
- Two flash memory on-board 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 for erase or programming of the entire flash memory. In user program mode, individual blocks can be erased or programmed.
- Automatic bit rate adjustment

  With 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

  Sets protection against flash memory programming/erasing via hardware, software, or error protection.
- Programmer mode

  In addition to on-board programming mode, programmer mode is supported to program or erase the flash memory using a PROM programmer.

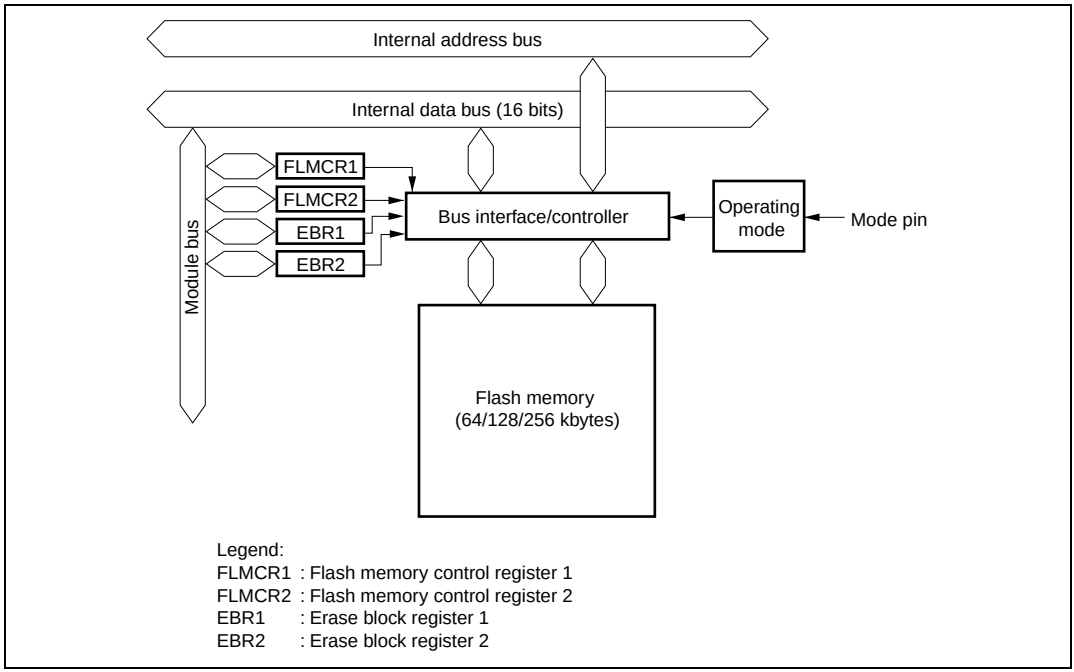


Figure 23.1 Block Diagram of Flash Memory

23.2 Mode Transitions

When the mode pins are set in the reset state and a reset-start is executed, this LSI enters an operating mode as shown in figure 23.2. 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 23.1. Figure 23.3 shows the boot mode and figure 23.4 shows the user program mode.

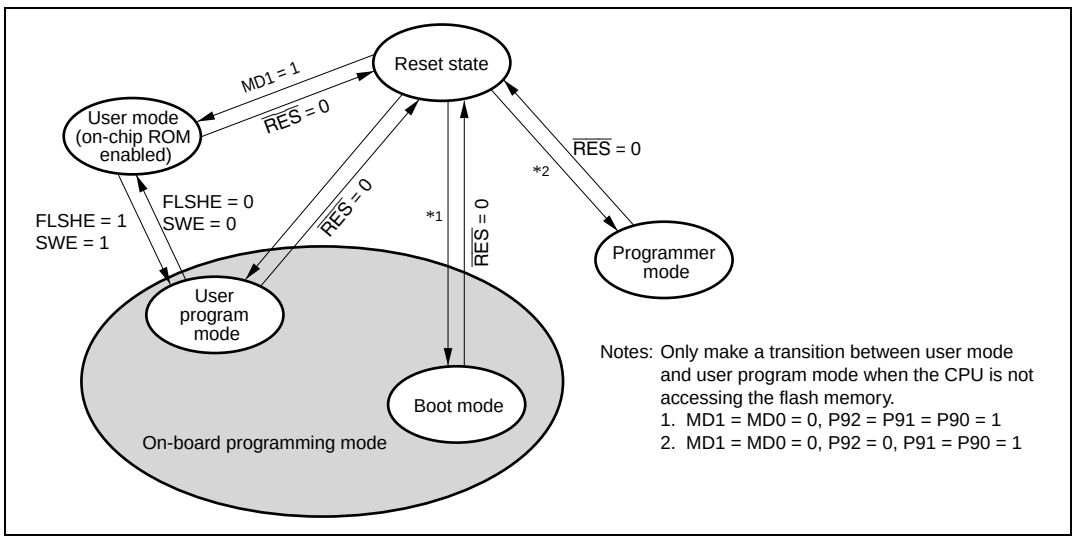


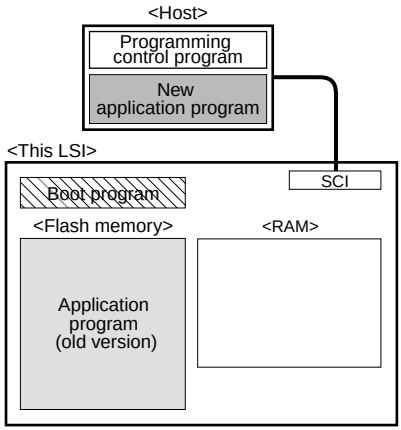
Figure 23.2 Flash Memory State Transitions

Table 23.1 Differences between Boot Mode and User Program Mode

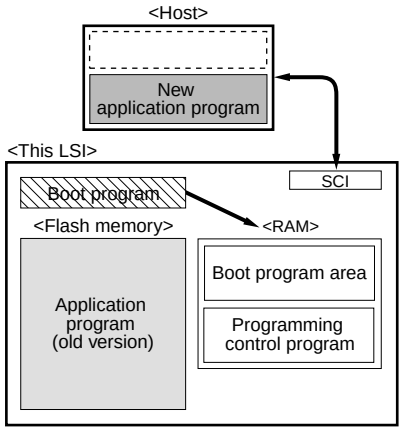
	Boot Mode	User Program Mode
Total erase	Yes	Yes
Block erase	No	Yes
Programming control program*	Program/program-verify	Program/program-verify Erase/erase-verify

Note: * Should be provided by the user, in accordance with the recommended algorithm.

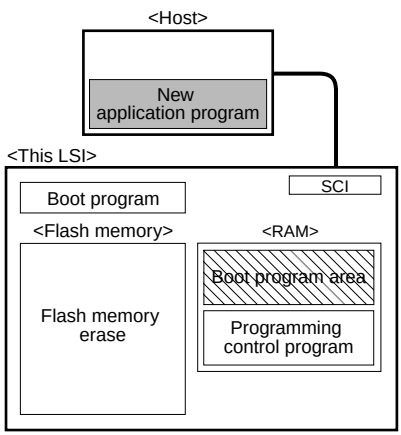
1. Initial state
The flash memory is erased at shipment. The following describes how to write over an old-version application program or data in the flash memory. The user should prepare the programming control program and new application program beforehand in the host.



2. SCI communication check
When boot mode is entered, the boot program in this LSI (originally incorporated in the chip) is started and SCI communication is checked. Then 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 via SCI communication is executed, and the new application program in the host is written into the flash memory.

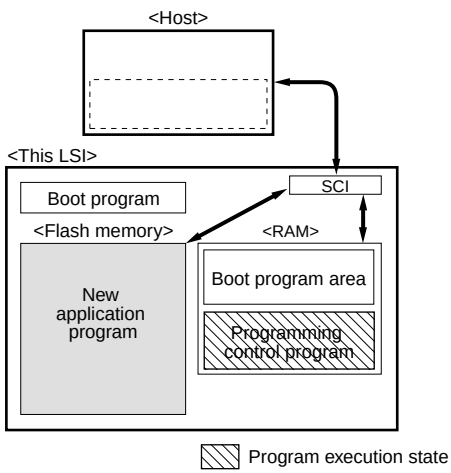
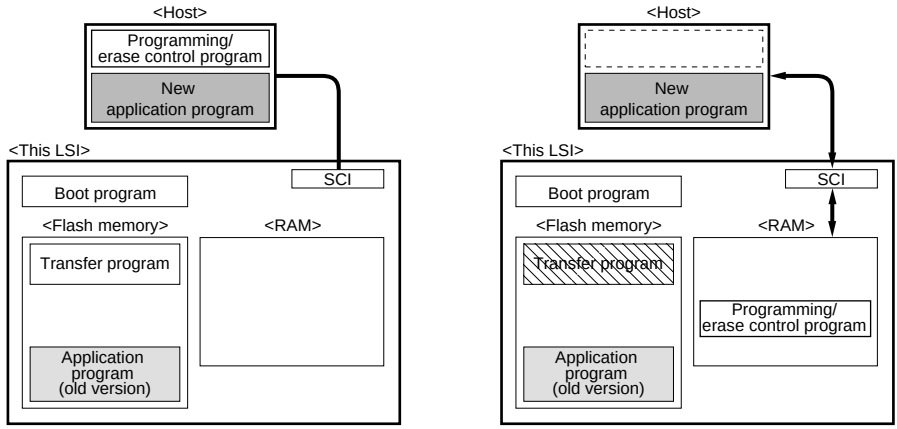


Figure 23.3 Boot Mode

1. Initial state
   (1) 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.
   (2) The programming/erase control program should be prepared in the host or in the flash memory.

2. Programming/erase control program transfer
   The transfer program in the flash memory is executed and the programming/erase control program is transferred 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.

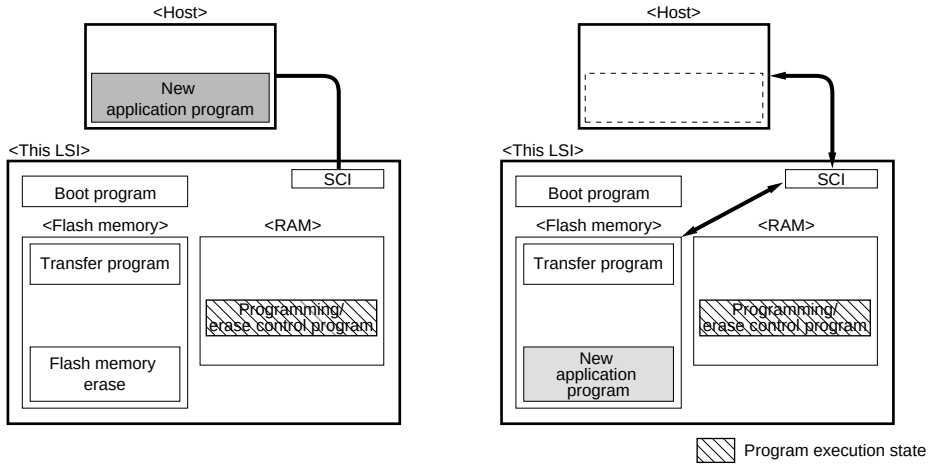


Figure 23.4 User Program Mode (Example)

23.3 Block Configuration

23.3.1 Block Configuration of 64-Kbyte Flash Memory

Figure 23.5 shows the block configuration of 64-kbyte flash memory. The thick lines indicate erasing units, the narrow lines indicate programming units, and the values are addresses. The flash memory is divided into 8 kbytes (2 blocks), 16 kbytes (1 block), 28 kbytes (1 block), and 1 kbyte (4 blocks). Erasing is performed in these divided units. Programming is performed in 128-byte units starting from an address whose lower bits are H'00 or H'80.

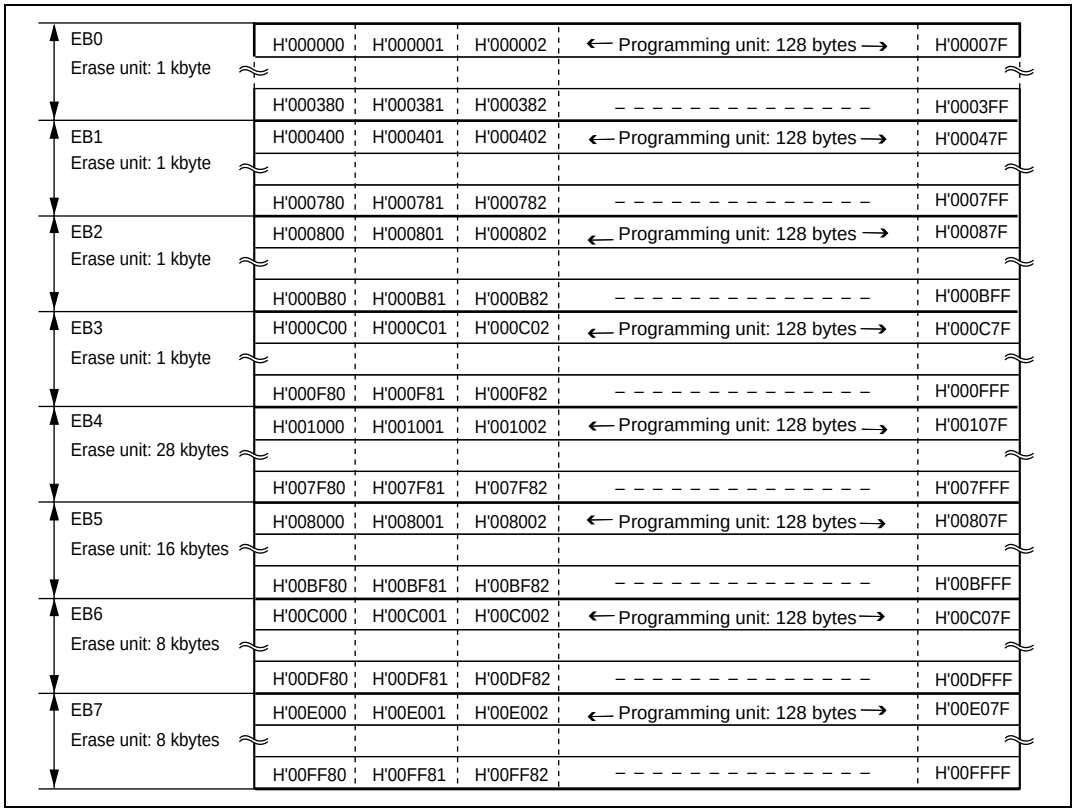


Figure 23.5 64-Kbyte Flash Memory Block Configuration

23.3.2 Block Configuration of 128-Kbyte Flash Memory

Figure 23.6 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 flash memory is divided into 32 kbytes (2 blocks), 8 kbytes (2 blocks), 16 kbytes (1 block), 28 kbytes (1 block), and 1 kbyte (4 blocks). Erasing is performed in these divided units. Programming is performed in 128-byte units starting from an address whose lower bits are H'00 or H'80.

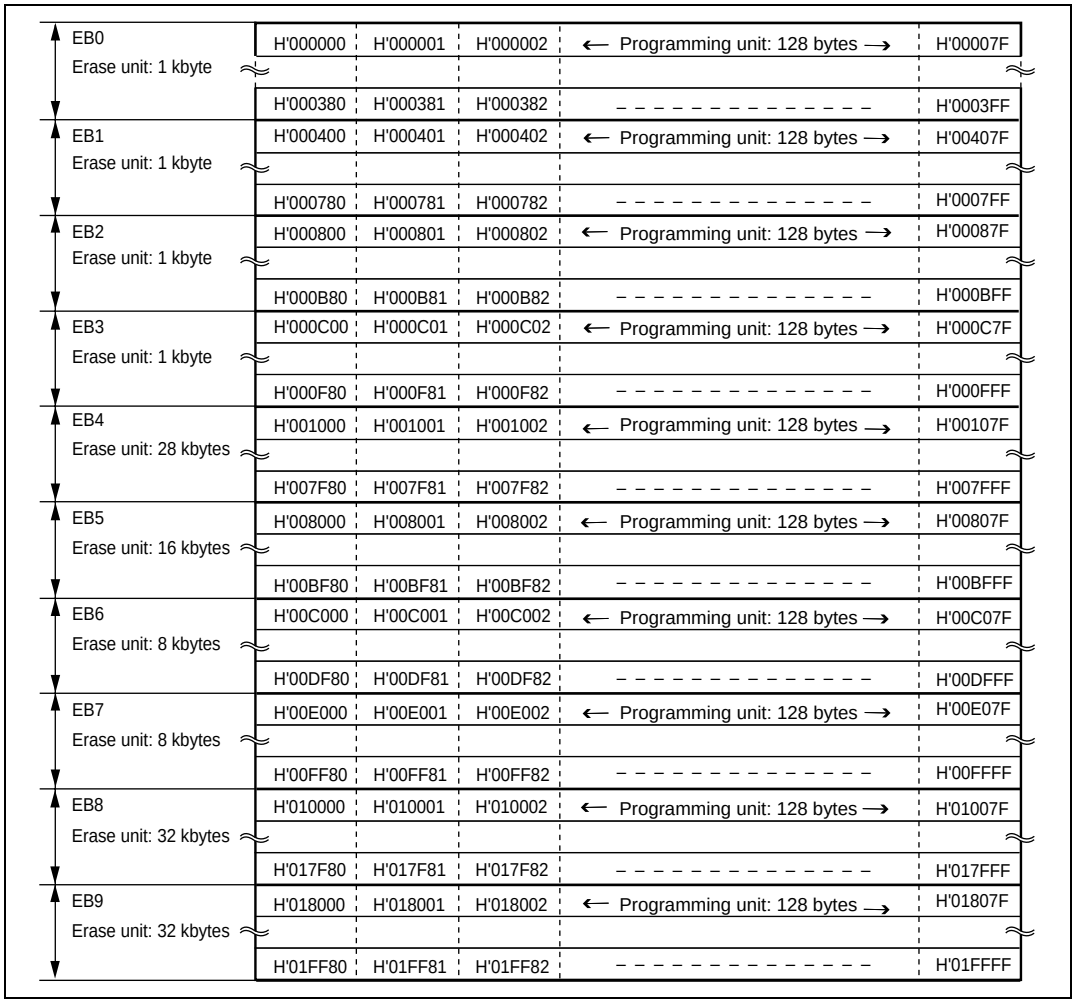


Figure 23.6 128-Kbyte Flash Memory Block Configuration

23.3.3 Block Configuration of 256-Kbyte Flash Memory

Figure 23.7 shows the block configuration of 256-kbyte flash memory. The thick lines indicate erasing units, the narrow lines indicate programming units, and the values are addresses. The flash memory is divided into 64 kbytes (3 blocks), 32 kbytes (1 block), and 4 kbytes (8 blocks). Erasing is performed in these divided units. Programming is performed in 128-byte units starting from an address whose lower bits are H'00 or H'80.

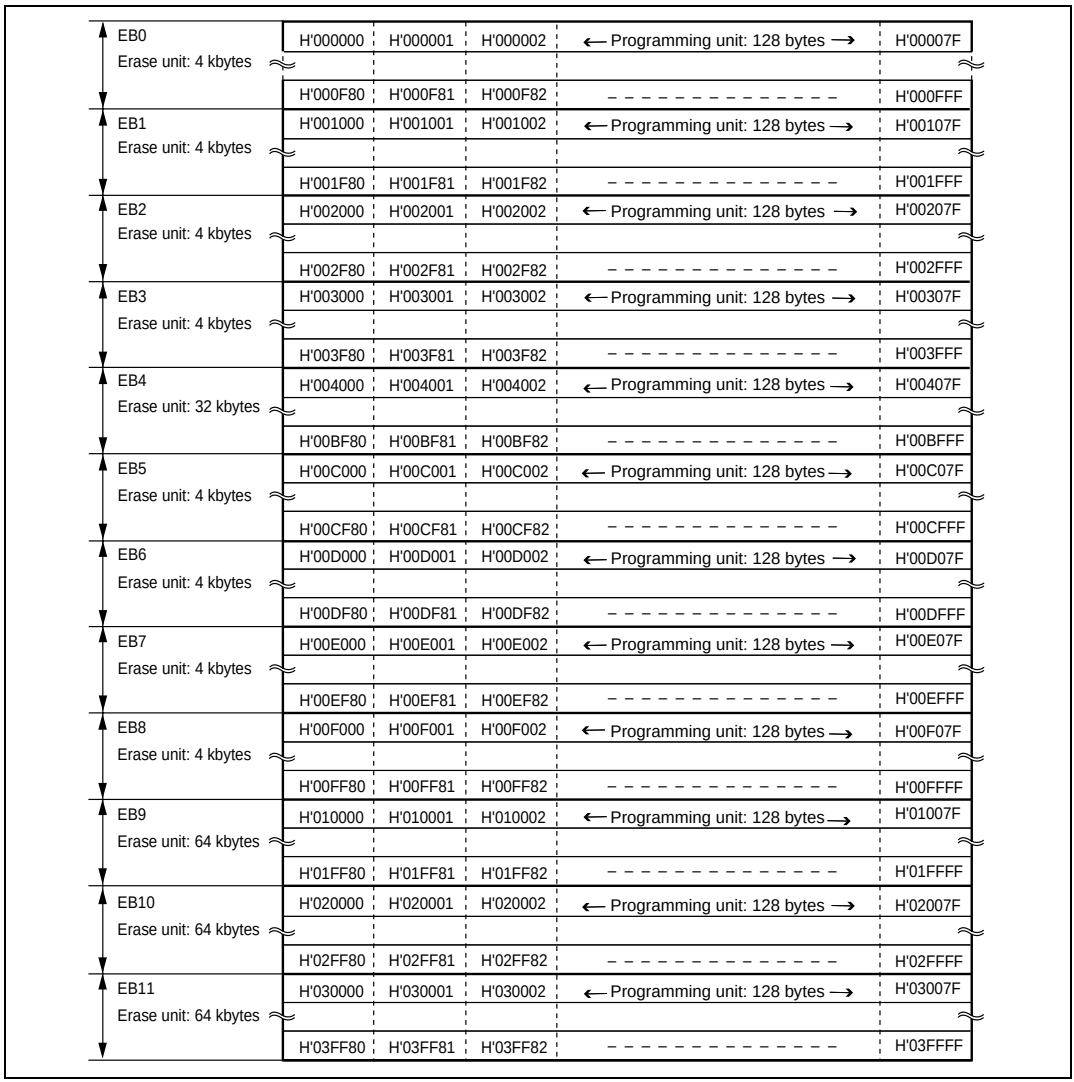


Figure 23.7 256-Kbyte Flash Memory Block Configuration

23.4 Input/Output Pins

The flash memory is controlled by means of the pins shown in table 23.2.

Table 23.2 Pin Configuration

Pin Name	I/O	Function
$\overline{\text{RES}}$	Input	Reset
MD1	Input	Sets this LSI's operating mode
MD0	Input	Sets this LSI's operating mode
P92	Input	Sets this LSI's operating mode
P91	Input	Sets this LSI's operating mode
P90	Input	Sets this LSI's operating mode
TxD1	Output	Serial transmit data output
RxD1	Input	Serial receive data input

23.5 Register Descriptions

The flash memory has the following registers. To access FLMCR1, FLMCR2, EBR1, or EBR2, the FLSHE bit in the serial/timer control register (STCR) should be set to 1. For details on the serial/timer control register, refer to section 3.2.3, Serial Timer Control Register (STCR).

- Flash memory control register 1 (FLMCR1)
- Flash memory control register 2 (FLMCR2)
- Erase block register 1 (EBR1)
- Erase block register 2 (EBR2)

23.5.1 Flash Memory Control Register 1 (FLMCR1)

FLMCR1, used together with FLMCR2, makes the flash memory transit to program mode, program-verify mode, erase mode, or erase-verify mode. For details on register setting, refer to section 23.8, Flash Memory Programming/Erasing.

FLMCR1 is initialized to H'80 by a reset, or in hardware standby mode, software standby mode, sub-active mode, sub-sleep mode, or watch mode.

Bit	Bit Name	Initial Value	R/W	Description
7	FWE	1	R	Flash Write Enable Controls programming/erasing of on-chip flash memory. This bit is always read as 0, and cannot be modified.
6	SWE	0	R/W	Software Write Enable When this bit is set to 1, flash memory programming/erasing is enabled. When this bit is cleared to 0, the EV, PV, E, and P bits in this register, the ESU and PSU bits in FLMCR2, and all EBR1 and EBR2 bits cannot be set to 1. Do not clear these bits and SWE to 0 simultaneously.
5, 4	—	All 0	R	Reserved These bits are always read as 0 and cannot be modified.
3	EV	0	R/W	Erase-Verify When this bit is set to 1 while SWE = 1, the flash memory transits to erase-verify mode. When it is cleared to 0, erase-verify mode is cancelled.
2	PV	0	R/W	Program-Verify When this bit is set to 1 while SWE = 1, the flash memory transits to program-verify mode. When it is cleared to 0, program-verify mode is cancelled.
1	E	0	R/W	Erase When this bit is set to 1 while SWE = 1 and ESU = 1, the flash memory transits to erase mode. When it is cleared to 0, erase mode is cancelled.
0	P	0	R/W	Program When this bit is set to 1 while SWE = 1 and PSU = 1, the flash memory transits to program mode. When it is cleared to 0, program mode is cancelled.

23.5.2 Flash Memory Control Register 2 (FLMCR2)

FLMCR2 monitors the state of flash memory programming/erasing protection (error protection) and sets up the flash memory to transit to programming/erasing mode. FLMCR2 is initialized to H'00 by a reset or in hardware standby mode. The ESU and PSU bits are cleared to 0 in software standby mode, sub-active mode, sub-sleep mode, or watch mode, or when the SWE bit in FLMCR1 is cleared to 0.

Bit	Bit Name	Initial Value	R/W	Description
7	FLER	0	R	Flash memory error Indicates that an error has occurred during flash memory programming/erasing. When this bit is set to 1, flash memory goes to the error-protection state. For details, see section 23.9.3, Error Protection.
6 to 2	—	All 0	R/(W)	Reserved The initial values should not be modified.
1	ESU	0	R/W	Erase Setup When this bit is set to 1 while SWE = 1, the flash memory transits 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 E bit in FLMCR1 to 1.
0	PSU	0	R/W	Program Setup When this bit is set to 1 while SWE = 1, the flash memory transits 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 P bit in FLMCR1 to 1.

23.5.3 Erase Block Registers 1 and 2 (EBR1, EBR2)

EBR1 and EBR2 are used to specify the flash memory erase block. EBR1 and EBR2 are initialized to H'00 by a reset, or in hardware standby mode, software standby mode, sub-active mode, sub-sleep mode, or watch mode, or when the SWE bit in FLMCR1 is cleared to 0. Set only one bit to 1 at a time, otherwise all bits in EBR1 and EBR2 are automatically cleared to 0.

- EBR1 (64-kbyte version)

Bit	Bit Name	Initial Value	R/W	Description
7 to 0	—	All 0	R/(W)	Reserved The initial values should not be modified.

- EBR2 (64-kbyte version)

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) are to be erased.
6	EB6	0	R/W	When this bit is set to 1, 8 kbytes of EB6 (H'00C000 to H'00DFFF) are to be erased.
5	EB5	0	R/W	When this bit is set to 1, 16 kbytes of EB5 (H'008000 to H'00BFFF) are to be erased.
4	EB4	0	R/W	When this bit is set to 1, 28 kbytes of EB4 (H'001000 to H'007FFF) are to be erased.
3	EB3	0	R/W	When this bit is set to 1, 1 kbyte of EB3 (H'000C00 to H'000FFF) is to be erased.
2	EB2	0	R/W	When this bit is set to 1, 1 kbyte of EB2 (H'000800 to H'000BFF) is to be erased.
1	EB1	0	R/W	When this bit is set to 1, 1 kbyte of EB1 (H'000400 to H'0007FF) is to be erased.
0	EB0	0	R/W	When this bit is set to 1, 1 kbyte of EB0 (H'000000 to H'0003FF) is to be erased.

Note: * In normal mode, this bit is always read as 0 and cannot be modified.

- EBR1 (128-kbyte version)

Bit	Bit Name	Initial Value	R/W	Description
7 to 2	—	All 0	R/(W)	Reserved The initial values should not be modified.
1	EB9	0	R/W*	When this bit is set to 1, 32 kbytes of EB9 (H'018000 to H'01FFFF) are to be erased.
0	EB8	0	R/W*	When this bit is set to 1, 32 kbytes of EB8 (H'010000 to H'017FFF) are to be erased.

- EBR2 (128-kbyte version)

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) are to be erased.
6	EB6	0	R/W	When this bit is set to 1, 8 kbytes of EB6 (H'00C000 to H'00DFFF) are to be erased.
5	EB5	0	R/W	When this bit is set to 1, 16 kbytes of EB5 (H'008000 to H'00BFFF) are to be erased.
4	EB4	0	R/W	When this bit is set to 1, 28 kbytes of EB4 (H'001000 to H'007FFF) are to be erased.
3	EB3	0	R/W	When this bit is set to 1, 1 kbyte of EB3 (H'000C00 to H'000FFF) is to be erased.
2	EB2	0	R/W	When this bit is set to 1, 1 kbyte of EB2 (H'000800 to H'000BFF) is to be erased.
1	EB1	0	R/W	When this bit is set to 1, 1 kbyte of EB1 (H'000400 to H'0007FF) is to be erased.
0	EB0	0	R/W	When this bit is set to 1, 1 kbyte of EB0 (H'000000 to H'0003FF) is to be erased.

Note: * In normal mode, this bit is always read as 0 and cannot be modified.

- EBR1 (256-kbyte version)

Bit	Bit Name	Initial Value	R/W	Description
7 to 4	—	All 0	R/(W)	Reserved The initial values should not be modified.
3	EB11	0	R/W*	When this bit is set to 1, 64 kbytes of EB11 (H'030000 to H'03FFFF) are to be erased.
2	EB10	0	R/W*	When this bit is set to 1, 64 kbytes of EB10 (H'020000 to H'02FFFF) are to be erased.
1	EB9	0	R/W*	When this bit is set to 1, 64 kbytes of EB9 (H'010000 to H'01FFFF) are to be erased.
0	EB8	0	R/W*	When this bit is set to 1, 4 kbytes of EB8 (H'00F000 to H'00FFFF) are to be erased.

- EBR2 (256-kbyte version)

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'00E000 to H'00EFFF) are to be erased.
6	EB6	0	R/W	When this bit is set to 1, 4 kbytes of EB6 (H'00D000 to H'00DFFF) are to be erased.
5	EB5	0	R/W	When this bit is set to 1, 4 kbytes of EB5 (H'00C000 to H'00CFFF) are to be erased.
4	EB4	0	R/W	When this bit is set to 1, 32 kbytes of EB4 (H'004000 to H'00BFFF) are to be erased.
3	EB3	0	R/W	When this bit is set to 1, 4 kbytes of EB3 (H'003000 to H'003FFF) is to be erased.
2	EB2	0	R/W	When this bit is set to 1, 4 kbytes of EB2 (H'002000 to H'002FFF) is to be erased.
1	EB1	0	R/W	When this bit is set to 1, 4 kbytes of EB1 (H'001000 to H'001FFF) is to be erased.
0	EB0	0	R/W	When this bit is set to 1, 4 kbytes of EB0 (H'000000 to H'000FFF) is to be erased.

Note: * In normal mode, this bit is always read as 0 and cannot be modified.

23.6 Operating Modes

The flash memory is connected to the CPU via a 16-bit data bus, enabling byte data and word data to be accessed in a single state. Even addresses are connected to the upper 8 bits and odd addresses are connected to the lower 8 bits. Note that word data must start from an even address.

On-chip ROM is enabled or disabled by the mode select pins (MD1 and MD0) and the EXPE bit in MDCR, as summarized in table 23.3.

In normal mode (mode 3), up to 56 kbytes of ROM can be used.

Table 23.3 Operating Modes and ROM

Operating Modes			Mode Pins		MDCR	
MCU Operating Mode	**CPU Operating Mode**	**Mode**	**MD1**	**MD0**	**EXPE**	**On-Chip ROM**
Mode 1	Normal	Expanded mode with on-chip ROM disabled	0	1	1	Disabled
Mode 2	Advanced	Single-chip mode	1	0	0	Enabled (64/128/256 kbytes)
	Advanced	Expanded mode with on-chip ROM enabled	1	0	1	
Mode 3	Normal	Single-chip mode	1	1	0	Enabled (56 kbytes)
	Normal	Expanded mode with on-chip ROM enabled	1	1	1	

23.7 On-Board Programming Modes

An on-board programming mode is used to perform on-chip flash memory programming, erasing, and verification. This LSI has two on-board programming modes: boot mode and user program mode. Table 23.4 shows pin settings for boot mode. In user program mode, operation by software is enabled by setting control bits. For details on flash memory mode transitions, see figure 23.2.

Table 23.4 On-Board Programming Mode Settings

Mode Setting		MD1	MD0	P92	P91	P90
Boot mode		0	0	1*	1*	1*
User program mode	Mode 2 (advanced mode)	1	0	—	—	—
	Mode 3 (normal mode)	1	1	—	—	—

Note: * Can be used as an I/O port after the boot mode activation.

23.7.1 Boot Mode

Table 23.5 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 23.8, Flash Memory Programming/Erasing. In boot mode, if any data exists in the flash memory (except in the case that all data are 1), all blocks in the flash memory are erased. Use boot mode at initial writing in the on-board state, or forced recovery when user program mode cannot be executed because the program to be initiated in user program mode was mistakenly erased.
2. The SCI_1 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, this LSI measures the low-level period of asynchronous SCI communication data (H'00) transmitted continuously from the host. This LSI then calculates the bit rate of transmission from the host, and adjusts the SCI_1 bit rate to match that of the host. The reset should end with the RxD1 pin high. The RxD1 and TxD1 pins should be pulled up on the board if necessary. After the reset ends, it takes approximately 100 states before this LSI is ready to measure the low-level period.
4. After matching the bit rates, this LSI transmits one H'00 byte to the host to indicate the end 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 this LSI. 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 this LSI. 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 23.6.
5. In boot mode, a part of the on-chip RAM area is used by the boot program. Addresses H'FFE080 to H'FFE87F*[1] is the area to which the programming control program is transferred from the host. Note, however, that ID codes are assigned to addresses H'FFE080 to H'FFE087*[2]. The boot program area cannot be used until the execution state in boot mode

switches to the programming control program. Figure 23.8 shows the on-chip RAM area in boot mode.

6. Before branching to the programming control program (H'FFE088[*3] in the RAM area), this LSI terminates transfer operations by the SCI_1 (by clearing the RE and TE bits in SCR to 0), but 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 TxD1 pin is in high-level output state. 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, since the stack pointer (SP), in particular, is used implicitly in subroutine calls, etc.
7. Boot mode can be cleared by a reset. Cancel the reset[*4] after driving the reset pin low, waiting at least 20 states, and then setting the mode pins. Boot mode is also cleared when a WDT overflow occurs.
8. Do not change the mode pin input levels in boot mode. If mode pin input levels are changed from low to high during reset, operating modes are switched and the state of ports that are also used for address output and bus control output signals ($\overline{AS}$, $\overline{RD}$, and $\overline{HWR}$) are changed[*5]. Therefore, set these pins carefully not to be output signals during reset or not to conflict with LSI external signals.
9. All interrupts are disabled during programming or erasing of the flash memory.

Notes: 1. Address area for the H8S/2140B, H8S/2141B, H8S/2148B, H8S/2160B, and H8S/2161B. On the H8S/2145B, the address area is from H'FFD080 to H'FFD87F.
2. Address area for the H8S/2140B, H8S/2141B, H8S/2148B, H8S/2160B, and H8S/2161B. On the H8S/2145B, the address area is from H'FFD080 to H'FFD087.
3. RAM address for the H8S/2140B, H8S/2141B, H8S/2148B, H8S/2160B, and H8S/2161B. On the H8S/2145B, the address is H'FFD088.
4. After reset is cancelled, mode pin input settings must satisfy the mode programming setup time (t_{MDS} = 4 states).
5. The ports that also have address output functions output low as address output when the mode pins are set to mode 1 during a reset. In modes other than mode 1, it enters the high impedance state. Bus control output signals output high when the mode pins are set to mode 1 during a reset. In modes other than mode 1, it enters the high impedance state.

Table 23.5 Boot Mode Operation

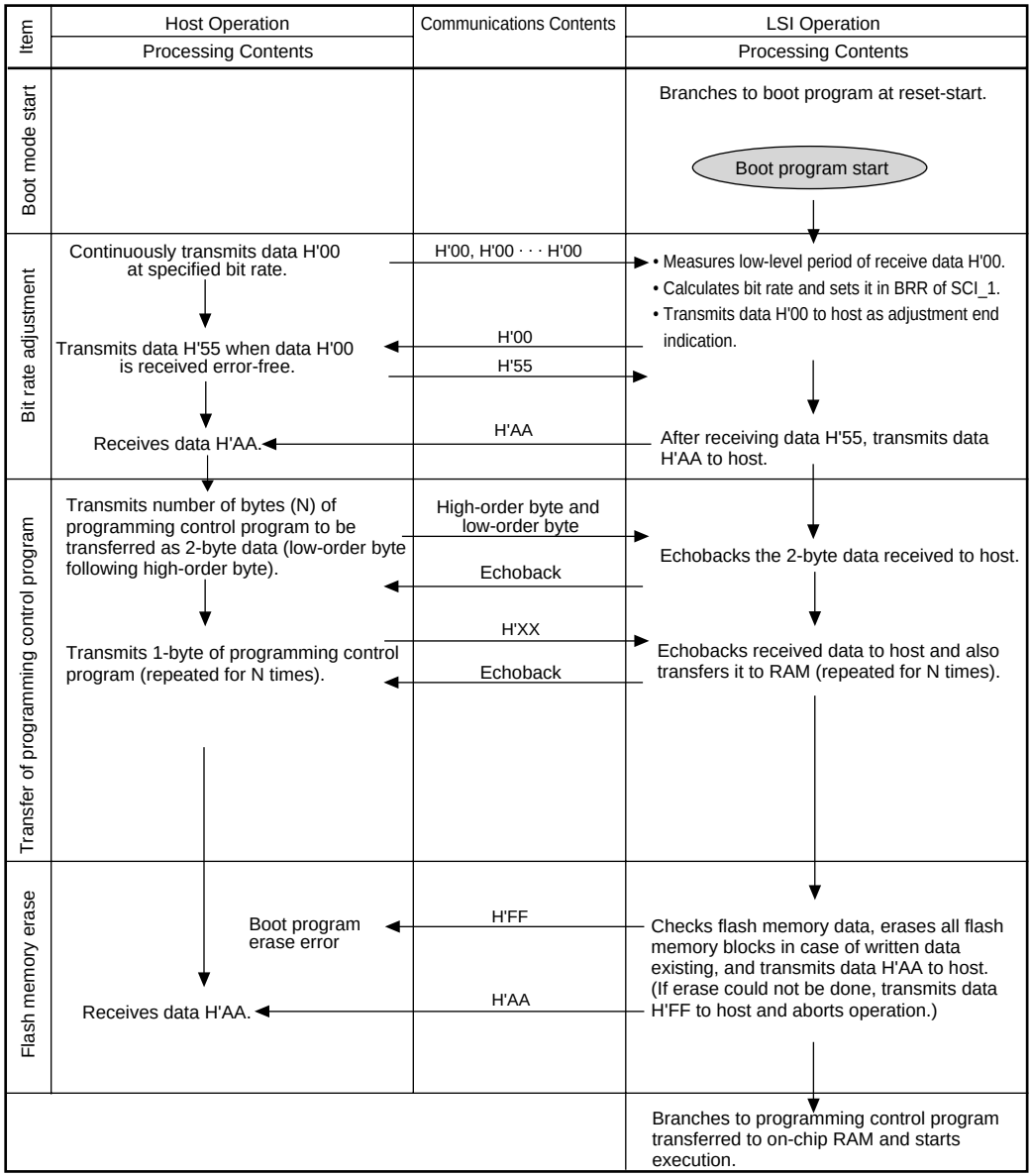


Table 23.6 System Clock Frequencies for which Automatic Adjustment of LSI Bit Rate Is Possible

Host Bit Rate	System Clock Frequency Range of LSI (3-V Version)	System Clock Frequency Range of LSI (5-V Version)
19200 bps	8 to 10 MHz	8 to 20 MHz
9600 bps	4 to 10 MHz	4 to 20 MHz
4800 bps	2 to 10 MHz	2 to 18 MHz

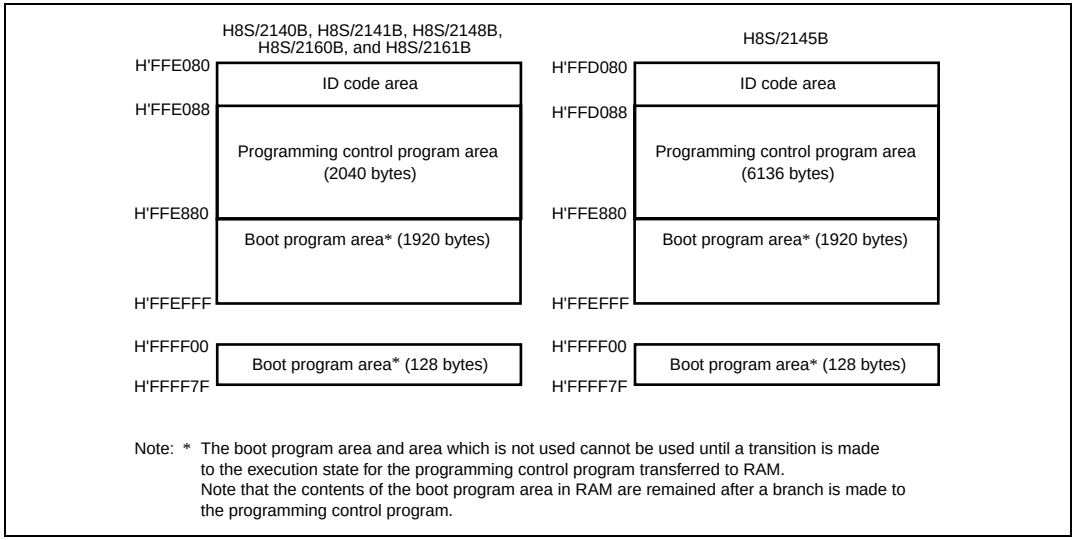


Figure 23.8 On-Chip RAM Area in Boot Mode

In boot mode, this LSI checks the contents of the 8-byte ID code area as shown below to confirm that the programming control program corresponds with this LSI. To originally write a programming control program to be used in boot mode, the above 8-byte ID code must be added at the beginning of the program.

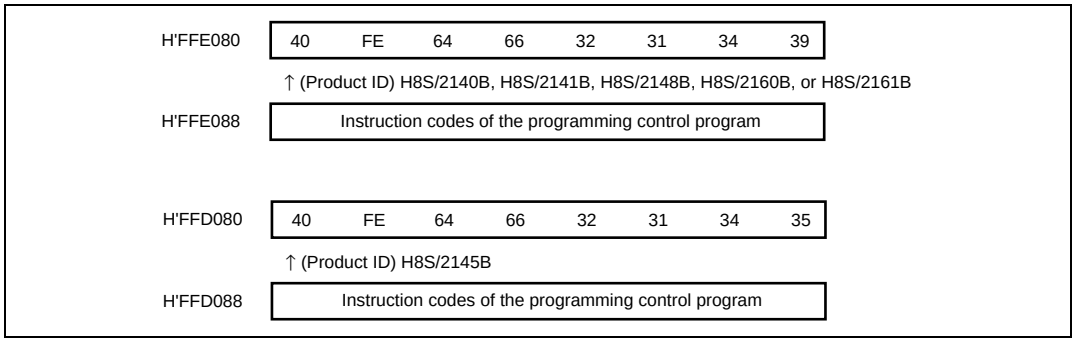


Figure 23.9 ID Code Area

23.7.2 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 set branching conditions and provide on-board means of supplying programming data. The flash memory must contain the user program/erase control program or a program which provides the user program/erase control program from external memory. Because the flash memory itself cannot be read during programming/erasing, transfer the user program/erase control program to on-chip RAM, as like in boot mode. Figure 23.10 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 23.8, Flash Memory Programming/Erasing.

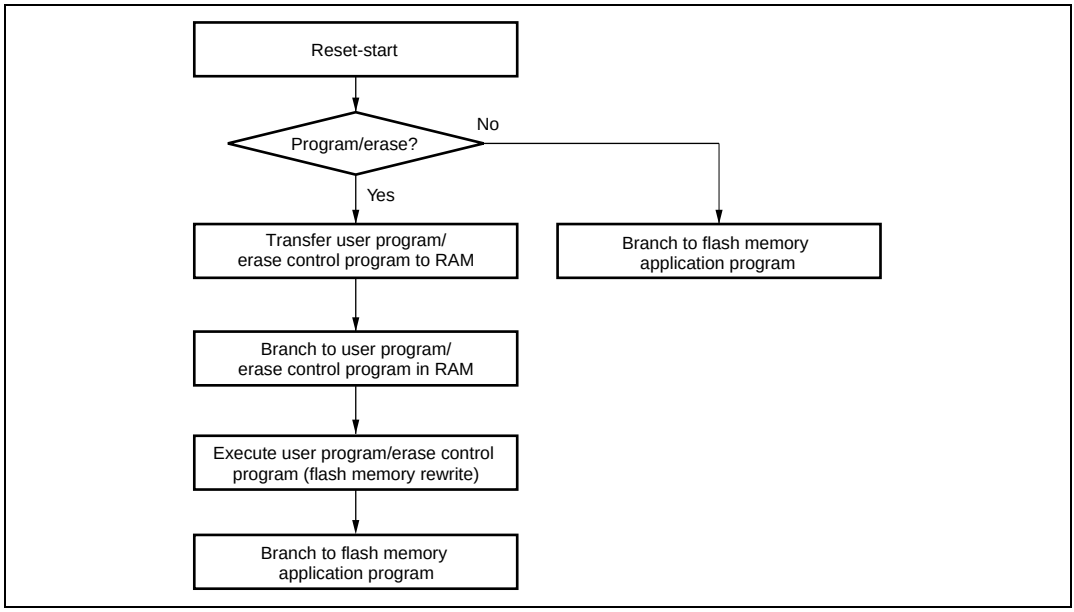


Figure 23.10 Programming/Erasing Flowchart Example in User Program Mode

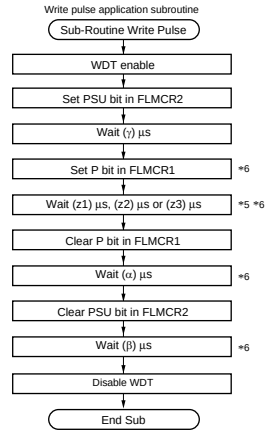
23.8 Flash Memory Programming/Erasing

A software method, using the CPU, is employed to program and erase flash memory in the on-board programming modes. Depending on the FLMCR1 and FLMCR2 settings, 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 23.8.1, Program/Program-Verify and section 23.8.2, Erase/Erase-Verify, respectively.

23.8.1 Program/Program-Verify

When writing data or programs to the flash memory, the program/program-verify flowchart shown in figure 23.11 should be followed. Performing programming operations according to this flowchart will enable data or programs to be written to the flash memory without subjecting this LSI to voltage stress or sacrificing program data reliability.

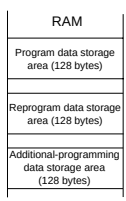
1. Programming must be done to an empty address. Do not reprogram an address to which programming has already been performed.
2. Programming should be carried out 128 bytes at a time. A 128-byte data transfer must be performed even if writing fewer than 128 bytes. In this case, H'FF data must be written 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 23.11.
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 P bit is set to 1 is the programming time. Figure 23.11 shows the allowable programming times.
6. The watchdog timer (WDT) is set to prevent overprogramming due to program runaway, etc. The overflow cycle should be longer than $(y + z2 + \alpha + \beta)$ μs.
7. For a dummy write to a verify address, write 1-byte data H'FF to an address whose lower 2 bits are B'00. Verify data can be read in words from the address to which a dummy write was performed.
8. The maximum number of repetitions of the program/program-verify sequence to the same bit is (N).

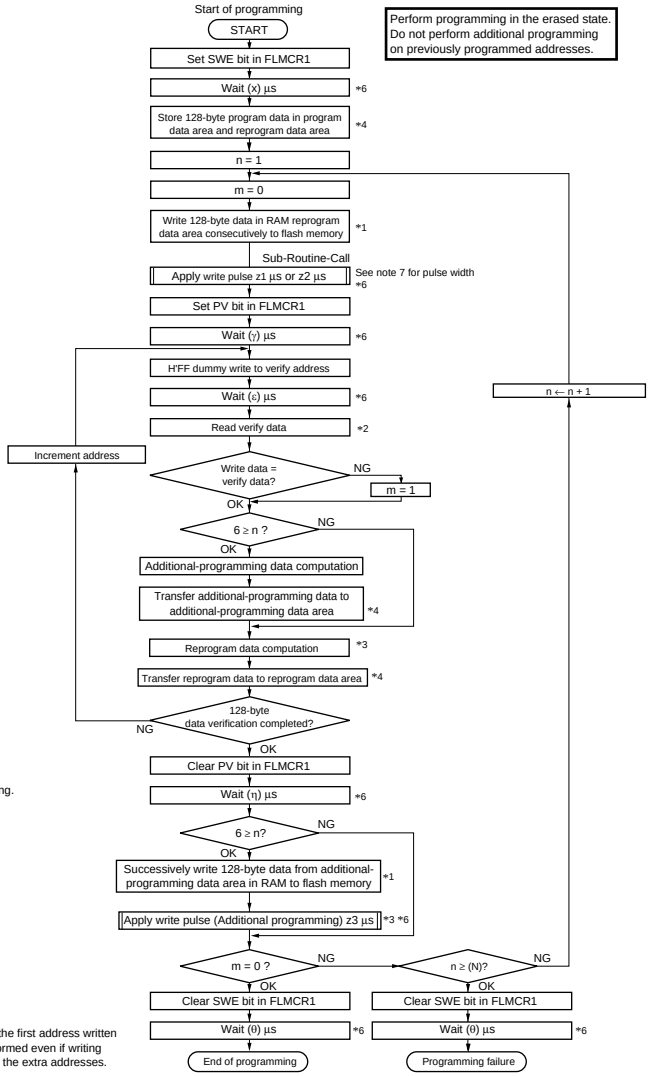


Note: 7. Write Pulse Width

Number of Writes n	Write Time (z) µs*6
1	z1
2	z1
3	z1
4	z1
5	z1
6	z1
7	z2
8	z2
9	z2
10	z2
11	z2
12	z2
13	z2
⋮	⋮
998	z2
999	z2
1000	z2

Note: Use a z3 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. 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 z1 µs or z2 µs is applied according to the progress of the programming operation. See note 7 for details of the pulse widths. When writing of additional-programming data is executed, a z3 µs write pulse should be applied. Reprogram data X' means reprogram data when the write pulse is applied.
6. The values of x, y, z1, z2, z3, α, β, γ, ε, η, θ, and N are shown in sections 28.1.6 and 28.2.6, Flash Memory Characteristics.

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

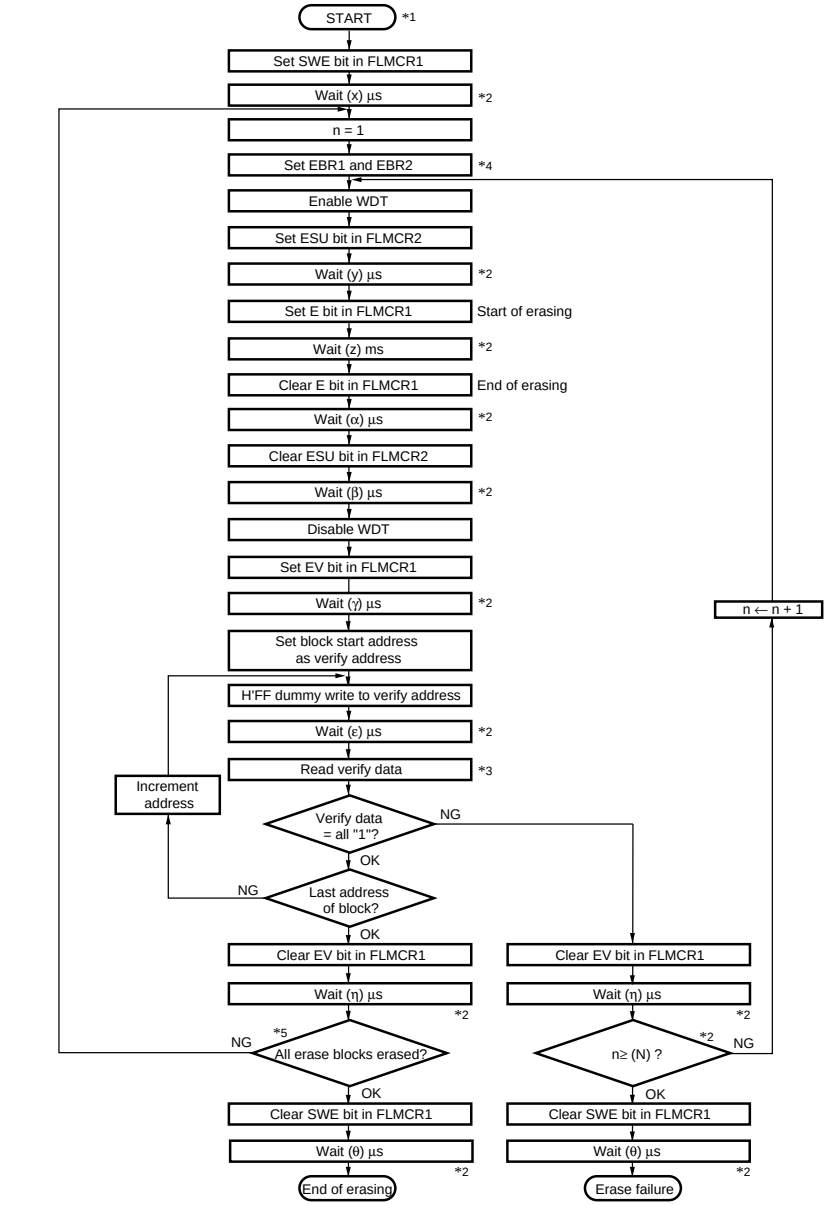
Reprogram Data (X')	Verify Data (V)	Additional-Programming Data (Y)	Comments
0	0	0	Additional programming to be executed
0	1	1	Additional programming not to be executed
1	0	1	
1	1	1	Additional programming not to be executed

Figure 23.11 Program/Program-Verify Flowchart

23.8.2 Erase/Erase-Verify

When erasing flash memory, the erase/erase-verify flowchart shown in figure 23.12 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-block specification in erase block registers 1 and 2 (EBR1 and EBR2). To erase multiple blocks, each block must be erased in turn.
3. The time during which the E 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. An overflow cycle of approximately $(y + z + \alpha + \beta)$ ms is allowed.
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 longwords from the address to which a dummy write was performed.
6. If the read data is unerased, 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. Prewriting (writing 0 to all data in erased block) is not necessary.
2. The values of x, y, z, α, β, γ, ε, η, θ, and N are shown in sections 28.1.6 and 28.2.6, Flash Memory Characteristics.
3. Verify data is read in 16-bit (word) units.
4. Set only a single bit in EBR1 and EBR2. Do not set more than one bit.
5. Erasing is performed in block units. To erase multiple blocks, each block must be erased in turn.

Figure 23.12 Erase/Erase-Verify Flowchart

23.9 Program/Erase Protection

There are three kinds of flash memory program/erase protection: hardware protection, software protection, and error protection.

23.9.1 Hardware Protection

Hardware protection is a state in which programming/erasing of flash memory is forcibly disabled or aborted by a reset (including WDT overflow reset), or a transition to hardware standby mode, software standby mode, sub-active mode, sub-sleep mode or watch mode. Flash memory control registers 1 and 2 (FLMCR1 and FLMCR2) and erase block registers 1 and 2 (EBR1 and EBR2) are initialized. In a reset via the $\overline{\text{RES}}$ pin, the reset state is not entered unless the $\overline{\text{RES}}$ pin is held low until oscillation stabilizes after powering on. In the case of a reset during operation, hold the $\overline{\text{RES}}$ pin low for the $\overline{\text{RES}}$ pulse width specified in the AC Characteristics section.

23.9.2 Software Protection

Software protection can be implemented against programming/erasing of all flash memory blocks by clearing the SWE bit in FLMCR1 to 0. When software protection is in effect, setting the P or E bit in FLMCR1 does not cause a transition to program mode or erase mode. By setting the erase block registers 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.

23.9.3 Error Protection

In error protection, an error is detected when the CPU’s 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 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 (transits to software standby mode, sleep mode, sub-active mode, sub-sleep mode, or watch mode) during programming/erasing
- When the bus ownership is released during programming/erasing

The FLMCR1, FLMCR2, EBR1, and EBR2 settings are retained, but program mode or erase mode is aborted at the point at which the error occurred. Program mode or erase mode cannot be entered by setting the P or E bit to 1. However, because the PV and EV bit settings are retained, a transition to verify mode can be made. The error protection state can be cancelled by a reset or in hardware standby mode.

23.10 Interrupts during Flash Memory Programming/Erasing

In order to give the highest priority to programming/erasing operations, disable all interrupts including NMI input during flash memory programming/erasing (the P or E bit in FlMCR1 is set to 1) or boot program execution*1.

1. If an interrupt is generated during programming/erasing, operation in accordance with the program/erase algorithm is not guaranteed.
2. CPU runaway may occur because normal vector reading cannot be performed in interrupt exception handling during programming/erasing*2.
3. If an interrupt occurs during boot program execution, the normal boot mode sequence cannot be executed.

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 for the following two reasons:

   If flash memory is read while being programmed or erased (while the P or E bit in FLMCR1 is set to 1), correct read data will not be obtained (undefined 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.

23.11 Programmer Mode

In programmer mode, the on-chip flash memory can be programmed/erased by a PROM programmer via a socket adapter, just like for a discrete flash memory. Use a PROM programmer that supports the Renesas 64/128/256-kbyte flash memory on-chip MCU device*. Figure 23.13 shows a memory map in programmer mode.

Note: * For 3-V and 5-V version products, set the programming voltage of the PROM programmer to 3.3V.

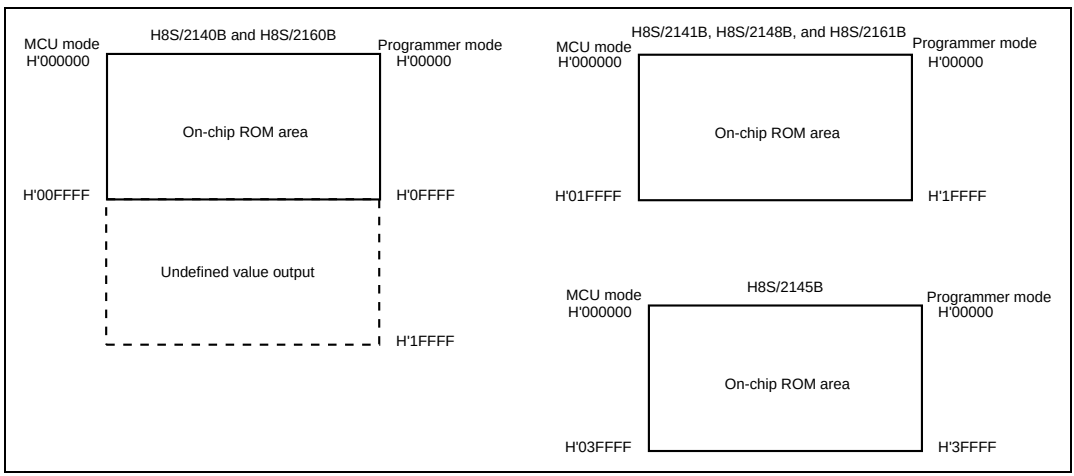


Figure 23.13 Memory Map in Programmer Mode

23.12 Usage Notes

The following lists notes on the use of on-board programming modes and programmer mode.

1. Perform programming/erasing with the specified voltage and timing.

   If a voltage higher than the rated voltage is applied, the product may be fatally damaged. For 3-V and 5-V version products, use a PROM programmer that supports the Renesas 64/128/256-kbyte flash memory on-chip MCU device at 3.3 V. Do not set the programmer to HN28F101 or the programming voltage to 5.0 V.
2. Notes on power on/off

   At powering on or off the Vcc power supply, fix the $\overline{\text{RES}}$ pin to low and set the flash memory to hardware protection state. This power on/off timing must also be satisfied at a power-off and power-on caused by a power failure and other factors.
3. Perform flash memory programming/erasing in accordance with the recommended algorithm

   In the recommended algorithm, flash memory programming/erasing can be performed without subjecting this LSI to voltage stress or sacrificing program data reliability. When setting the P or E bit in FLMCR1 to 1, set the watchdog timer against program runaway.
4. Do not set/clear the SWE bit during program execution in the flash memory.

   Do not set/clear the SWE bit during program execution in the flash memory. An interval of at least 100 μs is necessary between program execution or data reading in flash memory and SWE bit clearing. When the SWE bit is set to 1, flash memory data can be modified, however, flash memory data can be read only in program-verify or erase-verify mode. Do not access the flash memory for a purpose other than verification during programming/erasing. Do not clear the SWE bit during programming, erasing, or verifying.
5. Do not use interrupts during flash memory programming/erasing

   In order to give the highest priority to programming/erasing operation, disable all interrupts including NMI input when the flash memory is programmed or erased.
6. Do not perform additional programming. Programming must be performed in the erased state.

   Program the area with 128-byte programming-unit blocks in on-board programming or programmer mode only once. Perform programming in the state where the programming-unit block is fully erased.
7. Ensure that the PROM programmer is correctly attached before programming.

   If the socket, socket adapter, or product index does not match the specifications, too much current flows and the product may be damaged.
8. Do not touch the socket adapter or LSI while programming.

   Touching either of these can cause contact faults and write errors.

Section 24 Clock Pulse Generator

This LSI incorporates a clock pulse generator, which generates the system clock (φ), bus master clock, and internal clock.

The clock pulse generator consists of an oscillator, duty correction circuit, clock select circuit, medium-speed clock divider, bus master clock select circuit, subclock input circuit, and waveform forming circuit. Figure 24.1 shows a block diagram of the clock pulse generator.

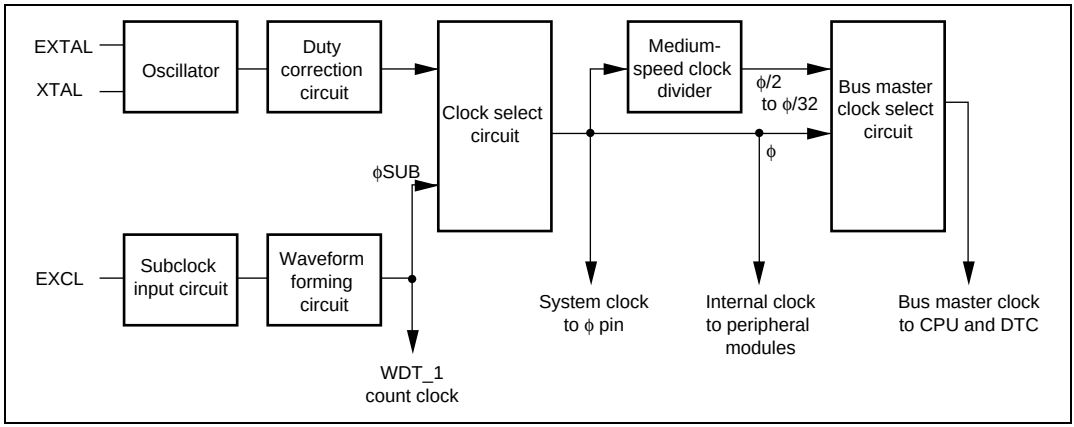


Figure 24.1 Block Diagram of Clock Pulse Generator

The bus master clock is selected as either high-speed mode or medium-speed mode by software according to the settings of the SCK2 to SCK0 bits in the standby control register. For details on the standby control register, refer to section 26.1.1, Standby Control Register (SBYCR).

The subclock input is controlled by software according to the EXCLE bit setting in the low power control register. For details on the low power control register, refer to section 26.1.2, Low-Power Control Register (LPWRCR).

24.1 Oscillator

Clock pulses can be supplied either by connecting a crystal resonator, or by providing external clock input.

24.1.1 Connecting Crystal Resonator

Figure 24.2 shows a typical method of connecting a crystal resonator. An appropriate damping resistance R_d, given in table 24.1, should be used. An AT-cut parallel-resonance crystal resonator should be used.

Figure 24.3 shows the equivalent circuit of a crystal resonator. A resonator having the characteristics given in table 24.2 should be used.

A crystal resonator with frequency identical to that of the system clock (ϕ) should be used.

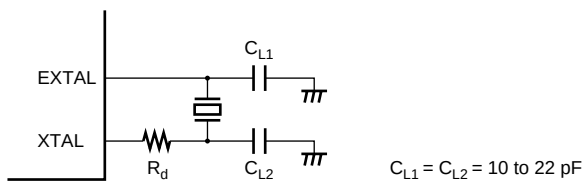


Figure 24.2 Typical Connection to Crystal Resonator

Table 24.1 Damping Resistance Values

Frequency (MHz)	2	4	8	10	12	16	20
R_d (Ω)	1 k	500	200	0	0	0	0

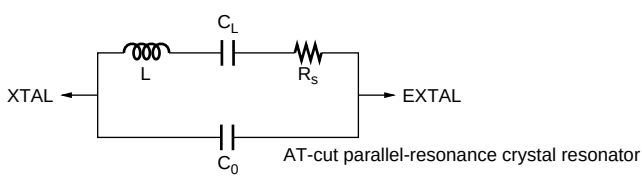


Figure 24.3 Equivalent Circuit of Crystal Resonator

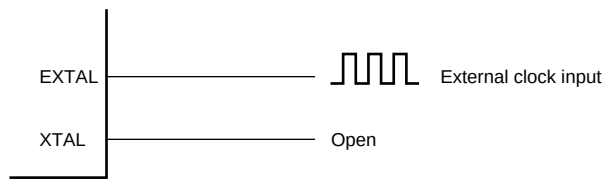
Table 24.2 Crystal Resonator Parameters

Frequency (MHz)	2	4	8	10	12	16	20
R_S (max) (Ω)	500	120	80	70	60	50	40
C_0 (max) (pF)	7	7	7	7	7	7	7

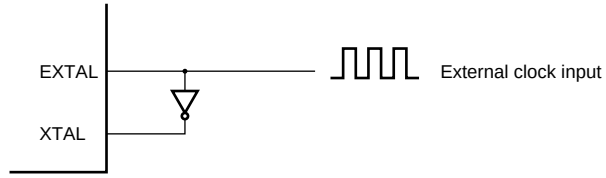
24.1.2 External Clock Input Method

Figure 24.4 shows a typical method of connecting an external clock signal. To leave the XTAL pin open, incidental capacitance should be 10 pF or less.

To input an inverted clock to the XTAL pin, the external clock should be set to high in standby mode, subactive mode, subsleep mode, and watch mode. External clock input conditions are shown in table 24.3. The frequency of the external clock should be the same as that of the system clock (ϕ).



(a) Example of external clock input when XTAL pin left open



(b) Example of external clock input when an inverted clock is input to XTAL pin

Figure 24.4 Example of External Clock Input

Table 24.3 External Clock Input Conditions

		V_{cc} = 2.7 to 3.6 V		V_{cc} = 5.0 V ± 10 %				
Item	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test Conditions**	
External clock input pulse width low level	t_{EXL}	40	—	20	—	ns	Figure 24.5	
External clock input pulse width high level	t_{EXH}	40	—	20	—	ns		
External clock rising time	t_{EXr}	—	10	—	5	ns		
External clock falling time	t_{EXf}	—	10	—	5	ns		
Clock pulse width low level	t_{CL}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5$ MHz	Figure 28.6
		80	—	80	—	ns	$\phi < 5$ MHz	
Clock pulse width high level	t_{CH}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5$ MHz	
		80	—	80	—	ns	$\phi < 5$ MHz	

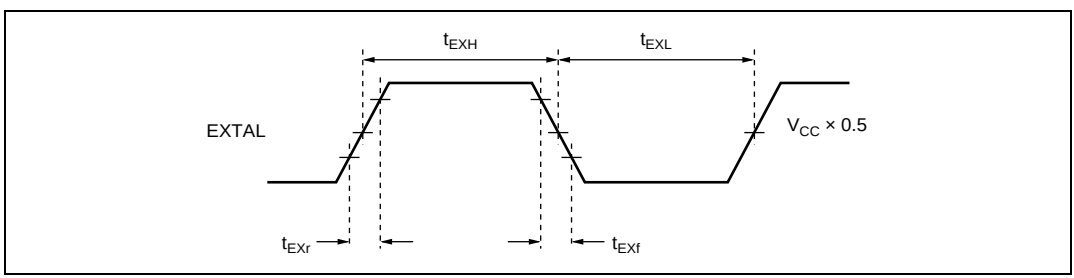


Figure 24.5 External Clock Input Timing

The oscillator and duty correction circuit have a function to adjust the waveform of the external clock input that is input to the EXTAL pin. When a specified clock signal is input to the EXTAL pin, internal clock signal output is determined after the external clock output stabilization delay time (t_{DEXT}) has passed. As the clock signal output is not determined during the t_{DEXT} cycle, a reset signal should be set to low to hold it in reset state. Table 24.4 shows the external clock output stabilization delay time. Figure 24.6 shows the timing of the external clock output stabilization delay time.

Table 24.4 External Clock Output Stabilization Delay Time

Conditions: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{SS} = AV_{SS} = 0 V

Item	Symbol	Min.	Max.	Unit	Remarks
External clock output stabilization delay time	t_{DEXT}*	500	—	µs	Figure 24.6

Note: * t_{DEXT} includes a $\overline{RES}$ pulse width (t_{RESW}).

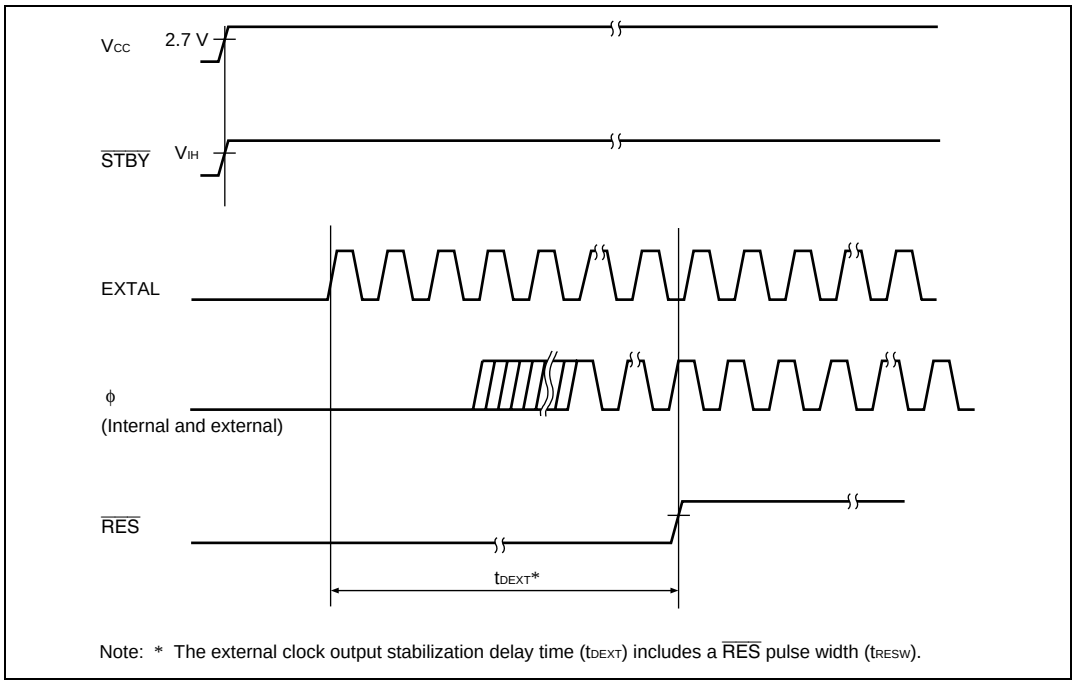


Figure 24.6 Timing of External Clock Output Stabilization Delay Time

24.2 Duty Correction Circuit

The duty correction circuit is valid when the oscillating frequency is 5 MHz or more. It corrects the duty of a clock that is output from the oscillator, and generates the system clock (ϕ).

24.3 Medium-Speed Clock Divider

The medium-speed clock divider divides the system clock (ϕ), and generates ϕ/2, ϕ/4, ϕ/8, ϕ/16, and ϕ/32 clocks.

24.4 Bus Master Clock Select Circuit

The bus master clock select circuit selects a clock to supply the bus master with either the system clock (φ) or medium-speed clock (φ/2, φ/4, φ/8, φ/16, or φ/32) by the SCK2 to SCK0 bits in SBYCR.

24.5 Subclock Input Circuit

The subclock input circuit controls subclock input from the EXCL pin.

Inputting the Subclock: To use the subclock, a 32.768-kHz external clock should be input from the EXCL pin. At this time, the P96DDR bit in P9DDR should be cleared to 0, and the EXCLE bit in LPWRCR should be set to 1.

Subclock input conditions are shown in table 24.5. When the subclock is not used, subclock input should not be enabled.

Table 24.5 Subclock Input Conditions

		Vcc = 2.7 to 5.5 V				
Item	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Measurement Condition**
Subclock input pulse width low level	t_{EXCLL}	—	15.26	—	µs	Figure 24.7
Subclock input pulse width high level	t_{EXCLH}	—	15.26	—	µs	
Subclock input rising time	t_{EXCLr}	—	—	10	ns	
Subclock input falling time	t_{EXCLf}	—	—	10	ns	

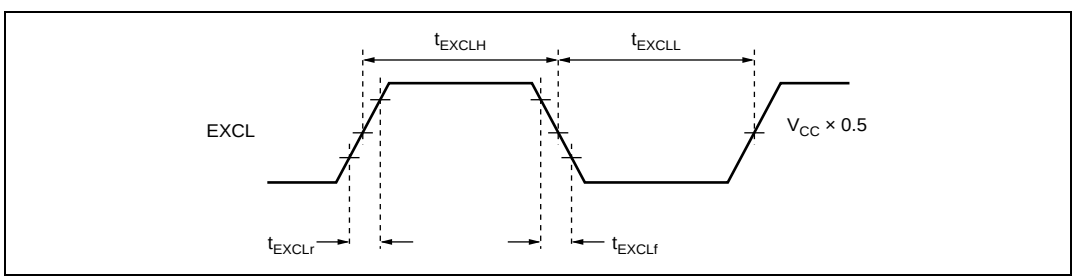


Figure 24.7 Subclock Input Timing

When Subclock Is Not Needed: Do not enable subclock input when the subclock is not needed.

Note on Subclock Usage: In transiting to power-down mode, if at least two cycles of the 32-kHz clock are not input after the 32-kHz clock input is enabled (EXCLE = 1) until the SLEEP instruction is executed (power-down mode transition), the subclock input circuit is not initialized and an error may occur in the microcomputer.

Before power-down mode is entered with using the subclock, at least two cycle of the 32-kHz clock should be input after the 32-kHz clock input is enabled (EXCLE = 1).

As described in the hardware manual (clock pulse generator/subclock input circuit), when the subclock is not used, the subclock input should not be enabled (EXCLE = 0).

24.6 Subclock Waveform Forming Circuit

To remove noise from the subclock input at the EXCL pin, the subclock is sampled by a divided ϕ clock. The sampling frequency is set by the NESEL bit in LPWRCR.

The subclock is not sampled in subactive mode, subsleep mode, or watch mode.

24.7 Clock Select Circuit

The clock select circuit selects the system clock that is used in this LSI.

A clock generated by an oscillator to which the EXTAL and XTAL pins are input is selected as a system clock when returning from high-speed mode, medium-speed mode, sleep mode, reset state, or standby mode.

A subclock input from the EXCL pin is selected as a system clock in subactive mode, subsleep mode, or watch mode. At this time, modules such as the CPU, TMR_0, TMR_1, WDT_0, WDT_1, ports, and interrupt controller and their functions operate depending on the ϕSUB. The count clock and sampling clock for each timer are divided ϕSUB clocks.

24.8 Processing for X1 and X2 Pins

The X1 and X2 pins should be open as shown in figure 24.8.

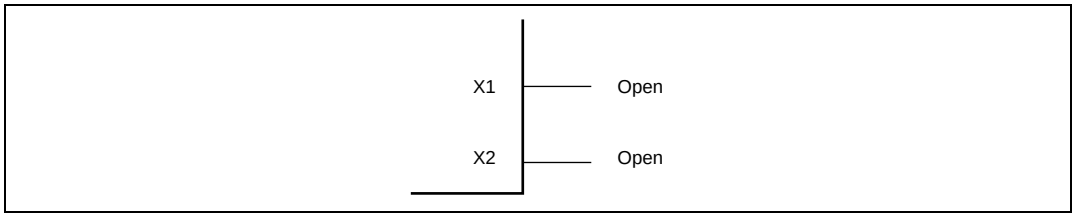


Figure 24.8 Processing for X1 and X2 Pins

24.9 Usage Notes

24.9.1 Note on Resonator

Since all kinds of characteristics of the resonator are closely related to the board design by the user, use the example of resonator connection in this document for only reference; be sure to use an resonator that has been sufficiently evaluated by the user. Consult with the resonator manufacturer about the resonator circuit ratings which vary depending on the stray capacitances of the resonator and installation circuit. Make sure the voltage applied to the oscillator pins does not exceed the maximum rating.

24.9.2 Notes on Board Design

When using a crystal resonator, the crystal resonator and its load capacitors should be placed as close as possible to the XTAL and EXTAL pins.

Other signal lines should be routed away from the oscillator circuit to prevent inductive interference with the correct oscillation as shown in figure 24.9.

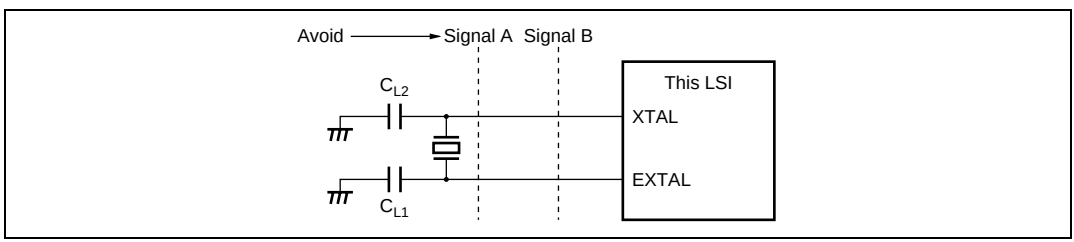


Figure 24.9 Note on Board Design of Oscillator Circuit Section

Section 25 Power-Down Modes

For operating modes after the reset state is cancelled, this LSI has not only the normal program execution state but also seven power-down modes in which power dissipation is significantly reduced. In addition, there is also module stop mode in which reduced power dissipation can be achieved by individually stopping on-chip peripheral modules.

- Medium-speed mode
  System clock frequency for the CPU operation can be selected as $\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$,or $\phi/32$.
- Subactive mode
  The CPU operates based on the subclock and on-chip peripheral modules other than TMR_0, TMR_1, WDT_0, and WDT_1 stop operating.
- Sleep mode
  The CPU stops but on-chip peripheral modules continue operating.
- Subsleep mode
  The CPU and on-chip peripheral modules other than TMR_0, TMR_1, WDT_0, and WDT_1 stop operating.
- Watch mode
  The CPU and on-chip peripheral modules other than WDT_1 stop operating.
- Software standby mode
  Clock oscillation stops, and the CPU and on-chip peripheral modules stop operating.
- Hardware standby mode
  Clock oscillation stops, and the CPU and on-chip peripheral modules enter reset state.
- Module stop mode
  Independently of above operating modes, on-chip peripheral modules that are not used can be stopped individually.

25.1 Register Descriptions

Power-down modes are controlled by the following registers. To access SBYCR, LPWRCR, MSTPCRH, and MSTPCRL, the FLSHE bit in the serial timer control register (STCR) must be cleared to 0. For details on STCR, see section 3.2.3, Serial Timer Control Register (STCR).

- Standby control register (SBYCR)
- Low power control register (LPWRCR)
- Module stop control register H (MSTPCRH)
- Module stop control register L (MSTPCRL)

25.1.1 Standby Control Register (SBYCR)

SBYCR controls power-down modes.

Bit	Bit Name	Initial Value	R/W	Description
7	SSBY	0	R/W	Software Standby Specifies the operating mode to be entered after executing the SLEEP instruction. When the SLEEP instruction is executed in high-speed mode or medium-speed mode: 0: Shifts to sleep mode 1: Shifts to software standby mode, subactive mode, or watch mode When the SLEEP instruction is executed in subactive mode: 0: Shifts to subsleep mode 1: Shifts to watch mode or high-speed mode Note that the SSBY bit is not changed even if a mode transition occurs by an interrupt.
6	STS2	0	R/W	Standby Timer Select 2 to 0 Selects the wait time for clock stabilization from clock oscillation start when canceling software standby mode, watch mode, or subactive mode. Select a wait time of 8 ms (oscillation stabilization time) or more, depending on the operating frequency. Table 25.1 shows the relationship between the STS2 to STS0 values and wait time. With an external clock, there are no specific wait requirements. Normally the minimum value is recommended.
5	STS1	0	R/W	
4	STS0	0	R/W	
3	—	0	R	Reserved This bit is always read as 0, and cannot be modified.

Bit	Bit Name	Initial Value	R/W	Description
2	SCK2	0	R/W	System Clock Select 2 to 0
1	SCK1	0	R/W	Selects a clock for the bus master in high-speed mode or medium-speed mode.
0	SCK0	0	R/W	When making a transition to subactive mode or watch mode, SCK2 to SCK0 must be cleared to B'000.
				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: —

Legend:
X: Don't care

Table 25.1 Operating Frequency and Wait Time

STS2	STS1	STS0	Wait Time	20 MHz	10 MHz	8 MHz	6 MHz	4 MHz	2 MHz	Unit
0	0	0	8192 states	0.4	0.8	1.0	1.3	2.0	4.1	ms
0	0	1	16384 states	0.8	1.6	2.0	2.7	4.1	8.2	
0	1	0	32768 states	2.0	3.3	4.1	5.5	8.2	16.4	
0	1	1	65536 states	4.1	6.6	8.2	10.9	16.4	32.8	
1	0	0	131072 states	8.2	13.1	16.4	21.8	32.8	65.5	
1	0	1	262144 states	16.4	26.2	32.8	43.6	65.6	131.2	
1	1	0	Reserved	—	—	—	—	—	—	—
1	1	1	16 states*	0.8	1.6	2.0	2.7	4.0	8.0	µs

Shaded cells indicate the recommended specification.

Note: * This setting cannot be made in the flash-memory version of this LSI.

25.1.2 Low-Power Control Register (LPWRCR)

LPWRCR controls power-down modes.

Bit	Bit Name	Initial Value	R/W	Description
7	DTON	0	R/W	Direct Transfer On Flag Specifies the operating mode to be entered after executing the SLEEP instruction. When the SLEEP instruction is executed in high-speed mode or medium-speed mode: 0: Shifts to sleep mode, software standby mode, or watch mode 1: Shifts directly to subactive mode, or shifts to sleep mode or software standby mode When the SLEEP instruction is executed in subactive mode: 0: Shifts to subsleep mode or watch mode 1: Shifts directly to high-speed mode, or shifts to subsleep mode
6	LSON	0	R/W	Low-Speed On Flag Specifies the operating mode to be entered after executing the SLEEP instruction. This bit also controls whether to shift to high-speed mode or subactive mode when watch mode is cancelled. When the SLEEP instruction is executed in high-speed mode or medium-speed mode: 0: Shifts to sleep mode, software standby mode, or watch mode 1: Shifts to watch mode or subactive mode When the SLEEP instruction is executed in subactive mode: 0: Shifts directly to watch mode or high-speed mode 1: Shifts to subsleep mode or watch mode When watch mode is cancelled: 0: Shifts to high-speed mode 1: Shifts to subactive mode

Bit	Bit Name	Initial Value	R/W	Description
5	NESEL	0	R/W	Noise Elimination Sampling Frequency Select Selects the frequency by which the subclock (φSUB) input from the EXCL pin is sampled using the clock (φ) generated by the system clock pulse generator. Clear this bit to 0 when φ is 5 MHz or more. 0: Sampling using φ/32 clock 1: Sampling using φ/4 clock
4	EXCLE	0	R/W	Subclock Input Enable Enables/disables subclock input from the EXCL pin. 0: Disables subclock input from the EXCL pin 1: Enables subclock input from the EXCL pin
3	—	0	R/W	Reserved An undefined value is read from this bit. This bit should not be set to 1.
2 to 0	—	All 0	R	Reserved These bits are always read as 0 and cannot be modified.

25.1.3 Module Stop Control Registers H and L (MSTPCRH, MSTPCRL)

MSTPCRH and MSTPCRL specify on-chip peripheral modules to shift to module stop mode in module units. Each module can enter module stop mode by setting the corresponding bit to 1.

- MSTPCRH

Bit	Bit Name	Initial Value	R/W	Corresponding Module
7	MSTP15	0*	R/W	
6	MSTP14	0	R/W	Data transfer controller (DTC)
5	MSTP13	1	R/W	16-bit free-running timer (FRT)
4	MSTP12	1	R/W	8-bit timers (TMR_0, TMR_1)
3	MSTP11	1	R/W	8-bit PWM timer (PWM), 14-bit PWM timer (PWMX)
2	MSTP10	1	R/W	D/A converter
1	MSTP9	1	R/W	A/D converter
0	MSTP8	1	R/W	8-bit timers (TMR_X, TMR_Y), timer connection

Note: * Do not set this bit to 1.

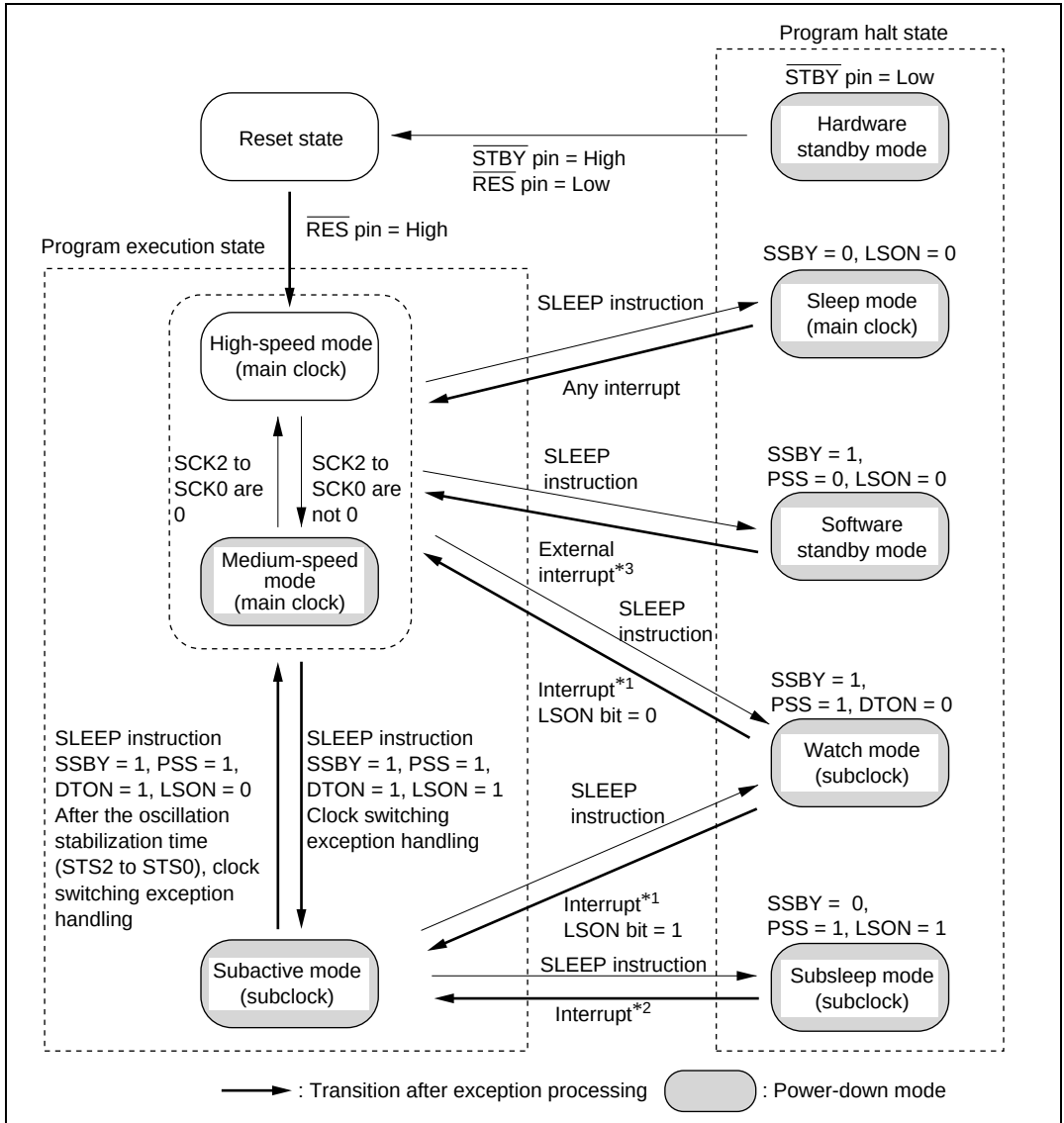
- MSTPCRL

Bit	Bit Name	Initial Value	R/W	Corresponding Module
7	MSTP7	1	R/W	Serial communication interface_0 (SCI_0)
6	MSTP6	1	R/W	Serial communication interface_1 (SCI_1)
5	MSTP5	1	R/W	Serial communication interface_2 (SCI_2)
4	MSTP4	1	R/W	I^2C bus interface_0 (IIC_0)
3	MSTP3	1	R/W	I^2C bus interface_1 (IIC_1)
2	MSTP2	1	R/W	Host interface (XBS), keyboard buffer controller, keyboard matrix interrupt mask register (KMIMR), keyboard matrix interrupt mask register A (KMIMRA), port 6 pull-up MOS control register (KMPCR)
1	MSTP1	1*	R/W	—
0	MSTP0	1	R/W	Host interface (LPC), wake-up event interrupt mask register B (WUEMRB)

Note: * This bit can be read from or written to, however, operation is not affected.

25.2 Mode Transitions and LSI States

Figure 25.1 shows the enabled mode transition diagram. The mode transition from program execution state to program halt state is performed by the SLEEP instruction. The mode transition from program halt state to program execution state is performed by an interrupt. The $\overline{\text{STBY}}$ input causes a mode transition from any state to hardware standby mode. The $\overline{\text{RES}}$ input causes a mode transition from a state other than hardware standby mode to the reset state. Table 25.2 shows the LSI internal states in each operating mode.



Notes: 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.
Always select high-speed mode before making a transition to watch mode or sub-active mode.

1. NMI, IRQ0 to IRQ2, IRQ6, IRQ7, and WDT1 interrupts
2. NMI, IRQ0 to IRQ7, WDT0, WDT1, TMR0, and TMR1 interrupts
3. NMI, IRQ0 to IRQ2, IRQ6, and IRQ7 interrupts

Figure 25.1 Mode Transition Diagram

Table 25.2 LSI Internal States in Each Mode

Function		High-Speed	Medium-Speed	Sleep	Module Stop	Watch	Sub-Active	Sub-Sleep	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	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Halted	Halted
CPU	Instruction execution	Function-ing	Medium-speed operation	Halted	Function-ing	Halted	Subclock operation	Halted	Halted	Halted
	Registers	Function-ing	Medium-speed operation	Retained	Function-ing	Retained	Subclock operation	Retained	Retained	Undefined
External interrupts	NMI	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Halted
	IRQ0 to IRQ7									
	KIN0 to KIN15									
	WUE0 to WUE7									
Peripheral modules	DTC	Function-ing	Medium-speed operation	Function-ing	Function-ing/Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (reset)
	WDT_1	Function-ing	Function-ing	Function-ing	Function-ing	Subclock operation	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	WDT_0	Function-ing	Function-ing	Function-ing	Function-ing	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	TMR_0, TMR_1	Function-ing	Function-ing	Function-ing	Function-ing/Halted (retained)	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	Halted (reset)
	FRT	Function-ing	Function-ing	Function-ing	Function-ing/Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (reset)
	TMR_X, TMR_Y									
	Timer connection									
	IIC_0									
	IIC_1									
	LPC									
	SCI_0	Function-ing	Function-ing	Function-ing	Function-ing/Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)
	SCI_1									
	SCI_2									
Peripheral modules	PWM	Function-ing	Function-ing	Function-ing	Function-ing/Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)
	PWMX									
	XBS, Keyboard buffer controller									
	D/A									
	A/D									
	RAM	Function-ing	Function-ing	Function-ing (DTC)	Function-ing	Retained	Function-ing	Retained	Retained	Retained
	I/O	Function-ing	Function-ing	Function-ing	Function-ing	Retained	Function-ing	Function-ing	Retained	High impedance

Note: * "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).

25.3 Medium-Speed Mode

The CPU makes a transition to medium-speed mode as soon as the current bus cycle ends according to the setting of the SCK2 to SCK0 bits in SBYCR. In medium-speed mode, the CPU operates on the operating clock ($\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, or $\phi/32$). On-chip peripheral modules other than the bus masters always operate on the system 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.

By clearing all of bits SCK2 to SCK0 to 0, a transition is made to high-speed mode 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 the 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 set to 1, the LSON bit cleared to 0, and the PSS bit in TCSR (WDT_1) cleared to 0, operation shifts to software standby mode. When software standby mode is cleared by an external interrupt, medium-speed mode is restored.

When the $\overline{\text{RES}}$ pin is set low and medium-speed mode is cancelled, operation shifts to the reset state. The same applies in the case of a reset caused by overflow of the watchdog timer.

When the $\overline{\text{STBY}}$ pin is driven low, medium-speed mode is cancelled and a transition is made to hardware standby mode.

Figure 25.2 shows an example of medium-speed mode timing.

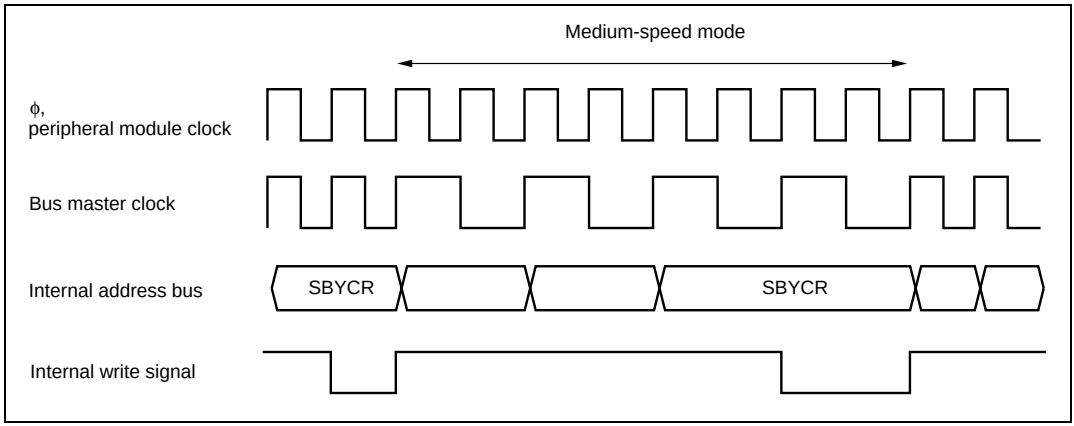


Figure 25.2 Medium-Speed Mode Timing

25.4 Sleep Mode

The CPU makes a transition to sleep mode if the SLEEP instruction is executed when the SSBY bit in SBYCR is cleared to 0 and the LSON bit in LPWRCR is cleared to 0. In sleep mode, CPU operation stops but the peripheral modules do not stop. The contents of the CPU's internal registers are retained.

Sleep mode is exited by any interrupt, the $\overline{\text{RES}}$ pin, or the $\overline{\text{STBY}}$ pin.

When an interrupt occurs, sleep mode is exited and interrupt exception handling starts. Sleep mode is not exited if the interrupt is disabled, or interrupts other than NMI are masked by the CPU.

Setting the $\overline{\text{RES}}$ pin level low cancels sleep mode and selects the reset state. After the oscillation stabilization time has passed, driving the $\overline{\text{RES}}$ pin high causes the CPU to start reset exception handling.

When the $\overline{\text{STBY}}$ pin level is driven low, sleep mode is cancelled and a transition is made to hardware standby mode.

25.5 Software Standby Mode

The CPU makes a transition to software standby mode when the SLEEP instruction is executed while the SSBY bit in SBYCR is set to 1, the LSON bit in LPWRCR is cleared to 0, and the PSS bit in TCSR (WDT_1) is cleared to 0.

In software standby mode, the CPU, on-chip peripheral modules, and clock pulse generator all stop. However, the contents of the CPU's internal registers, on-chip RAM data, I/O ports, and the states of on-chip peripheral modules other than the SCI, PWM, and PWMX, are retained as long as the prescribed voltage is supplied.

Software standby mode is cleared by an external interrupt (NMI, IRQ0 to IRQ2, IRQ6, or IRQ7), the $\overline{\text{RES}}$ pin input, or $\overline{\text{STBY}}$ pin input.

When an external interrupt request signal is input, system clock oscillation starts, and after the elapse of the time set in bits STS2 to STS0 in SBYCR, software standby mode is cleared, and interrupt exception handling is started. When clearing software standby mode with an IRQ0 to IRQ2, IRQ6, or IRQ7 interrupt, set the corresponding enable bit to 1 and ensure that no interrupt with a higher priority than interrupts IRQ0 to IRQ2, IRQ6, and IRQ7 is generated. Software standby mode cannot be cleared if an interrupt enable bit corresponding to an IRQ0 to IRQ2, IRQ6, or IRQ7 interrupt is cleared to 0 or if the interrupt has been masked on the CPU side.

When the $\overline{\text{RES}}$ pin is driven low, system clock oscillation is started. At the same time as system clock oscillation starts, the system clock is supplied to the entire LSI. Note that the $\overline{\text{RES}}$ pin must be held low until clock oscillation stabilizes. When the $\overline{\text{RES}}$ pin goes high after clock oscillation stabilizes, the CPU begins reset exception handling.

When the $\overline{\text{STBY}}$ pin is driven low, software standby mode is cancelled and a transition is made to hardware standby mode.

Figure 25.3 shows an example in which a transition is made to software standby mode at the falling edge of the NMI pin, and software standby mode is cleared at the rising edge of 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 of the NMI pin.

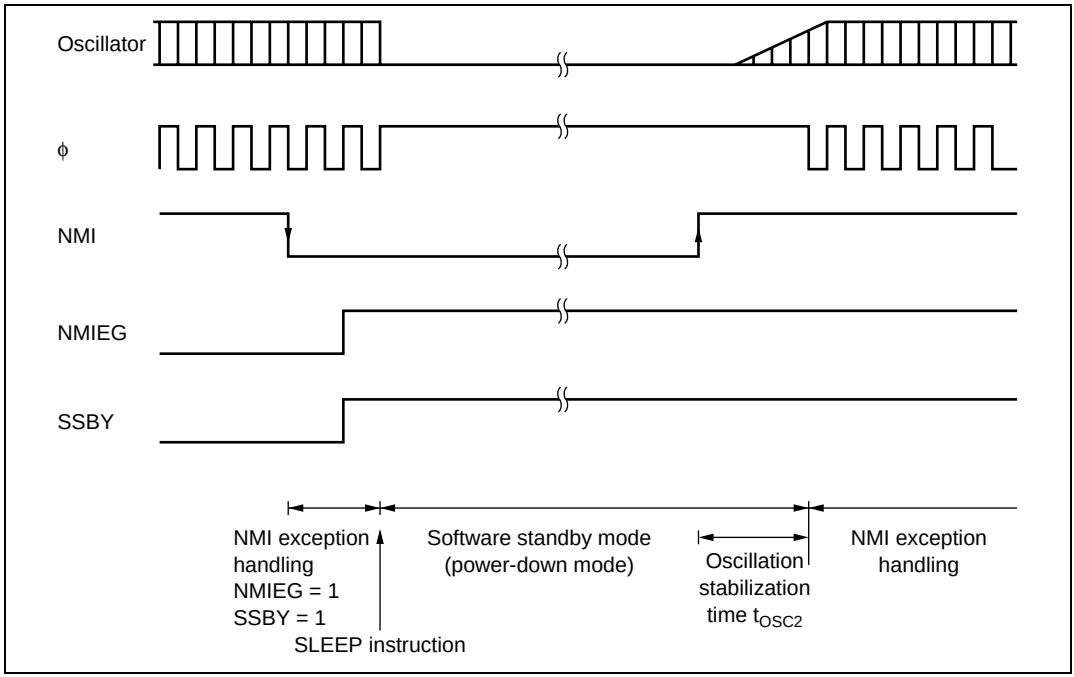


Figure 25.3 Application Example in Software Standby Mode

25.6 Hardware Standby Mode

The CPU makes a transition to hardware standby mode from any mode when the $\overline{\text{STBY}}$ pin is driven low.

In hardware standby mode, all functions enter the reset state. As long as the prescribed voltage is supplied, on-chip RAM data is retained. The I/O ports are set to the high-impedance state.

In order to retain on-chip RAM data, the RAME bit in SYSCR should be cleared to 0 before driving the $\overline{\text{STBY}}$ pin low. Do not change the state of the mode pins (MD1 and MD0) while this LSI is in hardware standby mode.

Hardware standby mode is cleared by the $\overline{\text{STBY}}$ pin input or the $\overline{\text{RES}}$ pin input.

When the $\overline{\text{STBY}}$ pin is driven high while the $\overline{\text{RES}}$ pin is low, clock oscillation is started. Ensure that the $\overline{\text{RES}}$ pin is held low until system clock oscillation stabilizes. When the $\overline{\text{RES}}$ pin is subsequently driven high after the clock oscillation stabilization time has passed, reset exception handling starts.

Figure 25.4 shows an example of hardware standby mode timing.

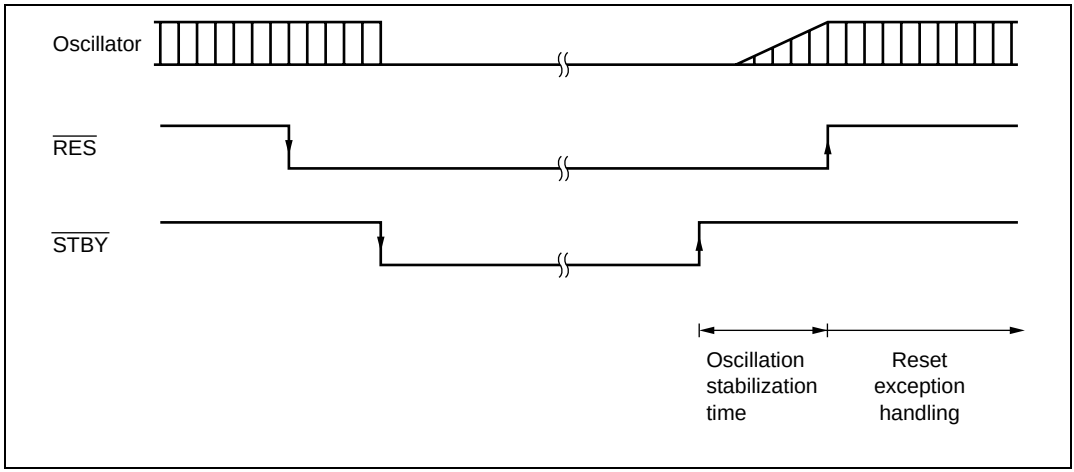


Figure 25.4 Hardware Standby Mode Timing

25.7 Watch Mode

The CPU makes a transition to watch mode when the SLEEP instruction is executed in high-speed mode or subactive mode with the SSBY bit in SBYCR set to 1, the DTON bit in LPWRCR cleared to 0, and the PSS bit in TCSR (WDT_1) set to 1.

In watch mode, the CPU is stopped and peripheral modules other than WDT_1 are also stopped. The contents of the CPU's internal registers, several on-chip peripheral module registers, and on-chip RAM data are retained and the I/O ports retain their values before transition as long as the prescribed voltage is supplied.

Watch mode is exited by an interrupt (WOVI1, NMI, IRQ0 to IRQ2, IRQ6, or IRQ7), $\overline{\text{RES}}$ pin input, or $\overline{\text{STBY}}$ pin input.

When an interrupt occurs, watch mode is exited and a transition is made to high-speed mode or medium-speed mode when the LSON bit in LPWRCR cleared to 0 or to subactive mode when the LSON bit is set to 1. When a transition is made to high-speed mode, a stable clock is supplied to the entire LSI and interrupt exception handling starts after the time set in the STS2 to STS0 bits in SBYCR has elapsed. In the case of an IRQ0 to IRQ2, IRQ6, or IRQ7 interrupt, watch mode is not exited if the corresponding enable bit has been cleared to 0. In the case of interrupts from the on-chip peripheral modules, watch mode is not exited if the interrupt enable register has been set to disable the reception of that interrupt, or the interrupt is masked by the CPU.

When the $\overline{\text{RES}}$ pin is driven low, system clock oscillation starts. Simultaneously with the start of system clock oscillation, the system clock is supplied to the entire LSI. Note that the $\overline{\text{RES}}$ pin must be held low until clock oscillation is stabilized. If the $\overline{\text{RES}}$ pin is driven high after the clock oscillation stabilization time has passed, the CPU begins reset exception handling.

If the $\overline{\text{STBY}}$ pin is driven low, the LSI enters hardware standby mode.

25.8 Subsleep Mode

The CPU makes a transition to subsleep mode when the SLEEP instruction is executed in subactive mode with the SSBY bit in SBYCR cleared to 0, the LSON bit in LPWRCR set to 1, and the PSS bit in TCSR (WDT_1) set to 1.

In subsleep mode, the CPU is stopped. Peripheral modules other than TMR_0, TMR_1, WDT_0, and WDT_1 are also stopped. The contents of the CPU's internal registers, several on-chip peripheral module registers, and on-chip RAM data are retained and the I/O ports retain their values before transition as long as the prescribed voltage is supplied.

Subsleep mode is exited by an interrupt (interrupts by on-chip peripheral modules, NMI, IRQ0 to IRQ7), the $\overline{\text{RES}}$ pin input, or the $\overline{\text{STBY}}$ pin input.

When an interrupt occurs, subsleep mode is exited and interrupt exception handling starts.

In the case of an IRQ0 to IRQ7 interrupt, subsleep mode is not exited if the corresponding enable bit has been cleared to 0. In the case of interrupts from the on-chip peripheral modules, subsleep mode is not exited if the interrupt enable register has been set to disable the reception of that interrupt, or the interrupt is masked by the CPU.

When the $\overline{\text{RES}}$ pin is driven low, system clock oscillation starts. Simultaneously with the start of system clock oscillation, the system clock is supplied to the entire LSI. Note that the $\overline{\text{RES}}$ pin must be held low until clock oscillation is stabilized. If the $\overline{\text{RES}}$ pin is driven high after the clock oscillation stabilization time has passed, the CPU begins reset exception handling.

If the $\overline{\text{STBY}}$ pin is driven low, the LSI enters hardware standby mode.

25.9 Subactive Mode

The CPU makes a transition to subactive mode when the SLEEP instruction is executed in high-speed mode with the SSBY bit in SBYCR set to 1, the DTON bit and LSON bit in LPWRCR set to 1, and the PSS bit in TCSR (WDT_1) set to 1. When an interrupt occurs in watch mode, and if the LSON bit in LPWRCR is 1, a direct transition is made to subactive mode. Similarly, if an interrupt occurs in subsleep mode, a transition is made to subactive mode.

In subactive mode, the CPU operates at a low speed based on the subclock and sequentially executes programs. Peripheral modules other than TMR_0, TMR_1, WDT_0, and WDT_1 are also stopped.

When operating the CPU in subactive mode, the SCK2 to SCK0 bits in SBYCR must be cleared to 0.

Subactive mode is exited by the SLEEP instruction, $\overline{\text{RES}}$ pin input, or $\overline{\text{STBY}}$ pin input.

When the SLEEP instruction is executed with the SSBY bit in SBYCR set to 1, the DTON bit in LPWRCR cleared to 0, and the PSS bit in TCSR (WDT_1) set to 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 cleared to 0, the LSON bit in LPWRCR set to 1, and the PSS bit in TCSR (WDT_1) set to 1, a transition is made to subsleep mode. When the SLEEP instruction is executed with the SSBY bit in SBYCR set to 1, the DTON bit and LSON bit in LPWRCR set to 10, and the PSS bit in TCSR (WDT_1) set to 1, a direct transition is made to high-speed mode.

For details of direct transitions, see section 25.11, Direct Transitions.

When the $\overline{\text{RES}}$ pin is driven low, system clock oscillation starts. Simultaneously with the start of system clock oscillation, the system clock is supplied to the entire LSI. Note that the $\overline{\text{RES}}$ pin must be held low until the clock oscillation is stabilized. If the $\overline{\text{RES}}$ pin is driven high after the clock oscillation stabilization time has passed, the CPU begins reset exception handling.

If the $\overline{\text{STBY}}$ pin is driven low, the LSI enters hardware standby mode.

25.10 Module Stop Mode

Module stop mode can be individually set for each on-chip peripheral module.

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. In turn, when the corresponding MSTP bit is cleared to 0, module stop mode is cancelled and the module operation resumes at the end of the bus cycle. In module stop mode, the internal states of modules other than the SCI, D/A converter, A/D converter, PWM, and PWMX are retained.

After the reset state is cancelled, all modules other than DTC are in module stop mode.

While an on-chip peripheral module is in module stop mode, read/write access to its registers is disabled.

25.11 Direct Transitions

The CPU executes programs in three modes: high-speed, medium-speed, and subactive. When a direct transition is made from high-speed mode to subactive mode, there is no interruption of program execution. A direct transition is enabled by setting the DTON bit in LPWRCR to 1 and then executing the SLEEP instruction. After a transition, direct transition exception handling starts.

The CPU makes a transition to subactive mode when the SLEEP instruction is executed in high-speed mode with the SSBY bit in SBYCR set to 1, the LSON bit and DTON bit in LPWRCR set to 11, and the PSS bit in TSCR (WDT_1) set to 1.

To make a direct transition to high-speed mode after the time set in the STS2 to STS0 bits in SBYCR has elapsed, execute the SLEEP instruction in subactive mode with the SSBY bit in SBYCR set to 1, the LSON bit and DTON bit in LPWRCR set to 01, and the PSS bit in TSCR (WDT_1) set to 1.

25.12 Usage Notes

25.12.1 I/O Port Status

The status of the I/O ports is retained in software standby mode. Therefore, when a high level is output, the current consumption is not reduced by the amount of current to support the high level output.

25.12.2 Current Consumption when Waiting for Oscillation Stabilization

The current consumption increases during oscillation stabilization.

25.12.3 DTC Module Stop Mode

If the DTC module stop mode specification and DTC bus request occur simultaneously, the bus is released to the DTC and the MSTP bit cannot be set to 1. After completing the DTC bus cycle, set the MSTP bit to 1 again.

Section 26 List of Registers

The register list gives information on the on-chip I/O register addresses, how the register bits are configured, and the register states in each operating mode. The information is given as shown below.

1. Register Addresses (address order)

- Registers are listed from the lower allocation addresses.
- The MSB-side address is indicated for 16-bit addresses.
- Registers are classified by functional modules.
- The access size is indicated.

2. Register Bits

- Bit configurations of the registers are described in the same order as the Register Addresses (address order) above.
- Reserved bits are indicated by — in the bit name column.
- The bit number in the bit-name column indicates that the whole register is allocated as a counter or for holding data.
- 16-bit registers are indicated from the bit on the MSB side.

3. Register States in Each Operating Mode

- Register states are described in the same order as the Register Addresses (address order) above.
- The register states described here are for the basic operating modes. If there is a specific reset for an on-chip peripheral module, refer to the section on that on-chip peripheral module.

4. Register Select Conditions

- Register states are described in the same order as the Register Addresses (address order) above.
- For details on the register select conditions, refer to section 3.2.2, System Control Register (SYSCR), 3.2.3, Serial Timer Control Register (STCR), 26.1.3, Module Stop Control Registers H and L (MSTPCRH, MSTPCRL), and the register descriptions for each module.

26.1 Register Addresses (Address Order)

The data bus width indicates the numbers of bits by which the register is accessed.

The number of access states indicates the number of states based on the specified reference clock.

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port G open drain control register	PGNOCR*1	8	H'FE16	PORT	8	3
Port E open drain control register	PENOCR*1	8	H'FE18	PORT	8	3
Port F open drain control register	PFNOCR*1	8	H'FE19	PORT	8	3
Port C open drain control register	PCNOCR*1	8	H'FE1C	PORT	8	3
Port D open drain control register	PDNOCR*1	8	H'FE1D	PORT	8	3
Bidirectional data register 0MW	TWR0MW	8	H'FE20	LPC	8	3
Bidirectional data register 0SW	TWR0SW	8	H'FE20	LPC	8	3
Bidirectional data register 1	TWR1	8	H'FE21	LPC	8	3
Bidirectional data register 2	TWR2	8	H'FE22	LPC	8	3
Bidirectional data register 3	TWR3	8	H'FE23	LPC	8	3
Bidirectional data register 4	TWR4	8	H'FE24	LPC	8	3
Bidirectional data register 5	TWR5	8	H'FE25	LPC	8	3
Bidirectional data register 6	TWR6	8	H'FE26	LPC	8	3
Bidirectional data register 7	TWR7	8	H'FE27	LPC	8	3
Bidirectional data register 8	TWR8	8	H'FE28	LPC	8	3
Bidirectional data register 9	TWR9	8	H'FE29	LPC	8	3
Bidirectional data register 10	TWR10	8	H'FE2A	LPC	8	3
Bidirectional data register 11	TWR11	8	H'FE2B	LPC	8	3
Bidirectional data register 12	TWR12	8	H'FE2C	LPC	8	3
Bidirectional data register 13	TWR13	8	H'FE2D	LPC	8	3
Bidirectional data register 14	TWR14	8	H'FE2E	LPC	8	3
Bidirectional data register 15	TWR15	8	H'FE2F	LPC	8	3
Input data register 3	IDR3	8	H'FE30	LPC	8	3
Output data register 3	ODR3	8	H'FE31	LPC	8	3
Status register 3	STR3	8	H'FE32	LPC	8	3

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
LPC channel address register H	LADR3H	8	H'FE34	LPC	8	3
LPC channel address register L	LADR3L	8	H'FE35	LPC	8	3
SERIRQ control register 0	SIRQCR0	8	H'FE36	LPC	8	3
SERIRQ control register 1	SIRQCR1	8	H'FE37	LPC	8	3
Input data register 1	IDR1	8	H'FE38	LPC	8	3
Output data register 1	ODR1	8	H'FE39	LPC	8	3
Status register 1	STR1	8	H'FE3A	LPC	8	3
Input data register 2	IDR2	8	H'FE3C	LPC	8	3
Output data register 2	ODR2	8	H'FE3D	LPC	8	3
Status register 2	STR2	8	H'FE3E	LPC	8	3
Host interface select register	HISEL	8	H'FE3F	LPC	8	3
Host interface control register 0	HICR0	8	H'FE40	LPC	8	3
Host interface control register 1	HICR1	8	H'FE41	LPC	8	3
Host interface control register 2	HICR2	8	H'FE42	LPC	8	3
Host interface control register 3	HICR3	8	H'FE43	LPC	8	3
Wakeup event interrupt mask register B	WUEMRB*2	8	H'FE44	INT	8	3
Port G output data register	PGODR*1	8	H'FE46	PORT	8	3
Port G input data register	PGPIN*1	8	H'FE47 (read)	PORT	8	3
Port G data direction register	PGDDR*1	8	H'FE47 (write)	PORT	8	3
Port E output data register	PEODR*1	8	H'FE48	PORT	8	3
Port F output data register	PFODR*1	8	H'FE49	PORT	8	3
Port E input data register	PEPIN*1	8	H'FE4A (read)	PORT	8	3
Port E data direction register	PEDDR*1	8	H'FE4A (write)	PORT	8	3
Port F input data register	PFPIN*1	8	H'FE4B (read)	PORT	8	3

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port F data direction register	PFDDR*1	8	H'FE4B (write)	PORT	8	3
Port C output data register	PCODR*1	8	H'FE4C	PORT	8	3
Port D output data register	PDODR*1	8	H'FE4D	PORT	8	3
Port C input data register	PCPIN*1	8	H'FE4E (read)	PORT	8	3
Port C data direction register	PCDDR*1	8	H'FE4E (write)	PORT	8	3
Port D input data register	PDPIN*1	8	H'FE4F (read)	PORT	8	3
Port D data direction register	PDDDR*1	8	H'FE4F (write)	PORT	8	3
Host interface control register 2	HICR2	8	H'FE80	XBS	8	2
Input data register_3	IDR_3	8	H'FE81	XBS	8	2
Output data register_3	ODR_3	8	H'FE82	XBS	8	2
Status register_3	STR_3	8	H'FE83	XBS	8	2
Input data register_4	IDR_4	8	H'FE84	XBS	8	2
Output data register_4	ODR_4	8	H'FE85	XBS	8	2
Status register_4	STR_4	8	H'FE86	XBS	8	2
I^2C bus extended control register_0	ICXR_0	8	H'FED4	IIC_0	8	2
I^2C bus extended control register_1	ICXR_1	8	H'FED5	IIC_1	8	2
Keyboard control register H_0	KBCRH_0	8	H'FED8	Keyboard buffer controller_0	8	2
Keyboard control register L_0	KBCRL_0	8	H'FED9	Keyboard buffer controller_0	8	2
Keyboard data buffer register_0	KBBR_0	8	H'FEDA	Keyboard buffer controller_0	8	2
Keyboard control register H_1	KBCRH_1	8	H'FEDC	Keyboard buffer controller_1	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Keyboard control register L_1	KBCRL_1	8	H'FEDD	Keyboard buffer controller_1	8	2
Keyboard data buffer register_1	KBBR_1	8	H'FEDE	Keyboard buffer controller_1	8	2
Keyboard control register H_2	KBCRH_2	8	H'FEE0	Keyboard buffer controller_2	8	2
Keyboard control register L_2	KBCRL_2	8	H'FEE1	Keyboard buffer controller_2	8	2
Keyboard data buffer register_2	KBBR_2	8	H'FEE2	Keyboard buffer controller_2	8	2
Keyboard comparator control register	KBCOMP	8	H'FEE4	IrDA/ Extended A/D	8	2
DDC switch register	DDCSWR	8	H'FEE6	IIC_0	8	2
Interrupt control register A	ICRA	8	H'FEE8	INT	8	2
Interrupt control register B	ICRB	8	H'FEE9	INT	8	2
Interrupt control register C	ICRC	8	H'FEEA	INT	8	2
IRQ status register	ISR	8	H'FEEB	INT	8	2
IRQ sense control register H	ISCRH	8	H'FEEC	INT	8	2
IRQ sense control register L	ISCRL	8	H'FEED	INT	8	2
DTC enable register A	DTCERA	8	H'FEEE	DTC	8	2
DTC enable register B	DTCERB	8	H'FEEF	DTC	8	2
DTC enable register C	DTCERC	8	H'FEF0	DTC	8	2
DTC enable register D	DTCERD	8	H'FEF1	DTC	8	2
DTC enable register E	DTCERE	8	H'FEF2	DTC	8	2
DTC vector register	DTVECR	8	H'FEF3	DTC	8	2
Address break control register	ABRKCR	8	H'FEF4	INT	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Break address register A	BARA	8	H'FEF5	INT	8	2
Break address register B	BARB	8	H'FEF6	INT	8	2
Break address register C	BARC	8	H'FEF7	INT	8	2
Flash memory control register 1	FLMCR1	8	H'FF80	FLASH	8	2
Flash memory control register 2	FLMCR2	8	H'FF81	FLASH	8	2
Peripheral clock select register	PCSR	8	H'FF82	PWM	8	2
Erase block register 1	EBR1	8	H'FF82	FLASH	8	2
System control register 2	SYSCR2	8	H'FF83	SYSTEM	8	2
Erase block register 2	EBR2	8	H'FF83	FLASH	8	2
Standby control register	SBYCR	8	H'FF84	SYSTEM	8	2
Low power control register	LPWRCR	8	H'FF85	SYSTEM	8	2
Module stop control register H	MSTPCRH	8	H'FF86	SYSTEM	8	2
Module stop control register L	MSTPCRL	8	H'FF87	SYSTEM	8	2
Serial mode register_1	SMR_1	8	H'FF88	SCI_1	8	2
I^2C bus control register_1	ICCR_1	8	H'FF88	IIC_1	8	2
Bit rate register_1	BRR_1	8	H'FF89	SCI_1	8	2
I^2C bus status register_1	ICSR_1	8	H'FF89	IIC_1	8	2
Serial control register_1	SCR_1	8	H'FF8A	SCI_1	8	2
Transmit data register_1	TDR_1	8	H'FF8B	SCI_1	8	2
Serial status register_1	SSR_1	8	H'FF8C	SCI_1	8	2
Receive data register_1	RDR_1	8	H'FF8D	SCI_1	8	2
Smart card mode register_1	SCMR_1	8	H'FF8E	SCI_1	8	2
I^2C bus data register_1	ICDR_1	8	H'FF8E	IIC_1	8	2
Second slave address register_1	SARX_1	8	H'FF8E	IIC_1	8	2
I^2C bus mode register_1	ICMR_1	8	H'FF8F	IIC_1	8	2
Slave address register_1	SAR_1	8	H'FF8F	IIC_1	8	2
Timer interrupt enable register	TIER	8	H'FF90	FRT	8	2
Timer control/status register	TCSR	8	H'FF91	FRT	8	2
Free running counter H	FRCH	8	H'FF92	FRT	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Free running counter L	FRCL	8	H'FF93	FRT	8	2
Output control register AH	OCRAH	8	H'FF94	FRT	8	2
Output control register BH	OCRBH	8	H'FF94	FRT	8	2
Output control register AL	OCRAL	8	H'FF95	FRT	8	2
Output control register BL	OCRBL	8	H'FF95	FRT	8	2
Timer control register	TCR	8	H'FF96	FRT	8	2
Timer output compare control register	TOCR	8	H'FF97	FRT	8	2
Input capture register AH	ICRAH	8	H'FF98	FRT	8	2
Output control register ARH	OCRARH	8	H'FF98	FRT	8	2
Input capture register AL	ICRAL	8	H'FF99	FRT	8	2
Output control register ARL	OCRARL	8	H'FF99	FRT	8	2
Input capture register BH	ICRBH	8	H'FF9A	FRT	8	2
Output control register AFH	OCRAFH	8	H'FF9A	FRT	8	2
Input capture register BL	ICRBL	8	H'FF9B	FRT	8	2
Output control register AFL	OCRAFL	8	H'FF9B	FRT	8	2
Input capture register CH	ICRCH	8	H'FF9C	FRT	8	2
Output compare register DMH	OCRDMH	8	H'FF9C	FRT	8	2
Input capture register CL	ICRCL	8	H'FF9D	FRT	8	2
Output compare register DML	OCRDML	8	H'FF9D	FRT	8	2
Input capture register DH	ICRDH	8	H'FF9E	FRT	8	2
Input capture register DL	ICRDL	8	H'FF9F	FRT	8	2
Serial mode register_2	SMR_2	8	H'FFA0	SCI_2	8	2
PWM (D/A) control register	DACR	8	H'FFA0	PWMX	8	2
PWM (D/A) data register AH	DADRAH	8	H'FFA0	PWMX	8	2
PWM (D/A) data register AL	DADRAL	8	H'FFA1	PWMX	8	2
Bit rate register_2	BRR_2	8	H'FFA1	SCI_2	8	2
Serial control register_2	SCR_2	8	H'FFA2	SCI_2	8	2
Transmit data register_2	TDR_2	8	H'FFA3	SCI_2	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Serial status register_2	SSR_2	8	H'FFA4	SCI_2	8	2
Receive data register_2	RDR_2	8	H'FFA5	SCI_2	8	2
Smart card mode register_2	SCMR_2	8	H'FFA6	SCI_2	8	2
PWM (D/A) counter H	DACNTH	8	H'FFA6	PWMX	8	2
PWM (D/A) data register BH	DADRBH	8	H'FFA6	PWMX	8	2
PWM (D/A) counter L	DACNTL	8	H'FFA7	PWMX	8	2
PWM (D/A) data register BL	DADRBL	8	H'FFA7	PWMX	8	2
Timer control/status register_0	TCSR_0	8	H'FFA8	WDT	8	2
Timer counter_0	TCNT_0	8	H'FFA8 (write)	WDT_0	8	2
Timer counter_0	TCNT_0	8	H'FFA9 (read)	WDT_0	8	2
Port A output data register	PAODR	8	H'FFAA	PORT	8	2
Port A input data register	PAPIN	8	H'FFAB	PORT	8	2
Port A data direction register	PADDR	8	H'FFAB	PORT	8	2
Port 1 pull-up MOS control register	P1PCR	8	H'FFAC	PORT	8	2
Port 2 pull-up MOS control register	P2PCR	8	H'FFAD	PORT	8	2
Port 3 pull-up MOS control register	P3PCR	8	H'FFAE	PORT	8	2
Port 1 data direction register	P1DDR	8	H'FFB0	PORT	8	2
Port 2 data direction register	P2DDR	8	H'FFB1	PORT	8	2
Port 1 data register	P1DR	8	H'FFB2	PORT	8	2
Port 2 data register	P2DR	8	H'FFB3	PORT	8	2
Port 3 data direction register	P3DDR	8	H'FFB4	PORT	8	2
Port 4 data direction register	P4DDR	8	H'FFB5	PORT	8	2
Port 3 data register	P3DR	8	H'FFB6	PORT	8	2
Port 4 data register	P4DR	8	H'FFB7	PORT	8	2
Port 5 data direction register	P5DDR	8	H'FFB8	PORT	8	2
Port 6 data direction register	P6DDR	8	H'FFB9	PORT	8	2
Port 5 data register	P5DR	8	H'FFBA	PORT	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Port 6 data register	P6DR	8	H'FFBB	PORT	8	2
Port B output data register	PBODR	8	H'FFBC	PORT	8	2
Port B input data register	PBPIN	8	H'FFBD (read)	PORT	8	2
Port 8 data direction register	P8DDR	8	H'FFBD (write)	PORT	8	2
Port 7 input data register	P7PIN	8	H'FFBE (read)	PORT	8	2
Port B data direction register	PBDDR	8	H'FFBE (write)	PORT	8	2
Port 8 data register	P8DR	8	H'FFBF	PORT	8	2
Port 9 data direction register	P9DDR	8	H'FFC0	PORT	8	2
Port 9 data register	P9DR	8	H'FFC1	PORT	8	2
Interrupt enable register	IER	8	H'FFC2	INT	8	2
Serial timer control register	STCR	8	H'FFC3	SYSTEM	8	2
System control register	SYSCR	8	H'FFC4	SYSTEM	8	2
Mode control register	MDCR	8	H'FFC5	SYSTEM	8	2
Bus control register	BCR	8	H'FFC6	BSC	8	2
Wait state control register	WSCR	8	H'FFC7	BSC	8	2
Timer control register_0	TCR_0	8	H'FFC8	TMR_0	8	2
Timer control register_1	TCR_1	8	H'FFC9	TMR_1	8	2
Timer control/status register_0	TCSR_0	8	H'FFCA	TMR_0	8	2
Timer control/status register_1	TCSR_1	8	H'FFCB	TMR_1	16	2
Time constant register A_0	TCORA_0	8	H'FFCC	TMR_0	16	2
Time constant register A_1	TCORA_1	8	H'FFCD	TMR_1	16	2
Time constant register B_0	TCORB_0	8	H'FFCE	TMR_0	16	2
Time constant register B_1	TCORB_1	8	H'FFCF	TMR_1	16	2
Timer counter_0	TCNT_0	8	H'FFD0	TMR_0	16	2
Timer counter_1	TCNT_1	8	H'FFD1	TMR_1	16	2
PWM output enable register B	PWOERB	8	H'FFD2	PWM	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
PWM output enable register A	PWOERA	8	H'FFD3	PWM	8	2
PWM data polarity register B	PWDPRB	8	H'FFD4	PWM	8	2
PWM data polarity register A	PWDPRA	8	H'FFD5	PWM	8	2
PWM register select	PWSL	8	H'FFD6	PWM	8	2
PWM data registers 0 to 15	PWDR0 to PWDR15	8	H'FFD7	PWM	8	2
Serial mode register_0	SMR_0	8	H'FFD8	SCI_0	8	2
I^2C bus control register_0	ICCR_0	8	H'FFD8	IIC_0	8	2
Bit rate register_0	BRR_0	8	H'FFD9	SCI_0	8	2
I^2C bus status register_0	ICSR_0	8	H'FFD9	IIC_0	8	2
Serial control register_0	SCR_0	8	H'FFDA	SCI_0	8	2
Transmit data register_0	TDR_0	8	H'FFDB	SCI_0	8	2
Serial status register_0	SSR_0	8	H'FFDC	SCI_0	8	2
Receive data register_0	RDR_0	8	H'FFDD	SCI_0	8	2
Smart card mode register_0	SCMR_0	8	H'FFDE	SCI_0	8	2
I^2C bus data register_0	ICDR_0	8	H'FFDE	IIC_0	8	2
Second slave address register_0	SARX_0	8	H'FFDE	IIC_0	8	2
I^2C bus mode register_0	ICMR_0	8	H'FFDF	IIC_0	8	2
Slave address register_0	SAR_0	8	H'FFDF	IIC_0	8	2
A/D data register AH	ADDRAH	8	H'FFE0	A/D converter	8	2
A/D data register AL	ADDRAL	8	H'FFE1	A/D converter	8	2
A/D data register BH	ADDRBH	8	H'FFE2	A/D converter	8	2
A/D data register BL	ADDRBL	8	H'FFE3	A/D converter	8	2
A/D data register CH	ADDRCH	8	H'FFE4	A/D converter	8	2
A/D data register CL	ADDRCL	8	H'FFE5	A/D converter	8	2
A/D data register DH	ADDRDH	8	H'FFE6	A/D converter	8	2
A/D data register DL	ADDRDL	8	H'FFE7	A/D converter	8	2
A/D control/status register	ADCSR	8	H'FFE8	A/D converter	8	2
A/D control register	ADCR	8	H'FFE9	A/D converter	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Timer control/status register_1	TCSR_1	8	H'FFEA	WDT_1	8	2
Timer counter_1	TCNT_1	8	H'FFEA (write)	WDT_1	8	2
Timer counter_1	TCNT_1	8	H'FFEB (read)	WDT_1	8	2
Host interface control register	HICR	8	H'FFF0	XBS	8	2
Timer control register_X	TCR_X	8	H'FFF0	TMR_X	16	2
Timer control register_Y	TCR_Y	8	H'FFF0	TMR_Y	16	2
Keyboard matrix interrupt register 6	KMIMR	8	H'FFF1	INT	8	2
Timer control/status register_X	TCSR_X	8	H'FFF1	TMR_X	16	2
Timer control/status register_Y	TCSR_Y	8	H'FFF1	TMR_Y	16	2
Pull-up MOS control register	KMPCR	8	H'FFF2	PORT	8	2
Input capture register R	TICRR	8	H'FFF2	TMR_X	16	2
Time constant register A_Y	TCORA_Y	8	H'FFF2	TMR_Y	16	2
Keyboard matrix interrupt register A	KMIMRA	8	H'FFF3	INT	8	2
Input capture register F	TICRF	8	H'FFF3	TMR_X	16	2
Time constant register B_Y	TCORB_Y	8	H'FFF3	TMR_Y	16	2
Input data register_1	IDR_1	8	H'FFF4	XBS	8	2
Timer counter_X	TCNT_X	8	H'FFF4	TMR_X	16	2
Timer counter_Y	TCNT_Y	8	H'FFF4	TMR_Y	16	2
Output data register_1	ODR_1	8	H'FFF5	XBS	8	2
Timer constant register C	TCORC	8	H'FFF5	TMR_X	16	2
Timer input select register	TISR	8	H'FFF5	TMR_Y	16	2
Status register_1	STR_1	8	H'FFF6	XBS	8	2
Timer constant register A_X	TCORA_X	8	H'FFF6	TMR_X	16	2
Timer constant register B_X	TCORB_X	8	H'FFF7	TMR_X	16	2
D/A data register 0	DADR0	8	H'FFF8	D/A converter	8	2
D/A data register 1	DADR1	8	H'FFF9	D/A converter	8	2
D/A control register	DACR	8	H'FFFA	D/A converter	8	2
Input data register_2	IDR_2	8	H'FFFC	XBS	8	2

Register Name	Abbreviation	Number of Bits	Address	Module	Data Bus Width	Number of Access States
Timer connection register I	TCONRI	8	H'FFFC	Timer connection	8	2
Output data register_2	ODR_2	8	H'FFFD	XBS	8	2
Timer connection register O	TCONRO	8	H'FFFD	Timer connection	8	2
Status register_2	STR_2	8	H'FFFE	XBS	8	2
Timer connection register S	TCONRS	8	H'FFFE	Timer connection	8	2
Edge sense register	SEDGR	8	H'FFFF	Timer connection	8	2

Notes: 1. Can be used on the H8S/2160B and H8S/2161B.
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

26.2 Register Bits

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

16-bit registers are shown as 2 lines.

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PGNOCR*1	PG7NOCR	PG6NOCR	PG5NOCR	PG4NOCR	PG3NOCR	PG2NOCR	PG1NOCR	PG0NOCR	PORT
PENOCR*1	PE7NOCR	PE6NOCR	PE5NOCR	PE4NOCR	PE3NOCR	PE2NOCR	PE1NOCR	PE0NOCR	
PFNOCR*1	PF7NOCR	PF6NOCR	PF5NOCR	PF4NOCR	PF3NOCR	PF2NOCR	PF1NOCR	PF0NOCR	
PCNOCR*1	PC7NOCR	PC6NOCR	PC5NOCR	PC4NOCR	PC3NOCR	PC2NOCR	PC1NOCR	PC0NOCR	
PDNOCR*1	PD7NOCR	PD6NOCR	PD5NOCR	PD4NOCR	PD3NOCR	PD2NOCR	PD1NOCR	PD0NOCR	
TWR0MW	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	LPC
TWR0SW	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR4	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR5	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR6	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR7	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR9	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR10	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR11	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR12	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR13	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR14	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TWR15	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
IDR3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ODR3	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
STR3*2	IBF3B	OBF3B	MWMF	SWMF	C/$\overline{D}$3	DBU32	IBF3A	OBF3A	
STR3*3	DBU37	DBU36	DBU35	DBU34	C/$\overline{D}$3	DBU32	IBF3A	OBF3A	
LADR3H	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
LADR3L	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	—	Bit 1	TWRE	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
SIRQCR0	Q/$\overline{C}$	SELREQ	IEDIR	SMIE3B	SMIE3A	SMIE2	IRQ12E1	IRQ1E1	LPC
SIRQCR1	IRQ11E3	IRQ10E3	IRQ9E3	IRQ6E3	IRQ11E2	IRQ10E2	IRQ9E2	IRQ6E2	
IDR1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ODR1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
STR1	DBU17	DBU16	DBU15	DBU14	C/$\overline{D}$1	DBU12	IBF1	OBF1	
IDR2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ODR2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
STR2	DBU27	DBU26	DBU25	DBU24	C/$\overline{D}$2	DBU22	IBF2	OBF2	
HISEL	SELSTR3	SELIRQ11	SELIRQ10	SELIRQ9	SELIRQ6	SELSMI	SELIRQ12	SELIRQ1	
HICR0	LPC3E	LPC2E	LPC1E	FGA20E	SDWNE	PMEE	LSMIE	LSCIE	
HICR1	LPCBSY	CLKREQ	IRQBSY	LRSTB	SDWNB	PMEB	LSMIB	LSCIB	
HICR2	GA20	LRST	SDWN	ABRT	IBFIE3	IBFIE2	IBFIE1	ERRIE	
HICR3	LFRAME	CLKRUN	SERIRQ	LRESET	LPCPD	PME	LSMI	LSCI	
WUEMRB*5	WUEMR7	WUEMR6	WUEMR5	WUEMR4	WUEMR3	WUEMR2	WUEMR1	WUEMR0	INT
PGODR*1	PG7ODR	PG6ODR	PG5ODR	PG4ODR	PG3ODR	PG2ODR	PG1ODR	PG0ODR	PORT
PGPIN*1	PG7PIN	PG6PIN	PG5PIN	PG4PIN	PG3PIN	PG2PIN	PG1PIN	PG0PIN	
PGDDR*1	PG7DDR	PG6DDR	PG5DDR	PG4DDR	PG3DDR	PG2DDR	PG1DDR	PG0DDR	
PEODR*1	PE7ODR	PE6ODR	PE5ODR	PE4ODR	PE3ODR	PE2ODR	PE1ODR	PE0ODR	
PFODR*1	PF7ODR	PF6ODR	PF5ODR	PF4ODR	PF3ODR	PF2ODR	PF1ODR	PF0ODR	
PEPIN*1	PE7PIN	PE6PIN	PE5PIN	PE4PIN	PE3PIN	PE2PIN	PE1PIN	PE0PIN	
PEDDR*1	PE7DDR	PE6DDR	PE5DDR	PE4DDR	PE3DDR	PE2DDR	PE1DDR	PE0DDR	
PFPIN*1	PF7PIN	PF6PIN	PF5PIN	PF4PIN	PF3PIN	PF2PIN	PF1PIN	PF0PIN	
PFDDR*1	PF7DDR	PF6DDR	PF5DDR	PF4DDR	PF3DDR	PF2DDR	PF1DDR	PF0DDR	
PCODR*1	PC7ODR	PC6ODR	PC5ODR	PC4ODR	PC3ODR	PC2ODR	PC1ODR	PC0ODR	
PDODR*1	PD7ODR	PD6ODR	PD5ODR	PD4ODR	PD3ODR	PD2ODR	PD1ODR	PD0ODR	
PCPIN*1	PC7PIN	PC6PIN	PC5PIN	PC4PIN	PC3PIN	PC2PIN	PC1PIN	PC0PIN	
PCDDR*1	PC7DDR	PC6DDR	PC5DDR	PC4DDR	PC3DDR	PC2DDR	PC1DDR	PC0DDR	
PDPIN*1	PD7PIN	PD6PIN	PD5PIN	PD4PIN	PD3PIN	PD2PIN	PD1PIN	PD0PIN	
PDDDR*1	PD7DDR	PD6DDR	PD5DDR	PD4DDR	PD3DDR	PD2DDR	PD1DDR	PD0DDR	
HICR2	—	—	—	—	—	IBFIE4	IBFIE3	—	XBS
IDR_3	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	
ODR_3	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	
STR_3	DBU	DBU	DBU	DBU	C/$\overline{D}$	DBU	IBF	OBF	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
IDR_4	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	XBS
ODR_4	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	
STR_4	DBU	DBU	DBU	DBU	C/$\overline{D}$	DBU	IBF	OBF	
ICXR_0	STOPIM	HNDS	ICDRF	ICDRE	ALIE	ALSL	FNC1	FNC0	IIC_0
ICXR_1	STOPIM	HNDS	ICDRF	ICDRE	ALIE	ALSL	FNC1	FNC0	IIC_1
KBCRH_0	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS	Keyboard buffer controller_0
KBCRL_0	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR0	
KBBR_0	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0	
KBCRH_1	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS	Keyboard buffer controller_1
KBCRL_1	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR0	
KBBR_1	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0	
KBCRH_2	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS	Keyboard buffer controller_2
KBCRL_2	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR0	
KBBR_2	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0	
KBCOMP	IrE	IrCKS2	IrCKS1	IrCKS0	KBADE	KBCH2	KBCH1	KBCH0	IrDA/ expanded A/D
DDCSWR	SWE	SW	IE	IF	CLR3	CLR2	CLR1	CLR0	IIC_0
ICRA	ICRA7	ICRA6	ICRA5	ICRA4	ICRA3	ICRA2	ICRA1	ICRA0	INT
ICRB	ICRB7	ICRB6	ICRB5	ICRB4	ICRB3	ICRB2	ICRB1	ICRB0	
ICRC	ICRC7	ICRC6	ICRC5	ICRC4	ICRC3	ICRC2	ICRC1	ICRC0	
ISR	IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F	IRQ0F	
ISCRH	IRQ7SCB	IRQ7SCA	IRQ6SCB	IRQ6SCA	IRQ5SCB	IRQ5SCA	IRQ4SCB	IRQ4SCA	
ISCRL	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0SCA	
DTCERA	DTCEA7	DTCEA6	DTCEA5	DTCEA4	DTCEA3	DTCEA2	DTCEA1	DTCEA0	DTC
DTCERB	DTCEB7	DTCEB6	DTCEB5	DTCEB4	DTCEB3	DTCEB2	DTCEB1	DTCEB0	
DTCERC	DTCEC7	DTCEC6	DTCEC5	DTCEC4	DTCEC3	DTCEC2	DTCEC1	DTCEC0	
DTCERD	DTCED7	DTCED6	DTCED5	DTCED4	DTCED3	DTCED2	DTCED1	DTCED0	
DTCERE	DTCEE7	DTCEE6	DTCEE5	DTCEE4	DTCEE3	DTCEE2	DTCEE1	DTCEE0	
DTVECR	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0	
ABRKCR	CMF	—	—	—	—	—	—	BIE	INT
BARA	A23	A22	A21	A20	A19	A18	A17	A16	
BARB	A15	A14	A13	A12	A11	A10	A9	A8	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
BARC	A7	A6	A5	A4	A3	A2	A1	—	INT
FLMCR1	FWE	SWE	—	—	EV	PV	E	P	FLASH
FLMCR2	FLER	—	—	—	—	—	ESU	PSU	
PCSR	—	—	—	—	—	PWCKB	PWCKA	—	PWM
EBR1*4	—	—	—	—	EB11	EB10	EB9	EB8	FLASH
SYSCR2	KWUL1	KWUL0	P6PUE	—	SDE	CS4E	CS3E	HI12E	SYSTEM
EBR2	EB7	EB6	EB5	EB4	EB3	EB2	EB1	EB0	FLASH
SBYCR	SSBY	STS2	STS1	STS0	—	SCK2	SCK1	SCK0	SYSTEM
LPWRCR	DTON	LSON	NESEL	EXCLE	—	—	—	—	
MSTPCRH	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	
MSTPCRL	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2	MSTP1	MSTP0	
SMR_1	C/$\overline{A}$	CHR	PE	O/$\overline{E}$	STOP	MP	CKS1	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	TDRE	RDRF	ORER	FER	PER	TEND	MPB	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	
TIER	ICIAE	ICIBE	ICICE	ICIDE	OCIAE	OCIBE	OVIE	—	FRT
TCSR	ICFA	ICFB	ICFC	ICFD	OCFA	OCFB	OVF	CCLRA	
FRCH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
FRCL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
OCRAH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
OCRBH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
OCRAL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
OCRBL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCR	IEDGA	IEDGB	IEDGC	IEDGD	BUFEA	BUFEB	CKS1	CKS0	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TOCR	ICRDMS	OCRAMS	ICRS	OCRS	OEA	OEB	OLVLA	OLVLB	FRT
ICRAH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
OCRARH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
ICRAL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
OCRARL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ICRBH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
OCRAFH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
ICRBL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
OCRAFL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ICRCH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
OCRDMH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
ICRCL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
OCRDML	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
ICRDH	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	
ICRDL	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SMR_2	C/$\overline{A}$	CHR	PE	O/$\overline{E}$	STOP	MP	CKS1	CKS0	SCI_2
DACR	TEST	PWME	—	—	OEB	OEA	OS	CKS	PWMX
DADRAH	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	
DADRAL	DA5	DA4	DA3	DA2	DA1	DA0	CFS	—	
BRR_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	SCI_2
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	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT	
RDR_2	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SCMR_2	—	—	—	—	SDIR	SINV	—	SMIF	
DACNTH	UC7	UC6	UC5	UC4	UC3	UC2	UC1	UC0	PWMX
DADRBH	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	
DACNTL	UC8	UC9	UC10	UC11	UC12	UC13	—	REGS	
DADRBL	DA5	DA4	DA3	DA2	DA1	DA0	CFS	REGS	
TCSR_0	OVF	WT/$\overline{IT}$	TME	—	RST/$\overline{NMI}$	CKS2	CKS1	CKS0	WDT_0
TCNT_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
PAODR	PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR	PA0ODR	PORT
PAPIN	PA7PIN	PA6PIN	PA5PIN	PA4PIN	PA3PIN	PA2PIN	PA1PIN	PA0PIN	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
PADDR	PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR	PA0DDR	PORT
P1PCR	P17PCR	P16PCR	P15PCR	P14PCR	P13PCR	P12PCR	P11PCR	P10PCR	
P2PCR	P27PCR	P26PCR	P25PCR	P24PCR	P23PCR	P22PCR	P21PCR	P20PCR	
P3PCR	P37PCR	P36PCR	P35PCR	P34PCR	P33PCR	P32PCR	P31PCR	P30PCR	
P1DDR	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR	
P2DDR	P27DDR	P26DDR	P25DDR	P24DDR	P23DDR	P22DDR	P21DDR	P20DDR	
P1DR	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR	
P2DR	P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR	P20DR	
P3DDR	P37DDR	P36DDR	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR	P30DDR	
P4DDR	P47DDR	P46DDR	P45DDR	P44DDR	P43DDR	P42DDR	P41DDR	P40DDR	
P3DR	P37DR	P36DR	P35DR	P34DR	P33DR	P32DR	P31DR	P30DR	
P4DR	P47DR	P46DR	P45DR	P44DR	P43DR	P42DR	P41DR	P40DR	
P5DDR	—	—	—	—	—	P52DDR	P51DDR	P50DDR	
P6DDR	P67DDR	P66DDR	P65DDR	P64DDR	P63DDR	P62DDR	P61DDR	P60DDR	
P5DR	—	—	—	—	—	P52DR	P51DR	P50DR	
P6DR	P67DR	P66DR	P65DR	P64DR	P63DR	P62DR	P61DR	P60DR	
PBODR	PB7ODR	PB6ODR	PB5ODR	PB4ODR	PB3ODR	PB2ODR	PB1ODR	PB0ODR	
PBPIN	PB7PIN	PB6PIN	PB5PIN	PB4PIN	PB3PIN	PB2PIN	PB1PIN	PB0PIN	
P8DDR	—	P86DDR	P85DDR	P84DDR	P83DDR	P82DDR	P81DDR	P80DDR	
P7PIN	P77PIN	P76PIN	P75PIN	P74PIN	P73PIN	P72PIN	P71PIN	P70PIN	
PBDDR	PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR	PB0DDR	
P8DR	—	P86DR	P85DR	P84DR	P83DR	P82DR	P81DR	P80DR	
P9DDR	P97DDR	P96DDR	P95DDR	P94DDR	P93DDR	P92DDR	P91DDR	P90DDR	
P9DR	P97DR	P96DR	P95DR	P94DR	P93DR	P92DR	P91DR	P90DR	
IER	IRQ7E	IRQ6E	IRQ5E	IRQ4E	IRQ3E	IRQ2E	IRQ1E	IRQ0E	INT
STCR	IICS	IICX1	IICX0	IICE	FLSHE	—	ICKS1	ICKS0	SYSTEM
SYSCR	CS2E	IOSE	INTM1	INTM0	XRST	NMIEG	HIE	RAME	
MDCR	EXPE	—	—	—	—	—	MDS1	MDS0	
BCR	—	ICIS0	BRSTRM	BRSTS1	BRSTS0	—	IOS1	IOS0	BSC
WSCR	—	—	ABW	AST	WMS1	WMS0	WC1	WC0	
TCR_0	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_0, TMR_1
TCR_1	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	
TCSR_0	CMFB	CMFA	OVF	ADTE	OS3	OS2	OS1	OS0	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCSR_1	CMFB	CMFA	OVF	—	OS3	OS2	OS1	OS0	TMR_0, TMR_1
TCORA_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCORA_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCORB_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCORB_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCNT_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
TCNT_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
PWOERB	OE15	OE14	OE13	OE12	OE11	OE10	OE9	OE8	PWM
PWOERA	OE7	OE6	OE5	OE4	OE3	OE2	OE1	OE0	
PWDPRB	OS15	OS14	OS13	OS12	OS11	OS10	OS9	OS8	
PWDPRA	OS7	OS6	OS5	OS4	OS3	OS2	OS1	OS0	
PWSL	PWCKE	PWCKS	—	—	RS3	RS2	RS1	RS0	
PWDR0–15	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
SMR_0	C/$\overline{A}$	CHR	PE	O/$\overline{E}$	STOP	MP	CKS1	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
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	TDRE	RDRF	ORER	FER	PER	TEND	MPB	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	
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	

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
ADDRDL	AD1	AD0	—	—	—	—	—	—	A/D converter
ADCSR	ADF	ADIE	ADST	SCAN	CKS	CH2	CH1	CH0	
ADCR	TRGS1	TRGS0	—	—	—	—	—	—	
TCSR_1	OVF	WT/$\overline{IT}$	TME	PSS	RST/$\overline{NMI}$	CKS2	CKS1	CKS0	WDT_1
TCNT_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
HICR	—	—	—	—	—	IBFIE2	IBFIE1	FGA20E	XBS
TCR_X	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_X
TCR_Y	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TMR_Y
KMIMR	KMIMR7	KMIMR6	KMIMR5	KMIMR4	KMIMR3	KMIMR2	KMIMR1	KMIMR0	INT
TCSR_X	CMFB	CMFA	OVF	ICF	OS3	OS2	OS1	OS0	TMR_X
TCSR_Y	CMFB	CMFA	OVF	ICIE	OS3	OS2	OS1	OS0	TMR_Y
KMPCR	KMIMR7	KMIMR6	KMIMR5	KMIMR4	KMIMR3	KMIMR2	KMIMR1	KMIMR0	PORT
TICRR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_X
TCORA_Y	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_Y
KMIMRA	KMIMR15	KMIMR14	KMIMR13	KMIMR12	KMIMR11	KMIMR10	KMIMR9	KMIMR8	INT
TICRF	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_X
TCORB_Y	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_Y
IDR_1	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	XBS
TCNT_X	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_X
TCNT_Y	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_Y
ODR_1	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	XBS
TCORC	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_X
TISR	—	—	—	—	—	—	—	IS	TMR_Y
STR_1	DBU17	DBU16	DBU15	DBU14	C/$\overline{D}$1	DBU12	IBF1	OBF1	XBS
TCORA_X	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	TMR_X
TCORB_X	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	—	—	—	—	—	
IDR_2	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	XBS
TCONRI	SIMOD1	SIMOD0	SCONE	ICST	HFINV	VFINV	HIINV	VIINV	Timer connection
ODR_2	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	XBS

Register Abbreviation	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module
TCONRO	HOE	VOE	CLOE	CBOE	HOINV	VOINV	CLOINV	CBOINV	Timer connection
STR_2	DBU27	DBU26	DBU25	DBU24	C/$\overline{D}$2	DBU22	IBF2	OBF2	XBS
TCONRS	TMRX/Y	ISGENE	HOMOD1	HOMOD0	VOMOD1	VOMOD0	CLMOD1	CLMOD0	Timer connection
SEDGR	VEDG	HEDG	CEDG	HFEDG	VFEDG	PREQF	IHI	IVI	

Notes: 1. Can be used on the H8S/2160B and H8S/2161B.
2. When TWRE = 1 or SELSTR3 = 0 in LADR3L
3. When TWRE = 0 and SELSTR3 = 1 in LADR3L
4. All bits are reserved in the 64-kbyte flash memory version.
The EB11 and EB10 bits are reserved in the 128-kbyte flash memory version.
5. Not supported by the H8S/2148B and H8S/2145B (5-V version).

26.3 Register States in Each Operating Mode

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
PGNOCR*1	Initialized	—	—	—	—	—	—	—	Initialized	PORT
PENOCR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PFNOCR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PCNOCR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PDNOCR*1	Initialized	—	—	—	—	—	—	—	Initialized	
TWR0MW	—	—	—	—	—	—	—	—	—	LPC
TWR0SW	—	—	—	—	—	—	—	—	—	
TWR1	—	—	—	—	—	—	—	—	—	
TWR2	—	—	—	—	—	—	—	—	—	
TWR3	—	—	—	—	—	—	—	—	—	
TWR4	—	—	—	—	—	—	—	—	—	
TWR5	—	—	—	—	—	—	—	—	—	
TWR6	—	—	—	—	—	—	—	—	—	
TWR7	—	—	—	—	—	—	—	—	—	
TWR8	—	—	—	—	—	—	—	—	—	
TWR9	—	—	—	—	—	—	—	—	—	
TWR10	—	—	—	—	—	—	—	—	—	
TWR11	—	—	—	—	—	—	—	—	—	
TWR12	—	—	—	—	—	—	—	—	—	
TWR13	—	—	—	—	—	—	—	—	—	
TWR14	—	—	—	—	—	—	—	—	—	
TWR15	—	—	—	—	—	—	—	—	—	
IDR3	—	—	—	—	—	—	—	—	—	
ODR3	—	—	—	—	—	—	—	—	—	
STR3	Initialized	—	—	—	—	—	—	—	Initialized	
LADR3H	Initialized	—	—	—	—	—	—	—	Initialized	
LADR3L	Initialized	—	—	—	—	—	—	—	Initialized	
SIRQCR0	Initialized	—	—	—	—	—	—	—	Initialized	
SIRQCR1	Initialized	—	—	—	—	—	—	—	Initialized	
IDR1	—	—	—	—	—	—	—	—	—	
ODR1	—	—	—	—	—	—	—	—	—	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
STR1	Initialized	—	—	—	—	—	—	—	Initialized	LPC
IDR2	—	—	—	—	—	—	—	—	—	
ODR2	—	—	—	—	—	—	—	—	—	
STR2	Initialized	—	—	—	—	—	—	—	Initialized	
HISEL	Initialized	—	—	—	—	—	—	—	Initialized	
HICR0	Initialized	—	—	—	—	—	—	—	Initialized	
HICR1	Initialized	—	—	—	—	—	—	—	Initialized	
HICR2	Initialized	—	—	—	—	—	—	—	Initialized	
HICR3	—	—	—	—	—	—	—	—	—	
WUEMRB*2	Initialized	—	—	—	—	—	—	—	Initialized	INT
PGODR*1	Initialized	—	—	—	—	—	—	—	Initialized	PORT
PGPIN*1	—	—	—	—	—	—	—	—	—	
PGDDR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PEODR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PFODR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PEPIN*1	—	—	—	—	—	—	—	—	—	
PEDDR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PFPIN*1	—	—	—	—	—	—	—	—	—	
PFDDR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PCODR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PDODR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PCPIN*1	—	—	—	—	—	—	—	—	—	
PCDDR*1	Initialized	—	—	—	—	—	—	—	Initialized	
PDPIN*1	—	—	—	—	—	—	—	—	—	
PDDDR*1	Initialized	—	—	—	—	—	—	—	Initialized	
HICR2	Initialized	—	—	—	—	—	—	—	Initialized	XBS
IDR_3	—	—	—	—	—	—	—	—	—	
ODR_3	—	—	—	—	—	—	—	—	—	
STR_3	Initialized	—	—	—	—	—	—	—	Initialized	
IDR_4	—	—	—	—	—	—	—	—	Initialized	
ODR_4	—	—	—	—	—	—	—	—	Initialized	
STR_4	Initialized	—	—	—	—	—	—	—	Initialized	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
ICXR_0	Initialized	—	—	—	—	—	—	—	Initialized	IIC_0
ICXR_1	Initialized	—	—	—	—	—	—	—	Initialized	IIC_1
KBCRH_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	Keyboard buffer controller_0
KBCRL_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
KBBR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
KBCRH_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	Keyboard buffer controller_1
KBCRL_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
KBBR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
KBCRH_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	Keyboard buffer controller_2
KBCRL_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
KBBR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
KBCOMP	Initialized	—	—	—	—	—	—	—	Initialized	IrDA/ A/D converter
DDCSWR	Initialized	—	—	—	—	—	—	—	Initialized	IIC_0
ICRA	Initialized	—	—	—	—	—	—	—	Initialized	INT
ICRB	Initialized	—	—	—	—	—	—	—	Initialized	
ICRC	Initialized	—	—	—	—	—	—	—	Initialized	
ISR	Initialized	—	—	—	—	—	—	—	Initialized	
ISCRH	Initialized	—	—	—	—	—	—	—	Initialized	
ISCRL	Initialized	—	—	—	—	—	—	—	Initialized	
DTCERA	Initialized	—	—	—	—	—	—	—	Initialized	DTC
DTCERB	Initialized	—	—	—	—	—	—	—	Initialized	
DTCERC	Initialized	—	—	—	—	—	—	—	Initialized	
DTCERD	Initialized	—	—	—	—	—	—	—	Initialized	
DTCERE	Initialized	—	—	—	—	—	—	—	Initialized	
DTVECR	Initialized	—	—	—	—	—	—	—	Initialized	
ABRKCR	Initialized	—	—	—	—	—	—	—	Initialized	INT
BARA	Initialized	—	—	—	—	—	—	—	Initialized	
BARB	Initialized	—	—	—	—	—	—	—	Initialized	
BARC	Initialized	—	—	—	—	—	—	—	Initialized	
FLMCR1	Initialized	—	Initialized	—	Initialized	Initialized	—	Initialized	Initialized	FLASH
FLMCR2	Initialized	—	Initialized	—	Initialized	Initialized	—	Initialized	Initialized	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
PCSR	Initialized	—	—	—	—	—	—	—	Initialized	PWM
EBR1	Initialized	—	Initialized	—	Initialized	Initialized	—	Initialized	Initialized	FLASH
SYSCR2	Initialized	—	—	—	—	—	—	—	Initialized	SYSTEM
EBR2	Initialized	—	Initialized	—	Initialized	Initialized	—	Initialized	Initialized	FLASH
SBYCR	Initialized	—	—	—	—	—	—	—	Initialized	SYSTEM
LPWRCR	Initialized	—	—	—	—	—	—	—	Initialized	
MSTPCRH	Initialized	—	—	—	—	—	—	—	Initialized	
MSTPCRL	Initialized	—	—	—	—	—	—	—	Initialized	
SMR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_1
ICCR_1	Initialized	—	—	—	—	—	—	—	Initialized	IIC_1
BRR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_1
ICSR_1	Initialized	—	—	—	—	—	—	—	Initialized	IIC_1
SCR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	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	—	Initialized	Initialized	Initialized	Initialized	Initialized	
ICDR_1	—	—	—	—	—	—	—	—	—	IIC_1
SARX_1	Initialized	—	—	—	—	—	—	—	Initialized	
ICMR_1	Initialized	—	—	—	—	—	—	—	Initialized	
SAR_1	Initialized	—	—	—	—	—	—	—	Initialized	
TIER	Initialized	—	—	—	—	—	—	—	Initialized	FRT
TCSR	Initialized	—	—	—	—	—	—	—	Initialized	
FRCH	Initialized	—	—	—	—	—	—	—	Initialized	
FRCL	Initialized	—	—	—	—	—	—	—	Initialized	
OCRAH	Initialized	—	—	—	—	—	—	—	Initialized	
OCRBH	Initialized	—	—	—	—	—	—	—	Initialized	
OCRAL	Initialized	—	—	—	—	—	—	—	Initialized	
OCRBL	Initialized	—	—	—	—	—	—	—	Initialized	
TCR	Initialized	—	—	—	—	—	—	—	Initialized	
TOCR	Initialized	—	—	—	—	—	—	—	Initialized	
ICRAH	Initialized	—	—	—	—	—	—	—	Initialized	
OCRARH	Initialized	—	—	—	—	—	—	—	Initialized	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
ICRAL	Initialized	—	—	—	—	—	—	—	Initialized	FRT
OCRARL	Initialized	—	—	—	—	—	—	—	Initialized	
ICRBH	Initialized	—	—	—	—	—	—	—	Initialized	
OCRAFH	Initialized	—	—	—	—	—	—	—	Initialized	
ICRBL	Initialized	—	—	—	—	—	—	—	Initialized	
OCRAFL	Initialized	—	—	—	—	—	—	—	Initialized	
ICRCH	Initialized	—	—	—	—	—	—	—	Initialized	
OCRDMH	Initialized	—	—	—	—	—	—	—	Initialized	
ICRCL	Initialized	—	—	—	—	—	—	—	Initialized	
OCRDML	Initialized	—	—	—	—	—	—	—	Initialized	
ICRDH	Initialized	—	—	—	—	—	—	—	Initialized	
ICRDL	Initialized	—	—	—	—	—	—	—	Initialized	
SMR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_2
DACR	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	PWMX
DADRAH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
DADRAL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
BRR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_2
SCR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	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	
DACNTH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	PWMX
DADRBH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
DACNTL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
DADRBL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
TCSR_0	Initialized	—	—	—	—	—	—	—	Initialized	WDT_0
TCNT_0	Initialized	—	—	—	—	—	—	—	Initialized	
PAODR	Initialized	—	—	—	—	—	—	—	Initialized	PORT
PAPIN	—	—	—	—	—	—	—	—	—	
PADDR	Initialized	—	—	—	—	—	—	—	Initialized	
P1PCR	Initialized	—	—	—	—	—	—	—	Initialized	
P2PCR	Initialized	—	—	—	—	—	—	—	Initialized	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
P3PCR	Initialized	—	—	—	—	—	—	—	Initialized	PORT
P1DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P2DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P1DR	Initialized	—	—	—	—	—	—	—	Initialized	
P2DR	Initialized	—	—	—	—	—	—	—	Initialized	
P3DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P4DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P3DR	Initialized	—	—	—	—	—	—	—	Initialized	
P4DR	Initialized	—	—	—	—	—	—	—	Initialized	
P5DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P6DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P5DR	Initialized	—	—	—	—	—	—	—	Initialized	
P6DR	Initialized	—	—	—	—	—	—	—	Initialized	
PBODR	Initialized	—	—	—	—	—	—	—	Initialized	
PBPIN	—	—	—	—	—	—	—	—	—	
P8DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P7PIN	—	—	—	—	—	—	—	—	—	
PBDDR	Initialized	—	—	—	—	—	—	—	Initialized	
P8DR	Initialized	—	—	—	—	—	—	—	Initialized	
P9DDR	Initialized	—	—	—	—	—	—	—	Initialized	
P9DR	Initialized	—	—	—	—	—	—	—	Initialized	
IER	Initialized	—	—	—	—	—	—	—	Initialized	INT
STCR	Initialized	—	—	—	—	—	—	—	Initialized	SYSTEM
SYSCR	Initialized	—	—	—	—	—	—	—	Initialized	
MDCR	Initialized	—	—	—	—	—	—	—	Initialized	
BCR	Initialized	—	—	—	—	—	—	—	Initialized	BSC
WSCR	Initialized	—	—	—	—	—	—	—	Initialized	
TCR_0	Initialized	—	—	—	—	—	—	—	Initialized	TMR_0, TMR_1
TCR_1	Initialized	—	—	—	—	—	—	—	Initialized	
TCSR_0	Initialized	—	—	—	—	—	—	—	Initialized	
TCSR_1	Initialized	—	—	—	—	—	—	—	Initialized	
TCORA_0	Initialized	—	—	—	—	—	—	—	Initialized	
TCORA_1	Initialized	—	—	—	—	—	—	—	Initialized	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
TCORB_0	Initialized	—	—	—	—	—	—	—	Initialized	TMR_0, TMR_1
TCORB_1	Initialized	—	—	—	—	—	—	—	Initialized	
TCNT_0	Initialized	—	—	—	—	—	—	—	Initialized	
TCNT_1	Initialized	—	—	—	—	—	—	—	Initialized	
PWOERB	Initialized	—	—	—	—	—	—	—	Initialized	PWM
PWOERA	Initialized	—	—	—	—	—	—	—	Initialized	
PWDPRB	Initialized	—	—	—	—	—	—	—	Initialized	
PWDPRA	Initialized	—	—	—	—	—	—	—	Initialized	
PWSL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
PWDR0 to PWDR15	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
SMR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_0
ICCR_0	Initialized	—	—	—	—	—	—	—	Initialized	IIC_0
BRR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_0
ICSR_0	Initialized	—	—	—	—	—	—	—	Initialized	IIC_0
SCR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	SCI_0
TDR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
SSR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
RDR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
SCMR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	
ICDR_0	—	—	—	—	—	—	—	—	—	IIC_0
SARX_0	Initialized	—	—	—	—	—	—	—	Initialized	
ICMR_0	Initialized	—	—	—	—	—	—	—	Initialized	
SAR_0	Initialized	—	—	—	—	—	—	—	Initialized	
ADDRAH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	A/D converter
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	

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
ADCR	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initialized	A/D converter
TCSR_1	Initialized	—	—	—	—	—	—	—	Initialized	WDT_1
TCNT_1	Initialized	—	—	—	—	—	—	—	Initialized	
HICR	Initialized	—	—	—	—	—	—	—	Initialized	XBS
TCR_X	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TCR_Y	Initialized	—	—	—	—	—	—	—	Initialized	TMR_Y
KMIMR	Initialized	—	—	—	—	—	—	—	Initialized	INT
TCSR_X	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TCSR_Y	Initialized	—	—	—	—	—	—	—	Initialized	TMR_Y
KMPCR	Initialized	—	—	—	—	—	—	—	Initialized	PORT
TICRR	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TCORA_Y	Initialized	—	—	—	—	—	—	—	Initialized	TMR_Y
KMIMRA	Initialized	—	—	—	—	—	—	—	Initialized	INT
TICRF	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TCORB_Y	Initialized	—	—	—	—	—	—	—	Initialized	TMR_Y
IDR_1	—	—	—	—	—	—	—	—	—	XBS
TCNT_X	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TCNT_Y	Initialized	—	—	—	—	—	—	—	Initialized	TMR_Y
ODR_1	—	—	—	—	—	—	—	—	—	XBS
TCORC	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TISR	Initialized	—	—	—	—	—	—	—	Initialized	TMR_Y
STR_1	Initialized	—	—	—	—	—	—	—	Initialized	XBS
TCORA_X	Initialized	—	—	—	—	—	—	—	Initialized	TMR_X
TCORB_X	Initialized	—	—	—	—	—	—	—	Initialized	
DADR0	Initialized	—	—	—	—	—	—	—	Initialized	D/A converter
DADR1	Initialized	—	—	—	—	—	—	—	Initialized	
DACR	Initialized	—	—	—	—	—	—	—	Initialized	
IDR_2	—	—	—	—	—	—	—	—	—	XBS
TCONRI	Initialized	—	—	—	—	—	—	—	Initialized	Timer connection
ODR_2	—	—	—	—	—	—	—	—	—	XBS

Register Abbreviation	Reset	High-Speed/ Medium-Speed	Watch	Sleep	Sub-Active	Sub-Sleep	Module Stop	Software Standby	Hardware Standby	Module
TCONRO	Initialized	—	—	—	—	—	—	—	Initialized	Timer connection
STR_2	Initialized	—	—	—	—	—	—	—	Initialized	XBS
TCONRS	Initialized	—	—	—	—	—	—	—	Initialized	Timer connection
SEDGR	Initialized	—	—	—	—	—	—	—	Initialized	

Notes: 1. Can be used on the H8S/2160B and H8S/2161B.
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

26.4 Register Select Conditions

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition	H8S/2160B, H8S/2161B Register Select Condition	Module Name
H'FE16	PGNOCR	—	No condition	PORT
H'FE18	PENOCR			
H'FE19	PFNOCR			
H'FE1C	PCNOCR			
H'FE1D	PDNOCR			
H'FE20	TWR0MW	MSTP = 0, (HI12E = 0)*	MSTP = 0, (HI12E = 0)*	LPC
	TWR0SW			
H'FE21	TWR1			
H'FE22	TWR2			
H'FE23	TWR3			
H'FE24	TWR4			
H'FE25	TWR5			
H'FE26	TWR6			
H'FE27	TWR7			
H'FE28	TWR8			
H'FE29	TWR9			
H'FE2A	TWR10			
H'FE2B	TWR11			
H'FE2C	TWR12			
H'FE2D	TWR13			
H'FE2E	TWR14			
H'FE2F	TWR15			

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition	H8S/2160B, H8S/2161B Register Select Condition	Module Name
H'FE30	IDR3	MSTP = 0, (HI12E = 0)*	MSTP = 0, (HI12E = 0)*	LPC
H'FE31	ODR3			
H'FE32	STR3			
H'FE34	LADR3H			
H'FE35	LADR3L			
H'FE36	SIRQCR0			
H'FE37	SIRQCR1			
H'FE38	IDR1			
H'FE39	ODR1			
H'FE3A	STR1			
H'FE3C	IDR2			
H'FE3D	ODR2			
H'FE3E	STR2			
H'FE3F	HISEL			
H'FE40	HICR0			
H'FE41	HICR1			
H'FE42	HICR2			
H'FE43	HICR3			
H'FE44	WUEMRB	No condition	No condition	INT
H'FE46	PGODR	—	No condition	PORT
H'FE47	PGPIN (read)			
	PGDDR (write)			
H'FE48	PEODR			
H'FE49	PFODR			
H'FE4A	PEPIN (read)			
	PEDDR (write)			
H'FE4B	PFPIN (read)			
	PFDDR (write)			
H'FE4C	PCODR			
H'FE4D	PDODR			

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition	H8S/2160B, H8S/2161B Register Select Condition	Module Name
H'FE4E	PCPIN (read)	—	No condition	PORT
	PCDDR (write)			
H'FE4F	PDPIN (read)			
	PDDDR (write)			
H'FE80	HICR2	MSTP2 = 0	MSTP2 = 0	XBS
H'FE81	IDR_3			
H'FE82	ODR_3			
H'FE83	STR_3			
H'FE84	IDR_4			
H'FE85	ODR_4			
H'FE86	STR_4			
H'FED4	ICXR_0	No condition	No condition	IIC_0
H'FED5	ICXR_1			IIC_1
H'FED8	KBCRH_0	MSTP2 = 0	MSTP2 = 0	Keyboard buffer controller
H'FED9	KBCRL_0			
H'FEDA	KBBR_0			
H'FEDC	KBCRH_1			
H'FEDD	KBCRL_1			
H'FEDE	KBBR_1			
H'FEE0	KBCRH_2			
H'FEE1	KBCRL_2			
H'FEE2	KBBR_2			
H'FEE4	KBCOMP	No condition	No condition	IrDA/ expanded A/D
H'FEE6	DDCSWR	MSTP4 = 0	MSTP4 = 0	IIC_0
H'FEE8	ICRA	No condition	No condition	INT
H'FEE9	ICRB			
H'FEEA	ICRC			
H'FEEB	ISR			
H'FEEC	ISCRH			
H'FEED	ISCRL			

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition	H8S/2160B, H8S/2161B Register Select Condition	Module Name
H'FEEE	DTCERA	No condition	No condition	DTC
H'FEEF	DTCERB			
H'FEF0	DTCERC			
H'FEF1	DTCERD			
H'FEF2	DTCERE			
H'FEF3	DTVECR			
H'FEF4	ABRKCR	No condition	No condition	INT
H'FEF5	BARA			
H'FEF6	BARB			
H'FEF7	BARC			
H'FF80	FLMCR1	FLSHE = 1 in STCR	FLSHE = 1 in STCR	FLASH
H'FF81	FLMCR2			
H'FF82	PCSR	FLSHE = 0 in STCR	FLSHE = 0 in STCR	PWM
	EBR1	FLSHE = 1 in STCR	FLSHE = 1 in STCR	FLASH
H'FF83	SYSCR2	FLSHE = 0 in STCR	FLSHE = 0 in STCR	SYSTEM
	EBR2	FLSHE = 1 in STCR	FLSHE = 1 in STCR	FLASH
H'FF84	SBYCR	FLSHE = 0 in STCR	FLSHE = 0 in STCR	SYSTEM
H'FF85	LPWRCR			
H'FF86	MSTPCRH			
H'FF87	MSTPCRL			
H'FF88	SMR_1	MSTP6 = 0, IICE = 0 in STCR	MSTP6 = 0,IICE = 0 in STCR	SCI_1
	ICCR_1	MSTP3 = 0, IICE = 1 in STCR	MSTP3 = 0, IICE = 1 in STCR	IIC_1
H'FF89	BRR_1	MSTP6 = 0, IICE = 0 in STCR	MSTP6 = 0, IICE = 0 in STCR	SCI_1
	ICSR_1	MSTP3 = 0, IICE = 1 in STCR	MSTP3 = 0, IICE = 1 in STCR	IIC_1

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition		H8S/2160B, H8S/2161B Register Select Condition		Module Name
H'FF8A	SCR_1	MSTP6 = 0		MSTP6 = 0		SCI_1
H'FF8B	TDR_1					
H'FF8C	SSR_1					
H'FF8D	RDR_1					
H'FF8E	SCMR_1	MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR		
	ICDR_1	MSTP3 = 0, IICE = 1 in STCR	ICE = 1 in ICCR1	MSTP3 = 0, IICE = 1 in STCR	ICE = 1 in ICCR1	IIC_1
	SARX_1		ICE = 0 in ICCR1		ICE = 0 in ICCR1	
H'FF8F	ICMR_1		ICE = 1 in ICCR1		ICE = 1 in ICCR1	
	SAR_1		ICE = 0 in ICCR1		ICE = 0 in ICCR1	
H'FF90	TIER	MSTP13 = 0		MSTP13 = 0		FRT
H'FF91	TCSR					
H'FF92	FRCH					
H'FF93	FRCL					
H'FF94	OCRAH	MSTP13 = 0	OCRS = 0 in TOCR	MSTP13 = 0	OCRS = 0 in TOCR	FRT
	OCRBH		OCRS = 1 in TOCR		OCRS = 1 in TOCR	
H'FF95	OCRAL		OCRS = 0 in TOCR		OCRS = 0 in TOCR	
	OCRBL		OCRS = 1 in TOCR		OCRS = 1 in TOCR	
H'FF96	TCR					
H'FF97	TOCR					
H'FF98	ICRAH		ICRS = 0 in TOCR		ICRS = 0 in TOCR	
	OCRARH		ICRS = 1 in TOCR		ICRS = 1 in TOCR	

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition		H8S/2160B, H8S/2161B Register Select Condition		Module Name
H'FF99	ICRAL	MSTP13 = 0	ICRS = 0 in TOCR	MSTP13 = 0	ICRS = 0 in TOCR	FRT
	OCRARL		ICRS = 1 in TOCR		ICRS = 1 in TOCR	
H'FF9A	ICRBH		ICRS = 0 in TOCR		ICRS = 0 in TOCR	
	OCRAFH		ICRS = 1 in TOCR		ICRS = 1 in TOCR	
H'FF9B	ICRBL		ICRS = 0 in TOCR		ICRS = 0 in TOCR	
	OCRAFL		ICRS = 1 in TOCR		ICRS = 1 in TOCR	
H'FF9C	ICRCH		ICRS = 0 in TOCR		ICRS = 0 in TOCR	
	OCRDMH		ICRS = 1 in TOCR		ICRS = 1 in TOCR	
H'FF9D	ICRCL		ICRS = 0 in TOCR		ICRS = 0 in TOCR	
	OCRDML		ICRS = 1 in TOCR		ICRS = 1 in TOCR	
H'FF9E	ICRDH					
H'FF9F	ICRDL					
H'FFA0	SMR_2	MSTP5 = 0, IICE = 0 in STCR		MSTP5 = 0, IICE = 0 in STCR		SCI_2
	DADRAH	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	PWMX
	DACR		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB	
H'FFA1	BRR_2	MSTP5 = 0, IICE = 0 in STCR		MSTP5 = 0, IICE = 0 in STCR		SCI_2
	DADRAL	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	PWMX

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition		H8S/2160B, H8S/2161B Register Select Condition		Module Name
H'FFA2	SCR_2	MSTP5 = 0		MSTP5 = 0		SCI_2
H'FFA3	TDR_2					
H'FFA4	SSR_2					
H'FFA5	RDR_2					
H'FFA6	SCMR_2	MSTP5 = 0, IICE = 0 in STCR		MSTP5 = 0, IICE = 0 in STCR		SCI_2
	DADRBH	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	PWMX
	DACNTH		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB	
H'FFA7	DADRBL		REGS = 0 in DACNT/ DADRB		REGS = 0 in DACNT/ DADRB	
	DACNTL		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB	
H'FFA8	TCSR_0	No condition		No condition		WDT_0
	TCNT_0 (write)					
H'FFA9	TCNT_0 (read)					
H'FFAA	PAODR	No condition		No condition		PORT
H'FFAB	PAPIN (read)					
	PADDR (write)					
H'FFAC	P1PCR					
H'FFAD	P2PCR					
H'FFAE	P3PCR					
H'FFB0	P1DDR					
H'FFB1	P2DDR					
H'FFB2	P1DR					
H'FFB3	P2DR					
H'FFB4	P3DDR					
H'FFB5	P4DDR					

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition	H8S/2160B, H8S/2161B Register Select Condition	Module Name
H'FFB6	P3DR	No condition	No condition	PORT
H'FFB7	P4DR			
H'FFB8	P5DDR			
H'FFB9	P6DDR			
H'FFBA	P5DR			
H'FFBB	P6DR			
H'FFBC	PBODR			
H'FFBD	P8DDR (write)			
	PBPIN (read)			
H'FFBE	P7PIN (read)			
	PBDDR (write)			
H'FFBF	P8DR			
H'FFC0	P9DDR			
H'FFC1	P9DR			
H'FFC2	IER	No condition	No condition	INT
H'FFC3	STCR	No condition	No condition	SYSTEM
H'FFC4	SYSCR			
H'FFC5	MDCR			
H'FFC6	BCR	No condition	No condition	BSC
H'FFC7	WSCR			
H'FFC8	TCR_0	MSTP12 = 0	MSTP12 = 0	TMR_0, TMR_1
H'FFC9	TCR_1			
H'FFCA	TCSR_0			
H'FFCB	TCSR_1			
H'FFCC	TCORA_0			
H'FFCD	TCORA_1			
H'FFCE	TCORB_0			
H'FFCF	TCORB_1			
H'FFD0	TCNT_0			
H'FFD1	TCNT_1			

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition		H8S/2160B, H8S/2161B Register Select Condition		Module Name
H'FFD2	PWOERB	No condition		No condition		PWM
H'FFD3	PWOERA					
H'FFD4	PWDPRB					
H'FFD5	PWDPRA					
H'FFD6	PWSL	MSTP11 = 0		MSTP11 = 0		PWM
H'FFD7	PWDR0 to PWDR15					
H'FFD8	SMR_0	MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR		SCI_0
	ICCR_0	MSTP4 = 0, IICE = 1 in STCR		MSTP4 = 0, IICE = 1 in STCR		IIC_0
H'FFD9	BRR_0	MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR		SCI_0
	ICSR_0	MSTP4 = 0, IICE = 1 in STCR		MSTP4 = 0, IICE = 1 in STCR		IIC_0
H'FFDA	SCR_0	MSTP7 = 0		MSTP7 = 0		SCI_0
H'FFDB	TDR_0					
H'FFDC	SSR_0					
H'FFDD	RDR_0					
H'FFDE	SCMR_0	MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR		
	ICDR_0	MSTP4 = 0, IICE = 1 in STCR	ICE = 1 in ICCR0	MSTP4 = 0, IICE = 1 in STCR	ICE = 1 in ICCR0	IIC_0
	SARX_0		ICE = 0 in ICCR0		ICE = 0 in ICCR0	
H'FFDF	ICMR_0	MSTP4 = 0, IICE = 1 in STCR	ICE = 1 in ICCR0	MSTP4 = 0, IICE = 1 in STCR	ICE = 1 in ICCR0	
	SAR_0		ICE = 0 in ICCR0		ICE = 0 in ICCR0	

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition		H8S/2160B, H8S/2161B Register Select Condition		Module Name
H'FFE0	ADDRAH	MSTP9 = 0		MSTP9 = 0		A/D
H'FFE1	ADDRAL					
H'FFE2	ADDRBH					
H'FFE3	ADDRBL					
H'FFE4	ADDRCH					
H'FFE5	ADDRCL					
H'FFE6	ADDRDH					
H'FFE7	ADDRDL					
H'FFE8	ADCSR					
H'FFE9	ADCR					
H'FFEA	TCSR_1	No condition		No condition		WDT_1
	TCNT_1 (write)					
H'FFEB	TCNT_1 (read)					
H'FFF0	HICR	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		XBS
	TCR_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
	TCR_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TMR_Y
H'FFF1	KMIMR	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		INT
	TCSR_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
	TCSR_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TMR_Y

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition		H8S/2160B, H8S/2161B Register Select Condition		Module Name
H'FFF2	KMPCR	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		PORT
	TICRR	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
	TCORA_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TMR_Y
H'FFF3	KMIMRA	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		INT
	TICRF	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
	TCORB_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TMR_Y
H'FFF4	IDR_1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		XBS
	TCNT_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
	TCNT_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TMR_Y
H'FFF5	ODR_1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		XBS
	TCORC	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
	TISR		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TMR_Y
H'FFF6	STR_1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		XBS
	TCORA_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TMR_X
H'FFF7	TCORB_X					

Lower Address	Register Name	H8S/2140B, H8S/2141B, H8S/2145B, H8S/2148B Register Select Condition	H8S/2160B, H8S/2161B Register Select Condition	Module Name
H'FFF8	DADR0	MSTP10 = 0	MSTP10 = 0	D/A
H'FFF9	DADR1			
H'FFFA	DACR			
H'FFFC	IDR_2	MSTP2 = 0, HIE = 1 in SYSCR	MSTP2 = 0, HIE = 1 in SYSCR	XBS
	TCONRI	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR	Timer connection
H'FFFD	ODR_2	MSTP2 = 0, HIE = 1 in SYSCR	MSTP2 = 0, HIE = 1 in SYSCR	XBS
	TCONRO	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR	Timer connection
H'FFFE	STR_2	MSTP2 = 0, HIE = 1 in SYSCR	MSTP2 = 0, HIE = 1 in SYSCR	XBS
	TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR	Timer connection
H'FFFF	SEDGR			

Note: * Although setting the XBS corresponding bits does not affected to the LPC operation, the HI12E bit in SYSCR2 must not be set to 1 to use the LPC according to the limitation depending on the program development tool (emulator) configuration.

Section 27 Electrical Characteristics

27.1 Electrical Characteristics of H8S/2140B, H8S/2141B, H8S/2160B, and H8S/2161B

27.1.1 Absolute Maximum Ratings

Table 27.1 lists the absolute maximum ratings.

Table 27.1 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}, V_{CL}	–0.3 to +4.3	V
I/O buffer power supply voltage	$V_{CC}B$	–0.3 to +7.0	V
Input voltage (except ports 6, 7, and A, P97, P86, P52, and P42) (Ports C to G are added in the H8S/2160B and H8S/2161B.)	V_{in}	–0.3 to V_{CC} + 0.3	V
Input voltage (CIN input not selected for port 6)	V_{in}	–0.3 to V_{CC} + 0.3	V
Input voltage (CIN input not selected for port A)	V_{in}	–0.3 to $V_{CC}B$ + 0.3	V
Input voltage (CIN input selected for port 6)	V_{in}	–0.3 V to lower of voltages V_{CC} + 0.3 and AV_{CC} + 0.3	V
Input voltage (CIN input selected for port A)	V_{in}	–0.3 V to lower of voltages $V_{CC}B$ + 0.3 and AV_{CC} + 0.3	V
Input voltage (P97, P86, P52, P42)	V_{in}	–0.3 to +7.0	V
Input voltage (port 7)	V_{in}	–0.3 to AV_{CC} + 0.3	V
Reference supply voltage	AV_{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}	–20 to +75	°C
Operating temperature (flash memory programming/erasing)	T_{opr}	–20 to +75	°C
Storage temperature	T_{stg}	–55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.
Ensure so that the impressed voltage does not exceed 4.3 V for pins for which the maximum rating is determined by the voltage on the V_{CC}, AV_{CC}, and V_{CL} pins, or 7.0 V for pins for which the maximum rating is determined by $V_{CC}B$.
The V_{CC} and V_{CL} pins must be connected to the Vcc power supply.

27.1.2 DC Characteristics

Table 27.2 lists the DC characteristics. Permitted output current values and bus drive characteristics are shown in tables 27.3 and 27.4, respectively.

Table 27.2 DC Characteristics (1)

Conditions: V_{CC} = 2.7 V to 3.6 V*9, $V_{CC}B$ = 2.7 V to 5.5 V, AV_{CC}*1 = 2.7 V to 3.6 V, AV_{ref}*1 = 2.7 V to AV_{CC}, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C

Item			Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60*2 *6, $\overline{KIN15}$ to $\overline{KIN8}$*7, $\overline{IRQ2}$ to $\overline{IRQ0}$*3, $\overline{IRQ5}$ to $\overline{IRQ3}$	(1)*8	V_T^-	$V_{cc} \times 0.2$ $V_{cc}B \times 0.2$	—	—	V	
			V_T^+	—	—	$V_{cc} \times 0.7$ $V_{cc}B \times 0.7$		
			$V_T^+ - V_T^-$	$V_{cc} \times 0.05$ $V_{cc}B \times 0.05$	—	—		
Schmitt trigger input voltage (in level switching)*6	P67 to P60 (KWUL = 00)		V_T^-	$V_{cc} \times 0.2$	—	—	V	
			V_T^+	—	—	$V_{cc} \times 0.7$		
			$V_T^+ - V_T^-$	$V_{cc} \times 0.05$	—	—		
	P67 to P60 (KWUL = 01)		V_T^-	$V_{cc} \times 0.3$	—	—		
			V_T^+	—	—	$V_{cc} \times 0.7$		
			$V_T^+ - V_T^-$	$V_{cc} \times 0.05$	—	—		
	P67 to P60 (KWUL = 10)		V_T^-	$V_{cc} \times 0.4$	—	—		
			V_T^+	—	—	$V_{cc} \times 0.8$		
			$V_T^+ - V_T^-$	$V_{cc} \times 0.03$	—	—		
	P67 to P60 (KWUL = 11)		V_T^-	$V_{cc} \times 0.45$	—	—		
			V_T^+	—	—	$V_{cc} \times 0.9$		
			$V_T^+ - V_T^-$	0.05	—	—		
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD1, MD0	(2)	V_{IH}	$V_{cc} \times 0.9$	—	$V_{cc} + 0.3$	V	
	EXTAL			$V_{cc} \times 0.7$	—	$V_{cc} + 0.3$		
	PA7 to PA0*7			$V_{cc}B \times 0.7$	—	$V_{cc}B + 0.3$		

Item			Symbol	Min	Typ	Max	Unit	Test Conditions
Input high voltage	Port 7	(2)	V_{IH}	$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V	
	P97, P86, P52, P42			$V_{CC} \times 0.7$	—	5.5		
	Input pins except (1) and (2) above (Ports C to G are added in the H8S/2160B and H8S/2161B.)			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$		
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD1, MD0	(3)	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	PA7 to PA0			–0.3	—	$V_{CC}B \times 0.2$		$V_{CC}B$ = 2.7 V to 4.0 V
						0.8		$V_{CC}B$ = 4.0 V to 5.5 V
	NMI, EXTAL, input pins except (1) and (3) above (Ports C to G are added in the H8S/2160B and H8S/2161B.)			–0.3	—	$V_{CC} \times 0.2$		V_{CC} = 2.7 V to 3.6 V
Output high voltage	All output pins (except P97, P86, P52, and P42)*4 *5 *8 (Ports C to F are added in the H8S/2160B and H8S/2161B.)		V_{OH}	V_{CC} – 0.5 $V_{CC}B$ – 0.5	—	—	V	I_{OH} = –200 µA
				V_{CC} – 1.0 $V_{CC}B$ – 1.0	—	—	V	I_{OH} = –1 mA, (V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 4.5 V)
	P97, P86, P52, and P42*4 (Port G is added in the H8S/2160B and H8S/2161B.)			0.5	—	—	V	I_{OH} = –200 µA

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	All output pins (except $\overline{\text{RESO}}$)*5 (Ports C to G are added in the H8S/2160B and H8S/2161B.)	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports 1 to 3		—	—	1.0	V	I_{OL} = 5 mA
	$\overline{\text{RESO}}$		—	—	0.4	V	I_{OL} = 1.6 mA

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. P67 to P60 include peripheral module inputs multiplexed on those pins.
3. $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.
4. P52/SCK0/SCL0, P97/SDA0, P86/SCK1/SCL1, P42/SCK2/SDA1, and port G are NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it is NMOS open-drain output. Therefore, an external pull-up resistor must be connected in order to output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are driven by NMOS.

An external pull-up resistor is necessary to provide high-level output from SCK0, SCK1, and SCK2.

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus drive function is selected is determined separately.
6. The upper limit of the port 6 applied voltage is V_{CC} + 0.3 V when CIN input is not selected, and the lower of V_{CC} + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
7. The upper limit of the port A applied voltage is $V_{CC}B$ + 0.3 V when CIN input is not selected, and the lower of $V_{CC}B$ + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC}.
9. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V to 3.6 V.

Table 27.2 DC Characteristics (2)

Conditions: V_{CC} = 2.7 V to 3.6 V*5, $V_{CC}B$ = 2.7 V to 5.5 V, AV_{CC}*1 = 2.7 V to 3.6 V, AV_{ref}*1 = 2.7 V to AV_{CC}, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input leakage current	$\overline{RES}$	$\lvert I_{in} \rvert$	—	—	10.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V
	$\overline{STBY}$, NMI, MD1, MD0		—	—	1.0		
	Port 7		—	—	1.0		V_{in} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A*4, and B (Ports C to G are added in the H8S/2160B and H8S/2161B.)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V, V_{in} = 0.5 to $V_{CC}B$ – 0.5 V
Input pull-up MOS current	Ports 1 to 3	$-I_P$	5	—	150	µA	V_{in} = 0 V, V_{CC} = 2.7 V to 3.6 V $V_{CC}B$ = 2.7 V to 5.5 V
	Ports 6 (P6PUE = 0) and B (Ports C to F are added in the H8S/2160B and H8S/2161B.)		30	—	300		
	Ports A*4		30	—	600		
	Port 6 (P6PUE = 1)		3	—	100		
Input capacitance	$\overline{RES}$ (4)	C_{in}	—	—	80	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
	NMI		—	—	50	pF	
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF	
	Input pins except (4) above (Ports C to G are added in the H8S/2160B and H8S/2161B.)		—	—	15	pF	

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Current dissipation*2	Normal operation	I_{CC}	—	30	40	mA	f = 10 MHz
	Sleep mode		—	20	32	mA	f = 10 MHz
	Standby mode*3		—	1	5.0	µA	$T_a \leq 50°C$
			—	—	20.0		$50°C < T_a$
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	µA	AV_{CC} = 2.0 V to 3.6 V
Reference power supply current	During A/D conversion	AI_{ref}	—	0.5	1.0	mA	
	During A/D, D/A conversion		—	2.0	5.0		
	Idle		—	0.01	5.0	µA	AV_{ref} = 2.0 V to AV_{CC}
Analog power supply voltage*1		AV_{CC}	2.7	—	3.6	V	Operating
			2.0	—	3.6		Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. Current dissipation values are for V_{IH} min = V_{CC} – 0.2 V, $V_{CC}B$ – 0.2 V, and V_{IL} max = 0.2 V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7$ V, V_{IH} min = V_{CC}– 0.2 V, $V_{CC}B$ – 0.2 V, and V_{IL} max = 0.2 V.
4. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC}.
5. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V to 3.6 V.

Table 27.2 DC Characteristics (3) When LPC Function Is Used

Conditions: V_{CC} = 3.0 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, AV_{CC}* = 2.7 V to 3.6 V, AV_{ref}* = 2.7 V to AV_{CC}, V_{SS} = AV_{SS}*[1] = 0 V, T_a = –20 to +75°C

	Item	Symbol	Min	Max	Unit	Test Conditions
Input high voltage	P37 to P30, P83 to P80, PB1, PB0	V_{IH}	$V_{CC} \times 0.5$	—	V	
Input low voltage	P37 to P30, P83 to P80, PB1, PB0	V_{IL}	—	$V_{CC} \times 0.3$	V	
Output high voltage	P37, P33 to P30, P82 to P80, PB1, PB0	V_{OH}	$V_{CC} \times 0.9$	—	V	I_{OH} = –0.5 mA
Output low voltage	P37, P33 to P30, P82 to P80, PB1, PB0	V_{OL}	—	$V_{CC} \times 0.1$	V	I_{OL} = 1.5 mA

Note: * Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

Table 27.3 Permissible Output Currents

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0, PS2AC to PS2CC, PS2AD to PS2CD, PA7 to PA4 (bus drive function selected)	I_{OL}	—	—	10	mA
	Ports 1 to 3		—	—	2	
	$\overline{\text{RESO}}$		—	—	1	
	Other output pins		—	—	1	
Permissible output low current (total)	Total of ports 1 to 3	$\sum I_{OL}$	—	—	40	mA
	Total of all output pins, including the above		—	—	60	
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	30	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 27.3.
2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 27.1 and 27.2.

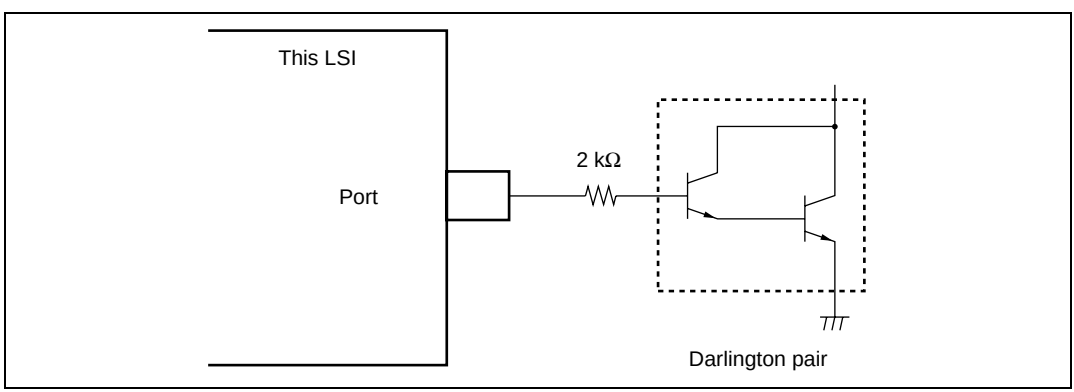


Figure 27.1 Darlington Pair Drive Circuit (Example)

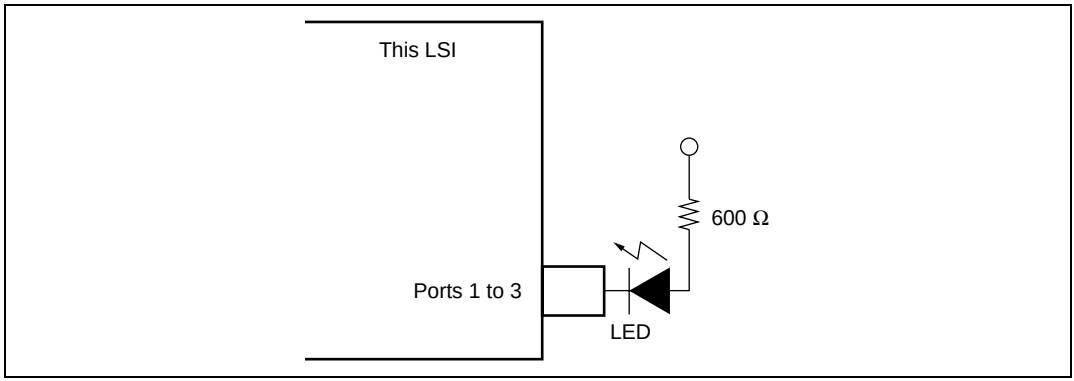


Figure 27.2 LED Drive Circuit (Example)

Table 27.4 Bus Drive Characteristics

Conditions: V_{CC} = 2.7 V to 3.6 V, V_{SS} = 0 V, Ta = –20 to +75°C

Applicable Pins: SCL1, SCL0, SDA1, SDA0 (bus drive function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	V_T^-	$V_{CC} \times 0.3$	—	—	V	V_{CC} = 2.7 V to 3.6 V
	V_T^+	—	—	$V_{CC} \times 0.7$		V_{CC} = 2.7 V to 3.6 V
	$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		V_{CC} = 2.7 V to 3.6 V
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	5.5	V	V_{CC} = 2.7 V to 3.6 V
Input low voltage	V_{IL}	–0.5	—	$V_{CC} \times 0.3$		V_{CC} = 2.7 V to 3.6 V
Output low voltage	V_{OL}	—	—	0.5	V	I_{OL} = 8 mA
		—	—	0.4		I_{OL} = 3 mA
Input capacitance	C_{in}	—	—	20	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
Three-state leakage current (off state)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V
SCL, SDA output fall time	t_{Of}	20 + 0.1Cb	—	250	ns	V_{CC} = 2.7 V to 3.6 V

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, Ta = –20 to +75°C

Applicable Pins: PS2AC, PS2AD, PS2BC, PS2BD, PS2CC, PS2CD, PA7 to PA4 (bus drive function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	V_{OL}	—	—	0.8	V	I_{OL} = 16 mA, $V_{CC}B$ = 4.5 V to 5.5 V
		—	—	0.5		I_{OL} = 8 mA
		—	—	0.4		I_{OL} = 3 mA

27.1.3 AC Characteristics

Figure 27.3 shows the test conditions for the AC characteristics.

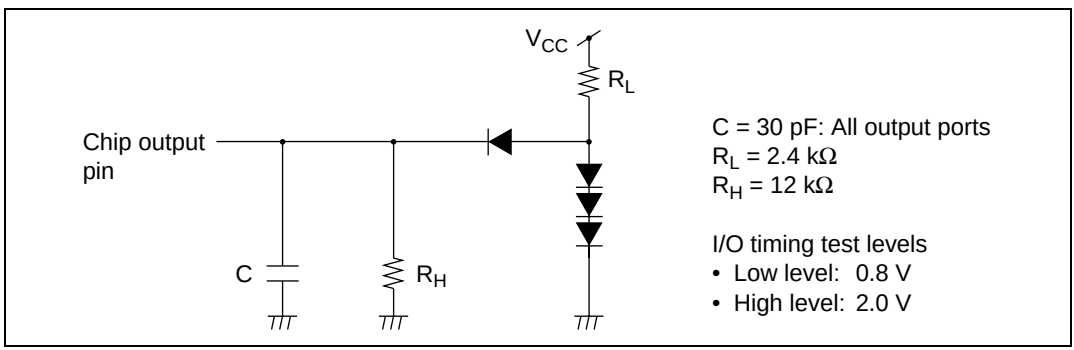


Figure 27.3 Output Load Circuit

Clock Timing: Table 27.5 shows the clock timing. The clock timing specified here covers clock (ϕ) output and clock pulse generator (crystal) and external clock input (EXTAL pin) oscillation settling times. For details on external clock input (EXTAL pin and EXCL pin) timing, see section 25, Clock Pulse Generator.

Table 27.5 Clock Timing

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition			
		10 MHz			
Item	**Symbol**	**Min**	**Max**	**Unit**	**Reference**
Clock cycle time	t_{cyc}	100	500	ns	Figure 27.6
Clock high pulse width	t_{CH}	30	—	ns	Figure 27.6
Clock low pulse width	t_{CL}	30	—	ns	
Clock rise time	t_{Cr}	—	20	ns	
Clock fall time	t_{Cf}	—	20	ns	
Oscillation settling time at reset (crystal)	t_{OSC1}	20	—	ms	Figure 27.7
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	ms	Figure 27.8
External clock output stabilization delay time	t_{DEXT}	500	—	µs	Figure 27.7

Control Signal Timing: Table 27.6 shows the control signal timing. The only external interrupts that can operate on the subclock (ϕ = 32.768 kHz) are NMI and IRQ0, 1, 2, 6, and 7.

Table 27.6 Control Signal Timing

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 32.768 kHz, 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition			
		10 MHz			
Item	Symbol	Min	Max	Unit	Test Conditions
$\overline{RES}$ setup time	t_{RESS}	300	—	ns	Figure 27.9
$\overline{RES}$ pulse width	t_{RESW}	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	250	—	ns	Figure 27.10
NMI hold time (NMI)	t_{NMIH}	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	ns	
IRQ setup time ($\overline{IRQ7}$ to $\overline{IRQ0}$)	t_{IRQS}	250	—	ns	
IRQ hold time($\overline{IRQ7}$ to $\overline{IRQ0}$)	t_{IRQH}	10	—	ns	
IRQ pulse width ($\overline{IRQ7}$, $\overline{IRQ6}$, $\overline{IRQ2}$ to $\overline{IRQ0}$) (exiting software standby mode)	t_{IRQW}	200	—	ns	

Bus Timing: Table 27.7 shows the bus timing. Operation in external expansion mode is not guaranteed when operating on the subclock (ϕ = 32.768 kHz).

Table 27.7 Bus Timing (1) (Normal Mode)

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition			
		10 MHz			
Item	Symbol	Min	Max	Unit	Test Conditions
Address delay time	t_{AD}	—	40	ns	Figures 27.11 to 27.15
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 30$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 20$	—	ns	
$\overline{CS}$ delay time ($\overline{IOS}$)	t_{CSD}	—	40	ns	
$\overline{AS}$ delay time	t_{ASD}	—	60	ns	
$\overline{RD}$ delay time 1	t_{RSD1}	—	60	ns	
$\overline{RD}$ delay time 2	t_{RSD2}	—	60	ns	
Read data setup time	t_{RDS}	35	—	ns	
Read data hold time	t_{RDH}	0	—	ns	
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 60$	ns	
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 50$	ns	
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 60$	ns	
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 50$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 60$	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 1	t_{WRD1}	—	60	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 2	t_{WRD2}	—	60	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 40$	—	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 40$	—	ns	
Write data delay time	t_{WDD}	—	60	ns	
Write data setup time	t_{WDS}	0	—	ns	
Write data hold time	t_{WDH}	20	—	ns	
$\overline{WAIT}$ setup time	t_{WTS}	60	—	ns	
$\overline{WAIT}$ hold time	t_{WTH}	10	—	ns	

Table 27.7 Bus Timing (2) (Advanced Mode)

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition			
		10 MHz			
Item	Symbol	Min	Max	Unit	Test Conditions
Address delay time	t_{AD}	—	60	ns	Figures 27.11 to 27.15
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 30$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 20$	—	ns	
$\overline{CS}$ delay time ($\overline{IOS}$)	t_{CSD}	—	60	ns	
$\overline{AS}$ delay time	t_{ASD}	—	60	ns	
$\overline{RD}$ delay time 1	t_{RSD1}	—	60	ns	
$\overline{RD}$ delay time 2	t_{RSD2}	—	60	ns	
Read data setup time	t_{RDS}	35	—	ns	
Read data hold time	t_{RDH}	0	—	ns	
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 80$	ns	
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 50$	ns	
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 80$	ns	
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 50$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 80$	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 1	t_{WRD1}	—	60	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 2	t_{WRD2}	—	60	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 40$	—	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 40$	—	ns	
Write data delay time	t_{WDD}	—	60	ns	
Write data setup time	t_{WDS}	0	—	ns	
Write data hold time	t_{WDH}	20	—	ns	
$\overline{WAIT}$ setup time	t_{WTS}	60	—	ns	
$\overline{WAIT}$ hold time	t_{WTH}	10	—	ns	

Timing of On-Chip Peripheral Modules: Tables 27.8 to 27.11 show the on-chip peripheral module timing. The only on-chip peripheral modules that can operate in subclock operation (ϕ = 32.768 kHz) are the I/O ports, external interrupts (NMI and IRQ0 to 2, 6, and 7), the watchdog timer, and the 8-bit timer (channels 0 and 1).

Table 27.8 Timing of On-Chip Peripheral Modules (1)

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 32.768 kHz*,
2 MHz to maximum operating frequency, T_a = –20 to +75°C

				Condition			
				10 MHz			
Item			Symbol	Min	Max	Unit	Test Conditions
I/O ports	Output data delay time		t_{PWD}	—	100	ns	Figure 27.16
	Input data setup time		t_{PRS}	50	—		
	Input data hold time		t_{PRH}	50	—		
FRT	Timer output delay time		t_{FTOD}	—	100	ns	Figure 27.17
	Timer input setup time		t_{FTIS}	50	—		
	Timer clock input setup time		t_{FTCS}	50	—		Figure 27.18
	Timer clock pulse width						
	Single edge		t_{FTCWH}	1.5	—	t_{cyc}	
	Both edges		t_{FTCWL}	2.5	—		
TMR	Timer output delay time		t_{TMOD}	—	100	ns	Figure 27.19
	Timer reset input setup time		t_{TMRS}	50	—		Figure 27.21
	Timer clock input setup time		t_{TMCS}	50	—		Figure 27.20
	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	t_{cyc}	
		Both edges	t_{TMCWL}	2.5	—		
PWM, PWMX	Pulse output delay time		t_{PWOD}	—	100	ns	Figure 27.22
SCI	Input clock cycle	Asynchronous	t_{Scyc}	4	—	t_{cyc}	Figure 27.23
		Synchronous		6	—		
	Input clock pulse width		t_{SCKW}	0.4	0.6	t_{Scyc}	
	Input clock rise time		t_{SCKr}	—	1.5	t_{cyc}	
	Input clock fall time		t_{SCKf}	—	1.5		

Item		Symbol	Condition 10 MHz Min	Max	Unit	Test Conditions
SCI	Transmit data delay time (synchronous)	t_{TXD}	—	100	ns	Figure 27.24
	Receive data setup time (synchronous)	t_{RXS}	100	—	ns	
	Receive data hold time (synchronous)	t_{RXH}	100	—	ns	
A/D converter	Trigger input setup time	t_{TRGS}	50	—	ns	Figure 27.25
WDT	$\overline{\text{RESO}}$ output delay time	t_{RESD}	—	200	ns	Figure 27.26
	$\overline{\text{RESO}}$ output pulse width	t_{RESOW}	132	—	t_{cyc}	

Note: * Only peripheral modules that can be used in subclock operation

Table 27.8 Timing of On-Chip Peripheral Modules (2)

Condition: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

Item			Symbol	Condition 10 MHz Min	Max	Unit	Test Conditions
XBS read cycle	$\overline{\text{CS}}$/HA0 setup time		t_{HAR}	10	—	ns	Figure 27.27
	$\overline{\text{CS}}$/HA0 hold time		t_{HRA}	10	—	ns	
	$\overline{\text{IOR}}$ pulse width		t_{HRPW}	220	—	ns	
	HDB delay time		t_{HRD}	—	200	ns	
	HDB hold time		t_{HRF}	0	40	ns	
	HIRQ delay time		t_{HIRQ}	—	200	ns	
XBS write cycle	$\overline{\text{CS}}$/HA0 setup time		t_{HAW}	10	—	ns	
	$\overline{\text{CS}}$/HA0 hold time		t_{HWA}	10	—	ns	
	$\overline{\text{IOW}}$ pulse width		t_{HWPW}	100	—	ns	
	HDB setup time	Fast A20 gate not used	t_{HDW}	50	—	ns	
		Fast A20 gate used		85	—	ns	
	HDB hold time		t_{HWD}	25	—	ns	
	GA20 delay time		t_{HGA}	—	180	ns	

Table 27.9 Keyboard Buffer Controller Timing

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

Item	Symbol	Ratings Min	Typ	Max	Unit	Test Conditions	Notes
KCLK, KD output fall time	t_{KBF}	20 + 0.1 Cb	—	250	ns		Figure 27.28
KCLK, KD input data hold time	t_{KBIH}	150	—	—	ns		
KCLK, KD input data setup time	t_{KBIS}	150	—	—	ns		
KCLK, KD output delay time	t_{KBOD}	—	—	450	ns		
KCLK, KD capacitive load	C_b	—	—	400	pF		

Table 27.10 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 to +75°C

Item	Symbol	Ratings Min	Typ	Max	Unit	Test Conditions	Notes
SCL input cycle time	t_{SCL}	12	—	—	t_{cyc}		Figure 27.29
SCL input high pulse width	t_{SCLH}	3	—	—	t_{cyc}		
SCL input low pulse width	t_{SCLL}	5	—	—	t_{cyc}		
SCL, SDA input rise time	t_{Sr}	—	—	7.5*	t_{cyc}		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse elimination time	t_{SP}	—	—	1	t_{cyc}		
SDA input bus free time	t_{BUF}	5	—	—	t_{cyc}		
Start condition input hold time	t_{STAH}	3	—	—	t_{cyc}		
Retransmission start condition input setup time	t_{STAS}	3	—	—	t_{cyc}		
Stop condition input setup time	t_{STOS}	3	—	—	t_{cyc}		
Data input setup time	t_{SDAS}	0.5	—	—	t_{cyc}		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA capacitive load	C_b	—	—	400	pF		

Note: * 17.5 t_{cyc} can be set according to the clock selected for use by the I^2C module. For details, see section 16.6, Usage Notes.

Table 27.11 LPC Module Timing

Conditions: V_{CC} = 3.0 V to 3.6 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
LPC	Input clock cycle	t_{Lcyc}	30	—	—	ns	Figure 27.30
	Input clock pulse width (H)	t_{LCKH}	11	—	—		
	Input clock pulse width (L)	t_{LCKL}	11	—	—		
	Transmit signal delay time	t_{TXD}	2	—	11		
	Transmit signal floating delay time	t_{OFF}	—	—	28		
	Receive signal setup time	t_{RXS}	7	—	—		
	Receive signal hold time	t_{RXH}	0	—	—		

27.1.4 A/D Conversion Characteristics

Tables 27.12 and 27.13 list the A/D conversion characteristics.

Table 27.12 A/D Conversion Characteristics (AN7 to AN0 Input: 134/266-State Conversion)

Conditions: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, AV_{ref} = 2.7 V to AV_{CC},
$V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

	Condition			
	10 MHz			
Item	**Min**	**Typ**	**Max**	**Unit**
Resolution	10	10	10	bits
Conversion time	—	—	13.4	µs
Analog input capacitance	—	—	20	pF
Permissible signal-source impedance	—	—	5	kΩ
Nonlinearity error	—	—	±7.0	LSB
Offset error	—	—	±7.5	LSB
Full-scale error	—	—	±7.5	LSB
Quantization error	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	LSB

Table 27.13 A/D Conversion Characteristics
(CIN15 to CIN0 Input: 134/266-State Conversion)

Conditions: V_{CC} = 3.0 V to 3.6 V, AV_{CC} = 3.0 V to 3.6 V, AV_{ref} = 3.0 V to AV_{CC},
$V_{CC}B$ = 3.0 V to 5.5 V, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

	Condition			
	10 MHz			
Item	**Min**	**Typ**	**Max**	**Unit**
Resolution	10	10	10	bits
Conversion time	—	—	13.4	µs
Analog input capacitance	—	—	20	pF
Permissible signal-source impedance	—	—	5	kΩ
Nonlinearity error	—	—	±11.0	LSB
Offset error	—	—	±11.5	LSB
Full-scale error	—	—	±11.5	LSB
Quantization error	—	—	±0.5	LSB
Absolute accuracy	—	—	±12.0	LSB

27.1.5 D/A Conversion Characteristics

Table 27.14 lists the D/A conversion characteristics.

Table 27.14 D/A Conversion Characteristics

Conditions: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, AV_{ref} = 2.7 V to AV_{CC},
$V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = AV_{SS} = 0 V,
ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition			
		10 MHz			
Item		Min	Typ	Max	Unit
Resolution		8	8	8	bits
Conversion time	With 20 pF load capacitance	—	—	10	µs
Absolute accuracy	With 2 MΩ load resistance	—	±2.0	±3.0	LSB
	With 4 MΩ load resistance	—	—	±2.0	

27.1.6 Flash Memory Characteristics

Table 27.15 shows the flash memory characteristics.

Table 27.15 Flash Memory Characteristics

Conditions: V_{CC} = 3.0 V to 3.6 V, V_{SS} = 0 V, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit	Test Condition
Programming time*1 *2 *4		t_P	—	10	200	ms/ 128 bytes	
Erase time*1 *3 *6		t_E	—	100	1200	ms/block	
Reprogramming count		N_{WEC}	100*8	10,000*9	—	times	
Data retention time*10		t_{DRP}	10	—	—	Years	
Programming	Wait time after SWE-bit setting*1	x	1	—	—	µs	
	Wait time after PSU-bit setting*1	y	50	—	—	µs	
	Wait time after P-bit setting*1 *4	z1	28	30	32	µs	1 ≤ n ≤ 6
		z2	198	200	202	µs	7 ≤ n ≤ 1000
		z3	8	10	12	µs	Additional write
	Wait time after P-bit clear*1	α	5	—	—	µs	
	Wait time after PSU-bit clear*1	β	5	—	—	µs	
	Wait time after PV-bit setting*1	γ	4	—	—	µs	
	Wait time after dummy write*1	ε	2	—	—	µs	
	Wait time after PV-bit clear*1	η	2	—	—	µs	
	Wait time after SWE-bit clear*1	θ	100	—	—	µs	
	Maximum programming count*1 *4 *5	N	—	—	1000	times	
Erase	Wait time after SWE-bit setting*1	x	1	—	—	µs	
	Wait time after ESU-bit setting*1	y	100	—	—	µs	
	Wait time after E-bit setting*1 *6	z	10	—	100	ms	
	Wait time after E-bit clear*1	α	10	—	—	µs	
	Wait time after ESU-bit clear*1	β	10	—	—	µs	
	Wait time after EV-bit setting*1	γ	20	—	—	µs	
	Wait time after dummy write*1	ε	2	—	—	µs	
	Wait time after EV-bit clear*1	η	4	—	—	µs	
	Wait time after SWE-bit clear*1	θ	100	—	—	µs	
	Maximum erase count*1 *6 *7	N	—	—	120	times	

Notes: 1. Set the times according to the program/erase algorithms.

2. Programming time per 128 bytes (Shows the total period for which the P-bit in FLMCR1 is set. It does not include the programming verification time.)
3. Block erase time (Shows the total period for which the E-bit in FLMCR1 is set. It does not include the erase verification time.)
4. Maximum programming time (t_P (max))

   t_P (max) = (wait time after P-bit setting (z1) + (z3)) $\times$ 6
   + wait time after P-bit setting (z2) $\times$ ((N) – 6)
5. The maximun number of writes (N) should be set according to the actual set value of z1, z2 and z3 to allow programming within the maximum programming time (t_P (max)).

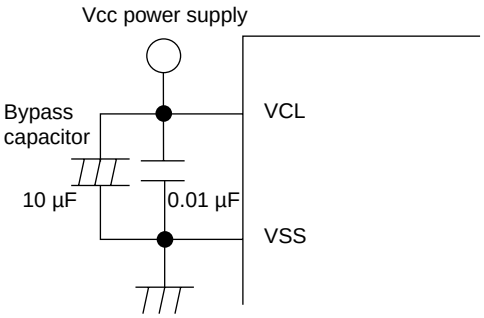
   The wait time after P-bit setting (z1, z2, and z3) should be alternated according to the number of writes (n) as follows:

   $1 \leq n \leq 6$ z1 = 30µs, z3 = 10µs
   $7 \leq n \leq 1000$ z2 = 200µs
6. Maximum erase time (t_E (max))

   t_E (max) = Wait time after E-bit setting (z) $\times$ maximum erase count (N)
7. The maximum number of erases (N) should be set according to the actual set value of z to allow erasing within the maximum erase time (t_E (max)).
8. Minimum number of times for which all characteristics are guaranteed after rewriting (Guarantee range is 1 to minimum value).
9. Reference value for 25°C (as a guideline, rewriting should normally function up to this value).
10. Data retention characteristic when rewriting is performed within the specification range, including the minimum value.

27.1.7 Usage Note

The method of connecting an external capacitor is shown in figure 27.4. Connect the system power supply to the VCL pin together with the VCC pins.



< Vcc = 2.7 V to 3.6 V >
Connect the Vcc power supply to the chip's VCL pin in the same way as the VCC pins.
It is recommended that a bypass capacitor be connected to the power supply pins. (Values are reference values.)

Figure 27.4 Connection of VCL Capacitor

27.2 Electrical Characteristics of H8S/2145B and H8S/2148B

27.2.1 Absolute Maximum Ratings

Table 27.16 lists the absolute maximum ratings.

Table 27.16 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage*1	V_{CC}	–0.3 to +7.0	V
I/O buffer power supply voltage (power supply for port A)	$V_{CC}B$	–0.3 to +7.0	V
Power supply voltage (3-V version product)*1	V_{CC}	–0.3 to +4.3	V
Power supply voltage (VCL pin)*2	V_{CL}	–0.3 to +4.3	V
Input voltage (except ports 6, 7, and A, P97, P86, P52, P42)	V_{in}	–0.3 to V_{CC} + 0.3	V
Input voltage (CIN input not selected for port 6)	V_{in}	–0.3 to V_{CC} + 0.3	V
Input voltage (CIN input not selected for port A)	V_{in}	–0.3 to $V_{CC}B$ + 0.3	V
Input voltage (CIN input selected for port 6)	V_{in}	–0.3 V to lower of voltages V_{CC} + 0.3 and AV_{CC} + 0.3	V
Input voltage (CIN input selected for port A)	V_{in}	–0.3 V to lower of voltages $V_{CC}B$ + 0.3 and AV_{CC} + 0.3	V
Input voltage (P97, P86, P52, P42)	V_{in}	–0.3 to +7.0	V
Input voltage (port 7)	V_{in}	–0.3 to AV_{CC} + 0.3	V
Reference supply voltage	AV_{ref}	–0.3 to AV_{CC} + 0.3	V
Analog power supply voltage	AV_{CC}	–0.3 to +7.0	V
Analog power supply voltage (3-V version product)	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}	Normal specification product: –20 to +75	°C
		Wide range temperature specification product: –40 to +85	

Item	Symbol	Value	Unit
Operating temperature (flash memory programming/erasing)	T_{opr}	Normal specification product: –20 to +75	°C
		Wide range temperature specification product: –40 to +85	
Storage temperature	T_{stg}	–55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.

Ensure that for 5-V/4-V version products, the input pin voltage does not exceed 7.0 V, and for 3-V version products, all the input voltage except for port A does not exceed 4.3 V.

Notes: 1. Voltage applied to the VCC1 pin. Since both the VCC1 pin and VCL pin are connected to the VCC power supply on low-power voltage (3-V) products, VCL ratings should not be exceeded.

2. Power supply voltage pin used for operation within the chip. Do not apply power supply voltage to the VCL pin on 5-V/4-V products. Be sure to insert an external capacitor between the VCL pin and GND to regulate the internal voltage.

27.2.2 DC Characteristics

Table 27.17 lists the DC characteristics. Permitted output current values and bus drive characteristics are shown in tables 27.18 and 27.19, respectively.

Table 27.17 DC Characteristics (1)

Conditions: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, AV_{CC}*1 = 5.0 V ±10%, AV_{ref}*1 = 4.5 V to AV_{CC}, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Item			Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 (KWUL = 00)*2*6, $\overline{KIN15}$ to $\overline{KIN8}$*7*8, $\overline{IRQ2}$ to $\overline{IRQ0}$*3, $\overline{IRQ5}$ to $\overline{IRQ3}$	(1)	V_T^-	1.0	—	—	V	
			V_T^+	—	—	$V_{CC} \times 0.7$ $V_{CC}B \times 0.7$		
			$V_T^+ - V_T^-$	0.4	—	—		
Schmitt trigger input voltage (in level switching)*6	P67 to P60 (KWUL = 01)		V_T^-	$V_{CC} \times 0.3$	—	—	V	
			V_T^+	—	—	$V_{CC} \times 0.7$		
			$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		
	P67 to P60 (KWUL = 10)		V_T^-	$V_{CC} \times 0.4$	—	—		
			V_T^+	—	—	$V_{CC} \times 0.8$		
			$V_T^+ - V_T^-$	$V_{CC} \times 0.03$	—	—		
	P67 to P60 (KWUL = 11)		V_T^-	$V_{CC} \times 0.45$	—	—		
			V_T^+	—	—	$V_{CC} \times 0.9$		
			$V_T^+ - V_T^-$	0.05	—	—		
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD1, MD0	(2)	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$		
	PA7 to PA0*7			$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$		
	Port 7			2.0	—	$AV_{CC} + 0.3$		
	P97, P86, P52, P42			$V_{CC} \times 0.7$	—	5.5		
	Input pins except (1) and (2) above			2.0	—	$V_{CC} + 0.3$		

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD1, MD0 (3)	V_{IL}	–0.3	—	0.5	V	
	PA7 to PA0		–0.3	—	1.0		
	NMI, EXTAL, input pins except (1) and (3) above		–0.3	—	0.8		
Output high voltage	All output pins (except P97, P86, P52, and P42)*5 *8	V_{OH}	V_{CC} – 0.5 $V_{CC}B$ – 0.5	—	—	V	I_{OH} = –200 µA
			3.5	—	—	V	I_{OH} = –1 mA,
	P97, P86, P52, and P42*4		2.0	—	—	V	I_{OH} = –200 µA
Output low voltage	All output pins (except $\overline{RESO}$)*5	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports 1 to 3		—	—	1.0	V	I_{OL} = 10 mA
	$\overline{RESO}$		—	—	0.4	V	I_{OL} = 2.6 mA

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. P67 to P60 include peripheral module inputs multiplexed on those pins.
3. $\overline{IRQ2}$ includes the $\overline{ADTRG}$ signal multiplexed on that pin.
4. P52/SCK0/SCL0, P97/SDA0, P86/SCK1/SCL1, P42/SCK2/SDA1, and port G are NMOS push-pull outputs.

   When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it is NMOS open-drain output. Therefore, an external pull-up resistor must be connected in order to output high level.

   P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are driven by NMOS.

   When the SCK0, SCK1, or SCK2 pin is used as an output, an external pull-up resistor must be connected in order to output high level.
5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus drive function is selected is determined separately.
6. The upper limit of the port 6 applied voltage is V_{CC} + 0.3 V when CIN input is not selected, and the lower of V_{CC} + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
7. The upper limit of the port A applied voltage is $V_{CC}B$ + 0.3 V when CIN input is not selected, and the lower of $V_{CC}B$ + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.

8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC} in output mode.

Table 27.17 DC Characteristics (2)

Conditions: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, AV_{CC}*1 = 5.0 V ±10%, AV_{ref}*1 = 4.5 V to AV_{CC}, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input leakage current	$\overline{RES}$	$\lvert I_{in} \rvert$	—	—	10.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V
	$\overline{STBY}$, NMI, MD1, MD0		—	—	1.0		
	Port 7		—	—	1.0		V_{in} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 1 to 6 Ports 8, 9, A*4, B	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V, V_{in} = 0.5 to $V_{CC}B$ – 0.5 V
Input pull-up MOS current	Ports 1 to 3	$-I_P$	30	—	300	µA	V_{in} = 0 V
	Ports A*4, B, 6 (P6PUE = 0)		60	—	600	µA	
	Port 6 (P6PUE = 1)		15	—	200	µA	
Input capacitance	$\overline{RES}$ (4)	C_{in}	—	—	80	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
	NMI		—	—	50		
	P52, P97, P42, P86, PA7 to PA2		—	—	20		
	Input pins except (4) above		—	—	15		
Current dissipation*2	Normal operation	I_{CC}	—	55	70	mA	f = 20 MHz
	Sleep mode		—	36	55	mA	f = 20 MHz
	Standby mode*3		—	1.0	5.0	µA	$T_a \leq$ 50°C
			—	—	20.0		50°C < T_a
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	µA	AV_{CC} = 2.0 V to 5.5 V

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Reference power supply current	During A/D conversion	AI_{ref}	—	0.5	1.0	mA	
	During A/D, D/A conversion		—	2.0	5.0		
	Idle		—	0.01	5.0	µA	AV_{ref} = 2.0 V to AV_{CC}
Analog power supply voltage*1		AV_{CC}	4.5	—	5.5	V	Operating
			2.0	—	5.5		Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. Current dissipation values are for V_{IH} min = V_{CC} – 0.2 V, $V_{CC}B$ – 0.2 V, and V_{IL} max = 0.2 V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 4.5$ V, V_{IH} min = V_{CC}– 0.2 V, $V_{CC}B$ – 0.2 V, and V_{IL} max = 0.2 V.
4. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC}.

Table 27.17 DC Characteristics (3)

Conditions: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, AV_{CC}*1 = 4.0 V to 5.5 V, AV_{ref}*1 = 4.0 V to AV_{CC}, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 (KWUL = 00)*2*6, $\overline{KIN15}$ to $\overline{KIN8}$*7*8, $\overline{IRQ2}$ to $\overline{IRQ0}$*3, $\overline{IRQ5}$ to $\overline{IRQ3}$ (1)	V_T^-	1.0	—	—	V	V_{CC} = 4.5 V to 5.5 V, $V_{CC}B$ = 4.5 V to 5.5 V
		V_T^+	—	—	$V_{CC} \times 0.7$ $V_{CC}B \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—		
		V_T^-	0.8	—	—	V	V_{CC} = 4.0 V to 4.5 V, $V_{CC}B$ = 4.0 V to 4.5 V
		V_T^+	—	—	$V_{CC} \times 0.7$ $V_{CC}B \times 0.7$		
		$V_T^+ - V_T^-$	0.3	—	—		
Schmitt trigger input voltage (in level switching)*6	P67 to P60 (KWUL = 01)	V_T^-	$V_{CC} \times 0.3$	—	—	V	V_{CC} = 4.0 V to 5.5 V
		V_T^+	—	—	$V_{CC} \times 0.7$		
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		
	P67 to P60 (KWUL = 10)	V_T^-	$V_{CC} \times 0.4$	—	—		
		V_T^+	—	—	$V_{CC} \times 0.8$		
		$V_T^+ - V_T^-$	$V_{CC} \times 0.03$	—	—		
	P67 to P60 (KWUL = 11)	V_T^-	$V_{CC} \times 0.45$	—	—		
		V_T^+	—	—	$V_{CC} \times 0.9$		
		$V_T^+ - V_T^-$	0.05	—	—		
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD1, MD0 (2)	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$		
	PA7 to PA0*7		$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$		
	Port 7		2.0	—	$AV_{CC} + 0.3$		
	P97, P86, P52, P42		$V_{CC} \times 0.7$	—	5.5		
	Input pins except (1) and (2) above		2.0	—	$V_{CC} + 0.3$		

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD1, MD0 (3)	V_{IL}	–0.3	—	0.5	V	
			–0.3	—	1.0		$V_{CC}B$ = 4.5 V to 5.5 V
	PA7 to PA0		–0.3	—	0.8		$V_{CC}B$ = 4.0 V to 4.5 V
	NMI, EXTAL, input pins except (1) and (3) above		–0.3	—	0.8		
Output high voltage	All output pins (except P97, P86, P52, and P42)*4 *5 *8	V_{OH}	V_{CC} – 0.5 $V_{CC}B$ – 0.5	—	—	V	I_{OH} = –200 µA
			3.5	—	—	V	I_{OH} = –1 mA, V_{CC} = 4.5 V to 5.5 V, $V_{CC}B$ = 4.5 V to 5.5 V
			3.0	—	—	V	I_{OH} = –1 mA, V_{CC} = 4.0 V to 4.5 V, $V_{CC}B$ = 4.0 V to 4.5 V
	P97, P86, P52, and P42*4		1.5	—	—	V	I_{OH} = –200 µA
Output low voltage	All output pins (except $\overline{RESO}$)*5	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports 1 to 3		—	—	1.0	V	I_{OL} = 10 mA
	$\overline{RESO}$		—	—	0.4	V	I_{OL} = 2.6 mA

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. P67 to P60 include peripheral module inputs multiplexed on those pins.
3. $\overline{IRQ2}$ includes the $\overline{ADTRG}$ signal multiplexed on that pin.
4. P52/SCK0/SCL0, P97/SDA0, P86/SCK1/SCL1, P42/SCK2/SDA1, and port G are NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it is NMOS open-drain output. Therefore, an external pull-up resistor must be connected in order to output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are driven by NMOS.

When the SCK0, SCK1, or SCK2 pin is used as an output, an external pull-up resistor must be connected in order to output high level.

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus drive function is selected is determined separately.
6. The upper limit of the port 6 applied voltage is V_{CC} + 0.3 V when CIN input is not selected, and the lower of V_{CC} + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
7. The upper limit of the port A applied voltage is $V_{CC}B$ + 0.3 V when CIN input is not selected, and the lower of $V_{CC}B$ + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC}.

Table 27.17 DC Characteristics (4)

Conditions: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, AV_{CC}*1 = 4.0 V to 5.5 V, AV_{ref}*1 = 4.0 V to AV_{CC}, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input leakage current	$\overline{RES}$	$\lvert I_{in} \rvert$	—	—	10.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V
	$\overline{STBY}$, NMI, MD1, MD0		—	—	1.0		
	Port 7		—	—	1.0		V_{in} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A*4, B	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V, V_{in} = 0.5 to $V_{CC}B$ – 0.5 V
Input pull-up MOS current	Ports 1 to 3	$-I_P$	30	—	300	µA	V_{in} = 0 V, V_{CC} = 4.5 V to 5.5 V, $V_{CC}B$ = 4.5 V to 5.5 V
	Ports A*4, B, 6 (P6PUE = 0)		60	—	600		
	Port 6 (P6PUE = 1)		15	—	200		
	Ports 1 to 3		20	—	200	µA	V_{in} = 0 V, V_{CC} = 4.0 V to 4.5 V, $V_{CC}B$ = 4.0 V to 4.5 V
	Ports A*4, B, 6 (P6PUE = 0)		40	—	500		
	Port 6 (P6PUE = 1)		10	—	150		
Input capacitance	$\overline{RES}$ (4)	C_{in}	—	—	80	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
	NMI		—	—	50		
	P52, P97, P42, P86, PA7 to PA2		—	—	20		
	Input pins except (4) above		—	—	15		
Current dissipation*2	Normal operation	I_{CC}	—	45	58	mA	f = 16 MHz
	Sleep mode		—	30	46	mA	f = 16 MHz
	Standby mode*3		—	1.0	5.0	µA	$T_a \leq$ 50°C
			—	—	20.0		50°C < T_a

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	µA	AV_{CC} = 2.0 V to 5.5 V
Reference power supply current	During A/D conversion	AI_{ref}	—	0.5	1.0	mA	
	During A/D, D/A conversion		—	2.0	5.0		
	Idle		—	0.01	5.0	µA	AV_{ref} = 2.0 V to AV_{CC}
Analog power supply voltage*1		AV_{CC}	4.0	—	5.5	V	Operating
			2.0	—	5.5		Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. Current dissipation values are for V_{IH} min = V_{CC} – 0.2 V, V_{CC}B – 0.2 V, and V_{IL} max = 0.2 V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
3. Current dissipation values are for V_{IH} min = V_{CC} – 0.2 V, V_{CC}B – 0.2 V, and V_{IL} max = 0.2 V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
4. The port A characteristics depend on VCCB, and the other pins characteristics depend on VCC.

Table 27.17 DC Characteristics (5)

Conditions: V_{CC} = 2.7 V to 3.6 V*9, $V_{CC}B$ = 2.7 V to 5.5 V, AV_{CC}*1 = 2.7 V to 3.6 V, AV_{ref} = 2.7 V to 3.6 V, V_{SS} = AV_{SS}*1 = 0 V, T_a = –20 to +75°C

Item			Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 (KWUL = 00)*2 *6, $\overline{KIN15}$ to $\overline{KIN8}$*7 *8, $\overline{IRQ2}$ to $\overline{IRQ0}$*3, $\overline{IRQ5}$ to $\overline{IRQ3}$	(1)	V_T^-	$V_{CC} \times 0.2$ $V_{CC}B \times 0.2$	—	—	V	
			V_T^+	—	—	$V_{CC} \times 0.7$ $V_{CC}B \times 0.7$		
			$V_T^+ - V_T^-$	$V_{CC} \times 0.05$ $V_{CC}B \times 0.05$	—	—		
Schmitt trigger input voltage (in level switching)*6	P67 to P60 (KWUL = 01)		V_T^-	$V_{CC} \times 0.3$	—	—	V	
			V_T^+	—	—	$V_{CC} \times 0.7$		
			$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		
	P67 to P60 (KWUL = 10)		V_T^-	$V_{CC} \times 0.4$	—	—		
			V_T^+	—	—	$V_{CC} \times 0.8$		
			$V_T^+ - V_T^-$	$V_{CC} \times 0.03$	—	—		
	P67 to P60 (KWUL = 11)		V_T^-	$V_{CC} \times 0.45$	—	—		
			V_T^+	—	—	$V_{CC} \times 0.9$		
			$V_T^+ - V_T^-$	0.05	—	—		
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD1, MD0	(2)	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V	
	EXTAL			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$		
	PA7 to PA0*7			$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$		
	Port 7			$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$		
	P97, P86, P52, P42			$V_{CC} \times 0.7$	—	5.5		
	Input pins except (1) and (2) above			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$		

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD1, MD0 (3)	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	PA7 to PA0		–0.3	—	$V_{CC}B \times 0.2$		$V_{CC}B$ = 2.7 V to 4.0 V
					0.8		$V_{CC}B$ = 4.0 V to 5.5 V
	NMI, EXTAL, input pins except (1) and (3) above		–0.3	—	$V_{CC} \times 0.2$		V_{CC} = 2.7 V to 3.6 V
Output high voltage	All output pins (except P97, P86, P52, and P42)*4 *5 *8	V_{OH}	V_{CC} – 0.5 $V_{CC}B$ – 0.5	—	—	V	I_{OH} = –200 µA
			V_{CC} – 1.0 $V_{CC}B$ – 1.0	—	—	V	I_{OH} = –1 mA, V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 4.0 V
	P97, P86, P52, and P42*4		0.5	—	—	V	I_{OH} = –200 µA
Output low voltage	All output pins (except $\overline{RESO}$)*5	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports 1 to 3		—	—	1.0	V	I_{OL} = 5 mA
	$\overline{RESO}$		—	—	0.4	V	I_{OL} = 1.6 mA

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. P67 to P60 include peripheral module inputs multiplexed on those pins.
3. $\overline{IRQ2}$ includes the $\overline{ADTRG}$ signal multiplexed on that pin.
4. P52/SCK0/SCL0, P97/SDA0, P86/SCK1/SCL1, P42/SCK2/SDA1, and port G are NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it is NMOS open-drain output. Therefore, an external pull-up resistor must be connected in order to output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are driven by NMOS.

When the SCK0, SCK1, or SCK 2 pin is used as an output, an external pull-up resistor must be connected in order to output high level.

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus drive function is selected is determined separately.
6. The upper limit of the port 6 applied voltage is V_{CC} + 0.3 V when CIN input is not selected, and the lower of V_{CC} + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
7. The upper limit of the port A applied voltage is $V_{CC}B$ + 0.3 V when CIN input is not selected, and the lower of $V_{CC}B$ + 0.3 V and AV_{CC} + 0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC}.
9. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V to 3.6 V.

Table 27.17 DC Characteristics (6)

Conditions: V_{CC} = 2.7 V to 3.6 V*5, $V_{CC}B$ = 2.7 V to 5.5 V, AV_{CC}*1 = 2.7 V to 3.6 V, AV_{ref}*1 = 2.7 V to 3.6 V, $V_{SS} = AV_{SS}$*1 = 0 V, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input leakage current	$\overline{RES}$	$\lvert I_{in} \rvert$	—	—	10.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V
	$\overline{STBY}$, NMI, MD1, MD0		—	—	1.0		
	Port 7		—	—	1.0		V_{in} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 1 to 6 Ports 8, 9, A*4, B	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V, V_{in} = 0.5 to $V_{CC}B$ – 0.5 V
Input pull-up MOS current	Ports 1 to 3	$-I_P$	5	—	150	µA	V_{in} = 0 V, V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 3.6 V
	Ports A*4, B, 6 (P6PUE = 0)		30	—	300		
	Port 6 (P6PUE = 1)		3	—	100		
Input capacitance	$\overline{RES}$ (4)	C_{in}	—	—	80	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
	NMI		—	—	50		
	P52, P97, P42, P86, PA7 to PA2		—	—	20		
	Input pins except (4) above		—	—	15		
Current dissipation*2	Normal operation	I_{CC}	—	30	40	mA	f = 10 MHz
	Sleep mode		—	20	32	mA	f = 10 MHz
	Standby mode*3		—	1.0	5.0	µA	$T_a \le 50°C$
			—	—	20.0		50°C < T_a
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	µA	AV_{CC} = 2.0 V to 3.6 V

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Reference power supply current	During A/D conversion	AI_{ref}	—	0.5	1.0	mA	
	During A/D, D/A conversion		—	2.0	5.0		
	Idle		—	0.01	5.0	µA	AV_{ref} = 2.0 V to AV_{CC}
Analog power supply voltage*1		AV_{CC}	2.7	—	3.6	V	Operating
			2.0	—	3.6		Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. Current dissipation values are for V_{IH} min = V_{CC} – 0.2 V, $V_{CC}B$ – 0.2 V, and V_{IL} max = 0.2 V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7$ V, V_{IH} min = V_{CC}– 0.2 V, $V_{CC}B$ – 0.2 V, and V_{IL} max = 0.2 V.
4. The port A characteristics depend on VCCB, and the other pins characteristics depend on VCC.
5. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V to 3.6 V.

Table 27.17 DC Characteristics (7) (3-V Version of H8S/2145BV) When LPC Function Is Used

Conditions: V_{CC} = 3.0 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, AV_{CC}* = 2.7 V to 3.6 V, AV_{ref}* = 2.7 V to AV_{CC}, V_{SS} = AV_{SS}*[1] = 0 V, T_a = –20 to +75°C

Item		Symbol	Min	Max	Unit	Test Conditions
Input high voltage	P37 to P30, P83 to P80, PB1, PB0	V_{IH}	$V_{CC} \times 0.5$	—	V	
Input low voltage	P37 to P30, P83 to P80, PB1, PB0	V_{IL}	—	$V_{CC} \times 0.3$	V	
Output high voltage	P37, P33 to P30, P82 to P80, PB1, PB0	V_{OH}	$V_{CC} \times 0.9$	—	V	I_{OH} = –0.5 mA
Output low voltage	P37, P33 to P30, P82 to P80, PB1, PB0	V_{OL}	—	$V_{CC} \times 0.1$	V	I_{OL} = 1.5 mA

Note: * Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter and D/A converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or some other method. Ensure that $AV_{ref} \leq AV_{CC}$.

Table 27.18 Permissible Output Currents

Conditions: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V,
T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

	Item	Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0, PS2AC to PS2CC, PS2AD to PS2CD, PA7 to PA4 (bus drive function selected)	I_{OL}	—	—	20	mA
	Ports 1 to 3		—	—	10	
	$\overline{\text{RESO}}$		—	—	3	
	Other output pins		—	—	2	
Permissible output low current (total)	Total of ports 1 to 3	$\sum I_{OL}$	—	—	80	mA
	Total of all output pins, including the above		—	—	120	
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	40	mA

Conditions: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, T_a = –20 to +75°C

	Item	Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0, PS2AC to PS2CC, PS2AD to PS2CD, PA7 to PA4 (bus drive function selected)	I_{OL}	—	—	10	mA
	Ports 1 to 3		—	—	2	
	$\overline{\text{RESO}}$		—	—	1	
	Other output pins		—	—	1	
Permissible output low current (total)	Total of ports 1 to 3	$\sum I_{OL}$	—	—	40	mA
	Total of all output pins, including the above		—	—	60	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	30	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 27.18.
2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 27.1 and 27.2.

Table 27.19 Bus Drive Characteristics

Conditions: V_{CC} = 4.0 V to 5.5 V, V_{CC} = 2.7 V to 3.6 V (3-V version product), V_{SS} = 0 V

Applicable Pins: SCL1, SCL0, SDA1, SDA0 (bus drive function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	V_T^-	$V_{CC} \times 0.3$	—	—	V	
	V_T^+	—	—	$V_{CC} \times 0.7$		
	$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	5.5	V	
Input low voltage	V_{IL}	–0.5	—	$V_{CC} \times 0.3$		
Output low voltage	V_{OL}	—	—	0.8	V	I_{OL} = 16 mA, V_{CC} = 4.5 V to 5.5 V
		—	—	0.5		I_{OL} = 8 mA
		—	—	0.4		I_{OL} = 3 mA
Input capacitance	C_{in}	—	—	20	pF	V_{in} = 0 V, f = 1 MHz, T_a = 25°C
Three-state leakage current (off state)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to V_{CC} – 0.5 V
SCL, SDA output fall time	t_{Of}	20 + 0.1 Cb	—	250	ns	

Conditions: V_{CC} = 4.0 V to 5.5 V, V_{CC} = 2.7 V to 3.6 V (3-V version product),
$V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V

Applicable Pins: PS2AC, PS2AD, PS2BC, PS2BD, PS2CC, PS2CD, PA7 to PA4 (bus drive function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	V_{OL}	—	—	0.8	V	I_{OL} = 16 mA, $V_{CC}B$ = 4.5 V to 5.5 V
		—	—	0.5		I_{OL} = 8 mA
		—	—	0.4		I_{OL} = 3 mA

27.2.3 AC Characteristics

The following shows the clock timing, control signal timing, bus timing, and on-chip peripheral function timing. For the AC characteristics test conditions, see figure 27.3.

Clock Timing: Table 27.20 shows the clock timing. The clock timing specified here covers clock (φ) output and clock pulse generator (crystal) and external clock input (EXTAL pin) oscillation settling times. For details of external clock input (EXTAL pin and EXCL pin) timing, see section 25, Clock Pulse Generator.

Table 27.20 Clock Timing

Condition A: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, V_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition A		Condition B		Condition C			
		10 MHz		16 MHz		20 MHz			
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
Clock cycle time	t_{cyc}	100	500	62.5	500	50	500	ns	Figure 27.6
Clock high pulse width	t_{CH}	30	—	20	—	17	—	ns	Figure 27.6
Clock low pulse width	t_{CL}	30	—	20	—	17	—	ns	
Clock rise time	t_{Cr}	—	20	—	10	—	8	ns	
Clock fall time	t_{Cf}	—	20	—	10	—	8	ns	
Oscillation settling time at reset (crystal)	t_{OSC1}	20	—	10	—	10	—	ms	Figure 27.7
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	8	—	ms	Figure 27.8
External clock output stabilization delay time	t_{DEXT}	500	—	500	—	500	—	µs	

Control Signal Timing: Table 27.21 shows the control signal timing. The only external interrupts that can operate on the subclock (ϕ = 32.768 kHz) are NMI and IRQ0, 1, 2, 6, and 7.

Table 27.21 Control Signal Timing

Condition A: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, V_{SS} = 0 V, ϕ = 32.768 kHz, 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V, ϕ = 32.768 kHz, 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 32.768 kHz, 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition A		Condition B		Condition C			
		10 MHz		16 MHz		20 MHz			
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
$\overline{RES}$ setup time	t_{RESS}	300	—	200	—	200	—	ns	Figure 27.9
$\overline{RES}$ pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	250	—	150	—	150	—	ns	Figure 27.10
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (NMI) (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time ($\overline{IRQ7}$ to $\overline{IRQ0}$)	t_{IRQS}	250	—	150	—	150	—	ns	
IRQ hold time ($\overline{IRQ7}$ to $\overline{IRQ0}$)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width ($\overline{IRQ7}$, $\overline{IRQ6}$, $\overline{IRQ2}$ to $\overline{IRQ0}$) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

Bus Timing: Table 27.22 shows the bus timing. Operation in external expansion mode is not guaranteed when operating on the subclock (ϕ = 32.768 kHz).

Table 27.22 Bus Timing (1) (Normal Mode)

Condition A: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition A		Condition B		Condition C			
		10 MHz		16 MHz		20 MHz			
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
Address delay time	t_{AD}	—	40	—	30	—	20	ns	Figures 27.11 to 27.15
Address setup time	t_{AS}	0.5 × t_{cyc} – 30	—	0.5 × t_{cyc} – 20	—	0.5 × t_{cyc} – 15	—	ns	
Address hold time	t_{AH}	0.5 × t_{cyc} – 20	—	0.5 × t_{cyc} – 15	—	0.5 × t_{cyc} – 10	—	ns	
$\overline{CS}$ delay time ($\overline{IOS}$)	t_{CSD}	—	40	—	30	—	20	ns	
$\overline{AS}$ delay time	t_{ASD}	—	60	—	45	—	30	ns	
$\overline{RD}$ delay time 1	t_{RSD1}	—	60	—	45	—	30	ns	
$\overline{RD}$ delay time 2	t_{RSD2}	—	60	—	45	—	30	ns	
Read data setup time	t_{RDS}	35	—	20	—	15	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns	
Read data access time 1	t_{ACC1}	—	1.0 × t_{cyc} – 60	—	1.0 × t_{cyc} – 40	—	1.0 × t_{cyc} – 30	ns	
Read data access time 2	t_{ACC2}	—	1.5 × t_{cyc} – 50	—	1.5 × t_{cyc} – 35	—	1.5 × t_{cyc} – 25	ns	

Item	Symbol	Condition A 10 MHz Min	Condition A 10 MHz Max	Condition B 16 MHz Min	Condition B 16 MHz Max	Condition C 20 MHz Min	Condition C 20 MHz Max	Unit	Test Conditions
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 60$	—	$2.0 \times t_{cyc} - 40$	—	$2.0 \times t_{cyc} - 30$	ns	Figures 27.11 to 27.15
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 50$	—	$2.5 \times t_{cyc} - 35$	—	$2.5 \times t_{cyc} - 25$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 60$	—	$3.0 \times t_{cyc} - 40$	—	$3.0 \times t_{cyc} - 30$	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 1	t_{WRD1}	—	60	—	45	—	30	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 2	t_{WRD2}	—	60	—	45	—	30	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 20$	—	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 40$	—	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 20$	—	ns	
Write data delay time	t_{WDD}	—	60	—	45	—	30	ns	
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns	
Write data hold time	t_{WDH}	20	—	15	—	10	—	ns	
$\overline{WAIT}$ setup time	t_{WTS}	60	—	45	—	30	—	ns	
$\overline{WAIT}$ hold time	t_{WTH}	10	—	5	—	5	—	ns	

Table 27.22 Bus Timing (2) (Advanced Mode)

Condition A: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, V_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Condition A		Condition B		Condition C			
		10 MHz		16 MHz		20 MHz			Test
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Conditions
Address delay time	t_{AD}	—	60	—	45	—	30	ns	Figures 27.11 to 27.15
Address setup time	t_{AS}	0.5 × t_{cyc} – 50	—	0.5 × t_{cyc} – 35	—	0.5 × t_{cyc} – 25	—	ns	
Address hold time	t_{AH}	0.5 × t_{cyc} – 20	—	0.5 × t_{cyc} – 15	—	0.5 × t_{cyc} – 10	—	ns	
$\overline{CS}$ delay time ($\overline{IOS}$)	t_{CSD}	—	60	—	45	—	30	ns	
$\overline{AS}$ delay time	t_{ASD}	—	60	—	45	—	30	ns	
$\overline{RD}$ delay time 1	t_{RSD1}	—	60	—	45	—	30	ns	
$\overline{RD}$ delay time 2	t_{RSD2}	—	60	—	45	—	30	ns	
Read data setup time	t_{RDS}	35	—	20	—	15	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns	
Read data access time 1	t_{ACC1}	—	1.0 × t_{cyc} – 80	—	1.0 × t_{cyc} – 55	—	1.0 × t_{cyc} – 40	ns	
Read data access time 2	t_{ACC2}	—	1.5 × t_{cyc} – 50	—	2.5 × t_{cyc} – 35	—	2.5 × t_{cyc} – 25	ns	
Read data access time 3	t_{ACC3}	—	2.0 × t_{cyc} – 80	—	3.0 × t_{cyc} – 55	—	3.0 × t_{cyc} – 40	ns	

Item	Symbol	Condition A 10 MHz Min	Condition A 10 MHz Max	Condition B 16 MHz Min	Condition B 16 MHz Max	Condition C 20 MHz Min	Condition C 20 MHz Max	Unit	Test Conditions
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 50$	—	$2.5 \times t_{cyc} - 35$	—	$2.5 \times t_{cyc} - 25$	ns	Figures 27.11 to 27.15
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 80$	—	$3.0 \times t_{cyc} - 55$	—	$3.0 \times t_{cyc} - 40$	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 1	t_{WRD1}	—	60	—	45	—	30	ns	
$\overline{HWR}$, $\overline{LWR}$ delay time 2	t_{WRD2}	—	60	—	45	—	30	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 20$	—	ns	
$\overline{HWR}$, $\overline{LWR}$ pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 40$	—	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 20$	—	ns	
Write data delay time	t_{WDD}	—	60	—	45	—	30	ns	
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns	
Write data hold time	t_{WDH}	20	—	15	—	10	—	ns	
$\overline{WAIT}$ setup time	t_{WTS}	60	—	45	—	30	—	ns	
$\overline{WAIT}$ hold time	t_{WTH}	10	—	5	—	5	—	ns	

Timing of On-Chip Peripheral Modules: Tables 27.23 to 27.26 show the on-chip peripheral module timing. The only on-chip peripheral modules that can operate in subclock operation (ϕ = 32.768 kHz) are the I/O ports, external interrupts (NMI and IRQ0, 1, 2, 6, and 7), the watchdog timer, and the 8-bit timer (channels 0 and 1).

Table 27.23 Timing of On-Chip Peripheral Modules (1)

Condition A: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, V_{SS} = 0 V,
ϕ = 32.768 kHz*, 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V,
ϕ = 32.768 kHz*, 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 32.768 kHz*,
2 MHz to maximum operating frequency, T_a = –20 to +75°C

				Condition A		Condition B		Condition C			
				10 MHz		16 MHz		20 MHz			
Item			Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
I/O ports	Output data delay time		t_{PWD}	—	100	—	50	—	50	ns	Figure 27.16
	Input data setup time		t_{PRS}	50	—	30	—	30	—		
	Input data hold time		t_{PRH}	50	—	30	—	30	—		
FRT	Timer output delay time		t_{FTOD}	—	100	—	50	—	50	ns	Figure 27.17
	Timer input setup time		t_{FTIS}	50	—	30	—	30	—		
	Timer clock input setup time		t_{FTCS}	50	—	30	—	30	—		Figure 27.18
	Timer clock pulse width	Single edge	t_{FTCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}	
		Both edges	t_{FTCWL}	2.5	—	2.5	—	2.5	—		
TMR	Timer output delay time		t_{TMOD}	—	100	—	50	—	50	ns	Figure 27.19
	Timer reset input setup time		t_{TMRS}	50	—	30	—	30	—		Figure 27.21
	Timer clock input setup time		t_{TMCS}	50	—	30	—	30	—		Figure 27.20

Item			Symbol	Condition A 10 MHz Min	Condition A 10 MHz Max	Condition B 16 MHz Min	Condition B 16 MHz Max	Condition C 20 MHz Min	Condition C 20 MHz Max	Unit	Test Conditions
TMR	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}	Figure 27.20
		Both edges	t_{TMCWL}	2.5	—	2.5	—	2.5	—		
PWM, PWMX	Pulse output delay time		t_{PWOD}	—	100	—	50	—	50	ns	Figure 27.22
SCI	Input clock cycle	Asynchronous	t_{Scyc}	4	—	4	—	4	—	t_{cyc}	Figure 27.23
		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 (clocked synchronous)		t_{TXD}	—	100	—	50	—	50	ns	Figure 27.24
	Receive data setup time (clocked synchronous)		t_{RXS}	100	—	50	—	50	—		
	Receive data hold time (clocked synchronous)		t_{RXH}	100	—	50	—	50	—		
A/D converter	Trigger input setup time		t_{TRGS}	50	—	30	—	30	—	ns	Figure 27.25
WDT	$\overline{\text{RESO}}$ output delay time		t_{RESD}	—	200	—	120	—	100	ns	Figure 27.26
	$\overline{\text{RESO}}$ output pulse width		t_{RESOW}	132	—	132	—	132	—	t_{cyc}	

Note: * Only peripheral modules that can be used in subclock operation

Table 27.23 Timing of On-Chip Peripheral Modules (2)

Condition A: V_{CC} = 5.0 V ±10%, $V_{CC}B$ = 5.0 V ±10%, V_{SS} = 0 V,
ϕ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, $V_{CC}B$ = 4.0 V to 5.5 V, V_{SS} = 0 V,
ϕ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, $V_{CC}B$ = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

				Condition A		Condition B		Condition C			
				10 MHz		16 MHz		20 MHz			
Item			Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
HIF read cycle	$\overline{CS}$/HA0 setup time		t_{HAR}	10	—	10	—	10	—	ns	Figure 27.27
	$\overline{CS}$/HA0 hold time		t_{HRA}	10	—	10	—	10	—		
	$\overline{IOR}$ pulse width		t_{HRPW}	220	—	120	—	120	—		
	HDB delay time		t_{HRD}	—	200	—	100	—	100		
	HDB hold time		t_{HRF}	0	40	0	25	0	25		
	HIRQ delay time		t_{HIRQ}	—	200	—	120	—	120		
HIF write cycle	$\overline{CS}$/HA0 setup time		t_{HAW}	10	—	10	—	10	—		
	$\overline{CS}$/HA0 hold time		t_{HWA}	10	—	10	—	10	—		
	$\overline{IOW}$ pulse width		t_{HWPW}	100	—	60	—	60	—		
	HDB setup time	Fast A20 gate not used	t_{HDW}	50	—	30	—	30	—		
		Fast A20 gate used		85	—	55	—	45	—		
	HDB hold time		t_{HWD}	25	—	15	—	15	—		
	GA20 delay time		t_{HGA}	—	180	—	90	—	90		

Table 27.24 Keyboard Buffer Controller Timing

Conditions: V_{CC} = 4.0 V to 5.5 V, V_{CC} = 2.7 V to 3.6 V (3-V product), V_{CC}B = 2.7 V to 5.5 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

		Ratings				Test	
Item	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**	**Notes**
KCLK, KD output fall time	t_{KBF}	20 + 0.1 Cb	—	250	ns		Figure 27.28
KCLK, KD input data hold time	t_{KBIH}	150	—	—	ns		
KCLK, KD input data setup time	t_{KBIS}	150	—	—	ns		
KCLK, KD output delay time	t_{KBOD}	—	—	450	ns		
KCLK, KD capacitive load	C_b	—	—	400	pF		

Table 27.25 I²C Bus Timing

Conditions: V_{CC} = 4.0 V to 5.5 V, V_{CC} = 2.7 V to 3.6 V (3-V product), V_{SS} = 0 V, ϕ = 5 MHz to maximum operating frequency,

		Ratings				Test	
Item	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**	**Notes**
SCL input cycle time	t_{SCL}	12	—	—	t_{cyc}		Figure 27.29
SCL input high pulse width	t_{SCLH}	3	—	—	t_{cyc}		
SCL input low pulse width	t_{SCLL}	5	—	—	t_{cyc}		
SCL, SDA input rise time	t_{Sr}	—	—	7.5*	t_{cyc}		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse elimination time	t_{SP}	—	—	1	t_{cyc}		
SDA input bus free time	t_{BUF}	5	—	—	t_{cyc}		
Start condition input hold time	t_{STAH}	3	—	—	t_{cyc}		
Retransmission start condition input setup time	t_{STAS}	3	—	—	t_{cyc}		
Stop condition input setup time	t_{STOS}	3	—	—	t_{cyc}		
Data input setup time	t_{SDAS}	0.5	—	—	t_{cyc}		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA capacitive load	C_b	—	—	400	pF		

Note: * $17.5t_{cyc}$ can be set according to the clock selected for use by the I²C module. For details, see section 16.6, Usage Notes.

Table 27.26 LPC Module Timing (For H8S/2145B Only)

Conditions: V_{CC} = 3.0 V to 3.6 V, V_{SS} = 0 V, ϕ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
LPC	Input clock cycle	t_{Lcyc}	30	—	—	ns	Figure 27.30
	Input clock pulse width (H)	t_{LCKH}	11	—	—		
	Input clock pulse width (L)	t_{LCKL}	11	—	—		
	Transmit signal delay time	t_{TXD}	2	—	11		
	Transmit signal floating delay time	t_{OFF}	—	—	28		
	Receive signal setup time	t_{RXS}	7	—	—		
	Receive signal hold time	t_{RXH}	0	—	—		

27.2.4 A/D Conversion Characteristics

Tables 27.27 and 27.28 list the A/D conversion characteristics.

Table 27.27 A/D Conversion Characteristics (AN7 to AN0 Input: 134/266-State Conversion)

Condition A: V_{CC} = 5.0 V ±10%, AV_{CC} = 5.0 V ±10%, AV_{ref} = 4.5 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, AV_{CC} = 4.0 V to 5.5 V, AV_{ref} = 4.0 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, AV_{ref} = 2.7 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C

	Condition C			Condition B			Condition A			
	10 MHz			16 MHz			20 MHz			
Item	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Resolution	10	10	10	10	10	10	10	10	10	bits
Conversion time*3	—	—	13.4	—	—	8.4	—	—	6.7	µs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	10*1 5*2	—	—	10*1 5*2	kΩ
Nonlinearity error	—	—	±7.0	—	—	±3.0	—	—	±3.0	LSB
Offset error	—	—	±7.5	—	—	±3.5	—	—	±3.5	LSB
Full-scale error	—	—	±7.5	—	—	±3.5	—	—	±3.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±4.0	—	—	±4.0	LSB

Notes: 1. When conversion time ≥ 11.17 µs (CKS = 0, or φ ≤ 12 MHz at CKS = 1)
2. When conversion time < 11.17 µs (φ > 12 MHz at CKS = 1)
3. At the maximum operating frequency in single mode.

Table 27.28 A/D Conversion Characteristics
(CIN15 to CIN0 Input: 134/266-State Conversion)

Condition A: V_{CC} = 5.0 V ±10%, AV_{CC} = 5.0 V ±10%, AV_{ref} = 4.5 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, AV_{CC} = 4.0 V to 5.5 V, AV_{ref} = 4.0 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 3.0 V to 3.6 V*4, AV_{CC} = 3.0 V to 3.6 V*4, AV_{ref} = 3.0 V to AV_{CC}*4,
$V_{CC}B$ = 3.0 V to 5.5 V*4, V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency, T_a = –20 to +75°C

	Condition C			Condition B			Condition A			
	10 MHz			16 MHz			20 MHz			
Item	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Resolution	10	10	10	10	10	10	10	10	10	bits
Conversion time*3	—	—	13.4	—	—	8.4	—	—	6.7	µs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	5	—	—	10*1 5*2	—	—	10*1 5*2	kΩ
Nonlinearity error	—	—	±11.0	—	—	±5.0	—	—	±5.0	LSB
Offset error	—	—	±11.5	—	—	±5.5	—	—	±5.5	LSB
Full-scale error	—	—	±11.5	—	—	±5.5	—	—	±5.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±12.0	—	—	±6.0	—	—	±6.0	LSB

Notes: 1. When conversion time ≥ 11.17 µs (CKS = 0, or φ ≤ 12 MHz at CKS = 1)
2. When conversion time < 11.17 µs (φ > 12 MHz at CKS = 1)
3. At the maximum operating frequency in single mode.
4. When using CIN, ensure that V_{CC} = 3.0 V to 3.6 V, AV_{CC} = 3.0 V to 3.6 V, AV_{ref} = 3.0 V to 3.6 V, $V_{CC}B$ = 3.0 V to 5.5 V.

27.2.5 D/A Conversion Characteristics

Table 27.29 lists the D/A conversion characteristics.

Table 27.29 D/A Conversion Characteristics

Condition A: V_{CC} = 5.0 V ±10%, AV_{CC} = 5.0 V ±10%, AV_{ref} = 4.5 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition B: V_{CC} = 4.0 V to 5.5 V, AV_{CC} = 4.0 V to 5.5 V, AV_{ref} = 4.0 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C (normal specification product),
T_a = –40 to +85°C (wide range temperature specification product)

Condition C: V_{CC} = 2.7 V to 3.6 V, AV_{CC} = 2.7 V to 3.6 V, AV_{ref} = 2.7 V to AV_{CC},
V_{SS} = AV_{SS} = 0 V, φ = 2 MHz to maximum operating frequency,
T_a = –20 to +75°C

		Condition C			Condition B			Condition A			
		10 MHz			16 MHz			20 MHz			
Item		**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Resolution		8	8	8	8	8	8	8	8	8	bits
Conversion time	With 20 pF load capacitance	—	—	10	—	—	10	—	—	10	µs
Absolute accuracy	With 2 MΩ load resistance	—	±2.0	±3.0	—	±1.0	±1.5	—	±1.0	±1.5	LSB
	With 4 MΩ load resistance	—	—	±2.0	—	—	±1.0	—	—	±1.0	

27.2.6 Flash Memory Characteristics

Table 27.30 shows the flash memory characteristics.

Table 27.30 Flash Memory Characteristics (Operation Range at Programming/Erasing)

5-V version conditions: V_{CC} = 4.0 V to 5.5 V, V_{SS} = 0 V, T_a = –20 to +75°C (normal specification product), T_a = –40 to +85°C (wide range temperature specification product)

3-V version conditions: V_{CC} = 3.0 V to 3.6 V, V_{SS} = 0 V, T_a = –20 to +75°C

Item		Symbol	Min	Typ	Max	Unit	Test Condition
Programming time*1 *2 *4		t_P	—	10	200	ms/ 128 bytes	
Erase time*1 *3 *6		t_E	—	100	1200	ms/block	
Reprogramming count		N_{WEC}	—	—	100	times	
Programming	Wait time after SWE-bit setting*1	x	1	—	—	µs	
	Wait time after PSU-bit setting*1	y	50	—	—	µs	
	Wait time after P-bit setting*1 *4	z1	28	30	32	µs	1 ≤ n ≤ 6
		z2	198	200	202	µs	7 ≤ n ≤ 1000
		z3	8	10	12	µs	Additional write
	Wait time after P-bit clear*1	α	5	—	—	µs	
	Wait time after PSU-bit clear*1	β	5	—	—	µs	
	Wait time after PV-bit setting*1	γ	4	—	—	µs	
	Wait time after dummy write*1	ε	2	—	—	µs	
	Wait time after PV-bit clear*1	η	2	—	—	µs	
	Wait time after SWE-bit clear*1	θ	100	—	—	µs	
	Maximum programming count*1 *4 *5	N	—	—	1000	times	
Erase	Wait time after SWE-bit setting*1	x	1	—	—	µs	
	Wait time after ESU-bit setting*1	y	100	—	—	µs	
	Wait time after E-bit setting*1 *6	z	10	—	100	ms	
	Wait time after E-bit clear*1	α	10	—	—	µs	
	Wait time after ESU-bit clear*1	β	10	—	—	µs	
	Wait time after EV-bit setting*1	γ	20	—	—	µs	
	Wait time after dummy write*1	ε	2	—	—	µs	
	Wait time after EV-bit clear*1	η	4	—	—	µs	
	Wait time after SWE-bit clear*1	θ	100	—	—	µs	
	Maximum erase count*1 *6 *7	N	—	—	120	times	

Notes: 1. Set the times according to the program/erase algorithms.
2. Programming time per 128 bytes (Shows the total period for which the P-bit in FLMCR1 is set. It does not include the programming verification time.)
3. Block erase time (Shows the total period for which the E-bit in FLMCR1 is set. It does not include the erase verification time.)
4. Maximum programming time (t_P (max))

   t_P (max) = (wait time after P-bit setting (z1) + (z3)) × 6
   + wait time after P-bit setting (z2) × ((N) – 6)
5. The maximun number of writes (N) should be set according to the actual set value of z1, z2 and z3 to allow programming within the maximum programming time (t_P (max)).

   The wait time after P-bit setting (z1, z2, and z3) should be alternated according to the number of writes (n) as follows:
   $1 \leq n \leq 6$ z1 = 30 µs, z3 = 10 µs
   $7 \leq n \leq 1000$ z2 = 200 µs
6. Maximum erase time (t_E (max))

   t_E (max) = Wait time after E-bit setting (z) × maximum erase count (N)
7. The maximum number of erases (N) should be set according to the actual set value of z to allow erasing within the maximum erase time (t_E (max)).

27.2.7 Usage Notes

1. Internal step-down products

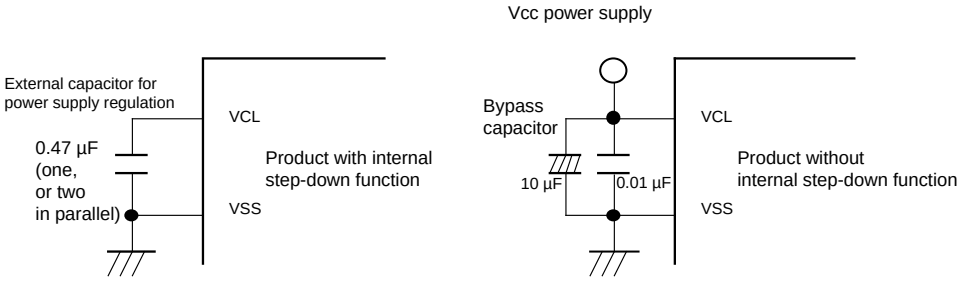
   The H8S/2148 B-masked product (HD64F2148B) includes an internal step-down circuit to step down the microprocessor internal power supply voltage to the appropriate level.

   One or two (in parallel) internal voltage regulating capacitors (0.47 µF) should be inserted between the internal step-down pin (VCL pin) and VSS pin. The method of connecting the external capacitor(s) is shown in figure 27.5.

   For the 5-V and 4-V version products whose power supply (VCC) voltage exceeds 3.6 V, do not connect the VCC power supply to the VCL pin of the internal step-down product. (Connect the VCC power supply to the VCC1 pin, as usual.)

   For the 3-V version product whose power supply (VCC) voltage is 3.6 V or less, connect the system power supply to the VCL pin together with the VCC1 pins.

   When switching from the F-ZTAT version product without the internal step-down function to the F-ZTAT B-masked product with the internal step-down function, note that the VCL pin is allocated to the same location as the VCC2 pin of the product without the internal step-down function. Therefore, the difference in the circuits between before and after the switchover should be considered when designing the PC board patterns.



The VCC power supply should not be connected to the VCL pin of the product with the internal step-down function. (Connect the VCC power supply to other VCC1 pins as usual.)
Be sure to connect power supply regulating capacitor(s) to the VCL pin. One or two (parallel) 0.47-µF multilayer capacitors should be used near the VCL pin.
For 3-V products used with the voltage of 3.6 V or less, connect the Vcc power supply in the same way as the products without the internal step-down function.

< Product with internal step-down function >
HD64F2145B
HD64F2148B

The VCC2 pin of the product without the internal step-down function is allocated at the same location as the VCL pin of the product with the internal step-down function.
It is recommended that a bypass capacitor be connected to the power supply pins. (The values are reference values.)

< Product without internal step-down function >
HD64F2145BV
HD64F2148BV

Figure 27.5 Connection of VCL Capacitor

27.3 Timing Chart

27.3.1 Clock Timing

The clock timings are shown below.

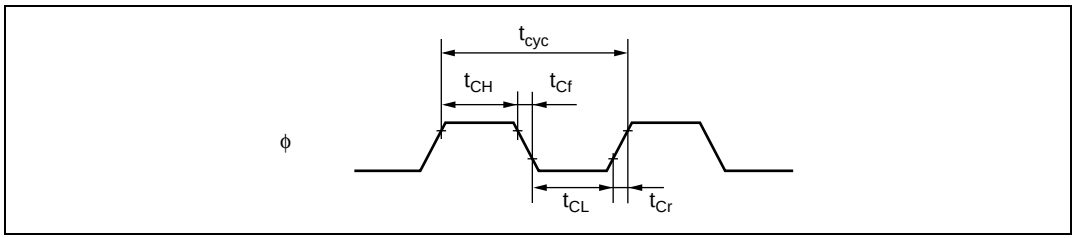


Figure 27.6 System Clock Timing

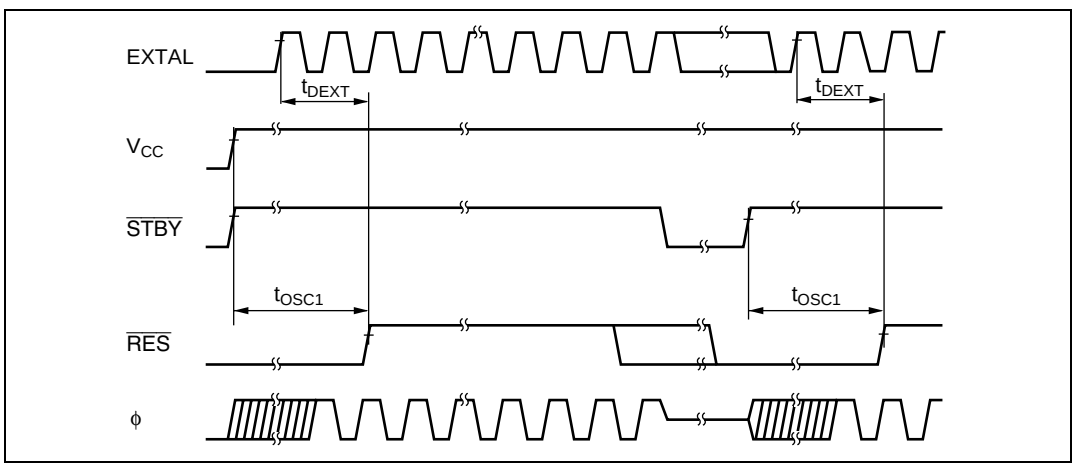


Figure 27.7 Oscillation Settling Timing

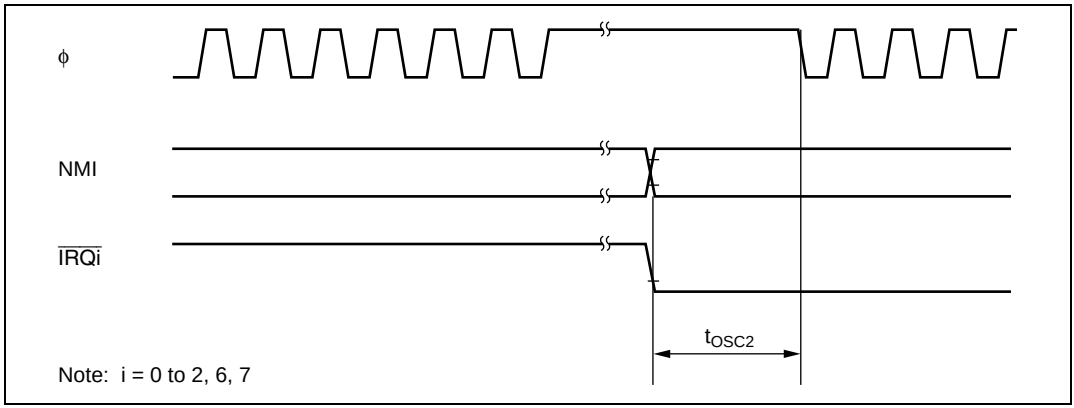


Figure 27.8 Oscillation Setting Timing (Exiting Software Standby Mode)

27.3.2 Control Signal Timing

The control signal timings are shown below.

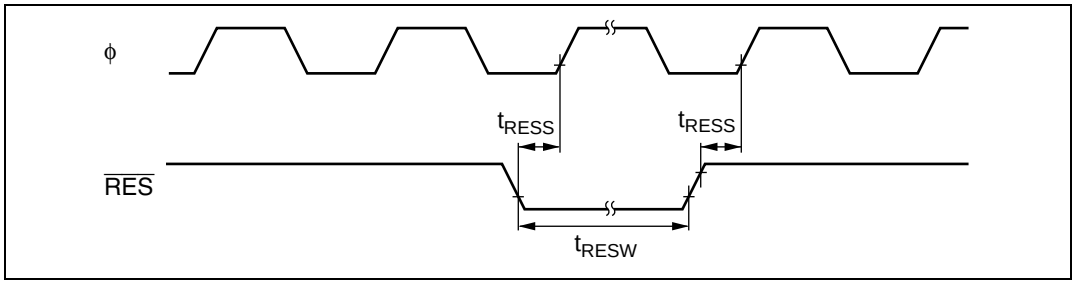


Figure 27.9 Reset Input Timing

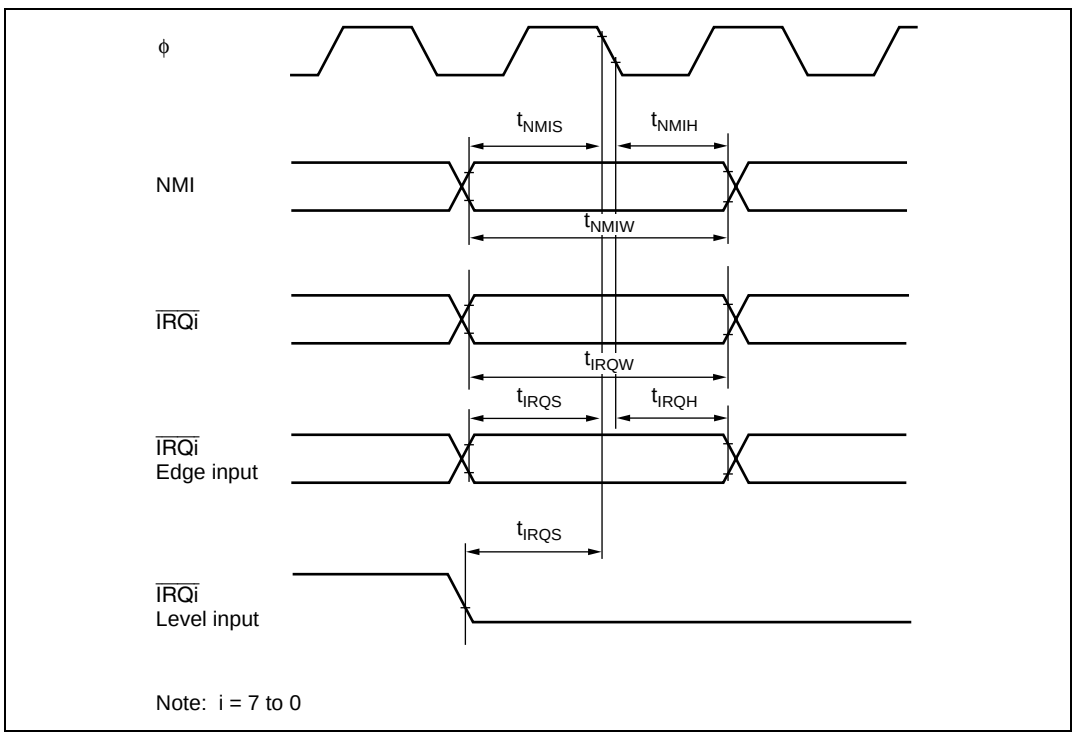
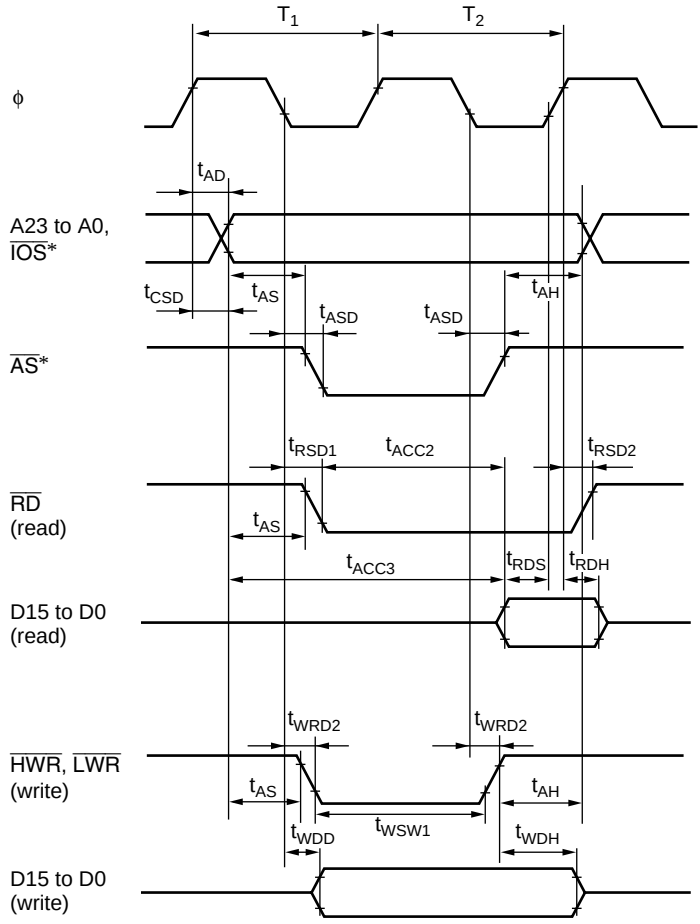


Figure 27.10 Interrupt Input Timing

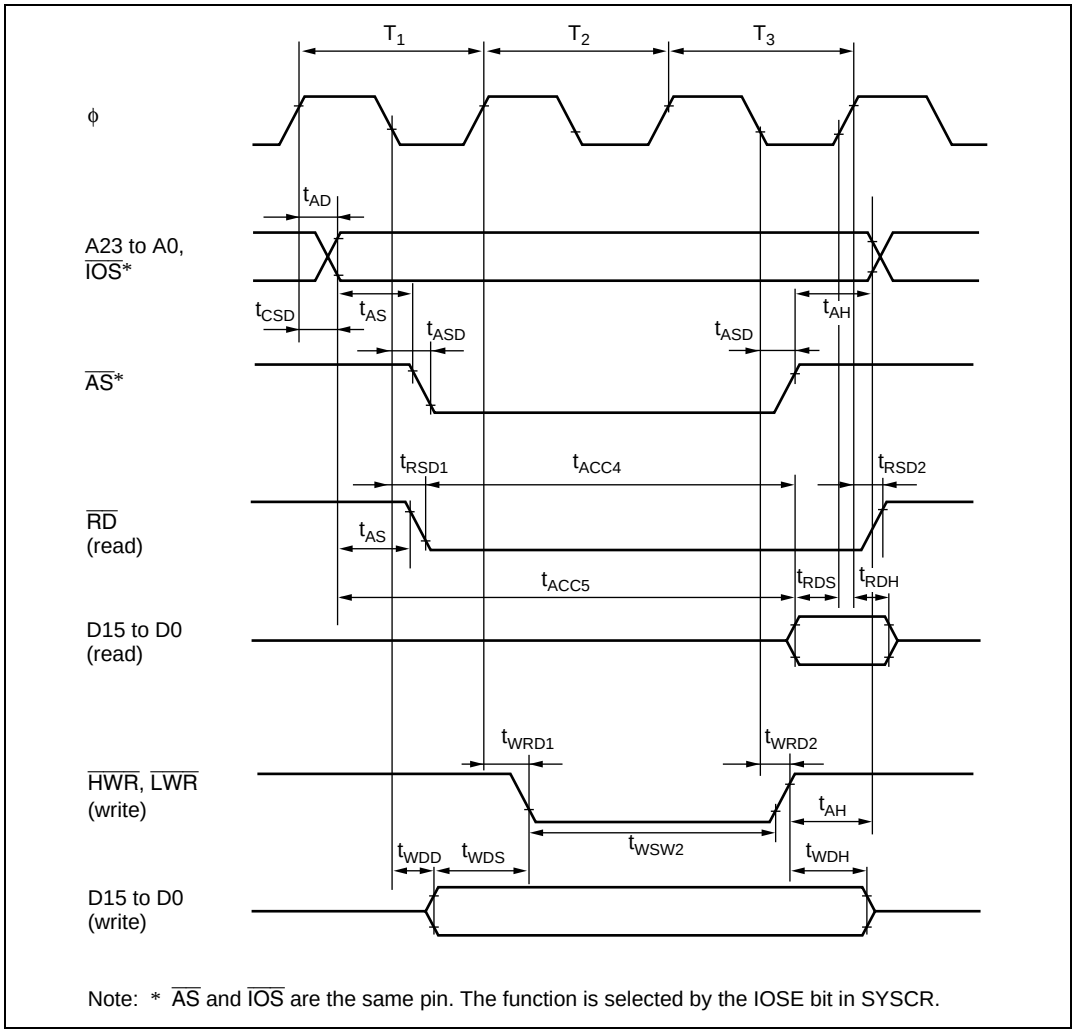
27.3.3 Bus Timing

The bus timings are shown below.



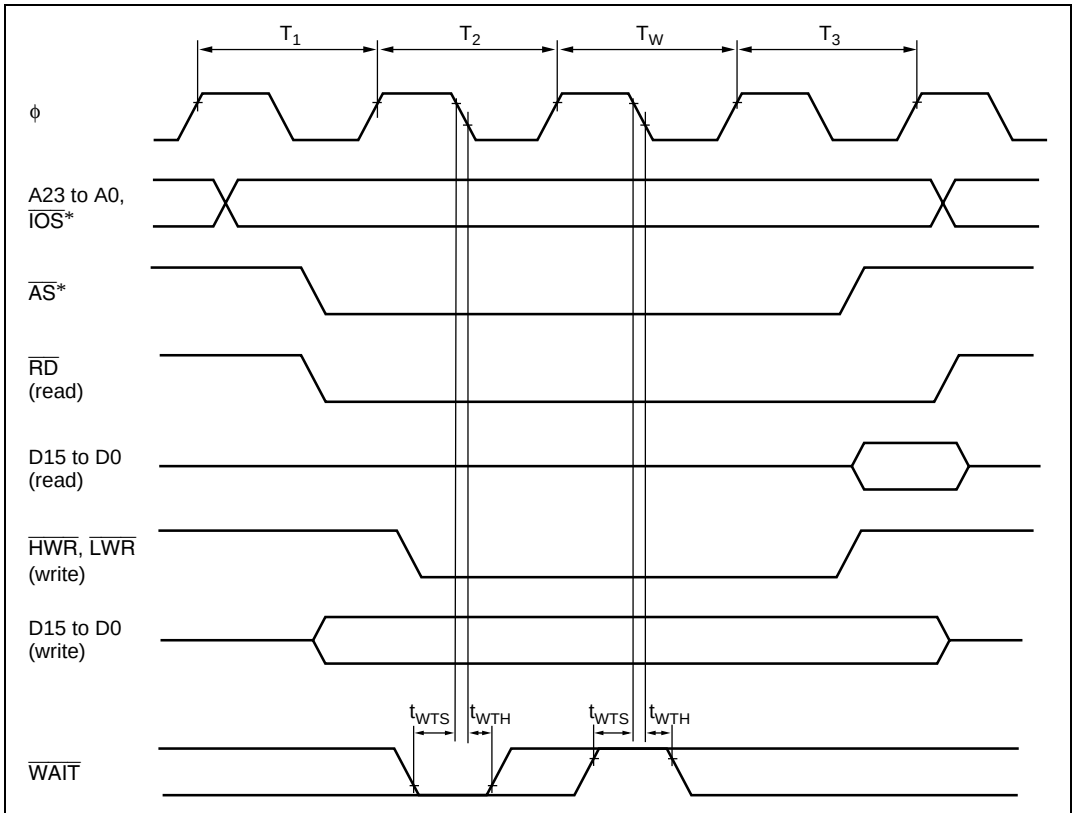
Note: * AS and IOS are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.11 Basic Bus Timing (Two-State Access)



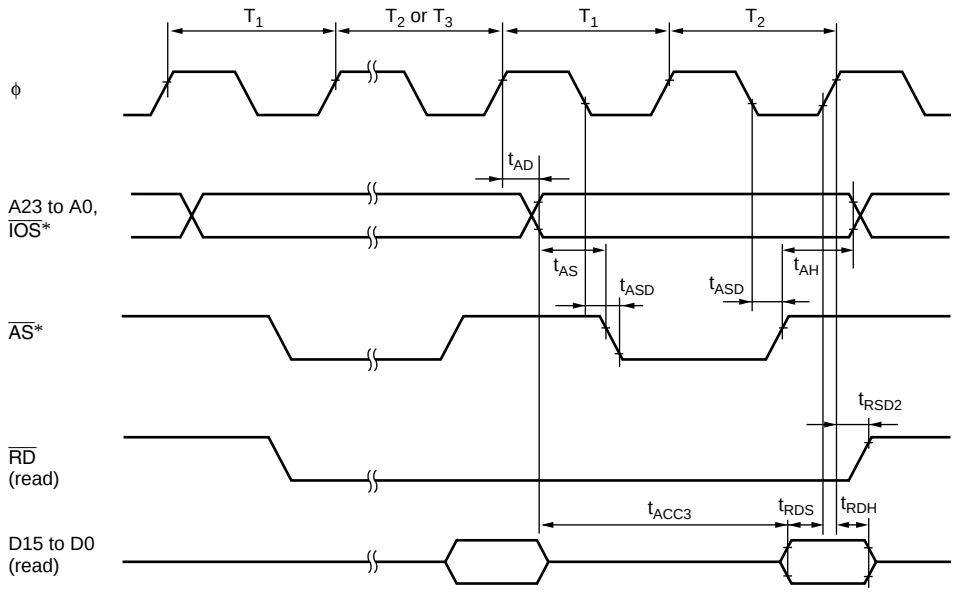
Note: * AS and IOS are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.12 Basic Bus Timing (Three-State Access)



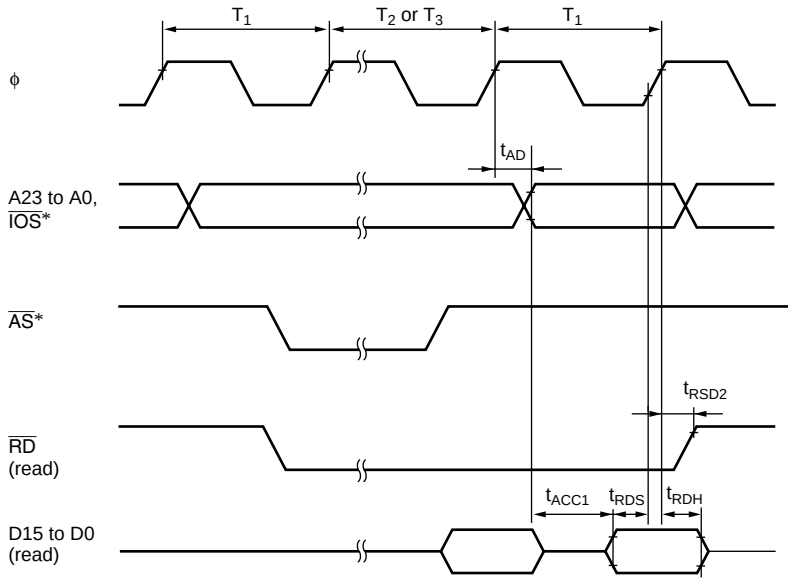
Note: * AS and IOS are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.13 Basic Bus Timing (Three-State Access with One Wait State)



Note: * AS and IOS are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.14 Burst ROM Access Timing (Two-State Access)



Note: * $\overline{AS}$ and $\overline{IOS}$ are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.15 Burst ROM Access Timing (One-State Access)

27.3.4 On-Chip Peripheral Module Timing

The on-chip peripheral module timings are shown below.

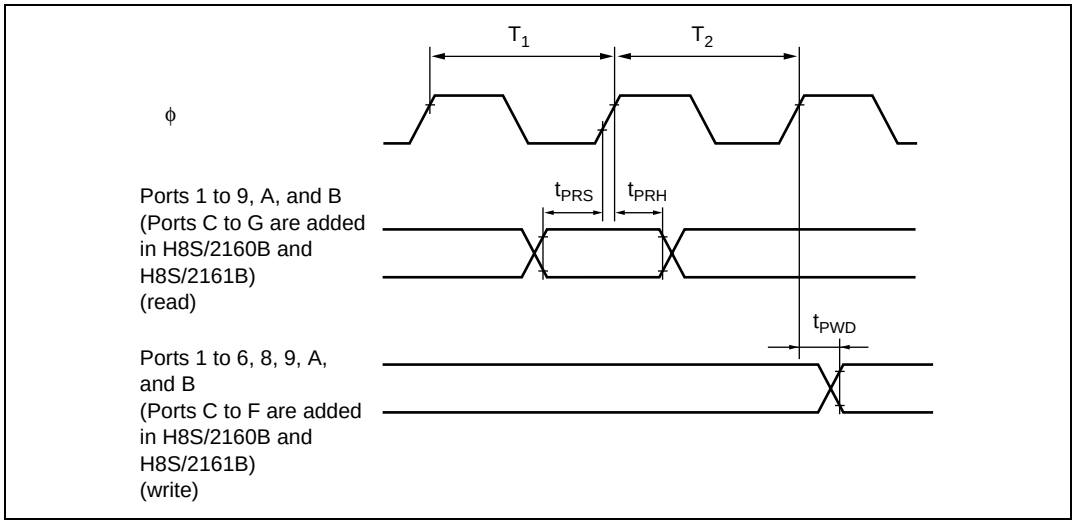


Figure 27.16 I/O Port Input/Output Timing

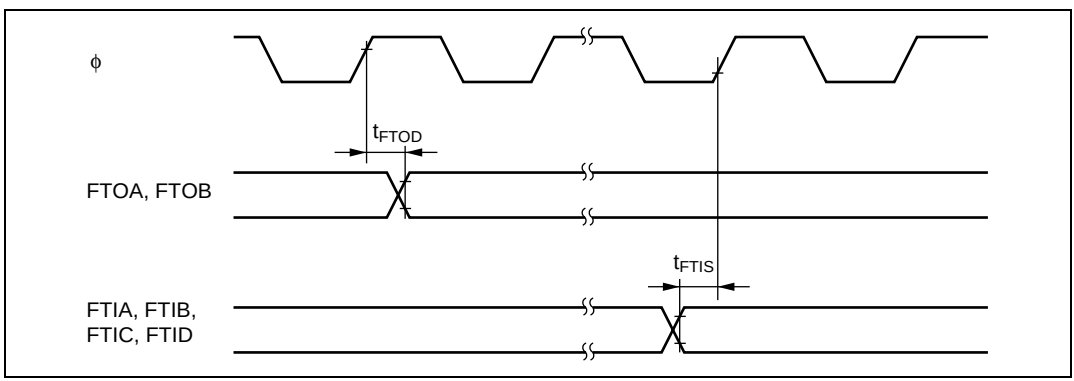


Figure 27.17 FRT Input/Output Timing

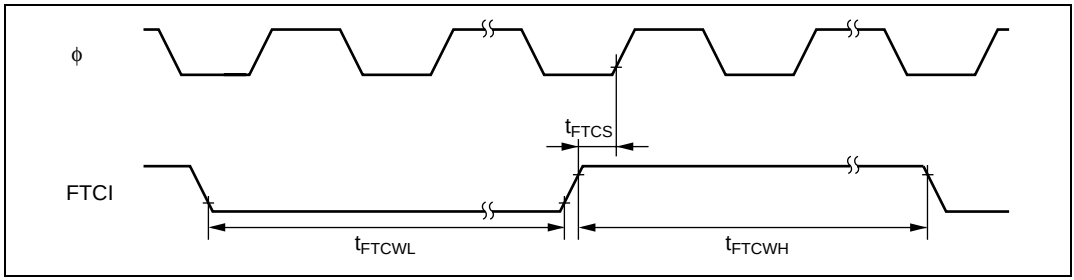


Figure 27.18 FRT Clock Input Timing

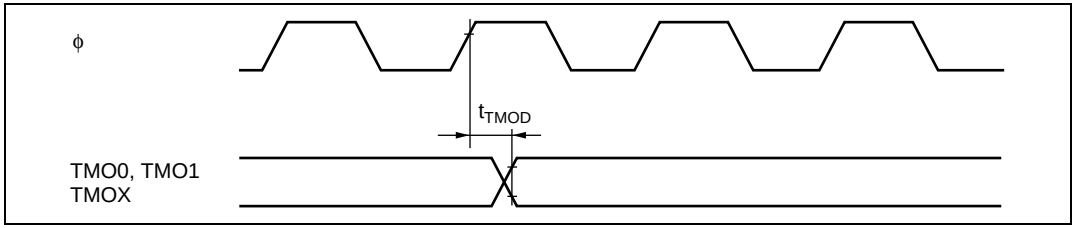


Figure 27.19 8-Bit Timer Output Timing

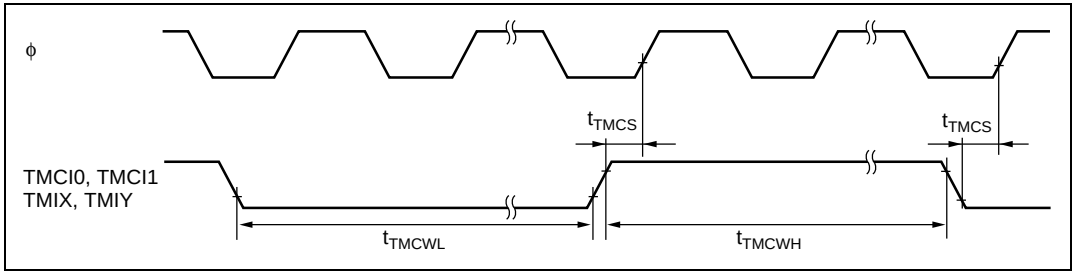


Figure 27.20 8-Bit Timer Clock Input Timing

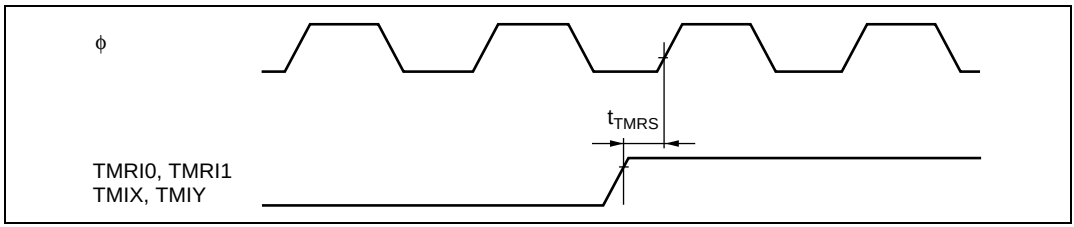


Figure 27.21 8-Bit Timer Reset Input Timing

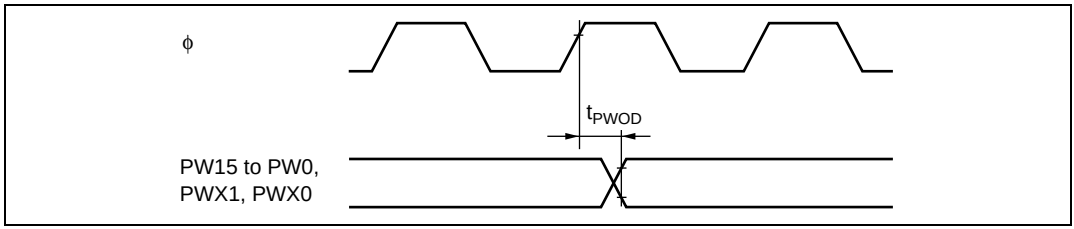


Figure 27.22 PWM, PWMX Output Timing

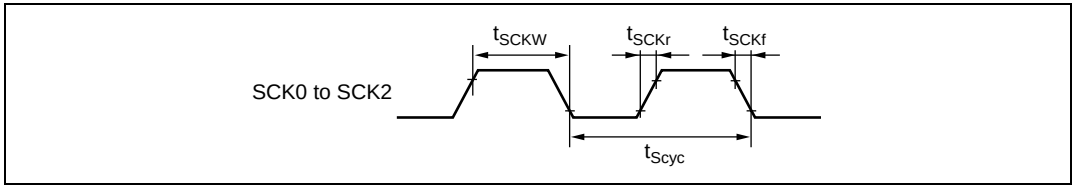


Figure 27.23 SCK Clock Input Timing

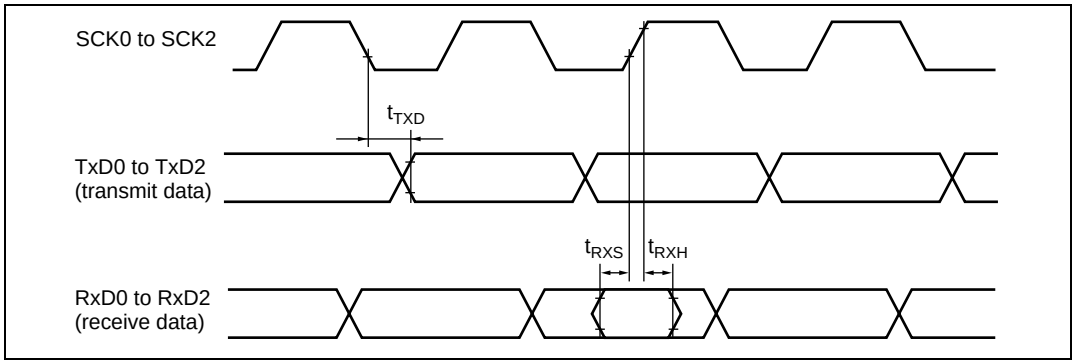


Figure 27.24 SCI Input/Output Timing (Synchronous Mode)

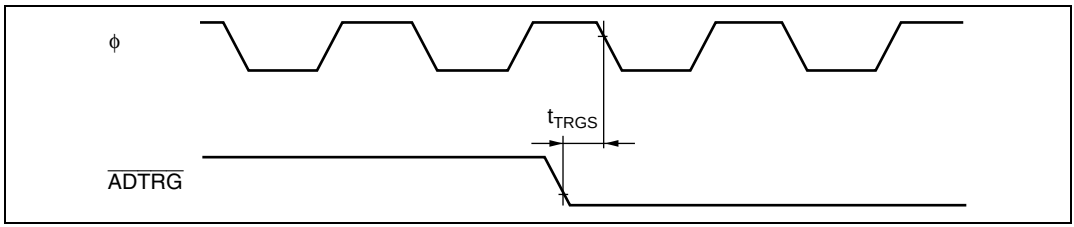


Figure 27.25 A/D Converter External Trigger Input Timing

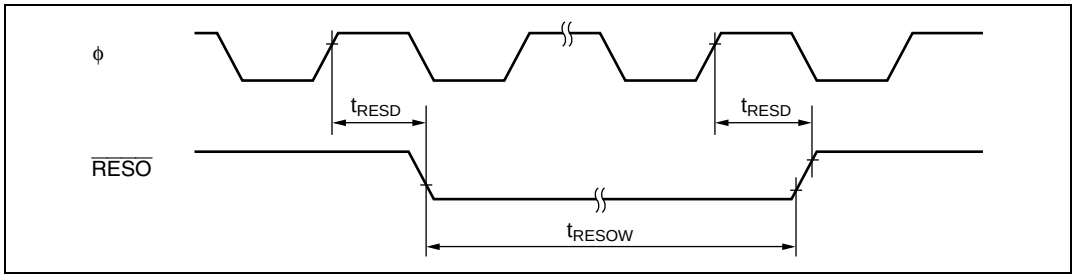
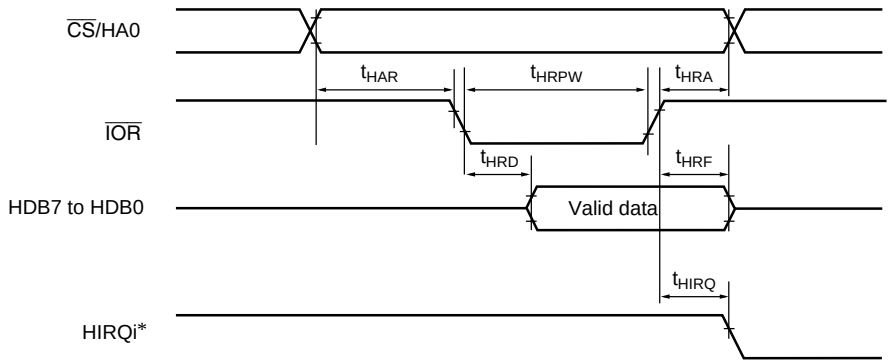


Figure 27.26 WDT Output Timing ($\overline{\text{RESO}}$)

Host interface (XBS) read timing



Notes: i = 1, 11, 12, 3, 4

* The rising edge timing is the same as the port 4 and port B output timing. See figure 28.16.

Host interface (XBS) write timing

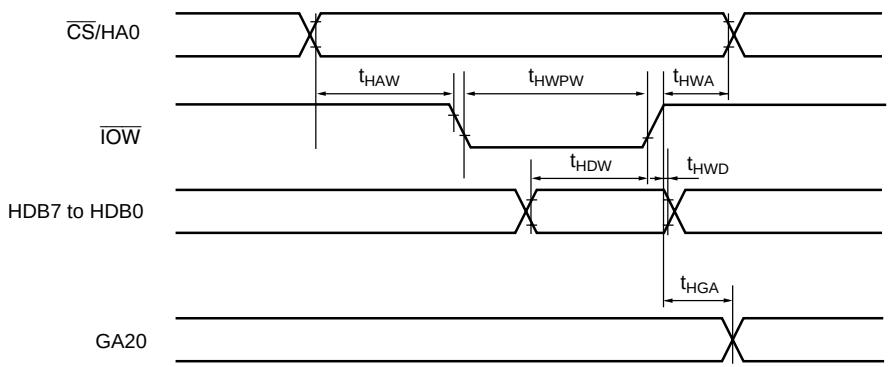
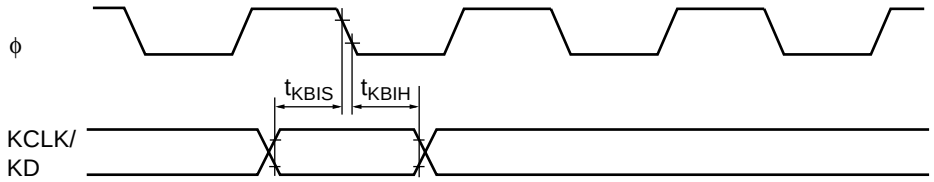
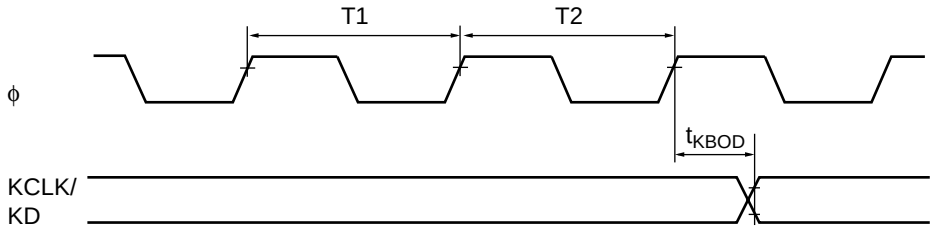


Figure 27.27 Host Interface (XBS) Timing

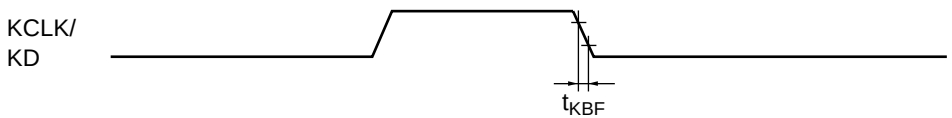
1. Reception



2. Transmission (a)



Transmission (b)



Legend:
KCLK: PS2AC to PS2CC
KD: PS2AD to PS2CD

Note: ϕ shown here is the clock scaled by 1/N when the operating mode is active medium-speed mode.

Figure 27.28 Keyboard Buffer Controller Timing

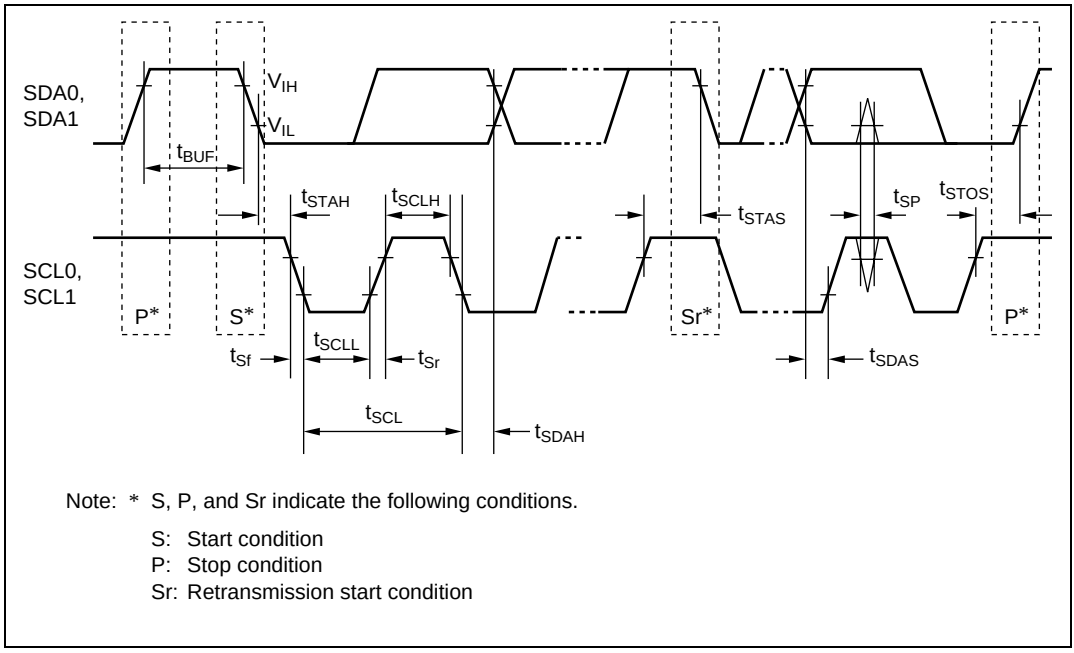


Figure 27.29 I²C Bus Interface Input/Output Timing

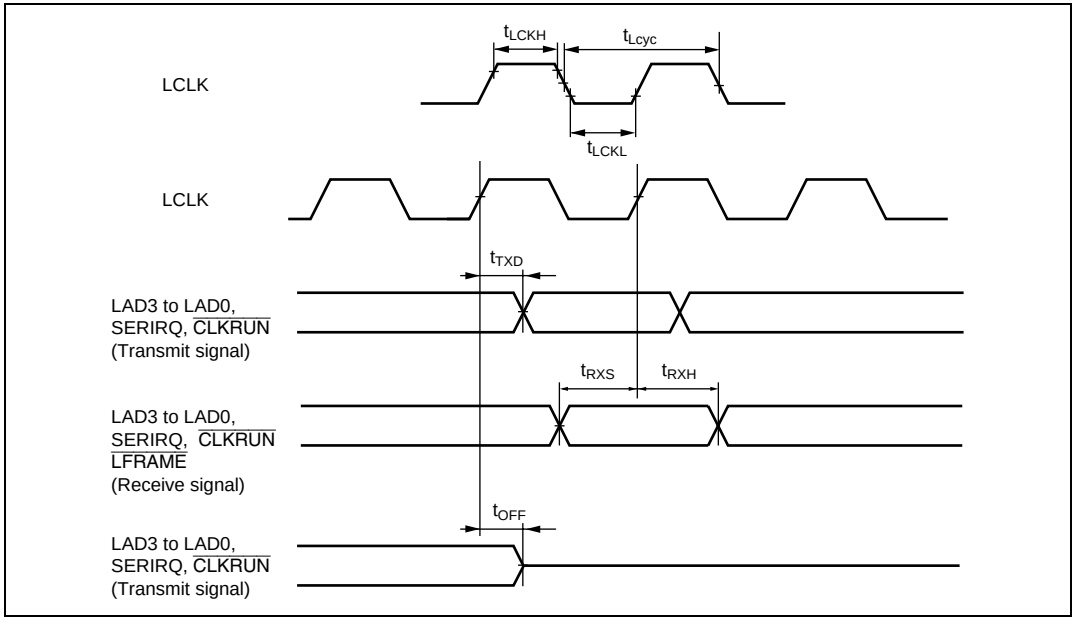


Figure 27.30 Host Interface (LPC) Timing

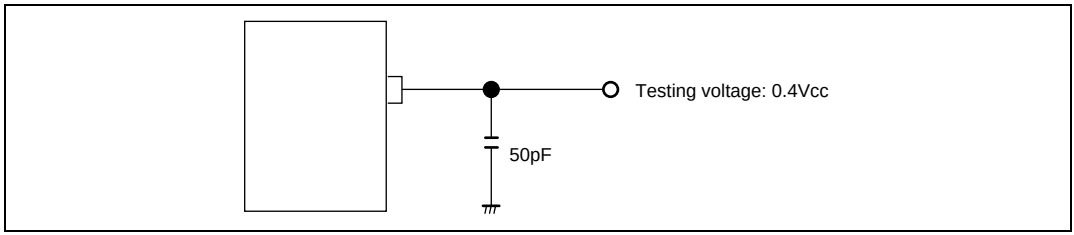


Figure 27.31 Tester Measurement Condition

Appendix A I/O Port States in Each Processing State

Table A.1 I/O Port States in Each Processing State

Port Name Pin Name	MCU Operating Mode	Reset	Hardware Standby Mode	Software Standby Mode	Watch Mode	Sleep Mode	Sub-sleep Mode	Subactive Mode	Program Execution State
Port 1 A7 to A0	1	L	T	kept*	kept*	kept*	kept*	A7 to A0	A7 to A0
	2, 3 (EXPE = 1)	T						Address output/ input port	Address output/ input port
	2, 3 (EXPE = 0)							I/O port	I/O port
Port 2 A15 to A8	1	L	T	kept*	kept*	kept*	kept*	A15 to A8	A15 to A8
	2, 3 (EXPE = 1)	T						Address output/ input port	Address output/ input port
	2, 3 (EXPE = 0)							I/O port	I/O port
Port 3 D15 to D8	1	T	T	T	T	T	T	D15 to D8	D15 to D8
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port	I/O port
Port 4	1	T	T	kept	kept	kept	kept	I/O port	I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								
Port 5	1	T	T	kept	kept	kept	kept	I/O port	I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								
Port 6	1	T	T	kept	kept	kept	kept	I/O port	I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								
Port 7	1	T	T	T	T	T	T	Input port	Input port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								
Port 8	1	T	T	kept	kept	kept	kept	I/O port	I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								
Port 97 $\overline{\text{WAIT}}$	1	T	T	T/kept	T/kept	T/kept	T/kept	$\overline{\text{WAIT}}$/ I/O port	$\overline{\text{WAIT}}$/ I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port	I/O port

Port Name Pin Name	MCU Operating Mode	Reset	Hardware Standby Mode	Software Standby Mode	Watch Mode	Sleep Mode	Sub-sleep Mode	Subactive Mode	Program Execution State
Port 96 φ EXCL	1	Clock output	T	[DDR = 1] H [DDR = 0] T	EXCL input	[DDR = 1] clock output [DDR = 0] T	EXCL input	EXCL input	Clock output/ EXCL input/ input port
	2, 3 (EXPE = 1)	T							
	2, 3 (EXPE = 0)								
Ports 95 to 93 $\overline{AS}$, $\overline{HWR}$, $\overline{RD}$	1	H	T	H	H	H	H	$\overline{AS}$, $\overline{HWR}$, $\overline{RD}$	$\overline{AS}$, $\overline{HWR}$, $\overline{RD}$
	2, 3 (EXPE = 1)	T							
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port	I/O port
Ports 92, 91	1	T	T	kept	kept	kept	kept	I/O port	I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								
Port 90 $\overline{LWR}$	1	T	T	H/kept	H/kept	H/kept	H/kept	$\overline{LWR}$/ I/O port	$\overline{LWR}$/ I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port	I/O port
Port A A23 to A16	1	T	T	kept*	kept*	kept*	kept*	I/O port	I/O port
	2, 3 (EXPE = 1)							A23 to A16/ I/O port	A23 to A16/ I/O port
	2, 3 (EXPE = 0)							I/O port	I/O port
Port B D7 to D0	1	T	T	T/kept	T/kept	T/kept	T/kept	D7 to D0/ I/O port	D7 to D0/ I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port	I/O port
Ports C to G (H8S/2160B, H8S/2161B)	1	T	T	kept	kept	kept	kept	I/O port	I/O port
	2, 3 (EXPE = 1)								
	2, 3 (EXPE = 0)								

Legend:

H: High

L: Low

T: High-impedance state

kept: Input ports are in the high-impedance state (when DDR = 0 and PCR = 1, input pull-up MOSs remain on).

Output ports maintain their previous state.

Depending on the pins, the on-chip peripheral modules may be initialized and the I/O port function determined by DDR and DR used.

DDR: Data direction register

Note: * In the case of address output, the last address accessed is retained.

Appendix B Product Codes

Product Type		Product Code	Mark Code	Package (Package Code)
H8S/2161B	Flash memory version (3-V version)	HD64F2161BV	F2161BVTE10	144-pin TQFP (TFP-144)
H8S/2160B	Flash memory version (3-V version)	HD64F2160BV	F2160BVTE10	
H8S/2141B	Flash memory version (3-V version)	HD64F2141BV	F2141BVFA10	100-pin QFP (FP-100B)
			F2141BVTE10	100-pin TQFP (TFP-100B)
H8S/2140B	Flash memory version (3-V version)	HD64F2140BV	F2140BVFA10	100-pin QFP (FP-100B)
			F2140BVTE10	100-pin TQFP (TFP-100B)
H8S/2145B	Flash memory version (3-V version)	HD64F2145BV	F2145BVFA10	100-pin QFP (FP-100B)
			F2145BVTE10	100-pin TQFP (TFP-100B)
	Flash memory version (5-V version)	HD64F2145B	F2145BFA20	100-pin QFP (FP-100B)
			F2145BTE20	100-pin TQFP (TFP-100B)
H8S/2148B	Flash memory version (3-V version)	HD64F2148BV	F2148BVFA10	100-pin QFP (FP-100B)
			F2148BVTE10	100-pin TQFP (TFP-100B)
	Flash memory version (5-V version)	HD64F2148B	F2148BFA20	100-pin QFP (FP-100B)
			F2148BTE20	100-pin TQFP (TFP-100B)

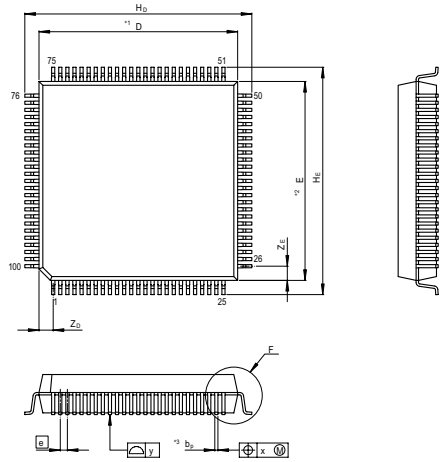
Legend:

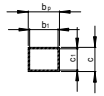
(***): ROM code

Note: * Some products above are in the developing or planning stage. Please contact Renesas agency to conform the present state of each product.

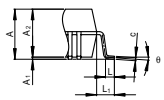
Appendix C Package Dimensions

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-QFP100-14x14-0.50	PRQP0100KA-A	FP-100B/FP-100BV	1.2g





Terminal cross section



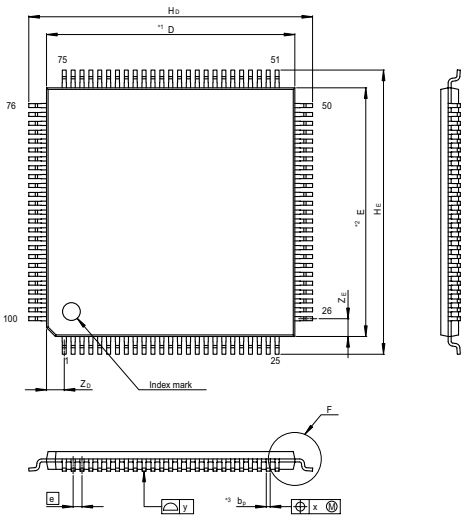
Detail F

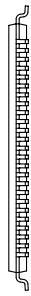
NOTE)
1. DIMENSIONS"*1"AND"*2" DO NOT INCLUDE MOLD FLASH
2. DIMENSION"*3"DOES NOT INCLUDE TRIM OFFSET.

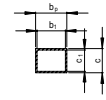
Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	—	14	—
E	—	14	—
A_2	—	2.70	—
H_D	15.7	16.0	16.3
H_E	15.7	16.0	16.3
A	—	—	3.05
A_1	0.00	0.12	0.25
b_p	0.17	0.22	0.27
b_1	—	0.20	—
c	0.12	0.17	0.22
c_1	—	0.15	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.10
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.3	0.5	0.7
L_1	—	1.0	—

Figure C.1 Package Dimensions (FP-100B)

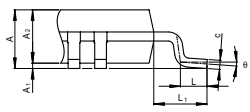
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-TQFP100-14x14-0.50	PTQP0100KA-A	TFP-100B/TFP-100BV	0.5g







Terminal cross section



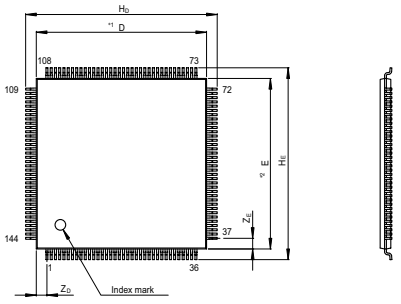
Detail F

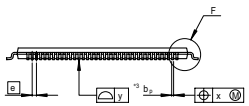
NOTE)
1. DIMENSIONS"*1"AND"*2" DO NOT INCLUDE MOLD FLASH
2. DIMENSION"*3"DOES NOT INCLUDE TRIM OFFSET.

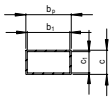
Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	—	14	—
E	—	14	—
A_2	—	1.00	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.20
A_1	0.00	0.10	0.20
b_p	0.17	0.22	0.27
b_1	—	0.20	—
c	0.12	0.17	0.22
c_1	—	0.15	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.10
Z_D	—	1.00	—
Z_E	—	1.00	—
L	0.4	0.5	0.6
L_1	—	1.0	—

Figure C.2 Package Dimensions (TFP-100B)

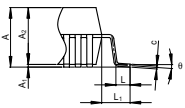
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-TQFP144-16x16-0.40	PTQP0144LC-A	TFP-144/TFP-144V	0.6g







Terminal cross section



Detail F

NOTE)
1. DIMENSIONS"*1"AND"*2" DO NOT INCLUDE MOLD FLASH
2. DIMENSION"*3"DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	—	16	—
E	—	16	—
A_2	—	1.00	—
H_D	17.8	18.0	18.2
H_E	17.8	18.0	18.2
A	—	—	1.20
A_1	0.05	0.10	0.15
b_p	0.13	0.18	0.23
b_1	—	0.16	—
c	0.12	0.17	0.22
c_1	—	0.15	—
θ	0°	—	8°
e	—	0.4	—
x	—	—	0.07
y	—	—	0.08
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.4	0.5	0.6
L_1	—	1.0	—

Figure C.3 Package Dimensions (TFP-144)

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Refer to "**http://www.renesas.com/en/network**" for the latest and detailed information.

Renesas Technology America, Inc.
450 Holger Way, San Jose, CA 95134-1368, U.S.A
Tel: <1> (408) 382-7500, Fax: <1> (408) 382-7501

Renesas Technology Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K.
Tel: <44> (1628) 585-100, Fax: <44> (1628) 585-900

Renesas Technology (Shanghai) Co., Ltd.
Unit 204, 205, AZIACenter, No.1233 Lujiazui Ring Rd, Pudong District, Shanghai, China 200120
Tel: <86> (21) 5877-1818, Fax: <86> (21) 6887-7898

Renesas Technology Hong Kong Ltd.
7th Floor, North Tower, World Finance Centre, Harbour City, 1 Canton Road, Tsimshatsui, Kowloon, Hong Kong
Tel: <852> 2265-6688, Fax: <852> 2730-6071

Renesas Technology Taiwan Co., Ltd.
10th Floor, No.99, Fushing North Road, Taipei, Taiwan
Tel: <886> (2) 2715-2888, Fax: <886> (2) 2713-2999

Renesas Technology Singapore Pte. Ltd.
1 Harbour Front Avenue, #06-10, Keppel Bay Tower, Singapore 098632
Tel: <65> 6213-0200, Fax: <65> 6278-8001

Renesas Technology Korea Co., Ltd.
Kukje Center Bldg. 18th Fl., 191, 2-ka, Hangang-ro, Yongsan-ku, Seoul 140-702, Korea
Tel: <82> (2) 796-3115, Fax: <82> (2) 796-2145

Renesas Technology Malaysia Sdn. Bhd
Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No.18, Jalan Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: <603> 7955-9390, Fax: <603> 7955-9510

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Renesas Technology Corp.
2-6-2, Ote-machi, Chiyoda-ku, Tokyo, 100-0004, Japan