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April 1st, 2010
Renesas Electronics Corporation

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User's Manual

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

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Rev.3.00 2006.03

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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
are in their open states, intermediate levels are induced by noise in the vicinity
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 throug
chip and a low level is input on the reset pin. During the period where the stat
undefined, the register settings and the output state of each pin are also undefi
your system so that it does not malfunction because of processing while it is in
undefined state. For those products which have a reset function, reset the LSI
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
may have been be allocated to these addresses. Do not access these registers; t
operation is not guaranteed if they are accessed.

The list of revisions is a summary of points that have been revised or added to earli
This does not include all of the revised contents. For details, see the actual location
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
   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. E
includes notes in relation to the descriptions given, and usage notes are given, as requir
final part of each section.

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

16 Mbytes linear address space.

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

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

A flash memory (F-ZTAT™*) version is available for this LSI's ROM. This provides
it can be reprogrammed in no time to cope with all situations from the early stages of
production to full-scale mass production. This is particularly applicable to application
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 G
design of application systems. Target users are expected to understand
fundamentals of electrical circuits, logical circuits, and microcompute

Objective: This manual was written to explain the hardware functions and electri
characteristics of the H8S/2140B Group to the target users.
Refer to the H8S/2600 Series, H8S/2000 Series Programming Manual
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 categorize
  on the CPU, system control functions, peripheral functions and electrical characte

implemented on more than one channel.
XXX_N (XXX is the register name and N is the
number)

Bit order: The MSB is on the left and the LSB is on the rig

Number notation: Binary is B'xxxx, hexadecimal is H'xxxx, decim

Signal notation: An overbar is added to a low-active signal: $\overline{xxxx}$

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H8S/2140B Group manuals:

Document Title	Docu
H8S/2140B Group Hardware Manual	This m
H8S/2600 Series, H8S/2000 Series Programming Manual	REJ09

User's manuals for development tools:

Document Title	Docu
H8S, H8/300 Series C/C++ Compiler, Assembler, Optimizing Linkage Editor User's Manual	REJ10
H8S, H8/300 Series Simulator/Debugger User's Manual	ADE-7
H8S, H8/300 Series High-performance Embedded Workshop, High-performance Debugging Interface Tutorial	ADE-7
High-performance Embedded Workshop User's Manual	ADE-7

1.1 Features	1	• Various peripheral functions Note * added Host Interface LPC interface* Note: * The LPC function is not supported by H8S/2 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 de
	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 supported by the H8S/2148B and H8S/2145B (5-V
Figure 1.2 Internal Block Diagram of H8S/2160B and H8S/2161B	4	Figure 1.2 amended (Before) ROM (Flash memory, Masked ROM) → (A (Flash memory)

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 supported by the H8S/2148B and H8S/2145B (5-V v
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 specif general register or memory operand and stores the resul 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 specifie general register or memory operand and stores the resul 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 assum

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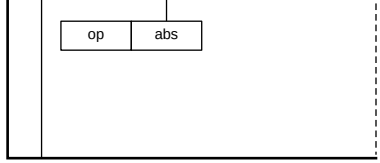
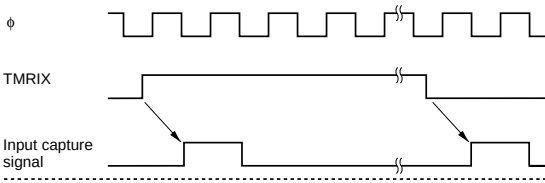
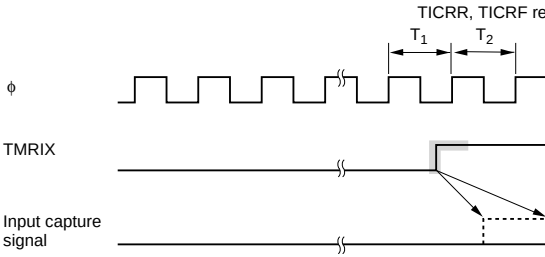
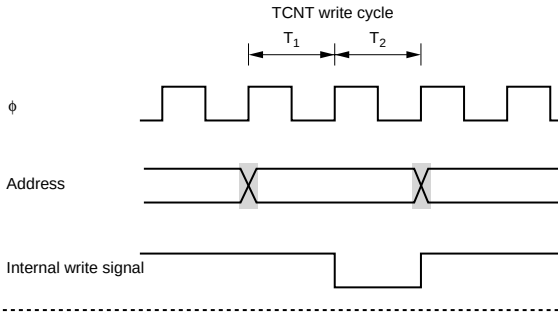


3.4 Address Map in Each Operating Mode Figure 3.7 Address Map for H8S/2145B (1) Figure 3.8 Address Map for H8S/2145B (2)	77, 78	Figure 3.7 and Figure 3.8 added
Figure 3.9 Address Map for H8S/2148B(1)	79	Figure 3.9 amended H'01FFFF H'020000 H'FFE080
4.7 Usage Note Figure 4.3 Operation when SP Value Is 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/ 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/ version).

5.6.5 DTC Activation by Interrupt	114	Description amended … the DTCE bit of DTC's DTCER, and the DISEL bit
7.2.8 DTC Vector Register (DTVECR)	151	Description amended … software activation interrupt. DTVECR is initialized to H'00 at a reset and in hardw 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/2 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/2 version).
8.4.4 Pin Functions	181	• P37/D15/HDB7/SERIRQ*, ... , P30/D8/HDB0/LAD Note amended Note: * Not supported by the H8S/2148B and H8S/2 version).

		version).
	199	• P80/HA0/$\overline{\text{PME}}$*3 Note 3 amended Note: 3. Not supported by the H8S/2148B and H8S version).
8.12.4 Pin Functions	213 to 215	• PB7/D7/$\overline{\text{WUE7}}$*2, PB6/D6/$\overline{\text{WUE6}}$*2, PB5/D5/$\overline{\text{WUE}}$ 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/2 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 

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) Serial interface mode register
16.3.5 I^2C 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 lose in a bus contention in master mode wit format. In slave receive mode with I^2C bus f R/$\overline{W}$ bit in the first frame immediately after t condition sets these bits in receive mode or automatically by hardware. Modification of the TRS bit during transfer is transfer is completed, and the changeover is completion of the transfer.

0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICD abo
0	1	1	0	0	1↑/0[*2]	—	0	0	0	0	—	1↑	Aut from with

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

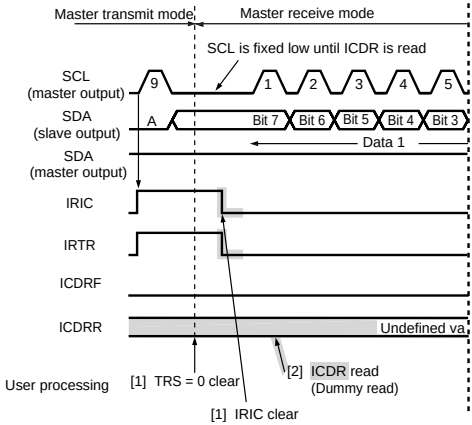


Figure 16.13 Example of Stop Condition Issuance Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)

451

Figure 16.13 amended

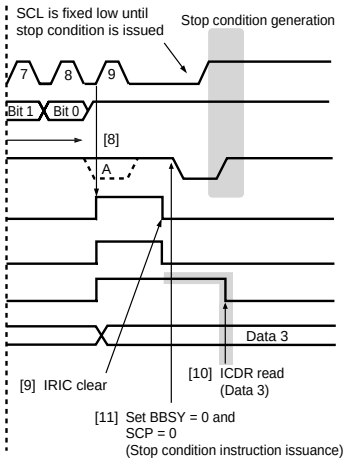
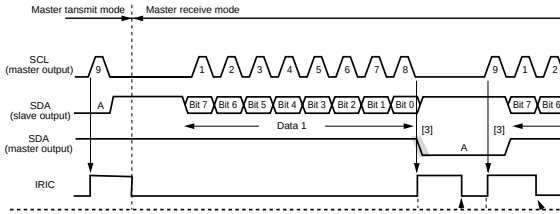


Figure 16.16 Example of Master Receive Mode Operation Timing (MLS = ACKB = 0, WAIT = 1)	456	Figure 16.16 amended 
16.4.5 Slave Receive Operation Figure 16.22 Example of Slave Receive Mode Operation Timing (1) (MLS = ACKB = 0, HNDS = 0)	464	Figure title amended
Figure 16.23 Example of Slave Receive Mode 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

19.4.4 Host Interface Shutdown Function (LPCPD) Table 19.5 Scope of Host Interface Pin Shutdown	569	Table 19.5 amended

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

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
	H8S/2160B	4 kbytes	H'E080–H'EFFF, H
	H8S/2141B	4 kbytes	H'E080–H'EFFF, H
	H8S/2140B	4 kbytes	H'E080–H'EFFF, H
	H8S/2145B	8 kbytes	H'D080–H'EFFF, H
	H8S/2148B	4 kbytes	H'E080–H'EFFF, H

Section 23 ROM	603	Description amended (Before) This LSI has an on-chip ROM (flash memo masked ROM). ··· → (After) This LSI has an on-chi memory. ···

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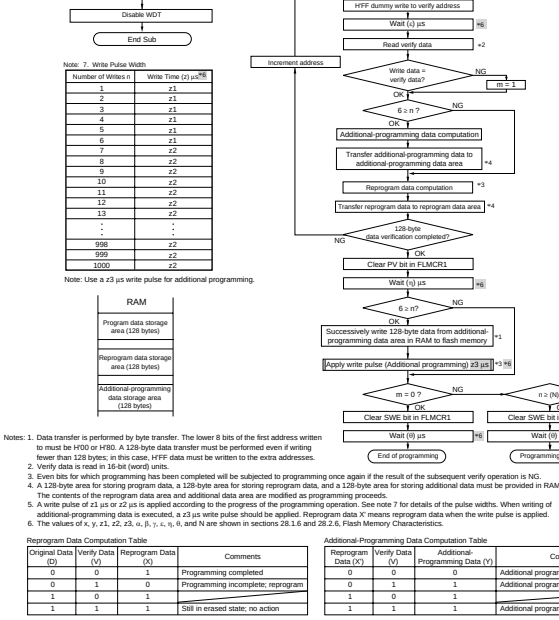

Note: 7. Write Pulse Width

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, 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 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)	Co
0	0	0	Additional program
0	1	1	Additional program
1	0	1	
1	1	1	Additional program

		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 “Subclock Usage” added
25.1.1 Standby Control Register (SBYCR)	643	Table amended … SCK2 to SCK0 must be cleared to B'000.

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Order)		version).
26.2 Register Bits	679	Note 5 amended Note: 5. Not supported by the H8S/2148B and H8S version).
26.3 Register States in Each Operating Mode	688	Note 2 amended Note: 2. Not supported by the H8S/2148B and H8S 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 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

are guaranteed after rewriting (Guarantee range is 1
minimum value).

9. Reference value for 25°C (as a guideline, rewriting
normally function up to this value).

10. Data retention characteristic when rewriting is pe
within the specification range, including the minimum

27.2.2 DC Characteristics Table 27.17 DC Characteristics (5)	736	Table 27.17 (5) amended

Item		Symbol	Min	Typ	Max	Uni
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 $\overline{IRQ3}$	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

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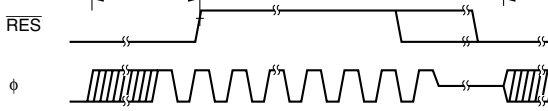

Appendix B Product Codes	779	Table amended	

Product Type		Product Code	Mark Code	Package (Packag
H8S/2145B	Flash memory version (3-V version)	HD64F2145BV	F2145BVFA10	100-pin Q
			F2145BVTE10	100-pin T
	Flash memory version (5-V version)	HD64F2145B	F2145BFA20	100-pin Q
			F2145BTE20	100-pin T

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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Section 2 CPU

Section 3 MCU Operating Modes

Section 4 Exception Handling

Section 6 Bus Controller (BSC)

Section 7 Data Transfer Controller (DTC)

RENESAS

Section 13 Timer Connection

Section 14 Watchdog Timer (WDT)

RENESAS

Section 21 A/D Converter

Section 23 ROM

Section 24 Clock Pulse Generator

Section 27 Electrical Characteristics

Section 2 CPU

Section 3 MCU Operating Modes

Section 4 Exception Handling

Section 5 Interrupt Controller

Section 7 Data Transfer Controller (DTC)

Section 8 I/O Ports

Section 9 8-Bit PWM Timer (PWM)

Section 10 14-Bit PWM Timer (PWMX)

Section 23 ROM

Section 24 Clock Pulse Generator

Section 25 Power-Down Modes

Section 27 Electrical Characteristics

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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

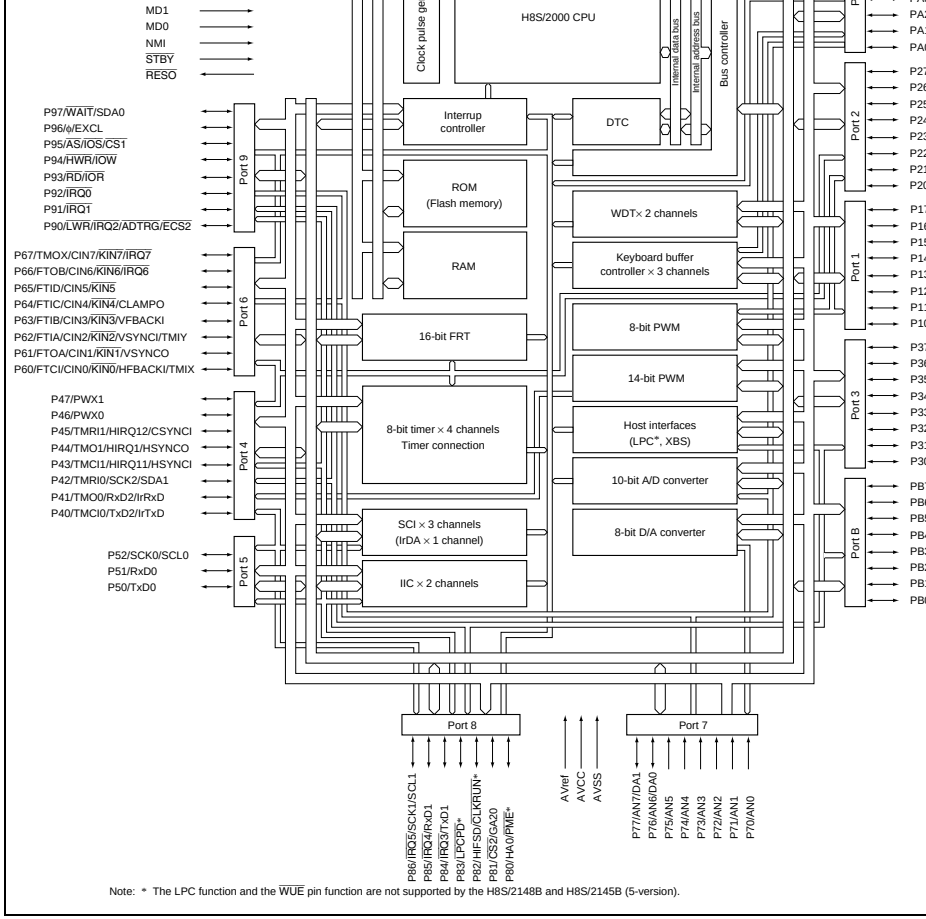
Note: * The LPC function is not supported by H8S/2148B and H8S/2145B (5-V ve

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
H8S/2161B, H8S/2160B	TQFP-144	TFP-144	16.0 × 16.0 mm	0.4
H8S/2141B, H8S/2140B	QFP-100B	FP-100B	14.0 × 14.0 mm	0.5
H8S/2145B, H8S/2148B	TQFP-100B	TFP-100B		



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

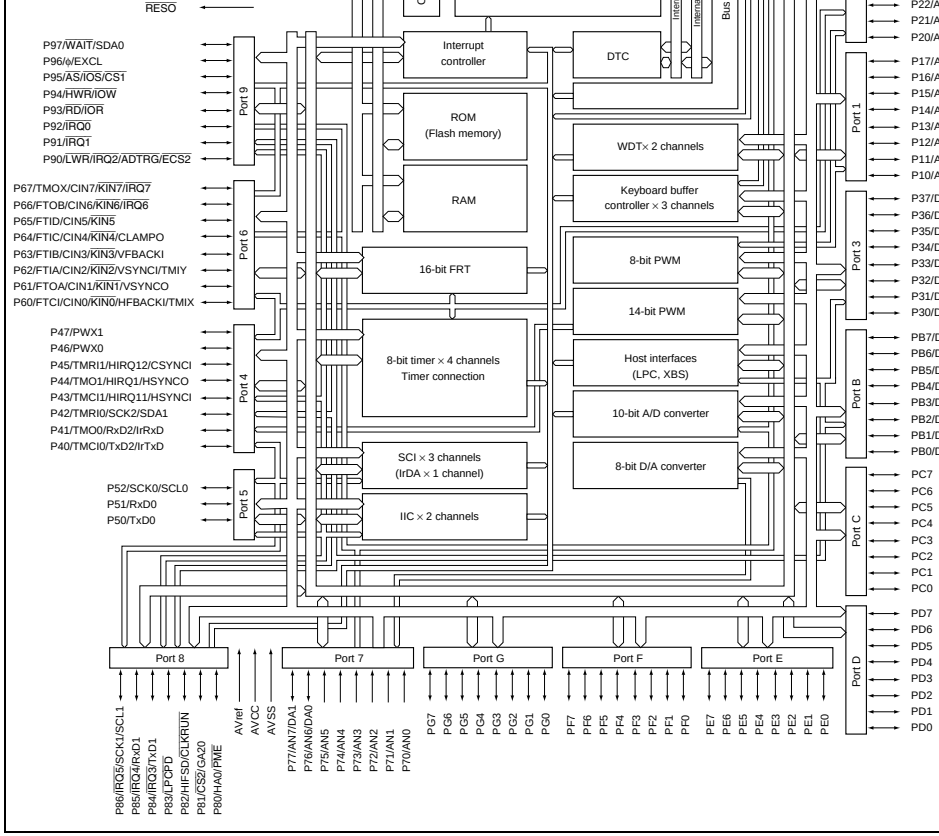
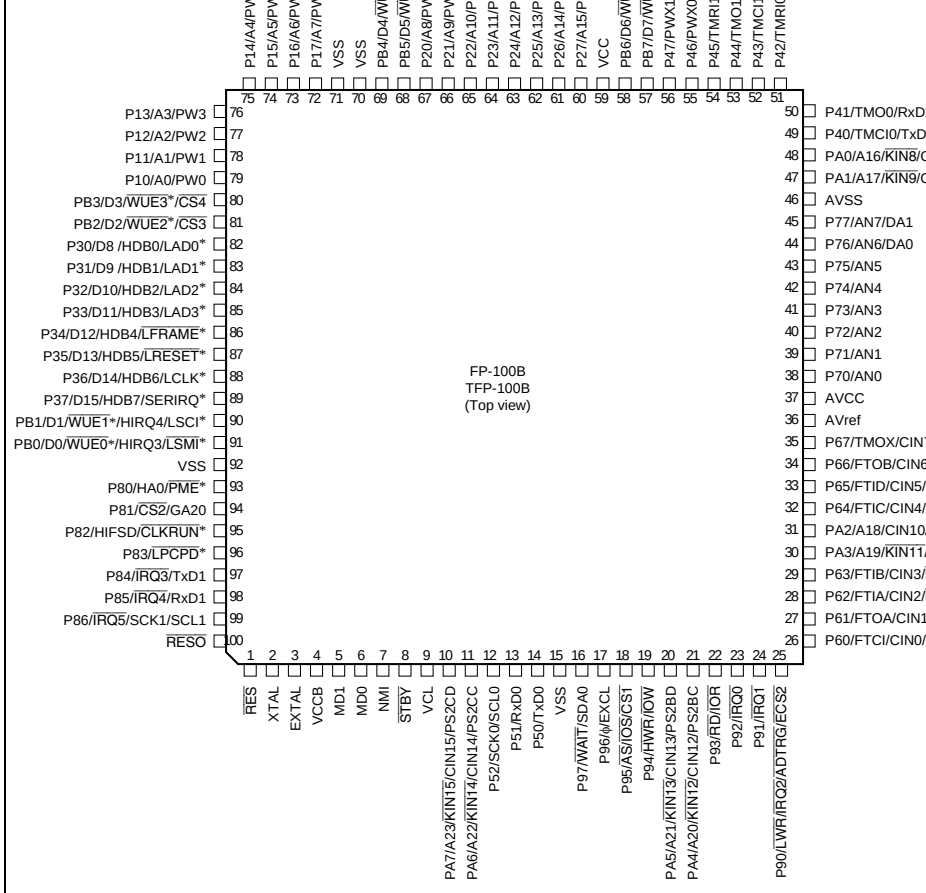


Figure 1.2 Internal Block Diagram of H8S/2160B and H8S/2161B



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 H8

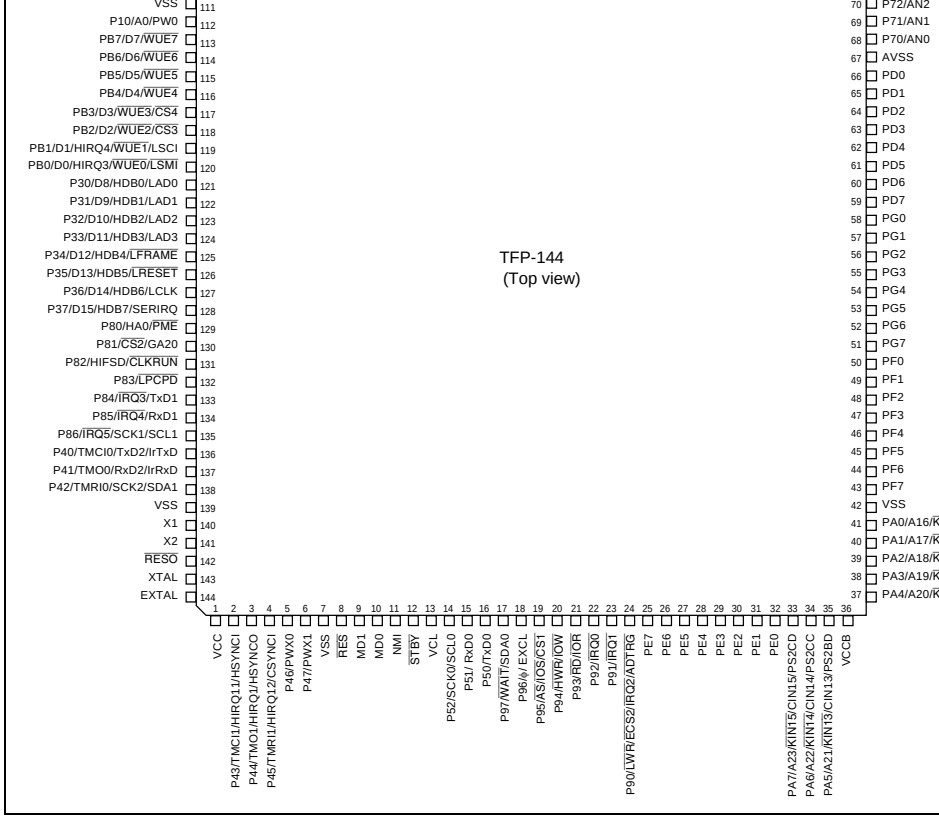


Figure 1.4 Pin Arrangement of H8S/2160B and H8S/2161B

TFP-100B	Mode 1	(EXPE = 1)	(EXPE = 0)	MO
1	$\overline{\text{RES}}$	$\overline{\text{RES}}$	$\overline{\text{RES}}$	$\overline{\text{RE}}$
2	XTAL	XTAL	XTAL	XT
3	EXTAL	EXTAL	EXTAL	EX
4	VCCB	VCCB	VCCB	VC
5	MD1	MD1	MD1	VS
6	MD0	MD0	MD0	VS
7	NMI	NMI	NMI	FA
8	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	VC
9	VCL	VCL	VCL	VC
10 (B)	PA7/CIN15/$\overline{\text{KIN15}}$/ PS2CD	PA7/A23/CIN15/ $\overline{\text{KIN15}}$/PS2CD	PA7/CIN15/$\overline{\text{KIN15}}$/ PS2CD	NC
11 (B)	PA6/CIN14/$\overline{\text{KIN14}}$/ PS2CC	PA6/A22/CIN14/ $\overline{\text{KIN14}}$/PS2CC	PA6/CIN14/$\overline{\text{KIN14}}$/ PS2CC	NC
12 (N)	P52/SCK0/SCL0	P52/SCK0/SCL0	P52/SCK0/SCL0	NC
13	P51/RxD0	P51/RxD0	P51/RxD0	FA
14	P50/TxD0	P50/TxD0	P50/TxD0	NC
15	VSS	VSS	VSS	VS
16 (N)	P97/$\overline{\text{WAIT}}$/SDA0	P97/$\overline{\text{WAIT}}$/SDA0	P97/SDA0	VC
17	P96/ϕ/EXCL	P96/ϕ/EXCL	P96/ϕ/EXCL	NC
18	$\overline{\text{AS}}$/$\overline{\text{IOS}}$	$\overline{\text{AS}}$/$\overline{\text{IOS}}$	P95/$\overline{\text{CS1}}$	FA
19	$\overline{\text{HWR}}$	$\overline{\text{HWR}}$	P94/$\overline{\text{IOW}}$	FA
20 (B)	PA5/CIN13/$\overline{\text{KIN13}}$/ PS2BD	PA5/A21/CIN13/ $\overline{\text{KIN13}}$/PS2BD	PA5/CIN13/$\overline{\text{KIN13}}$/ PS2BD	NC
21 (B)	PA4/CIN12/$\overline{\text{KIN12}}$/ PS2BC	PA4/A20/CIN12/ $\overline{\text{KIN12}}$/PS2BC	PA4/CIN12/$\overline{\text{KIN12}}$/ PS2BC	NC

25	P90/LWR/IRQ2/ ADTRG	P90/LWR/IRQ2/ ADTRG	P90/ECS2/IRQ2/ ADTRG	VC
26	P60/FTCI/CIN0/ KIN0/HFBACKI/ TMIX	P60/FTCI/CIN0/ KIN0/HFBACKI/ TMIX	P60/FTCI/CIN0/ KIN0/HFBACKI/ TMIX	NC
27	P61/FTOA/CIN1/ KIN1/VSYNCO	P61/FTOA/CIN1/ KIN1/VSYNCO	P61/FTOA/CIN1/ KIN1/VSYNCO	NC
28	P62/FTIA/CIN2/ KIN2/VSYNCI/TMIY	P62/FTIA/CIN2/ KIN2/VSYNCI/TMIY	P62/FTIA/CIN2/ KIN2/VSYNCI/TMIY	NC
29	P63/FTIB/CIN3/ KIN3/VFBACKI	P63/FTIB/CIN3/ KIN3/VFBACKI	P63/FTIB/CIN3/ KIN3/VFBACKI	NC
30 (B)	PA3/CIN11/KIN11/ PS2AD	PA3/A19/CIN11/ KIN11/PS2AD	PA3/CIN11/KIN11/ PS2AD	NC
31 (B)	PA2/CIN10/KIN10/ PS2AC	PA2/A18/CIN10/ KIN10/PS2AC	PA2/CIN10/KIN10/ PS2AC	NC
32	P64/FTIC/CIN4/ KIN4/CLAMPO	P64/FTIC/CIN4/ KIN4/CLAMPO	P64/FTIC/CIN4/ KIN4/CLAMPO	NC
33	P65/FTID/CIN5/ KIN5	P65/FTID/CIN5/ KIN5	P65/FTID/CIN5/ KIN5	NC
34	P66/FTOB/CIN6/ KIN6/IRQ6	P66/FTOB/CIN6/ KIN6/IRQ6	P66/FTOB/CIN6/ KIN6/IRQ6	NC
35	P67/TMOX/CIN7/ KIN7/IRQ7	P67/TMOX/CIN7/ KIN7/IRQ7	P67/TMOX/CIN7/ KIN7/IRQ7	VS
36	AVref	AVref	AVref	VC
37	AVCC	AVCC	AVCC	VC
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

45	P77/AN7/DA1	P77/AN7/DA1	P77/AN7/DA1	NC
46	AVSS	AVSS	AVSS	VS
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	VC
60	A15	P27/A15/PW15/ CBLANK	P27/PW15/ CBLANK	$\overline{\text{CE}}$
61	A14	P26/A14/PW14	P26/PW14	FA
62	A13	P25/A13/PW13	P25/PW13	FA
63	A12	P24/A12/PW12	P24/PW12	FA
64	A11	P23/A11/PW11	P23/PW11	FA

68	PB5/D5/WUE5	PB5/D5/WUE5	PB5/WUE5	NC
69	PB4/D4/$\overline{\text{WUE4}}$*	PB4/D4/$\overline{\text{WUE4}}$*	PB4/$\overline{\text{WUE4}}$*	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/$\overline{\text{WUE3}}$*	PB3/D3/$\overline{\text{WUE3}}$*	PB3/$\overline{\text{WUE3}}$*/$\overline{\text{CS4}}$	NC
81	PB2/D2/$\overline{\text{WUE2}}$*	PB2/D2/$\overline{\text{WUE2}}$*	PB2/$\overline{\text{WUE2}}$*/$\overline{\text{CS3}}$	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/ $\overline{\text{LFRAME}}$*	FO4
87	D13	D13	P35/HDB5/ $\overline{\text{LRESET}}$*	FO5
88	D14	D14	P36/HDB6/LCLK*	FO6
89	D15	D15	P37/HDB7/SERIRQ*	FO7
90	PB1/D1/$\overline{\text{WUE1}}$*	PB1/D1/$\overline{\text{WUE1}}$*	PB1/HIRQ4/$\overline{\text{WUE1}}$*/ LSCI*	NC

94	P81	P81	P81/$\overline{CS2}$/GA20	NC
95	P82	P82	P82/HIFSD/ $\overline{CLKRUN}$*	NC
96	P83	P83	P83/$\overline{LPCPD}$*	NC
97	P84/$\overline{IRQ3}$/TxD1	P84/$\overline{IRQ3}$/TxD1	P84/$\overline{IRQ3}$/TxD1	NC
98	P85/$\overline{IRQ4}$/RxD1	P85/$\overline{IRQ4}$/RxD1	P85/$\overline{IRQ4}$/RxD1	NC
99 (N)	P86/$\overline{IRQ5}$/SCK1/ SCL1	P86/$\overline{IRQ5}$/SCK1/ SCL1	P86/$\overline{IRQ5}$/SCK1/ SCL1	NC
100	$\overline{RESO}$	$\overline{RESO}$	$\overline{RESO}$	NC

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

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

	HSYNCI	HSYNCI	HSYNCI	
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	FA1
15	P51/RxD0	P51/RxD0	P51/RxD0	FA1
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/$\overline{\text{CS1}}$	FA1
20	$\overline{\text{HWR}}$	$\overline{\text{HWR}}$	P94/$\overline{\text{IOW}}$	FA1
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

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	VC
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	VS
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

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

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/ $\overline{\text{KIN7}}$/$\overline{\text{IRQ7}}$	VS
86	VCC	VCC	VCC	VC
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	VS
96	A15	P27/A15/PW15/ CBLANK	P27/PW15/ CBLANK	$\overline{\text{CE}}$
97	A14	P26/A14/PW14	P26/PW14	FA

101	A10	P22/A10/PW10	P22/PW10	FA1
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

128	D15	D15	P37/HDB7/SERIRQ	FC
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	VS
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	XT
144	EXTAL	EXTAL	EXTAL	EX

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

	VCL	9	13	Input	Power supply pin. Connect t VCC.
	VCCB	4	36	Input	The power supply for the por input/output buffer.
	VSS	15, 70, 71, 92	7, 42, 95, 111, 139	Input	Ground pin. Connect to the s power supply (0 V).
Clock	XTAL	2	143	Input	Pins for connection to crysta resonators. The EXTAL pin c input an external clock. See section 25, Clock Pulse for typical connection diagra
	EXTAL	3	144	Input	
	ϕ	17	18	Output	Supplies the system clock to devices.
	EXCL	17	18	Input	Input a 32.768 kHz external s
	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 These pins should not be cha while the MCU is operating.
System control	$\overline{\text{RES}}$	1	8	Input	Reset pin. When this pin becomes low, reset.
	$\overline{\text{RESO}}$	100	142	Output	Outputs reset signal to exter
	$\overline{\text{STBY}}$	8	12	Input	When this pin is driven low, a is made to hardware standby

		72 to 79	110, 112		
Data bus	D15 to D8	89 to 82	128 to 121	Input/ output	Bidirectional data bus for up 16-bit data.
	D7 to D0	57, 58, 68, 69, 80, 81, 90, 91	113 to 120	Input/ output	Bidirectional data bus for lo 16-bit data.
Bus control	$\overline{\text{WAIT}}$	16	17	Input	Requests insertion of a wait bus cycle when accessing e state address space.
	$\overline{\text{RD}}$	22	21	Output	When this pin is low, it indic external address space is b
	$\overline{\text{HWR}}$	19	20	Output	When this pin is low, it indic external address space is b to. The upper half of the dat valid.
	$\overline{\text{LWR}}$	25	24	Output	When this pin is low, it indic external address space is b to. The lower half of the dat valid.
	$\overline{\text{AS}}$/$\overline{\text{IOS}}$	18	19	Output	When this pin is low, it indic address output on the addre valid.
Interrupt signals	NMI	7	11	Input	Input pin for a nonmaskable 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 maska interrupt.

	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 fo compare function.
	TMCI0 TMCI1	49 52	136 2	Input	Input pins for the external clo 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 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 pu
SCI with IrDA (SCI_2)	IrTxD	49	136	Output	Input and output pins for data for IrDA use.
	IrRxD	50	137	Input	

	PS2CD	10	33		
Host interface (XBS)	HDB7 to HDB0	89 to 82	128 to 121	Input/ Output	Bidirectional 8-bit bus for ac 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 to 4. The $\overline{CS2}$ or $\overline{ECS2}$ inpu selected with the system co register.
	$\overline{IOR}$	22	21	Input	Input pin that enables readi XBS.
	$\overline{IOW}$	19	20	Input	Input pin that enables writin
	HA0	93	129	Input	Input pin that indicates whe access is a data access or c access.
	GA20	94	130	Output	A20 gate control signal outp
	HIRQ11 HIRQ1 HIRQ12 HIRQ3 HIRQ4	52 53 54 91 90	2 3 4 120 119	Output	Output pins for interrupt req host.
	HIFSD	95	131	Input	Control input pin used to pla input/output pins in the high cutoff state.
Host interface (LPC)	LAD3 to LAD0	85 to 82	124 to 121	Input/ Output	LPC command, address, ar input/output pins.
	$\overline{LFRAME}$	86	125	Input	Input pin that indicates the s LPC cycle or forced termina abnormal LPC cycle.
	$\overline{LRESET}$	87	126	Input	Input pin that indicates an L
	LCLK	88	127	Input	The LPC clock input pin.

	GA20	94	130	Input/ Output	A20 gate control signal outpu Output state monitoring input possible.
	$\overline{\text{CLKRUN}}$	95	131	Input/ Output	Input/output pin that requests of LCLK operation when LCL stopped.
	$\overline{\text{LPCPD}}$	96	132	Input	Input pin that controls LPC m 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. $\overline{\text{K}}$ $\overline{\text{KIN15}}$ are used as key-scan P10 to P17 and P20 to P27 a key-scan outputs. This allows maximum 16-output × 16-inp 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. Th allow the same kind of wakeu 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, bu they are also used as digital input/output pins, accuracy w
	$\overline{\text{ADTRG}}$	25	24	Input	Pin for input of an external tri start A/D conversion.
D/A converter	DA0 DA1	44 45	74 75	Output	Analog output pins.

	AVref	36	77	Input	The reference power supply A/D converter and D/A conv When the A/D and D/A conv not used, this pin should be to the system power supply
	AVSS	46	67	Input	The ground pin for the A/D and D/A converter. This pin connected to the system po (0 V).
Timer connection	VSYNCI HSYNCI CSYNCI VFBACKI HFBACKI	28 52 54 29 26	80 2 4 81 78	Input	Timer connection synchron input pins.
	VSYNCO HSYNCO CLAMPO CBLANK	27 53 32 60	79 3 82 96	Output	Timer connection synchron output pins.
I^2C bus interface (IIC)	SCL0 SCL1	12 99	14 135	Input/ Output	I^2C clock I/O pins. The outp NMOS open-drain output.
	SDA0 SDA1	16 51	17 138	Input/ Output	I^2C data I/O pins. The outpu 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 N pull.)

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 NM 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 NM 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 P H8S/2160B and the H8S/216 NMOS push-pull.)

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
- 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)

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 belo

- 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
  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, po
modes, etc., depending on the model.

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 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 enhanceme

- 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.

The exception vector table and stack have the same structure as in the H8/300 CPU in n
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
  segments of 32-bit registers.

  When extended register En is used as a 16-bit register it can contain any value, even
  corresponding general register (Rn) is used as an address register. (If general registe
  referenced in the register indirect addressing mode with pre-decrement (@–Rn) or p
  increment (@Rn+) and a carry or borrow occurs, the value in the corresponding ext
  register (En) will be affected.)

- Instruction set

  All instructions and addressing modes can be used. Only the lower 16 bits of effecti
  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 t
  branch address is stored per 16 bits. The exception vector table in normal mode is sh
  figure 2.1. For details on the exception vector table, see section 4, Exception Handli

  The memory indirect addressing mode (@@aa:8) employed in the JMP and JSR ins
  uses an 8-bit absolute address included in the instruction code to specify a memory
  that contains a branch address. In normal mode, the operand is a 16-bit (word) opera
  providing a 16-bit branch address. Branch addresses can be stored in the top area fr
  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 subro
  in normal mode, and the PC and condition-code register (CCR) are pushed onto the
  exception handling, they are stored as shown in figure 2.2. The extended control reg
  (EXR) is not pushed onto the stack. For details, see section 4, Exception Handling.

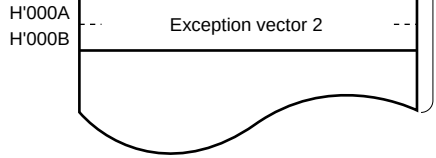


Figure 2.1 Exception Vector Table (Normal Mode)

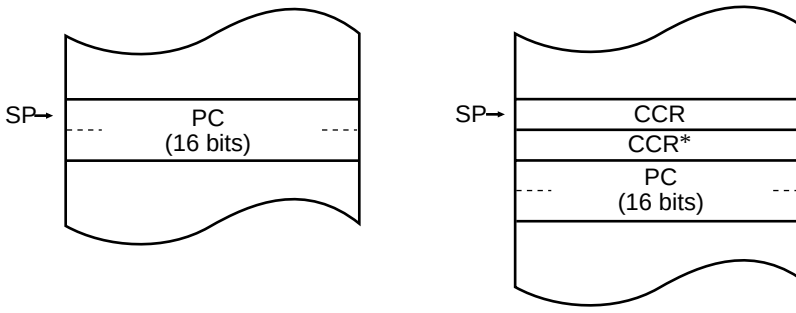


Figure 2.2 Stack Structure in Normal Mode

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 upper 16-bit segments of 32-bit registers or address registers.

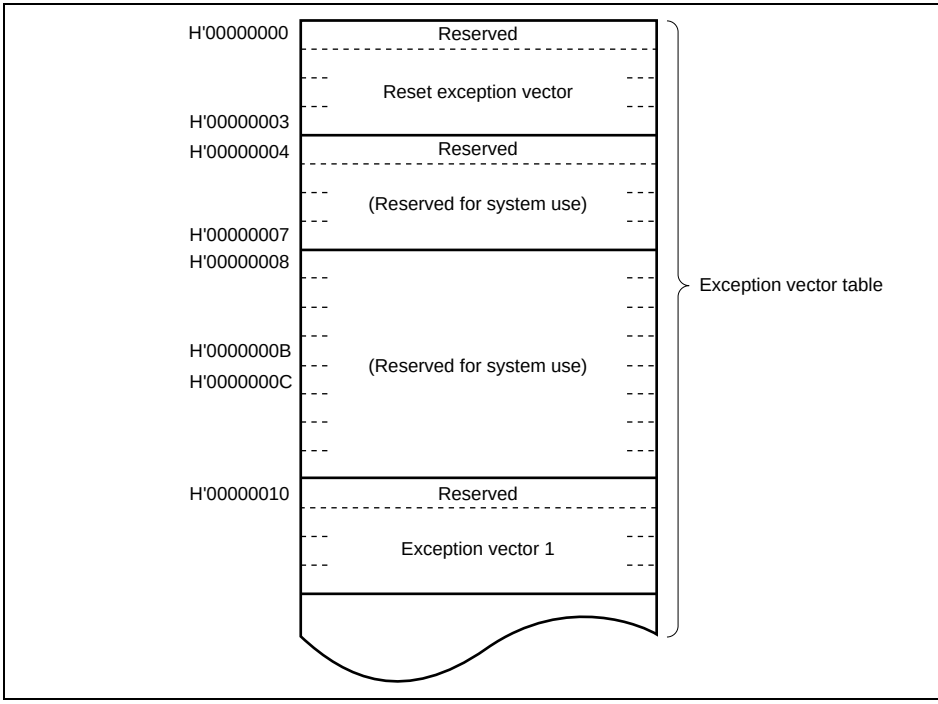


Figure 2.3 Exception Vector Table (Advanced Mode)

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

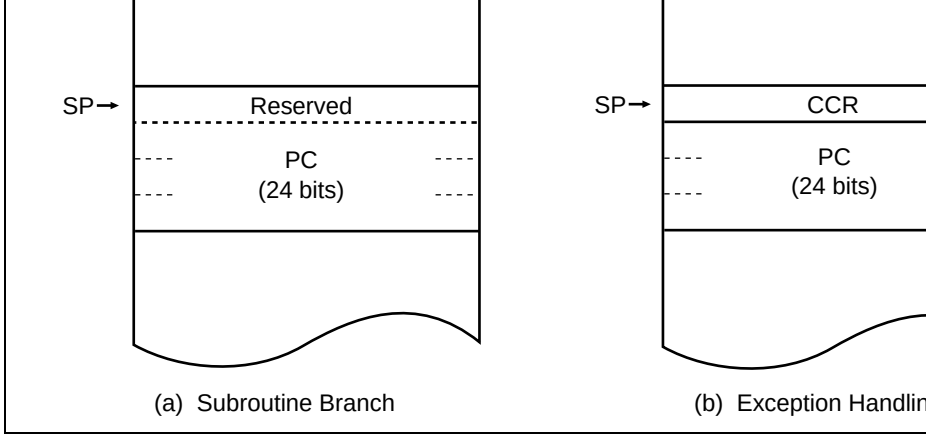


Figure 2.4 Stack Structure in Advanced Mode

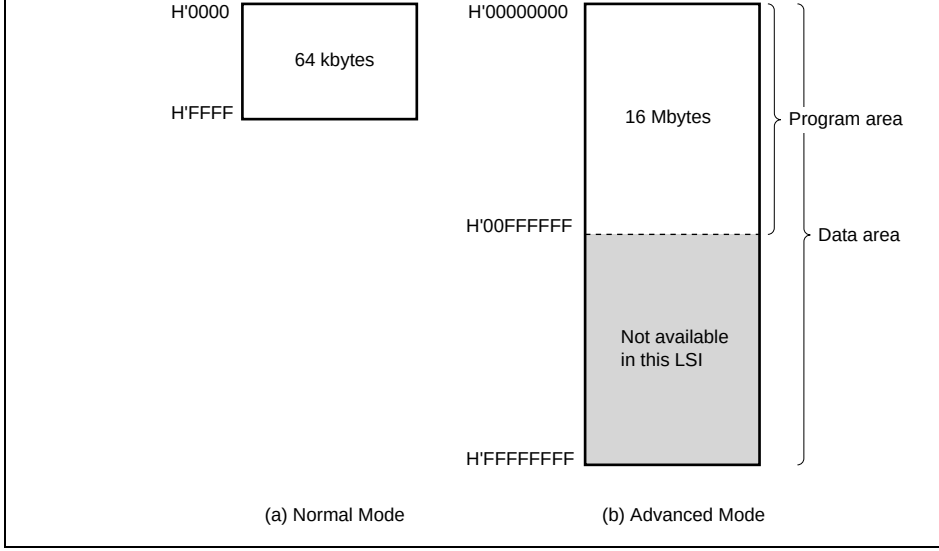
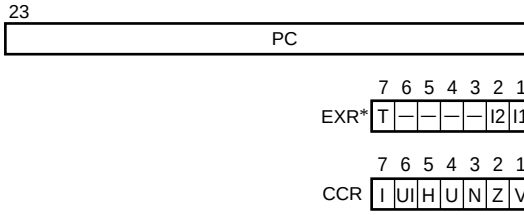


Figure 2.5 Memory Map

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



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

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

When the general registers are used as 8-bit registers, the R registers are divided into 8- registers designated by the letters RH (R0H to R7H) and RL (R0L to R7L). These regis 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 genera function, and is used implicitly in exception handling and subroutine calls. Figure 2.8 s stack.

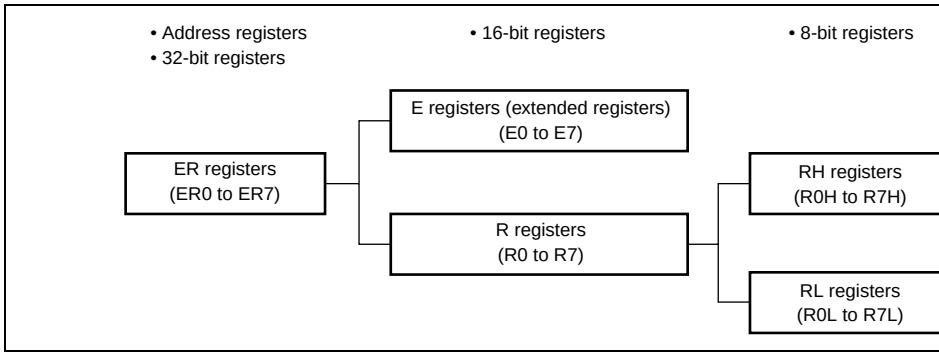


Figure 2.7 Usage of General Registers

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. of all CPU instructions is 2 bytes (one word), so the least significant PC bit is ignored 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 ma half-carry (H), negative (N), zero (Z), overflow (V), and carry (C) flags. Operations ca performed on the CCR bits by the LDC, STC, ANDC, ORC, and XORC instructions. and C flags are used as branching conditions for conditional branch (Bcc) instructions

				LDC, STC, ANDC, ORC, and XORC instructio
5	H	Undefined	R/W	Half-Carry Flag When the ADD.B, ADDX.B, SUB.B, SUBX.B, (NEG.B instruction is executed, this flag is set t is a carry or borrow at bit 3, and cleared to 0 o When the ADD.W, SUB.W, CMP.W, or NEG.W instruction is executed, the H flag is set to 1 if carry or borrow at bit 11, and cleared to 0 othe When the ADD.L, SUB.L, CMP.L, or NEG.L in executed, the H flag is set to 1 if there is a car 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 u LDC, STC, ANDC, ORC, and XORC instructio
3	N	Undefined	R/W	Negative Flag Stores the value of the most significant bit of d sign bit.
2	Z	Undefined	R/W	Zero Flag Set to 1 to indicate zero data, and cleared to 0 non-zero data.
1	V	Undefined	R/W	Overflow Flag Set to 1 when an arithmetic overflow occurs, a to 0 otherwise.
0	C	Undefined	R/W	Carry Flag Set to 1 when a carry occurs, and cleared to 0 Used by • Add instructions, to indicate a carry • Subtract instructions, to indicate a borrow • Shift and rotate instructions, to indicate a c The carry flag is also used as a bit accumulato manipulation instructions.

2.5 Data Formats

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

2.5.1 General Register Data Formats

Figure 2.9 shows the data formats of general registers.

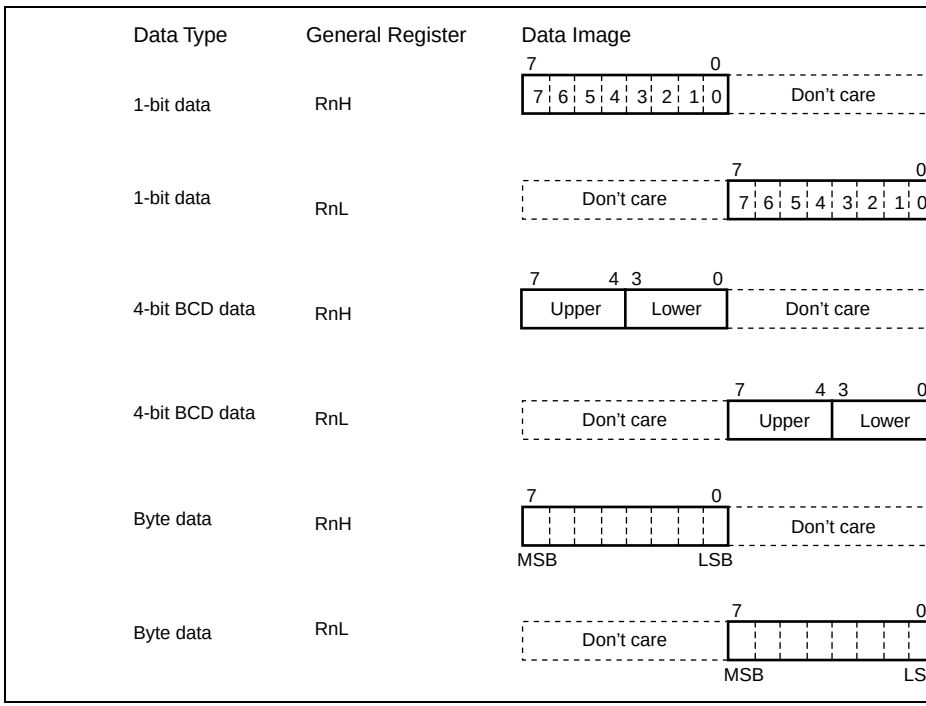
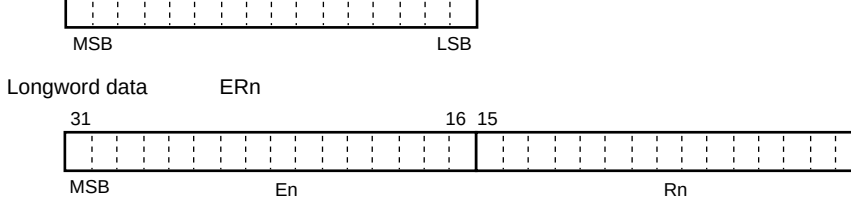


Figure 2.9 General Register Data Formats (1)



Legend:

ERn : General register ER
En : General register E
Rn : General register R
RnH : General register RH
RnL : General register RL
MSB : Most significant bit
LSB : Least significant bit

Figure 2.9 General Register Data Formats (2)

size or longword size.

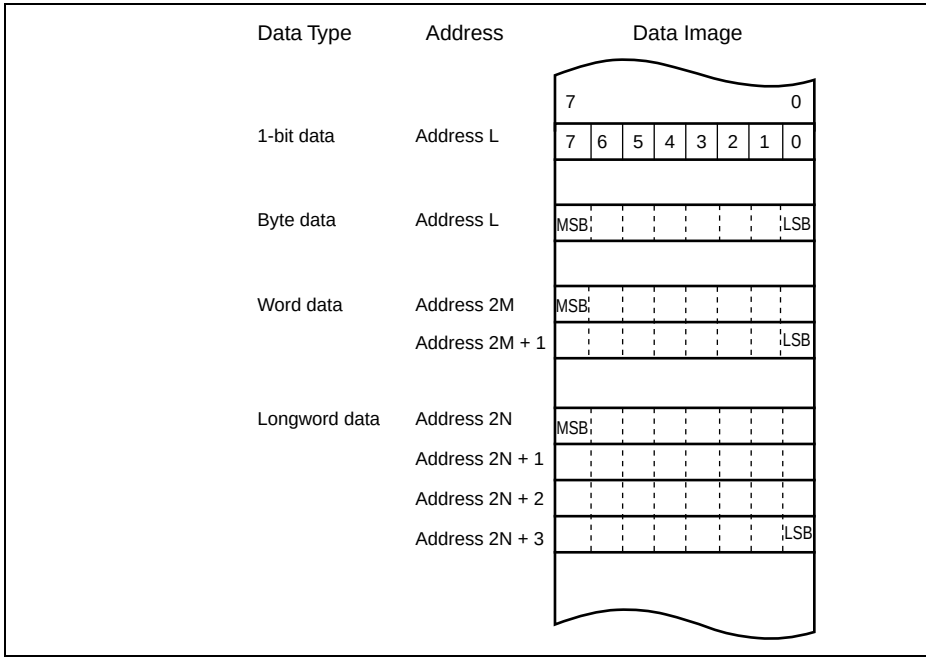


Figure 2.10 Memory Data Formats

	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
	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
Shift	SHAL, SHAR, SHLL, SHLR, ROTL, ROTR, ROTXL, ROTXR	B/W/L
Bit manipulation	BSET, BCLR, BNOT, BTST, BLD, BILD, BST, BIST, BAND, BIAND, BOR, BIOR, BXOR, BIXOR	B
Branch	Bcc*2, JMP, BSR, JSR, RTS	—
System control	TRAPA, RTE, SLEEP, LDC, STC, ANDC, ORC, XORC, NOP	—
Block data transfer	EEPMOV	—

To

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 @–SP. POP.L ERn and PUSH.L ERn are identical to MOV.L @SP+, ERn an 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) wh STM/LDM instruction, because ER7 is the stack pointer.

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 r
to R7, E0 to E7), and 32-bit registers (ER0 to ER7).

POP	W/L	@SP+ → Rn Pops a general register from the stack. POP.W Rn is identica @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 iden MOV.W Rn, @–SP. PUSH.L ERn is identical to MOV.L ERn,
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) wh
STM/LDM instruction, because ER7 is the stack pointer.

SUBX		Performs addition or subtraction with carry on data in two ge registers, or on immediate data and data in a general registe
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 gener (Only the value 1 can be added to or subtracted from byte o
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
DAA	B	Rd (decimal adjust) → Rd
DAS		Decimal-adjusts an addition or subtraction result in a genera referring to CCR to produce 4-bit BCD data.
MULXU	B/W	Rd × Rs → Rd
		Performs unsigned multiplication on data in two general regi 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 registe 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: bits ÷ 8 bits → 8-bit quotient and 8-bit remainder or 32 bits ÷ 16-bit quotient and 16-bit remainder.

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

		Compares data in a general register with data in another gen or with immediate data, and sets the CCR bits according to th
NEG	B/W/L	0 – Rd → Rd Takes the two's complement (arithmetic complement) of data general register.
EXTU	W/L	Rd (zero extension) → Rd Extends the lower 8 bits of a 16-bit register to word size, or th bits of a 32-bit register to longword size, by padding with zero left.
EXTS	W/L	Rd (sign extension) → Rd Extends the lower 8 bits of a 16-bit register to word size, or th bits of a 32-bit register to longword size, by extending the sig
TAS*2	B	@ERd – 0, 1 → (<bit 7> of @ERd) Tests memory contents, and sets the most significant bit (bit

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.

		general register or immediate data.
XOR	B/W/L	Rd ⊕ Rs → Rd, Rd ⊕ #IMM → Rd Performs a logical exclusive OR operation on a general regi another general register or immediate data.
NOT	B/W/L	~ Rd → Rd Takes the one's complement (logical complement) of data in 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- shift is possible.
SHLL	B/W/L	Rd (shift) → Rd
SHLR		Performs a logical shift on data in a general register. 1-bit or possible.
ROTL	B/W/L	Rd (rotate) → Rd
ROTR		Rotates data in a general register. 1-bit or 2 bit rotation is po
ROTXL	B/W/L	Rd (rotate) → Rd
ROTXR		Rotates data including the carry flag in a general register. 1- rotation is possible.

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

		Clears a specified bit in a general register or memory operand bit number is specified by 3-bit immediate data or the lower th a general register.
BNOT	B	~ (<bit-No.> of <EAd>) → (<bit-No.> of <EAd>) Inverts a specified bit in a general register or memory operan number is specified by 3-bit immediate data or the lower three general register.
BTST	B	~ (<bit-No.> of <EAd>) → Z Tests a specified bit in a general register or memory operand clears the Z flag accordingly. The bit number is specified by 3 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 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 b general register or memory operand and stores the result in t 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 re 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 general register or memory operand and stores the result in t flag. The bit number is specified by 3-bit immediate data.

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

		in a general register or memory operand and stores the res 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 op carry flag.
BILD	B	~ (<bit-No.> of <EAd>) → C Transfers the inverse of a specified bit in a general register 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 memory operand.
BIST	B	~ C → (<bit-No.>. of <EAd>) Transfers the inverse of the carry flag value to a specified b general register or memory operand. The bit number is specified by 3-bit immediate data.

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

BHI	High	$C \vee Z = 0$
BLS	Low or same	$C \vee Z = 1$
BCC (BHS)	Carry clear (high or same)	$C = 0$
BCS (BLO)	Carry set (low)	$C = 1$
BNE	Not equal	$Z = 0$
BEQ	Equal	$Z = 1$
BVC	Overflow clear	$V = 0$
BVS	Overflow set	$V = 1$
BPL	Plus	$N = 0$
BMI	Minus	$N = 1$
BGE	Greater or equal	$N \oplus V = 0$
BLT	Less than	$N \oplus V = 1$
BGT	Greater than	$Z \vee (N \oplus V) = 0$
BLE	Less or equal	$Z \vee (N \oplus V) = 1$

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

		EXR. Although CCR and EXR are 8-bit registers, word-size are performed between them and memory. The upper 8 bit
STC	B/W	CCR → (EAd), EXR → (EAd) Transfers CCR or EXR contents to a general register or me operand. Although CCR and EXR are 8-bit registers, word- transfers are performed between them and memory. The u are valid.
ANDC	B	CCR ∧ #IMM → CCR, EXR ∧ #IMM → EXR Logically ANDs the CCR or EXR contents with immediate d
ORC	B	CCR ∨ #IMM → CCR, EXR ∨ #IMM → EXR Logically ORs the CCR or EXR contents with immediate da
XORC	B	CCR ⊕ #IMM → CCR, EXR ⊕ #IMM → EXR Logically exclusive-ORs the CCR or EXR contents with imm data.
NOP	—	PC + 2 → PC Only increments the program counter.

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

Repeat @ER5 + → @ER6+
R4–1 → R4
Until R4 = 0
else next;

Transfers a data block. Starting from the address set in ER5
data for the number of bytes set in R4L or R4 to the address
set in ER6.

Execution of the next instruction begins as soon as the trans
completed.

2.6.2 Basic Instruction Formats

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

Figure 2.11 shows examples of instruction formats.

- Operation field

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

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

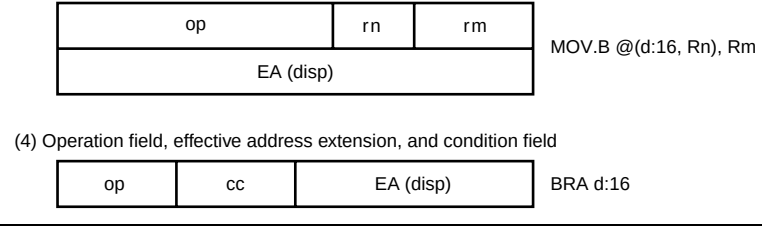


Figure 2.11 Instruction Formats (Examples)

2.7 Addressing Modes and Effective Address Calculation

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

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

5	Absolute address	@aa:8/@aa:16/@aa:24/@aa:3
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 w
contains the operand. R0H to R7H and R0L to R7L can be specified as 8-bit registers. E
and E0 to E7 can be specified as 16-bit registers. ER0 to ER7 can be specified as 32-bit

2.7.2 Register Indirect—@ERn

The register field of the instruction code specifies an address register (ERn) which cont
address of a memory operand. If the address is a program instruction address, the lower
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
(ERn) specified by the register field of the instruction, and the sum gives the address of
operand. A 16-bit displacement is sign-extended when added.

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

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

The instruction code contains the absolute address of a memory operand. The absolute
may be 8 bits long (@aa:8), 16 bits long (@aa:16), 24 bits long (@aa:24), or 32 bits lo
(@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
(@aa:32) long. For an 8-bit absolute address, the upper 24 bits are all assumed to be 1
For a 16-bit absolute address, the upper 16 bits are a sign extension. For a 32-bit absol
the entire address space is accessed.

A 24-bit absolute address (@aa:24) indicates the address of a program instruction. The
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'F
	16 bits (@aa:16)	H'0000 to H'FFFF	H'000000 to H'00 H'FF8000 to H'FF
	32 bits (@aa:32)		H'000000 to H'FF
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 i
code can be used directly as an operand.

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

+16384 words) from the branch instruction. The resulting value should be an even num

2.7.8 Memory Indirect—@@aa:8

This mode can be used by the JMP and JSR instructions. The instruction code contains absolute address specifying a memory operand which contains a branch address. The u the 8-bit absolute address are all assumed to be 0, so the address range is 0 to 255 (H'00 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 b advanced mode, the memory operand is a longword operand, the first byte of which is a be 0 (H'00). Note that the top area of the address range in which the branch address is s also used for the exception vector area. For further details, refer to section 4, Exception

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

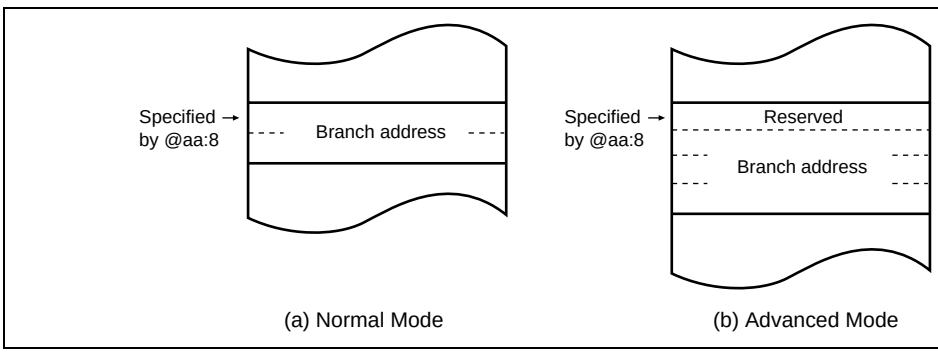
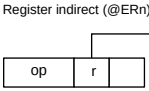
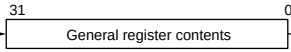
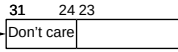
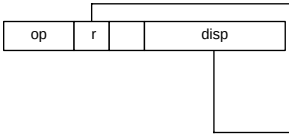
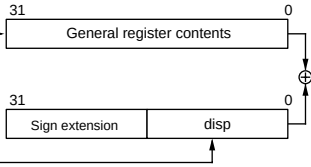
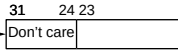
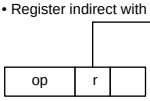
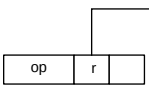
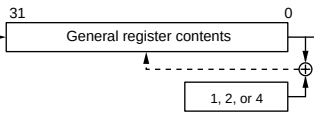
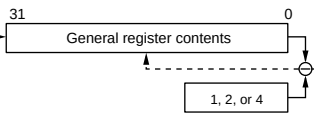
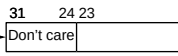
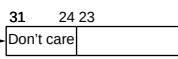
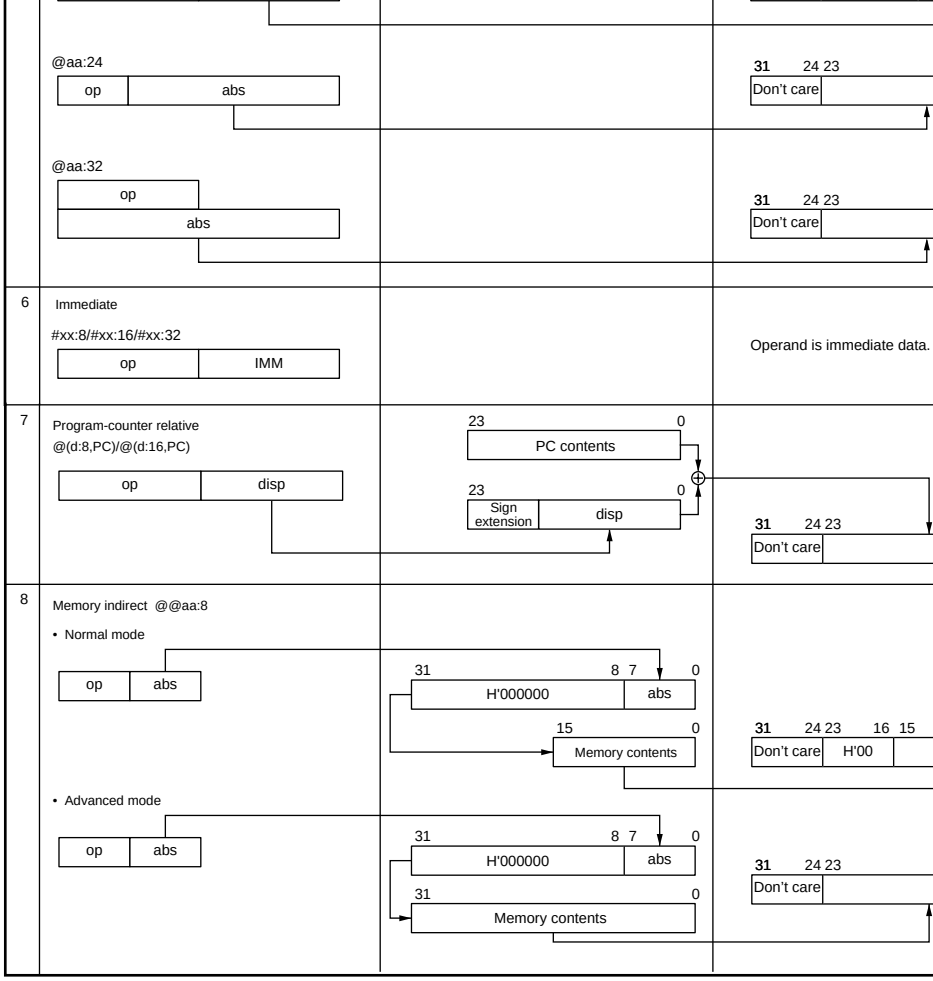


Figure 2.12 Branch Address Specification in Memory Indirect Addressing

	op rm rn		Operand is general registe
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	 


@aa:24
op
abs
31
24 23
Don't care
@aa:32
op
abs
31
24 23
Don't care
6
Immediate
#xx:8/#xx:16/#xx:32
op
IMM
Operand is immediate data.
7
Program-counter relative
@(d:8,PC)/@(d:16,PC)
op
disp
23
0
PC contents
23
0
Sign extension
disp
31
24 23
Don't care
8
Memory indirect @@aa:8
• Normal mode
op
abs
31
8 7
0
H'000000
abs
15
0
Memory contents
31
24 23
16 15
Don't care
H'00
• Advanced mode
op
abs
31
8 7
0
H'000000
abs
31
0
Memory contents
31
24 23
Don't care

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 $\overline{RES}$ 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 processing flow due to an exception source, such as, a reset, trace, interrupt, or trap. The CPU fetches a start address (vector) from the exception vector table and branches address. For further details, refer to section 4, Exception Handling.

- Program execution state

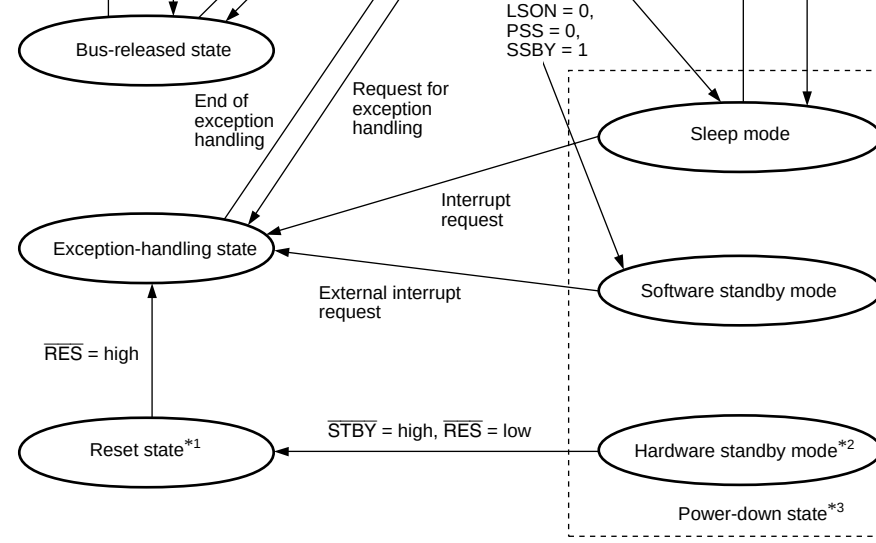
  In this state the CPU executes program instructions in sequence.

- 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 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 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 d refer to section 26, Power-Down Modes.

Figure 2.13 State Transitions

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 S
instruction, because ER7 is the stack pointer. Two, three, or four registers can be save
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 Technolog
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 a
byte units, manipulate the data of the target bit, and write data to the same address aga
units. Special care is required when using these instructions in cases where a register c
write-only bit is used or a bit is directly manipulated for a port, because this may rewr
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 signa
P46. P45 to P40 are output pins and output low-level signals. The following shows an
which P40 is set to be an input pin with the BCLR instruction.

BCLR instruction executed:

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

The BCLR instruction is executed for DDR in port 4.

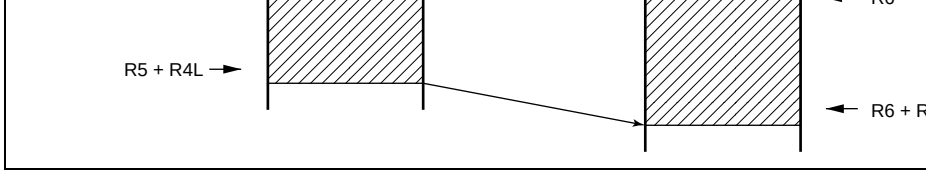
After executing BCLR:

	P47	P46	P45	P44	P43	P42	P41
Input/output	Output	Output	Output	Output	Output	Output	Output
Pin state	Low level	High level	Low level	Low level	Low level	Low level	Low level
DDR	1	1	1	1	1	1	1
DR	1	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 P4D
   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
However, bits 7 and 6 of DDR are modified to 1, therefore P47 and P46 become output



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

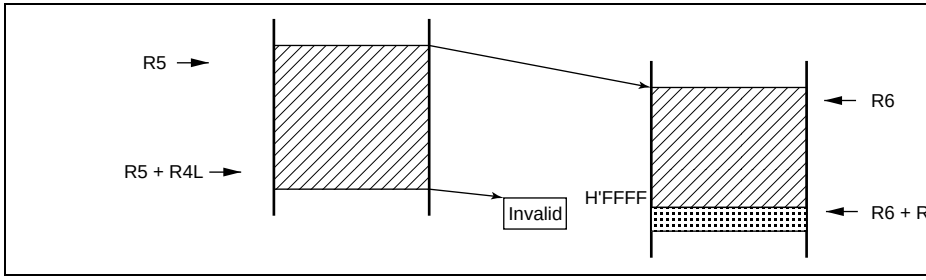


Table 3.1 lists the MCU operating modes.

Table 3.1 MCU Operating Mode Selection

MCU Operating Mode	MD1	MD0	CPU Operating Mode	Description
0	0	0	—	—
1		1	Normal	Expanded mode with on-chip ROM disabled
2	1	0	Advanced	Expanded mode with on-chip ROM 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 de
modes 2 and 3, operation begins in single-chip mode after reset release, but a transitio
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
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 contro
(BCR), refer to section 6.3.1, Bus Control Register (BCR).

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

				0: Single-chip mode 1: Extended mode
6 to 2	—	All 0	R	Reserved These bits are always read as 0. These bits modified.
1	MDS1	—*	R	Mode Select 1 and 0
0	MDS0	—*	R	These bits indicate the input levels at mode and MD0) (the current operating mode). Bits and MDS0 correspond to MD1 and MD0, re These bits are read-only bits and they cann written to. The mode pin (MD1 and MD0) in are latched into these bits when MDCR is re latches are canceled by a reset.

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

				Specifies the location of the control pin ($\overline{CS}$ host interface together with the FGA20E b See section 18, Host Interface X-Bus Inter for details.
6	IOSE	0	R/W	IOS Enable Enables or disables $\overline{AS}$/$\overline{IOS}$ pin function in mode. 0: $\overline{AS}$ pin Outputs low when an external area is ac 1: $\overline{IOS}$ pin Outputs low when a specified address c H'(FF)F000 to H'(FF)F7FF is accessed.
5	INTM1	0	R	These bits select the control mode of the i
4	INTM0	0	R/W	controller. For details on the interrupt contr and interrupt control select modes 1 and 0 5.6, Interrupt Control Modes and Interrupt 00: Interrupt control mode 0 01: Interrupt control mode 1 10: Setting prohibited 11: Setting prohibited
3	XRST	1	R	External Reset This bit indicates the reset source. A reset by an external reset input, or when the wa overflows. 0: A reset is caused when the watchdog ti overflows. 1: A reset is caused by an external reset.

				Controls CPU access to the host interface r (HICR, IDR1, ODR1, STR1, IDR2, ODR2, a the keyboard matrix interrupt and MOS inpu control registers (KMIMR, KMPCR, and KM 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_ TCORB_X), and the timer connection regist (TCONRI, TCONRO, TCONRS, and SEDG 0: In areas H'(FF)FFF0 to H'(FF)FFF7 and I to H'(FF)FFFF, CPU access to 8-bit timer and TMR_Y) registers and timer connect registers is permitted 1: In areas H'(FF)FFF0 to H'(FF)FFF7 and I to H'(FF)FFFF, CPU access to host interf registers and keyboard matrix interrupt a input pull-up control registers is permitted
0	RAME	1	R/W	RAM Enable Enables or disables on-chip RAM. The RAM 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 memo selects the input clock of the timer counter.

6	IICX1	0	R/W	I^2C Transfer Rate Select 1 and 0
5	IICX0	0	R/W	These bits control the IIC operation. The a transfer rate in master mode together v CKS2 to CKS0 in the I^2C bus mode regis For details on the transfer rate, refer to ta
4	IICE	0	R/W	I^2C Master Enable Enables or disables CPU access for IIC (ICCR, ICSR, ICDR/SARX, ICMR/SAR), registers (DADRAH/DACR, DADRAL, DADRBH/DACNTH, DADRBL/DACNTL) registers (SMR, BRR, SCMR). 0: SCI_1 registers are accessed in an ar H'(FF)FF88 to H'(FF)FF89 and from H to H'(FF)FF8F. SCI_2 registers are accessed in an ar H'(FF)FFA0 to H'(FF)FFA1 and from H to H'(FF)FFA7. SCI_0 registers are accessed in an ar H'(FF)FFD8 to H'(FF)FFD9 and from H to H'(FF)FFDF. 1: IIC_1 registers are accessed in an are H'(FF)FF88 to H'(FF)FF89 and from H to H'(FF)FF8F. PWMX registers are accessed in an a H'(FF)FFA0 to H'(FF)FFA1 and from H to H'(FF)FFA7. IIC_0 registers are accessed in an are H'(FF)FFD8 to H'(FF)FFD9 and from H to H'(FF)FFDF.

				accessed in an area from H'(FF)FF80 t H'(FF)FF87. 1: Control registers of flash memory are a an area from H'(FF)FF80 to H'(FF)FF8
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 counter (TCNT) and a count condition tog bits CKS2 to CKS0 in the timer control reg (TCR). For details, refer to section 12.3.4, Control Register (TCR).

3.3.2 Mode 2

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

After a reset, the LSI is set to single-chip mode. To access an external address space, b
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
Ports 1, 2 and A output an address by setting 1 to the corresponding port data direction
(DDR). Port 3 functions as a data bus, and parts of port 9 carry bus control signals. Po
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 e
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, b
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 r
and 2 function as an address bus by setting 1 to the corresponding port data direction r
(DDR). Port 3 functions as a data bus, and parts of port 9 carry bus control signals. Po
functions as a data bus when the ABW bit in WSCR is cleared to 0.

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:

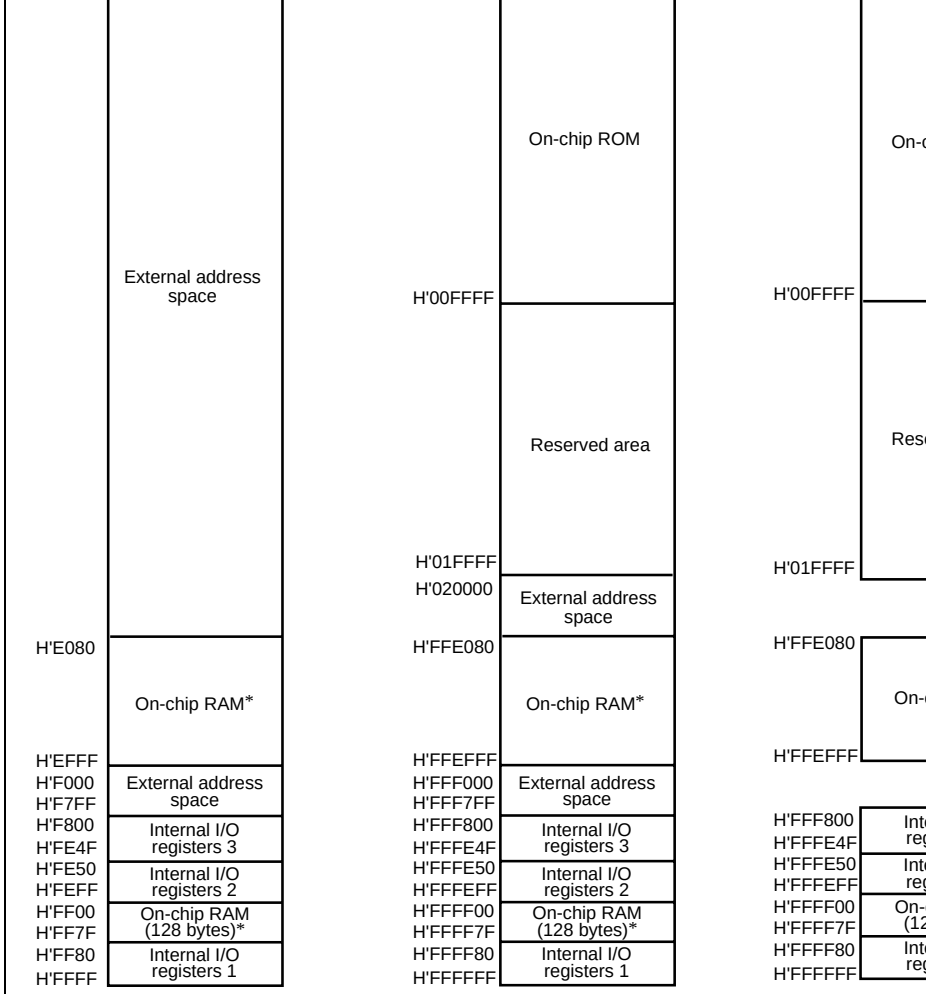
P: I/O port

A: Address bus output

D: Data bus I/O

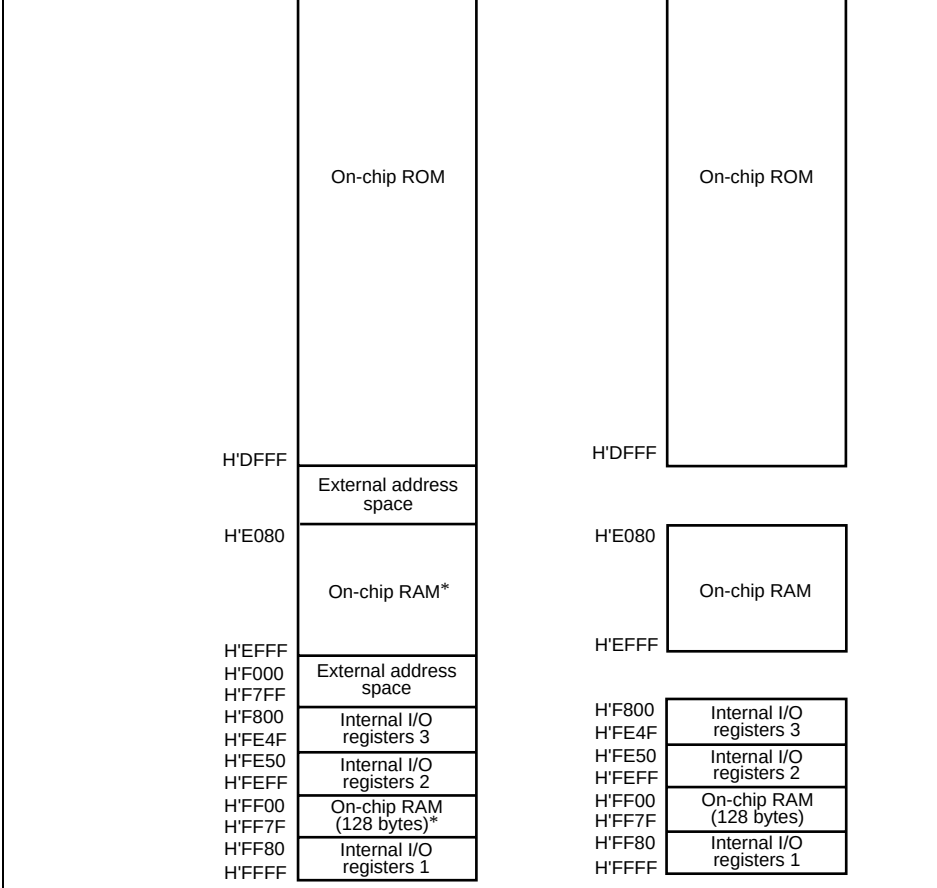
C: Control signals, clock I/O

*: Immediately after reset



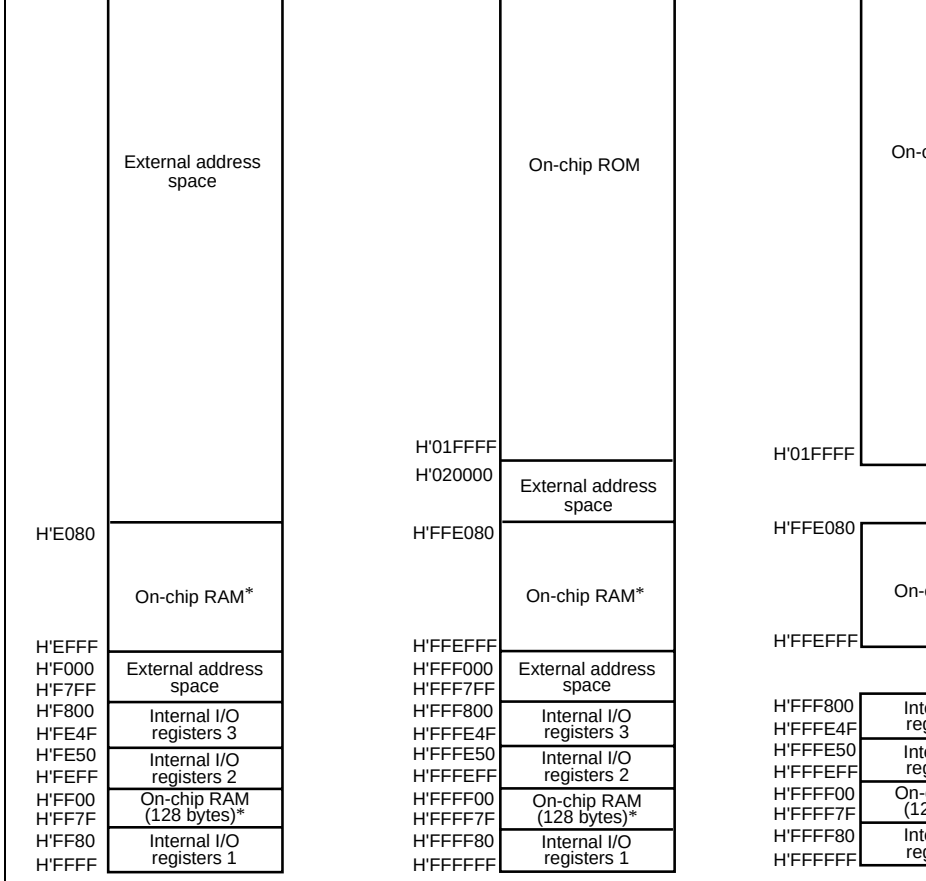
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0

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



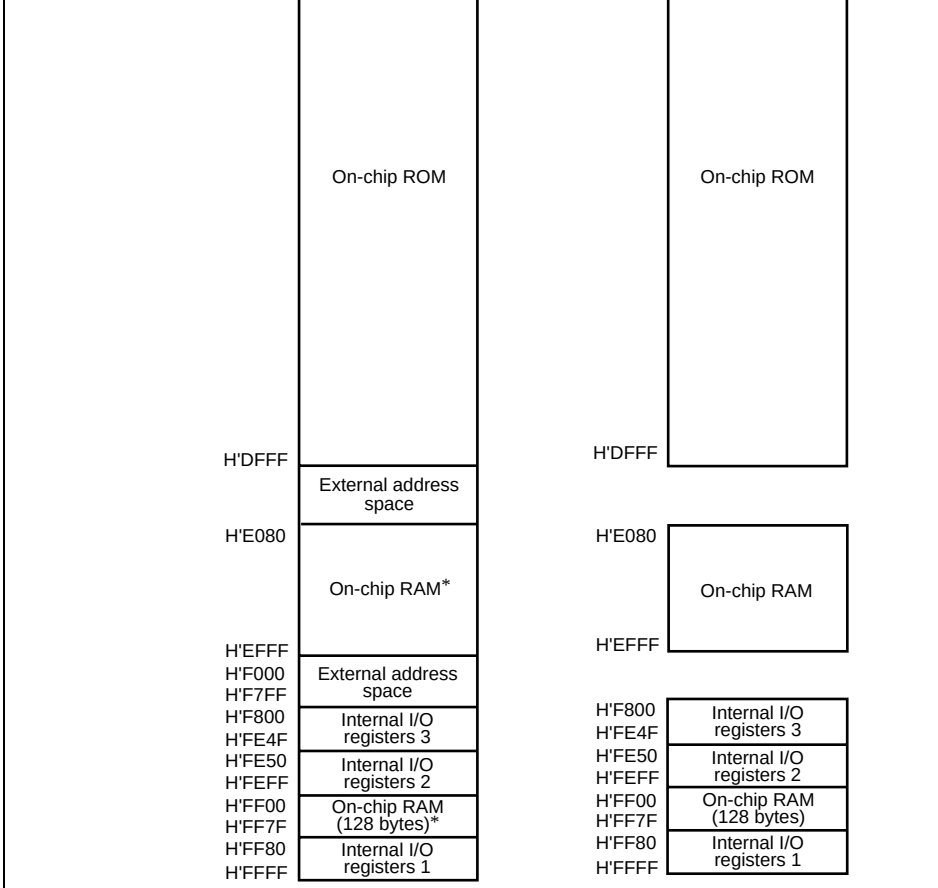
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to

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



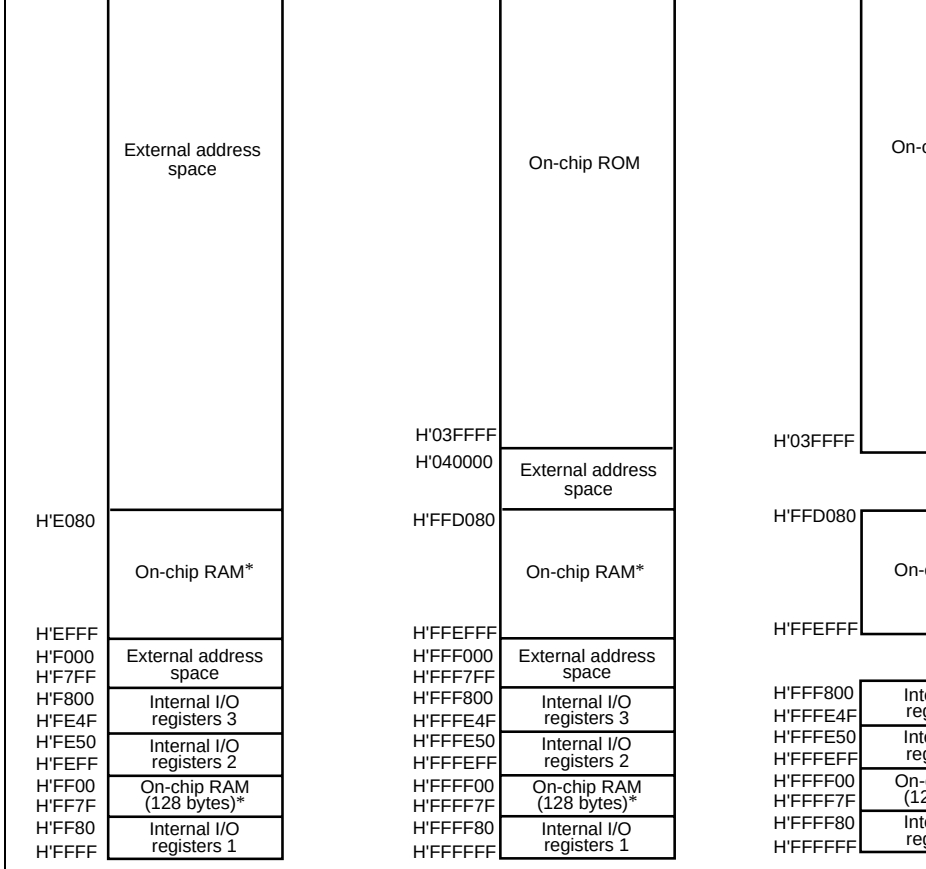
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0

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



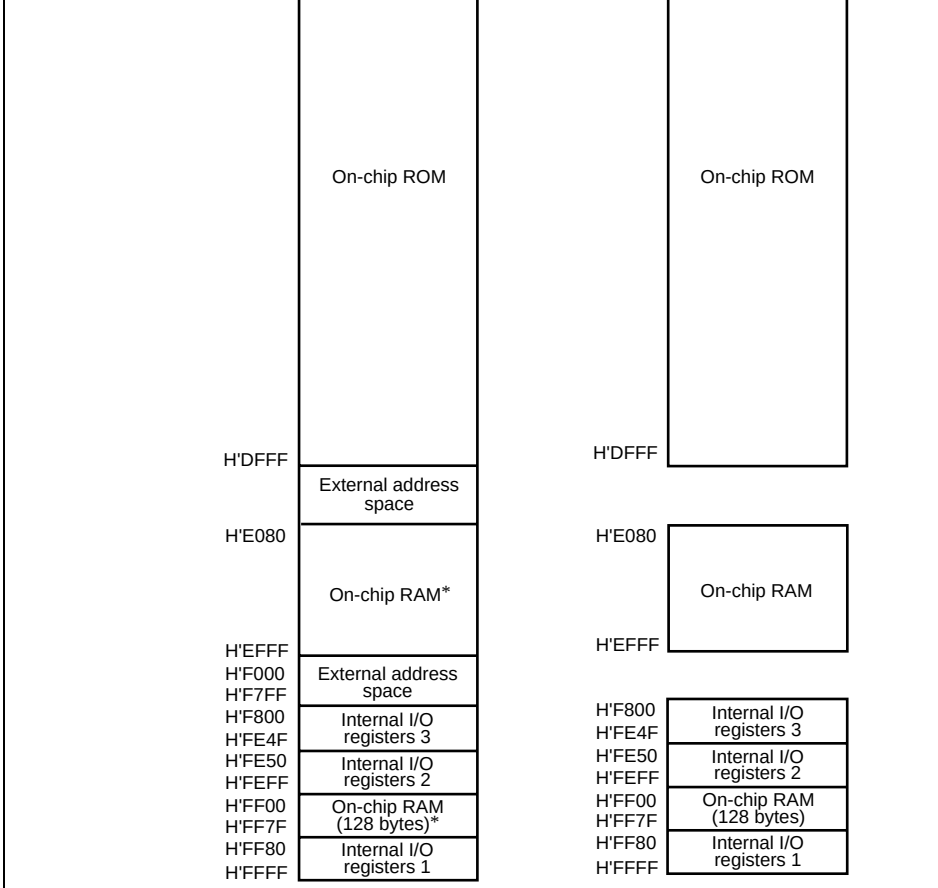
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to

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



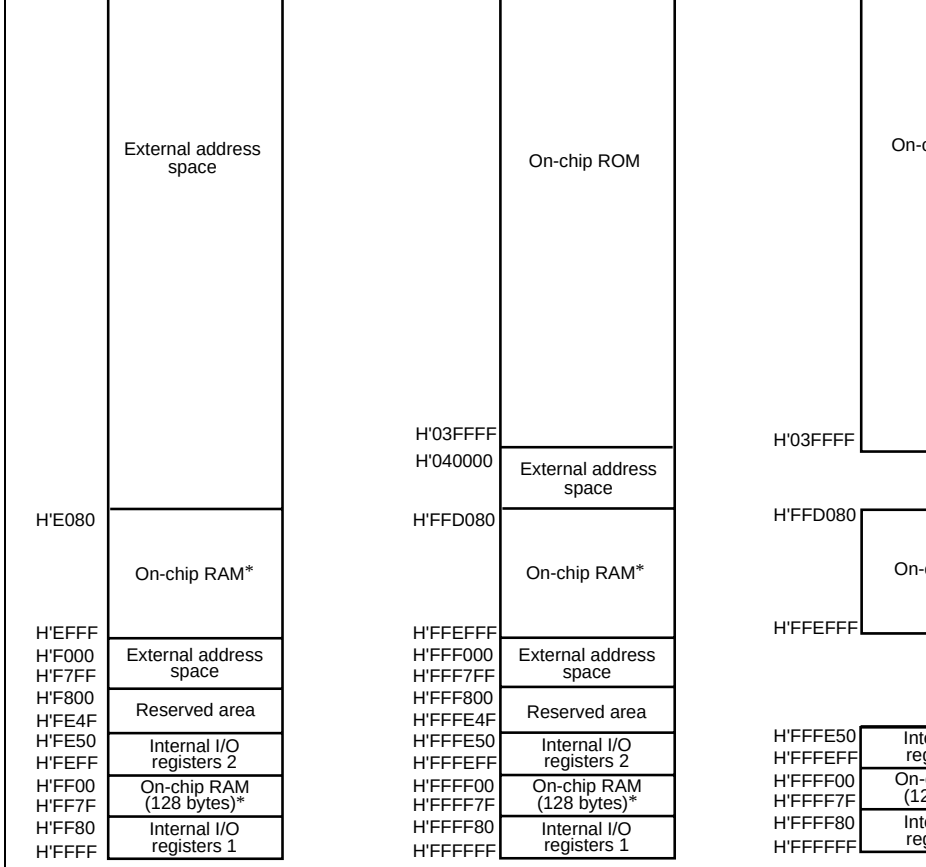
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0

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



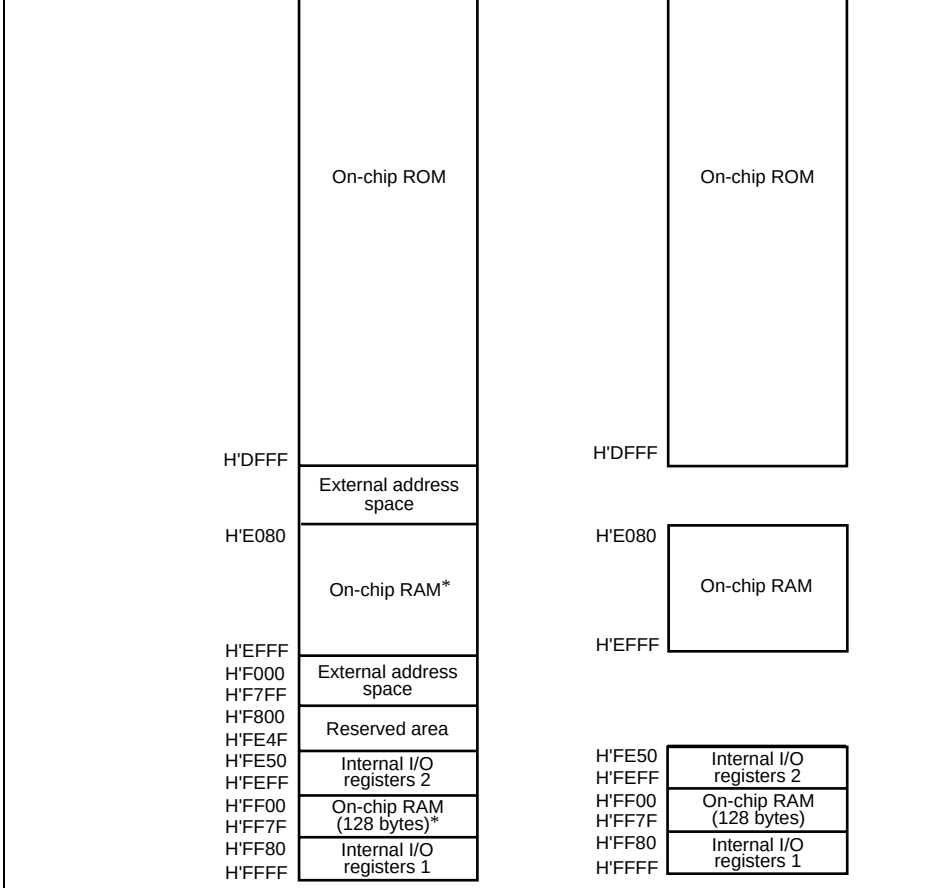
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to

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



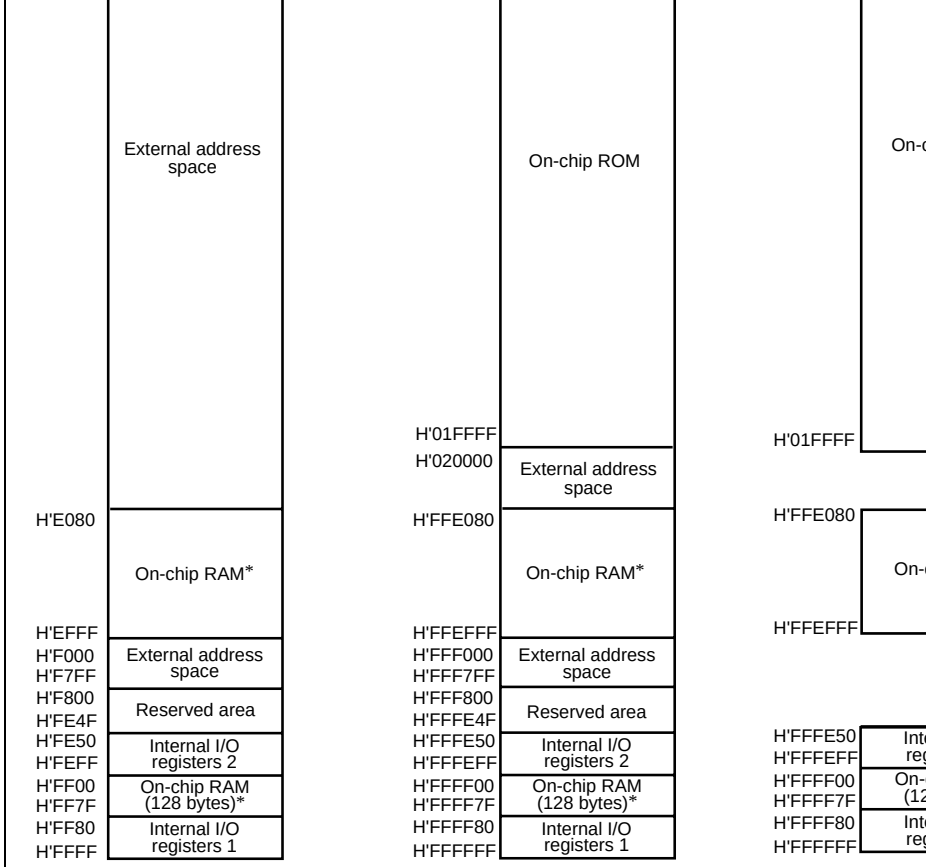
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to 0.

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



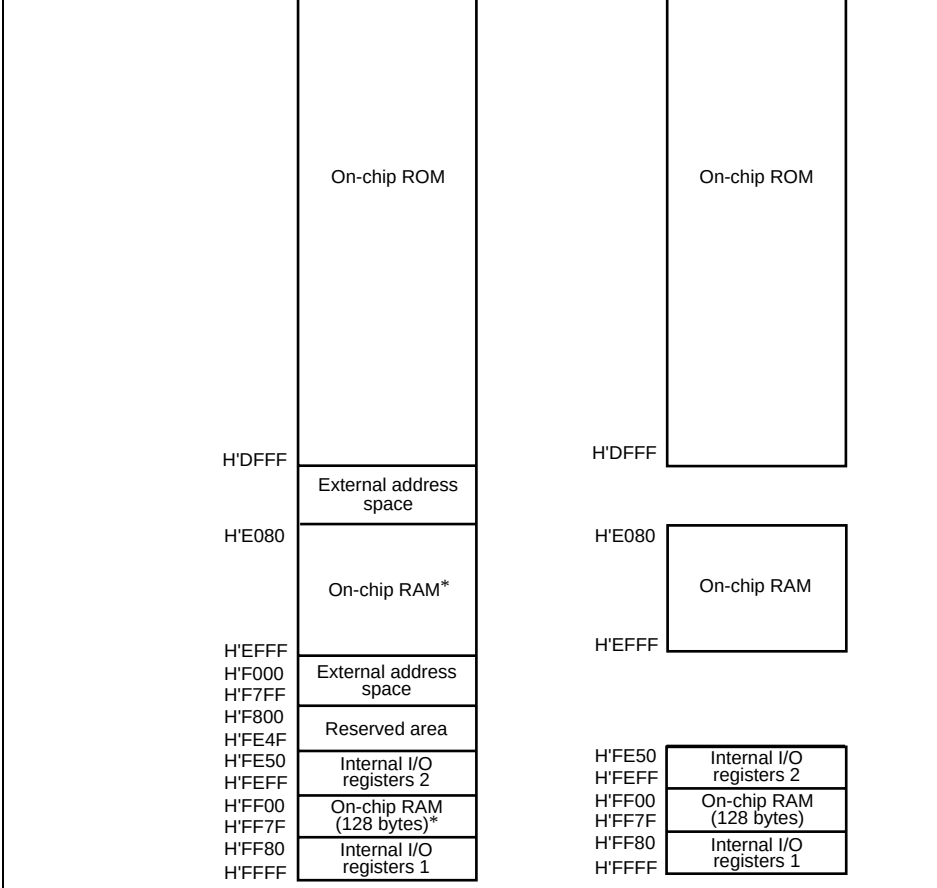
Note: * These areas can be used as an external address space by clearing bit RAME in SYSCR to

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

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

Table 4.1 Exception Types and Priority

Priority	Exception Type	Start of Exception Handling
High ▲	Reset	Starts immediately after a low-to-high transition pin, or when the watchdog timer overflows.
	Interrupt	Starts when execution of the current instruction handling ends, if an interrupt request has been Interrupt detection is not performed on completi ORC, XORC, or LDC instruction execution, or c completion of reset exception handling.
	Direct transition	Starts when a direction transition occurs as the SLEEP instruction execution.
	Trap instruction	Started by execution of a trap (TRAPA) instruct instruction exception handling requests are acc times in program execution state.
Low		

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

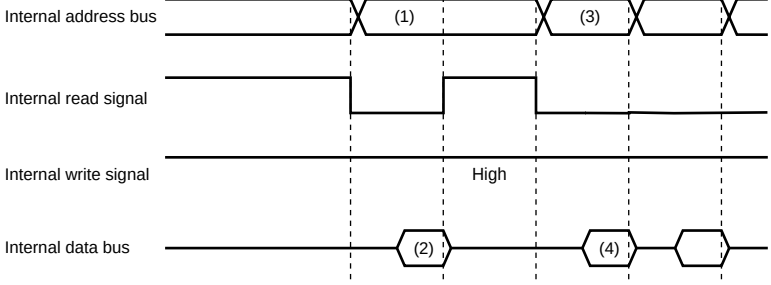
Note: * For details on the internal interrupt vector table, see section 5.5, Interrupt Ex Handling Vector Table.

4.3.1 Reset Exception Handling

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

1. The internal state of the CPU and the registers of the on-chip peripheral modules a
   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
   execution starts from the address indicated by the PC.

Figure 4.1 shows an example of the reset sequence.



(1) Reset exception handling vector address ((1) = H'0000)
(2) Start address (contents of reset exception handling vector address)
(3) Start address ((3) = (2))
(4) First program instruction

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, th
CCR will not be saved correctly, leading to a program crash. To prevent this, all interru
including NMI, are disabled immediately after a reset. Since the first instruction of a pr
always executed immediately after the reset state ends, make sure that this instruction i
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, a
modules except the DTC operate in module stop mode. Therefore, the registers of on-c
peripheral modules cannot be read from or written to. To read from and write to these r
clear module stop mode.

1. The values in the program counter (PC) and condition code register (CCR) are sav stack.
2. A vector address corresponding to the interrupt source is generated, the start addre 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. Tra 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 sav stack.
2. A vector address corresponding to the interrupt source is generated, the start addre from the vector table to the PC, and program execution starts from that address.

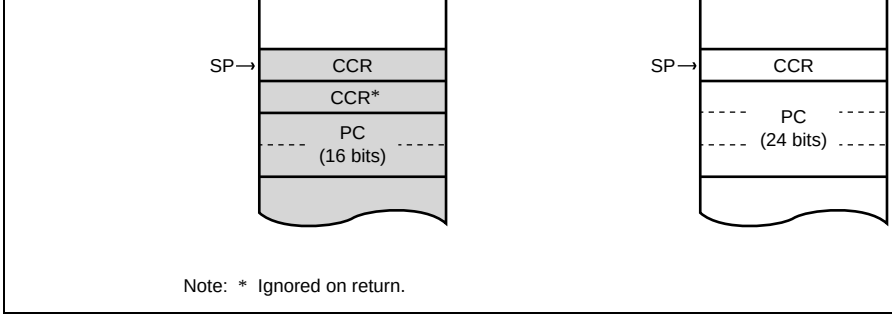
The TRAPA instruction fetches a start address from a vector table entry correspondin number from 0 to 3, as specified in the instruction code.

Table 4.3 shows the status of CCR after execution of trap instruction exception handli

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



Note: * Ignored on return.

Figure 4.2 Stack Status after Exception Handling

```
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
happens when the SP value is odd.

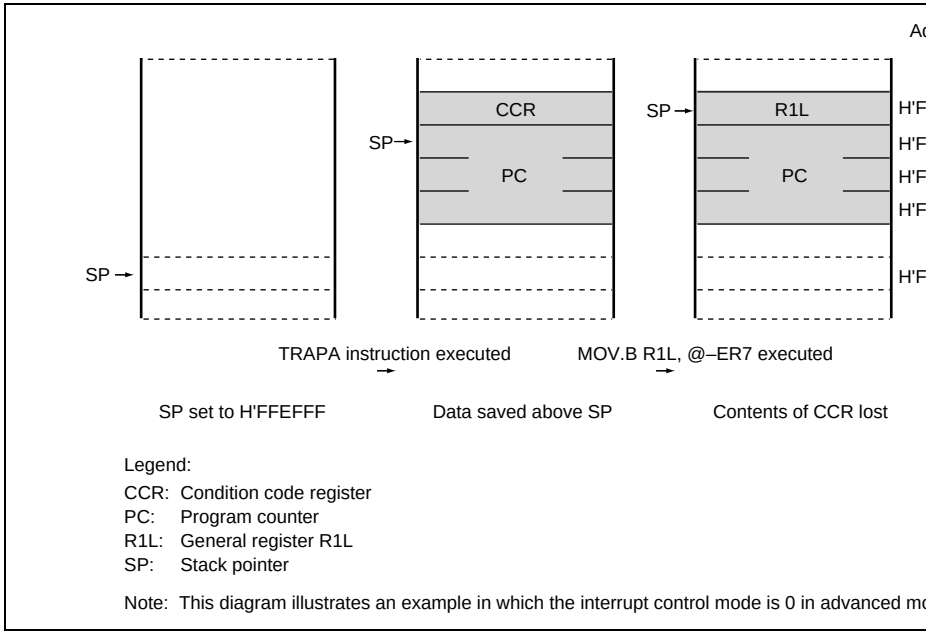


Figure 4.3 Operation when SP Value Is Odd

- Priorities settable with ICR

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

- Independent vector addresses

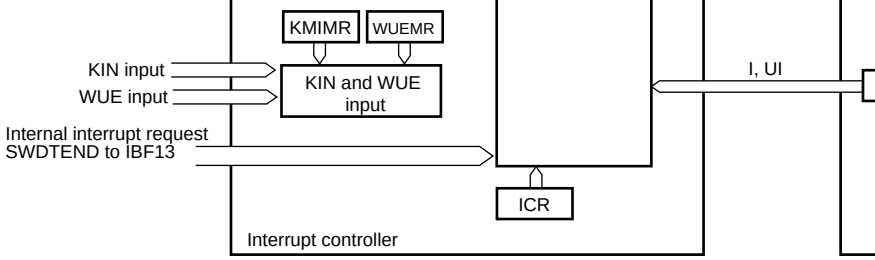
  All interrupt sources are assigned independent vector addresses, making it unnecessary source to be identified in the interrupt handling routine.

- Thirty-one external interrupts

  NMI is the highest-priority interrupt, and is accepted at all times. Rising edge or falling detection can be selected for NMI. Falling-edge, rising-edge, or both-edge detection 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.



Legend:

ICR	: Interrupt control register
ISCR	: IRQ sense control register
IER	: IRQ enable register
ISR	: IRQ status register
KMIMR	: Keyboard matrix interrupt mask register
WUEMR	: Wake-up event interrupt mask register
SYSCR	: System control register

Figure 5.1 Block Diagram of Interrupt Controller

		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 s 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 r (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)

to	to	
0	IRCn0	0: Corresponding interrupt source is control level 0 (no priority) 1: Corresponding interrupt source is 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 a

				address specified by BARA to BAR prefetched. [Setting condition] When an address specified by BAR is prefetched while the BIE flag is s [Clearing condition] When an exception handling is exe address break interrupt.
6 to 1	—	All 0	R	Reserved These bits are always read as 0 an modified.
0	BIE	0	R/W	Break Interrupt Enable Enables or disables address break. 0: Disabled 1: Enabled

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 w 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 wit 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 in the internal address bus.
0	—	0	R	Reserved This bit is always read as 0 and cann modified.

6	IRQ7SCA	0	R/W	IRQn Sense Control A
5	IRQ6SCB	0	R/W	00: Interrupt request generated at $\overline{\text{IRQn}}$ input
4	IRQ6SCA	0	R/W	
3	IRQ5SCB	0	R/W	01: Interrupt request generated at of $\overline{\text{IRQn}}$ input
2	IRQ5SCA	0	R/W	10: Interrupt request generated at of $\overline{\text{IRQn}}$ input
1	IRQ4SCB	0	R/W	
0	IRQ4SCA	0	R/W	11: Interrupt request generated at 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 $\overline{\text{IRQn}}$ input
4	IRQ2SCA	0	R/W	
3	IRQ1SCB	0	R/W	01: Interrupt request generated at of $\overline{\text{IRQn}}$ input
2	IRQ1SCA	0	R/W	10: Interrupt request generated at of $\overline{\text{IRQn}}$ input
1	IRQ0SCB	0	R/W	
0	IRQ0SCA	0	R/W	11: Interrupt request generated at and rising edges of $\overline{\text{IRQn}}$ input
				(n = 3 to 0)

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 rec

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 b registers occurs
5	IRQ5F	0	R/(W)*2	[Clearing conditions]
4	IRQ4F	0	R/(W)*2	• When reading IRQnF flag when I then writing 0 to IRQnF flag
3	IRQ3F	0	R/(W)*2	• When interrupt exception handlin executed when low-level detectio and $\overline{\text{IRQ}}$n input is high (n = 7 to
2	IRQ2F	0	R/(W)*2	• When IRQn interrupt exception h executed when falling-edge, risin 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 not automatically cleared even when exception handing is executed. For det section 5.8.4, Setting on a Product Incorporating DTC.

2. Only 0 can be written, for flag clearing.

7	KMIMR15	1	R/W	Keyboard Matrix Interrupt Mask 15
6	KMIMR14	1	R/W	These bits enable or disable a key-
5	KMIMR13	1	R/W	input interrupt request (KIN15 to KI
4	KMIMR12	1	R/W	0: Enables a key-sensing input inte
3	KMIMR11	1	R/W	1: Disables a key-sensing input inte
2	KMIMR10	1	R/W	request
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 t
6	KMIMR6	0	R/W	These bits enable or disable a key-
5	KMIMR5	1	R/W	input interrupt request (KIN7 to KIN
4	KMIMR4	1	R/W	KMIMR6 also performs interrupt re
3	KMIMR3	1	R/W	control for pin $\overline{\text{IRQ6}}$.
2	KMIMR2	1	R/W	0: Enables a key-sensing input inte
1	KMIMR1	1	R/W	1: Disables a key-sensing input inte
0	KMIMR0	1	R/W	request

2	WUEMR2	1	R/W	1: Disables a wake-up event input in request
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 interrupts WUE7 to WUE0, and registers KMIMRA, KMIMR, and WUEMRB.

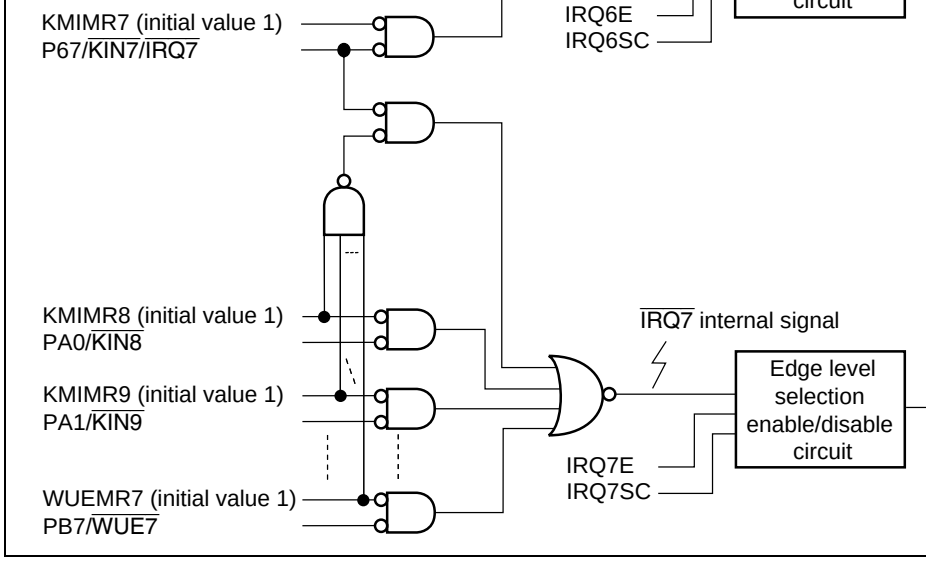


Figure 5.2 Relationship between Interrupts IRQ7 and IRQ6, Interrupts KIN1 Interrupts WUE7 to WUE0, and Registers KMIMR, KMIMRA, and WUE

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

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

IRQ7 to IRQ0 Interrupts: Interrupts IRQ7 to IRQ0 are requested by an input signal a
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
independent vector address.
- Using ISCR, it is possible to select whether an interrupt is generated by a low level,
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
by software.

The detection of IRQ7 to IRQ0 interrupts does not depend on whether the relevant pin
set for input or output. However, when a pin is used as an external interrupt input pin, c
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.

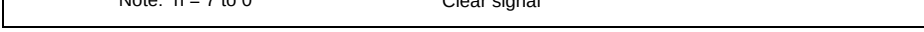


Figure 5.3 Block Diagram of Interrupts IRQ7 to IRQ0

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 KMIMR WUEMR7 to WUEMR0 to 1. If any of these bits is cleared to 0, IRQ7 interrupt input $\overline{\text{IRQ7}}$ pin will be ignored.

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

KIN15 to KIN0 Interrupts, WUE7 to WUE0 Interrupts: Interrupts KIN15 to KIN0 to WUE0 are requested by an input signal at pins $\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$ and $\overline{\text{WUE7}}$ to $\overline{\text{WUE}}$ pins $\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$ and $\overline{\text{WUE7}}$ to $\overline{\text{WUE0}}$ are used for key-sense input or wakeup eve corresponding KMIMR and WUEMR bits to 0 in order to enable their key-sense inpu wakeup event interrupts. Remaining unused KMIMR and WUEMR bits for key-sense should be set to 1 in order to disable interrupts. Interrupts WUE7 to WUE0 and KIN1 generate IRQ7 interrupts, and interrupts KIN7 to KIN0 generate IRQ6 interrupts. The conditions for interrupt request generation, enable of interrupt requests, settings of int control levels, and status display of interrupt requests depend on each setting and disp 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 input pins or wakeup event interrupt input pins, either low-level sensing or falling-edg must be designated as the interrupt sense condition for the corresponding interrupt sou or IRQ7).

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 modul
4. An interrupt request that activates the DTC is not affected by the interrupt control m 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 prio default priorities, the lower the vector number, the higher the priority. Modules set at th 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 requests from modules that are set to control level 1 (priority) by the ICR bit setting and UI bits in CCR are given priority and processed before interrupt requests from modules to control level 0 (no priority).

	IRQ2	18	H'0024	H'000048	ICRA
	IRQ3	19	H'0026	H'00004C	
	IRQ4	20	H'0028	H'000050	ICRA
	IRQ5	21	H'002A	H'000054	
	IRQ6, KIN7 to KIN0	22	H'002C	H'000058	ICRA
	IRQ7, KIN15 to KIN8, WUE7 to WUE0	23	H'002E	H'00005C	
DTC	SWDTEND (Software activation data transfer end)	24	H'0030	H'000060	ICRA
WDT_0	WOVI0 (Interval timer)	25	H'0032	H'000064	ICRA
WDT_1	WOVI1 (Interval timer)	26	H'0034	H'000068	ICRA
—	Address break	27	H'0036	H'00006C	—
A/D converter	ADI (A/D conversion end)	28	H'0038	H'000070	ICRE
—	Reserved for system use	29 to 47	H'003A to H'005E	H'000074 to H'0000BC	—
FRT	ICIA (Input capture A)	48	H'0060	H'0000C0	ICRE
	ICIB (Input capture B)	49	H'0062	H'0000C4	
	ICIC (Input capture C)	50	H'0064	H'0000C8	
	ICID (Input capture D)	51	H'0066	H'0000CC	
	OCIA (Output compare A)	52	H'0068	H'0000D0	
	OCIB (Output compare B)	53	H'006A	H'0000D4	
	FOVI (Overflow)	54	H'006C	H'0000D8	
	Reserved for system use	55	H'006E	H'0000DC	
—	Reserved for system use	56 to 63	H'0070 to H'007E	H'0000E0 to H'0000FC	—
TMR_0	CMIA0 (Compare match A)	64	H'0080	H'000100	ICRE
	CMIB0 (Compare match A)	65	H'0082	H'000104	
	OVI0 (Overflow)	66	H'0084	H'000108	
	Reserved for system use	67	H'0086	H'00010C	

	OVI1 (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	

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

Interrupt Control Mode	SYSCR		Priority Setting Registers	Interrupt Mask Bits	Description
	INTM1	INTM0			
0	0	0	ICR	I	Interrupt mask control is pe the I bit. Priority levels can ICR.
1		1	ICR	I, UI	3-level interrupt mask cont performed by the I and UI 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
ICR and the I bit of the CCR in the CPU. Figure 5.4 shows a flowchart of the interrup
operation.

1. If an interrupt source occurs when the corresponding interrupt enable bit is set to 1
interrupt request is sent to the interrupt controller.
2. According to the interrupt control level specified in ICR, the interrupt controller o
an interrupt request with interrupt control level 1 (priority), and holds pending an i
request with interrupt control level 0 (no priority). If several interrupt requests are
interrupt request with the highest priority is accepted according to the priority orde
interrupt handling is requested to the CPU, and other interrupt requests are held pe
3. If the I bit in CCR is set to 1, only NMI and address break interrupts are accepted
interrupt controller, and other interrupt requests are held pending. If the I bit is cle
any interrupt request is accepted.
4. When the CPU accepts an interrupt request, it starts interrupt exception handling a
execution of the current instruction has been completed.
5. The PC and CCR are saved to the stack area by interrupt exception handling. The
the stack shows the address of the first instruction to be executed after returning fr
interrupt handling routine.

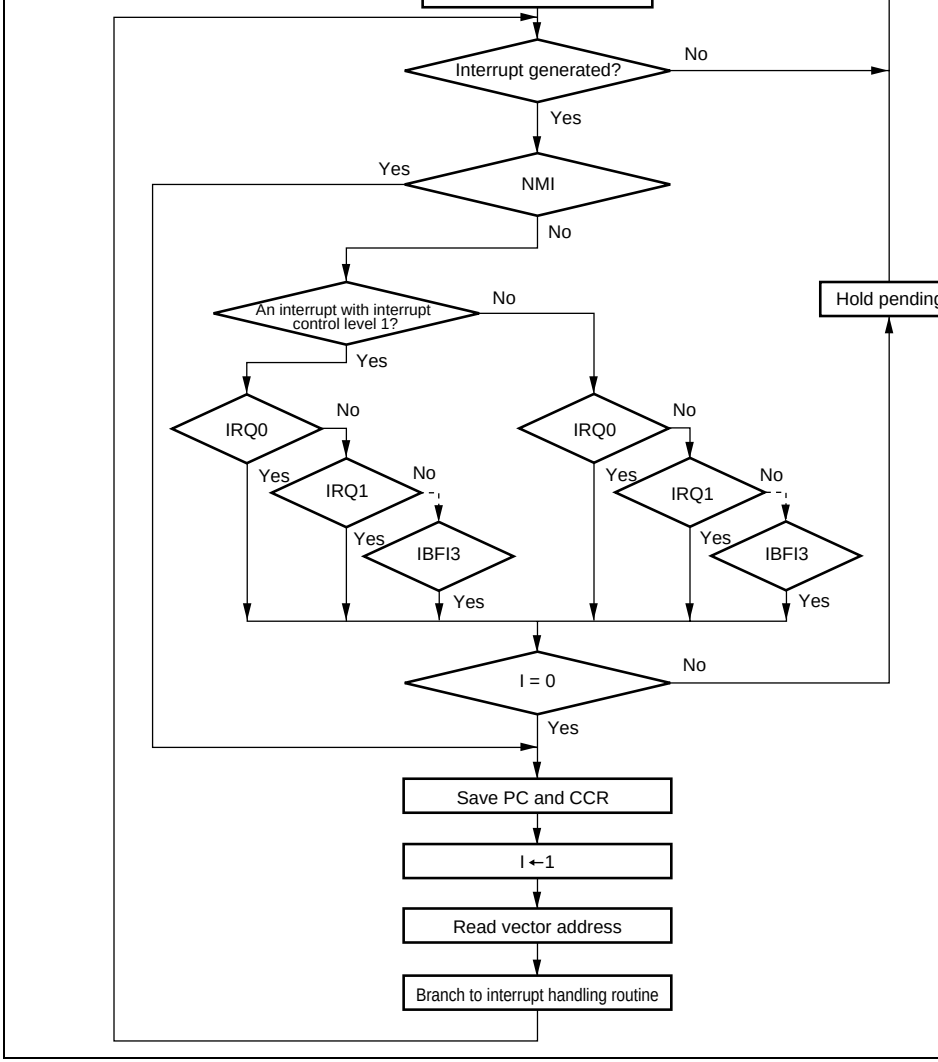


Figure 5.4 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Cont

cleared to 0. When both I and UI bits are set to 1, the interrupt request is held pend

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

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

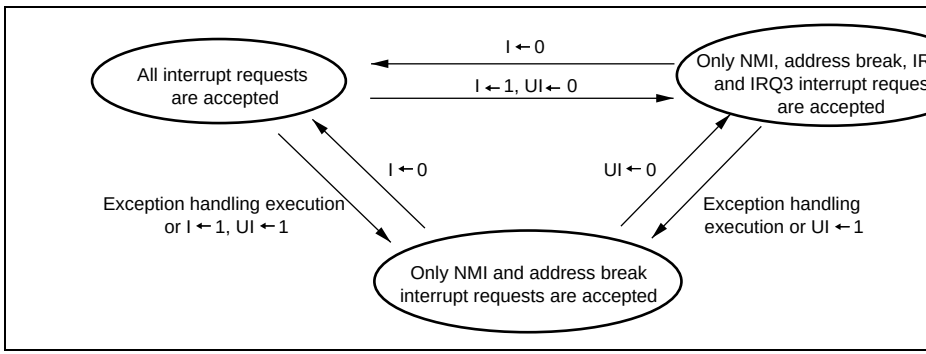


Figure 5.5 State Transition in Interrupt Control Mode 1

interrupt handling is requested to the CPU, and other interrupt requests are held pen

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

   When both the I and UI bits are set to 1, only an NMI or address break interrupt req 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 af execution of the current instruction has been completed.
5. The PC and CCR are saved to the stack area by interrupt exception handling. The P the stack shows the address of the first instruction to be executed after returning fro interrupt handling routine.
6. The I and UI bits in CCR are set to 1. This masks all interrupts except for an NMI o break interrupt.
7. The CPU generates a vector address for the accepted interrupt and starts execution interrupt handling routine at the address indicated by the contents of the vector addr vector table.

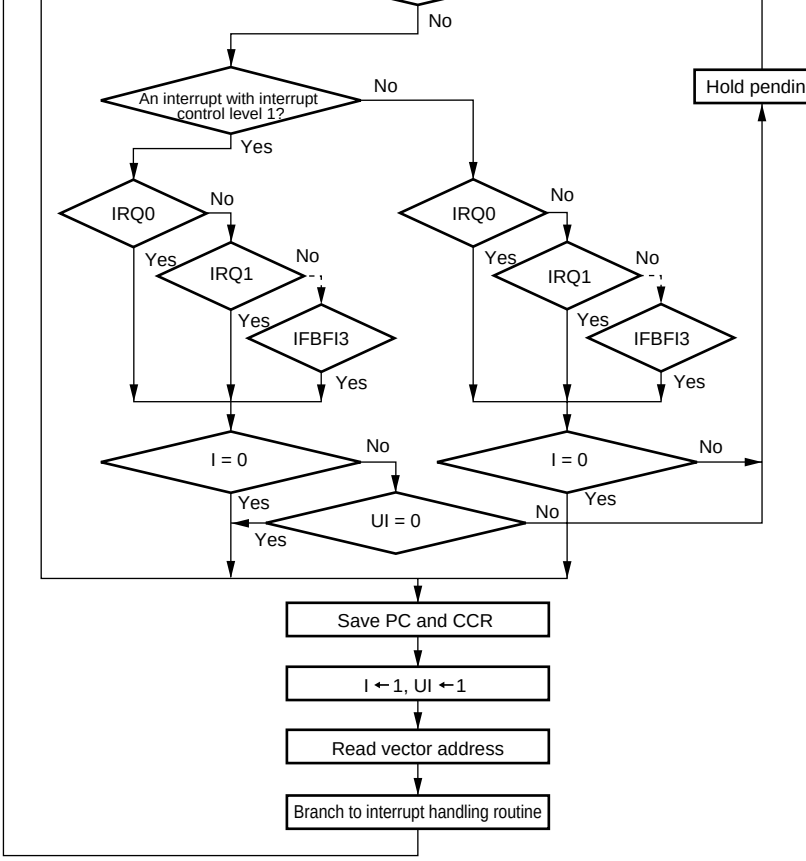


Figure 5.6 Flowchart of Procedure up to Interrupt Acceptance in Interrupt Control Mode 1

Figure 5.7 Interrupt Exception Handling

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
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 v

Table 5.6 Number of States in Interrupt Handling Routine Execution Status

		Object of Access			
			External Device		
			8-Bit Bus		16-Bi
Symbol		**Internal Memory**	**2-State Access**	**3-State Access**	**2-State Access**
Instruction fetch	S_I	1	4	6 + 2m	2
Branch address read	S_J				
Stack manipulation	S_K				

Legend:
m: Number of wait states in external device access

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

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

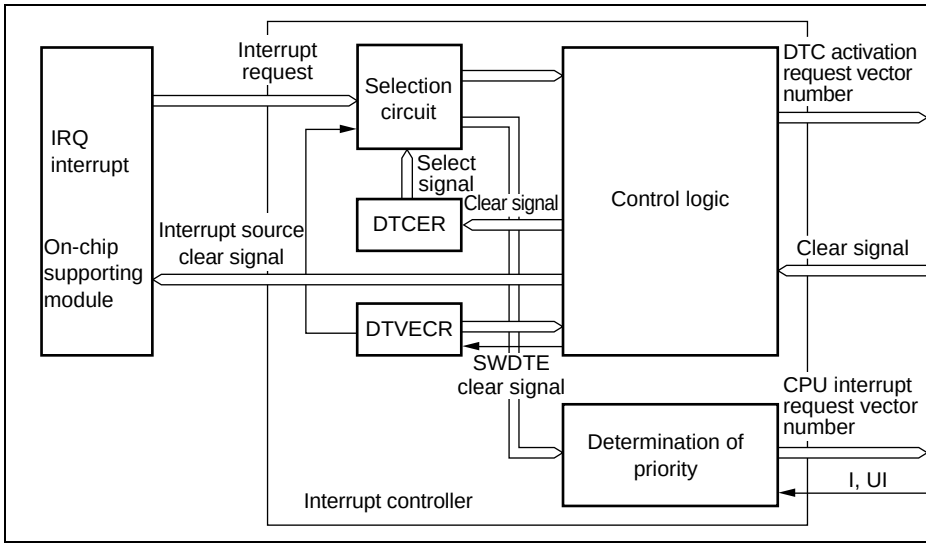


Figure 5.8 DTC and Interrupt Controller

Selection of Interrupt Source: Interrupt factors are selected as DTC activation sourc
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 t
DTC data transfer, and request a CPU interrupt.

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

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/Clearin	
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 writes to the prescribed register, and is not dependent upon the DISEL bit.

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.

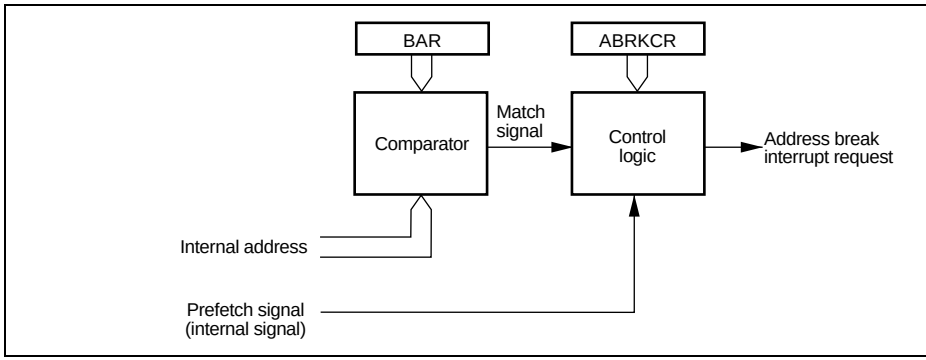


Figure 5.9 Address Break Block Diagram

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

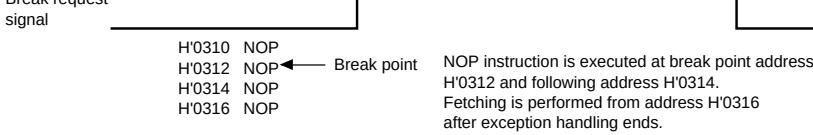
1. Set a break address in the A23 to A1 bits in BAR.
2. Set the BIE bit in ABRKCR to 1 to enable the address break.
   When the BIE bit is cleared to 0, an address break is not requested.

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

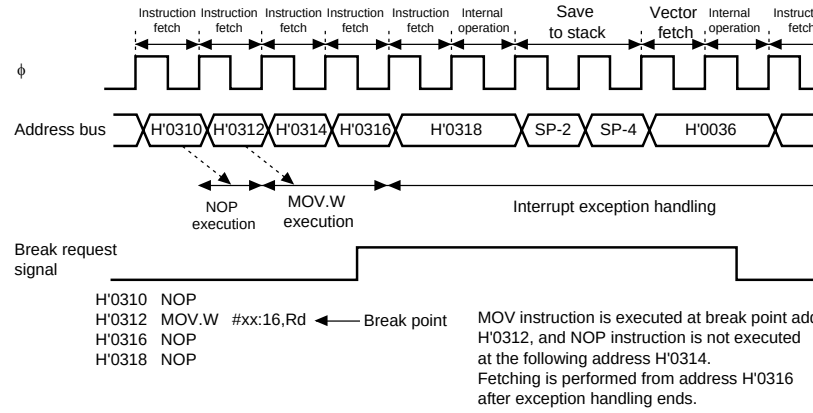
5.7.4 Usage Notes

1. In an address break, the break address should be an address where the first byte of t
   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 instr
   RTE instruction are placed immediately prior to the address specified by BAR, a pr
   signal to the address may be output to request an address break by executing these i
   It is necessary to take countermeasures: do not set a break address to an address imm
   after these instructions, or determine whether interrupt handling is performed by sat
   a normal condition.
4. An address break interrupt is generated by combining the internal prefetch signal ar
   address. Therefore, the timing to enter the interrupt exception handling differs acco
   instructions at the specified and at prior addresses and execution cycles.

Figure 5.10 shows an example of address timing.



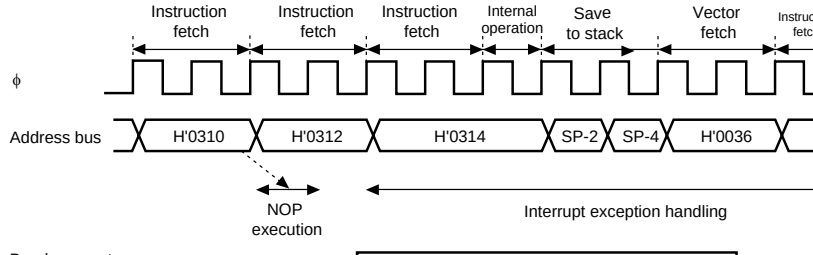
(2) When a break address specified instruction is executed for two states in the program area and on-chip memor



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 add
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 a
Fetching is performed from address H'0312
after exception handling ends.

Figure 5.10 Address Break Timing Example

interrupt exception handling for that interrupt will be executed on completion of the ins
However, if there is an interrupt request of higher priority than that interrupt, interrupt
handling will be executed for the higher-priority interrupt, and the lower-priority interr
ignored. The same rule is also applied when an interrupt source flag is cleared to 0. Fig
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
interrupt is masked.

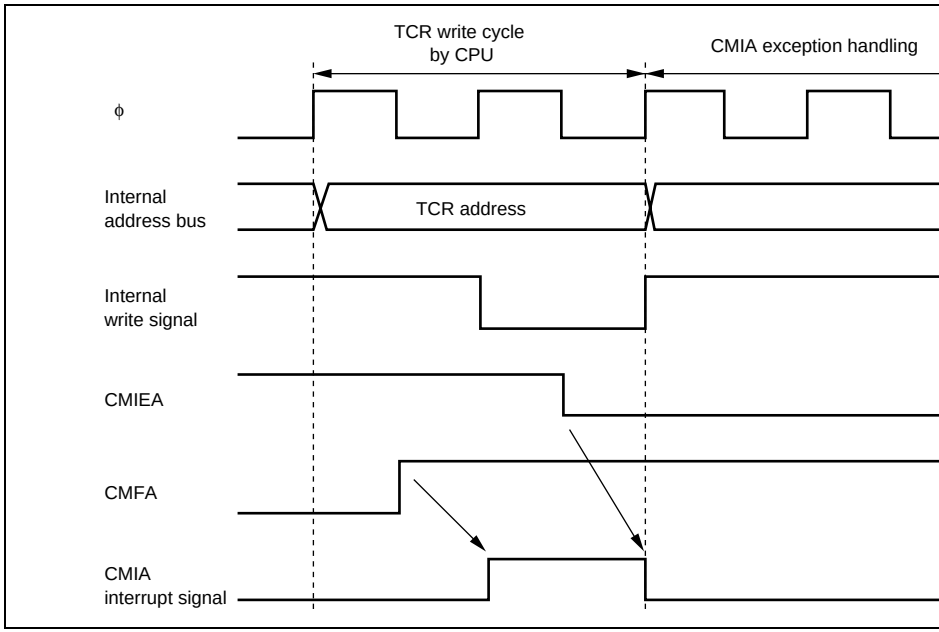


Figure 5.11 Conflict between Interrupt Generation and Disabling

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

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

With the EEPMOV.W instruction, if an interrupt request is issued during the transfer,
exception handling starts at a break in the transfer cycle. The PC value saved on the st
case is the address of the next instruction. Therefore, if an interrupt is generated durin
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, whi
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 aut
   cleared.
2. When DTCEA2 is set to 1(ICIA is set to an interrupt source), IRQ5F flag is not au
   cleared.
3. When DTCEA1 is set to 1(ICIB is set to an interrupt source), IRQ6F flag is not au
   cleared.
4. When DTCEA0 is set to 1(OCIA is set to an interrupt source), IRQ7F flag is not a
   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 t
corresponding IRQ.

- 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 r
- Bus arbitration function
  Includes a bus arbiter that arbitrates bus mastership between the CPU and DTC

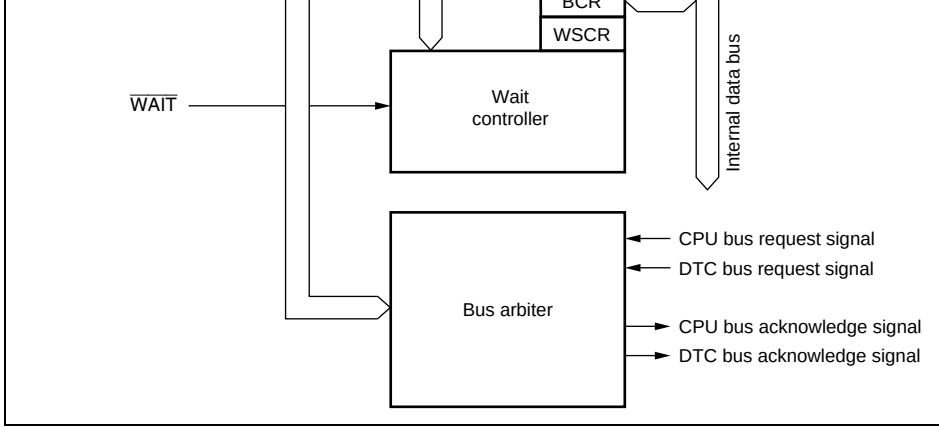


Figure 6.1 Block Diagram of Bus Controller

$\overline{IOS}$	Output	I/O select signal (when the IOSE bit in SYSCR is
$\overline{RD}$	Output	Strobe signal indicating that the external address being read.
$\overline{HWR}$	Output	Strobe signal indicating that the external address being written to, and the upper half (D15 to D8) o bus is enabled.
$\overline{LWR}$	Output	Strobe signal indicating that the external address being written to, and the lower half (D7 to D0) of t is enabled.
$\overline{WAIT}$	Input	Wait request signal when accessing the external access space.

6.3 Register Descriptions

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

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

6	ICIS0	1	R/W	Idle Cycle Insertion Selects whether or not to insert 1-state of th cycle between bus cycles when the externa cycle follows the external read cycle. 0: Idle cycle not inserted when the external follows the external read cycle 1: 1-state idle cycle inserted when the exte cycle follows the external read cycle
5	BRSTRM	0	R/W	Burst ROM Enable Selects the bus interface for the external ac 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 cy 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 ac 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 $\overline{\text{IOS}}$ sig output. For details, refer to table 6.3.

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 exte 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 address space. This bit also enables or di state insertion. 0: 2-state access space. Wait state inserti in external address space access 1: 3-state access space. Wait state inserti 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 ext address space when the AST bit is set to 00: Program wait mode 01: Wait disabled mode 10: Pin wait mode 11: Pin auto-wait mode

6.4 Bus Control

6.4.1 Bus Specifications

The external address space bus specifications consist of three elements: Bus width, the
access states, and the wait mode and the number of program wait states. The bus width
number of access states for on-chip memory and internal I/O registers are fixed, and ar
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 i
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
setting.

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

	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 on-chip ROM enable extended mode, the address space other than on-chip ROM, on-c internal I/O registers, and their reserved areas is specified as the external address spac chip RAM and its reserved area are enabled when the RAME bit in SYSCR is set to 1 chip RAM and its reserved area are disabled and corresponding addresses are the exte 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 on-chip ROM disable extended mode, the address space other than on-chip RAM and registers is specified as the external address space. In on-chip ROM enable extended m address space other than on-chip ROM, on-chip RAM, internal I/O registers, and their areas is specified as the external address space. The on-chip RAM area is enabled whe

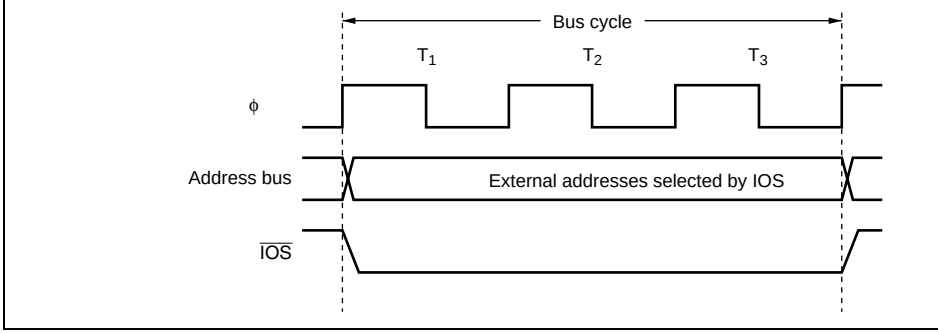


Figure 6.2 $\overline{\text{IOS}}$ Signal Output Timing

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

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

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

IOS1	IOS0	$\overline{\text{IOS}}$ 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 (In

a data alignment function, and controls whether the upper data bus (D15 to D8) or low
(D7 to D0) is used when the external address space is accessed, according to the bus s
for the area being accessed (8-bit access space or 16-bit access space) and the data siz

8-Bit Access Space: Figure 6.3 illustrates data alignment control for the 8-bit access s
the 8-bit access space, the upper data bus (D15 to D8) is always used for accesses. Th
data that can be accessed at one time is one byte: a word access is performed as two b
and a longword access, as four byte accesses.

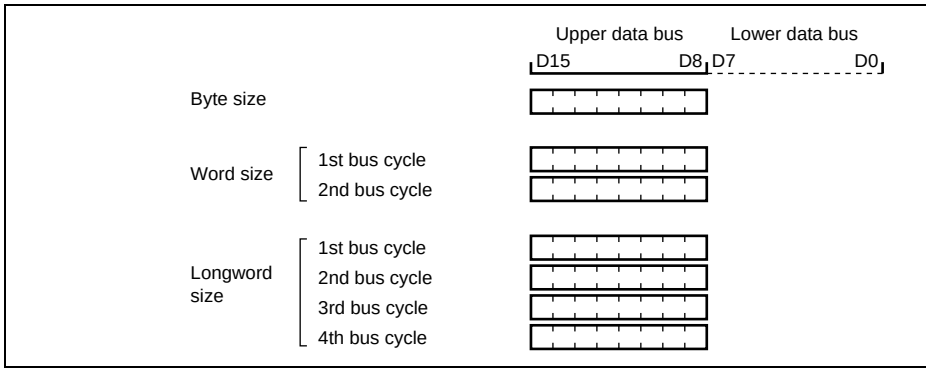


Figure 6.3 Access Sizes and Data Alignment Control (8-Bit Access Spa

16-Bit Access Space: Figure 6.4 illustrates data alignment control for the 16-bit acces
With the 16-bit access space, the upper data bus (D15 to D8) and lower data bus (D7 t
used for accesses. The amount of data that can be accessed at one time is one byte or
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 t
even or odd. The upper data bus is used for an even address, and the lower data bus fo
address.

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

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
$\overline{HWR}$ signal is valid for the upper half of the data bus, and the $\overline{LWR}$ signal for the lowe

Table 6.4 Data Buses Used and Valid Strobes

Area	Access Size	Read/ Write	Address	Valid Strobe	Upper Data Bus (D15 to D8)	Lowe Bus
8-bit access space	Byte	Read	—	$\overline{RD}$	Valid	Ports
		Write	—	$\overline{HWR}$		Ports
16-bit access space	Byte	Read	Even	$\overline{RD}$	Valid	Invali
			Odd		Invalid	Valid
		Write	Even	$\overline{HWR}$	Valid	Unde
			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 ar
as the data bus.

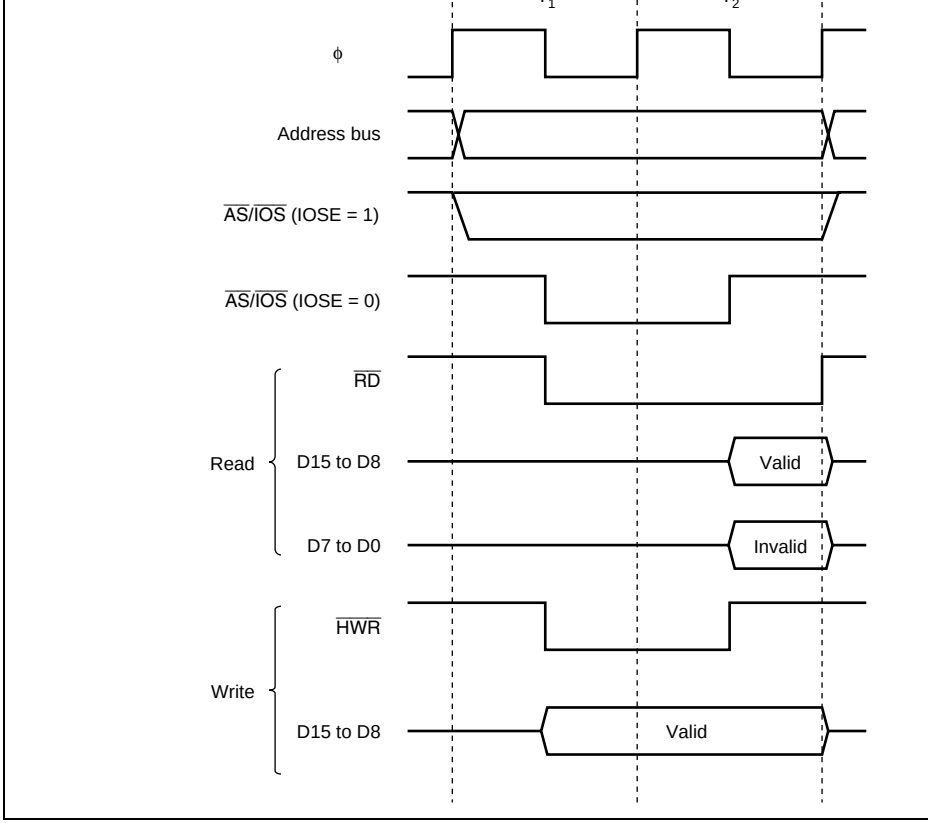


Figure 6.5 Bus Timing for 8-Bit, 2-State Access Space

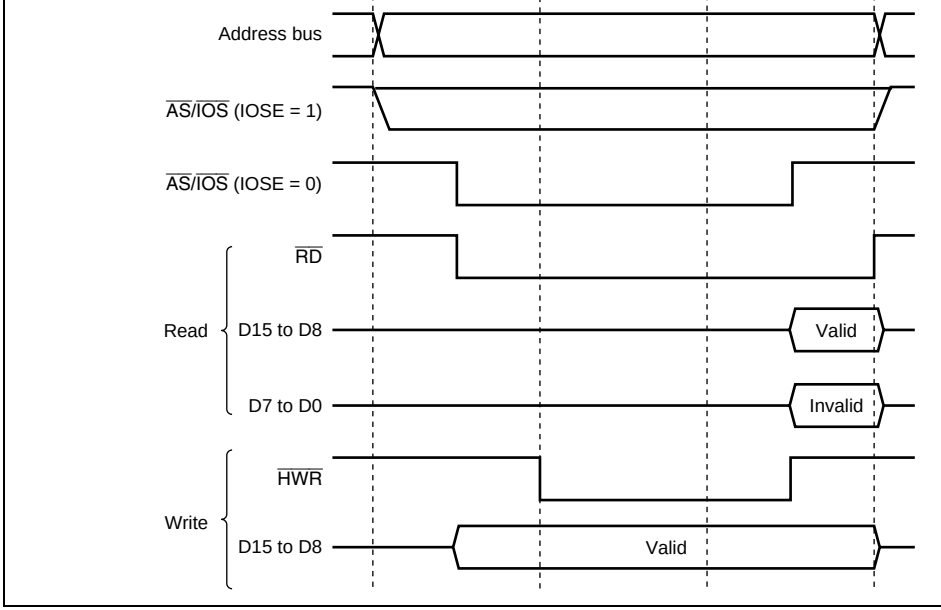


Figure 6.6 Bus Timing for 8-Bit, 3-State Access Space

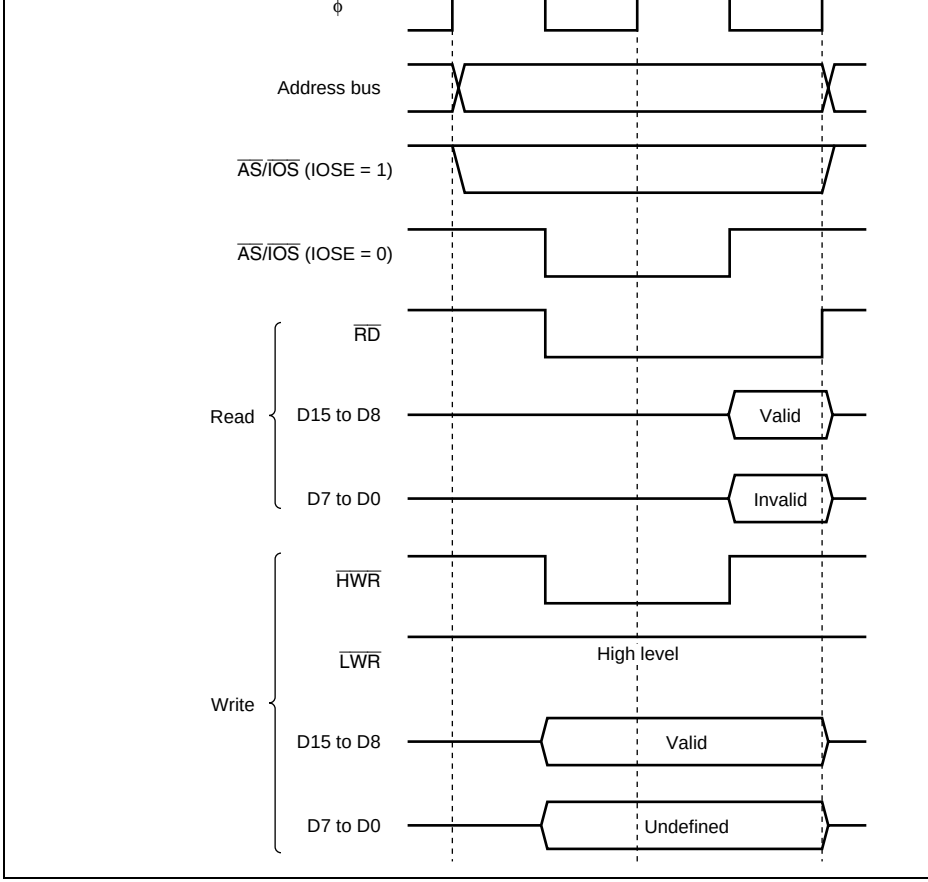


Figure 6.7 Bus Timing for 16-Bit, 2-State Access Space (Even Byte Acc

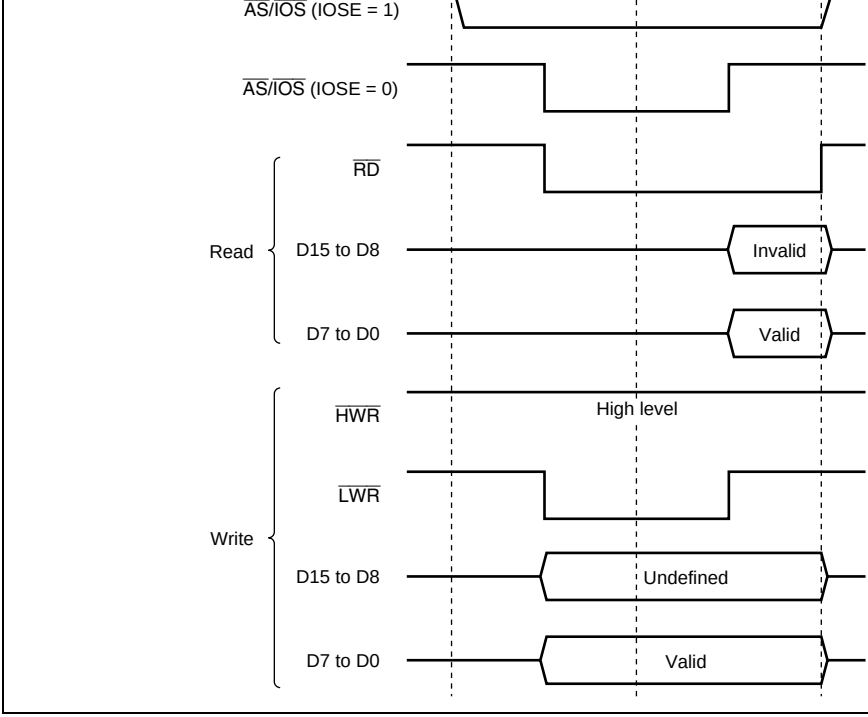


Figure 6.8 Bus Timing for 16-Bit, 2-State Access Space (Odd Byte Acces

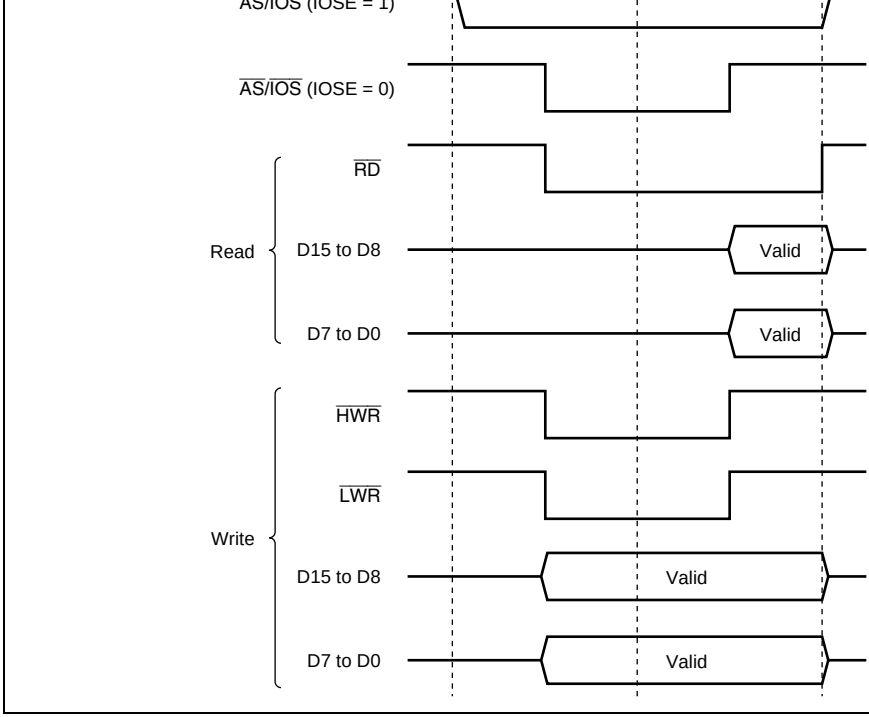


Figure 6.9 Bus Timing for 16-Bit, 2-State Access Space (Word Access

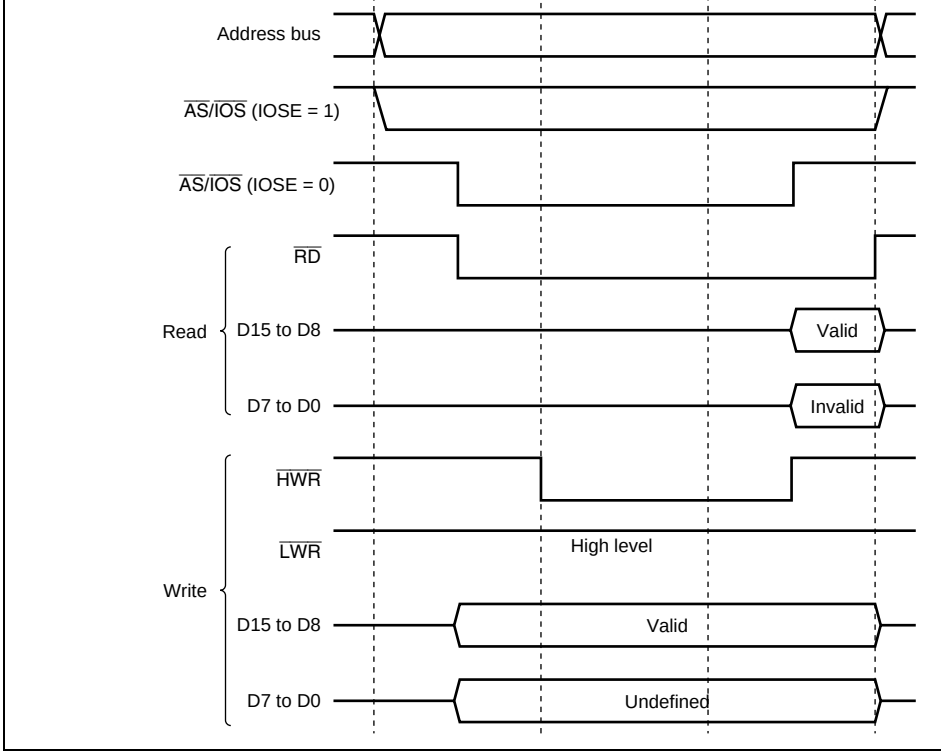


Figure 6.10 Bus Timing for 16-Bit, 3-State Access Space (Even Byte Acce

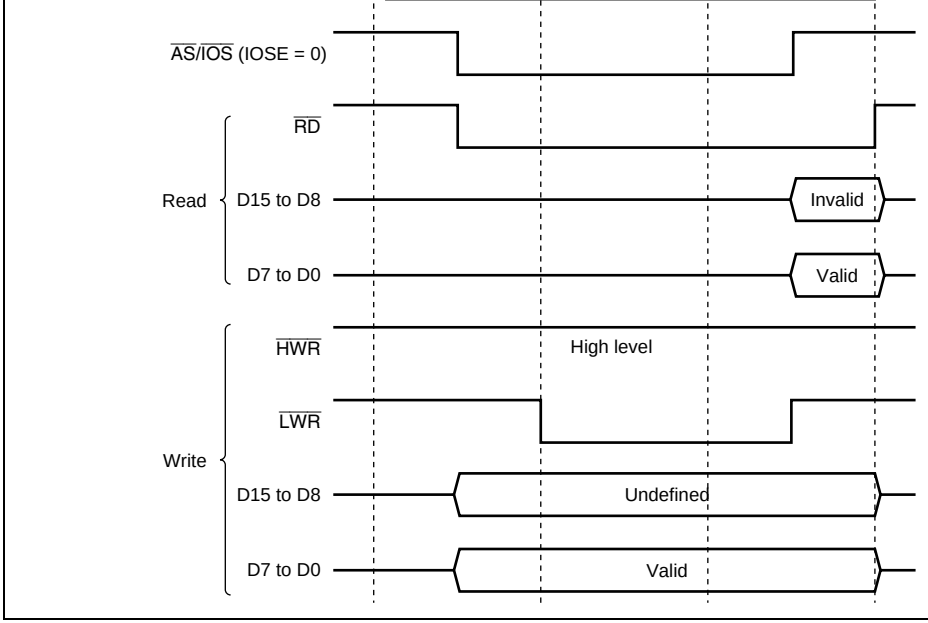


Figure 6.11 Bus Timing for 16-Bit, 3-State Access Space (Odd Byte Acc

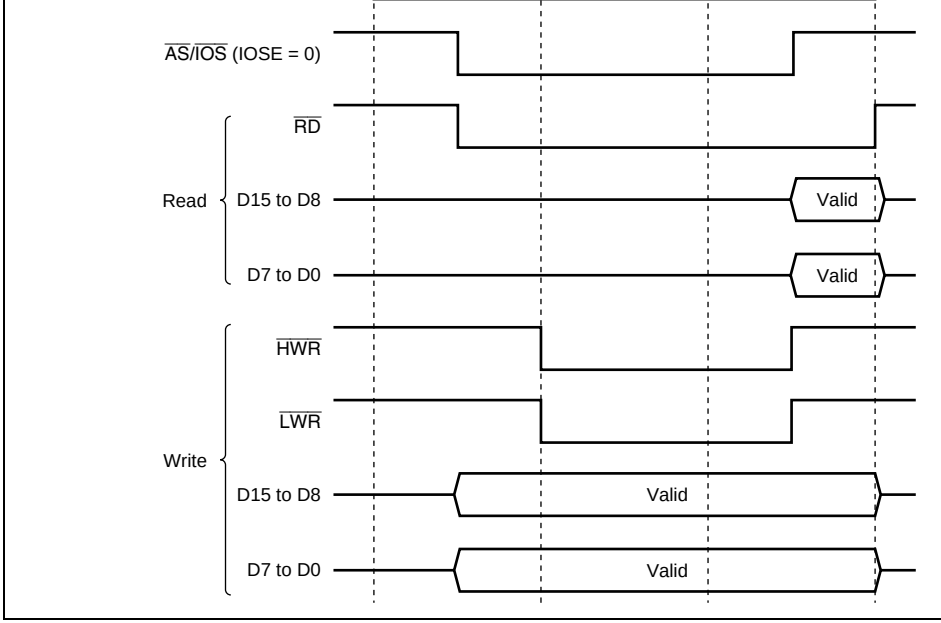


Figure 6.12 Bus Timing for 16-Bit, 3-State Access Space (Word Access

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 b
T_2 state and T_3 state when accessing the external address space always according to th
the WC1 and WC0 bits. If the $\overline{\text{WAIT}}$ pin is low at the falling edge of ϕ in the last T_2 o
another T_W state is inserted. If the $\overline{\text{WAIT}}$ pin is held low, T_W states are inserted until it

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

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

This function enables the low-speed memory interface only by inputting the chip selec
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 i
disabled.

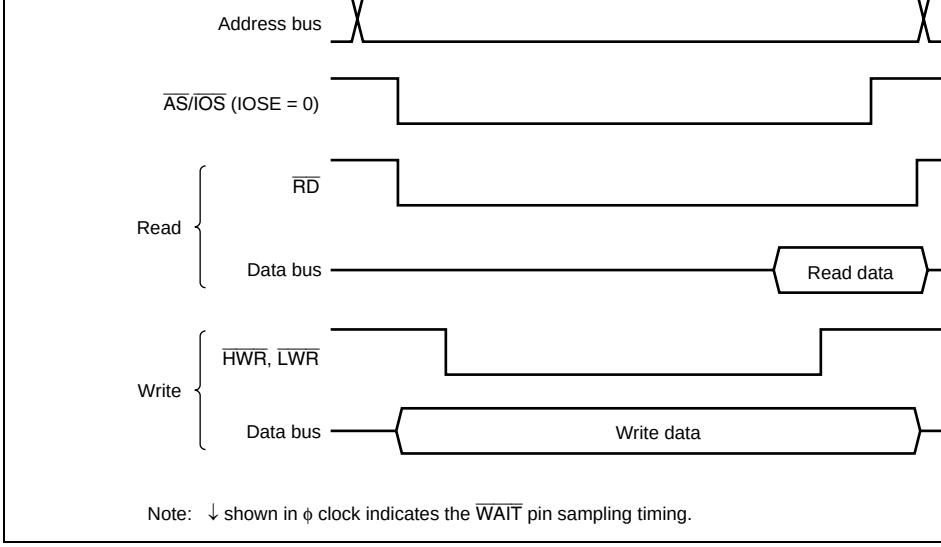


Figure 6.13 Example of Wait State Insertion Timing (Pin Wait Mode)

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

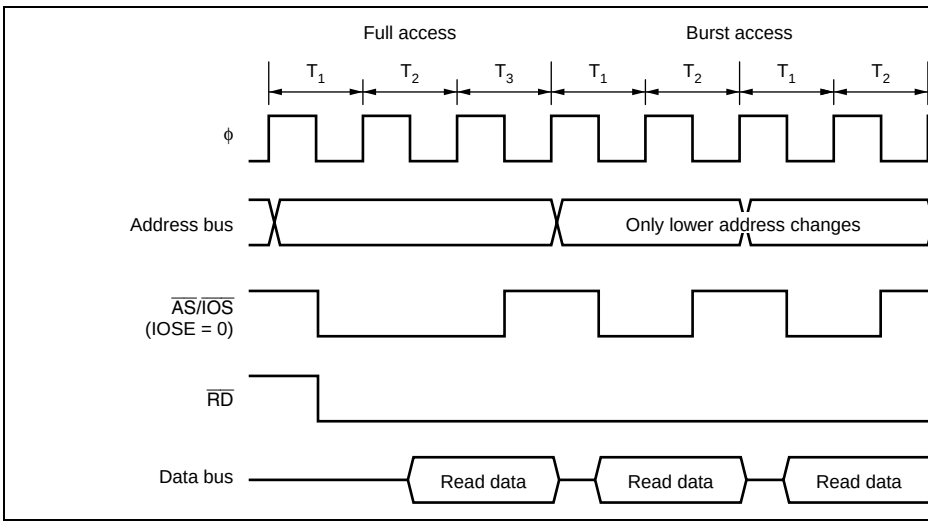


Figure 6.14 Access Timing Example in Burst ROM Space (AST = BRSTS

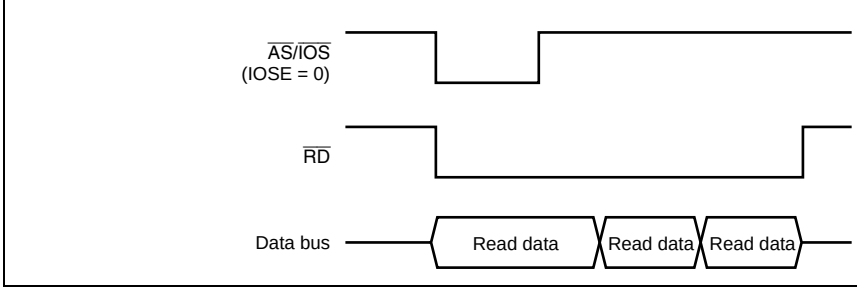


Figure 6.15 Access Timing Example in Burst ROM Space (AST = BRSTS1

6.6.2 Wait Control

As with the basic bus interface, program wait insertion or pin wait insertion using the $\overline{W}$ can be used in the initial cycle (full access) of the burst ROM interface. For details, see 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) bus cycles when a write cycle occurs immediately after a read cycle. By inserting an id possible, for example, to avoid data collisions between ROM with a long output floatin 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, 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 for ROM with a long output floating time, and bus cycle B is a CPU write cycle. In figu with no idle cycle inserted, a collision occurs in bus cycle B between the read data from the CPU write data. In figure 6.16 (b), an idle cycle is inserted, thus preventing data col

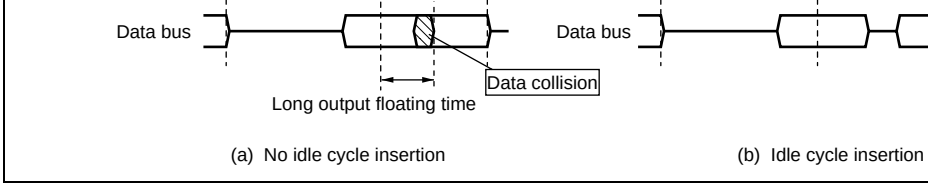


Figure 6.16 Examples of Idle Cycle Operation

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 c
D15 to D0	High impedance
$\overline{AS}$	High
$\overline{RD}$	High
$\overline{HWR}$, $\overline{LWR}$	High

Each bus master requests the bus by means of a bus request signal. The bus arbiter dete
masters' bus request signals, and if a bus request occurs, it sends a bus request acknowl
to the bus master making the request at the designated timing. If there are bus requests
than one bus master, the bus request acknowledge signal is sent to the one with the high
priority. When a bus master receives the bus request acknowledge signal, it takes posse
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
that has acquired the bus and is currently operating, the bus is not necessarily transferre
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 bus arbiter transfers the bus to the DTC.

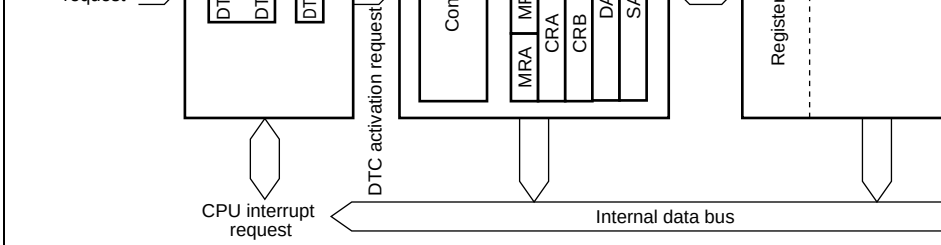
- DTC bus transfer timing
  - The bus is transferred at a break between bus cycles. However, if a bus cycle is
    discrete operations, as in the case of a longword-size access, the bus is not trans
    between the component operations. For details, refer to the H8S/2600 Series, H8
    Series Programming 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 re
the bus when an activation request is generated. The DTC does not release the bus until
completes its operation.

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



Legend:

MRA, MRB	: DTC mode register A, B
CRA, CRB	: DTC transfer count register A, B
SAR	: DTC source address register
DAR	: DTC destination register
DTCERA to DTCERE	: DTC enable registers A to E
DTVECR	: DTC vector register

Figure 7.1 Block Diagram of DTC

- 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 source occurs, the DTC reads a set of register information that is stored in on-chip RA corresponding DTC registers and transfers data. After the data transfer, it writes a set 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.

				(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 d 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 des side is set to be a repeat area or block area mode or block transfer mode. 0: Destination side is repeat area or block ar 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

				In data transfer with CHNE set to 1, determ the end of the specified number of data tra clearing of the interrupt source flag, and cle DTCER are not performed.
6	DISEL	Undefined	—	DTC Interrupt Select When this bit is set to 1, a CPU interrupt re generated every time data transfer ends (th clears the interrupt source flag for the activa source). When this bit is cleared to 0, a CP request is generated only when the specifie data transfer ends (the DTC does not clear source flag for the activation source).
5 to 0	—	Undefined	—	Reserved These bits have no effect on DTC operation 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 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 transferre DTC. For word-size transfer, specify an even destination address.

functions as an 8-bit transfer counter (1 to 256). CRAL is decremented by 1 every time 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 block transfer mode. It functions as a 16-bit transfer counter (1 to 65536) that is decrem 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 regist DTCERA to DTCERE. The correspondence between interrupt sources and DTCE bits table 7.1. For DTCE bit setting, use bit manipulation instructions such as BSET and BC Multiple DTC activation sources can be set at one time (only at the initial setting) by m 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 interru as a DTC activation source.
5	DTCE5	0	R/W	[Clearing conditions]
4	DTCE4	0	R/W	• When data transfer has ended with the DI MRB set to 1.
3	DTCE3	0	R/W	• When the specified number of transfers h
2	DTCE2	0	R/W	[Holding condition]
1	DTCE1	0	R/W	When the DISEL bit is 0 and the specified nu transfers have not been completed.
0	DTCE0	0	R/W	

				Setting this bit to 1 activates DTC. Only 1 c written to this bit. 0 can be written to after re from this bit. [Clearing conditions] • When the DISEL bit is 0 and the specifi transfers have not ended. • When 0 is written to the DISEL bit after activated data transfer end interrupt (SW request has been sent to the CPU. [Holding conditions] • When the DISEL bit is 1 and data transf ended • When the specified number of transfers • During data transfer activated by softwa
6	DTVEC6	0	R/W	DTC Software Activation Vectors 6 to 0 These bits specify a vector number for DTC activation. The vector address is expressed as H'0400 + (vector number × 2). For example, when DTVEC6 t H'10, the vector address is H'0420. When th 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	

and interrupt controller priorities have no effect. If there is more than one activation sou
same time, the DTC operates in accordance with the default priorities. Figure 7.2 shows
diagram of DTC activation source control. For details on the interrupt controller, see se
Interrupt Controller.

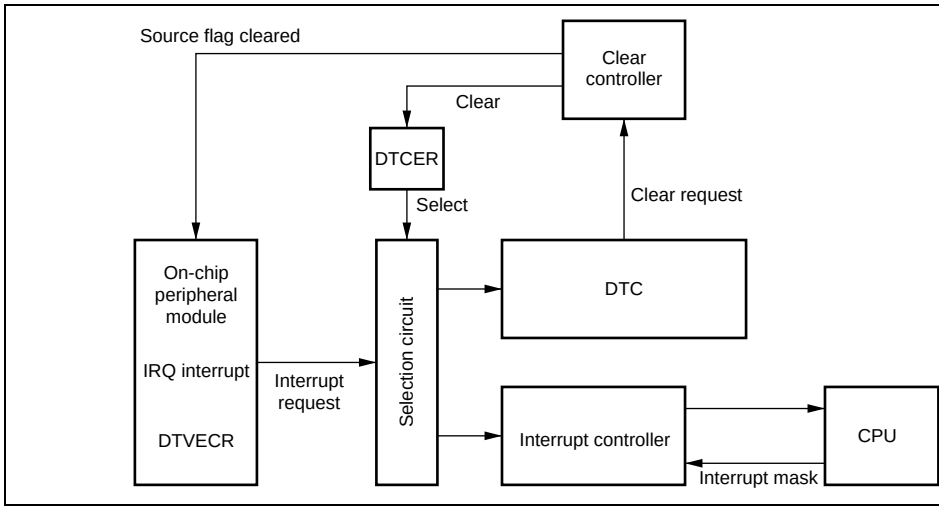


Figure 7.2 Block Diagram of DTC Activation Source Control

vector address corresponding to the interrupt source in the DTC vector table. The DTC start address of the register information from the vector table set for each activation so 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 mod unit is used in both cases. Specify the lower two bits of the register information start a

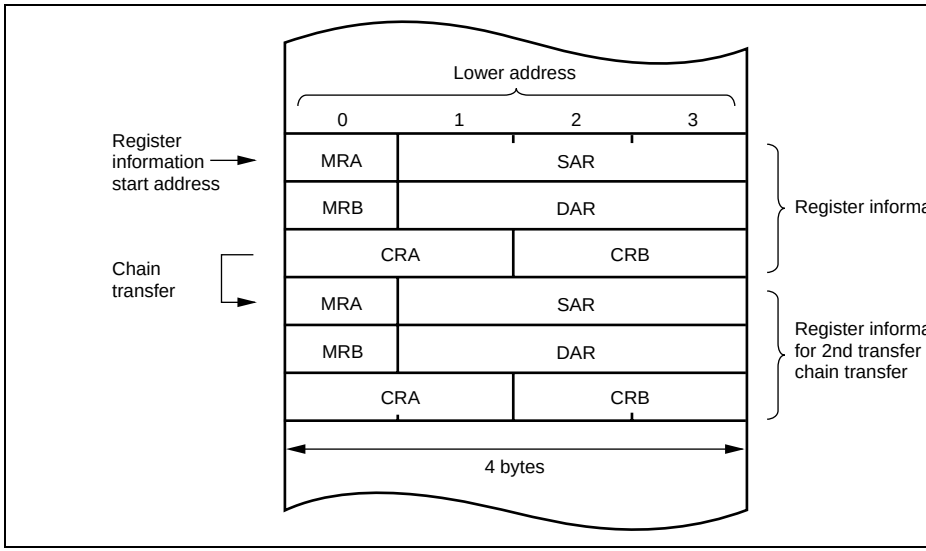


Figure 7.3 DTC Register Information Location in Address Space

	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

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

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

The 24-bit SAR designates the DTC transfer source address, and the 24-bit DAR desig
transfer destination address. After each transfer, SAR and DAR are independently inc
decremented, or left fixed depending on its register information.

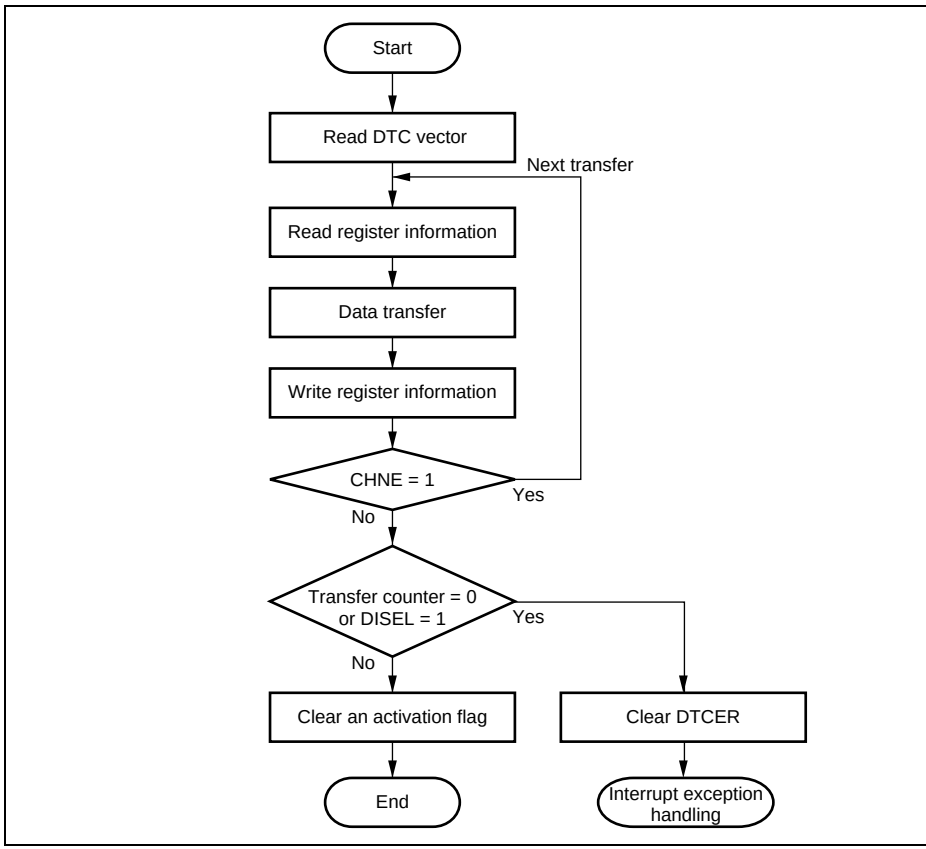


Figure 7.4 DTC Operation Flowchart

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

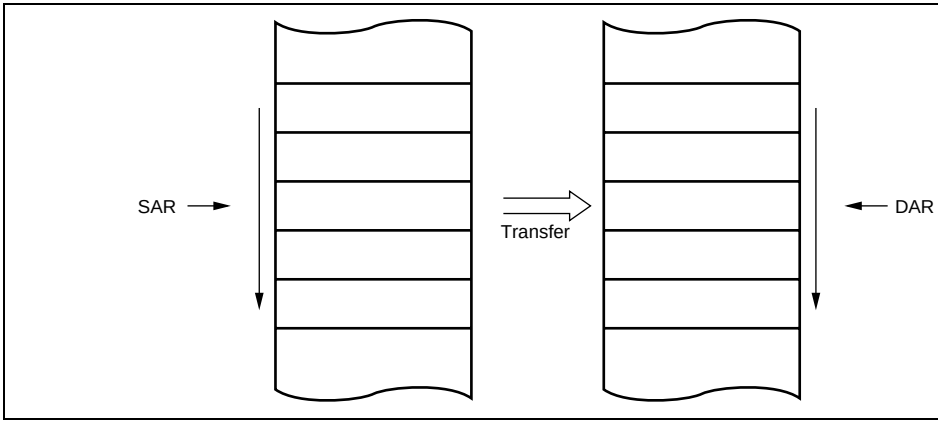


Figure 7.5 Memory Mapping in Normal Mode

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 addr
DTC transfer count register AH	CRAH	Holds number of transfer
DTC transfer count register AL	CRAL	Transfer Count
DTC transfer count register B	CRB	Not used

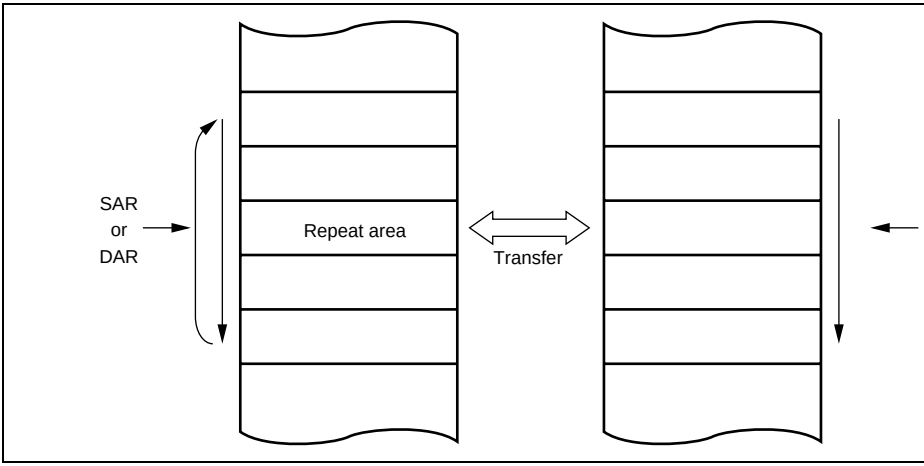


Figure 7.6 Memory Mapping in Repeat Mode

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 addre
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

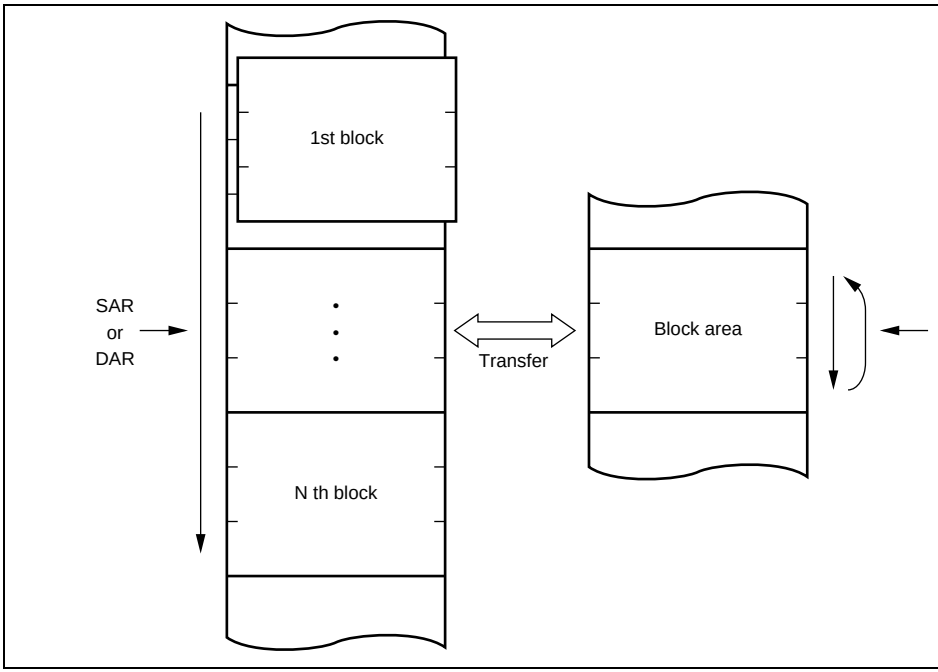


Figure 7.7 Memory Mapping in Block Transfer Mode

been set to 1, DTC reads the next register information located in a consecutive area an
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 n
at the end of the specified number of transfers or by setting of the DISEL bit to 1, and
source flag for the activation source is not affected.

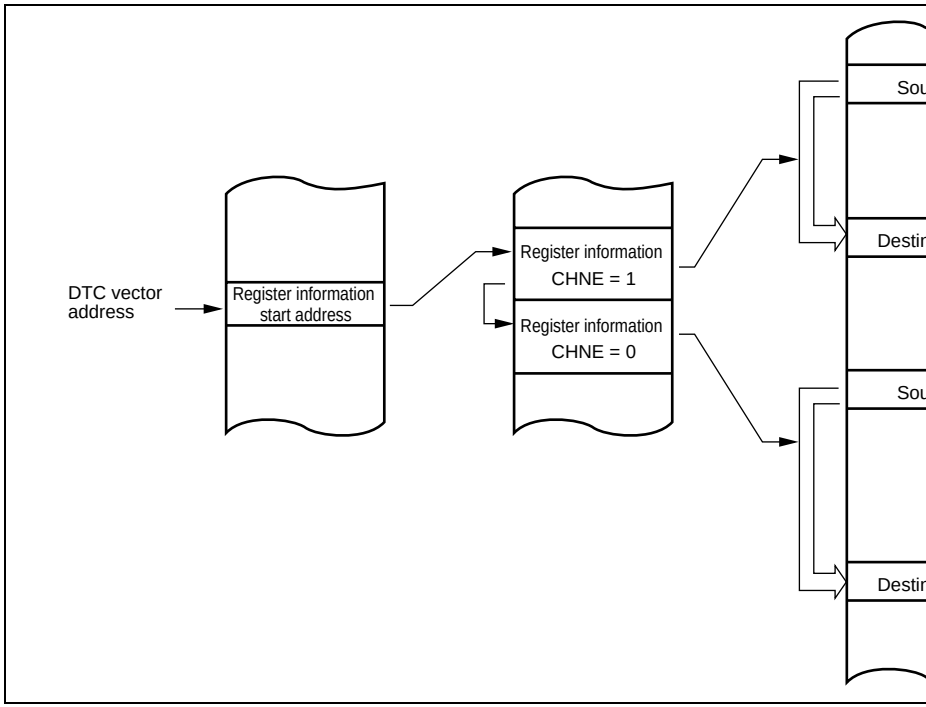


Figure 7.8 Chain Transfer Operation

When the DISEL bit is 1 and one data transfer has been completed, or the specified nur
transfers have been completed, after data transfer ends, the SWDTE bit is held at 1 and
SWDTEND interrupt is generated. The interrupt handling routine will then clear the SW
to 0.

When the DTC is activated by software, an SWDTEND interrupt is not generated durin
transfer wait or during data transfer even if the SWDTE bit is set to 1.

7.5.6 Operation Timing

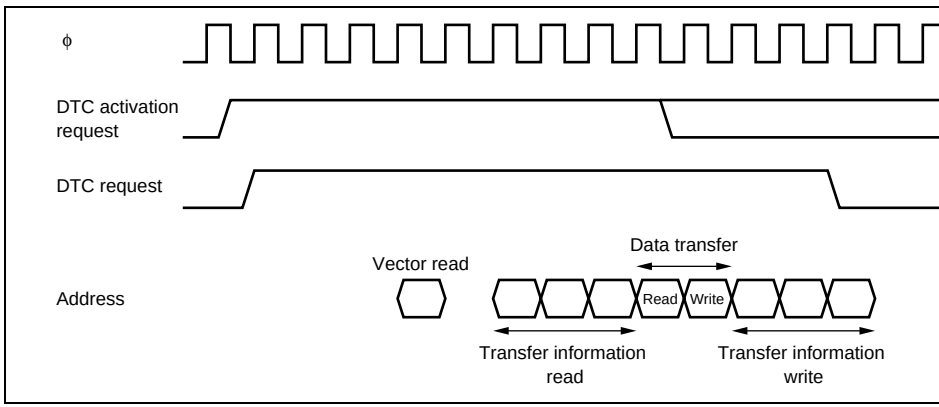


Figure 7.9 DTC Operation Timing (Example in Normal Mode or Repeat M

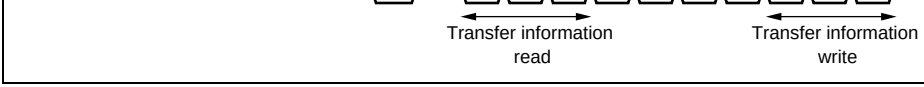


Figure 7.10 DTC Operation Timing (Example of Block Transfer Mod with Block Size of 2)

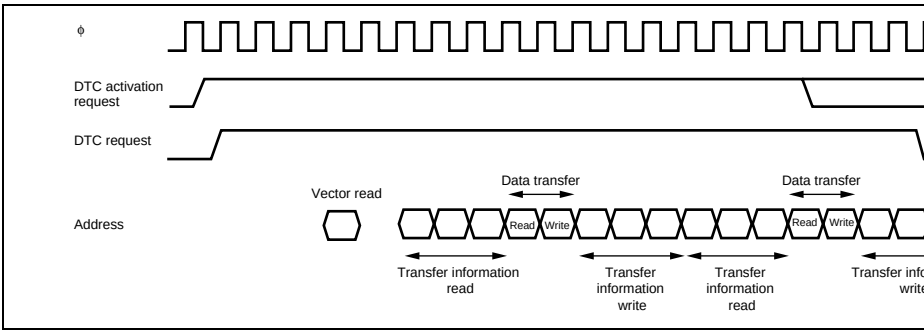


Figure 7.11 DTC Operation Timing (Example of Chain Transfer)

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 of states required for each execution status.

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 Dev		
Bus width			32	16	8	16	8		
Access states			1	1	2	2	2	3	2
Execution status	Vector read	S_I	—	1	—	—	4	6 + 2m	2
	Register information read/write	S_J	1	—	—	—	—	—	—
	Byte data read	S_K	1	1	2	2	2	3 + m	2
	Word data read	S_K	1	1	4	2	4	6 + 2m	2
	Byte data write	S_L	1	1	2	2	2	3 + m	2
	Word data write	S_L	1	1	4	2	4	6 + 2m	2
	Internal operation	S_M	1						

The number of execution states is calculated from using the formula below. Note that Σ of all transfers activated by one activation source (the number in which the CHNE bit is 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 m and data is transferred from on-chip ROM to an internal I/O register, then the time requ DTC operation is 13 states. The time from activation to the end of data write is 10 state

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 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 tr been completed, the DTCE bit is cleared to 0 and a CPU interrupt is requested. If t 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 R
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 interru requested, the SWDTE bit is cleared to 0. If the DTC is to continue transferring da SWDTE bit to 1. When the DISEL bit is 1 or after the specified number of data tra been completed, the SWDTE bit is held at 1 and a CPU interrupt is requested.

any value. Set MRB for one data transfer by one interrupt (CHNE = 0, DISEL = 0). SCI, RDR address in SAR, the start address of the RAM area where the data will be 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 th complete (RXI) interrupt. Since the generation of a receive error during the SCI rec operation will disable subsequent reception, the CPU should be enabled to accept re interrupts.
5. Each time the reception of one byte of data has been completed on the SCI, the RDI SSR is set to 1, an RXI interrupt is generated, and the DTC is activated. The receive transferred from RDR to RAM by the DTC. DAR is incremented and CRA is decre The RDRF flag is automatically cleared to 0.
6. When CRA becomes 0 after 128 data transfers have been completed, the RDRF flag 1, the DTCE bit is cleared to 0, and an RXI interrupt request is sent to the CPU. The handling routine will perform wrap-up processing.

0). The DTS bit can have any value. Set MRB for one block transfer by one interru
0). Set the transfer source address (H'1000) in SAR, the transfer destination addres
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 trans
by software.
4. Write 1 to the SWDTE bit and the vector number (H'60) to DTVECR. The write d
5. Read DTVECR again and check that it is set to the vector number (H'60). If it is n
indicates that the write failed. This is presumably because an interrupt occurred be
3 and 4 and led to a different software activation. To activate this transfer, go back
6. If the write was successful, the DTC is activated and a block of 128 bytes of data i
7. After the transfer, an SWDTEND interrupt occurs. The interrupt handling routine
the SWDTE bit to 0 and perform wrap-up processing.

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 D
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 r
writing. Multiple DTC activation sources can be set at one time (only at the initial setti
masking all interrupts and writing data after executing a dummy read on the relevant re

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
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 Converte

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

for H8S/2100B and H8S/2101B.

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

Each port includes a data direction register (DDR) that controls input/output (not prov 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 on/off status of the input pull-up MOS is controlled by DDR and ODR. Ports 1 to 3 ar input pull-up MOS control register (PCR), in addition to DDR, to control the on/off st 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 ports can drive a Darlington transistor when in output mode. Ports 1 to 3 can drive an mA sink current).

Port A input and output use by the VccB power supply, which is independent of the V 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 outp P97, P86 and P42 are thus 5-V tolerant, with DC characteristics that are dependent on voltage.

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

		A3	A3/P13/PW3	P13/PW3
		A2	A2/P12/PW2	P12/PW2
		A1	A1/P11/PW1	P11/PW1
		A0	A0/P10/PW0	P10/PW0
Port 2	General I/O port also functioning as address output pin, PWM output pin, and timer connection output pin	A15	A15/P27/PW15/ CBLANK	P27/PW15/CBLANK
		A14	A14/P26/PW14	P26/PW14
		A13	A13/P25/PW13	P25/PW13
		A12	A12/P24/PW12	P24/PW12
		A11	A11/P23/PW11	P23/PW11
		A10	A10/P22/PW10	P22/PW10
		A9	A9/P21/PW9	P21/PW9
		A8	A8/P20/PW8	P20/PW8
Port 3	General I/O port also functioning as data bus input/output, XBS data bus input/output, and LPC input/output pins	D15		P37/HDB7/SERIRQ*
		D14		P36/HDB6/LCLK*
		D13		P35/HDB5/$\overline{\text{LRESET}}$*
		D12		P34/HDB4/$\overline{\text{LFRAME}}$*
		D11		P33/HDB3/LAD3*
		D10		P32/HDB2/LAD2*
		D9		P31/HDB1/LAD1*
		D8		P30/HDB0/LAD0*

	interface input/output, and IIC_1 input/output pins	P41/TMO0/RxD2/IrRxD P40/TMCI0/TxD2/IrTxD	P43/TMCI1/HIRQ11/HSYNCI P42/TMRI0/SCK2/SDA 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	
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	

		P80		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		P97/SDA0
		P96/ϕ/EXCL		P96/ϕ/EXCL
		$\overline{\text{AS}}$/$\overline{\text{IOS}}$		P95/$\overline{\text{CS1}}$
		$\overline{\text{HWR}}$		P94/$\overline{\text{IOW}}$
		$\overline{\text{RD}}$		P93/$\overline{\text{IOR}}$
		P92/$\overline{\text{IRQ0}}$		P92/$\overline{\text{IRQ0}}$
		P91/$\overline{\text{IRQ1}}$		P91/$\overline{\text{IRQ1}}$
		P90/$\overline{\text{LWR}}$/$\overline{\text{IRQ2}}$/$\overline{\text{ADTRG}}$		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	PA7/A23/$\overline{\text{KIN15}}$/ CIN15/PS2CD	PA7/$\overline{\text{KIN15}}$/CIN15/ PS2CD
		PA6/$\overline{\text{KIN14}}$/ CIN14/PS2CC	PA6/A22/$\overline{\text{KIN14}}$/ CIN14/PS2CC	PA6/$\overline{\text{KIN14}}$/CIN14/ PS2CC
		PA5/$\overline{\text{KIN13}}$/ CIN13/PS2BD	PA5/A21/$\overline{\text{KIN13}}$/ CIN13/PS2BD	PA5/$\overline{\text{KIN13}}$/CIN13/ PS2BD
		PA4/$\overline{\text{KIN12}}$/ CIN12/PS2BC	PA4/A20/$\overline{\text{KIN12}}$/ CIN12/PS2BC	PA4/$\overline{\text{KIN12}}$/CIN12/ PS2BC
		PA3/$\overline{\text{KIN11}}$/ CIN11/PS2AD	PA3/A19/$\overline{\text{KIN11}}$/ CIN11/PS2AD	PA3/$\overline{\text{KIN11}}$/CIN11/ PS2AD
		PA2/$\overline{\text{KIN10}}$/ CIN10/PS2AC	PA2/A18/$\overline{\text{KIN10}}$/ CIN10/PS2AC	PA2/$\overline{\text{KIN10}}$/CIN10/ PS2AC
		PA1/$\overline{\text{KIN9}}$/ CIN9	PA1/A17/$\overline{\text{KIN9}}$/CIN9	PA1/$\overline{\text{KIN9}}$/CIN9
		PA0/$\overline{\text{KIN8}}$/ CIN8	PA0/A16/$\overline{\text{KIN8}}$/CIN8	PA0/$\overline{\text{KIN8}}$/CIN8

		PB1/D1/$\overline{\text{WUE1}}$* PB0/D0/$\overline{\text{WUE0}}$*	PB1/$\overline{\text{WUE1}}$*/HIRQ4/LSCI* PB0/$\overline{\text{WUE0}}$*/HIRQ3/$\overline{\text{LSMI}}$*

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

- 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:
6	P16DDR	0	W	Each pin of port 1 is address output reg
5	P15DDR	0	W	the set value of P1DDR.
4	P14DDR	0	W	In modes 2 and 3 (EXPE=1):
3	P13DDR	0	W	The corresponding port 1 pins are addre
2	P12DDR	0	W	or PWM output ports when P1DDR bits 1, and input ports when cleared to 0.
1	P11DDR	0	W	In modes 2 and 3 (EXPE=0):
0	P10DDR	0	W	The corresponding port 1 pins are outpu PWM outputs when the P1DDR bits are and input ports when cleared to 0.

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 tu 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	

P1nDDR	—	0	1		0	1
OEn	—	—	0	1	—	0
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

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. T
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 Operatio
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 of

- 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:
6	P26DDR	0	W	The corresponding port 2 pins are ado outputs, regardless of the P2DDR set
5	P25DDR	0	W	Modes 2 and 3 (EXPE = 1):
4	P24DDR	0	W	The corresponding port 2 pins are ado outputs or PWM outputs when P2DDR set to 1, and input ports when cleared P24 are switched from address output ports by setting the IOSE bit to 1.
3	P23DDR	0	W	
2	P22DDR	0	W	
1	P21DDR	0	W	
0	P20DDR	0	W	P27 can be used as an on-chip periph output pin regardless of the P27DDR to ensure normal access to external s should not be set as an on-chip periph module output pin when port 2 pins ar address output pins.
				Modes 2 and 3 (EXPE = 0):
				The corresponding port 2 pins are out PWM outputs when P2DDR bits are s input ports when cleared to 0.
				P27 can be used as an on-chip periph output pin regardless of the P27DDR

4	P24DR	0	R/W	the pin states are read.
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 MO
6	P26PCR	0	R/W	on when a P2PCR bit is set to 1 in the
5	P25PCR	0	R/W	state.
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	

the P27DDR bit, and operating mode.

Operating Mode	Mode 1	Mode 2, 3 (EXPE = 1)					Mode 2, 3 (EXP		
CBOE	—	0				1	0		
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	PW outp pi

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

  The pin function is switched as shown below according to the combination of the I
  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 (E	
P2nDDR	—	0	1			0	
OEm	—	—	0		1	—	0
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 t P24 outpu pins

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

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

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. T
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 Operatio
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 of

- 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)
6	P36DDR	0	W	The input/output direction specified by ignored, and pins automatically functio I/O pins.
5	P35DDR	0	W	
4	P34DDR	0	W	Modes 2 and 3 (EXPE = 0)
3	P33DDR	0	W	The corresponding port 3 pins are outp when P3DDR bits are set to 1, and inp when cleared to 0.
2	P32DDR	0	W	
1	P31DDR	0	W	
0	P30DDR	0	W	

4	P34DR	0	R/W	the pin states are read.
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 up MOS is turned on when a P3PCR bi in the input port state.
6	P36PCR	0	R/W	
5	P35PCR	0	R/W	The input pull-up MOS function cannot
4	P34PCR	0	R/W	when the host interface is enabled.
3	P33PCR	0	R/W	
2	P32PCR	0	R/W	
1	P31PCR	0	R/W	
0	P30PCR	0	R/W	

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			
HI12E	0	0		1	
P3nDDR	—	0	1	—	
Pin Function	D15 to D8 input/output pins	P37 to P30 input pins	P37 to P30 output pins	HDB7 to HDB0 input/output pins	i

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 t
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. T
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 Othe Operat
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 o

- 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 outpu when cleared to 0, as an input port.
6	P46DDR	0	W	
5	P45DDR	0	W	As 14-bit PWM and SCI_2 are initialized software standby mode, the pin states a determined by the TMR_0, TMR_1, XBS P4DDR, and P4DR specifications.
4	P44DDR	0	W	
3	P43DDR	0	W	
2	P42DDR	0	W	
1	P41DDR	0	W	
0	P40DDR	0	W	

4	P44DR	0	R/W	the pin states are read.
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 C
  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 ou

- P46/PWX0

  The pin function is switched as shown below according to the combination of the C
  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 ou

Note: * When bits CCLR1 and CCLR0 in TCR1 of TMR_1 are set to 1, this pin is use
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 H
  SYSCR2, the OS3 to OS0 bits in TCSR of TMR_1, the HOE bit in TCONRO of the
  connection function, and the P44DDR bit.

HOE	0				
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	H c

- P43/TMCI1/HIRQ11/HSYNCI

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

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

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

CKE0	0		1	—	—	
P42DDR	0	1	—	—	—	
Pin Function	P42 input pin	P42 output pin	SCK2 output pin	SCK2 output pin	SCK2 input pin	
	TMRI0 input pin*					

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

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

When the P42 output pin and SCK2 output pin are set, the output type is N pull output.

- P41/TMO0/RxD2/IrRxD

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

OS3 to OS0	All 0			N
RE	0		1	
P41DDR	0	1	—	
Pin Function	P41 input pin	P41 output pin	RxD2/IrRxD input pin	o

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

	TMCI0 input pin*

Note: * When an external clock is selected with bits CKS2 to CKS0 in TCR0 of TMR 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 and SCK0 are NMOS push-pull outputs, and SCL0 is an NMOS open-drain output. Por 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 outp when P5DDR bits are set to 1, and inpu when cleared to 0. As SCI_0 is initialize software standby mode, the pin states determined by the IIC_0 ICCR, P5DDR P5DR specifications.
1	P51DDR	0	W	
0	P50DDR	0	W	

1	P51DR	0	R/W	set to 1, the P5DR values are read dir regardless of the actual pin states. If a
0	P50DR	0	R/W	is performed while P5DDR bits are cle the pin states are read.

8.6.3 Pin Functions

- P52/SCK0/SCL0

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

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

Note: When this pin is used as the SCL0 I/O pin, bits CKE1 and CKE0 in SCR of SCI
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-

- P50/TxD0

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

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

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 pi
TMR_Y input pin, timer connection I/O pins, key-sense interrupt input pins, expansion
converter input pins, and external interrupt input pins. The port 6 input level can be swi
four stages. Port 6 pin functions are the same in all operating modes. For details on the
control register 2 (SYSCR2), refer to section 18, Host Interface X-Bus Interface (XBS)
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)

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 P6D set to 1, the P6DR values are read dir regardless of the actual pin states. If a is performed while P6DDR bits are cle 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	

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 O bits in TCSR of TMR_X and the P67DDR bit.

OS3 to OS0	All 0		Not a
P67DDR	0	1	–
Pin Function	P67 input pin	P67 output pin	TMOX ou
	$\overline{\text{IRQ7}}$ 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 ca be used as the $\overline{\text{KIN7}}$ or CIN7 input pin.

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

- 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
  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
	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	

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

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

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

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

Note: * When this pin is used as the VSYNCO pin, bit OEA in TOCR of the FRT mus
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 CIN0 input pin*	

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

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

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In Other Operati
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

8.8 Port 7

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

- Port 7 input data register (P7PIN)

4	P74PIN	Undefined*	R	changed.
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 D
  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 outp
	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 D
  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 outp
	AN6 input pin*		

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

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 p pins, LPC I/O pins, and interrupt input pins. The output type of P86 and SCK1 is NM output. The output type of SCL1 is NMOS open drain output and direct bus driving is Port 8 pin functions are the same in all operating modes except host interface function 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 PBI read, the port B state will be returned. The corresponding port 8 pins are out when P8DDR bits are set to 1, and inp 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	

5	P85DR	0	R/W	set to 1, the P8DR values are read dire
4	P84DR	0	R/W	regardless of the actual pin states. If a
3	P83DR	0	R/W	is performed while P8DDR bits are clea
2	P82DR	0	R/W	the pin states are read.
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 C
  CKE0 bits in SCR of SCI_1, the C/$\overline{\text{A}}$ bit in SMR of SCI_1, the ICE bit in ICCR of
  the P86DDR bit.

ICE	0					
CKE1	0				1	
C/$\overline{\text{A}}$	0			1	—	
CKE0	0		1	—	—	
P86DDR	0	1	—	—	—	
Pin Function	P86 input pin	P86 output pin	SCK1 output pin	SCK1 output pin	SCK1 input 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.
pin is used as the SCL1 I/O pin, bits CKE1 and CKE0 in SCR of SCI_1 and
SMR of SCI_1 must all be cleared to 0. When the P86 output pin and SCK1
are set, the output type is NMOS push-pull output. SCL1 is an NMOS-only o
has direct bus drive capability.

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 T
  SCR of SCI_1 and the P84DDR bit.

TE	0		1
P84DDR	0	1	–
Pin Function	P84 input pin	P84 output pin	TxD1 ou
	$\overline{\text{IRQ3}}$ 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 u
$\overline{\text{LPCPD}}$ input pin. The $\overline{\text{LPCPD}}$ input pin can only be used in mode 2 or 3 (E
2. Not supported by the H8S/2148B and H8S/2145B (5-V version).

P82DDR	0	1	0	1	—
Pin Function	P82 input pin	P82 output pin	P82 input pin	P82 output pin	HIFSD input pin

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

1. When at least one of bits LPC3E to LPC1E is set to 1, bits HI12E and P82DI 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 H SYSCR2, the CS2E bit in SYSCR, the FGA20E bit in HICR, the FGA20E bit in HI the P81DDR bit.

FGA20E (LPC)	0						
HI12E	0		1				
FGA20E (XBS)	—		0			1	
CS2E	—		0		1	—	
P81DDR	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 input pin*2						

Notes: 1. When bit FGA20E is set to 1 in HICR0, bits HI12E and P81DDR should be c

2. The GA20 output pin and $\overline{\text{CS2}}$ input pin can only be used in mode 2 or 3 (EX

	$\overline{\text{PME}}$ input pin*2*3			

Notes: 1. When bit PMEE is set to 1 in HICR0, bits HI12E and P80DDR should be cl
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 converter input pin, host interface (XBS) input pins, the IIC_0 I/O pin, the subclock in control signal I/O pins, and the system clock (ϕ) output pin. P97 is an NMOS push-pu SDA0 is an NMOS open-drain output, and has direct bus drive capability. Port 9 has t registers.

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

5	P95DDR	0	W	
4	P94DDR	0	W	
3	P93DDR	0	W	
2	P92DDR	0	W	
1	P91DDR	0	W	
0	P90DDR	0	W	

Pin P97 functions as a bus control input (WAIT
IIC_0 I/O pin (SDA0), or an I/O port, according
mode setting. When P97 functions as an I/O p
becomes an output port when P97DDR is set t
an input port when P97DDR is cleared to 0.

Pin P96 functions as the φ output pin when P9
set to 1, and as the subclock input (EXCL) or a
port when P96DDR is cleared to 0.

Pins P95 to P93 automatically become bus co
outputs (AS/IOS, HWR, RD), regardless of the
input/output direction indicated by P95DDR to

Pins P92 and P91 become output ports when
and P91DDR are set to 1, and input ports whe
and P91DDR are cleared to 0.

When the ABW bit in WSCR is cleared to 0, pi
becomes a bus control output (LWR), regardle
input/output direction indicated by P90DDR. W
ABW bit is 1, pin P90 becomes an output port
is set to 1, and an input port if P90DDR is clea

Modes 2 and 3 (EXPE = 0):

When the corresponding P9DDR bits are set t
P96 functions as the φ output pin and pins P97
to P90 become output ports. When P9DDR bit
cleared to 0, the corresponding pins become i

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

4	P94DR	0	R/W	while P9DDR bits are cleared to 0, the are read.
3	P93DR	0	R/W	
2	P92DR	0	R/W	For P96, the pin state is always read.
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 oper 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 (EXI	
WMS1	0			1	—	
ICE	0		1	—	0	
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 pi

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

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

  The pin function is switched as shown below according to the combination of opera
  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		
P95DDR	—		0	1	
IOSE	0	1	—	—	
Pin Function	$\overline{AS}$ output pin	$\overline{IOS}$ output pin	P95 input pin	P95 output pin	i

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

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

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

Pin Function	$\overline{RD}$ output pin	P93 input pin	P93 output pin	$\overline{IC}$

- P92/$\overline{IRQ0}$

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

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

- P91/$\overline{IRQ1}$

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

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

HI12E	—			Any one 0		
FGA20E	—					
CS2E	—					
P90DDR	—	0	1	0	1	
Pin Function	$\overline{\text{LWR}}$ output pin	P90 input pin	P90 output pin	P90 input pin	P90 output pin	$\overline{\text{I}}$
		$\overline{\text{IRQ2}}$ 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
WSCR set to 1, or in mode 2 and 3 (EXPE = 0), this pin is used as the $\overline{\text{IRQ2}}$
When TRGS1 and TRGS0 in ADCR of the A/D converter are both set to 1, t
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 p
sense interrupt input pins, expansion A/D converter input pins, and address output pins
functions change according to the operating mode. Port A input/output operates by Vcc
independent from the Vcc power. Up to 5 V can be applied to port A pins if VccB pow
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)

4	PA4DDR	0	W	In mode 2 (EXPE = 1): The corresponding port A pins are ad when PADDR bits are set to 1, and in when cleared to 0. The port A pins ch the address I/O ports to output ports b the IOSE bit to 1. PA7 to PA2 pins are used as the keyb controller I/O pins by setting the KBIO regardless of the operating mode, whi direction according to PA7DDR to PA ignored. PADDR has the same address as PA port A status is returned.
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 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	

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 opera
  the KBIOE bit in KBCRH_2 of the keyboard buffer controller, the IOSE bit in SYS
  the PA7DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)		
KBIOE	0		1	0		
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
	$\overline{\text{KIN15}}$ 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 a
open-drain output, and has direct bus drive capability. This pin can always b
the PS2CD, $\overline{\text{KIN15}}$, or CIN15 input pin.

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
	$\overline{\text{KIN14}}$ 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 open-drain output, and has direct bus drive capability. This pin can always 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 oper the KBIOE bit in KBCRH_1 of the keyboard buffer controller, the IOSE bit in SY the PA5DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)		
KBIOE	0		1	0		
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
	$\overline{\text{KIN13}}$ 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 open-drain output, and has direct bus drive capability. This pin can always the PS2BD, $\overline{\text{KIN13}}$, or CIN13 input pin.

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
	$\overline{\text{KIN12}}$ 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 a open-drain output, and has direct bus drive capability. This pin can always b 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 opera the KBIOE bit in KBCRH_0 of the keyboard buffer controller, the IOSE bit in SYS the PA3DDR bit.

Operating Mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE = 1)		
KBIOE	0		1	0		
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
	$\overline{\text{KIN11}}$ 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 bus drive capability. This pin can always be used as the PS2AD, $\overline{\text{KIN11}}$, or C pin.

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
	$\overline{\text{KIN10}}$ 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 bus drive capability. This pin can always be used as the PS2AC, $\overline{\text{KIN10}}$, or pin.

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

  The pin function is switched as shown below according to the combination of oper 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	
Pin Function	PA1 input pin	PA1 output pin	PA1 input pin	A17 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.

Pin Function	PA0 input pin	PA0 output pin	PA0 input pin	A16 output pin	ou
	$\overline{\text{KIN8}}$ 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. T 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 keyboard buffer control pin function is selected for pins PA7 to PA2, the input pull-up 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 Operatio
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 o

- 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 P7D read, the port 7 pin states will be retur • Modes 1, 2, and 3 (EXPE = 1) When the ABW bit in WSCR is cle port B pins automatically become pins (D7 to D0), regardless of the direction indicated by PBDDR. Wh ABW bit is 1, a port B pin becomes port if the corresponding PBDDR b 1, and an input port if the bit is clea • Modes 2 and 3 (EXPE = 0) A port B pin becomes an output po corresponding PBDDR bit is set to 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	

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
6	PB6PIN	Undefined*	R	PBPIN has the same address as P8DD
5	PB5PIN	Undefined*	R	write is performed, data will be written t
4	PB4PIN	Undefined*	R	and the port 8 settings will change.
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.

ABW	0	1		—	
PBnDDR	—	0	1	0	
Pin Function	Dn I/O pin	PBn input pin	PBn output pin	PBn input 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 $\overline{\text{W}}$ 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 mode, the HI12E and CS4E bits in SYSCR2, the ABW bit in WSCR, and the PB3

Operating Mode	Mode 1 and Modes 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE =	
HI12E	—			Either cleared to 0	
CS4E	—				
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
		$\overline{\text{WUE3}}$ input pin*1			

Notes: 1. Except when used as a data bus pin, this pin can always be used as the $\overline{\text{W}}$ 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 mode, the HI12E and CS3E bits in SYSCR2, the ABW bit in WSCR, and the PB2

		$\overline{WUE2}$ input pin*1				

Notes: 1. Except when used as a data bus pin, this pin can always be used as the $\overline{WU}$ 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 op mode, the HI12E and CS4E bits in SYSCR2, the LSCIE bits in HICR0 of host inter 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		
HI12E	—			Either cleared to 0		1
CS4E	—					1
ABW	0	1		—		—
PB1DDR	—	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 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 cle
2. Except when used as a data bus pin, this pin can always be used as the $\overline{WU}$ pin. The HIRQ4 output pin and LSCI I/O pin can only be used in mode 2 or 3 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).

HI12E	—			Either cleared to 0		1
CS3E	—					1
ABW	0	1		—		—
PB0DDR	—	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
				$\overline{\text{LSMI}}$ 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 cl

2. Except when used as a data bus pin, this pin can always be used as the $\overline{\text{W}}$ pin. The HIRQ3 output pin and $\overline{\text{LSMI}}$ I/O pin can only be used in mode 2 c 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).

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

Mode	Reset	Hardware Standby Mode	Software Standby Mode	In O Ope
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/C

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 o

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 o only port (port 7).

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

Each extra port includes a data direction register (DDR) that controls input/output, and 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, whet 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 por capable of driving a Darlington transistor when they are in output.

Port C	8-bit I/O port	PC7 to PC0	On-c pull-
Port D	8-bit I/O port	PD7 to PD0	On-c pull-
Port E	8-bit I/O port	PE7 to PE0	On-c pull-
Port F	8-bit I/O port	PF7 to PF0	On-c pull-
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 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)

4	PC4DDR	0	W	read, the port C pin states will be return
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 PDP
4	PD4DDR	0	W	read, the port D pin states will be return
3	PD3DDR	0	W	
2	PD2DDR	0	W	
1	PD1DDR	0	W	
0	PD0DDR	0	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 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	

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. PDPI
6	PD6PIN	Undefined*	R	same address as PDDDR. If a write is
5	PD5PIN	Undefined*	R	the port D settings will change.
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.

5	PC5NOCR	0	R/W	disabled)
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 dr
5	PD5NOCR	0	R/W	disabled)
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		
ODR	0	1	0	1	0
N-ch. driver	OFF		ON	OFF	ON
P-ch. driver	OFF		OFF	ON	O
Input pull-up MOS	OFF	ON	OFF		
Pin function	Input pin		Output pin		

Mode	Reset	Hardware Standby Mode	Software Standby Mode	Other Operati
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); otherwis

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 sam 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)

4	PE4DDR	0	W	read, the port E pin states will be retu
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 PFI
4	PF4DDR	0	W	read, the port F pin states will be retur
3	PF3DDR	0	W	
2	PF2DDR	0	W	
1	PF1DDR	0	W	
0	PF0DDR	0	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 t
6	PF6ODR	0	R/W	regardless of the contents of PFDDR.
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	

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. PFP same address as PFDDR. If a write is 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.

5	PE5NOCR	0	R/W	disabled)
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 dri
5	PF5NOCR	0	R/W	disabled)
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	
N-ch. driver	OFF		ON	OFF	ON	
P-ch. driver	OFF		OFF	ON	OF	
Input pull-up MOS	OFF	ON	OFF			
Pin function	Input pin		Output pin			

Mode	Reset	Hardware Standby Mode	Software Standby Mode	Other Opera
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); otherwis

8.16 Port G

Port G is an 8-bit I/O port. Port G pin functions are the same in all operating modes. T 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)

4	PG4DDR	0	W	read, the port G pin states will be return
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 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	

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 o
bit-by-bit basis.

Bit	Bit Name	Initial Value	R/W	Description
7	PG7NOCR	0	R/W	0: NMOS push-pull (Vcc-side n-chan enabled)
6	PG6NOCR	0	R/W	
5	PG5NOCR	0	R/W	1: Vss-side N-channel open drain (Vc channel driver disabled)
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	

Pin function	Input pin	Output pin

- Operable at a maximum carrier frequency of 625 kHz using pulse division (at 10 M operation)
- Duty cycles from 0 to 100% with 1/256 resolution (100% duty realized by port ou
- Direct or inverted PWM output, and PWM output enable/disable control

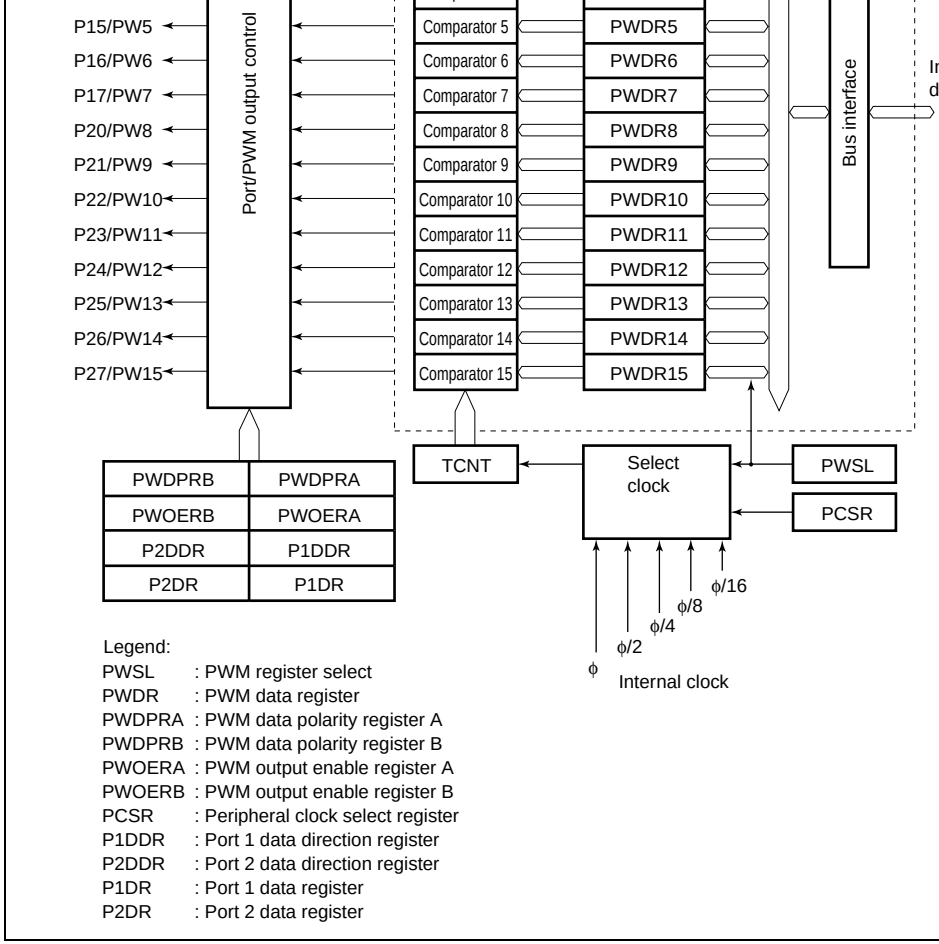


Figure 9.1 Block Diagram of PWM Timer

9.3 Register Descriptions

The PWM has the following registers. To access PCSR, the FLSHE bit in the serial ti
register (STCR) must be cleared to 0. For details on the serial timer control register (S
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)

				PCSR, select the internal clock input to TCN PWM. For details, see table 9.2. The resolution, PWM conversion period, and frequency depend on the selected internal cl can be obtained from the following equations Resolution (minimum pulse width) = 1/intern frequency PWM conversion period = resolution × 256 Carrier frequency = 16/PWM conversion per With a 10 MHz system clock (ϕ), the resoluti conversion period, and carrier frequency are in table 9.3.
5	—	1	R	Reserved This bit is always read as 1 and cannot be m
4	—	0	R	Reserved This bit is always read as 0 and cannot be m

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
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

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 PWDR specifies the duty cycle of the basic pulse to be output, and the number of addit pulses. The value set in PWDR corresponds to a 0 or 1 ratio in the conversion period. T four bits specify the duty cycle of the basic pulse as 0/16 to 15/16 with a resolution of 1 lower four bits specify how many extra pulses are to be added within the conversion pe comprising 16 basic pulses. Thus, a specification of 0/256 to 255/256 is possible for 0/ within the conversion period. For 256/256 (100%) output, port output should be used. I 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. Bit OS0 correspond to outputs PW7 to PW0.
5	OS5	0	R/W	
4	OS4	0	R/W	0: PWM direct output (PWDR value correspo width of output)
3	OS3	0	R/W	
2	OS2	0	R/W	1: PWM inverted output (PWDR value corres low width of output)
1	OS1	0	R/W	
0	OS0	0	R/W	

2	OS10	0	R/W	1: PWM inverted output (PWDR value corre low width of output)
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 th pin state. Bits OE7 to OE0 correspond to ou 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

2	OE10	0	R/W	0X: Port input 10: Port output or PWM 256/256 output 11: PWM output (0 to 255/256 output)
1	OE9	0	R/W	
0	OE8	0	R/W	

Legend:
X: Don't care

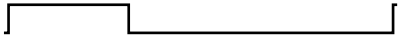
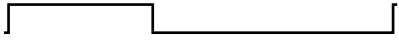
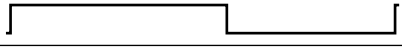
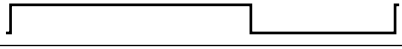
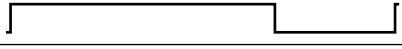
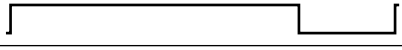
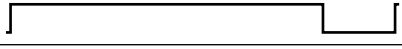
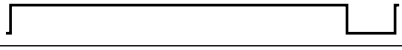
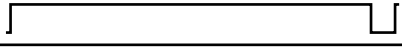
To perform PWM 256/256 output when DDR = 1 and OE = 0, the corresponding pin sh
to port output. The corresponding pin can be set as port output in single-chip mode or v
= 1 and CS256E = 0 in SYSCR in extended mode with on-chip ROM. Otherwise, it sho
noted that an address bus is output to the corresponding pin.

DR data is output when the corresponding pin is used as port output. A value correspon
PWM 256/256 output is determined by the OS bit, so the value should have been set to
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 be changed.
2	PWCKB	0	R/W	PWM Clock Select B, A
1	PWCKA	0	R/W	Together with bits PWCKE and PWCKS in P these bits select the internal clock input to T PWM. For details, see table 9.2.
0	—	0	R	Reserved This bit is always read as 0. The initial value be changed.

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 puls
additional pulse adds a high period (when OS = 0) with a width equal to the resolution
rising edge of a basic pulse. When the upper four bits of PWDR are 0000, there is no
of the basic pulse, but the timing for adding pulses is the same. Table 9.5 shows the p

0001														
0010								Yes						
0011								Yes				Yes		
0100				Yes				Yes				Yes		
0101				Yes				Yes				Yes		Yes
0110				Yes		Yes		Yes				Yes		Yes
0111				Yes		Yes		Yes		Yes		Yes		Yes
1000		Yes		Yes		Yes		Yes		Yes		Yes		Yes
1001		Yes		Yes		Yes		Yes		Yes		Yes		Yes
1010		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes
1011		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes
1100		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes
1101		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes
1110		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

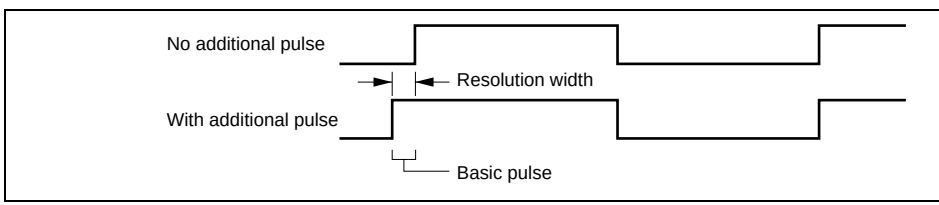


Figure 9.2 Example of Additional Pulse Timing (when Upper 4 Bits of PWDR

- 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 cyc

Figure 10.1 shows a block diagram of the PWM (D/A) module.

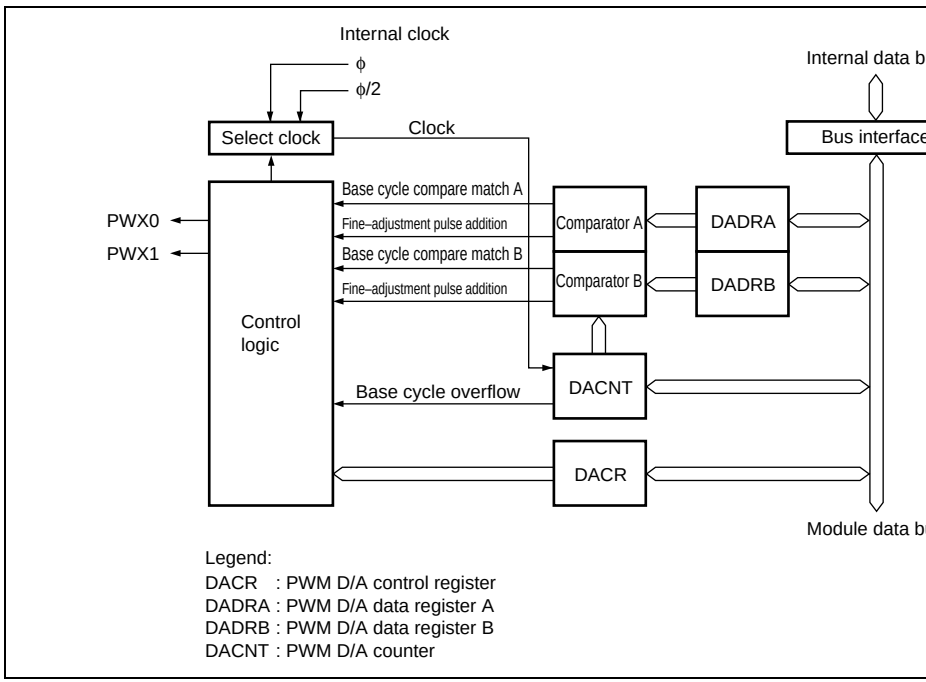


Figure 10.1 PWM (D/A) Block Diagram

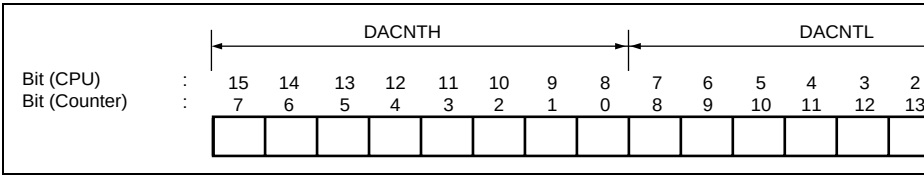
PWM output pin X1	PWX1	Output	PWM output of PWMX channel

10.3 Register Descriptions

The PWM (D/A) module has the following registers. The PWM (D/A) registers are ass
same addresses with other registers. The registers are selected by the IICE bit in the ser
control register (STCR). For details on STCR, see section 3.2.3, Serial Timer Control R
(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 D
Switching is performed by the REGS bit in DACNT or DADRB.



- 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
0	REGS	1	R/W	Register Select DADRA and DACR, and DADRB and DAC located at the same addresses. The REGS which registers can be accessed. 0: DADRA and DADRB can be accessed 1: DACR and DACNT can be accessed

15	DA13	1	R/W	D/A Data 13 to 0
14	DA12	1	R/W	These bits set a digital value to be converted
13	DA11	1	R/W	analog value.
12	DA10	1	R/W	In each base cycle, the DACNT value is con
11	DA9	1	R/W	compared with the DADR value to determine
10	DA8	1	R/W	cycle of the output waveform, and to decide
9	DA7	1	R/W	output a fine-adjustment pulse equal in width
8	DA6	1	R/W	resolution. To enable this operation, this regi
7	DA5	1	R/W	be set within a range that depends on the CF
6	DA4	1	R/W	DADR value is outside this range, the PWM
5	DA3	1	R/W	held constant.
4	DA2	1	R/W	A channel can be operated with 12-bit precis
3	DA1	1	R/W	keeping the two lowest data bits (DA1 and D
2	DA0	1	R/W	to 0. The two lowest data bits correspond to
				highest bits in DACNT.
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 m

10	DA8	1	R/W	output a fine-adjustment pulse equal in widt
9	DA7	1	R/W	resolution. To enable this operation, this reg
8	DA6	1	R/W	be set within a range that depends on the C
7	DA5	1	R/W	DADR value is outside this range, the PWM
6	DA4	1	R/W	held constant.
5	DA3	1	R/W	A channel can be operated with 12-bit prec
4	DA2	1	R/W	keeping the two lowest data bits (DA1 and
3	DA1	1	R/W	to 0. The two lowest data bits correspond to
2	DA0	1	R/W	highest bits in DACNT.
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 DACI located at the same addresses. The REGS which registers can be accessed. 0: DADRA and DADRB can be accessed 1: DACR and DACNT can be accessed

				Normally this bit should be cleared to 0. 0: PWM (D/A) in user state: Normal operatio 1: PWM (D/A) in test state: Correct conversi unobtainable
6	PWME	0	R/W	PWM Enable Starts or stops the PWM D/A counter (DACN 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 modified.
3	OEB	0	R/W	Output Enable B Enables or disables output on PWM (D/A) ch 0: PWM (D/A) channel B output (at the PWX disabled 1: PWM (D/A) channel B output (at the PWX enabled

				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 sy (ϕ) frequency is 10 MHz, resolutions of 100 ns, can be selected. 0: Operates at resolution (T) = system clock (t_{cyc}) 1: Operates at resolution (T) = system clock (t_{cyc}) $\times$ 2

when the lower byte is written to, the lower-byte write data and TEMP value are combi
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
lower-byte value is transferred to TEMP. Next, when the lower byte is read from, the lo
value in TEMP is transferred to the CPU.

These registers should always be accessed 16 bits at a time with a MOV instruction, an
byte should always be accessed before the lower byte. Correct data will not be transfer
the upper byte or only the lower byte is accessed. Also note that a bit manipulation inst
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**	**Byt**
DADRA and DADRB	Yes	Yes	Yes	×
DACNT	Yes	×	Yes	×

Legend:

Yes: Permitted type of access. Word access includes successive byte accesses to the
(first) and lower byte (second).

×: This type of access may give incorrect results.

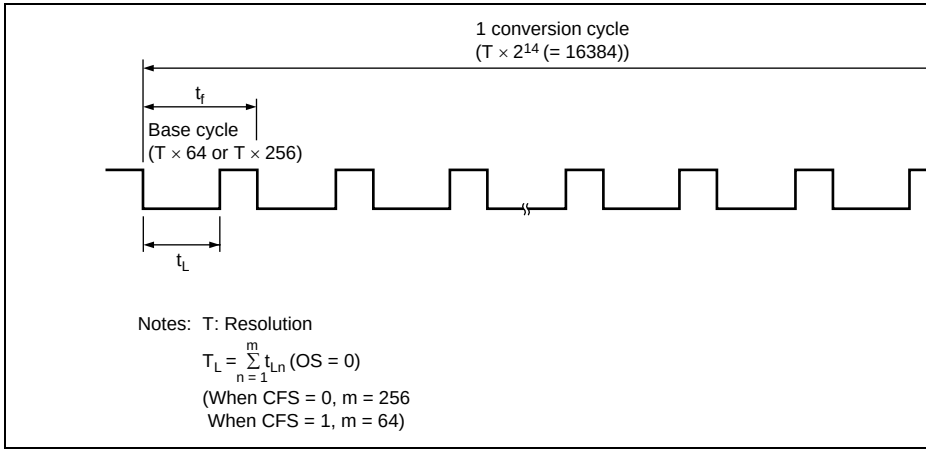


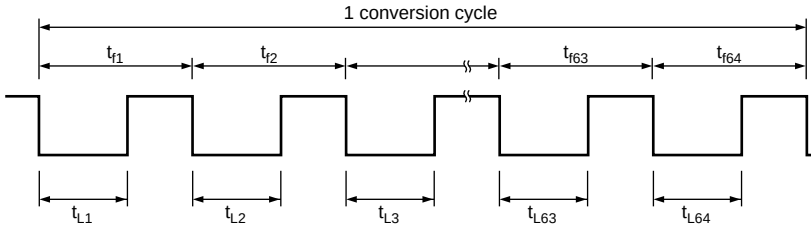
Figure 10.2 PWM D/A Operation

0	0.1	0	6.4	1638.4	1. Always low (or high) (DADR = H'0001 to H'03FD) 2. (Data value) × T (DADR = H'0401 to H'FFFD)	14				
						12			0	0
						10	0	0	0	0
		1	25.6		1. Always low (or high) (DADR = H'0003 to H'00FF) 2. (Data value) × T (DADR = H'0103 to H'FFFF)	14				
						12			0	0
						10	0	0	0	0
1	0.2	0	12.8	3276.8	1. Always low (or high) (DADR = H'0001 to H'03FD) 2. (Data value) × T (DADR = H'0401 to H'FFFD)	14				
						12			0	0
						10	0	0	0	0
		1	51.2		1. Always low (or high) (DADR = H'0003 to H'00FF) 2. (Data value) × T (DADR = H'0103 to H'FFFF)	14				
						12			0	0
						10	0	0	0	0

Note: * This column indicates the conversion cycle when specific DADR bits are fixe

$t_{L1} + t_{L2} + t_{L3} + \cdots + t_{L255} + t_{L256} = T_L$

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)

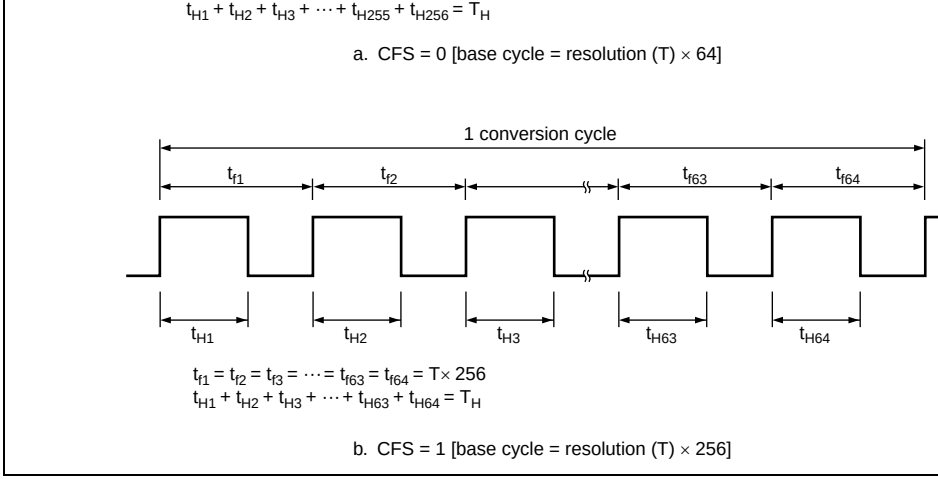


Figure 10.4 Output Waveform (OS = 1, DADR Corresponds to T_H)

An example of setting CFS to 1 (basic cycle = resolution (T) × 256) and OS to 1 (PWM output) is shown as an additional pulse. When CFS is set to 1, the duty ratio of the basi determined by the upper eight bits (DA13 to DA6) in DADR, and the position of the ad 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.

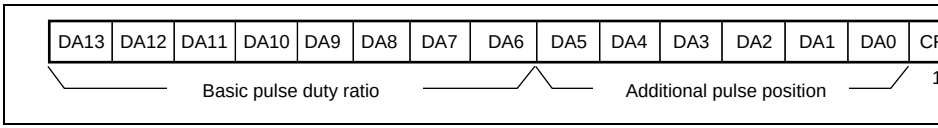


Figure 10.5 D/A Data Register Configuration when CFS = 1

Here, the case of DADR = H'0207 (B'0000 0010 0000 0111) is considered. Figure 10.6 output waveform. Because CFS = 1 and the value of upper eight bits is B'0000 0010, th ratio of the basic pulse is 2/256 × (T) of high width.

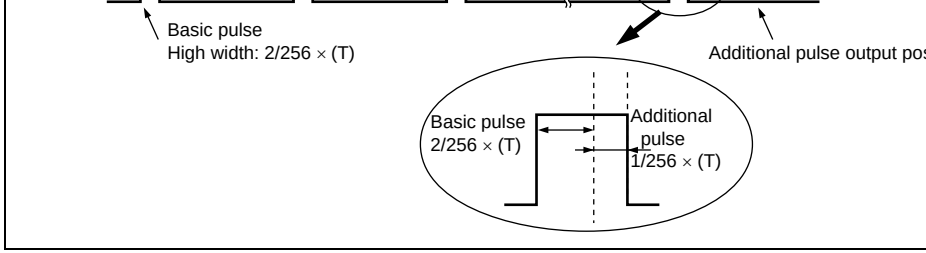


Figure 10.6 Output Waveform when DADR = H'0207 (OS = 1)

Note that the case of CFS = 0 (basic cycle = resolution (T) × 64) is similar other than t
of the basic pulse is determined by the upper six bits, and the position of the additiona
determined by the following eight bits.

Lower 6 bits							Basic Pulse No.																																																		
							0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	0	0	0	0	0	0																																																			
0	0	0	0	0	1	1																																																			
0	0	0	0	1	0	2																																Yes																			
0	0	0	0	1	1	3																																Yes																Yes			
0	0	0	1	0	0	4																Yes																Yes																Yes			
0	0	0	1	0	1	5																Yes																Yes																Yes			
0	0	0	1	1	0	6																Yes								Yes								Yes																Yes			
0	0	0	1	1	1	7																Yes								Yes								Yes								Yes								Yes			
0	0	1	0	0	0	8								Yes								Yes								Yes								Yes								Yes								Yes			
0	0	1	0	0	1	9								Yes								Yes								Yes								Yes								Yes								Yes			
0	0	1	0	1	0	10								Yes								Yes								Yes				Yes				Yes								Yes								Yes			
0	0	1	0	1	1	11								Yes								Yes								Yes				Yes				Yes								Yes				Yes				Yes			
0	0	1	1	0	0	12								Yes				Yes				Yes								Yes				Yes				Yes								Yes				Yes				Yes			
0	0	1	1	0	1	13								Yes				Yes				Yes								Yes				Yes				Yes								Yes				Yes				Yes			
0	0	1	1	1	0	14								Yes				Yes				Yes				Yes				Yes				Yes				Yes								Yes				Yes				Yes			
0	0	1	1	1	1	15								Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes			
0	1	0	0	0	0	16				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes			
0	1	0	0	0	1	17				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes				Yes			
0	1	0	0	1	0	18				Yes				Yes				Yes				Yes				Yes				Yes				Yes		Yes		Yes				Yes				Yes				Yes				Yes			
0	1	0	0	1	1	19				Yes				Yes				Yes				Yes				Yes				Yes				Yes		Yes		Yes				Yes				Yes				Yes		Yes		Yes			
0	1	0	1	0	0	20				Yes				Yes				Yes		Yes		Yes				Yes				Yes				Yes		Yes		Yes				Yes				Yes				Yes		Yes		Yes			
0	1	0	1	0	1	21				Yes				Yes				Yes		Yes		Yes				Yes				Yes				Yes		Yes		Yes				Yes				Yes				Yes		Yes		Yes			
0	1	0	1	1	0	22				Yes				Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes				Yes				Yes		Yes		Yes			
0	1	0	1	1	1	23				Yes				Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes			
0	1	1	0	0	0	24				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes			
0	1	1	0	0	1	25				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes			
0	1	1	0	1	0	26				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes			
0	1	1	0	1	1	27				Yes		Yes		Yes				Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes			
0	1	1	1	0	0	28				Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes			
0	1	1	1	0	1	29				Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
0	1	1	1	1	0	30				Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
0	1	1	1	1	1	31				Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
1	0	0	0	0	0	32		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
1	0	0	0	0	1	33		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
1	0	0	0	1	0	34		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
1	0	0	0	1	1	35		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	0	1	0	0	36		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	0	1	0	1	37		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	0	1	1	0	38		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	0	1	1	1	39		Yes		Yes		Yes		Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	1	0	0	0	40		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	1	0	0	1	41		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	
1	0	1	0	1	0	42		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	
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1	0	1	1	0	1	45		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes
1	0	1	1	1	0	46		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes
1	0	1	1	1	1	47		Yes		Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes
1	1	0	0	0	0	48		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes
1	1	0	0	0	1	49		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes
1	1	0	0	1	0	50		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes
1	1	0	0	1	1	51		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	0	1	0	0	52		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	0	1	0	1	53		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	0	1	1	0	54		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	0	1	1	1	55		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	1	0	0	0	56		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	1	0	0	1	57		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	1	0	1	0	58		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	1	0	1	1	59		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	1	1	0	0	60		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
1	1	1	1	0	1	61		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1	1	1	1	1	0	62		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1	1	1	1	1	1	63		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- Selection of four clock sources

  One of the three internal clocks (ϕ/2, ϕ/8, or ϕ/32), or an external clock input can b
  (enabling use as an external event counter).
- Two independent comparators

  Two independent waveforms can be output.
- Four independent input capture channels

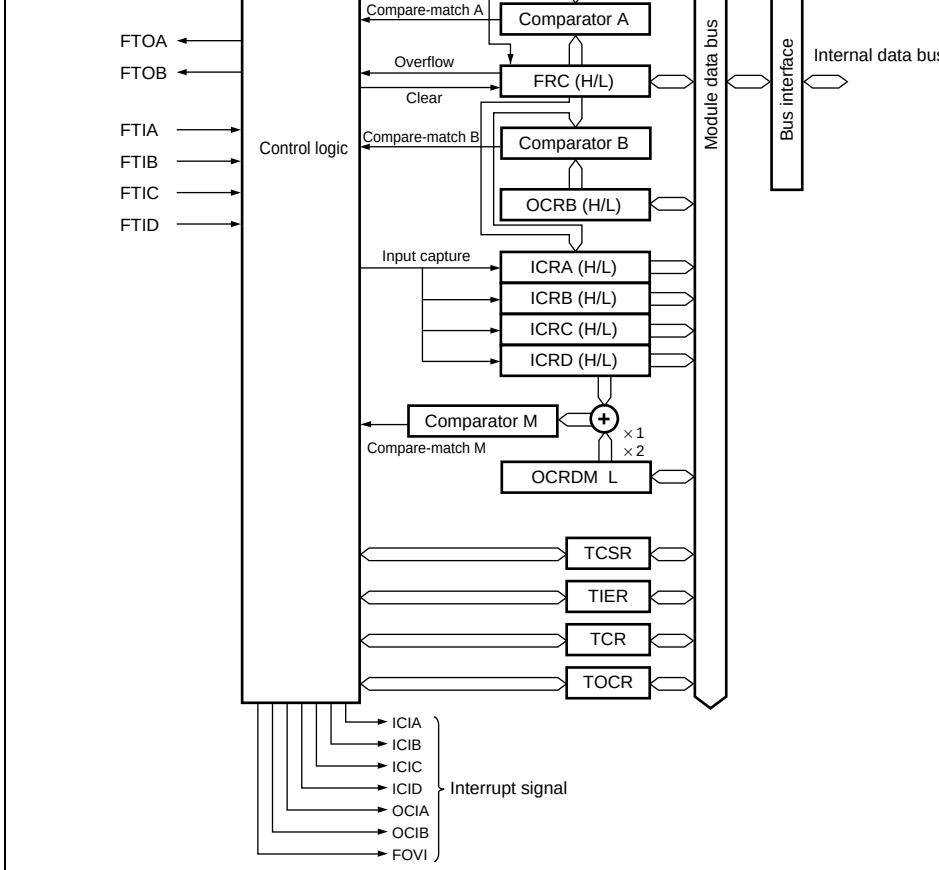
  The rising or falling edge can be selected.

  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 int
  requested independently.
- Special functions provided by automatic addition function

  The contents of OCRAR and OCRAF can be added to the contents of OCRA auto
  enabling a periodic waveform to be generated without software intervention. The c
  ICRD can be added automatically to the contents of OCRDM × 2, enabling input c
  operations in this interval to be restricted.



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 registe
ICRA to D	: Input capture registers A to D (16-bit)		

Figure 11.1 Block Diagram of 16-Bit Free-Running Timer

Output compare B output pin	FTOB	Output	Output compare B outpu
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 bit in TOCR. ICRA, ICRB, and ICRC share the same addresses with OCRAR and OCRDM. Register selection is controlled by the ICRS bit in TOCR.

The FRT has two output compare registers, OCRA and OCRB, each of which is a 16-b readable/writable register whose contents are continually compared with the value in F a match is detected (compare-match), the corresponding output compare flag (OCFA o set to 1 in TCSR. If the OEA or OEB bit in TOCR is set to 1, when the OCR and FRC match, the output level selected by the OLVLA or OLVLB bit in TOCR is output at the compare output pin (FTOA or FTOB). Following a reset, the FTOA and FTOB output until the first compare-match. OCR should always be accessed in 16-bit units; cannot b 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 rea register. When the rising or falling edge of the signal at an input capture input pin (FTI is detected, the current FRC value is transferred to the corresponding input capture regi to ICRD). At the same time, the corresponding input capture flag (ICFA to ICFD) in T to 1. The FRC contents are transferred to ICR regardless of the value of ICF. The input 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 mea enable bits A and B (BUFEA and BUFEB) in TCR. For example, if an input capture oc ICRC is specified as the ICRA buffer register, the FRC contents are transferred to ICR transferred to the buffer register ICRC.

To ensure input capture, the input capture pulse width should be at least 1.5 system clo a single edge. When triggering is enabled on both edges, the input capture pulse width least 2.5 system clocks (ϕ).

ICRA to ICRD should always be accessed in 16-bit units; cannot be accessed in 8-bit u initialized to H'0000.

OCRAF. The value of the OLVEA bit in TOCR is ignored, and 1 is output on a compa
following addition of OCRAF, while 0 is output on a compare-match A following add
OCRAR.

When using the OCRA automatic addition function, do not select internal clock $\phi/2$ as
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
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'
the ICRDMS bit in TOCR is set to 1 and the contents of OCRDM are other than H'00
operation of ICRD is changed to include the use of OCRDM. The point at which inpu
occurs is taken as the start of a mask interval. Next, twice the contents of OCRDM is
contents of ICRD, and the result is compared with the FRC value. The point at which
match is taken as the end of the mask interval. New input capture D events are disable
mask interval. A mask interval is not generated when the contents of OCRDM are H'0
the ICRDMS bit is set to 1.

OCRDM should always be accessed in 16-bit units; cannot be accessed in 8-bit units.
initialized to H'0000.

				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 inter request (ICIB) when input capture flag B (ICF 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 inter request (ICIC) when input capture flag C (ICF 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 inter request (ICID) when input capture flag D (ICF 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 in request (OCIA) when output compare flag A TCSR is set to 1. 0: OCIA requested by OCFA is disabled 1: OCIA requested by OCFA is enabled

				Selects whether to enable a free-running ti request interrupt (FOVI) when the timer ove (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

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 valu transferred to ICRA by means of an input c signal. When BUFEA = 1, ICFA indicates th ICRA value has been moved into ICRC and FRC value has been transferred to ICRA. C written to this bit to clear the flag. [Setting condition] When an input capture signal causes the F be transferred to ICRA [Clearing condition] Read ICFA when ICFA = 1, then write 0 to

				[Setting condition]
				When an input capture signal causes the FR be transferred to ICRB
				[Clearing condition]
				Read ICFB when ICFB = 1, then write 0 to IC
5	ICFC	0	R/(W)*	Input Capture Flag C
				This status flag indicates that the FRC value transferred to ICRC by means of an input ca signal. When BUFEA = 1, on occurrence of a capture signal specified by the IEDGC bit at input pin, ICFC is set but data is not transfer ICRC. In buffer operation, ICFC can be used external interrupt signal by setting the ICICE Only 0 can be written to this bit to clear the fl
				[Setting condition]
				When an input capture signal is received
				[Clearing condition]
				Read ICFC when ICFC = 1, then write 0 to IC
4	ICFD	0	R/(W)*	Input Capture Flag D
				This status flag indicates that the FRC value transferred to ICRD by means of an input ca signal. When BUFEB = 1, on occurrence of a capture signal specified by the IEDGD bit at input pin, ICFD is set but data is not transfer ICRD. In buffer operation, ICFD can be used external interrupt signal by setting the ICIDE Only 0 can be written to this bit to clear the fl
				[Setting condition]
				When an input capture signal is received
				[Clearing condition]
				Read ICFD when ICFD = 1, then write 0 to IC

				Read OCFA when OCFA = 1, then write 0 t
2	OCFB	0	R/(W)*	Output Compare Flag B This status flag indicates that the FRC valu the OCRB value. Only 0 can be written to th clear the flag. [Setting condition] When FRC = OCRB [Clearing condition] Read OCFB when OCFB = 1, then write 0 t
1	OVF	0	R/(W)*	Timer Overflow This status flag indicates that the FRC has Only 0 can be written to this bit to clear the [Setting condition] When FRC overflows (changes from H'FFF [Clearing condition] Read OVF when OVF = 1, then write 0 to C
0	CCLRA	0	R/W	Counter Clear A This bit selects whether the FRC is to be cl compare-match A (when the FRC and OCR match). 0: FRC clearing is disabled 1: FRC is cleared at compare-match A

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

				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 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 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 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 buf for ICRA. 0: ICRC is not used as a buffer register for IC 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 buf for ICRB. 0: ICRD is not used as a buffer register for IC 1: ICRD is used as a buffer register for ICRB

11.3.9 Timer Output Compare Control Register (TOCR)

TOCR enables output from the output compare pins, selects the output levels, switche between output compare registers A and B, controls the ICRD and OCRA operating m 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 norm mode or in the operating mode using OCRD 0: The normal operating mode is specified f 1: The operating mode using OCRDM is sp ICRD
6	OCRAMS	0	R/W	Output Compare A Mode Select Specifies whether OCRA is used in the nor operating mode or in the operating mode us and OCRAF. 0: The normal operating mode is specified f 1: The operating mode using OCRAR and specified for OCRA
5	ICRS	0	R/W	Input Capture Register Select The same addresses are shared by ICRA a by ICRB and OCRAF, and by ICRC and OC ICRS bit determines which registers are sel the shared addresses are read from or writt operation of ICRA, ICRB, and ICRC is not a 0: ICRA, ICRB, and ICRC are selected 1: OCRAR, OCRAF, and OCRDM are selec

3	OEA	0	R/W	Output Enable A Enables or disables output of the output com 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 com 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 c output pin (FTOA) in response to compare-m (signal indicating a match between the FRC values). When the OCRAMS bit is 1, this bit 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 c output pin (FTOB) in response to compare-m (signal indicating a match between the FRC values). 0: 0 is output at compare-match B 1: 1 is output at compare-match B

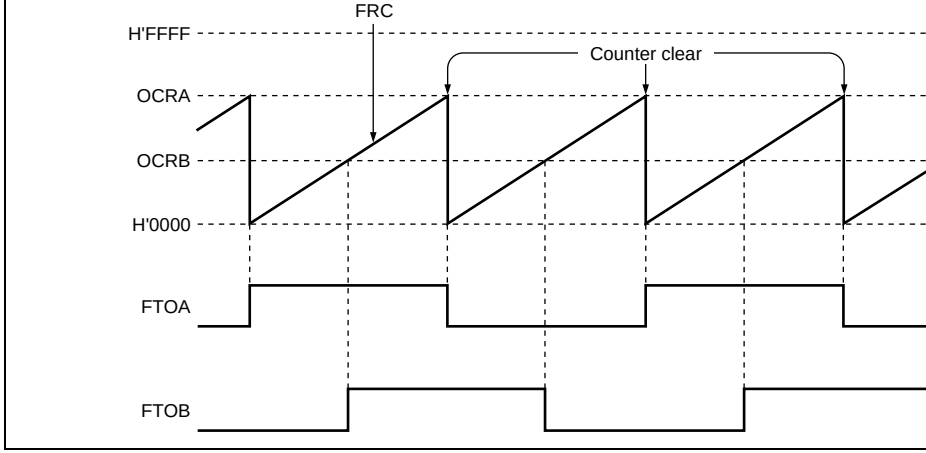


Figure 11.2 Example of Pulse Output

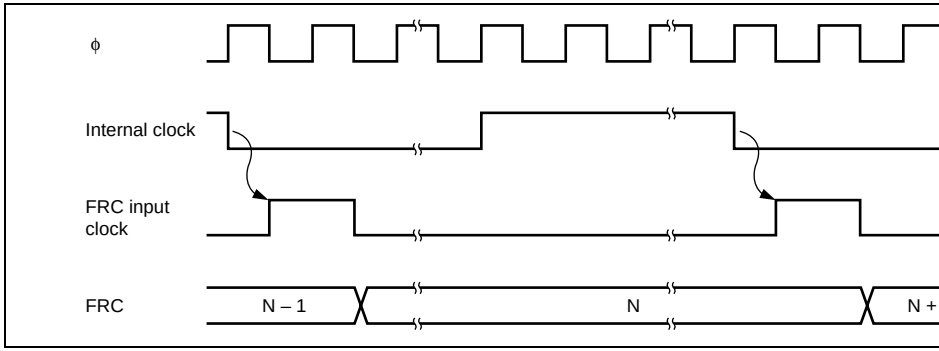


Figure 11.3 Increment Timing with Internal Clock Source

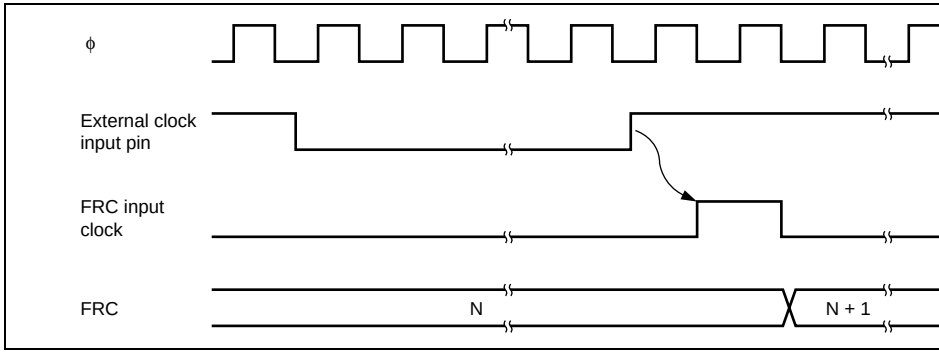


Figure 11.4 Increment Timing with External Clock Source

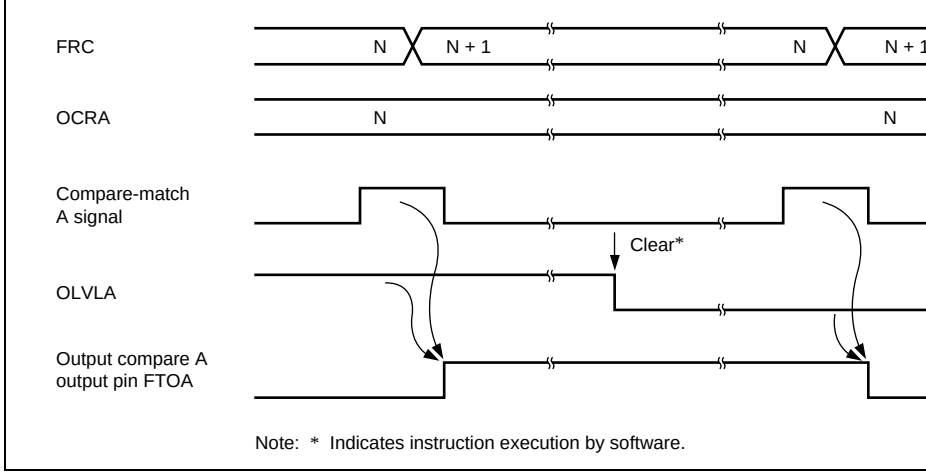


Figure 11.5 Timing of Output Compare A Output

11.5.3 FRC Clear Timing

FRC can be cleared when compare-match A occurs. Figure 11.6 shows the timing of t
operation.

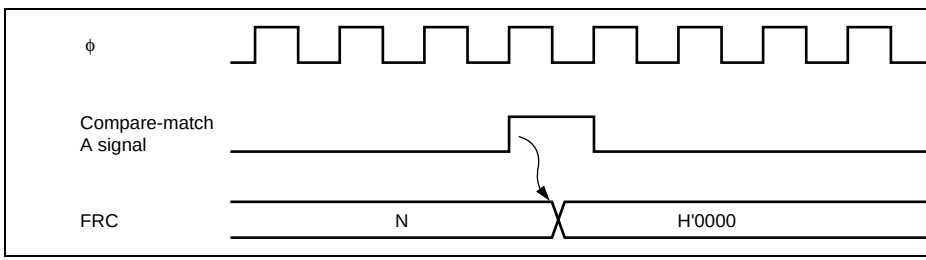


Figure 11.6 Clearing of FRC by Compare-Match A Signal

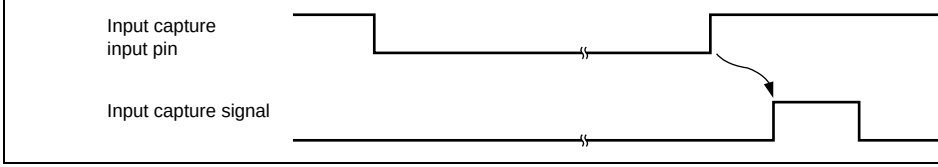


Figure 11.7 Input Capture Input Signal Timing (Usual Case)

If ICRA to ICRAD are read when the corresponding input capture signal arrives, the in
capture signal is delayed by one system clock (ϕ). Figure 11.8 shows the timing for this

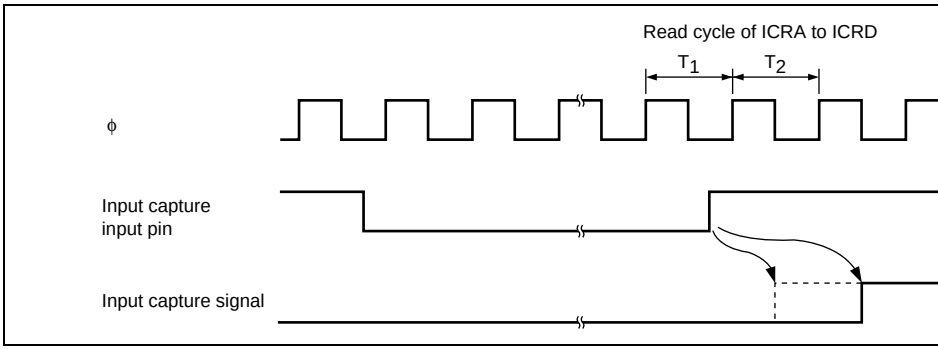


Figure 11.8 Input Capture Input Signal Timing (When ICRA to ICRD are

11.5.5 Buffered Input Capture Input Timing

ICRC and ICRD can operate as buffers for ICRA and ICRB, respectively. Figure 11.9 s
input capture operates when ICRC is used as ICRA's buffer register (BUFEA = 1) and
IEDGC are set to different values (IEDGA = 0 and IEDGC = 1, or IEDGA = 1 and IED
so that input capture is performed on both the rising and falling edges of FTIA.

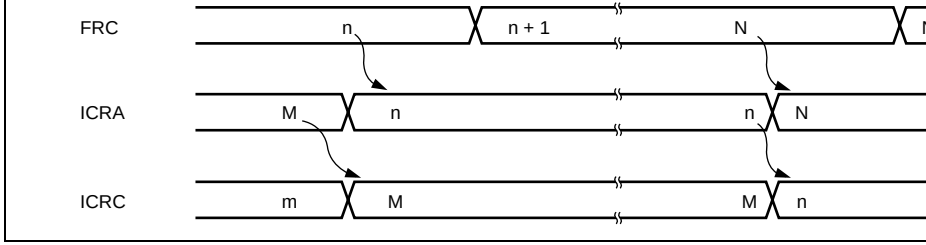


Figure 11.9 Buffered Input Capture Timing

Even when ICRC or ICRD is used as a buffer register, its input capture flag is set by t
transition of its input capture signal. For example, if ICRC is used to buffer ICRA, wh
transition selected by the IEDGC bit occurs on the FTIC input capture line, ICFC will
if the ICICE bit is set at this time, an interrupt will be requested. The FRC value will n
transferred to ICRC, however. In buffered input capture, if either set of two registers t
will be transferred (ICRA and ICRC, or ICRB and ICRD) is being read when the inpu
input signal arrives, input capture is delayed by one system clock (ϕ). Figure 11.10 sh
timing when BUFEA = 1.

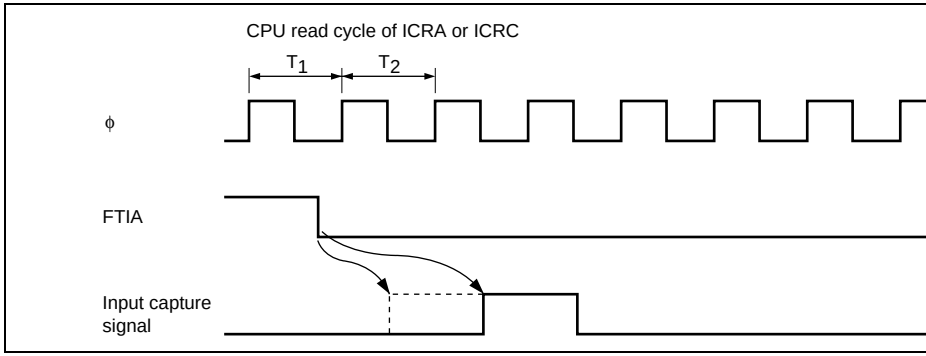


Figure 11.10 Buffered Input Capture Timing (BUFEA = 1)

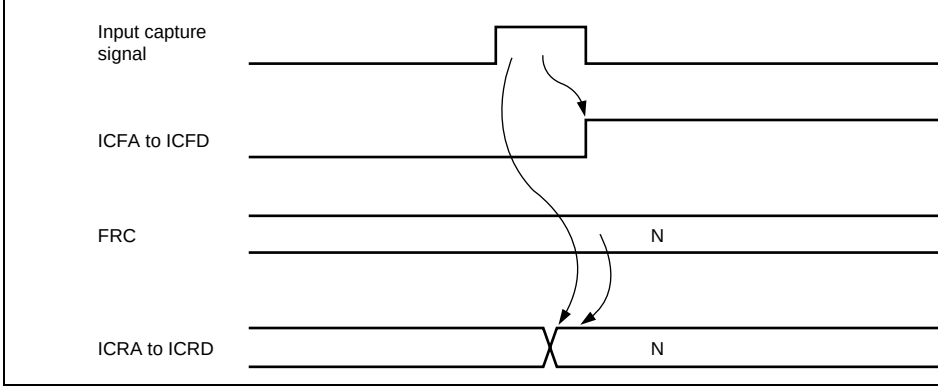


Figure 11.11 Timing of Input Capture Flag (ICFA, ICFB, ICFC, or ICFD) S

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 gener the FRC value matches the OCRA or OCRB value. This compare-match signal is gene last state in which the two values match, just before FRC increments to a new value. W FRC and OCRA or OCRB value match, the compare-match signal is not generated unti cycle of the clock source. Figure 11.12 shows the timing of setting the OCFA or OCFB

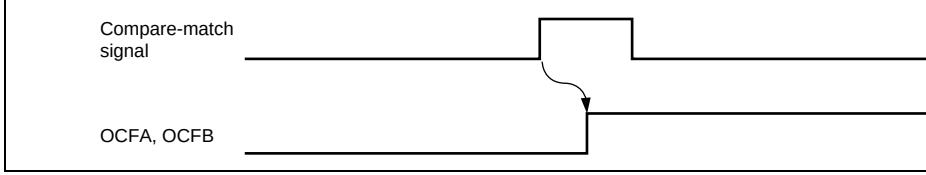


Figure 11.12 Timing of Output Compare Flag (OCFA or OCFB) Setti

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 Figure 11.13 shows the timing of setting the OVF flag.

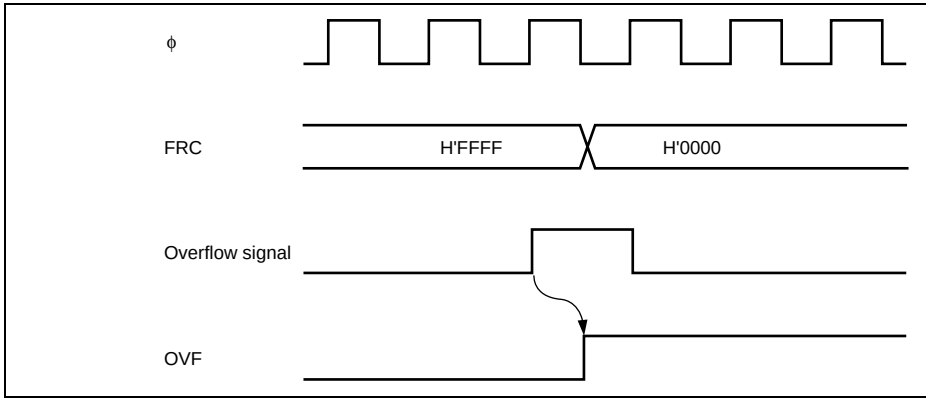


Figure 11.13 Timing of Overflow Flag (OVF) Setting

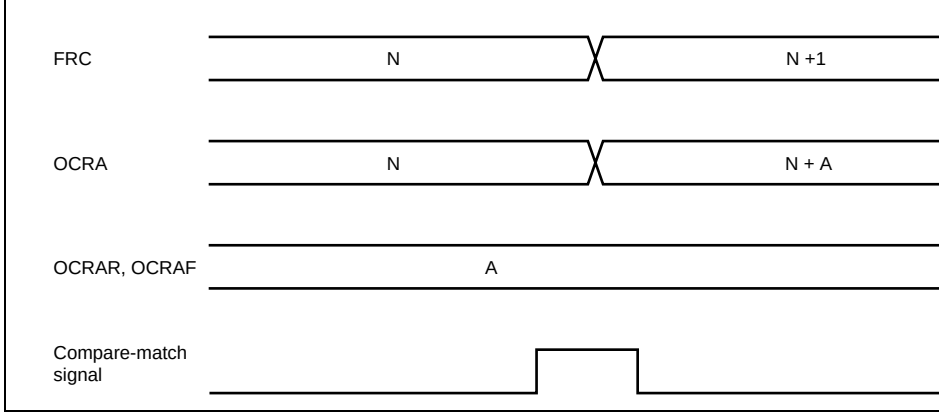


Figure 11.14 OCRA Automatic Addition Timing

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 signal that masks the ICRD input capture signal is generated. The mask signal is set by capture signal. The mask signal is cleared by the sum of the ICRD contents and twice t OCRDM contents, and an FRC compare-match. Figure 11.15 shows the timing of setti signal. Figure 11.16 shows the timing of clearing the mask signal.

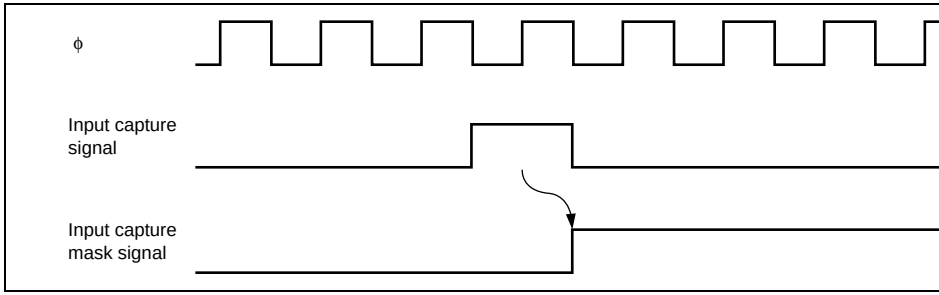


Figure 11.15 Timing of Input Capture Mask Signal Setting

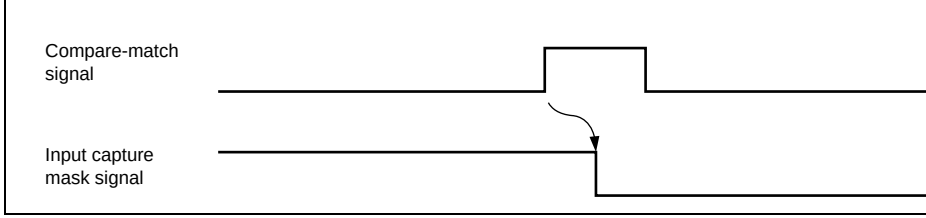


Figure 11.16 Timing of Input Capture Mask Signal Clearing

11.6 Interrupt Sources

The free-running timer can request seven interrupts: ICIA to ICID, OCIA, OCIB, and interrupt can be enabled or disabled by an enable bit in TIER. Independent signals are interrupt controller for each interrupt. Table 11.2 lists the sources and priorities of thes

The ICIA, ICIB, OCIA, and OCIB interrupts can be used as the on-chip DTC activatio

Table 11.2 FRT Interrupt Sources

Interrupt	Interrupt Source	Interrupt Flag	DTC Activation
ICIA	Input capture of ICRA	ICFA	Enabled
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

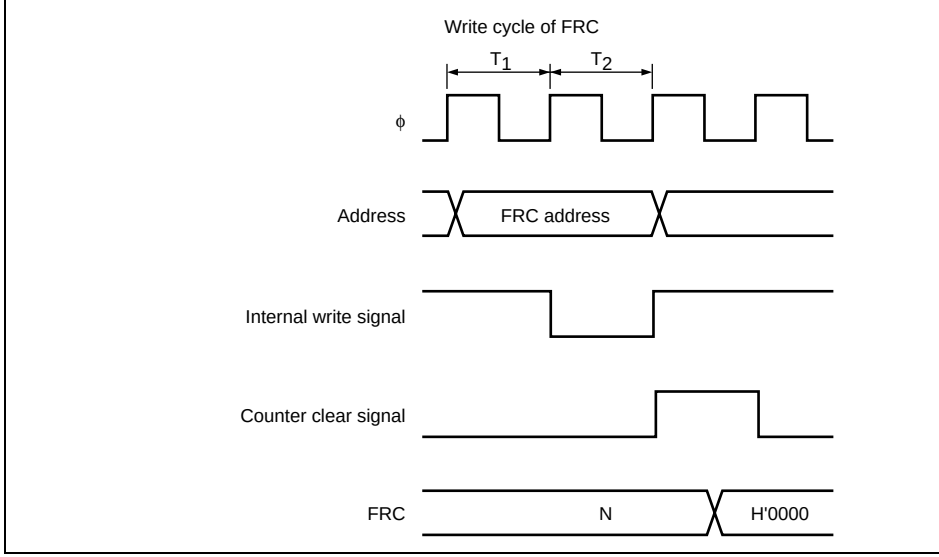


Figure 11.17 FRC Write-Clear Conflict

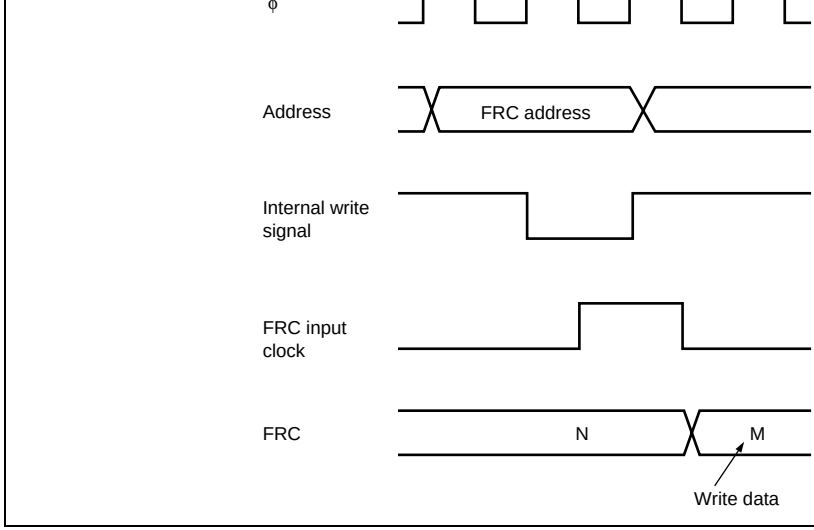


Figure 11.18 FRC Write-Increment Conflict

the automatic addition is not written to OCRA. Figure 11.20 shows the timing for this t
conflict.

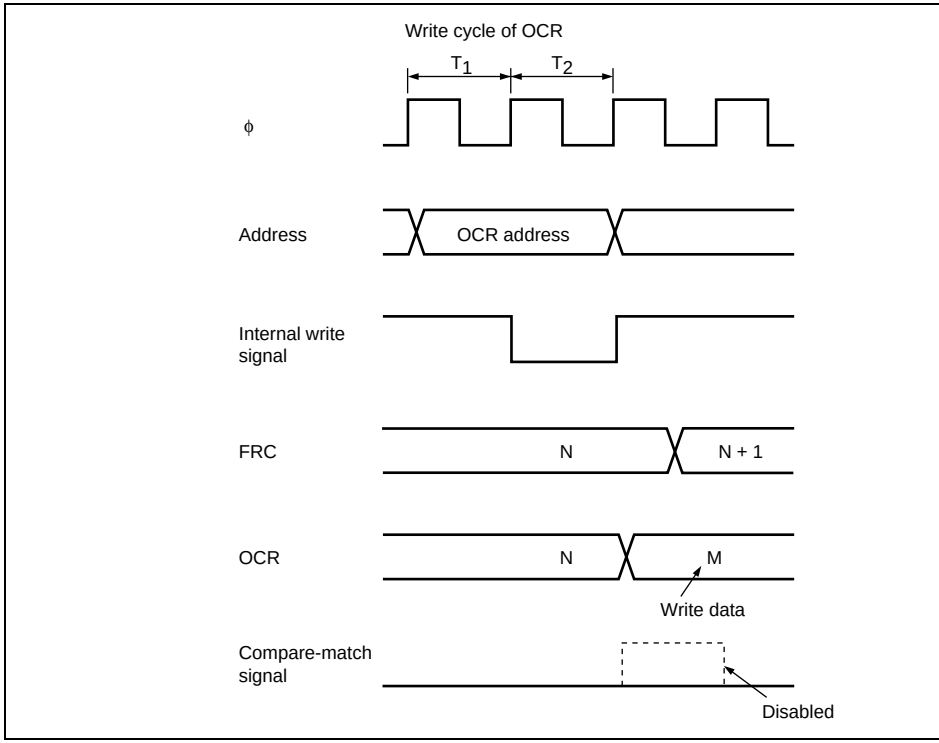


Figure 11.19 Conflict between OCR Write and Compare-Match (When Automatic Addition Function Is Not Used)

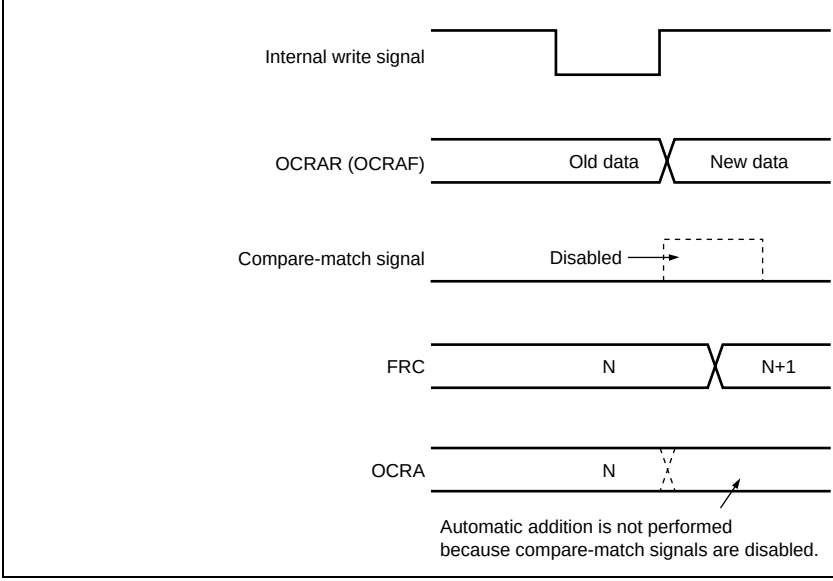
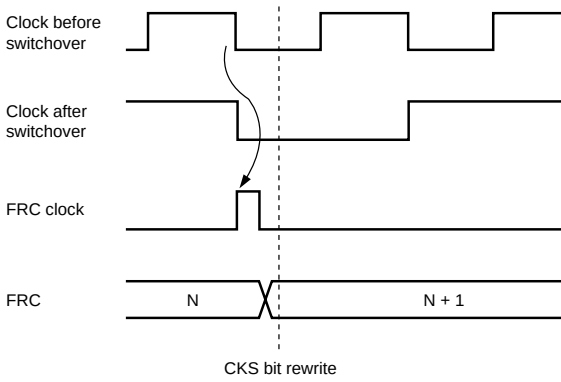
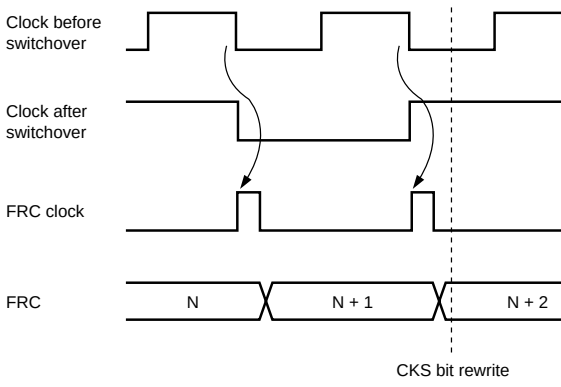
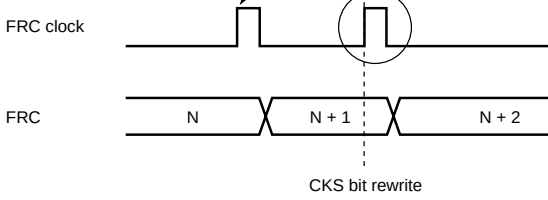


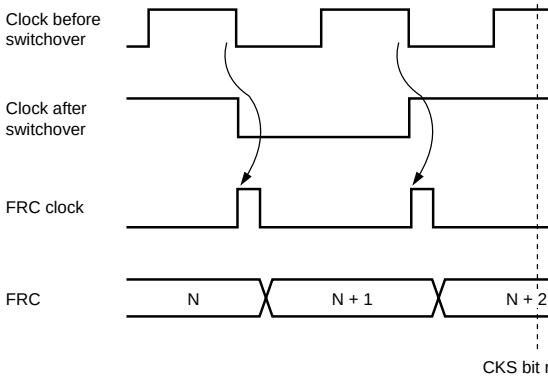
Figure 11.20 Conflict between OCRAR/OCRAF Write and Compare-M (When Automatic Addition Function Is Used)

edge that triggers the FRC clock, and FRC is incremented. Switching between an interr
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	



4	Switching from high to high	

Note: * Generated on the assumption that the switchover is a falling edge; FRC is i

11.7.5 Module Stop Mode Setting

FRT operation can be enabled or disabled using the module stop control register. The setting is for FRT operation to be halted. Register access is enabled by canceling the mode. For details, refer to section 26, Power-Down Modes.

This LSI also has a similar on-chip 8-bit timer module (TMR_Y and TMR_X) with tw
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 clo external clock
  - TMR_Y, TMR_X: The counter input clock can be selected from three internal 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 a reset signal.
- Timer output controlled by two compare-match signals
  - The timer output signal in each channel is controlled by two independent comp signals, enabling the timer to be used for various applications, such as the gene pulse output or PWM output with an arbitrary duty cycle. (The TMR_Y does n 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 a as the lower half (16-bit count mode).

    TMR_1 can be used to count TMR_0 compare-match occurrences (compare-m mode).
- Multiple interrupt sources for each channel
  - TMR_0, TMR_1, and TMR_Y: Three types of interrupts: Compare-match A, c match B, and overflow
  - TMR_X: Input capture

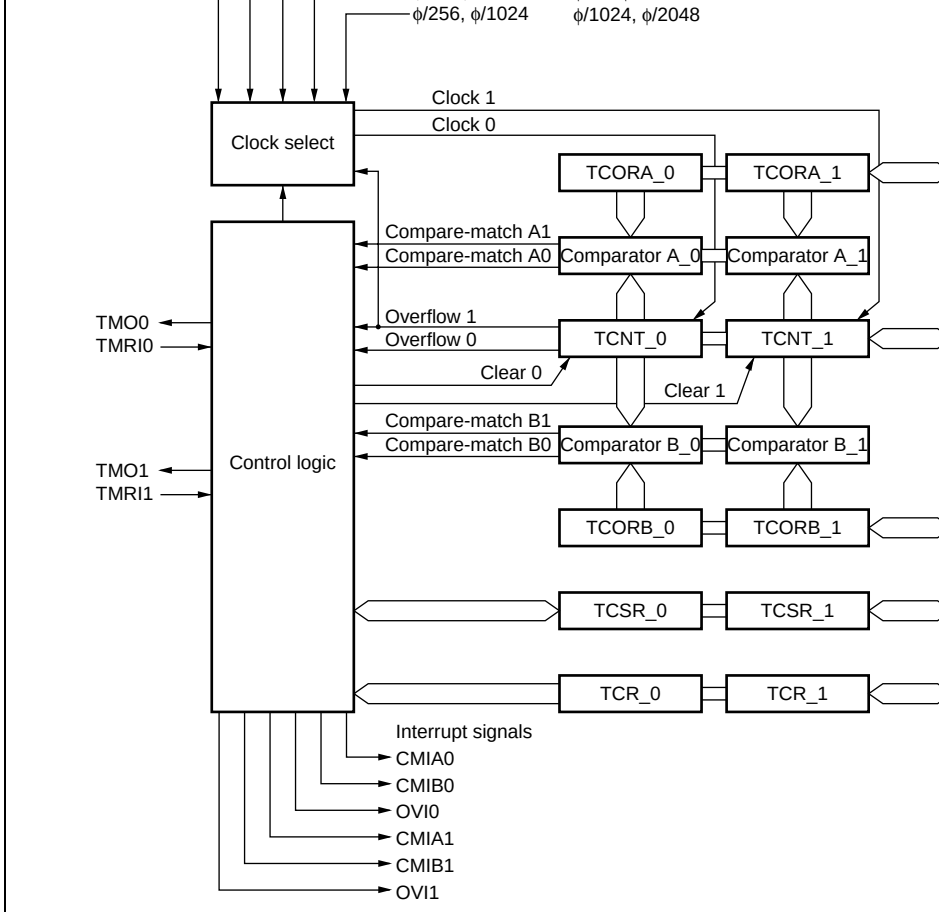
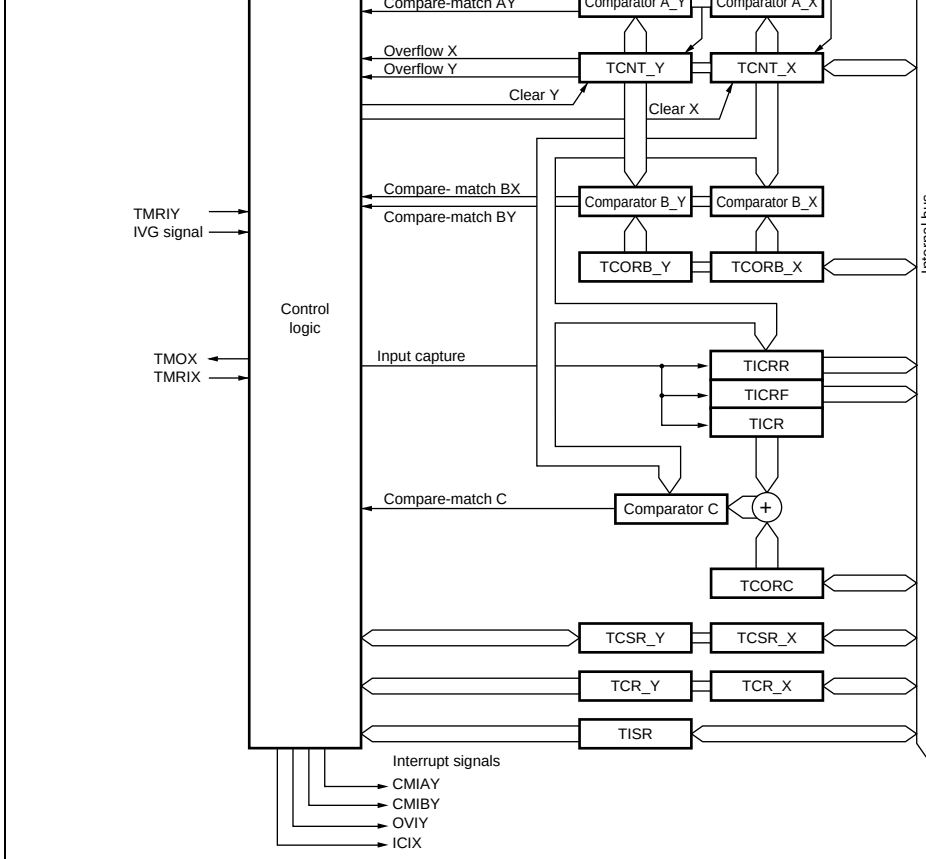


Figure 12.1 Block Diagram of 8-Bit Timers (TMR_0 and TMR_1)



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)

	Timer reset input	TMRI0	Input	External reset input for the
TMR_1	Timer output	TMO1	Output	Output controlled by comp
	Timer clock input	TMCI1	Input	External clock input for the
	Timer reset input	TMRI1	Input	External reset input for the
TMR_Y	Timer clock/reset input	VSYNCI/TMIY (TMCIY/TMRIY)	Input	External clock input/extern input for the counter
TMR_X	Timer output	TMOX	Output	Output controlled by comp
	Timer clock/reset input	HFBACKI/TMIX (TMCIX/TMRIX)	Input	External clock input/extern input for the counter

12.3 Register Descriptions

The TMR has the following registers. For details on the serial timer control register, ref section 3.2.3, Serial Timer Control Register (STCR). For details on timer connection re 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.

12.3.2 Time Constant Register A (TCORA)

TCORA is an 8-bit readable/writable register. TCORA_0 and TCORA_1 comprise a s
register, so they can be accessed together by word access. TCORA is continually com
the value in TCNT. When a match is detected, the corresponding compare-match flag
in TCSR is set to 1. Note however that comparison is disabled during the T2 state of a
write cycle. The timer output from the TMO pin can be freely controlled by these com
A signals and the settings of output select bits OS1 and OS0 in TCSR. TCORA is initi
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 s
register, so they can be accessed together by word access. TCORB is continually com
the value in TCNT. When a match is detected, the corresponding compare-match flag
in TCSR is set to 1. Note however that comparison is disabled during the T2 state of a
write cycle. The timer output from the TMO pin can be freely controlled by these com
B signals and the settings of output select bits OS3 and OS2 in TCSR. TCORB is initi
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.

6	CMIEA	0	R/W	Compare-Match Interrupt Enable A Selects whether the CMFA interrupt request (CM enabled or disabled when the CMFA flag in TCS 1. Note that a CMIA interrupt is not generated by 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) or disabled when the OVF flag in TCSR is set to 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 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 inpu
2	CKS2	0	R/W	Clock Select 2 to 0
1	CKS1	0	R/W	These bits select the clock input to TCNT and co
0	CKS0	0	R/W	condition, together with the ICKS1 and ICKS0 bi For details, see table 12.2.

	0	1	0	—	1	Increments at falling edge of internal c
	0	1	1	—	0	Increments at falling edge of internal c
	0	1	1	—	1	Increments at falling edge of internal c
	1	0	0	—	—	Increments at overflow signal from TC
TMR_1	0	0	0	—	—	Disables clock input
	0	0	1	0	—	Increments at falling edge of internal c
	0	0	1	1	—	Increments at falling edge of internal c
	0	1	0	0	—	Increments at falling edge of internal c
	0	1	0	1	—	Increments at falling edge of internal c
	0	1	1	0	—	Increments at falling edge of internal c
	0	1	1	1	—	Increments at falling edge of internal c
	1	0	0	—	—	Increments at compare-match A from
TMR_Y	0	0	0	—	—	Disables clock input
	0	0	1	—	—	Increments at falling edge of internal c
	0	1	0	—	—	Increments at falling edge of internal c
	0	1	1	—	—	Increments at falling edge of internal c
	1	0	0	—	—	Disables clock input
TMR_X	0	0	0	—	—	Disables clock input
	0	0	1	—	—	Increments at falling edge of internal c
	0	1	0	—	—	Increments at falling edge of internal c
	0	1	1	—	—	Increments at falling edge of internal c
	1	0	0	—	—	Disables clock input
Common	1	0	1	—	—	Increments at rising edge of external c
	1	1	0	—	—	Increments at falling edge of external
	1	1	1	—	—	Increments at both rising and falling e external clock.

Note: * If the TMR_0 clock input is set as the TCNT_1 overflow signal and the TMR_1 clock in the TCNT_0 compare-match signal simultaneously, a count-up clock cannot be genera

				[Setting condition] When the values of TCNT_0 and TCORB_0 m [Clearing conditions] • Read CMFB when CMFB = 1, then write 0 • When the DTC is activated by a CMIB inte
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When the values of TCNT_0 and TCORA_0 m [Clearing conditions] • Read CMFA when CMFA = 1, then write 0 • When the DTC is activated by a CMIA inte
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 reque compare-match A. 0: A/D converter start requests by compare-m disabled 1: A/D converter start requests by compare-m enabled

				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 TMO0 pin output changed by compare-match A of TCORA_0 TCNT_0. 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_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 [Clearing conditions] • Read CMFB when CMFB = 1, then write • When the DTC is activated by a CMIB int
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When the values of TCNT_1 and TCORA_1 [Clearing conditions • Read CMFA when CMFA = 1, then write • When the DTC is activated by a CMIA int

				This bit is always read as 1 and cannot be mo
3	OS3	0	R/W	Output Select 3, 2
2	OS2	0	R/W	These bits specify how the TMO1 pin output l changed by compare-match B of TCORB_1 a 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 l changed by compare-match A of TCORA_1 a 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.

				• When the DTC is activated by a CMIB int
6	CMFA	0	R/(W)*1	Compare-Match Flag A [Setting condition] When the values of TCNT_Y and TCORA_Y [Clearing conditions] • Read CMFA when CMFA = 1, then write • When the DTC is activated by a CMIA int
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 OV
4	ICIE	0	R/W	Input Capture Interrupt Enable Enables or disables the ICF interrupt reques the ICF bit in TCSR_X is set to 1. 0: ICF interrupt request (ICIX) is disabled 1: ICF interrupt request (ICIX) is enabled

				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 outpu be changed by compare-match A of TCORA_ 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 r [Clearing conditions] • Read CMFB when CMFB = 1, then write 0 • When the DTC is activated by a CMIB inte
6	CMFA	0	R/(W)*	Compare-Match Flag A [Setting condition] When the values of TCNT_X and TCORA_X r [Clearing conditions] • Read CMFA when CMFA = 1, then write 0 • When the DTC is activated by a CMIA inte

				[Setting condition] When a rising edge and falling edge is detec external reset signal in that order, after the IC 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
2	OS2	0	R/W	These bits specify how the TMOX pin output changed by compare-match B of TCORB_X TCNT_X. 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 TMOX pin output changed by compare-match A of TCORA_X TCNT_X. 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.

TCORC is an 8-bit readable/writable register. The sum of contents of TCORC and TIC
compared with TCNT. When a match is detected, a compare-match C signal is generate
However, comparison at the T2 state in the write cycle to TCORC and at the input capt
TICR is disabled. TCORC is initialized to H'FF. The TCORC function is used for the ti
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
rising edge and falling edge of the external reset input in that order, when the ICST bit
of the timer connection is set to 1. The ICST bit is cleared to 0 when one capture opera
TICRR and TICRF are initialized to H'00. The TICRR and TICRF functions are used f
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 timer clock/reset input pin VSYNCI/TMIY (TMC as the signal source of external clock/reset inp TMR_Y counter. 0: IVG signal is selected 1: VSYNCI/TMIY (TMCIY/TMRIY) is selected

2. Set the OS3 to OS0 bits in TCSR to B'0110 so that 1 is output according to the cor 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 p can be output without the intervention of software.

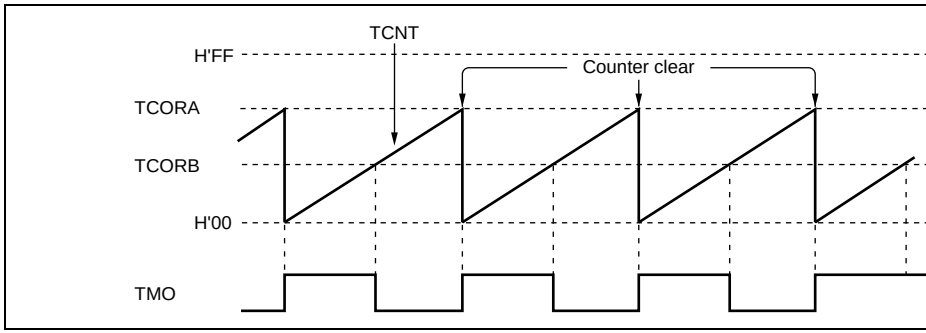


Figure 12.3 Pulse Output Example

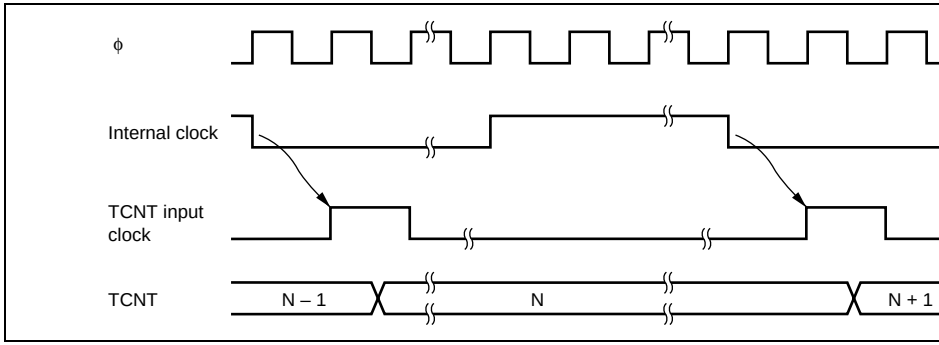


Figure 12.4 Count Timing for Internal Clock Input

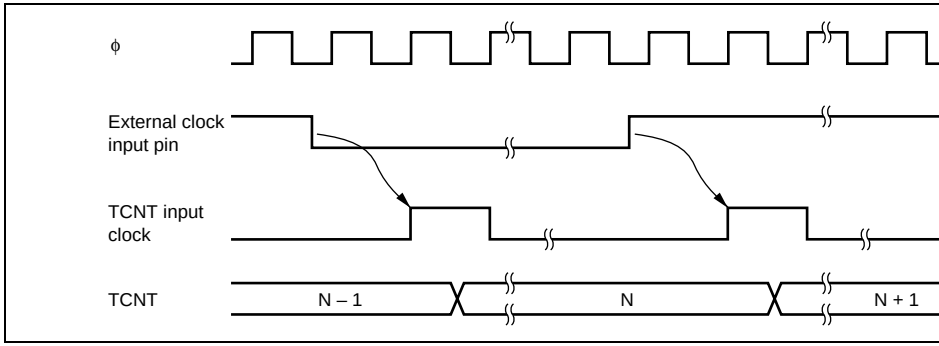


Figure 12.5 Count Timing for External Clock Input (Both Edges)

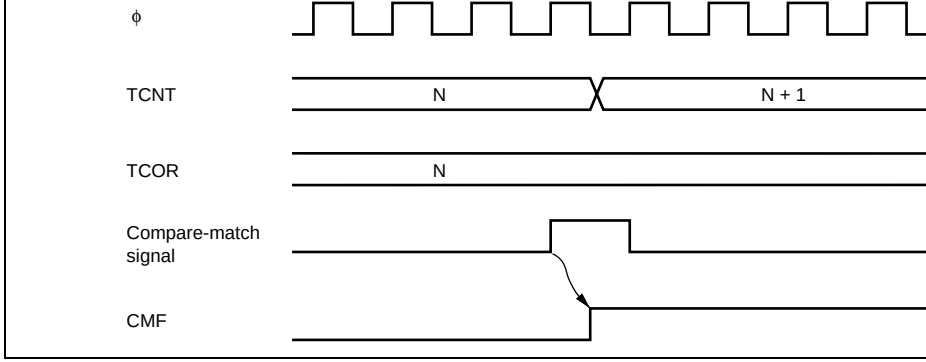


Figure 12.6 Timing of CMF Setting at Compare-Match

12.5.3 Timing of Timer Output at Compare-Match

When a compare-match signal occurs, the timer output changes as specified by the OS bits in TCSR. Figure 12.7 shows the timing of timer output when the output is set to to compare-match A signal.

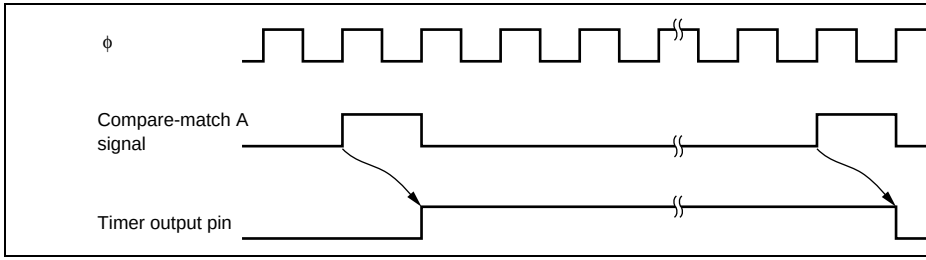


Figure 12.7 Timing of Toggled Timer Output by Compare-Match A Sig

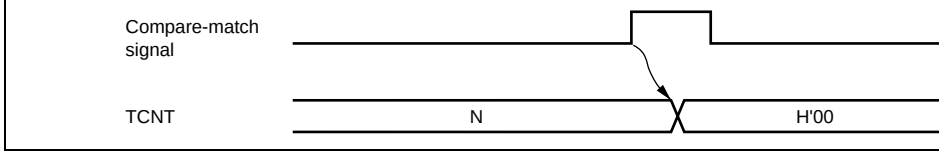


Figure 12.8 Timing of Counter Clear by Compare-Match

12.5.5 TCNT External Reset Timing

TCNT is cleared at the rising edge of an external reset input, depending on the settings CCLR1 and CCLR0 bits in TCR. The width of the clearing pulse must be at least 1.5 st 12.9 shows the timing of clearing the counter by an external reset input.

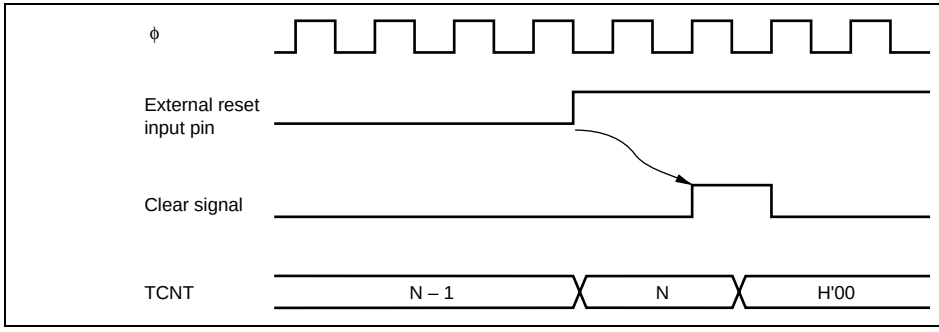


Figure 12.9 Timing of Counter Clear by External Reset Input

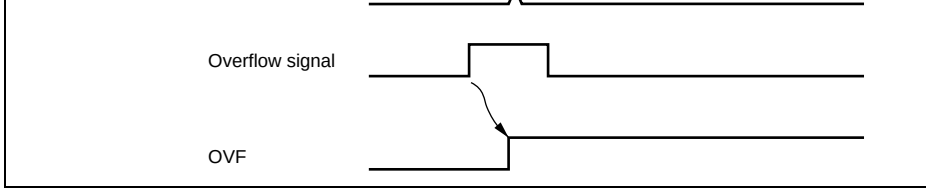


Figure 12.10 Timing of OVF Flag Setting

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 t
channels are cascaded. With this configuration, a single 16-bit timer can be used (16-b
mode) or the compare-matches of the 8-bit timer of channel 0 can be counted by the 8
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 1
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.

Pin Output:

- Control of output from the TMO0 pin by bits OS3 to OS0 in TCSR_0 is in accordan 16-bit compare-match conditions.
- Control of output from the TMO1 pin by bits OS3 to OS0 in TCSR_1 is in accordan 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 com A for channel 0. Channels 0 and 1 are controlled independently. Conditions such as set CMF flag, generation of interrupts, output from the TMO pin, and counter clearing are 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 measured with TICRR and TICRF, using a single capture operation controlled by the I TCONRI of the timer connection. If the falling edge of TMRIX is detected after its risi been detected while the ICST bit is set to 1, the value of TCNT at that time is transferre 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

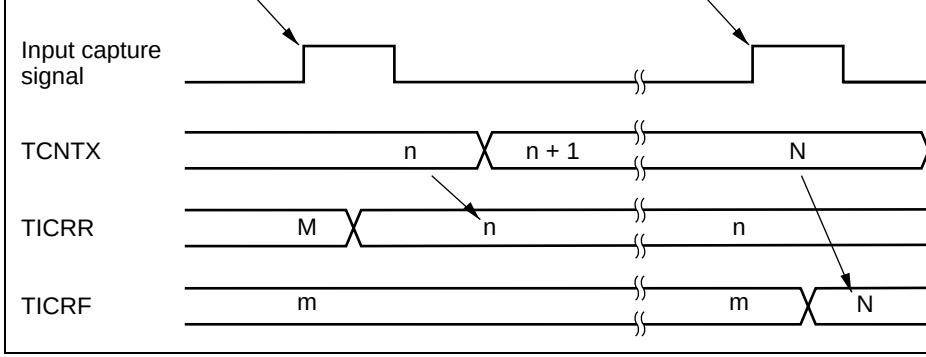


Figure 12.11 Timing of Input Capture Operation

If the input capture signal is input while TICRR and TICRF are being read, the input c
signal is delayed by one system clock (ϕ) cycle. Figure 12.12 shows the timing of this

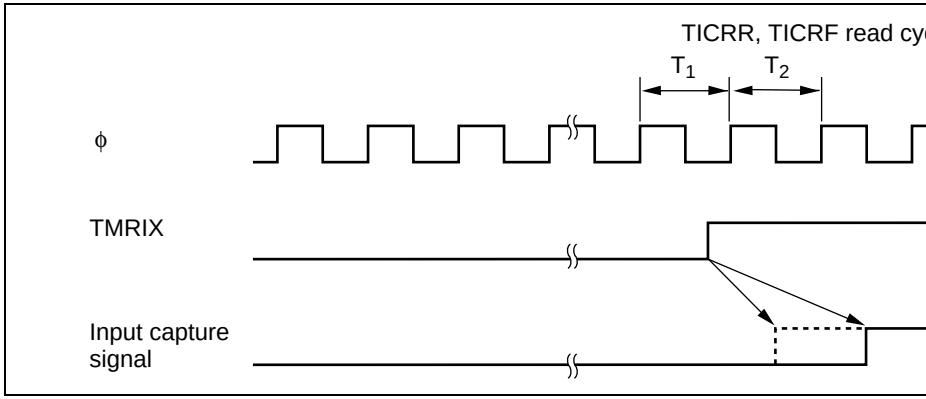


Figure 12.12 Timing of Input Capture Signal
(Input Capture Signal Is Input during TICRR and TICRF Read)

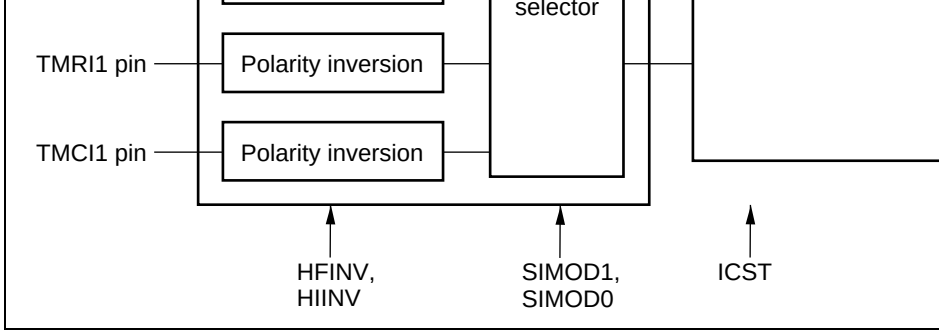


Figure 12.13 Input Capture Signal Selection

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 us
1	0	0	0	—	TMIX pin input selection
			1	—	Inverted TMIX pin input sele
		1	—	0	TMRI1 pin input selection
			—	1	Inverted TMRI1 pin input se
	1	1	—	0	TMCI1 pin input selection
			—	1	Inverted TMCI1 pin input se

Table 12.4 Interrupt Sources of 8-Bit Timers TMR_0, TMR_1, TMR_Y, and T

Channel	Name	Interrupt Source	Interrupt Flag	DTC Activation	Int Pr
TMR_0	CMIA0	TCORA_0 compare-match	CMFA	Enabled	Hig
	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	Lo

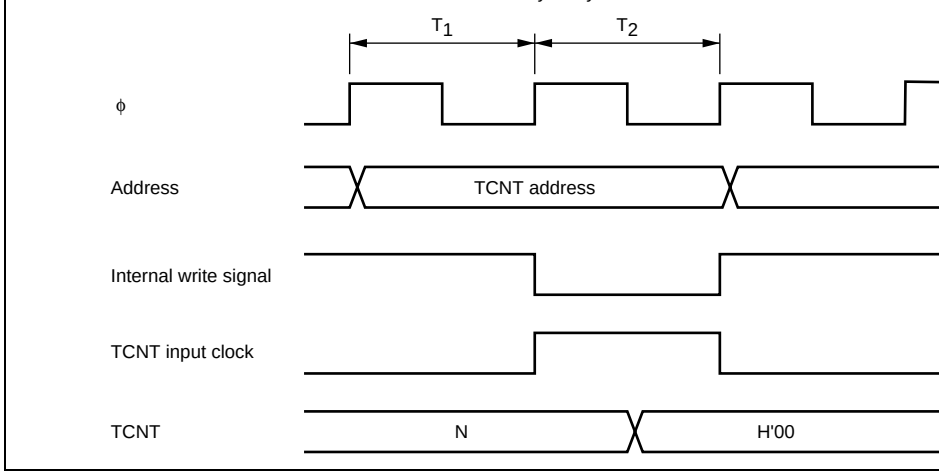


Figure 12.14 Conflict between TCNT Write and Clear

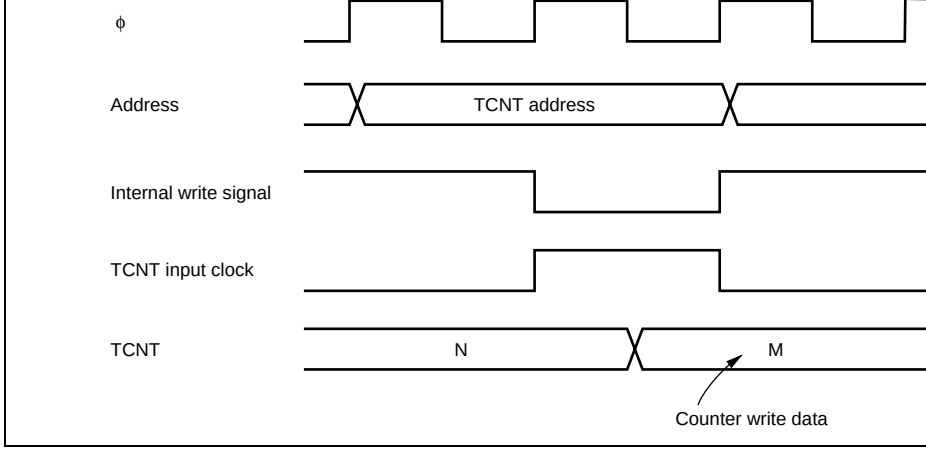


Figure 12.15 Conflict between TCNT Write and Increment

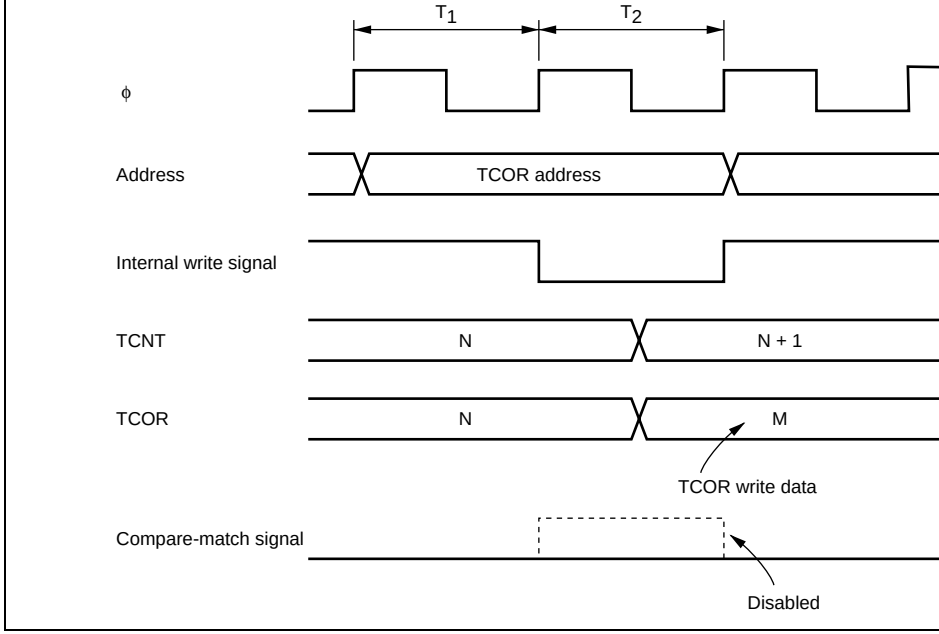


Figure 12.16 Conflict between TCOR Write and Compare-Match

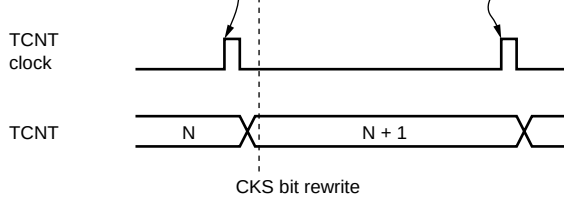
Toggle output	High
1 output	
0 output	
No change	Low

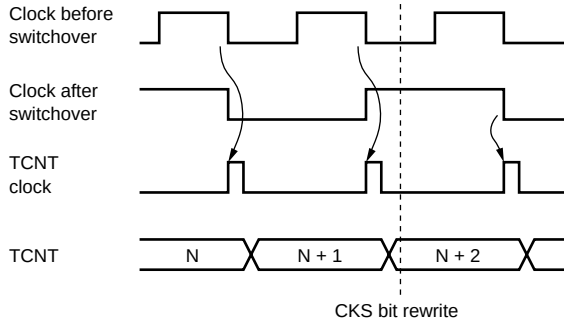
12.9.5 Switching of Internal Clocks and TCNT Operation

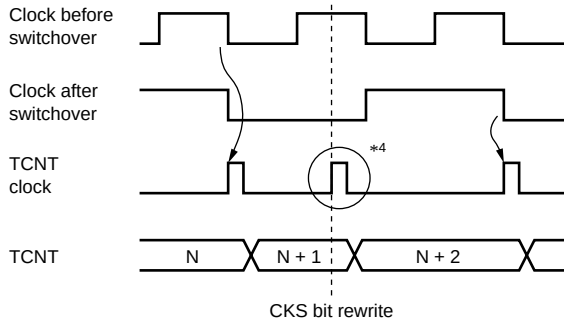
TCNT may increment erroneously when the internal clock is switched over. Table 12.
relationship between the timing at which the internal clock is switched (by writing to t
and CKS0 bits) and the TCNT operation.

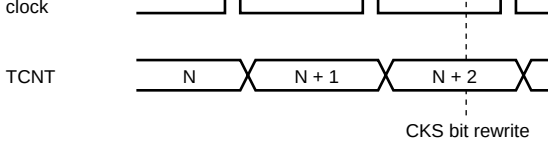
When the TCNT clock is generated from an internal clock, the falling edge of the inte
pulse is detected. If clock switching causes a change from high to low level, as shown
table 12.6, a TCNT clock pulse is generated on the assumption that the switchover is a
edge, and TCNT is incremented.

Erroneous incrementation can also happen when switching between internal and exter



2	Clock switching from low to high level*2	

3	Clock switching from high to low level*3	



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 in pulses for TCNT_0 and TCNT_1 are not generated, and thus the counters will stop op 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 setting is for TMR operation to be halted. Register access is enabled by canceling the mode. For details, refer to section 26, Power-Down Modes.

- Five input pins and four output pins, all of which can be designated for phase inve
  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 d
- 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
- 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 sel
  output.

Figure 13.1 shows a block diagram of the timer connection facility.

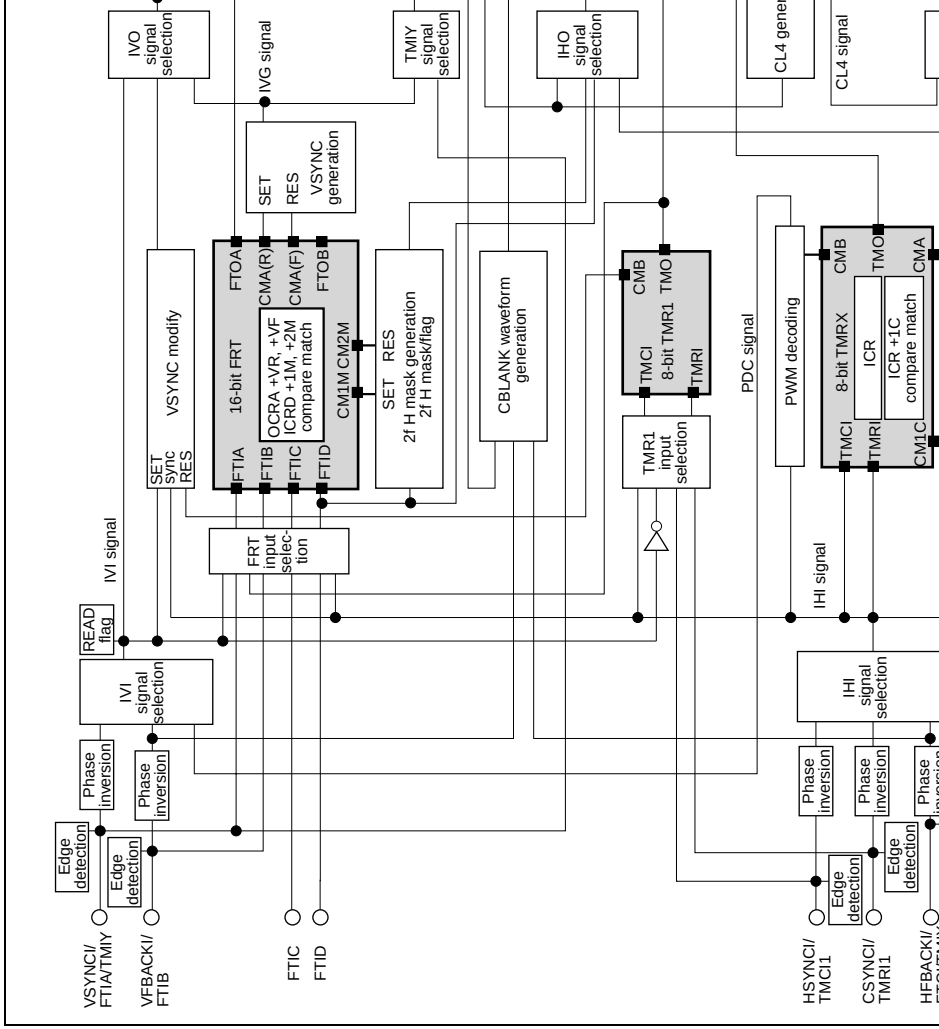


Figure 13.1 Block Diagram of Timer Connection

input pin			input pin or FTIA inpu input pin
Horizontal synchronization signal input pin	HSYNCI	Input	Horizontal synchroniz input pin or TMCI1 in
Composite synchronization signal input pin	CSYNCI	Input	Composite synchroni input pin or TMRI1 in
Spare vertical synchronization signal input pin	VFBACKI	Input	Spare vertical synchr signal input pin or FT
Spare horizontal synchronization signal input pin	HFBACKI	Input	Spare horizontal sync signal input pin or FT pin/TMIX input pin
Vertical synchronization signal output pin	VSYNCO	Output	Vertical synchronizati output pin or FTOA o
Horizontal synchronization signal output pin	HSYNCO	Output	Horizontal synchroniz output pin or TMO1 o
Clamp waveform output pin	CLAMPO	Output	Clamp waveform outp FTIC input pin
Blanking waveform output pin	CBLANK	Output	Blanking waveform o

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)

				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
5	SCONE	0	R/W	Synchronization Signal Connection Enable Selects the signal source of the FRT FTI in TMR_1 TMI1 input and TMCI1/TMRI1 inpu details, see table 13.2.

1, the contents of TCNT at those points a
into TICRR and TICRF, respectively, and
is cleared to 0.

[Clearing condition]

When a rising edge followed by a falling e
detected on TMRIX

[Setting condition]

When 1 is written in ICST after reading IC

0: The HFBACKI pin state is used directly a
HFBACKI input

1: The HFBACKI pin state is inverted befor
the HFBACKI input

- VFINV

0: The VFBACKI pin state is used directly a
VFBACKI input

1: The VFBACKI pin state is inverted befor
the VFBACKI input

- HIINV

0: The HSYNCI and CSYNCI pin states are
directly as the HSYNCI and CSYNCI inp

1: The HSYNCI and CSYNCI pin states are
before use as the HSYNCI and CSYNCI

- VIINV

0: The VSYNCI pin state is used directly as
VSYNCI input

1: The VSYNCI pin state is inverted before
VSYNCI input

Legend:
X: Don't care

Table 13.2 Synchronization Signal Connection Enable

Bit 5		Description				
SCONE	**Mode**	**FTIA**	**FTIB**	**FTIC**	**FTID**	**TMCI1**
0	Normal connection (Initial value)	FTIA input	FTIB input	FTIC input	FTID input	TMCI1 input
1	Synchronization signal connection mode	IVI signal	TMO1 signal	VFBACKI input	IHI signal	IHI signal

4	CBOE	0	R/W	(CLAMPO), and blanking waveform (CBL output is disabled, the state of the relevar determined by port DR and DDR, FRT, T PWM settings. Output enabling/disabling control does no port, FRT, or TMR input functions, but so TMR input signal sources are determined SCONE bit in TCONRI. HOE: 0: The P44/TMO1/HIRQ1/HSYNCO pin fu the P44/TMO1/HIRQ1 pin 1: The P44/TMO1/HIRQ1/HSYNCO pin fu the HSYNCO pin VOE: 0: The P61/FTOA/CIN1/$\overline{\text{KIN1}}$/VSYNCO p as the P61/FTOA/CIN1/$\overline{\text{KIN1}}$ pin 1: The P61/FTOA/CIN1/$\overline{\text{KIN1}}$/VSYNCO p as the VSYNCO pin CLOE: 0: The P64/FTIC/CIN4/$\overline{\text{KIN4}}$/CLAMPO pi as the P64/FTIC/CIN4/$\overline{\text{KIN4}}$ pin 1: The P64/FTIC/CIN4/$\overline{\text{KIN4}}$/CLAMPO pi as the CLAMPO pin CBOE: 0: The P27/A15/PW15/CBLANK pin funct P27/A15/PW15 pin In mode 1: 1: The P27/A15/PW15/CBLANK pin funct A15 pin In modes 2 and 3: 1: The P27/A15/PW15/CBLANK pin funct CBLANK pin

0: The IHO signal is used directly as the H output

1: The IHO signal is inverted before use as HSYNCO output

- VOINV:

0: The IVO signal is used directly as the V output

1: The IVO signal is inverted before use as VSYNCO output

- CLOINV:

0: The CLO signal (CL1, CL2, CL3, or CL4 used directly as the CLAMPO output

1: The CLO signal (CL1, CL2, CL3, or CL4 inverted before use as the CLAMPO out

- CBOINV:

0: The CBLANK signal is used directly as t output

1: The CBLANK signal is inverted before u CBLANK output

				0: The TMR_X registers are accessed a H'(FF)FFF0 to H'(FF)FFF5 1: The TMR_Y registers are accessed a H'(FF)FFF0 to H'(FF)FFF5
6	ISGENE	0	R/W	Internal Synchronization Signal Selects internal synchronization signals and CL4 signals) as the signal sources f IVO, and CLO signals together with the HOMOD0, VOMOD1, VOMOD0, CLMO CLMOD0 bits.
5	HOMOD1	0	R/W	Horizontal Synchronization Output Mode
4	HOMOD0	0	R/W	These bits select the signal source and method for the IHO signal. • ISGENE = 0 00: The IHI signal (without 2fH modificat selected 01: The IHI signal (with 2fH modification 1X: The CL1 signal is selected • ISGENE = 1 XX: The IHG signal is selected

				synchronization) is selected 10: The IVI signal (with fall modification, w synchronization) is selected 11: The IVI signal (with fall modification a 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 (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
0	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
1	TMR_Y	TMR_Y	TMR_Y	TMR_Y	TMR_Y	TMR_Y	
	TCR_Y	TCSR_Y	TCORA_Y	TCORB_Y	TCNT_Y	TISR	

				[Clearing condition]
				When 0 is written in VEDG after reading V
				[Setting condition]
				When a rising edge is detected on the VS
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 H
				[Setting condition]
				When a rising edge is detected on the HS
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 C
				[Setting condition]
				When a rising edge is detected on the CS
4	HFEDG	0	R/(W)*1	HFBACKI Edge
				Detects a rising edge on the HFBACKI pi
				[Clearing condition]
				When 0 is written in HFEDG after reading
				[Setting condition]
				When a rising edge is detected on the HF

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 interval is expressed as the occurrence of modification condition. For details, see sec 2fH Modification of IHI Signal. [Clearing condition] When 0 is written in PREQF after reading [Setting condition] When an IHI signal 2fH modification condit detected
1	IHI	Undefined*2	R	IHI Signal Level Indicates the current level of the IHI signal. source and phase inversion selection for th signal depends on the contents of TCONR bit to determine whether the input signal is negative, then maintain the IHI signal at po 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. source and phase inversion selection for th depends on the contents of TCONRI. Read determine whether the input signal is posit negative, then maintain the IVI signal at po 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.

The timer counter (TCNT) in TMR_X is set to count the internal clock pulses and to b the rising edge of the external reset signal (IHI signal). The value to be used as the thr deciding the pulse width is written in TCORB. The PWM decoder contains a delay lat uses the IHI signal as data and compare-match signal B (CMB) as a clock, and the sta signal (the result of the pulse width decision) at the first compare-match signal B timi 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 determin width decision threshold. Examples of TCR and TCORB settings of TMR_X are show 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 are disabled
6	CMIEA	0	
5	OVIE	0	
4 and 3	CCLR1 and CCLR0	11	TCNT is cleared by the rising edge of 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 M
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

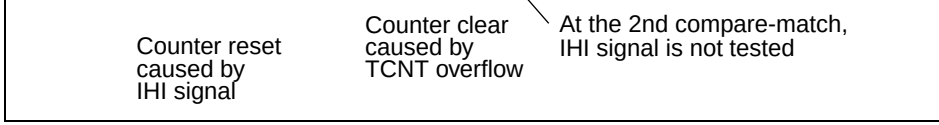


Figure 13.2 Timing Chart for PWM Decoding

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 differen cycles and rising/falling edges (clamp waveforms) in synchronization with the input sig signal). Three clamp waveforms can be generated: the CL1 to CL3 signals. In addition, signal can be generated using TMR_Y.

The CL1 signal rises simultaneously with the rise of the IHI signal, and when the CL1 high, the CL2 signal rises simultaneously with the fall of the IHI signal. The fall of bot and CL2 signals can be specified by TCORA. The rise of the CL3 signal can be specifi simultaneous with the sampling of the fall of the IHI signal using the system clock, and the CL3 signal can be specified by TCORC. The CL3 signal can also fall when the IHI rises.

TCNT in TMR_X is set to count internal clock pulses and to be cleared on the rising ed external reset signal (IHI signal).

The value to be used as the CL1 signal pulse width is written in TCORA. Write a value more in TCORA when internal clock ϕ is selected as the TMR_X counter clock, and a H'01 or more when $\phi/2$ is selected. When internal clock ϕ is selected, the CL1 signal pu is (TCORA set value + 3 ± 0.5). When the CL2 signal is used, the setting must be made 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 captures the value of TCNT at the inverse of the external reset signal edge (in this case, edge of the IHI signal). The timing of the fall of the CL3 signal is determined by the su

Both the rise and the fall of the CL3 signal are synchronized with the system clock and
width is fixed, but there is a variation in the phase relationship with the IHI signal equ
the resolution of the system clock.

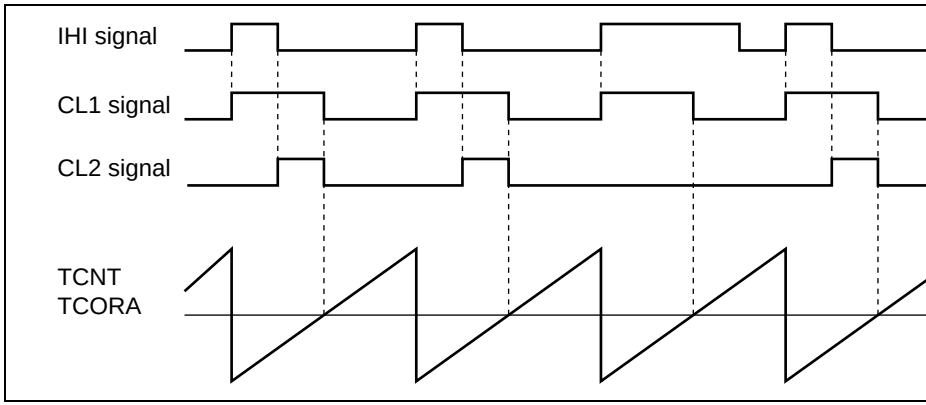


Figure 13.3 Timing Chart for Clamp Waveform Generation (CL1 and CL2

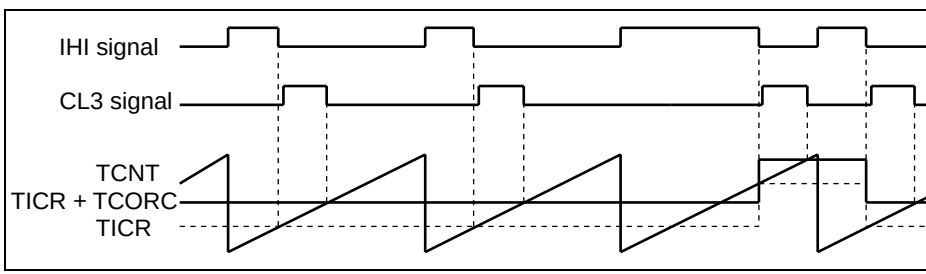


Figure 13.4 Timing Chart for Clamp Waveform Generation (CL3 Sign

(inverse of the IVI signal). The value to be used as the division factor is written in TCC
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 FI
shown in table 13.6, and the timing chart for measurement of the IVI signal and IHI sig
waveform periods is shown in figure 13.5. The period of the IHI signal divided wavefo
by (ICRD(3) – ICRD(2)) × resolution.

				the IVI signal)
	2 to 0	CKS2 to CKS0	101	TCNT is incremented on edge of the external cloc
TCSR in TMR_1	3 to 0	OS3 to OS0	0011	Not changed by compare output inverted by compa (toggle output): Division
			1001	When TCORB < TCORA on compare-match B, an on compare-match A: Div 256
TCR in FRT	6	IEDGB	0/1	0: FRC value is transferr on falling edge of inpu input B (IHI divided sig waveform) 1: FRC value is transferr on rising edge of input input B (IHI divided sig waveform)
	1 and 0	CKS1 and CKS0	01	FRC is incremented on i clock: ϕ/8
TCSR in FRT	0	CCLRA	0	FRC clearing is disabled

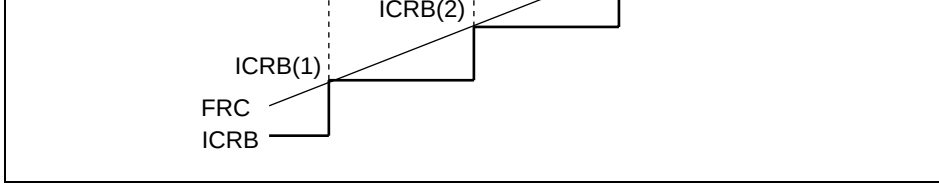


Figure 13.5 Timing Chart for Measurement of IVI Signal and IHI Signal Divided Waveform Periods

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 the frequency, this can be eliminated. In order for this function to operate properly, the 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 captured in ICRD in the FRT, and compare-matches generated at these points. The inte between the two compare-matches is called a mask interval. A value equivalent to appr 1/3 the IHI signal period is written in OCRDM. ICRD is set so that capture is performe rise of the IHI signal.

Since the IHI signal supplied to the IHO signal selection circuit is normally set on the r IHI signal and reset on the fall, its waveform is the same as that of the original IHI sign 2fH modification is selected, IHI signal edge detection is disabled during mask interval is also disabled during these intervals.

Examples of TCR, TCSR, TOCR, and OCRDM settings in the FRT are shown in table the 2fH modification timing chart is shown in figure 13.6.

TOCR in FRT	7	ICRDMS	1	ICRD is set to the operat which OCRDM is used
OCRDM in FRT	7 to 0	OCRDM7 to OCRDM0	H'01 to H'FF	Specifies the period duri ICRD operation is maske

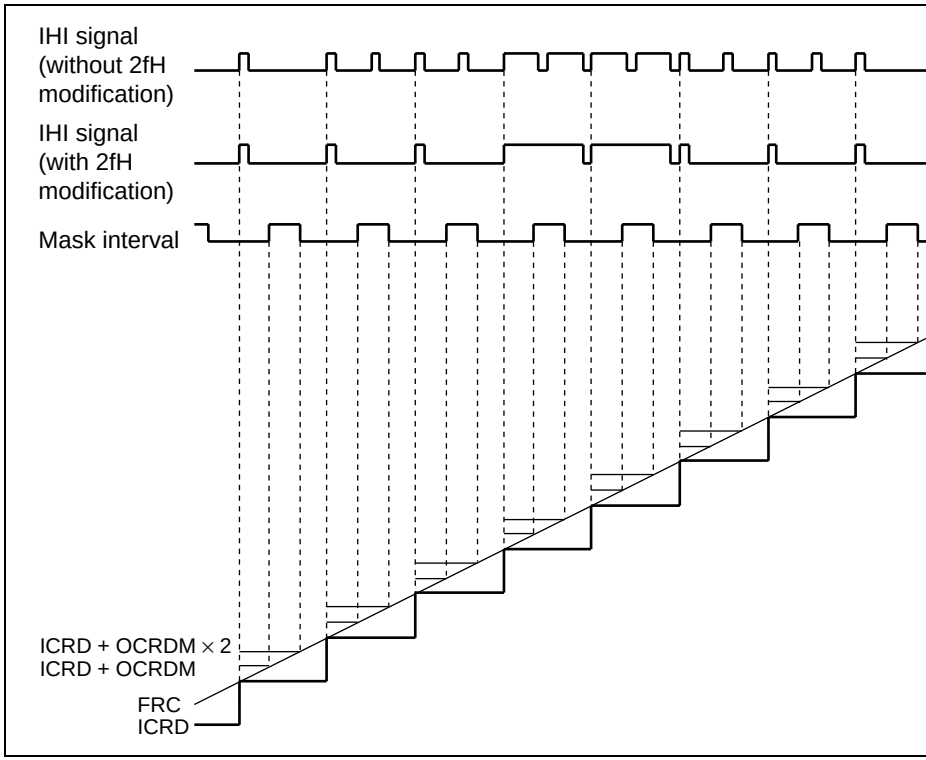


Figure 13.6 2fH Modification Timing Chart

written in TCORB.

Since the IVI signal supplied to the IVO signal selection circuit is normally set on the r
IVI signal and reset on the fall, its waveform is the same as that of the original IVI sign
fall modification is selected, a reset is performed on a TMR_1 TCORB compare-match
TMR_1.

The fall of the waveform generated in this way can be synchronized with the rise of the
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
modification/IHI synchronization timing chart is shown in figure 13.7.

				signal)
	2 to 0	CKS2 to CKS0	101	TCNT is incremented on the r of the external clock (IHI sign
TCSR in TMR_1	3 to 0	OS3 to OS0	0011	Not changed by compare-mat output inverted by compare-m (toggle output)
			1001	When TCORB < TCORA, 1 o compare-match B, 0 output o match A
TCORB in TMR_1			H'03 (example)	Compare-match on the 4th (e rise of the IHI signal after the inverse of the IVI signal

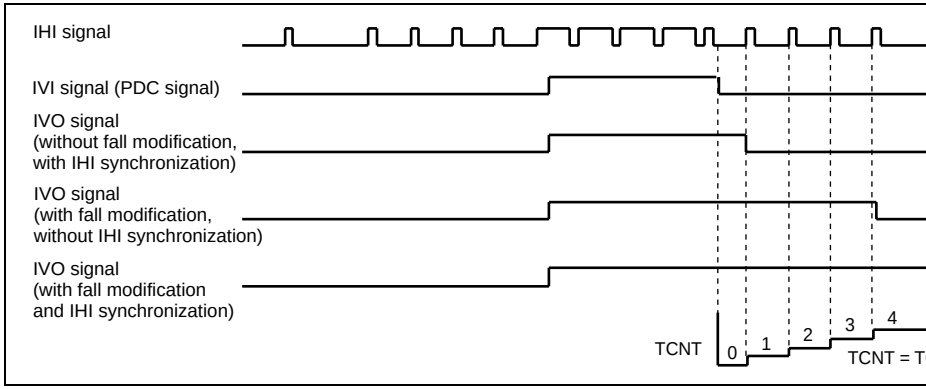


Figure 13.7 Fall Modification and IHI Synchronization Timing Char

OCRAR or OCRAF, alternately, each time a compare-match occurs. A value correspon
0 interval of the IVG signal is written in OCRAR, and a value corresponding to the 1 in
the IVG signal is written in OCRAF. The IVG signal is set by a compare-match after an
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 pulse
be cleared on a TCORA compare-match, to fix the period and set the timer output. TCO
so as to reset the timer output. The IVG signal is connected as the TMR_Y reset input (
and the rise of the IVG signal can be treated in the same way as a TCORA compare-ma

The CL4 signal is a waveform that rises within one system clock period after the fall of
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, OCRA
OCRAF, and TOCR settings in the FRT are shown in table 13.9, and the IHG signal/IV
timing chart is shown in figure 13.8.

	2 to 0	CKS2 to CKS0	001	TCNT is incremented on inter $\phi/4$	
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 intern	
OCRAR in FRT			H'7FEF (example)	IVG signal 0 interval = $\phi \times 262016$	IVG sign $\phi \times 262$ times IH
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 which OCRAR and OCRAF a	

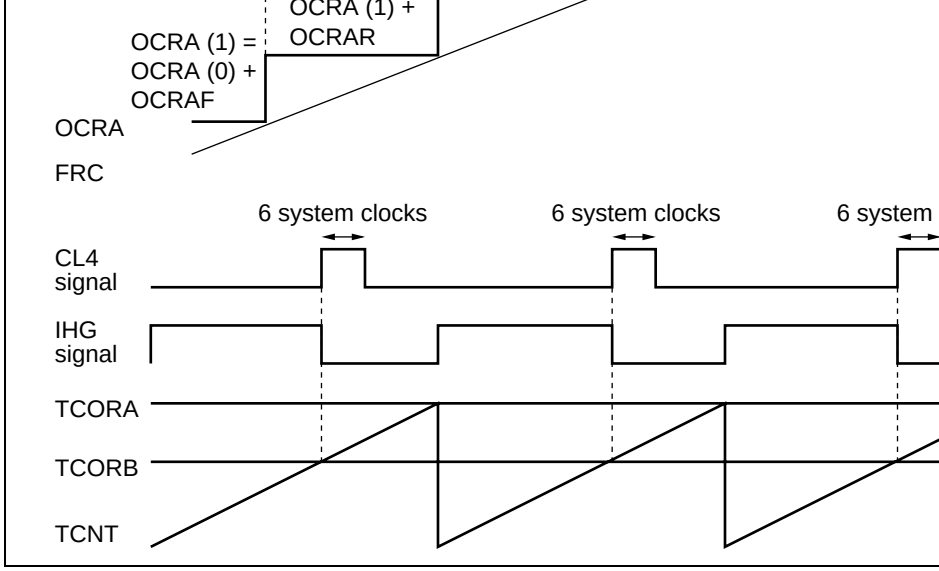


Figure 13.8 IVG Signal/IHG Signal/CL4 Signal Timing Chart

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-f part in the HFBACKI input
		CL1 signal	HFBACKI input 1 interval is changed b
		IHG signal	Internal synchronization signal is outpu
S-on-G mode	CSYNCI input	IHI signal (without 2fH modification)	CSYNCI input (composite synchroniza is output directly
		IHI signal (with 2fH modification)	Double-frequency part of CSYNCI inpu synchronization signal) is eliminated be
		CL1 signal	CSYNCI input (composite synchroniza horizontal synchronization signal part i before output
		IHG signal	Internal synchronization signal is outpu
Composite mode	HSYNCI input	IHI signal (without 2fH modification)	HSYNCI input (composite synchroniza is output directly
		IHI signal (with 2fH modification)	Double-frequency part of HSYNCI inpu synchronization signal) is eliminated be
		CL1 signal	HSYNCI input (composite synchroniza horizontal synchronization signal part i before output
		IHG signal	Internal synchronization signal is outpu
Separate mode	HSYNCI input	IHI signal (without 2fH modification)	HSYNCI input (horizontal synchronizat output directly
		IHI signal (with 2fH modification)	Meaningless unless there is a double-f part in the HSYNCI input (horizontal synchronization signal)
		CL1 signal	HSYNCI input (horizontal synchronizat interval is changed before output
		IHG signal	Internal synchronization signal is outpu

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 inpu synchronized with HFBACKI input
		IVI signal (with fall modification, without IHI synchronization)	VFBACKI input fall is modified befo
		IVI signal (with fall modification and IHI synchronization)	VFBACKI input fall is modified and synchronized with HFBACKI input output
		IVG signal	Internal synchronization signal is o
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 sepa before output
		IVI signal (without fall modification, with IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is sepa signal is synchronized with CSYNC input before output
		IVI signal (with fall modification, without IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is sepa fall is modified before output
		IVI signal (with fall modification and IHI synchronization)	CSYNCI/HSYNCI input (composite synchronization signal) vertical synchronization signal part is sepa modified, and signal is synchronize CSYNCI/HSYNCI input before outp
		IVG signal	Internal synchronization signal is o

modification, without IHI synchronization)	fall is modified before output
IVI signal (with fall modification and IHI synchronization)	VSYNCI input (vertical synchroniz fall is modified and signal is synch HSYNCI input (horizontal synchro signal) before output
IVG signal	Internal synchronization signal is

13.4.9 CBLANK Output

Using the signals generated/selected with timer connection, it is possible to generate a based on the composite synchronization signal (blanking waveform).

One kind of blanking waveform is generated by combining HFBACKI and VFBACKI with the phase polarity made positive by means of bits HFINV and VFINV in TCONI IVO signal.

The logic of CBLANK output waveform generation is shown in figure 13.9.

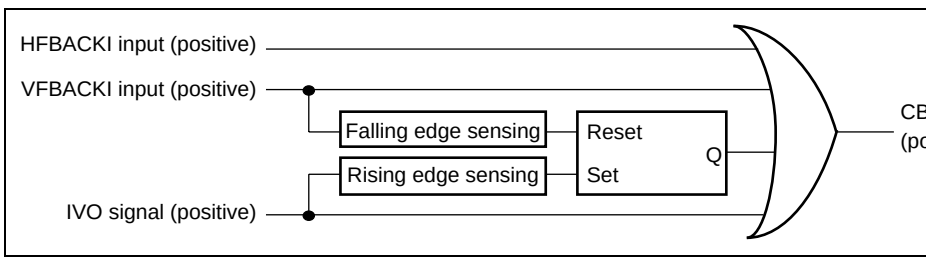


Figure 13.9 CBLANK Output Waveform Generation

timer operation, an interval timer interrupt is generated each time the counter overflow
diagram of the WDT_0 and WDT_1 is shown in figure 14.1.

14.1 Features

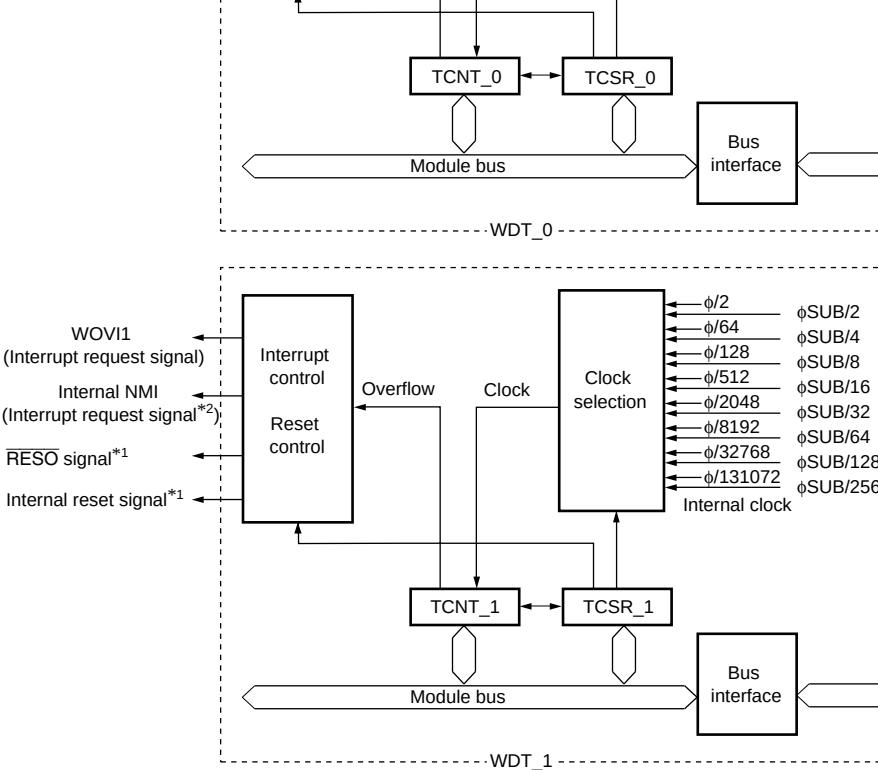
- Selectable from eight (WDT_0) or 16 (WDT_1) counter input clocks.
- Switchable between watchdog timer mode and interval timer mode

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 sig 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 $\overline{\text{RESO}}$ 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

External sub-clock input pin	EXCL	Input	Inputs the clock pulses to the WD prescaler counter

14.3 Register Descriptions

The WDT has the following registers. To prevent accidental overwriting, TCSR and T to be written to in a method different from normal registers. For details, refer to sectio Notes on Register Access. For details on the system control register, refer to section 3 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 (TCS cleared to 0.

7	OVF	0	R/(W)	Overflow Flag Indicates that TCNT has overflowed (changes to H'00). [Setting condition] When TCNT overflows (changes from H'FF to However, when internal reset request generat selected in watchdog timer mode, OVF is clea automatically by the internal reset. [Clearing conditions] • When TCSR is read when OVF = 1*2, then 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 watchd 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 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 when TCNT has overflowed. 0: An NMI interrupt is requested 1: An internal reset is requested

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 mus least twice.

				However, when internal reset request generat selected in watchdog timer mode, OVF is clea automatically by the internal reset. [Clearing conditions] • When TCSR is read when OVF = 1*2, ther 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 watchd 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 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 presca 1: Counts the divided cycle of φSUB–based pr (PSS)
3	RST/$\overline{NMI}$	0	R/W	Reset or NMI Selects to request an internal reset or an NMI when TCNT has overflowed. 0: An NMI interrupt is requested 1: An internal reset is requested

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)

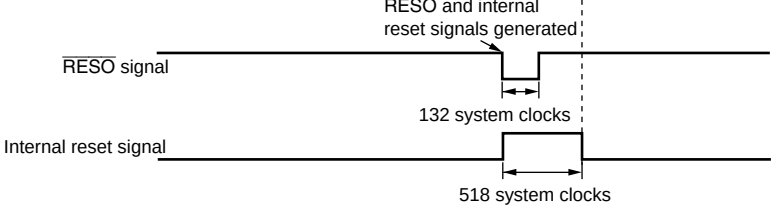
Notes: 1. Only 0 can be written, to clear the flag.
2. When OVF is polled with the interval timer interrupt disabled, OVF = 1 mus least twice.

overflows by rewriting the TCNT value (normally be writing H'00) before overflows oc

If the RST/$\overline{\text{NMI}}$ bit of TCSR is set to 1, when the TCNT overflows, an internal reset sig LSI is issued for 518 system clocks, and the low level signal is simultaneously output f $\overline{\text{RESO}}$ pin for 132 states, as shown in figure 14.2. If the RST/$\overline{\text{NMI}}$ bit is cleared to 0, w TCNT overflows, an NMI interrupt request is generated. Here, the output from the $\overline{\text{RES}}$ remains high.

An internal reset request from the watchdog timer and a reset input from the $\overline{\text{RES}}$ pin a processed in the same vector. Reset source can be identified by the XRST bit status in S a reset caused by a signal input to the $\overline{\text{RES}}$ pin occurs at the same time as a reset caused overflow, the $\overline{\text{RES}}$ 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 N processed in the same vector. Do not handle an NMI interrupt request from the watchdo 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

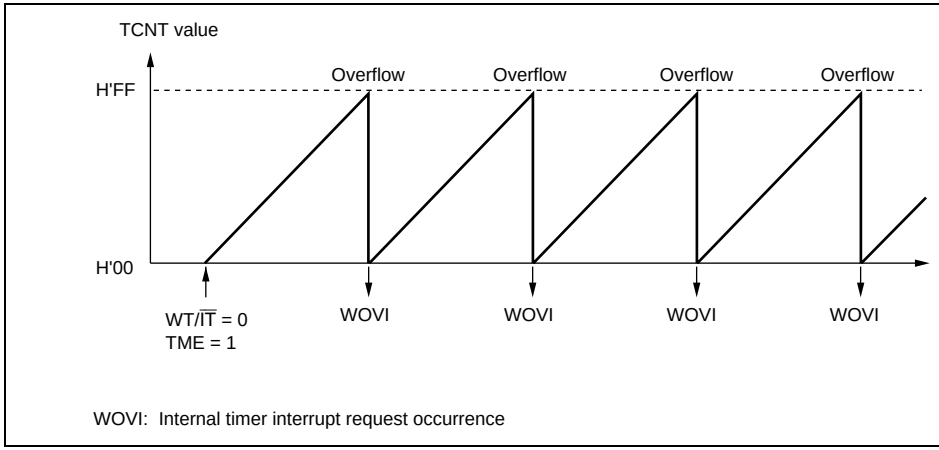


Figure 14.3 Interval Timer Mode Operation

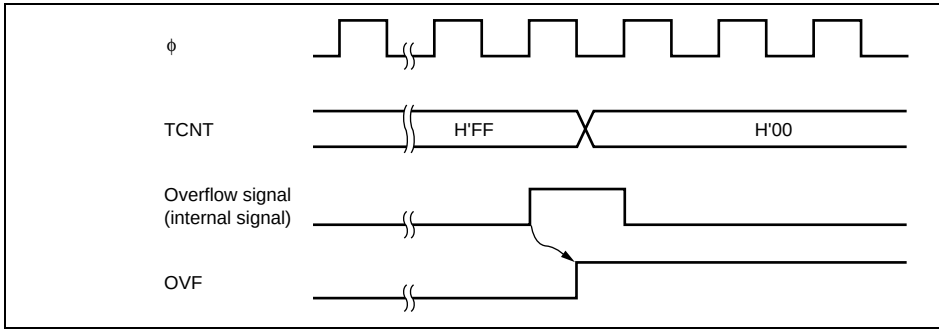


Figure 14.4 OVF Flag Set Timing

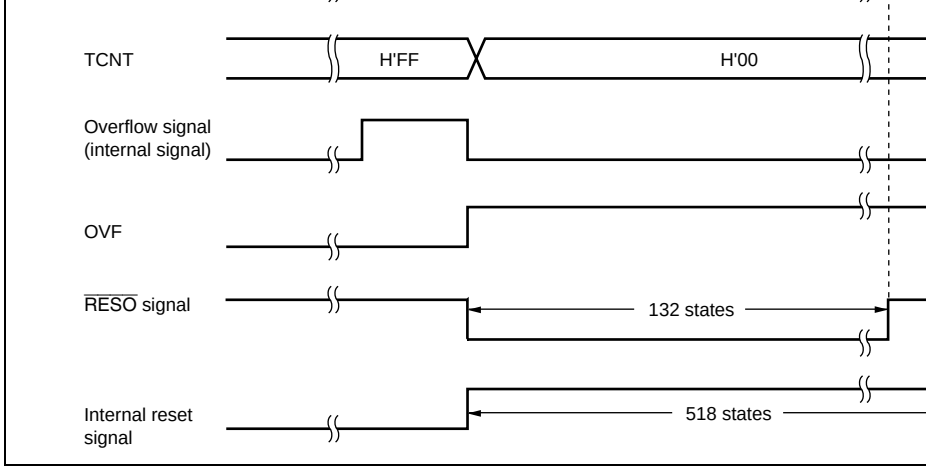


Figure 14.5 Output Timing of $\overline{\text{RESO}}$ signal

14.5 Interrupt Sources

During interval timer mode operation, an overflow generates an interval timer interrup
The interval timer interrupt is requested whenever the OVF flag is set to 1 in TCSR. C
cleared to 0 in the interrupt handling routine.

When the NMI interrupt request is selected in watchdog timer mode, an NMI interrup
generated by an overflow.

Table 14.2 WDT Interrupt Source

Name	Interrupt Source	Interrupt Flag	DTC Ac
WOVI	TCNT overflow	OVF	Not poss

Writing to TCNT and TCSR (Example of WDT_0): These registers must be written
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 conc
shown in figure 14.6 to write to TCNT or TCSR. To write to TCNT, the upper bytes m
the value H'5A and the lower bytes must contain the write data before the transfer instr
execution. To write to TCSR, the upper bytes must contain the value H'A5 and the low
must contain the write data.

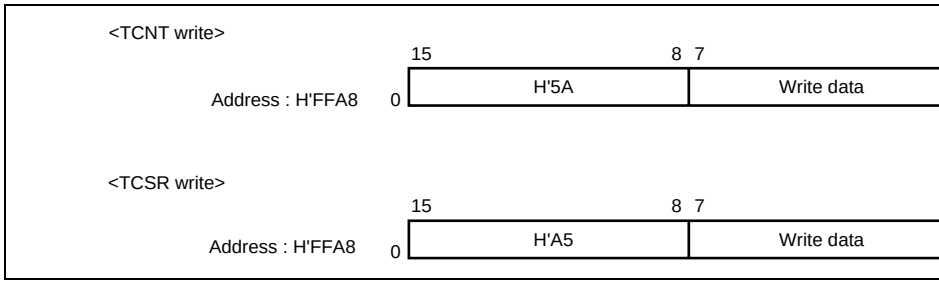


Figure 14.6 Writing to TCNT and TCSR (WDT_0)

Reading from TCNT and TCSR (Example of WDT_0): These registers are read in t
way as other registers. The read address is H'FFA8 for TCSR and H'FFA9 for TCNT.

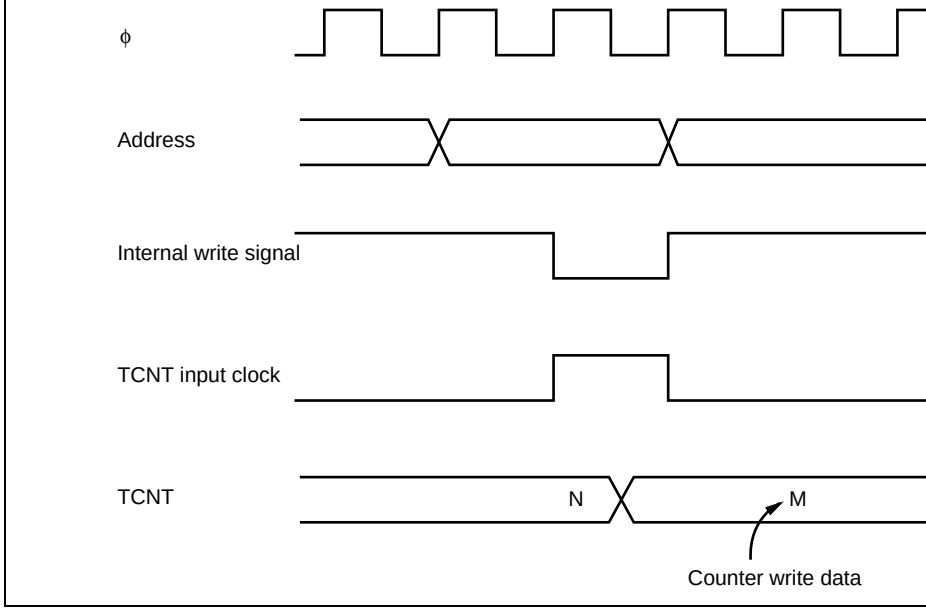


Figure 14.7 Conflict between TCNT Write and Increment

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 coul
the incrementation. Software must stop the watchdog timer (by clearing the TME bit t
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 oper
could occur in the incrementation. Software must stop the watchdog timer (by clearing
bit to 0) before switching the mode.

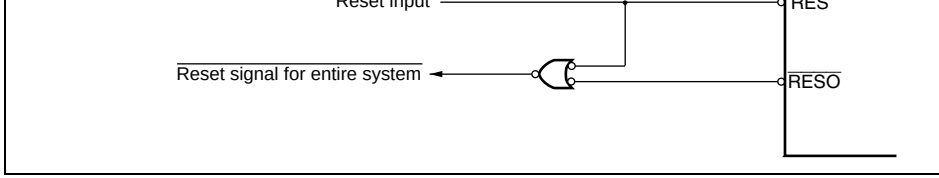


Figure 14.8 Sample Circuit for Resetting System by $\overline{\text{RESO}}$ Signal

14.6.6 Counter Values during Transitions between High-Speed, Sub-Active, and Modes

When WDT_1 is used as a clock counter and is allowed to transit between high-speed m sub-active or watch mode, the counter does not display the correct value due to internal switching.

Specifically, when transiting from high-speed mode to sub-active or watch mode, that i control clock for WDT_1 switches from the main clock to the sub-clock, the counter in timing is delayed for approximately two to three clock cycles.

Similarly, when transiting from sub-active or watch mode to high-speed mode, the cloc supplied until stabilized internal oscillation is available because the main clock oscillat in sub-clock mode. The counter is therefore prevented from incrementing for the time s the STS2 to STS0 bits in SBYCR after internal oscillation starts, thus producing counte differences for this time.

Special care must be taken when using WDT_1 as a clock counter. Note that no counte difference is produced while operated in the same mode.

SCI_2 can handle communication using the waveform based on the Infrared Data Ass
(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
  be executed simultaneously. Double-buffering is used in both the transmitter and t
  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 mod
- Four interrupt sources

  Four interrupt sources — transmit-end, transmit-data-empty, receive-data-full, and
  error — that can issue requests.

  The transmit-data-empty and receive-data-full interrupt sources can activate the D

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 ca
  framing error

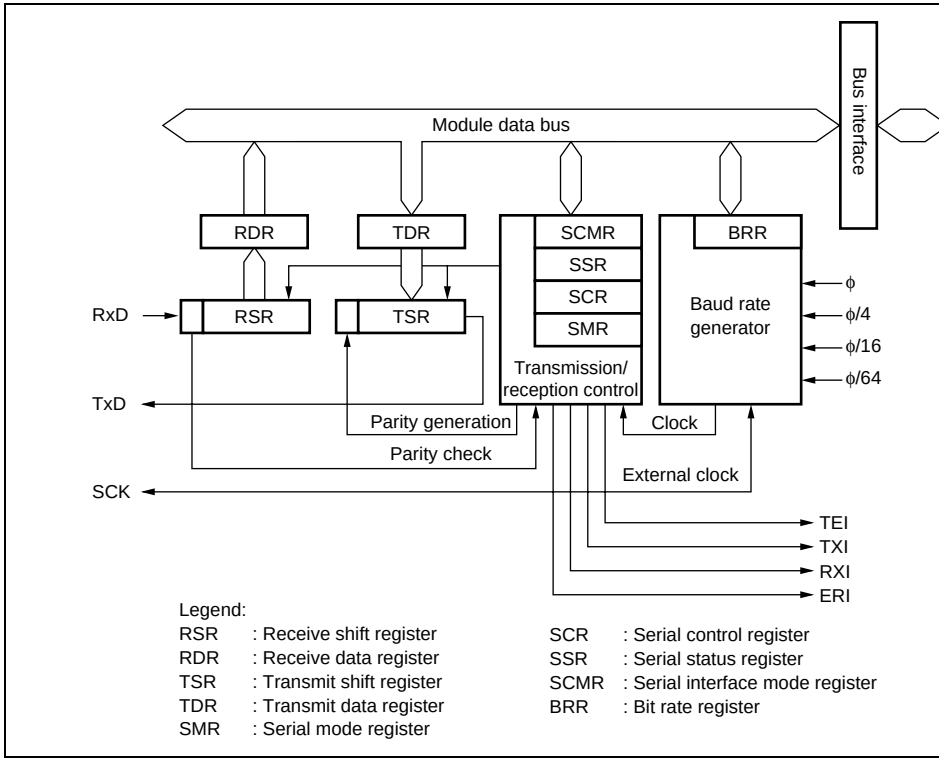


Figure 15.1 Block Diagram of SCI

	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/IrD
	TxD2/IrTxD	Output	Channel 2 transmit data output (normal/I

Note: * Pin names SCK, RxD, and TxD are used in the text for all channels, omittin 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)

RDR is an 8-bit register that stores receive data. When the SCI has received one frame
data, it transfers the received serial data from RSR to RDR where it is stored. After this
receive the next data. Since RSR and RDR function as a double buffer in this way, cont
receive operations can be performed. After confirming that the RDRF bit in SSR is set
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 emp
transfers the transmit data written in TDR to TSR and starts transmission. The double-b
structures of TDR and TSR enables continuous serial transmission. If the next transmit
already been written to TDR when one frame of data is transmitted, the SCI transfers th
data to TSR to continue transmission. Although TDR can be read from or written to by
all times, to achieve reliable serial transmission, write transmit data to TDR for only on
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, th
transfers transmit data from TDR to TSR, then sends the data to the TxD pin. TSR cann
directly accessed by the CPU.

				1: Clocked synchronous mode
6	CHR	0	R/W	Character Length (enabled only in asynch mode) 0: Selects 8 bits as the data length. 1: Selects 7 bits as the data length. LSB-fi and the MSB of TDR is not transmitted transmission. In clocked synchronous mode, a fixed data bits is used.
5	PE	0	R/W	Parity Enable (enabled only in asynchronc When this bit is set to 1, the parity bit is ad transmit data before transmission, and the checked in reception. For a multiprocesso parity bit addition and checking are not pe regardless of the PE bit setting.
4	O/$\overline{E}$	0	R/W	Parity Mode (enabled only when the PE bi asynchronous mode) 0: Selects even parity. 1: Selects odd parity.
3	STOP	0	R/W	Stop Bit Length (enabled only in asynchro Selects the stop bit length in transmission. 0: 1 stop bit 1: 2 stop bits In reception, only the first stop bit is check second stop bit is 0, it is treated as the sta next transmit frame.

				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 registe and the baud rate, see section 15.3.9, Bit R Register (BRR). n is the decimal display 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 inte requests, and selection of the transfer clock source. For details on interrupt requests, ref 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 req enabled.
6	RIE	0	R/W	Receive Interrupt Enable When this bit is set to 1, RXI and ERI interr are enabled.
5	TE	0	R/W	Transmit Enable When this bit is set to 1, transmission is ena
4	RE	0	R/W	Receive Enable When this bit is set to 1, reception is enable

				Multiprocessor Communication Function.
2	TEIE	0	R/W	Transmit End Interrupt Enable When this bit is set to 1, a TEI interrupt re enabled.
1	CKE1	0	R/W	Clock Enable 1, 0
0	CKE0	0	R/W	These bits select the clock source and SC function. Asynchronous mode 00: Internal clock (SCK pin functions as I/O port.) 01: Internal clock (Outputs a clock of the same frequency as from the SCK pin.) 1X: External clock (Inputs a clock with a frequency 16 times f from the SCK pin.) Clocked synchronous mode 0X: Internal clock (SCK pin functions as cl 1X: External clock (SCK pin functions as c

Legend:

X: Don’t care

				[Setting conditions] • When the TE bit in SCR is 0 • When data is transferred from TDR to TDR is ready for data write [Clearing conditions] • When 0 is written to TDRE after readi TDRE = 1 • When a TXI interrupt request is issue the DTC to write data to TDR
6	RDRF	0	R/(W)*	Receive Data Register Full Indicates that receive data is stored in RD [Setting condition] When serial reception ends normally and data is transferred from RSR to RDR [Clearing conditions] • When 0 is written to RDRF after read RDRF = 1 • When an RXI interrupt request is issu the DTC to read data from RDR The RDRF flag is not affected and retains previous value when the RE bit in SCR is 0.
5	ORER	0	R/(W)*	Overrun Error [Setting condition] When the next data is received while RD [Clearing condition] When 0 is written to ORER after reading ORER = 1

3	PER	0	R/(W)*	Parity Error [Setting condition] When a parity error is detected during re [Clearing condition] When 0 is written to PER after reading P
2	TEND	1	R	Transmit End [Setting conditions] • When the TE bit in SCR is 0 • When TDRE = 1 at transmission of t a 1-byte serial transmit character [Clearing conditions] • When 0 is written to TDRE after rea TDRE = 1 • When a TXI interrupt request is issu the DTC to write data to TDR
1	MPB	0	R	Multiprocessor Bit MPB stores the multiprocessor bit in the frame. When the RE bit in SCR is cleare previous state is retained.
0	MPBT	0	R/W	Multiprocessor Bit Transfer MPBT stores the multiprocessor bit to b the transmit frame.

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

3	SDIR	0	R/W	Data Transfer Direction Selects the serial/parallel conversion form 0: TDR contents are transmitted with LSE Receive data is stored as LSB first in RD 1: TDR contents are transmitted with MS Receive data is stored as MSB first in RD The SDIR bit is valid only when the 8-bit is used for transmission/reception; when 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 bit does not affect the logic level of the pa When the parity bit is inverted, invert the SMR. 0: TDR contents are transmitted as they Receive data is stored as it is in RDR. 1: TDR contents are inverted before bein transmitted. Receive data is stored in i form in RDR.
1	—	1	R	Reserved This bit is always read as 1 and cannot b
0	SMIF	0	R/W	Serial Communication Interface Mode Se 0: Normal asynchronous or clocked sync mode 1: Reserved mode

Mode	Bit Rate	Error
Asynchronous mode	$B = \frac{\phi \times 10^6}{64 \times 2^{2n-1} \times (N+1)}$	Error (%) = { $\frac{\phi \times 10^6}{B \times 64 \times 2^{2n-1} \times (N$
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 maximum bit rate settable for each frequency. Table 15.6 shows sample N settings in clocked synchronous mode. Tables 15.5 and 15.7 show the maximum bit rates with ex input.

300	0	207	0.16	0	217	0.21	0	255	0.00	1	7
600	0	103	0.16	0	108	0.21	0	127	0.00	0	15
1200	0	51	0.16	0	54	–0.70	0	63	0.00	0	7
2400	0	25	0.16	0	26	1.14	0	31	0.00	0	3
4800	0	12	0.16	0	13	–2.48	0	15	0.00	0	1
9600	—	—	—	0	6	–2.48	0	7	0.00	0	9
19200	—	—	—	—	—	—	0	3	0.00	0	4
31250	0	1	0.00	—	—	—	—	—	—	0	2
38400	—	—	—	—	—	—	0	1	0.00	—	–

	Operating Frequency ϕ (MHz)										
	3.6864			4			4.9152				
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N
110	2	64	0.70	2	70	0.03	2	86	0.31	2	8
150	1	191	0.00	1	207	0.16	1	255	0.00	2	6
300	1	95	0.00	1	103	0.16	1	127	0.00	1	1
600	0	191	0.00	0	207	0.16	0	255	0.00	1	6
1200	0	95	0.00	0	103	0.16	0	127	0.00	0	1
2400	0	47	0.00	0	51	0.16	0	63	0.00	0	6
4800	0	23	0.00	0	25	0.16	0	31	0.00	0	3
9600	0	11	0.00	0	12	0.16	0	15	0.00	0	1
19200	0	5	0.00	—	—	—	0	7	0.00	0	7
31250	—	—	—	0	3	0.00	0	4	–1.70	0	4
38400	0	2	0.00	—	—	—	0	3	0.00	0	3

Legend:

—: Can be set, but there will be a degree of error.

Note: Make the settings so that the error does not exceed 1%.

600	1	77	0.16	1	79	0.00	1	95	0.00	1	1
1200	0	155	0.16	0	159	0.00	0	191	0.00	0	2
2400	0	77	0.16	0	79	0.00	0	95	0.00	0	1
4800	0	38	0.16	0	39	0.00	0	47	0.00	0	5
9600	0	19	–2.34	0	19	0.00	0	23	0.00	0	2
19200	0	9	–2.34	0	9	0.00	0	11	0.00	0	1
31250	0	5	0.00	0	5	2.40	—	—	—	0	1
38400	0	4	–2.34	0	4	0.00	0	5	0.00	—	-

	Operating Frequency ϕ (MHz)										
	9.8304			10			12				
Bit Rate (bit/s)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	I
110	2	174	–0.26	2	177	–0.25	2	212	0.03	2	2
150	2	127	0.00	2	129	0.16	2	155	0.16	2	1
300	1	255	0.00	2	64	0.16	2	77	0.16	2	1
600	1	127	0.00	1	129	0.16	1	155	0.16	1	1
1200	0	255	0.00	1	64	0.16	1	77	0.16	1	1
2400	0	127	0.00	0	129	0.16	0	155	0.16	0	1
4800	0	63	0.00	0	64	0.16	0	77	0.16	0	1
9600	0	31	0.00	0	32	–1.36	0	38	0.16	0	3
19200	0	15	0.00	0	15	1.73	0	19	–2.34	0	1
31250	0	9	–1.70	0	9	0.00	0	11	0.00	0	1
38400	0	7	0.00	0	7	1.73	0	9	–2.34	0	9

Legend:

—: Can be set, but there will be a degree of error.

Note: Make the settings so that the error does not exceed 1%.

600	1	181	0.16	1	191	0.00	1	207	0.16	1	2
1200	1	90	0.16	1	95	0.00	1	103	0.16	1	1
2400	0	181	0.16	0	191	0.00	0	207	0.16	0	2
4800	0	90	0.16	0	95	0.00	0	103	0.16	0	1
9600	0	45	–0.93	0	47	0.00	0	51	0.16	0	5
19200	0	22	–0.93	0	23	0.00	0	25	0.16	0	2
31250	0	13	0.00	0	14	–1.70	0	15	0.00	0	1
38400	—	—	—	0	11	0.00	0	12	0.16	0	1

	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%.

3.6864	115200	0	0	14	437500	0
4	125000	0	0	14.7456	460800	0
4.9152	153600	0	0	16	500000	0
5	156250	0	0	17.2032	537600	0
6	187500	0	0	18	562500	0
6.144	192000	0	0	19.6608	614400	0
7.3728	230400	0	0	20	625000	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)	Ma Rat
2	0.5000	31250	9.8304	2.4576	153
2.097152	0.5243	32768	10	2.5000	156
2.4576	0.6144	38400	12	3.0000	187
3	0.7500	46875	12.288	3.0720	192
3.6864	0.9216	57600	14	3.5000	218
4	1.0000	62500	14.7456	3.6864	230
4.9152	1.2288	76800	16	4.0000	250
5	1.2500	78125	17.2032	4.3008	268
6	15.000	93750	18	4.5000	281
6.144	1.5360	96000	19.6608	4.9152	307
7.3728	1.8432	115200	20	5.0000	312
8	2.0000	125000			

1k	1	124	1	249	2	124	—	—	2	249	–
2.5k	0	199	1	99	1	199	1	249	2	99	2
5k	0	99	0	199	1	99	1	124	1	199	1
10k	0	49	0	99	0	199	0	249	1	99	1
25k	0	19	0	39	0	79	0	99	0	159	0
50k	0	9	0	19	0	39	0	49	0	79	0
100k	0	4	0	9	0	19	0	24	0	39	0
250k	0	1	0	3	0	7	0	9	0	15	0
500k	0	0*	0	1*	0	3	0	4	0	7	0
1M			0	0	0	1			0	3	0
2.5M							0	0*			0
5M											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

ϕ (MHz)	External Input Clock (MHz)	Maximum Bit Rate (bit/s)	ϕ (MHz)	External Input Clock (MHz)	Max Rate
2	0.3333	333333.3	12	2.0000	2000
4	0.6667	666666.7	14	2.3333	2333
6	1.0000	1000000.0	16	2.6667	2666
8	1.3333	1333333.3	18	3.0000	3000
10	1.6667	1666666.7	20	3.3333	3333

				and RxD2 pins, respectively 1: TxD2/IrTxD and RxD2/IrRxD pins functi 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 t pulse during IrTxD output pulse encoding 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, Keyboa Comparator Control Register (KBCOMP).

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.

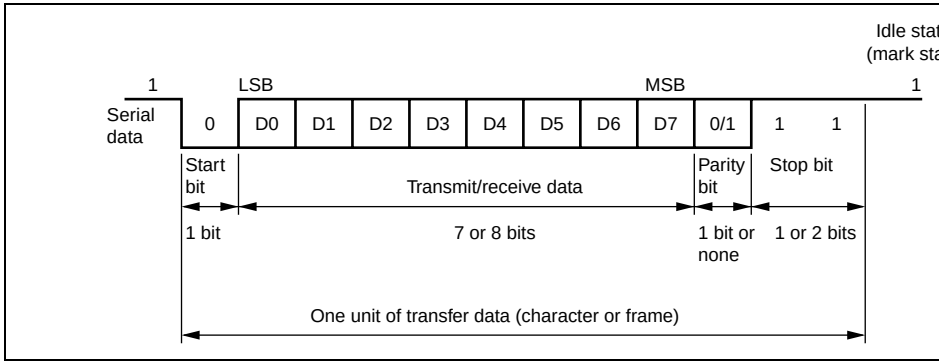


Figure 15.2 Data Format in Asynchronous Communication (Example with 8-Bit Data, Parity, Two Stop Bits)

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

$$M = \{ (0.5 - \frac{1}{2N}) - \frac{D - 0.5}{N} (1 + F) - (L - 0.5) F \} \times 100 \quad [\%] \quad \cdots \text{ Formula (1)}$$

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 determine 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 allow system design.

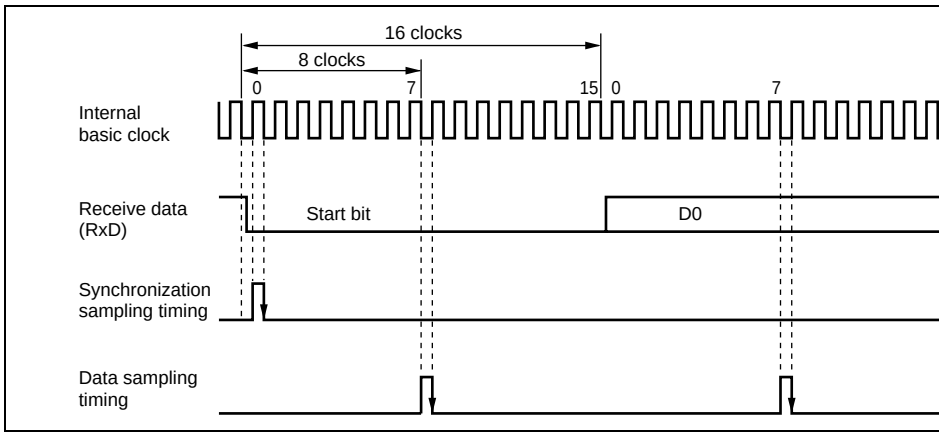


Figure 15.3 Receive Data Sampling Timing in Asynchronous Mode

rising edge of the clock is in the middle of the transmit data, as shown in figure 15.4.

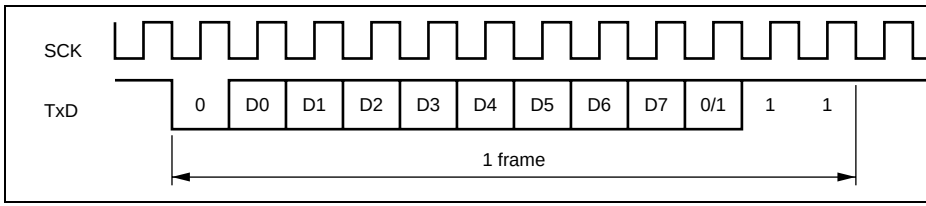
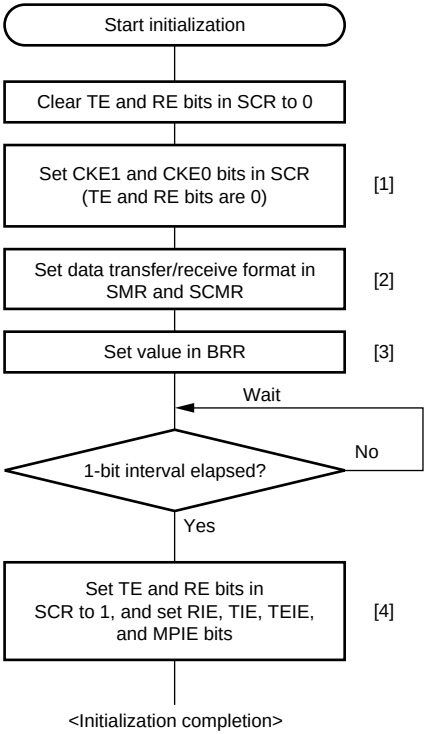


Figure 15.4 Relation between Output Clock and Transmit Data Phas
(Asynchronous Mode)

supplied even during initialization.



[1] Set the clock selection in SCR. Be sure to clear bits RIE, TIE, TEIE, and MPIE, and bits TE and RE, to 0.

When the clock is selected in asynchronous mode, it is output immediately after SCR settings are made.

[2] Set the data transfer/receive format in SMR and SCMR.

[3] Write a value corresponding to the bit rate to BRR. Not necessary if an external clock is used.

[4] Wait at least one bit interval, then set the TE bit or RE bit in SCR to 1. Also set the RIE, TIE, TEIE, and MPIE bits.

Setting the TE and RE bits enables the TxD and RxD pins to be used.

Figure 15.5 Sample SCI Initialization Flowchart

transmission. If the TIE bit in SCR is set to 1 at this time, a transmit data empty in
request (TXI) is generated. Because the TXI interrupt routine writes the next transi
TDR before transmission of the current transmit data has finished, continuous tran
be enabled.

3. Data is sent from the TxD pin in the following order: start bit, transmit data, parity
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
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 the
state" is entered in which 1 is output. If the TEIE bit in SCR is set to 1 at this time
interrupt request is generated.

Figure 15.7 shows a sample flowchart for transmission in asynchronous mode.

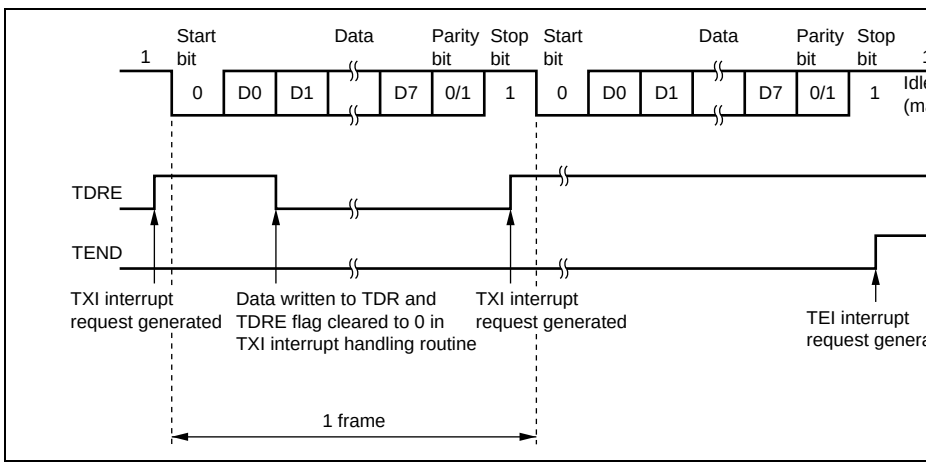
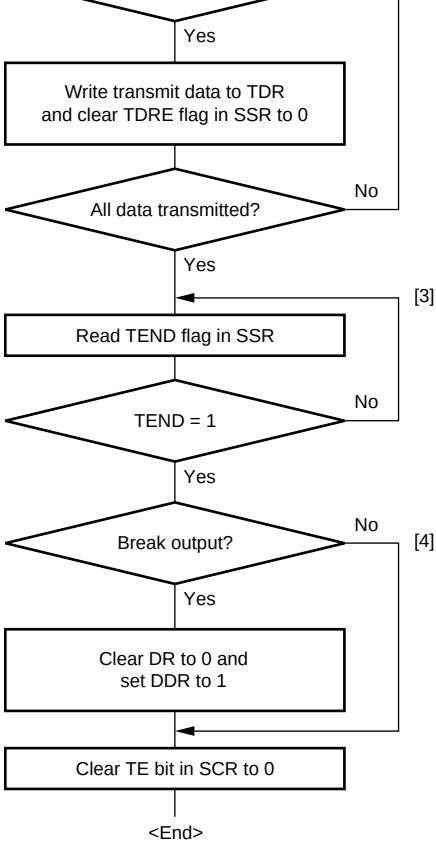


**Figure 15.6 Example of SCI Transmit Operation in Asynchronous Mode (Exam
Bit Data, Parity, One Stop Bit)**



Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR and clear th 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 cleare 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 por corresponding to the TxD pin to 1 clear DR to 0, then clear the TE b in SCR to 0.

Figure 15.7 Sample Serial Transmission Flowchart

is still set to 1) occurs, the ORER bit in SSR is set to 1. If the RIE bit in SCR is set time, an ERI interrupt request is generated. Receive data is not transferred to RDR 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 transf RDR. If the RIE bit in SCR is set to 1 at this time, an ERI interrupt request is gene
4. If a framing error (when the stop bit is 0) is detected, the FER bit in SSR is set to 1 data is transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an ERI int request is generated.
5. If reception finishes successfully, the RDRF bit in SSR is set to 1, and receive data transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an RXI interrupt r generated. Because the RXI interrupt routine reads the receive data transferred to R reception of the next receive data has finished, continuous reception can be enable

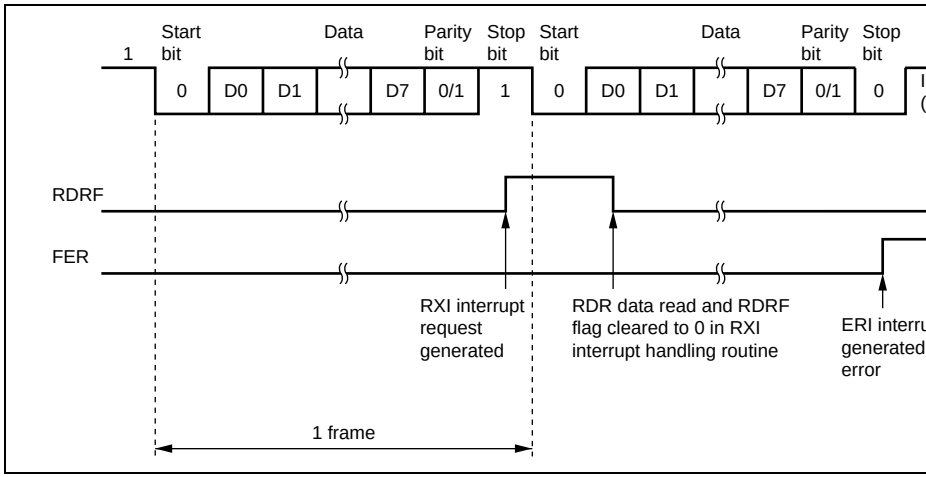
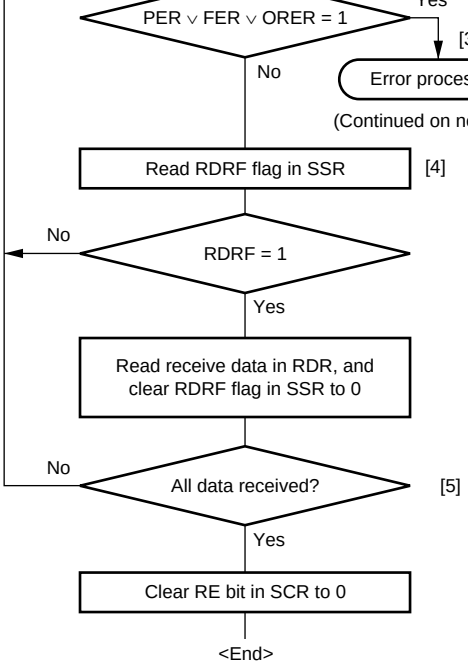


Figure 15.8 Example of SCI Receive Operation in Asynchronous Mod (Example with 8-Bit Data, Parity, One Stop Bit)

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 + frami
1	1	0	1	Lost	Overrun error + parity
0	0	1	1	Transferred to RDR	Framing error + parity
1	1	1	1	Lost	Overrun error + frami parity error

Note: * The RDRF flag retains the state it had before data reception.



appropriate error processing, e
that the ORER, PER, and FER
all cleared to 0. Reception can
resumed if any of these flags a
1. In the case of a framing erro
break can be detected by readi
value of the input port correspo
the RxD pin.

[4] SCI status check and receive d
Read SSR and check that RDR
then read the receive data in R
clear the RDRF flag to 0. Trans
the RDRF flag from 0 to 1 can a
identified by an RXI interrupt.

[5] Serial reception continuation pr
To continue serial reception, be
stop bit for the current frame is
received, read the RDRF flag, r
RDR, and clear the RDRF flag
However, the RDRF flag is clea
automatically when the DTC is
by an RXI interrupt and reads d
RDR.

Legend:
∨ : Logical OR

Figure 15.9 Sample Serial Reception Flowchart (1)

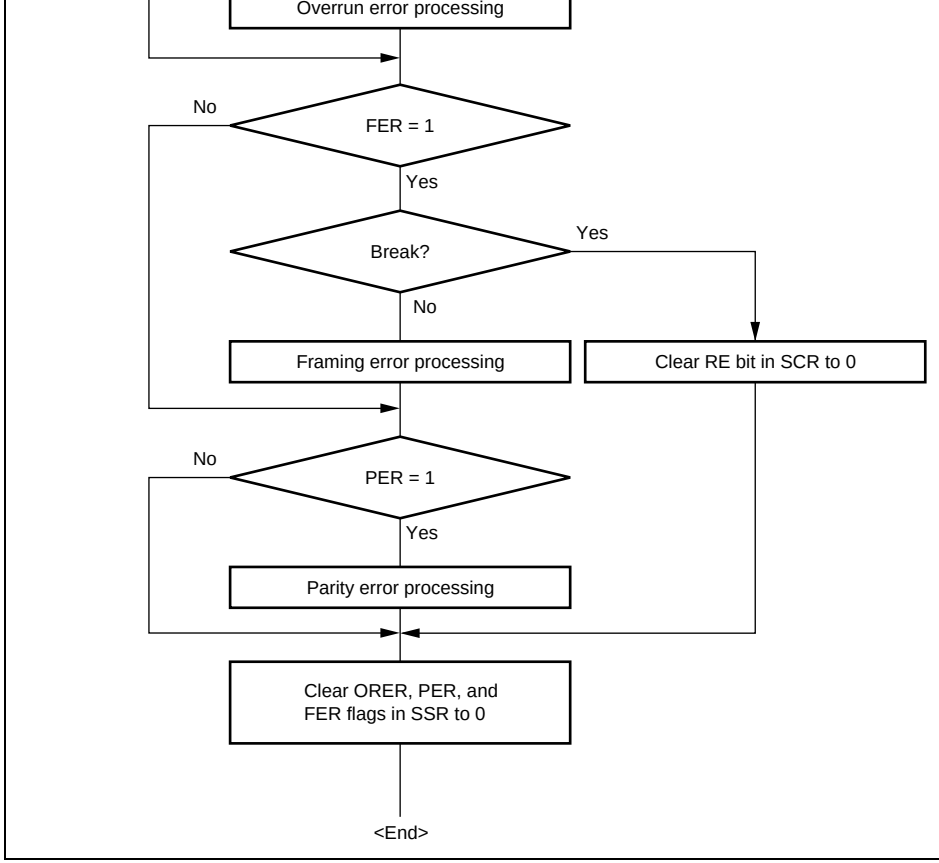


Figure 15.9 Sample Serial Reception Flowchart (2)

the specified receiving station. The multiprocessor bit is used to differentiate between
transmission cycle and the data transmission cycle. If the multiprocessor bit is 1, the c
transmission cycle, and if the multiprocessor bit is 0, the cycle is a data transmission c
15.10 shows an example of inter-processor communication using the multiprocessor f
transmitting station first sends the ID code of the receiving station with which it wants
serial communication as data with a 1 multiprocessor bit added. It then sends transmit
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 recei
compares that data with its own ID. The station whose ID matches then receives the d
Stations whose ID does not match continue to skip data until data with a 1 multiproces
again received.

The SCI uses the MPIE bit in SCR to implement this function. When the MPIE bit is s
transfer of receive data from RSR to RDR, error flag detection, and setting the SSR st
RDRF, FER, and ORER in SSR to 1 are prohibited until data with a 1 multiprocessor
received. On reception of a receive character with a 1 multiprocessor bit, the MPB bit
to 1 and the MPIE bit is automatically cleared, thus normal reception is resumed. If th
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 b
are the same as those in normal asynchronous mode. The clock used for multiprocesso
communication is the same as that in normal asynchronous mode.

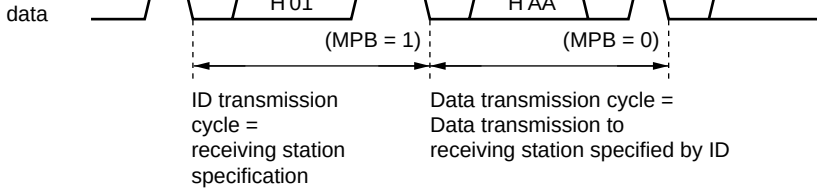
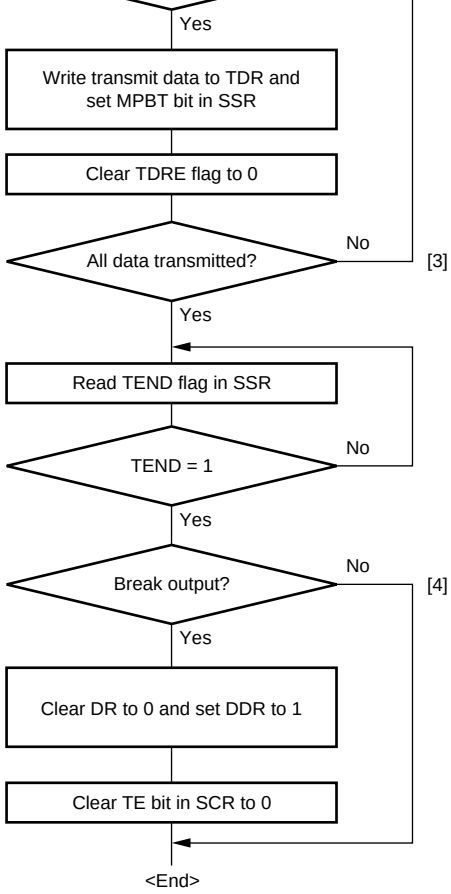


Figure 15.10 Example of Communication Using Multiprocessor Forma (Transmission of Data H'AA to Receiving Station A)

15.5.1 Multiprocessor Serial Data Transmission

Figure 15.11 shows a sample flowchart for multiprocessor serial data transmission. For transmission cycle, set the MPBT bit in SSR to 1 before transmission. For a data transm cycle, clear the MPBT bit in SSR to 0 before transmission. All other SCI operations are as those in asynchronous mode.



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 write 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

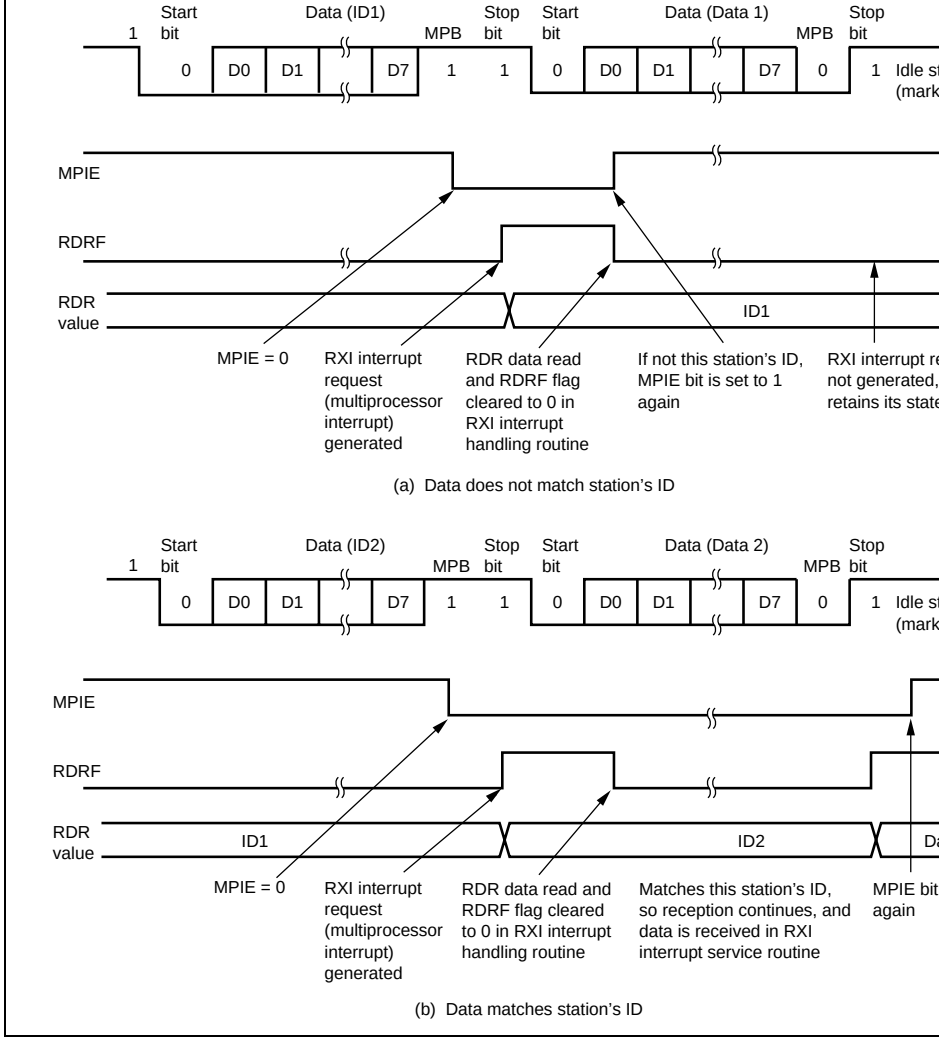
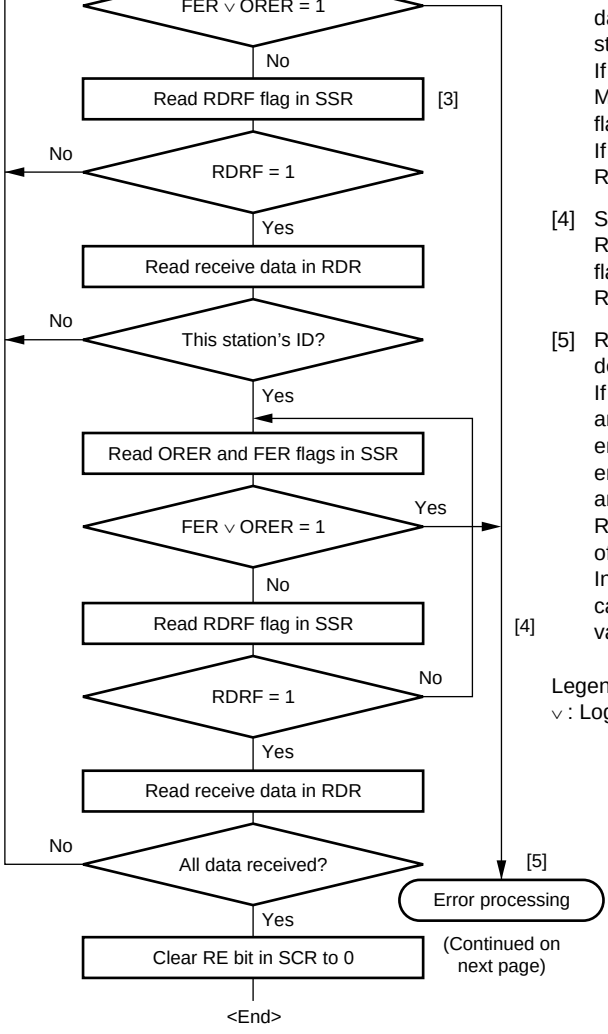


Figure 15.12 Example of SCI Receive Operation (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)



[3] Serial mode register status check and data reception:
Read SSR and check that the RDRF flag is set to 1, then read the 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 RDR value.

Legend:
∨ : Logical OR

Figure 15.13 Sample Multiprocessor Serial Reception Flowchart (1)

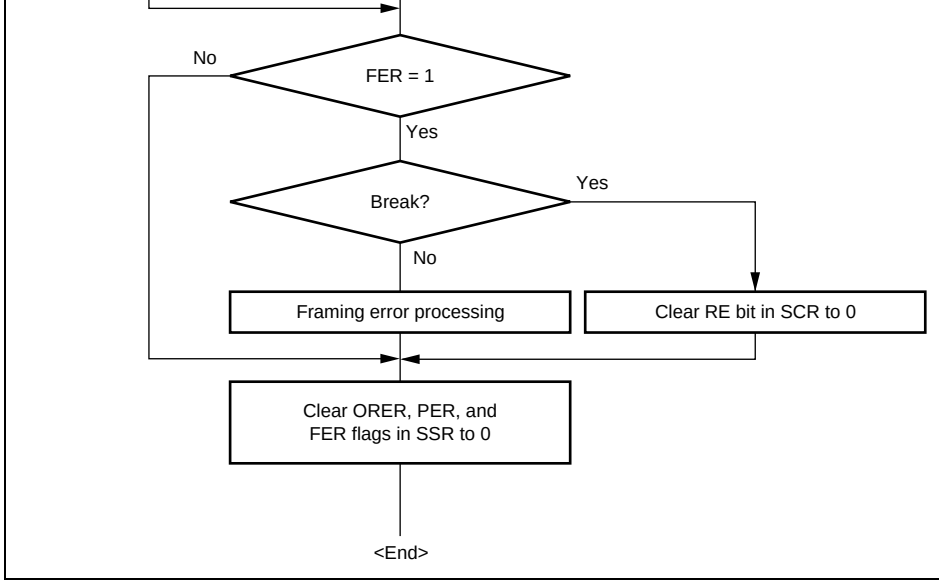


Figure 15.13 Sample Multiprocessor Serial Reception Flowchart (2)

bit is added. Inside the SCI, the transmitter and receiver are independent units, enabli
duplex communication by use of a common clock. Both the transmitter and the receiv
a double-buffered structure, so that the next transmit data can be written during transm
previous receive data can be read during reception, enabling continuous data transfer.

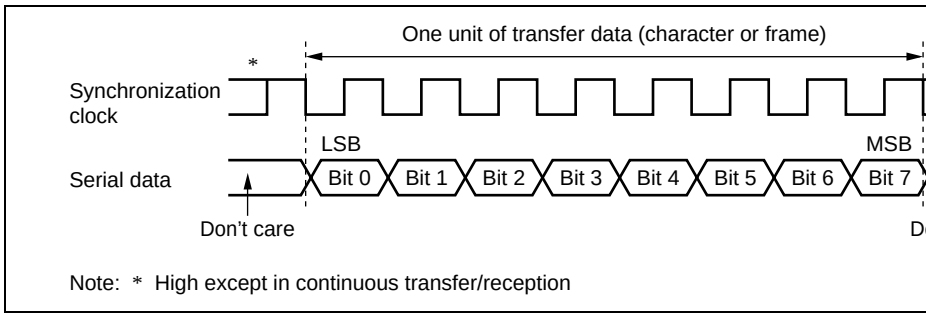
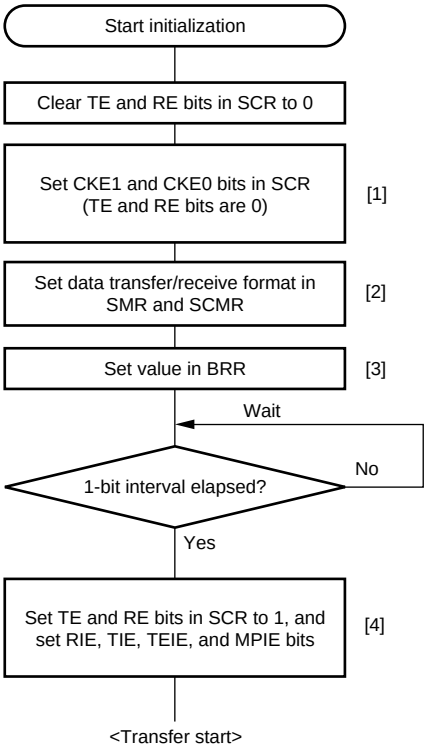


Figure 15.14 Data Format in Clocked Synchronous Communication (LSB

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 and CKE0 bits in SCR. When the SCI is operated on an internal clock, the synchroniz is output from the SCK pin. Eight synchronization clock pulses are output in the trans character, and when no transfer is performed the clock is fixed high.



[1] Set the clock selection in SCR. Be s
to clear bits RIE, TIE, TEIE, and MP
TE and RE to 0.

[2] Set the data transfer/receive format
SMR and SCMR.

[3] Write a value corresponding to the b
rate to BRR. This step is not neces
if an external clock is used.

[4] Wait at least one bit interval, then se
the TE bit or RE bit in SCR to 1.
Also set the RIE, TIE TEIE, and MP
bits.
Setting the TE and RE bits enables
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
set to 1 simultaneously.

Figure 15.15 Sample SCI Initialization Flowchart

transmission. If the TIE bit in SCR is set to 1 at this time, a TXI interrupt request i
Because the TXI interrupt routine writes the next transmit data to TDR before tran
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 outpu
mode has been specified and synchronized with the input clock when use of an ext
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 tr
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 ma
output state of the last bit. If the TEIE bit in SCR is set to 1 at this time, a TEI inte
is generated. The SCK pin is fixed high.

Figure 15.17 shows a sample flow chart for serial data transmission. Even if the TDRE
cleared to 0, transmission will not start while a receive error flag (ORER, FER, or PER
Make sure to clear the receive error flags to 0 before starting transmission. Note that c
RE bit to 0 does not clear the receive error flags.

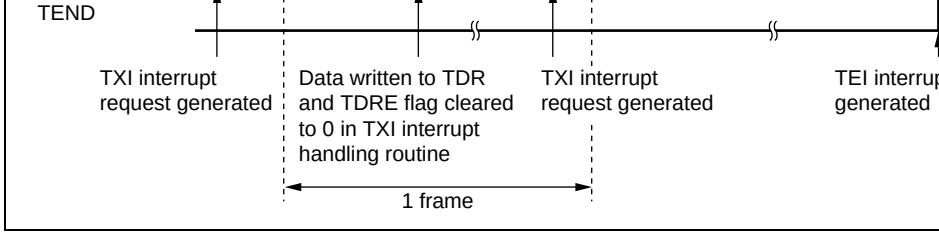
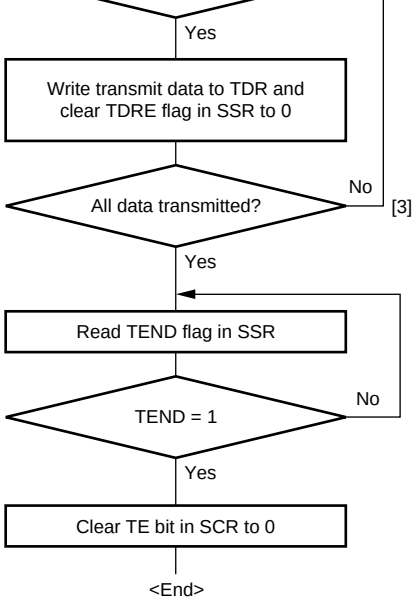


Figure 15.16 Example of SCI Transmit Operation in Clocked Synchronous



[3] Serial transmission continuation procedure:
To continue serial transmission, b
sure to read 1 from the TDRE fla
confirm that writing is possible, th
write data to TDR, and then clear
TDRE flag to 0.
However, the TDRE flag is check
and cleared automatically when t
DTC is initiated by a transmit dat
empty interrupt (TXI) request and
writes data to TDR.

Figure 15.17 Sample Serial Transmission Flowchart

an ERI interrupt request is generated. Receive data is not transferred to RDR. The R
remains to be set to 1.

3. If reception finishes successfully, the RDRF bit in SSR is set to 1, and receive data
transferred to RDR. If the RIE bit in SCR is set to 1 at this time, an RXI interrupt re
generated. Because the RXI interrupt routine reads the receive data transferred to R
reception of the next receive data has finished, continuous reception can be enabled

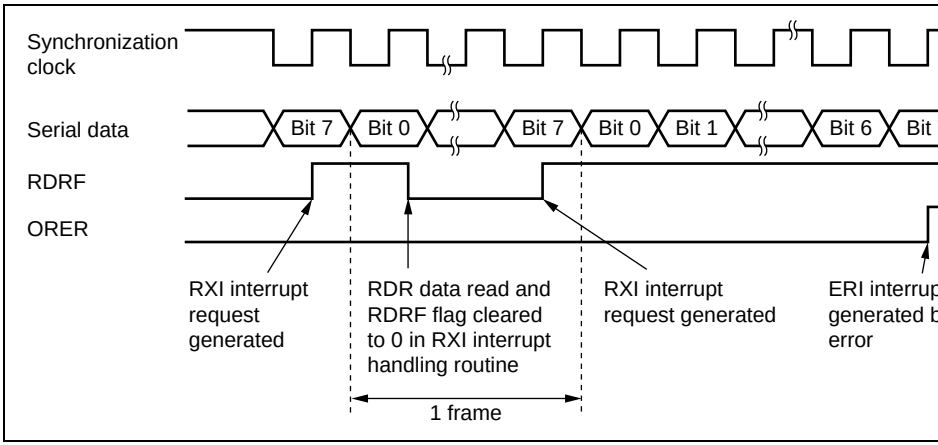
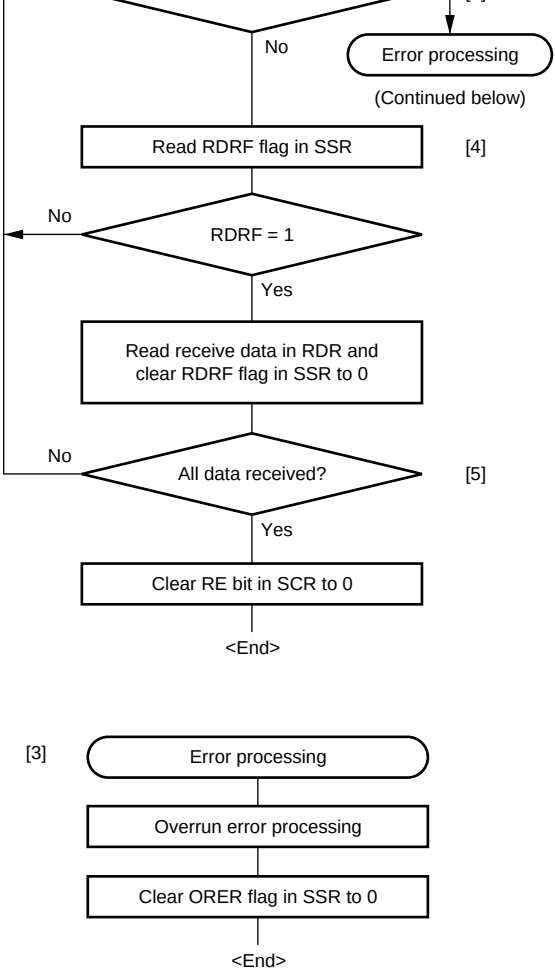


Figure 15.18 Example of SCI Receive Operation in Clocked Synchronous M

Reception cannot be resumed while a receive error flag is set to 1. Accordingly, clear th
FER, PER, and RDRF bits to 0 before resuming reception. Figure 15.19 shows a sampl
for serial data reception.



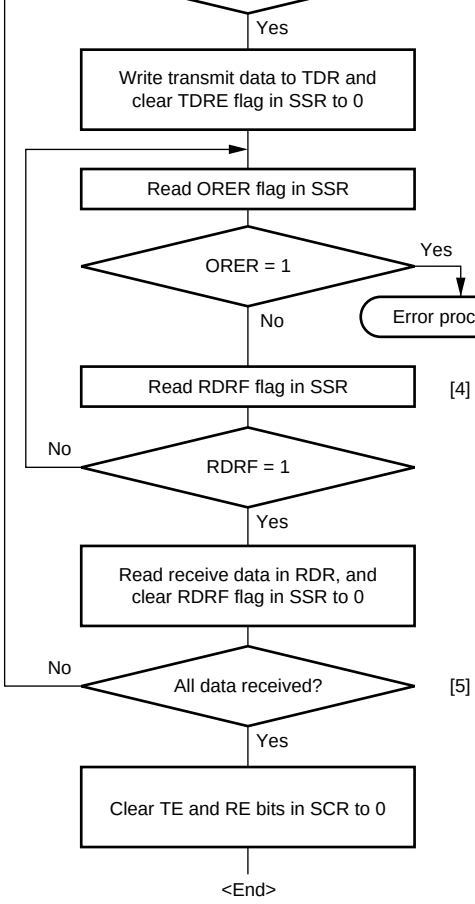
Transfer cannot be resumed
ORER flag is set to 1.

[4] SCI status check and receive
read:
Read SSR and check that the
flag is set to 1, then read the
data in RDR and clear the RD
to 0.
Transition of the RDRF flag fr
can also be identified by an R
interrupt.

[5] Serial reception continuation
procedure:
To continue serial reception,
the MSB (bit 7) of the current
received, reading the RDRF f
reading RDR, and clearing th
flag to 0 should be finished.
However, the RDRF flag is cl
automatically when the DTC i
initiated by a receive data full
(RXI) and reads data from RD

Figure 15.19 Sample Serial Reception Flowchart

a single instruction. To switch from receive mode to simultaneous transmit and receive check that the SCI has finished reception, and clear the RE bit to 0. Then after checking RDRF bit in SSR and receive error flags (ORER, FER, and PER) are cleared to 0, set th 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.

data to TDR and clear the
to 0.
Transition of the TDRE fla
1 can also be identified by
interrupt.

[3] Receive error processing:
If a receive error occurs, r
ORER flag in SSR, and a
performing the appropriat
processing, clear the ORE
Transmission/reception ca
resumed if the ORER flag

[4] SCI status check and rec
read:
Read SSR and check tha
flag is set to 1, then read
data in RDR and clear the
to 0. Transition of the RD
0 to 1 can also be identifie
interrupt.

[5] Serial transmission/recept
continuation procedure:
To continue serial transm
reception, before the MSE
the current frame is receiv
reading the RDRF flag, re
and clearing the RDRF fla
before the MSB (bit 7) of
frame is transmitted, read
TDRE flag to confirm that
possible. Then write data
clear the TDRE flag to 0.
However, the TDRE flag i
and cleared automatically
DTC is initiated by a trans
empty interrupt (TXI) requ
writes data to TDR. Simil
RDRF flag is cleared auto
when the DTC is initiated
data full interrupt (RXI) an
data from RDR.

Figure 15.20 Sample Flowchart of Simultaneous Serial Transmission and R

In the system defined by the IrDA standard version 1.0, communication is started at a t
of 9600 bps, which can be modified as required. The IrDA interface provided by this L
incorporate the capability of automatic modification of the transfer rate; the transfer rat
modified through programming.

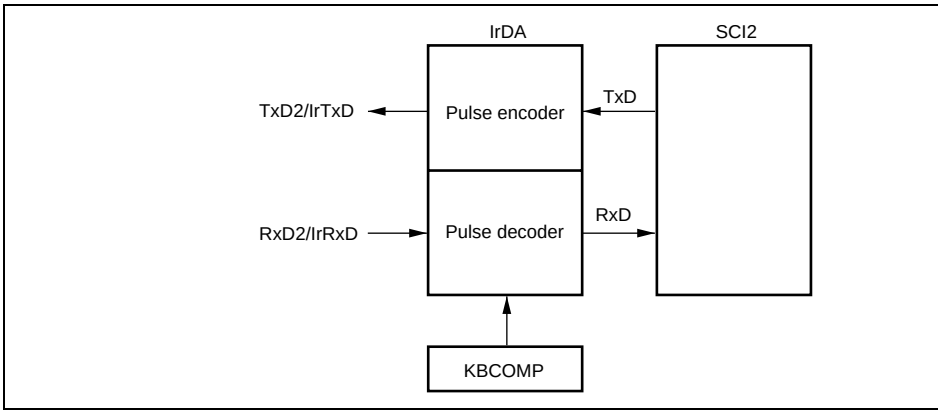


Figure 15.21 IrDA Block Diagram

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.

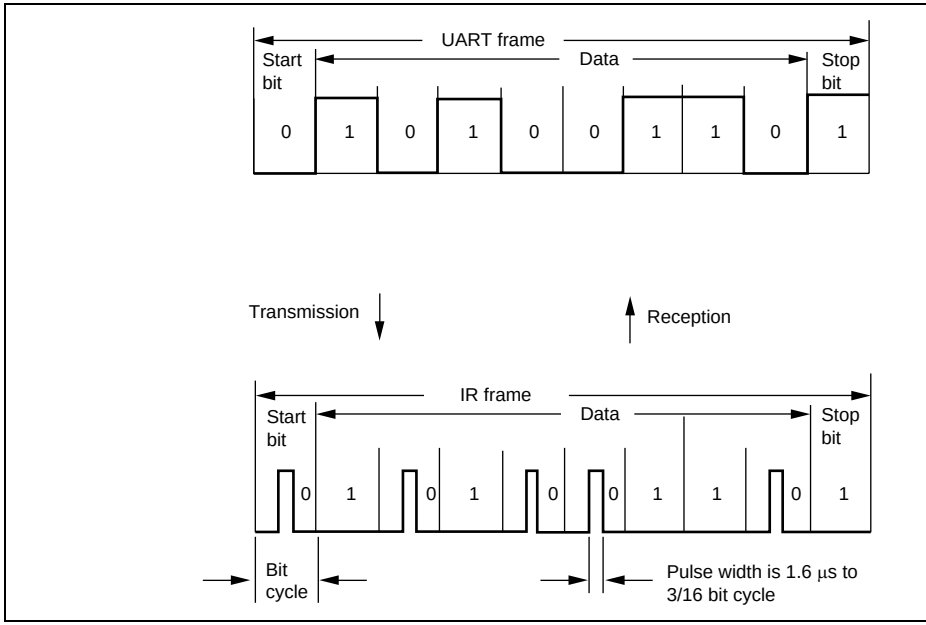


Figure 15.22 IrDA Transmission and Reception

Reception: During reception, IR frames are converted to UART frames using the IrD 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 no pulse is detected in a bit cycle. If a pulse has a high-level width of less than 1.41 µs minimum width allowed, the pulse is recognized as level 0.

ϕ (MHz)						
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	01
4.9152	011	011	011	011	011	01
5	011	011	011	011	011	01
6	100	100	100	100	100	10
6.144	100	100	100	100	100	10
7.3728	100	100	100	100	100	10
8	100	100	100	100	100	10
9.8304	100	100	100	100	100	10
10	100	100	100	100	100	10
12	101	101	101	101	101	10
12.288	101	101	101	101	101	10
14	101	101	101	101	101	10
14.7456	101	101	101	101	101	10
16	101	101	101	101	101	10
16.9344	101	101	101	101	101	10
17.2032	101	101	101	101	101	10
18	101	101	101	101	101	10
19.6608	101	101	101	101	101	10
20	101	101	101	101	101	10

Legend:

—: An SCI bit rate setting cannot be made.

When the RDRF flag in SSR is set to 1, an RXI interrupt request is generated. When t
PER, or FER flag in SSR is set to 1, an ERI interrupt request is generated. An RXI int
activate the DTC to allow data transfer. The RDRF flag is automatically cleared to 0 a
transfer by the DTC.

A TEI interrupt is requested when the TEND flag is set to 1 while the TEIE bit is set t
interrupt and a TXI interrupt are requested simultaneously, the TXI interrupt has prior
acceptance. However, note that if the TDRE and TEND flags are cleared simultaneous
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
0	ERI0	Receive error	ORER, FER, PER	Not possible
	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

15.9.2 Break Detection and Processing

When framing error detection is performed, a break can be detected by reading the RxD directly. In a break, the input from the RxD pin becomes all 0s, and so the FER flag in and the PER flag may also be set. Note that, since the SCI continues the receive operati 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 and level are determined by DR and DDR of the port. This can be used to set the TxD p 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 is cleared to 0 at this point, the TxD pin becomes an I/O port, and 1 is output from the T send a break during serial transmission, first set DDR to 1 and DR to 0, and then clear t to 0. When the TE bit is cleared to 0, the transmitter is initialized regardless of the curr 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 M

Transmission cannot be started when a receive error flag (ORER, FER, or RER) is SSR even if the TDRE flag in SSR is cleared to 0. Be sure to clear the receive error flags to starting transmission. Note also that the receive error flags cannot be cleared to 0 even 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 th is written to TDR when the TDRE flag is 0, that is, when the previous data has not beer transferred to TSR yet, the previous data in TDR is lost. Be sure to write transmit data t after verifying that the TDRE flag is set to 1.

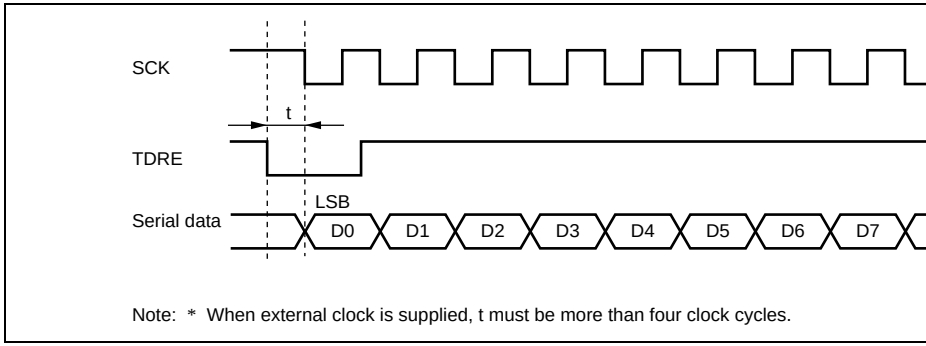


Figure 15.23 Example of Transmission Using DTC in Clocked Synchronou

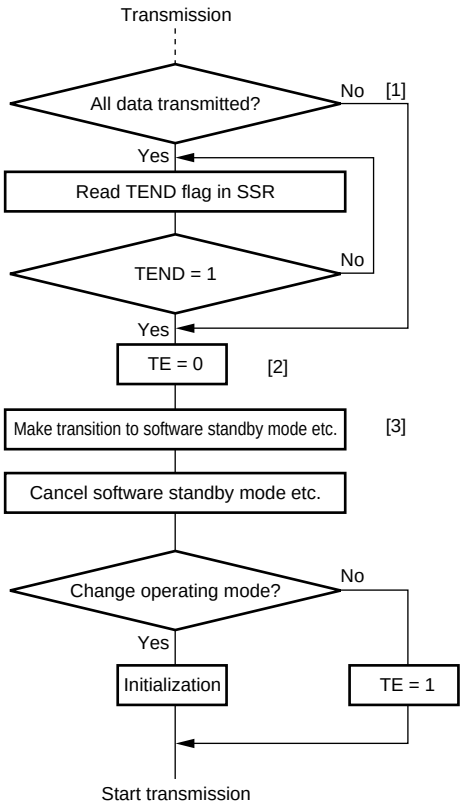
15.9.7 SCI Operations during Mode Transitions

Transmission: Before making a transition to module stop, software standby, or sub-sl stop all transmit operations (TE = TIE = TEIE = 0). TSR, TDR, and SSR are reset. Th the output pins during each mode depend on the port settings, and the pins output a hi signal after mode cancellation. If a transition is made during data transmission, the da transmitted will be undefined.

To transmit data in the same transmission mode after mode cancellation, set TE to 1, r write to TDR, clear TDRE in this order, and then start transmission. To transmit data i transmission mode, initialize the SCI first.

Figure 15.24 shows a sample flowchart for mode transition during transmission. Figur 15.26 show the pin states during transmission.

Before making a transition from the transmission mode using DTC transfer to module software standby, or sub-sleep mode, stop all transmit operations (TE = TIE = TEIE = TE and TIE to 1 after mode cancellation generates a TXI interrupt request to start tran using the DTC.



[1] Data being transmitted is lost halfway. Data can be normally transmitted from the CPU by setting TE to 1, reading SSR, writing to TDR, and clearing TDRE to 0 after mode cancellation; however, if the DTC has been initiated, the data remaining in DTC RAM will be transmitted when TE and TIE are set to 0.

[2] Also clear TIE and TEIE to 0 when they are 1.

[3] Module stop, watch, sub-active, and sub-sleep modes are included.

Figure 15.24 Sample Flowchart for Mode Transition during Transmissi

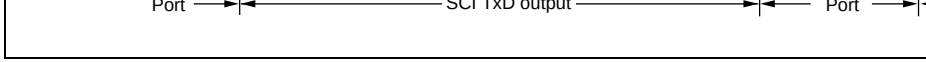


Figure 15.25 Pin States during Transmission in Asynchronous Mode (Intern

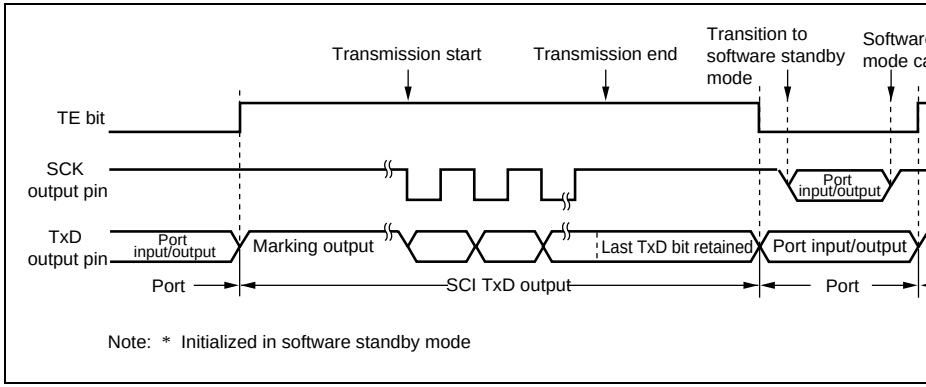


Figure 15.26 Pin States during Transmission in Clocked Synchronous M (Internal Clock)

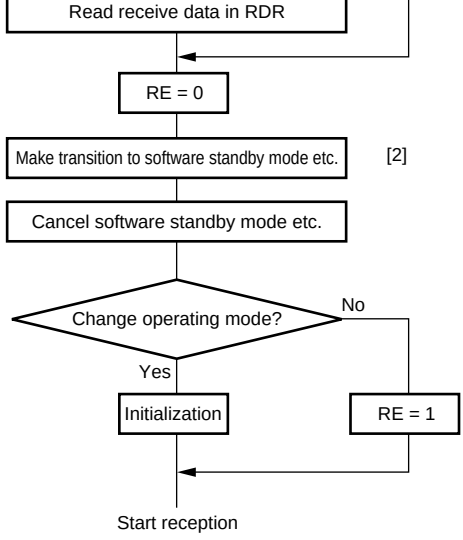


Figure 15.27 Sample Flowchart for Mode Transition during Reception

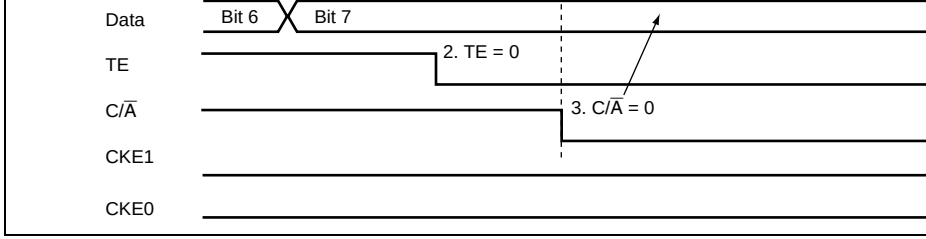


Figure 15.28 Switching from SCK Pins to Port Pins

To prevent the low pulse output that is generated when switching the SCK pins to the
specify the SCK pins for input (pull up the SCK/port pins externally), and follow the p
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

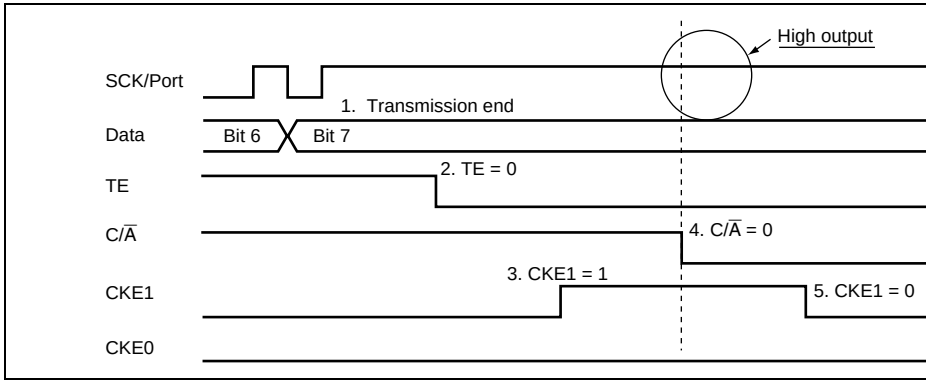


Figure 15.29 Prevention of Low Pulse Output at Switching from SCK Pins to

This LSI has a two-channel I²C bus interface. The I²C bus interface conforms to and p
subset of the Philips I²C bus (inter-IC bus) interface functions. The register configurat
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 op
  - — Clocked synchronous serial format: non-addressing format without an acknowl master operation only
  - — Formatless (for IIC_0 only): non-addressing format with a clock pin dedicated 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, excludin 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 fo when ICDR data is transferred, or during a wait state)

pull outputs) function as NMOS open-drain outputs when the bus drive function

- Automatic switching from formatless mode to I^2C bus format (IIC_0 only)
  - Formatless operation (no start/stop conditions, non-addressing mode) in slave m
  - Operation using a common data pin (SDA) and independent clock pins (VSYN
  - Automatic switching from formatless mode to I^2C bus format on the fall of the S

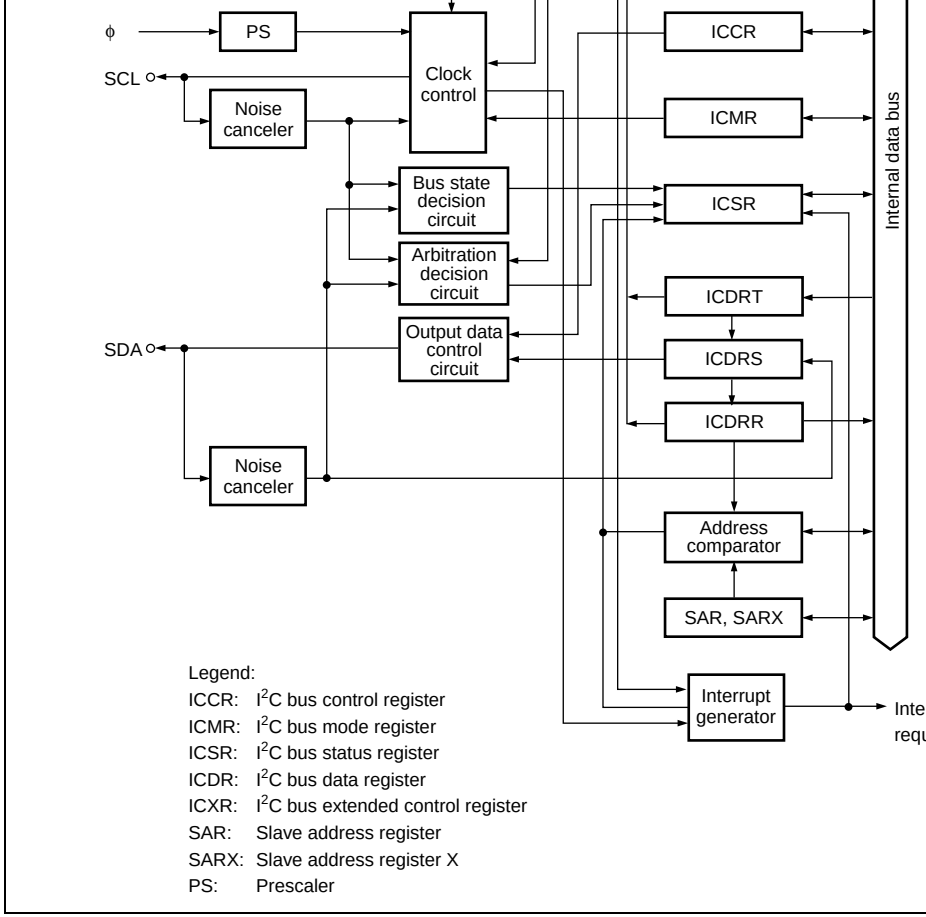


Figure 16.1 Block Diagram of I²C Bus Interface

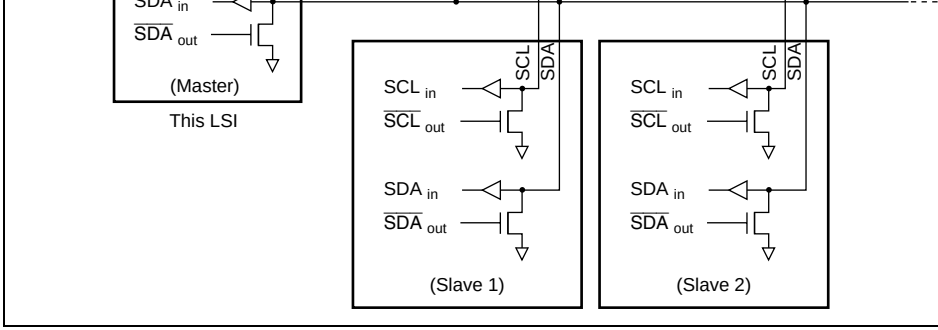


Figure 16.2 I²C Bus Interface Connections (Example: This LSI as Maste

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
	SDA0	Input/Output	Serial data input/output pin of IIC
	VSYNCI	Input	Formatless serial clock input pin
1	SCL1	Input/Output	Serial clock input/output pin of IIC
	SDA1	Input/Output	Serial data input/output pin of IIC

Note: * In the text, the channel subscript is omitted, and only SCL and SDA are used

- 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 register (ICDRS), receive buffer (ICDRR), and transmit buffer (ICDRT). Data transfer these three registers are performed automatically in accordance with changes in the bus 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 performed after start condition detection. When the start condition is detected, previous is ignored. In slave transmit mode, writing should be performed after the slave address 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 IC 0) after successful transmission/reception of one frame of data using ICDRS, data is tr automatically from ICDRT to ICDRS.

If the IIC is in transmit mode (TRS = 1) and ICDRT has the next data (the ICDRE flag is transferred automatically from ICDRT to ICDRS, following transmission of one fra using ICDRS. When the ICDRE flag is 1 and the next transmit data writing is waited, transferred automatically from ICDRT to ICDRS by writing to ICDR. If I²C is in recei (TRS = 0), no data is transferred from ICDRT to ICDRS. Note that data should not be ICDR in receive mode.

and receive data are stored differently. Transmit data should be written justified toward side when MLS = 0 in ICMR, and toward the LSB side when MLS = 1. Receive data b 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 in 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 the I^2C bus format selected, when the FS bit is set to 0 and the upper 7 bits of SAR mat upper 7 bits of the first frame received after a start condition, the LSI operates as the sla specified by the master device. SAR can be accessed only when the ICE bit in ICCR is 0.

Bit	Bit Name	Initial Value	R/W	Description
7	SVA6	0	R/W	Slave Address 6 to 0
6	SVA5	0	R/W	Set a slave address.
5	SVA4	0	R/W	
4	SVA3	0	R/W	
3	SVA2	0	R/W	
2	SVA1	0	R/W	
1	SVA0	0	R/W	
0	FS	0	R/W	Format Select Selects the communication format together wit bit in SARX and the SW bit in DDCSWR. Refe 16.2. This bit should be set to 0 when general call ac recognition is performed.

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 wi in SAR and the SW bit in DDCSWR. Refer to

			• SAR slave address recognized • SARX slave address ignored • General call address recognized
	1	0	I^2C 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 detec
		1	• Acknowledge bit used
	1	0	
		1	Formatless mode (start/stop conditions not detec • No acknowledge bit Do not set this mode when automatic switching t bus format is performed by means of the DDCSW

- I^2C bus format: addressing format with an acknowledge bit
- Clocked synchronous serial format: non-addressing format without an acknowledge master mode only
- Formatless mode (for IIC_0 only): non-addressing format with or without an ackno slave mode only, start/stop conditions not detected

				1: LSB-first Set this bit to 0 when the I^2C bus format is use
6	WAIT	0	R/W	Wait Insertion Bit This bit is valid only in master mode with the I format. 0: Data and the acknowledge bit are transferr consecutively with no wait inserted. 1: After the fall of the clock for the final data b the IRIC flag is set to 1 in ICCR, and a wait (with SCL at the low level). When the IRIC cleared to 0 in ICCR, the wait ends and the acknowledge bit is transferred. For details, refer to section 16.4.7, IRIC Settir and SCL Control.
5	CKS2	0	R/W	Transfer Clock Select 2 to 0
4	CKS1	0	R/W	These bits are used only in master mode.
3	CKS0	0	R/W	These bits select the required transfer rate, to the IICX1 (IIC_1) and IICX0 (IIC_0) bits in ST table 16.3.

transfer.

I²C Bus Format	Clocked Synchronous Serial
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

0	0	1	0	φ/48	104 kHz	167 kHz	208 kHz	333 kHz
0	0	1	1	φ/64	78.1 kHz	125 kHz	156 kHz	250 kHz
0	1	0	0	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz
0	1	0	1	φ/100	50.0 kHz	80.0 kHz	100 kHz	160 kHz
0	1	1	0	φ/112	44.6 kHz	71.4 kHz	89.3 kHz	143 kHz
0	1	1	1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz
1	0	0	0	φ/56	89.3 kHz	143 kHz	179 kHz	286 kHz
1	0	0	1	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz
1	0	1	0	φ/96	52.1 kHz	83.3 kHz	104 kHz	167 kHz
1	0	1	1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz
1	1	0	0	φ/160	31.3 kHz	50.0 kHz	62.5 kHz	100 kHz
1	1	0	1	φ/200	25.0 kHz	40.0 kHz	50.0 kHz	80.0 kHz
1	1	1	0	φ/224	22.3 kHz	35.7 kHz	44.6 kHz	71.4 kHz
1	1	1	1	φ/256	19.5 kHz	31.3 kHz	39.1 kHz	62.5 kHz

Note: * Outside the I^2C bus interface specifications (standard mode: max. 100 kHz; mode: max. 400 kHz)

				1: I^2C bus interface modules can perform transf operation, and the ports function as the SCL input/output pins. ICMR and ICDR can be ac
6	IEIC	0	R/W	I^2C Bus Interface Interrupt Enable 0: Disables interrupts from the I^2C bus interface CPU 1: Enables interrupts from the I^2C bus interface 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 wh lose in a bus contention in master mode with th format. In slave receive mode with I^2C bus form R/$\overline{W}$ bit in the first frame immediately after the condition sets these bits in receive mode or tra automatically by hardware. Modification of the TRS bit during transfer is de transfer is completed, and the changeover is m completion of the transfer.

				condition 1) 2. When 1 is written in MST after reading MS MST clearing condition 2) [TRS clearing conditions] 1. When 0 is written by software (except for condition 3) 2. When 0 is written in TRS after reading TR TRS setting condition 3) 3 When lost in bus contention in I^2C bus forr mode 4. When the SW bit in DDCSWR is changed [TRS setting conditions] 1. When 1 is written by software (except for conditions 3 and 4) 2. When 1 is written in TRS after reading TR TRS clearing conditions 3 and 4) 3. When 1 is received as the R/$\overline{W}$ bit after th address matching in I^2C bus format slave
3	ACKE	0	R/W	Acknowledge Bit Decision and Selection 0: The value of the acknowledge bit is ignore continuous transfer is performed. The valu received acknowledge bit is not indicated bit in ICSR, which is always 0. 1: If the received acknowledge bit is 1, contir transfer is halted. Depending on the receiving device, the ackno may be significant, in indicating completion of of the received data, for instance, or may be f have no significance.

In slave mode:

- Writing to the BBSY flag is disabled.

[BBSY setting condition]

When the SDA level changes from high to low u
condition of SCL = high, assuming that the start
has been issued.

[BBSY clearing condition]

When the SDA level changes from low to high u
condition of SCL = high, assuming that the stop
has been issued.

To issue a start/stop condition, use the MOV ins

The I^2C bus interface must be set in master tran
before the issue of a start condition. Set MST to
to 1 before writing 1 in BBSY and 0 in SCP.

The BBSY flag can be read to check whether th
(SCL, SDA) is busy or free.

The SCP bit is always read as 1. If 0 is written, t
not stored.

[Setting conditions]

I^2C bus format master mode:

- When a start condition is detected in the bu
  after a start condition is issued (when the I
  set to 1 because of first frame transmission
- When a wait is inserted between the data a
  acknowledge bit when the WAIT bit is 1 (fa
  transmit/receive clock)
- At the end of data transfer (rise of the 9th
  transmit/receive clock while no wait is inser
- When a slave address is received after bus
  is lost (the first frame after the start conditio
- If 1 is received as the acknowledge bit (wh
  bit in ICSR is set to 1) when the ACKE bit i
- When the AL flag is set to 1 after bus arbitr
  while the ALIE bit is 1

I^2C bus format slave mode:

- When the slave address (SVA or SVAX) m
  (when the AAS or AASX flag in ICSR is set
  the end of data transfer up to the subseque
  retransmission start condition or stop condi
  detection (rise of the 9th transmit/receive c
- When the general call address is detected
  received as the R/$\overline{W}$ bit and the ADZ flag in
  to 1) and at the end of data reception up to
  subsequent retransmission start condition o
  condition detection (rise of the 9th receive c
- If 1 is received as the acknowledge bit (wh
  bit in ICSR is set to 1) while the ACKE bit is
- When a stop condition is detected (when th
  ESTP flag in ICSR is set to 1) while the ST

When the ICDRE or ICDRF flag is set to 1 in an
mode:

- When a start condition is detected in transm
(when a start condition is detected in transm
and the ICDRE flag is set to 1)
- When data is transferred among the ICDR r
buffer (when data is transferred from ICDRT
in transmit mode and the ICDRE flag is set t
when data is transferred from ICDRS to ICD
receive mode and the ICDRF flag is set to 1

[Clearing conditions]

- When 0 is written in IRIC after reading IRIC
- When ICDR is read from or written to by the
may not function as a clearing condition dep
the situation. For details, see the description
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 co
without CPU intervention.

When, with the I^2C bus format selected, IRIC is set to 1 and an interrupt is generated, o
must be checked in order to identify the source that set IRIC to 1. Although each source
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
DTC start request flag) is not set at the end of a data transfer up to detection of a retrans
start condition or stop condition after a slave address (SVA) or general call address mat
bus format slave mode.

Even when the IRIC flag and IRTR flag are set, the ICDRE or ICDRF flag may not be
IRIC and IRTR flags are not cleared at the end of the specified number of transfers in c

1	1	1↑	0	0	1↑	0	0	0	0	0	—	1↑	Start cond
1	—	1	0	0	—	0	0	0	0	—	—	—	Wait state
1	1	1	0	0	—	0	0	0	0	1↑	—	—	Transmiss (ACKE=1
1	1	1	0	0	1↑	0	0	0	0	0	—	1↑	Transmiss ICDRE=0
1	1	1	0	0	—	0	0	0	0	0	—	0↓	ICDR write state
1	1	1	0	0	—	0	0	0	0	0	—	1	Transmiss ICDRE=1
1	1	1	0	0	—	0	0	0	0	0	—	0↓	ICDR write state or af condition
1	1	1	0	0	1↑	0	0	0	0	0	—	1↑	Automatic from ICDR the above
1	0	1	0	0	1↑	0	0	0	0	—	1↑	—	Reception ICDRF=0
1	0	1	0	0	—	0	0	0	0	—	0↓	—	ICDR read state
1	0	1	0	0	—	0	0	0	0	—	1	—	Reception ICDRF=1
1	0	1	0	0	—	0	0	0	0	—	0↓	—	ICDR read state
1	0	1	0	0	1↑	0	0	0	0	—	1↑	—	Automatic from ICDR with the al
0↓	0↓	1	0	0	—	0	1↑	0	0	—	—	—	Arbitration
1	—	0↓	0	0	—	0	0	0	0	—	—	0↓	Stop cond

Legend:

0: 0-state retained

1: 1-state retained

—: Previous state retained

0↓: Cleared to 0

1↑: Set to 1

													(SARX ≠ H
0	1↑/0*1	1	0	0	1↑	1↑	—	0	0	0	1↑	1	SARS mat frame (SAR
0	1	1	0	0	—	—	—	—	0	1↑	—	—	Transmissi = 1 and AC
0	1	1	0	0	1↑/0*2	—	—	—	0	0	—	1↑	Transmissi ICDRE = 0
0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICDR write above state
0	1	1	0	0	—	—	—	—	0	0	—	1	Transmissi ICDRE = 1
0	1	1	0	0	—	—	0↓	0↓	0	0	—	0↓	ICDR write above state
0	1	1	0	0	1↑/0*2	—	0	0	0	0	—	1↑	Automatic from ICDR with the ab
0	0	1	0	0	1↑/0*2	—	—	—	—	—	1↑	—	Reception ICDRF=0
0	0	1	0	0	—	—	0↓	0↓	0↓	—	0↓	—	ICDR read state
0	0	1	0	0	—	—	—	—	—	—	1	—	Reception ICDRF = 1
0	0	1	0	0	—	—	0↓	0↓	0↓	—	0↓	—	ICDR read state
0	0	1	0	0	1↑/0*2	—	0	0	0	—	1↑	—	Automatic from ICDR with the ab
0	—	0↓	1↑/0*3	0/1↑*3	—	—	—	—	—	—	—	0↓	Stop condi

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.

				When a stop condition is detected during frame [Clearing conditions] • When 0 is written in ESTP after reading ES • 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 I^2C bus format slave mode. [Setting condition] When a stop condition is detected after frame t completion. [Clearing conditions] • When 0 is written in STOP after reading ST • When the IRIC flag is cleared to 0

				[Setting conditions] I²C bus format slave mode: • When the ICDRE or ICDRF flag in ICDR is s when AASX = 1 Master mode or clocked synchronous serial forn 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
4	AASX	0	R/(W)*	Second Slave Address Recognition Flag In I²C bus format slave receive mode, this flag is the first frame following a start condition matche SVAX6 to SVAX0 in SARX. [Setting condition] When the second slave address is detected in s receive mode and FSX = 0 in SARX [Clearing conditions] • When 0 is written in AASX after reading AAS • When a start condition is detected • In master mode

				• If the internal SCL line is high at the fall of S master transmit mode When ALSL = 1 • If the internal SDA and SDA pin disagree a SCL in master transmit mode • If the SDA pin is driven low by another dev the I²C bus interface drives the SDA pin low start condition instruction was executed in m transmit mode [Clearing conditions] • When ICDR is written to (transmit mode) or (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 the first frame following a start condition match to SVA0 in SAR, or if the general call address detected. [Setting condition] When the slave address or general call addres including a R/$\overline{W}$ bit is H'00) is detected in slave mode and FS = 0 in SAR [Clearing conditions] • When ICDR is written to (transmit mode) or (receive mode) • When 0 is written in AAS after reading AAS • In master mode

FSX = 0

[Clearing conditions]

- When ICDR is written to (transmit mode) or
  (receive mode)
- When 0 is written in ADZ after reading ADZ
- In master mode

If a general call address is detected while FS=1
FSX=0, the ADZ flag is set to 1; however, the g
address is not recognized (AAS flag is not set t

[Clearing conditions]

- When 0 is received as the acknowledge bit ACKE=1 in transmit mode
- When 0 is written to the ACKE bit

Receive mode:

0: Returns 0 as acknowledge data after data re

1: Returns 1 as acknowledge data after data re

When this bit is read, the value loaded from the (returned by the receiving device) is read in tra (when TRS = 1). In reception (when TRS = 0), by internal software is read.

When this bit is written, acknowledge data that after receiving is rewritten regardless of the TR the ICSR register bit is written using bit-manipu instructions, the acknowledge data should be r the acknowledge data setting is rewritten by th reading value.

Write the ACKE bit to 0 to clear the ACKB flag transmission is ended and a stop condition is is master mode, or before transmission is ended released to issue a stop condition by a master

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

				formatless mode to I²C bus format 1: Enables automatic switching of IIC channel 0 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 SWE = 1
5	IE	0	R/W	DDC Mode Switch Interrupt Enable Bit 0: Disables interrupts when automatic format sw executed 1: Enables interrupts when automatic format sw executed
4	IF	0	R/(W)*1	DDC Mode Switch Interrupt Flag Indicates an interrupt request to the CPU is gen when automatic format switching is executed fo [Setting condition] When a falling edge is detected on the SCL pin SWE = 1 [Clearing condition] When 0 is written in IF after reading IF = 1

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 signal is generated for the internal latch circuit corresponding module, and the internal state o module is initialized.

These bits can only be written to; they are alwa 1. Write data to this bit is not retained.

To perform IIC clearance, bits CLR3 to CLR0 r written to simultaneously using an MOV instruc use a bit manipulation instruction such as BCL

When clearing is required again, all the bits mu to in accordance with the setting.

If the function of these bits is not used, set all c 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.

				condition is detected in slave mode. 0: Enables IRIC flag setting and interrupt genera the stop condition is detected (STOP = 1 or E slave mode. 1: Disables IRIC flag setting and interrupt gener the stop condition is detected.
6	HNDS	0	R/W	Handshake Receive Operation Select Enables or disables continuous receive operatio mode. 0: Enables continuous receive operation 1: Disables continuous receive operation When the HNDS bit is cleared to 0, receive ope performed continuously after data has been rec successfully while ICDRF flag is 0. When the HNDS bit is set to 1, SCL is fixed to t and the next data transfer is disabled after data received successfully while the ICDRF flag is 0. line is released and next receive operation is en reading the receive data in ICDR.

[Setting conditions]

- When data is received successfully and tra
  from ICDRS to ICDRR.

(1) When data is received successfully while
(at the rise of the 9th clock pulse).

(2) When ICDR is read successfully in receiv
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 t
  CLR0 bits in DDCSWR.

When ICDRF is set due to the condition (2) ab
is temporarily cleared to 0 when ICDR (ICDRR
however, since data is transferred from ICDRS
immediately, ICDRF is set to 1 again.

Note that ICDR cannot be read successfully in
mode (TRS = 1) because data is not transferre
ICDRS to ICDRR. Be sure to read data from IC
receive mode (TRS = 0).

thus allowing the next data to be written to.

[Setting conditions]

- When the start condition is detected from th state with I^2C bus format or serial format.
- When I^2C bus mode is switched to formatles SW bit in DDCSWR is set to 1).
- When data is transferred from ICDRT to ICD
  1. When data transmission completed while 0 (at the rise of the 9th clock pulse).
  2. When data is written to ICDR in transmit data transmission was completed while I

[Clearing conditions]

- When data is written to ICDR (ICDRT).
- When the stop condition is detected with I^2C or serial format.
- When 0 is written to the ICE bit.
- When the IIC is internally initialized using th CLR0 bits in DDCSWR.

Note that if the ACKE bit is set to 1 with I^2C bus enabling acknowledge bit decision, ICDRE is no data transmission is completed while the ackno is 1.

When ICDRE is set due to the condition (2) abo is temporarily cleared to 0 when data is written t (ICDRT); however, since data is transferred fro ICDRS immediately, ICDRE is set to 1 again. D data to ICDR when TRS = 0 because the ICDR is invalid during the time.

				Selects the condition under which arbitration is 0: When the SDA pin state disagrees with the bus interface outputs at the rise of SCL, or v SCL pin is driven low by another device. 1: When the SDA pin state disagrees with the bus interface outputs at the rise of SCL, or v SDA line is driven low by another device in i after the start condition instruction was exec
1	FNC1	0	R/W	Function Bit
0	FNC0	0	R/W	Cancels some restrictions on usage. For detail section 16.6, Usage Notes. 00: Restrictions on operation remaining in effe 01: Setting prohibited 10: Setting prohibited 11: Restrictions on operation canceled

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
16.5.

Figure 16.6 shows the I^2C bus timing.

The symbols used in figures 16.3 to 16.6 are explained in table 16.6.

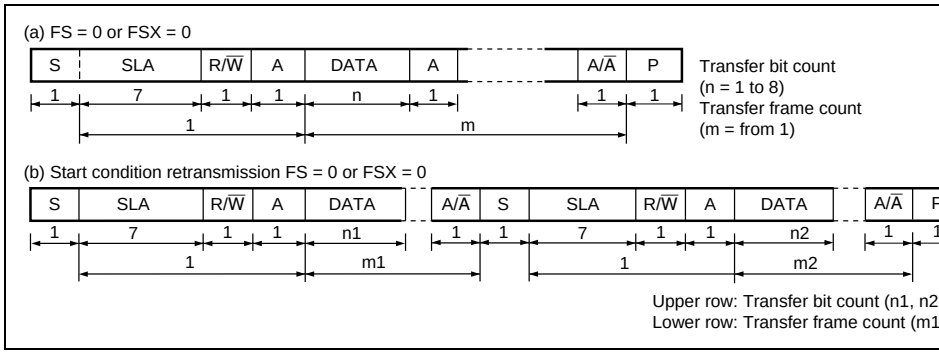


Figure 16.3 I^2C Bus Data Format (I^2C Bus Format)

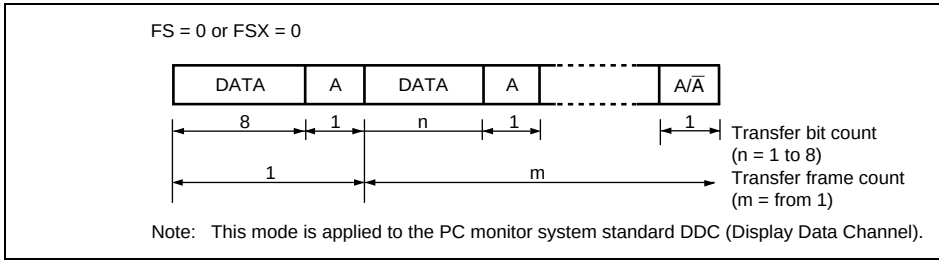


Figure 16.4 I^2C Bus Data Format (Formatless) (IIC_0 Only)

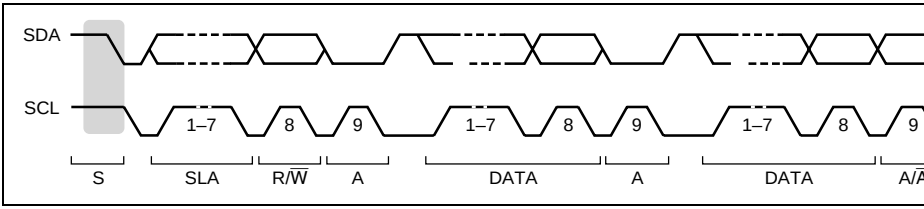


Figure 16.6 I²C Bus Timing

Table 16.6 I²C Bus Data Format Symbols

Legend	
S	Start condition. The master device drives SDA from high to low while SCL
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 maste when R/$\overline{W}$ is 1, or from the master device to the slave device when R/$\overline{W}$ is
A	Acknowledge. The receiving device drives SDA low to acknowledge a tran slave device returns acknowledge in master transmit mode, and the maste returns acknowledge in master receive mode.)
DATA	Transferred data. The bit length of transferred data is set with the BC2 to I 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

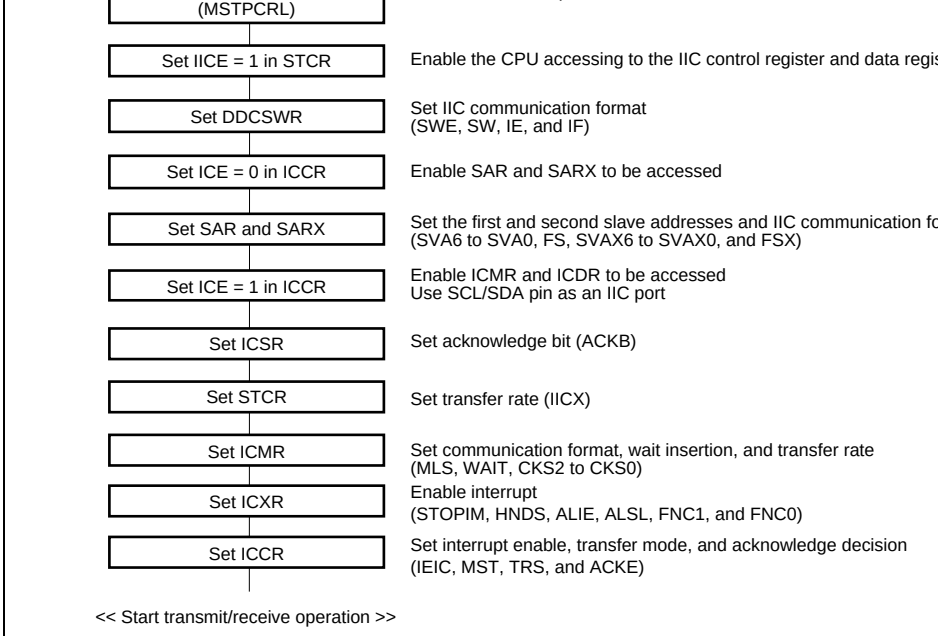


Figure 16.7 Sample Flowchart for IIC Initialization

Note: Be sure to modify the ICMR register after transmit/receive operation has been c
If the ICMR register is modified during transmit/receive operation, bit counter
BC0 will be modified erroneously, thus causing incorrect operation.

16.4.3 Master Transmit Operation

In I^2C bus format master transmit mode, the master device outputs the transmit clock ar
data, and the slave device returns an acknowledge signal.

Figure 16.8 shows the sample flowchart for the operations in master transmit mode.

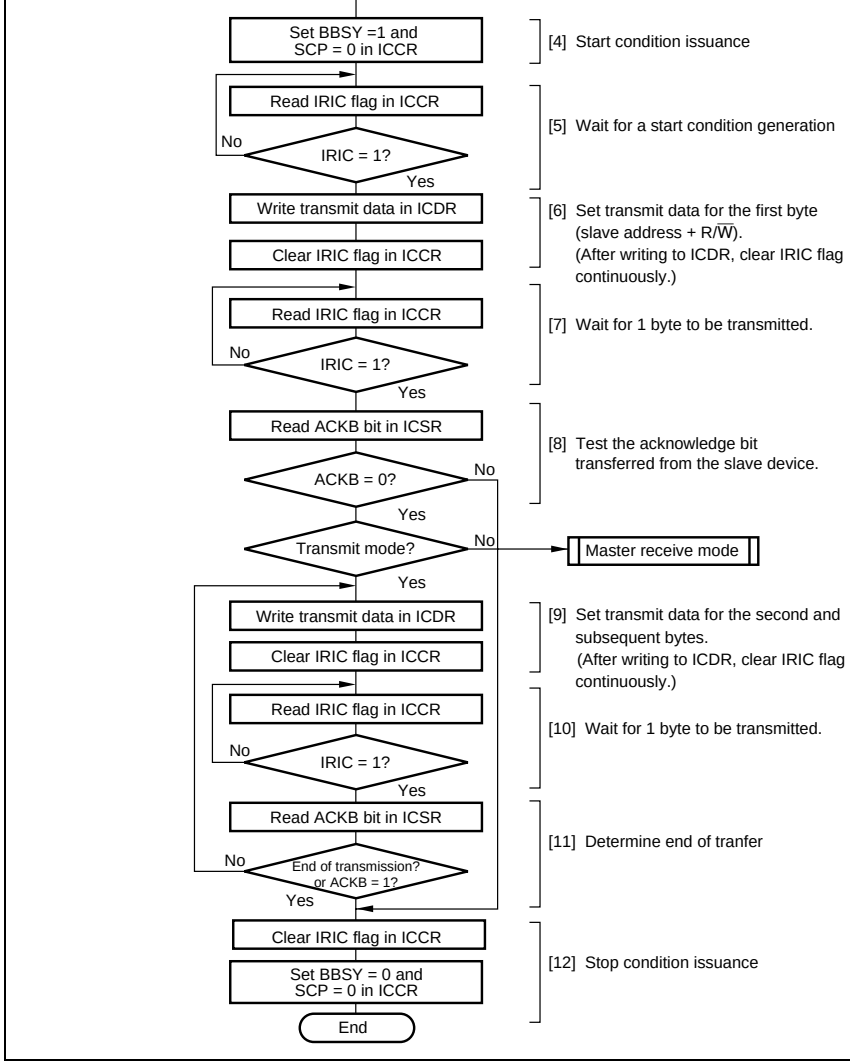


Figure 16.8 Sample Flowchart for Operations in Master Transmit Mo

5. Then the IRIC and IRTR flags are set to 1. If the IEIC bit in ICCR has been set to 1 interrupt request is sent to the CPU.
6. Write the data (slave address + R/$\overline{W}$) to ICDR.

   With the I^2C bus format (when the FS bit in SAR or the FSX bit in SARX is 0), the data following the start condition indicates the 7-bit slave address and transmit/rece direction (R/$\overline{W}$).

   To determine the end of the transfer, the IRIC flag is cleared to 0. After writing to I 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 tra cannot be determined. The master device sequentially sends the transmission clock data written to ICDR. The selected slave device (i.e. the slave device with the matc address) drives SDA low at the 9th transmit clock pulse and returns an acknowledg
7. When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of transmit clock pulse. After one frame has been transmitted, SCL is automatically fi 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 not acknowledged (ACKB bit is 1), operate step [12] to end transmission, and retry 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 the IRIC flag clearing sequentially, just as in step [6]. Transmission of the next fram 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 transmit clock pulse. After one frame has been transmitted, SCL is automatically fi 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 to be transmitted, go to step [9] to continue the next transmission operation. When t device has not acknowledged (ACKB bit is set to 1), operate step [12] to end transm

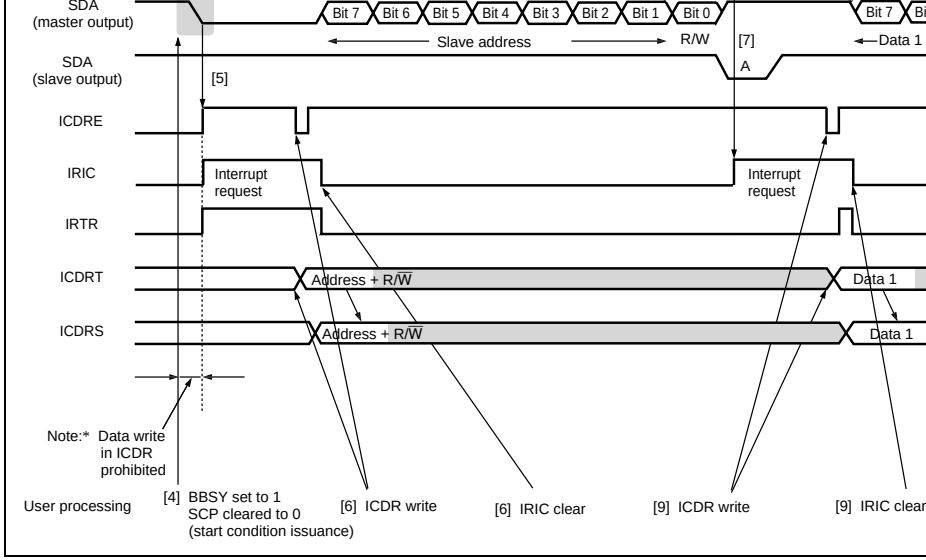


Figure 16.9 Example of Operation Timing in Master Transmit Mode (MLS = V

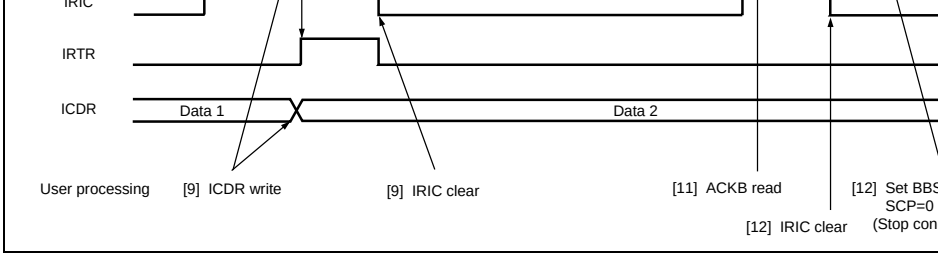


Figure 16.10 Example of Stop Condition Issuance Operation Timing in Master Transmit Mode (MLS = WAIT = 0)

16.4.4 Master Receive Operation

In I^2C bus format master receive mode, the master device outputs the receive clock, rec 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 following the start condition issuance in master transmit mode, selects the slave device, switches the mode for receive operation.

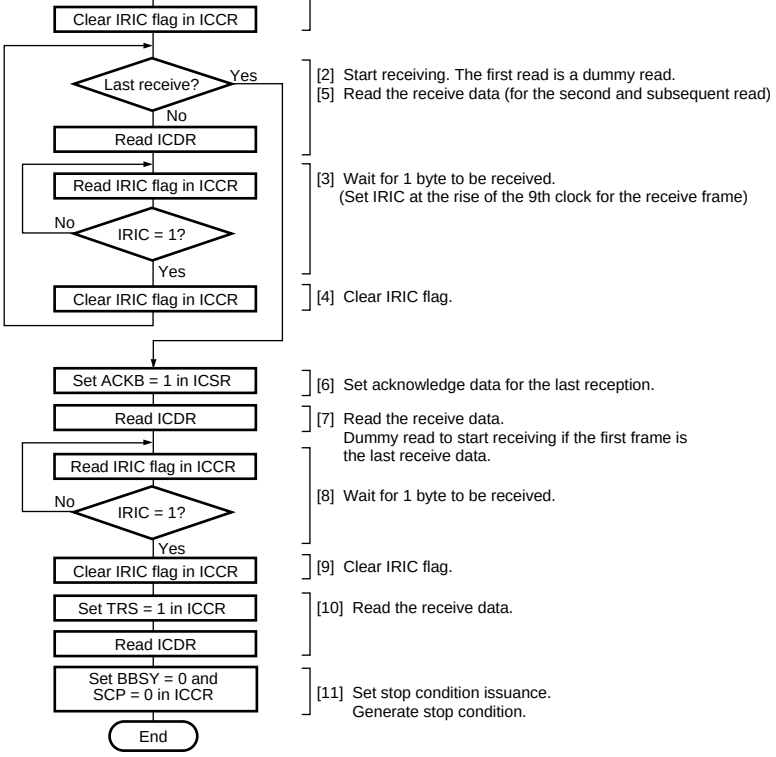


**Figure 16.11 Sample Flowchart for Operations in Master Receive Mo
(HNDS = 1)**

2. When ICDR is read (dummy data read), reception is started, the receive clock is out synchronization with the internal clock, and data is received. (Data from the SDA p sequentially transferred to ICDRS in synchronization with the rise of the receive clo
3. The master device drives SDA low to return the acknowledge data at the 9th receiv pulse. The receive data is transferred from ICDRS to ICDRR at the rise of the 9th c setting the ICDRF, IRIC, and IRTR flags to 1. If the IEIC bit has been set to 1, an i request is sent to the CPU.

   The master device drives SCL low from the fall of the 9th receive clock pulse to the 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 output 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 output receive clock to receive data.
8. When one frame of data has been received, the ICDRF, IRIC, and IRTR flags are se 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 is high, and generates the stop condition.

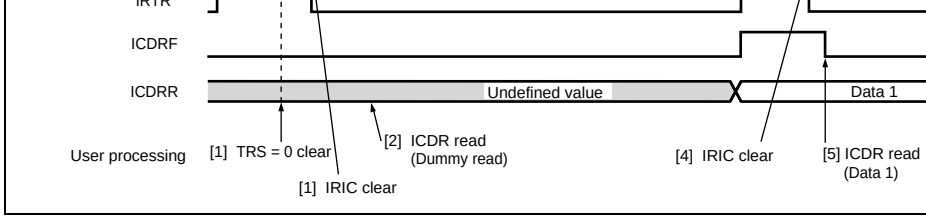


Figure 16.12 Example of Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)

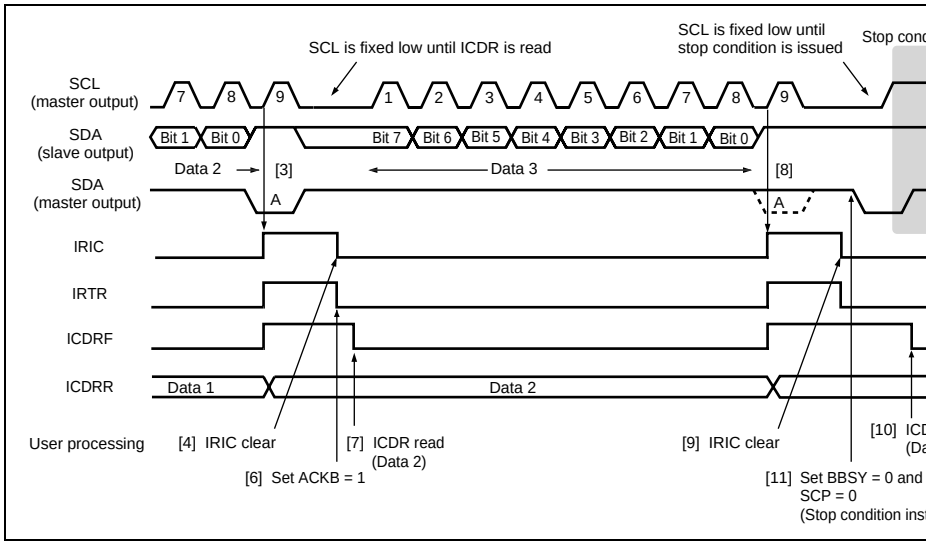


Figure 16.13 Example of Stop Condition Issuance Operation Timing in Master Receive Mode (MLS = WAIT = 0, HNDS = 1)

Receive Operation Using the Wait Function:

Figures 16.14 and 16.15 show the sample flowcharts for the operations in master recei (WAIT = 1).

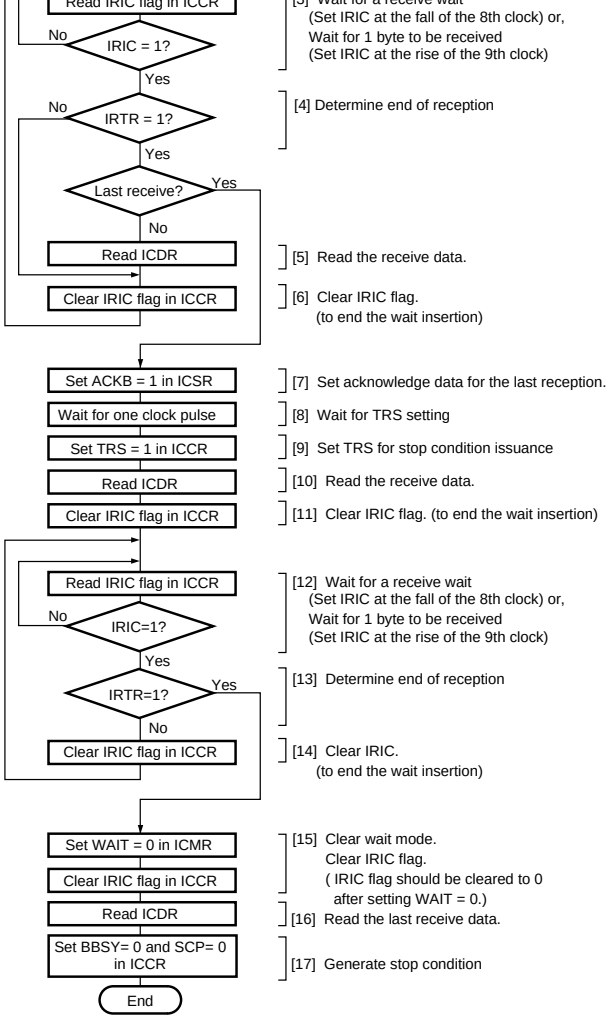


Figure 16.14 Sample Flowchart for Operations in Master Receive Mod (Receiving Multiple Bytes) (WAIT = 1)

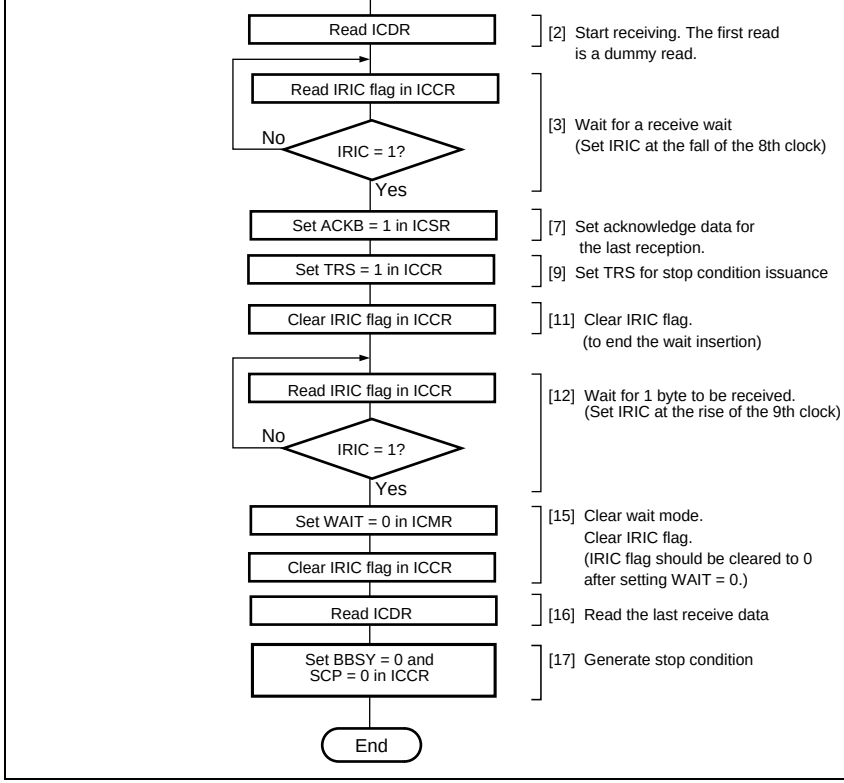


Figure 16.15 Sample Flowchart for Operations in Master Receive Mo (Receiving a Single Byte) (WAIT = 1)

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 o 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 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 t 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 be received. The master device outputs the receive clock continuously to receive th
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 s

   If the IRTR flag is 1 and the next data is the last receive data, execute step [7] to ha
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 devi the 9th clock and drives SDA low at the 9th receive clock pulse to return an acknow 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 rece
8. After the IRIC flag is set to 1, wait for at least one clock pulse until the rise of the fi pulse for the next receive data.
9. Set the TRS bit in ICCR to 1 to switch from receive mode to transmit mode. The TI becomes valid when the rising edge of the next 9th clock pulse is input.
10. Read the ICDR receive 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 wa

    If the IRTR flag is 1 and data reception is complete, execute step [15] to issue the 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 = WAIT bit is cleared to 0 after clearing the IRIC flag and then an instruction to issu 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 is high, and generates the stop condition.

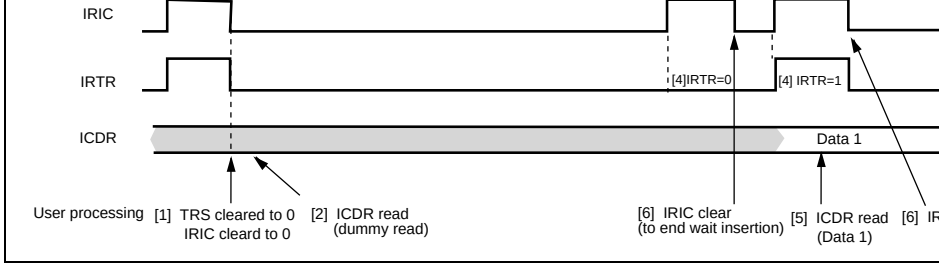


Figure 16.16 Example of Master Receive Mode Operation Timing (MLS = ACKB = 0, WAIT = 1)

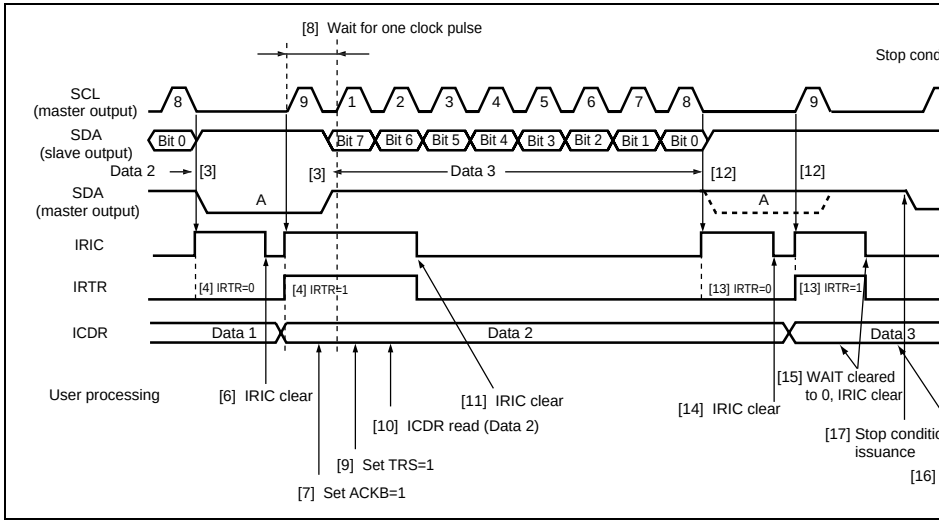


Figure 16.17 Example of Stop Condition Issuance Timing in Master Receive (MLS = ACKB = 0, WAIT = 1)

Receive Operation Using the HNDS Function (HNDS = 1):

Figure 16.18 shows the sample flowchart for the operations in slave receive mode (HN

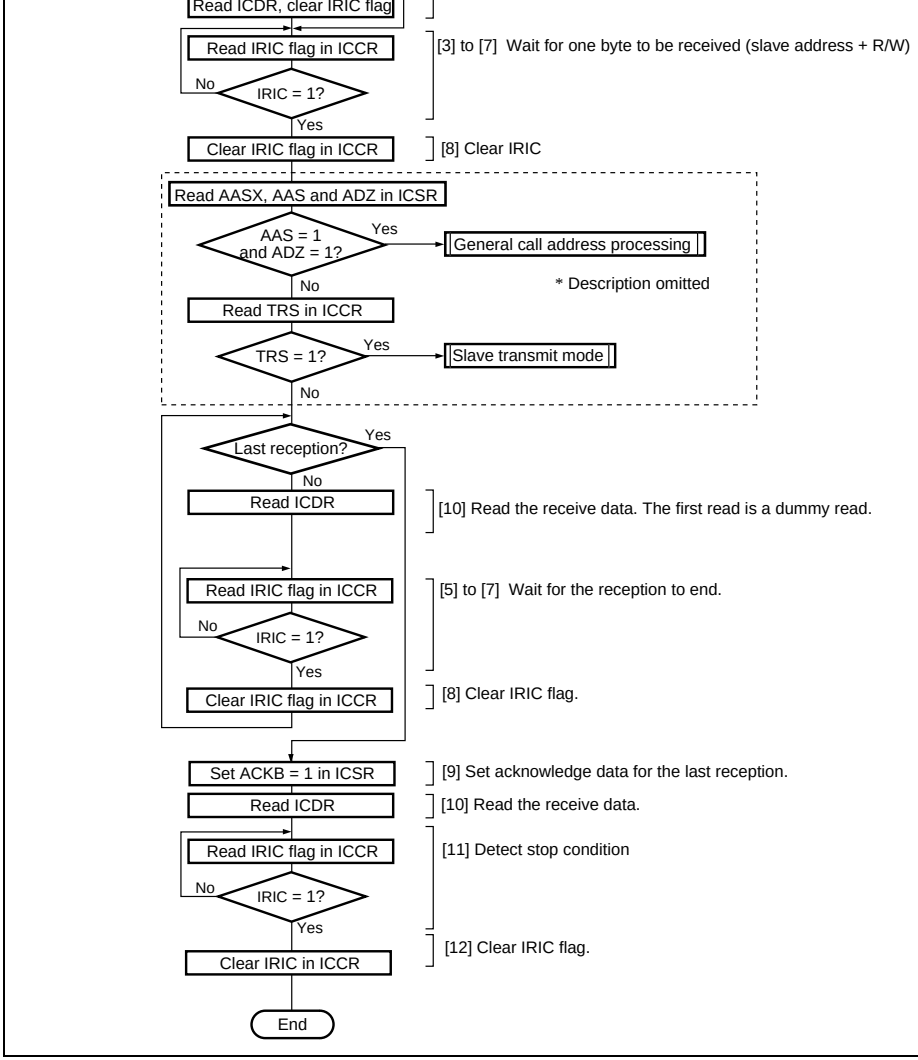


Figure 16.18 Sample Flowchart for Operations in Slave Receive Mode (HND

the IRIC flag to 0.

3. When the start condition output by the master device is detected, the BBSY flag in to 1. The master device then outputs the 7-bit slave address and transmit/receive d (R/W), in synchronization with the transmit clock pulses.
4. When the slave address matches in the first frame following the start condition, th operates as the slave device specified by the master device. If the 8th data bit (R/$\overline{W}$ TRS bit remains cleared to 0, and slave receive operation is performed. If the 8th d (R/$\overline{W}$) is 1, the TRS bit is set to 1, and slave transmit operation is performed. Whe address does not match, receive operation is halted until the next start condition is
5. At the 9th clock pulse of the receive frame, the slave device returns the data in the 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 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 IC setting the ICDRF flag to 1. The slave device drives SCL low from the fall of the 9 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 en 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 BBSY flag is cleared to 0 and the STOP bit is set to 1. If the STOPIM bit has been 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.

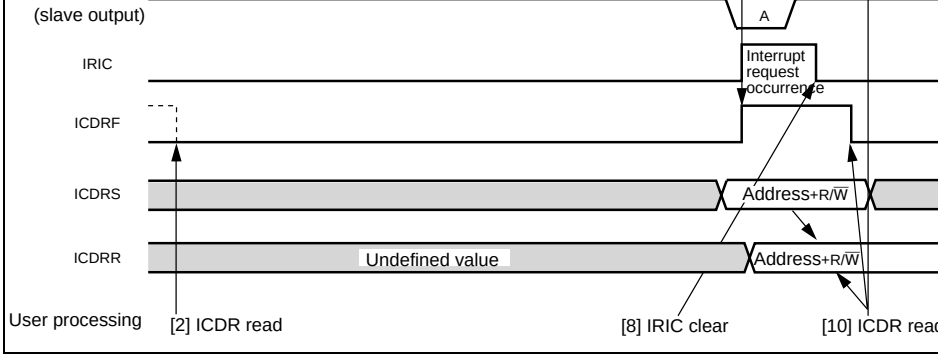


Figure 16.19 Example of Slave Receive Mode Operation Timing (1) (MLS = 0, HNDS= 1)

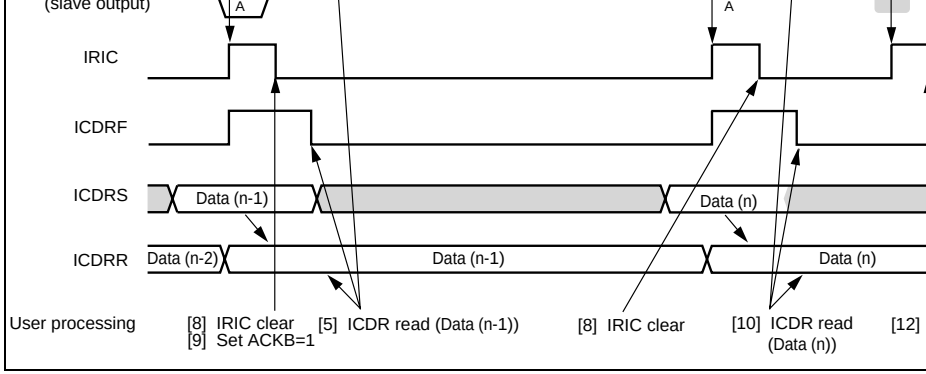


Figure 16.20 Example of Slave Receive Mode Operation Timing (2)
(MLS = 0, HNDS= 1)

Continuous Receive Operation:

Figure 16.21 shows the sample flowchart for the operations in slave receive mode (HN

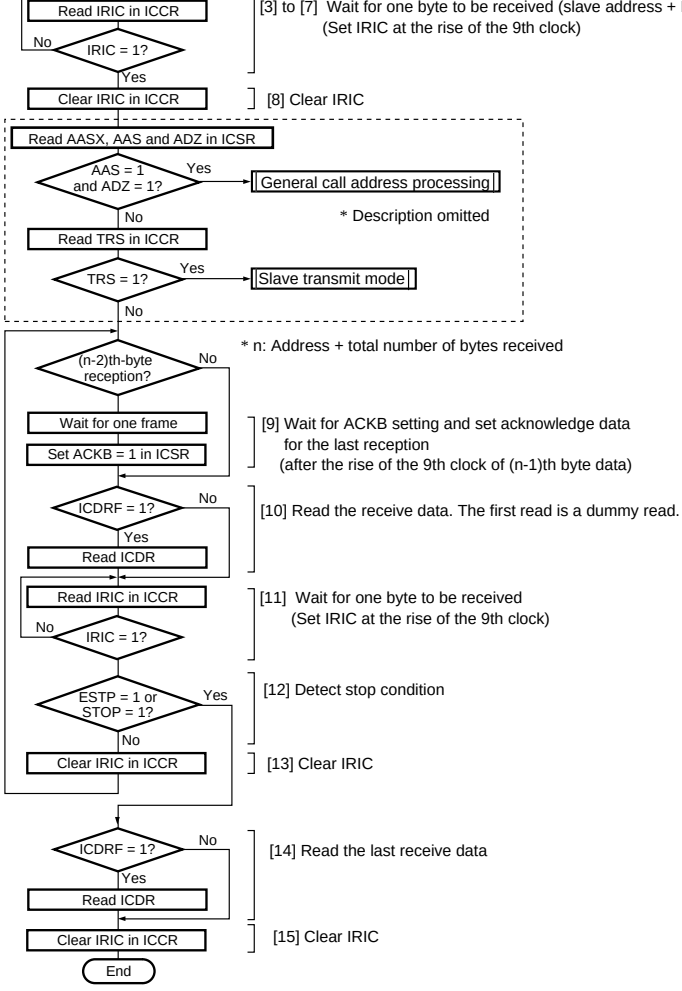


Figure 16.21 Sample Flowchart for Operations in Slave Receive Mode (HND

to 1. The master device then outputs the 7-bit slave address and transmit/receive d
(R/W) in synchronization with the transmit clock pulses.

4. When the slave address matches in the first frame following the start condition, th
operates as the slave device specified by the master device. If the 8th data bit (R/$\overline{W}$
TRS bit remains cleared to 0, and slave transmit operation is performed. When the
address does not match, receive operation is halted until the next start condition is
5. At the 9th clock pulse of the receive frame, the slave device returns the data in the
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
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 IC
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
ACKB bit. Set the ACKB bit after the rise of the 9th clock pulse of the second last
frame.
10. Confirm that the ICDRF flag is set to 1 and read ICDR. This clears the ICDRF flag
11. At the rise of the 9th clock pulse or when the receive data is transferred from IRDR
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
BBSY flag is cleared to 0 and the STOP or ESTP flag is set to 1. If the STOPIM b
cleared to 0, the IRIC flag is set to 1. In this case, execute step [14] to read the last
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.

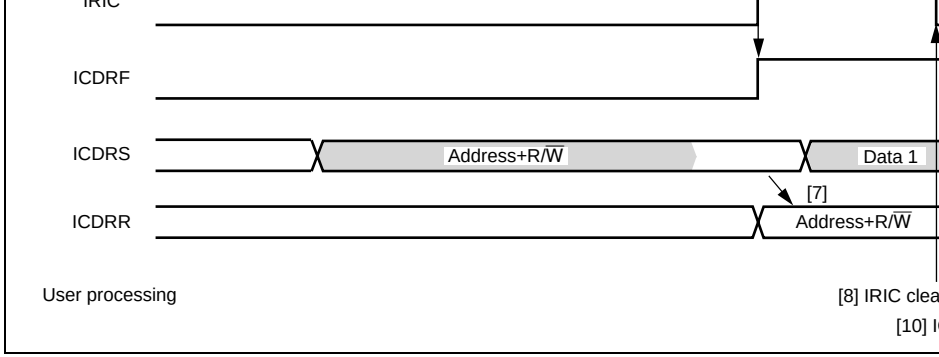


Figure 16.22 Example of Slave Receive Mode Operation Timing (1)
(MLS = ACKB = 0, HNDS = 0)

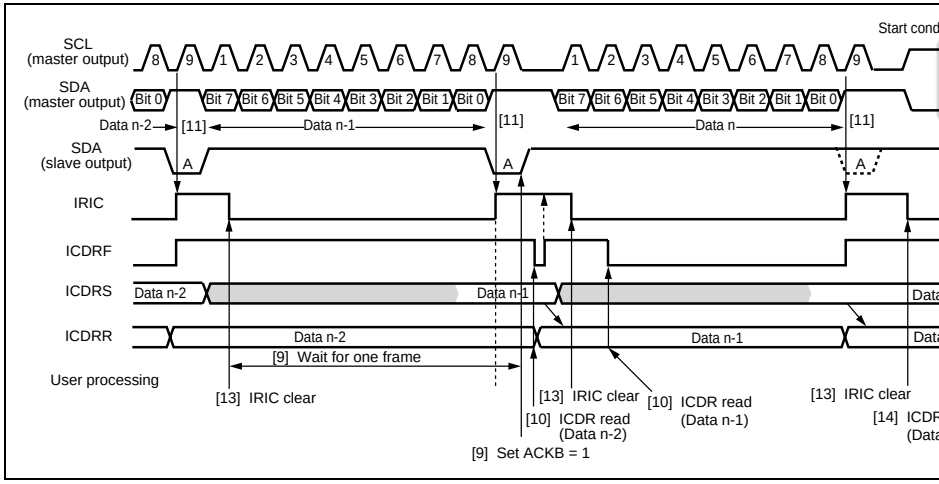


Figure 16.23 Example of Slave Receive Mode Operation Timing (2)
(MLS = ACKB = 0, HNDS = 0)

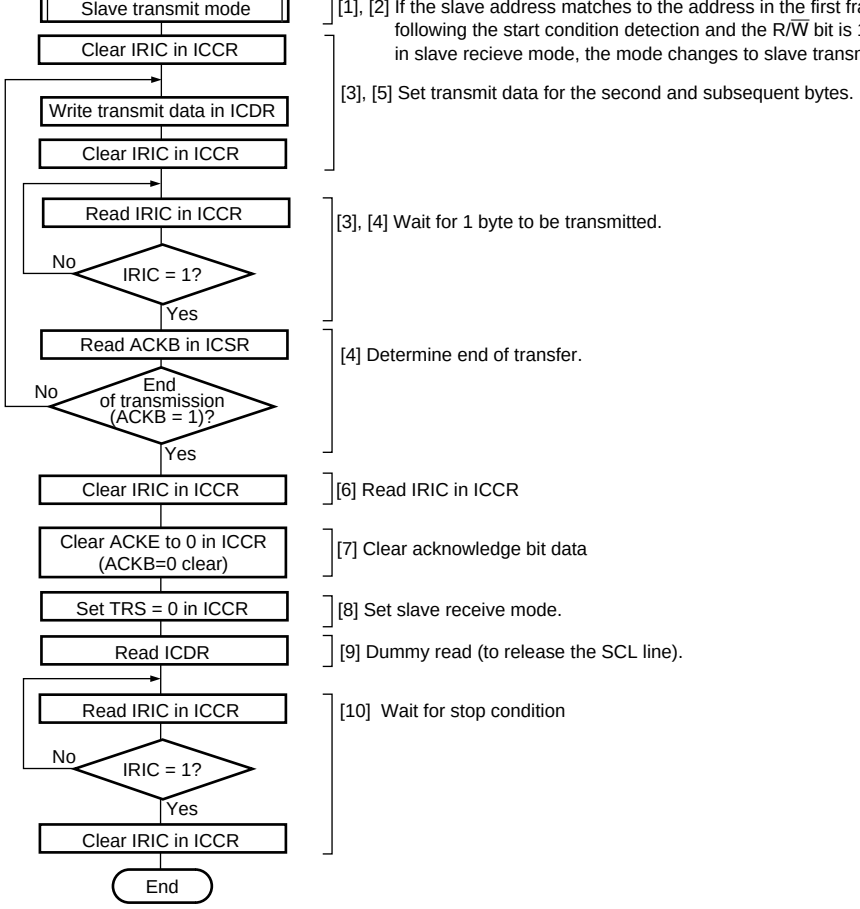


Figure 16.24 Sample Flowchart for Slave Transmit Mode

transmit mode automatically. The IRIC flag is set to 1 at the rise of the 9th clock. If bit in ICCR has been set to 1, an interrupt request is sent to the CPU. At the same ti ICDRE flag is set to 1. The slave device drives SCL low from the fall of the transm until ICDR data is written, to disable the master device to output the next transfer cl

3. After clearing the IRIC flag to 0, write data to ICDR. At this time, the ICDRE flag i 0. The written data is transferred to ICDRS, and the ICDRE and IRIC flags are set t The slave device sequentially sends the data written into ICDRS in accordance with output by the master device.

   The IRIC flag is cleared to 0 to detect the end of transmission. Processing from the register writing to the IRIC flag clearing should be performed continuously. Preven interrupt processing from being inserted.

4. The master device drives SDA low at the 9th clock pulse, and returns an acknowled As this acknowledge signal is stored in the ACKB bit in ICSR, this bit can be used determine whether the transfer operation was performed successfully. When one fra has been transmitted, the IRIC flag in ICCR is set to 1 at the rise of the 9th transmit pulse. When the ICDRE flag is 0, the data written into ICDR is transferred to ICDR transmission starts, and the ICDRE and IRIC flags are set to 1 again. If the ICDRE been set to 1, this slave device drives SCL low from the fall of the transmit clock u written to ICDR.
5. To continue transmission, write the next data to be transmitted into ICDR. The ICD cleared to 0. The IRIC flag is cleared to 0 to detect the end of transmission. Process the ICDR register writing to the IRIC flag clearing should be performed continuous 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 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.

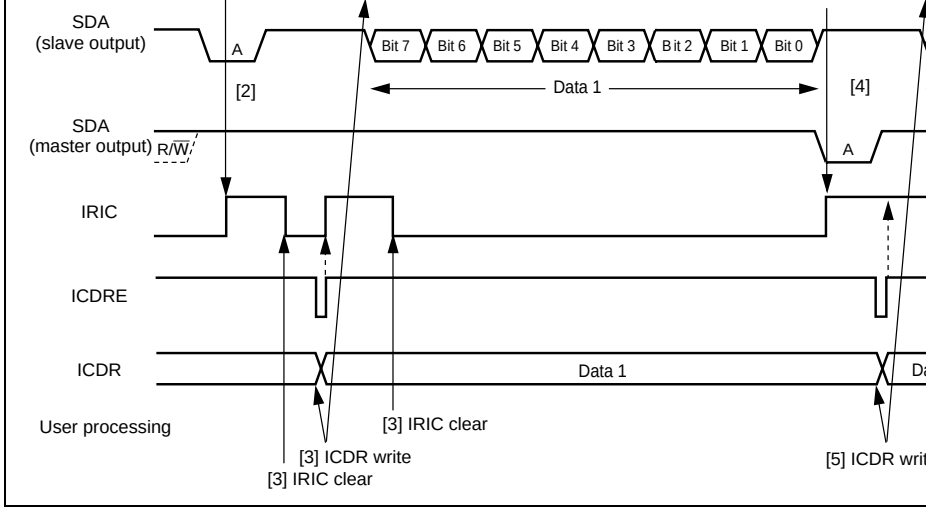
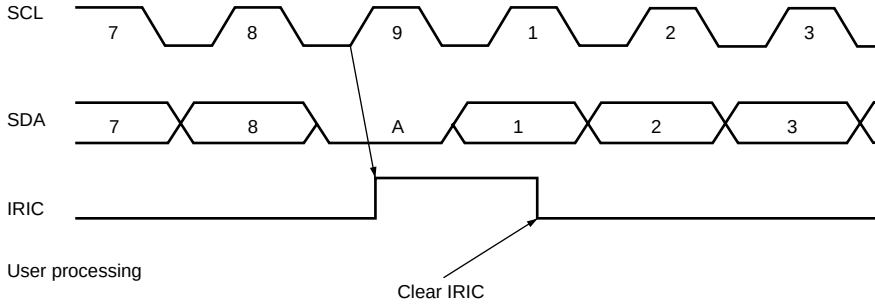
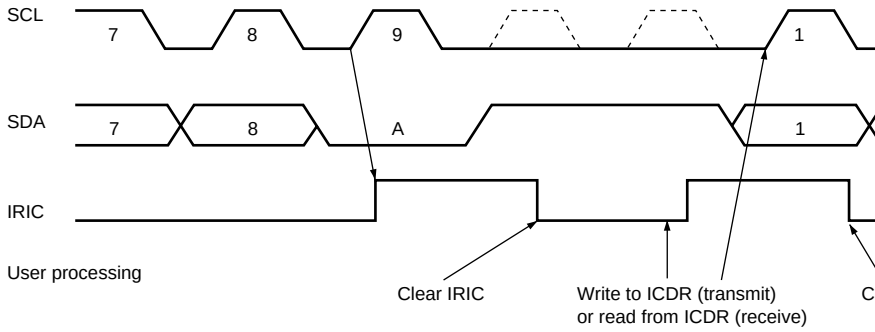


Figure 16.25 Example of Slave Transmit Mode Operation Timing (MLS = 0)

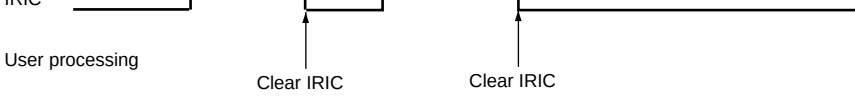


(a) Data transfer ends with ICDRE = 0 at transmission, or ICDRF = 0 at reception

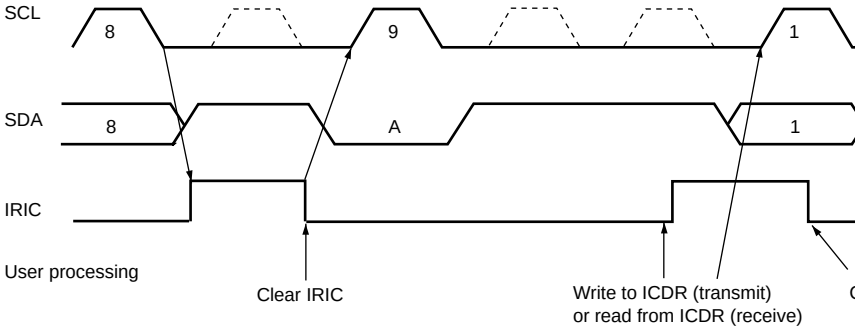


(b) Data transfer ends with ICDRE = 1 at transmission, or ICDRF = 1 at reception

Figure 16.26 IRIC Setting Timing and SCL Control (1)



(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)

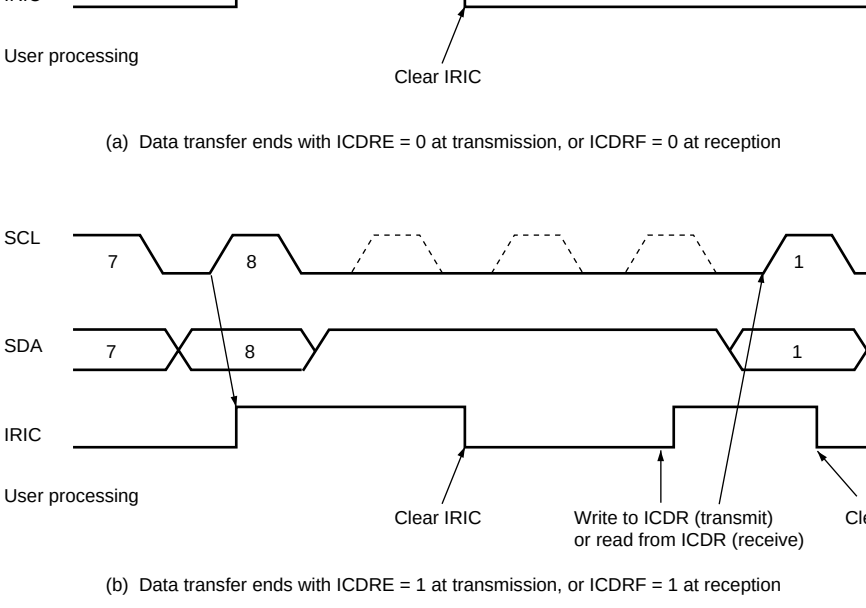


Figure 16.28 IRIC Setting Timing and SCL Control (3)

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_ operating mode. Switching from formatless mode to the I²C bus format (slave mode) is 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 operatio
- A fixed 1 level for the SCL pin during formatless operation (the SCL pin does not c level)

bit to 1 or clear it to 0 according to the transfer direction (transmission or reception) in
mode, then set the SW bit to 1. After automatic switching from formatless mode to the
format (slave mode), the TRS bit is automatically cleared to 0 in order to wait for slave
reception.

If a falling edge is detected on the SCL pin during formatless operation, the mode of t
interface is immediately switched to I^2C 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 wh
flag is set to 1, which is one of the two interrupt flags (IRTR and IRIC). When the AC
the ICDRE, IRIC, and IRTR flags are set at the end of data transmission regardless of
acknowledge bit value. If the ACKE bit is 1, the ICDRE, IRIC, and IRTR flags are set
transmission is completed with the acknowledge bit value of 0, and if the ACKE bit is
IRIC flag is set when data transmission is completed with the acknowledge bit value o

When initiated, the DTC transfers specified number of bytes, clears the ICDRE, IRIC,
flags to 0. Therefore, no interrupt is generated during continuous data transfer; howev
transmission is completed with the acknowledge bit value of 1 when the ACKE bit is
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 p
for some receiving devices, and for other receiving devices, the acknowledge bit may
1, indicating no specific events.

The I^2C bus format provides for selection of the slave device and transfer direction by
the slave address and the R/$\overline{W}$ bit, confirmation of reception with the acknowledge bit
of the last frame, and so on. Therefore, continuous data transfer using the DTC must b
in conjunction with CPU processing by means of interrupts.

Table 16.7 shows some examples of processing using the DTC. These examples assum
number of transfer data bytes is known in slave mode.

read		CPU (ICDR read)		
Actual data transmission/ reception	Transmission by DTC (ICDR write)	Reception by DTC (ICDR read)	Transmission by DTC (ICDR write)	Receptio (ICDR re
Dummy data (H'FF) write	—	—	Processing by DTC (ICDR write)	—
Last frame processing	Not necessary	Reception by CPU (ICDR read)	Not necessary	Receptio (ICDR re
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 nece
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))	Receptio data cou

16.4.10 Noise Canceler

The logic levels at the SCL and SDA pins are routed through noise cancelers before bei 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 input signal is sampled on the system clock, but is not passed forward to the next circui outputs of both latches agree. If they do not agree, the previous value is held.

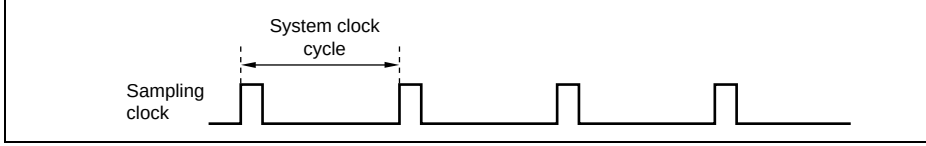


Figure 16.29 Block Diagram of Noise Canceler

16.4.11 Initialization of Internal State

The IIC has a function for forcible initialization of its internal state if a deadlock occu
communication.

Initialization is executed in accordance with the setting of bits CLR3 to CLR0 in DDC
clearing ICE bit. For details on the setting of bits CLR3 to CLR0, see section 16.3.7, I
Register (DDCSWR).

Scope of Initialization: The initialization executed by this function covers the follow

- 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
  output, etc.)

The following items are not initialized:

- Actual register values (ICDR, SAR, SARX, ICMR, ICCR, ICSR, ICXR (except fo
  and ICDRF flags), DDCSWR)
- Internal latches used to retain register read information for setting/clearing flags in
  ICCR, ICSR, and DDCSWR
- The value of the ICMR bit counter (BC2 to BC0)
- Generated interrupt sources (interrupt sources transferred to the interrupt controlle

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 simultaneo accordance with the setting.
- If a flag clearing setting is made during transmission/reception, the IIC module will transmitting/receiving at that point and the SCL and SDA pins will be released. Wh transmission/reception is started again, register initialization, etc., must be carried o necessary to enable correct communication as a system.

The value of the BBSY bit cannot be modified directly by this module clear function, b stop condition pin waveform is generated according to the state and release timing of th SDA pins, the BBSY bit may be cleared as a result. Similarly, state switching of other l flags may also have an effect.

To prevent problems caused by these factors, the following procedure should be used w initializing the IIC state.

1. Execute initialization of the internal state according to the setting of bits CLR3 to C ICE bit clearing.
2. Execute a stop condition issuance instruction (write 0 to BBSY and SCP) to clear th 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 t ICE bit clearing.
4. Initialize (re-set) the IIC registers.

Channel	Name	Enable Bit	Interrupt Source	Interrupt Flag	DTC Activation
0	IICI0	IEIC	I^2C bus interface interrupt request	IRIC	Possible
	DDCSWI	IE	Format automatic switch interrupt	IF	Not possible
1	IICI1	IEIC	I^2C bus interface interrupt request	IRIC	Possible

16.6 Usage Notes

1. In master mode, if an instruction to generate a start condition is issued and then an to generate a stop condition is issued before the start condition is output to the I^2C condition will be output correctly. To output the start condition followed by the sto after issuing the instruction that generates the start condition, read DR in each I^2C pin, and check that SCL and SDA are both low. The pin states can be monitored by DR even if the ICE bit is set to 1. Then issue the instruction that generates the stop 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 conditions when accessing to ICDR.
   - Write to ICDR when ICE = 1 and TRS = 1 (including automatic transfer from ICDRS)
   - Read from ICDR when ICE = 1 and TRS = 0 (including automatic transfer fro ICDRR)
3. Table 16.9 shows the timing of SCL and SDA outputs in synchronization with the clock. Timings on the bus are determined by the rise and fall times of signals affec bus load capacitance, series resistance, and parallel resistance.

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 A therefore depends on the system clock cycle t_{cyc}, as shown in section 28, Electrical Characteristics. Note that the I^2C bus interface AC timing specifications will not be system clock frequency of less than 5 MHz.
5. The I^2C bus interface specification for the SCL rise time t_{sr} is 1000 ns or less (300 n speed mode). In master mode, the I^2C bus interface monitors the SCL line and synch one bit at a time during communication. If t_{sr} (the time for SCL to go from low to V the time determined by the input clock of the I^2C bus interface, the high period of S extended. The SCL rise time is determined by the pull-up resistance and load capac the SCL line. To insure proper operation at the set transfer rate, adjust the pull-up re and load capacitance so that the SCL rise time does not exceed the values given in t

1	17.5 t_{cyc}	Standard mode	1000	100	1000	1000	1000
		High-speed mode	300	300	300	300	300

6. The I^2C bus interface specifications for the SCL and SDA rise and fall times are u
and 300 ns. The I^2C bus interface SCL and SDA output timing is prescribed by t_{cyc},
table 16.9. However, because of the rise and fall times, the I^2C bus interface specif
not be satisfied at the maximum transfer rate. Table 16.11 shows output timing cal
different operating frequencies, including the worst-case influence of rise and fall

   t_{BUFO} fails to meet the I^2C bus interface specifications at any frequency. The solutio
to provide coding to secure the necessary interval (approximately 1 µs) between is
stop condition and issuance of a start condition, or (b) to select devices whose inpu
permits this output timing for use as slave devices connected to the I^2C bus.

   t_{SCLLO} in high-speed mode and t_{STASO} in standard mode fail to satisfy the I^2C bus inter
specifications for worst-case calculations of t_{Sr}/t_{Sf}. Possible solutions that should be
include (a) adjusting the rise and fall times by means of a pull-up resistor and capa
(b) reducing the transfer rate to meet the specifications, or (c) selecting devices wh
timing permits this output timing for use as slave devices connected to the I^2C bus.

t_{SCLLO}	0.5 t_{SCLO} ($-t_{Sr}$)	Standard mode	–250	4700	4750	4750	4750	4750
		High-speed mode	–250	1300	1000*1	1000*1	1000*1	1000
t_{BUFO}	0.5 t_{SCLO}–1 t_{cyc} ($-t_{Sr}$)	Standard mode	–1000	4700	3800*1	3875*1	3900*1	3938
		High-speed mode	–300	1300	750*1	825*1	850*1	888*1
t_{STAHO}	0.5 t_{SCLO}–1 t_{cyc} ($-t_{Sr}$)	Standard mode	–250	4000	4550	4625	4650	4688
		High-speed mode	–250	600	800	875	900	938
t_{STASO}	1 t_{SCLO} ($-t_{Sr}$)	Standard mode	–1000	4700	9000	9000	9000	9000
		High-speed mode	–300	600	2200	2200	2200	2200
t_{STOSO}	0.5 t_{SCLO} + 2 t_{cyc} ($-t_{Sr}$)	Standard mode	–1000	4000	4400	4250	4200	4125
		High-speed mode	–300	600	1350	1200	1150	1075
t_{SDASO} (master)	1 t_{SCLLO}*3 –3 t_{cyc} ($-t_{Sr}$)	Standard mode	–1000	250	3100	3325	3400	3513
		High-speed mode	–300	100	400	625	700	813
t_{SDASO} (slave)	1 t_{SCLL}*3 –12 t_{cyc}*2 ($-t_{Sr}$)	Standard mode	–1000	250	1300	2200	2500	2950
		High-speed mode	–300	100	–1400*1	–500*1	–200*1	250
t_{SDAHO}	3 t_{cyc}	Standard mode	0	0	600	375	300	188
		High-speed mode	0	0	600	375	300	188

Notes: 1. Does not meet the I^2C bus interface specification. Remedial action such as t
is necessary: (a) secure a start/stop condition issuance interval; (b) adjust th
fall times by means of a pull-up resistor and capacitive load; (c) reduce the tr
(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
CKS0 to CKS2. Depending on the frequency it may not be possible to achiev
maximum transfer rate; therefore, whether or not the I^2C bus interface specif
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 valu
($t_{SCLL} - 6t_{cyc}$).
3. Calculated using the I^2C bus specification values (standard mode: 4700 ns m
speed mode: 1300 ns min.).

BBSY bit in ICCR is cleared to 0, the stop condition has been generated, and the b
released, then read ICDR with TRS cleared to 0.

Note that if the receive data (ICDR data) is read in the interval between execution
instruction for issuance of the stop condition (writing of 0 to BBSY and SCP in IC
actual generation of the stop condition, the clock may not be output correctly in su
master transmission.

Clearing of the MST bit after completion of master transmission/reception, or other m
of IIC control bits to change the transmit/receive operating mode or settings, must be
during interval (a) in figure 16.30 (after confirming that the BBSY bit in ICCR has be
0).

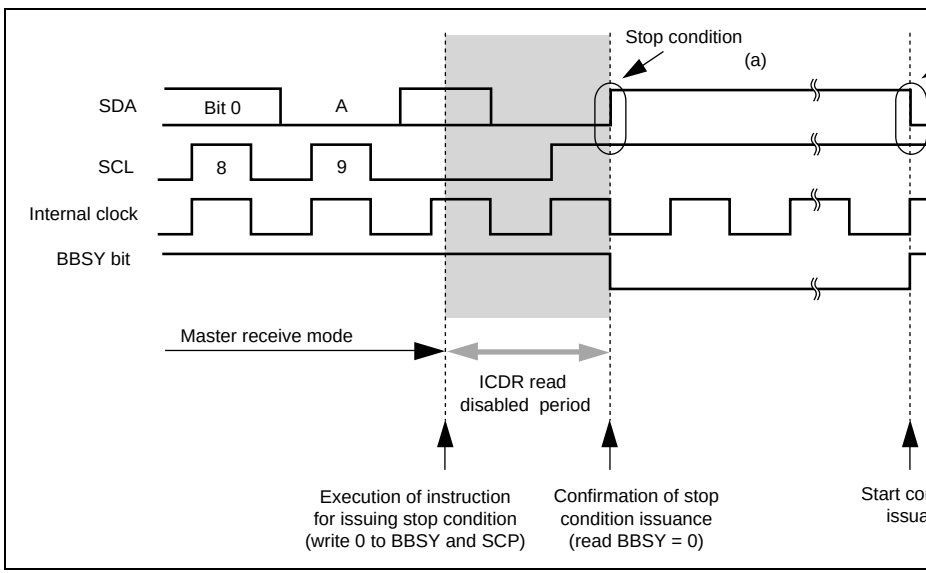


Figure 16.30 Notes on Reading Master Receive Data

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits
ICXR.

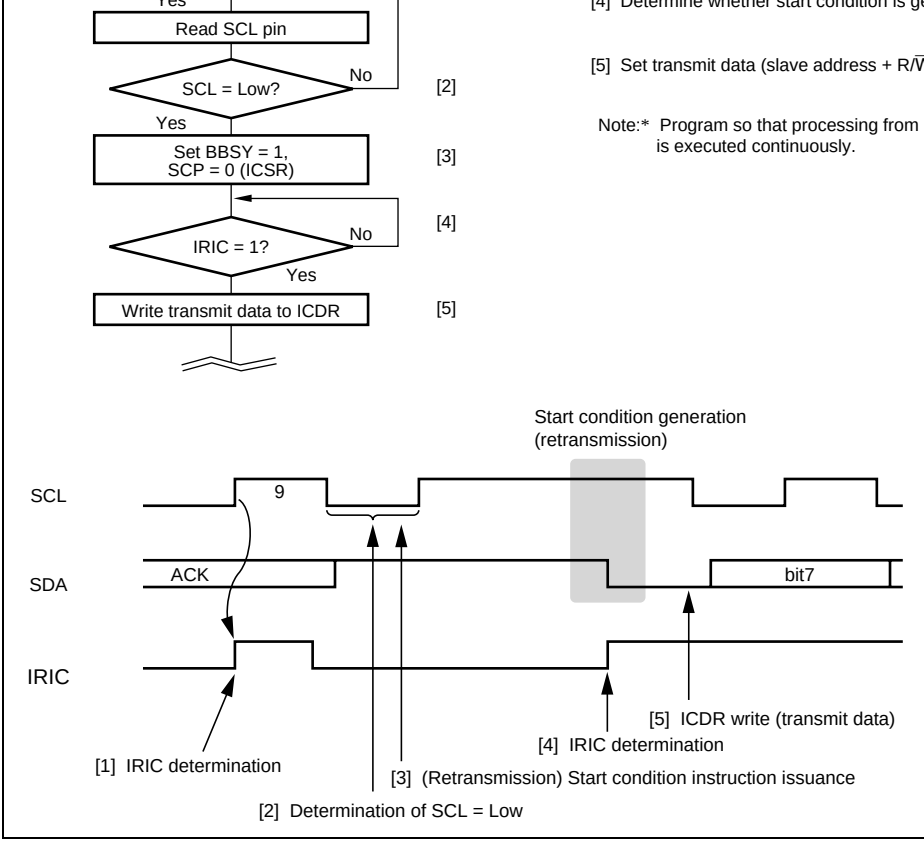


Figure 16.31 Flowchart for Start Condition Issuance Instruction for Retransm Timing

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits ICXR.

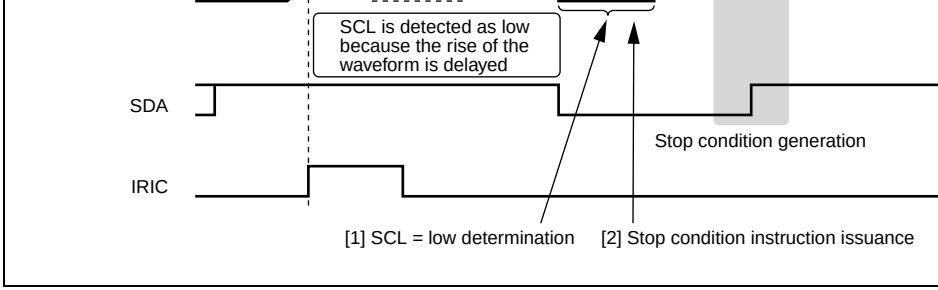


Figure 16.32 Stop Condition Issuance Timing

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to
ICXR.

— Error phenomenon

Normally, WAIT State will be cancelled by clearing the IRIC flag bit from 1 to
fall of the 8th clock in WAIT State. In this case, if the IRIC flag bit is cleared b
7th clock fall and the 8th clock fall, the IRIC flag clear- data will be retained in
Therefore, the WAIT State will be cancelled right after WAIT insertion on 8th

— Restrictions

Please clear the IRIC flag before the rise of the 7th clock (the counter value of
through BC0 should be 2 or greater), after the IRIC flag is set to 1 on the rise o
clock.

If the IRIC flag-clear is delayed due to the interrupt or other processes and the
counter is turned to 1 or 0, please confirm the SCL pins are in L' state after the
value of BC2 through BC0 is turned to 0, and clear the IRIC flag. (See figure 1

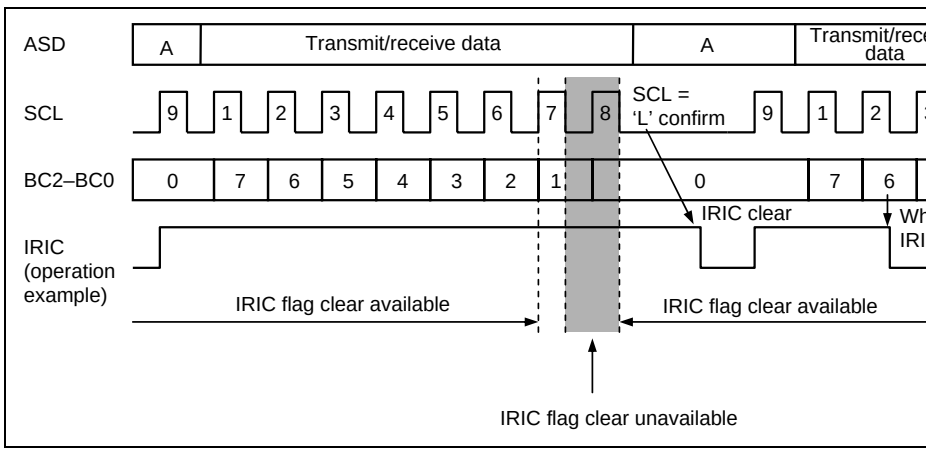


Figure 16.33 IRIC Flag Clear Timing on WAIT Operation

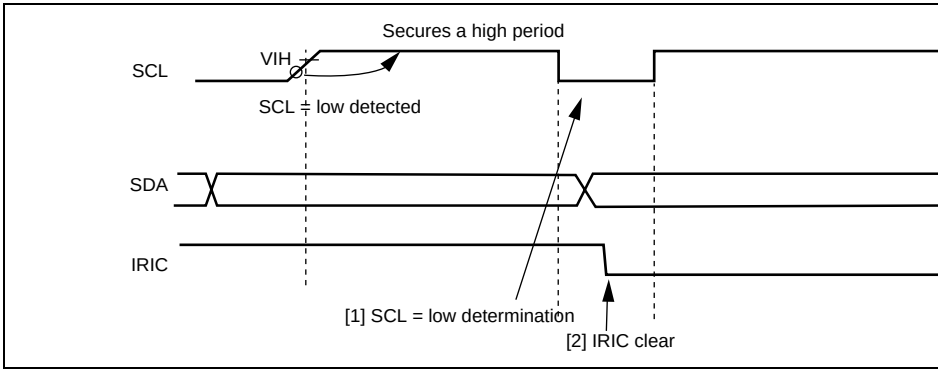


Figure 16.34 IRIC Flag Clearing Timing When WAIT = 1

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to
ICXR.

the receive operation of the next slave address.

— Monitor the BC2 to BC0 bit counter in ICMR; when the count is 000 (8th or 9t pulse), wait for at least two transfer clock times in order to read ICDR or read/ ICCR during the time other than the shaded time.

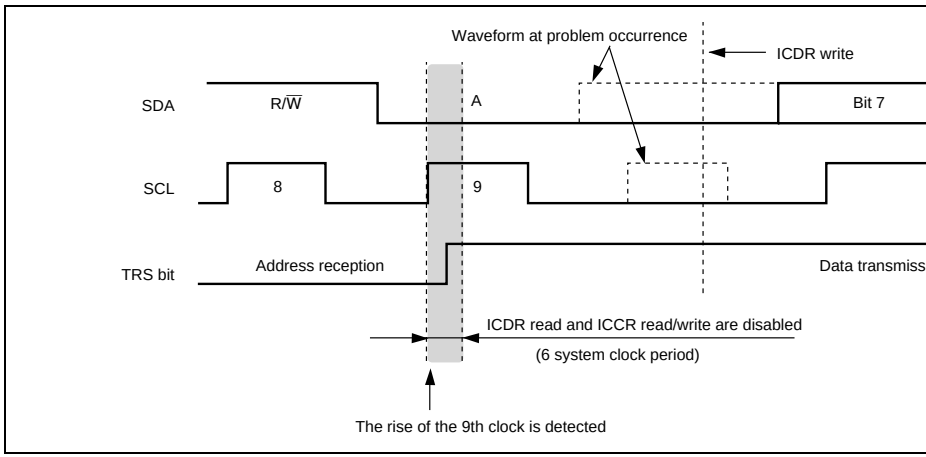


Figure 16.35 ICDR Read and ICCR Access Timing in Slave Transmit M

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits ICXR.

(transmit mode) internally and thus the acknowledge bit is not transmitted after the
been received at the 9th clock pulse.

To receive the address in slave mode, clear the TRS bit to 0 during the time indicate
figure 16.36. To release the SCL low level that is held by means of the wait functio
mode, clear the TRS bit to and then dummy-read ICDR.

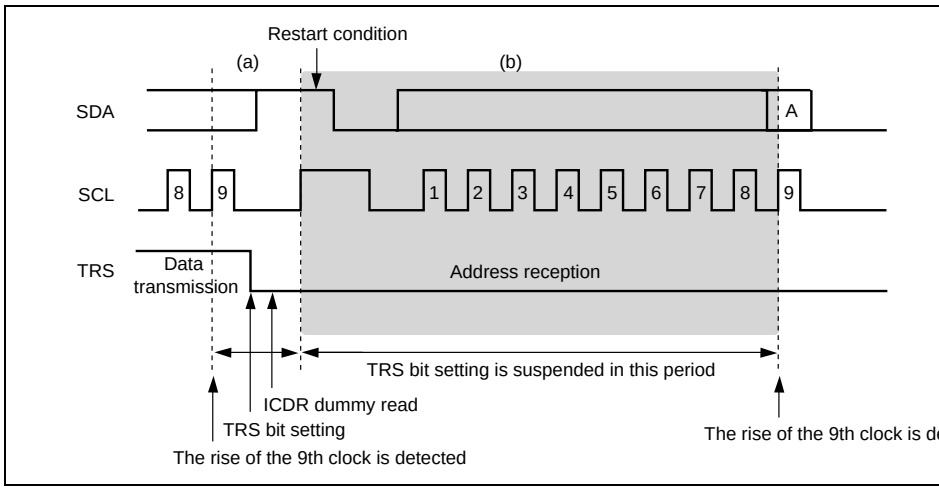


Figure 16.36 TRS Bit Set Timing in Slave Mode

Note: This restriction on usage can be canceled by setting the FNC1 and FNC0 bits to
ICXR.

figure 16.37.)

In multi-master mode, a bus conflict could happen. When The I²C bus interface is master mode, check the state of the AL bit in the ICSR register every time after on data has been transmitted or received.

When arbitration is lost during transmitting the second frame or subsequent frame, avoidance measures.

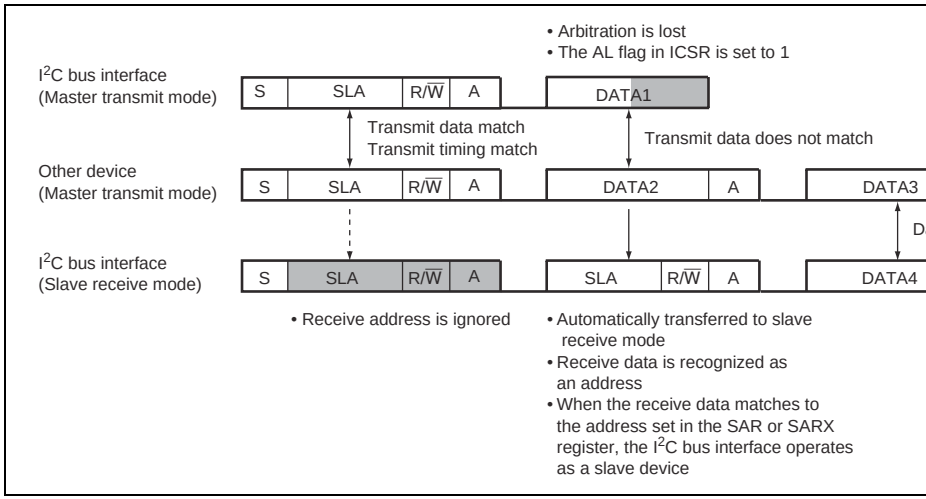


Figure 16.37 Diagram of Erroneous Operation when Arbitration is Lo

Though it is prohibited in the normal I²C protocol, the same problem may occur w bit is erroneously set to 1 and a transition to master mode is occurred during data t or reception in slave mode. In multi-master mode, pay attention to the setting of th when a bus conflict may occur. In this case, the MST bit in the ICCR register shou according to the order below.

(a) Make sure that the BBSY flag in the ICCR register is 0 and the bus is free befo the MST bit.

(b) Set the MST bit to 1.

ICDR is accessed correctly. To access ICDR correctly, read ICDR after setting rece
or write to ICDR after setting transmit mode.

16. Note on ACKE and TRS bits in slave mode

    In the I^2C bus interface, if 1 is received as the acknowledge bit value (ACKB = 1) in
    mode (TRS = 1) and then the address is received in slave mode without performing
    processing, interrupt handling may start at the rising edge of the 9th clock pulse eve
    address does not match. Similarly, if the start condition or address is transmitted fro
    master device in slave transmit mode (TRS = 1), the IRIC flag may be set after the
    is set and 1 received as the acknowledge bit value (ACKB = 1), thus causing an inte
    source even when the address does not match.

    To use the I^2C bus interface module in slave mode, be sure to follow the procedures

    A. When having received 1 as the acknowledge bit value for the last transmit data a
       of a series of transmit operation, clear the ACKE bit in ICCR once to initialize t
       bit to 0.

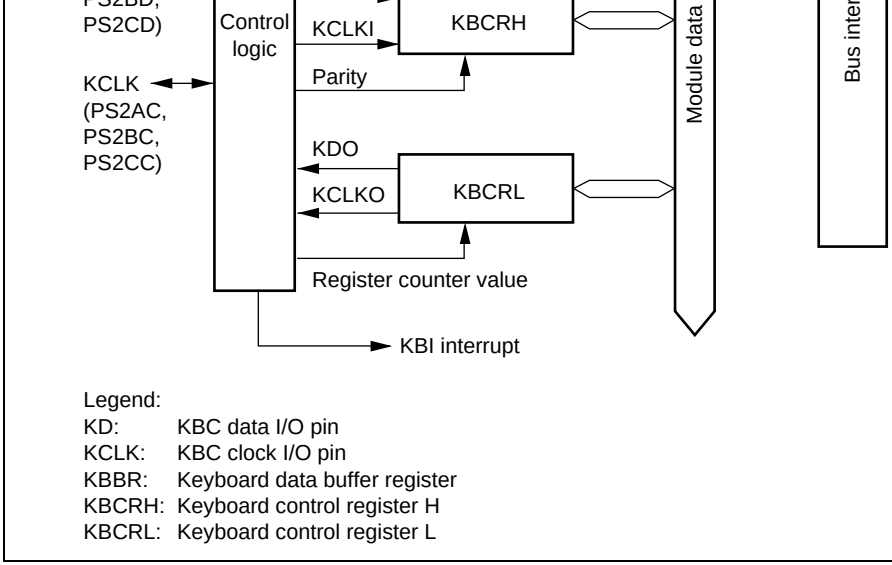
    B. Set receive mode (TRS = 0) before the next start condition is input in slave mod
       Complete transmit operation by the procedure shown in figure 16.24, in order to
       from slave transmit mode to slave receive mode.

16.6.1 Module Stop Mode Setting

The IIC operation can be enabled or disabled using the module stop control register. Th
setting is for the IIC operation to be halted. Register access is enabled by canceling mo
mode. For details, refer to section 26, Power-Down Modes.

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



Legend:

KD:	KBC data I/O pin
KCLK:	KBC clock I/O pin
KBBR:	Keyboard data buffer register
KBCRH:	Keyboard control register H
KBCRL:	Keyboard control register L

Figure 17.1 Block Diagram of Keyboard Buffer Controller

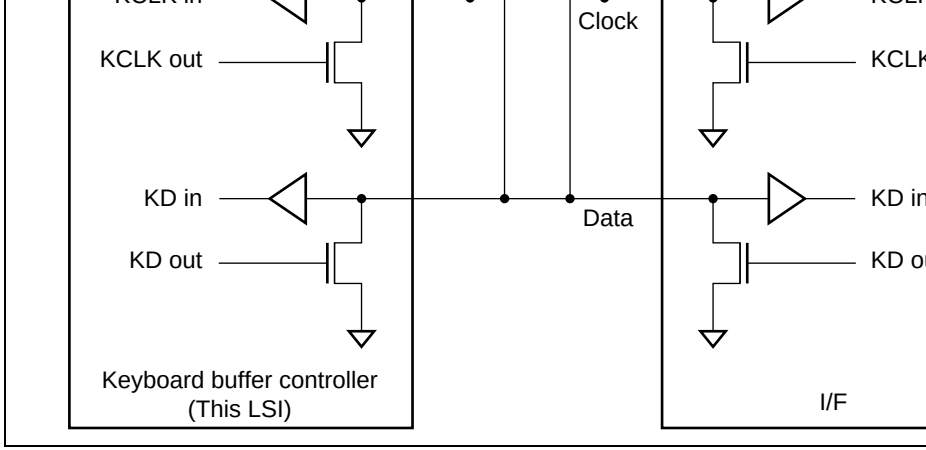


Figure 17.2 Keyboard Buffer Controller Connection

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 i
	KBC data I/O pin (KD0)	PS2AD	I/O	KBC data in
1	KBC clock I/O pin (KCLK1)	PS2BC	I/O	KBC clock i
	KBC data I/O pin (KD1)	PS2BD	I/O	KBC data in
2	KBC clock I/O pin (KCLK2)	PS2CC	I/O	KBC clock i
	KBC data I/O pin (KD2)	PS2CD	I/O	KBC data in

Note: * These are the external I/O pin names. In the text, clock I/O pins are referre and data I/O pins as KD, omitting the channel designations.

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 is used. 0: The keyboard buffer controller is non-op (KCLK and KD signal pins have port fun 1: The keyboard buffer controller is enable transmission and reception (KCLK and K pins are in the bus drive state)
6	KCLKI	1	R	Keyboard Clock In Monitors the KCLK I/O pin. This bit cannot 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 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 buffer register full flag or as the KCLK fall i flag. When KBFSEL is cleared to 0, the KB KBCRL should be cleared to 0 to disable re 0: KBF bit is used as KCLK fall interrupt fla 1: KBF bit is used as keyboard buffer regis

				the received data is in KBBR. 0: [Clearing condition] Read KBF when KBF =1, then write 0 in K 1: [Setting conditions] • When data has been received normal been transferred to KBBR while KBFS (keyboard buffer register full flag) • When a KCLK falling edge is detected KBFSEL = 0 (KCLK interrupt flag)
1	PER	0	R/(W)*	Parity Error Indicates that an odd parity error has occu 0: [Clearing condition] Read PER when PER =1, then write 0 in 1: [Setting condition] When an odd parity error occurs
0	KBS	0	R	Keyboard Stop Indicates the receive data stop bit. Valid d KBF = 1. 0: 0 stop bit received 1: 1 stop bit received

Note: * Only 0 can be written for clearing the flag.

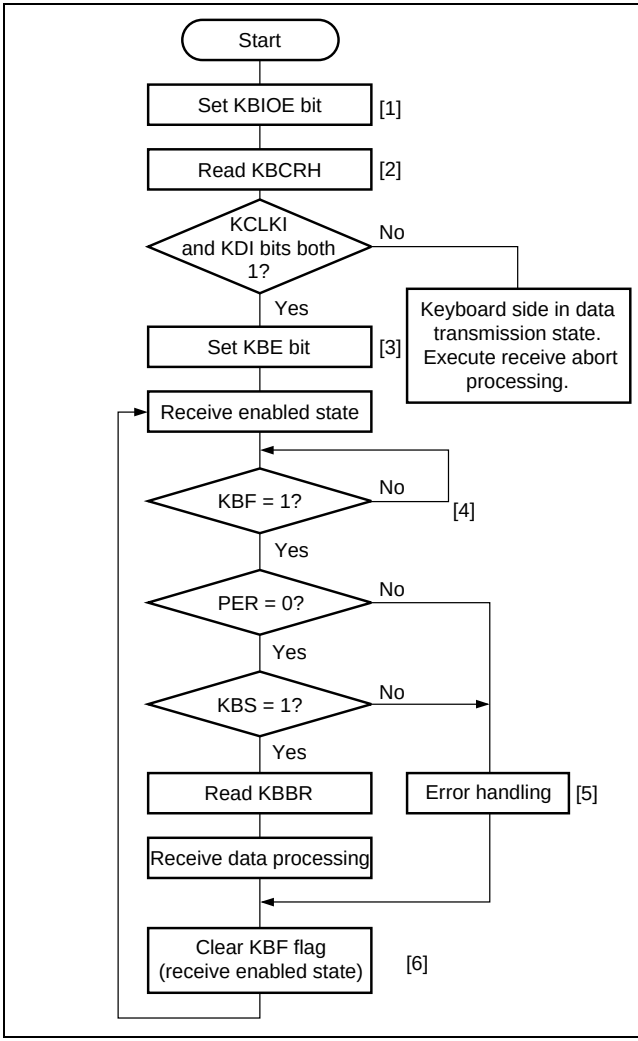
				0: Loading of receive data into KBBR is dis
				1: Loading of receive data into KBBR is en
6	KCLKO	1	R/W	Keyboard Clock Out Controls KBC clock I/O pin output. 0: KBC clock I/O pin is low 1: KBC clock I/O pin is high
5	KDO	1	R/W	Keyboard Data Out Controls KBC data I/O pin output. 0: KBC data I/O pin is low 1: KBC data I/O pin is high
4	—	1	—	Reserved This bit is always read as 1 and cannot be

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 m
4	KB4	0	R	mode, subactive mode, subsleep mode, a
3	KB3	0	R	stop mode, and when KBIOE is cleared to
2	KB2	0	R	
1	KB1	0	R	
0	KB0	0	R	



[1] Set the KBIOE bit to 1 in KBCRL.

[2] Read KBCRH, and if the KCLKI and KDI bits are both 1, set the KBE bit (receive enabled state).

[3] Detect the start bit output on the keyboard side and receive data in synchronization with the fa of KCLK.

[4] When a stop bit is received the keyboard buffer controller drives KCLK low to disable keyboard transmission (automatic I/O inhibit).
If the KBIE bit is set to 1 in KBCRH, an interrupt request is sent to the CPU at the same time.

[5] Perform receive data processing.

[6] Clear the KBF flag to 0 in KBCRL. At the same time, the system automatically drives KCLK high, setting the receive enabled state.

The receive operation can be continued by repeating steps [3] to [6].

Figure 17.3 Sample Receive Processing Flowchart

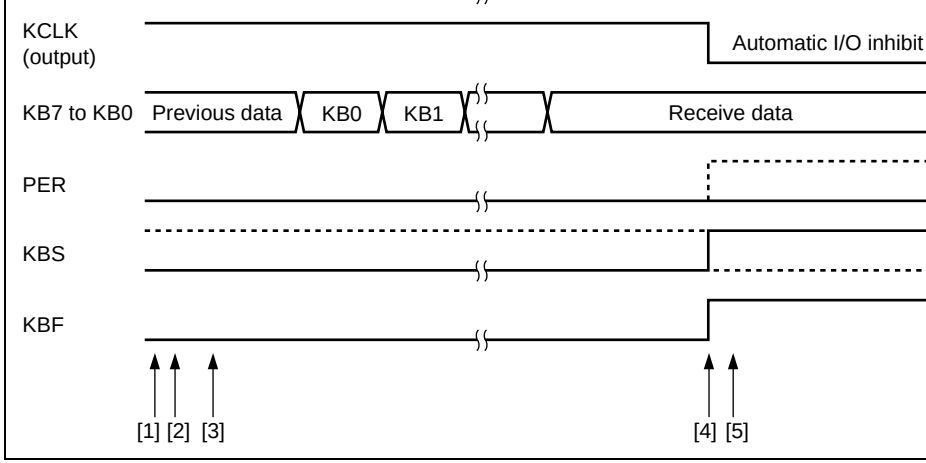


Figure 17.4 Receive Timing

17.4.2 Transmit Operation

In a transmit operation, KCLK (clock) is an output on the keyboard side, and KD (dat output on the chip (system) side. KD outputs a start bit, 8 data bits (LSB-first), an odd and a stop bit, in that order. The KD value is valid when KCLK is high. A sample tran processing flowchart is shown in figure 17.5, and the transmit timing in figure 17.6.

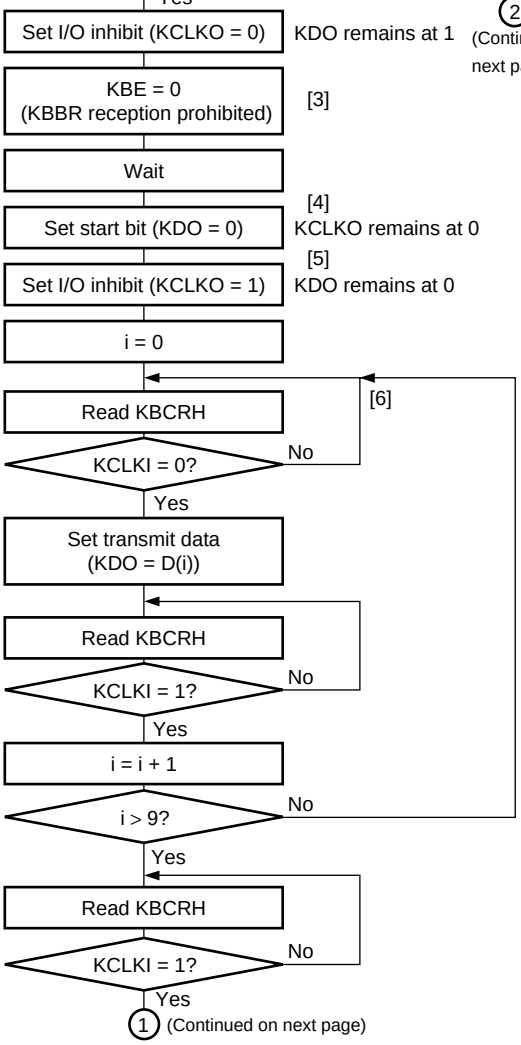
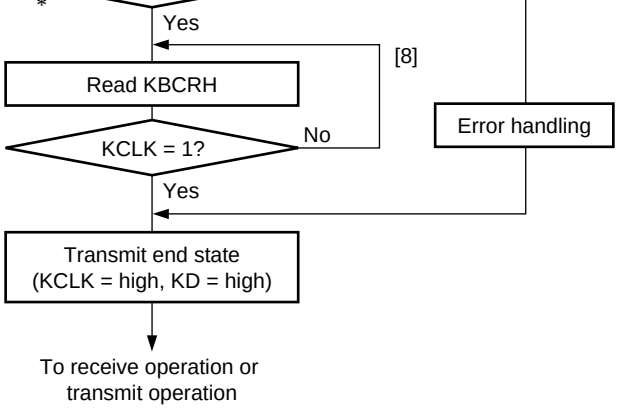


Figure 17.5 (1) Sample Transmit Processing Flowchart



Note: * To switch to reception after transmission, set KBE to 1 (KBBR receive enable) while K

Figure 17.5 (2) Sample Transmit Processing Flowchart

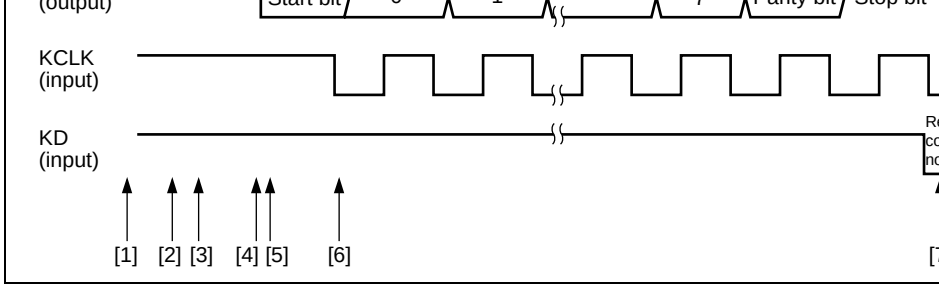


Figure 17.6 Transmit Timing

17.4.3 Receive Abort

This LSI (system side) can forcibly abort transmission from the device connected to it (side) in the event of a protocol error, etc. In this case, the system holds the clock low. D reception, the keyboard also outputs a clock for synchronization, and the clock is monit the keyboard output clock is high. If the clock is low at this time, the keyboard judges t an abort request from the system, and data transmission from the keyboard is aborted. T system can abort reception by holding the clock low for a certain period. A sample rece processing flowchart is shown in figure 17.7, and the receive abort timing in figure 17.8

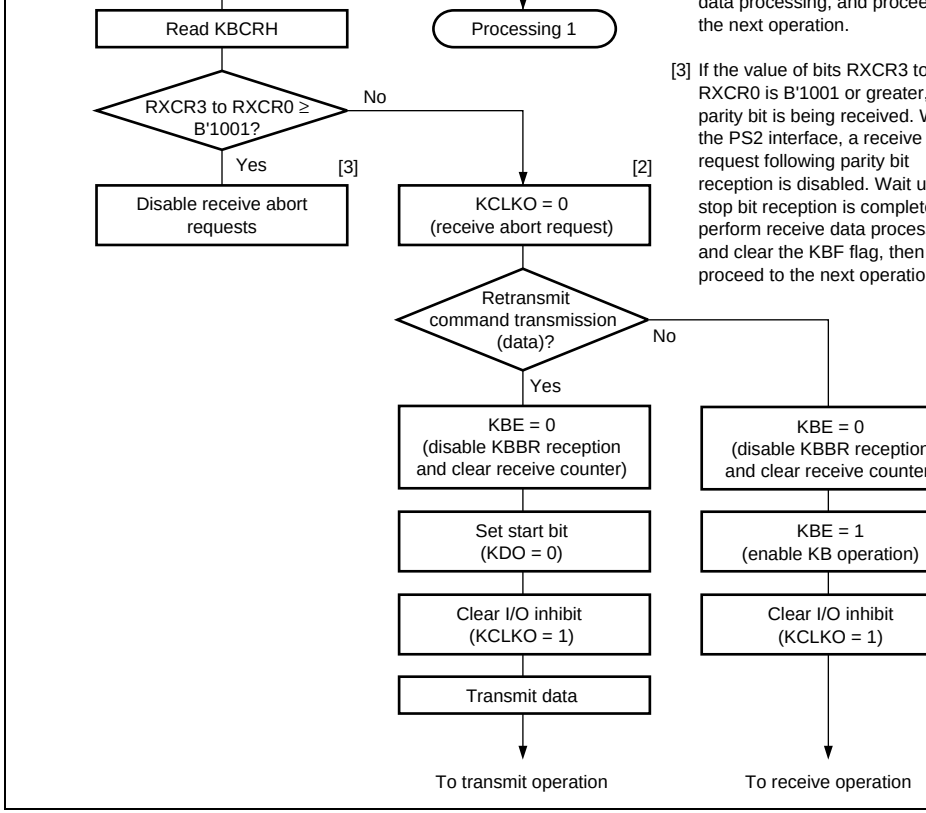


Figure 17.7 (1) Sample Receive Abort Processing Flowchart

Figure 17.7 (2) Sample Receive Abort Processing Flowchart

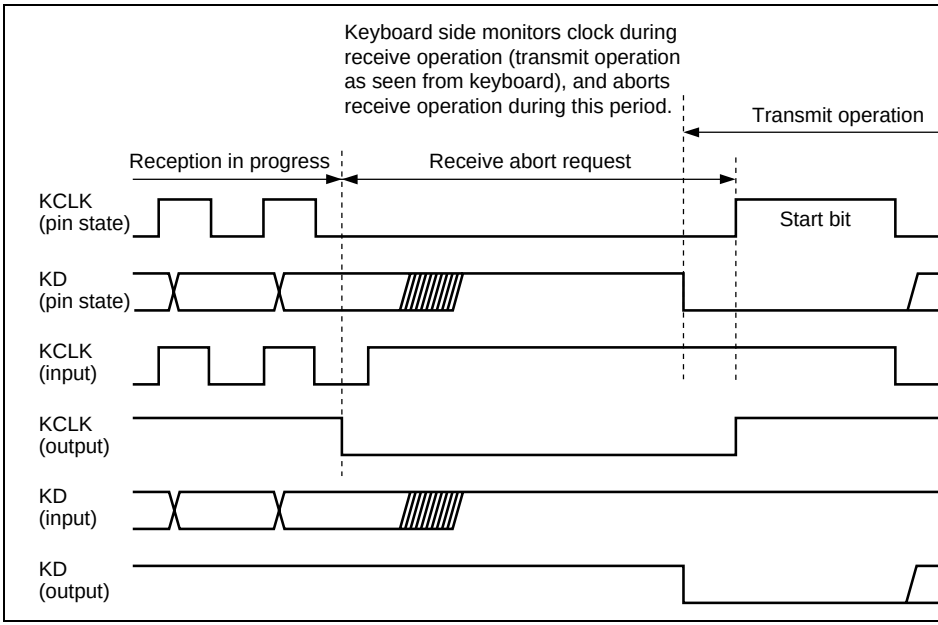
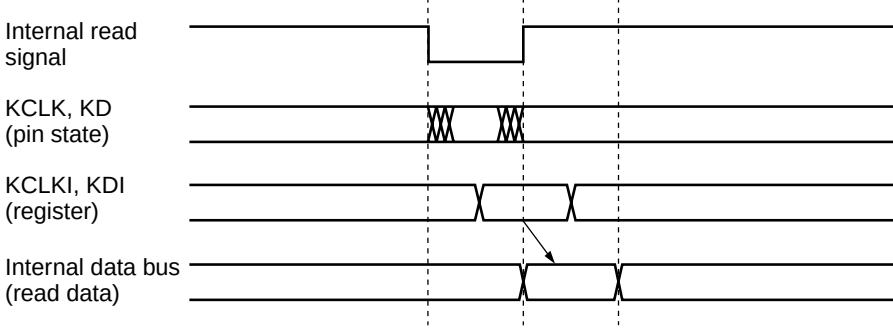
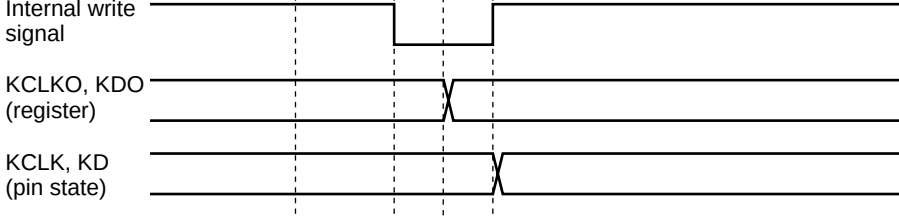


Figure 17.8 Receive Abort and Transmit Start (Transmission/Reception Switchover) Timing



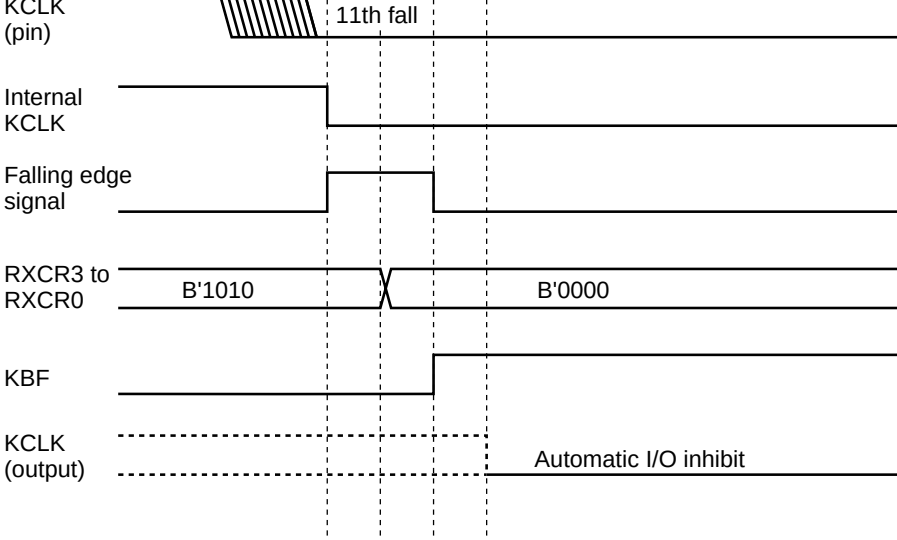
Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the o
mode is active mode.

Figure 17.9 KCLKI and KDI Read Timing



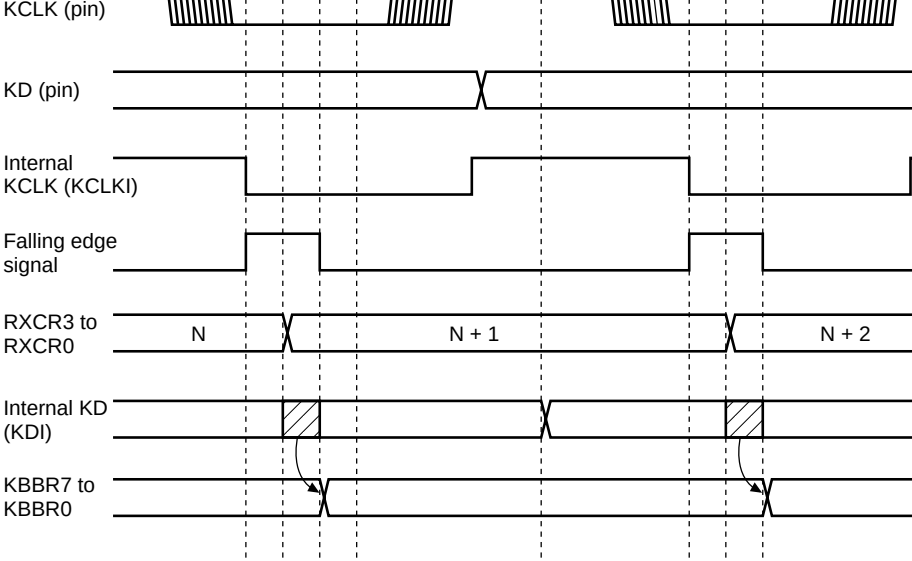
Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the opera mode is active mode.

Figure 17.10 KCLKO and KDO Write Timing



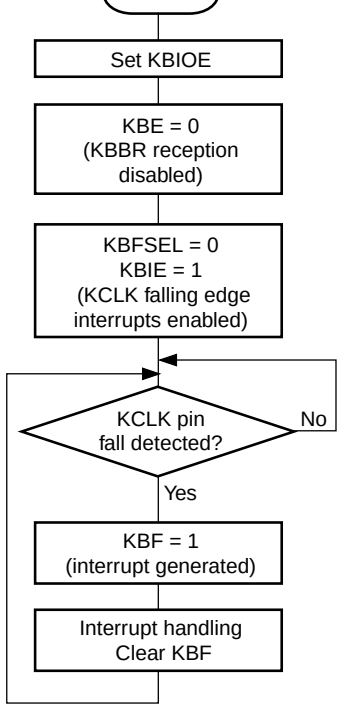
Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the o
mode is active mode.

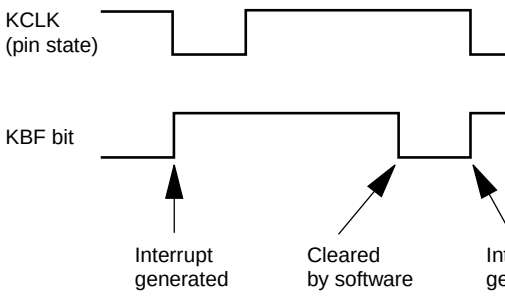
Figure 17.11 KBF Setting and KCLK Automatic I/O Inhibit Generation T



Note: * The ϕ clock shown here is scaled by 1/N in medium-speed mode when the operating mod
mode.

Figure 17.12 Receive Counter and KBBR Data Load Timing





Note: * The KBF setting timing is the same as the timing of KBF setting and KCLK automatic I/O generation in figure 17.11. When the KBF bit is used as the KCLK input fall interrupt flag, automatic I/O inhibit function does not operate.

Figure 17.13 Example of KCLK Input Fall Interrupt Operation

If the KBFSEL bit and KBE bit are both 0 at this time, the KBF bit is set. Figure 17.14 timing of KBIOE setting and KCLK falling edge detection.

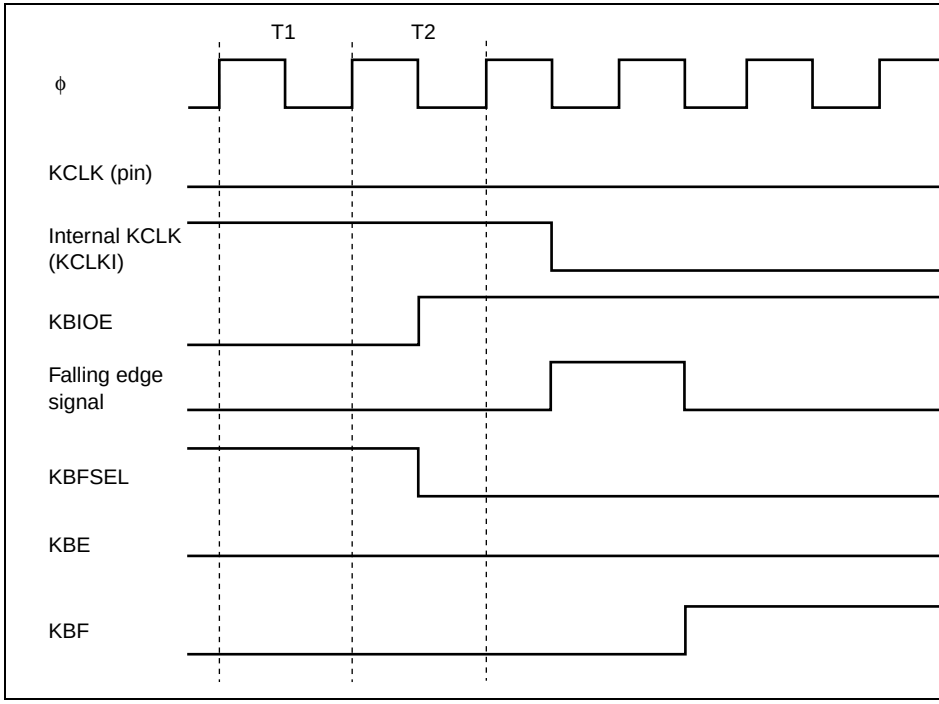


Figure 17.14 KBIOE Setting and KCLK Falling Edge Detection Timin

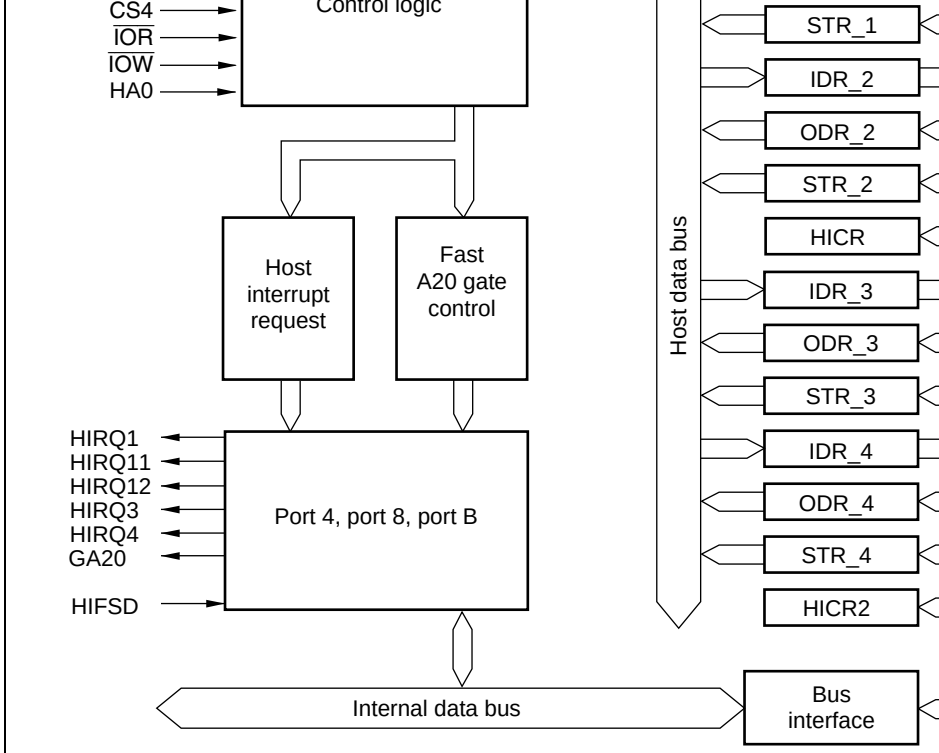
17.5.2 Module Stop Mode Setting

Keyboard buffer controller operation can be enabled or disabled using the module stop register. The initial setting is for keyboard buffer controller operation to be halted. Regi is enabled by canceling module stop mode. For details, refer to section 26, Power-Dow

Communication is carried out via seven control signals from the host processor ($\overline{CS1}$, $\overline{ECS2}$, $\overline{CS3}$, $\overline{CS4}$, HA0, $\overline{IOR}$, and $\overline{IOW}$), six output signals to the host processor (GA2 HIRQ11, HIRQ12, HIRQ3, and HIRQ4), and an 8-bit bidirectional command/data bus HDB0). The $\overline{CS1}$, $\overline{CS2}$ (or $\overline{ECS2}$), $\overline{CS3}$ and $\overline{CS4}$ signals select one of the four interfac

18.1 Features

- Control of the fast GATE A20 function
- Shutdown of the XBS module by the HIFSD pin
- Five host interrupt requests



Legend:

IDR_1:	Input data register_1	IDR_3:	Input data register_3
IDR_2:	Input data register_2	IDR_4:	Input data register_4
ODR_1:	Output data register_1	ODR_3:	Output data register_3
ODR_2:	Output data register_2	ODR_4:	Output data register_4
STR_1:	Status register_1	STR_3:	Status register_3
STR_2:	Status register_2	STR_4:	Status register_4
HICR:	Host interface control register	HICR2:	Host interface control register 2

Figure 18.1 Block Diagram of XBS

Chip select 1	$\overline{CS1}$	P95	Input	Host interface chip select signal ODR_1, STR_1
Chip select 2*	$\overline{CS2}$	P81	Input	Host interface chip select signal ODR_2, STR_2
	$\overline{ECS2}$	P90		
Chip select 3	$\overline{CS3}$	PB2	Input	Host interface chip select signal ODR_3, STR_3
Chip select 4	$\overline{CS4}$	PB3	Input	Host interface chip select signal ODR_4, STR_4
Command/data	HA0	P80	Input	Host interface address select sig In host read access, this signal s status registers (STR_1 to STR_ registers (ODR_1 to ODR_4). In access to the data registers (IDR IDR_4), this signal indicates whe host is writing a command or da
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

Note: * Selection of $\overline{CS2}$ or $\overline{ECS2}$ is by means of the CS2E bit in STCR and the FG HICR. XBS channel 2 and the $\overline{CS2}$ pin can be used when CS2E = 1. When $\overline{CS2}$ is used when FGA20E =0, and $\overline{ECS2}$ is used when FGA20E = 1. In th both are referred to as $\overline{CS2}$.

- 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 o multiplexing pins is also changed by these 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 specificatio 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.

2	CS4E	0	R/W	CS4 Enable 0: Channel 4 functions disabled 1: Channel 4 functions enabled (channel 4 enabled) Enabling setting is valid when the HI12E b
1	CS3E	0	R/W	CS3 Enable 0: Channel 3 functions disabled 1: Channel 3 functions enabled (channel 3 enabled) Enabling setting is valid when the HI12E b
0	HI12E	0	R/W	Host Interface Enable Bit 0: Host interface functions are disabled 1: Host interface functions are enabled (se CS2E to CS4E, FGA20E, and SDE are Enabling setting is valid in single-chip mod

Bit	Bit Name	Initial Value	Slave	Host	Description
7 to 3	—	All 1	—	—	Reserved These bits are always read as 1 and c modified.
2	IBFIE2	0	R/W	—	Input Data Register Full Interrupt Enal Enables or disables the IBF2 interrupt internal CPU. 0: Input data register (IDR_2) receptio completed interrupt request disable 1: Input data register (IDR_2) receptio completed interrupt request enable
1	IBFIE1	0	R/W	—	Input Data Register Full Interrupt Enal Enables or disables the IBF1 interrupt internal CPU. 0: Input data register (IDR_1) receptio completed interrupt request disable 1: Input data register (IDR_1) receptio completed interrupt request enable

0: XBS fast A20 gate function disable

1: XBS fast A20 gate function enable

When the fast A20 gate is disabled, t
A20 gate can be implemented by the
operation of the P81 output.

When the host interface (XBS) fast A
function is enabled, the DDR bit for P
set to 1. Therefore, the state of the P
cannot be monitored by reading the
P81.

A fast A20 gate function is also provi
LPC. The state of the P81/GA20 pin
monitored by reading the LPC's GA2

					Enables or disables the IBF4 interrupt internal CPU. 0: Input data register (IDR_4) receptio completed interrupt request disable 1: Input data register (IDR_4) receptio completed interrupt request enable
1	IBFIE3	0	R/W	—	Input Data Register Full Interrupt Enal Enables or disables the IBF3 interrupt internal CPU. 0: Input data register (IDR_3) receptio completed interrupt request disable 1: Input data register (IDR_3) receptio completed interrupt request enable
0	—	0	—	—	Reserved The initial value should not be change

6	IDR6	—	R	W	host data bus is written into IDR_n a edge of IOW. The HA0 state is also l
5	IDR5	—	R	W	the C/D bit in STR_n to indicate whe
4	IDR4	—	R	W	written information is a command or
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 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 t bus when HA0 is low, CSn (n = 1 to 4 and 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	

3	C/$\overline{D}$	0	R	R	Command/Data Receives the HA0 input when the hos writes to IDR, and indicates whether I contains data or a command. 0: Contents of input data register (IDR 1: Contents of input data register (IDR command
2	DBU	0	R/W	R	Defined by User The user can use these bits as neces
1	IBF	0	R	R	Input Buffer Full This bit is an internal interrupt source processor (this LSI). The IBF flag setting and clearing cond different when the fast A20 gate is us details see table 18.5. [Clearing Condition] 0: When the slave processor reads ID [Setting Condition] 1: When the host processor writes to
0	OBF	0	R/(W)*	R	Output Buffer Full [Clearing Condition] 0: When the host processor reads OD slave writes 0 in the OBF bit [Setting Condition] 1: When the slave processor writes to

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

OBF	Falling edge of slave's internal write signal when writing to ODR1	Rising edge of host's read signal (Ī reading ODR1

Note: * The IBF flag setting and clearing conditions are different when the fast A20 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 When the host interface is activated, all related I/O ports (data port 3, control ports 8 a host interrupt request port 4) become dedicated host interface ports. Setting the CS3E CS4E bit to 1 enables the number of host interface channels to be extended to four, an channel 3 and 4 related I/O port (part of port B for control and host interrupt requests) host interface port.

			Pins P43, P81, P90, and PB0 to PB3 operate as I/O 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 p 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 p or $\overline{ECS2}$ and $\overline{CS4}$ inputs do not operate.
		1	Host interface channel 1, 3, and 4 functions operatin Operation of channel 2 halted Pins P43, P81, and P90 operate as I/O ports. $\overline{CS2}$ o 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 $\overline{CS4}$ not operate.
		1	Host interface channel 1, 2, and 4 functions operatin Operation of channel 3 halted Pins PB0 and PB2 operate as I/O ports. $\overline{CS3}$ input d 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 d operate.
		1	Host interface channel 1 to 4 functions operating

		1	Setting prohibited
	1	0	Data read from output data register n
		1	Status read from status register n (ST
1	0	0	Data written to input data register n (I
		1	Command written to input data regist
	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 pe computers with an 8086*-family CPU. A regular-speed A20 gate signal can be output firmware control. Fast A20 gate output is enabled by setting the FGA20E bit (bit 0) to (H'FFF0).

Note: * Intel microprocessor.

Regular A20 Gate Operation: Output of the A20 gate signal can be controlled by an command followed by data. When the slave processor (this LSI) receives data, it norm interrupt routine activated by the IBF1 interrupt to read IDR1. If the data follows an H 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 o fast A20 gate signal. Bit P81DDR must be set to 1 to assign this pin for output. When for P81 is set to 1, the state of the P81/GA20 pin cannot be monitored by reading the I P81. The state of the P81/GA20 pin can be monitored by reading the GA20 bit in the H HICR2 register. The initial output from this pin will be a logic 1, which is the initial v Afterward, the host processor can manipulate the output from this pin by sending com data. This function is available only when register IDR1 is accessed using $\overline{CS1}$. The sl processor (this LSI) decodes the commands input from the host processor. When an H

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 ($\overline{IOW}$) when bit 1 of the written and the data follows an H'D1 h command Also, when bit FGA20E in HICF to 0

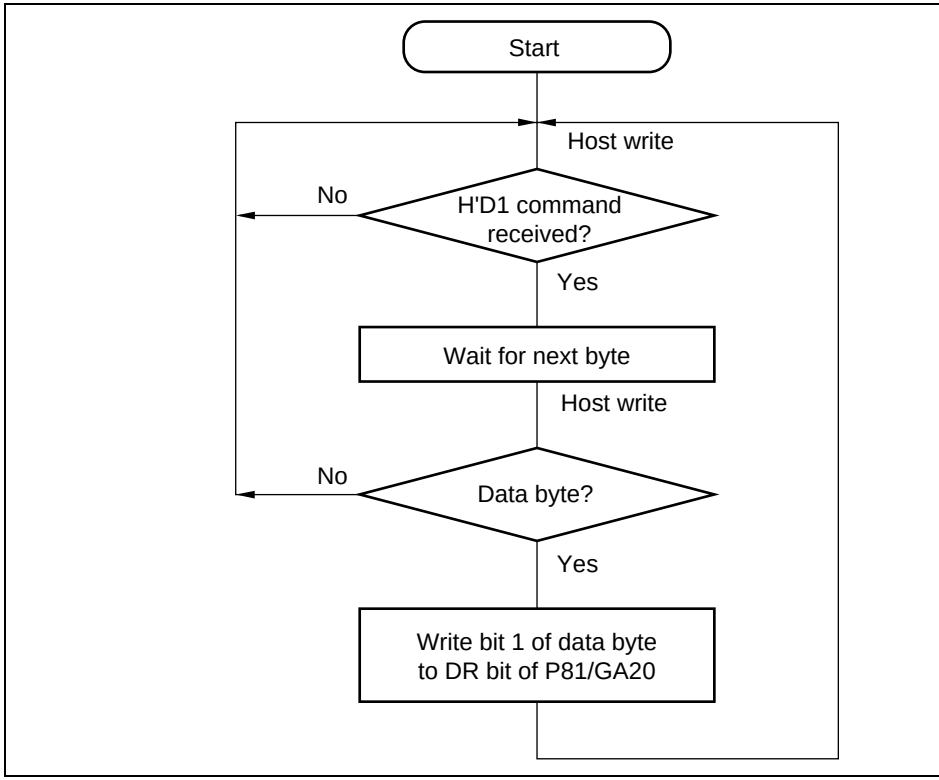


Figure 18.2 GA20 Output

0	0 data*2	0	0	
1	H'FF command	0	Q (0)	
1	H'D1 command	0	Q	Turn-on seque
0	1 data*1	0	1	(abbreviated f
1/0	Command other than H'FF and H'D1	1	Q (1)	
1	H'D1 command	0	Q	Turn-off seque
0	0 data*2	0	0	(abbreviated f
1/0	Command other than H'FF and H'D1	1	Q (0)	
1	H'D1 command	0	Q	Cancelled seq
1	Command other than H'D1	1	Q	
1	H'D1 command	0	Q	Retriggered s
1	H'D1 command	0	Q	
1	H'D1 command	0	Q	Consecutively
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 HIFSD pin. Setting the SDE bit to 1 in the SYSCR2 register when the HI12E bit is se the HIFSD pin. The HIF constantly monitors the HIFSD pin, and when this pin goes l the host interface output pins (HIRQ1, HIRQ11, HIRQ12, HIRQ3, HIRQ4, and GA20 high-impedance state. At the same time, the host interface input pins ($\overline{CS1}$, $\overline{CS2}$ or $\overline{EC}$ $\overline{CS4}$, $\overline{IOW}$, $\overline{IOR}$, and HA0) are disabled (fixed at the high input state internally) regard pin states, and the signals of the multiplexed functions of these pins (input block) are fixed internally. As a result, the host interface I/O pins (HDB7 to HDB0) also go to th impedance state.

Abbreviation	Port	Slave Mode	I/O	Selection Conditions
$\overline{IOR}$	P93	O	Input	HI12E = 1
$\overline{IOW}$	P94	O	Input	HI12E = 1
$\overline{CS1}$	P95	O	Input	HI12E = 1
$\overline{CS2}$	P81	Δ	Input	HI12E = 1 and CS2E = 1 and FGA
$\overline{ECS2}$	P90	Δ	Input	HI12E = 1 and CS2E = 1 and FGA
$\overline{CS3}$	PB2	Δ	Input	HI12E = 1 and CS3E = 1
$\overline{CS4}$	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 P43D
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 PB0D
HIRQ4	PB1	Δ	Output	HI12E = 1 and CS4E = 1 and PB1D
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 $\overline{IRQ2}/\overline{ADTRG}$ input signal is also fixed in the case of P90 shutdown, the TMCI1 signal in the case of P43 shutdown, and the TMRI/CSYNCI in the case of P45 shut

Δ: Pins shut down only when the XBS function is selected by means of a register setti

—: Pin not shut down

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 PB0O
port B data register (PBODR) can be used as host interrupt request latches. When they
host interrupt request output, set each bit in the data direction register (DDR) of the pi

The corresponding bits in P4DR are cleared to 0 by the host processor's read signal ($\overline{I}$
and HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_1, HIRQ1 and HIRQ1
to 0. If $\overline{CS2}$ and HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_2, HIRQ1
to 0. The corresponding bit in PBODR is cleared to 0 by the host's read signal ($\overline{IOR}$).
HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_3, HIRQ3 is cleared to 0.
HA0 are low, when $\overline{IOR}$ goes low and the host reads ODR_4, HIRQ4 is cleared to 0.
a host interrupt request, normally on-chip firmware writes 1 in the corresponding bit.
the interrupt, the host's interrupt handling routine reads the output data register (ODR
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 process
flowchart form.

		(ODR_1)
HIRQ12 (P45)	Internal CPU reads 0 from bit P45DR, then writes 1	Internal CPU writes 0 in bit host reads output data regi (ODR_1)
HIRQ3 (PB0)	Internal CPU reads 0 from bit PB0ODR, then writes 1	Internal CPU writes 0 in bit or host reads output data r (ODR_3)
HIRQ4 (PB1)	Internal CPU reads 0 from bit PB1ODR, then writes 1	Internal CPU writes 0 in bit or host reads output data r (ODR_4)

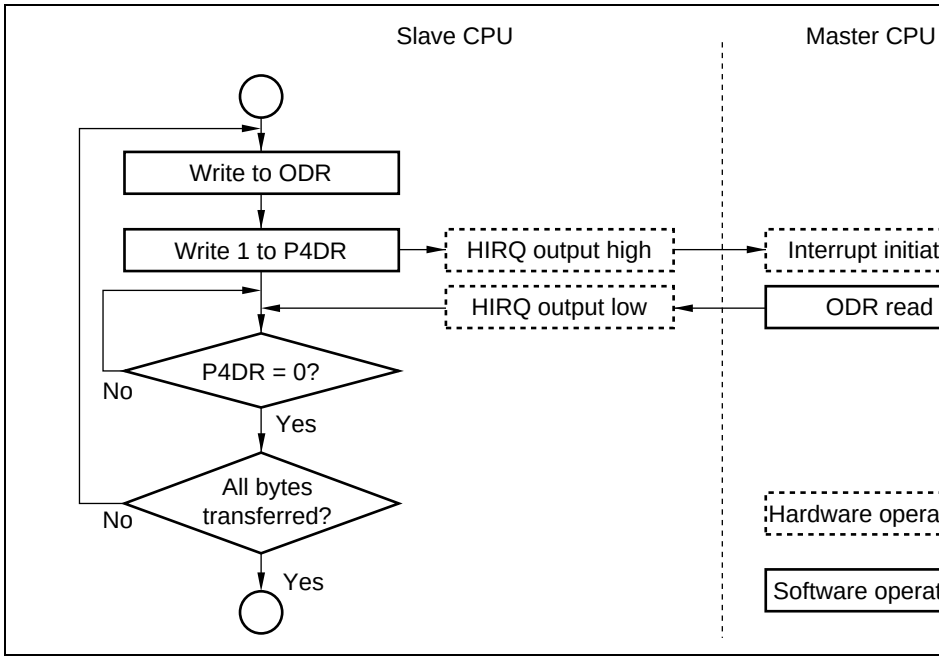


Figure 18.3 HIRQ Output Flowchart (Example of Channels 1 and 2)

The host interface provides buffering of asynchronous data from the host processor an
processor (this LSI), but an interface protocol must be followed to implement necessa
and avoid data contention. For example, if the host and slave processors try to access t
input or output data register simultaneously, the data will be corrupted. Interrupts can
design a simple and effective protocol.

Also, if two or more of pins $\overline{CS1}$ to $\overline{CS4}$ are driven low simultaneously in attempting
access, signal contention will occur within the chip, and a through-current may result.
must therefore be avoided.

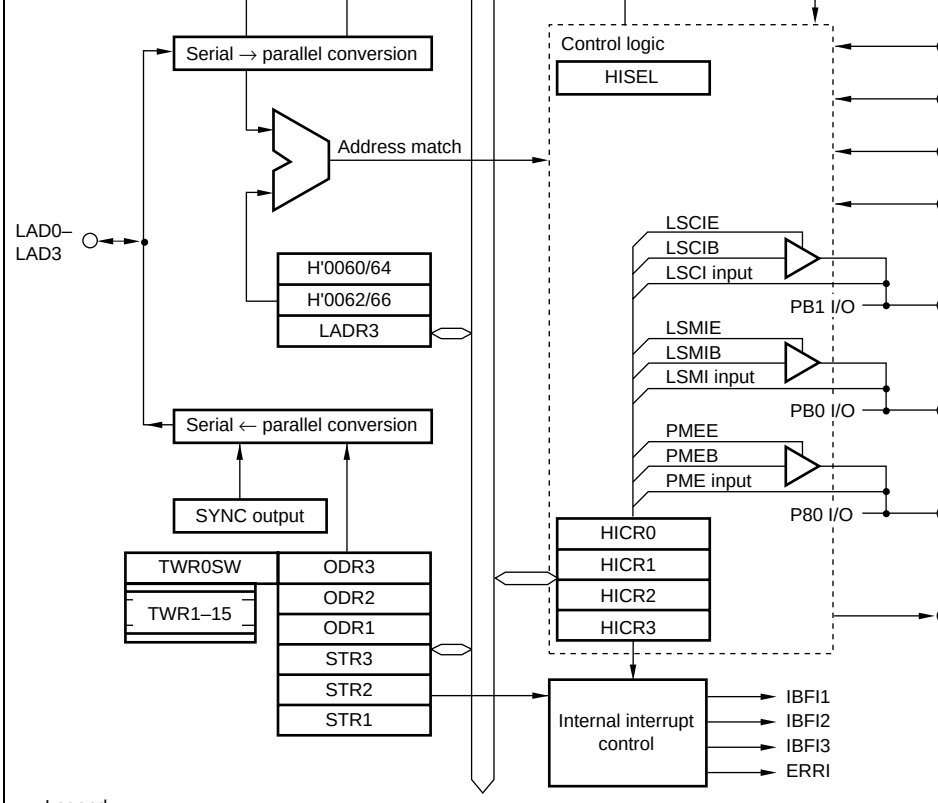
18.6.2 Module Stop Mode Setting

XBS operation can be enabled or disabled using the module stop control register. The
setting is for XBS operation to be halted. Register access is enabled by canceling mod
mode. For details, refer to section 26, Power-Down Modes.

It is also provided with power-down functions that can control the PCI clock and shut
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
  - Uses three control signals: clock (LCLK), reset ($\overline{\text{LRESET}}$), and frame ($\overline{\text{LFRAM}}$
- Has three register sets comprising data and status registers
  - The basic register set comprises three bytes: an input register (IDR), output reg and status register (STR).
  - Channels 1 and 2 have fixed I/O addresses of H'60/H'64 and H'62/H'66, respec A20 gate function is also provided.
  - The I/O address can be set for channel 3. Sixteen bidirectional data register byt 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.



Legend:

HICR0 to HICR3:	Host interface control registers 0 to 3
LADR3H, 3L:	LPC channel 3 address register 3H and 3L
IDR1 to IDR3:	Input data registers 1 to 3
ODR1 to DOR3:	Output data registers 1 to 3
STR1 to STR3:	Status registers 1 to 3
TWR0MW:	Two-way register 0MW
TWR0SW:	Two-way register 0SW
TWR1 to TWR15:	Two-way data registers
SERIRQ0, 1:	SERIEQ control registe
HISEL:	Host interface select re

Figure 19.1 Block Diagram of LPC

				synchronized with LCLK
LPC frame	$\overline{\text{LFRAME}}$	P34	Input*1	Transfer cycle start and termination signal
LPC reset	$\overline{\text{LRESET}}$	P35	Input*1	LPC interface reset sign
LPC clock	LCLK	P36	Input	33 MHz PCI clock signa
Serialized interrupt request	SERIRQ	P37	Input/ output*1	Serialized host interrupt signal, synchronized wit (SMI, IRQ1, IRQ6, IRQ9
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
LPC clock run	$\overline{\text{CLKRUN}}$	P82	Input/ output*1*2	LCLK restart request sig of serial host interrupt re
LPC power-down	$\overline{\text{LPCPD}}$	P83	Input*1	LPC module shutdown

Notes: 1. Pin state monitoring input is possible in addition to the LPC interface contro input/output function.

2. Only 0 can be output. If 1 is output, the pin goes to the high-impedance sta external resistor is necessary to pull the signal up to V_{CC}.

- 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)

Bit	Bit Name	Initial Value	Slave	Host	Description
7	LPC3E	0	R/W	—	LPC Enable 3 to 1
6	LPC2E	0	R/W	—	Enable or disable the host interface func
5	LPC1E	0	R/W	—	single-chip mode. When the host interfac (one of the three bits is set to 1), process transfer between the slave processor (th the host processor is performed using pi LAD0, $\overline{\text{LFRAME}}$, $\overline{\text{LRESET}}$, LCLK, SERIF $\overline{\text{CLKRUN}}$, and $\overline{\text{LPCPD}}$. • LPC3E 0: LPC channel 3 operation is disabled No address (LADR3) matches for IDR3, 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 IDI STR2 1: LPC channel 2 operation is enabled • LPC1E 0: LPC channel 1 operation is disabled No address (H'0060, 64) matches for IDI STR1 1: LPC channel 1 operation is enabled

					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 1: Fast A20 gate function enabled • GA20 pin output is open-drain (externa up resistor required)
3	SDWNE	0	R/W	—	LPC Software Shutdown Enable Controls host interface shutdown. For det LPC shutdown function, and the scope of by an LPC reset and an LPC shutdown, s 19.4.4, Host Interface Shutdown Function 0: Normal state, LPC software shutdown s enabled [Clearing conditions] • Writing 0 • LPC hardware reset or LPC software r • LPC hardware shutdown release (risin $\overline{\text{LPCPD}}$ signal) 1: LPC hardware shutdown state setting e • Hardware shutdown state when $\overline{\text{LPCP}}$ low [Setting condition] • Writing 1 after reading SDWNE = 0

						for P80 must not be set to 1. PMEE PMEB 0 x: PME output disabled, other pin is enabled 1 0: PME output enabled, $\overline{\text{PME}}$ goes to 0 level 1 1: PME output enabled, $\overline{\text{PME}}$ high-impedance
1	LSMIE	0	R/W	—		LSMI output Enable Controls LSMI output in combination with bit in HICR1. $\overline{\text{LSMI}}$ pin output is open-dra external pull-up resistor is needed to pull up to V_{CC} When the LSMI output function is used, for PB0 must not be set to 1. LSMIE LSMIB 0 x: LSMI output disabled, other pin is enabled 1 0: LSMI output enabled, $\overline{\text{LSMI}}$ goes to 0 level 1 1: LSMI output enabled, $\overline{\text{LSMI}}$ high-impedance

for PB1 must not be set to 1.

LSCIE	LSCIB	
0	x:	LSCI output disabled, other f pin is enabled
1	0:	LSCI output enabled, LSCI p goes to 0 level
1	1:	LSCI output enabled, LSCI p high-impedance

Legend:
X: Don't care

- Bus idle, or transfer cycle not subject
  processing is in progress
- Cycle type or address indeterminate
  transfer cycle

[Clearing conditions]

- LPC hardware reset or LPC software
- LPC hardware shutdown or LPC soft
  shutdown
- Forced termination (abort) of transfer
  subject to processing
- Normal termination of transfer cycle s
  processing

1: Host interface is performing transfer c
   processing

[Setting condition]

Match of cycle type and address

					• LPC hardware reset or LPC software r • LPC hardware shutdown or LPC softw shutdown • SERIRQ is set to continuous mode • There are no further interrupts for tran host in quiet mode 1: LCLK restart request issued [Setting condition] In quiet mode, SERIRQ interrupt output b necessary while LCLK is stopped
5	IRQBSY	0	R	—	SERIRQ Busy Indicates that the host interface's SERIRQ engaged in transfer processing. 0: SERIRQ transfer frame wait state [Clearing conditions] • LPC hardware reset or LPC software r • LPC hardware shutdown or LPC softw shutdown • End of SERIRQ transfer frame 1: SERIRQ transfer processing in progres [Setting condition] Start of SERIRQ transfer frame

					• 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 de LPC shutdown function, and the scope o initialization by an LPC reset and an LPC see section 19.4.4, Host Interface Shutd Function (LPCPD). 0: Normal state [Clearing conditions] • Writing 0 • LPC hardware reset or LPC software • LPC hardware shutdown • LPC hardware shutdown release (rising edge of $\overline{\text{LPCPD}}$ signal when S 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 bit. For details, refer to description on the in HICR0.

	bit. For details, refer to description on the 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 slav 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 op state of the functions that use pin multiplexing.

- HICR2

			R/W		
Bit	**Bit Name**	**Initial Value**	**Slave**	**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 in when an LPC hardware reset occurs. 0: [Clearing condition] Writing 0 after reading LRST = 1 1: [Setting condition] LRESET pin falling edge detection

					• LPC hardware reset and LPC softwa 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 when a forced termination (abort) of an L cycle occurs. 0: [Clearing conditions] • Writing 0 after reading ABRT = 1 • LPC hardware reset and LPC softwa • LPC hardware shutdown and LPC so shutdown 1: [Setting condition] $\overline{\text{LFRAME}}$ pin falling edge detection durin transfer cycle
3	IBFIE3	0	R/W	—	IDR3 and TWR Receive Completion Inte Enable Enables or disables IBFI3 interrupt to the processor (this LSI). 0: Input data register IDR3 and TWR rec completed interrupt requests disabled 1: [When TWRIE = 0 in LADR3] Input data register (IDR3) receive co interrupt requests enabled [When TWRIE = 1 in LADR3] Input data register (IDR3) and TWR completed interrupt requests enabled

					interrupt requests enabled
1	IBFIE1	0	R/W	—	IDR1 Receive Completion Interrupt Enabl Enables or disables IBFI1 interrupt to the processor (this LSI). 0: Input data register (IDR1) receive comp interrupt requests disabled 1: Input data register (IDR1) receive comp interrupt requests enabled
0	ERRIE	0	R/W	—	Error Interrupt Enable Enables or disables ERRI interrupt to the 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

			R/W		
Bit	**Bit Name**	**Initial Value**	**Slave**	**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

7	Bit 15	0	R/W	Channel 3 Address Bits 15 to 8:
6	Bit 14	0	R/W	When LPC3E = 1, an I/O address received in a
5	Bit 13	0	R/W	cycle is compared with the contents of LADR3.
4	Bit 12	0	R/W	determining an IDR3, ODR3, or STR3 address
3	Bit 11	0	R/W	of LADR3 is regarded as 0, and the value of bit When determining a TWR0 to TWR15 address
2	Bit 10	0	R/W	of LADR3 is inverted, and the values of bits 3 t
1	Bit 9	0	R/W	ignored. Register selection according to the bit
0	Bit 8	0	R/W	address match determination is as shown in ta

- 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 sh 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 o 0: TWR operation is disabled TWR-related I/O address match determination 1: TWR operation is enabled

Bit 4	0	0	0	0	I/O write	TWR0MW write
Bit 4	0	0	0	1	I/O write	TWR1 to TWR15 write
	1	1	1	1		
Bit 4	0	0	0	0	I/O read	TWR0SW read
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-
only registers for the host processor. The registers selected from the host according to t
address are shown in the following table. For information on IDR3 selection, see sectio
LPC Channel 3 Address Register (LADR3). Data transferred in an LPC I/O write cycle
to the selected register. The state of bit 2 of the I/O address is latched into the C/$\overline{D}$ bit i
indicate whether the written information is a command or data. The initial values of ID
are undefined.

I/O Address					Transfer	
Bits 15 to 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**Cycle**	**Host Register S**
0000 0000 0110	0	0	0	0	I/O write	IDR1 write, C/$\overline{D}$1
0000 0000 0110	0	1	0	0	I/O write	IDR1 write, C/$\overline{D}$1
0000 0000 0110	0	0	1	0	I/O write	IDR2 write, C/$\overline{D}$2
0000 0000 0110	0	1	1	0	I/O write	IDR2 write, C/$\overline{D}$2

Bits 15 to 4	Bit 3	Bit 2	Bit 1	Bit 0	Transfer Cycle	Host Register S
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 proce
LSI) and the host processor. In TWR0, however, two registers (TWR0MW and TWR0
allocated to the same address for both the host address and the slave address. TWR0M
write-only register for the host processor, and a read-only register for the slave proces
TWR0SW is a write-only register for the slave processor and a read-only register for t
processor. When the host and slave processors begin a write, after the respective TWR
have been written to, access right arbitration for simultaneous access is performed by
status flags to see if those writes were valid. For the registers selected from the host ac
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
cycle, the data in the selected register is transferred to the host. The initial values of T
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 interf
processing. Bits 3, 1, and 0 of STR1 to STR3, and bits 7 to 4 of STR3, are read-only b
the host processor and the slave processor (this LSI). However, only 0 can be written t
STR1 to STR3 and bits 6 and 4 of STR3, from the slave processor (this LSI), in order
flags to 0. The registers selected from the host processor according to the I/O address
the following table. For information on STR3 selection, see section 19.3.3, LPC Chan
Address Register (LADR3). In an LPC I/O read cycle, the data in the selected register
transferred to the host processor. The initial values of STR1 to STR3 are H'00.

Bit	Bit Name	Initial Value	R/W		Description
			Slave	Host	
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 bit 2 of the I/O address is written into this indicate whether IDR contains data or a c
					0: Contents of data register (IDR) are data
					1: Contents of data register (IDR) are a co
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 bit is an internal interrupt source to the sla processor (this LSI). IBF is cleared to 0 w slave processor reads IDR.
					The IBF1 flag setting and clearing conditio different when the fast A20 gate is used. F see table 19.3.
					0: [Clearing condition]
					When the slave processor reads IDR
					1: [Setting condition]
					When the host processor writes to IDR us write cycle

					cycle, or the slave processor writes 0 to
					1: [Setting condition]
					When the slave processor writes to ODR

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

- STR2

			R/W		
Bit	**Bit Name**	**Initial Value**	**Slave**	**Host**	**Description**
7	DBU27	0	R/W	R	Defined by User
6	DBU26	0	R/W	R	The user can use these bits as necessar
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 ID bit 2 of the I/O address is written into this indicate whether IDR contains data or a
					0: Contents of data register (IDR) are da
					1: Contents of data register (IDR) are a c
2	DBU22	0	R/W	R	Defined by User
					The user can use this bit as necessary.

				different when the fast A20 gate is used. F see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR us cycle
0	OBF2	0	R/(W)* R	Output Buffer Full Set to 1 when the slave processor (this LS ODR. Cleared to 0 when the host process ODR. 0: [Clearing condition] When the host processor reads ODR usin cycle, or the slave processor writes 0 to th 1: [Setting condition] When the slave processor writes to ODR

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

					slave processor reads TWR15. 0: [Clearing condition] When the slave processor reads TWR15 1: [Setting condition] When the host processor writes to TWR1 write cycle
6	OBF3B	0	R/(W)*	R	Bidirectional Data Register Output Buffe Set to 1 when the slave processor (this L TWR15. OBF3B is cleared to 0 when the processor reads TWR15. 0: [Clearing condition] When the host processor reads TWR15 read cycle, or the slave processor writes OBF3B bit 1: [Setting condition] When the slave processor writes to TWR
5	MWMF	0	R	R	Master Write Mode Flag Set to 1 when the host processor writes MWMF is cleared to 0 when the slave pr (this LSI) reads TWR15. 0: [Clearing condition] When the slave processor reads TWR15 1: [Setting condition] When the host processor writes to TWR0 write cycle while SWMF = 0

					When the host processor reads TWR15 u read cycle, or the slave processor writes 0 SWMF bit 1: [Setting condition] When the slave processor writes to TWR0 MWMF = 0
3	C/D3	0	R	R	Command/Data When the host processor writes to an IDR bit 2 of the I/O address is written into this indicate whether IDR contains data or a co 0: Contents of data register (IDR) are data 1: Contents of data register (IDR) are a co
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 bit is an internal interrupt source to the sla processor (this LSI). IBF is cleared to 0 w slave processor reads IDR. The IBF1 flag setting and clearing conditio different when the fast A20 gate is used. F see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR us write cycle

					cycle, or the slave processor writes 0 to
					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)

			R/W		
Bit	**Bit Name**	**Initial Value**	**Slave**	**Host**	**Description**
7	DBU37	0	R/W	R	Defined by User
6	DBU36	0	R/W	R	The user can use these bits as necessar
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 ID bit 2 of the I/O address is written into this indicate whether IDR contains data or a
					0: Contents of data register (IDR) are da
					1: Contents of data register (IDR) are a c
2	DBU32	0	R/W	R	Defined by User
					The user can use this bit as necessary.

				different when the fast A20 gate is used. F see table 19.3. 0: [Clearing condition] When the slave processor reads IDR 1: [Setting condition] When the host processor writes to IDR us write cycle
0	OBF3A	0	R/(W)* R	Output Buffer Full Set to 1 when the slave processor (this LS ODR. OBF3A is cleared to 0 when the hos processor reads ODR. 0: [Clearing condition] When the host processor reads ODR usin cycle, or the slave processor writes 0 to th 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 specify SERIRQ interrupt sources.

					[Clearing conditions] • LPC hardware reset, LPC software r • Specification by SERIRQ transfer cy frame 1: Quiet mode [Setting condition] Specification by SERIRQ transfer cycle s
6	SELREQ	0	R/W	—	Start Frame Initiation Request Select Selects whether start frame initiation is r when one or more interrupt requests are when all interrupt requests are cleared, i mode. 0: Start frame initiation is requested whe interrupt requests are cleared in quiet 1: Start frame initiation is requested whe more interrupt requests are cleared in
5	IEDIR	0	R/W	—	Interrupt Enable Direct Mode Specifies whether LPC channel 2 and ch SERIRQ interrupt source (SMI, IRQ6, IR IRQ11) generation is conditional upon O controlled only by the host interrupt enab 0: Host interrupt is requested when host enable bit and corresponding OBF are 1 1: Host interrupt is requested when host enable bit is set to 1

					• Writing 0 to SMIE3B • LPC hardware reset, LPC software res • Clearing OBF3B to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host SMI interrupt request by setting O 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 r when OBF3A is set by an ODR3 write. 0: Host SMI interrupt request by OBF3A a SMIE3A is disabled [Clearing conditions] • Writing 0 to SMIE3A • LPC hardware reset, LPC software res • Clearing OBF3A to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host SMI interrupt request by setting O is enabled [When IEDIR = 1] Host SMI interrupt is requested [Setting condition] Writing 1 after reading SMIE3A = 0

					• Writing 0 to SMIE2 • LPC hardware reset, LPC software r • Clearing OBF2 to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host SMI interrupt request by setting 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 interru when OBF1 is set by an ODR1 write. 0: Host IRQ12 interrupt request by OBF1 IRQ12E1 is disabled [Clearing conditions] • Writing 0 to IRQ12E1 • LPC hardware reset, LPC software r • Clearing OBF1 to 0 1: Host IRQ12 interrupt request by settin is enabled [Setting condition] Writing 1 after reading IRQ12E1 = 0

					• Writing 0 to IRQ1E1 • LPC hardware reset, LPC software res • Clearing OBF1 to 0 1: Host IRQ1 interrupt request by setting C 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 interrup when OBF3A is set by an ODR3 write. 0: Host IRQ11 interrupt request by OBF3A IRQ11E3 is disabled [Clearing conditions] • Writing 0 to IRQ11E3 • LPC hardware reset, LPC software res • Clearing OBF3A to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host IRQ11 interrupt request by settin to 1 is enabled [When IEDIR = 1] Host IRQ11 interrupt is requested. [Setting condition] Writing 1 after reading IRQ11E3 = 0

						• Writing 0 to IRQ10E3 • LPC hardware reset, LPC software r • Clearing OB3FA to 0 (when IEDIR = 1: [When IEDIR = 0] Host IRQ10 interrupt request by setti 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 interrup when OBF3A is set by an ODR3 write. 0: Host IRQ9 interrupt request by OBF3A IRQ9E3 is disabled [Clearing conditions] • Writing 0 to IRQ9E3 • LPC hardware reset, LPC software r • Clearing OBF3A to 0 (when IEDIR = 1: [When IEDIR = 0] Host IRQ9 interrupt request by settin 1 is enabled [When IEDIR = 1] Host IRQ9 interrupt is requested. [Setting condition] Writing 1 after reading IRQ9E3 = 0	

					• Writing 0 to IRQ6E3 • LPC hardware reset, LPC software res • Clearing OBF3A to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host IRQ6 interrupt request by setting 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 interrup when OBF2 is set by an ODR2 write. 0: Host IRQ11 interrupt request by OBF2 IRQ11E2 is disabled [Clearing conditions] • Writing 0 to IRQ11E2 • LPC hardware reset, LPC software res • Clearing OBF2 to 0 (when IEDIR = 0) 1: [When IEDIR = 0] Host IRQ11 interrupt request by settin 1 is enabled [When IEDIR = 1] Host IRQ11 interrupt is requested. [Setting condition] Writing 1 after reading IRQ11E2 = 0

						• Writing 0 to IRQ10E2 • LPC hardware reset, LPC software r • Clearing OBF2 to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host IRQ10 interrupt request by setti 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 interrup when OBF2 is set by an ODR2 write. 0: Host IRQ9 interrupt request by OBF2 is disabled [Clearing conditions] • Writing 0 to IRQ9E2 • LPC hardware reset, LPC software r • Clearing OBF2 to 0 (when IEDIR = 0 1: [When IEDIR = 0] Host IRQ9 interrupt request by settin is enabled [When IEDIR = 1] Host IRQ9 interrupt is requested. [Setting condition] Writing 1 after reading IRQ9E2 = 0	

- Writing 0 to IRQ6E2
- LPC hardware reset, LPC software res
- Clearing OBF2 to 0 (when IEDIR = 0)

1: [When IEDIR = 0]

Host IRQ6 interrupt request by setting OB enabled

[When IEDIR = 1]

Host IRQ6 interrupt is requested.

[Setting condition]

Writing 1 after reading IRQ6E2 = 0

					Selects the function of bits 7 to 4 in STR combination with the TWRE bit in LADR3 description on STR3 in section 19.3.7, S Registers 1 to 3 (STR1 to STR3), for det 0: Bits 7 to 4 in STR3 are status bits of th interface. 1: [When TWRE = 1] Bits 7 to 4 in STR3 are status bits of t interface. [When TWRE = 0] Bits 7 to 4 in STR3 are user bits.
6	SELIRQ11	0	W	—	SERIRQ Output Select
5	SELIRQ10	0	W	—	Selects the pin output status of host inter
4	SELIRQ9	0	W	—	requests (HIRQ11, HIRQ10, HIRQ9, HIR
3	SELIRQ6	0	W	—	HIRQ12, and HIRQ1) of the LPC.
2	SELSMI	0	W	—	0: [When host interrupt request is cleare SERIRQ pin output is in the high-impe
1	SELIRQ12	1	W	—	state.
0	SELIRQ1	1	W	—	[When host interrupt request is set] SERIRQ pin output is 0. 1: [When host interrupt request is cleare SERIRQ pin output is 0. [When host interrupt request is set] SERIRQ pin output is in the high-impe state.

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 the LPC module is initialized internally.
2. When using channel 3, set LADR3 to determine the channel 3 I/O address and whet 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 function 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 c 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 w read, DMA write, bus master memory read, bus master memory write, bus master I/O r bus master I/O write. Of these, the chip's LPC supports only I/O read and I/O write cyc

An LPC transfer cycle is started when the $\overline{\text{LFRAME}}$ signal goes low in the bus idle stat $\overline{\text{LFRAME}}$ signal goes low when the bus is not idle, this means that a forced termination 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 t following order, in synchronization with LCLK. The host can be made to wait by sendi value other than B′0000 in the slave's synchronization return cycle, but with the chip's value of B′0000 is always returned.

1	Start	Host	0000	Start	Host
2	Cycle type/direction	Host	0000	Cycle type/direction	Host
3	Address 1	Host	Bits 15 to 12	Address 1	Host
4	Address 2	Host	Bits 11 to 8	Address 2	Host
5	Address 3	Host	Bits 7 to 4	Address 3	Host
6	Address 4	Host	Bits 3 to 0	Address 4	Host
7	Turnaround (recovery)	Host	1111	Data 1	Host
8	Turnaround	None	ZZZZ	Data 2	Host
9	Synchronization	Slave	0000	Turnaround (recovery)	Host
10	Data 1	Slave	Bits 3 to 0	Turnaround	None
11	Data 2	Slave	Bits 7 to 4	Synchronization	Slave
12	Turnaround (recovery)	Slave	1111	Turnaround (recovery)	Slave
13	Turnaround	None	ZZZZ	Turnaround	None

The timing of the $\overline{\text{LFRAME}}$, LCLK, and LAD signals is shown in figures 19.2 and 19

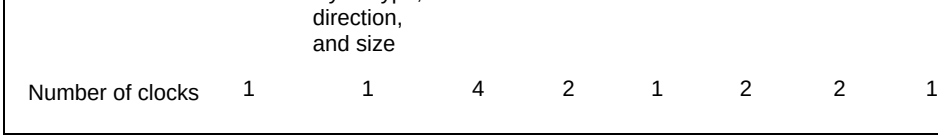


Figure 19.2 Typical $\overline{\text{LFRAME}}$ Timing

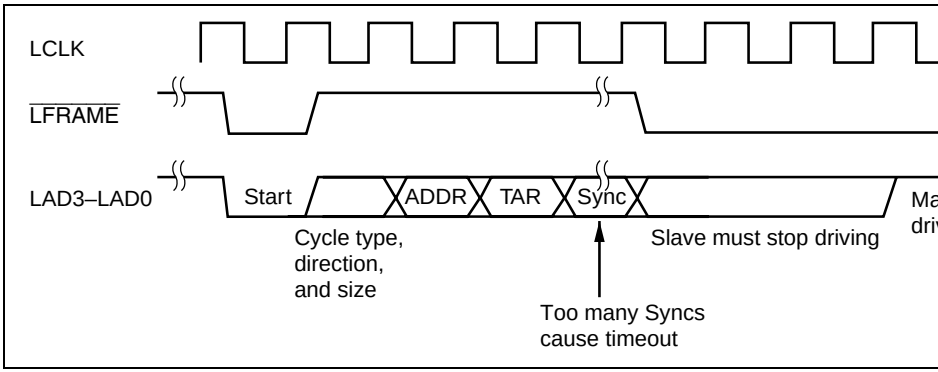


Figure 19.3 Abort Mechanism

Regular A20 Gate Operation: Output of the A20 gate signal can be controlled by an command followed by data. When the slave processor (this LSI) receives data, it norm interrupt routine activated by the IBF1 interrupt to read IDR1. At this time, firmware 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 0. When the FGA20E bit is set to 1, P81/GA20 is used for output of a fast A20 gate si 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, processor can manipulate the output from this pin by sending commands and data. Thi only available via the IDR1 register. The host interface decodes commands input from When an H'D1 host command is detected, bit 1 of the data following the host comman from the GA20 output pin. This operation does not depend on firmware or interrupts, than the regular processing using interrupts. Table 19.3 shows the conditions that set a GA20 (P81). Figure 19.4 shows the GA20 output in flowchart form. Table 19.4 indica 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 H'D1 host command is 0

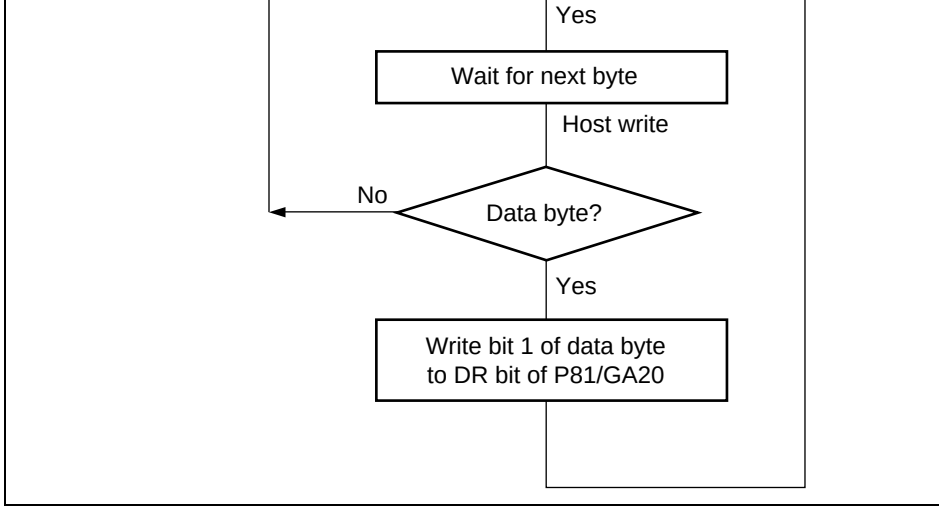


Figure 19.4 GA20 Output

1	H'D1 command	0	Q	Turn-off seq
0	0 data*2	0	0	
1	H'FF command	0	Q (0)	
1	H'D1 command	0	Q	Turn-on seq
0	1 data*1	0	1	(abbreviated
1/0	Command other than H'FF and H'D1	1	Q (1)	
1	H'D1 command	0	Q	Turn-off seq
0	0 data*2	0	0	(abbreviated
1/0	Command other than H'FF and H'D1	1	Q (0)	
1	H'D1 command	0	Q	Cancelled s
1	Command other than H'D1	1	Q	
1	H'D1 command	0	Q	Retriggered
1	H'D1 command	0	Q	
1	H'D1 command	0	Q	Consecutive
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.

Placing the slave processor in sleep mode or software standby mode is effective in redu current dissipation in the shutdown state. If software standby mode is set, some means provided for exiting software standby mode before clearing the shutdown state with the signal.

If the SDWNE bit has been set to 1 beforehand, the LPC hardware shutdown state is en same time as the $\overline{\text{LPCPD}}$ signal falls, and prior preparation is not possible. If the LPC s shutdown state is set by means of the SDWNB bit, on the other hand, the LPC software state cannot be cleared at the same time as the rise of the $\overline{\text{LPCPD}}$ signal. Taking these p consideration, the following operating procedure uses a combination of LPC software s 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 in 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 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 ris 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 automatical to 0. If the slave processor has been placed in sleep mode, the mode is exited by me $\overline{\text{LRESET}}$ signal input, on completion of the LPC transfer cycle, or by some other m

$\overline{\text{LRESET}}$	P35	×	Input	LPC hardware reset function
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 st

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 initializ 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

CLKREQ and IRQBST flags			
Host interface flags (IBF1, IBF2, IBF3A, IBF3B, MWMF, C/$\overline{D}$1 to C/$\overline{D}$3, OBF1, OBF2, OBF3A, OBF3B, SWMF, DBU), GA20 (internal state)	Initialized	Initialized	R
Host interrupt enable bits (IRQ1E1, IRQ12E1, SMIE2, IRQ6E2, IRQ9E2 to IRQ11E2, SMIE3B, SMIE3A, IRQ6E3, IRQ9E3 to IRQ11E3), Q/$\overline{C}$ flag, SELREQ bit	Initialized	Initialized	R
LRST flag	Initialized (0)	Can be set/cleared	C se
SDWN flag	Initialized (0)	Initialized (0)	C se
LRSTB bit	Initialized (0)	HR: 0 SR: 1	0
SDWNB bit	Initialized (0)	Initialized (0)	H S
SDWNE bit	Initialized (0)	Initialized (0)	H S
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	R
$\overline{\text{LRESET}}$ signal	Input (port function	Input	In
$\overline{\text{LPCPD}}$ signal		Input	In
LAD3 to LAD0, $\overline{\text{LFRAME}}$, LCLK, SERIRQ, $\overline{\text{CLKRUN}}$ signals		Input	H
$\overline{\text{PME}}$, $\overline{\text{LSMI}}$, LSCI, GA20 signals (when function is selected)		Output	H
$\overline{\text{PME}}$, $\overline{\text{LSMI}}$, LSCI, GA20 signals (when function is not selected)		Port function	P

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 shutdo

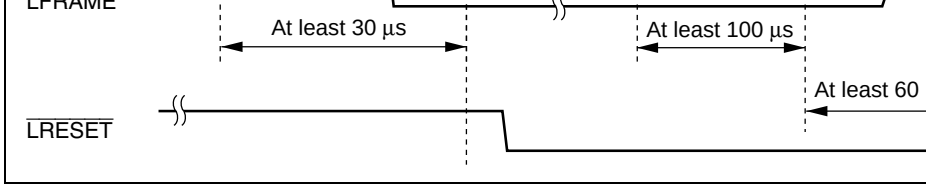


Figure 19.5 Power-Down State Termination Timing

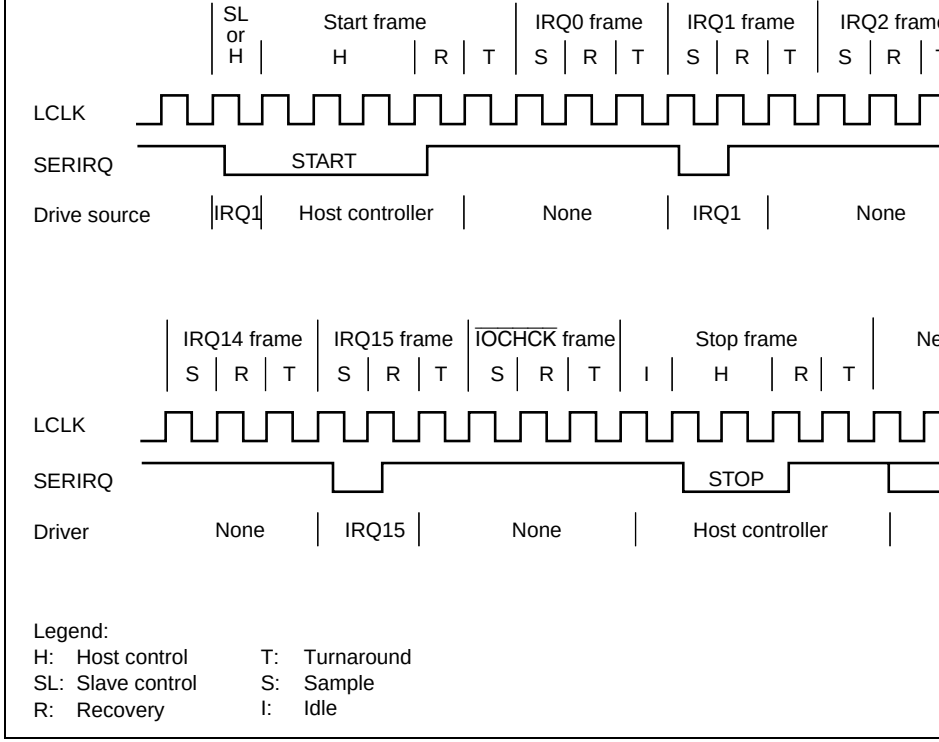


Figure 19.6 SERIRQ Timing

The serialized interrupt transfer cycle frame configuration is as follows. Two of the stat
comprising each frame are the recover state in which the SERIRQ signal is returned to
at the end of the frame, and the turnaround state in which the SERIRQ signal is not driv
recover state must be driven by the host or slave processor that was driving the precedi

4	IRQ3	Slave	3	
5	IRQ4	Slave	3	
6	IRQ5	Slave	3	
7	IRQ6	Slave	3	Drive possible in LPC channels 2 a
8	IRQ7	Slave	3	
9	IRQ8	Slave	3	
10	IRQ9	Slave	3	Drive possible in LPC channels 2 a
11	IRQ10	Slave	3	Drive possible in LPC channels 2 a
12	IRQ11	Slave	3	Drive possible in LPC channels 2 a
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 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. Th
initiated in the next transfer cycle is selected by the stop frame of the serialized interru
cycle that ended before that cycle.

In continuous mode, the host initiates host interrupt transfer cycles at regular intervals
mode, the slave processor with interrupt sources requiring a request can also initiate a
transfer cycle, in addition to the host. In quiet mode, since the host does not necessaril
interrupt transfer cycles, it is possible to suspend the clock (LCLK) supply and enter t
down state. In order for a slave to transfer an interrupt request in this case, a request to

interrupt request is generated the CLKRUN signal is driven and a clock (LCLK) restart sent to the host. The timing for this operation is shown in figure 19.7.

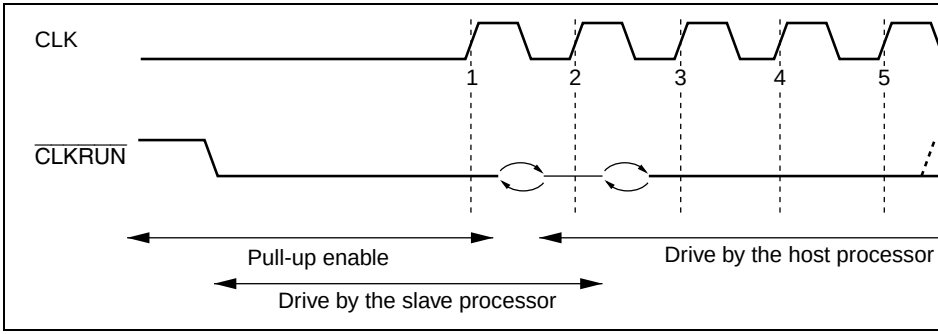


Figure 19.7 Clock Start Request Timing

Cases other than SERIRQ in quiet mode when clock restart is required must be handled different protocol, using the $\overline{\text{PME}}$ signal, etc.

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 T 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

19.5.2 SMI, HIRQ1, HIRQ6, HIRQ9 to HIRQ12

The host interface can request seven kinds of host interrupt by means of SERIRQ. HI
HIRQ12 are used on LPC channel 1 only, while SMI, HIRQ6, HIRQ9 to HIRQ11 can
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 chan
linked to the host interrupt request enable bits. When the OBF flag is cleared to 0 by a
ODR or TWR15 by the host in the corresponding LPC channel, the corresponding hos
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 a
only upon the host interrupt enable bits. The host interrupt enable bit is not cleared wh
channel 2 or 3 is cleared. Therefore, SMIE2, SMIE3A and SMIE3B, IRQ6E2 and IRQ
IRQ9E2 and IRQ9E3, IRQ10E2 and IRQ10E3, and IRQ11E2 and IRQ11E3 lose their
functional differences. In order to clear a host interrupt request, it is necessary to clear
interrupt enable bit.

HIRQ12 (independent from IEDIR)	Internal CPU writes to ODR1, then reads 0 from bit IRQ12E1 and writes 1	Internal CPU writes 0 to b 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, o reads ODR2 • writes 0 to bit SMIE3A, reads ODR3 • writes 0 to bit SMIE3B, 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, o reads ODR2 • CPU writes 0 to bit IRQ 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

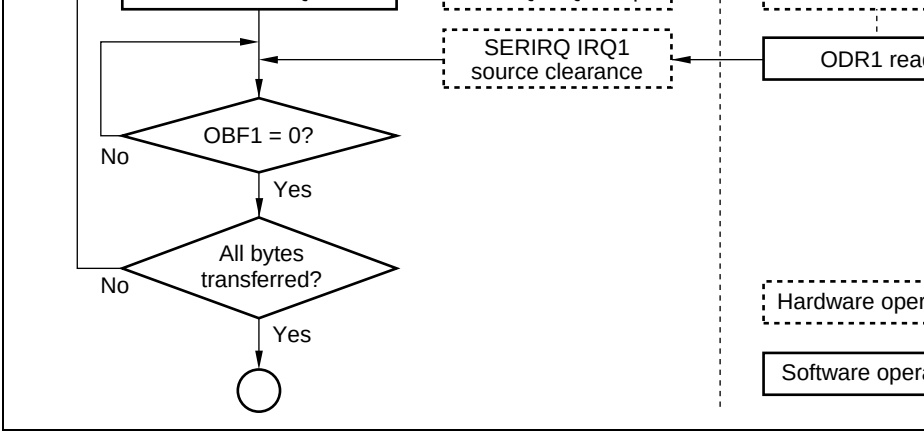


Figure 19.8 HIRQ Flowchart (Example of Channel 1)

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
setting is for LPC operation to be halted. Register access is enabled by canceling mod
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 an
processor (this LSI), but an interface protocol that uses the flags in STR must be follo
data contention. For example, if the host and slave processor both try to access IDR o
same time, the data will be corrupted. To prevent simultaneous accesses, IBF and OB
used to allow access only to data for which writing has finished.

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

- Output voltage: 0 V to AVref
- D/A output retaining function in software standby mode

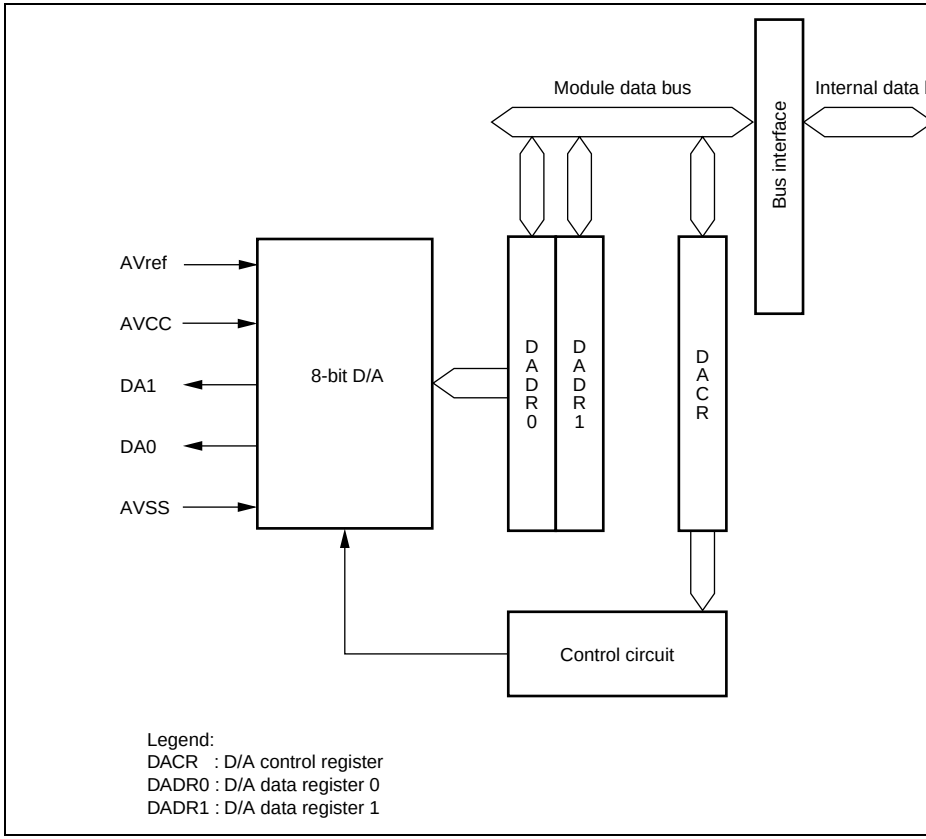


Figure 20.1 Block Diagram of D/A Converter

Analog ground pin	AVSS	Input	Analog block ground and referen
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 conve
When analog output is permitted, D/A data register contents are converted and output t
output pins. DADR0 and DADR1 are initialized to H'00.

				1: D/A conversion for channel 1 and analog 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 are enabled
5	DAE	0	R/W	D/A Enable Controls D/A conversion in conjunction with and DAOE1 bits. When the DAE bit is cleare conversion for channels 0 and 1 is controlled When the DAE bit is set to 1, D/A conversion channels 0 and 1 are controlled as one. Con result output is controlled by the DAOE0 and bits. For details, see table 20.2 below.
4 to 0	—	All 1	R	Reserved These bits are always read as 1 and cannot

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 re
output.

An example of D/A conversion of channel 0 is shown below. The operation timing is sh
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
   conversion results are output from the analog output pin DA0. The conversion resul
   output continuously until DADR0 is modified or the DAOE0 bit is cleared to 0. The
   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.

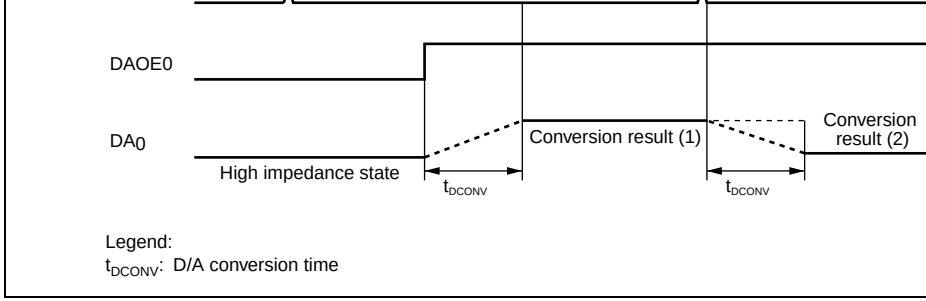


Figure 20.2 D/A Converter Operation Example

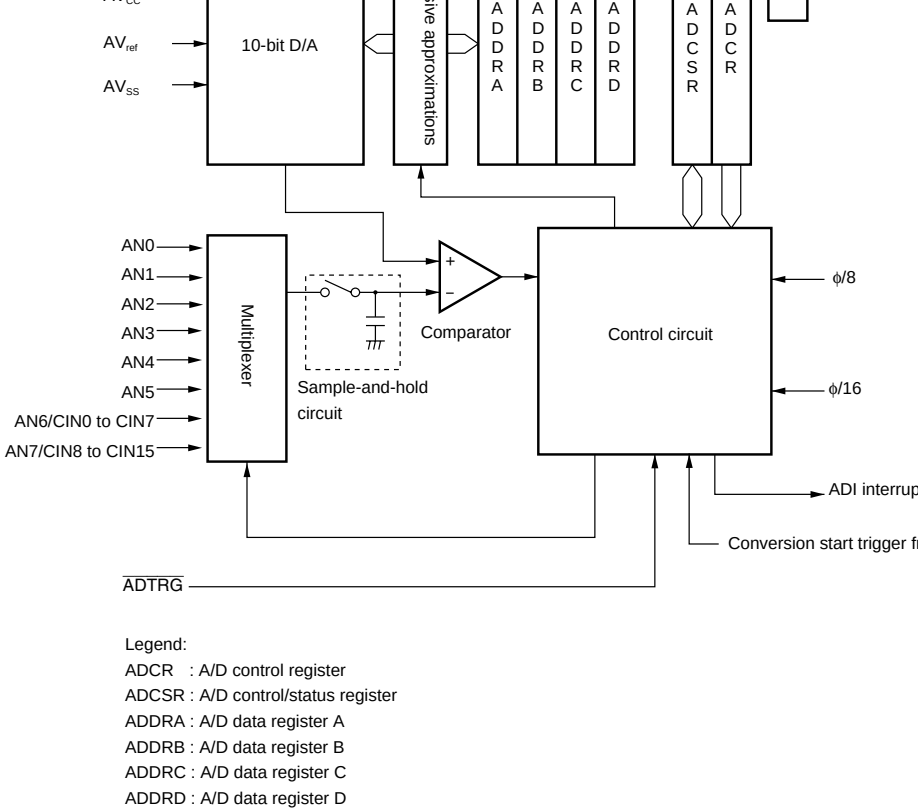
20.5 Usage Note

When this LSI enters software standby mode with D/A conversion enabled, the D/A o retained, and the analog power supply current is equal to as during D/A conversion. If power supply current needs to be reduced in software standby mode, clear the DAOE 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 reg initial setting is for D/A converter operation to be halted. Register access is enabled by module stop mode. For details, refer to section 26, Power-Down Modes.

- 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 suppl 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



Legend:
ADCR : A/D control register
ADCSR : A/D control/status register
ADDRA : A/D data register A
ADDRB : A/D data register B
ADDRC : A/D data register C
ADDRD : A/D data register D

Figure 21.1 Block Diagram of 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 refere
Analog ground pin	AV_{SS}	Input	Analog block ground and reference vo
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 conversion
Expanded A/D conversion input pins 0 to 15	CIN0 to CIN15	Input	Expanded A/D conversion input (digit channels 0 to 15 Can be used as digital input pins

- 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 A/D conversion. The ADDR registers, which store a conversion result for each channel in table 21.2.

The converted 10-bit data is stored to bits 15 to 6. The lower 6-bit data is always read a

The data bus between the CPU and the A/D converter is 8-bit width. The upper byte ca directly from the CPU, but the lower byte should be read via a temporary register. The register contents are transferred from the ADDR when the upper byte data is read. Whe 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

				• When A/D conversion ends in single m • When A/D conversion ends on all cha specified in scan mode [Clearing conditions] • When 0 is written after reading ADF = • When DTC starts by an ADI interrupt a read
6	ADIE	0	R/W	A/D Interrupt Enable Enables ADI interrupt by ADF when this b
5	ADST	0	R/W	A/D Start Setting this bit to 1 starts A/D conversion. this bit to 0 stops A/D conversion. In singl bit is cleared to 0 automatically when con the specified channel ends. In scan mode continues sequentially on the specified ch this bit is cleared to 0 by software, a reset transition to standby mode or module stop
4	SCAN	0	R/W	Scan Mode Selects the A/D conversion operating mod setting of this bit must be made when con halted (ADST = 0). 0: Single mode 1: Scan mode
3	CKS	0	R/W	Clock Select Sets A/D conversion time. The input chan must be made when conversion is halted 0: Conversion time is 266 states (max) 1: Conversion time is 134 states (max) Switch conversion time while ADST is 0.

				010: AN2
				011: AN3
				100: AN4
				101: AN5
				110: AN6, or CIN0 to CIN7
				111: AN7, or CIN8 to CIN15

				010: AN0 to
				011: AN0 to
				100: AN4
				101: AN4 ar
				110: AN4 to CIN0 to CIN
				111: AN4 to CIN0 to CIN or CIN8 to C

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 trig Only set bits TRGS1 and TRGS0 when con halted (ADST = 0). 00: A/D conversion start by external trigger 01: A/D conversion start by external trigger 10: A/D conversion start by conversion trig TMR is enabled 11: A/D conversion start by $\overline{\text{ADTRG}}$ pin is
5 to 0	—	All 1	R	Reserved These bits are always read as 1 and cannc modified.

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/ are used as analog pins or digital pins, in c with the KBCH2 to KBCH0 bits. For details, description for bits 2 to 0. Analog pins of th converter are set to digital pins (CIN0 to CI 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 p
0	KBCH0	0	R/W	conversion, in combination with the KBADE input channel setting must be made while c halted.

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

21.4.1 Single Mode

In single mode, A/D conversion is to be performed only once on the specified single ch
Operations are as follows.

1. A/D conversion on the specified channel is started when the ADST bit in ADCSR is
   by software or an external trigger input.
2. When A/D conversion is completed, the result is transferred to the A/D data registe
   corresponding to the channel.
3. On completion of A/D conversion, the ADF bit in ADCSR is set to 1. If the ADIE b
   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
   automatically cleared to 0, and the A/D converter enters wait state.

21.4.2 Scan Mode

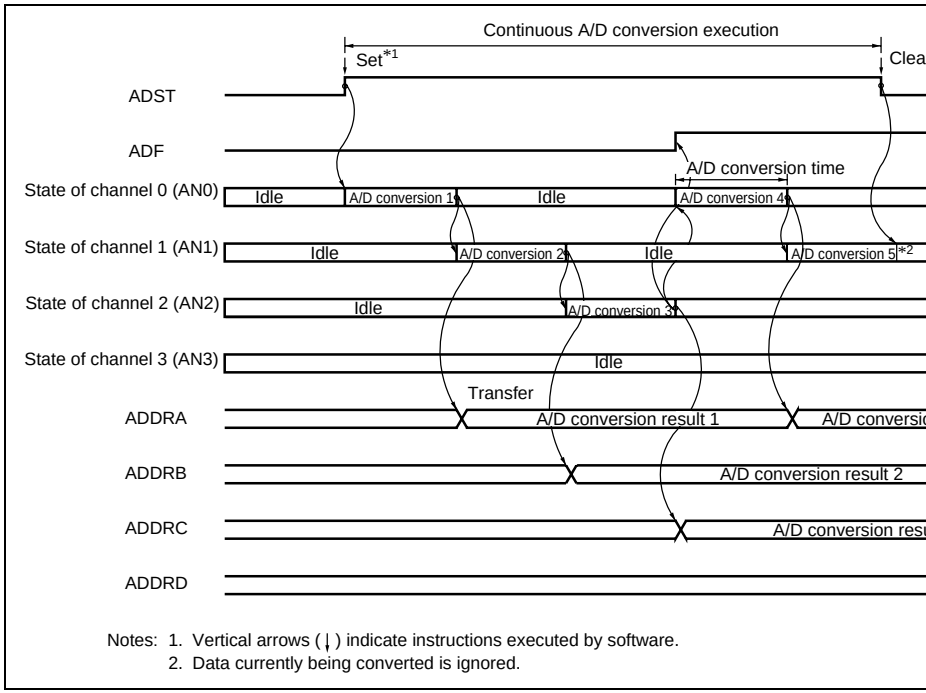
Scan mode is useful for monitoring analog inputs in a group of one or more channels. W
ADST bit is set to 1 by software, or by timer or external trigger input, A/D conversion s
first channel in the group (AN0 when CH2 = 0; AN4 when CH2 = 1).

When two or more channels are selected, after conversion of the first channel ends, con
the second channel (AN1 or AN5) starts immediately. A/D conversion continues cyclic
selected channels until the ADST bit is cleared to 0. The conversion results are transfer
storage into the ADDR registers corresponding to the channels.

Typical operations when three channels (AN0 to AN2) are selected in scan mode are de
below.

to 1 and conversion of the first channel (AN0) starts again. If the ADIE bit is set to
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
cleared to 0, A/D conversion stops. After that, if the ADST bit is set to 1, A/D con
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)

(t_{SPL}) and the A/D conversion time (t_D). The A/D 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 se
subsequent conversions, the conversion time is 256 state (fixed) when CKS = 0 and 128
(fixed) when CKS = 1.

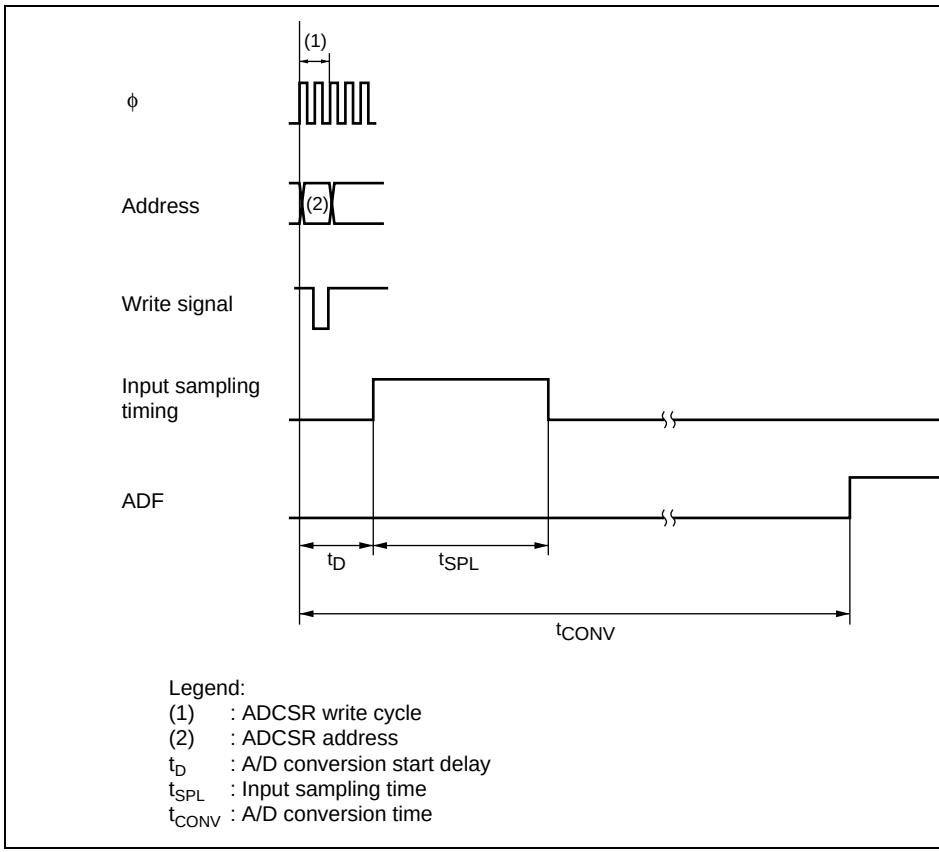


Figure 21.3 A/D Conversion Timing

21.4.4 External Trigger Input Timing

A/D conversion can be externally triggered. When the TRGS1 and TRGS0 bits are set
ADCR, external trigger input is enabled at the $\overline{\text{ADTRG}}$ pin. A falling edge at the $\overline{\text{ADT}}$
the ADST bit to 1 in ADCSR, starting A/D conversion. Other operations, in both sing
modes, are the same as when the ADST bit has been set to 1 by software. Figure 21.4
timing.

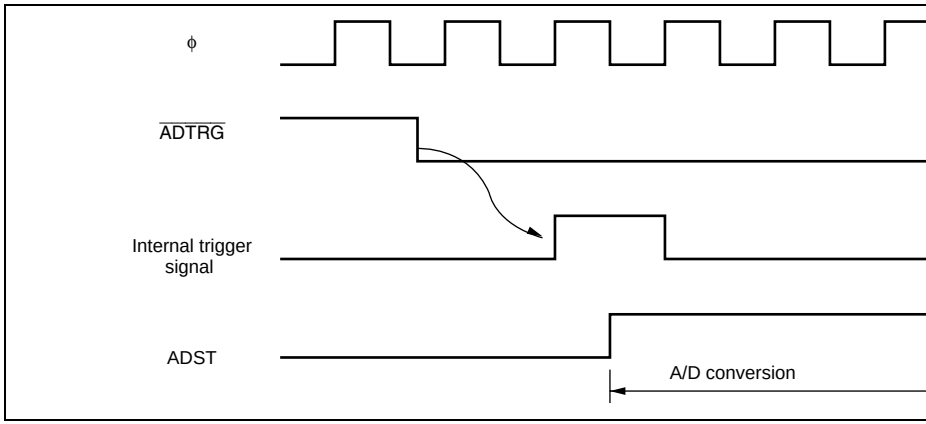


Figure 21.4 External Trigger Input Timing

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 char
  when the digital output changes from the minimum voltage value B'0000000000 (H
  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 char
  when the digital output changes from B'1111111110 (H'3FE) to B'1111111111 (H'3
  figure 21.6).
- Nonlinearity error

  The error with respect to the ideal A/D conversion characteristics between the zero
  the full-scale voltage. Does not include the offset error, full-scale error, or quantizat
  (see figure 21.6).
- Absolute accuracy

  The deviation between the digital value and the analog input value. Includes the off
  full-scale error, quantization error, and nonlinearity error.

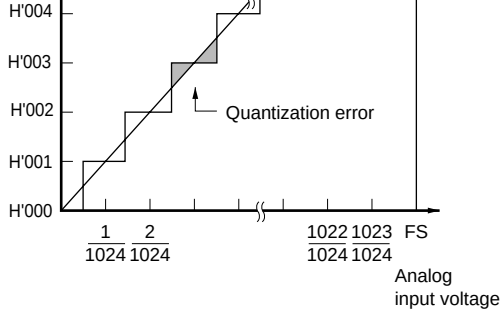


Figure 21.5 A/D Conversion Accuracy Definitions

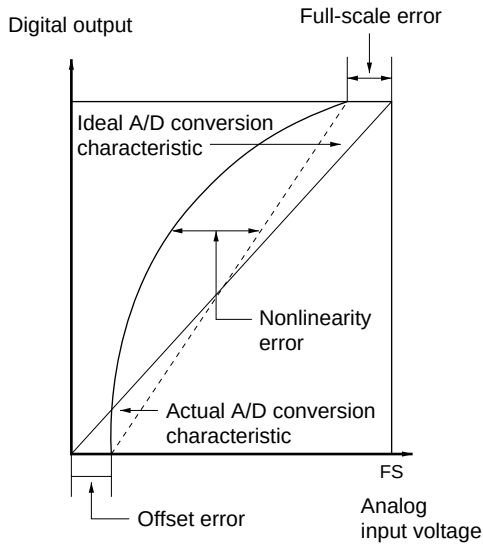


Figure 21.6 A/D Conversion Accuracy Definitions

insufficient and it may not be possible to guarantee the A/D conversion accuracy. How
large capacitance is provided externally in single mode, the input load will essentially c
only the internal input resistance of 10 kΩ, and the signal source impedance is ignored.
since a low-pass filter effect is obtained in this case, it may not be possible to follow an
signal with a large differential coefficient (e.g., voltage fluctuation ratio of 5 mV/µs or
(see figure 21.7). When converting a high-speed analog signal or converting in scan mo
impedance buffer should be inserted. For details on the 5-V version, refer to section 28,
Characteristics.

21.7.2 Influences on Absolute Accuracy

Adding capacitance results in coupling with ground, and therefore noise in ground may
affect the absolute accuracy. Be sure to make the connection to an electrically stable gr
as AVss.

Care is also required to insure that filter circuits do not communicate with digital signal
mounting board, so acting as antennas.

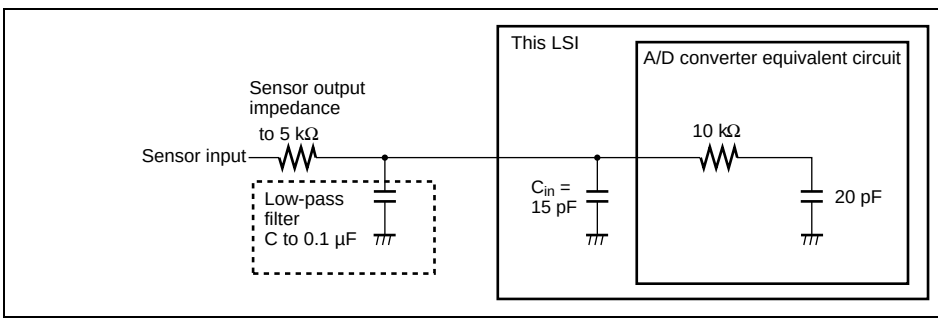


Figure 21.7 Example of Analog Input Circuit

The voltage applied to digital input pin CINn should be in the range AVss ≤ CINn 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/ 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 and layout in which digital circuit signal lines and analog circuit signal lines cross or a proximity should be avoided as far as possible. Failure to do so may result in incorrec of the analog circuitry due to inductance, adversely affecting A/D conversion values. A circuitry must be isolated from the analog input signals (AN0 to AN7), analog referen (AV_{ref}), and analog power supply (AV_{CC}) by the analog ground (AV_{SS}). Also, the analo (AV_{SS}) should be connected at one point to a stable digital ground (V_{SS}) on the board.

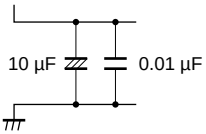
21.7.5 Notes on Noise Countermeasures

A protection circuit connected to prevent damage due to an abnormal voltage such as surge at the analog input pins (AN0 to AN7) and analog reference voltage (AV_{ref}) shou connected between AVcc and AVss as shown in figure 21.8. Also, the bypass capacito connected to AVcc and AV_{ref}, and the filter capacitor connected to AN2 to AN7, must connected to AV_{SS}.

If a filter capacitor is connected, the input currents at the analog input pins (AN0 to A averaged, and so an error may arise. Also, when A/D conversion is performed frequen scan mode, if the current charged and discharged by the capacitance of the sample-and in the A/D converter exceeds the current input via the input impedance (R_{in}), an error v the analog input pin voltage. Careful consideration is therefore required when decidin constants.

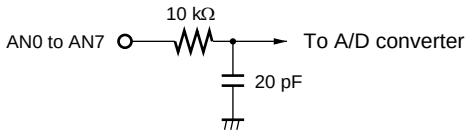
Notes: Values are reference values.

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 regis initial setting is for A/D converter operation to be halted. Register access is enabled by module stop mode. For details, refer to section 26, Power-Down Modes.

Product Classification		RAM Capacitance	RAM Address
Flash memory version	H8S/2161B	4 kbytes	H'E080–H'EFFF, H'FF0
	H8S/2160B	4 kbytes	H'E080–H'EFFF, H'FF0
	H8S/2141B	4 kbytes	H'E080–H'EFFF, H'FF0
	H8S/2140B	4 kbytes	H'E080–H'EFFF, H'FF0
	H8S/2145B	8 kbytes	H'D080–H'EFFF, H'FF0
	H8S/2148B	4 kbytes	H'E080–H'EFFF, H'FF0

- Size

Product Classification	RAM Capacitance	RAM Address
H8S/2161B	128 kbytes	H'000000–H'01FFFF (mod H'0000–H'DFFF (mode 3)
H8S/2160B	64 kbytes	H'000000–H'00FFFF (mod H'0000–H'DFFF (mode 3)
H8S/2141B	128 kbytes	H'000000–H'01FFFF (mod H'0000–H'DFFF (mode 3)
H8S/2140B	64 kbytes	H'000000–H'00FFFF (mod H'0000–H'DFFF (mode 3)
H8S/2145B	256 kbytes	H'000000–H'03FFFF (mod H'0000–H'DFFF (mode 3)
H8S/2148B	128 kbytes	H'000000–H'01FFFF (mod H'0000–H'DFFF (mode 3)

- Programming/erase methods

  The flash memory is programmed 128 bytes at a time. Erase is performed in single
  The flash memory is configured as follows:

  — 64-kbyte version: 8 kbytes × 2 blocks, 16 kbytes × 1 block, 28 kbytes × 1 block
  kbyte × 4 blocks

  — 128-kbyte version: 32 kbytes × 2 blocks, 8 kbytes × 2 blocks, 16 kbytes × 1 blo
  kbytes × 1 block, and 1 kbyte × 4 blocks

  — 256-kbyte version: 64 kbytes × 3 blocks, 32 kbytes × 1 block, and 4 kbytes × 8

  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.)
  Erasing one block takes 100 ms (typ.).

- Automatic bit rate adjustment

  With data transfer in boot mode, this LSI's bit rate can be automatically adjusted to transfer bit rate of the host.

- Programming/erasing protection

  Sets protection against flash memory programming/erasing via hardware, software, protection.

- Programmer mode

  In addition to on-board programming mode, programmer mode is supported to prog erase the flash memory using a PROM programmer.

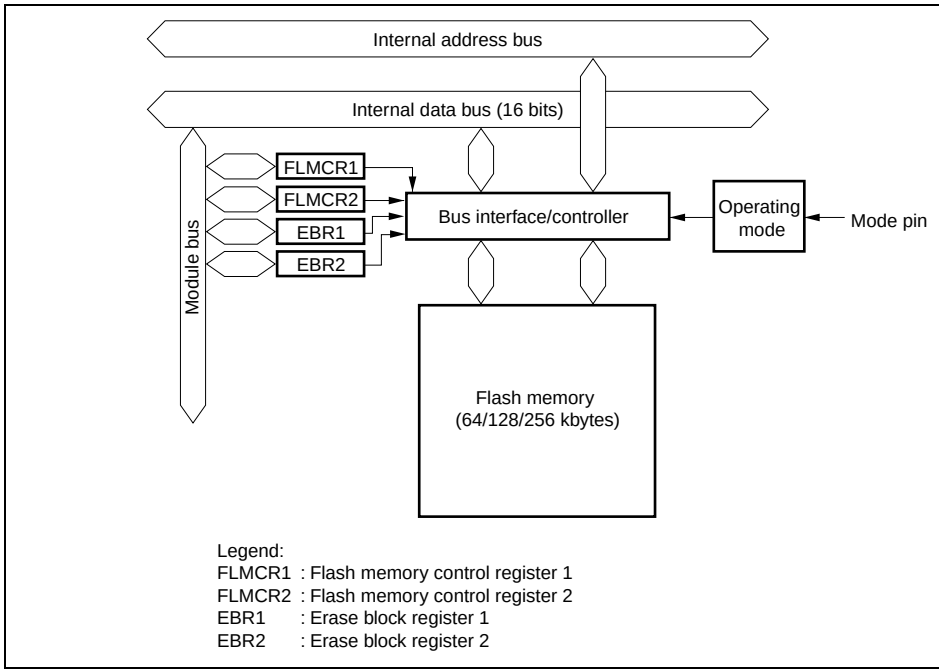


Figure 23.1 Block Diagram of Flash Memory

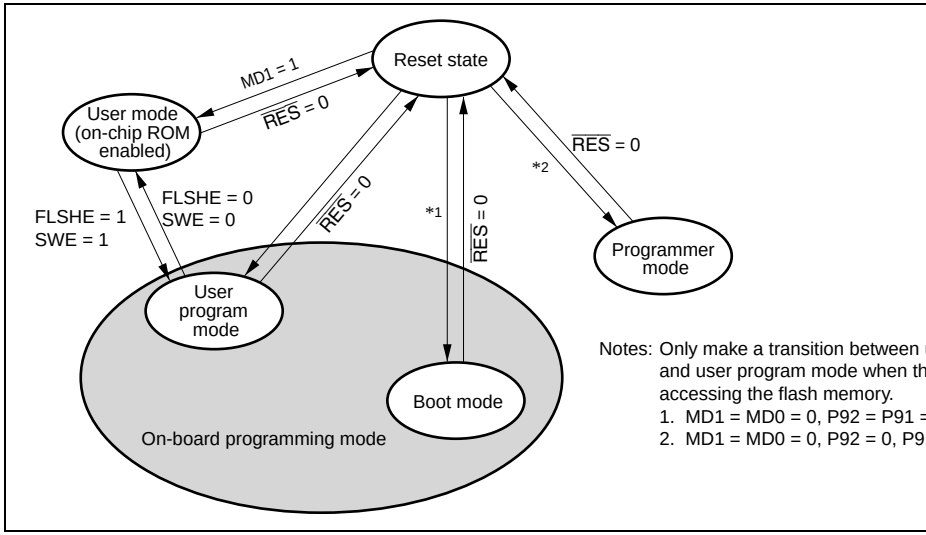


Figure 23.2 Flash Memory State Transitions

Table 23.1 Differences between Boot Mode and User Program Mode

	Boot Mode	User Program Mo
Total erase	Yes	Yes
Block erase	No	Yes
Programming control program*	Program/program-verify	Program/program-
		Erase/erase-verify

Note: * Should be provided by the user, in accordance with the recommended algo

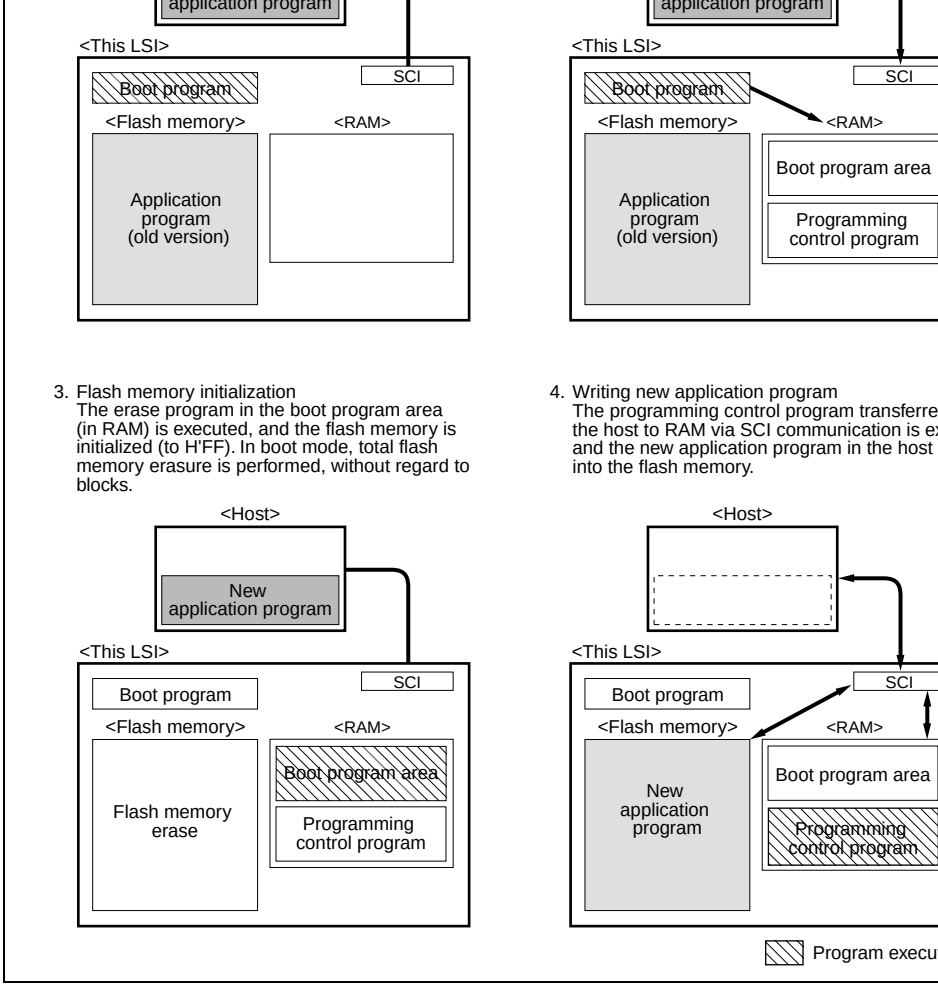
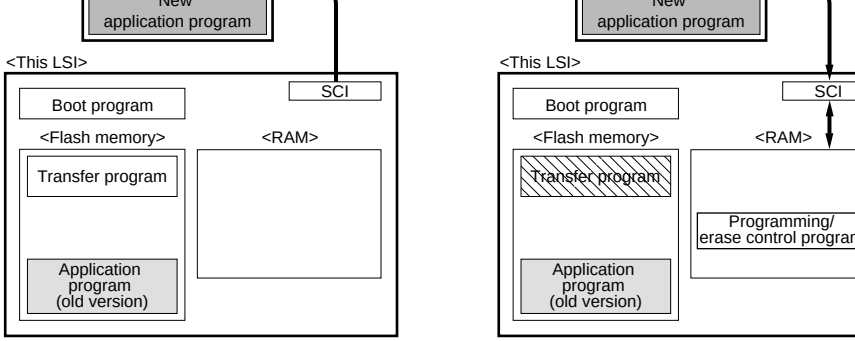


Figure 23.3 Boot Mode



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 w
the erased flash memory blocks. Do not write to u
blocks.

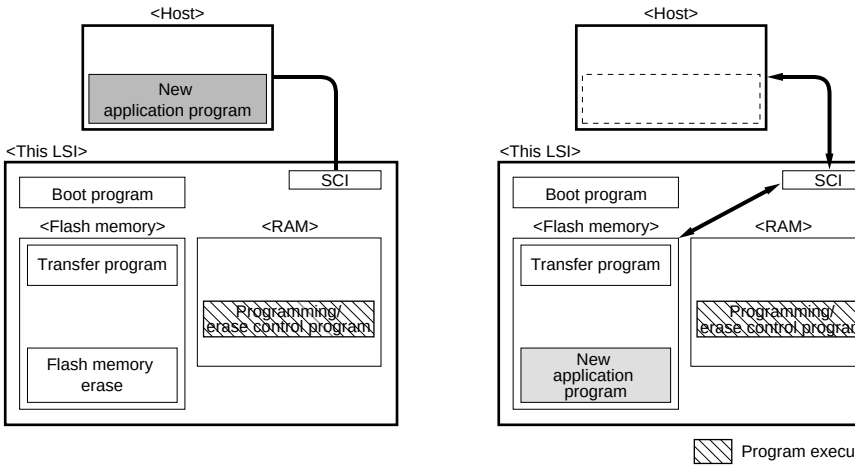


Figure 23.4 User Program Mode (Example)

units starting from an address whose lower bits are H'00 or H'80.

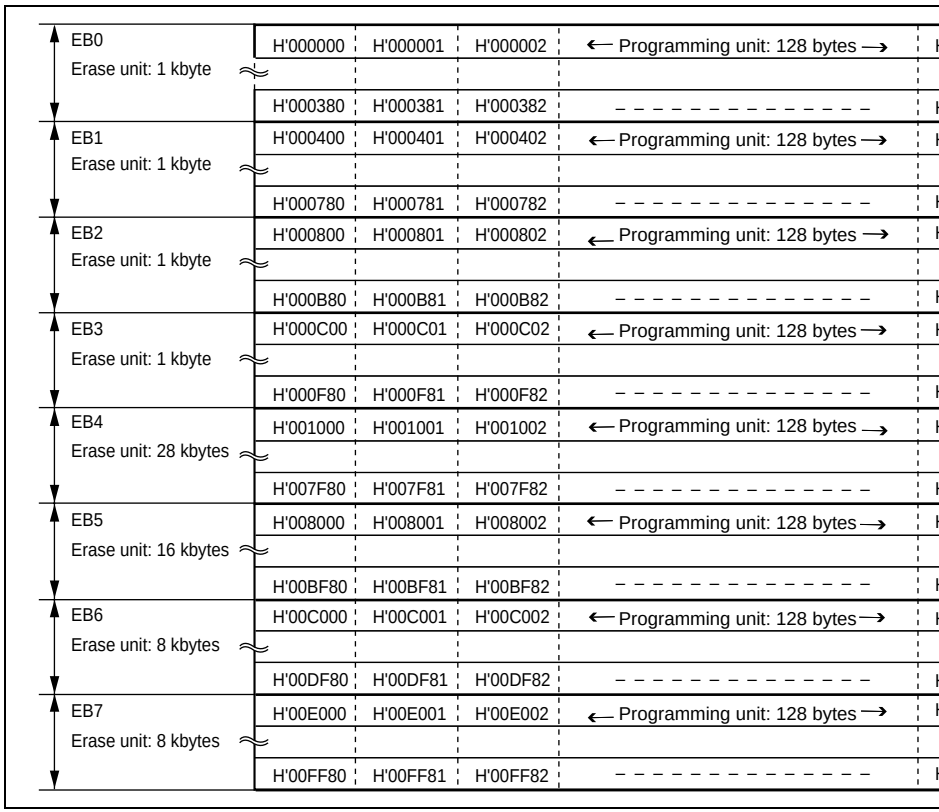


Figure 23.5 64-Kbyte Flash Memory Block Configuration

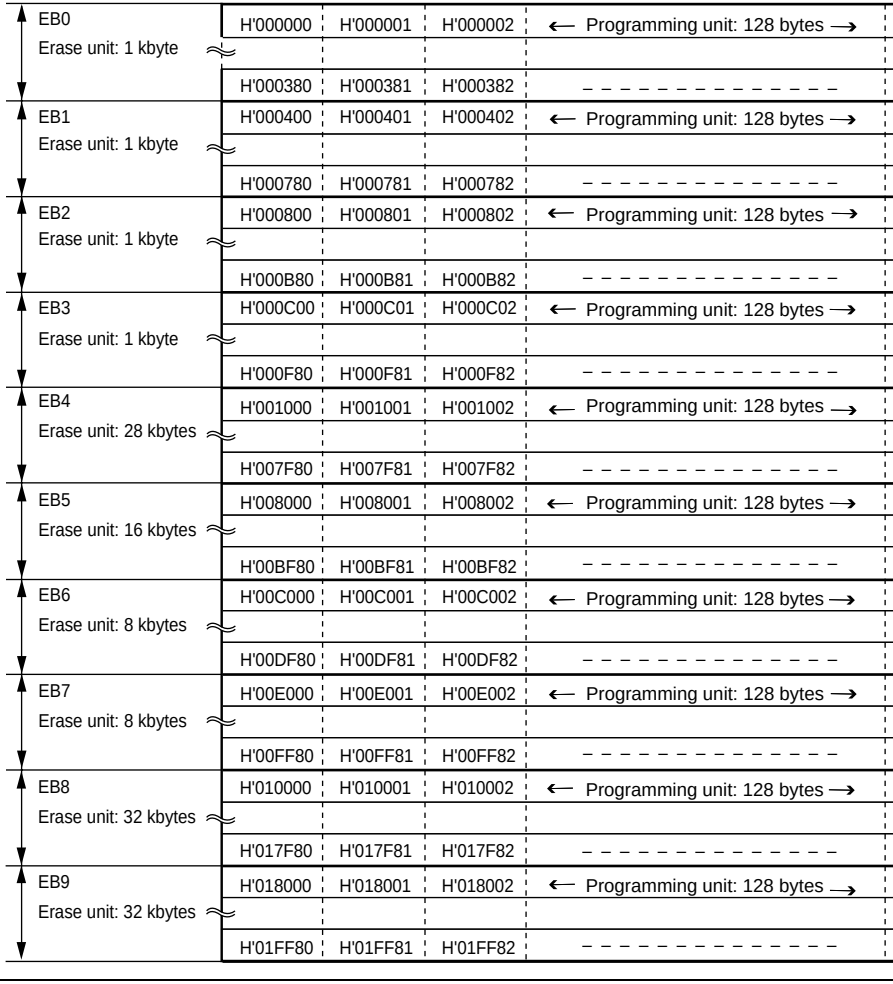


Figure 23.6 128-Kbyte Flash Memory Block Configuration

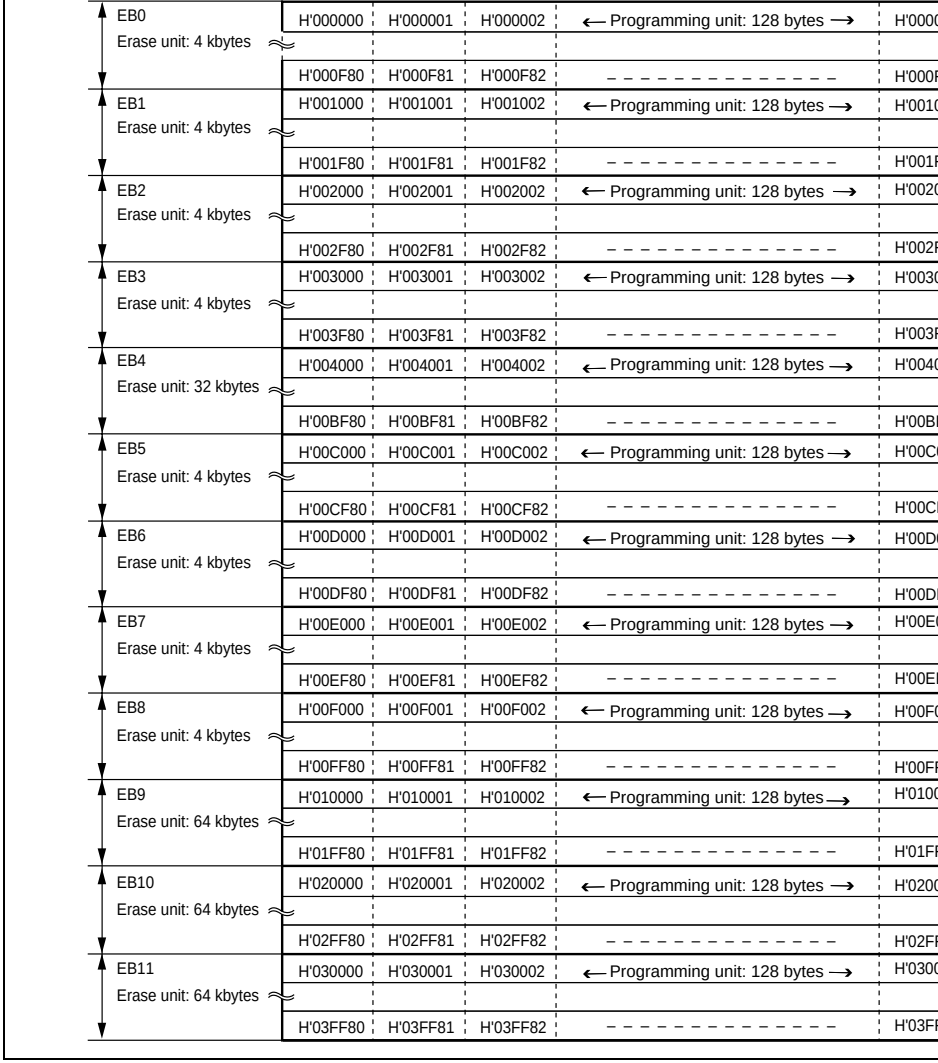


Figure 23.7 256-Kbyte Flash Memory Block Configuration

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, the FLSHE bit in the serial/timer control register (STCR) should be set to 1. For detail serial/timer control register, refer to section 3.2.3, Serial Timer Control Register (STC

- 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 m program-verify mode, erase mode, or erase-verify mode. For details on register setting section 23.8, Flash Memory Programming/Erasing.

FLMCR1 is initialized to H'80 by a reset, or in hardware standby mode, software stan sub-active mode, sub-sleep mode, or watch mode.

				cleared to 0, the EV, PV, E, and P bits in this the ESU and PSU bits in FLMCR2, and all E EBR2 bits cannot be set to 1. Do not clear th and SWE to 0 simultaneously.
5, 4	—	All 0	R	Reserved These bits are always read as 0 and cannot modified.
3	EV	0	R/W	Erase-Verify When this bit is set to 1 while SWE = 1, the memory transits to erase-verify mode. When 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 memory transits to program-verify mode. Wh cleared to 0, program-verify mode is cancell
1	E	0	R/W	Erase When this bit is set to 1 while SWE = 1 and the flash memory transits to erase mode. W cleared to 0, erase mode is cancelled.
0	P	0	R/W	Program When this bit is set to 1 while SWE = 1 and the flash memory transits to program mode. cleared to 0, program mode is cancelled.

7	FLER	0	R	Flash memory error Indicates that an error has occurred dur memory programming/erasing. When th to 1, flash memory goes to the error-pro state. For details, see section 23.9.3, Error Pr
6 to 2	—	All 0	R/(W)	Reserved The initial values should not be modifie
1	ESU	0	R/W	Erase Setup When this bit is set to 1 while SWE = 1, memory transits to the erase setup stat cleared to 0, the erase setup state is ca this bit to 1 before setting the E bit in FL
0	PSU	0	R/W	Program Setup When this bit is set to 1 while SWE = 1, memory transits to the program setup s is cleared to 0, the program setup state Set this bit to 1 before setting the P bit i to 1.

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 erase
6	EB6	0	R/W	When this bit is set to 1, 8 kbytes of EB6 (H'00C000 to H'00DFFF) are to be eras
5	EB5	0	R/W	When this bit is set to 1, 16 kbytes of EB (H'008000 to H'00BFFF) are to be erase
4	EB4	0	R/W	When this bit is set to 1, 28 kbytes of EB (H'001000 to H'007FFF) are to be erase
3	EB3	0	R/W	When this bit is set to 1, 1 kbyte of EB3 to H'000FFF) is to be erased.
2	EB2	0	R/W	When this bit is set to 1, 1 kbyte of EB2 to H'000BFF) is to be erased.
1	EB1	0	R/W	When this bit is set to 1, 1 kbyte of EB1 to H'0007FF) is to be erased.
0	EB0	0	R/W	When this bit is set to 1, 1 kbyte of EB0 to H'0003FF) is to be erased.

Note: * In normal mode, this bit is always read as 0 and cannot be modified.

(H'010000 to H'017FFF) are to be eras

- 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 EB (H'00E000 to H'00FFFF) are to be eras
6	EB6	0	R/W	When this bit is set to 1, 8 kbytes of EB (H'00C000 to H'00DFFF) are to be era
5	EB5	0	R/W	When this bit is set to 1, 16 kbytes of E (H'008000 to H'00BFFF) are to be eras
4	EB4	0	R/W	When this bit is set to 1, 28 kbytes of E (H'001000 to H'007FFF) are to be eras
3	EB3	0	R/W	When this bit is set to 1, 1 kbyte of EB3 to H'000FFF) is to be erased.
2	EB2	0	R/W	When this bit is set to 1, 1 kbyte of EB2 to H'000BFF) is to be erased.
1	EB1	0	R/W	When this bit is set to 1, 1 kbyte of EB1 to H'0007FF) is to be erased.
0	EB0	0	R/W	When this bit is set to 1, 1 kbyte of EB0 to H'0003FF) is to be erased.

Note: * In normal mode, this bit is always read as 0 and cannot be modified.

				(H'020000 to H'02FFFF) are to be erase
1	EB9	0	R/W*	When this bit is set to 1, 64 kbytes of EB (H'010000 to H'01FFFF) are to be erase
0	EB8	0	R/W*	When this bit is set to 1, 4 kbytes of EB8 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 erase
6	EB6	0	R/W	When this bit is set to 1, 4 kbytes of EB6 (H'00D000 to H'00DFFF) are to be eras
5	EB5	0	R/W	When this bit is set to 1, 4 kbytes of EB5 (H'00C000 to H'00CFFF) are to be eras
4	EB4	0	R/W	When this bit is set to 1, 32 kbytes of EB (H'004000 to H'00BFFF) are to be erase
3	EB3	0	R/W	When this bit is set to 1, 4 kbytes of EB3 to H'003FFF) is to be erased.
2	EB2	0	R/W	When this bit is set to 1, 4 kbytes of EB2 to H'002FFF) is to be erased.
1	EB1	0	R/W	When this bit is set to 1, 4 kbytes of EB1 to H'001FFF) is to be erased.
0	EB0	0	R/W	When this bit is set to 1, 4 kbytes of EB0 to H'000FFF) is to be erased.

Note: * In normal mode, this bit is always read as 0 and cannot be modified.

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**
Mode 1	Normal	Expanded mode with on-chip ROM disabled	0	1	1
Mode 2	Advanced	Single-chip mode	1	0	0
	Advanced	Expanded mode with on-chip ROM enabled	1	0	1
Mode 3	Normal	Single-chip mode	1	1	0
	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 programmi and verification. This LSI has two on-board programming modes: boot mode and user mode. Table 23.4 shows pin settings for boot mode. In user program mode, operation is enabled by setting control bits. For details on flash memory mode transitions, see fi

23.7.1 Boot Mode

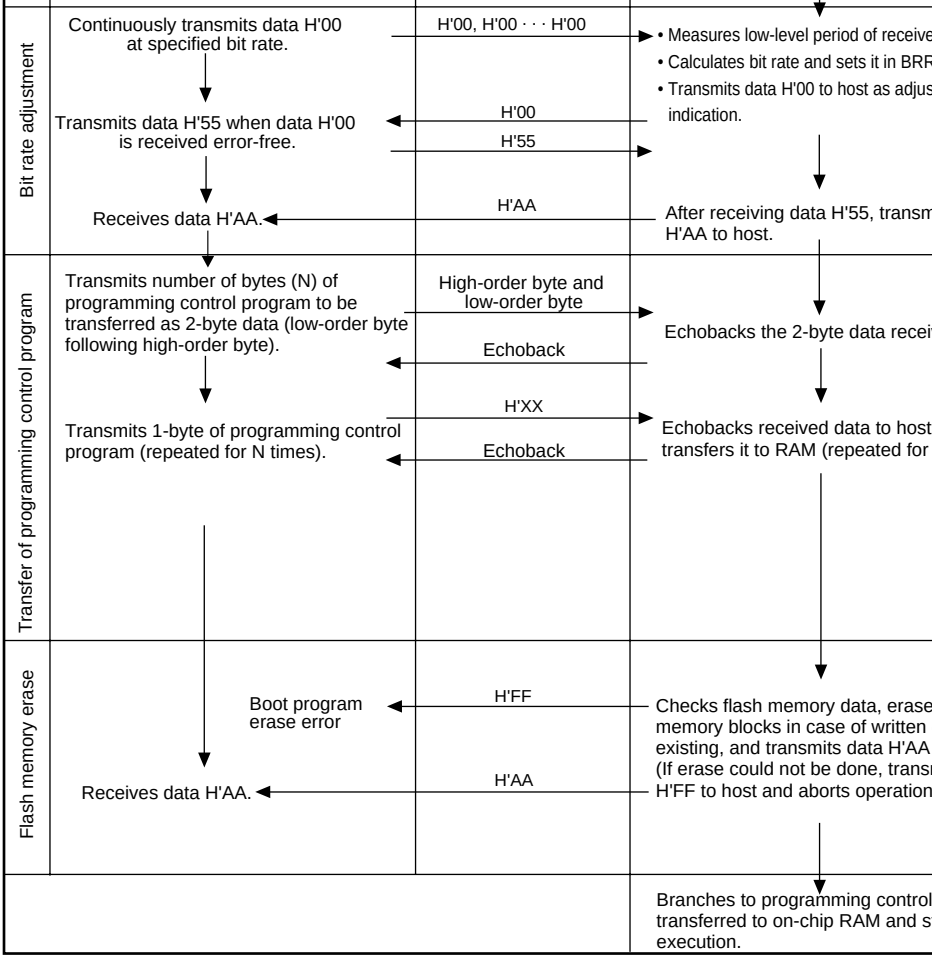
Table 23.5 shows the boot mode operations between reset end and branching to the pro control program.

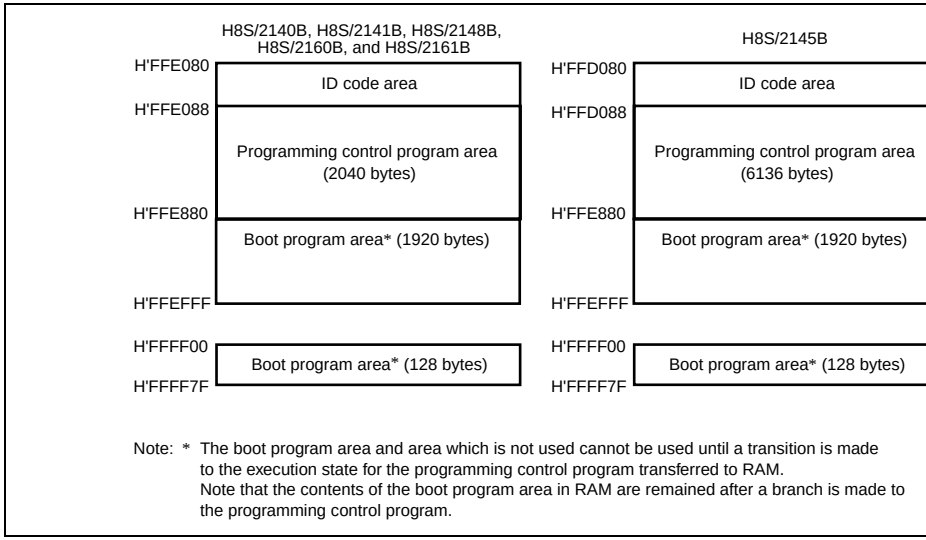
1. When boot mode is used, the flash memory programming control program must be the host beforehand. Prepare a programming control program in accordance with th description in section 23.8, Flash Memory Programming/Erasing. In boot mode, if a exists in the flash memory (except in the case that all data are 1), all blocks in the fl memory are erased. Use boot mode at initial writing in the on-board state, or forced when user program mode cannot be executed because the program to be initiated in program mode was mistakenly erased.
2. The SCI_1 should be set to asynchronous mode, and the transfer format as follows: 1 stop bit, and no parity.
3. When the boot program is initiated, this LSI measures the low-level period of asyn SCI communication data (H'00) transmitted continuously from the host. This LSI th calculates the bit rate of transmission from the host, and adjusts the SCI_1 bit rate t that of the host. The reset should end with the RxD1 pin high. The RxD1 and TxD1 should be pulled up on the board if necessary. After the reset ends, it takes approxi 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 bit rate adjustment. The host should confirm that this adjustment end indication (H' been received normally, and transmit one H'55 byte to this LSI. If reception could n performed normally, initiate boot mode again by a reset. Depending on the host's tr rate and system clock frequency of this LSI, there will be a discrepancy between th of the host and this LSI. To operate the SCI properly, set the host's transfer bit rate 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. Address H'FFE080 to H'FFE87F[*1] is the area to which the programming control program is 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 boo

beginning of the programming control program, since the stack pointer (SP), in pa
used implicitly in subroutine calls, etc.

7. Boot mode can be cleared by a reset. Cancel the reset[*4] after driving the reset pin l
at least 20 states, and then setting the mode pins. Boot mode is also cleared when a
overflow occurs.
8. Do not change the mode pin input levels in boot mode. If mode pin input levels ar
from low to high during reset, operating modes are switched and the state of ports
used for address output and bus control output signals ($\overline{AS}$, $\overline{RD}$, and $\overline{HWR}$) are ch
Therefore, set these pins carefully not to be output signals during reset or not to co
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, a
H8S/2161B. On the H8S/2145B, the address area is from H'FFD080 to H'F
2. Address area for the H8S/2140B, H8S/2141B, H8S/2148B, H8S/2160B, a
H8S/2161B. On the H8S/2145B, the address area is from H'FFD080 to H'F
3. RAM address for the H8S/2140B, H8S/2141B, H8S/2148B, H8S/2160B, a
H8S/2161B. On the H8S/2145B, the address is H'FFD088.
4. After reset is cancelled, mode pin input settings must satisfy the mode prog
setup time (t_{MDS} = 4 states).
5. The ports that also have address output functions output low as address out
the mode pins are set to mode 1 during a reset. In modes other than mode 1
the high impedance state. Bus control output signals output high when the
are set to mode 1 during a reset. In modes other than mode 1, it enters the h
impedance state.


Bit rate adjustment
Continuously transmits data H'00 at specified bit rate.
H'00, H'00 · · · H'00
• Measures low-level period of receive
• Calculates bit rate and sets it in BRR
• Transmits data H'00 to host as adjus
indication.
Transmits data H'55 when data H'00 is received error-free.
H'00
H'55
Receives data H'AA.
H'AA
After receiving data H'55, transm
H'AA to host.
Transfer of programming control program
Transmits number of bytes (N) of programming control program to be transferred as 2-byte data (low-order byte following high-order byte).
High-order byte and low-order byte
Echobacks the 2-byte data recei
Echoback
H'XX
Transmits 1-byte of programming control program (repeated for N times).
Echobacks received data to host
transfers it to RAM (repeated for
Echoback
Flash memory erase
Boot program erase error
H'FF
Checks flash memory data, erase
memory blocks in case of written
existing, and transmits data H'AA
(If erase could not be done, trans
H'FF to host and aborts operation
Receives data H'AA.
H'AA
Branches to programming control
transferred to on-chip RAM and s
execution.



Note: * The boot program area and area which is not used cannot be used until a transition is made to the execution state for the programming control program transferred to RAM.
Note that the contents of the boot program area in RAM are remained after a branch is made to the programming control program.

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 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 mus the beginning of the program.

H'FFD088	Instruction codes of the programming control 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 perfor
program mode by branching to a user program/erase control program. The user must se
conditions and provide on-board means of supplying programming data. The flash mem
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
read during programming/erasing, transfer the user program/erase control program to o
RAM, as like in boot mode. Figure 23.10 shows a sample procedure for programming/e
user program mode. Prepare a user program/erase control program in accordance with t
description in section 23.8, Flash Memory Programming/Erasing.

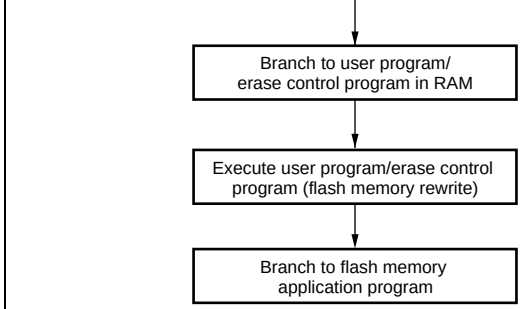
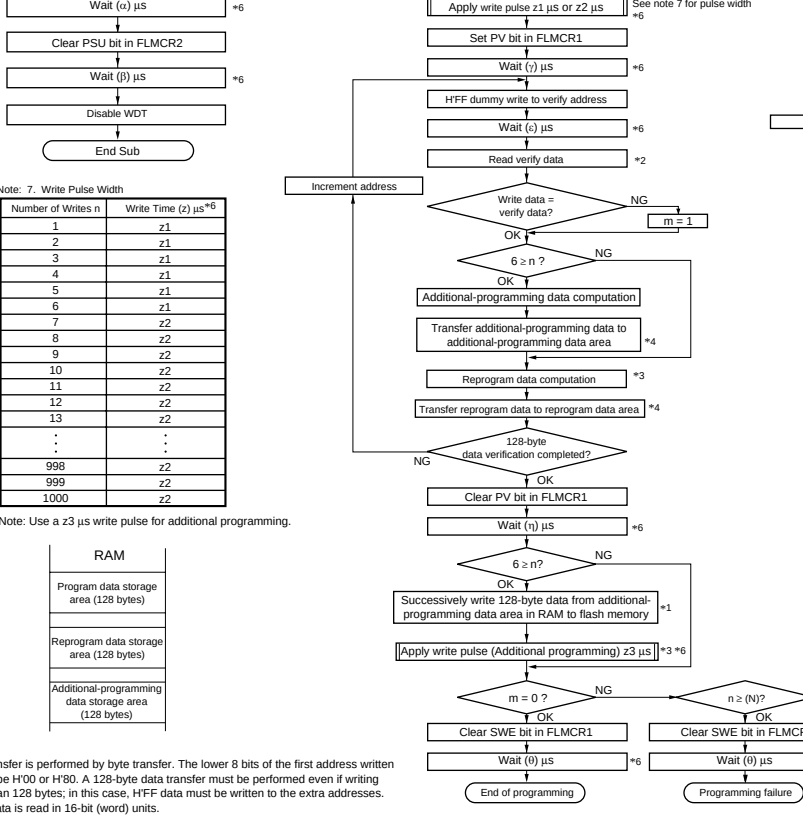


Figure 23.10 Programming/Erasing Flowchart Example in User Program

23.8 Flash Memory Programming/Erasing

A software method, using the CPU, is employed to program and erase flash memory i
board programming modes. Depending on the FLMCR1 and FLMCR2 settings, the fl
operates in one of the following four modes: program mode, program-verify mode, er
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 co
perform programming/erasing. Flash memory programming and erasing should be per
accordance with the descriptions in section 23.8.1, Program/Program-Verify and secti
Erase/Erase-Verify, respectively.

2. Programming should be carried out 128 bytes at a time. A 128-byte data transfer mu performed even if writing fewer than 128 bytes. In this case, H'FF data must be wri extra addresses.
3. Prepare the following data storage areas in RAM: a 128-byte programming data are byte reprogramming data area, and a 128-byte additional-programming data area. P reprogramming data computation and additional programming data computation ac figure 23.11.
4. Consecutively transfer 128 bytes of data in byte units from the reprogramming data additional-programming data area to the flash memory. The program address and 1 data are latched in the flash memory. The lower 8 bits of the start address in the flas 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 sh allowable programming times.
6. The watchdog timer (WDT) is set to prevent overprogramming due to program runa 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 are B'00. Verify data can be read in words from the address to which a dummy writ performed.
8. The maximum number of repetitions of the program/program-verify sequence to th 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

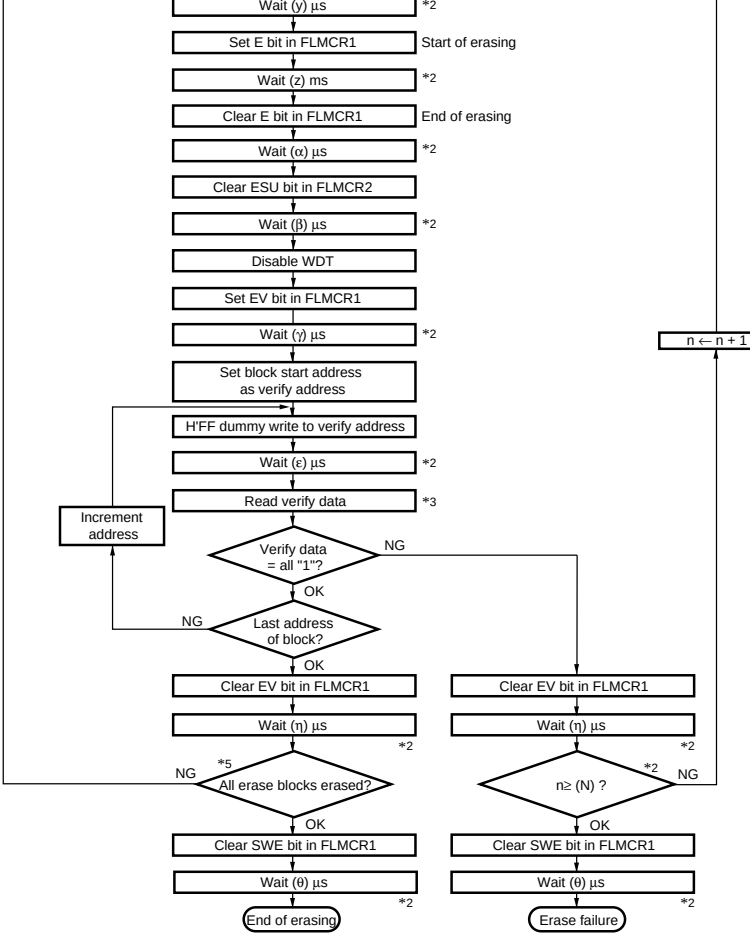
Additional-Programming Data Computation Table

Reprogram Data (X')	Verify Data (V)	Additional-Programming Data (Y)	Comments
0	0	0	Additional programming to
0	1	1	Additional programming no
1	0	1	
1	1	1	Additional programming no

Figure 23.11 Program/Program-Verify Flowchart

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 runa
   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
   bits are B'00. Verify data can be read in longwords from the address to which a dum
   was performed.
6. If the read data is unerased, set erase mode again, and repeat the erase/erase-verify s
   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

or aborted by a reset (including WDT overflow reset), or a transition to hardware stand
software standby mode, sub-active mode, sub-sleep mode or watch mode. Flash memor
registers 1 and 2 (FLMCR1 and FLMCR2) and erase block registers 1 and 2 (EBR1 an
are initialized. In a reset via the $\overline{\text{RES}}$ pin, the reset state is not entered unless the $\overline{\text{RES}}$ p
low until oscillation stabilizes after powering on. In the case of a reset during operation
$\overline{\text{RES}}$ 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 mem
by clearing the SWE bit in FLMCR1 to 0. When software protection is in effect, setting
bit in FLMCR1 does not cause a transition to program mode or erase mode. By setting
block registers 1 and 2 (EBR1 and EBR2), erase protection can be set for individual blo
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 m
programming/erasing, or operation is not performed in accordance with the program/er
algorithm, and the program/erase operation is aborted. Aborting the program/erase oper
prevents damage to the flash memory due to overprogramming or overerasing.

When the following errors are detected during programming/erasing of flash memory, t
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 re
  instruction fetch)
- Immediately after exception handling (excluding a reset) during programming/erasi
- When a SLEEP instruction is executed (transits to software standby mode, sleep mo
  active mode, sub-sleep mode, or watch mode) during programming/erasing
- When the bus ownership is released during programming/erasing

In order to give the highest priority to programming/erasing operations, disable all int
including NMI input during flash memory programming/erasing (the P or E bit in FlM
to 1) or boot program execution*[1].

1. If an interrupt is generated during programming/erasing, operation in accordance v
   program/erase algorithm is not guaranteed.
2. CPU runaway may occur because normal vector reading cannot be performed in ir
   exception handling during programming/erasing*[2].
3. If an interrupt occurs during boot program execution, the normal boot mode seque
   be executed.

Notes: 1. Interrupt requests must be disabled inside and outside the CPU until the pr
   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
   FLMCR1 is set to 1), correct read data will not be obtained (undefined v
   returned).

   If the interrupt entry in the vector table has not been programmed y
   exception handling will not be executed correctly.

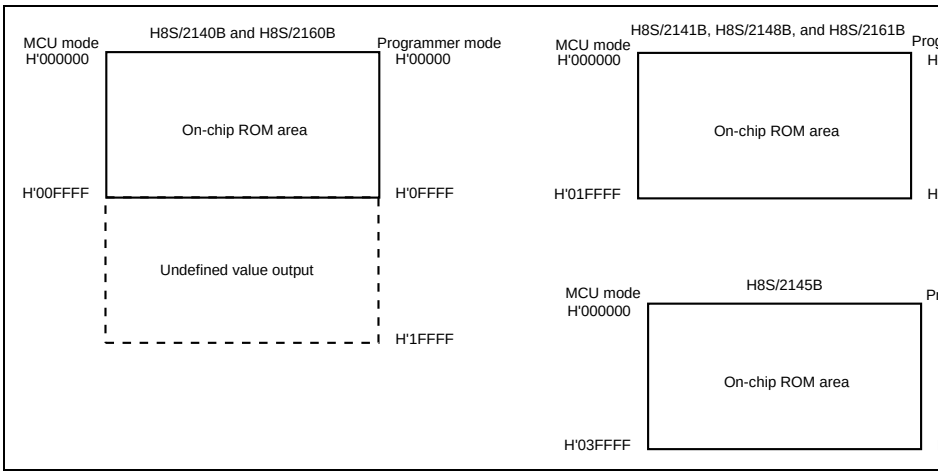


Figure 23.13 Memory Map in Programmer Mode

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 fla
   to hardware protection state. This power on/off timing must also be satisfied at a p
   power-on caused by a power failure and other factors.

3. Perform flash memory programming/erasing in accordance with the recommended

   In the recommended algorithm, flash memory programming/erasing can be perfor
   subjecting this LSI to voltage stress or sacrificing program data reliability. When s
   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 in
   least 100 µs is necessary between program execution or data reading in flash mem
   SWE bit clearing. When the SWE bit is set to 1, flash memory data can be modifie
   flash memory data can be read only in program-verify or erase-verify mode. Do no
   flash memory for a purpose other than verification during programming/erasing. D
   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 i
   including NMI input when the flash memory is programmed or erased.

6. Do not perform additional programming. Programming must be performed in the e

   Program the area with 128-byte programming-unit blocks in on-board programmin
   programmer mode only once. Perform programming in the state where the progra
   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, to
   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.

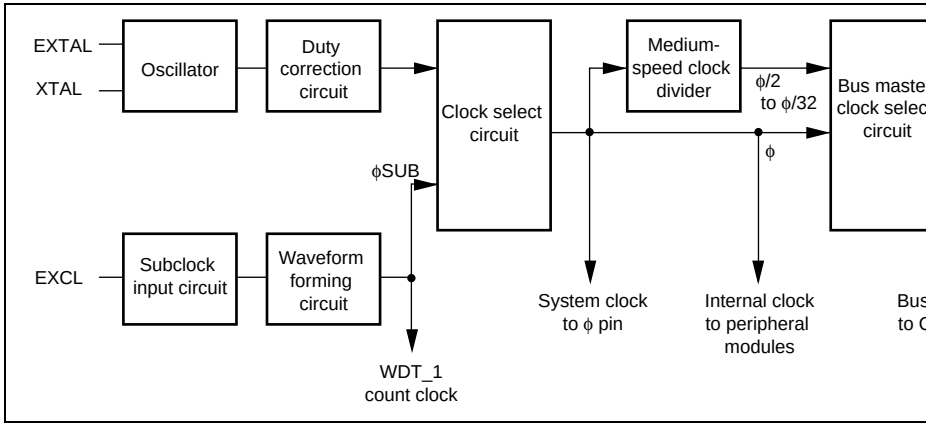


Figure 24.1 Block Diagram of Clock Pulse Generator

The bus master clock is selected as either high-speed mode or medium-speed mode by according to the settings of the SCK2 to SCK0 bits in the standby control register. For 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 control register. For details on the low power control register, refer to section 26.1.2, L Control Register (LPWRCR).

resistance R_d, given in table 24.1, should be used. An AT-cut parallel-resonance crystal 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 us

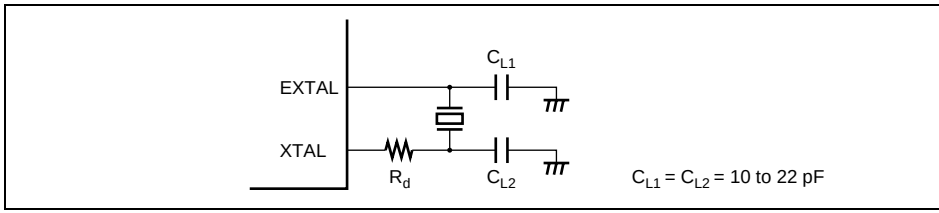


Figure 24.2 Typical Connection to Crystal Resonator

Table 24.1 Damping Resistance Values

Frequency (MHz)	2	4	8	10	12	16
R_d (Ω)	1 k	500	200	0	0	0

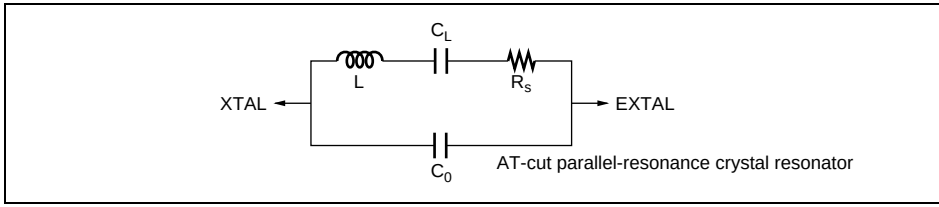
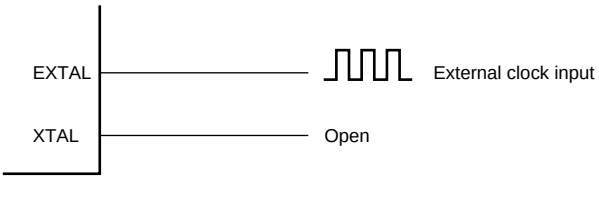


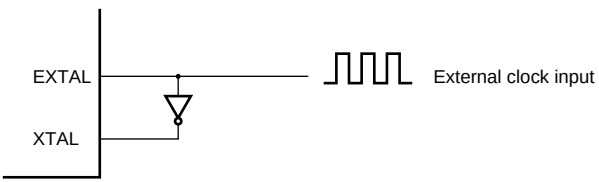
Figure 24.3 Equivalent Circuit of Crystal Resonator

Figure 24.4 shows a typical method of connecting an external clock signal. To leave th
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
mode, subactive mode, subsleep mode, and watch mode. External clock input conditio
shown in table 24.3. The frequency of the external clock should be the same as that of
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

high level							
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}	$\phi \geq 5$ MH
		80	—	80	—	ns	$\phi < 5$ MH
Clock pulse width high level	t_{CH}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5$ MH
		80	—	80	—	ns	$\phi < 5$ MH

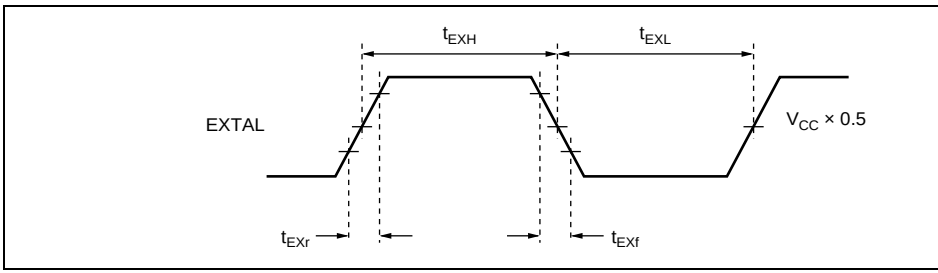
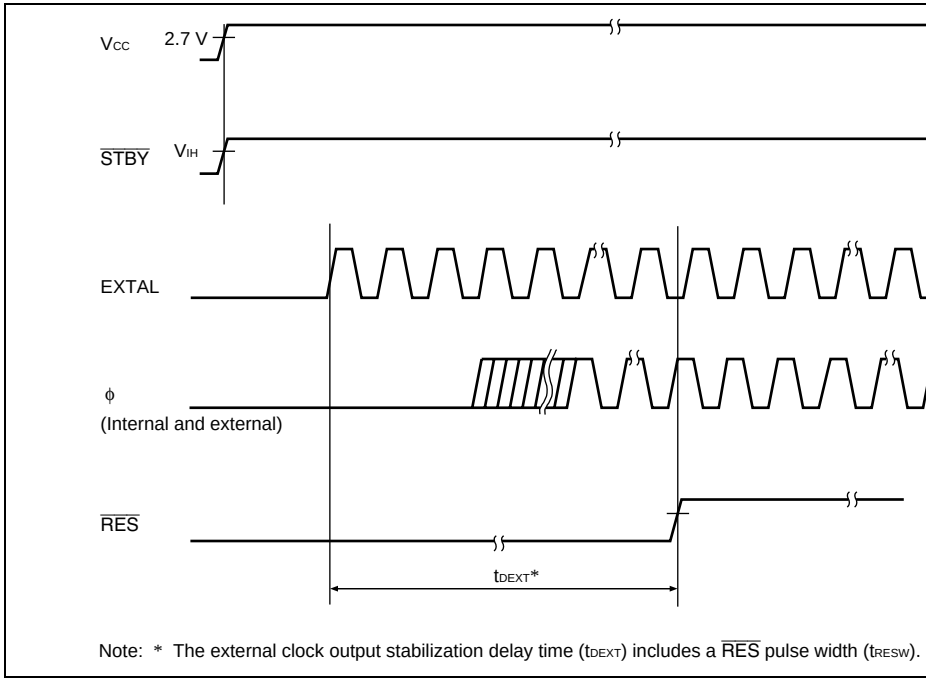


Figure 24.5 External Clock Input Timing

The oscillator and duty correction circuit have a function to adjust the waveform of the clock input that is input to the EXTAL pin. When a specified clock signal is input to th pin, internal clock signal output is determined after the external clock output stabilizati time (t_{DEXT}) has passed. As the clock signal output is not determined during the t_{DEXT} cyc signal should be set to low to hold it in reset state. Table 24.4 shows the external clock stabilization delay time. Figure 24.6 shows the timing of the external clock output stabi delay time.



Note: * The external clock output stabilization delay time (t_{DEXT}) includes a $\overline{RES}$ pulse width (t_{RESW}).

Figure 24.6 Timing of External Clock Output Stabilization Delay Tim

24.2 Duty Correction Circuit

The duty correction circuit is valid when the oscillating frequency is 5 MHz or more. T
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,
and ϕ/32 clocks.

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 i the EXCL pin. At this time, the P96DDR bit in P9DDR should be cleared to 0, and the in LPWRCR should be set to 1.

Subclock input conditions are shown in table 24.5. When the subclock is not used, subc should not be enabled.

Table 24.5 Subclock Input Conditions

		Vcc = 2.7 to 5.5 V				Meas
Item	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Cond**
Subclock input pulse width low level	t_{EXCLL}	—	15.26	—	µs	Figure
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	

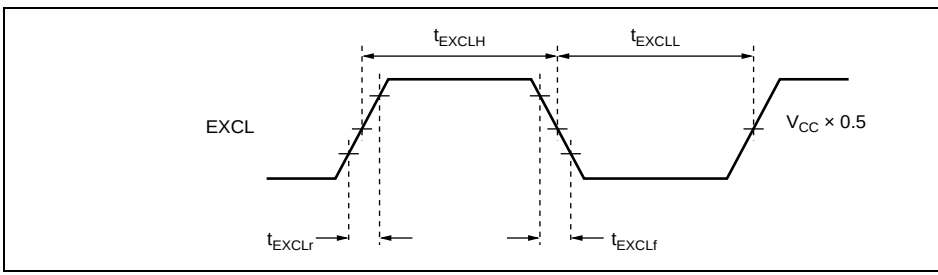


Figure 24.7 Subclock Input Timing

As described in the hardware manual (clock pulse generator/subclock input circui
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
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 s
system clock when returning from high-speed mode, medium-speed mode, sleep mod
or standby mode.

A subclock input from the EXCL pin is selected as a system clock in subactive mode,
mode, or watch mode. At this time, modules such as the CPU, TMR_0, TMR_1, WDT
WDT_1, ports, and interrupt controller and their functions operate depending on the ϕ
count clock and sampling clock for each timer are divided ϕSUB clocks.

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 user, use the example of resonator connection in this document for only reference; be su 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 capa the resonator and installation circuit. Make sure the voltage applied to the oscillator pin 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 p 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.

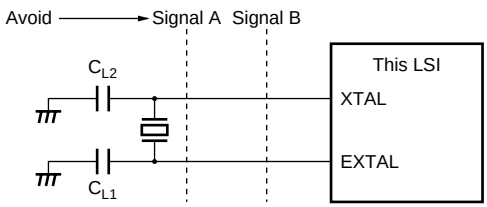


Figure 24.9 Note on Board Design of Oscillator Circuit Section

System clock frequency for the CPU operation can be selected as ϕ/2, ϕ/4, ϕ/8, ϕ/1

- Subactive mode

  The CPU operates based on the subclock and on-chip peripheral modules other tha
  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, a
  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 operatin
- Hardware standby mode

  Clock oscillation stops, and the CPU and on-chip peripheral modules enter reset st
- Module stop mode

  Independently of above operating modes, on-chip peripheral modules that are not
  stopped individually.

25.1 Register Descriptions

Power-down modes are controlled by the following registers. To access SBYCR, LPW
MSTPCRH, and MSTPCRL, the FLSHE bit in the serial timer control register (STCR
cleared to 0. For details on STCR, see section 3.2.3, Serial Timer Control Register (ST

- Standby control register (SBYCR)
- Low power control register (LPWRCR)
- Module stop control register H (MSTPCRH)
- Module stop control register L (MSTPCRL)

				When the SLEEP instruction is executed in high mode or medium-speed mode: 0: Shifts to sleep mode 1: Shifts to software standby mode, subactive m watch mode When the SLEEP instruction is executed in suba 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 transition occurs by an interrupt.
6	STS2	0	R/W	Standby Timer Select 2 to 0
5	STS1	0	R/W	Selects the wait time for clock stabilization from
4	STS0	0	R/W	oscillation start when canceling software standb watch mode, or subactive mode. Select a wait ti (oscillation stabilization time) or more, dependin operating frequency. Table 25.1 shows the relat between the STS2 to STS0 values and wait time With an external clock, there are no specific wai requirements. Normally the minimum value is recommended.
3	—	0	R	Reserved This bit is always read as 0, and cannot be mod

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 M
0	0	0	8192 states	0.4	0.8	1.0	1.3	2.0	4.1
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
1	1	0	Reserved	—	—	—	—	—	—
1	1	1	16 states*	0.8	1.6	2.0	2.7	4.0	8.0

Shaded cells indicate the recommended specification.

Note: * This setting cannot be made in the flash-memory version of this LSI.

				When the SLEEP instruction is executed in high mode or medium-speed mode: 0: Shifts to sleep mode, software standby mode mode 1: Shifts directly to subactive mode, or shifts to s or software standby mode When the SLEEP instruction is executed in suba mode: 0: Shifts to subsleep mode or watch mode 1: Shifts directly to high-speed mode, or shifts to mode
6	LSON	0	R/W	Low-Speed On Flag Specifies the operating mode to be entered after the SLEEP instruction. This bit also controls whe to high-speed mode or subactive mode when wa is cancelled. When the SLEEP instruction is executed in high mode or medium-speed mode: 0: Shifts to sleep mode, software standby mode mode 1: Shifts to watch mode or subactive mode When the SLEEP instruction is executed in suba mode: 0: Shifts directly to watch mode or high-speed m 1: Shifts to subsleep mode or watch mode When watch mode is cancelled: 0: Shifts to high-speed mode 1: Shifts to subactive mode

4	EXCLE	0	R/W	Subclock Input Enable Enables/disables subclock input from the EXCL 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 b be set to 1.
2 to 0	—	All 0	R	Reserved These bits are always read as 0 and cannot be

25.1.3 Module Stop Control Registers H and L (MSTPCRH, MSTPCRL)

MSTPCRH and MSTPCRL specify on-chip peripheral modules to shift to module sto
module units. Each module can enter module stop mode by setting the corresponding

- 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
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 conne

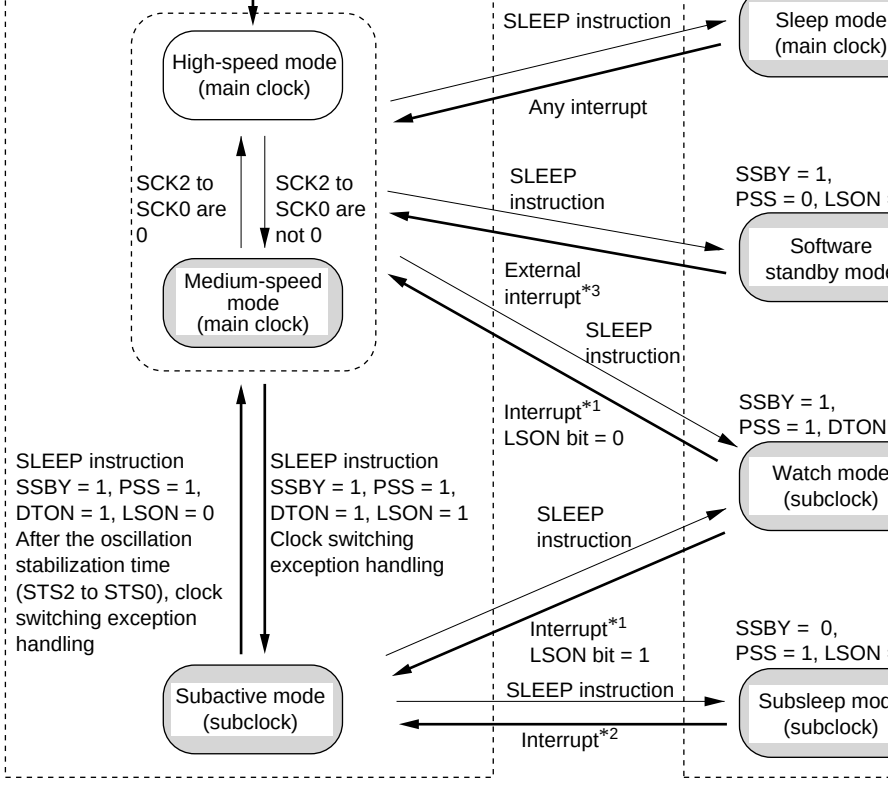
Note: * Do not set this bit to 1.

2	MSTP2	1	R/W	Host interface (XBS), keyboard buffer contro keyboard matrix interrupt mask register (KM keyboard matrix interrupt mask register A (K port 6 pull-up MOS control register (KMPCR
1	MSTP1	1*	R/W	—
0	MSTP0	1	R/W	Host interface (LPC), wake-up event interrup 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 prog
execution state to program halt state is performed by the SLEEP instruction. The mode
from program halt state to program execution state is performed by an interrupt. The $\overline{ST}$
causes a mode transition from any state to hardware standby mode. The $\overline{RES}$ input caus
transition from a state other than hardware standby mode to the reset state. Table 25.2 s
LSI internal states in each operating mode.



Notes: When a transition is made between modes by means of an interrupt, the transition canno
on interrupt source generation alone. Ensure that interrupt handling is performed after ac
interrupt request.
Always select high-speed mode before making a transition to watch mode or sub-active

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

		ing	Medium-speed operation		ing			operation	
External interrupts	NMI	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing	Function-ing
	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)
	WDT_1	Function-ing	Function-ing	Function-ing	Function-ing	Subclock operation	Subclock operation	Subclock operation	Halted (retained)
	WDT_0	Function-ing	Function-ing	Function-ing	Function-ing	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)
	TMR_0, TMR_1	Function-ing	Function-ing	Function-ing	Function-ing/Halted (retained)	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)
	FRT	Function-ing	Function-ing	Function-ing	Function-ing/Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)
	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)
	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)
	PWMX								
	XBS, Keyboard buffer controller								
	D/A								
	A/D								
	RAM	Function-ing	Function-ing	Function-ing (DTC)	Function-ing	Retained	Function-ing	Retained	Retained
	I/O	Function-ing	Function-ing	Function-ing	Function-ing	Retained	Function-ing	Function-ing	Retained

Note: * "Halted (retained)" means that internal register values are retained. The internal state is "operation
"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 re

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 current bus cycle.

If a SLEEP instruction is executed when the SSBY bit in SBYCR is cleared to 0, and bit in LPWRCR is cleared to 0, a transition is made to sleep mode. When sleep mode an interrupt, medium-speed mode is restored. When the SLEEP instruction is executed SSBY bit set to 1, the LSON bit cleared to 0, and the PSS bit in TCSR (WDT_1) clear operation shifts to software standby mode. When software standby mode is cleared by interrupt, medium-speed mode is restored.

When the $\overline{\text{RES}}$ pin is set low and medium-speed mode is cancelled, operation shifts to state. The same applies in the case of a reset caused by overflow of the watchdog time

When the $\overline{\text{STBY}}$ pin is driven low, medium-speed mode is cancelled and a transition i 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 t bit in SBYCR is cleared to 0 and the LSON bit in LPWRCR is cleared to 0. In sleep mo operation stops but the peripheral modules do not stop. The contents of the CPU's inter 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. is not exited if the interrupt is disabled, or interrupts other than NMI are masked by the

Setting the $\overline{\text{RES}}$ pin level low cancels sleep mode and selects the reset state. After the c stabilization time has passed, driving the $\overline{\text{RES}}$ pin high causes the CPU to start reset ex handling.

When the $\overline{\text{STBY}}$ pin level is driven low, sleep mode is cancelled and a transition is mad hardware standby mode.

states of on-chip peripheral modules other than the SCI, PWM, and PWMX, are retain
as the prescribed voltage is supplied.

Software standby mode is cleared by an external interrupt (NMI, IRQ0 to IRQ2, IRQ6
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
elapse of the time set in bits STS2 to STS0 in SBYCR, software standby mode is clea
interrupt exception handling is started. When clearing software standby mode with an
IRQ2, IRQ6, or IRQ7 interrupt, set the corresponding enable bit to 1 and ensure that n
with a higher priority than interrupts IRQ0 to IRQ2, IRQ6, and IRQ7 is generated. So
standby mode cannot be cleared if an interrupt enable bit corresponding to an IRQ0 to
IRQ6, or IRQ7 interrupt is cleared to 0 or if the interrupt has been masked on the CPU

When the $\overline{\text{RES}}$ pin is driven low, system clock oscillation is started. At the same time
clock oscillation starts, the system clock is supplied to the entire LSI. Note that the $\overline{\text{RE}}$
be held low until clock oscillation stabilizes. When the $\overline{\text{RES}}$ pin goes high after clock
stabilizes, the CPU begins reset exception handling.

When the $\overline{\text{STBY}}$ pin is driven low, software standby mode is cancelled and a transitio
hardware standby mode.

Figure 25.3 shows an example in which a transition is made to software standby mode
falling edge of the NMI pin, and software standby mode is cleared at the rising edge o
pin.

In this example, an NMI interrupt is accepted with the NMIEG bit in SYSCR cleared
edge specification), then the NMIEG bit is set to 1 (rising edge specification), the SSB
to 1, and a SLEEP instruction is executed, causing a transition to software standby mo

Software standby mode is then cleared at the rising edge of the NMI pin.

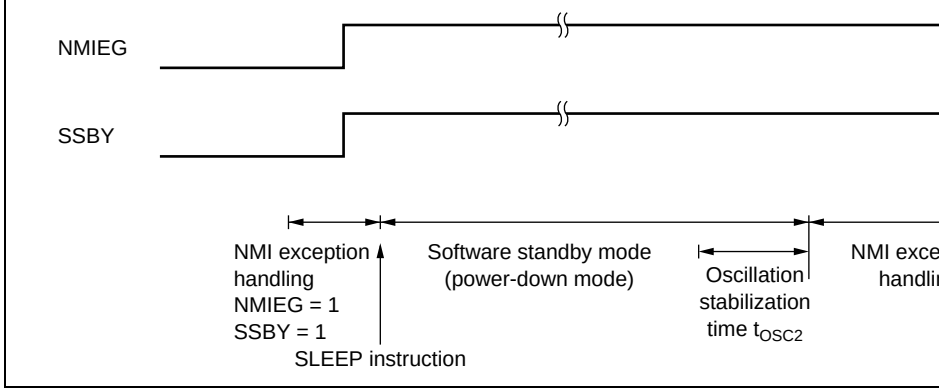


Figure 25.3 Application Example in Software Standby Mode

25.6 Hardware Standby Mode

The CPU makes a transition to hardware standby mode from any mode when the $\overline{\text{STBY}}$
driven low.

In hardware standby mode, all functions enter the reset state. As long as the prescribed
supplied, on-chip RAM data is retained. The I/O ports are set to the high-impedance sta

In order to retain on-chip RAM data, the RAME bit in SYSCR should be cleared to 0 b
driving the $\overline{\text{STBY}}$ pin low. Do not change the state of the mode pins (MD1 and MD0) v
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
that the $\overline{\text{RES}}$ pin is held low until system clock oscillation stabilizes. When the $\overline{\text{RES}}$ pin
subsequently driven high after the clock oscillation stabilization time has passed, reset
handling starts.

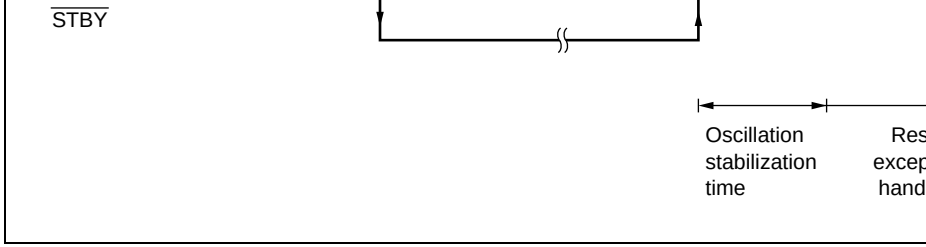


Figure 25.4 Hardware Standby Mode Timing

25.7 Watch Mode

The CPU makes a transition to watch mode when the SLEEP instruction is executed i mode or subactive mode with the SSBY bit in SBYCR set to 1, the DTON bit in LPW 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 als The contents of the CPU's internal registers, several on-chip peripheral module regist chip RAM data are retained and the I/O ports retain their values before transition as lo prescribed voltage is supplied.

Watch mode is exited by an interrupt (WOVI1, NMI, IRQ0 to IRQ2, IRQ6, or IRQ7), input, or $\overline{\text{STBY}}$ pin input.

When an interrupt occurs, watch mode is exited and a transition is made to high-speed medium-speed mode when the LSON bit in LPWRCR cleared to 0 or to subactive mo LSON bit is set to 1. When a transition is made to high-speed mode, a stable clock is s the entire LSI and interrupt exception handling starts after the time set in the STS2 to SBYCR has elapsed. In the case of an IRQ0 to IRQ2, IRQ6, or IRQ7 interrupt, watch exited if the corresponding enable bit has been cleared to 0. In the case of interrupts fr chip peripheral modules, watch mode is not exited if the interrupt enable register has b disable the reception of that interrupt, or the interrupt is masked by the CPU.

The CPU makes a transition to subsleep mode when the SLEEP instruction is executed subactive mode with the SSBY bit in SBYCR cleared to 0, the LSON bit in LPWRCR 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 and WDT_1 are also stopped. The contents of the CPU's internal registers, several on-c peripheral module registers, and on-chip RAM data are retained and the I/O ports retain values before transition as long as the prescribed voltage is supplied.

Subsleep mode is exited by an interrupt (interrupts by on-chip peripheral modules, NM 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 sta

In the case of an IRQ0 to IRQ7 interrupt, subsleep mode is not exited if the correspond bit has been cleared to 0. In the case of interrupts from the on-chip peripheral modules, mode is not exited if the interrupt enable register has been set to disable the reception o interrupt, or the interrupt is masked by the CPU.

When the $\overline{\text{RES}}$ pin is driven low, system clock oscillation starts. Simultaneously with th system clock oscillation, the system clock is supplied to the entire LSI. Note that the $\overline{\text{RE}}$ be held low until clock oscillation is stabilized. If the $\overline{\text{RES}}$ pin is driven high after the c 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.

executes programs. Peripheral modules other than TMR_0, TMR_1, WDT_0, and WD
also stopped.

When operating the CPU in subactive mode, the SCK2 to SCK0 bits in SBYCR must
0.

Subactive mode is exited by the SLEEP instruction, $\overline{\text{RES}}$ pin input, or $\overline{\text{STBY}}$ pin inpu

When the SLEEP instruction is executed with the SSBY bit in SBYCR set to 1, the D
LPWRCR cleared to 0, and the PSS bit in TCSR (WDT_1) set to 1, the CPU exits sub
and a transition is made to watch mode. When the SLEEP instruction is executed with
bit in SBYCR cleared to 0, the LSON bit in LPWRCR set to 1, and the PSS bit in TCS
set to 1, a transition is made to subsleep mode. When the SLEEP instruction is execute
SSBY bit in SBYCR set to 1, the DTON bit and LSON bit in LPWRCR set to 10, and
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
system clock oscillation, the system clock is supplied to the entire LSI. Note that the $\overline{\text{R}}$
be held low until the clock oscillation is stabilized. If the $\overline{\text{RES}}$ pin is driven high after
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.

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 reg
disabled.

25.11 Direct Transitions

The CPU executes programs in three modes: high-speed, medium-speed, and subactive
direct transition is made from high-speed mode to subactive mode, there is no interrupt
program execution. A direct transition is enabled by setting the DTON bit in LPWRCR
then executing the SLEEP instruction. After a transition, direct transition exception han
starts.

The CPU makes a transition to subactive mode when the SLEEP instruction is executed
speed mode with the SSBY bit in SBYCR set to 1, the LSON bit and DTON bit in LPW
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 b
SBYCR has elapsed, execute the SLEEP instruction in subactive mode with the SSBY
SBYCR set to 1, the LSON bit and DTON bit in LPWRCR set to 01, and the PSS bit in
(WDT_1) set to 1.

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 simultaneousl
released to the DTC and the MSTP bit cannot be set to 1. After completing the DTC b
the MSTP bit to 1 again.

- 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 A (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 allocate 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 above.
- The register states described here are for the basic operating modes. If there is a sp for an on-chip peripheral module, refer to the section on that on-chip peripheral mo

4. Register Select Conditions
- Register states are described in the same order as the Register Addresses (address above.
- For details on the register select conditions, refer to section 3.2.2, System Control (SYSCR), 3.2.3, Serial Timer Control Register (STCR), 26.1.3, Module Stop Cont H and L (MSTPCRH, MSTPCRL), and the register descriptions for each module.

Register Name	Abbreviation	of Bits	Address	Module	Width
Port G open drain control register	PGNOCR[*1]	8	H'FE16	PORT	8
Port E open drain control register	PENOCR[*1]	8	H'FE18	PORT	8
Port F open drain control register	PFNOCR[*1]	8	H'FE19	PORT	8
Port C open drain control register	PCNOCR[*1]	8	H'FE1C	PORT	8
Port D open drain control register	PDNOCR[*1]	8	H'FE1D	PORT	8
Bidirectional data register 0MW	TWR0MW	8	H'FE20	LPC	8
Bidirectional data register 0SW	TWR0SW	8	H'FE20	LPC	8
Bidirectional data register 1	TWR1	8	H'FE21	LPC	8
Bidirectional data register 2	TWR2	8	H'FE22	LPC	8
Bidirectional data register 3	TWR3	8	H'FE23	LPC	8
Bidirectional data register 4	TWR4	8	H'FE24	LPC	8
Bidirectional data register 5	TWR5	8	H'FE25	LPC	8
Bidirectional data register 6	TWR6	8	H'FE26	LPC	8
Bidirectional data register 7	TWR7	8	H'FE27	LPC	8
Bidirectional data register 8	TWR8	8	H'FE28	LPC	8
Bidirectional data register 9	TWR9	8	H'FE29	LPC	8
Bidirectional data register 10	TWR10	8	H'FE2A	LPC	8
Bidirectional data register 11	TWR11	8	H'FE2B	LPC	8
Bidirectional data register 12	TWR12	8	H'FE2C	LPC	8
Bidirectional data register 13	TWR13	8	H'FE2D	LPC	8
Bidirectional data register 14	TWR14	8	H'FE2E	LPC	8
Bidirectional data register 15	TWR15	8	H'FE2F	LPC	8
Input data register 3	IDR3	8	H'FE30	LPC	8
Output data register 3	ODR3	8	H'FE31	LPC	8
Status register 3	STR3	8	H'FE32	LPC	8

Input data register 1	IDR1	8	H'FE38	LPC	8
Output data register 1	ODR1	8	H'FE39	LPC	8
Status register 1	STR1	8	H'FE3A	LPC	8
Input data register 2	IDR2	8	H'FE3C	LPC	8
Output data register 2	ODR2	8	H'FE3D	LPC	8
Status register 2	STR2	8	H'FE3E	LPC	8
Host interface select register	HISEL	8	H'FE3F	LPC	8
Host interface control register 0	HICR0	8	H'FE40	LPC	8
Host interface control register 1	HICR1	8	H'FE41	LPC	8
Host interface control register 2	HICR2	8	H'FE42	LPC	8
Host interface control register 3	HICR3	8	H'FE43	LPC	8
Wakeup event interrupt mask register B	WUEMRB*2	8	H'FE44	INT	8
Port G output data register	PGODR*1	8	H'FE46	PORT	8
Port G input data register	PGPIN*1	8	H'FE47 (read)	PORT	8
Port G data direction register	PGDDR*1	8	H'FE47 (write)	PORT	8
Port E output data register	PEODR*1	8	H'FE48	PORT	8
Port F output data register	PFODR*1	8	H'FE49	PORT	8
Port E input data register	PEPIN*1	8	H'FE4A (read)	PORT	8
Port E data direction register	PEDDR*1	8	H'FE4A (write)	PORT	8
Port F input data register	PFPIN*1	8	H'FE4B (read)	PORT	8

Port C input data register	PCPIN[*1]	8	H'FE4E (read)	PORT	8
Port C data direction register	PCDDR[*1]	8	H'FE4E (write)	PORT	8
Port D input data register	PDPIN[*1]	8	H'FE4F (read)	PORT	8
Port D data direction register	PDDDR[*1]	8	H'FE4F (write)	PORT	8
Host interface control register 2	HICR2	8	H'FE80	XBS	8
Input data register_3	IDR_3	8	H'FE81	XBS	8
Output data register_3	ODR_3	8	H'FE82	XBS	8
Status register_3	STR_3	8	H'FE83	XBS	8
Input data register_4	IDR_4	8	H'FE84	XBS	8
Output data register_4	ODR_4	8	H'FE85	XBS	8
Status register_4	STR_4	8	H'FE86	XBS	8
I^2C bus extended control register_0	ICXR_0	8	H'FED4	IIC_0	8
I^2C bus extended control register_1	ICXR_1	8	H'FED5	IIC_1	8
Keyboard control register H_0	KBCRH_0	8	H'FED8	Keyboard buffer controller_0	8
Keyboard control register L_0	KBCRL_0	8	H'FED9	Keyboard buffer controller_0	8
Keyboard data buffer register_0	KBBR_0	8	H'FEDA	Keyboard buffer controller_0	8
Keyboard control register H_1	KBCRH_1	8	H'FEDC	Keyboard buffer controller_1	8

				controller_1	
Keyboard control register H_2	KBCRH_2	8	H'FEE0	Keyboard buffer controller_2	8
Keyboard control register L_2	KBCRL_2	8	H'FEE1	Keyboard buffer controller_2	8
Keyboard data buffer register_2	KBBR_2	8	H'FEE2	Keyboard buffer controller_2	8
Keyboard comparator control register	KBCOMP	8	H'FEE4	IrDA/ Extended A/D	8
DDC switch register	DDCSWR	8	H'FEE6	IIC_0	8
Interrupt control register A	ICRA	8	H'FEE8	INT	8
Interrupt control register B	ICRB	8	H'FEE9	INT	8
Interrupt control register C	ICRC	8	H'FEEA	INT	8
IRQ status register	ISR	8	H'FEEB	INT	8
IRQ sense control register H	ISCRH	8	H'FEEC	INT	8
IRQ sense control register L	ISCRL	8	H'FEED	INT	8
DTC enable register A	DTCERA	8	H'FEEE	DTC	8
DTC enable register B	DTCERB	8	H'FEEF	DTC	8
DTC enable register C	DTCERC	8	H'FEF0	DTC	8
DTC enable register D	DTCERD	8	H'FEF1	DTC	8
DTC enable register E	DTCERE	8	H'FEF2	DTC	8
DTC vector register	DTVECR	8	H'FEF3	DTC	8
Address break control register	ABRKCR	8	H'FEF4	INT	8

Flash memory control register 2	FLMCR2	8	H'FF81	FLASH	8
Peripheral clock select register	PCSR	8	H'FF82	PWM	8
Erase block register 1	EBR1	8	H'FF82	FLASH	8
System control register 2	SYSCR2	8	H'FF83	SYSTEM	8
Erase block register 2	EBR2	8	H'FF83	FLASH	8
Standby control register	SBYCR	8	H'FF84	SYSTEM	8
Low power control register	LPWRCR	8	H'FF85	SYSTEM	8
Module stop control register H	MSTPCRH	8	H'FF86	SYSTEM	8
Module stop control register L	MSTPCRL	8	H'FF87	SYSTEM	8
Serial mode register_1	SMR_1	8	H'FF88	SCI_1	8
I^2C bus control register_1	ICCR_1	8	H'FF88	IIC_1	8
Bit rate register_1	BRR_1	8	H'FF89	SCI_1	8
I^2C bus status register_1	ICSR_1	8	H'FF89	IIC_1	8
Serial control register_1	SCR_1	8	H'FF8A	SCI_1	8
Transmit data register_1	TDR_1	8	H'FF8B	SCI_1	8
Serial status register_1	SSR_1	8	H'FF8C	SCI_1	8
Receive data register_1	RDR_1	8	H'FF8D	SCI_1	8
Smart card mode register_1	SCMR_1	8	H'FF8E	SCI_1	8
I^2C bus data register_1	ICDR_1	8	H'FF8E	IIC_1	8
Second slave address register_1	SARX_1	8	H'FF8E	IIC_1	8
I^2C bus mode register_1	ICMR_1	8	H'FF8F	IIC_1	8
Slave address register_1	SAR_1	8	H'FF8F	IIC_1	8
Timer interrupt enable register	TIER	8	H'FF90	FRT	8
Timer control/status register	TCSR	8	H'FF91	FRT	8
Free running counter H	FRCH	8	H'FF92	FRT	8

Output control register BL	OCRBL	8	H'FF95	FRT	8
Timer control register	TCR	8	H'FF96	FRT	8
Timer output compare control register	TOCR	8	H'FF97	FRT	8
Input capture register AH	ICRAH	8	H'FF98	FRT	8
Output control register ARH	OCRARH	8	H'FF98	FRT	8
Input capture register AL	ICRAL	8	H'FF99	FRT	8
Output control register ARL	OCRARL	8	H'FF99	FRT	8
Input capture register BH	ICRBH	8	H'FF9A	FRT	8
Output control register AFH	OCRAFH	8	H'FF9A	FRT	8
Input capture register BL	ICRBL	8	H'FF9B	FRT	8
Output control register AFL	OCRAFL	8	H'FF9B	FRT	8
Input capture register CH	ICRCH	8	H'FF9C	FRT	8
Output compare register DMH	OCRDMH	8	H'FF9C	FRT	8
Input capture register CL	ICRCL	8	H'FF9D	FRT	8
Output compare register DML	OCRDML	8	H'FF9D	FRT	8
Input capture register DH	ICRDH	8	H'FF9E	FRT	8
Input capture register DL	ICRDL	8	H'FF9F	FRT	8
Serial mode register_2	SMR_2	8	H'FFA0	SCI_2	8
PWM (D/A) control register	DACR	8	H'FFA0	PWMX	8
PWM (D/A) data register AH	DADRAH	8	H'FFA0	PWMX	8
PWM (D/A) data register AL	DADRAL	8	H'FFA1	PWMX	8
Bit rate register_2	BRR_2	8	H'FFA1	SCI_2	8
Serial control register_2	SCR_2	8	H'FFA2	SCI_2	8
Transmit data register_2	TDR_2	8	H'FFA3	SCI_2	8

PWM (D/A) data register BH	DADRBH	8	H'FFA6	PWMX	8
PWM (D/A) counter L	DACNTL	8	H'FFA7	PWMX	8
PWM (D/A) data register BL	DADRBL	8	H'FFA7	PWMX	8
Timer control/status register_0	TCSR_0	8	H'FFA8	WDT	8
Timer counter_0	TCNT_0	8	H'FFA8 (write)	WDT_0	8
Timer counter_0	TCNT_0	8	H'FFA9 (read)	WDT_0	8
Port A output data register	PAODR	8	H'FFAA	PORT	8
Port A input data register	PAPIN	8	H'FFAB	PORT	8
Port A data direction register	PADDR	8	H'FFAB	PORT	8
Port 1 pull-up MOS control register	P1PCR	8	H'FFAC	PORT	8
Port 2 pull-up MOS control register	P2PCR	8	H'FFAD	PORT	8
Port 3 pull-up MOS control register	P3PCR	8	H'FFAE	PORT	8
Port 1 data direction register	P1DDR	8	H'FFB0	PORT	8
Port 2 data direction register	P2DDR	8	H'FFB1	PORT	8
Port 1 data register	P1DR	8	H'FFB2	PORT	8
Port 2 data register	P2DR	8	H'FFB3	PORT	8
Port 3 data direction register	P3DDR	8	H'FFB4	PORT	8
Port 4 data direction register	P4DDR	8	H'FFB5	PORT	8
Port 3 data register	P3DR	8	H'FFB6	PORT	8
Port 4 data register	P4DR	8	H'FFB7	PORT	8
Port 5 data direction register	P5DDR	8	H'FFB8	PORT	8
Port 6 data direction register	P6DDR	8	H'FFB9	PORT	8
Port 5 data register	P5DR	8	H'FFBA	PORT	8

Port 8 data direction register	P8DDR	8	H'FFBD (write)	PORT	8
Port 7 input data register	P7PIN	8	H'FFBE (read)	PORT	8
Port B data direction register	PBDDR	8	H'FFBE (write)	PORT	8
Port 8 data register	P8DR	8	H'FFBF	PORT	8
Port 9 data direction register	P9DDR	8	H'FFC0	PORT	8
Port 9 data register	P9DR	8	H'FFC1	PORT	8
Interrupt enable register	IER	8	H'FFC2	INT	8
Serial timer control register	STCR	8	H'FFC3	SYSTEM	8
System control register	SYSCR	8	H'FFC4	SYSTEM	8
Mode control register	MDCR	8	H'FFC5	SYSTEM	8
Bus control register	BCR	8	H'FFC6	BSC	8
Wait state control register	WSCR	8	H'FFC7	BSC	8
Timer control register_0	TCR_0	8	H'FFC8	TMR_0	8
Timer control register_1	TCR_1	8	H'FFC9	TMR_1	8
Timer control/status register_0	TCSR_0	8	H'FFCA	TMR_0	8
Timer control/status register_1	TCSR_1	8	H'FFCB	TMR_1	16
Time constant register A_0	TCORA_0	8	H'FFCC	TMR_0	16
Time constant register A_1	TCORA_1	8	H'FFCD	TMR_1	16
Time constant register B_0	TCORB_0	8	H'FFCE	TMR_0	16
Time constant register B_1	TCORB_1	8	H'FFCF	TMR_1	16
Timer counter_0	TCNT_0	8	H'FFD0	TMR_0	16
Timer counter_1	TCNT_1	8	H'FFD1	TMR_1	16
PWM output enable register B	PWOERB	8	H'FFD2	PWM	8

PWM data registers 0 to 15	PWDR0 to PWDR15	8	H'FFD7	PWM	8
Serial mode register_0	SMR_0	8	H'FFD8	SCI_0	8
I^2C bus control register_0	ICCR_0	8	H'FFD8	IIC_0	8
Bit rate register_0	BRR_0	8	H'FFD9	SCI_0	8
I^2C bus status register_0	ICSR_0	8	H'FFD9	IIC_0	8
Serial control register_0	SCR_0	8	H'FFDA	SCI_0	8
Transmit data register_0	TDR_0	8	H'FFDB	SCI_0	8
Serial status register_0	SSR_0	8	H'FFDC	SCI_0	8
Receive data register_0	RDR_0	8	H'FFDD	SCI_0	8
Smart card mode register_0	SCMR_0	8	H'FFDE	SCI_0	8
I^2C bus data register_0	ICDR_0	8	H'FFDE	IIC_0	8
Second slave address register_0	SARX_0	8	H'FFDE	IIC_0	8
I^2C bus mode register_0	ICMR_0	8	H'FFDF	IIC_0	8
Slave address register_0	SAR_0	8	H'FFDF	IIC_0	8
A/D data register AH	ADDRAH	8	H'FFE0	A/D converter	8
A/D data register AL	ADDRAL	8	H'FFE1	A/D converter	8
A/D data register BH	ADDRBH	8	H'FFE2	A/D converter	8
A/D data register BL	ADDRBL	8	H'FFE3	A/D converter	8
A/D data register CH	ADDRCH	8	H'FFE4	A/D converter	8
A/D data register CL	ADDRCL	8	H'FFE5	A/D converter	8
A/D data register DH	ADDRDH	8	H'FFE6	A/D converter	8
A/D data register DL	ADDRDL	8	H'FFE7	A/D converter	8
A/D control/status register	ADCSR	8	H'FFE8	A/D converter	8
A/D control register	ADCR	8	H'FFE9	A/D converter	8

			(read)		
Host interface control register	HICR	8	H'FFF0	XBS	8
Timer control register_X	TCR_X	8	H'FFF0	TMR_X	16
Timer control register_Y	TCR_Y	8	H'FFF0	TMR_Y	16
Keyboard matrix interrupt register 6	KMIMR	8	H'FFF1	INT	8
Timer control/status register_X	TCSR_X	8	H'FFF1	TMR_X	16
Timer control/status register_Y	TCSR_Y	8	H'FFF1	TMR_Y	16
Pull-up MOS control register	KMPCR	8	H'FFF2	PORT	8
Input capture register R	TICRR	8	H'FFF2	TMR_X	16
Time constant register A_Y	TCORA_Y	8	H'FFF2	TMR_Y	16
Keyboard matrix interrupt register A	KMIMRA	8	H'FFF3	INT	8
Input capture register F	TICRF	8	H'FFF3	TMR_X	16
Time constant register B_Y	TCORB_Y	8	H'FFF3	TMR_Y	16
Input data register_1	IDR_1	8	H'FFF4	XBS	8
Timer counter_X	TCNT_X	8	H'FFF4	TMR_X	16
Timer counter_Y	TCNT_Y	8	H'FFF4	TMR_Y	16
Output data register_1	ODR_1	8	H'FFF5	XBS	8
Timer constant register C	TCORC	8	H'FFF5	TMR_X	16
Timer input select register	TISR	8	H'FFF5	TMR_Y	16
Status register_1	STR_1	8	H'FFF6	XBS	8
Timer constant register A_X	TCORA_X	8	H'FFF6	TMR_X	16
Timer constant register B_X	TCORB_X	8	H'FFF7	TMR_X	16
D/A data register 0	DADR0	8	H'FFF8	D/A converter	8
D/A data register 1	DADR1	8	H'FFF9	D/A converter	8
D/A control register	DACR	8	H'FFFA	D/A converter	8
Input data register_2	IDR_2	8	H'FFFC	XBS	8

				connection	
Status register_2	STR_2	8	H'FFFE	XBS	8
Timer connection register S	TCONRS	8	H'FFFE	Timer connection	8
Edge sense register	SEDGR	8	H'FFFF	Timer connection	8

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).

PENOCR*1	PE7NOCR	PE6NOCR	PE5NOCR	PE4NOCR	PE3NOCR	PE2NOCR	PE1NOCR	PE0NO
PFNOCR*1	PF7NOCR	PF6NOCR	PF5NOCR	PF4NOCR	PF3NOCR	PF2NOCR	PF1NOCR	PF0NO
PCNOCR*1	PC7NOCR	PC6NOCR	PC5NOCR	PC4NOCR	PC3NOCR	PC2NOCR	PC1NOCR	PC0NO
PDNOCR*1	PD7NOCR	PD6NOCR	PD5NOCR	PD4NOCR	PD3NOCR	PD2NOCR	PD1NOCR	PD0NO
TWR0MW	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
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

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}$2	DBU22	IBF2	OBF2
HISEL	SELSTR3	SELIRQ11	SELIRQ10	SELIRQ9	SELIRQ6	SELSMI	SELIRQ12	SELIRQ
HICR0	LPC3E	LPC2E	LPC1E	FGA20E	SDWNE	PMEE	LSMIE	LSCIE
HICR1	LPCBSY	CLKREQ	IRQBSY	LRSTB	SDWNB	PMEB	LSMIB	LSCIB
HICR2	GA20	LRST	SDWN	ABRT	IBFIE3	IBFIE2	IBFIE1	ERRIE
HICR3	LFRAME	CLKRUN	SERIRQ	LRESET	LPCPD	PME	LSMI	LSCI
WUEMRB*5	WUEMR7	WUEMR6	WUEMR5	WUEMR4	WUEMR3	WUEMR2	WUEMR1	WUEMR
PGODR*1	PG7ODR	PG6ODR	PG5ODR	PG4ODR	PG3ODR	PG2ODR	PG1ODR	PG0OD
PGPIN*1	PG7PIN	PG6PIN	PG5PIN	PG4PIN	PG3PIN	PG2PIN	PG1PIN	PG0PIN
PGDDR*1	PG7DDR	PG6DDR	PG5DDR	PG4DDR	PG3DDR	PG2DDR	PG1DDR	PG0DD
PEODR*1	PE7ODR	PE6ODR	PE5ODR	PE4ODR	PE3ODR	PE2ODR	PE1ODR	PE0OD
PFODR*1	PF7ODR	PF6ODR	PF5ODR	PF4ODR	PF3ODR	PF2ODR	PF1ODR	PF0OD
PEPIN*1	PE7PIN	PE6PIN	PE5PIN	PE4PIN	PE3PIN	PE2PIN	PE1PIN	PE0PIN
PEDDR*1	PE7DDR	PE6DDR	PE5DDR	PE4DDR	PE3DDR	PE2DDR	PE1DDR	PE0DD
PFPIN*1	PF7PIN	PF6PIN	PF5PIN	PF4PIN	PF3PIN	PF2PIN	PF1PIN	PF0PIN
PFDDR*1	PF7DDR	PF6DDR	PF5DDR	PF4DDR	PF3DDR	PF2DDR	PF1DDR	PF0DD
PCODR*1	PC7ODR	PC6ODR	PC5ODR	PC4ODR	PC3ODR	PC2ODR	PC1ODR	PC0OD
PDODR*1	PD7ODR	PD6ODR	PD5ODR	PD4ODR	PD3ODR	PD2ODR	PD1ODR	PD0OD
PCPIN*1	PC7PIN	PC6PIN	PC5PIN	PC4PIN	PC3PIN	PC2PIN	PC1PIN	PC0PIN
PCDDR*1	PC7DDR	PC6DDR	PC5DDR	PC4DDR	PC3DDR	PC2DDR	PC1DDR	PC0DD
PDPIN*1	PD7PIN	PD6PIN	PD5PIN	PD4PIN	PD3PIN	PD2PIN	PD1PIN	PD0PIN
PDDDR*1	PD7DDR	PD6DDR	PD5DDR	PD4DDR	PD3DDR	PD2DDR	PD1DDR	PD0DD
HICR2	—	—	—	—	—	IBFIE4	IBFIE3	—
IDR_3	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0
ODR_3	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0
STR_3	DBU	DBU	DBU	DBU	C/$\overline{D}$	DBU	IBF	OBF

KBCRL_0	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR
KBBR_0	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0
KBCRH_1	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS
KBCRL_1	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR
KBBR_1	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0
KBCRH_2	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS
KBCRL_2	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR
KBBR_2	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0
KBCOMP	IrE	IrCKS2	IrCKS1	IrCKS0	KBADE	KBCH2	KBCH1	KBCH

DDCSWR	SWE	SW	IE	IF	CLR3	CLR2	CLR1	CLR0
ICRA	ICRA7	ICRA6	ICRA5	ICRA4	ICRA3	ICRA2	ICRA1	ICRA0
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	IRQ4S
ISCRL	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0S
DTCERA	DTCEA7	DTCEA6	DTCEA5	DTCEA4	DTCEA3	DTCEA2	DTCEA1	DTCE
DTCERB	DTCEB7	DTCEB6	DTCEB5	DTCEB4	DTCEB3	DTCEB2	DTCEB1	DTCE
DTCERC	DTCEC7	DTCEC6	DTCEC5	DTCEC4	DTCEC3	DTCEC2	DTCEC1	DTCE
DTCERD	DTCED7	DTCED6	DTCED5	DTCED4	DTCED3	DTCED2	DTCED1	DTCE
DTCERE	DTCEE7	DTCEE6	DTCEE5	DTCEE4	DTCEE3	DTCEE2	DTCEE1	DTCE
DTVECR	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVE
ABRKCR	CMF	—	—	—	—	—	—	BIE
BARA	A23	A22	A21	A20	A19	A18	A17	A16
BARB	A15	A14	A13	A12	A11	A10	A9	A8

EBR2	EB7	EB6	EB5	EB4	EB3	EB2	EB1	EB0
SBYCR	SSBY	STS2	STS1	STS0	—	SCK2	SCK1	SCK0
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
ICCR_1	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP
BRR_1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ICSR_1	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB
SCR_1	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0
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
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	—
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

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
DACR	TEST	PWME	—	—	OEB	OEA	OS	CKS
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
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
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
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	PA0OI
PAPIN	PA7PIN	PA6PIN	PA5PIN	PA4PIN	PA3PIN	PA2PIN	PA1PIN	PA0PI

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
STCR	IICS	IICX1	IICX0	IICE	FLSHE	—	ICKS1	ICKS0
SYSCR	CS2E	IOSE	INTM1	INTM0	XRST	NMIEG	HIE	RAME
MDCR	EXPE	—	—	—	—	—	MDS1	MDS0
BCR	—	ICIS0	BRSTRM	BRSTS1	BRSTS0	—	IOS1	IOS0
WSCR	—	—	ABW	AST	WMS1	WMS0	WC1	WC0
TCR_0	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0
TCR_1	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0
TCSR_0	CMFB	CMFA	OVF	ADTE	OS3	OS2	OS1	OS0

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
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
ICCR_0	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP
BRR_0	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ICSR_0	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB
SCR_0	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0
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
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
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

TCR_X	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0
TCR_Y	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0
KMIMR	KMIMR7	KMIMR6	KMIMR5	KMIMR4	KMIMR3	KMIMR2	KMIMR1	KMIMR0
TCSR_X	CMFB	CMFA	OVF	ICF	OS3	OS2	OS1	OS0
TCSR_Y	CMFB	CMFA	OVF	ICIE	OS3	OS2	OS1	OS0
KMPCR	KMIMR7	KMIMR6	KMIMR5	KMIMR4	KMIMR3	KMIMR2	KMIMR1	KMIMR0
TICRR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TCORA_Y	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
KMIMRA	KMIMR15	KMIMR14	KMIMR13	KMIMR12	KMIMR11	KMIMR10	KMIMR9	KMIMR8
TICRF	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TCORB_Y	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IDR_1	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0
TCNT_X	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TCNT_Y	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ODR_1	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0
TCORC	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TISR	—	—	—	—	—	—	—	IS
STR_1	DBU17	DBU16	DBU15	DBU14	C/$\overline{D}$1	DBU12	IBF1	OBF1
TCORA_X	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
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
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
TCONRI	SIMOD1	SIMOD0	SCONE	ICST	HFINV	VFINV	HIINV	VIINV
ODR_2	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0

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

PCNOCR[*1]	Initialized	—	—	—	—	—	—	—	Initializ
PDNOCR[*1]	Initialized	—	—	—	—	—	—	—	Initializ
TWR0MW	—	—	—	—	—	—	—	—	—
TWR0SW	—	—	—	—	—	—	—	—	—
TWR1	—	—	—	—	—	—	—	—	—
TWR2	—	—	—	—	—	—	—	—	—
TWR3	—	—	—	—	—	—	—	—	—
TWR4	—	—	—	—	—	—	—	—	—
TWR5	—	—	—	—	—	—	—	—	—
TWR6	—	—	—	—	—	—	—	—	—
TWR7	—	—	—	—	—	—	—	—	—
TWR8	—	—	—	—	—	—	—	—	—
TWR9	—	—	—	—	—	—	—	—	—
TWR10	—	—	—	—	—	—	—	—	—
TWR11	—	—	—	—	—	—	—	—	—
TWR12	—	—	—	—	—	—	—	—	—
TWR13	—	—	—	—	—	—	—	—	—
TWR14	—	—	—	—	—	—	—	—	—
TWR15	—	—	—	—	—	—	—	—	—
IDR3	—	—	—	—	—	—	—	—	—
ODR3	—	—	—	—	—	—	—	—	—
STR3	Initialized	—	—	—	—	—	—	—	Initializ
LADR3H	Initialized	—	—	—	—	—	—	—	Initializ
LADR3L	Initialized	—	—	—	—	—	—	—	Initializ
SIRQCR0	Initialized	—	—	—	—	—	—	—	Initializ
SIRQCR1	Initialized	—	—	—	—	—	—	—	Initializ
IDR1	—	—	—	—	—	—	—	—	—
ODR1	—	—	—	—	—	—	—	—	—

HICR0	Initialized	—	—	—	—	—	—	—	Initiali
HICR1	Initialized	—	—	—	—	—	—	—	Initiali
HICR2	Initialized	—	—	—	—	—	—	—	Initiali
HICR3	—	—	—	—	—	—	—	—	—
WUEMRB*2	Initialized	—	—	—	—	—	—	—	Initiali
PGODR*1	Initialized	—	—	—	—	—	—	—	Initiali
PGPIN*1	—	—	—	—	—	—	—	—	—
PGDDR*1	Initialized	—	—	—	—	—	—	—	Initiali
PEODR*1	Initialized	—	—	—	—	—	—	—	Initiali
PFODR*1	Initialized	—	—	—	—	—	—	—	Initiali
PEPIN*1	—	—	—	—	—	—	—	—	—
PEDDR*1	Initialized	—	—	—	—	—	—	—	Initiali
PFPIN*1	—	—	—	—	—	—	—	—	—
PFDDR*1	Initialized	—	—	—	—	—	—	—	Initiali
PCODR*1	Initialized	—	—	—	—	—	—	—	Initiali
PDODR*1	Initialized	—	—	—	—	—	—	—	Initiali
PCPIN*1	—	—	—	—	—	—	—	—	—
PCDDR*1	Initialized	—	—	—	—	—	—	—	Initiali
PDPIN*1	—	—	—	—	—	—	—	—	—
PDDDR*1	Initialized	—	—	—	—	—	—	—	Initiali
HICR2	Initialized	—	—	—	—	—	—	—	Initiali
IDR_3	—	—	—	—	—	—	—	—	—
ODR_3	—	—	—	—	—	—	—	—	—
STR_3	Initialized	—	—	—	—	—	—	—	Initiali
IDR_4	—	—	—	—	—	—	—	—	Initiali
ODR_4	—	—	—	—	—	—	—	—	Initiali
STR_4	Initialized	—	—	—	—	—	—	—	Initiali

KBCRH_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
KBCRL_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
KBBR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
KBCRH_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
KBCRL_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
KBBR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
KBCOMP	Initialized	—	—	—	—	—	—	—	Initializ
DDCSWR	Initialized	—	—	—	—	—	—	—	Initializ
ICRA	Initialized	—	—	—	—	—	—	—	Initializ
ICRB	Initialized	—	—	—	—	—	—	—	Initializ
ICRC	Initialized	—	—	—	—	—	—	—	Initializ
ISR	Initialized	—	—	—	—	—	—	—	Initializ
ISCRH	Initialized	—	—	—	—	—	—	—	Initializ
ISCRL	Initialized	—	—	—	—	—	—	—	Initializ
DTCERA	Initialized	—	—	—	—	—	—	—	Initializ
DTCERB	Initialized	—	—	—	—	—	—	—	Initializ
DTCERC	Initialized	—	—	—	—	—	—	—	Initializ
DTCERD	Initialized	—	—	—	—	—	—	—	Initializ
DTCERE	Initialized	—	—	—	—	—	—	—	Initializ
DTVECR	Initialized	—	—	—	—	—	—	—	Initializ
ABRKCR	Initialized	—	—	—	—	—	—	—	Initializ
BARA	Initialized	—	—	—	—	—	—	—	Initializ
BARB	Initialized	—	—	—	—	—	—	—	Initializ
BARC	Initialized	—	—	—	—	—	—	—	Initializ
FLMCR1	Initialized	—	Initialized	—	Initialized	Initialized	—	Initialized	Initializ
FLMCR2	Initialized	—	Initialized	—	Initialized	Initialized	—	Initialized	Initializ

LPWRCR	Initialized	—	—	—	—	—	—	—	Initiali
MSTPCRH	Initialized	—	—	—	—	—	—	—	Initiali
MSTPCRL	Initialized	—	—	—	—	—	—	—	Initiali
SMR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
ICCR_1	Initialized	—	—	—	—	—	—	—	Initiali
BRR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
ICSR_1	Initialized	—	—	—	—	—	—	—	Initiali
SCR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
TDR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
SSR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
RDR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
SCMR_1	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initiali
ICDR_1	—	—	—	—	—	—	—	—	—
SARX_1	Initialized	—	—	—	—	—	—	—	Initiali
ICMR_1	Initialized	—	—	—	—	—	—	—	Initiali
SAR_1	Initialized	—	—	—	—	—	—	—	Initiali
TIER	Initialized	—	—	—	—	—	—	—	Initiali
TCSR	Initialized	—	—	—	—	—	—	—	Initiali
FRCH	Initialized	—	—	—	—	—	—	—	Initiali
FRCL	Initialized	—	—	—	—	—	—	—	Initiali
OCRAH	Initialized	—	—	—	—	—	—	—	Initiali
OCRBH	Initialized	—	—	—	—	—	—	—	Initiali
OCRAL	Initialized	—	—	—	—	—	—	—	Initiali
OCRBL	Initialized	—	—	—	—	—	—	—	Initiali
TCR	Initialized	—	—	—	—	—	—	—	Initiali
TOCR	Initialized	—	—	—	—	—	—	—	Initiali
ICRAH	Initialized	—	—	—	—	—	—	—	Initiali
OCRARH	Initialized	—	—	—	—	—	—	—	Initiali

OCRAFL	Initialized	—	—	—	—	—	—	—	Initializ
ICRCH	Initialized	—	—	—	—	—	—	—	Initializ
OCRDMH	Initialized	—	—	—	—	—	—	—	Initializ
ICRCL	Initialized	—	—	—	—	—	—	—	Initializ
OCRDML	Initialized	—	—	—	—	—	—	—	Initializ
ICRDH	Initialized	—	—	—	—	—	—	—	Initializ
ICRDL	Initialized	—	—	—	—	—	—	—	Initializ
SMR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
DACR	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
DADRAH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
DADRAL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
BRR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
SCR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
TDR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
SSR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
RDR_2	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
SCMR_2	Initialized	—	—	—	—	—	—	—	Initializ
DACNTH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
DADRBH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
DACNTL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
DADRBL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
TCSR_0	Initialized	—	—	—	—	—	—	—	Initializ
TCNT_0	Initialized	—	—	—	—	—	—	—	Initializ
PAODR	Initialized	—	—	—	—	—	—	—	Initializ
PAPIN	—	—	—	—	—	—	—	—	—
PADDR	Initialized	—	—	—	—	—	—	—	Initializ
P1PCR	Initialized	—	—	—	—	—	—	—	Initializ
P2PCR	Initialized	—	—	—	—	—	—	—	Initializ

P3DDR	Initialized	—	—	—	—	—	—	—	Initiali
P4DDR	Initialized	—	—	—	—	—	—	—	Initiali
P3DR	Initialized	—	—	—	—	—	—	—	Initiali
P4DR	Initialized	—	—	—	—	—	—	—	Initiali
P5DDR	Initialized	—	—	—	—	—	—	—	Initiali
P6DDR	Initialized	—	—	—	—	—	—	—	Initiali
P5DR	Initialized	—	—	—	—	—	—	—	Initiali
P6DR	Initialized	—	—	—	—	—	—	—	Initiali
PBODR	Initialized	—	—	—	—	—	—	—	Initiali
PBPIN	—	—	—	—	—	—	—	—	—
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P7PIN	—	—	—	—	—	—	—	—	—
PBDDR	Initialized	—	—	—	—	—	—	—	Initiali
P8DR	Initialized	—	—	—	—	—	—	—	Initiali
P9DDR	Initialized	—	—	—	—	—	—	—	Initiali
P9DR	Initialized	—	—	—	—	—	—	—	Initiali
IER	Initialized	—	—	—	—	—	—	—	Initiali
STCR	Initialized	—	—	—	—	—	—	—	Initiali
SYSCR	Initialized	—	—	—	—	—	—	—	Initiali
MDCR	Initialized	—	—	—	—	—	—	—	Initiali
BCR	Initialized	—	—	—	—	—	—	—	Initiali
WSCR	Initialized	—	—	—	—	—	—	—	Initiali
TCR_0	Initialized	—	—	—	—	—	—	—	Initiali
TCR_1	Initialized	—	—	—	—	—	—	—	Initiali
TCSR_0	Initialized	—	—	—	—	—	—	—	Initiali
TCSR_1	Initialized	—	—	—	—	—	—	—	Initiali
TCORA_0	Initialized	—	—	—	—	—	—	—	Initiali
TCORA_1	Initialized	—	—	—	—	—	—	—	Initiali

PWOERA	Initialized	—	—	—	—	—	—	—	Initializ
PWDPRB	Initialized	—	—	—	—	—	—	—	Initializ
PWDPRA	Initialized	—	—	—	—	—	—	—	Initializ
PWSL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
PWDR0 to PWDR15	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
SMR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ICCR_0	Initialized	—	—	—	—	—	—	—	Initializ
BRR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ICSR_0	Initialized	—	—	—	—	—	—	—	Initializ
SCR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
TDR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
SSR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
RDR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
SCMR_0	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ICDR_0	—	—	—	—	—	—	—	—	—
SARX_0	Initialized	—	—	—	—	—	—	—	Initializ
ICMR_0	Initialized	—	—	—	—	—	—	—	Initializ
SAR_0	Initialized	—	—	—	—	—	—	—	Initializ
ADDRAH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRAL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRBH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRBL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRCH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRCL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRDH	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADDRDL	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ
ADCSR	Initialized	—	Initialized	—	Initialized	Initialized	Initialized	Initialized	Initializ

TCR_X	Initialized	—	—	—	—	—	—	—	Initiali
TCR_Y	Initialized	—	—	—	—	—	—	—	Initiali
KMIMR	Initialized	—	—	—	—	—	—	—	Initiali
TCSR_X	Initialized	—	—	—	—	—	—	—	Initiali
TCSR_Y	Initialized	—	—	—	—	—	—	—	Initiali
KMPCR	Initialized	—	—	—	—	—	—	—	Initiali
TICRR	Initialized	—	—	—	—	—	—	—	Initiali
TCORA_Y	Initialized	—	—	—	—	—	—	—	Initiali
KMIMRA	Initialized	—	—	—	—	—	—	—	Initiali
TICRF	Initialized	—	—	—	—	—	—	—	Initiali
TCORB_Y	Initialized	—	—	—	—	—	—	—	Initiali
IDR_1	—	—	—	—	—	—	—	—	—
TCNT_X	Initialized	—	—	—	—	—	—	—	Initiali
TCNT_Y	Initialized	—	—	—	—	—	—	—	Initiali
ODR_1	—	—	—	—	—	—	—	—	—
TCORC	Initialized	—	—	—	—	—	—	—	Initiali
TISR	Initialized	—	—	—	—	—	—	—	Initiali
STR_1	Initialized	—	—	—	—	—	—	—	Initiali
TCORA_X	Initialized	—	—	—	—	—	—	—	Initiali
TCORB_X	Initialized	—	—	—	—	—	—	—	Initiali
DADR0	Initialized	—	—	—	—	—	—	—	Initiali
DADR1	Initialized	—	—	—	—	—	—	—	Initiali
DACR	Initialized	—	—	—	—	—	—	—	Initiali
IDR_2	—	—	—	—	—	—	—	—	—
TCONRI	Initialized	—	—	—	—	—	—	—	Initiali
ODR_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).

H'FE1C	PCNOCR			
H'FE1D	PDNOCR			
H'FE20	TWR0MW	MSTP = 0, (HI12E = 0)*	MSTP = 0, (HI12E = 0)*	L
	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			

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	IN
H'FE46	PGODR	—	No condition	PG
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			

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	I
H'FED5	ICXR_1			I
H'FED8	KBCRH_0	MSTP2 = 0	MSTP2 = 0	K b c
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	I e
H'FEE6	DDCSWR	MSTP4 = 0	MSTP4 = 0	I
H'FEE8	ICRA	No condition	No condition	I
H'FEE9	ICRB			
H'FEEA	ICRC			
H'FEEB	ISR			
H'FEEC	ISCRH			
H'FEED	ISCRL			

H'FEF3	DTVECR			
H'FEF4	ABRKCR	No condition	No condition	IN
H'FEF5	BARA			
H'FEF6	BARB			
H'FEF7	BARC			
H'FF80	FLMCR1	FLSHE = 1 in STCR	FLSHE = 1 in STCR	FL
H'FF81	FLMCR2			
H'FF82	PCSR	FLSHE = 0 in STCR	FLSHE = 0 in STCR	PW
	EBR1	FLSHE = 1 in STCR	FLSHE = 1 in STCR	FL
H'FF83	SYSCR2	FLSHE = 0 in STCR	FLSHE = 0 in STCR	SY
	EBR2	FLSHE = 1 in STCR	FLSHE = 1 in STCR	FL
H'FF84	SBYCR	FLSHE = 0 in STCR	FLSHE = 0 in STCR	SY
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	SC
	ICCR_1	MSTP3 = 0, IICE = 1 in STCR	MSTP3 = 0, IICE = 1 in STCR	IIC
H'FF89	BRR_1	MSTP6 = 0, IICE = 0 in STCR	MSTP6 = 0, IICE = 0 in STCR	SC
	ICSR_1	MSTP3 = 0, IICE = 1 in STCR	MSTP3 = 0, IICE = 1 in STCR	IIC

		STCR		STCR		
	ICDR_1	MSTP3 = 0, IICE = 1 in STCR	ICE = 1 in ICCR1	MSTP3 = 0, IICE = 1 in STCR	ICE = 1 in ICCR1	I
	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		F
H'FF91	TCSR					
H'FF92	FRCH					
H'FF93	FRCL					
H'FF94	OCRAH	MSTP13 = 0	OCRS = 0 in TOCR	MSTP13 = 0	OCRS = 0 in TOCR	F
	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	

	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		SC
	DADRAH	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	PW
	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		SC
	DADRAL	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	PW

		STCR		STCR		
	DADRBH	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	P
	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		W
	TCNT_0 (write)					
H'FFA9	TCNT_0 (read)					
H'FFAA	PAODR	No condition		No condition		P
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					

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	IN
H'FFC3	STCR	No condition	No condition	SY
H'FFC4	SYSCR			
H'FFC5	MDCR			
H'FFC6	BCR	No condition	No condition	BS
H'FFC7	WSCR			
H'FFC8	TCR_0	MSTP12 = 0	MSTP12 = 0	TM
H'FFC9	TCR_1			TM
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			

H'FFD7	PWDR0 to PWDR15					
H'FFD8	SMR_0	MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR		S
	ICCR_0	MSTP4 = 0, IICE = 1 in STCR		MSTP4 = 0, IICE = 1 in STCR		I
H'FFD9	BRR_0	MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR		S
	ICSR_0	MSTP4 = 0, IICE = 1 in STCR		MSTP4 = 0, IICE = 1 in STCR		I
H'FFDA	SCR_0	MSTP7 = 0		MSTP7 = 0		S
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	I
	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	

H'FFE5	ADDRCL					
H'FFE6	ADDRDH					
H'FFE7	ADDRDL					
H'FFE8	ADCSR					
H'FFE9	ADCR					
H'FFEA	TCSR_1	No condition		No condition		W
	TCNT_1 (write)					
H'FFEB	TCNT_1 (read)					
H'FFF0	HICR	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		XE
	TCR_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TM
	TCR_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TM
H'FFF1	KMIMR	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		IN
	TCSR_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	TM
	TCSR_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	TM

			in TCONRS			in TCONRS
H'FFF3	KMIMRA	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		I
	TICRF	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	T
	TCORB_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	T
H'FFF4	IDR_1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		X
	TCNT_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	T
	TCNT_Y		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	T
H'FFF5	ODR_1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		X
	TCORC	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	T
	TISR		TMRX/Y = 1 in TCONRS		TMRX/Y = 1 in TCONRS	T
H'FFF6	STR_1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		X
	TCORA_X	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	T
H'FFF7	TCORB_X					

	TCONRI	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR	Tir co
H'FFFD	ODR_2	MSTP2 = 0, HIE = 1 in SYSCR	MSTP2 = 0, HIE = 1 in SYSCR	XE
	TCONRO	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR	Tir co
H'FFFE	STR_2	MSTP2 = 0, HIE = 1 in SYSCR	MSTP2 = 0, HIE = 1 in SYSCR	XE
	TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR	Tir co
H'FFFF	SEDGR			

Note: * Although setting the XBS corresponding bits does not affected to the LPC op the HI12E bit in SYSCR2 must not be set to 1 to use the LPC according to th depending on the program development tool (emulator) configuration.

Table 27.1 lists the absolute maximum ratings.

Table 27.1 Absolute Maximum Ratings

Item	Symbol	Value
Power supply voltage	V_{CC}, V_{CL}	–0.3 to +4.3
I/O buffer power supply voltage	$V_{CC}B$	–0.3 to +7.0
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
Input voltage (CIN input not selected for port 6)	V_{in}	–0.3 to V_{CC} + 0.3
Input voltage (CIN input not selected for port A)	V_{in}	–0.3 to $V_{CC}B$ + 0.3
Input voltage (CIN input selected for port 6)	V_{in}	–0.3 V to lower of voltag V_{CC} + 0.3 and AV_{CC} + 0.3
Input voltage (CIN input selected for port A)	V_{in}	–0.3 V to lower of voltag $V_{CC}B$ + 0.3 and AV_{CC} + 0
Input voltage (P97, P86, P52, P42)	V_{in}	–0.3 to +7.0
Input voltage (port 7)	V_{in}	–0.3 to AV_{CC} + 0.3
Reference supply voltage	AV_{ref}	–0.3 to AV_{CC} + 0.3
Analog power supply voltage	AV_{CC}	–0.3 to +4.3
Analog input voltage	V_{AN}	–0.3 to AV_{CC} + 0.3
Operating temperature	T_{opr}	–20 to +75
Operating temperature (flash memory programming/erasing)	T_{opr}	–20 to +75
Storage temperature	T_{stg}	–55 to +125

Caution: Permanent damage to the chip may result if absolute maximum ratings are ex
Ensure so that the impressed voltage does not exceed 4.3 V for pins for whic
maximum rating is determined by the voltage on the V_{CC}, AV_{CC}, and V_{CL} pins, o
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.

Item			Symbol	Min	Typ	Max	Unit
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]			$V_{cc}B \times 0.7$	—	$V_{cc}B + 0.3$	

	H8S/2160B and H8S/2161B.)						
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	—	$V_{CC}B \times 0.2$	
						0.8	
	NMI, EXTAL, input pins except (1) and (3) above (Ports C to G are added in the H8S/2160B and H8S/2161B.)			–0.3	—	$V_{CC} \times 0.2$	
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
				$V_{CC} – 1.0$ $V_{CC}B – 1.0$	—	—	V
	P97, P86, P52, and P42*4 (Port G is added in the H8S/2160B and H8S/2161B.)			0.5	—	—	V

$\overline{RESO}$	—	—	0.4	V	I_O

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter a converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in th V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or 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 NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it open-drain output. Therefore, an external pull-up resistor must be connected output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are NMOS.

An external pull-up resistor is necessary to provide high-level output from SC and SCK2.

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driv 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 selected, and the lower of V_{CC} + 0.3 V and AV_{CC} + 0.3 V when CIN input is se When a pin is in output mode, the output voltage is equivalent to the applied
7. The upper limit of the port A applied voltage is $V_{CC}B$ + 0.3 V when CIN input selected, and the lower of $V_{CC}B$ + 0.3 V and AV_{CC} + 0.3 V when CIN input is s When a pin is in output mode, the output voltage is equivalent to the applied
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics on V_{CC}.
9. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V

current	MD0					
	Port 7		—	—	1.0	
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
Input pull-up MOS current	Ports 1 to 3	$-I_P$	5	—	150	µA
	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
	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

supply current	Idle		—	0.01	5.0	µA	A to
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	A to
Analog power supply voltage*1		AV_{CC}	2.7	—	3.6	V	C
			2.0	—	3.6		Id
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 ar converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in th V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or s 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 i 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 on V_{CC}.
5. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V

	PB1, PB0					
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} = –
Output low voltage	P37, P33 to P30, P82 to P80, PB1, PB0	V_{OL}	—	$V_{CC} \times 0.1$	V	I_{OL} = 1

Note: * Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter a converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC} other method. Ensure that $AV_{ref} \leq AV_{CC}$.

	function selected)				
	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
	Total of all output pins, including the above		—	—	60
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	30

Notes: 1. To protect chip reliability, do not exceed the output current values in table 27

2. When driving a Darlington pair or LED, always insert a current-limiting resist output line, as show in figures 27.1 and 27.2.

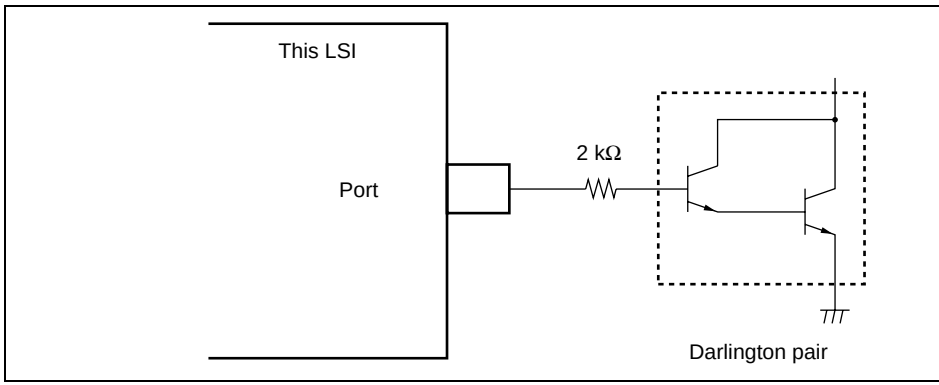


Figure 27.1 Darlington Pair Drive Circuit (Example)

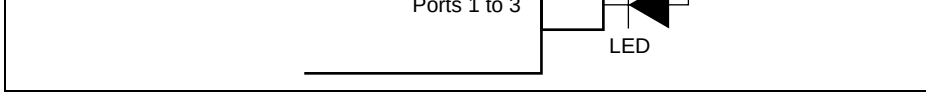


Figure 27.2 LED Drive Circuit (Example)

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 Cond
Schmitt trigger input voltage	V_T^-	$V_{CC} \times 0.3$	—	—	V	V_{CC} = 2.7 V
	V_T^+	—	—	$V_{CC} \times 0.7$		V_{CC} = 2.7 V
	$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		V_{CC} = 2.7 V
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	5.5	V	V_{CC} = 2.7 V
Input low voltage	V_{IL}	–0.5	—	$V_{CC} \times 0.3$		V_{CC} = 2.7 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 T_a = 25°C
Three-state leakage current (off state)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to
SCL, SDA output fall time	t_{Of}	20 + 0.1Cb	—	250	ns	V_{CC} = 2.7 V

—	—	0.4	I_{OL} = 3 mA

27.1.3 AC Characteristics

Figure 27.3 shows the test conditions for the AC characteristics.

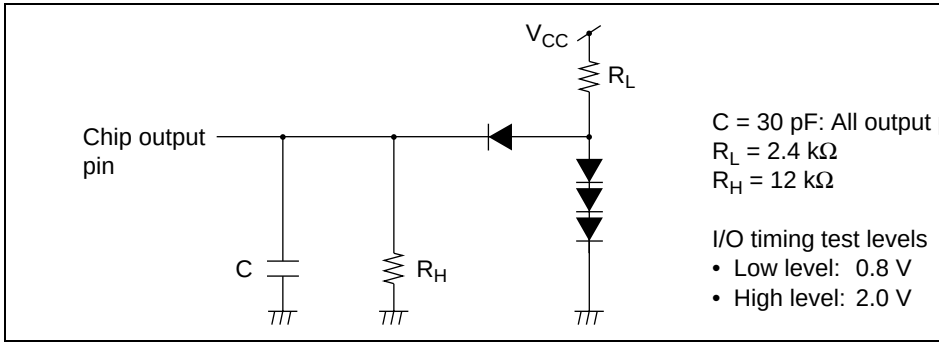


Figure 27.3 Output Load Circuit

		Condition			
		10 MHz			
Item	**Symbol**	**Min**	**Max**	**Unit**	
Clock cycle time	t_{cyc}	100	500	ns	
Clock high pulse width	t_{CH}	30	—	ns	
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	
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	ms	
External clock output stabilization delay time	t_{DEXT}	500	—	µs	

Item	Symbol	10 MHz Min	10 MHz Max	Unit	T C
$\overline{\text{RES}}$ setup time	t_{RESS}	300	—	ns	Fi
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	250	—	ns	Fi
NMI hold time (NMI)	t_{NMIH}	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	ns	
IRQ setup time ($\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$)	t_{IRQS}	250	—	ns	
IRQ hold time($\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$)	t_{IRQH}	10	—	ns	
IRQ pulse width ($\overline{\text{IRQ7}}$, $\overline{\text{IRQ6}}$, $\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$) (exiting software standby mode)	t_{IRQW}	200	—	ns	

Item	Symbol	10 MHz Min	10 MHz Max	Unit	Te Co
Address delay time	t_{AD}	—	40	ns	Fi to
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	

Address delay time	t_{AD}	—	60	ns
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

Item			Symbol	Condition 10 MHz Min	Max	Unit	Test
I/O ports	Output data delay time		t_{PWD}	—	100	ns	Figu
	Input data setup time		t_{PRS}	50	—		
	Input data hold time		t_{PRH}	50	—		
FRT	Timer output delay time		t_{FTOD}	—	100	ns	Figu
	Timer input setup time		t_{FTIS}	50	—		
	Timer clock input setup time		t_{FTCS}	50	—		Figu
	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	Figu
	Timer reset input setup time		t_{TMRS}	50	—		Figu
	Timer clock input setup time		t_{TMCS}	50	—		Figu
	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	Figu
SCI	Input clock cycle	Asynchronous	t_{Scyc}	4	—	t_{cyc}	Figu
		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		

A/D converter	Trigger input setup time	t_{TRGS}	50	—	ns	Figure
WDT	$\overline{\text{RESO}}$ output delay time	t_{RESD}	—	200	ns	Figure
	$\overline{\text{RESO}}$ 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 max operating frequency, T_a = –20 to +75°C

			Condition			
			10 MHz			
Item		Symbol	Min	Max	Unit	Test
XBS read cycle	$\overline{\text{CS}}$/HA0 setup time	t_{HAR}	10	—	ns	Figur
	$\overline{\text{CS}}$/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	
	HDB setup time — Fast A20 gate used		85	—	ns	
	HDB hold time	t_{HWD}	25	—	ns	
	GA20 delay time	t_{HGA}	—	180	ns	

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 I²C Bus Timing

Conditions: V_{CC} = 2.7 V to 3.6 V, V_{SS} = 0 V, ϕ = 5 MHz to maximum operating frequ
T_a = –20 to +75°C

Item	Symbol	Ratings Min	Typ	Max	Unit	Test Conditions
SCL input cycle time	t_{SCL}	12	—	—	t_{cyc}	
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 I²C modul
details, see section 16.6, Usage Notes.

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	—	—

	Condition		
	10 MHz		
Item	**Min**	**Typ**	**Max**
Resolution	10	10	10
Conversion time	—	—	13.4
Analog input capacitance	—	—	20
Permissible signal-source impedance	—	—	5
Nonlinearity error	—	—	±7.0
Offset error	—	—	±7.5
Full-scale error	—	—	±7.5
Quantization error	—	—	±0.5
Absolute accuracy	—	—	±8.0

Item	Min	Typ	Max
Resolution	10	10	10
Conversion time	—	—	13.4
Analog input capacitance	—	—	20
Permissible signal-source impedance	—	—	5
Nonlinearity error	—	—	±11.0
Offset error	—	—	±11.5
Full-scale error	—	—	±11.5
Quantization error	—	—	±0.5
Absolute accuracy	—	—	±12.0

Item		Condition		
		10 MHz		
		Min	Typ	Max
Resolution		8	8	8
Conversion time	With 20 pF load capacitance	—	—	10
Absolute accuracy	With 2 MΩ load resistance	—	±2.0	±3.0
	With 4 MΩ load resistance	—	—	±2.0

Item		Symbol	Min	Typ	Max	Unit
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
		z2	198	200	202	µs
		z3	8	10	12	µs
	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

z1, z2 and z3 to allow programming within the maximum programming time

The wait time after P-bit setting (z1, z2, and z3) should be alternated accord number of writes (n) as follows:

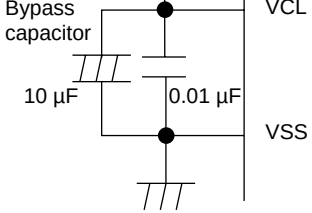
$1 \leq n \leq 6$ z1 = 30µs, z3 = 10µs

$7 \leq n \leq 1000$ z2 = 200µs

6. Maximum erase time (t_E (max))

   t_E (max) = Wait time after E-bit setting (z) × maximum erase count (N)

7. The maximum number of erases (N) should be set according to the actual s to allow erasing within the maximum erase time (t_E (max)).
8. Minimum number of times for which all characteristics are guaranteed after (Guarantee range is 1 to minimum value).
9. Reference value for 25°C (as a guideline, rewriting should normally functio value).
10. Data retention characteristic when rewriting is performed within the specific including the minimum value.



< 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

Power supply voltage*1	V_{CC}	–0.3 to +7.0
I/O buffer power supply voltage (power supply for port A)	$V_{CC}B$	–0.3 to +7.0
Power supply voltage (3-V version product)*1	V_{CC}	–0.3 to +4.3
Power supply voltage (VCL pin)*2	V_{CL}	–0.3 to +4.3
Input voltage (except ports 6, 7, and A, P97, P86, P52, P42)	V_{in}	–0.3 to V_{CC} + 0.3
Input voltage (CIN input not selected for port 6)	V_{in}	–0.3 to V_{CC} + 0.3
Input voltage (CIN input not selected for port A)	V_{in}	–0.3 to $V_{CC}B$ + 0.3
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
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
Input voltage (P97, P86, P52, P42)	V_{in}	–0.3 to +7.0
Input voltage (port 7)	V_{in}	–0.3 to AV_{CC} + 0.3
Reference supply voltage	AV_{ref}	–0.3 to AV_{CC} + 0.3
Analog power supply voltage	AV_{CC}	–0.3 to +7.0
Analog power supply voltage (3-V version product)	AV_{CC}	–0.3 to +4.3
Analog input voltage	V_{AN}	–0.3 to AV_{CC} + 0.3
Operating temperature	T_{opr}	Normal specification product: –20 to +
		Wide range temperature specification product: –40 to +85

Notes: 1. Voltage applied to the VCC1 pin. Since both the VCC1 pin and VCL pin are
to the VCC power supply on low-power voltage (3-V) products, VCL ratings
be exceeded.
2. Power supply voltage pin used for operation within the chip. Do not apply po
voltage to the VCL pin on 5-V/4-V products. Be sure to insert an external ca
between the VCL pin and GND to regulate the internal voltage.

product), T_a = –40 to +85°C (wide range temperature specification produ

Item			Symbol	Min	Typ	Max	Unit
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	

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_O
			3.5	—	—	V	I_O
	P97, P86, P52, and P42*4		2.0	—	—	V	I_O
Output low voltage	All output pins (except $\overline{RESO}$)*5	V_{OL}	—	—	0.4	V	I_O
	Ports 1 to 3		—	—	1.0	V	I_O
	$\overline{RESO}$		—	—	0.4	V	I_O

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter ar converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in th 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), 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 NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it open-drain output. Therefore, an external pull-up resistor must be connected output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are NMOS.

When the SCK0, SCK1, or SCK2 pin is used as an output, an external pull-u must be connected in order to output high level.

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driv 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 selected, and the lower of V_{CC} + 0.3 V and AV_{CC} + 0.3 V when CIN input is se When a pin is in output mode, the output voltage is equivalent to the applied
7. The upper limit of the port A applied voltage is $V_{CC}B$ + 0.3 V when CIN input selected, and the lower of $V_{CC}B$ + 0.3 V and AV_{CC} + 0.3 V when CIN input is s When a pin is in output mode, the output voltage is equivalent to the applied

Item			Symbol	Min	Typ	Max	Unit
Input leakage current	$\overline{RES}$		$\lvert I_{in} \rvert$	—	—	10.0	µA
	$\overline{STBY}$, NMI, MD1, MD0			—	—	1.0	
	Port 7			—	—	1.0	
Three-state leakage current (off state)	Ports 1 to 6 Ports 8, 9, A*4, B		$\lvert I_{TSI} \rvert$	—	—	1.0	µA
Input pull-up MOS current	Ports 1 to 3		$-I_P$	30	—	300	µA
	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
	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
	Sleep mode			—	36	55	mA
	Standby mode*3			—	1.0	5.0	µA
				—	—	20.0	
Analog power supply current	During A/D, D/A conversion		AI_{CC}	—	1.2	2.0	mA
	Idle			—	0.01	5.0	µA

		2.0	—	5.5	I
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 ar converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in th V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or s 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} 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 on V_{CC}.

trigger input voltage	= 00)*2 *6, $\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$*7 *8, $\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$*3, $\overline{\text{IRQ5}}$ to $\overline{\text{IRQ3}}$		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_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_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	$\overline{\text{RES}}$, $\overline{\text{STBY}}$, 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	—	$V_{CC} + 0.3$	

	input pins except (1) and (3) above						
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_O
			3.5	—	—	V	I_O V 5 4
			3.0	—	—	V	I_O V 4 4
	P97, P86, P52, and P42*4		1.5	—	—	V	I_O
Output low voltage	All output pins (except $\overline{\text{RESO}}$)*5	V_{OL}	—	—	0.4	V	I_O
	Ports 1 to 3		—	—	1.0	V	I_O
	$\overline{\text{RESO}}$		—	—	0.4	V	I_O

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter ar converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in th 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), 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 NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, it open-drain output. Therefore, an external pull-up resistor must be connected output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels are NMOS.

When a pin is in output mode, the output voltage is equivalent to the applie

8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristi on V_{CC}.

leakage current	$\overline{STBY}$, NMI, MD1, MD0		—	—	1.0		V
	Port 7		—	—	1.0		V A
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A*4, B	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V V V V
Input pull-up MOS current	Ports 1 to 3	$-I_P$	30	—	300	µA	V
	Ports A*4, B, 6 (P6PUE = 0)		60	—	600		V to
	Port 6 (P6PUE = 1)		15	—	200		V to
	Ports 1 to 3		20	—	200	µA	V
	Ports A*4, B, 6 (P6PUE = 0)		40	—	500		V to
	Port 6 (P6PUE = 1)		10	—	150		V to
Input capacitance	$\overline{RES}$ (4)	C_{in}	—	—	80	pF	V f
	NMI		—	—	50		T
	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
	Sleep mode		—	30	46	mA	f
	Standby mode*3		—	1.0	5.0	µA	T
			—	—	20.0		5

supply current	conversion					
	Idle		—	0.01	5.0	µA
Analog power supply voltage*1	AV_{CC}		4.0	—	5.5	V
			2.0	—	5.5	
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 a converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in t 2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC} 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 V with all output pins unloaded and the on-chip pull-up MOSs in the off stat
3. Current dissipation values are for V_{IH} min = V_{CC} – 0.2 V, $V_{CC}B$ – 0.2 V, and V V with all output pins unloaded and the on-chip pull-up MOSs in the off stat
4. The port A characteristics depend on VCCB, and the other pins characteris on VCC.

voltage	$\overline{KIN15}$ to $\overline{KIN8}$*3, $\overline{IRQ2}$ to $\overline{IRQ0}$*3, $\overline{IRQ5}$ to $\overline{IRQ3}$		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			$V_{cc} \times 0.7$	—	$V_{cc} + 0.3$	

	NMI, EXTAL, input pins except (1) and (3) above		–0.3	—	$V_{CC} \times 0.2$		V 3
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	
			V_{CC} – 1.0 V_{CC}B – 1.0	—	—	V	
	P97, P86, P52, and P42*4		0.5	—	—	V	
Output low voltage	All output pins (except $\overline{\text{RESO}}$)*5	V_{OL}	—	—	0.4	V	
	Ports 1 to 3		—	—	1.0	V	
	$\overline{\text{RESO}}$		—	—	0.4	V	

Notes: 1. Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter a converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in t V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or 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 NMOS push-pull outputs.

When the SCL0, SDA0, SCL1, or SDA1 (ICE = 1) pin is used as an output, open-drain output. Therefore, an external pull-up resistor must be connecte output high level.

P52/SCK0, P97, P86/SCK1, P42/SCK2 (ICE = 0), and port G high levels ar NMOS.

When the SCK0, SCK1, or SCK 2 pin is used as an output, an external pull must be connected in order to output high level.

on V_{CC}.

9. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V

current	MD0					
	Port 7		—	—	1.0	
Three-state leakage current (off state)	Ports 1 to 6 Ports 8, 9, A*4, B	$\lvert I_{TSI} \rvert$	—	—	1.0	µA
Input pull-up MOS current	Ports 1 to 3	$-I_P$	5	—	150	µA
	Ports A*4, B, 6 (P6PUE = 0)		30	—	300	
	Port 6 (P6PUE = 1)		3	—	100	
Input capacitance	$\overline{RES}$ (4)	C_{in}	—	—	80	pF
	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
	Sleep mode		—	20	32	mA
	Standby mode*3		—	1.0	5.0	µA
			—	—	20.0	
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	µA

		2.0	—	3.6		I
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 ar converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in th 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), 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} 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 characteristi on VCC.
5. For flash memory programming/erasure, the applicable range is V_{CC} = 3.0 V

	PB1, PB0					
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} = –
Output low voltage	P37, P33 to P30, P82 to P80, PB1, PB0	V_{OL}	—	$V_{CC} \times 0.1$	V	I_{OL} = 1

Note: * Do not leave the AV_{CC}, AV_{ref}, and AV_{SS} pins open even if the A/D converter a converter are not used.

Even if the A/D converter and D/A converter are not used, apply a value in 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC} other method. Ensure that $AV_{ref} \leq AV_{CC}$.

	PS2AD to PS2CD, PA7 to PA4 (bus drive function selected)				
	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
	Total of all output pins, including the above		—	—	120
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	40

	$\overline{\text{RESO}}$		—	—	1
	Other output pins		—	—	1
Permissible output low current (total)	Total of ports 1 to 3	$\sum I_{OL}$	—	—	40
	Total of all output pins, including the above		—	—	60
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	30

Notes: 1. To protect chip reliability, do not exceed the output current values in table 2

2. When driving a Darlington pair or LED, always insert a current-limiting resis output line, as show in figures 27.1 and 27.2.

	$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		
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 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 = T_a = 25°C
Three-state leakage current (off state)	$\lvert I_{TSI} \rvert$	—	—	1.0	µA	V_{in} = 0.5 to
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 (bu
function selected)

Item	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Test Conditio**
Output low voltage	V_{OL}	—	—	0.8	V	I_{OL} = 16 mA, $V_{CC}B$ = 4.5 V t
		—	—	0.5		I_{OL} = 8 mA
		—	—	0.4		I_{OL} = 3 mA

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 maxi
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 m
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 m
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
Clock cycle time	t_{cyc}	100	500	62.5	500	50	500	ns
Clock high pulse width	t_{CH}	30	—	20	—	17	—	ns
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
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	8	—	ms
External clock output stabilization delay time	t_{DEXT}	500	—	500	—	500	—	µs

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 sp product), T_a = –40 to +85°C (wide range temperature specification produ

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**
$\overline{\text{RES}}$ setup time	t_{RESS}	300	—	200	—	200	—	ns
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}
NMI setup time (NMI)	t_{NMIS}	250	—	150	—	150	—	ns
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 ($\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$)	t_{IRQS}	250	—	150	—	150	—	ns
IRQ hold time ($\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$)	t_{IRQH}	10	—	10	—	10	—	ns
IRQ pulse width ($\overline{\text{IRQ7}}$, $\overline{\text{IRQ6}}$, $\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns

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 m
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 m
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**
Address delay time	t_{AD}	—	40	—	30	—	20	ns
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

access time 5	t_{ACC5}		$t_{cyc} - 60$		$t_{cyc} - 40$		$t_{cyc} - 30$	
$\overline{HWR}$, $\overline{LWR}$ 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

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 m
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**
Address delay time	t_{AD}	—	60	—	45	—	30	ns
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

delay time 1	t_{WRD1}							
$\overline{HWR}$, $\overline{LWR}$ delay time 2	t_{WRD2}	—	60	—	45	—	30	ns
$\overline{HWR}$, $\overline{LWR}$ pulse width 1	t_{WSW1}	1.0 × t_{cyc} – 40	—	1.0 × t_{cyc} – 30	—	1.0 × t_{cyc} – 20	—	ns
$\overline{HWR}$, $\overline{LWR}$ pulse width 2	t_{WSW2}	1.5 × t_{cyc} – 40	—	1.5 × t_{cyc} – 30	—	1.5 × 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

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**
I/O ports	Output data delay time		t_{PWD}	—	100	—	50	—	50	ns
	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
	Timer input setup time		t_{FTIS}	50	—	30	—	30	—	
	Timer clock input setup time		t_{FTCS}	50	—	30	—	30	—	
	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
	Timer reset input setup time		t_{TMRS}	50	—	30	—	30	—	
	Timer clock input setup time		t_{TMCS}	50	—	30	—	30	—	

PWMX										
SCI	Input clock cycle	Asynchronous	t_{Scyc}	4	—	4	—	4	—	t_{cyc}
		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
	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
WDT	$\overline{\text{RESO}}$ output delay time		t_{RESD}	—	200	—	120	—	100	ns
	$\overline{\text{RESO}}$ output pulse width		t_{RESOW}	132	—	132	—	132	—	t_{cyc}

Note: * Only peripheral modules that can be used in subclock operation

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 m
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**
HIF read cycle	$\overline{CS}$/HA0 setup time		t_{HAR}	10	—	10	—	10	—	ns
	$\overline{CS}$/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	

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,

Item	Symbol	Ratings Min	Typ	Max	Unit	Test Conditions
SCL input cycle time	t_{SCL}	12	—	—	t_{cyc}	
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. see section 16.6, Usage Notes.

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	—	—

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**
Resolution	10	10	10	10	10	10	10	10	10
Conversion time[*3]	—	—	13.4	—	—	8.4	—	—	6.7
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	5	—	—	10[*1] 5[*2]	—	—	10[*1] 5[*2]
Nonlinearity error	—	—	±7.0	—	—	±3.0	—	—	±3.0
Offset error	—	—	±7.5	—	—	±3.5	—	—	±3.5
Full-scale error	—	—	±7.5	—	—	±3.5	—	—	±3.5
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5
Absolute accuracy	—	—	±8.0	—	—	±4.0	—	—	±4.0

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.

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} *
$V_{CC}B$ = 3.0 V to 5.5 V*4, V_{SS} = AV_{SS} = 0 V, ϕ = 2 MHz to maximum op
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**	**Ma**
Resolution	10	10	10	10	10	10	10	10	10
Conversion time*3	—	—	13.4	—	—	8.4	—	—	6.7
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	5	—	—	10*1 5*2	—	—	10 5*
Nonlinearity error	—	—	±11.0	—	—	±5.0	—	—	±5
Offset error	—	—	±11.5	—	—	±5.5	—	—	±5
Full-scale error	—	—	±11.5	—	—	±5.5	—	—	±5
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0
Absolute accuracy	—	—	±12.0	—	—	±6.0	—	—	±6

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
3.6 V, $V_{CC}B$ = 3.0 V to 5.5 V.

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		
		10 MHz			16 MHz			20 MHz		
Item		**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**M**
Resolution		8	8	8	8	8	8	8	8	8
Conversion time	With 20 pF load capacitance	—	—	10	—	—	10	—	—	1
Absolute accuracy	With 2 MΩ load resistance	—	±2.0	±3.0	—	±1.0	±1.5	—	±1.0	±
	With 4 MΩ load resistance	—	—	±2.0	—	—	±1.0	—	—	±

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
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
		z2	198	200	202	µs
		z3	8	10	12	µs
	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

z1, z2 and z3 to allow programming within the maximum programming time (

The wait time after P-bit setting (z1, z2, and z3) should be alternated accordi 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 se 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 ci step down the microprocessor internal power supply voltage to the appropriate leve

   One or two (in parallel) internal voltage regulating capacitors (0.47 µF) should be in between the internal step-down pin (VCL pin) and VSS pin. The method of connect external capacitor(s) is shown in figure 27.5.

   For the 5-V and 4-V version products whose power supply (VCC) voltage exceeds not connect the VCC power supply to the VCL pin of the internal step-down produc 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, co 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 f the F-ZTAT B-masked product with the internal step-down function, note that the V allocated to the same location as the VCC2 pin of the product without the internal s function. Therefore, the difference in the circuits between before and after the switc should be considered when designing the PC board patterns.

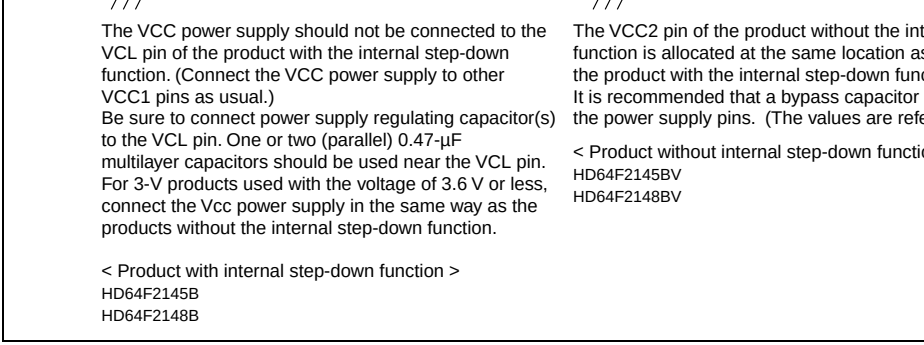


Figure 27.5 Connection of VCL Capacitor

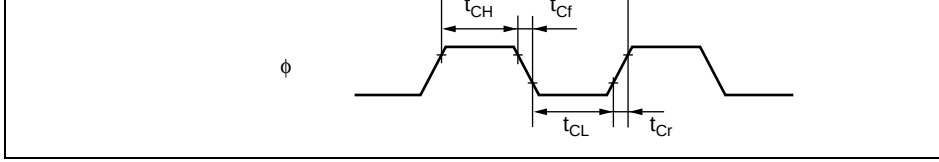


Figure 27.6 System Clock Timing

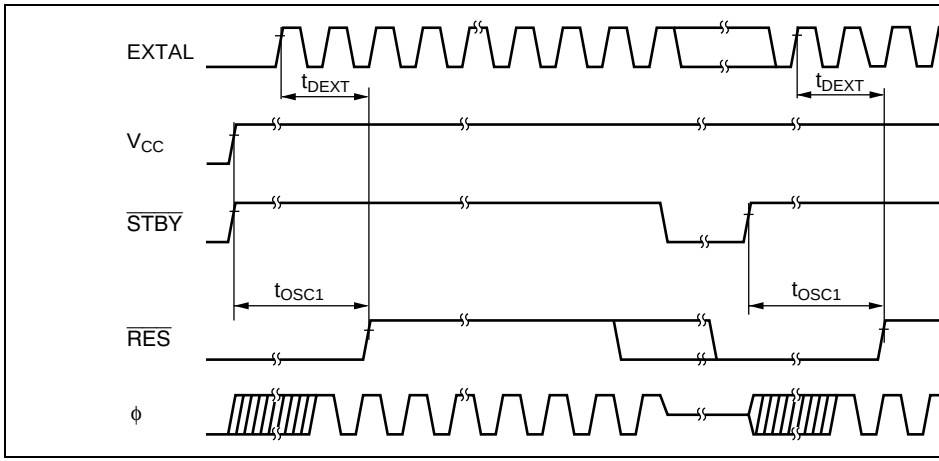


Figure 27.7 Oscillation Settling Timing

Note: i = 0 to 2, 6, 7

Figure 27.8 Oscillation Setting Timing (Exiting Software Standby Mod

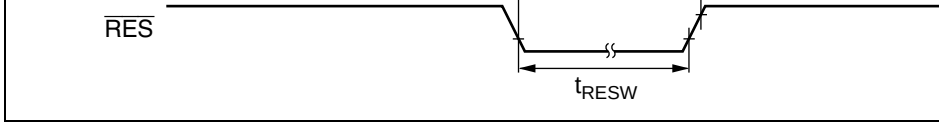


Figure 27.9 Reset Input Timing

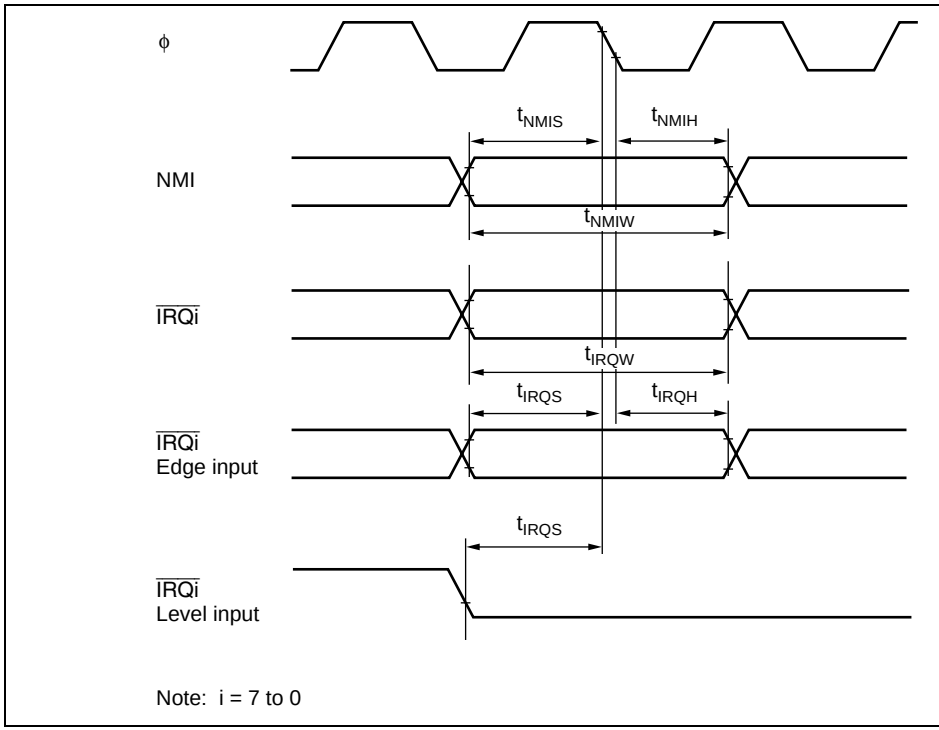
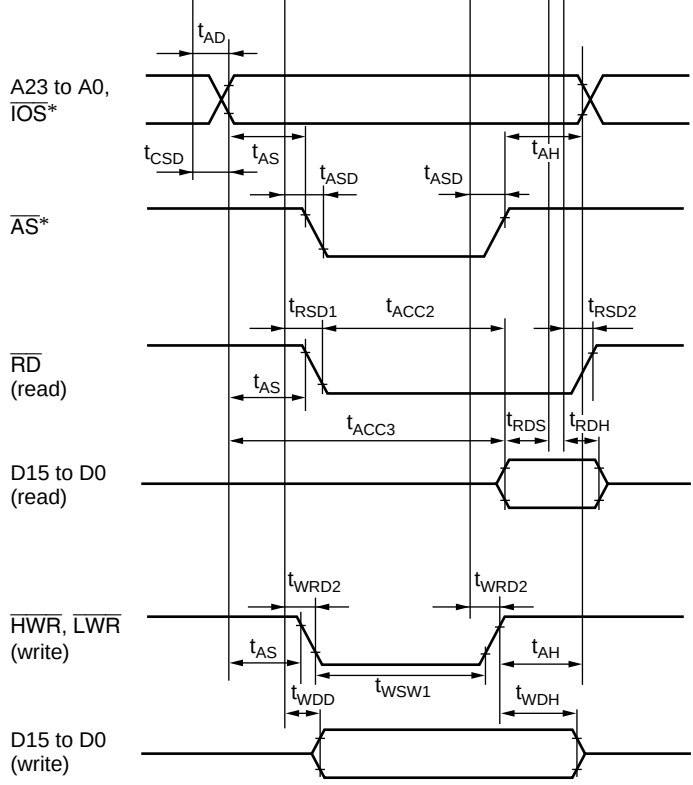
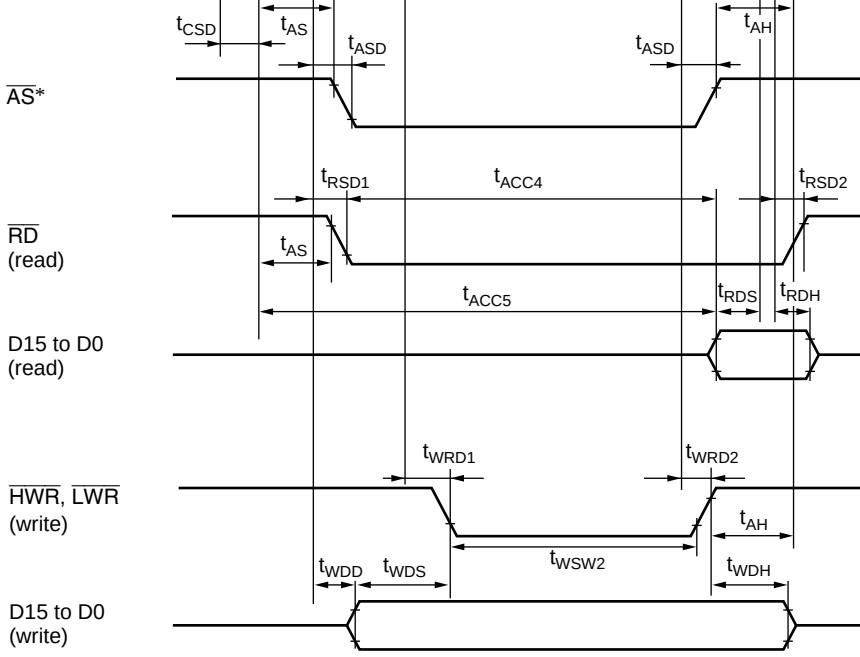


Figure 27.10 Interrupt Input Timing



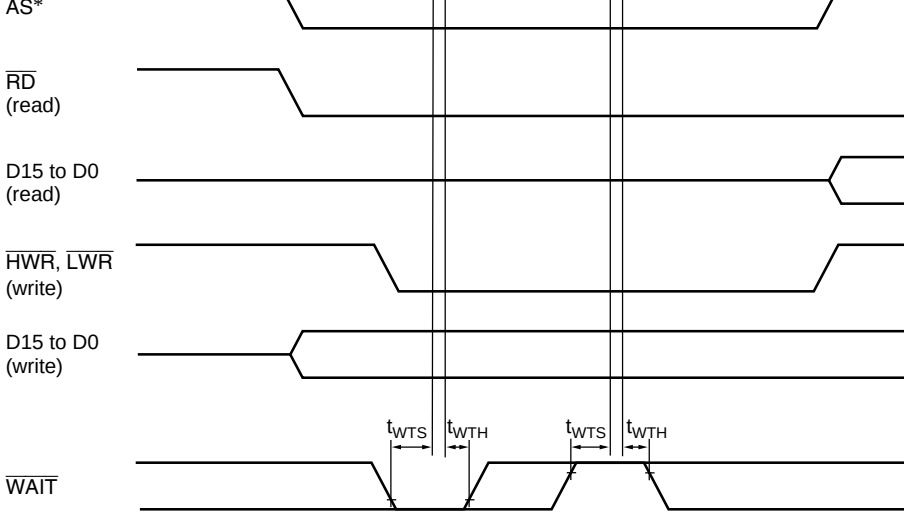
Note: * $\overline{AS}$ and $\overline{IOS}$ are the same pin. The function is selected by the IOSE bit in SYS

Figure 27.11 Basic Bus Timing (Two-State Access)



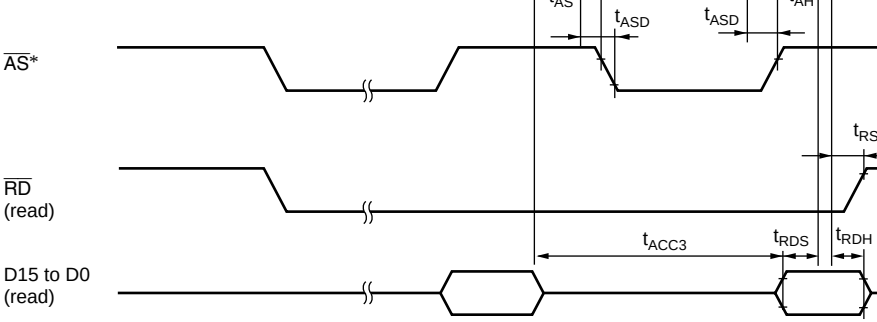
Note: * AS and IOS are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.12 Basic Bus Timing (Three-State Access)



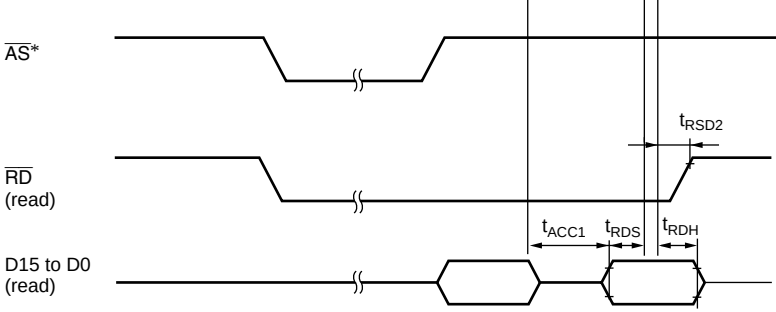
Note: * AS and IOS are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 27.13 Basic Bus Timing (Three-State Access with One Wait Sta



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: * AS and 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)

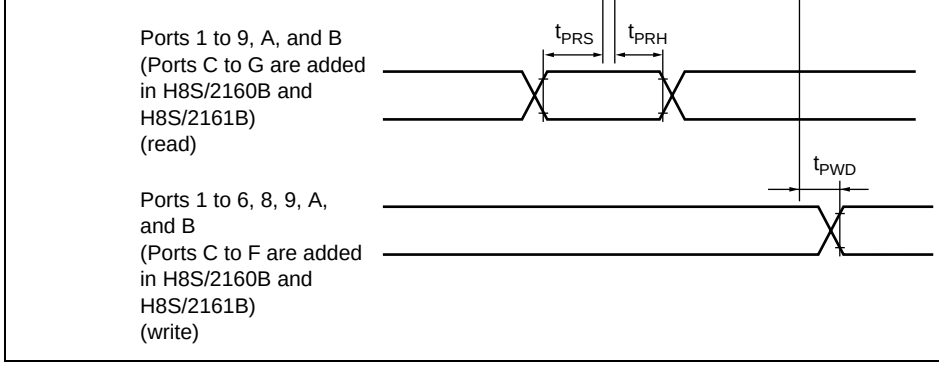


Figure 27.16 I/O Port Input/Output Timing

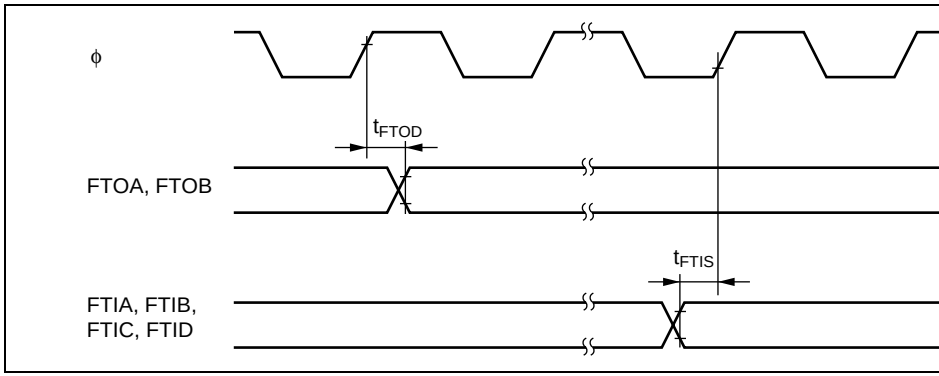


Figure 27.17 FRT Input/Output Timing

Figure 27.18 FRT Clock Input Timing

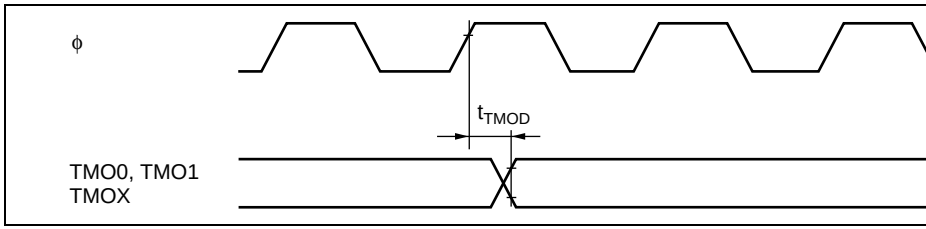


Figure 27.19 8-Bit Timer Output Timing

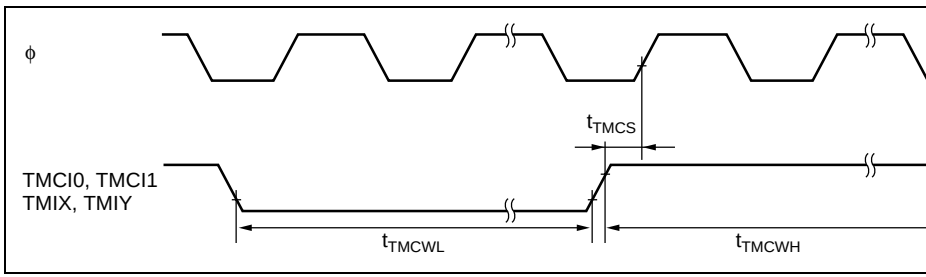


Figure 27.20 8-Bit Timer Clock Input Timing

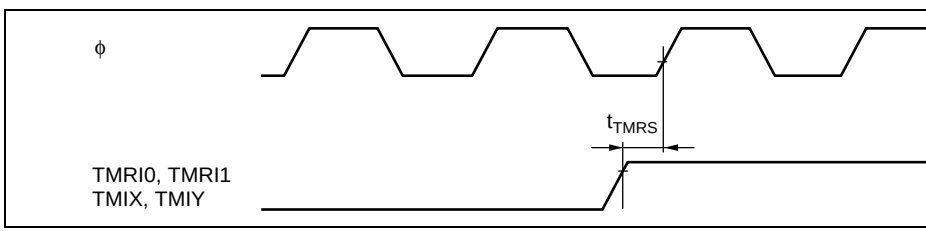


Figure 27.21 8-Bit Timer Reset Input Timing

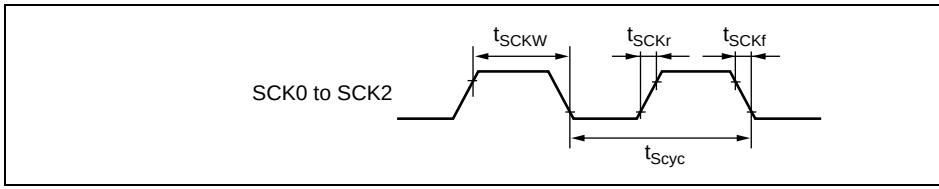


Figure 27.23 SCK Clock Input Timing

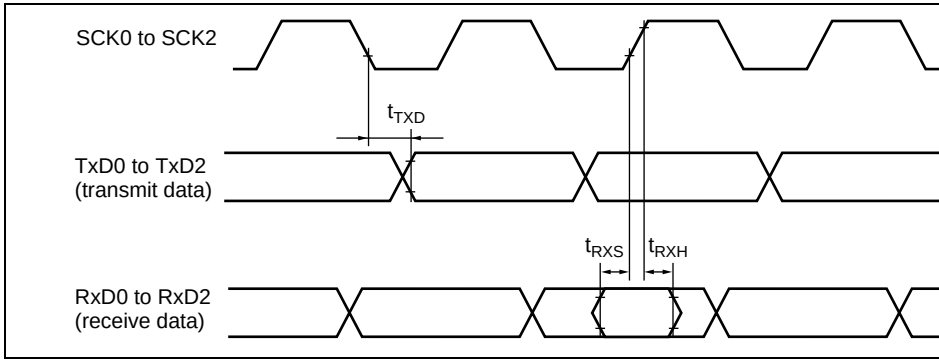


Figure 27.24 SCI Input/Output Timing (Synchronous Mode)

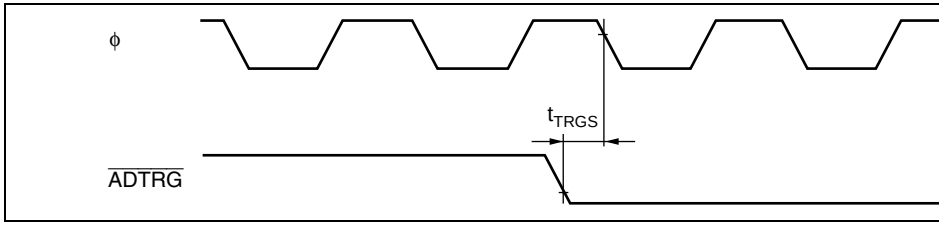
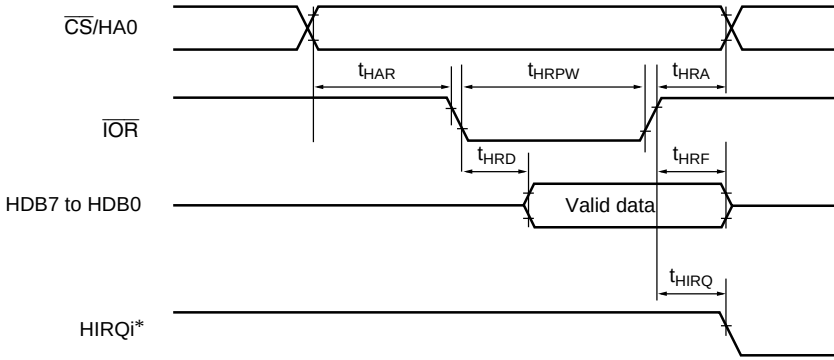


Figure 27.25 A/D Converter External Trigger Input Timing

Figure 27.26 WDT Output Timing ($\overline{RESO}$)

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 timin
See figure 28.16.

Host interface (XBS) write timing

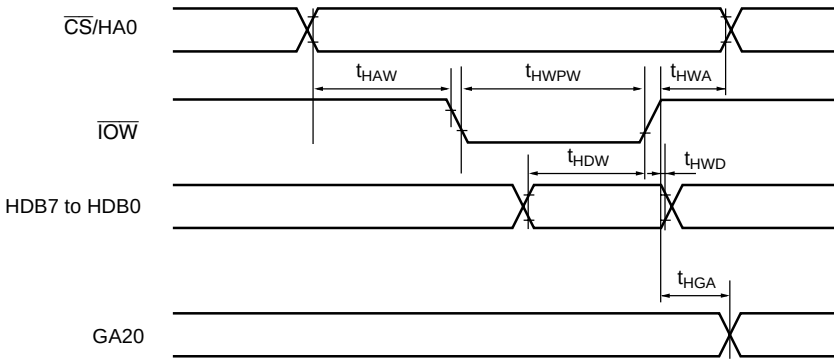
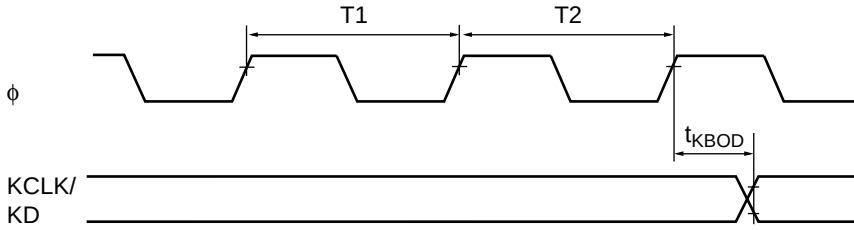
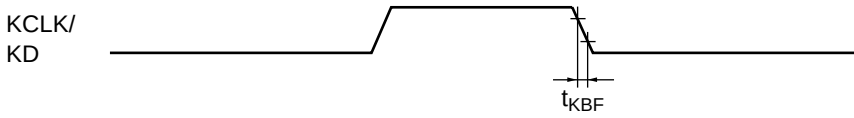


Figure 27.27 Host Interface (XBS) Timing

2. Transmission (a)



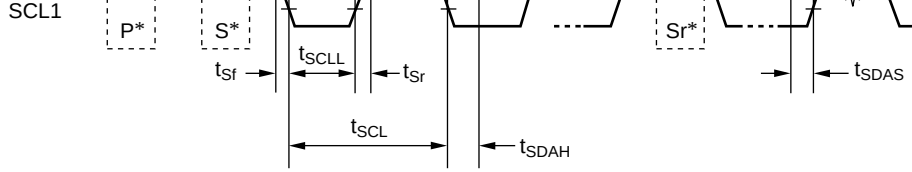
Transmission (b)



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



Note: * S, P, and Sr indicate the following conditions.

S: Start condition
P: Stop condition
Sr: Retransmission start condition

Figure 27.29 I²C Bus Interface Input/Output Timing

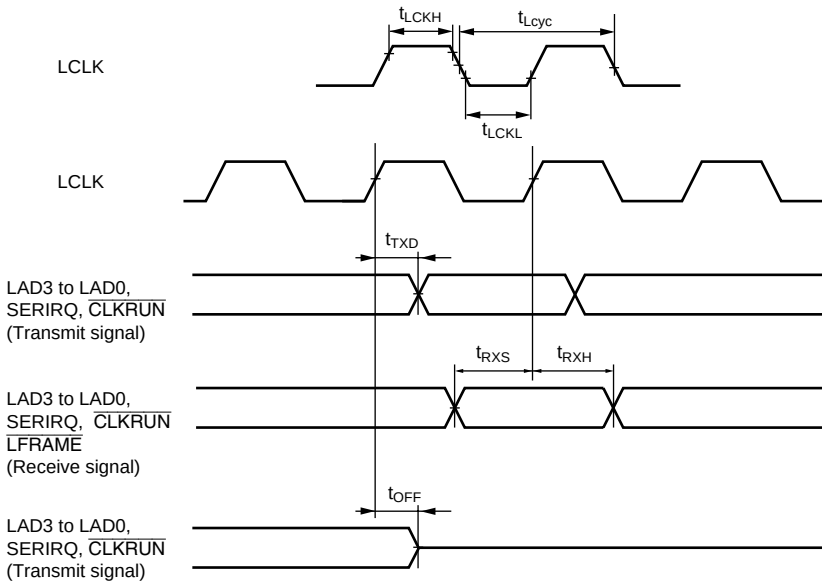


Figure 27.30 Host Interface (LPC) Timing

								output/ input port
	2, 3 (EXPE = 0)							I/O port
Port 2 A15 to A8	1	L	T	kept*	kept*	kept*	kept*	A15 to A8
	2, 3 (EXPE = 1)	T						Address output/ input port
	2, 3 (EXPE = 0)							I/O port
Port 3 D15 to D8	1	T	T	T	T	T	T	D15 to D8
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port
Port 4	1	T	T	kept	kept	kept	kept	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 5	1	T	T	kept	kept	kept	kept	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 6	1	T	T	kept	kept	kept	kept	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 7	1	T	T	T	T	T	T	Input port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 8	1	T	T	kept	kept	kept	kept	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
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port

	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port
Ports 92, 91	1	T	T	kept	kept	kept	kept	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 90 $\overline{\text{LWR}}$	1	T	T	H/kept	H/kept	H/kept	H/kept	$\overline{\text{LWR}}$/ I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port
Port A A23 to A16	1	T	T	kept*	kept*	kept*	kept*	I/O port
	2, 3 (EXPE = 1)							A23 to A16/ I/O port
	2, 3 (EXPE = 0)							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
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			kept	kept	kept	kept	I/O port
Ports C to G (H8S/2160B, H8S/2161B)	1	T	T	kept	kept	kept	kept	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 p
MOSs remain on).

Output ports maintain their previous state.

Depending on the pins, the on-chip peripheral modules may be initialized and th
function determined by DDR and DR used.

DDR: Data direction register

Note: * In the case of address output, the last address accessed is retained.

	(3-V version)		F2141BVTE10	100-pin TQFI
H8S/2140B	Flash memory version (3-V version)	HD64F2140BV	F2140BVFA10	100-pin QFP
			F2140BVTE10	100-pin TQFI
H8S/2145B	Flash memory version (3-V version)	HD64F2145BV	F2145BVFA10	100-pin QFP
			F2145BVTE10	100-pin TQFI
	Flash memory version (5-V version)	HD64F2145B	F2145BFA20	100-pin QFP
			F2145BTE20	100-pin TQFI
H8S/2148B	Flash memory version (3-V version)	HD64F2148BV	F2148BVFA10	100-pin QFP
			F2148BVTE10	100-pin TQFI
	Flash memory version (5-V version)	HD64F2148B	F2148BFA20	100-pin QFP
			F2148BTE20	100-pin TQFI

Legend:

(***): ROM code

Note: * Some products above are in the developing or planning stage. Please cont
agency to conform the present state of each product.

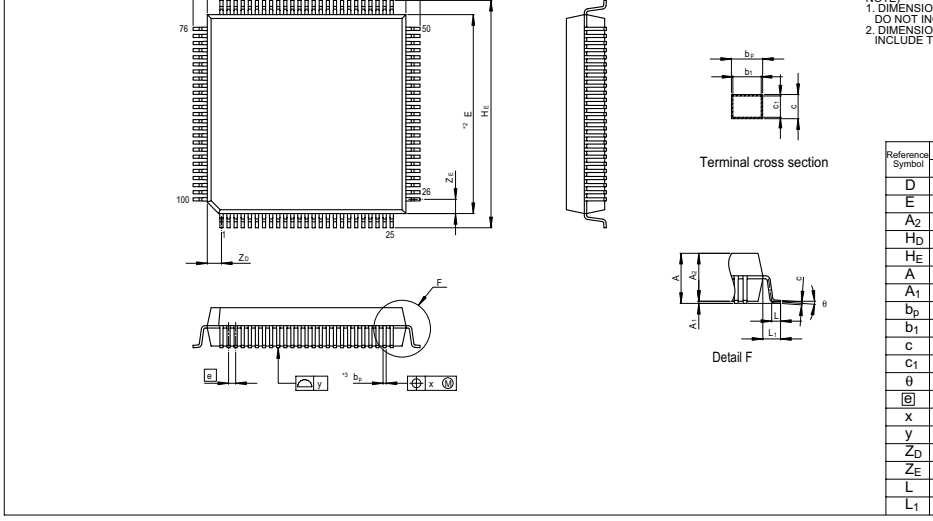
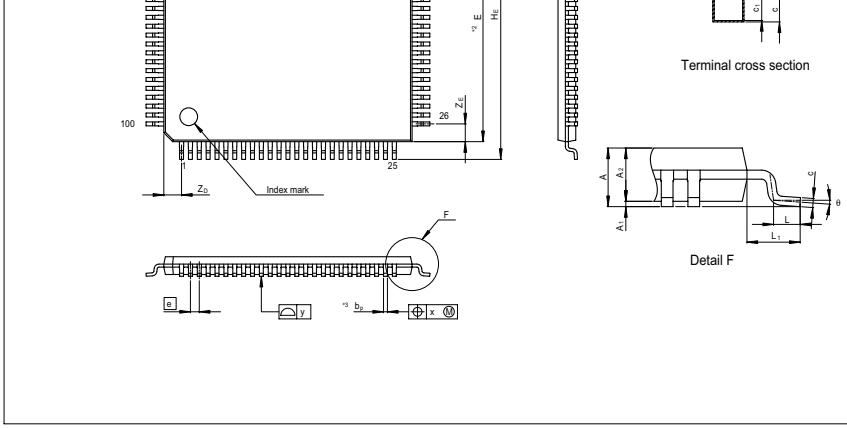
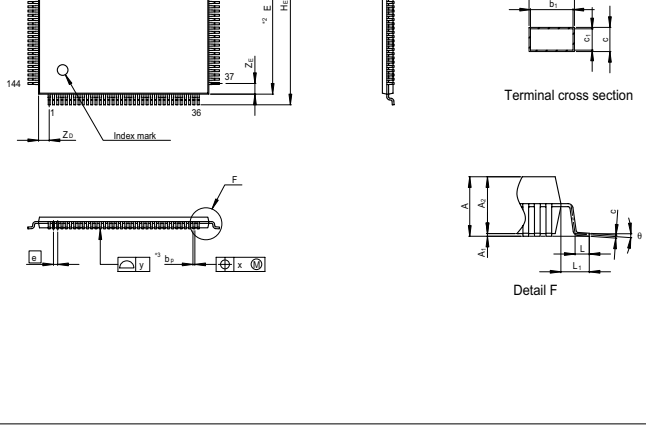


Figure C.1 Package Dimensions (FP-100B)



Reference Symbol	
D	
E	
A_2	
H_D	
H_E	
A	
A_1	
b_p	
b_1	
c	
c_1	
θ	
e	
x	
y	
Z_D	
Z_E	
L	
L_1	

Figure C.2 Package Dimensions (TFP-100B)



Reference Symbol
D
E
A_2
H_D
H_E
A
A_1
b_p
b_1
c
c_1
θ
e
x
y
Z_D
Z_E
L
L_1

Figure C.3 Package Dimensions (TFP-144)

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Hardware Manual
H8S/2140B Group

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